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Diagnosing Carpal Tunnel Syndrome by Ultrasound

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Abstract

Background **Carpal tunnel syndrome (CTS) is traditionally diagnosed by clinical evaluation and nerve conduction studies (NCS). Ultrasound is now widely used in the diagnosis of musculoskeletal disorders. The objective of this study was to compare the sonographic measurements of median nerve in patients of CTS with NCS results, taking NCS as gold standard and to evaluate the diagnostic role of ultrasound so that it could be used in the diagnosis of CTS.**

Methods: **This cross sectional Analytical study was carried out at Department of Radiology, Combined Military Hospital Lahore over a period of one year from 21st August 2006 to 20th August 2007. One hundred and twenty wrists in sixty CTS patients were imaged by high resolution ultrasound. The cross sectional area of the median nerve was measured at the level of pisiform bone. All patients had nerve conduction studies. The ultrasound measurements of the median nerve cross sectional area and the results of nerve conduction studies were compared and analyzed.**

Results: **The mean cross sectional area of the median nerve at the level of pisifom was 13mm² in CTS patients. When NCS results were taken as gold standard, the ultrasound yielded a sensitivity of 94.7%, specificity of 63.6% and diagnostic accuracy of 87.8%.**

Conclusion: **High resolution ultrasound is quite accurate and it can be used reliably and cost effectively in the diagnosis of CTS especially for screening of large population of CTS patients.**

Key words: **Carpal tunnel syndrome, Ultrasound, Nerve conduction studies**

Introduction

Carpal tunnel syndrome (CTS) is the compressive neuropathy of the median nerve as it passes under the flexor retinaculum at the volar aspect of wrist [1]. It is characterized by numbness and pain in the lateral three digits. In advanced cases there may be wasting of thenar muscles[2].

The etiology of CTS is multifactorial, with both local and systemic factors contributing to varying degrees. Any lesion which reduces the size of the carpal tunnel increases the pressure in the carpal tunnel. Compression of the nerve interferes with the nerve's microvasculature and induces an inflammatory reaction in the epineurium. This causes epineurial edema. Sustained edema of the epineurium may cause fibrosis, damage the myelin sheath and lead to axonal degeneration, with permanent loss of nerve function and atrophy of the innervated muscles [3, 4].It is more prevalent in women aged 45-54 years [1, 2] and is usually bilateral [3].

Although CTS can be diagnosed on the basis of history and certain provocative tests[2], in certain atypical cases and in other confusing situations, such as entrapment of other nerves, cervical neural compression, demyelinating disease, or peripheral neuritis, nerve conduction studies are used to confirm the diagnosis[6]. NCS have a sensitivity ranging from 49% to 93% and specificity of 87% to 95%[5, 7]. However they are quite time consuming, uncomfortable and not easily available [3]. NCS indicate the level of the lesion but they do not provide spatial information about the nerve and its surroundings that could help in determining its etiology [8]. NCS cannot diagnose clinically mild cases of CTS [8].

The advantage of early diagnosis of the condition lies in its early treatment.

In recent years the imaging techniques like, MRI and ultrasound have been shown to be of value in the diagnosis of CTS. Both of these show the anatomy of the carpal tunnel and the morphology of the median nerve quite accurately, and therefore provide information about local causes of CTS, which cannot be gained by the NCS [4, 10, 11, 12].

Ultrasound techniques using high frequency transducer of 7-15 MHz provide excellent display of carpal tunnel and superficially situated median nerve and quantitative analysis may prove useful in the diagnosis of nerve entrapment at carpal tunnel [3,4,10].

Studies carried out so far show that in CTS, the cross sectional area of median nerve is increased more than 10mm^2 when measured at proximal boundary of carpal tunnel (as compared to 6mm^2 to 9mm^2 in asymptomatic individuals)[3,4,6,10]. There is anterior bowing of flexor retinaculum more than 2.5mm from a line drawn from tubercle of triquetrum to the hook of hamate bone [4, 14]. There is flattening of the median nerve at tunnel outlet[4, 11].

The present study was carried out to find out the diagnostic accuracy of ultrasound so that it could be used to diagnose CTS in place of NCS, being a cheap, easily available and quick to perform noninvasive test.

Patients and Methods

Patients of both sexes, between 20-60 years of age, coming to Combined Military Hospital of Lahore with symptoms of nerve compression at wrist were referred to Hand and Upper Limb Surgery Centre of the same hospital to be examined by an orthopedic surgeon. Patients having suspicion of CTS based on American Academy of Neurology clinical criteria were referred for NCS and ultrasound of wrist. Grading of severity of condition was subjective, assessed by patients' symptoms and clinical examination as no established scoring system to grade the severity of CTS clinically, could be found in the literature. Patients who had symptoms of nerve compression at wrist and already had NCS with positive findings were also included in the study. Patients with previous wrist surgery /injury, wrist deformity and diabetes mellitus were not included. Those found to have anatomical variants of median nerve on ultrasound were also excluded. Total patients included were 60(120 wrists), each wrist was considered separately in the clinical diagnosis.

Ultrasound of the wrist

All patients had high resolution real time ultrasound of the wrist with a 7-10 MHz small foot print linear array transducer (Aloka SSD 5500 – Aloka Company Limited). The patient was made to sit in a comfortable position on a stool, across the examination table, facing the examiner. The forearm was resting on the table with palm in a supine neutral position, the fingers in a semi flexed position.

The ultrasound examination was started at the proximal boundary of the carpal tunnel at the intersection of the distal transverse wrist crease with the longitudinal wrist crease. The carpal tunnel appears as a lentiform hypoechoic area at the anterior aspect of wrist bounded medially and laterally by strongly reflecting bones and anteriorly by flexor retinaculum which appears as an echogenic linear structure slightly convex anteriorly.

The median nerve here was identified on the basis of its superficial position at the radial aspect of the carpal tunnel, its internal fascicular echotexture, isotropy and lack of motion in contrast to the moving tendons as the fingers were extended and flexed.

After identification of the median nerve, it was imaged from approximately 4 cm proximal to the wrist crease to distally until the median nerve was no longer visible. The mobility of the median nerve was exhibited as slight rocking caused by the movement of adjacent tendons as the fingers were flexed and extended one by one. Next, the median nerve was imaged in a sagittal plane. The continuity of the median nerve, any area of constriction and irregularity of the outline were assessed. The entire carpal tunnel was scanned from side to side. The amount of synovial fluid and any focal lesion were assessed.

The median nerve cross sectional area was measured in mm^2. This was done in a transverse plane and taken at the level of the proximal wrist crease. The pisiform bone was taken as a landmark. To ensure that the orientation of the transverse images remains consistent and that the area measured reflected a true cross sectional area the following precautions were taken.

(i)The ulnar artery was identified in cross section just medial to the longitudinal wrist crease along the ulnar aspect,

(ii) The probe was kept perpendicular to the long axis of the nerve

(iii) The smallest cross sectional area was recorded after 3 measurements per nerve.

First the area was measured using an ellipse then it was measured by tracing method. To take the measurements the cursor was placed at the echogenic rim around the nerve and the area was traced along that echogenic rim. The area was displayed only when the final trace was complete.

The patients who did not have NCS done were sent to Department of Physical Rehabilitation Medicine for the nerve conduction studies of the symptomatic wrists. Both investigations were performed on the same day or within 48 hours of each other and before starting any invasive treatment.

Nerve conduction studies (NCS)

NCS measurements included median nerve motor and sensory distal latencies and sensory conduction velocities of symptomatic wrists. A

sensory latency longer than 3.5 m/sec and a motor latency longer than 4.4 m/sec were considered abnormal. Normal ulnar nerve motor and sensory latencies with increased median nerve latencies were considered diagnostic of CTS.

Data analysis:

All the data collected was entered in computer program SPSS version 14 and analyzed. The qualitative variables analyzed were sex and history of present illness, for which frequency, proportion and percentage were calculated. The quantitative variables analyzed were age and median nerve measurements i.e. cross sectional area and distal motor latency (DML).

Mean and standard deviation were calculated for age and area measurements.

Median nerve cross sectional area and DML were entered in a 2 x 2 table and were compared taking NCS as gold standard. Sensitivity, specificity, diagnostic accuracy and predictive values were calculated.

Results

Sixty patients were included in the study. Both wrists (120 wrists) were examined by ultrasound, out of which 98 had CTS clinically while 22 were asymptomatic. NCS were performed on 98 symptomatic wrists and the results of NCS and ultrasound from those 98 wrists were compared.

Table 1: Distribution of Cases by Age and Sex

Age groups	Male		Female		Total	
	n	%	n	%	n	%
30- 39	-		14	25.0	14	23.3
40- 49	-		26	46.4	26	43.3
=>50	4	100	16	8.6	20	33.4
Total	4	6.7	36	93.3	60	100

Out of 60 patients examined, 56 were females (93.3%) and 4 were males (6.7%) The minimum age was 30 years and maximum age was 60 years; mean age 45.2 years and SD 8.8.Out of female patients 46.4% were in the age range 40-49 years. The 4 male patients were above 50 years(Table 1). In 38(63.33%) patients both the wrists were involved. In18 (30%) patients there was involvement of right wrist only while in 4(6.66%) patients only the left wrist was involved.

Table 2: Distribution of Cases by Duration of Symptoms

Duration (months)	Right		Left		Both	
	n	%	n	%	n	%
< 6	16	28.6	12	28.6	28	28.6
6- 11	20	35.7	18	42.9	36	38.8
12- 17	10	17.9	4	9.5	14	14.3
> 18	10	17.9	8	19.0	18	18.4
Total	56	57.1	42	42.9	98	100

Table 3: Distribution of Cases by Associated Illness

Idiopathic CTS	80% (n =48)
Degenerative joint disease	10% (n =6)
Double crush syndrome	3.3% (n =2)
Hypothyroidism	3.3 % (n =2)
Pregnancy	3.3% (n =2)

Table4: Median Nerve Measurements in 98 Symptomatic Wrists

MN measure	Min	Max	Mean	SD
DML (msec)	3.6	11	5.3	1.5
CSA-1 (mm^2)	6	18	13	2.9
CSA-2 (mm^2)	4	17	12.1	2.6

*****_CSA 1 = cross sectional area trace CSA 2 = cross sectional area ellipse_
DML = distal motor latency, Min = minimum Max, = maximum msec = milliseconds mm^2 = millimeter square SD = standard deviation

Table 5: Comparative Diagnostic Table Gold standard (NCS)

Test results (Ultrasound)	Positive	Negative	Total
Positive	**72**	**8**	**80**

Negative	**4**	**14**	**18**
Total	**76**	**22**	**98**

Table 6: Diagnostic Value of Sonography

Parameter	Value	Percentage
Sensitivity	72/76 x 100	94.7
Specificity	14/22 x 100	63.6
Positive Predictive Value	72/80 x 100	90
Negative Predictive Value	14/18 x 100	77.7
Diagnostic Accuracy	(72 + 14)/98 x 100	87.8

Out of 98 symptomatic wrists, 57.1% were right while 42.9% were left. In 18.2% cases the severity of symptoms was mild, in 48.4% moderate and in 32.4% it was severe. In 28.6% cases the duration of symptoms was less than 6 months, in 38.8% 6-11 months, in 14.3% 12-17 months and in 18.4% it was 18 months or more.(Table2)

In 80% cases (48 out of 60) CTS was idiopathic and no etiology was found. However in remaining 20% an underlying cause was identified, 6 patients had degenerative changes at the wrist, 2 patients had hypothyroidism and in 2 cases, it was pregnancy related. In 2 patients median nerve compression at cervical spine, along with CTS (double crush syndrome) was found (as was diagnosed on NCS). (Table 3).

Ultrasound and NCS measurements of median nerve in 98 symtomatic wrists are shown in Table 4

Comparative diagnostic results are shown in Table 5. It shows the comparison of ultrasound and NCS results taking NCS as gold standard.

Diagnostic value of sonography is calculated in Table 6 which shows 87.8% accuracy.

Discussion

Various studies carried out so far have used different measurements for the diagnosis of CTS. The most persistent finding by those studies was the increased cross sectional area of median nerve just proximal to the flexor retinaculum i.e. at the level of pisiform [7, 14, 15, 18, 21, 22]. Therefore this measurement was selected in the present study as well. The cause for maximum area measurement at this level is proximal swelling as a result of distal compression as the median nerve dips posteriorly under the flexor retinaculum [4].

The qualitative analysis of the median nerve in both transverse and longitudinal scans revealed that there was irregularity of the outline of the median nerve. This irregularity is due to fibrosis of the epineurium in longstanding cases of CTS [18, 19]. Longitudinal evaluation of the median nerve in patients with clinically moderate to severe CTS frequently showed that there is marked dilation proximal to the flexor retinaculum with a sharp anterior caliber change distally . These findings were consistent with the observations by Al Meidany et al[6].

The median nerve cross sectional area was measured by both direct (area trace) and indirect (area ellipse) methods, the methods used by various other researchers [6,8,16]. It was revealed that measurements by two methods were same when there was smooth enlargement of the median nerve. However when there was irregularity of the nerve outline because of fibrosis, area trace gave higher measurements. This was because by indirect method the irregular margins of the nerve could not be included in the measurements and lower values of the median nerve cross sectional area were obtained . The finding was same as by Al Meidany et al[6] and Duncan et al [8].

In the present study the mean cross sectional area of median nerve at the pisiform level in patients of CTS was 13 $mm^2 \pm 2.7$ by area trace and 12.1 $mm^2 \pm 2.6$ by area ellipse. This was similar to the 14 mm^2mean cross sectional area by Weisler et al[4] and 11mm^2 by Duncane et al[8]. El Miedany [6] found mean cross sectional area of 15mm^2. This value is higher, however it is not mentioned in that study whether the echogenic boundary of the median nerve was included or not while measuring the cross sectional area. Hammer et al [22] gives mean cross sectional area 15.7mm^2, but that study was conducted on patients of arthritis only, in whom higher values of area measurements are likely to be obtained.

To calculate the sensitivity and specificity of ultrasound as a diagnostic test the NCS results were taken as gold standard. A cut off point of 10mm^2 or higher for the median nerve cross sectional area on ultrasound and a value of > 4.4 m sec for median nerve DML on NCS was used. It was found that ultrasound had 94.7% sensitivity. Out of 76 cases having CTS on nerve conduction studies, ultrasound

correctly diagnosed 72 cases (i.e. 72 had an ultrasound value ≥ 10mm^2), but missed 4 (who had ultrasound value < 10mm^2). However in those cases when the median nerve cross sectional area was compared with the contra lateral asymptomatic wrist it was found increased in the symptomatic wrist, even if the measurement was within normal limit i.e. < 10mm^2. The studies using asymptomatic wrists as controls have proved that there is significant difference between two groups in the median nerve cross sectional area at proximal boundary of carpal tunnel[4, 6, 13, 20]. Problem was faced in diagnosing CTS when it was bilateral and the area measurement was < 10mm^2. In those cases flattening ratio and swelling ratio of the median nerve could be more appropriate indicators for median nerve compression under the flexor retinaculum[10, 16].

Specificity of ultrasound was found to be 63.6%. Ultrasound correctly identified 14 subjects out of 22 who were declared negative for CTS by NCS but it was unable to identify 8 cases who had negative NCS (i.e. 8 subjects had ultrasound value >10mm^2 although they had normal NCS). The reason for this could be that NCS are unable to detect mild cases of CTS. NCS is only positive when there is significant demyelination or axonal loss[17]. Therefore ultrasound could be of value in diagnosing patients having CTS clinically but negative NCS as was shown in study by Koyuncuoglu et al [23].

The sensitivity of present study was almost equal to that calculated by Weisler et al.[4] which was 91% using a cut off point of 11mm^2. The specificity in weisler's study was 94% which was quite high because it was calculated from data of 43 asymptomatic individuals (72 of 86 wrists). Lee et al[24] found ultrasound 88 % sensitive in the diagnosis of CTS, but in that study a higher cut off point (15mm^2) for area measurement was used. The specificity in that study was calculated as 96% and diagnostic accuracy was 92%. This was because mild cases of CTS were excluded from the study. Sensitivity of 73% was found by Sarria et al[13] and 70% by Swen et al[21]. Sarria et al used a cut off point of 11mm^2 for the cross sectional area and a value > 4.2 msec for the DML of median nerve thereby reducing the sensitivity as well as specificity (57%) of ultrasound (as compared to the present study). In a study by Swen et al. the cut off point of 10 mm^2 was used with a cut off value of > 4.3 msec for the DML thereby further lowering the sensitivity (70%) but increasing the specificity (63%) which is equal to the present study. Diagnostic criteria used by Swen et al were also different. It was response to operative treatment (>= 90 % relief of symptoms after surgery). Whereas surgical decompression, often considered the definitive solution, gives excellent results in only 75% of cases in ordinary practice and leaves 8% of patients worse than previous[9].

In the present study, the diagnostic accuracy was 87.8%. The positive and negative predictive values were 90.0% and 77.7% respectively. The diagnostic accuracy in the present study is almost equal to 88% diagnosic accuracy given by Duncan et al[8]. In study by Lee et al [24] 92% diagnostic accuracy for ultrasound is documented. However the NCS criteria for CTS are not mentioned in that study. The diagnostic accuracy of studies by Sarria et al. was 68% and by Swen et al it was also 68%. As mentioned earlier, different diagnostic criteria and cut off values were used in those studies.

Difficulty was found in comparing the results with the results of other studies as no standardization of diagnostic criteria and examination technique for ultrasound in CTS patients is present yet. Furthermore all the studies referenced have used asymptomatic individuals as control group, which was not present in our series as it was a comparative diagnostic study.

Conclusion

Sonography is an accurate technique for the evaluation of median nerve in patients of CTS. It has high sensitivity however it suffers from low specificity. Therefore it can be used for screening large population of patients as it is simple, has relatively low cost and is easily available. It is also quick to perform non invasive test. Ultrasound is also useful in evaluating and excluding local causes of nerve compression like tenosinovitis. It is good in identifying the anatomic variations in carpal tunnel therefore it can help in deciding the patient management.

To further establish the role of ultrasound in diagnosis of CTS, more studies are needed taking asymptomatic individuals as controls. Sonography should be compared to NCS using a strictly defined clinical gold standard and the examination techniques should be standardized.

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