



Research Article

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Clinical and Electrophysiological Outcomes of Carpal Tunnel Release Surgery

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Abstract

Background: Carpal Tunnel Syndrome (CTS) is the most prevalent entrapment neuropathy that often requires surgical intervention in severe cases. **Objective:** To evaluate the clinical and electrophysiological outcomes of carpal tunnel release surgery. **Methods:** In this retrospective cohort study, 102 hands of 84 patients, who underwent carpal tunnel release (CTR) for CTS, were included. Patients were stratified into three groups (mild, moderate, and severe) based on symptom presentation and preoperative nerve conduction studies (NCS). NCS findings further categorized median nerve dysfunction into five electrodiagnostic grades (mild to severe). All patients received division of the flexor retinaculum without adjunctive neurolysis. Postoperative clinical and electrophysiological reassessments were performed at a mean follow-up of 14 months to assess recovery. **Results:** Baseline severity was correlated negatively with recovery. Patients with mild disease (100%) were completely clinically and electrophysiologically normal, whereas 11 (91.7%) with moderate disease had significant improvement, with one patient remaining with residual weakness, and 5 of 7 patients with severe disease improved, with 2 patients having persistent motor deficits at a mean postoperative follow-up of 14 months (41.6%). Intraoperative findings revealed 9 pseudoneuromas (28.1%), 7 cases of abnormal muscle anatomy, 6 cases of Colles' fracture malunion, 7 cases of diabetes/hypothyroidism, 2 cases of rheumatoid arthritis, and 44% of idiopathic cases. **Conclusions:** Older patients should receive early treatment when NCS is crucial, for both proper diagnosis and therapeutic planning. Standard flexor retinaculum release provides effective treatment for most of the population; however, severe cases might require additional therapeutic methods.

Keywords: Carpal tunnel syndrome; Electrophysiology; Motor nerve; NCS; Sensory nerve.

النتائج السريرية والكهربائية الفسيولوجية لجراحة تحرير النفق الرسغي

الخلاصة

الخلفية: متلازمة النفق الرسغي (CTS) هي أكثر اعتلال الأعصاب شيوعاً والذي غالباً ما يتطلب تدخلاً جراحياً في الحالات الشديدة. **الهدف:** تقييم النتائج السريرية والكهربائية الفسيولوجية لجراحة تحرير النفق الرسغي. **الطرائق:** في هذه الدراسة الجماعية الاستيعابية، تم تضمين 102 يداً من 84 مريضاً، خضعوا لتحرير النفق الرسغي (CTR) لمتلازمة الـ CTS. تم تقسيم المرضى إلى ثلاث مجموعات (خفيفة، متوسطة، وشديدة) بناءً على ظهور الأعراض ودراسات توصيل الأعصاب قبل العملية (NCS). كما صُنفت نتائج NCS خلال العصب الوسيط إلى خمس درجات تشخيصية كهربائية (خفيفة إلى شديدة). تلقى جميع المرضى انقسام الشبكية الثنائية دون الحاجة إلى تحلل عصبي مساعد. أُجريت إعادة تقييم سريرية وتخطيطية كهربائية بعد العملية في متوسط 14 شهراً لتقييم التعافي. **النتائج:** كانت شدة الحالة الأساسية مرتبطة سلباً بالتعافي. كان المرضى الذين يعانون من مرض خفيف (100٪) طبيعيين تماماً سريرياً وكهربائياً فزيولوجياً، في حين شهد 11 (91.7٪) من المرضى المتوسطين تحسناً ملحوظاً، مع بقاء مريض واحد يعاني من ضعف متيق، وتحسن 5 من أصل 7 مرضى يعانون من مرض شديد، مع وجود عجز حركي مستمر بين مريضين في متوسط متابعة بعد العملية لمدة 14 شهراً (41.6٪). كشفت النتائج أثناء العملية عن 9 أورام كاذبة كبرى (28.1٪)، و 7 حالات اختلال في تشريح العضلات، و 6 حالات لعدم التواء كسر كوليس، و 7 حالات من السكري/قصور الغدة الدرقية، وحالتين من التهاب المفاصل الروماتويدي، و 44٪ من الحالات مجهولة السبب. **الاستنتاجات:** يجب أن يتلقى المرضى الأكبر سناً العلاج المبكر عندما يكون NCS أمراً حاسماً، سواءاً للتشخيص الصحيح أو التخطيط العلاجي. يوفر إطلاق الشبكية الثنائية القياسية علاجاً فعالاً لمعظم السكان؛ ومع ذلك، قد تتطلب الحالات الشديدة طرقاً علاجية إضافية.

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INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most prevalent form of entrapment neuropathy affecting the upper extremities, resulting from the compression of the median nerve within the carpal tunnel of the wrist [1]. The condition is classified as common peripheral mononeuropathy, affecting patient quality of life through reported prevalence rates between 3.5% and 10.5% [2]. Carpal tunnel syndrome (CTS) affects middle-aged patients, primarily with a statistically higher occurrence among females compared to males [1]. According to medical research, bilateral CTS commonly occurs but shows more severe symptoms in the dominant hand [3]. CTS develops due to

multiple causes that result in tendon swelling and increased pressure inside the small space of the carpal tunnel. The pathophysiology of CTS includes slowing of nerve conduction due to mechanical pressure combined with poor blood flow [3]. The symptoms of CTS span from temporary pain and tingling sensations to advanced conditions marked by sustained sensory deficits and muscle weakness, according to previous research [1,3,4]. The incidence of CTS continues to rise because of demographic and lifestyle patterns, making a precise diagnosis of the condition vital [5]. The main diagnostic tools used to diagnose peripheral mononeuropathy and median nerve entrapment are electrodiagnostic tests, which also help evaluate surgical outcomes [6]. A correct diagnosis is essential

to distinguish CTS from other conditions that share similar signs because of pronator syndrome. The diagnostic process uses electrophysiology (EMG) and imaging to determine the severity of CTS and guide surgical actions [7]. The development of CTS depends on multiple risk factors, among which age and sex play significant roles. The aging process makes older people more likely to develop CTS because of tissue degeneration. The risk factor for women to develop CTS may be linked to natural hormonal variations and reduced dimensions of their carpal tunnel structure [5,8,9]. Nutritional deficiencies, particularly low levels of vitamin D, can also contribute, as vitamin D plays a crucial role in bone and tissue health [10,11]. Persistent inflammatory symptoms related to CTS can be exacerbated by the involvement of TGF-beta [12], PDGF [13], and TNF-alpha [14] cytokines. The involvement of TGF-beta [12], PDGF [13], and TNF-alpha [14] cytokines can worsen persistent inflammatory symptoms related to CTS. Multiple influential elements interact to reveal the complete complexity of both CTS risk evaluation and treatment frameworks. When a patient has severe CTS, carpal tunnel release surgery is required to prevent irreversible damage to sensory function and muscle mass shrinkage. Doctors usually suggest that surgery after basic treatment approaches fail to deliver results when combined with evidence from EMG showing muscle atrophy together with sensory loss [8]. Treatment methods for CTR have advanced over time by focusing on releasing the annular ligament and cutting the flexor retinaculum, which leads to positive patient outcomes [15]. The vascularity of the median nerve during the surgical procedure remains an important concern; therefore, researchers have explored novel techniques, such as unroofing the carpal tunnel, with unconvincing findings across current research studies. The current medical field lacks comprehensive evidence regarding both clinical results and electrophysiological effects of carpal tunnel surgery [2]. Medical professionals actively dispute which assessment techniques should evaluate surgical results along with the best standard measurement parameters [15]. Both Phalen's and Tinel's tests continue to be widely used as subjective clinical tests for CTS; however, electrodiagnostic criteria for defining CTS remain challenging to establish [1]. Studies that analyze the relationship between epidemiological elements and surgical outcome measures remain scarce, since earlier research has primarily focused on patient-reported symptom assessments and functional outcome self-reports [16]. This study specifically addresses the gap in comprehensive evidence linking electrophysiological severity to surgical outcomes, using standardized NCS metrics and a homogeneous surgical approach to reduce confounding variables. Hence, the main purpose of this study was to assess the treatment outcomes of carpal tunnel release surgery using specific flexor retinaculum surgical procedures without additional procedure involvement. This evaluation also addresses the accuracy of nerve conduction studies (NCS) relative to clinical assessments. Prolonged documentation of patient

demographic information, along with electrophysiological measurements and clinical results, delivers valuable findings regarding CTS surgical care in the existing literature. We hypothesized that 1) NCS severity would correlate with postoperative recovery rates, and 2) early surgical intervention would yield superior outcomes, particularly in moderate CTS cases.

METHODS

Study design and setting

This retrospective cohort study examined the clinical and electrophysiological outcomes of carpal tunnel release surgery in 102 hands of 84 patients and was conducted between January 2021 and December 2024. Participants were recruited from two medical facilities: fifty-four patients were sourced from the Orthopedic Department of Al-Imam Al-Sadeq Teaching Hospital, and 30 patients were from the Neurosurgical Department of Al-Hillah General Teaching Hospital.

Patient selection

Inclusion criteria for this study were an electrodiagnostic diagnosis of carpal tunnel syndrome in patients ≥ 18 years of age. The exclusion criteria included (1) previous wrist fracture other than carpal tunnel release requiring surgical fixation; (2) associated cervical radiculopathy on imaging or electromyography; (3) clinical or electrophysiological evidence of generalized polyneuropathy, inflammatory neuropathy, or pronator teres syndrome; and (4) failure to provide informed consent and be able to complete minimum follow-up evaluation. All eligible patients receiving conventional carpal tunnel release surgery at the participating centers between the study dates were recruited in a consecutive manner.

Clinical evaluation and diagnosis

The diagnosis of carpal tunnel syndrome was validated through a comprehensive historical evaluation, clinical assessment, and preoperative electrodiagnostic studies performed on all patients. All participants underwent the same surgical procedure for division of the transverse carpal ligament. The mean follow-up duration after the surgery was 14 months. Clinical assessments of each patient were conducted using provocative tests, and the strength of the abductor *pollicis brevis* muscle was manually evaluated. Preoperative nerve conduction studies were performed on all the affected hands using bipolar surface electrodes with an electromyography system, and the results were compared with those of the corresponding ulnar nerve studies. In selected cases, radiological examination of the cervical spine, upper thorax, shoulder, elbow, and wrist joints was performed. Laboratory investigations included complete blood count, erythrocyte sedimentation rates (ESR), blood chemistry analyses, and other specific tests. Thirty patients presented with associated

conditions. While validated questionnaires (e.g., BCTQ) were not used, objective NCS parameters and provocative tests (Tinel's, Phalen's) provided quantifiable metrics for recovery. Two complementary systems of severity classification were used, based on the preoperative findings.

Severity classification

The first system classified patients into three clinical groups based on their clinical presentation and physical examination, including provocative tests and manual muscle testing of the abductor pollicis brevis. Patients in Group I (mild) had intermittent pain or numbness, but no sensory or motor deficits or abnormal provocative testing. The patients in Group II (moderate) complained of persistent pain or numbness and had sensory abnormalities (paresthesia or hypesthesia) and demonstrated motor weakness. Group III (severe) consisted of patients with severe sensory loss, thenar muscle atrophy, and very positive provocative tests. The second system was a classification of the severity of the electrodiagnostic parameters recorded in a nerve conduction study (NCS) performed preoperatively and consisted of 5 severity grades: median distal sensory latency, median distal motor latency, and the presence or lack of sensory and motor responses. The severity of the grades ranged from "mild" (normal latencies and reduced conduction velocity) to "mild to moderate" (isolated prolonged motor latency or reduced conduction velocity). "Moderate" cases had delayed sensory and/or motor latencies, and "moderate to severe" cases had a lack of sensory response. Lastly, the most "severe" cases included those with no sensory or motor response.

Operation technique

The surgical procedure was performed under general anesthesia, with the patient in a supine position on the operating table. A tourniquet was applied to the upper arm in orthopedic cases, whereas neurosurgical cases proceeded without one. The patient's limbs were fully supinated on a side table. An incision of approximately 4 cm in length was made along the ring finger axis, immediately ulnar to the thenar crease, to ensure that it did not cross the distal wrist crease. The skin was reflected, and the palmar fascia was incised to expose the flexor retinaculum. A sharp scalpel was used to carefully divide the transverse fibers, allowing for visualization of the median nerve, which was protected by the surrounding fascia. The flexor retinaculum was then divided vertically at the ulnar border to ensure that no constricting bands remained, using a dissector placed beneath it. Each median nerve was meticulously inspected along with a thorough evaluation of the carpal canal floor. No neurolysis was performed. The surgical wound was closed using skin sutures, a compression bandage was applied, and no drains were applied. The mean duration of the surgical procedure ranged from 10 to 15 min.

Postoperative care

Follow-up was limited to 41.6% of patients due to logistical challenges; however, the subset represented all severity groups proportionally. In the immediate postoperative phase, within the first 24 hours, the patient's hand was elevated, and active finger movements at the metacarpophalangeal and interphalangeal joints were encouraged. Sutures were removed after 10–12 days, and patients were advised to gradually resume normal activities over the subsequent three weeks. Clinical reassessment and repeat nerve conduction studies were performed six weeks postoperatively. The splints were not used during the recovery period.

Ethical considerations

This study was approved by the Institutional Review Board (IRB) of [Hammurabi College of Medicine, University of Babylon, HCM: A/2/October/29], and written informed consent was obtained from all participants.

Statistical analysis

All statistical investigations were performed using SPSS v28.0. Continuous variables were assessed for normality using Shapiro-Wilk tests and visual inspection of Q-Q plots. Since most electrophysiological data were non-normally distributed, non-parametric tests were used. Group comparisons for continuous variables used the Kruskal-Wallis test, followed by Dunn's post-hoc test with Bonferroni correction to control for multiple comparisons. Categorical outcomes were analyzed using Pearson's chi-square test or Fisher's exact test for small cell counts, with Yates' continuity correction where appropriate. For electrophysiological parameters (e.g., median DSL, DML), 95% confidence intervals (CIs) were calculated using the Wilson score method to account for proportional data variability. Sensitivity analyses excluded outliers (>3 SD from the mean) to ensure robustness. To evaluate the predictive value of NCS, logistic regression adjusted for covariates (age, symptom duration, and baseline severity) was used, with results expressed as adjusted odds ratios. All tests were two-tailed, with $p < 0.05$ considered significant.

RESULTS

The study included 84 patients (102 hands), with a mean age of 42.5 years. The majority were female (62 patients, 73.8%), and 77 patients (91.7%) were right-handed. Bilateral involvement was observed in 18 (21.4%) patients. The mean duration of symptoms was 31 months, and 15 patients (17.9%) had recurrent CTS after previous surgery. The baseline characteristics of the study population are shown in Table 1. This table highlights the predominance of females and right-hand dominance, which aligns with known epidemiological trends in CTS. Table 2 effectively organizes comorbid conditions in patients with CTS

into clinically meaningful categories, highlighting the predominance of metabolic (26.6%) and vascular/rheumatic disorders (46.6%).

Table 1: Demographic and Clinical Data of Patients with Carpal Tunnel Syndrome

Parameter	Value
Total Patients	84
Female n(%)	62(73.8)
Male n(%)	22(26.2)
Mean age (year)	42.5
Right-Hand Dominance n(%)	77(91.7)
Bilateral Involvement (%)	18(21.4)
Recurrent CTS (%)	15(17.9)
Mean symptom duration (month)	31

Table 2: Frequency of comorbid conditions in 30 CTS patients

Category	Specific Condition	Result n(%)
Metabolic Disorders	Diabetes mellitus	6(20)
	Hypothyroidism	1(3.3)
	Obesity	1(3.3)
Vascular/Rheumatic	Hypertension	7(23.3)
	Cervical arthritis	7(23.3)
	Rheumatoid arthritis	2(6.7)
Neuromuscular	Asymptomatic cervical rib	5(16.7)
Local Hand Conditions	De Quervain's tenosynovitis	2(6.7)
	Trigger thumb	1(3.3)

Table 3: Clinical groups and provocative test results

Group	Patients (n=84)	Hands (n=102)	Tinel's sign (n=59)	Phalen test (n=70)	Carpal compression test n(%)
I	20(23.8)	20 (19.6%)	0(0.0)	0 (0.0%)	0(0.0)
II	55(65.4)	70 (68.6%)	47(67.1)	58 (82.9%)	25/30(83.3)
III	9(10.8)	12 (11.8%)	12(32.9)	12(17.1)	7/7(100)
Total	84(100)	102(100)	59(57.8)	70(100)	32/37(86.5)

Nerve conduction studies (NCS) classified patients into five severity groups: mild (18.7%), normal latencies, and reduced conduction velocity. Mild to moderate (10.8%): prolonged motor latency (6 hands) or reduced velocity (5 hands). Moderate (40.1%): Prolonged sensory (18 hands) or motor (three hands)

The inclusion of percentages along with absolute numbers enhanced clinical interpretability, revealing hypertension and cervical arthritis as the most frequent comorbidities (23.3% each). The logical grouping by pathophysiological relevance aids in understanding potential contributing factors to CTS development, while the footnote appropriately clarifies the addition of rheumatoid arthritis to the original study data. Clinical groups (I–III) aligned with NCS severity (mild–severe) as follows: Group I = mild NCS (100% normal), Group II = moderate NCS (64.3% abnormal DSL), and Group III = severe NCS (92.3% combined abnormalities). Group I individuals revealed intermittent pain/numbness, normal sensory/motor function, and negative provocative tests (23.8%). Patients in group II (65.4%) had persistent pain/numbness, sensory abnormalities (paresthesia/hypesthesia), and motor weakness. Patients in group III (10.8%) showed severe sensory loss and marked thenar muscle atrophy. Provocative tests were highly positive in Groups II and III, supporting their utility in diagnosing moderate-to-severe CTS. The carpal compression test had the highest sensitivity (86.5%) (Table 3).

latencies. Moderate-severe (17.6%): absent sensory response (12 hands). Severe (12.8%): absent sensory/motor response. NCS effectively stratified CTS severity, with 62.7% showing abnormal sensory latency. The absence of responses in severe cases underscores irreversible nerve damage (Table 4).

Table 4: Results of nerve conduction studies (NCS) classified patients into five severity groups (n=102 hands)

Severity	Hands	Prolonged DSL	Prolonged DML	Prolonged Both	Normal
Mild	19(18.7)	0(0.0)	0(0.0)	0(0.0)	19 (100)
Mild-Moderate	11(10.8)	0(0.0)	6(54.5)	0(0.0)	5(45.5)
Moderate	41(40.1)	18(43.9)	3(7.3)	15(36.6)	5(12.2)
Moderate/Severe	18(17.6)	12(66.7)	0(0.0)	6(33.3)	0(0.0)
Severe	13(12.8)	12(92.3)	0(0.0)	1(7.7)	0 (0.0)
Total	102	42(41.2)	9(8.8)	22(21.6)	29(28.4)

Results are presented as frequency and percentage.

The electrodiagnostic results revealed strong progression of nerve dysfunction related to the clinical severity of CTS. Early moderate cases mostly display sensory abnormalities, with 64.3% showing extended DSL, whereas motor involvement becomes clear in progressive disease, affecting 92.3% of severe cases. The data revealed a distinct evolution of neural injury: mild cases displayed normal findings entirely, moderate cases developed isolated sensory nerve dysfunction (median DSL 4.1 ms), and severe cases might exhibit combined sensorimotor abnormalities (median DSL 5.0 ms and DML 5.3 ms). This change was statistically significant across all variables ($p < 0.05$), with most alterations detected in motor nerve dysfunction in the moderate and severe groups (27.1%

vs. 92.3%, $p < 0.001$). The confidence intervals (CIs) revealed consistent sensory nerve dysfunctions in moderate cases (64.3% [52.1–75.3]), while the broader CIs in severe cases (e.g., 53.8% [25.1–80.8] for combined nerve dysfunctions) reflect more diagnostic ambiguity in small samples. These results support the use of sensory NCS as a sensitive primary diagnostic method, whereas motor nerve studies serve as biomarkers of disease progression. The incidence of combined nerve abnormalities strongly indicates progressive neural damage, necessitating prompt intervention. Significant increases in both median DSL and DML measures across severity groups ($p < 0.05$ vs. mild cases) accurately measured deteriorating neuronal abnormalities. This electrophysiological

evolution matches the clinical outcomes, confirming the use of NCS for staging severity and guiding therapeutic choices in CTS. Statistical tests included Pearson's χ^2 (with Yates' correction) for proportions

and Kruskal-Wallis/Dunn's tests for non-parametric data. Confidence intervals were calculated using the Wilson score method (Table 5).

Table 5: Electrodiagnostic abnormalities by clinical severity group in CTS (n=102 hands) with 95% CI (Wilson score method)

Parameter	All hands	Group I (Mild)	Group II (Moderate)	Group III (Severe)	p-value
Abnormal DSL (%)	62.7	0.0	64.3	92.3	<0.001
[95%CI]	[52.8-72]	[0-17.6]	[52.1-75.3]	[64.0-99.8]	
Abnormal DML (%)	30.4	0.0	27.1	92.3	<0.001
[95%CI]	[21.6-40.2]	[0-17.6]	[17.2-39.1]	[64.0-99.8]	
Both Abnormal (%)	21.6	0.0	21.4	53.8	0.002
[95%CI]	[14-30.8]	[0-17.6]	[12.4-33]	[25.1-80.8]	
Normal NCS (%)	28.4	100	7.1	0.0	<0.001
[95%CI]	[19.9-38.2]	[82.4-100]	[2.4-15.9]	[0-24.7]	
Median DSL (ms) (%)	4.1	3.2	4.1*	5.0*	<0.001
[95%CI]	[3.9-4.3]	[3.0-3.4]	[3.9-4.3]	[4.7-5.3]	
Median DML (ms) (%)	4.5	3.8	4.5*	5.3*	0.003
[95%CI]	[4.3-4.7]	[3.6-4.0]	[4.3-4.7]	[5.0-5.6]	

Proportions: Pearson's χ^2 (with Yates' correction for small groups). Post-hoc Analysis: Group II vs. III: Motor abnormalities differed the most (27.1% vs. 92.3%, $p<0.001$). *These values are statistically significantly higher than those of Group I (mild cases) based on post-hoc pairwise tests (e.g., Dunn's test after the Kruskal-Wallis test). Group II (Moderate): Median DSL = 4.1 ms* → Early nerve damage is detectable. Group III (severe): Median DSL = 5.0 ms* → Advanced demyelination/axonal loss. Key Trend: Sensory → Motor → Combined abnormalities increased with severity.

The pie chart in Figure 1 illustrates the distribution of patients across clinical severity groups.

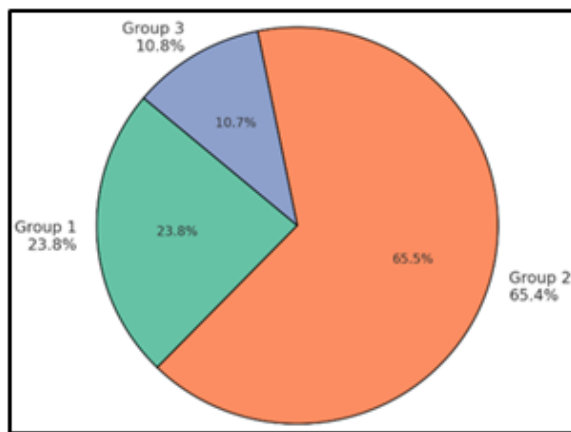


Figure 1: Pie chart showing the proportion of patients in each clinical severity group.

Group 2 (persistent pain and numbness with variable sensory and motor involvement) represented the majority (65.4%), followed by Group 1 (intermittent symptoms, 23.8%) and Group 3 (severe sensory and motor deficits, 10.8%). This finding suggests that most patients experience moderate symptoms, whereas severe cases are less common. Figure 2 shows the distribution of the different electrophysiological abnormalities in the affected hand. The most common category was moderate (40.1%), followed by mild (18.7%) and moderate-to-severe (17.6%). Severe abnormalities (12.8%) and mild-to-moderate abnormalities (10.8%) were less

frequent. This suggests a progression pattern, with most cases falling in the moderate range rather than at extreme ends. Postoperative follow-up (mean: 14 months) in 35 patients revealed Group I (16 patients) and full recovery for all patients. In group II (12 patients), 11 (91.7%) showed improvement, and 1 had residual weakness. In group III (7 patients), 5 (71.4%) improved, and 2 had persistent weakness.

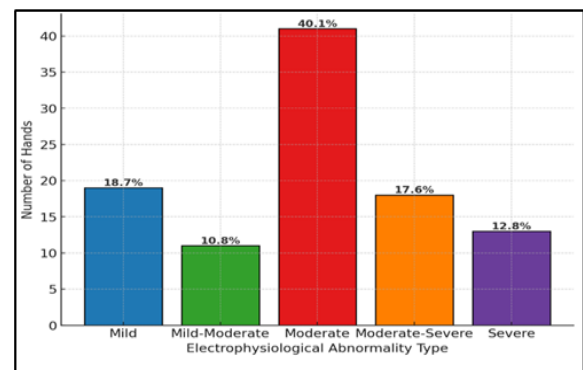


Figure 2: Bar graph comparing the different electrophysiological abnormalities. Each bar represents the number of hands affected in each category, with percentages labeled for clarity.

Surgical decompression yielded excellent outcomes in mild to moderate cases, whereas severe CTS showed partial recovery, emphasizing the importance of early intervention. Recovery rates differed significantly by severity group ($\chi^2=9.82$, $p=0.007$; Cramér's $V=0.54$), with severe CTS showing poorer motor recovery (Fisher's exact $p=0.02$ vs. mild/moderate groups) (Table 6).

Table 6: Postoperative follow-up results

Group	n	Follow-Up Period	Sensory recovery	Motor recovery	NCS improvement
I	16	6 weeks–1 year	16(100)	16(100)	16 (100)
II	12	1.5 months–2 years	11(91.7)	11(91.7)	12 (100)
III	7	3 months–2 years	5(71.4)	5(71.4)	7(100)

Values are presented as frequency and percentage.

Operative findings identified pseudoneuroma as the cause in 38% of patients (9 patients). Abnormal muscle anatomy (n= 7). Collefracture malunion (n= 6). Idiopathic cases predominated (44%), but identifiable causes such as trauma and systemic diseases emphasize the necessity of a thorough preoperative evaluation (Table 7).

Table 7: Etiologies of carpal tunnel syndrome (n=32)

Etiology	Result n(%)
Pseudoneuroma	9(28.1)
Abnormal muscles	7(21.9)
Colles' fracture	6(18.8)
Rheumatoid arthritis	2(6.3)
Diabetes/Hypothyroidism	7(21.9)

DISCUSSION

The present study offers a quantitative assessment of the clinical and electrophysiological results after standard carpal tunnel release (CTR) in 84 patients (102 hands). Our results confirm the epidemiological findings of Dec and Zyluk (2018) and Ganjoo et al. (2018), indicating that there is a higher susceptibility to CTS in females [3] with a female-to-male ratio of more than 4:1 and a mean age of 42.5 years [3,17]. This finding indicates that hormonal and anatomical gender distinctions probably drive increased vulnerability in women. The large percentage of right-handedness (91.7%) also matches the occupational and biomechanical risk patterns reported in the literature [3,18]. The most important finding of this study is the strong association between the severity of the nerve conduction study (NCS) preoperatively and the recovery after surgery. Our results also show the electrophysiologic continuum from isolated sensory abnormalities (64.3% of moderate cases having prolonged DSL) to combined sensorimotor dysfunction (92.3% of severe cases), reflecting the critical role of sensory NCS as an early biomarker. The present finding is consistent with the findings of Sonoo et al. [20], who had suggested sensory latencies as the most sensitive electrodiagnostic parameter in CTS. Importantly, stepwise increases in the median DSL (from 3.2 to 5.0 ms, mild to severe cases, respectively, $p<0.001$) and DML (from 3.8 to 5.3 ms, mild to severe cases, respectively, $p=0.003$) give objective and quantifiable thresholds that correlate with progressive neural injury. Surgical results showed that the conventional flexor retinaculum release was very effective, especially when performed early, as in our cases. A total of 100% of mild cases and 91.7% of moderate cases had complete recovery or significant improvement, which is comparable to the reported satisfaction ranges of 85–95% in large-scale retrospective series by a preceding study [17]. In our severe group, however, the recovery rate was only 71.4%, and 28.6% of patients had persistent motor weakness. This reduction in response in advanced CTS is consistent with the recent systematic review [8], which stated that motor function, even after successful decompression, is likely irreversible if there is sufficient motor denervation and irreversible

axonal loss. Together, the findings suggest a critical therapeutic window—intervention in mild to moderate stages produces almost full recovery, while severe cases only partially recover; this evidence indicates the need for early surgical referral when there is progressive deterioration on NCS. Etiological findings during the operation were added to our analysis. Causes were identified for a significant number of patients (pseudoneuroma 28.1%, anomalous muscles 21.9%, and Colles' fracture malunion 18.8%), highlighting the importance of careful surgical exploration in addition to splitting the ligaments. The high sensitivity (86.5%) of the carpal compression test in our cohort is greater than the ranges previously reported [1] in their meta-analysis, making the test a strong bedside screening tool when used in conjunction with the NCS for moderate-to-severe disease. As a summary of the main findings of this study, it is important to note: (1) The severity of the NCS reliably predicts surgical recovery, and surgical intervention should be planned earlier to avoid residual deficits in severe cases; (2) a standard flexor retinaculum release provides excellent outcomes in mild and moderate CTS, with over 90% of patients making a satisfactory recovery; and (3) severe cases have favorable outcomes but often have residual deficits; therefore, surgical intervention should be planned to occur earlier to avoid them. These findings are consistent throughout the international literature and offer specific quantitative recovery rates (100%, 91.7%, and 71.4% by severity group) that will help guide clinical prognostication and future studies.

Study Limitations

This study has four principal limitations: (1) its retrospective, non-randomized design may introduce selection bias; (2) the substantial loss to follow-up (58.4%) limits the statistical power of recovery analyses and risks differential bias; (3) the absence of validated functional outcome instruments (e.g., Boston Carpal Tunnel Questionnaire) restricts patient-reported assessment; and (4) the demographic homogeneity of our cohort (exclusively Iraqi, predominantly female) constrains generalizability to other populations.

Conclusion

The present study elucidates the multifactorial nature of CTS and emphasizes the critical role of early intervention informed by comprehensive assessments, including the indispensable use of NCS. This study shows that standard flexor retinaculum release works well for mild to moderate CTS. In more severe cases, there is only partial recovery, which may be because of damage to the axon-neural system. Nevertheless, the homogeneous cohort, retrospective design, and limited follow-up (41.6%) constrain generalizability. Future prospective multicenter studies with validated functional outcome measures and extended follow-up are warranted to validate our findings across diverse populations. Forthcoming prospective research should

prioritize various populations and long-term functional assessments to improve surgery indications. Clinically, integrating symptom severity with NCS may guide timely intervention, particularly in moderate cases of CTS, where the outcomes are most robust.

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Conflict of interests

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Data sharing statement

The data that supports the findings of this study are available from the corresponding author upon a reasonable request.

REFERENCES

1. Zaki HA, Shaban E, Salem W, Bilal F, Fayed M, Hendy M, et al. A Comparative analysis between ultrasound and electromyographic and nerve conduction studies in diagnosing carpal tunnel syndrome (CTS): A systematic review and meta-analysis. *Cureus*. 2022;14:e30476. doi: 10.7759/cureus.30476.
2. Lee K, Park JM, Yoon SY, Kim MS, Kim YW, Shin JI, et al. Ultrasound-guided nerve hydrodissection for the management of carpal tunnel syndrome: A systematic review and network meta-analysis. *Yonsei Med J*. 2025;66:111-120. doi: 10.3349/ymj.2024.0089.
3. Dec P, Zyluk A. Bilateral carpal tunnel syndrome - A review. *Neurol Neurochir Pol*. 2018;52:79-83. doi: 10.1016/j.pjnns.2017.09.009.
4. Dahlin LB, Zimmerman M, Calcagni M, Hundepool CA, van Alfen N, Chung KC. Carpal tunnel syndrome. *Nat Rev Dis Primers*. 2024;10:37. doi: 10.1038/s41572-024-00521-1.
5. Riccò M, Cattani S, Signorelli C. Personal risk factors for carpal tunnel syndrome in female visual display unit workers. *Int J Occup Med Environ Health*. 2016;29:927-936. doi: 10.13075/ijom.1896.00781.
6. Kadhim ZME, Jabir B. The incidence of ulnar nerve subluxation in patients with ulnar neuropathy at the elbow and healthy control: A clinical, electrodiagnostic, and ultrasonographic study. *Med J Babylon*. 2023;20:477-480. doi: 10.4103/mjbl.Mjbl_471_23.
7. Binsaleem S. Median nerve entrapment neuropathy: a review on the pronator syndrome. *JSES Rev Rep Tech*. 2025;5:70-78. doi: 10.1016/j.xrrt.2024.10.001.
8. Meyers A, Annunziata MJ, Rampazzo A, Bassiri Gharb B. A systematic review of the outcomes of carpal ligament release in severe carpal tunnel syndrome. *J Hand Surg Am*. 2023;48:408.e1-e18. doi: 10.1016/j.jhsa.2021.11.015.
9. Vernick RC, Beckwitt CH, Fowler JR. Subjective and objective differences in patients with unilateral and bilateral carpal tunnel syndrome and the role of obesity in syndrome severity. *Plastic Reconstruct Surg*. 2024; 153(2):423-429. doi: 10.1097/PRS.00000000000010773.
10. Al-Joda BMS, Al-Hindy HAM, Mousa MJ. Exploring the role of vitamin D2, parathyroid hormone, and C-peptides as biomarkers in diabetic neuropathy development. *Med J Babylon*. 2024;21(2):438-443. doi: 10.4103/MJBL.MJBL_1568_23.
11. Al-Shimmery AHS, Mahdi ZA, Abdul-Amir HM, Al-Mammori RTO, Mokif TA, Al-Dahmashi HOM, et al. Immunological study of IFN- γ , ICAM-4, and vitamin D3 markers among gastrointestinal tumor patients in Babylon province, Iraq. *Asian Pac J Cancer Prev*. 2023;24:301-305. doi: 10.31557/apjcp.2023.24.1.301.
12. Ramadan GM, Makki HAA, Mousa MJ, Al-Sadi HI. Evaluation of transforming growth factor-beta 1 (TGF β 1) levels in cases with multiple myeloma: Case-control study among Iraqis. *J ReAttach Ther Dev Diversities*. 2022;5:516-523.
13. Saito Y, Chikenji T, Ozasa Y, Fujimiya M, Yamashita T, Gingery A, et al. PDGFR signaling mediates hyperproliferation and fibrotic responses of subsynovial connective tissue cells in idiopathic carpal tunnel syndrome. *Sci Rep*. 2017;7:16192. doi: 10.1038/s41598-017-16443-w.
14. Wang Y, Guo L, Yin X, McCarthy EC, Cheng MI, Hoang AT. Pathogenic TNF- α drives peripheral nerve inflammation in an Aire-deficient model of autoimmunity. *Proc Natl Acad Sci U S A*. 2022;119. doi: 10.1073/pnas.2114406119.
15. Alrayes MS, Altawili M, Alsaffar MH, Alfarhan GZ, Owedah RJ, Bodal IS, et al. Surgical interventions for the management of carpal tunnel syndrome: A narrative review. *Cureus*. 2024;16:e55593. doi: 10.7759/cureus.55593.
16. Wiberg A, Smillie RW, Dupré S, Schmid AB, Bennett DL, Furniss D. Replication of epidemiological associations of carpal tunnel syndrome in a UK population-based cohort of over 400,000 people. *J Plast Reconstr Aesthet Surg*. 2022;75(3):1034-1040. doi: 10.1016/j.bjps.2021.11.025.
17. English JH, Gwynne-Jones DP. Incidence of carpal tunnel syndrome requiring surgical decompression: A 10.5-year review of 2,309 patients. *J Hand Surg Am*. 2015;40:2427-2434. doi: 10.1016/j.jhsa.2015.07.029.
18. Ganjoo S, Kaul D, Shah PA. Carpal tunnel syndrome in females: pregnancy and lactation the major risk factors. *Int J Reprod Contracept Obstet Gynecol*. 2018;7:3512-3515. doi: 10.18203/2320-1770.ijrcog20183366.
19. Sonoo M, Menkes DL, Bland JDP, Burke D. Nerve conduction studies and EMG in carpal tunnel syndrome: Do they add value? *Clin Neurophysiol Pract*. 2018;3:78-88. doi: 10.1016/j.cnp.2018.02.005.