ORIGINAL ARTICLE

NATIONAL JOURNAL NJMR MEDICAL RESEARCH

Diagnostic Ability of Nerve Conduction Study, Ultrasonography and Magnetic Resonance Imaging in Diagnosis of Carpel Tunnel Syndrome

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Keywords:
Carpel Tunnel Syndrome,
CTS,
median nerve cross sectional area,
Nerve conduction study,
velocity,
Amplitude,
sensory nerve action potential

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Date of Acceptance:
28-10-2023

DOI:
10.55489/njmr.13042023981

ABSTRACT

Introduction: Current diagnostic criteria for Carpel Tunnel Syndrome (CTS) include a patient's medical history, physical exam results, and electrophysiological findings. The purpose of the study is to evaluate the diagnostic ability of nerve conduction study, ultrasonography and magnetic resonance imaging for the diagnosis of carpal tunnel syndrome with the use of clinical findings as the gold standard.

Methodology: The study was conducted among 30 patients clinically diagnosed having CTS based on the criteria given by American Academy of Neurology and American Academy of Physical Medicine and Rehabilitation. All patients included in the study were underwent USG of affected wrist joint, CT scan as well MRI of the same.

Results: Out of total 30 participants, 14 (46.7%) were found moderate severity followed by 11 (36.7%) were found mild severity. Only 5 (16.7%) were found severe carpel tunnel syndrome. Amongst all three investigation methods, nerve conduction study having the lowest sensitivity (83.33%). The sensitivity of the ultrasonography and MRI was 90% each.

Conclusion: It is clear from this study that the sensitivity of the parameters utilized in NCS (maximum observed 83.33%) is lower than that of the median nerve cross-sectional area detected on USG (90%) and MRI (90%). The most sensitive, practical, and cost-effective metric of all those seen in the research turned out to be the median nerve cross sectional area evaluated at the wrist crease by USG.

INTRODUCTION

The most typical occupationally associated illness that affects the peripheral nerves is CTS [1], which is also the most typical neuropathy leading to entrapment. [2] Chronic conditions like obesity, diabetes, gout, arthritis, hypothyroidism, or work-related conditions like clerical, office, or data entry work, industrial construction or mining, kitchen work, or supermarket dealing, among others, have all been linked to CTS. [3] These conditions are characterized by rigid, forceful, and repetitive hand movements, uncomfortable postures, mechanical stress at the base of the palm, and vibration.

Current diagnostic criteria for CTS include a patient's medical history, physical exam results, and electrophysiological findings. [4] The clinical history, physical examination, and electro-diagnostics (EDx), which combines NCS and electromyography investigations, are the main components of the diagnosis of this illness. Even though NCS is helpful for detecting the pathology site and assessing the severity of the condition, it still has drawbacks, such being uncomfortable, being unable to see intrinsic nerve abnormalities, and not providing any details on the structures around the nerve. [5] A technique

called NCS has a false negative rate and a sensitivity range of 49 to 86%. [6]

According to earlier research, [7,8] musculoskeletal USG may provide diagnostic accuracy in a similar way.[9] When the median nerve in the carpal tunnel is compressed, it causes swelling of the nerve nearby and farther away from the compression site.

USG has long been regarded as a reliable diagnostic tool for conducting thorough examinations and assessments of CTS patients. For the diagnosis of CTS, Buchberger W et al. were the first to demonstrate that USG is as accurate to magnetic resonance imaging (MRI).[7] Altinok T et al[10], utilising NCS as the reference standard, further validated their study. When compared to other USG metrics, Duncan I et al [11] research demonstrated that the CSA diagnostic parameter is an excellent criterion for CTS identification. Numerous other earlier studies [12,13] that established the measurement of carpal tunnel inlet at the level of pisiform to be viewed as standard lent credence to this.

Patients with CTS symptoms and signs and a positive NCS were the subject of a study by Baiee RH et al. [14] Age and the NCS-determined illness severity were significantly correlated. Additionally, they found positive associations between the USG results and every other NCS method indicator for disease severity in Carpal Tunnel patients. The median nerve's CSA varied considerably across the severe and moderate CTS groups, according to Kwon HK et al analysis of the mild, moderate, and severe CTS participants. [15] This component was also found to connect with EDx parameters in both severe and mild CTS wrists.

In the case-control strategy, Kasundra GM et al. evaluated and contrasted patients with clinical and electro diagnostic confirmation of CTS with healthy volunteers. [16] At the inlet and outlet of the carpal tunnel, the median nerve's CSA was calculated, and the Inlet Outlet Ratio (IOR) was calculated for each wrist. The IOR provided better diagnostic information than the inlet CSA (p = 1.3). Additionally, they did a comparison of diagnostic techniques for CTS in patients and controls. The USG had a low sensitivity, but a good specificity, and the MRI had a moderate sensitivity. BCTQ-S, USG, and NCS both revealed a strong association.

Average CSA at the carpal tunnel inlet was 0.11 ± 0.0275 cm2, 76.43%, 72.72%, 89.47%, and 68%, respectively, for sensitivity, accuracy, positive predictive value, and negative predictive value, according to Kanikannan MA et al study [17]. (p-value-0.0001).

The purpose of the study is to evaluate the diagnostic ability of nerve conduction study, ultrasonography and magnetic resonance imaging for the diagnosis of carpal tunnel syndrome with the use of clinical findings as the gold standard.

The study was conducted to assess utility of nerve conduction study, ultrasonography and magnetic resonance imaging in diagnosing symptomatically early cases of CTS; and also, to evaluate median nerve cross section in early diagnosed cases of carpal tunnel syndrome diagnosed with clinical findings by using ultrasonography and magnetic resonance imaging and do comparative analysis of median nerve cross section assessment.

METHODOLOGY

The study was conducted in the department of Orthopaedics, AJ Institute of Medical Sciences, Kuntikan, Mangaluru, Karnataka, India which is a tertiary health care center. Patients from local and surrounding districts mainly avail services from the hospital.

All the patients diagnosed with Carpal tunnel syndrome and admitted in Krishna Hospital for the same diagnosis were considered for inclusion in the study.

Study Proceedings: The present study was undertaken in orthopedic department of the hospital. Patients attending orthopedics OPD or casualty and diagnosed with carpel tunnel syndrome and admitted in the hospital were included in the study. These patients were then followed up with their radio graphical images of the involved wrist and also by clinically examining the patient according to American Academy of Neurology and American Academy of Physical Medicine and Rehabilitation. Patients were evaluated by using clinical examination, nerve conduction study, ultrasonography and magnetic resonance imaging.

Design of study: This was a cross sectional analytical study for evaluation of diagnostic efficacy of various diagnostic utility like nerve conduction study, ultrasonography and magnetic resonance imaging in diagnosis of carpel tunnel syndrome determined by clinical findings.

Sample size: Sample size of the study was calculated by using following formula: Sample size $N = \frac{z^2pq}{l^2}$

Where, z is standard normal variate which is 1.96 for 95% confidence limit; p is proportion of clinical CTS found positive in NCS study which is 13% according to a research paper by Aroori S et al [19]; q is1-p; l is the precision of the estimate. Here in this calculation an absolute precision of 12% was taken. So, using the above formula the calculated the calculated sample size was 29 which was rounded to 30.

Eligibility criteria

Patients age > 18 years, either sex, with paresthesia, numbnesss or tingling affecting the first three digits and the radial half of the fourth digit, Autoimmune diseases like rheumatoid arthritis, space occupying lesions such as ganglion cyst, hypothyroidism, and positive findings of any of the following physical examinations: Phalens test, Tinels sign, direct compression test and evidence of median nerve neuropathy in EMG-NCV were included in the study.

Any patient with past history of traumatic or surgical intervention, arthritis, median nerve injection, history of

previous entrapment release procedure, bifid median nerve, or any patients with nerve conduction study (NCS) findings suggestive of diabetic neuropathy rather than entrapment neuropathy at the carpal tunnel was excluded from the study.

Diagnosis of CTS

History of patient in diagnosing CTS was based on the a) Symptom onset- which in the early stage is mainly nocturnal paraesthesias; b) Provocative factors- such as hand positions and repeated movements; c) Working activity- instrument use, vibrating tools; d) pain localization and irradiation- in the cutaneous median nerve region with ascending, sometimes up to the shoulder, or descending irradiation; e) Manoeuvers which alleviate symptoms- eg hand shaking, position changes; f) Presence of predisposing factors- eg diabetes, adiposity, chronic polyarthritis, myxoedema, acromegaly, pregnancy; and f) Sports activity- eg baseball, bodybuilding.

All patients included in the study were underwent USG of affected wrist joint, CT scan as well MRI of the same. All these three procedures conducted among all cases following the standard operating procedure of the institute.

Statistical Methods

Data was analyzed and appropriate statistical methods like frequency, percentage, Mean, Standard Deviation (SD), chi-square test, and 't' test were employed to analyze data throughout study.

Approval of "Institutional Ethics Committee" was sought before start of the study. Participation in the study was purely on voluntary bases. Duly signed informed consent form was sought from patient before inclusion. Anonymity and confidentiality of the participant was maintained at all levels. The Participant was given right to opt out of the study at any stage without having to give any reason.

RESULTS

Out of total 30 cases, 19 (63.3%) were right-hand and 11 (36.7%) were left-hand. Right hands are more compared to left hand. Out of 30 cases, 14 (46.7%) were bilateral (7x2 = 14 hands) and 16 (53.3%) were unilateral. Majority 11 (36.7%) of the patients were in 40-50 years age group followed by 7 (23.3%) cases were found in age group of 50 – 60 years. The mean age of the study participants was 46.66 year. Out of total 30 cases, 20 (66.7%) were female and 10 (33.3%) were Male. Most common co-morbidities are diabetes, hypothyroidism and hyperlipidemia. Among the study participants majority 5 (16.7%) were found hypothyroidism, followed by 4 (13.3%) diabetes. (Table 1)

Out of total 30 participants, 14 (46.7%) were found moderate severity followed by 11 (36.7%) were found mild severity. Only 5 (16.7%) were found severe carpel tunnel syndrome.

Out of total 30 cases, 25 (83.3%) were found to have carpel tunnel syndrome by nerve conduction study, 27 (90.0%) were found to have carpel tunnel syndrome by USG, 27 (90.0%) were found to have carpel tunnel syndrome by MRI.

The motor and sensory electrodiagnostic parameters among the patient's was mentioned in table 2. Median nerve CMAP distal latency was prolonged (4.64 milliseconds) among 30 patients. Median nerve CMAP Amplitudes was 10.23 mv, CMAP distal latency difference between median & ulnar nerves was 2.18 milliseconds among 30 patients. The velocity was 44.93 meter per seconds and F wave latency was 24.83 milliseconds among the study participants. Median SNAP distal latency was 2.39 ± 0.08 milliseconds in study participants. SNAP latency difference between median and ulnar nerves was 0.83 milliseconds, Median SNAP amplitude was 8.62 millivolts and Median SNAP conduction velocity was 33.20 meter per seconds among 30 patients.

The mean of flattening ratio was 2.71 ± 0.47. The mean of Cross-Sectional Area was 14.88 ± 4.21 mm^2. The mean of Flexor Retinaculum was 1.08 ± 0.3 mm. The mean of Anteroposterior dimension of Carpal Tunnel was 12.1 ± 1.2 mm.

Out of total cases majority of the cases were found CTS by MRI. Among the study participants 27 (90.0%) were found to have CTS followed by 9 (30%) Osteoarthritis, 1 (3.3%) fracture, 3 (10%) cyst, 3 (10%) ganglion. 3 (10.0%) were not found having CTS by MRI.

Table 1: Sociodemographic profile and comorbidity status of the study participants (n=30)

Study Variables	Cases (%)
Hands	
Right hand	19 (63.33)
Left Hand	11 (36.67)
Hands	
Bilateral (x2 hands)	7 (14) (46.67)
Unilateral	16 (53.33)
Age (years)	
Mean ± SD	46.66 (1116)
<30	2 (6.67)
30-40	6 (20)
40-50	11 (36.67)
50-60	7 (23.33)
>60	4 (13.33)
Sex	
Male	10 (33.33)
Female	20 (66.67)
Comorbidity	
Diabetes	4 (13.33)
Hypothyroidism	5 (16.67)
Hyperlipidemia	2 (6.67)
Rheumatoid arthritis	0 (0)

Table 2: Nerve Conduction study and ultrasound finding of the cases

Variables	Value (Mean ± SD)
Nerve Conduction Study	
Motor	
Median nerve Mean CMAP distal latency (ms)	4.64 ± 1.49
Median nerve Mean CMAP Amplitudes (mv)	10.23 ± 0.81
Mean CMAP distal latency difference between median & ulnar nerves (ms)	2.18 ± 0.02
Mean median nerve CMAP conduction velocity (m/s)	44.93 ± 1.92
Mean median nerve F wave Latency (ms)	24.83 ± 1.37
Sensory	
Mean median sensory nerve action potential (SNAP) distal latency (ms)	2.39 ± 0.08
Mean SNAP latency difference (in milliseconds) between median and ulnar nerves (ms)	0.83 ± 0.02
Mean median SNAP amplitude (mv)	8.62 ± 0.19
Mean median SNAP conduction velocity (m/s)	33.20 ± 1.13
USG Findings	
Flattening ratio	2.71 ± 0.47
Cross Sectional Area (mm2)	14.88 ± 4.21
Flexor Retinaculum (mm)	1.08 ± 0.3
Anteroposterior dimension of Carpal Tunnel (mm)	12.1 ± 1.2

Table 3: Comparison of clinical gradings of CTS with grading by other investigation methods

Investigations	Clinical CTS Grade			
	Mild (n=11) (%)	Moderate (n=14) (%)	Severe (n=5) (%)	Total (n=30) (%)
USG Grade*				
No CTS	2(18.18)	1(7.14)	0(0)	3(10)
Mild	8(72.73)	2(14.29)	0(0)	10(33.33)
Moderate	1(9.09)	10(71.43)	1(20)	12(40)
Severe	0(0)	1(7.14)	4(80)	5(16.67)
NCS Grade#				
No CTS	3(27.27)	1(7.14)	1(20)	5(16.67)
Mild	7(63.64)	1(7.14)	0(0)	8(26.67)
Moderate	1(9.09)	9(64.29)	1(20)	11(36.67)
Severe	0(0)	3(21.43)	3(60)	6(20)
MRI Grade				
No CTS	1(9.09)	2(14.29)	0(0)	3(10)
CST	10(90.91)	12(85.71)	5(100)	27(90)

*USG Grade Normal CTS - Cross sectional area of median nerve at outlet of carpel tunnel <8.5 mm^2; Mild CTS - Cross sectional area of median nerve at outlet of carpel tunnel 8.5 mm^2 – 10.5mm^2; Moderate CTS - Cross sectional area of median nerve at outlet of carpel tunnel 10.5mm^2 – 13mm^2; Severe CTS - Cross sectional area of median nerve at outlet of carpel tunnel >13 mm^2

#NCS Mild grade CTS- CTS detected by only PWDSLD* or Median DML <4.5 and sensory NCV <40; Moderately grade CTS- Median DML >4.5 and <6.5 with preserved SNAP; Severe grade CTS- Median DML >4.5 and <6.5 with absent SNAP or Median DML >6.5 with CMAP >0.2 mv or Median CMAP from APB <0.2 mv

PWDSLD: Palm wrist distal sensory latency difference; DML: Distal motor latency; NCV: Nerve conduction velocity; APB: Abductor pollicis brevis

Table 4: Sensitivity of NCS, USG and MRI for diagnosis of CTS in comparison with clinical diagnosis

Investigations	CTS	Sensitivity	95% CI
NCS	25	83.33%	65.28% to 94.36%
USG	27	90.00%	73.47% to 97.89%
MRI	27	90.00%	73.47% to 97.89%

NCS – Nerve conduction study; USG – Ultra sound graphy; MRI – Magnetic resonance imaging; CTS – Carpel tunnel syndrome

As shown in table 3, out of total 11 clinically diagnosed as mild cases, NCS confirm 3 mild, 1 moderate and 1 case as normal (No CTS). Out of total 14 clinically diagnosed as moderate cases, NCS confirm 9 moderate, 3 severe, 1 mild and 1 case as normal. Out of total 5 clinically diagnosed as severe cases, NCS confirm 3 severe, 1 case as moderate and 1 as no CTS. Out of total 11 clinically diagnosed as mild cases, USG confirm 7 mild, 1 moderate and 2 cases as normal (No CTS). Out of total 14 clinically diagnosed as moderate cases, USG confirm 10 moderate, 1 severe, 2 mild and 1 case as normal. Out of total 5 clinically diagnosed as severe cases, USG confirm 4 severe and 1 moderate cases. Out of total 11 clinically diagnosed as mild cases, MRI confirm 10 cases having CTS and 1 case as normal (No CTS). Out of total

14 clinically diagnosed as moderate cases, MRI confirm 12 cases having CTS and 2 cases as normal. Out of 5 severe cases, MRI confirm all 5 cases having CTS.

Amongst all three investigation methods, nerve conduction study having the lowest sensitivity. The sensitivity of the nerve conduction study is 83.33% while the sensitivity of ultrasonography and MRI was 90% each.

DISCUSSION

The most common compressive focal mononeuropathy found in clinical practise is carpal tunnel syndrome (CTS). The median nerve at the wrist is compressed locally, causing mechanical compression and/or local ischemia, which can cause numbness, tingling, burning, and/or pain. [19] Provocative stress tests, including the Phalen's test, Tinel's test, hand elevation test, pressure provocation test, tethered median nerve stress test, tourniquet test, and others, can be used to make a clinical diagnosis at the bedside. [20] Nerve Conduction Studies (NCS) act as objective adjunctive modalities in the diagnosis and evaluation of therapy effectiveness in patients of CTS in addition to the subjective clinical signs. [21] With a high degree of sensitivity and specificity, NCS are used more frequently to determine the severity of CTS and are regarded as the gold standard for diagnosis. [22,23]

The question of whether clinical signs of CTS correlate well with neurophysiologic results has long been up for discussion. Electro diagnostic methods that show anomalies of the median nerve fibres inside the carpal tunnel can be used to confirm clinical CTS.[19,24]

Out of total 30 cases of clinical CTS, 25 (83.3%) were found to have carpel tunnel syndrome by nerve conduction study, 27 (90.0%) were found to have carpel tunnel syndrome by USG, 27 (90.0%) were found to have carpel tunnel syndrome by MRI.

In present study, median nerve CMAP distal latency was prolonged (4.64 milliseconds) among 30 patients. Median nerve CMAP Amplitudes was 10.23 mv; CMAP distal latency difference between median & ulnar nerves was 2.18 milliseconds among 30 patients. The velocity was 44.93 meter per seconds and F wave latency was 24.83 milliseconds among the study participants. In the study by Srikanteswara PK et al [25] (2016), 39 patients had right-sided median nerve CMAP distal delay that was extended (> 4.4 milliseconds) (including 19 right CTS and 20 bilateral CTS) and among 31 patients, the left sided median nerve CMAP distal delay was extended (> 4.4 milliseconds) (including 11 left CTS and 20 bilateral CTS). On both sides, the p-value was significant when compared to control participants.

In present study, median SNAP distal latency was 2.39 ± 0.08 milliseconds in study participants. SNAP latency difference between median and ulnar nerves was 0.83 milliseconds, Median SNAP amplitude was 8.62 millivolts and Median SNAP conduction velocity was 33.20 meter per seconds among 30 patients. In the study by Srikanteswara PK et al [25] (2016), between patients and the healthy control participants, the median and ulnar nerves' mean SNAP distal latency differences (measured in milliseconds) were 0.78±0.01 and 0.19±0.15 on the right side and 0.54±0.01 and 0.18±0.02 on the left side, respectively (p - 0.001 on both sides).

The mean of flattening ratio in this study was 2.71 ± 0.47. The mean of Cross-Sectional Area was 14.88 ± 4.21 mm^2. The mean of Flexor Retinaculum was 1.08 ± 0.3 mm. The mean of Anteroposterior dimension of Carpal Tunnel was 12.1 ± 1.2 mm. This result is almost similar with the study conducted by the El Miedany YM et al [26]. (2004). The findings of the El Miedany YM et al [26] (2004) investigation revealed a trend of rising flattening ratio and flexor retinaculum measurements along with rising carpal tunnel syndrome severity as shown by US and electromyography findings. A cross-sectional area of 9.8 mm^2 was chosen as a trustworthy criterion for CTS in a recent study by Wong et al[18] and the diagnostic value of sonography was made to resemble that of an electrophysiological investigation.

Out of total 11 clinically diagnosed as mild cases, NCS confirm 3 mild, 1 moderate and 1 case as normal (No CTS). Out of total 14 clinically diagnosed as moderate cases, NCS confirm 9 moderate, 3 severe, 1 mild and 1 case as normal. Out of total 5 clinically diagnosed as severe cases, NCS confirm 3 severe, 1 case as moderate and 1 as no CTS. Out of total 11 clinically diagnosed as mild cases, USG confirm 7 mild, 1 moderate and 2 cases as normal (No CTS). Out of total 14 clinically diagnosed as moderate cases, USG confirm 10 moderate, 1 severe, 2 mild and 1 case as normal. Out of total 5 clinically diagnosed as severe cases, USG confirm 4 severe and 1 moderate cases. According to several studies in the literature, sonography and electrophysiological data are directly correlated, and it even enables us to gauge the severity of CTS.[26,27,28] Later, Karadag et al. examined this theory and discovered that sonography and electrophysiological results had a high degree of agreement in characterizing the severity of CTS. [29]

In present study amongst all three investigation methods, nerve conduction study having the lowest sensitivity. The sensitivity of the nerve conduction study is 83.33% while the sensitivity of ultrasonography and MRI was 90% each. Srikanteswara PK et al [25] (2016), study found the sensitivity of ultrasonography and MRI had 30.1% and 53.8% respectively. In kasundra GM et al[16] investigation, a comparison of USG and NCS revealed a generally substantial connection between area and CIR with NCS. Correlations between CIR-M and sensory latency in the ACTS group, CIR-O and sensory latency in the mild group, and sensory amplitude in the moderate group were discovered among the subgroups. Additionally, in the mild-moderate group and in the ACTS group, CSA-M correlated with sensory latency, while CSA-I connected with sensory latency, motor latency, and motor amplitude in the ACTS group.

Limitation of the study

The possible limitations of our study include small sample size, which may be due to less availability of the eligible cases and somewhat the stringent exclusion criteria. Probable influence of various forms of treatment being received by the patients including physiotherapy, drugs for neuropathic pain, wrist splints and therapy for underlying co-morbid factors may influence the results. However, none of our patients had received local corticosteroid injections or underwent surgery for CTS prior to enrolment and NCS. Asymptomatic hands were not included and inclusion of asymptomatic hand as a control to be beneficial as it helps eliminate the bias of the normal anatomical variation in median nerve and the carpal tunnel structures. However, some clinical researchers are of the opinion that inclusion of asymptomatic hand leads to selection bias.

CONCLUSION

Clinical history, symptoms, and signs have often been used in the past to diagnose CTS, with the NCS still being the gold standard. It is clear from this study that the sensitivity of the parameters utilized in NCS (maximum observed 83.33%) is lower than that of the median nerve cross-sectional area detected on USG (90%) and MRI (90%). Some instances that NCS may have missed could be detected by USG and MRI. However, NCS measurement may be utilized to more accurately categories cases into mild, moderate, and severe. Additionally, except from in advanced situations when MRI signal alterations are more obvious, USG has numerous benefits over MRI since it is widely accessible and financially viable. The most sensitive, practical, and cost-effective metric of all those seen in the research turned out to be the median nerve cross sectional area evaluated at the wrist crease by USG.

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