ORIGINAL ARTICLE

Ultrasonography Study of Median Nerve in Patients of Carpal Tunnel Syndrome and its Correlation with Nerve Conduction Study in A Tertiary Care Institute of Eastern India

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Abstract

Introduction: Carpal tunnel syndrome (CTS) involves symptoms from median nerve compression in carpal tunnel. Diagnosis relies on symptoms, signs and median nerve conduction study (NCS). High-resolution ultrasonography (HRUS) and MRI are non-invasive methods for assessing the median nerve, with HRUS being better for dynamic examinations.**Aims & Objectives:** This study aims to evaluate diagnostic utility of B-mode ultrasonography and Doppler study in clinically diagnosed CTS and to assess its specificity and sensitivity for CTS diagnosis.**Materials and Methods:** HRUS of median nerve was performed on 130 clinically diagnosed CTS patients. Sonomorphologic features and intraneural vascularity were assessed and USG parameters were correlated with NCS to determine accuracy and reliability.**Results:** Nerve swelling had the highest sensitivity (80.3%) and accuracy (80.67%). Difference in cross-sectional area at tunnel inlet and pronator quadratus showed high accuracy (98.67%) and 100% sensitivity compared to NCS. Intraneural vascularity using Doppler had 100% specificity and PPV for CTS.**Conclusion:** Among USG criteria, nerve swelling provided best detect ability of CTS with tunnel inlet being most accurate location for increase in area of median nerve. Differences in CSA at level of tunnel inlet and pronator quadratus showed comparable accuracy to NCS. Intraneural vascularity was highly specific for CTS.Hence ultrasonography can be an alternative diagnostic modality for CTS.

Key Words

Carpal tunnel syndrome, Ultrasonography, Nerve conduction test

Introduction

Carpal tunnel syndrome (CTS) is one of the most common Peripheral entrapment neuropathies of the upper extremity leading to workplace morbidity. It is defined as the spectrum of Signs and symptoms due to compression of the median nerve at the carpal tunnel.

Currently, the prevalence of carpal tunnel syndrome is approximately 2.7-5.8% of the general adult population, with a lifetime incidence of 10-15%, depending on occupational risk[1]. The commonly affected age group is 30 - 60 years with high prevalence in women (F: M- 2-5:1). Various factors including obesity, diabetes, increased

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age, and occupational strain govern its prevalence.The diagnosis of carpal tunnel syndrome is based on the amalgamation of symptoms, clinical signs such as Phalen's and Tinel's sign[2,3], and electrophysiological study of the median nerve. However, false positive and negative results of nerve conduction studies have been cited, encouraging us to find a new alternative and evolved investigational modality for the diagnosis.

High-resolution ultrasonography (HRUS) and MRI have emerged as feasible non-invasive alternative modalities for assessing median nerve in CTS patients[4,5]. Both techniques enable the perception of nerve compression characteristics including altered signal, increased cross-sectional area, flattening of the median nerve, and bowing of the flexor retinaculum. Diagnostic Ultrasonography has become popular because of its non-invasiveness, lack of radiation, readiness of use, cost-effectiveness, and ability to make dynamic examinations possible. Recently, MRI imaging has also become an alternative, but less cost-effective.

The present study aims to evaluate the role and diagnostic utility of B-mode Ultrasonography and Doppler study in carpal tunnel syndrome and to evaluate the specificity and sensitivity of Ultrasonography as a diagnostic tool for the diagnosis of carpal tunnel syndrome comparing it to the gold standard electro-physiological studies.

Material and Methods

The present study was carried out in the Department of Radiodiagnosis of our institute in collaboration with Department of General Medicine & Neurology over two years. The study was approved by the ethical committee of this institute (IEC Appln. No- 664, dt-10/03/2021).

130 patients and 150 wrists with clinically suspected carpal tunnel syndrome (as per American Academy of Neurology 1993) of any age group were included in this cross-sectional study after obtaining due consent. They were subjected to Ultrasonography and Colour Doppler test and were followed up with nerve conduction test to diagnose carpal tunnel syndrome.

The patients were grouped according to age, sex, presenting symptoms, laterality, and USG parameters like nerve edema, nerve swelling, nerve flattening, palmar bowing of flexor retinaculum, and intraneural vascularity using Colour Doppler.

High-frequency ultrasound and Doppler Sonography examinations were performed using the Samsung HS 70A Ultrasound Machine frequency transducer with a range of 4-18 MHz. Patients were seated in front of the examiner with hands kept on the lap of the patient in the supine and neutral wrist position and fingers semi-flexed. Very little pressure and a thick layer of gel (gel standoff pad) were applied for better results.

The following characteristics of the median nerve were noted [6]:

1. **Nerve edema:** Loss of normal honeycomb structure of nerve was observed.
2. **Nerve swelling:** It was defined as an enlargement of the cross-sectional area (CSA) of the nerve to 0.11 cm^2 or more within or proximal to the carpal tunnel. They were measured at 3 locations namely at the distal radio-ulnar joint, at the carpal tunnel inlet, and at pronator quadratus. The difference between the maximum CSA and CSA measured at the level of pronator quadratus was also calculated and assessed as a predictor for carpal tunnel syndrome.
3. **Nerve flattening:** It was defined as a decrease in the minor axis combined with an increase in the major axis of the median nerve in the carpal tunnel and flattening ratio (nerve's major to its minor axis) of at least 3.
4. **Bowing of flexor retinaculum:** It was determined as displacement of the palmar apex of the retinaculum 2 mm or more from the straight line between its attachments to the trapezium tubercle and the hamate hook.
5. **Colour Doppler** study of median nerve was done to determine the presence of any intraneural vascular structures not related to a persistent median artery.

Patients with a history of trauma, tumor, or surgery are excluded from the study.

Statistical Analysis

The data collected was analyzed with IBM-SPSS statistical software (version 23.0). In the analysis, stepwise logistic regression analysis was used to determine the threshold value of the median nerve's cross-sectional area for diagnosis of carpal tunnel syndrome, for the categorical variables such as sex, laterality, symptoms, certain USG parameters and Doppler flow, frequency analysis or percentage analysis were used. To find the significance in the categorical data, chi-square test was used. All the statistical tools were carried out at the level of significance of 95% and the probability – p value <0.05 was considered significant. Multivariate stepwise logistic

Table 1: USG Parameters Correlation With Nerve Conduction Study

USG PARAMETER		NCS POSITIVE	NCS NEGATIVE
NERVE SWELLING	POSITIVE	106	3
	NEGATIVE	26	15
NERVE EDEMA	POSITIVE	49	2
	NEGATIVE	83	16
NERVE FLATTENING	POSITIVE	58	3
	NEGATIVE	74	15

Table 2: USG Parameters Correlation With Nerve Conduction Study

USG PARAMETER		NCS POSITIVE	NCS NEGATIVE
PALMAR BOWING OF FLEXOR RETINACULUM	POSITIVE	44	2
	NEGATIVE	88	16
INTRANEURAL VASCULARITY	POSITIVE	25	0
	NEGATIVE	107	18

Table 3: Results of ROC Curve

	AREA (IN MM)	P VALUE	SENSITIVI	SPECIFICI	PPV	NPV	ACCURAC	95 % CONFIDEN INTERVAL
CSA AT DISTAL RADIO-ULNAR JOINT	0.865	<0.003	69.70%	83.33%	96.84%	27.27%	71.33%	0.795-0.935
CSA AT TUNNEL INLET	0.890	<0.001	80.30%	83.33%	97.25%	36.59%	80.67%	0.836-0.944
CSA AT PRONATOR QUADRATUS	0.779	<0.001	68.18%	83.33%	96.77%	26.32%	70.00%	0.686-0.873

Table 4: Comparison Between Diagnostic Performance of Individual B Mode Criteria and Doppler Findings

USG PARAMETERS	SENSITIVITY(%)	SPECIFICITY(%)	PPV(%)	NPV(%)	ACCURACY(%)	P VALUE
NERVE SWELLING	80.3	83.33	97.25	36.59	80.67	<0.001
NERVE EDEMA	37.12	88.89	96.08	16.16	43.33	<0.001
NERVE FLATTENING	43.94	83.33	95.08	16.85	48.67	<0.004
PALMAR BOWING OF FLEXOR RETINACULUM	33.33	88.89	95.65	15.38	40.00	<0.001
INTRANEURAL VASCULARITY	18.94	100	100	14.4	28.67	<0.001
DIFFERENCE IN CSA	100	88.89	98.51	100	98.67	<0.001

regression analysis was performed to determine the best sonographic predictors (presence of nerve edema, swelling, vascularity, flattening, and bowing of flexor retinaculum).

The receiver operating characteristics (ROC) curves were used and area under the curve was calculated to find sensitivity, specificity, PPV and NPV for cross-sectional areas at proximal wrist, tunnel inlet and pronator teres and results were compared.

Results

In our study, the mean age of the patients was 38 years with maximum number of cases between 30-39 years of age. Female preponderance was found with more involvement of the right-side wrist.

We defined nerve swelling as an increase in the cross-

sectional area of the nerve to 11 mm^2 or more at tunnel inlet. Out of all the three locations, the inlet of carpal tunnel was found to be the most reliable one as found after comparing the ROC curves (table 3). The tunnel inlet CSA had the highest sensitivity of 80.30% and accuracy of 80.67% with P value of <0.001 suggesting it is highly significant (*Fig. 2*).

The difference in cross-sectional areas at the level of tunnel inlet and pronator quadratus ranged from 1 to 8 mm2. The mean difference was found to be 3.39 mm^2 with a median of 3 mm2. Our study showed that it had a sensitivity of 100%, specificity of 88.89% and NPV of 100% with an accuracy of 98.67%, which was remarkably high as compared to NCS (*Fig. 3*).

The nerve edema had a sensitivity of 37.12% and specificity of 88.89% with an accuracy of 43.33%. The sensitivity and specificity of nerve flattening were found to be 43.94% and 83.33% respectively with an accuracy of 48.67%, which was lower than that of nerve swelling parameter results (*Table 1*).

The palmar bowing of the flexor retinaculum had a sensitivity of 33.33% and a specificity of 88.89%. The accuracy was found to be 40.00% (*Fig. 4*).

Our study depicted that intraneural vascularity had 100% specificity with 100 % PPV in diagnosing carpal tunnel syndrome, suggesting that the presence of vascularity was highly specific for carpal tunnel syndrome (P-value <0.001) (*Table 2, Fig. 5*).

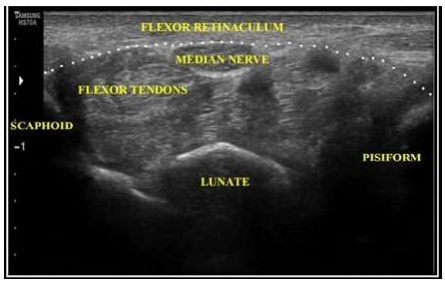

Fig.1 Normal Anatomy of Carpal Tunnel Inlet on USG

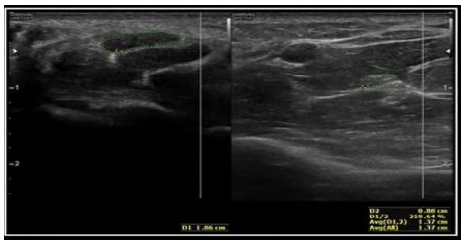

Fig.3 CSA of Median Nerve at Tunnel Inlet is 18 mm2 (nerve swelling), CSA of Median Nerve at Pronator Quadratus level is 8 mm2. Difference in CSA is >2 mm2.

Discussion

In a study conducted by Mondelli *et al*.[7], the prevalence of carpal tunnel was found to be 79.7% among women and 20.3% among men. In our study, there was a female preponderance with 65.38 Percentage of prevalence. This points towards the anatomical difference of wrist in males and females with a smaller volume of carpal tunnel in females.

We defined nerve swelling as an increase in the cross-sectional area of the nerve to 11 mm^2 or more at tunnel inlet. Out of all the three locations, the inlet of carpal tunnel was found to be the most reliable one as was found out after comparing the ROC curves. The tunnel inlet CSA had the highest sensitivity of 80.30% and accuracy of 80.67% with P value of <0.001 suggesting it is highly significant. our study is in accordance with the Lin *et al* [8] study &Mallouhi *et al*.[9] study stating in comparison with nerve conduction studies, nerve swelling showed the highest accuracy (91%) among Grayscale Sonography criteria with a CSA cut-off of 0.11 cm^2.

We also calculated the difference in cross-sectional areas at the level of tunnel inlet and pronator quadratus and correlated with the nerve conduction study results. The difference in the cross-sectional area ranged from 1 to 8 mm^2. The mean difference was found to be 3.39 mm^2 with a median of 3 mm^2. Our study showed that it had a

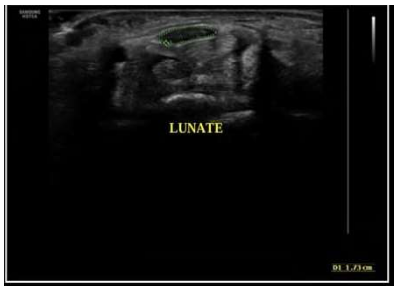

Fig.2 Increased CSA of Median Nerve Indicating Nerve Swelling at Tunnel inlet in Electro-Physically Diagnosed Case of Carpal Tunnel Syndrome.

Fig 4. Bowing of Flexor Retinaculum (>3 mm) Seen at Tunnel Inlet in Electro-Physically Diagnosed Case of Carpal Tunnel Syndrome

Fig.5 Intra Subtance Vacularity of Median Nerve in NCS Postive Patient Using Doppler Scan

sensitivity of 100%, specificity of 88.89% and NPV of 100% with an accuracy of 98.67%, which was remarkably high as compared to NCS. This is in agreement with Klauser *et al* [10].

The nerve edema had a sensitivity of 37.12% and specificity of 88.89% with an accuracy of 43.33%. This did not confer any additional diagnostic value compared with NCS for diagnosis of carpal tunnel syndrome which was in agreement with the study conducted by Miedany *et al* [11].

The sensitivity and specificity of nerve flattening were found to be 43.94% and 83.33% respectively. This criterion had an accuracy of 48.67%, which was lower than that of nerve swelling parameter results. This corresponds with a study conducted by Buchberger *et al* [12], where he studied 20 wrists with symptoms of carpal tunnel syndrome using USG and found that nerve flattening was present in 13 of them and deduced nerve flattening a reliable indicator of carpal tunnel syndrome.

The palmar bowing of the flexor retinaculum had a sensitivity of 33.33% and a specificity of 88.89%. The accuracy was found to be 40.00%. This was lower than the findings described in the Kim *et al*[13] study indicating sensitivity and specificity of 87.2% and 93.3% respectively.

Our study depicted that intraneural vascularity had 100% specificity with 100% PPV in diagnosing carpal tunnel syndrome, suggesting that the presence of vascularity was highly specific for carpal tunnel syndrome which was much higher than Ghasemi-Esfe *et al*.[14] Study, but in accordance with the study conducted by Shintenawy *et al* [15] & Lin *et al*[8]**.** The P-vale was <0.001 suggesting the association to be very significant.

In our study, the sensitivity and accuracy of nerve swelling and flattening were higher in comparison with previous studies, while that of nerve edema and palmar bowing of FR were concordant with other studies (*Table 4*).

The additional parameter that we measured in our study-difference in CSA between tunnel inlet and at pronator quadratus showed 100% sensitivity and NPVV with 98.67 % accuracy which agreed with previous studies (*Table 4)*.

We found out that high-resolution USG can enable us to get precise median nerve cross-sectional area and therefore better characterization of nerve involvement.

Conclusion

The conclusions derived from our study are:

- High Frequency with Doppler Ultrasound is a useful tool for the evaluation of carpal tunnel syndrome.
- Out of all the criteria, nerve swelling provided the best detectability of carpal tunnel syndrome. Sonography is comparable to NCS in the diagnosis of CTS and should be used as the initial test of choice.
- Out of the 3 locations, the tunnel inlet was found to be the most accurate location to look for an increase in the area of the median nerve.
- The difference in cross-sectional areas at the level of tunnel inlet and pronator quadratus had remarkably high accuracy as compared to the NCS with 100% sensitivity and NPV. Hence this criterion should be included in the initial USG screening of CTS.

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