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**Original research article**

# HIGH RESOLUTION ULTRASOUND IN EVALUATION OF CARPAL TUNNEL SYNDROME IN CORRELATION WITH ELECTRONEUROMYOGRAPHY

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## Abstract

**Background:** Entrapment of median nerve lead to carpel tunnel syndrome. Diagnosis of carpel tunnel syndrome requires a combination of clinical examination, radiological imaging and nerve conduction studies. This study aims to evaluate and to compare the efficacy of high resolution ultrasound with electroneuromyography studies in diagnosing this condition.

**Materials and Methods:** This prospective observational study was conducted in Department of Radio diagnosis of a Tertiary care hospital at Hyderabad, over a period of 12 months. The study was conducted including 55 subjects who presented with clinically suspected/diagnosed of carpal tunnel syndrome or patients with ENMG findings suggestive of Carpal tunnel syndrome **Results:** The mean age of study is 50.34 years ± 12.0 years. Females were more affected than males. Left hand was predominantly involved. Most common symptom was tingling sensation. ENMG detected 52 out of 55 patients to have carpel tunnel syndrome, while HR ultrasound was able to detect only 50 patients

**Conclusion:** High resolution ultrasound is a affordable, easily accessible diagnostic modality which can be used to detect the anatomical abnormalities of carpel tunnel so as to makes decisions during surgery easier.

**Keywords:** Carpel tunnel syndrome, high resolution ultrasound, electroneuromyography, entrapment neuropathy

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## Introduction

Carpal tunnel syndrome (CTS) is a combination of signs and symptoms resulting from compression of the median nerve as it pass through the rigid carpal tunnel in the wrist. Carpal tunnel syndrome, a common peripheral entrapment neuropathy, is recognized as one of the most important causes of workplace morbidity. Diagnosis of carpal tunnel syndrome is usually based on a combination of clinical signs such as the Tinel sign (tapping over the median nerve producing dysesthesias) and the Phalen sign (wrist flexion producing dysesthesias), and nerve conduction studies [1]. Nerve conduction studies remains an expensive and time-consuming procedure not readily accessible to many physicians who are encountering the disease. Recently Ultrasonography has emerged as an important alternative diagnostic investigation for CTS. More over imaging studies like ultrasound has the advantage of directly visualising the median nerve and rule out structural anomalies and pathological lesions causing compression of median nerve. Recent studies suggest that diagnostic imaging play an important role in the diagnosis of CTS, with the sensitivity of sonography approaching that of a nerve conduction study [2, 3, 4, 5]. Hence this study was conducted to evaluate the role of High resolution ultrasound in the diagnosis of Carpal tunnel syndrome in clinically suspected patients of having the disease in correlation with Electroneuromyography.

## Objectives

To determine various findings of High resolution ultrasound in carpal tunnel syndrome and to compare High resolution ultrasound with Electroneuromyography in diagnosis of Carpal tunnel syndrome.

## Materials and Methods

A prospective observational study was conducted among 55 subjects with clinically suspected/diagnosed of carpal tunnel syndrome or ENMG findings suggestive of Carpal tunnel syndrome in Department of Radio diagnosis of a Tertiary care hospital at Hyderabad, over a period of 12 months. Patients who were suspected of having other coexisting disorders, such as polyneuropathy or thoracic outlet obstruction and patients with history of previous wrist surgery and patients with a bifid median nerve were excluded from the study. Informed written consent taken from all the subjects and institutional ethical clearance was obtained prior to the start of the study.

**Sonography Technique:** Gray-scale and color Doppler sonography examinations were performed using a linear 5-12 MHz transducer (PHILIPS IU 22 Machine). All standard measures were considered during the process of USG.

**Image Analysis*:*** Median nerve involvement was characterized by evaluating five sonography features on a 2-point ordinal scale: present or absent. First, we assessed the presence of fasicular thickening. The normal median nerve is a bundle of hypoechoic nerve fascicles surrounded by hyperechoic epineural connective tissue, all of which is encased in the hyperechoic perineural sheath. Nerve edema alters the signal produced by nerve components and results in increased hypoechoic signal of the nerve. The mean cross-sectional area (CSA) of the median nerve was measured at proximal to carpal tunnel, mid tunnel and outlet. Median nerve cross sectional area $\geq$10 $mm^2$ was

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considered as positive for carpal tunnel syndrome
The 'tunnel inlet' referred to the level immediately deep to the proximal edge of the flexor retinaculum. The 'tunnel outlet' referred to the level immediately deep to the distal edge of the flexor retinaculum. Color Doppler sonography settings were adjusted for investigating low-flow vessels. Pulse repetition frequency was set at 800 Hz, and Doppler gain was adjusted to the maximum level that does not produce clutter.

**Gold Standard*:*** The diagnosis of carpal tunnel syndrome was indicated by the patient's history (nocturnal hand discomfort and sensory impairment in the distribution of the median nerve) and clinical examinations (Tinel and Phalen signs). Clinical diagnosis was confirmed by electro diagnostic testing. All patients underwent NCS on a MATUS (NICOLET) ENMG machine, VIKING QUEST Model. Standardized nerve conduction studies were performed by an electro diagnostician with 10 years experience, using surface electrodes and adjustment for skin temperature, which was kept above 33 °C. Abnormal nerve conduction was defined Diagnosis of CTS when the difference of more than 0.4 msec between the median and Ulnar sensory peak latencies or a prolonged median distal motor latency of more than 4 msec without abnormalities in the Ulnar nerve or proximal median nerve parameters.

**Statistical analysis:** Data was analyzed using SPSS 22 (IBM SPSS Statistics, Somers NY, USA) version software. Chi-square test or Fischer's exact test (for 2x2 tables only) was used as test of significance for qualitative data. Validity of USG was assessed by sensitivity, specificity, Positive predictive value, Negative predictive value and Diagnostic accuracy. P value of <0.05 was considered as statistically significant after assuming all the rules of statistical tests [6, 7, 8, 9].

**Results**

A total of 55 subjects with Clinical features of carpal tunnel syndrome were evaluated during the study period. Mean age of study population is 50.34 years ± 12.0 years in the range of 21-71 years. Females (64.8%) are more commonly affected than males and left hand (54.5%) was most common hand affected in Carpel tunnel syndrome. 40% of subjects presented with pain, 87.3% had Tingling sensation and 32.7% had Numbness.
Among the study population symptoms were present in both hands in 18 patients and only in one hand in 19 patients (Table 1).

**Table 1:** Profile of subjects in the study

| | | **Count** | **Percentage %** |
|---|---|---|---|
| Age | <40 years | **14** | **25.5%** |
| | 41 to 50 years | 13 | 23.6% |
| | 51 to 60 years | 19 | 34.5% |
| | >60 years | 9 | 16.4% |
| Gender | Female | 24 | 64.86% |
| | Male | 13 | 35.14% |
| | Pain in Hand | 22 | 40.0% |

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| | | | |
|---|---|---|---|
| Symptoms | Tingling sensation | 48 | 87.3% |
| | Numbness | 18 | 32.7% |
| Side | Left Hand | 30 | 54.5% |
| | Right Hand | 25 | 45.5% |

In our study out of 52 subjects positive in nerve conduction studies, 50 subjects show positive changes in high resolution ultrasound. Only 2 subjects were given as normal on ultrasound. Among 3 subjects negative in nerve conduction studies, 2 were given as positive in USG and 1 was negative.

When we consider individual parameters like cross section area 92.3% were positive in CSA and 7.7% were negative. In our study the mean CSA of the median nerve proximal to the tunnel in our study group is 13.9 $mm^2$ $\pm$ 3.1. Using CSA proximal to tunnel alone (CSA$\geq$10 $mm^2$) the sensitivity to diagnose CTS is 92.31%, positive predictive value is 94.12%, with diagnostic accuracy of 87.27% which is in accordance with previous studies. The mean CSA of the median nerve distal to the tunnel in our study is 11.3$mm^2$ $\pm$ 2.4, with a sensitivity of 73.08%, positive predictive value of 95% and diagnostic accuracy of 70.91%.

In our study a hazy homogenous with loss of fascicular discrimination had a high sensitivity with diagnostic accuracy of 87.27%. Hypervascularity of median nerve is noted in 49 subjects in our study and is absent in 6. When used alone it had a sensitivity of 90.38%, positive predictive value of 95.52% and diagnostic accuracy of 87.27%. (Table 2).

**Table 2:** Validity of Ultrasound findings in comparison with ENMG

| | | ENMG | | | | P value |
|---|---|---|---|---|---|---|
| | | Positive | | Negative | | |
| | | Count | % | Count | % | |
| Ultrasound Impression | Positive | 50 | 96.2% | 2 | 66.7% | 0.3152 |
| | Negative | 2 | 3.8% | 1 | 33.3% | |
| Median Nerve CSA Proximal to Tunnel | Positive | 48 | 92.3% | 3 | 100.0% | 0.7938 |
| | Negative | 4 | 7.7% | 0 | 0.0% | |
| Median Nerve CSA Distal to Tunnel | Positive | 38 | 73.1% | 2 | 66.7% | >0.999 |
| | Negative | 14 | 26.9% | 1 | 33.3% | |
| Fascicular Pattern | Thickened | 47 | 90.4% | 2 | 66.7% | 0.595 |
| | Not Thickened | 5 | 9.6% | 1 | 33.3% | |
| Median Nerve Vascularity | Hyper vascular | 47 | 90.4% | 2 | 66.7% | 0.595 |
| | Normal | 5 | 9.6% | 1 | 33.3% | |

In the study over all USG impression (i.e. when two (or) more individual parameters were postitve) had highest sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value and Diagnostic Accuracy when compared to individual parameters in USG (Table 3).

When we consider individual ultrasound parameters Diagnostic accuracy of Median Nerve CSA Proximal to Tunnel = Fasicular Pattern = Vascularity > Median Nerve CSA Distal to Tunnel.

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Sensitivity was highest for Median Nerve CSAProximal to Tunnel > Fasicular Pattern. = Vascularity > Median Nerve CSA Distal to Tunnel.
Specificity was highest for Median Nerve CSA Proximal to Tunnel = Fasicular Pattern = Vascularity >Median Nerve CSA Distal to Tunnel.

**Table 3:** Validity of all the parameters in Comparison with ENMG

| Parameter | CSA proximal to Tunnel | CSA Distal to Tunnel | Fascicular Pattern | Vascularity |
|---|---|---|---|---|
| Sensitivity | 92.31% | 73.08% | 90.38% | 90.38% |
| Specificity | -- | 33.33% | 33.33% | 33.33% |
| Positive Predictive Value | 94.12% | 95% | 95.92% | 95.92% |
| Negative Predictive Value | -- | 6.667% | 16.67% | 16.67% |
| Diagnostic Accuracy | 87.27% | 70.91% | 87.27% | 87.27% |

**Discussion**

Accurate detection of median nerve entrapment in patients with a clinical suspicion of carpal tunnel syndrome is essential. Many studies show that Ultrasonography can be an attractive alternative method in comparison with NCS for the primary evaluation of CTS in daily practice. In the present study, the efficacy of ultrasound for the diagnosis of CTS was evaluated. Nerve conduction studies (ENMG) were used as the gold standard diagnostic test for carpal tunnel syndrome [10]. The various ultrasonographic parameters used in the diagnosis of carpal tunnel syndrome are Cross Section Area of the median nerve proximal to the tunnel, distal to the tunnel, hypervascularity of median nerve and fasciular pattern.

A number of authors have reported the accuracy of sonography criteria of median nerve entrapment, and several studies have addressed the quantification of the nerve cross sectional area and its role in diagnosing carpal tunnel syndrome [2, 3, 4, 5, 11]. Review of these studies reveals a number of discrepancies in the accuracy of various sonography criteria in diagnosing carpal tunnel syndrome. Although, almost all published studies on the sonographic diagnosis of carpal tunnel syndrome agree that nerve swelling is the main sonography criterion indicating carpal tunnel syndrome, the swelling position (i.e., proximal to the carpal tunnel or at the tunnel inlet or outlet) and the critical threshold for nerve cross- sectional area differ considerably among those studies. The sensitivity and specificity of ultrasonographic measurements vary widely among studies. Many authors demonstrated that the increase in CSA at the tunnel inlet had the highest sensitivity and specificity [11, 12]. There was also disagreement about the exact localization of tunnel inlet. Most authors considered the proximal edge of the flexor retinaculum, approximately at the level of the distal radioulnar joint, as the tunnel inlet.

The sensitivity of the CSAs ranged from 48% to 89% and the CSA cut off at which the value was considered abnormal varied from 9 to 15 $mm^2$. These discrepancies result from many factors: selection criteria of patients and controls, gold standard for diagnosis of CTS, electro diagnostic methods, levels of CSA measurement and ultrasonographic cut-off values.

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Mallouhi *et al*., [5] in their study examining the relationship of age and sex to carpal tunnel syndrome revealed that female sex and age greater than 50 years were significantly associated with carpal tunnel syndrome. In particular, age between 50 and 69 years showed the highest association with carpal tunnel syndrome. The mean age in our study group is 50 yrs, the most commonly affected age group is 50-60 yrs and woman are more affected by the disease than men with 24 (64.86%) females and 13 (36.4%) males which is in accordance to the above studies [3, 5].

The most common clinical symptoms in our study population is tingling sensation of the hand area innervated by the median nerve (with approximately 87% of the patients) followed by pain in the affected hand. Although subjects with bifid median nerve were excluded from the study, ultrasound has the additional advantage of directly visualizing the structural anomalies like bifid median nerve and persistent median artery which cannot be diagnosed on nerve conduction studies. Diagnosing these structural anomalies is crucial before undertaking for surgery.

In a study conducted by Kok Yu-chan *et al*. concluded that CSA proximal to the tunnel inlet with a threshold of 0.10 cm2 gave the best diagnostic accuracy with a sensitivity of 70.4. In our study the mean CSA of the median nerve proximal to the tunnel is 13.9 $mm^2$ $\pm$ 3.1. Using CSA proximal to tunnel alone (CSA>10 $mm^2$) the sensitivity to diagnose CTS is 92.31%, positive predictive value is 94.12%, with diagnostic accuracy of 87.27% which is in accordance with previous studies.[13] However the specificity and negative predictive values are very low, these may be attributed to the fact that sample size is small and no controls were selected.

The mean CSA of the median nerve distal to the tunnel in our study is 11.3$mm^2$ ± 2.4, with a sensitivity of 73.08%, positive predictive value of 95% and diagnostic accuracy of 70.91%. In concordance with previous studies median nerve CSA proximal to the tunnel is more sensitive in diagnosing CTS. The sensitivity of Ultrasonography may increase if more than one parameter is combined in the diagnostic criteria. In our study, combined CSA criteria at either of 2 levels (proximal to or at the tunnel inlet) yielded higher sensitivity and specificity than if they were considered alone.

Qualitative appearance of the median nerve is a useful ultrasonographic parameter. Several studies have commented on the fascicular thickening in the median nerve [14, 15]. Other qualitative features reported included the compressed appearance of the nerve on longitudinal view and the presence of intraneural hypervascularization using Colour Doppler ultrasound.[5] In our study, a hazy, homogeneous appearance with fascicular thickening in the enlarged nerve at the level of proximal to the tunnel inlet had a relatively high sensitivity of 90.38% with diagnostic accuracy of 87.27%. However, qualitative assessment of the nerve is subjective and as such cannot be used as a standalone criterion for CTS but as complementary to quantitative measurements.

Hypervascularity of median nerve is noted in 49 hands in our study and is absent in 6 hands. When used alone it showed a sensitivity of 90.38% positive predictive value of 95.92% and diagnostic accuracy of 87.27%.

An interesting observation made in our study is median nerve hypervascularity is positive in cases in which nerve swelling proximal to tunnel was absent and are positive on NCS. This can be correlated with pathophysiology of carpal tunnel syndrome as hypervascularity is present in early stages of the disease process which is followed by nerve swelling. Similar observation is made in a study done by Mallouhi *et al*., [5] that

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color Doppler sonography tends to show the pathologic intraneural vasculature, thus permitting recognition of hypervascularization in the median nerve even before the development of nerve swelling and edema. This indicates that color Doppler sonography may allow early detection of median nerve involvement in carpal tunnel syndrome and therefore enable early initiation of suitable treatment, which may well improve prognosis [5].

Another observation made in our study is that rather than using single ultrasound parameter when two (or) more parameters were used as a criteria for giving positive diagnosis of carpal tunnel syndrome the sensitivity, specificity, positive predictive value and diagnostic accuracy was higher. When we consider individual ultrasound parameters median nerve Cross section Area proximal to the tunnel and median nerve hypervascualrity are the most important parameters in the diagnosis of carpal tunnel syndrome. Our study also estabilishes the fact the median nerve CSA cut off of CSA>10mm$^2$ proximal to tunnel can be used as the ultrasound criteria for diagnosing the carpal tunnel syndrome in Indian population as there were no significant previous studies conducted in Indian population.

**Table 4:** Comparison with previous studies

| | **Sensitivity of CSA Proximal To Tunnel** | **Sensitivity of CSA Distal To Tunnel** | **Sensitivity of Median Nerve Hyper Vascularity** | **Sensitivity of Fascicular Pattern** |
|---|---|---|---|---|
| Present Study | 92.31% | 73.08% | 90.38% | 90.38% |
| Mallouhi *et al.* [5] | 91% | - | 95% | 80% |
| Azami *et al.* [3] | 99.2% | 96.7% | - | - |
| Kok Yu-Chan *et al.* [13] | 70.4% | 66.7% | - | 81.5% |
| Moghtaderi *et al.* [16] | 83% | 36% | - | - |

## Conclusion

From the present study we conclude that the high resolution ultrasound is an effective alternative diagnostic modality to nerve conduction studies in diagnosing carpal tunnel syndrome. Ultrasound has the advantages of ease of accessibility with lower cost and more acceptance than nerve conduction studies. Ultrasound also helps in identifying the structural abnormalities and anatomical variations of the carpal tunnel which are critical before undergoing surgery. This study also establishes the diagnostic accuracy of high resolution ultrasound in diagnosing carpal tunnel syndrome in Indian population.

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**Limitations of the Study**

- The main limitation of our study is that only patients with nerve conduction studies were included. Because nerve conduction studies are performed only in patients with a high clinical suspicion of carpal tunnel syndrome.
- Spectrum and selection bias are inherent in this type of hospital based study because the patients represented those with severe enough symptoms to warrant a referral in the first place. Generalization of our results regarding accuracy ultrasonography might not be applicable in primary care.

**Conflict of Interest:** None.

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