Original Research Paper

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Orthopaedics

COMPARISON OF THE FINDINGS OF NERVE CONDUCTION STUDY, ULTRASONOGRAPHY AND MAGNETIC RESONANCE IMAGING IN EVALUATION OF CLINICALLY SYMPTOMATIC PATIENTS OF CARPAL TUNNEL SYNDROME

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ABSTRACT **Objective:** Carpal tunnel syndrome (CTS) is diagnosed based on history, physical examination, nerve conduction testing, ultrasound and magnetic resonance imaging, however the best diagnostic criteria for the syndrome have not been established, and there is considerable disagreement as to the relative importance of various clinical findings. The purpose of this study was to compare the findings of nerve conduction study, ultrasound and magnetic resonance imaging in patients with clinical symptoms and signs of carpal tunnel syndrome.**Methods:** In this study, 30 patients with clinically determined CTS underwent nerve conduction study (NCS), ultrasonography (USG) and magnetic resonance imaging (MRI). Distal motor latency (DML), median nerve conduction velocity, sensory latency and amplitude were measured using NCS. On USG cross sectional area (CSA) of the nerve at the wrist crease was determined. On MRI, Median nerve swelling with cut off of 15mm2 and T2 weighted hyperintensity in the nerve and thenar muscles were the parameters considered. Results: Out of the 30 patients of clinically determined CTS, 20 were female and 10 were male with a mean age of 41. Median duration of symptoms was 12 months. All these patients were then sent for NCS, MRI and USG and report was sought according to the parameters enlisted above for standardization. Abductor pollicis brevis (APB)-DML was abnormal in 23 patients (76%). Compound muscle action potential (CMAP) was not recordable in 2 patients. Lumbar interosseous comparison studies were abnormal in 22 patients (55%) and CMAP was unrecordable in 4 patients. Terminal latency index (TLI) of abductor pollicis brevis was abnormal in 21 patients (73%), of lumbricals in 20 patients (66.66%). All sensory studies had a sensitivity of at least 72.5% (sensory median-radial comparison test). For motor studies, sensitivity was generally lesser except for the TLI-APB. On Ultrasound, it was determined that patients with CSA > 11.2mm2 had CTS with 90% sensitivity. The least diameter observed was 11.2 mm2 and largest was 19.5 mm2. MRI was abnormal in 27 patients (90%) with highest value observed being 21.4 mm2. **Conclusions:**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 utilised 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 utilised to more accurately categorise 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.

KEYWORDS :

Research paper at Krishna institute of medical science, Karad, Malkapur, Maharastra, Inida.Study done from september 2020 to december 2022.Introduction.

The most typical occupationally associated illness that affects the peripheral nerves is CTS, which is also the most typical neuropathy leading to entrapment. 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. 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. 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. A technique called NCS has a false negative rate and a sensitivity range of 49 to 86%. According to earlier research, musculoskeletal USG may provide diagnostic accuracy in a similar way. 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). Altinok T et al., utilising NCS as the reference standard, further validated their study. When compared to other USG metrics, Duncan I et al research demonstrated that the CSA diagnostic parameter is an excellent criterion for CTS identification. Numerous other earlier studies 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. 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. 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. 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. (p-value-0.0001). When making a USG diagnosis of CTS, Billakota S and Hobson Webb LD employed a median nerve CSA larger than 9 mm2 and/or a wrist-to-forearm ratio greater than 1.4. EDx studies were the gold standard for diagnosis. USG was positive in 97.6% of CTS that had been confirmed by EDx. According to Roghani RS et al analysis of 203 clinically ill individuals, the inlet-to-antecubital CSA ratio of 0.65 and the tunnel's CSA of 8.5 mm2 provided the best diagnostic accuracy for CTS.

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.

Aim and objectives

AIM:

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.

OBJECTIVES:

1. To perform nerve conduction study, ultrasonography and magnetic resonance imaging in clinically determined cases of carpal tunnel syndrome .
2. To assess utility of nerve conduction study, ultrasonography and magnetic resonance imaging in diagnosing clinically determined cases of carpal tunnel syndrome.
3. To evaluate the diagnostic ability of various parameters of the above mentioned investigations and determining their sensitivity in diagnosing carpal tunnel syndrome

Materials and Methods

Place of study: The study was conducted in the department of Orthopaedics, Krishna Institute of Medical Sciences and Hospital, Karad. Patients from local and surrounding districts mainly avail services from the hospital.

Study Population: All the patients clinically diagnosed with Carpal tunnel syndrome in the opd or admitted in Krishna Hospital after for the same clinical 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 and clinically diagnosed with carpel tunnel syndrome or admitted in the hospital were included in the study. Patients were then evaluated using nerve conduction study, ultrasonography and magnetic resonance imaging.

Design of study: This was an observational study for evaluation of diagnostic ability of various diagnostic utilities 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:

$$\text{Sample size } N = \frac{z^2 pq}{l^2}$$

Where, z = standard normal variate which is 1.96 for 95% confidence limit

p = proportion of clinical CTS found positive in NCS study which is 13% according to a research paper by Aroori S et al.

q = 1-p

l = 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. The patients in this study, who have fulfilled the following inclusion and exclusion criteria were selected.

INCLUSION CRITERIA

1. Age > 18 years
2. Adults of either sex
3. Patients with paresthesia, numbnesss or tingling affecting the first three digits and the radial half of the fourth digit.
4. Positive findings of the following physical examinations: Phalens test, Tinels sign, direct compression test, tourniquet test, pressure provocation test, hand elevation test and tethered median nerve stress test.
5. Autoimmune diseases like rheumatoid arthritis
6. Space occupying lesions such as ganglion cyst
7. Hypothyroidism

EXCLUSION CRITERIA

1. Age <18 years
2. Past history of traumatic or surgical intervention, median nerve injection.
3. Patients with history of previous entrapment release procedure

Material used in the study:

1. Nerve Conduction Electromyography Machine
2. Ultra-Sonography Machine
3. Magnetic Resonance Imaging Machine

Diagnosis

History of patient in diagnosing CTS must focus on following points
1. Symptom onset- which in the early stage is mainly nocturnal paraesthesias
2. Provocative factors- such as hand positions and repeated movements
3. Working activity- instrument use, vibrating tools.
4. pain localization and irradiation- in the cutaneous median nerve region with ascending, sometimes up to the shoulder, or descending irradiation.
5. Manoeuvers which alleviate symptoms- eg hand shaking, position changes
6. Presence of predisposing factors- eg diabetes, adiposity, chronic polyarthritis, myxoedema, acromegaly, pregnancy.
7. Sports activity- eg baseball, bodybuilding

The two provocative tests most used in the clinical setting are Phalen's and Tinel's tests

Carpal Tunnel Syndrome – Tinel's Sign

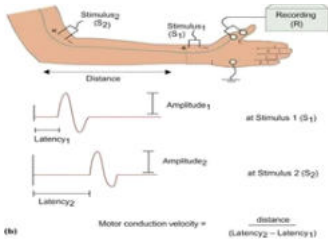
- Tinel's Sign – When therapist taps over the carpal tunnel, the client will feel parasthesias or tingling distally

Phalen's Test

- Therapist flexes client's wrists manually and holds together for one minute. Positive test elicits tingling in thumb, index finger, and middle and lateral half of the ring finger and is indicative of Carpal Tunnel Syndrome.

Nerve conduction study (NCS) is the most commonly used diagnostic test for CTS. Ultrasonography (USG) magnetic resonance imaging (mri) may also be used for the diagnosis. Thre are numerus studies on each particular diagnostic test. Most of the studies accept NCS as the gold standard and attempt to determine the accuracy of other tests in comparison with NCS. The aim of this study was to compare the

diagnostic accuracy of NCS, US, MRI for the diagnosis of CTS with the use of the clinical findings as the gold standard



Nerve Conduction Study

Figure 1. Transverse sonogram in a patient with clinical evidence of mild carpal tunnel syndrome. A large eccentric space occupying fluid-filled ganglion is seen (arrowheads) abutting the flexor tendons and dislocating the median nerve (arrow).

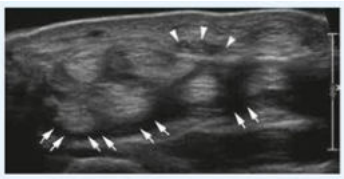
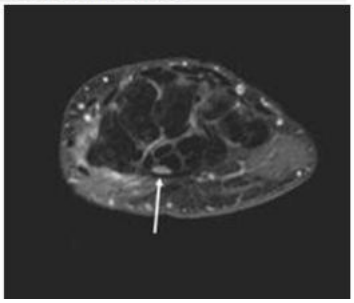


Figure 2. Transverse sonogram through the distal carpal tunnel in a patient with secondary carpal tunnel syndrome. Marked hypoechoic fluid collections (small arrows) are seen between the mildly swollen flexor tendons diagnostic of tendovaginitis. The median nerve is flattened (arrowheads).



Magnetic Resonance Imaging in CTS

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. Descriptive and inferential statistical analysis was carried out in the present study. Results on continuous measurements were presented on Mean ± SD (Min-Max) and results on categorical measurements were presented in Number (%). Significance was assessed at 95 % level of significance. The following assumptions on data was made for the statistical analysis:

Assumptions:
1. Dependent variables should be normally distributed, Samples drawn from the population should be random, Cases of the samples should be independent.

Student t test (two tailed, independent) was be used to find the significance of study parameters on continuous scale between two groups (Inter group analysis) on metric parameters. Chi-square/ Fisher Exact test was used to find the significance of study parameters on categorical scale between two or more groups.

ETHICAL ISSUES

1. The prospective participants were explained about the purpose and nature of the study by me in the language he/she understands.
2. Duly signed informed consent form was sought from patient.

The participant shall be recruited only after patient willingly signs the Informed Consent Form (ICF).

4. Anonymity and confidentiality of the participant was maintained at all levels.

5. The Participant was given right to opt out of the study at any stage without having to give any reason. This was not jeopardizing his/her right to receive appropriate treatment and care.

6. No Participant had to bear any extra cost exclusively for the purpose of this study. If extra cost is required to be incurred purely for the purpose of this study, it was borne by the investigator.

7. Approval of "Institutional Ethics Committee" was sought before start of the study. I was committed to inform "Institutional Ethics Committee" about any change in study, protocol, or design in advance for approval, however, no such instance arise during the course of the study. If any ethical issue arises after completion of the study, it will be informed to the ethics committee.

Results

The study was conducted in 30 hands to compare the diagnostic ability of nerve conduction study, ultrasonography, and magnetic resonance imaging in diagnosis of carpel tunnel syndrome determined by clinical findings. The following tables show observations of the study.

Table 1: Distribution of side of hands among the study samples

Hands	Cases	Percentage
Right hand	19	63.3%
Left Hand	11	36.7%
Total	30	100.0%

Table one shows that the distribution of side of hands among the study samples. 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.

Figure 1: Distribution of side of hands among the study Samples

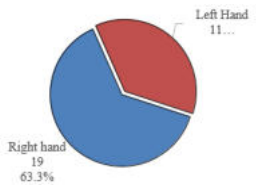


Table 2: Distribution of dominance of hands among the study samples

Hands	Cases	Percentage
Dominant hand	21	70%
Non dominant Hand	9	30%
Total	30	100.0%

Table 2 shows that the distribution of dominance of hands among the study samples. Out of total 30 cases, 21 (70%) were dominant hand and 9 (30%) were non dominant hand. Dominant hands are more compared to non dominant hand.

Figure2 : Distribution of dominance of hands among the study samples

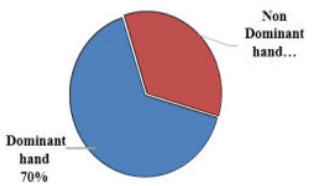


Table 3: Distribution of unilateral and bilateral hands among the study samples

Hands	Cases	Percentage
Bilateral (x2 hands)	7 (14)	46.7%
Unilateral	16	53.3%
Total	30	100.0%

Figure 3: Distribution of unilateral and bilateral hands among the study samples

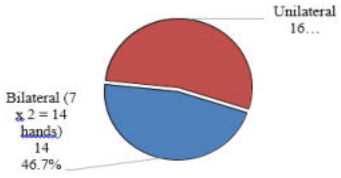


Table 4: Age distribution of the study samples

Age (years)	Cases	Percentage
<30	2	6.7%
30-40	6	20.0%
40-50	11	36.7%
50-60	7	23.3%
>60	4	13.3%
Total	30	100.0%
Mean ± SD	46.66	11.16

Table 4 shows that the age wise distribution of the study samples. Out of 30 cases, 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.

Figure 4: Age distribution of the study samples

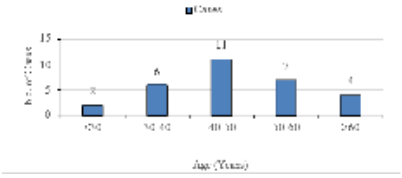


Table 5: Gender Distribution of the study sample

Sex	Cases	Percentage
Male	10	33.3%
Female	20	66.7%
Total	30	100.0%

Table 5 shows that the gender wise distribution of the study sample. Out of total 30 cases, 20 (66.7%) were female and 10 (33.3%) were Male.

Figure 5: Gender Distribution of the study sample

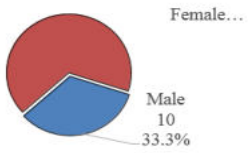


Table 6: Distribution of co-morbidities among the study sample

Comorbidity	Cases	Percentage
Diabetes	4	13.3%
Hypothyroidism	5	16.7%
Hyperlipidemia	2	6.7%
Rheumatoid arthritis	0	0.0%

Table 6 shows distribution of co-morbidities among the study sample. 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 7: Clinical severity of carpel tunnel syndrome in the study sample

Clinical Severity	Cases	Percentage
Mild	11	36.7%
Moderate	14	46.7%
Severe	5	16.7%
Total	30	100.0%

Figure 6: Distribution of co-morbidities among the study sample

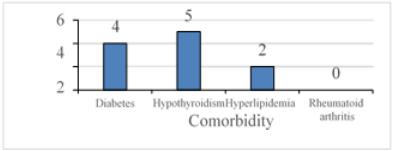
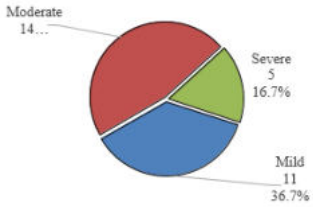


Table 7 shows clinical severity of carpel tunnel syndrome in the study sample. Out of total 30 participants, 14 (46.7%) were found moderate severity followed by 11 (36.7%) were found mild severity. Only 5 (16.7%) were found severe carpel tunnel syndrome.

Figure 7: Clinical severity of carpel tunnel syndrome in the study sample



STAGE 1 (MILD): Patients with stage 1 carpal tunnel typically experience numbness, pain, and tingling, primarily at night, and can make the symptoms go away by shaking out their hands. Affected hands often feel stiff in the morning.

STAGE 2 (MODERATE): Patients with stage 2 carpal tunnel also experience symptoms during the day, when their hands are in the same position for a long time, or while doing repetitive movements. Their hands often start to feel weak, and it's not uncommon for them to drop objects they're holding.

STAGE 3 (SEVERE): Patients with stage 3 carpal tunnel often experience atrophy, where the muscles connected to the median nerve permanently shrink. Because the nerve is injured and no longer sending signals to the brain, the tingling sensation might have gone away.

Table 8: Results of various clinical test related to carpel tunnel syndrome

Clinical Test	Cases	Sensitivity	95% CI
Phalen Test	22	73.33%	54.11%to87.72%
Tinel's Test	25	83.33%	65.28%to94.36%
Hand Elevation Test	27	90.00%	73.47%to97.89%
Pressure Provocation Test	25	83.33%	65.28%to94.36%
Tethered Median Nerve Stress Test	22	73.33%	54.11%to87.72%
Torniquet Test	23	76.67%	57.72%to90.07%

Table 8 shows results of various clinical test related to carpel tunnel syndrome. Various different test was performed for CTS. Among the all test the sensitivity of Hand Elevation Test is higher which is 90% followed by Tinel's Test 83.33%, Pressure Provocation Test 83.33%, Torniquet Test 76.67%, Phalen Test 73.33% and Tethered Median Nerve Stress Test 73.33%.

Figure 8: Results of various clinical test related to carpel tunnel syndrome

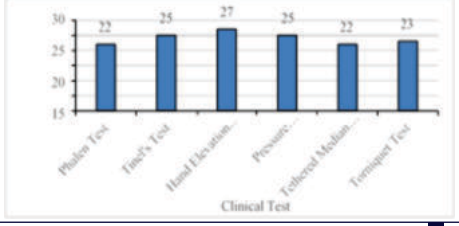


Table 9: Results of nerve conduction study in clinical cases of CTS

Nerve conduction study	Cases	Percentage
CTS	25	83.3%
No CTS	5	16.7%
Total	30	100.0%

Table 9 shows results of nerve conduction study in clinical cases of CTS. Out of total 30 cases, 25 (83.3%) were found having carpel tunnel syndrome by nerve conduction study. 5 (16.7%) were not found having carpel tunnel syndrome by nerve conduction study.

Figure 9: Results of nerve conduction study in clinical cases of CTS

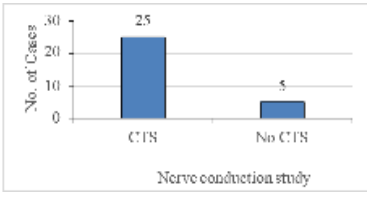


Table 10: Results of USG in clinical cases of CTS

USG	Cases	Percentage
CTS	27	90.0%
No CTS	3	10.0%
Total	30	100.0%

Table 10 shows that the results of ultrasonography in clinical cases of Carpel Tunnel Syndrome. Out of total 30 cases, 27 (90.0%) were found having carpel tunnel syndrome by USG. 3 (10.0%) were not found having carpel tunnel syndrome by USG.

Figure 10: Results of USG in clinical cases of CTS

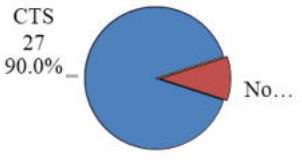


Table 11: Results of MRI in clinical cases of CTS

MRI	Cases	Percentage
CTS	27	90.0%
No CTS	3	10.0%
Total	30	100.0%

Table 11 shows that the results of MRI in clinical cases of Carpel Tunnel Syndrome. Out of total 30 cases, 27 (90.0%) were found having carpel tunnel syndrome by MRI. 3 (10.0%) were not found having carpel tunnel syndrome by MRI.

Figure 11: Results of MRI in clinical cases of CTS

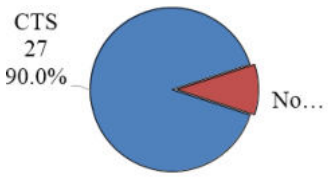


Table 12: Various Electrodiagnostic Parameters in NCS

Electrodiagnostic Parameters	Mean ± SD
Motor	
Median nerve CMAP distal latency (ms)	4.64 ± 1.49
Median nerve CMAP Amplitudes (mv)	10.23 ± 0.81
CMAP distal latency difference between median & ulnar nerves (ms)	2.18 ± 0.02
Median nerve CMAP conduction velocity (m/s)	44.93 ± 1.92
Median nerve F wave Latency (ms)	24.83 ± 1.37
Sensory	
Median SNAP distal latency (ms)	2.39 ± 0.08
SNAP latency difference between median and ulnar nerves (ms)	0.83 ± 0.02
Median SNAP amplitude (mv)	8.62 ± 0.19
Median SNAP conduction velocity (m/s)	33.20 ± 1.13

CMAP= compound motor action potential, SNAP =sensory nerve action potential ms= millisecond, mv=millivolts, m/s= meter per second

Table 12 shows that various electrodiagnostic parameters (Motor and Sensory) in Nerve Conduction Study.

The motor electrodiagnostic parameters among the patient's was mentioned in table 11. 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.

The sensory electrodiagnostic parameters among the patient's was mentioned in table 11. 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.

Table 13: Various dimensions in USG

USG Findings	Mean values ± SD
Flattening ratio	2.71 ± 0.47
Cross Sectional Area (mm^2)	14.88 ± 4.21
Flexor Retinaculum (mm)	1.08 ± 0.3
Anteroposterior dimension of Carpal Tunnel (mm)	12.1 ± 1.2

Table 13 shows that various dimensions in ultrasonography findings.
The mean of flattening ratio was 2.71 ± 0.47.
The mean of Cross-Sectional Area was 14.88 ± 4.21 mm2.
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.

Table 14: Sensitivity of various parameters used in USG to diagnose Carpal tunnel syndrome

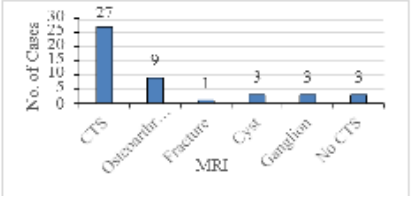
USG Findings	Diagnosis of CTS	
	Sensitivity	95% CI
Flattening ratio	73.33%	54.11% to 87.72%
Median nerve Cross 2 Sectional Area(mm)	80.00%	61.43% to 92.29%
Flexor Retinaculum (mm)	60.00%	40.60% to 77.34%
Anteroposterior dimension of Carpal Tunnel (mm)	66.67%	47.19% to 82.71%

Table 15: Findings of MRI

MRI	Cases	Percentage
CTS	27	90.0%
Osteoarthritis	9	30.0%
Fracture	1	3.3%
Cyst	3	10.0%
Ganglion	3	10.0%
No CTS	3	10.0%

Table 15 shows that findings of MRI in carpel tunnel syndrome. 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.

Figure 12: Findings of MRI



Classifications of NSC Grades used in the current study

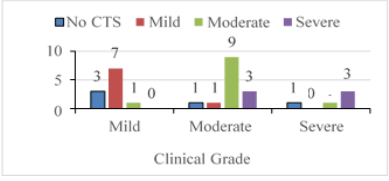
NSC Grades used in the current study	Grading criteria	NCS abnormality
Mild	Grade 1: Very mild	CTS detected by only PWDSLD*
	Grade 2: Mild	Median DML <4.5 and sensory NCV <40
Moderately	Grade 3: Moderately severe	Median DML >4.5 and <6.5 with preserved SNAP
Severe	Grade 4: Severe	Median DML >4.5 and <6.5 with absent SNAP
	Grade 5: Very severe	Median DML >6.5 with CMAP >0.2 mv
	Grade 6: Extremely severe	Median CMAP from APB <0.2 mv

Table 16: Comparison of clinical grade and NCS grade

Clinical Grade	NCS Grade				
	No CTS	Mil d	Moderat e	Severe	Tota l
Mild	3	7	1	0	11
Moderate	1	1	9	3	14
Severe	1	0	1	3	5
Total	5	8	11	6	30

Table 16 shows that the comparison of clinical grade and NCS grade. Out of total 11 clinically diagnosed as mild cases, NCS confirm 3 mild, 1 moderate and 1 cases 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.

Figure 13: Comparison of clinical grade and NCS grade



Classifications of USG Grades used in the current study

	Cross sectional area of median nerve at outlet of carpel tunnel
Normal	<8.5 mm2
Mild	8.5 mm2 – 10.5mm2
Moder ately	10.5mm2 – 13mm2
Severe	>13 mm2.

Table 17: Comparison of clinical grade and USG grade

Clinical Grade	USG Grade				
	No CTS	Mild	Moderate	Severe	Total
Mild	2	8	1	0	11
Moderate	1	2	10	1	14
Severe	0	0	1	4	5
Total	3	10	12	5	30

Table 17 shows that the comparison of clinical grade and USG grade. 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.

Figure 15: Comparison of clinical grade and USG grade

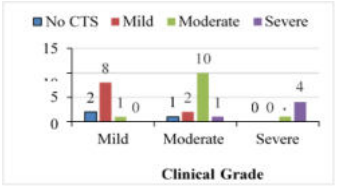


Table 18: Comparison of clinical grade and MRI grade

Clinical Grade	MRI Grade		
	No CTS	CTS	Total
Mild	1	10	11
Moderate	2	12	14
Severe	0	5	5
Total	3	27	30

Table 18 shows that the comparison of clinical grade and MRI grade. Out of total 11 clinically diagnosed as mild cases, MRI confirm 10 cases having CTS and 1 cases 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 total 5 clinically diagnosed as severe cases, MRI confirm all 5 cases having CTS.

Figure 14: Comparison of clinical grade and MRI grade

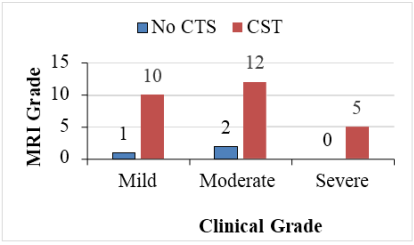
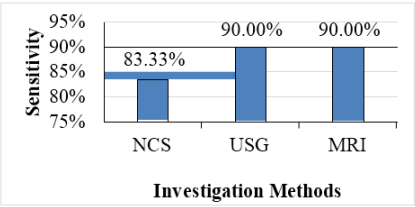


Table 19: Sensitivity of various investigation methods in comparison to the clinical diagnosis

Investigation Methods	Carpel Tunnel Syndrome	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%

Table 19 shows that the sensitivity of various investigation methods in comparison to the clinical diagnosis. Amongst the all three investigation methods, nerve conduction study having the highest sensitivity. The sensitivity of the nerve conduction study is 90% while the sensitivity of ultrasonography is 83.33% followed by MRI is 76.67%.

Figure 15: Sensitivity of various investigation methods in comparison to the clinical diagnosis



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. 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.

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. 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.

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. The present study was conducted in 30 hands to compare the diagnostic ability of nerve conduction study, ultrasonography, and magnetic resonance imaging in diagnosis of carpel tunnel syndrome determined by clinical findings.

In present study 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. In present study out of 30 cases, 14 (46.7%) were bilateral (7 x 2 = 14 hands) and 16 (53.3%) were unilateral.

In the study by Srikanteswara PK et al (2016) conducted a prospective case control study with 50 patients included in 10 months of research. In this study, they found 11 left hand, 19 right hand and 20 bilateral patients.

In the study by Kasundra GM et al (2019), performed a prospective study with 60 patients out of them 54 (93 hands) were found having carpel tunnel syndrome. Out of total patients they found 39 (72.2%) were bilateral followed by 14 (25.9%) unilateral- with dominant hand and 1 (1.9%) was unilateral with non- dominant hand.

El Miedany YM et al (2004) performed study on 78 patients (96 hands). Out of total 78cases, 41 were right hand, 19 were left hand and 17 were bilateral.

In present study out of 30 cases, majority 11 (36.7%) of the patients were in 40-50 years age group followed by7 (23.3%) cases were found in age group of 50 – 60 years. The mean age of the study participants was 46.66 year. The mean age is almost similar with the study performed by Srikanteswara PK et al (2016).

In the study by Srikanteswara PK et al (2016), out of total 50 cases, most of the patient's age were in 25-81 years. The mean age of the study group is 49.68 ± 11.7 years. In the study by Kasundra GM et al (2019), found the mean age war 43.9 ±14 years.

In El Miedany YM et al (2004) study, the age range was between the 29 years to 67 years. For both men and women, a 5-year interval was the maximum allowed for age matching. The age of the patients group was 44.9±6.16 years.

In present study out of total 30 cases, 20 (66.7%) were female and 10 (33.3%) were Male.

In the study by Srikanteswara PK et al (2016), out of total 50 cases, 11 were male and 39 were female. 78% of the patients in the study by Srikanteswara PK et al (2016) were female, with a male to female ratio of 3.5 to 1. Fluid retention during pregnancy or menopause is frequently linked to the development of the condition, and female gender is an independent risk factor for the development of CTS. Although hormonal considerations may play a role in the increased prevalence in women, it is generally thought that women are more prone to and experience musculoskeletal disorders more frequently.

In the study by Kasundra GM et al (2019), found that out of total 54 cases most of the case were female. Male to female ratio was 13:79.
Nakamichi K et al (2002) evaluated, 275 patients (40 men, 235 women) with idiopathic CTS, aged 40–70 (mean, 55 years), had their 414 wrists evaluated by Nakamichi K et al., and 408 controls (74 men, 334 women), also aged 40–70 (mean, 57 years), had their 408 dominant-side wrists checked.

In El Miedany YM et al (2004) study, the majority of the cases were female. In their study out of total 51 cases were female and 27 cases were male.

In present study, 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.

In the study of Srikanteswara PK et al (2016), the most prevalent co-morbidities were postpartum (4%), rheumatoid arthritis (12%), diabetes mellitus (10%), hyperlipidemia (6%), and repeated hand twisting and turning while working (4%).

The common co-morbidities and risk factor in the study by Kasundra GM et al (2019), was Obesity (15%), followed by hypothyroidism (12.9%), diabetes mellitus (10.75%), factors at work (8.6%), and postpartum condition (7.53%). Only one patient (1.1%) had rheumatoid arthritis as an accompanying condition.

In present study 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 50 cases, 16 patients (32%) in the study by Srikanteswara PK et al (2016) had mild CTS, 25 (50%) had moderate CTS, and 9 (18%) had severe CTS clinically.

In present study various test was performed for CTS. Among the all test, the sensitivity of Hand Elevation Test is higher which is 90% followed by Tinel's Test 83.33%,Pressure Provocation Test 83.33%, Torniquet Test 76.67%, Phalen Test 73.33% and Tethered Median Nerve Stress Test 73.33%.

In the study by Srikanteswara PK et al (2016), Tingling - 48 (98%) Tinel's sign - 36 (72%) Phalen's test - 44 (88%) were found.

In Kasundra GM et al (2019) study, When compared to other clinical tests, Tinel's test showed a moderate sensitivity (78.5%) but a high specificity (91%), while Phalen's test and hand elevation tests had high sensitivities (84.9% each) and specificities (74-83%). The tethered median nerve test and the tourniquet test exhibited only moderate sensitivities (70%) and specificities (65-70%), but the pressure provocation test had high sensitivity (81.7%) but moderate specificity (69.6%).

In present study out of total 30 cases, 25 (83.3%) were found to have carpel tunnel syndrome by nerve conduction study. 5 (16.7%) were not found to have carpel tunnel syndrome by nerve conduction study.

In present study out of total 30 cases, 27 (90.0%) were found to have carpel tunnel syndrome by USG. 3 (10.0%) were not found to have carpel tunnel syndrome by USG.

In present study out of total 30 cases, 27 (90.0%) were found to have carpel tunnel syndrome by MRI. 3 (10.0%) were not 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 (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. It is noteworthy that right-sided CTS patients had longer median and ulnar nerve latency differences than left-sided CTS patients did.

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 (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 median nerve SNAP conduction velocities (measured in meters/second) were 34.22±1.11 and 52.09±2.21 and 32.09±1.07 and 51.21±2.3 correspondingly among the patients and healthy control participants on the right side and left side, respectively (p <0.001 on both sides).

In present study, the mean of flattening ratio was 2.71 ± 0.47. The mean of Cross-Sectional Area was 14.88 ± 4.21 mm2. 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. (2004).

The findings of the El Miedany YM et al. (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. The mean of flattening ratio was 2.65±0.52 for symptomatic hands and 1.75±0.15 for asymptomatic hands. The mean of Cross-Sectional Area was 15.18 ± 4.38 mm2 and 8.81±3.2 mm2 for symptomatic and asymptomatic hands respectively. The mean of Flexor Retinaculum was 1.05 ± 0.2 mm and 0.85 ± 0.46 mm for symptomatic and asymptomatic hands respectively. The mean of Anteroposterior dimension of Carpal Tunnel was 11.9 ± 1.3 mm and 11.9 ± 0.9 mm for symptomatic and asymptomatic hands respectively.

A cross-sectional area of 9.8 mm2 was chosen as a trustworthy criterion for CTS in a recent study by Wong et al and the diagnostic value of sonography was made to resemble that of an electrophysiological investigation. In present study 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. According to a study by Srikanteswara PK et al (2016), osteoarthritis (41.03%), cysts (12.82%), ganglions (5.13%), and accidental fractures (5.13%) are some of the related diseases. Thus, it appears that MRI has a low overall sensitivity.

In present study 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.

In present study 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.

El Miedany advised cross-section area cut off points of 10–13 mm2 for mild symptoms, 13–15 mm2 for moderate symptoms, and >15 mm2 for severe patients in order to distinguish between different categories of CTS severity. 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.

In present study 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 total 5 clinically diagnosed as severe cases, MRI confirm all 5 cases having CTS.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 (2016), study found the sensitivity of ultrasonography and MRI had 30.1% and 53.8% respectively.

In kasundra GM et al 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. Other studies have not looked at CIR of the median nerve, although they do demonstrate a substantial association between CSA and NCS. Nakamichi K et al (2002) discovered that the NCS was highly reproducible (coefficients of variation 5%) in terms of dependability. When five measurements were averaged, the ultrasonographic measurement was less repeatable but still acceptable for clinical application (coefficients of variation 10%). It is too soon to draw the conclusion that ultrasonography's function has been established. The current gold standard for the diagnosis of CTS is a combination of the clinical symptoms and NCS, and NCS is well established in this context. NCS is useful for gauging the extent of nerve dysfunction and tracking the effectiveness of treatment. Ultrasonography cannot evaluate nerve function, and its value in observing the effectiveness of treatment is still being explored. However, prior research. and Nakamichi K et al indicate that ultrasonographic measurement can be utilised in addition to NCS as an objective test.

MRI was performed on 39 CTS patients by Srikanteswara PK et al (2016), and 21 individuals (53.8%) had CTS. On MRI, CTS is recognized as median nerve edoema and T2-weighted hyper-intensity of the median nerve and thenar muscles. These results are also similar with studies performed by Jarvik JG et al (2008), Kleindienst A et al (1996) and Radack DM et al (1997).

Sonography was used for the first time by Buchberger et al to quantify alterations in carpal tunnel syndrome. They found that the results of past MRI investigations were accurate. Later, additional studies on sonography and MRI for CTS were released. Current criteria for MRI and sonography include the median nerve swelling at the carpal tunnel's entry and the median nerve flattening and palmar bending of the flexor retinaculum at the tunnel's departure. An additional requirement for MRI in CTS cases is an increase in signal intensity within the median nerve on T2-weighted images at the carpal tunnel exit. Both MRI and sonography literature mentions thickening of the flexor retinaculum and an increased height of the carpal tunnel, as measured from the apex of the flexor retinaculum convexity to the underlying carpal bone. As a result, the criteria for MRI and sonography have converged but are still up for debate.

The mild group had longer sensory latencies (left > right) compared to the clinical grading, but there were no sensory waves in 25 hands (right 11; left 14).

The best accuracy for confirming the clinical diagnosis can be achieved by comparing the median sensory latency to the ulnar, or median, sensory latencies (segments outside the carpal tunnel). This comparison also aids in controlling for other confounding factors like temperature, age, height, and other patient-specific variability. The ring diff is a common antidromic technique that uses ring electrodes to stimulate the median and ulnar nerves at the wrist and record data 14 cm from the ring finger. Since both the median and ulnar nerves innervate the ring finger, comparing their latencies can be a useful way to determine how much the median nerve slows down in comparison to the ulnar across the wrist. Due to the location of ring finger fibres near the outer margin of the median nerve beneath the transverse carpal ligament, the ring finger's median nerve fibres may be more susceptible to compression. Due to its high variability, the sensory nerve action potential amplitude has not been reported as being particularly accurate in the diagnosis of CTS. In more severe cases of CTS, the median response might not be present due to the modest SNAP amplitudes.

SUMMARY

1. The study was conducted in 30 hands to compare the diagnostic ability of nerve conduction study, ultrasonography, and magnetic resonance imaging in diagnosis of carpel tunnel syndrome determined by clinical findings.

2. 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.

3. Out of 30 cases, 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.

4. 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.

5. 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.

6. Various tests were performed for CTS. Among all tests the sensitivity of Hand Elevation Test is higher which is 90% followed by Tinel's Test 83.33%, Pressure Provocation Test 83.33%, Torniquet Test 76.67%, Phalen Test 73.33%, and Tethered Median Nerve Stress Test 73.33%.

7. Out of total 30 cases, 25 (83.3%) were found to have carpel tunnel syndrome by nerve conduction study.
5 (16.7%) were not found to have carpel tunnel syndrome by nerve conduction study.

8. Out of total 30 cases, 27 (90.0%) were found to have carpel tunnel syndrome by USG. 3 (10.0%) were not found to have carpel tunnel syndrome by USG.

9. Out of total 30 cases, 27 (90.0%) were found to have carpel tunnel syndrome by MRI. 3 (10.0%) were not found to have carpel tunnel syndrome by MRI.

10. The motor electrodiagnostic parameters among the patient's was mentioned in table 11. 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.

11. The sensory electrodiagnostic parameters among the patient's was mentioned in table 11. 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.

12. The mean of flattening ratio was 2.71 ± 0.47. The mean of Cross-Sectional Area was 14.88 ± 4.21 mm2. 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.

13. 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.

14. 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.

15. 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.

16. 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 total 5 clinically diagnosed as severe cases, MRI confirm all 5 cases having CTS.

17. 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.

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 utilised 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 utilised to more accurately categorise 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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