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Role of power Doppler and gray-scale ultrasound of the median nerve in the evaluation of carpal tunnel syndrome: A comparative analysis between sonographic and surgical measurements of the median nerve

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ABSTRACT

Background: Carpal tunnel syndrome (CTS) is the prevalent cause of pain, numbness, tingling, and weakness. It is known that whenever the median nerve, a major peripheral nerve of the upper limb, originating from the forearm into the palm of the hand, becomes pressed or squeezed at the wrist, it leads to a condition commonly known as CTS. **Aims and Objectives:** The present study has been objectively conducted to assess the role of grey scale and power Doppler ultrasound of the median nerve at the wrist in evaluating CTS. The comparative analysis between USG findings and surgical findings of median nerve in CTS will also be made. **Materials and Methods:** The present prospective study has been conducted at the SKIMS-MC, Srinagar for a period of 6 months from January 2022 to June 2022 in the Department of Radio diagnosis and Imaging in association with the Department of Orthopedics. A total of 30 patients have been included in the study. The cases were referred from Department of Orthopedics with clinically characterized CTS. **Results:** Out of total 30 patients; 03 (10%) were males and 27 (90%) were females with a male to female ratio of 1:9. We observe that vascularity of median nerve was present in (56.7%) and absent in (43.3%) patients. The median nerve thinning and indentation were reflected by (80%) patients and the same was absent among (20%) patients, we did not find any agreement between surgical and sonographic parameters with the mean difference of 2.527 mm between sonographic and intraoperative perimeters, the difference was statistically significant (P<0.001, CI 95%). **Conclusion:** The present study demonstrated that ultrasonography aided with power Doppler precisely detected CTS cases. Evidently, we find a significant difference between surgical and sonographic parameters with the mean difference of 2.527 mm between sonographic and intraoperative perimeters.

Key words: Carpal tunnel syndrome; Gray scale; Median nerve; Power Doppler

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INTRODUCTION

There is no doubt that carpal tunnel syndrome (CTS) is the prevalent cause of pain, numbness, tingling, and weakness. It is known that whenever the median nerve, a major peripheral nerve of the upper limb, originating from the forearm into the palm of the hand, becomes pressed or squeezed at the wrist, it leads to a condition commonly known as CTS. This very syndrome was firstly explained in mid-eighties; however, the first elucidation of surgery for opening the carpal tunnel dates back to 1933.[1] Even if the majority of cases suffering with CTS are idiopathic, albeit trauma, acromegaly, intake of oral contraceptive pills, chronic disease such as diabetes, hypertension,

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thyroid, autoimmune disorder, and pregnancy trimesters can also be its causal factors.[2] In the literature, population studies have reported a difference in the prevalence of CTS between male and females; for women, it has been reported around 9% in women and 0.6% among males.[3] The prompt and timely diagnosis always leads to good outcomes and restricts permanent and further affliction of CTS; however, unattended management and delaying diagnosis often results in the permanent damage of median nerve. The symptomatic features of CTS may be apparently different from patient to patient but swollen hands, tingling, or numbness in palm and fingers are some commonest symptomatic characteristics. In spite of the fact, CTS is commonly diagnosed with the help of clinical history and physical examination but at times, it is very difficult to diagnose such a thenar muscle atrophy by merely clinical and physical examination. Electomyography has been treated as a gold standard for the complicated diagnosis of CTS but given the fact that it produces false negatives with a plausibility rate varying from 10% to 20% and lacks information specific to median nerve itself surrounding tissues.[4,5] MRI and ultrasonography has been exploited by a good corpus of radiologists over the last layers to diagnose possible CTN with satisfactory precision.[6] Because apart from the fact that USG is a simple, non-invasive, and valuable tool for confirming the diagnosis of CTS, it can specifically detect the features of median nerve compression and space occupying lesions such as ganglia, neural tumors, and tenosynovitis.[7] Moreover, to assess the degree of severity of CTS before operational management, the power Doppler ultrasound might be a useful imaging method. The present study has been objectively conducted to assess the role of grey scale and power Doppler ultrasound of the median nerve at the wrist in evaluating CTS. The comparative analysis between USG findings and surgical findings of median nerve in CTS will also be made.

Aims and objectives

The present study has been objectively conducted to assess the role of grey scale and power Doppler ultrasound of the median nerve at the wrist in evaluating CTS. The comparative analysis between USG findings and surgical findings of median nerve in CTS will also be made.

MATERIALS AND METHODS

The present prospective study has been conducted at the SKIMS-MC, Srinagar for a period of 6 months from January 01, 2022, to June 22, 2022, in the Department of Radio diagnosis and Imaging in association with the Department of Orthopedics. A total of 30 patients have been included in the study. The cases were referred from Department of Orthopedics with clinically characterized CTS. Following inclusion and exclusion criteria were adopted to randomly select the patients:

Ethical consideration

A properly written informed consent was taken from each participant/guardians. To maintain the confidentiality of participants, covertness, and dignity, the details were not disclosed. Moreover, the ethical approval of the study was taken from the Institute of Ethical Committee, SKIMS, Medical College, Srinagar.

Inclusion criteria

Patients with clinically characterized CTS were included in the study.

Exclusion criteria

The following criteria were excluded from the study:

1) Pregnant patients, patients with the previous wrist surgery or injury, clinical suspicion of any other neuropathies, for example cervical spondylosis were excluded from the study.
2) All patients with suspected underlying disorders that might be associated with neuropathies diabetes mellitus, thyroid disease, connective tissue disorders, and renal and hepatic diseases.

Imaging

All imaging examinations were performed using a linear array transducer of 9–13 mega-Hertz (MHz) frequency connected to a real-time ultrasound machine with pulsed and color Doppler options. The patient was seated supine with the forearm extended and the fingers semi extended on a flat surface facing the examiner. Undue excess pressure of the transducer over the wrist was avoided to minimize sampling errors. The median nerve was examined axially and longitudinally along the carpal tunnel by gray-scale and power Doppler US. The gray-scale was used to detect the compression criteria of the median nerve including median nerve edema, swelling, and flattening as well as increased bowing of the flexor retinaculum. The power Doppler was used to detect intra neural hyper vascularization of the median nerve. The normal median nerve is formed of hypoechoic bundle of fascicles surrounded by hyperechoic epineuria connective tissue; all are enclosed in a hyperechoic nerve sheath. Nerve edema causes altered signals of the nerve structures resulting in an increase in the hypoechoic nerve signal. Nerve swelling was defined as an enlargement of the cross-sectional area (CSA) of the median nerve to 11 mm 2 or more within the carpal tunnel. The CSA of the nerve was defined as the area of the nerve bundles in the perineural fibrous tissue. Axial images of the median nerve were taken at three levels. Level (1), located just 10 cm proximal to pisiform bone in forearm (in the distal forearm at the level of proximal third of pronator quadratus) (CSA1). Level (2) located at the pisiform bone level (CSA2). Level (3) located at the hamate bone level. A CSA of the median nerve was measured by means of direct tracing with electronic calipers around the margin of the nerve on sonograms at the first and second levels. The cross-sectional area difference (DCSA) was obtained by subtracting CSA1 from CSA2. Level (3) was used to calculate the flattening degree by calculating the ratio (the flattening ratio) between the largest diameter and the diameter perpendicular to this finding. The presence of increased palmar bowing of the flexor retinaculum was detected when the palmar apex of the retinaculum was displaced 2 mm or more from the straight line between the trapezium tubercle and the hamate bone. Power Doppler US was done after the gray-scale US to calculate the number of vessels in the median nerve along the carpal tunnel. Standardized machine settings were selected to reach the highest degree of sensitivity of detection of low velocity and low blood flow volume. The color box of the power Doppler was limited to the region of interest. The pulsed wave spectral Doppler imaging was performed after visualization of power-flow signals, using the lowest filter setting (125 Hz). Moreover, to confirm the power Doppler signals that represent true arterial or venous flow, a spectral Doppler tracing was acquired. The sonographic perimeter of the median nerve was obtained by drawing a continuous line around the boundary of the nerve. A single surgeon operated all the patients to standardize the surgical technique. Median nerve surgical perimeter was measured by means of a suture thread placed around the nerve in the same location of the sonographic measurement. Thinning and indentation of the median nerve were noted. Hyperemia of the median nerve was noted.

RESULTS

In this section, the results of the study will be described in tabular and graphical form: Out of total 30 patients; 03 (10%) were males and 27 (90%) were females with a male to female ratio of 1:9. The mean age of patients in our study was 43 years with majority of patients belonging to the age group of (40–49) years.

We observe that "paresthesia only" was the predominant symptom accounting for (56.6%) cases followed by "paresthesia with nocturnal pain" observed in (16.7%) cases. Noctural pain only was observed in 6.7% cases (Table 1).

We observe that the most of the patients accounting for (63.3%) had tinel test positive followed by (16.7%) patients with phalen test positive. Around (10%) patients tested positive for both tinel and phalen, while as (3.3%) had thenar atropy. However, (6.7%) patients with thenar atropy had both tinel and phalen test positive (Figure 1).

The mean cross-sectional area of median nerve at forearm level (CSA1) and carpal tunnel inlet (CSA2) was 7 mm² and 15.33 mm², respectively. The areal difference (DCSA) between CSA1 and CSA2 was 8.27 mm². The mean flattening ratio in our study was 2.5 ranging from 1.8 to 3.8, with flattening ratio of 2 or more was observed in 83.3% of patients. Moreover, the mean bowing of flexor retinaculum in our study was observed as 2.5 mm (Table 2).

We observe that vascularity of median nerve was present in (56.7%) and absent in (43.3%) patients (Table 3).

Table 4, displays the median nerve thinning and indentation were reflected by (80%) patients and the same was absent among (20%) patients.

We assessed hyperemic and edematous median nerve among patients and found that it is present in (63.3%) and absent in (36.7%) patients (Table 5).

Table 1: The distribution of symptoms among patients

Symptoms	Frequency	Percent
Paresthesia only	17	56.6
Paresthesia and Nocturnal Pain	5	16.7
Noctural Pain only	5	16.7
Noctural Pain and Weakness	2	6.7
Weakness only	1	3.3
TOTAL	30	100

Table 2: Flattening ratio of patients

FR	Frequency	Percent
2 or More	25	83.3
Less than 2	5	16.7
Total	30	100
Mean	2.5	Range: (1.8–3.8)

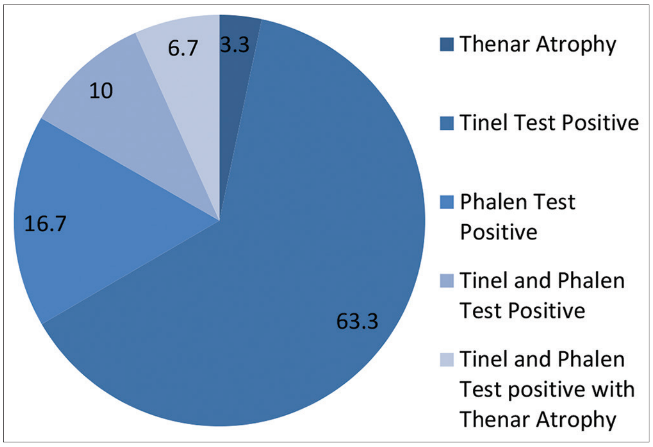

Figure 1: Showing distribution of patients as per physical signs

The patient showed mean sonographic perimeter of 16.250 mm with upper and lower values of 17.1201 mm and 15.3799 mm (95% CI). Same patients show mean surgical perimeter of 18.777 mm with the upper and lower values of 19.6327 mm and 17.9206 mm (95% CI) and the difference was significant (Table 6).

DISCUSSION

In the present study on the assessment of the role of grey scale and power Doppler USG on the median nerve at the wrist in evaluating CTS and to compare sonographic findings with surgical findings, we have comprehensively analyzed patients' data on the basis of demographic, clinical, radiological, and surgical data. We observed that out of 30 studied patients; (90%) were females and only (10%) were males. In consonance to the literature, the predominance of females with CTS has been reported by a good corpus of medicos.[3,8,9] In the present study, we found that the average age of patients was 43 years, with majority of them belonging to the age interval group of (40–49) years, consistent with this; CTS among individuals has been reported to occur in the age group of (40–60) years.[10] The most common symptom among studied subjects was found to be "paresthesia only" accounting for (56.6%) cases followed by "paresthesia with nocturnal pain" observed in (16.7%) cases. Noctural pain only was observed in 6.7% cases. Contemporary to the literature; CTS has been reported to be commonly accompanied with paresthesia, pain, and less commonly associated with weakness.[11] In Kendall's series on 327 patients, around (95.7%) had paresthesia, (38%) had nocturnal symptoms only, (58%) reported mild symptoms through day and night, but severe at night, however, (5%) had symptoms during the day only.[12] The present study revealed that the most of the patients accounting for (63.3%) had only Tinel test positive followed by (16.7%) patients with only Phalen test positive. Around (10%) patients tested positive for both Tinel and Phalen, while as (3.3%) had thenar atropy. However, (6.7%) patients with thenar atropy had both Tinel and Phalen test positive, these results are comparable with the studies of numerous authors.[3,8] It is known that CTS is largely diagnosed with the presence of clinical symptoms and nerve conduction, albeit it has been reported that some patients around 13–27% patients have false normal nerve conduction studies; therefore, alternative diagnosis with the help USG is useful. Buchberger et al., were first to quantifiably enumerate the anatomic changes in CTS with the help of sonography; they showed that an rise in the proximal or middle CSA of median nerve to 10 mm², a distal flattening ratio above 3, or a displacement of the flexor retinaculum above 4 mm are essentially suggestive sonographic signs of CTS.[13] It is known that there is a sudden change in the diameter of the median nerve in the longitudinal view, especially at the entry of the tunnel in cases of CTS. Therefore, the measurement of the nerve diameter just before the tunnel inlet in addition to measurement at the carpel tunnel might contribute to sonographic diagnosis of CTS.[14] If the degree of the nerve swelling in the carpal tunnel is compared with the proximal CSA of the nerve, a DCSA measurement (area difference between CSA1 and CSA2) will compensate for the inter individual variability in the CSA of the median nerve and yield a more accurate diagnosis of CTS and provide additional confirmatory criterion for the diagnosis of CTS.[7] With this in mind, we measured the CSA at two levels and obtained CSA1 and CSA2 values. The mean cross-sectional area of median nerve at forearm level (CSA1) and carpal tunnel inlet (CSA2) was 7 mm² and 15.33 mm², respectively.[15] The areal difference (DCSA) between CSA1 and CSA2 was 8.27 mm². CSA1 values ranged from 4 to 12 mm², CSA2 values ranged from 12 to 20mm² and DCSA ranged from 7 to 13 mm. Likewise to our study, the authors like Mallouhi et al., and Sarría et al., reported comparable measurements on CSA and DCSA.[16,17] Multiple studies have proposed a cutoff range of values for CSA

Table 3: Vascularity distribution of median nerve on Doppler

Status	Frequency	Percent
Present	17	56.7
Absent	13	43.3
Total	30	100

Table 4: Median nerve thinning and indentation distribution

Status	Frequency	Percent
Present	24	80
Absent	06	20
Total	30	100

Table 5: Hyperemic and edematous median nerve distribution

Status	Frequency	Percent
Present	19	63.3
Absent	11	36.7
Total	30	100

Table 6: Sonographic versus surgical perimeter of median nerve

	N	Mean	Min	Max	P-value
Sonographic parameter	30	16.250±2.330	15.37	17.12	0.001
Surgical parameter	30	18.777±2.29	17.92	19.63	

of median nerve and reported thresholds for the CTS diagnosis in the literature vary from 9 to 15 mm^2. Median CSA measurement is reliably accepted diagnostic method but at times, only CSA measurement may vary with other patient's characteristics factors. The mean flattening ratio in our study was 2.5 ranging from 1.8 to 3.8, with flattening ratio of 2 or more was observed in 83.3% of patients. Moreover, the mean bowing of flexor retinaculum in our study was observed as 2.67 mm. However, mean flattening ratio has been reported by some authors as poor predictive of CTS because of its high variability.[18-20] The presence of increased palmar bowing of the flexor retinaculum was determined to be 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. Determination of its degree was seldom done in the previous studies due to its low sensitivity and specificity of sonographic diagnosis. In our study, patients of CTS showed palmar bowing of flexor retinaculum varying from 1.5 to 4.6 mm with an average value of 2.67 mm. Power Doppler US is the most sensitive to flow and is used to document diminished blood flow in the median nerve as a result of high sensitivity to slow flow, no angle dependency, and no aliasing.[21,22] We observed that vascularity with arterial waveform of median nerve was present in (56.7%) and absent in (43.3%) patients. Nerve vascularity was found associated with symptoms such as paresthesia and pain. We found that 80% of our patients had thinning and indentation of the median nerve while as hyperemic and swollen median nerve was seen in 63.3%. The study evaluated the correlation between the sonographic and surgical perimeters in CTS. The surgical perimeter was considered as an actual of the median nerve, since the nerve was measured during surgery and confirmed with a certified ruler. In our study, we observed that generally, the sonographic perimeter is smaller than the surgical perimeter. The patient showed mean sonographic perimeter of 16.250 mm with the upper and lower values of 17.1201 mm and 15.3799 mm (95% CI). Same patients show mean surgical perimeter of 18.777 mm with the upper and lower values of 19.6327 mm and 17.9206 mm (95% CI). After the application of paired t-test, we did not find any agreement between surgical and sonographic parameters with the mean difference of 2.527 mm between sonographic and intraoperative perimeters, the difference was statistically significant ($P<0.001$, CI 95%). Likewise to our study, Alves et al., and others also reported higher mean values of sonographic parameter compared to surgical parameter.[6,23]

Limitations of the study

The limitation of the study was that the studied patients constituted a sample and therefore a large sample studies are warranted.

CONCLUSION

The present study demonstrated that ultrasonography aided with power Doppler precisely detected CTS cases. Evidently, we find a significant difference between surgical and sonographic parameters with the mean difference of 2.527 mm between sonographic and intraoperative perimeters. We recommend large sample studies to evaluate median nerve measurements in other diseases different from CTS, objectively to verify whether changes in median nerve perimeter are accompanied with the post-carpal tunnel release among patients without compressive derangement of the nerve in the wrist.

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Authors Contribution:
MF- Designed the study and prepared the draft of manuscript; **SB-** Performed review literature and wrote discussion; **HAL-** Did the cases and performed statistical analysis and interpreted the same; and **TAD-** contributed in writing orthopedic terminology and disease status

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