Original Article

Ultrasound: A Screening Tool for Carpal Tunnel Syndrome

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Abstract

Background: Electrodiagnostic test is considered as the gold standard for diagnosis of carpal tunnel syndrome (CTS). Ultrasonography provides a simple non-invasive means of visualising peripheral nerve pathology.

Objective: The objective of the study was to assess the role of ultrasonography in CTS and its correlation with the present day gold standard of nerve conduction studies (NCS).

Materials and Methods: A prospective cohort size of 100 subjects was calculated based on a hypothesized sensitivity of 90% and a confidence interval of 85-95%. All 100 subjects, 64 controls and 36 patients underwent nerve conduction studies and USG. Transverse images of the median nerve were obtained at three levels: proximal to the carpal tunnel inlet, at the carpal tunnel inlet and at the carpal tunnel outlet. The flattening ratio was also assessed at the tunnel inlet and outlet. Statistical analysis was done to corelate the ultrasound findings at each level with nerve conduction studies and calculation of the positive and negative predictive values. The cut offs of the cross-sectional areas of the median nerve at the three anatomical levels on ultrasonography were taken at the best sensitivity and specificity according to the ROC curve.

Results: We found that at any one anatomical level, the sensitivity of ultrasound to detect carpal tunnel syndrome by increase in the cross-sectional area of median nerve as compared to the nerve conduction studies is 90%.

Conclusions: At 45% specificity, ultrasonography could be used as a non-invasive and easily available screening tool in carpal tunnel syndrome. Also, the best level to look for nerve compression is at the level of the carpal tunnel inlet.

Key words: **Carpal tunnel syndrone, ultrasound, median nerve.**

Introduction:

Carpal tunnel syndrome (CTS) is a common upper limb entrapment neuropathy caused by the compression of the median nerve in the wrist[1]. CTS became widely known among the general public in the 1990s because of the rapid expansion of office jobs and increased use of computers. CTS was found to have an estimated lifetime risk of 10% and its prevalence being 5% in the general population with a female preponderance ranging from 3:1 to 23:1[2]. Diagnosis of this condition is mainly based on the history of symptoms (tingling, numbness, pain and burning sensation in the hand), provocative factors (repetitive movement of the wrist, sleep), mitigating factors (shaking the hand, changes in hand posture) followed by electrodiagnostic tests which are considered as the gold standard.

Diagnostic ultrasonography is non-invasive, there is no radiation, its readiness of use, cost-effectiveness and ability to make dynamic examinations possible, makes it a popular investigation tool for musculoskeletal disorders and pain management interventions. Peripheral nerve ultrasonography is emerging as a promising diagnostic tool for entrapment neuropathies particularly CTS, by demonstrating enlargement of the nerve, bowing of the flexor retinaculum, swelling ratio, and increase in the cross-sectional area of the media nerve in the carpal tunnel [3-18] as it provides a simple non-invasive means of visualising nerve pathology.

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Most of these studies, however, have not demonstrated the true diagnostic use of US as the NCS results have been used as reference standards. This study was done to see if ultrasonography can be used as a screening tool for CTS based on the sensitivity and specificity, and also compares the US and NCS for CTS. This study is aimed to find the value of sonography for CTS diagnosis so that it can be used especially in medical set-ups where tests like electrodiagnostic studies and MRI are not easily available.

Materials and Methods:

The study was conducted in the Department of Physical Medicine and Rehabilitation, in a tertiary care hospital in south India. The participants were patients with symptoms of CTS, referred from the out-patient services of the departments of Hand and Leprosy Reconstructive Surgery (HLRS), Orthopaedics and PMR for nerve conduction studies (NCS).

The total sample size of 100 subjects was required to find a hypothesised sensitivity of 90% with a 95% confidence interval of 85-95%. Of this number, 36 were in the patient group and 64 in the control group.

The study was approved by the Institution Review Board of the Institute and an informed consent was obtained from all the participants.

Control Group:

Normative data was collected from 64 age-group matched subjects recruited from the hospital staff or relatives accompanying the patients, who did not have any signs or symptoms of CTS (33 males and 31 females). They were subjected to history and neurological examination to rule out any abnormality. NCS and ultrasonography of both wrists were done for all subjects included in the control group.

Patient Group:

Thirty-six patients were included in the study. The patient group were selected based on the diagnostic criteria put forward by the American Academy of Neurology (1993)[19] – paresthesia; pain; swelling; weakness or clumsiness of hand provoked or worsened by sleep; sustained hand or arm position; repetitive action of the hand or wrist that is mitigated by changing posture or by shaking of the hand; sensory deficit or atrophy of the median nerve innervated thenar muscle; symptoms elicited by the Phalen's test performed on each patient.

A detailed history was taken using the modified Boston carpal tunnel questionnaire, which assessed the symptoms (pain, paresthesia, numbness, weakness and nocturnal symptoms) and functional status (writing, buttoning, holding, gripping, opening jars, carrying grocery bags, household chores, bathing and dressing). This questionnaire was modified to be used in the Indian population by virtue of being translated into Indian regional languages, utilising a translated visual analogue scale and assessing functions (eg, activities like buttons/hooks/sari pleats) relevant to our population[20].

A clinical examination was done for any sensory deficits in the median innervated area in the hand (categorised as impaired sensations/ normal sensations) and for motor weakness of the abductor pollicis brevis (categorised as weakness present or normal). Tinel's and Phalen's tests known to be highly sensitive (0.97 and 0.92) and specific (0.91 and 0.88) for diagnosis of CTS, was also performed for each subject [21]. The radiologist was blinded to the clinical findings.

Thirteen out of the 36 patients were found to have predominant motor symptoms and 23 people were found to have mainly sensory impairment in the hand in the median innervated areas, namely the thumb, index, middle and radial half of the ring finger. Laboratory investigations (blood sugars and thyroid functions) were also done to rule out any other cause for CTS. Informed consent was taken from all the patients.

Electrodiagnostic evaluation:

Electrodiagnostic studies were performed for all subjects included in the study according to the protocol put forth by the American Association of Electrodiagnostic Medicine recommendations [19,22,23] using Medelec Synergy (VIAsys Healthcare EMG and EP systems, UK Ltd, software version 11).

The nerve conduction study was carried out by the same physician, in the elecrodiagnostic lab with specified ambient room temperature of 32 degrees. Standard tests for median sensory and motor conductions, included recording of distal latency, conduction velocity across the wrist and amplitude.

The criteria for diagnosis of CTS were [19, 23-25] :

-Distal sensory latency recorded from the index finger (antidromic stimulation) using ring electrodes is >3.3 ms.

- Distal motor latency of median nerve recorded from the abductor pollicis brevis using disc electrodes, with stimulation 3cm proximal to the distal crease of the wrist > 4.4 ms.

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When standard tests mentioned above yielded normal results, a comparative median/ ulnar studies were done.

- Difference between distal motor latency of median and ulnar nerves > 1.1ms
- Difference between distal sensory latency of median and ulnar nerves > 0.2ms[23].

F wave was done for all patients.

In accordance to with the results of the electrodiagnostic studies, the hands were categorised into 3 groups:

1. Mild to moderate CTS – characterised by slowing of the median sensory distal latency with normal distal motor latency or abnormal distal motor latency with or without delay in conduction velocity and diminished amplitudes.
2. Severe CTS – absence of a median sensory response and prolonged distal motor latency with delayed conduction velocity and diminished amplitude or absence of CMAPs.
3. Normal – motor and sensory distal latency, conduction velocity and amplitude within normal limits.

Sonography:

All 100 subjects underwent high-resolution ultrasound performed by two radiologists who were experienced in the field of musculoskeletal sonography using Seimens Antares Ultrasonography machine, with a 7-13 MHz linear array transducer. The radiologist was blinded to the clinical findings and electrodiagnostic results. The sonographic examination was done within 3 days of the electrodiagnostic study. The examination was performed with the patient seated in a comfortable position facing the radiologist with the forearm resting on the table in supination with the wrist in the neutral position and fingers semi-flexed. Transverse images of the median nerve were obtained at three levels: Immediately proximal to the carpal tunnel inlet (distal radio-ulnar joint level), at the carpal tunnel inlet (level of scaphoid and pisiform) and at the carpal tunnel outlet (trapezium and hook of hammate level). The cross-sectional area was measured by tracing it with an electronic calliper around the margin of the median nerve (Fig1). The flattening ratio, defined as the ratio of the major axis of the median nerve to the minor axis, was also assessed at the tunnel inlet and outlet (Fig 2). Of the 100 subjects included in the study (36 patients with CTS and 64 normal subjects), 18 were found to have unilateral bifid median nerve (Fig 3). Among the patient group, there were 8 people with this variant but in the asymptomatic hand. Among the normal subjects, 10 individuals had the variant, hence the wrist with the variant nerve was excluded from the study and the normal wrist was included.

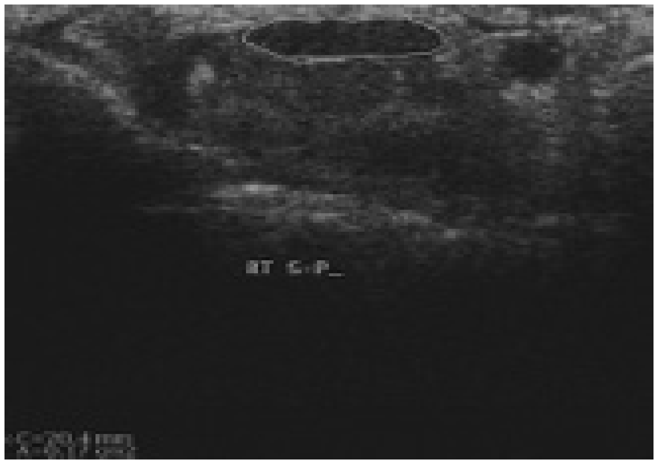

Fig 1: Cross-sectional Area of the Median Nerve Measured by an Electronic Calliper

Fig 2: Flattening Ratio (Ratio of Major Axis of Median Nerve to the Minor Axis).

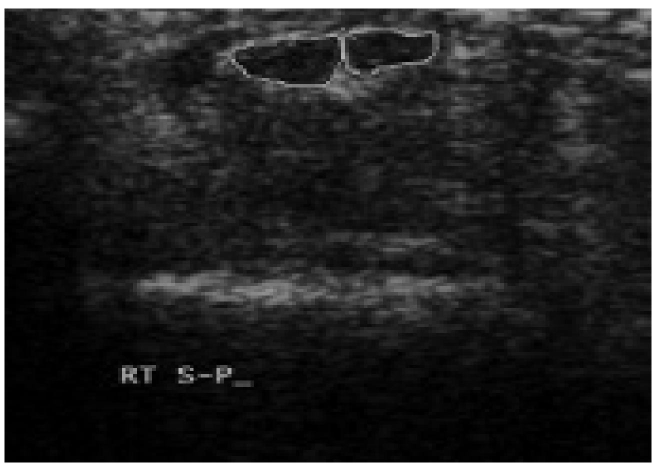

Fig 3: Bifid Median Nerve.

Statistical analysis:

The statistical analysis was done using the STATA 8.0. The cut off values of the cross-sectional area for each of the three levels (proximal to inlet, at the inlet and at the outlet) were calculated according to the receiver operating characteristic (ROC) curves for each level (Figs 4-6). The co-relation of the positive ultrasound findings at each level and nerve conduction studies was done along with calculation of the positive and negative predictive values. The mean flattening ratio for cases, controls and the combined group were also calculated.

Results:

Among the 36 patients recruited for the study 10 were males and 26 were female and among the control population of 64 subjects, there were 33 males and 31 females. The age distribution in the patient population was between 18 and 56 years with a mean of 38.33. Among the control group the age distribution was 18-58 years with a mean of 29.89.

A total of 177 wrists were studied, 59 from the patient group and 118 of the control group. In the patient group, 23 subjects were found to have bilateral CTS and 13 were found to have unilateral disease (11 right sided and 2 left sided).

Among the patient group, 29 were classified under group 1 (mild to moderate CTS), 7 individuals were classified under group 2 (severe CTS), and 64 in group 3 (normal findings. Eighteen subjects among the cases as well as the control group were found to have a bifid median nerve, which has been described in literature as a normal variant [26].

Receiver operating characteristic (ROC curve) analysis was done for the cross sectional areas for the 3 levels of measurement for the best cut-off values.

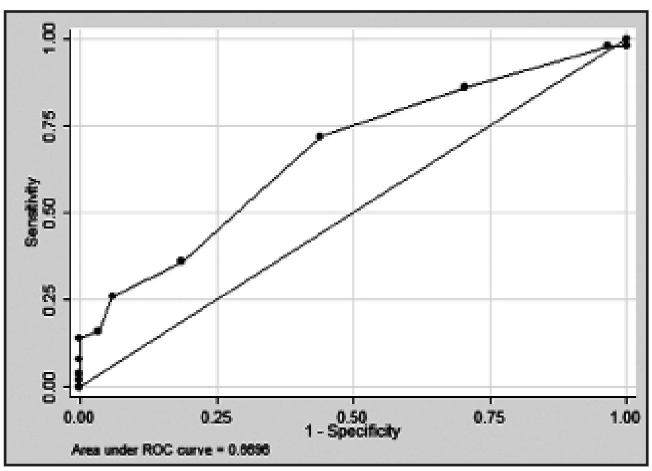

Fig 4: Roc Curve for the Level Proximal to the Inlet

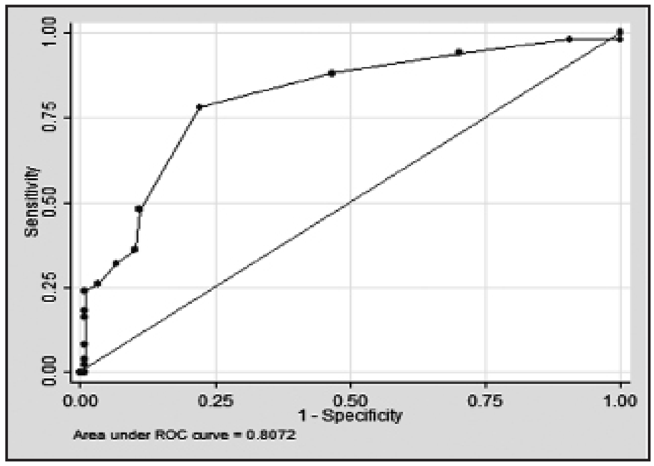

Fig 5: Roc Curve for the Level at the Tunnel Inlet

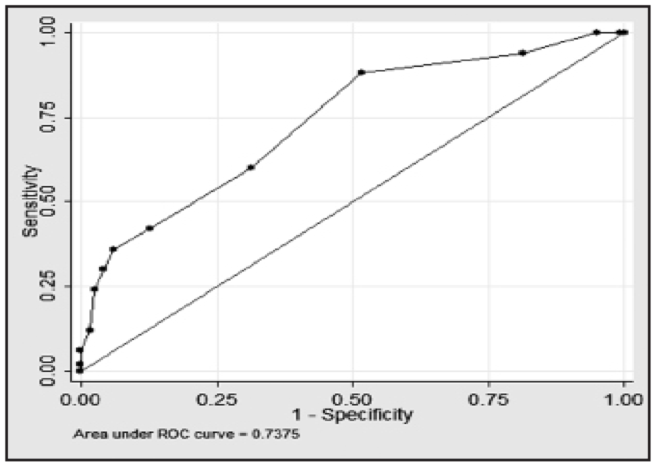

Fig 6: Roc Curve for the Level of the Tunnel Outlet

Based on the ROC curve, the cut-off for CSA for CTS in patients were 0.09 cm^2 at the level of the distal radio-ulnar joint (sensitivity 68% and specificity 68.64%), 0.10 cm^2 at the level of the inlet of the carpal tunnel (sensitivity 78% and specificity 77.97%), and 0.08cm^2 at the level of the outlet of the carpal tunnel (sensitivity 72% and specificity 55.93%).

The sensitivity of ultrasound to diagnose CTS by the increase in CSA at the level of the distal radio-ulnar joint for group 1 (mild to moderate CTS on NCS) is 58.54% and that for group 2 (severe CTS) is 66.67%. The specificity of ultrasound at this level compared to the electrodiagnostic study was 68.64%. The sensitivity of ultrasound to diagnose CTS at the level of inlet to the carpal tunnel (level of pisiform) in group 1 (mild to moderate CTS on NCS) was 78.05% and that for group 2 (severe CTS) was 77.78%. The specificity as compared to the electrodiagnostic study at this level was 92%. The sensitivity at the level of the outlet of the carpal tunnel (level of hook of hamate) in group 1 (mild to moderate CTS on NCS) was 70.73% and that for group 2 (severe CTS) was 77.78%. The specificity compared to the electrodiagnostic study at this level was 66%.

The ability of the USG to pick up an increased CSA at any level according to the severity of the disease was 86.20% for group 1, and for group 2 was 85.7%

The mean of flattening ratio for the combined group at the level of proximal inlet was 3.06 with standard deviation of 0.75, at the inlet the mean was 2.74 with standard deviation of 0.58 and at the tunnel outlet it was 3.22 with standard deviation of 0.78. No significant correlation could be established between the flattening ratio and disease condition.

The positive predictive value and the negative predictive values of ultrasound vs. nerve conduction studies were calculated at each level.

1. Proximal inlet of the carpal tunnel
   Positive predictive value = 45
   Negative predictive value = 80
2. Inlet of the carpal tunnel
   Positive predictive value = 60
   Negative predictive value = 90
3. Outlet of the carpal tunnel
   Positive predictive value = 41
   Negative predictive value = 83

Discussion:

The clinical diagnosis of CTS usually relies on typical signs and symptoms which are followed by electrodiagnostic studies for confirmation. Stand-alone signs and symptoms have shown to limit diagnostic accuracy, while electrodiagnostic study cause discomfort, is time consuming, expensive and not widely available. Electrodiagnostic studies demonstrate the physiological malfunctioning of the median nerve while ultrasonography picks up the structural abnormalities.

In literature, US measurement used in CTS diagnosis is the cross-sectional area of the nerve at various levels of the carpal canal, the flattening ratio, the swelling ratio, and the increased palmar bowing of the flexor retinaculum. In some studies cross-sectional area was performed at a single level [4,5, 27-30] mostly at the proximal carpal tunnel. In several studies CSA was measured by ellipsoid formula [10, 28, 31] but a more accurate measure is obtained by using continuous boundary trace of the nerve, because the nerve does not always have a perfect ellipsoid shape, which the method used in our study. Nakamichi and Tachibana[11] directly compared the measurements of the median nerve obtained sonographically with the measurements found in anatomical cross-sections in cadaver limbs. Ultrasound is a precise method for determining these measurements, later confirmed by Kamolz *et al*[32].

Kamolz *et al*[33]. stressed the need for standardisation of the median nerve CSA cut-offs. In our study, the cut off for an abnormal nerve was taken as 0.09 cm^2 at the level proximal to the inlet, 0.10 cm^2 at the inlet and 0.08 cm^2 at the tunnel outlet with sensitivities of 68%, 78% and 72% respectively and specificities of 68.64%, 77.97% and 55.93%; also the cross-sectional area at inlet of the carpal tunnel showed higher sensitivity and specificity (78% and 77.97%) for CTS as compared to the proximal inlet and outlet of the tunnel. The majority of the studies published previously had values ranging from 9mm^2 to 12 mm^2 in different populations, which corroborates with our findings also.

In our study, the sensitivity and specificity of the flattening ratio was not calculated, as it did not show any significant correlation with the presence of the disease. However, the mean of the flattening ratios for the cases and the controls was taken separately.

Ultrasonography is useful in CTS diagnosis, providing anatomic images of the median nerve, neighbouring structures, and mass-occupying space in the carpal canal. The advantages of ultrasonography is that it is low cost, takes a shorter duration to perform the investigation compared to nerve conduction studies and it is more commonly available, besides it is painless and non-invasive; and gives dynamic images. US is operator dependent, but shows high reproducibility after adequate training of the operators[34].

The sensitivity of ultrasound to detect CTS by the increase in the cross-sectional area of the median nerve as compared to the nerve conduction studies is 90% with the US value being positive at any one anatomical level. The specificity for this is 45%. According to this study, based on the sensitivity, the best level to look for the compression of the nerve by increase in the cross-sectional area is at the level of the carpal tunnel inlet, however a combination of the CSA at the inlet and outlet of the carpal tunnel will improve the screening accuracy of the test.

Conclusions:

Ultrasonography is useful in CTS diagnosis, providing anatomic images of the median nerve, neighbouring structures, and mass-occupying space in the carpal canal. The advantages of ultrasonography is that it is low cost, takes a shorter duration to perform the investigation compared to nerve conduction studies and it is more commonly available, besides being painless, non-invasive and gives dynamic images. US is operator dependent, but shows high reproducibility after adequate training of the operators[34]. Therefore in conclusion as ultrasonography is more widely available as compared to NCS, is non- invasive with the added benefit of being cost-effective, it can be used as a good screening tool for the diagnosis of CTS. This investigation becomes especially useful when the availability of nerve conduction studies is difficult.

Future Directions:

For further studies, it may be useful to look for the cross-sectional area of the median nerve at the 3 different levels (at the distal radio-ulnar joint, the level of the pisiform and at the level of the hamate) 3-6 months post surgery or conservative management along with concomitant nerve conduction studies and compare with the pre-operative values. This may be especially useful in those patients who continue to have symptoms despite treatment especially surgical management.

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