

Ultrasound for Carpal Tunnel Syndrome Screening in Manual Laborers

By: Michael S. Cartwright, Francis O. Walker, Jill N. Blocker, [Mark R. Schulz](#), Thomas A. Arcury, Joseph G. Grzywacz, Dana Mora, Haiying Chen, Antonio J. Marín, Sara A. Quandt

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Abstract:

Introduction:

Manual laborers are at increased risk for carpal tunnel syndrome (CTS), and a combination of history, physical examination, and nerve conduction studies is often used to screen for CTS in this population. Neuromuscular ultrasound may be a better screening tool, because it is painless. In this study we compare the accuracy of nerve conduction studies and ultrasound for CTS screening.

Methods:

Five hundred thirteen manual laborers were screened prospectively for CTS using nerve conduction studies and neuromuscular ultrasound, and the accuracy of the 2 techniques was compared using the Katz hand diagram as the diagnostic standard.

Results:

The ROC curves for the 2 techniques were not significantly different ($P = 0.542$), indicating that the approaches had similar diagnostic accuracy.

Conclusions:

Neuromuscular ultrasound is a painless technique that has diagnostic accuracy similar to nerve conduction studies and can be used to screen large populations at risk for CTS.

Abbreviations

CTS: carpal tunnel syndrome

ROC: receiver operating characteristic

Keywords: accuracy | carpal tunnel syndrome | clinical neurophysiology | screening test | ultrasound

Article:

Carpal tunnel syndrome (CTS) is a condition that affects about 3% of the general population and results in over \$500 million in medical costs in the USA annually.[1,2] CTS is caused by chronic compression of the median nerve at the wrist as it passes through the rigid carpal tunnel, and it therefore occurs more commonly among workers in occupations involving manual labor and repetitive use of the hands.[3-5] The diagnosis of CTS is typically established through history and clinical examination. Affected individuals have pain, numbness, and paresthesias in the median nerve territory and sometimes weakness in the affected hand.[6] Traditionally, nerve conduction studies that demonstrate median mononeuropathy at the wrist are used to confirm the diagnosis of CTS.[7] Although many cases of CTS are straightforward, the diagnosis can be less clear if it is complicated by atypical symptoms or if some, but not all, of the nerve conduction study techniques, each with varying levels of sensitivity and specificity, suggest an abnormality.

Just as the diagnosis of CTS in an individual can be complicated, screening and defining CTS in at-risk populations can also be challenging. Studies using surveys or brief interviews alone often result in very high rates of CTS, some with prevalence exceeding 70% in certain populations,[8] whereas screening protocols in which nerve conduction studies are used to define CTS are more specific and result in lower prevalence values.[9] Although nerve conduction studies are useful in diagnosing and screening for CTS, they have limitations; they require warming of cool extremities, they are technically challenging with regard to performance and interpretation, they may be painful, and they require anatomic inferences to be made based on electrical data. For these reasons, new techniques are being examined to assist in the diagnosis of CTS, and over the past several years neuromuscular ultrasound has emerged as an accurate diagnostic tool which correlates with nerve conduction studies.[10-12] Despite its diagnostic value, the application of neuromuscular ultrasound for CTS screening is underutilized. We therefore designed this prospective study to compare the accuracy of nerve conduction studies and neuromuscular ultrasound for screening a large population of manual laborers at risk for CTS.

METHODS

Participants

As part of a large study on occupational health disparities, Latinos in poultry and non-poultry manual labor occupations were recruited in 4 western North Carolina counties from June 2009 to November 2010 to participate in a study of musculoskeletal, dermatologic, and respiratory conditions. The data collection that took place in this study has been described elsewhere,[5] but

aspects pertinent to this study are highlighted in the following sections. Community-based sampling of dwelling units was performed with a focus on regions with a high proportion of Latino residents in order to recruit a population-based sample across multiple industries and job sites. Only those who self-identified as Latino or Hispanic, were ≥ 18 years of age, and who worked ≥ 35 hours per week in a manual labor job were recruited. Study participants underwent a 1-hour-long interview, which focused on several aspects of their health and occupation, and they then attended a clinical examination clinic. These clinics occurred on 7 Sundays evenly dispersed throughout the study period. All participants provided signed informed consent, and the study was approved by the institutional review board of the Wake Forest University School of Medicine.

Over the course of the study 1526 individuals were screened, and 957 were eligible for enrollment. Of these, 742 underwent interviews, and 518 attended the clinics. Five individuals left the clinics prior to undergoing nerve conduction studies or ultrasound, which resulted in 513 who had nerve conduction studies, neuromuscular ultrasound, and completed hand diagrams (1026 wrists).

Clinical Evaluations

At the clinic, participants were asked if they had numbness, pain, tingling, or weakness in their hands for ≥ 2 days in the previous month. If they answered affirmatively, they completed the Katz hand diagram to indicate distribution of symptoms. The hand diagrams were scored “unlikely” (0), “possible” (1), “probable” (2), or “classic” (3) for CTS based on previously published methods for scoring of the diagram, and each diagram was scored by 2 clinicians (M.S.C. and F.O.W.), who were blinded to all participant information.[13] The Katz diagram was used as the reference standard for the diagnosis of CTS.

All participants underwent bilateral nerve conduction studies using an electromyograph (TD10; Teca Corp., Pleasantville, New York). The studies were performed by experienced technicians blinded to the participant's occupation, clinical evaluation, and ultrasound data. Hands were warmed to 32°C, and median and ulnar antidromic sensory studies were performed, stimulating the wrist and recording with ring electrodes 140 mm distally on the second and fifth fingers. The onset and peak latencies were recorded, and those without median sensory potentials underwent orthodromic median motor studies recording from the abductor pollicis brevis muscle.

Finally, all participants underwent bilateral neuromuscular ultrasound evaluations of the median nerve at the wrist using a Biosound MyLab25ultrasound device (Esaote Group, Genoa, Italy) with an 18-MHz linear-array transducer. Three neurologists experienced with neuromuscular ultrasound performed all studies, and they were blinded to occupation, clinical information, and nerve conduction results. The participants were seated with their arms supine and forward on a table. The median nerve at the wrist was imaged in cross-sectional view and scanned from 3 cm distal to 3 cm proximal to the distal wrist crease to identify the site of maximal nerve

enlargement. The cross-sectional area of the median nerve at the site of maximal enlargement was obtained by using the freehand trace function and outlining the nerve, erring just to the inside of the epineurium (Fig. 1).

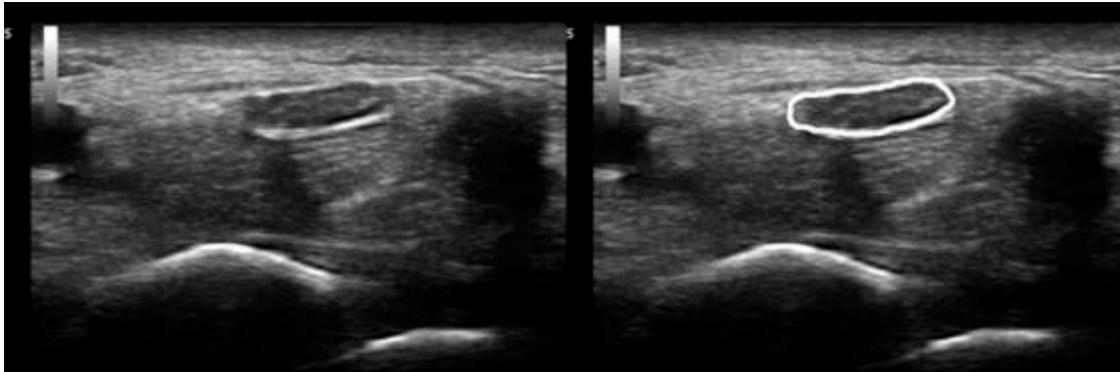


Figure 1. The left and right images are the same, except that in the right image the measuring technique for outlining the median nerve at the wrist and measuring cross-sectional area is depicted by the white tracing. This median nerve had a cross-sectional area of 11 mm².

The ultrasonographer also made assessments of the echogenicity, mobility, and vascularity of the median nerve at the site of maximal enlargement, using the same techniques as reported previously.[14] Echogenicity was rated as either “normal” (0), “slightly decreased” (1), or “decreased” (2), based on visual inspection of the image, with normal nerve echogenicity showing a honeycomb pattern with a mixture of dark fascicles interspersed among a brighter background. To assess median nerve mobility, the participant was asked to repeatedly flex and extend the fingers and wrist, while the transducer was maintained over the distal wrist crease. Mobility was rated as “normal” (0), “slightly decreased” (1), or “decreased” (2). Normal mobility is when the median nerve dives deep to the flexor tendons during finger and wrist flexion. Vascularity was assessed by placing the power Doppler box over the median nerve, and slowly increasing the gain. If color flow was seen in the nerve prior to other structures (in particular, the flexor tendons), then vascularity was rated as either “increased” (2) or “slightly increased” (1), based on the degree of color flow, and “normal” (0) when there was no early color Doppler signal in the nerve.

Statistical Analyses

Descriptive statistics were calculated as means and standard deviations for continuous variables, and percentages and frequencies for discrete variables. The standard for the diagnosis of CTS was the Katz hand diagram, and all analyses of nerve conduction study and ultrasound accuracy were performed using different Katz diagram scoring cut-offs, with the most sensitive definition being all participants who scored 1, 2, or 3 and the most strict being only those who scored a 3 on the diagram.

The sensitivity and specificity of nerve conduction studies and neuromuscular ultrasound were first calculated using pre-specified cut-off levels. For the nerve conduction studies, peak median and ulnar sensory latencies were compared, and 2 different cut-offs were used to define a study consistent with CTS: a median latency either 0.5 ms or 0.8 ms longer than the ulnar latency, as described in previous studies.[15] For neuromuscular ultrasound the pre-specified cut-off for a positive result was a median nerve cross-sectional area $\geq 12 \text{ mm}^2$, based on previous studies.[16, 17] Next, receiver operating characteristic (ROC) curves were generated for nerve conduction studies and neuromuscular ultrasound to determine the optimal cut-off for CTS diagnosis for both modalities, based on the collected data. This was done using the Youden index to maximize sensitivity and specificity.[18] These curves were also compared with each other to determine whether 1 modality was more accurate than the other by comparing the area under the curves using a chi-square test.

Finally, several parameters were explored to maximize the sensitivity and, alternately, the specificity of neuromuscular ultrasound for the diagnosis of CTS. This included adjusting the median nerve cross-sectional area cut-off and including the measures of echogenicity, mobility, and vascularity in combination with median nerve area. All *P*-values were considered significant at the 0.05 level, and statistical calculations were performed using SAS, version 9.2 (SAS, Cary, North Carolina).

RESULTS

The personal characteristics for all 513 participants in the study are described in Table 1, which also includes the personal characteristics for those with CTS (34 participants with CTS in at least 1 hand) and without CTS (479 participants), when the diagnosis is based on the Katz hand diagram. Those with CTS were older (41.7 vs. 34.2, $P < 0.001$), weighed more (77.6 kg vs. 71.5 kg, $P = 0.011$), and had greater body mass index (31.5 vs. 28.7, $P = 0.001$) than those without CTS. There was also a trend toward a greater percentage of those in the CTS group being women than in the group without CTS (61.8% vs. 44.7%, $P = 0.053$).

Table 1. Characteristics of study participants

Demographics	All participants (N = 513)	With CTS^a (n = 34)	Without CTS (n = 479)	P-value^b
Age	34.7 (10.4)	41.7 (11.0)	34.2 (10.2)	<0.001
Height (cm)	157.7 (8.4)	157.3 (9.0)	157.8 (8.4)	0.733
Weight (kg)	71.9 (13.6)	77.6 (14.1)	71.5 (13.5)	0.011
Body mass index	28.9 (4.9)	31.5 (5.4)	28.7 (4.8)	0.001

Gender				0.053
Men	278 (54.2)	13 (38.2)	265 (55.3)	
Women	235 (45.8)	21 (61.8)	214 (44.7)	

Data expressed as mean (SD) or number (%).

a CTS defined by scoring a “2” or “3” on the hand diagram in either or both hands.

b *P*-value from Student *t*-test or chi-square test of association.

Altering the reference standard definition of CTS based on the Katz hand diagram to include or exclude scores of 1 or 2 only changed the diagnostic accuracy of the different nerve conduction and neuromuscular ultrasound parameters by 1–2 percentage points. Therefore, the sensitivity and specificity numbers presented in Table 2 (and all other calculations) are based on a score of 0 (unlikely) or 1 (possible) on the Katz hand diagram indicating no CTS, and a score of 2 (probable) or 3 (classic) indicating the presence of CTS. No disagreements occurred between the 2 clinicians who graded the hand diagrams.

Table 2. Sensitivity and specificity of diagnostic tests for CTS

Diagnostic parameter	Sensitivity (%)	Specificity (%)
NCS (difference >0.5 ms)	50	69
NCS (difference >0.8 ms)	39	83
NCS (difference >0.6 ms)	48	75
Ultrasound (>12 mm ²)	56	63
Ultrasound (>13 mm ²)	48	77
Ultrasound (combined parameters) ^a	89	27
Ultrasound (>8 mm ²)	96	6
Ultrasound (>18 mm ²)	17	97

NCS, nerve conduction studies.

a “Combined parameters” ultrasound data resulted in a diagnosis of CTS when: median nerve cross-sectional area >12 mm²; or mobility = 1 or 2; or echo = 1 or 2; or vascularity = 1 or 2.

The ROC curves (Fig. 2) demonstrate that nerve conduction studies and neuromuscular ultrasound had similar diagnostic accuracy, with an area under the curve for nerve conduction studies of 0.6317 and for neuromuscular ultrasound of 0.6394, which are not significantly

different ($P = 0.542$). A calculation of the Youden index (the point of the ROC curve farthest from the diagonal) showed the optimal median-to-ulnar latency difference to be 0.6 ms and the optimal median nerve cross-sectional area cut-off to be 13 mm² (Table 2). The median nerve cross-sectional area that maximized sensitivity (>95%) was 8 mm², and an area that maximized specificity (>95%) was 18 mm² (Table 2). A combination of median nerve cross-sectional area >12 mm², or abnormal mobility, echogenicity, or vascularity, resulted in a sensitivity of 89%. Borderline median nerve cross-sectional area (8–12 mm²) occurred in 69.3% of wrists, but only 2.4% of those in this category had abnormal hand diagrams, and only 10.8% had abnormal nerve conduction studies.

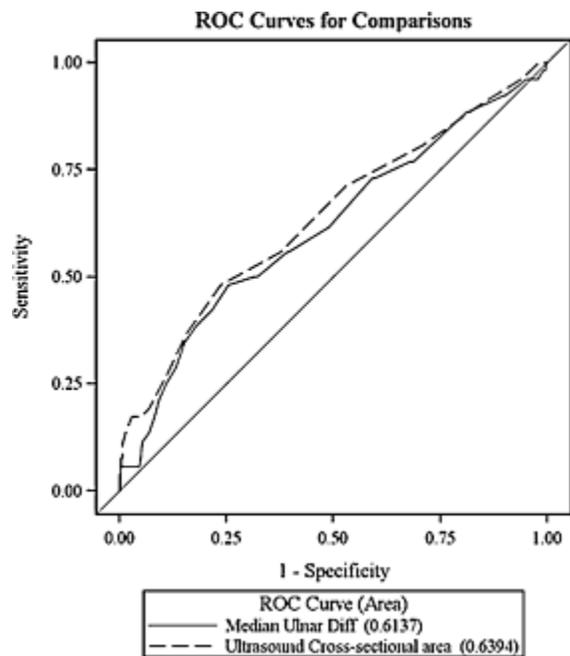


Figure 2. ROC curves to assess the diagnostic accuracy of nerve conduction studies (solid line: difference between the median and ulnar sensory velocities) and neuromuscular ultrasound (dashed line: cross-sectional area of median nerve at the wrist) are presented. No significant difference ($P = 0.542$) in diagnostic accuracy was detected between the 2 modalities.

DISCUSSION

In this study the accuracy of neuromuscular ultrasound as a screening tool for the diagnosis of CTS in a large population was assessed prospectively, and it was compared with nerve conduction studies, a more traditional diagnostic test for CTS. Neuromuscular ultrasound measurement of a single parameter (median nerve cross-sectional area at the wrist) demonstrated similar sensitivity and specificity to nerve conduction studies in which the median sensory nerve conduction velocity was compared with that of the ulnar nerve. This indicates that neuromuscular ultrasound, which is a painless, quick, inexpensive, and radiation-free imaging

modality, can be considered for screening large populations at risk for CTS in a manner similar to what has been done previously with nerve conduction studies.[9, 19]

Interestingly, neither ultrasound nor nerve conduction studies were particularly accurate in this study, which may have been due to several factors. First, and most importantly, the reference standard in this study was the Katz hand diagram. Although the hand diagram has a high negative predictive value, it is only moderately accurate itself for the diagnosis of CTS when used in large epidemiological studies, with a sensitivity of 64% and specificity of 73%.[20] The moderate accuracy of this reference standard likely resulted in lowered accuracy of the nerve conduction studies and neuromuscular ultrasound, which was a limitation acknowledged during conceptualization of this study. Although it would be ideal for each participant to have a detailed history and examination for CTS, and to use this conclusion as the reference standard, it was not feasible from a time and financial perspective. Participants already underwent a 1-hour-long interview, conducted by a non-clinician researcher, that focused on many aspects of their health and occupation, so further detailed assessment for CTS was not feasible. Using a different reference standard for diagnosis, such as one involving nerve conduction studies, would not have allowed for direct comparison of the accuracy of nerve conduction studies and ultrasound.

Other potential causes of decreased diagnostic accuracy of both modalities included limitations of the testing environment, such as electrical noise and a bright room. The ideal of using the most advanced electrodiagnostic and ultrasonographic equipment in electrically shielded dark rooms, with time to employ the most sophisticated comparative techniques (such as mixed-palmar or multidigit studies for electrodiagnosis and wrist-to-forearm ratio for ultrasound[21]) were likewise not feasible. Fortunately, the limitations, were systematic and unlikely to have affected 1 modality more than the other. In addition, both nerve conduction studies and neuromuscular ultrasound have demonstrated much higher accuracy when used in populations in which the diagnosis of CTS was established through traditional history and physical examination.[22] This suggests that both modalities likely would have higher accuracy as screening tests in this population if the reference standard was more accurate.

The sensitivity of neuromuscular ultrasound for the diagnosis of CTS greatly improved when other parameters were included in addition to nerve cross-sectional area. In those with at least 1 abnormality in median nerve cross-sectional area, echogenicity, mobility, or vascularity, the sensitivity of ultrasound increased to 89%. Another way to maximize sensitivity was to decrease the cut-off of the cross-sectional area to $<8 \text{ mm}^2$, which raised the sensitivity to 96%. Conversely, a cross-sectional area cut-off of $>18 \text{ mm}^2$ increased the specificity to 97%. Therefore, future screening studies could accurately include or exclude those with CTS based on the goals of the study using solely a single, quickly obtained parameter (median nerve cross-sectional area). In fact, a recently published study addressed just this issue and found that a median nerve cross-sectional area at the wrist $>9 \text{ mm}^2$ resulted in a sensitivity of 99% for the diagnosis of CTS, so the investigators suggested a potential change in the typical testing paradigm for CTS may be warranted, with ultrasound used as the initial screening modality.[23]

The strengths of this study include the prospective data collection, large number of participants, blinding of all examiners, inclusion of a broad spectrum of participants at risk for CTS, use of an appropriate and pre-specified gold standard, and generation of measures of diagnostic accuracy (sensitivity and specificity). As stated previously, the main limitation is that the Katz hand diagram is only moderately accurate for the diagnosis of CTS, but it is an appropriate reference standard. Other modest limitations are that the study involved a homogeneous population (Latino manual laborers); older nerve conduction study equipment was used; and ultrasonographic measures of mobility, echogenicity, and vascularity lack the quantitative rigor of the cross-sectional area measurement. Despite these limitations, the strengths of the study design would qualify this as a Class I study based on the American Academy of Neurology criteria for rating an article for diagnostic accuracy.[24]

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