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Ultrasound Evaluation of Median Nerve In Carpal Tunnel Syndrome and Correlation with Nerve Conduction Study

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ABSTRACT

Background: This study aimed to investigate the morphology of the Median Nerve in Carpal Tunnel Syndrome (CTS) through ultrasound and establish a correlation with findings from the nerve conduction velocity study.

Methods: After receiving ethical clearance and informed consent, 42 patients were enrolled from the Department of Neurology and underwent assessment in the Department of Radiodiagnosis. These patients underwent laboratory examinations to rule out secondary causes of CTS. Each underwent an ultrasound, with examiners blind to the Nerve Conduction Study (NCS) outcomes. Using NCS as the benchmark, we calculated the sensitivity and specificity of the ultrasound, focusing on the cross-sectional area (CSA) of the Median nerve. Statistical analysis using paired t-tests and the Wilcoxon Sign rank test compared the ultrasound and NCS findings.

Results: 42 CTS patients were studied. When benchmarked against NCS, the ultrasound showed concurrence in diagnosing Median Nerve entrapment neuropathy. There was significant variation between the ultrasound diagnosis and NCS parameters, as evidenced by a significance level of 0.000. Furthermore, the unaffected nerve's CSA proximal to the tunnel inlet displayed minimal variance between the two methods.

Conclusion: Variations in ultrasound metrics exist between CTS patients with moderate NCS irregularities and those with normal NCS. This indicates ultrasound's potential as an additional diagnostic tool, especially for early CTS cases without evident nerve conduction anomalies.

Key Words: *Carpal Tunnel Syndrome, Nerve Conduction Studies, Ultrasound*

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INTRODUCTION

The carpal tunnel (CT) is defined by wrist structures, including the triquetrum, hook of the hamate bone, and the pisiform bone on its medial side, alongside the flexor retinaculum. Within this tunnel, the median nerve and the flexor tendon are housed. The flexor digitorum superficialis and profundus tendons mark the medial boundary of the tunnel, with the median nerve situated superficially over the flexor pollicis longus tendon (1).

With an annual cost of $500 million, Carpal Tunnel Syndrome (CTS) impacts approximately 2.7% of the U.S. population. Predominantly, the diagnosis leverages electrodiagnostic tests like nerve conduction studies, although they can be uncomfortable and may not provide comprehensive insight into the median nerve's structure (2).

Gender disparities in CTS are evident. Women have a higher likelihood (0.7-9.2%) compared to men (0.4–2.1%) of developing CTS. Notably, incidence rates per 100,000 stand at 324 to 542 for women and 125 to 303 for men (3). For severe CTS cases, clinical signs include thumb movement restrictions, evident atrophy in the thenar eminence, and sensory alterations in the hand supplied by the median nerve. However, mild cases can be challenging to diagnose through clinical examinations alone, as the symptom distribution might not be distinctively related to CTS (4).

Provocative techniques such as the Phalen and Tinel tests, alongside carpal compression and hand elevation, offer diagnostic avenues. However, their sensitivity and specificity are moderate. Meta-analysis indicates a 68% sensitivity and 73% specificity for a positive Phalen's test, while Tinel signals have a 77% specificity but are less sensitive (5).

Diagnosing older individuals becomes intricate as their symptoms could be easily mistaken for other upper limb or hand musculoskeletal disorders, for instance, osteoarthritis in different joints or conditions like trigger finger and elbow degenerative diseases (6).

CTS's hallmark symptoms include paresthesia and pain covering the median nerve distribution, including the little, ring, and middle fingers (7).

CTS, the most prevalent nerve entrapment neuropathy, arises when the median nerve is compressed beneath the wrist's flexor retinaculum. Notably, its CSA increases proximally to the entrapment site. Though often idiopathic, contributing factors include persistent median arteries or a bifid median nerve. Additionally, conditions such as trauma, pregnancy, and diseases like diabetes or hypothyroidism can trigger it (8).

CTS diagnosis integrates physical examinations, neurophysiological results, and medical history. Here, electrophysiology emerges as the gold standard (9).

Ultrasonography (US) is gaining traction as an effective, non-invasive diagnostic tool for CTS. By detailing the nerve anatomy, US serves as a painless investigative approach. The CSA of the median nerve, as studied via sonography, holds potential as a diagnostic marker for CTS, as evidenced by Class A research. Multiple studies have highlighted a strong correlation between clinical severity and the median nerve's CSA at the wrist (10) (11).

In the realm of medical ultrasonography (MUS), EMG results of CTS reveal structural abnormalities like nerve swelling. MUS's efficacy extends to detecting other conditions and symptoms, such as nerve compression and enlargement in CTS patients. Moreover, space-occupying lesions like tenosynovitis, ganglions, and nerve tumors can be discerned using MUS (12) (13).

Intriguingly, several studies have posited US's diagnostic prowess in NCS-negative CTS patients, exhibiting typical CTS signs but normal ECGs. However, including patients with severe lesions in comparative studies could introduce bias. Thus, a more balanced approach would be to focus on mild NCS-positive CTS patients (14).

A challenge in diagnosing CTS is the absence of a definitive gold standard. For instance, ultrasound detected anomalies in a third of NCS-negative hands. In alignment with prior research, a strong correlation was observed between sonographic and electrophysiological parameters (15).

Despite its capabilities, sonography's effectiveness hinges on the operator's expertise and the equipment quality. Modern ultrasonic techniques like microvascular imaging and elastography may boost the specificity and sensitivity of CTS assessments. However, while MUS elucidates structural anomalies, it doesn't provide insights into nerve functionality, a domain where EMG is unparalleled (16).

Understanding anatomical anomalies, such as a bifid median nerve, is crucial for CTS treatment strategies. Prior to invasive interventions, recognizing these anomalies could be instrumental in assessing treatment outcomes (17).

Research highlights that mere ultrasonographic measurements at the carpal tunnel inlet might be insufficient to conclusively ascertain the degree of median nerve entrapment or its electrophysiological severity (18).

In exploring other imaging techniques, CT-MRI emerges as a reliable tool for analyzing wrist morphology, including tendons, muscles, and carpal bones. A plethora of studies have leveraged CT/MRI to delve deeper into CTS, unearthing unique insights (19) (20).

AIMS &OBJECTIVES

1. Evaluation of the Median Nerve morphology in Carpal Tunnel Syndrome using ultrasound
2. To correlate the ultrasound results with those obtained from the nerve conduction velocity study

METHODS AND MATERIALS

Source of data:

This study included Patients presenting with symptoms of Carpal Tunnel Syndrome referred to the Department of Radiodiagnosis and Imaging in Vydehi Institute of Medical Sciences and Research Institute, Bangalore. The institutional ethics committee prior to start of the data collection approved the study. Inclusion and exclusion criteria for the study were as follows:

Duration of study: March 2021 to July 2022

Inclusion criteria:

- Patients with any age group
- Clinical suspicion of unilateral carpal tunnel
- Nerve conduction study
- Patients who have given written informed consent for the study

Exclusion criteria:

- Patients with known malignant tumours in the wrist
- Patients who had undergone wrist surgery
- Who hadn't undergone Nerve Conduction Study

Methods of Data Collection:

After the patients were included in the study written informed consent were taken from all of them. Patients referred to the Department of Radiodiagnosis from the Department of Neurology with the clinical diagnosis of carpal tunnel syndrome and who have undergone Nerve conduction study will be evaluated by ultrasound. The usual procedure always included a comprehensive neurophysiological evaluation, in addition to a full clinical history and a careful physical examination. All of the patients underwent studies in the laboratory to determine whether CTS was caused by a secondary condition. The ultrasonographic examination was done in every patient. The examiner was blinded to the results of the Nerve Conduction Study.

RESULTS

The study was conducted in the Department of Radiodiagnosis at Vydehi Institute of Medical Sciences. The 'cases' were patients that were referred to the Department of Radiodiagnosis by the Department of Neurology. These patients had undergone a Nerve Conduction Study and showed findings of unilateral Carpal Tunnel Syndrome.

The 'control' was considered to be the contralateral wrist in the same patient with carpal tunnel syndrome.

In the current investigation, an increase in CSA was found in all of the median nerves that were involved in the "cases." This increase was found either at the level of the carpal tunnel inlet or within the carpal tunnel.

Neither at the location proximal to the carpal tunnel inlet nor at the location within the carpal tunnel did any of the median nerves that were part of the "control" group demonstrate an increase in CSA.

The amplitude and latency in wrists with normal nerve conduction study findings were compared with the CSA of the median nerve in the same wrist & the same parameters were compared with the abnormal/contralateral side.

A total sample size of 42 subjects was considered for statistical analysis. Amongst these 38 individuals, 33 were females & 9 were males.

Sensitivity & specificity was calculated based on the values extracted from the data as shows below:

1. Column A: CSA of the 'case' proximal to the Carpal Tunnel

Statistic	Value	95% CI
Sensitivity	100.00%	66.37% to 100.00%
Specificity	100.00%	2.50% to 100.00%
Positive Likelihood Ratio		
Negative Likelihood Ratio	0.00	
Disease Prevalence (*)	90%	
Positive Predictive Value (*)	100.00%	
Negative Predictive Value (*)	100.00%	
Accuracy (*)	100.00%	69.15% to 100.00%

2. Column B: CSA of the 'case' within the tunnel inlet:

:Statistic	Value	95% CI
Sensitivity	100.00%	54.07% to 100.00%
Specificity	50.00%	11.81% to 88.19%
Positive Likelihood Ratio	2.00	1.47 to 6.14
Negative Likelihood Ratio	0.00	
Disease Prevalence (*)	50.00%	21.09% to 78.91 %
Positive Predictive Value (*)	66.67%	47.33% to 81.66%
Negative Predictive Value (*)	100.00%	
Accuracy (*)	75.00%	42.81% to 94.51%

3. Column C: CSA of the 'control' proximal to the carpal tunnel inlet:

Statistic	Value	95% CI
Sensitivity	55.56%	21.20% to 86.30%
Specificity	62.50%	24.49% to 91.48%
Positive Likelihood Ratio	1.48	0.51to 4.31

Negative Likelihood Ratio	0.71	0.29 to 1.76
Disease Prevalence (*)	52.94%	27.81% to 77.02%
Positive Predictive Value (*)	62.50%	36.41% to 82.91%
Negative Predictive Value (*)	55.56%	33.55% to 75.58%
Accuracy (*)	58.82%	32.92% to 81.56%

4. Column D: CSA of the 'control' within the tunnel inlet:

Statistic	Value	95% CI
Sensitivity	40%	16.34% to 67.71%
Specificity	50%	11.81% to 88.19%
Positive Likelihood Ratio	0.80	0.29 to 2.20
Negative Likelihood Ratio	1.20	0.49 to 2.95
Disease Prevalence (*)	71.43%	47.82% to 88.72%
Positive Predictive Value (*)	66.67%	42.09% to 84.062
Negative Predictive Value (*)	25.00%	11.93% to 45.06%
Accuracy (*)	42.86%	21.82% to 65.98%

The continuous and categorical variables was represented in terms of their means +/- std deviation and percentages/proportions respectively. SPSS version 25 was used to analyse the data. Correlation between the ultrasound and nerve conduction findings was evaluated using Pearson's/Spearman's correlation. Comparison of the continuous variables (CSA and WFR) and categorical variables between the two techniques was done using paired t test and Wilcoxon Sign rank test respectively. A p value of <0.05 was considered significant for all analyses.

Our significance (alpha) level is .05. The Sig. column displays the p-value for the test. The results show that the p-value is 0.001 and 0.000 are less than .05 which means that the values are significant.

The t- test shows that the CSA of the control (N CSA) proximal to tunnel inlet has small t-value which means that there is very small difference in the sample .i.e that the sample taken in the study are similar to each other.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between ab N CSA prox to CT and N CSA proximal to tunnel inlet equals 0.	Related-Samples Wilcoxon Signed Rank Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .050.

In the above mentioned results the significant value is 0.008 based on the Wilcoxon Signed Rank Test. So the null hypothesis is rejected.

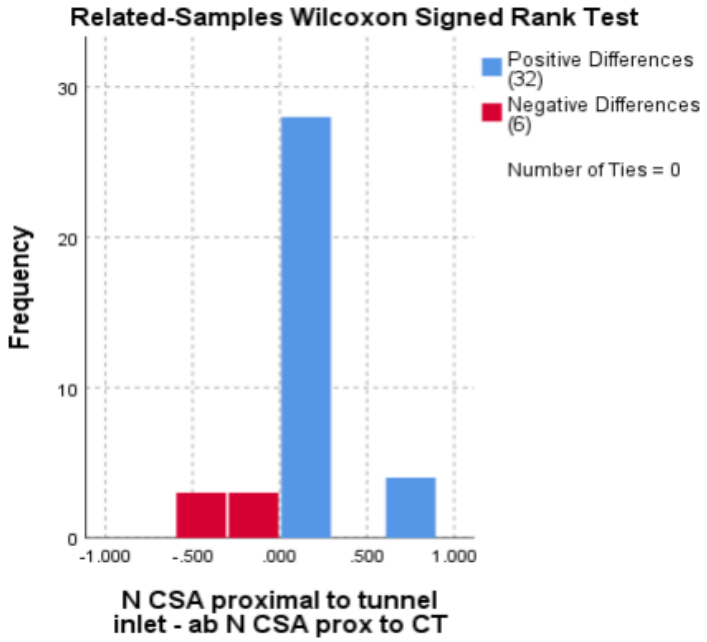
Related-Samples Wilcoxon Signed Rank Test Summary

Total N	38
Test Statistic	552.000
Standard Error	68.759
Standardized Test Statistic	2.640
Asymptotic Sig.(2-sided test)	.008

The Wilcoxon signed rank test compares your sample median against a hypothetical median. The Wilcoxon matched-pairs signed rank test computes the difference between each set of matched pairs, then follows the same procedure as the signed rank test to compare the sample against some median. Here the hypothesis says that there is a difference between the CSA of the 'case' proximal to CT and CSA of the 'control' proximal to the CT. This hypothesis is rejected as per the Wilcoxon Signed Rank test.

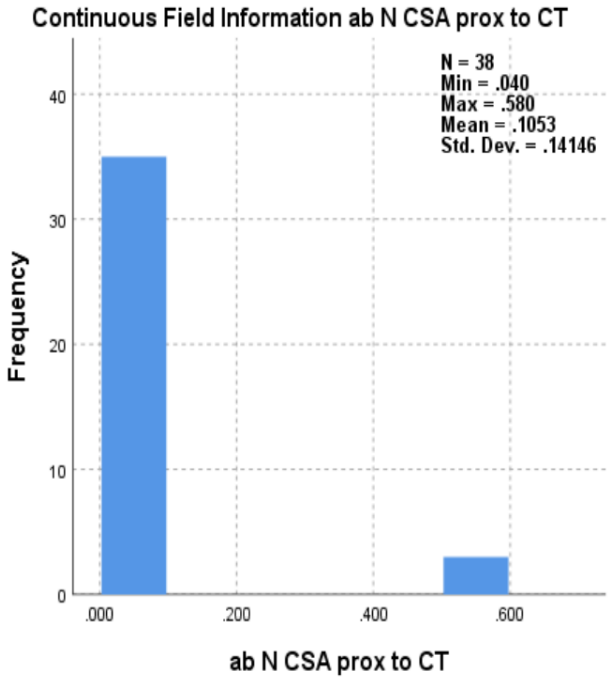
In the above table Wilcoxon Signed Rank test summary is presented where the standard error is 68.759 and the value of Asymptotic significance of 2-sided test is 0.008.

Fig. 1: Wilcoxon signed rank test of the CSA in control and CSA of the case proximal to the tunnel:



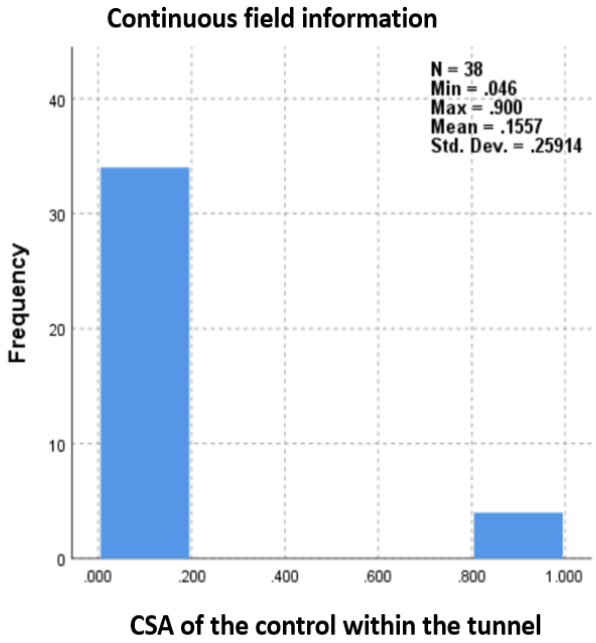
In the above displayed graph of Wilcoxon Signed Rank Test the Positive difference is 32 and the negative difference is 6. Here the number of ties is equal to zero.

Fig. 12: Continuous field information of the CSA in control proximal to the tunnel:



The graph shows the frequency distribution of CSA in case proximal to CT where the minimum value is .040 and the maximum value is 0.480. the Mean value is .1053.

Fig. 3: Continuous field information of the CSA in control within the tunnel:



The graph depicts the continuous field information CSA of the case proximal to tunnel. Here the minimum value is .046 and the maximum value is .900.The Mean value is .1557.

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between abN CSA at tunnel and N CSA at tunnel equals 0.	Related-Samples Wilcoxon Signed Rank Test	.202	Retain the null hypothesis.
Asymptotic significances are displayed. The significance level is .050.				

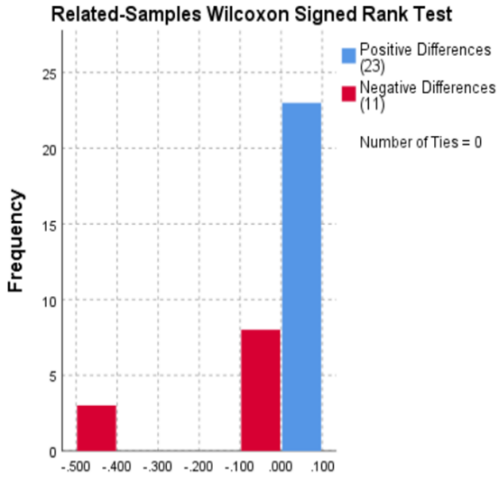
In this Hypothesis test summary the Median of difference between CSA of the 'case' at tunnel and CSA of the 'control' at tunnel equals is 0.202 based on Wilcoxon Signed rank test and the result is to retain the null hypothesis.

Null Hypothesis states that difference between the CSA of the 'case' and CSA of the 'control' which is accepted according to the test.

Related-Samples Wilcoxon Signed Rank Test Summary	
Total N	34
Test Statistic	372.000
Standard Error	58.408
Standardized Test Statistic	1.276
Asymptotic Sig.(2-sided test)	.202

Wilcoxon Signed Rank Test summary result is mentioned in the above table where the value of standard error is 58.408 and here the asymptotic significant value of 2-sided test is 0.202.

Fig. 4: Wilcoxon Signed Rank Test of the CSA in control & case within the tunnel:



CSA of the median nerve in the control & case – within the tunnel

This graph shows the frequency distribution of Wilcoxon Signed Rank test. Here this can be observed that the positive difference is 23 and the negative difference is 11. The number of ties is equal to zero.

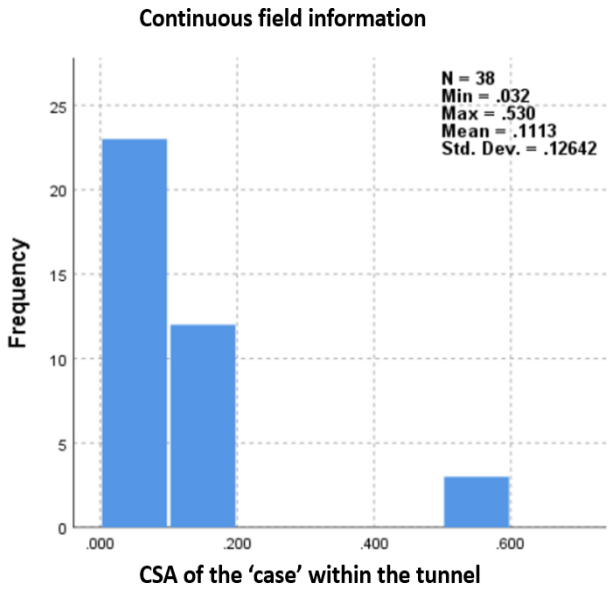
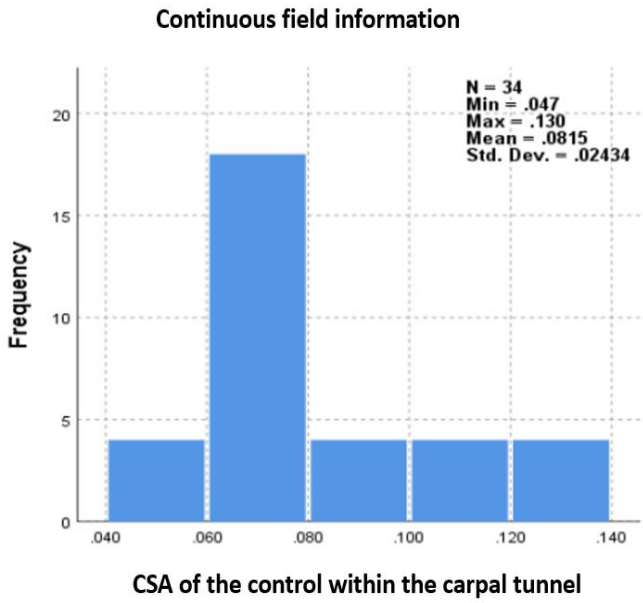


Fig. 16: Wilcoxon Signed Rank Test of the CSA of the case withinthetunnel:

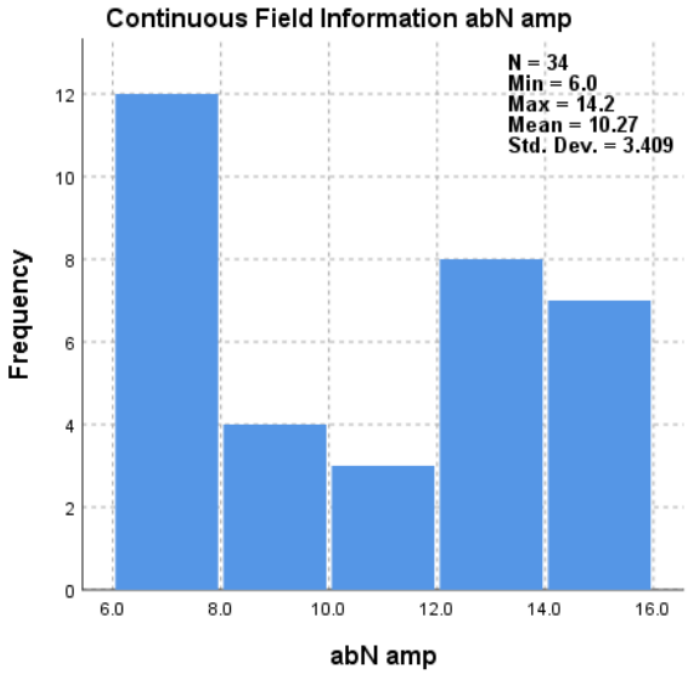
The graph depicts the CSA of the 'case' at tunnel where the minimum value is .032 and the maximum value is 0.530. The standard deviation value is .12642.

Fig. 5: Wilcoxon Signed Rank Test of the CSA of the control withinthetunnel:



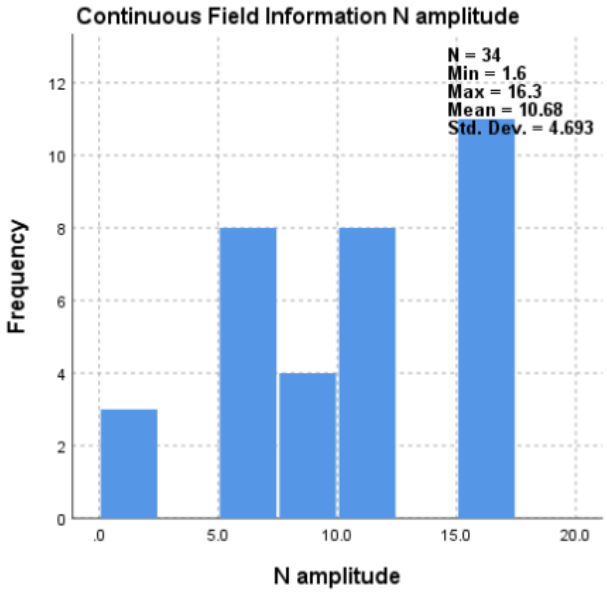
The above showed graph depicts the continuous field information of CSA of the control at tunnel where N=34. The minimum and maximum value are .047 and .130 respectively. The Mean value is .0815

Fig. 6: Continuous field information of amplitude in case:



The continuous information amplitude of the case graph depicts the minimum and maximum values as 6.0 and 14.2 respectively. The value of standard deviation in this case is 3.409.

Fig. 7: Continuous field information of amplitude in control:



The continuous field information amplitude of the control graph where N=34, the minimum and maximum values are 1.6 and 16.3 respectively. The standard deviation is 4.693.

DISCUSSION

The most prevalent kind of peripheral entrapment neuropathy is referred to as carpal tunnel syndrome (CTS). Over the course of the last several decades, there has been a dramatic rise in the study and diagnosis of musculoskeletal problems through the utilisation of sonography. Sonography was investigated as a potential replacement for nerve conduction studies (NCS) as a diagnostic tool for carpal tunnel syndrome (CTS), which was the focus of this particular investigation. However, nerve conduction examinations, despite the fact that they frequently show the level of the lesion, do not supply any geographic information about the nerve or its surroundings, which could be helpful in diagnosing the cause of the condition [(21)].

In spite of the fact that ultrasonography is a standard procedure in CTS, particularly for preoperative cases, electrophysiological tests are still necessary because the criteria for ultrasonography are not well established in respect to the Indian setting. It was reported that diagnostic ultrasound to make a diagnosis of CTS is an approach that is more cost-effective than the use of electrophysiological investigations [(22)].

In the present study, total 38 patients were included. The study results showed that there exists as negative correlation between the US and the nerve conduction study results. The Value of Pearson correlation of latency in controls is 1.

Ajeena et al (2013) reported that US examination of the median nerve is a better diagnostic method for CTS. In this prospective cross-sectional study, 35 female patients with varying degrees of CTS were included. Total 63 wrists of HRUS done (as proved by NCS)[(23)].

According to the results of this study, there are significant disparities in terms of sonography among clinically CTS individuals who have normal NCS and those who have mild NCS abnormalities[(24)]. We have demonstrated that the CSA is significantly reduced at the wrist when the NCS is negative, in compared to the CSA measured at the wrist when the NCS is only slightly positive. The significance of these sonographic changes was demonstrated in a group of patients who only had a marginally positive NCS for congenital heart disease (CTS). Previous studies have included participants who had severe electrophysiological anomalies, which may have the effect of magnifying the differences between the two groups [(25)]. As a result, eliminating bias and providing a more realistic picture of the link between NCS abnormalities and early changes in the morphology of the median nerve can be accomplished by restricting the population of NCS-positive individuals to those who only exhibit mild abnormalities.

Due to the lack of a "gold standard" for the identification of CTS, the accuracy of a great number of different diagnostic methods is substantially compromised. In addition, a patient with clinical CTS may be categorised as mildly NCS-positive in one laboratory, while being categorised as NCS-negative in another laboratory due to technical reasons and changes in normative values between centres. This can occur for a number of reasons. This is feasible because the normative values of each centre can be different from one another [26)].

Our research demonstrates that there are discernible distinctions between patients with mild NCS who test positive and those who test negative for NCS. Furthermore, the presence of an expanded nerve in this scenario substantially strengthens the likelihood that the patient has CTS.

This is because ultrasonography technique is capable of indicating changes in CT anatomy. Persistent median artery, Martin-Gruber anastomosis, median nerve bifid, variants of motor and inverted palmaris longus muscle, palmar cutaneous median nerve branches, etc[(1)].

These asymptomatic alterations can resemble the symptoms of CTS. Cartwright et al. investigated the wrists of 1026 manual labourers and discovered that CTS sufferers had more anatomical alterations at the CT than healthy workers [(2)].

In the present study the ultrasonographic examination of the median nerve showed that in patients with CTS this technique could diagnose presence of the condition with a 100% sensitivity and specificity. However, in controls where there is no disease present the technique were not as sensitive and specific as that of cases. The 100% positive predictive value of the technique in the cases showed the significance of this technique.

Torres-Cuenca et al. investigated the diagnostic sensitivity of ultrasound in patients with carpal tunnel syndrome. There were found to be statistically significant differences between the electrophysiological categories (mild, moderate, and severe; $p = 0.000$), in terms of the area of the median nerve [(27)].

Kortlever et al evaluated 565 NCS individuals for possible CTS. This study showed a sensitivities of 83%, 64%, and 97% and specificities of 96%, 97%, and 96%, respectively, using specific cut-off values [(28)].

In a variety of analytical techniques, the cut-off value for diagnostic median nerve pathology is kept in the range of 7.5-14 mm^2. However, the most reliable cut-off value for median nerve pathology in CTS investigations supported by NCSs is 9 mm^2 for CSA. The sensitivity of the NCA parameter in the CTS evaluation has been reported to range from 62% to 98%. Using a practical approach, Mhoon suggested that only patients with CSA greater than 9 mm^2 and less than 17 mm^2 might require additional NCS study to assess nerve status. This was supported by a comparison study with clinical testing and NCSs made on a diverse and sizable group of patients ($n = 127$) [(29)].

These modifications were observed in a variety of degrees proportional to the amount of growth. This was demonstrated by the fact that we discovered a substantial association between the cross-sectional area and the flexor retinaculum while researching the relationship between the various findings obtained from ultrasonography and one another.

CONCLUSION

Nerve-conduction tests have historically been used to diagnose CTS; however, there are differences in the cut-off points utilised to define what constitutes abnormalities.

Previous investigations are encouraging, and ultrasonography (US) has established itself as a reliable method for evaluating peripheral nerve health. This technique is also widely used in the evaluation of median nerve. It can give structural or anatomical details that make it easier to identify anatomical variations and coexisting conditions such ganglion cysts or tenosynovitis. In order to evaluate people with CTS, a variety of median nerve and carpal tunnel ultrasonographic measurements have been used.

According to the findings of the current study, there are differences in the US parameters of CTS patients who have substantial abnormalities on NCS and those who have normal NCS in those who have normal NCS. These distinctions are observable in people who have normal neurocognitive status (NCS). According to the results of the study, there are also indications that certain participants in the NCS-negative group can demonstrate variations in US parameters. This demonstrates that ultrasound has the potential to be a helpful supplemental test in individuals with early CTS, particularly in those patients who do not exhibit nerve conduction abnormalities.

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