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Effects of Wrist Splinting for Carpal Tunnel Syndrome and Motor Nerve Conduction Measurements

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Abstract

Background: Carpal tunnel syndrome (CTS) is one of the most common disease among the entrapment neuropathies. Wrist splinting has been conventionally used for the CTS treatment. The purposes of this study were to assess the efficacy of wrist splinting for CTS, and to evaluate the value of the motor nerve conduction measurement as a prognostic indicator for CTS.

Methods: Two hundred and fourteen hands with CTS were treated by wrist splinting, and reviewed after a mean follow up of seven months. Severity of symptoms were minimal lesions in 177 hands, intermediate lesions in 33 hands, and severe lesions in four hands. Motor nerve conduction measurement was performed in all cases before and after treatment, and distal latency (DL) and amplitude on compound muscle action potential (CMAP) from the abductor pollicis brevis (APB) muscle were analyzed.

Results: According to Kelly's grading of outcome, results were excellent in 41 hands, good in 110 hands, fair in 45 hands, and poor in 18 hands. Excellent or good results were obtained in 131 hands (74 percent) with minimal lesions, 20 hands (61 percent) with intermediate lesions, and in no cases with severe lesions. The ratio of excellent or good results was 79 percent in patients in whom DL of pre-treatment APB-CMAP was less than 8 milliseconds (ms), and 62 percent in patients whose DL was 8 ms or more, which showed a significant difference. In nine hands whose pre-treatment APB-CMAP was unrecordable, the results were good in one hand, fair in five, and poor in three.

Conclusions: Wrist splinting is most effective in cases of minimal or intermediate lesions with DL of APB-CMAP less than 8 ms. If relief of symptoms is not obtained after five months of treatment by splinting, that would be the limit of splinting. Surgical release is recommended for cases with severe lesions and with unrecordable APB-CMAP.

Introduction

Carpal tunnel syndrome (CTS) is a compression neuropathy of the median nerve at the wrist, and is one of the most common entrapment neuropathies (1, 2). Majority of patients with CTS were treated conservatively before having surgery of carpal tunnel release (1–5). The conservative treatments for CTS have included wrist splinting, steroid injection in the carpal tunnel, and the use of non-steroidal anti-inflammatory agents. The purposes of this study were to assess the efficacy of

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wrist splinting for CTS, and to investigate the value of the motor nerve conduction measurement as a prognostic indicator for CTS treated by wrist splinting.

Materials and methods

Between 1998 and 2007, 214 hands in 167 patients (47 bilateral) with CTS were treated by wrist splinting in our institute, and reviewed after a mean follow up of 7 months (4–24). Diagnosis of CTS was established when a patient had pain or paraesthesiae in the median nerve distribution and objective clinical findings of CTS including delayed distal motor latency as mentioned later. Twenty-four patients (30 hands) were men and 143 patients (184 hands) were women. The average age was 58 years (29–81). The duration of symptoms varied from one to 240 months, the mean being 18 months. Two hundred and six hands were idiopathic CTS, six had a preexisting Colles fracture, and two had Kienboeck disease. According to Hamada's classification of severity of symptoms (6), 177 hands had minimal lesions with sensory disorders (grade 1), 33 hands had intermediate ones with some thenar atrophy (grade 2), and four hands had severe ones with marked thenar atrophy and loss of thumb opposition (grade 3). Four patients with severe lesions refused surgery of carpal tunnel release and agreed to undergo treatment by wrist splinting.

The wrist splint was custom designed and molded using thermoplastic material, and was applied from the volar side with rigid fixation at a neutral position (Figure 1 A, B, C). Patients were instructed to wear the splint at night and during daytime when symptomatic. Patients were followed once per month in our institute,

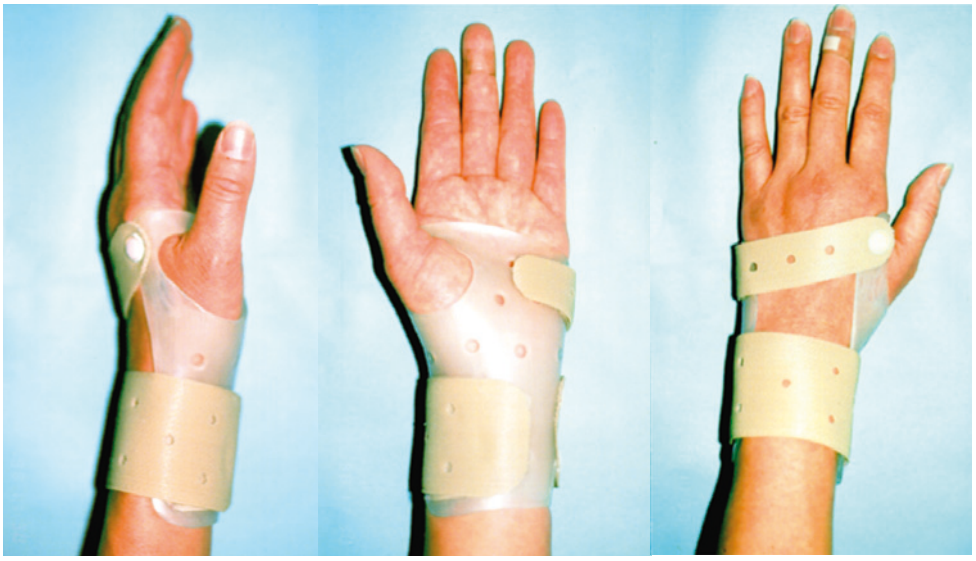

Figure 1. A: Wrist splint design. Custom-molded, thermoplastic material, volar side, and rigid fixation at a neutral position of the wrist (radial view).
B: Volar view.
C: Dorsal view.

and anti-inflammatory agents or steroid injection were not used in any patient.

Motor nerve conduction measurement was performed in all hands before and after treatment. Patients were examined with the arm in an outstretched position. Palmar skin temperatures were not allowed to fall below 32°C. Nicolet Viking electromyography (Nicolet Instruments, Madison, WI, USA) with a 10-mm silver disc was used. Compound muscle action potential (CMAP) from the abductor pollicis brevis (APB) muscle was recorded with surface electrodes by supramaximal stimulation of the median nerve at the wrist. Distal latency (DL) was measured from the stimulus artifact to the onset of the potential. Amplitude was measured from the baseline to the negative peak of the potential. The criterion for the normal value of DL at our department was below 4.8 milliseconds (ms) and the normal value of minimum amplitude was 0.9 millivolts (mV) (7). CTS was diagnosed when the DL of APB-CMAP was 4.8 ms or more. If APB-CMAP was not recordable, CMAP from the second lumbrical (SL) muscle was recorded and analyzed. Normal value of DL was below 4.0 ms, and minimum amplitude was 0.3 mV in SL-CMAP (7).

The post-treatment results were evaluated into four categories according to relief of symptoms by Kelly et al. (8). Excellent was complete relief of symptoms, good meant persistence of occasional minor symptoms, fair was with some constant or annoying symptoms, and poor meant symptoms unchanged or worse. We compared clinical results with pre- and post-treatment DL and amplitude of APB-CMAP. The data were analyzed statistically by the Student's t-test and the Chi-square test. P-values of less than 0.05 were considered statistically significant.

Results

Clinical results were excellent in 41 hands (19.2 percent), good in 110 hands (51.4 percent), fair in 45 hands (21.0 percent), and poor in 18 hands (8.4 percent). Satisfactory results (excellent or good) were obtained in 131 hands (74 percent) with minimal lesions, 20 hands (61 percent) with intermediate lesions, and no cases with severe lesions (Table 1). Pre-treatment APB-CMAP was recordable in 205 hands and unrecordable in nine hands. In nine hands with unrecordable APB-CMAP, one hand was good, five hands were fair, and three hands were poor. In 205 hands with recorded APB-CMAP, mean DL on pre-treatment APB-CMAP was 6.0 ms (SD 1.3) in hands with excellent results, 7.0 ms (SD 2.1) with good, and 7.8 ms (SD 2.1) with fair or poor, which showed a significant difference between each two of the three groups (Table 2). For comparison of results, we divided 205 hands with recorded APB-CMAP into two groups: group A, with slightly delayed DL of pre-treatment APB-CMAP (< 8 ms); and group B, with largely delayed DL of pre-treatment APB-CMAP (≤ 8 ms) (Figure 2 A, B). The ratio of satisfactory results (excellent or good) in group A was 78.6 percent, and that in group B was 61.5 percent, which showed a significant difference ($p<0.025$, Table 3). Mean amplitude on pre-treatment APB-CMAP was 4.7 mV (SD 3.0) in hands with excellent results, 3.7 mV (SD 2.5) with good, and 3.1 mV (SD 2.5) with fair or poor, which showed

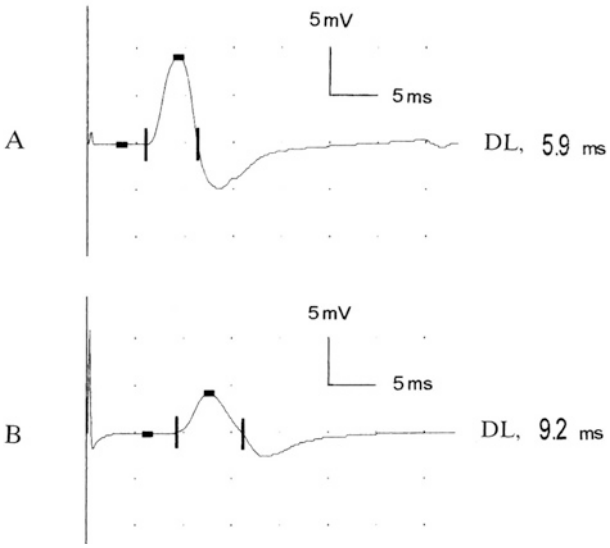

Figure 2. A: slightly delayed distal latency (DL) of pre-treatment APB-CMAP (<8 ms) in Group A; B: largely delayed DL of pre-treatment APB-CMAP (≥8 ms) in Group B. APB, abductor pollicis brevis; CMAP, compound muscle action potential

a significant difference both between the excellent and good groups, and between the excellent and fair or poor groups (Table 2). Mean DL on post-treatment APB-CMAP was 5.2 ms (SD 1.1) in the excellent group, 6.2 ms (SD 1.8) in good, and 8.0 ms (SD 2.1) in fair or poor, which showed a significant difference between each two of the three groups. Post-treatment mean DL had shortened compared with pre-treatment DL in cases with excellent and good results, but that was unchanged in cases with fair or poor results (Table 2). Mean amplitude on post-treatment APB-CMAP was 5.7 mV (SD 3.3) in the excellent group, 4.5 mV (SD 2.8) in good, and 3.3 mV (SD 2.8) in fair or poor, which showed a significant difference between each two of the three groups. Post-treatment mean amplitude was larger than pre-treatment amplitude in all groups (Table 2). Surgery of open carpal tunnel release was performed in 24 hands later, and the results of wrist splinting in these cases were fair in 7 hands and poor in 17 hands.

Several other factors were examined statistically to determine whether they could predict clinical results. Duration of symptoms was 11.2 ±11.7 months in the excellent cases, 16.7 ±29.2 months in good cases, and 25.9 ±47.3 months for the fair or poor cases. Duration of symptoms revealed wide ranges and it was difficult to compare these data. Age of the patients in the excellent, good, and fair or poor cases were 53.6 ±9.7 years, 57.9 ±11.0 years, and 59.5 ±11.3 years, respectively, which showed a significant difference both between the excellent and good groups ($p<0.05$), and between the excellent and fair or poor groups ($p<0.01$). The time of final evaluation of results in the excellent cases was 4.3 ±1.6 months, while that for the good cases was 4.7 ±1.9 months and that for the fair or poor cases was 5.2 ±2.1 months, which showed a significant difference between the excellent cases and fair or poor cases ($p<0.05$). The time of the start in relief of symptoms in the excellent cases was 1.5 ±0.7 months, while that for the good cases was 2.0 ±1.3 months and

Table 1. Clinical results of 214 hands according to the severity of symptoms

	Number of hands (%)			
Results	Minimal	Intermediate	Severe	Total
Excellent	38	3	0	41 (19.2%)
Good	93	17	0	110 (51.4%)
Fair	35	9	1	45 (21.0%)
Poor	11	4	3	18 (8.4%)
Total	177	33	4	214 (100%)

Table 2. Parameters of APB-CMAP before(pre-) and at final follow-up (post-)

	Excellent (n=41)	Good (n=109)	Fair, Poor (n=55)	P value
Pre-APB-CMAP ; DL	6.0±1.3	7.0±2.1	7.8±2.1	* P<0.001 ** P<0.01 *** P<0.05
Pre-APB-CMAP ; Amp.	4.7±3.0	3.7±2.5	3.1±2.5	* P<0.001 ** P<0.05
Post-APB-CMAP ; DL	5.2±1.1	6.2±1.8	8.0±2.1	* P<0.001 ** P<0.01 *** P<0.01
Post-APB-CMAP ; Amp.	5.7±3.3	4.5±2.8	3.3±2.8	* P<0.001 ** P<0.05 *** P<0.02

DL, distal latency (ms) ; Amp., amplitude (mV) ; N.S., not significant

that for the fair cases was 2.8 ±1.3 months, which showed a significant difference between each two of the three groups ($p<0.05$).

According to the self-report by the patients, symptoms recurred in 11 hands after ending wrist splinting. The time of recurrence after ending was 7 to 36 months, the mean being 22 months. In these 11 recurred cases, 5 cases started wrist splinting again and had relief of symptoms, and 6 cases had surgery for open carpal tunnel release later.

Discussion

CTS is usually diagnosed by the characteristic symptoms of paraesthesiae in the

Table 3. A relationship between DL of pre-treatment APB-CMAP and results

Groups divided by DL	Results (hands)		Ratio of excellent or good results
	Excellent or Good(n=150)	Fair or Poor (n=55)	
Group A (n=140)	110	30	78.6% (110/140)
Group B (n=65)	40	25	61.5% (40/65)

Group A, slightly delayed distal latency (DL) of pre-treatment APB-CMAP (<8ms); group B, largely delayed DL of pre-treatment APB-CMAP (≧8ms).
The ratio of satisfactory results (excellent or good) in group A and that in group B showed a significant difference (Chi-square test, $p<0.025$)

distribution of the median nerve, positive Tinel's sign at the wrist, Phalen's provocation test, and some thenar atrophy accompanying loss of thumb opposition. Surgery of open or endoscopic carpal tunnel release is usually indicated for severe lesions, whereas most patients with minimal lesions are treated initially with conservative methods (1–6).

The rationale for wrist splinting was originally based on the observation that symptoms with CTS improve with rest and worsen with activity (9, 10). Synovial inflammation of the flexor tendons can cause increased pressure in the carpal tunnel and contribute to median nerve compression (11). Carpal tunnel pressure is elevated during repetitive hand activity, and the pathophysiology of CTS is probably related to the duration as well as magnitude of the pressure increase within the carpal tunnel (12). However, Lundborg (13) described that because of decreased muscular activity or faulty position during sleep at night, venous return was reduced and carpal tunnel pressure was increased, thus nocturnal symptoms in CTS patients were frequent. Werner et al. (14) reported that the pathophysiology of CTS involved a combination of mechanical trauma and ischemic injury to the median nerve within the carpal tunnel, but the role of tendonitis and tendinosis was not well defined.

With regard to the effect of wrist splinting for CTS, previous studies showed minimizing carpal tunnel pressure by reducing synovitis through resting of the wrist. Luchetti et al. (15) reported that slightly low pressures were found when the wrist was splinted, but critical pressure levels were not prevented by splinting. About the angle of wrist immobilization, Gelberman et al. (16) showed that carpal tunnel pressure was lower when the wrist was in a neutral position than when in flexion or extension. Flexion of the wrist seems to cause the flexor tendons of the fingers to be displaced against the palmar side of the carpal tunnel, increasing the pressure on both tendons and the median nerve. Phalen (11) reported splinting the wrist in slight extension, whereas Weiss et al. (17) described that the ideal position for immobilization is closer to neutral because wrist splinting in a functional position of extension did not minimize carpal tunnel pressure. Regarding the rigidity of

splints, Rempel et al. (12) showed that flexible wrist splints failed to control carpal tunnel pressure during activities. In our patients, custom-molded rigid thermoplastic splints were developed because this splint design with a neutral angle was fit to achieve a neutral wrist position, and seemed to be comfortable for wearing at night.

Concerning splint wearing time, our patients were instructed to wear at night only in principle, and during daytime when symptomatic. Walker et al. (18) reported that efficacy of neutral wrist splints was best with full-time wear instructions compared with night-only wear after six weeks of follow-up. Kruger et al. (5) and Nagaoka (19) also instructed the use of splint at night and during the day as much as possible. However, Burke et al. (20) emphasized night-only wear of splints because wearing the splints during the day seemed restrictive, making it difficult to continue wearing them. Manente et al. (21) reported excellent effects of night-only wear of an innovative hand brace with stretching the middle and ring fingers for CTS. Many patients indicated that nighttime symptoms were most troublesome, and were pleased with the relief that these splints afforded. We believe that a practical method of wrist splinting is wearing the splint at night and during the day as much as possible when symptomatic.

About the relationship between clinical results and other factors, Celiker et al. (22) described that patients with symptom duration more than 9 months did not respond well to treatment in splinting with an anti-inflammatory drug or steroid injection. Kruger et al. (5) revealed that optimal results would be obtained if the splint was applied within the first three months of onset. Graham et al. (23) reported that symptom duration of less than three months and absence of sensory impairment were predictive of a lasting response to wrist splinting and steroid injections. Kaplan et al. (4) showed that five factors of unresponsiveness to treatment by wrist splint and anti-inflammatory medication were age over 50 years, duration over 10 months, constant paraesthesiae, stenosing flexor tenosynovitis, and a Phalen's test positive in less than 30 seconds. However, Burke et al. (20) stated that duration of symptoms did not correlate with the symptom relief provided by splinting. Weiss et al. (24) reported that patients 40 years of age or younger had a significant decrease in the rate of symptom resolutions with wrist splinting and steroid injection when compared with patients over 40 years of age. In our patients, duration of symptoms revealed a wide range of time and it was difficult to be analyzed. Age of our patients correlated with the results. There was a tendency for patients over 59 years to have an unsatisfactory outcome. Concerning period of treatment, Gerritsen et al. (25) reported that the success rate based on general improvement was 54 percent after three months, and was 75 percent after 18 months of wrist splinting. Mean time of final evaluation in our patients was 4.3 months in the excellent group and 4.7 months in the good, and 5.2 months in the fair or poor. Thus, we believe that if relief of symptoms is not seen after five months of splinting, this treatment should be discontinued and other treatments should be employed.

Steroid injection in the carpal tunnel is a commonly used treatment similarly to wrist splinting (1, 2, 4, 11, 22, 24). Goodman et al. (26) showed that the early

dramatic relief of symptoms after steroid injection was associated with a decrease in the nerve conduction delay, but this improvement was not maintained. Gelberman et al. (1) reported that symptoms recurred in most patients by nine to fifteen months after injection. In contrast, in the present series with wrist splinting, early relief of symptoms could not be obtained and the mean time of the start in relief of symptoms was 1.5 months or more. However, it is noteworthy that recurrence of symptoms was seen in only 11 hands and most cases received long-term relief from splinting.

Nerve conduction study is accepted as a standard for the diagnosis of CTS (27), and delayed conduction time by recording APB-CMAP was first reported by Simpson (28). Concerning nerve conduction study for CTS, Kruger et al. (5) showed that in patients treated by wrist splinting, motor latency improved in the symptom relief group while it deteriorated in the non-relief group, and that improvement in motor latency was probably associated with patient perception of relief. Gelberman et al. (1) stated that poor results were seen in the cases with delayed DL of more than 6 ms and absence of sensory response. In our patients, the ratio of excellent or good results in the group with delayed DL of less than 8 ms was higher than that in the group with delayed DL of 8 ms or more, and post-treatment DL had shortened in cases with excellent and good results, while it was unchanged in cases with fair or poor results compared with pre-treatment DL (Tables 2, and 3). It has been said that segmental demyelination of motor fibers causes slowing of motor conduction (29), and that the degree of delayed DL of APB-CMAP is based on the severity of demyelination of thenar motor fibers. Thenar motor fibers are vulnerable to compression in the carpal tunnel (30). In the treatment of wrist splinting, the delayed DL of 8 ms or more may reflect the irreversible severe demyelination of the median nerve in the carpal tunnel. However, in our patients, unsatisfactory results were obtained in 21 percent of our cases with delayed DL of less than 8 ms, and satisfactory results were gained in 62 percent of cases with delayed DL of 8 ms or more. In these cases, tendonitis and tendinosis seemed to have a more important role than median nerve impairment from a viewpoint of pathophysiology. In eight of nine cases with unrecordable APB-CMAP, results were unsatisfactory. Axonal degeneration results in the loss of conductive elements, which leads to reduced amplitude of potentials (29). Thus, unrecordable APB-CMAP indicates severe axonal degeneration of thenar motor fibers, which warrants early surgical release. Werner et al. (14) reported that motor and sensory nerve conduction studies were the best means for assessing the function of the median nerve. In nerve conduction study, the most sensitive method is the median sensory conduction measurement (31), but motor conduction study is technically easy to record because of high amplitude (7). In this study, we measured only the motor nerve conduction.

We evaluated the results according to relief of symptoms by Kelly et al. (8), which is a simple and subjective method of evaluation. In recent years, a self-administered questionnaire assessing symptom severity and functional status for CTS was reported (32). This instrument is highly reproducible, internally consistent, valid, and responsible to clinical change (18). This questionnaire can be used

to check whether a certain therapy relieves symptoms and improves the functional status (33). You et al. (27) reported that the primary symptom severity scale correlated more strongly with the nerve conduction measures than did the secondary symptom scale. Gerritsen et al. (34) described that final success rate of splinting for CTS was 31 percent, and prognostic indicators were a short duration of CTS complaints (one year or less) and a score of 6 or less for severity of paraesthesia at night. However, Mondelli et al. (33) showed that the degree of improvement in the symptoms and functional status after surgical release could not be predicted from the pre-surgical self-administered questionnaire. In our series using subjective assessment and nerve conduction, a motor nerve conduction measurement was fairly valuable as a prognostic indicator for CTS. The combination of electrophysiologic measurement and evaluation of the characteristic symptoms will provide the most accurate information for CTS (31).

There are some limitations in this study. First, results were evaluated according to relief of symptoms as subjective findings only. Second, the follow-up period was variable (from 4 to 24 months). Third, this study was not controlled and was retrospective. Finally, in our patients, wrist splints were worn basically at night, but during the daytime also in some patients according to their symptoms.

Conclusions

Wrist splinting is effective for CTS with minimal or intermediate severity with DL of APB-CMAP less than 8 ms. If relief of symptoms is not obtained after five months application of splinting, other treatment options should be employed. Surgical release is recommended for cases with severe lesions, or with unrecordable APB-CMAP.

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