Original Article

Electrophysiological Outcomes Before and After Surgery and Complications in Patients with Carpal Tunnel Syndrome

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Abstract

Background: Carpal Tunnel Syndrome (CTS) is the most common entrapment neuropathy, significantly affecting individuals engaged in repetitive hand movements and forceful gripping, leading to median nerve compression within the carpal tunnel. It is a major cause of functional disability, impacting daily activities and work productivity. The present study aimed to evaluate electrophysiological outcomes of open carpal tunnel release (OCTR) surgery, assessing its effectiveness in relieving symptoms and restoring nerve conduction over a six-month follow-up period. **Material and Methods:** This prospective observational study was conducted among Patients diagnosed with carpal tunnel syndrome in the Department of Orthopaedics, SHKM GMC Nalhar, Nuh, Haryana over a period of 12 months. The study was commenced after obtaining Institutional Ethics Committee (IEC) approval. **Results:** Nerve conduction studies (NCS) demonstrated a significant reduction in distal motor latency (DML) and sensory latency (SL) postoperatively, indicating progressive nerve recovery following decompression. The preoperative DML was 5.10 ± 0.56 ms, which improved to 3.44 ± 0.80 ms by six months. Similarly, preoperative SL was 3.93 ± 0.52 ms, improving to 2.54 ± 0.56 ms at 6 months. The statistically significant improvement in both DML and SL confirmed the positive impact of OCTR on nerve conduction. At six months postoperatively, 30.4% of patients achieved full recovery, while 60.9% had mild residual symptoms such as minor numbness or occasional discomfort, which did not significantly impact daily activities. A small proportion (8.7%) experienced persistent symptoms, possibly due to chronic preoperative nerve compression or incomplete nerve recovery. Postoperative complications were observed in 52.2% of patients, with the most common being delayed healing (17.4%), nerve irritation (17.4%), minor infections (13%), and scar tenderness (4.3%). However, these complications were minor and manageable, resolving with proper wound care, physiotherapy, and rehabilitation exercises. **Conclusion:** The statistically significant improvements in nerve conduction latency (DML and SL) validate the long-term benefits of OCTR in enhancing hand function and quality of life.

Keywords: Electrophysiological Outcomes, Complications, Carpal Tunnel Syndrome.

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Introduction

Carpal Tunnel Syndrome (CTS) is the most prevalent upper extremity neuropathy, significantly impacting the quality of life of affected individuals. It results from compression of the median nerve within the carpal tunnel, leading to sensory and motor deficits in the hand. Clinical evaluation, supported by electrophysiological studies such as nerve conduction studies (NCS), plays a crucial role in diagnosing CTS and determining its severity. While non-surgical interventions are effective for mild cases, surgical decompression, particularly open carpal tunnel release (OCTR), remains the definitive treatment for severe or refractory cases. Understanding the clinical, functional, and electrophysiological outcomes before and after surgery is essential in optimising treatment strategies.

The estimated prevalence of CTS ranges from 1% to 5% among adults worldwide, with a study reporting a clinically confirmed prevalence of 3.8%.[1,2] This condition is more common in individuals aged 40 to 60 years, with women being three times more likely than men to develop CTS.[3] In India, CTS is recognised as a major health concern, with research suggesting approximately 10 million cases nationwide.[4]

The pathophysiology of CTS involves multiple mechanisms, including ischemia, focal demyelination, axonal narrowing, and, in advanced cases, axonal loss.[2] Several systemic conditions are associated with an increased risk of CTS, including obesity, diabetes mellitus, thyroid dysfunction, amyloidosis, rheumatoid arthritis, and Raynaud's disease.[5] Additionally, habitual sleeping posture with acute wrist flexion and repetitive hand motions, such as in labourers using vibrating machinery, contribute to nerve compression. However, the role of light,

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repetitive activities, such as office work, remains controversial.[5] Pregnant women commonly experience transient CTS symptoms, which often resolve after delivery, suggesting hormonal and fluid retention-related causes in pregnancy.[5]

Grip strength assessment is a valuable diagnostic tool for CTS, as it quantifies muscle weakness and helps determine the urgency for surgical intervention. Studies have documented postoperative changes in grip strength, with 28% of preoperative strength at 3 weeks, 73% at 6 weeks, and a full return to baseline at 3 months, with further improvement to 116% of preoperative levels at 6 months. Similarly, pinch strength shows 96% recovery at 6 weeks and 126% at 6 months, demonstrating progressive functional recovery following surgical intervention.[6]

Postoperative care focuses on pain management, reducing swelling, and providing physical therapy. Patients are advised to avoid heavy lifting and repetitive wrist movements during the early recovery phase to prevent complications.[7]

MATERIALS AND METHODS

This prospective observational study was conducted among patients diagnosed with carpal tunnel syndrome in the Department of Orthopaedics, SHKM GMC Nalhar, Nuh, Haryana, over 12 months. The study was commenced after obtaining Institutional Ethics Committee (IEC) approval

Sample Size & Sampling

- A minimum of 20 patients were enrolled based on hospital records.
- If fewer than 20 patients were available, data collection continued until the target was met.
- All consenting CTS patients meeting inclusion criteria were included in the study.

Inclusion Criteria:

- Age > 30 years
- Clinical and electrophysiological diagnosis of CTS scheduled for surgery
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- Medically fit for surgery
- Willing to give informed written consent

Exclusion Criteria:

- Patients with rheumatoid arthritis, polyneuropathy
- Pregnancy, thyroid disorders, and other systemic conditions
- Patients unwilling for surgery

Methodology

1. Demographic details were collected using a pre-designed proforma.
2. Electrophysiological assessments of CTS patients were conducted.
3. Preoperative evaluation included:
- medical history
- Clinical examination (Tinel's sign, Phalen's test, Durkan's test, hand diagrams
- Duration of symptoms
- Nerve conduction studies (NCS)
- Grip strength measurement using a Hand Dynamometer
- QuickDASH questionnaire
4. Surgical Procedure:
- All patients underwent open carpal tunnel release (OCTR) surgery under brachial block or general anaesthesia.
5. Postoperative Care:
- Limb elevation using an arm sling
- Early active finger movements initiated from day one
- Suture removal performed after two weeks
- Hand physiotherapy for grip strengthening
- Patients were advised to avoid repetitive hand use for one month
6. Follow-up Evaluations at 3 Weeks, 3 Months, and 6 Months included:
- Nerve conduction study
- Any complications will be noted
- Outcome was assessed

Data Collection & Outcome Measures

Electrophysiological Assessment:

- Distal Motor Latency
- Sensory Latency

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS 20.0 statistical software.

Results were expressed as percentages and proportions, with appropriate statistical tests applied.

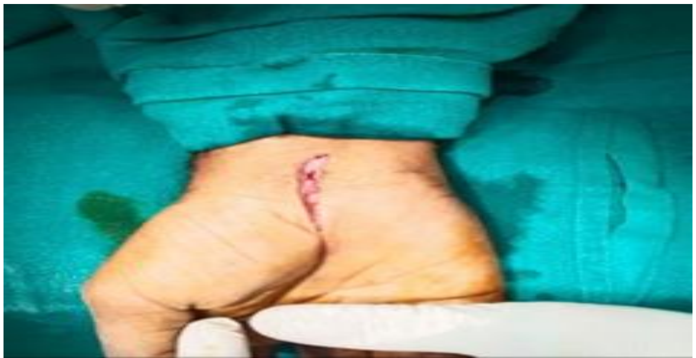

Exhibit 1: Skin Incision

Exhibit 2: Flexor retinaculum release

Exhibit 3: Median nerve decompression

Results

Peak incidence in middle-aged individuals, particularly between 51 and 60 years, suggesting that Carpal Tunnel Syndrome (CTS) is most prevalent in this age bracket. Among the 23 patients studied, males constitute a slightly higher proportion (56.5%) compared to females (43.5%), Our study reveals a near-equal distribution of the affected side.

Distal motor latency, a key measure of nerve conduction efficiency, demonstrates significant improvement postoperatively. The preoperative mean latency of 5.10 ± 0.56 ms indicates prolonged conduction time due to nerve impairment. At 3 months post-op, the latency decreases to 4.33 ± 0.63 ms, showing early nerve recovery. By 6 months post-op, the latency further improves to 3.44 ± 0.80 ms, suggesting substantial neural regeneration and restoration of normal function.

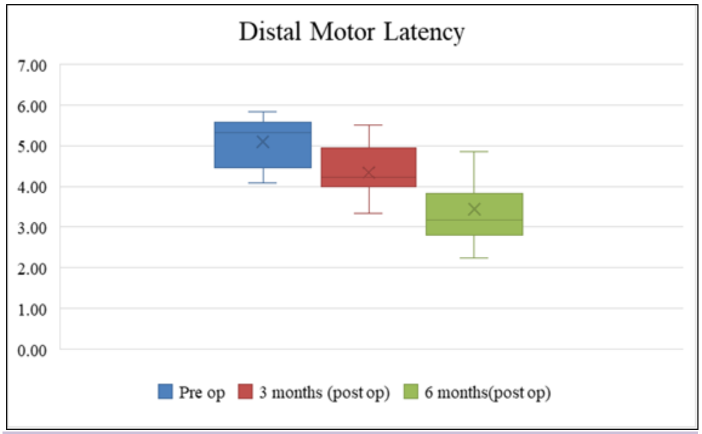

Figure 1: Box plots demonstrating change in Distal motor latency over time

The box plot visually represents the steady decline in motor latency, showing a shift toward lower values over time, indicating progressive recovery of nerve function. The reduction in the spread of values at 6 months suggests that most patients showed significant improvement, with fewer outliers compared to the preoperative phase.

Table 1: Mean distal motor latency on Nerve conduction study of patient's pre-op and post- op follow ups

Distal Motor latency (Nerve conduction Study)	Mean ± SD	Min	Max
Pre op	5.10ms ± 0.56	4.08	5.84
3 months (post op)	4.33ms ± 0.63	3.33	5.51
6 months (post op)	3.44ms ± 0.80	2.23	4.86

Table 2: Mean rank Friedman test of distal motor latency on Nerve conduction study on pre-op and follow ups

Distal Motor latency (Nerve conduction Study)	Mean Rank	χ2, p value
Pre op	3	χ2= 46, p value < 0.001
3 months (post op)	2	
6 months (post op)	1	

The Friedman test (χ2=46, p<0.001) confirms that the observed reductions in distal motor latency over time are statistically significant. The mean rank is highest preoperatively (3.0), indicating the most severe impairment, and it progressively declines at 3 months (2.0) and further at 6 months (1.0), reflecting improvement.

The line graph [Figure 2] effectively captures this decline in latency, showing a downward trend that corresponds with the statistical findings. This demonstrates the impact of the intervention in enhancing nerve conduction over time with statistically significant p-value (p <0.001).

Sensory latency follows a pattern similar to motor latency, with a preoperative mean of 3.93 ± 0.52 ms, indicating delayed sensory conduction. At 3 months post-op, the latency reduces to 3.26 ±0.55 ms, and by 6 months, it further improves to 2.54 ± 0.56 ms, suggesting significant sensory nerve recovery, as depicted in [Table 3]. The box plot [Figure 3] further illustrates this improvement, with the median and range shifting towards lower latency values at 6 months.

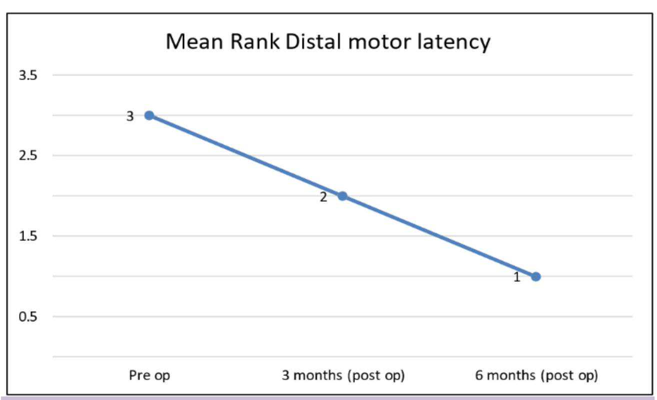

Figure 2: Line graph demonstrating change in mean Friedman rank of distal motor latency over time

Table 3: Mean sensory latency on Nerve conduction study of patient's pre-op and post-op follow ups

Sensory latency (Nerve conduction Study)	Mean ± SD	Min	Max
Pre op	3.93 ± 0.52	3.01	4.95
3 months (post op)	3.26 ± 0.55	2.20	4.18
6 months (post op)	2.54 ± 0.56	1.72	3.69

Table 4: Mean rank Friedman test of Sensory latency on Nerve conduction study on pre- op and follow ups

Sensory latency (Nerve conduction Study)	Mean Rank	χ2, p value
Pre op	3	χ2=46, p value < 0.001
3 months (post op)	2	
6 months (post op)	1	

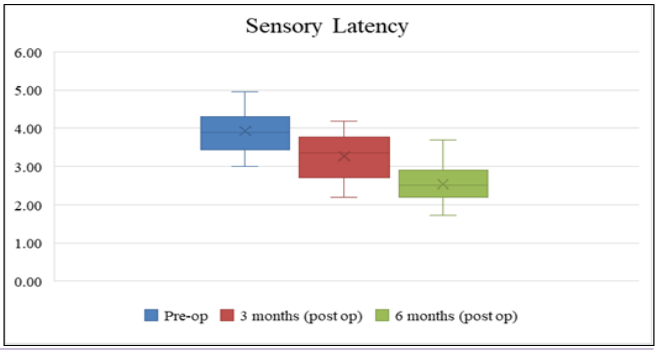

Figure 3: Box plots demonstrating change in Sensory latency over time

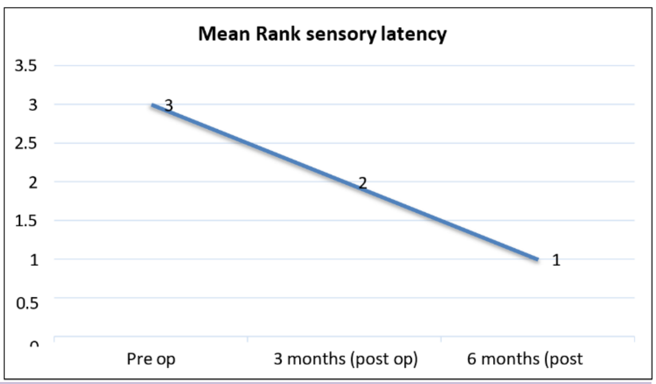

Figure 4: Line graph demonstrating change in mean Friedman rank of sensory latency over time

The Friedman test (χ2=46, p<0.001) demonstrates a statistically significant reduction in sensory latency. The highest mean rank (3.0) is seen preoperatively, indicating the most impaired conduction, followed by a decrease at 3 months (2.0) and 6 months (1.0), confirming progressive sensory nerve recovery, as depicted in Table 4.

The line graph (Figure 4) presents a clear downward trend, reinforcing the statistical results with highly significant p-value (<0.001).

Outcomes of this study indicates that 47.8% of patients had full recovery, meaning that while they improved significantly, some minor symptoms persisted. 43.5% of patients had mild residual symptoms, experiencing complete symptom resolution. A small proportion (8.7%) had persistent symptoms, indicating an incomplete response to treatment, as shown in [Table 5].

Table 5: Distribution of outcome in study patients

Final Outcome	No. of patients	Percentage
Full Recovery	11	47.8%
Mild Residual	10	43.5%
Persistent symptoms	2	8.7%
Total	23	100%

Table 6: Relation of Time duration between onset of symptoms and operation with final outcome

Duration b/w onset of symptoms and operation	Final Outcome			Total
	Full Recovery	Mild Residual	Persistent symptoms	
< 3 months	5	1	0	6
3-6 months	4	1	0	5
6-9 months	2	7	1	10
>9 months	0	1	1	2
Total	11	10	2	23

This study establishes a significant correlation between the time to surgery and outcome, with a chi-square value of 13.40 (p-value 0.037), indicating statistical significance ($p < 0.05$). Patients who underwent surgery within 3 months showed the highest rate of full recovery (83.3%), followed closely by those in the 3-6 months category (80%). However, for those who delayed surgery to 6-9 months, only 20% achieved full recovery, while 70% had mild residual symptoms, and 10% experienced persistent symptoms. Notably, none of the patients who underwent surgery after 9 months achieved full recovery, with 50% experiencing mild residual symptoms and 50% persistent symptoms, as depicted in [Table 6].

Table 7: Distribution of post-op complications in patients

Complications	No. of Patients	Percentage
Delayed healing	4	17.4%
Minor infection	3	13%
Nerve irritation	4	17.4%
None	11	47.8%
Scar Tenderness	1	4.3%
Total	23	100%

Postoperative complications were observed in 52.2% of patients, while 47.8% experienced no complications. Among complications, delayed healing and nerve irritation were the most common (17.4% each), followed by minor infections (13%) and scar tenderness (4.3%), as shown in [Table 7].

Discussion

Electrophysiological testing plays a crucial role in diagnosing Carpal Tunnel Syndrome (CTS) and monitoring postoperative recovery following open carpal tunnel release (OCTR) surgery. Nerve conduction studies (NCS) are considered the gold standard for assessing median nerve function, as they provide objective measurements of nerve latency, conduction velocity, and response amplitude.8 In the present study, significant postoperative improvements were observed in both distal motor latency (DML) and sensory latency (SL), confirming restoration of nerve function after surgical decompression.

The preoperative mean DML was 5.10 ± 0.56 ms, which showed a progressive reduction to 4.33 ± 0.63 ms at three months and further improved to 3.44 ± 0.80 ms at six months. Similarly, preoperative SL was 3.93 ± 0.52 ms, which improved to 3.26 ± 0.55 ms at three months and 2.54 ± 0.56 ms at six months. The statistically significant reduction in both DML and SL in this study indicates progressive nerve recovery, suggesting that median nerve function begins to normalise within six months postoperatively. These results are consistent with Soltani et al. (2017) 9, who reported significant nerve conduction recovery within six months post-OCTR.

Notably, sensory recovery preceded motor recovery, aligning with the findings of Ayache et al. (2020), who attributed this to differences in axonal repair mechanisms. Sensory nerves, being thinner and more responsive to decompression, often regenerate more quickly than motor fibers, resulting in earlier improvements in sensory latency measurements (De Roo et al., 2021).[10]

The findings of this study align with previous research indicating that early postoperative improvements in nerve conduction predict better functional outcomes. Orhurhu et al,[11] (2020) found that persistent latency delays beyond six months may indicate irreversible nerve damage, especially in cases where preoperative compression was severe. Furthermore, Soltani et al,[12] (2017) reported that patients with severe preoperative nerve dysfunction tend to have slower recovery rates. These observations suggest that while OCTR effectively restores nerve function, the extent of recovery is influenced by preoperative severity, the duration of nerve compression, and adherence to postoperative rehabilitation.

While the present study demonstrated notable improvements in NCS parameters within six months, future studies with longer follow-up durations (12–24 months) could provide further insights into long-term electrophysiological recovery. Additionally, comparing open vs. endoscopic carpal tunnel release techniques could help determine whether minimally invasive approaches result in faster nerve function restoration and better long-term outcomes.

Final Outcome

The outcome of open carpal tunnel release (OCTR) surgery was assessed at 6 months postoperatively, with 47.8% of patients achieving full recovery, 43.5% experiencing mild residual symptoms, and 8.7% having persistent symptoms. These findings align with research by Ayache et al,[12] (2020) who found that mild residual symptoms are common in up to 70% of patients post-OCTR but continue to improve over time.

The presence of mild residual symptoms in 43.5% of patients in the present study could be attributed to prolonged preoperative nerve compression, which may have led to partial axonal degeneration. Several factors influence the presence of residual symptoms. De Roo et al,[10] (2021) suggested that early surgical intervention leads to higher rates of full recovery, as prolonged nerve compression can result in irreversible axonal damage. Patients with persistent symptoms (8.7%) may require additional interventions, such as physiotherapy, nerve gliding exercises, or, in rare cases, revision surgery.

Complications

Postoperative complications were observed in 52.2% of patients, with the most common being delayed healing (17.4%), nerve irritation (17.4%), minor infections (13%), and scar tenderness (4.3%). These findings are comparable to previously reported complication rates in OCTR patients (Ayache et al., 2020).[12]

Delayed wound healing was the most commonly reported complication in this study (17.4% of patients), which is in line with Studies by Soltani et al. (2017).[12] Ayache et al,[12] (2020) indicate that patients with a history of smoking, peripheral vascular disease, or previous wrist surgeries have an increased risk of delayed wound healing due to reduced blood flow and impaired oxygen delivery to tissues. Most cases of delayed healing resolved with proper wound care and time, without requiring additional surgical intervention.

Nerve irritation, observed in 17.4% of patients, manifested as transient tingling, burning pain, or hypersensitivity in the median nerve distribution. This finding aligns with the studies by Orhurhu et al,[11] (2020) and Pace et al,[14] (2023) which suggest that this may result from nerve regeneration and local inflammation following decompression. Most cases are self-limiting and improve with time, nerve mobilisation exercises, and anti-inflammatory medications.

Minor infections occurred in 13% of patients, which is slightly higher than the 5–10% infection rates reported in previous studies.[14] This could be due to poor postoperative hygiene, delayed wound healing, or environmental factors. Most infections in CTS surgery are superficial and resolve with oral antibiotics and wound care, with very few cases requiring surgical debridement.

Scar tenderness was noted in 4.3% of patients, which has been linked to variations in surgical technique and tissue healing (Duetzmann et al., 2018).[15] Management strategies such as scar desensitisation therapy, massage, and topical agents have been shown to help reduce tenderness over time. Despite these minor complications, OCTR remains a safe and effective procedure, with most complications being temporary and easily manageable. Studies suggest that proper postoperative rehabilitation, early mobilisation, and patient education on wound care can significantly reduce complication rates.[16] Future research should explore strategies to minimise postoperative discomfort and enhance recovery through targeted physiotherapy and scar management techniques.

Conclusion

The statistically significant improvements in nerve conduction latency (DML and SL) confirm the long-term benefits of OCTR in enhancing hand function and quality of life. Given that nerve regeneration continues beyond six months, further research with longer follow-up durations is warranted to assess long-term functional outcomes and potential late-onset complications.

Open carpal tunnel release surgery is a safe and effective intervention for relieving symptoms, restoring hand function, and improving nerve conduction in patients with CTS. Future studies should explore larger sample sizes, compare outcomes between open and endoscopic techniques, and examine the role of postoperative rehabilitation strategies to optimise treatment approaches further and enhance patient satisfaction.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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