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A Study of Electrophysiological Profile of Carpal Tunnel Syndrome in a Tertiary Care Hospital

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Abstract: ***Carpal Tunnel Syndrome (CTS) is a prevalent entrapment neuropathy caused by median nerve compression at the wrist, significantly impacting quality of life and functionality. This study aimed to evaluate the electrophysiological profiles of CTS through a retrospective analysis of 86 patients, including 172 hands tested with nerve conduction studies (NCS). Results revealed 70% clinical involvement and 72% abnormalities in routine NCS. Moderate CTS was the most common severity level, observed in 68% of affected hands. Comparison studies identified subclinical CTS in asymptomatic hands, underscoring their diagnostic importance when routine NCS appears normal. The findings highlight the necessity of lifestyle modifications and targeted diagnostic approaches to manage CTS effectively, especially in the dominant hand and in women within the 21–40 age group.***

Keywords: Carpal Tunnel Syndrome, Nerve Conduction Studies, Comparison Studies, Electrophysiological Profile, Subclinical CTS, Peripheral Neuropathy

1. Introduction and Background

Carpal Tunnel Syndrome (CTS) is a clinical syndrome that results from compression of median nerve within the carpal tunnel at the wrist. Carpal tunnel syndrome is the most common peripheral nerve entrapment syndrome worldwide [1] with a life time risk of 10%. It accounts for about 90% of all entrapment neuropathies. The incidence and prevalence vary from 0.1–1% and 5–16% respectively [2]. The peak incidence between the ages of 45 and 54 years, and women are three times more likely to be afflicted by CTS than men. Carpal tunnel syndrome (CTS) is one of the important causes of pain, paresthesia and functional limitation of the hand [3] In most cases, it is idiopathic and has a significant impact on individual well-being and economic activity [4].

CTS is often listed as an occupational hazard, which requires repetitive motion of the hands. Dominant hand is most affected. The clinical features of CTS are variable, and includes pain and paresthesia in the thumb, index, middle finger, and the radial-half of the ring finger. Pain frequently radiates proximally into the forearm, and occasionally to the shoulder [5]. Many patients experience pain at night and are awakened by abnormal sensations. Shaking hands relieves the symptoms [5]. The two major sites of compression are at the outlet of the tunnel under the flexor retinaculum roof and at the hamulus of the hamate. Compression can arise from increased compartmental pressure in the carpal tunnel, and the most common mechanism of this is hypertrophy of the synovial tissue that surrounds the extrinsic tendons of the forearm. Certain clinical conditions may predispose a person to CTS including obesity, diabetes mellitus, rheumatoid arthritis, hypothyroidism, acromegaly, etc.

Provocative tests help in clinical diagnosis. Like Durkan's test, Phalen test, reverse Phalen test and Tinel's sign [5]. Durkan's test is the most sensitive test to diagnose carpal tunnel syndrome and is performed by pressing thumbs over the carpal tunnel and holding pressure for 30 seconds. Occurrence of pain or paresthesia in the median nerve distribution within 30 seconds is a positive result. Phalen test is wrist volar flexion against gravity for ~60 sec produces symptoms. Reverse Phalen test also called as prayer sign, is tested by extension of the hands at wrists. Tinel's test is performed by tapping the median nerve over the volar carpal tunnel [3,4].

The gold standard for diagnosis is the combination of the clinical findings and the electrophysiological study [5]. Nerve Conduction Studies (NCS) are valid and reliable in confirming the diagnosis of CTS, with a sensitivity of >85% and a specificity of 95%. The value of NCS is to confirm the clinical diagnosis of CTS and assess its severity. Approximately 10–15% of patients with clinically defined CTS have normal NCS. This could occur because of intermittent median nerve compression at the wrist that has not caused demyelination or axonal loss to be detected by Electro Diagnostic Studies (EDx) studies [5,10]. In 90% of symptomatic patients, localized sensory conduction slowing was observed. A routine median nerve conduction study is valuable. Prolonged latency of sensory or motor nerves would be found in most CTS hands. If the routine study showed equivocal results, more sensitive methods are needed. Those include a segmental sensory conduction study across the carpal tunnel by median nerve stimulation at the midpalm, a comparison of median and ulnar sensory nerve latencies at the ring finger, and a comparison of median and radial sensory nerve latencies at the thumb. In addition, the inching method can localize the compression site. Using these techniques, the diagnosis of CTS would become more reliable [5,6].

Combined Sensory Index (CSI): The CSI has been proposed to increase the sensitivity and specificity of NCS for the confirmation of CTS. The CSI is the sum of the latency differences of three comparison tests (palmdiff, ringdiff, and thumbdiff). A CSI score ≥ 1.0 is considered abnormal, having a sensitivity of 83% and a specificity of 95%. However, an unequivocally high latency difference in any one of the three

tests (palm diff ≥ 0.4 ms, ring diff ≥ 0.5 ms, thumb diff >0.7 ms) confidently predicts an abnormal CSI without losing its specificity [7].

In some cases of chronic CTS, CMAP (Compound Motor Action Potential) amplitudes are higher on elbow stimulation than wrist stimulation because of anomalous innervation of the thenar muscles. EMG is useful to determine denervation and reinnervation. Electromyography (EMG) of median nerve innervated muscles shows reduced recruitment of motor units (demyelination) or signs of chronic partial denervation and reinnervation in distal muscles (axonal) changes [6].

1) Mild CTS: Prolonged sensory peak latency (SNAP) with or without decreased sensory amplitude.
2) Moderate CTS: Abnormal median sensory peak latency with prolonged distal motor latency.
3) Severe CTS: Prolonged sensory and motor latency, either with low compound motor action potential (CMAP) and/or reduced or absent sensory nerve action potential (SNAP).
4) Very severe CTS: Absent thenar motor or sensory response, either with a present or absent lumbrical response [4]. F wave nerve conduction study use supramaximal stimulation of a motor nerve and records action potentials from a muscle supplied by the nerve. It assesses motor nerve conduction between distal stimulation sites in the arm and leg and related motoneurons in the spinal cord. It is useful for evaluating polyneuropathies, focal proximal nerve dysfunction, and lumbosacral radiculopathies where F waves are prolonged or absent [6,9].

Management of CTS: Milder cases usually respond to medical treatment with non-steroidal anti-inflammatory drugs (NSAIDs) or local corticosteroid injections at the carpal tunnel to reduce inflammation of the synovial tissue. Immobilizing the wrist with a wrist brace, weight reduction, and resting the affected area are required. Ultrasound has been found to have a diagnostic and therapeutic use for CTS. Delivery of high-frequency waves can produce anti-inflammatory effects and improve nerve conduction [8].

Aim of the study

To study the electrophysiological profile of carpal tunnel syndrome.

2. Materials and Methods

Study design: An open-label hospital-based retrospective, observational study. Sample size: 86. Duration of study: data collected from January 2023 to December 2023 Routine Nerve Conduction Studies were done (Sensory and motor conduction studies in bilateral Median and Ulnar nerves) in all patients. Additional tests, like internal comparison studies, were also done in some patients, if necessary.

Nerve conduction study consisted of sensory nerve conduction, motor nerve conduction, and F-wave studies of the median and ulnar nerves. The nature of the procedure was explained to the subjects. They sit on a padded table with the upper limb supported.

Inclusion Criteria: All patients aged between 18 and 85 who presented to the Department of Neurology in our institute with symptoms such as pain, tingling, and numbness and nocturnal sleep disturbance with paresthesia in the median nerve distribution for more than 2 months duration.

Exclusion Criteria: Age <18 years and >85 years, pregnancy, all patients with generalized neuropathies, history of trauma, and severe systemic diseases like malignancy were excluded from the study.

3. Results

Table 1: Clinical CTS in Tested Hands

Age	Number of hands studied		Total	Number of hands Affected		Total
	Male	Female		Male	Female	
< 20						
21–40	18	86	104 (60%)	8	64	72
41- 60	16	48	64 (37.2%)	11	35	46
>60	2	2	4 (2.32%)	1	2	3
Total	36	136	172	20(17%)	101(83%)	121(70%)

Total number of patients: 86
The mean age is 40.4 years

Routine NCS was done in 86 patients, of which 18 were men and 68 were women. 121 hands are affected among 172 hands tested (70%). Among males 20 hands are affected out of 36 hands tested (55%). Among females 101 hands are affected out of 136 hands tested (74%). Individuals of 21- 40 years age group are affected most (60%) compared to other age groups.

Table 2: Duration of symptoms

	Male	Female	Total
< 6M	14	21	35 (39%)
6M – 1 year	3	8	11 (12%)
Ø 1 year	1	39	40 (49%)

Forty out of eighty-six patients (49%) had symptoms beyond one year. Thirty five out of eighty-six (39%) subjects had symptoms for less than 6 months. Eleven out of eighty-six (12%) subjects had symptom duration ranging between 6 months to one year. Carpal tunnel syndrome is a chronic condition, and it persists if adequate line of management like lifestyle modifications are not practiced by the individual.

Table 3: Risk Factors

R/f	Number of Patients	Male	Female
DM	5	2	3
Hypothyroidism	1	0	1
Others	6	0	6
Total	12	2	10

Among the 86 subjects, one is hypothyroid, five are diabetics. Among 5 diabetics three were females, two were males. Others include rheumatoid arthritis, postpartum and acromegaly. This suggests that, apart from the above, there might be other risk factors like obesity, occupational risk that are not included in the study.

Table 4: Unilateral or bilateral:

Clinically	Number of Patients	%	Male	Female
Right Hand	34	39.50%	7	27
Left Hand	17	19.70%	5	12
Bil CTS	35	40.60%	5	30

Clinically, thirty four out of eighty-six (39.5%) of the subjects had carpal tunnel syndrome on the right side. Thirty five out of eighty-six (40.6%) had bilateral involvement. i.e., the majority of the patients had carpal tunnel syndrome either on the right side or both sides. When it was bilateral, the majority had asymmetry, with the right hand being more affected than the left. Among the study population all are right-handed individuals.

Table 5: Severity

	No of Hands	%	Male	Female
Mild CTS	30	24.20%	6(20%)	24(80%)
Moderate CTS	84	67.70%	11(13%)	73(86%)
Severe CTS	10	8%	3(30%)	7(70%)

Mild carpal tunnel syndrome was considered when there were mild sensory demyelinating changes. Severe CTS is considered when sensory and motor amplitudes and conduction velocities are decreased severely or are not recordable. Thirty out of 124 hands affected had mild CTS. Eighty four out of 124 hands affected had moderate CTS. Ten out of 124 hands affected had severe CTS. Majority of the subjects had moderate CTS.

Table 6: Routine nerve conduction studies

	Male right	Left	Female right	Left	Total
Only sensory abnormality	3	3	22	16	44(35%)
Both sensory and motor abnormalities	8	6	38	28	80(65%)
Total	11	9	60	44	124

On routine nerve conduction studies, abnormalities were detected in 124 of 172 hands tested. Only sensory abnormalities were noted in 44 tested hands (35%). Sensory and motor abnormalities are noted in 80 hands (65%). Mild cases had only sensory involvement. Moderate cases had both sensory and motor involvement in the form of prolonged latencies or decreased conduction velocity. Some had decreased CMAP amplitudes also, indicating a severe form. Out of 44 sensory nerve conduction affected hands six hands belonged to males and thirty hands belonged to females. Sensory and motor involvement in 80 hands, of which 14 belonged to males and 66 belonged to females. Among males 8 had right hand involvement,6 had left hand involvement. Among the 66 females, 38 had right-hand involvement and 28 had left-hand involvement.

Table 7: F waves in hands

	Absent	Prolonged	Abnormal
Right hand	7	8	15(17.4%)
Left hand	7	6	13(15%)

F waves were absent in 14 hands and prolonged in 14 hands. Seven were absent in right and seven in left. Eight were prolonged in the right hand and six in the left hand. F-wave abnormality in right hand is seen in 15 hands (17.4%) and in the left hand in 13 hands (15%).

Table 8: Correlation of Clinical and Electrodiagnostic study:

Clinical	Male right	Male left	Female right	Female left	Total
clinical CTS	12	10	58	41	121
EDX CTS routine NCS	10	9	60	45	124

Clinically, 86 patients had symptoms of CTS, and a nerve conduction study was advised. Among them, right-sided CTS seen in 34. Left-sided CTS in 17. Bilateral CTS observed in 35. So, 121 hands (70%) are affected by CTS clinically. But nerve conduction studies were done for both hands, though they presented with unilateral symptoms, i.e., for 172 hands. Abnormalities were detected in 124 hands (72%) in electrodiagnostic tests. 48 hands were normal in routine NCS.

Table 9: Comparison Studies

	Hands tested	Affected
u/l affected	51	46
Normal NCS	22	14
Total	73	60

A routine NCS study showed abnormalities in 124 hands. The next step of our study was to detect abnormalities in the hands that were normal in routine NCS. This is done through comparison studies. Median digit 2 sensory nerve conduction is compared to digit 5 ulnar sensory study. Comparison study was done in 73 hands. 48 hands were normal in a routine NCS. Among them, 11 subjects had both hands normal NCS, 22 hands. A comparison study done in these 22 hands showed abnormalities in 14 hands. In unilaterally affected 51 subjects; when a comparison study done, on the other hand, showed abnormalities in 46 hands. i.e., only five hands on the opposite side were normal. This suggests that when one-sided CTS starts, the other side also gets involved eventually, in most cases. Finally, only 13 hands were normal after comparison study is done.

4. Discussion

A total of 86 subjects diagnosed as CTS clinically were studied. The mean age of patients was 40.4 years with a M:F ratio of 9:34. Symptoms were bilateral in 35 (40%) patients. In the study by Vinay G et al., the mean age was 44.21 years with female predominance (M:F 3:11), and sixty-four (91.4%) patients had bilateral involvement. [2] The patients' mean age was 43.9 ± 14 years, with the male-to-female ratio being 13:79 in the study by Kasundra G. M. et al. [2].

In our study 60% of subjects are between the 21 to 40 years age groups. 37% were in the 41- to 60-year-old age group. This was different from the previous studies. Gelfman et al.

found the prevalence of CTS to be highest in the age group of 50–59 years, followed by the age group of 41–49 years for females, and for males, the prevalence was higher in the age group of 70–79 years. In a study by AS Bahar-Moni et al. in Malaysia, the incidence of CTS was highest in the 41–60-year-old age group. This suggests CTS is not age-based and has multiple other etiological aspects [4].

In our study 100% of the study population was right-handed, and the right hand was affected in 70% of them with or without involvement of the left hand. This result was consistent with the study by Bagatur et al., where they suggested that CTS was a bilateral disorder and showed that the dominant hand involvement was more [4].

In our study 74 out of 86 (86%) were idiopathic. The risk factors studied were diabetes mellitus (in five subjects), hypothyroidism (in one subject), postpartum (3 subjects), rheumatoid arthritis (in two subjects), acromegaly (in one subject). In a study by Kasundra G. M. et al., the most common risk factor was obesity (15%), followed by hypothyroidism (12.9%), diabetes mellitus (10.75%), work-related (8.6%), and postpartum state (7.50%). [2] This suggests that there can be other etiological factors that could have contributed to the disease process.

The most common electrophysiological abnormality was an increase in onset latency. An increased inter-latency difference was the only electrophysiological abnormality observed in 35 (20%) hands. The least common abnormality was un-recordable CMAP seen in 10 hands (8%). In severely affected patients' amplitudes also decreased, and in some NCS is not recordable. The possible explanations are that the presence of a conduction block at the carpal tunnel and/or the occurrence of retrograde degeneration of the fastest conducting fibers proximal to the carpal tunnel will exclude these fibres from contributing to the measured CMAP, leaving the slower conducting Fibers as the main contributors to the calculation of CV.

In the present study, 30 hands (24%) had mild involvement, 84 hands (68%) had moderate involvement, 10 hands (8%) had severe involvement. That is, most of the subjects had moderate CTS. Bilateral involvement is noted in 40% of cases. If the subject had unilateral complaints when another uninvolved hand was tested, few had abnormal routine NCS suggestive of CTS. When the comparison study was done, it showed abnormalities suggestive of CTS in 45 out of 51 hands (88%). This suggests that when routine NCS is normal, comparison studies can help in picking up subclinical CTS. The difference between the median and ulnar nerve latency measurements with palmar stimulation has also been found quite useful by many authors [2].

Routine electrodiagnostic study done in 172 hands showed abnormalities in 124(70%). 48 hands (27%) had normal basic NCS. When a comparison study was done, 35 are abnormal (73%). Only 13 hands (27%) were normal among the 172 hands tested.

In our study, 28 hands (16%) had abnormal f-waves. Among them, 15 (17%) had an abnormal f-wave on the right hand and 13 (15%) had an abnormal f-wave in the left hand. Any pathologic condition involving C8 and/or T1 roots or the medial cord of the brachial plexus is expected to prolong F-wave latencies (FWLs) of both the median and ulnar nerves, whereas CTS is expected to prolong F wave latencies of the median nerve solely [6]. In an extensive literature review by the American Association of Neuromuscular And Electrodiagnostic Medicine (AANEM) Quality Assurance Committee, Jablecki *et al*. found that, comparison of median sensory nerve conduction to *the* ulnar or radial sensory nerve conduction in the same limb was best documented tests in the electrodiagnosis of CTS.[11] They found that absent or delayed peak sensory latencies occur in 49 to 66% of the CTS patients, with 97.5 to 100% specificity and delayed motor distal latencies (MDL) occurring in 60 to 74% of the CTS patients with 95 to 99% specificity[11].

Limitations of the study are small sample size and inadequate history to correlate other risk factors like occupational hazards, obesity etc., which could be contributing to disease process.

5. Conclusion

Carpal tunnel syndrome is a common entrapment neuropathy diagnosed in outpatient settings. It often results from repetitive wrist movement apart from systemic diseases.

Majority of subjects affected are females in the 21–40-year age group with long standing disease of more than a year and right hand is more affected.

Some of the clinically affected hands had normal NCS, and some asymptomatic hands had abnormal nerve conduction studies.
In asymptomatic hands, if routine nerve conduction studies were normal, comparison studies showed abnormalities, suggesting underlying subclinical carpal tunnel syndrome.

6. Summary

Carpal tunnel syndrome is diagnosed by clinical examination and electrophysiological studies. When routine NCS is normal, better to perform other methods like comparison studies or midpalm conduction studies, so that one can diagnose or rule out carpal tunnel syndrome definitively. Grading of carpal tunnel syndrome is possible with electrophysiological studies which will guide the treating doctors for the appropriate management protocol whether medical or surgical management apart from lifestyle, occupational modifications.

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