

Original Article

Comparison of Accuracy of High-Resolution Ultrasound with Nerve Conduction Studies in Diagnosing Carpal Tunnel Syndrome

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Abstract

Background: Carpal Tunnel Syndrome (CTS) affects millions worldwide, causing hand pain, numbness, and weakness. Current diagnostic methods, like nerve conduction studies, have limitations. Recent data suggests high-resolution ultrasound offers comparable accuracy. With treatment options varying from conservative to surgical, precise diagnosis is essential. Ultrasound shows promise in improving diagnostic accuracy and patient outcomes.

Objective: To determine the diagnostic accuracy of high resolution ultrasound in diagnosing carpal tunnel syndrome taking nerve conduction test as gold standard.

Methods: The study obtained approval from the Hospital Ethical Board and enrolled 76 patients meeting selection criteria from Orthopedics, Neurosurgery, and Medicine OPD at the Department of Radiology, Sir Ganga Ram Hospital, Lahore. After obtaining consent and noting demographics, patients underwent wrist ultrasound using a 7.5MHz linear array transducer. The cross-sectional area of the median nerve at the carpal tunnel entrance was measured, categorizing patients by disease severity. Nerve conduction tests at Mayo Hospital determined sensory and motor fiber function. Results were categorized, confirming patients as positive or negative. Standard protocols were followed for patient management, and data were recorded in a proforma.

Results: The mean age of patients in this study was 39.95 ± 11.83 years, ranging from 20 to 60 years. Of the 76 participants, 39 (51.3%) were aged 20-40, and 37 (48.7%) were aged 41-60. Females comprised 59.2% of the population. Right side involvement was seen in 48.7%, and left side in 51.3%. The mean symptom duration was 31.67 ± 7.55 months, with 55.3% having symptoms ≤ 30 months. High-resolution ultrasound detected carpal tunnel syndrome in 90.79%, with diagnostic accuracy of 98.70%.

Conclusion: This study supports high-resolution ultrasound as an effective diagnostic tool for carpal tunnel syndrome, with strong sensitivity and specificity, suggesting its integration into clinical assessments for comprehensive diagnosis.

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Introduction

CTS presents a significant wrist condition characterized by the narrowing of the carpal tunnel, leading to compression of the median nerve by trauma or tumors.¹ This compression results in swelling of the

nerve and initial symptoms typically include tingling, numbness, and weakness in the distribution of the median nerve, which may progress to muscle atrophy.² Recognizing common symptoms such as discomfort, sensory abnormalities in the median nerve region, and compromised dexterity often prompts consideration of CTS.^{2,3}

Its diagnosis relies on a combination of clinical symptoms, physical examination findings, and positive provocative testing.⁴ Traditionally, nerve conduction investigations have been utilized for diagnosing CTS, although the cut-off points for anomalies vary.⁵ Despite its utility, nerve conduction testing has limitations, including false-negative and false-positive results, as well as being time-consuming, costly, and uncomfortable.^{6,7}

In contrast, high-resolution ultrasound has emerged as a reliable, non-invasive, and cost-effective diagnostic tool for CTS.⁸ A higher sensitivity and specificity of ultrasound has been reported, with values reaching 97% and 89%, respectively, on established thresholds.⁹ Additionally, ultrasound allows for real-time visualization of median nerve within the carpal tunnel, facilitating detection of nerve morphological changes and aiding in ruling out anatomical variations and space-occupying lesions.^{10,11}

While electrodiagnostic testing is often considered the "gold-standard" for diagnosing CTS, its drawbacks, including patient discomfort and variable false-negative rates, have prompted interest in alternative approaches.^{1,12} High-resolution ultrasound offers advantages such as non-invasiveness, widespread availability, affordability, and shorter procedural time, making it particularly advantageous in settings with limited resources and underdeveloped healthcare infrastructure.^{13,14}

Aggarwal et al.¹² previously identified carpal tunnel syndrome (CTS) prevalence at 96.0% using nerve conduction studies (NCS). Their study reported a diagnostic accuracy of 97%. Shan et al.¹³ added to this spectrum, presenting diverse diagnostic parameters, including positive predictive value (86.5%), negative predictive value (87.3%), sensitivity (90.6%), and specificity (82.5%). Additionally, Perteu et al.¹⁴ showcased remarkable ultrasound sensitivity (94.8%) and specificity (99.6%) in CTS diagnosis. However, the evidence is limited and needs further probe. By leveraging the advantages of ultrasound, clinicians can enhance diagnostic precision and facilitate timely intervention, thereby improving patient outcomes in the management of this prevalent wrist condition.

Methods

This comparative analytical study was conducted during the period between August, 2023 to July, 2024 and the patients were enrolled through non-probability convenient sampling after approval of synopsis from Ethical Review Committee, FJMU, Lahore. Sample size of 76 cases was calculated. Inclusion criteria were patients of both the genders with age 20-60 years and suffering from symptoms like tingling, numbness, pain, burning, and shock-like sensation, which radiates to thumb, index & middle fingers, hand weakness or clumsiness with nocturnal exacerbation. However, pregnant women and patients with vitamin B12 deficiency were excluded. Moreover, patients with uncontrolled hypertension (BP \geq 160/110mmHg), diabetes (BSR $>$ 200 mg/dl), anemia (hb $<$ 10g/dl), with thenar muscle atrophy, cervical radiculopathy, polyneuropathy, rheumatoid arthritis (on clinical examination) and suffering from chronic kidney disease/ chronic liver disease were also excluded. Consent forms were obtained and demographics i.e like name, age, gender, duration of symptoms, anatomical side were also noted. Then patients underwent ultrasound of wrist while patient was in sitting position facing towards examiner and forearm in supine position by using 7.5MHz linear array transducer (Aplio) by the researcher under supervision of the supervisor. The aim was to measure the cross-sectional area of the median nerve at the entrance of the carpal tunnel, using the pisiform bone as a fixed reference point. This was achieved by tracing a continuous line around the margins of the nerve with a caliper at cut-off of 10.5 mm².¹⁵ Margins of the nerve referred to margin outside the hypoechoic nerve fascicles and inside the hyperechoic nerve sheath. Patients were categorized into mild, moderate and severe disease. Then patients undergone nerve conduction test in mayo hospital, performed by consultant neurologist with assistance of researcher by testing sensory and motor fibers of median nerve. Sensory velocity and distal latencies were noted and findings were categorized according. Patients were confirmed as positive or negative on nerve conduction studies. All the patients were managed as per standard protocol. All the data was recorded in proforma. Data analysis was done in SPSS version 26.0. Numerical data like age, symptoms duration have been presented as mean \pm standard-deviation. Categorical data like gender, symptoms, anatomical site, have been presented as frequency and %. 2 \times 2 contingency table was developed to calculate the sensitivity, specificity, PPV, NPV and diagnostic accuracy of ultrasound." Data has been stratified for effect modifiers. Post-stratification, accuracy based analysis was done in each strata.

Results

Mean age of the patients in this study was 39.95 ± 11.83 years in the range of 20-60 years wherein 39 (51.3%) participants were in the age group of 20-40 years while remaining 37 (48.7%) were in age group of 41-60 years. Females were dominant in the study population as 45 (59.2%) were females. As regards anatomical side, right side was involved in 37 (48.7%) patients and left side was involved in 39 (51.3%) patients. Mean duration of symptoms in the study cohort was 31.67 ± 7.55 month wherein 42 (55.3%) patients had duration of symptoms equal or less than 30 months while 34 (44.7%) had duration of symptoms greater than 30 months. Data is given in Table 1. Symptoms of the patients at presentation have given in Figure 1. Frequency of carpal tunnel syndrome as per high resolution ultrasound was 90.79% while it was noted as 92.11% on nerve conduction studies. Data is given in Table 2. Diagnostic performance of solution ultrasound while taking nerve conduction studies as gold standard was noted as; sensitivity (98.57%), specificity (100.0%), positive predictive value (100.0%), negative predictive value (87.66%) and diagnostic accuracy to be 98.70% whereas prevalence of the disease was 90.79%. Data is given in Table 3. Stratification of diagnostic accuracy showed that in individuals aged ≤ 40 years ($n=39$), ultrasound (USG) demonstrated 100% sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), achieving 100% accuracy and a prevalence rate of 94.87%. For those aged >40 years ($n=37$), sensitivity decreased to 83.33%, though specificity remained 100%, with accuracy at 85.59% and NPV at 48.4%. Among males ($n=31$), USG exhibited perfect diagnostic performance, while in

females ($n=45$), sensitivity dropped to 80%, with an accuracy of 81.05%. For symptom duration, USG showed perfect accuracy for ≤ 30 months, but sensitivity decreased for >30 months, though specificity remained high at 100%. These findings highlight USG's overall strong diagnostic performance, with slight variations based on age, gender, and symptom duration. Pictures of normal and abnormal nerves on USG have been given as Figure 2.

Table 2: Frequency of CTS as per USG and NCS

Modality	Carpal Tunnel Syndrome	Frequency (n)	Percent (%)
High Resolution Ultrasound	Yes	69	90.79%
	No	7	9.21%
	Total	76	100.0 %
Nerve Conduction Studies	Yes	70	92.11 %
	No	6	7.89 %
	Total	76	100.0 %

Table 3: 2x2 Contingency Table to Determine Diagnostic Performance of High Resolution Ultrasound in diagnosing CTS taking NCS as Gold Standard

High Resolution USG	NCS		Total
	CTS	No	
CTS	69 ^a	0 ^c	79
No	1 ^b	6 ^d	7
Total	70	6	76

^a True Positive = 70,

^c False Positive = 0,

^b False Negative = 1,

^d True Negative = 5

Table 1: Baseline Characteristics of Study Sample

Characteristics	Participants (n=76)
Age (20-60 years)	39.95±11.83
• 20-40	39 (51.3%)
• 41-60	37 (48.7%)
Gender	
• Male	31 (40.8%)
• Female	45 (59.2%)
Anatomical Side	
• Right	37 (48.7%)
• Left	39 (51.3%)
Duration of Symptoms (months)	31.67±7.55
• ≤ 30 Months	42 (55.3%)
• >30 Months	34 (44.7%)

Statistic	Formula	Value
Sensitivity	$\frac{a}{a+b}$	98.57%
Specificity	$\frac{d}{c+d}$	100.0%
Accuracy	$\frac{a+d}{a+b+c+d}$	98.70%
Disease prevalence	$\frac{a+b}{a+b+c+d}$	90.79%
Positive Predictive Value	$\frac{a}{a+c}$	100.0%
Negative Predictive Value	$\frac{d}{b+d}$	87.66%

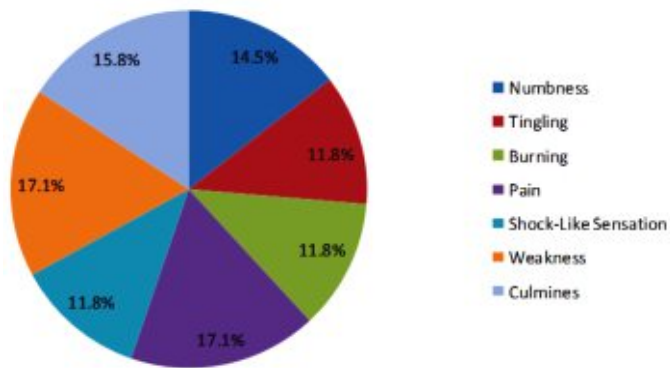


Figure 1: *Symptoms of Patients at Presentation*

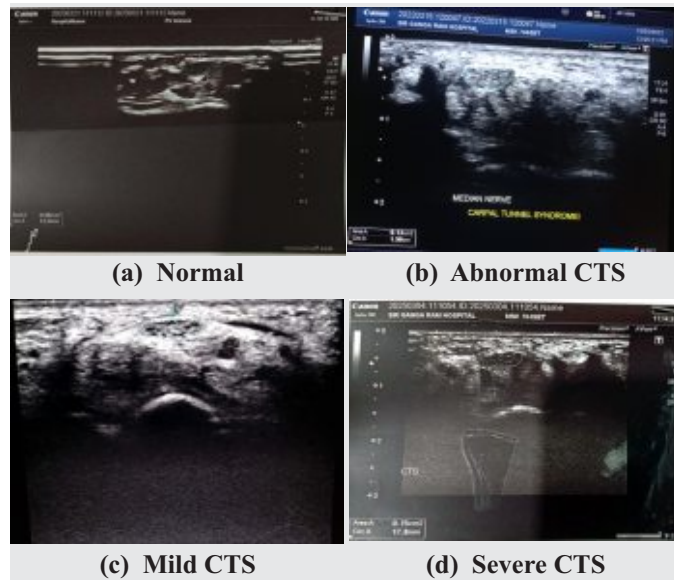


Figure 2: *Nerve Images on USG*

Discussion

CTS is a prevalent entrapment neuropathy characterized by compression of the median nerve within the carpal tunnel, leading to debilitating symptoms such as pain, numbness, and tingling in the hand.¹³ Accurate and timely diagnosis is crucial for effective management, and clinicians often rely on a combination of clinical assessments, nerve conduction studies (NCS), and high-resolution ultrasound (HRUS). This study aims to compare the diagnostic accuracy of HRUS with NCS in identifying CTS, assessing their respective strengths and limitations.^{14,16} The availability and cost-effectiveness of these diagnostic modalities play a pivotal role in healthcare decision-making.^{17,18} Understanding the comparative effectiveness of these tools is essential for clinicians to make informed decisions regarding diagnostic approaches, ultimately enhancing patient care and resource utilization. This investigation seeks to contribute valuable insights into optimizing diagnostic strategies for CTS, addressing the pragmatic consid-

erations of accessibility and economic feasibility in clinical settings.

Mean age of the patients in this study was 39.95 ± 11.83 years. Previously, a similar mean age in such study was reported as 40.7 ± 11.8 years by Roghani et al. in the United States. A little lower mean age of 36.02 ± 8.4 years was reported by El-Shintenany et al. in Egypt.^{19,20} However, Elnady et al. in Egypt and Draghichi et al. in Romania reported quite higher mean age of 50.2 ± 11.2 years and 62.7 ± 6.37 years, respectively.^{21,22} This variation in mean age is however, associated with different inclusion criteria of each study and geographical variations that must be addressed before interpretation.

In this study, males were dominant with 59.2% presentation while females were 40.8% of the study cohort. Our findings aligns with results of Roghani et al. who reported it 54.0%, Shan et al. who reported it 68.8% and El-Shintenany et al. who reported it 97.5%.^{19,13,20} This variation in gender representation in the backdrop of diagnosis of carpal tunnel syndrome highlights need to consider specific factors of diagnosis and its management.

As regards, anatomical side, right side was affected in 48.7% of the study population. El-Shintenany et al reported left side in 7.5%, right side in 42.5% and both sides in 50.0% patients.²⁰ Mean duration of symptoms in this study cohort was 31.67 ± 7.55 months which closely aligns with results of Draghichi et al. who reported mean duration of symptoms as 30 months (range 12-48 months).²² In this study, frequency of carpal tunnel syndrome as per high resolution ultrasound was 90.79% while it was noted as 92.11% on nerve conduction studies. Agarwal et al. reported frequency of carpal tunnel syndrome on NCS to be 96.0%.¹²

In our study, the frequency of carpal tunnel syndrome, as determined by high-resolution ultrasound, was identified in 90.79% of the participants. In comparison, nerve conduction studies revealed a slightly higher frequency of 92.11%. These figures contribute to the understanding of diagnostic prevalence using different modalities within the study population. It is noteworthy that our findings are consistent with previous research, as reported by Aggarwal et al.¹², where the prevalence of carpal tunnel syndrome determined through nerve conduction studies was noted to be 96.0%. The observed variations between ultrasound and nerve conduction studies frequencies highlight the nuanced diagnostic landscape of carpal tunnel syndrome. These results emphasize the importance of employing a comprehensive diagnostic approach and considering multiple modalities for accurate identification and characteri-

zation of the condition, thus informing optimal clinical decision-making and management strategies.

In our study, the diagnostic performance of high-resolution ultrasound, using nerve conduction studies as the gold standard, demonstrated a sensitivity of 98.57%, specificity 100.0%, PPV 100.0%, NPV 87.66%, and an overall diagnostic accuracy of 98.70%. Notably, prevalence of CTS in our study population was 90.79%. These results provide a comprehensive overview of the efficacy of high-resolution ultrasound in diagnosing carpal tunnel syndrome in comparison to the reference standard of nerve conduction studies. In contrast, Aggarwal et al.¹² reported a diagnostic accuracy of 97%. Additionally, Shan et al.¹³ presented PPV (86.5%), NPV (87.3%), sensitivity (90.6%), and specificity (82.5%) in their study, reflecting the diversity in diagnostic parameters. Furthermore, Perteu et al.¹⁴ reported impressive sensitivity (94.8%) and specificity (99.6%) for ultrasound in diagnosing carpal tunnel syndrome. These varied findings highlight the multifaceted nature of diagnostic modalities and emphasize the need for nuanced interpretation and consideration of different performance metrics when assessing the utility of high-resolution ultrasound in clinical settings.

The strengths of this study lie in its robust sample size, providing statistical power for meaningful conclusions. The inclusion of a comparative analysis with established diagnostic modalities, such as nerve conduction studies, enhances the study's clinical relevance. The comprehensive evaluation of HRS for CTS contributes valuable insights into its diagnostic performance. However, notable limitations should be acknowledged. The retrospective nature of the study may introduce information bias, and the sample may not fully represent diverse demographics, potentially introducing selection bias. Variations in operator skills and equipment in the ultrasound assessments could impact results. Despite these limitations, the study's findings offer valuable contributions to the understanding of diagnostic tools for carpal tunnel syndrome.

Conclusion

In conclusion, our study highlights the potential of high-resolution ultrasound as a valuable diagnostic tool for carpal tunnel syndrome. While acknowledging variations in diagnostic parameters across studies, the favorable sensitivity and specificity observed in our research support its clinical utility, suggesting integrating high-resolution ultrasound into the diagnostic armamentarium for carpal tunnel syndrome, emphasizing its role in comprehensive assessments.

Ethical Approval: The Institutional Review Board, Fatima Jinnah Medical University, Lahore approved this study vide letter No. 16-MS-Gynaecology/IRB.

Conflict of Interest: The authors declare no conflict of interest.

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Authors' Contribution:

SC: Analysis & interpretation of data, approval of final draft

H: Conception & design, acquisition of data, analysis & interpretation of data

VA: Data analysis, drafting of article

KS: Conception & design, Analysis & interpretation of data

MN: Interpretation of data, critical revision

AM: Analysis & interpretation of data.

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