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Original Article

Time Course Changes of Nerve Conduction Velocity in Idiopathic Carpal Tunnel Syndrome after Endoscopic Surgery

Yasunari Kabuto[a*], Masuo Senda[b], Hiroyuki Hashizume[a], Atsushi Kinoshita[b], and Hajime Inoue[a]

[a]*Department of Orthopaedic Surgery, Okayama University Medical School, Okayama 700-8558, Japan, and*
[b]*Division of Physical Medicine and Rehabilitation, Okayama University Hospital, Okayama 700-8558, Japan*

A total of 49 patients (71 hands) underwent endoscopic carpal tunnel release according to the method of Okutsu [1] accompanied by electrophysiological studies performed for idiopathic carpal tunnel syndrome at our department between August 1993 and May 1998. Among them, 41 patients (55 hands) who were followed-up for 12 months or more postoperatively were studied. The clinical outcome was favorable in 50 out of 55 hands (90.9%). In the 5 hands showing poor surgical results, distal motor latency or sensory nerve conduction velocity was not recordable before surgery and had not improved at 1 month postoperatively. In the present study, it is highly likely that the long-term prognosis will be poor when distal motor latency or sensory nerve conduction velocity is not recordable at 1 month after surgery as well as preoperatively. It is possible to identify patients with a poor outcome by performing electrophysiological studies at 1 month after surgery.

Key words: endoscopic carpal tunnel release, electrophysiological studies, the long-term prognosis

The diagnosis and assessment of the severity or the outcome of treatment for carpal tunnel syndrome are based primarily on clinical findings such as symptoms, and are seldom evaluated objectively. Electrophysiological examination is an objective assessment and is widely used as an adjunct for the diagnosis of CTS [2, 3]. However, the results of electrophysiological studies are not necessarily in agreement with the severity of the patient's symptoms [4, 5], and there are very few reports on long-term postoperative electrophysiological follow-up. We performed electrophysiological studies in patients with idiopathic CTS before endoscopic carpal tunnel release (ECTR) and at fixed times postoperatively in order to determine whether the results of this test correlated with clinical outcome and whether it was possible to identify patients with a poor long-term outcome of ECTR by performing electrophysiological studies soon after surgery. The objective of the present study was to follow-up patients using the nerve conduction velocity obtained by electrophysiological studies as an objective index and to compare the findings with the results of more subjective clinical assessment.

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*Corresponding author. Phone: +81-868-26-8941; Fax: +81-86-223-9727

Subjects

A total of 49 patients (71 hands) underwent both ECTR for idiopathic CTS at our department and electrophysiological studies performed at the Division of Physical Medicine and Rehabilitation between August 1993 and May 1998. Diagnosis for CTS was based on sensory disturbance of the median nerve, thenar muscle atrophy,

Tinel's sign, Phalen's sign, and electrophysiological results. Among them, 41 patients (55 hands) who were followed-up for 12 months or more postoperatively were studied. These 55 hands studied consisted of one man's hand and 54 hands in 40 women, with the age of the patients at surgery ranging from 19 to 93 years (mean age: 55.0 years). The period from onset to surgery ranged from 1 month to 240 months with a mean of 29.8 months. The right hand was affected in 20 patients, the left hand in 7 patients, and both hands in 14 patients (28 hands).

Methods

Nerve conduction velocity was measured using an electromyograph (Neuromatic 2000 M, Dantec Ltd., Tronsbaken, Denmark) at a constant room temperature of 22 °C. The motor nerve conduction velocity was measured using a recording electrode placed on the center of the belly of the abductor pollicis brevis muscle and a reference electrode placed on the metacarpal phalangeal joint of the thumb. Stimuli were applied to the wrist joint at 7 cm proximal to the recording electrode. Distal motor latency (DML) was measured. Sensory nerve conduction velocity (SCV) was measured using stimulating ring electrodes, with a negative electrode placed on the proximal interphalangeal joint and a positive electrode on the distal interphalangeal joint. The recording electrode was placed immediately over the median nerve at the wrist joint. Measurements were summed 20 times when calculating SCV. DML was considered normal when it was less than 4.3 msec, while SCV was considered normal at 45 m/s or more.

DML and SCV data were graded using the following categories.

DML: D0, not recordable; D1, $7.1 \leqq$ DML; D2, $5.2 \leqq$ DML < 7.1; D3, $4.3 \leqq$ DML < 5.2; D4, DML < 4.3

SCV: S0, not recordable; S1, SCV < 35; S2, $35 \leqq$ SCV < 40; S3, $40 \leqq$ SCV < 45; S4, $45 \leqq$ SCV (Fig. 1)

The preoperative severity of CTS was graded according to Hirooka's classification system [6].

Grade 1-mild symptoms: numbness, paresthesia, no atrophy of the thenar muscle, and complete opposition possible.

Grade 2-moderate symptoms: some atrophy of the thenar muscle, complete opposition possible.

Grade 3-severe symptoms: significant atrophy of the thenar muscle with incomplete opposition.

The authors performed electrophysiological studies preoperatively, and 1 month, 3 months, 6 months, and 12 months postoperatively. Postoperative clinical assessment was done according to the classification of Kelly *et al.* [7]. The results within Tables 1 and 3 were compared using Wilcoxon's signed rank test, and correlations within Table 2 were assessed using calculating Spearman's rank correlation coefficients. Statistical procedures were performed using StatView-J 4.11 software for Macintosh.

Results

Clinical outcome. When the clinical outcome was assessed at 12 months postoperatively according to the classification of Kelly *et al.*, 43 hands were classified as 'excellent', 7 hands as 'good', 3 hands as 'fair', and 2 hands as 'poor'. No complications developed after surgery, and no patient complained of any symptom associated with the surgery site. The authors defined Kelly's grades of excellent and good as "good result", and Kelly's fair and poor as "poor result". The clinical outcome was favorable in 50 out of 55 hands (90.9%).

Nerve conduction velocity.

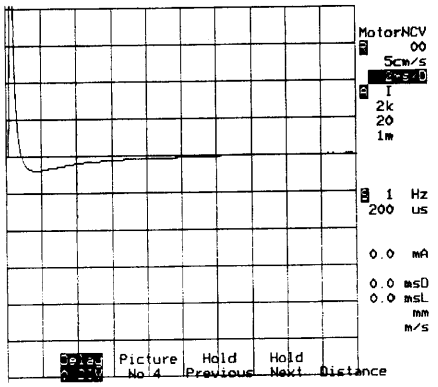
1. DML

The preoperative DML grade was D0 for 7 hands, D1 for 22 hands, D2 for 16 hands, D3 for 8 hands, and D4 for 2 hands. At 12 months postoperatively, the DML grade was D0 for 3 hands, D2 for 12 hands, D3 for 27 hands, and D4 for 13 hands (Table 1). When the DML data were compared before and after surgery, a significant difference was seen between before surgery and 1 month after surgery ($P < 0.01$), as well as between 1 and 3 months after surgery ($P < 0.01$), and between 3 and 6 months after surgery ($P < 0.05$).

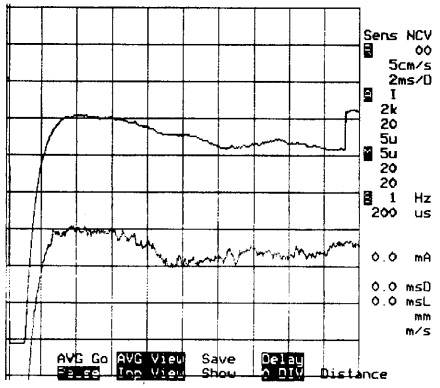
A correlation was noted between the preoperative severity of thenar muscle involvement and the preoperative DML grade, but these parameters were not always in agreement (Table 2).

2. SCV

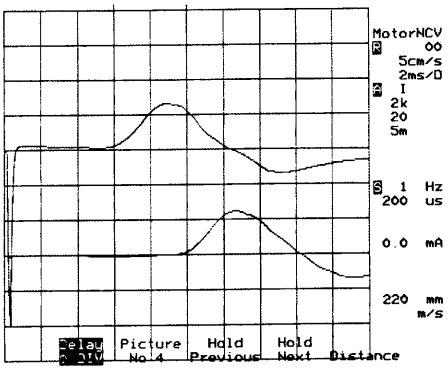
The preoperative SCV grade was S0 for 19 hands, S1 for 25 hands, S2 for 7 hands, S3 for 1 hand, and S4 for 3 hands. At 12 months postoperatively, the SCV grade was S0 for 2 hands, S1 for 10 hands, S2 for 18 hands, S3 for 9 hands, and S4 for 16 hands (Table 3). When SCV was compared before and after surgery, a



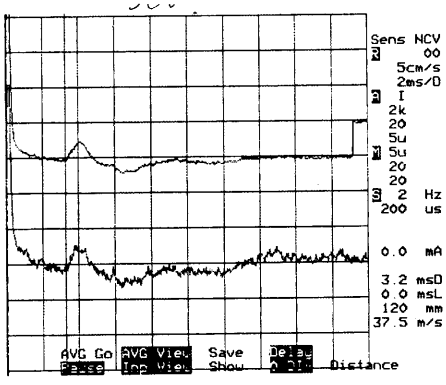
D0 (not recordable)



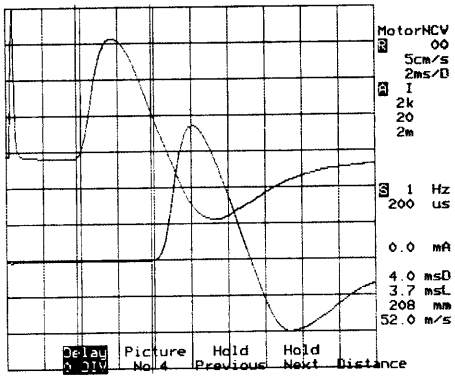
S0 (not recordable)



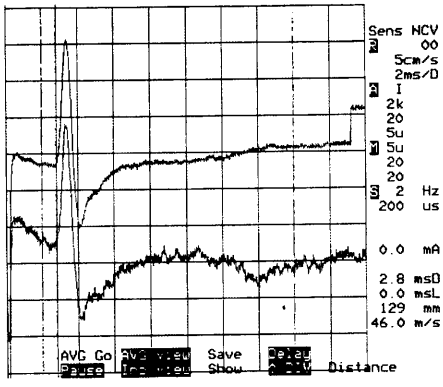
D2 (6.0msec)



S2 (37.5m/s)



D4 (3.7msec)



S4 (46.0m/s)

Fig. 1 Typical records.

Table 1 Time course changes of DML (distal motor latency) grade

DML grade	Preop.	1 M postop.	3 M postop.	6 M postop.	12 M postop.
D0	7	5	4	4	3
D1	22	8	2	1	0
D2	16	12	12	10	12
D3	8	13	22	22	27
D4	2	6	11	14	13
Not tested	0	11	4	4	0

A significant difference was seen between DML grade before surgery and 1 month after surgery ($P < 0.01$), and between 1 and 3 months after surgery ($P < 0.01$), and between 3 and 6 months after surgery ($P < 0.05$).
D0, not recordable; D1, $7.1 \leqq$ DML; D2, $5.2 \leqq$ DML < 7.1; D3, $4.3 \leqq$ DML < 5.2; D4, DML < 4.3 (normal value).

Table 2 A correlation between preoperative DML grade and the preoperative severity of thenar muscle involvement

Preop. severity	DML grade				
	D0	D1	D2	D3	D4
Grade 1	0	11	9	5	2
Grade 2	3	7	6	1	0
Grade 3	4	4	1	2	0

A correlation was noted between the preoperative DML grade and the preoperative severity of thenar muscle involvement, but these parameters were not always in agreement.

significant difference existed between all time points: before surgery and 1 month after surgery ($P < 0.01$), 1 and 3 months after surgery ($P < 0.01$), 3 and 6 months after surgery ($P < 0.05$), and 6 and 12 months after surgery ($P < 0.01$). Preoperatively, no correlation was seen between the SCV grade and the results of the Semmes-Weinstein test in 20 patients (Table 4).

3. Recordable data

DML and SCV were recordable at all times of testing in 34 hands and 27 hands respectively. The mean DML was 7.1 msec before surgery and it improved to 5.6 msec at 1 month postoperatively. Subsequently, the mean DML showed gradual further improvement, and was 4.4 msec at 12 months postoperatively. Mean SCV was 31.5 m/s before surgery and improved to 36.3 m/s at 1 month postoperatively. Mean SCV gradually improved further, and was 43.6 m/s at 12 months postoperatively (Table 5).

No significant correlation existed between the clinical outcome and preoperative factors (age at surgery, duration of disease).

Assessment of poor results and an anomalous case. The preoperative severity of thenar muscle involvement was classified as grade 3 for all 5 hands with a poor result (Table 6). One patient (1 hand) was 93 years old. In the other 2 patients (2 hands), the preoperative duration was extremely long, being 240 months and 180 months, respectively.

Preoperative electrophysiological studies performed on a 19-year-old female (1 hand) suggested selective involvement of the recurrent branch of the median nerve, but not entrapment at the carpal tunnel. Time course changes of nerve conduction velocity in the patients with poor results are shown in Table 7.

Discussion

ECTR is a widely used surgical procedure for CTS that employs the Universal Subcutaneous Endoscope system developed by Okutsu *et al.* in 1986, in which a clear endoscopic mantle tube is inserted subcutaneously. The advantage of this procedure is that it avoids various problems associated with the skin incision in open surgery (scarring, pain, and contracture at the wrist joint). It has been used in place of open surgery, and achieves favorable results comparable to those obtained by the traditional operation [8, 9]. Although neurolysis cannot be performed at ECTR, neurolysis has been frequently reported to be unnecessary for CTS [10, 11].

Electrophysiological studies have been widely used for the supplementary diagnosis of CTS. The results achieved by this method are objective and quantitative, but there are very few reports on long-term postoperative follow-up of CTS with regular electrophysiological examination.

Table 3 Time course changes of SCV (sensory nerve conduction velocity) grade

SCV grade	Preop.	1 M postop.	3 M postop.	6 M postop.	12 M postop.
S0	19	11	7	4	2
S1	25	16	12	12	10
S2	7	9	15	11	18
S3	1	4	7	11	9
S4	3	4	10	13	16
Not tested	0	11	4	4	0

When SCV grade was compared before and after surgery, a significant difference was seen between all time points: before surgery and 1 month after surgery ($P < 0.01$), 1 and 3 months after surgery ($P < 0.01$), 3 and 6 months after surgery ($P < 0.05$), and 6 and 12 months after surgery ($P < 0.01$).
S0, not recordable; S1, SCV < 35; S2, $35 \leqq$ SCV < 40; S3, $40 \leqq$ SCV < 45; S4, $45 \leqq$ SCV (normal value).

Table 4 A correlation between preoperative SCV grade and the preoperative results of the Semmes-Weinstein test

S-W Test	SCV grade				
	S0	S1	S2	S3	S4
2.36 (Green No. 2)	-	-	-	-	-
2.44 (Green No. 3)	-	-	1	-	-
2.83 (Green No. 4)	-	1	2	-	-
3.22 (Blue No. 5)	1	3	-	-	-
3.61 (Blue No. 6)	1	2	1	1	-
3.84 (Yellow No. 7)	-	3	-	-	-
4.08 (Yellow No. 8)	1	1	-	-	-
4.17 (Yellow No. 9)	-	1	1	-	-
4.31 (Yellow No. 10)	-	-	-	-	-

Preoperatively, no correlation was seen between SCV grade and the results of the Semmes-Weinstein test in 20 patients.
n = 20 hands; -, no cases.

Table 6 A correlation between clinical outcome and the preoperative severity of thenar muscle involvement

Preop. severity	Clinical outcome			
	Excellent	Good	Fair	Poor
Grade 1	22	5	-	-
Grade 2	15	2	-	-
Grade 3	6	-	3	2

The preoperative severity of thenar muscle involvement was classified as grade 3 for all 5 hands showing a poor result.
-, no cases.

Table 5 Nerve conduction velocity (only where the velocity was recordable at the follow-up examinations)

NCV	Preop.	1 M postop.	3 M postop.	6 M postop.	12 M postop.
DML (msec) (n = 34 hands)	7.1 ± 2.3	5.6 ± 1.5	4.8 ± 0.8	4.7 ± 0.7	4.4 ± 0.6
SCV (m/s) (n = 27 hands)	31.5 ± 8.0	36.3 ± 8.8	39.6 ± 5.9	41.7 ± 6.4	43.6 ± 6.2

Data are expressed as mean ± standard deviation.

Table 7 DML and SCV grade changes at follow-up in patients showing poor results (5 hands)

	Preop.	1 M postop.	3 M postop.	6 M postop.	12 M postop.
19y. F Rt	D0S4	D0S4	D0S4	D0S4	D0S4
48y. F Lt	D3S0	D4S0	D3S0	D3S1	D0S1
93y. F Rt	D0S1	D0S0	D1S2	D2S1	D2S1
66y. F Rt	D1S0	D2S0	D0S0	Not tested	D0S0
66y. F Lt	D0S0	D0S0	D3S0	Not tested	D3S0

In the 5 hands, DML and SCV were graded as D0 or S0 before surgery and had not improved at 1 month postoperatively.
D, DML grade; S, SCV grade.

Nishimura *et al.* [12] performed open carpal tunnel release (OCTR) on 57 hands in 39 patients with CTS, and they also performed electrophysiological studies preoperatively, and at 1 day, 1 week, 1, 3, and 6 months, and 1 and 2-3 years postoperatively. They reported that DML improved significantly from 1 day to 6 months postoperatively, and also gradually improved thereafter, while SCV tended to improve from 1 week postoperatively without showing a significant change. However, their study had several weaknesses such as exclusion of patients when data were not recordable. DML and SCV are continuous variables, so it is very difficult to determine how missing data should be handled statistically. We classified DML and SCV findings into 5 groups from 'not recordable' to 'normal', so that patients with missing data could be included in the statistical analysis. Although the accuracy of the data may be decreased, there is the great advantage that all patients studied can be included in the analysis.

Okutsu *et al.* [13] performed follow-up on 39 hands with idiopathic CTS for 12 months after ECTR, and found that DML was abnormal before surgery and became normal after surgery in 61% of 38 hands (23/38). In addition, DSL was abnormal before surgery and became normal in 75% of 28 hands (21/28), while it also improved in the other hands although not to normal. However, they did not report on the time-course of these changes.

Nancollas *et al.* [14] followed-up 60 patients with CTS for a mean of 5 years after OCTR and reported that the results were favorable in 87%. They performed electrophysiological studies, but only reported that electrophysiological data were abnormal in 40 out of 53 hands before surgery and showed no correlation with the clinical outcome similarly to the other preoperative assessments.

As in these latter 2 reports, electrophysiological data are usually handled as one of many parameters and only compare preoperative measurements with those made at the last follow-up. We measured nerve conduction velocity before and after surgery at fixed times in order to assess the changes postoperatively and to determine whether a poor long-term result could be predicted from nerve conduction velocity data obtained early after surgery.

In the present study, the nerve conduction velocity improved significantly with time. However, recovery to normal was observed only in 20.8% (11/53) for DML, 25.0% (13/52) for SCV, and 15.1% (8/53) for both parameters. In contrast, symptoms completely resolved in 78.2% (43/55) of the patients, who were graded as 'excellent' according to the classification of Kelly *et al.* This suggests that symptoms of CTS may completely resolve in many patients in whom DML and SCV do not return to normal [15]. Thus, the clinical outcome is better than that shown by DML and SCV data.

The chronological changes of DML grade and SCV grade is shown in Table 8. At 12 months postoperatively, the findings were in approximate agreement with the results of clinical assessment.

In the 5 hands showing poor results, DML and SCV were graded as D0 or S0 before surgery and had not improved at 1 month postoperatively. That is, when both DML and SCV were recordable (33 out of 55 hands) preoperatively, the postoperative result was favorable regardless of the DML and SCV values. Even when DML or SCV was not recordable preoperatively, the postoperative results were favorable in the 10 hands where these parameters were recordable 1 month postoperatively. In contrast, the results were poor in approximately half of the hands (5/12) in which these parameters were recordable neither preoperatively nor at 1 month

Table 8 Chronological changes of DML grade and SCV grade, and assessment (No. of good results/No. of poor results)

Preoperatively					
SCV grade	DML grade				
	D0	D1	D2	D3	D4
S0	3/1	9/1	3/0	1/1	-
S1	1/1	11/0	10/0	2/0	-
S2	-	1/0	3/0	3/0	-
S3	-	-	-	1/0	-
S4	0/1	-	-	-	2/0
1 M postoperatively					
	D0	D1	D2	D3	D4
S0	2/2	2/0	1/1	1/0	1/1
S1	-	5/0	7/0	3/0	1/0
S2	-	1/0	3/0	5/0	-
S3	-	-	-	4/0	-
S4	0/1	-	-	-	3/0
3 M postoperatively					
	D0	D1	D2	D3	D4
S0	1/1	-	2/0	1/2	-
S1	1/0	-	7/0	3/0	1/0
S2	-	0/1	2/0	11/0	1/0
S3	-	1/0	1/0	3/0	2/0
S4	0/1	-	-	2/0	7/0
6 M postoperatively					
	D0	D1	D2	D3	D4
S0	1/0	-	1/0	1/0	1/0
S1	1/0	1/0	3/0	5/1	-
S2	1/0	-	5/0	5/0	-
S3	-	-	-	7/0	4/0
S4	0/1	-	-	3/0	9/0
12 M postoperatively					
	D0	D1	D2	D3	D4
S0	0/1	-	-	0/1	-
S1	0/1	-	3/1	5/0	-
S2	-	-	8/0	10/0	-
S3	-	-	-	6/0	3/0
S4	0/1	-	-	5/0	10/0

At 12 months postoperatively, the findings were in approximate agreement with the results of clinical assessment.
-, no cases.

after surgery. However, it was impossible to distinguish the 5 cases of a final poor result from among these 12 hands based only on the early postoperative nerve conduction velocity data. It is highly likely that the long-term prognosis will be poor when DML or SCV is not recordable at 1 month after surgery as well as preoperatively.

Therefore, DML and SCV findings may serve as predictors of long-term results in idiopathic CTS.

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