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Electrophysiological Changes in Patients with Carpal Tunnel Syndrome after Open Carpal Tunnel Release

Chaehyun Song[1], Seung Jun Lee[1], Seong Woo Kim[1], Sung Hoon Kim[2], Ha Ra Jeon[1]

[1]Department of Physical Medicine and Rehabilitation, National Health Insurance Service Ilsan Hospital, Goyang, Korea
[2]Department of Orthopedic Surgery, National Health Insurance Service Ilsan Hospital, Goyang, Korea

Objective: Carpal tunnel syndrome (CTS) is the most common peripheral neuropathy affecting the upper limbs. Various treatment methods exist for this disease, but only a few reports have compared the effects of various treatments using objective indicators. This study analyzed the changes in electrophysiological parameters after carpal tunnel release.
Methods: In patients planning to undergo surgical treatment for CTS, electrophysiological studies, including nerve conduction studies and electromyography (EMG), of both upper extremities were performed before and 6 to 8 weeks after mini-open transverse carpal ligament release and median nerve neurolysis.
Results: After surgical intervention, the onset latency and amplitude of the sensory nerve action potential (SNAP) and the onset latency of the compound muscle action potential (CMAP) of the median nerve improved. Additionally, the grade of abnormal spontaneous activity in needle EMG of the abductor pollicis brevis (APB) and the severity of the electrodiagnostic study results significantly decreased after the intervention compared to the initial evaluation.
Conclusion: This study shows that the onset latency of SNAP and CMAP, the amplitude of SNAP of the median nerve, and EMG findings in the APB can be useful electrodiagnostic parameters for postoperative monitoring in CTS patients.

Keywords: Carpal tunnel syndrome; Electrophysiology; Surgical procedure

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Corresponding author:
Ha Ra Jeon
Department of Physical Medicine and Rehabilitation, National Health Insurance Service Ilsan Hospital, 100 Ilsan-ro, Ilsandong-gu, Goyang 10444, Korea
Tel: +82-31-900-0970
Fax: +82-31-900-0028
E-mail: jeon1021@nhimc.or.kr

Introduction

Carpal tunnel syndrome (CTS) is the most common peripheral neuropathy affecting the upper extremities. This syndrome is characterized by median nerve entrapment at or around the wrist level, resulting in dysfunction of the median nerve [1,2]. CTS can be diagnosed based on clinical symptoms and physical examination findings. Patients often report pain and paresthesia in the distribution of the median nerve and show positive physical examination findings, such as the Tinel sign or Phalen maneuver [1,2]. Ultrasonography and electrodiagnosis (EDx) are useful for confirming the diagnosis of CTS and ruling out other causes. Ultrasonography analyzes anatomical structures and nerves to assess the cross-sectional area of the median nerve, which is altered by the disease. However, in general, EDx is the gold-standard test for the diagnosis of CTS. Among various EDx methods, nerve conduction studies (NCS) can confirm CTS by detecting impaired median nerve conduction across the carpal tunnel, and electromyography (EMG) expresses pathological changes in the abductor pollicis brevis (APB) muscle innervated by the median nerve. EDx has the advantage of being able to classify the severity of the disease to determine the treatment strategy and predict the prognosis after surgery. The severity is classi-

fied into 4 categories: normal, mild, moderate, and severe. Patients with prolonged latency in median nerve sensory conduction, but normal motor conduction, are classified as mild. Moderate disease is defined as prolonged latency in median motor nerve conduction. In patients with severe CTS, EDx shows (1) decreased sensory nerve action potential (SNAP) amplitude, (2) decreased compound muscle action potential (CMAP) amplitude, or (3) the appearance of fibrillation potential or motor unit potential changes on needle EMG [2–5].

Several treatment options exist for CTS, including surgical and nonsurgical methods. In patients with moderate to severe CTS, surgical treatment is performed by dividing the transverse carpal ligament to increase the space of the carpal tunnel and reduce the pressure on the median nerve. Nonsurgical methods for patients with mild to moderate CTS include hand bracing, wrist splinting, oral medications, and local corticosteroid injections [1,6].

Multiple treatment options can be considered for CTS, but only a few reports have compared treatment effectiveness using objective indicators [7–11]. Commonly used outcome assessment tools include the visual analog scale (VAS) rating system, self-reported symptom questionnaires, follow-up NCS, and EMG. Previous studies mainly used self-reported function and symptom improvement questionnaires to investigate the preoperative and postoperative status of patients with CTS in terms of symptom improvement. Few reports have investigated the main neurophysiological changes after surgical interventions in patients with CTS [12,13]. In this study, we analyzed and compared electrophysiological parameters and pain scale scores before and after carpal tunnel release (CTR) to determine whether any significant changes took place.

Materials and Methods

Among the patients with suspected CTS, those who met the following inclusion criteria and did not meet the exclusion criteria were included in this study. The inclusion criteria were as follows: (1) electrophysiologically diagnosed CTS, (2) unilateral or bilateral involvement, and (3) no history of surgical intervention. The following cutoff values were applied for the diagnosis of CTS: 3.5 ms for SNAP onset latency, 20 μV for SNAP amplitude, 4 ms for CMAP onset latency, and 5 mV for CMAP amplitude [14]. The exclusion criteria were as follows: (1) no abnormal EDx findings or other neurological problems such as cervical radiculopathy, polyneuropathy, or myelopathy; (2) discontinuation of postsurgical follow-up; and (3) a requested to withdraw from the study.

This study was conducted prospectively and approved by the Institutional Review Board (IRB) of National Health Insurance Service Ilsan Hospital (IRB no. 2015-06-019-008). Informed consent was obtained from all participants who agreed to participate in this study, and an initial clinical evaluation was performed by a specialist in physical medicine and rehabilitation.

After the initial NCS and EMG were performed, the patients were referred to the Department of Orthopedic Surgery and underwent surgical treatment by the same surgeon. After confirming the results of EDx and patient-reported symptoms, CTR was performed when the clinician determined that surgery was necessary. The patients were followed up 6-8 weeks after surgery.

Electrophysiological studies, including NCS and EMG, of both upper extremities were performed before and 6 to 8 weeks after the mini-open transverse carpal ligament release and neurolysis of the median nerve. The objective of the NCS was to examine the onset latency and amplitude of the median SNAP and the onset latency and amplitude of CMAP. The objective of EMG was to assess the grade of abnormal spontaneous activity (ASA), which is reported as a gradation of either positive sharp waves (PSWs) or fibrillation potentials in the APB muscle. ASA was rated on a scale of 1 (transient but reproducible discharges) to 4 (abundant spontaneous potentials). All EDx cases were graded as electrophysiologically normal, mild, moderate, or severe according to the criteria presented by Werner and Andary [5].

The pain scales reflecting patients' subjective discomfort were also compared before and after surgery. In this study, the short-form McGill Pain Questionnaire (SF-MPQ) and VAS were used to identify the quality of pain associated with CTS. The SF-MPQ is a shorter version of the original MPQ, which has 2 subscales (sensory and affective). The sensory subscale contains 11 items, and the affective subscale contains 4 items. Each item is rated on an intensity scale ranging from 0 (no pain) to 3 (severe pain). The VAS and present pain intensity (PPI) were also used to provide overall intensity scores [15].

Statistical analysis was performed using IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA). Comparisons between groups were performed using the paired t-test for paired continuous and ordinal variables, and comparisons between categorical data were performed using the McNemar test. Any p-value < 0.05 was considered significant.

Results

After screening, 49 wrists in 33 patients were included in this study. Twenty-nine female patients (87.9%) and 4 male patients (12.1%) were evaluated, and all completed the follow-up studies.

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The mean age was 63.7 years, and the average disease duration was 21.6 months. Eleven (33.3%) patients underwent surgical intervention on the right hand, 6 (18.2%) on the left hand, and 16 (48.5%) on both hands (Table 1).

In the initial EDx, the onset latencies of the median SNAP and CMAP were prolonged, and the amplitudes of the median SNAP and CMAP were low. After surgical intervention, the onset latencies and amplitudes of the median SNAP and the onset latencies of CMAP significantly improved (Table 2).

In addition, the ASA grade on needle EMG observed in the APB was significantly better after the surgical intervention than on the initial needle EMG. The proportion of ASA grade 0 increased, while those of ASA grades 1, 2, and 3 decreased after the surgical intervention (Table 3).

The severity of EDx significantly improved after the surgical intervention. The proportion of patients with normal EDx increased, and that of patients with severe EDx decreased after the surgical intervention (Table 4).

The degree of pain significantly reduced after surgery. The scores of the sensory and affective subscales of the SF-MPQ significantly improved after the surgical intervention. The VAS and PPI scores also significantly improved after the surgical intervention (Table 5).

Discussion

Patients who undergo surgical intervention for CTS have been reported to show symptom improvement within 1 to 2 weeks after surgery [1]. The patients in our study also showed improvements in the degree of VAS and PPI and severity of EDx 6 to 8

Table 1. Demographic and Clinical Characteristics of Patients (n = 33)

Characteristic	Value
Sex	
Male	4 (12.1)
Female	29 (87.9)
Age (y)	63.7 ± 10.9
Affected side	
Right	11 (33.3)
Left	6 (18.2)
Both	16 (48.5)
Diabetes mellitus	
No	7 (21.2)
Yes	26 (78.8)

Values are presented as number (%) or mean ± standard deviation.

Table 2. NCS of the Median Nerve before and after Surgical Intervention

Median nerve	Before	After	p-value
SNAP			
Onset latency (ms)	5.6 ± 2.9	3.7 ± 2.0	< 0.001*
Amplitude (μV)	9.3 ± 9.1	15.6 ± 9.8	< 0.001*
CMAP			
Onset latency (ms)	5.3 ± 2.3	4.2 ± 1.2	0.002*
Amplitude (mV)	6.9 ± 4.1	7.2 ± 3.6	0.508

Values are mean ± standard deviation. The cutoff values are 3.5 ms for SNAP onset latency, 20 μV for SNAP amplitude, 4 ms for CMAP onset latency, and 5 mV for CMAP amplitude.
NCS, nerve conduction study; SNAP, sensory nerve action potential; CMAP, compound muscle action potential.
*p < 0.05.

Table 3. The Grade of ASA on Needle EMG Observed in the APB before and after Surgical Intervention (n = 49)

The grade of ASA	Before	After	p-value
0	5 (10.2)	28 (57.1)	
1	18 (36.7)	12 (24.5)	
2	12 (24.5)	2 (4.1)	< 0.001*
3	13 (26.5)	6 (12.2)	
4	1 (2.0)	1 (2.0)	

Values are presented as number (%).
ASA, abnormal spontaneous activity; EMG, electromyography; APB, abductor pollicis brevis.
*p < 0.05.

Table 4. The Severity of Electrodiagnostic Study Findings after Surgical Intervention (n = 49)

	Initial	Follow-up	p-value
Normal	0 (0)	13 (26.5)	
Mild	1 (2.0)	1 (2.0)	< 0.001*
Moderate	20 (40.8)	28 (57.1)	
Severe	28 (57.1)	7 (14.3)	

Values are presented as number (%).
*p < 0.05.

Table 5. The Degree of Pain before and after Surgical Intervention

Pain scale	Before	After	p-value
MPQ			
MPQ-sensory	19.1 ± 7.3	9.6 ± 5.6	< 0.001*
MPQ-affective	2.7 ± 3.2	1.5 ± 2.2	0.017*
MPQ-total	21.8 ± 9.8	11.1 ± 7.4	< 0.001*
VAS	6.9 ± 0.8	4.0 ± 2.1	< 0.001*
PPI	2.9 ± 1.0	1.6 ± 0.8	< 0.001*

Values are mean ± standard deviation.
MPQ, McGill Pain Questionnaire; VAS, visual analog scale; PPI, present pain intensity.
* p < 0.05.

weeks after surgery.

CTR is the treatment for patients with severe sensory or motor impairments in the hand, worsening axonal loss, or findings indicating denervation of the median nerve. Most patients who received surgical intervention for CTS showed moderate or severe abnormal findings on EDx, and the severity of EDx after surgery improved. Previous studies categorized severity into 3 grades (1, normal to mild; 2, moderate; 3, severe), whereas our study considered 4 grades for a more detailed comparison. Earlier studies showed improvements in the Michigan Hand Outcomes Questionnaire score or subjective symptoms after surgery within each grade, but changes in the grade itself were not compared [16,17]. Other studies analyzed EDx before and after surgery, confirming that CMAP latency, amplitude, and sensory conduction velocity improved postoperatively; however, a comparative analysis of disease severity was not performed [18].

This study presented the electrophysiological changes after surgical intervention in patients with CTS. All NCS and EMG parameters improved after the surgical intervention, and none of the participants showed any worsening findings on electrophysiological studies or clinical symptoms at follow-up. In particular, the onset latency and amplitude of SNAP, onset latency of CMAP, and ASA grade on needle EMG of the APB significantly improved after the surgical intervention. In severe CTS, the APB and first and second lumbricals innervated by the median nerve may show abnormal findings, such as fibrillations or PSWs, on needle EMG. The ASA grade in the APB improved after surgery. The severity of CTS (i.e., the grade according to the criteria presented by Werner and Andary [5]) also showed a significant improvement after the surgical intervention.

As pointed out in the Introduction section, various treatment methods exist for CTS, but only a few reports have compared the effects and predicted the outcomes of various treatments using objective indicators. Some studies have investigated neurological changes after surgery [12,13,18]. These studies mainly monitored the SNAP latency, amplitude, and sensory conduction velocity of the median or ulnar nerves and reported improvements in SNAP amplitude and conduction velocity of the median and ulnar nerves after intervention. In our study, we compared motor conduction study findings, EMG changes, and EDx severity before and after the surgical intervention. The results of our study suggest that the improvements in EDx severity can be attributed to improvements in SNAP onset latency, amplitude, and ASA grade. Based on the results of this study, the onset latency of SNAP and CMAP, amplitude of SNAP, and EMG findings can be useful parameters for monitoring patients with CTS after surgery.

Owing to the limited follow-up time and sample size, further studies with larger sample sizes and long-term follow-up are required to achieve more accurate and comprehensive results. In addition, as we evaluated the outcomes using electrophysiological indicators before and after open CTR, the indicators can be used to compare the efficacy between different types of surgical approaches or between surgical and nonsurgical treatments for CTS.

Conclusion

Various EDx parameters and the patients' symptoms improved after open CTR. In particular, the onset latency of SNAP and CMAP of the median nerve, amplitude of SNAP of the median nerve, and EMG findings of the APB can be used to assess outcomes after surgical interventions in patients with CTS.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

ORCID

Chaehyun Song, https://orcid.org/0000-0002-0689-1524
Seung Jun Lee, https://orcid.org/0000-0002-7152-2880
Seong Woo Kim, https://orcid.org/0000-0002-1548-8147
Sung Hoon Kim, https://orcid.org/0000-0003-1831-7930
Ha Ra Jeon, https://orcid.org/0000-0001-9446-9552

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