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Original Article

Sensitivity of Mixed and Comparative Electrodiagnostic Methods in Diagnosis of Carpal Tunnel Syndrome

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Abstract

Objective: Carpal Tunnel Syndrome is a prevalent mononeuropathy caused by compression of the median nerve at the wrist. Early and accurate diagnosis is critical to prevent progressive nerve damage and optimize patient outcomes. This study compared the sensitivity of mixed and comparative electrodiagnostic methods in diagnosing Carpal Tunnel Syndrome, particularly in early stages, to enhance diagnostic accuracy and guide management strategies.

Methods: The comparative assessment between Median and Ulnar nerves in the Lumbrical Interossei muscles demonstrated the highest sensitivity (84.8%), followed by the Median-Ulnar fourth digit comparison (75.0%) and the Median versus Radial Digit One study (69.1%). Mixed palmar and segmental studies had lower sensitivity (61.3% and 51.9%, respectively). Conventional methods, including median motor and sensory studies, demonstrated limited accuracy (53% to 57%). Females were predominant (2.3:1 ratio), and 75% of patients had bilateral symptoms.

Results: Among all techniques evaluated, the Median-Ulnar Lumbrical Interossei comparison demonstrated the highest sensitivity (84.8%), followed by the Median-Ulnar fourth digit comparison (75.0%) and the Median versus Radial Digit One study (69.1%). In contrast, the mixed palmar study and segmental study showed lower sensitivity (61.3% and 51.9%, respectively). Conventional electrodiagnostic approaches, including median motor and sensory studies, had limited diagnostic accuracy (53% to 57%). Females were predominate (2.3:1), and bilateral symptoms were observed in 75% of the patients.

Conclusion: Conventional electrodiagnostic approaches have limited sensitivity in diagnosing carpal tunnel syndrome, particularly in cases of mild-to-moderate severity. Comparative studies, such as the Median versus Ulnar Lumbrical Interossei and Median versus Ulnar Digit Four studies, significantly improve diagnostic accuracy. Integrating these advanced methods into routine protocols is essential to minimize false-negative results and enhance early detection.

Keywords: Carpal Tunnel Syndrome (CTS), Electrodiagnosis, Comparative Studies, Diagnostic Sensitivity

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Introduction

Carpal Tunnel Syndrome is a clinical syndrome characterized by symptoms such as burning, numbness, or tingling sensations on the lateral portion of the hand's palmar surface. This neuropathy, caused by compression of the median nerve at the wrist beneath the transverse carpal ligament, is the most prevalent upper extremity neuropathy.[1] The incidence of CTS ranges from 1% to 5% in the general population, with females being three times more affected than males.[2] Obesity, smoking, and repetitive hand movements are among the most significant risk factors for CTS.[3] Clinically, CTS is diagnosed based on patient history and physical examinations, such as Phalen's and Tinel's tests. However, these clinical methods often lack sufficient sensitivity and specificity, particularly in mild or early-stage cases. For instance, studies have shown that Phalen's test has a sensitivity of only 68–85%, while Tinel's test has an even lower sensitivity of 50–60%, making them unreliable for definitive diagnosis in many patients.[4] While clinical symptoms form the basis of diagnosis, electrophysiological testing is essential for confirmation.

Electrodiagnostic studies, including nerve conduction studies and electromyography, are widely used to confirm CTS diagnosis and assess its severity. A variety of sensory and motor nerve conduction studies are used for CTS diagnosis, with sensory changes typically appearing before motor changes.[5] Common motor studies include the comparative analysis of Median versus Ulnar nerve in Lumbrical muscles (MVU-LS), median motor conduction studies, and median motor palmar studies. Among sensory studies, the median nerve sensory conduction study (MSCS), median sensory palmar study (MPS), and mixed palmar study (Mix MVU) are frequently employed.[6] While conventional electrodiagnostic methods, such as median motor and sensory studies, are commonly employed, their diagnostic sensitivity is limited, especially in mild-to-moderate cases. This limitation often results in false-negative outcomes, delaying appropriate treatment and potentially worsening patient outcomes.

Recent research has highlighted the potential of comparative and mixed electrodiagnostic methods, such as the Median versus Ulnar Lumbrical Interossei study and the Median versus Ulnar Digit Four study, to improve diagnostic accuracy. For instance, Owolabi (2021) found that only 55.26% of clinically diagnosed CTS patients showed abnormal conduction studies, underscoring the risk of underdiagnosis, particularly in mild-to-moderate cases.[7] However, disagreement persists regarding the optimal diagnostic approach, and these techniques have not been consistently adopted in routine clinical settings.

This investigation was undertaken stems from recognizing the need to bridge these diagnostic gaps. By evaluating the sensitivity of advanced comparative electrodiagnostic methods, this research aims to identify the most effective techniques for early and accurate CTS diagnosis. The findings will provide evidence-based recommendations for refining diagnostic protocols, ultimately improving patient care and outcomes.

Methods

A cross-sectional comparative study was conducted at the Neurology Department of Mayo Hospital, Lahore, Pakistan, to evaluate the sensitivity of various electrodiagnostic methods in diagnosing carpal tunnel syndrome. Ethical approval for the study was obtained from the Institutional Review Board of King Edward Medical University and Mayo Hospital, Lahore, Pakistan (Approval No: 520/RC/KEMU, dated 17/11/2023). Written informed consent was obtained from all participants before enrollment, and confidentiality of patient data was maintained throughout the study. A total of eighty participants were included, comprising forty clinically diagnosed CTS patients and forty age- and sex-matched healthy controls. Patients were included based on clinical symptoms such as numbness, tingling, or pain in the median nerve distribution. Individuals with a history of peripheral neuropathy, cervical radiculopathy, or other conditions mimicking CTS symptoms were excluded.

The skin temperature of the hand was maintained at or above 32°C to ensure accurate electrodiagnostic measurements. All patients underwent a series of electrodiagnostic studies for Carpal Tunnel Syndrome. Latencies, except for motor studies, were measured to the negative peak, while amplitudes were determined from baseline to the negative peak. A single Nihon Koden model no 2016 instrument was used for all tests, with supramaximal percutaneous stimulation applied. The pulse duration was set at specific intervals for sensory, mixed, and motor nerve stimulation. Filters were set at standard frequencies, and the sweep speed was standardized. Mixed nerve studies utilized disc electrodes, while sensory studies employed ring electrodes. A ground electrode was appropriately placed between the stimulating and recording electrode sites.

The motor median conduction study at the wrist involved recording from the muscle belly of Abductor Pollicis Brevis and the first metacarpophalangeal joint. Stimulation was delivered at two distinct sites: the mid-wrist, and the antecubital fossa. Abnormal results were defined by a distal latency of 4.4 milliseconds or greater, reduced amplitude, or slowed conduction velocity. The motor study at the palm also involved recording from the Abductor Pollicis Brevis muscle belly and the first metacarpophalangeal joint, with stimulation applied at the wrist and palm. A palm-to-wrist compound muscle action potential amplitude ratio exceeding 1.2 was considered abnormal.

The comparative study between the median and ulnar nerves in lumbrical-interossei involved recording from the third metacarpal and the second metacarpophalangeal joint. Stimulation was applied to the median and ulnar nerves at the wrist, with a latency difference exceeding 0.5 milliseconds considered abnormal. The median sensory study used an orthodromic procedure, recording from the median nerve with electrodes placed at mid-wrist. The index finger was stimulated, and a peak latency greater than 3.7 milliseconds was considered abnormal. The sensory study at the palm also used an orthodromic procedure, with electrodes placed over proximal interphalangeal joint and stimulation applied at the wrist and palm. A palm-to-wrist sensory nerve action potential amplitude ratio greater than 1.6 was considered abnormal.

The comparison study evaluating Median versus Ulnar nerve in the fourth digit involved recording from the fourth digit, with electrodes placed over the metacarpophalangeal joint and the distal interphalangeal joint. Stimulation was applied to the median and ulnar nerves at the wrist, and a latency difference greater than 0.5 milliseconds defined abnormality. Median versus Radial Digit 1 study involved recording from the first digit, with electrodes placed over the metacarpophalangeal joint and the distal interphalangeal joint. Stimulation was applied to the median nerve at the wrist slightly lateral to the mid-wrist between the tendons to the FCR and PL, radial nerve at the wrist medial forearm, over the radial bone, with a latency difference exceeding 0.5 milliseconds defined abnormality.

The mixed palmar study compared the median and ulnar nerves, with recording electrodes placed at slightly lateral to the mid-wrist between the tendons to the FCR and PL for Median Nerve and over the medial wrist, adjacent to the FCU tendon and stimulation applied in the palm. A latency difference less than 0.4 milliseconds was considered abnormal. The segmental study involved stimulating the median nerve at the wrist and palm, with recordings obtained from the third digit using ring electrodes. Conduction velocities were calculated for wrist-to-palm and palm-to-digit segments, and a conduction velocity difference greater than 10 meters per second between the two segments was considered abnormal.

Data was analyzed using statistical SPSS software 23 version. For each electrodiagnostic technique, we determined sensitivity, specificity, positive predictive value, and negative predictive value. Continuous data were summarized using mean ± standard deviation, whereas categorical data were reported as counts and percentages. The independent t-test was employed to assess differences in continuous measures between CTS patients and controls. A p-value below 0.05 indicated statistical significance.

Results

A total of 80 hands were evaluated, comprising 40 patients from clinically diagnosed carpal tunnel syndrome patients and 40 patients from healthy controls. The experimental group consisted of 28 females (70.0%) and 12 males (30.0%), with a female-to-male ratio of 2.3:1. The experimental group's mean age was 43.75 ± 13.80 years, while the control group had a mean age of 25.65 ± 6.95 years. The mean duration of symptoms in the experimental group was 1.55 ± 0.81 years. Bilateral symptoms were present in 30 (75.0%) patients, while 10 (25.0%) had unilateral symptoms. Positive Tinel's sign was observed in 6 (15.0%) patients, and positive Phalen's sign was observed in 14 (35.0%) patients **(Table 1)**.

Electrodiagnostic findings revealed significant differences between the CTS and control groups. The distal median motor latency at the abductor pollicis brevis was significantly delayed in CTS hands compared to controls (4.02 ± 0.39 ms vs. 2.75 ± 0.54 ms, p=0.001). Similarly, peak sensory latency was also delayed in CTS hands (3.1 ± 6.17 ms vs. 2.31 ± 0.31 ms, p=0.0001). All comparative motor, sensory, and mixed studies showed significant differences between the groups (p<0.0001), except for the segmental study, which did not demonstrate statistical significance (p=0.83) (**Table 2**).

The most sensitive test was the Median versus Ulnar Lumbrical Interossei study (84.8%), followed by the Median versus Ulnar Digit 4 comparison (75.0%), the Median versus Radial Digit 1 study (69.1%), the Median versus Ulnar Mixed Palmar study (61.3%), and the Segmental study (51.9%). Specificity, positive predictive value (PPV), and negative predictive value (NPV) for each test are detailed in Table 3.

Discussion

Table 1: *Clinical Characteristics of the Experimental Population.*

Characteristic	Females (28, 70.0%)	Males (12, 30.0%)	Total (40, 100.0%)
Age (years, mean ± SD)	38.85 ± 10.83	55.16 ± 13.58	43.75 ± 13.80
Symptoms (Bilateral)	8 (20.0%)	1 (2.5%)	9 (22.5%)
Symptoms (Unilateral)	20 (50.0%)	11 (27.5%)	31 (77.5%)
Duration of disease (years)	1.7	1.1	1.55 ± 0.81
Phalen's sign (positive)	10 (25.0%)	4 (10.0%)	14 (35.0%)
Tinel's sign (positive)	4 (10.0%)	2 (5.0%)	6 (15.0%)

Table 2: *Comparison of Electrodiagnostic Methods Between CTS and Control Groups.*

Electrodiagnostic Method	Experimental Group (n=40)	Control Group (n=40)	t-value	p-value
Median Motor APB study at wrist	4.02 ± 0.39	2.75 ± 0.54	8.29	<0.001
Median Motor APB study at palm	1.99 ± 0.33	1.70 ± 0.29	4.108	<0.0001
Median vs Ulnar Lumbrical/Interossei	1.50 ± 1.30	-0.31 ± 0.66	7.875	<0.0001
Median sensory study	3.1 ± 6.17	2.31 ± 0.31	1.843	<0.0001
Median sensory study at palm	1.60 ± 0.53	1.21 ± 0.15	4.505	<0.0001
Median vs Ulnar Digit 4 study	1.01 ± 0.92	0.975 ± 0.17	6.18	<0.0001
Median vs Radial Digit 1 study	0.78 ± 0.81	0.17 ± 0.25	4.467	<0.0001
Median vs Ulnar palmar mixed study	0.47 ± 0.66	0.10 ± 0.15	3.44	<0.001
Median segmental study	1.92 ± 2.66	2.00 ± 0.00	-1.778	0.83

All electrodiagnostic tests showed significant differences between CTS and control groups (p<0.0001), except for the segmental study (p=0.83).

Table 3: *Comparison of Electrodiagnostic Method Between CTS and Control Groups.*

Electrodiagnostic Method	Sensitivity	Specificity	PPV	NPV	95% Confidence Level
MVU (Lumbrical interossei study)	84.80%	97.10%	97.50%	82.50%	0.9012–0.2888
MVU Digit 4	75.00%	96.40%	97.50%	67.50%	0.7370–0.3780
MVR Digit 1	69.10%	92.00%	95.00%	57.50%	0.6282–0.3293
Mix MVU	61.30%	88.90%	95.00%	40.00%	0.3991–0.1709
Segmental study	51.90%	99.10%	99.10%	7.50%	2.0050–1.9200

All electrodiagnostic tests showed significant differences between CTS and control groups (p<0.0001), except for the segmental study (p=0.83). ***MVU:*** *Median vs Ulnar;* ***MVR:*** *Median vs Radial;* ***PPV:*** *Positive Predictive Value ;* ***NPV:*** *Negative Predictive Value.*

This study evaluated the sensitivity of various electrodiagnostic methods in diagnosing carpal tunnel syndrome , with a focus on comparative and mixed electrodiagnostic approaches. The findings highlight the superior sensitivity of the Median-Ulnar Lumbrical Interossei comparison (84.8%) and the Median versus Ulnar Digit 4 study (75.0%) compared to conventional methods. Similarly, Owolabi et al. (2021) emphasized the importance of advanced electrodiagnostic techniques in reducing false-negative outcomes, which is consistent with our findings.[7] This study results also align with Jain et al. (2019), who reported that comparative studies significantly improve diagnostic accuracy, particularly in mild-to-moderate CTS cases.[8]

Although clinical assessment is the primary method for diagnosing CTS, electrophysiological testing is essential to rule out other possibilities, especially in cases with mild or indistinct symptoms. Conventional electrodiagnostic tests typically demonstrate a specificity ranging between 60% and 85%.[5] In this study, the diagnostic accuracy of routine testing was 53–57%, which may be attributed to differences in threshold values. For instance, the threshold for median motor distal latency was set at 4.4 milliseconds, while the threshold for median sensory latency was 3.7 milliseconds.[9]

Individuals with clinically diagnosed CTS but normal median nerve values on routine tests should undergo additional unconventional tests for comparison. In a study by Omar (2023), the Median versus Radial Digit 1 comparison demonstrated the highest sensitivity (92.2%), followed by the Median versus Ulnar mixed palmar study. (85.2%), the Median versus Ulnar Digit 4 comparison (78.2%), and the Median versus Ulnar Lumbrical Interossei study (66.9%).[10] Similarly, Chang et al. (2024) found that the Median versus Ulnar Digit 4 comparison had the highest sensitivity (84%), followed by the Median versus Radial Digit 1 comparison (63%).[11]

However, our results diverged from these studies. The Median versus Ulnar Lumbrical Interossei study emerged as the most sensitive test (84.8%), followed by the Median versus Ulnar Digit 4 study (75.0%) and the Median versus Radial Digit 1 study (69.1%). The Median versus Ulnar Mixed Palmar study and the Segmental study had the lowest sensitivity (61.3% and 51.9%, respectively). These discrepancies may be due to differences in technical conditions, cut-off values, or the severity of CTS cases included in the studies.

One of the key strengths of this study is the inclusion of a comprehensive battery of electrodiagnostic tests, allowing for a direct comparison of their diagnostic performance. The use of age- and sex-matched controls further strengthens the validity of the results. However, the study has some limitations. The participant count, while sufficient for initial evaluation, was modest in size, potentially affecting how broadly the conclusions can be applied. Additionally, the study was conducted at a single center, which may introduce selection bias. Additional investigations involving multiple institutions and expanded participant groups would help confirm these observations.

The primary takeaway from this study is that comparative electrodiagnostic methods, particularly the Median versus Ulnar Lumbrical Interossei study, are highly effective in diagnosing CTS, especially in mild-to-moderate cases. These methods should be integrated into standard diagnostic protocols to enhance accuracy and reduce false-negative results. Early and accurate diagnosis is critical for timely intervention, which can significantly improve patient outcomes and quality of life.

Conclusion

This study highlights the importance of integration of advanced electrodiagnostic techniques in the diagnostic workup of carpal tunnel syndrome. The Median versus Ulnar Lumbrical Interossei and Digit 4 studies showed superior sensitivity, especially in mild-to-moderate cases. Early diagnosis is crucial for prevention of irreversible nerve damage and ultimately results in improved clinical outcomes. Future research should focus on validating these findings and exploring emerging technologies to enhance diagnostic precision.

Ethical Approval: The IRB/EC approved this study via letter no. 392/RC/KEMU, dated September 18, 2023.

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Authors' Contribution

NF: Conception.

SB, AN: Design of the work.

MZ, ANu: Data acquisition, analysis, or interpretation.

SB, AN, MZ: Draft the work.

NF, ANu: Review critically for important intellectual content.

All authors approve the version to be published.

All authors agree to be accountable for all aspects of the work.

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References

1. Dahlin LB, Zimmerman M, Calcagni M, Hundepool CA, van Alfen N, Chung KC . Carpal tunnel syndrome (Primer). Nat Rev: Dis Primers. 2024;10(1):37.
2. Zamborsky R, Kokavec M, Simko L, Bohac M. Carpal tunnel syndrome: symptoms, causes and treatment options. Literature review. Ortoped Traumatol Rehab. 2017;19(1):1-8.
3. Melhorn JM, Talmage JB. Prevalence of carpal tunnel syndrome in motorcyclists. Orthopedics. 2013;36(7):497-8.
4. Salamh F, Habib SS, AlRouq F, Albarrak A, Al-Khlaiwi T, Khan A. A. Relationship of obesity indices with clinical severity and nerve conduction studies in females presenting with median nerve compression neuropathy at the wrist. J Fam Med Prim Care. 2024 Apr 1;13(4):1291-5.
5. Dabbagh A, MacDermid JC, Yong , Packham TL, Grewal R, Boutsikari EC. Diagnostic test accuracy of provocative maneuvers for the diagnosis of carpal tunnel syndrome: a systematic review and meta-analysis. Phys Ther. 2023;103(6):pzad029 .
6. Mazaheri S, Poorolajal J, Mazaheri A. Sensitivity and specificity of electrodiagnostic parameters in diagnosing carpal tunnel syndrome: a case-control study. Bone Joint Open. 2024;5(10):898.
7. Owolabi LF, Reda AA, Raafat A, Fares DM, Enwere OO, Mba UA, et al. Nerve conduction study findings and their predictors in clinically diagnosed patients with carpal tunnel syndrome in a Saudi population. Nig J Clin Pract. 2021;24(10):1423-9.
8. Jain D, Saini PK, Sharma CM. Comparative analysis of nerve conduction study methods in patients with carpal tunnel syndrome. Indian J Med Special. 2019;10(3):131-6.

9. Srikanteswara PK, Cheluvaiah JD, Agadi JB, Nagaraj K. The relationship between nerve conduction study and clinical grading of carpal tunnel syndrome. J Clin Diag Res.2017;11(7):OC13-OC16 .

10. El-Hady AO. The sensitivity of median versus ulnar palmar mixed nerve study in the early diagnosis of carpal tunnel syndrome. Egypt Rheumatol Rehab. 2023;50(1):1.

11. Chang YW, Hsieh TC, Tzeng IS, Chiu V, Huang PJ, Horng YS. Ratio and difference of the cross-sectional area of median nerve to ulnar nerve in diagnosing carpal tunnel syndrome: a case control study. BMC Med Imag. 2019;19:1-9.