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Electrophysiological Assessment for Splinting in the Treatment of Carpal Tunnel Syndrome

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Abstract

An electrophysiological study is commonly used to decide a therapeutic strategy for carpal tunnel syndrome (CTS). In this study, the electrophysiological parameter measurement as a prognostic indicator for CTS after wrist splinting was assessed to identify appropriate candidates for wrist splinting for CTS. One hundred and six hands in 78 patients with CTS were treated by wrist splinting, and three electrophysiological parameters; median distal motor latency (DML) of the abductor pollicis brevis (APB) muscle, median distal sensory latency (DSL) of the index finger, and second lumbrical-interossei latency difference (2L-INT LD); were statistically analyzed to compare with clinical results by Kelly's evaluation respectively. Clinical results were excellent in 15 hands, good in 51 hands, fair in 19 hands, and poor in 21 hands. The recordable rate in 2L-INT LD (99.1%) was higher than DML (96.2%) and DSL (79.2%). Patients with DML less than 6.5 ms, DSL less than 5.7 ms, or 2L-INT LD less than 2.5 ms had significantly excellent or good clinical results. The odds ratios of the DML, DSL, and the 2L-INT LD were 7.93, 8.81, and 12.8, respectively. This study demonstrated that CTS patients with DML less than 6.5 ms, DSL less than 5.7 ms, or 2L-INT less than 2.5 ms were good candidates for wrist splinting. Especially, the 2L-INT LD could be the most reliable indicator to predict clinical results for all grades of CTS. This electrophysiological information could be useful in further improvement of accurate diagnosis of CTS, and may help in the assessment of appropriate treatment for CTS with wrist splinting.

Key words: electrophysiological study, wrist splinting, carpal tunnel syndrome, distal latency, second lumbrical-interossei latency difference

Introduction

Carpal tunnel syndrome (CTS) is one of the most common entrapment neuropathies caused by compression of the median nerve at the wrist, and consequently, is the most frequent reason of referral to an electrodiagnostic study. A wrist splinting is widely and mainly used in conservative treatments of CTS, especially in mild or moderate patients.[1,2] Additionally, therapeutic effects of the splinting for CTS have been described in many previous studies.[1–4] However, there is insufficient evidence regarding the detailed prognostic indication of the splint treatment success in CTS patients yet.[1,2] Generally, the treatments for CTS are thought to depend on the CTS severity. Therefore, it is necessary to evaluate precisely the severity of the CTS, in order to determine the appropriate treatment for each patient.

An electrophysiological study is commonly used to confirm the clinical diagnosis of CTS.[1,2,5–7] Moreover, it provides useful information for an objective and quantitative assessment of the neurophysiological severity and a decision of therapeutic strategy in patients with CTS.[5–7] The electrophysiological standard examination is conventionally performed by recording the distal motor latency (DML) of the abductor pollicis brevis (APB) muscle and the distal sensory latency (DSL) of the index finger, for evaluation and classification of the severity of the CTS.[5–7] These studies must have high sensitivity and specificity for diagnosis of CTS.[1,8] Actually, the DSL is often unrecordable in the severe CTS with the atrophy of the APB.[2,5,7] Conversely, it is difficult to detect the early mild CTS with the DML study.[5,7] Only the evaluation by two standard elecrophysiological studies would be not enough to determine the indication and efficacy of wrist splinting for

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the specific CTS. Recently, several studies have reported the high diagnostic sensitivity of second lumbrical-interossei latency difference (2L-INT LD) in CTS, leading the American Association of Electrodiagnostic Medicine to recommend the 2L-INT LD study for the diagnosis of CTS.[5,7,8] Furthermore, some studies reported the 2L-INT LD to be a more accurate and reliable technique than the DML and the DSL in patients with various severities of CTS.[5–7] However, there are few studies that have described in detail the indication of the wrist splinting in CTS patients using the electrophysiological studies. The early detection of CTS patients who exhibit good effect with splinting is important to avoid delay in deciding the appropriate treatment. Therefore, the investigation of prognostic indication on electrophysiological study would be necessary to determine good candidates for CTS by splinting.

The aims of this study were to evaluate the efficacy of wrist splinting for CTS, and to investigate quantitatively the value of electrophysiological studies as a prognostic indicator for CTS treated by wrist splinting. We consider that this electrophysiological information can offer further accurate diagnostic assessment of CTS, and provide a better understanding of the appropriate candidates for wrist splinting for CTS and the prognosis of the CTS patient.

Materials and Methods

106 hands in 78 patients with a diagnosis of idiopathic CTS were treated by wrist splinting in our hospital between 2010 and 2014. Thirteen patients were men and 65 patients were women. The average age was 53.7 years (23–87). The affected hands were the right in 31 hands, the left in 19 hands, and bilateral in 28 hands. The duration of symptoms varied from one to 120 months, with a mean of 12.6 months. All hands were idiopathic CTS. Mean follow-up period was 7.6 months (4–27). CTS patients were clinically diagnosed by the clinical criteria of sensory deficit, numbness, tingling, and/or pain in the distribution of the median nerve area, and/or accompanying thenar muscle atrophy, and/or positive provocative tests, such as the Phalen- and Tinel-like tests and confirmed by electrophysiological studies. Patients with a history of diabetic polyneuropathy, rheumatoid arthritis, cervical disc herniation, or any trauma or surgery of the hand, wrist, or forearm were excluded from the study. All examinations proceeded after signed consent was obtained from all patients in this study.

According to Visser's classification of clinical severity of CTS,[8] before the wrist splinting therapy, 12 hands were normal with no sensory disorders, 47 hands had mild lesions with only sensory disorders, 28 hands had moderate lesions with sensory loss and weakness of APB or opponens pollicis, and 19 hands had severe lesions with sensory loss and severe muscle weakness (less than grade 4 on the Medical Research Council scale) or atrophy of the APB or opponens pollicis. Incidentally, at baseline, 19 patients with severe lesions refused carpal tunnel release and agreed to undergo treatment by wrist splinting.

The wrist splinting therapy

Patients were instructed to use a custom-designed and molded neutral wrist splint made of polyester (Manu Comfort Stable 4058, Otto Bock, Duderstadt, Germany) at night and as much as possible during the daytime for more than 8 weeks. Mean splinting period was 4.7 months (2–20). No other medication or physical therapy was allowed during the study. No patients were lost to follow-up. During this study, we found no complication related to the procedures.

Evaluation of clinical results

The clinical results obtained after the wrist splinting therapy were evaluated and classified into four categories according to relief of symptoms in accordance with Kelly et al.[9] 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. Additionally, for the clinical evaluation before and after wrist splinting, we used two patient-oriented questionnaires which have been recognized as important tools and which have been widely used for CTS; the Japanese Society for Surgery of the Hand version-Quick Disability of Arm, Shoulder, and Hand questionnaire (QuickDASH-JSSH)[10,11] and the Japanese Society for Surgery of the Hand version of the Carpal Tunnel Syndrome Instrument (CTSI-JSSH),[11,12] which consisted of a Symptom Severity Scale (CTSI-JSSH-SS) and Functional Status Scale (CTSI-JSSH-FS). The QuickDASH was developed as a shortened version of the Disability of Arm, Shoulder, and Hand questionnaire (DASH) outcome measurement.[13] It has been established that the Japanese version of QuickDASH has evaluation capacities equivalent to those of the original QuickDASH.[10,11] The CTSI-JSSH is a Japanese version of the self-administered disease-specific questionnaire for the assessment of the symptom severity and functional score consisting of two scales.[11,12] The CTSI-JSSH-SS and the CTSI-JSSH-FS have 11 and

8 questions, respectively. The assessment of each question was on a score of 1 point to 5 points, in which 1 indicates no symptom and 5 indicates severe symptoms. The two scales are calculated as the mean of the responses of the individual question. Levine demonstrated that the questionnaire was highly reproducible, internally consistent, valid and responsive for clinical change.[14]

Electrophysiological study

All electrophysiological examinations were performed according to the American Association of Electrodiagnostic Medicine (AAEM) guidelines[15] by one examiner (M.N.) using a Neuropack X1 MEB 2312 (Nihon Kohden Corporation, Tokyo, Japan) before the wrist splinting therapy in all patients and immediately after splinting therapy in 42 patients. The examinations consisted of median DML of the APB, DSL of the median nerve of the index finger, and 2L-INT LD of the median and ulnar motor nerve. All studies were performed under standard room temperature of 25°C. The skin temperature of the hands was maintained at 32°C or greater. The filter band pass was 10 Hz to 5 kHz for DML and 2L-INT LD, and 20 Hz to 2 kHz for DSL. Stimulus duration was 0.2 ms, sweep speed was 5 ms/division for DML and 2L-INT LD, and 2 ms/division for DSL. Electrical stimulation was performed using a bipolar electrical stimulator with 0.2 ms duration. The ground electrode was placed on the dorsum of the hand.

Median DML were examined with stimulating electrodes for the median nerve at the wrist and recording surface electrodes placed on the abductor pollicis brevis muscle 7 cm from stimulus electrodes. The reference electrode was placed over the first metacarpophalangeal joint. Median DSL were examined using an antidromic technique with stimulating electrodes for the median nerve at the wrist and ring recording electrodes placed at the proximal and distal interphalangeal joints of the index finger for the median nerve 14 cm from stimulus electrodes. 2L-INT LD was examined as described by Preston et al.[5–7,16] The distal motor latency of the median nerve recording the second lumbrical muscle was compared to the ulnar motor latency recording the second interossei. The median and ulnar nerves were stimulated at the wrist at identical linear distances (10 cm) from a recording electrode, and their two latencies were obtained respectively by placing a surface recording electrode just lateral to the midpoint of the third metacarpal. The reference electrode was placed over the proximal interphalangeal joint of the index finger. The compound muscle action potentials (CMAPs) were recorded from the second lumbrical and interosseous muscles, respectively. The difference between the two distal latencies was also examined. Furthermore, according to the AAEM guidelines[15] and several published reports,[4–8,17] the criteria used to confirm the diagnosis of CTS in this study were as follows: DML greater than 4.2 ms. DSL greater than 3.5 ms. 2L-INT LD greater than 0.5 ms, corresponding to the widely-accepted values of abnormality.

We evaluated correlation between the severity of CTS and clinical results after the wrist splint therapy. Moreover, we compared with clinical results evaluated by the QuickDASH-JSSH and the CTSI-JSSH between before and after the wrist splinting. We also examined the correlation between clinical results and electrophysiological parameters, to provide prognostic indicators of the efficacy for splinting in the treatment for CTS.

Statistical analysis

The results were expressed as the mean and standard deviation. All analyses were performed with the software program IBM SPSS Statistics 21.0J (IBM Japan Ltd., Tokyo, Japan). The DML, DSL, and 2L-INT LD were statistically analyzed among each severity of CTS using the unpaired Student's *t*-test, respectively. The clinical results, such as the QuickDASH, the CTSI-SS, and the CTSI-FS, before and after the wrist splinting were analyzed using the Student's paired *t*-test. In addition, the electrophysiological parameters were statistically examined using the chi-square test to evaluate each appropriate value of DML, DSL, and 2L-INT LD for predicting satisfactory clinical results with the wrist splint therapy, respectively. A P-value of less than 0.05 was considered to indicate statistical significance.

Results

Relationship between clinical results and severity of CTS

The clinical results by Kelly's evaluation in four different severities of CTS according to Visser's classification are shown in Table 1. Clinical results were excellent in 15 hands (14.2%), good in 51 hands (48.1%), fair in 19 hands (17.9%), and poor in 21 hands (19.8%) after the wrist splint therapy. Of 21 poor hands, 18 hands underwent carpal tunnel release with minimal incision after the wrist splint therapy.

For informative comparison of clinical results, we divided 106 hands into two groups: satisfactory results group with excellent or good results (group EG) and unsatisfactory results with fair or poor results (group FP). Group EG had 10 hands (83.3%)

normal, 44 hands (93.6%) with mild lesions, 12 hands (42.9%) with moderate lesions and no hand with severe lesions (Table 1).

Comparison of clinical results at before and after wrist splinting

Clinical results of QuickDASH and CTSI before and after splinting in both groups EG and FP are shown in Table 2. There were statistically significant differences in the QuickDASH in both the groups EG and FP between before and after splinting ($P < 0.01$). Moreover, there were statistically significant differences in the QuickDASH between group EG and group FP before and after splinting, respectively. Mean differences of QuickDASH before and after splinting were significantly lower in group EG than group FP ($P < 0.01$). There were also statistically significant differences in the CTSI-SS in both the groups EG and FP between before and after splinting ($P < 0.01$) (Table 2). Conversely, there were no statistically significant differences in the CTSI-FS in both the groups EG and FP between before and after splinting. Furthermore, there were statistically significant differences in the both CTSI-SS and CTSI-FS between groups EG and FP before and after splinting, respectively ($P < 0.01$).

Electrophysiological evaluation for clinical results

The DML, DSL, and 2L-INT LD were examined before the wrist splint therapy in all patients with CTS. The DML was recordable in 102 of all 106 hands (96.2%) and unrecordable in 4 hands with severe CTS. The DSL was recordable in 84 of 106 hands (79.2%) and unrecordable in 22 hands with 11 moderate and 11 severe CTS. The 2L-INT LD were recordable in 105 of 106 hands (99.1%) and unrecordable in one hand with severe CTS. The recordable rate in the 2L-INT LD was higher than that in the DML and the DSL.

The relationship between electrophysiological studies before splinting therapy and clinical results is shown in Table 3. In 102 hands with recorded DML, mean DML was 4.74 ± 0.74 ms in hands with excellent results, 6.35 ± 1.49 ms in hands with good results, 6.74 ± 0.99 ms in hands with fair results, and 7.96 ± 2.88 ms in hands with poor results, which showed significant difference between each of the four results. In 84 hands with recorded DSL, mean DSL was 4.27 ± 0.69 ms in hands with excellent results, 5.48 ± 1.03 ms in hands with good results, 6.13 ± 1.03 ms in hands with fair results, and 5.85 ± 0.89 ms in hands with poor results, which showed significant difference between each of the four results (Table 3). In 105 hands with recorded 2L-INT LD, mean 2L-INT LD was 0.47 ± 0.33 ms in hands with excellent results, 2.02 ± 1.36 ms in hands with good results, 2.96 ± 1.40 ms in hands with fair results, and 4.49 ± 2.29 ms in hands with poor results, which revealed significant difference between each of the four results. All electrophysiological parameters of DML, DSL, and 2L-INT LD demonstrated statistically

Table 1 Relationship between clinical results and severity of CTS. The severity of the CTS was classified into four degrees by Visser's criteria. The clinical results were also classified into four categories according to Kelly's evaluation

Severity	Clinical results			
	Excellent (n = 15)	Good (n = 51)	Fair (n = 19)	Poor (n = 21)
Normal (n = 12)	6	4	2	0
Mild (n = 47)	9	35	2	1
Moderate (n = 28)	0	12	11	5
Severe (n = 19)	0	0	4	15

Table 2 Comparison of clinical results before and after wrist splinting

Kelly's evaluation	Clinical evaluation					
	Quick DASH		CTSI-SS		CTSI-FS	
	Group EG	Group FP	Group EG	Group FP	Group EG	Group FP
	*		*			
Before splinting	31.8 ± 15.3	38.6 ± 17.2	2.34 ± 0.6	2.64 ± 0.7	2.00 ± 0.7	2.50 ± 0.5
	*	*	*	*		
After splinting	18.2 ± 15.1	31.8 ± 16.6	1.27 ± 0.8	2.00 ± 0.8	1.91 ± 0.5	2.25 ± 0.6
	*		*			

*$P < 0.01$, QuickDASH: Japanese Society for Surgery of the Hand version - Quick Disability of Arm, Shoulder, and Hand questionnaire, CTSI-SS and CTSI-FS: Japanese Society for Surgery of the Hand version of the Carpal Tunnel Syndrome Instrument, Symptom Severity Score and Functional Score, Group EG: Group with excellent or good results classified according to Kelly's evaluation, Group FP: Group with fair or poor results classified according to Kelly's evaluation.

significant differences among all four of the clinical results, respectively. The worse the clinical results, the more delayed were the DML, DSL, and 2L-INT LD. These results demonstrated that prolonged DML, DSL, and 2L-INT LD were statistically significant poor prognostic factors. However, mean DSL in hands with poor results was shorter than that in hands with fair results, because of the high unrecodable rate of DSL in hands with poor results.

Additionally, DML, DSL, and 2L-INT LD were examined immediately after the wrist splint therapy in 42 patients with CTS. The DML was recordable in 41 of all 42 hands (97.62%) and unrecordable in one hands. The DSL was recordable in 37 of 42 hands (88.1%) and unrecordable in 5 hands. The 2L-INT LD were recordable in 42 of 42 hands (100%). In 41 hands with recorded DML, mean DML was 4.32 ± 0.37 ms in hands with excellent results, 6.14 ± 1.55 ms in hands with good results, 6.82 ± 1.21 ms in hands with fair results, and 8.55 ± 1.35 ms in hands with poor results, which showed significant difference between each of the four results (Table 4). In 37 hands with recorded DSL, mean DSL was 4.08 ± 0.26 ms in hands with excellent results, 5.26 ± 1.41 ms in hands with good results, 6.34 ± 1.37 ms in hands with fair results, and 6.62 ± 1.67 ms in hands with poor results, which showed significant difference between each of the four results (Table 4). In 42 hands with recorded 2L-INT LD, mean 2L-INT LD was 0.42 ± 0.62 ms in hands with excellent results, 1.37 ± 1.22 ms in hands with good results, 3.01 ± 1.03 ms in hands with fair results, and 5.33 ± 2.47 ms in hands with poor results, which revealed significant difference between each of the four results (Table 4). All electrophysiological parameters of DML, DSL, and 2L-INT LD demonstrated statistically significant differences among all four of the clinical results, respectively. Furthermore, all parameters of DML, DSL, and 2L-INT LD after splint therapy decreased in the groups EG, and they prolonged in the groups FP, compared before splint therapy.

Moreover, we investigated the value of the electrophysiological studies as a prognostic indicator for CTS treated by wrist splinting. Firstly, the discriminant analysis with the Maharanobis's distance was used to distinguish three electrophysiological parameters, namely DML, DSL, and 2L-INT LD, between groups EG and FP. Consequently, the patients whose DML was less than 6.5 ms, DSL was less than 5.7 ms, or 2L-INT LD was less than 2.5 ms were distinguished to belong with the group EG with the wrist splinting.

Table 3 Electrophysiological evaluation before splinting for clinical results

Electrophysiological parameter	Clinical results			
	Excellent (n = 15)	Good (n = 51)	Fair (n = 19)	Poor (n = 21)
DML (ms)	4.74 ± 0.74	6.35 ± 1.49	6.74 ± 0.99	7.96 ± 2.88
DSL (ms)	4.27 ± 0.69	5.48 ± 1.03	6.13 ± 1.03	5.85 ± 0.89
2L-INT LD (ms)	0.47 ± 0.33	2.02 ± 1.36	2.96 ± 1.40	4.49 ± 2.29

*$P < 0.01$.

Table 4 Electrophysiological evaluation after splinting for clinical results

Electrophysiological parameter	Clinical results			
	Excellent (n = 3)	Good (n = 12)	Fair (n = 15)	Poor (n = 16)
DML (ms)	4.32 ± 0.37	6.14 ± 1.55	6.72 ± 1.21	8.55 ± 1.35
DSL (ms)	4.08 ± 0.26	5.26 ± 1.41	6.24 ± 1.37	6.62 ± 1.67
2L-INT LD (ms)	0.42 ± 0.62	1.73 ± 1.22	3.01 ± 1.03	5.33 ± 2.47

*$P < 0.01$.

Furthermore, each electrophysiological parameter was examined statistically to determine whether it predicted clinical results using chi-square test. We detected a significant correlation between electrophysiological parameters and clinical results, as follows.

For informative comparison of results, the patients were divided into two categories: category DML ≤ 6.5 ms with moderately delayed DML; and category DML > 6.5 ms with largely delayed DML. The ratio of group EG in category DML ≤ 6.5 ms was 81.0% and that in category DML > 6.5 ms was 34.9%, which showed a significant difference ($P < 0.001$) (Odds ratio 7.93) (Table 5). We also divided the patients into two categories: category DSL ≤ 5.7 ms with moderately delayed DSL; and category DSL > 5.7 ms with largely delayed DSL. The ratio of excellent or good results in category DSL ≤ 5.7 ms was 86.0% and that in category DSL > 5.7 ms was 41.1%, which showed a significant difference ($P < 0.001$) (Odds ratio 8.81) (Table 6). In addition, we divided the patients into two categories: category 2L-INT LD ≤ 2.5 ms with moderately delayed 2L-INT LD; and category 2L-INT LD > 2.5 ms with largely delayed 2L-INT LD. The ratio of group EG in category 2L-INT LD ≤ 2.5 ms was 85.2% and that in category 2L-INT LD > 2.5% was 31.1%, which showed a significant difference ($P < 0.001$) (Odds ratio 12.8) (Table 7). Moreover, the ratio of excellent or good results (i.e. correct answer ratio) of the DML, DSL, and the 2L-INT LD were high, and 81.0%, 86.0%, and 85.2%, respectively. These findings showed that the appropriate indication of the wrist splinting in CTS patients was DML less than 6.5 ms, DSL less than 5.7 ms, or 2L-INT LD less than 2.5 ms. Furthermore, the odds ratios of the DML, DSL, and the 2L-INT LD were 7.93, 8.81, and 12.8, respectively. Therefore, the 2L-INT LD had the strongest correlation with the clinical results among the three electrophysiological parameters.

Discussion

Several studies have suggested that the wrist splint therapy is effective in patients with mild or moderate CTS.[1–4] This study also demonstrated that the splinting could produce significant improvement in the clinical symptoms of mild or moderate CTS. Satisfactory results were obtained in no cases with severe lesions. Moreover, the QuickDASH and the CTSI-SS, which were patient-oriented questionnaire evaluations, showed statistically significant differences between before and after splinting ($P < 0.01$). Some authors similarly reported significant improvement in the QuickDASH and CTSI-SS after splinting in comparison with before splinting.[1,3] Although, there are a number of reports about the efficacy of using a wrist splint for CTS,[1–4] little is known about objective evaluation for its indication. Especially, concerning Visser's classification, it is difficult to evaluate objectively and quantitatively sensory loss, weakness and atrophy of the thenar muscle. Because the treatment strategies for the CTS depend on the severity of the CTS, electrophysiological study is important to evaluate early and accurately the indication of wrist splinting.

Electrophysiological study is frequently used as a diagnostic method for confirming the severity of CTS.[2,4–8,18] Therefore, the electrophysiological parameters might have a certain utility as a reliable indicator of the efficacy of the wrist splinting therapy.

Table 5 Correlation between DML and clinical results

Electrophysiological parameter	Clinical results		
	Excellent or good (n = 68)	Fair or poor (n = 40)	Ratio of excellent or good results
DML ≤ 6.5 ms (n = 63)	51	12	81.0% (51/63)
DML > 6.5 ms (n = 43)	15	28	34.9% (15/43)

*$P < 0.01$, DML: Median distal motor latency of the abductor pollicis brevis, $\chi^2 = 23.1$, $P < 0.001$, Odds ratio 7.93, 95% Confidence Interval (6.65–9.36).

Table 6 Correlation between DSL and clinical results

Electrophysiological parameter	Clinical results		
	Excellent or good (n = 68)	Fair or poor (n = 40)	Ratio of excellent or good results
DSL ≤ 5.7 ms (n = 50)	43	7	86.0% (43/50)
DML > 5.7 ms (n = 56)	23	33	41.1% (23/56)

*$P < 0.01$. DSL: Distal sensory latency (DSL) of the median nerve of the index finger, $\chi^2 = 22.7$, $P < 0.001$, Odds ratio 8.81, 95% Confidence Interval (7.29–10.7).

Table 7 Correlation between 2L-INT LD and clinical results

Electrophysiological parameter	Clinical results		
	Excellent or good (n = 68)	Fair or poor (n = 40)	Ratio of excellent or good results
2L-INT LD ≤ 2.5 ms (N = 61)	52	9	85.2% (52/61)
2L-INT LD > 2.5 ms (N = 45)	14	31	31.1% (14/45)

*P < 0.01, 2L-INT LD: second lumbrical-interossei latency difference of the median and ulnar motor nerve, χ^2 = 32.3, P < 0.001, Odds ratio 12.8, 95% Confidence Interval (11.0–14.9).

Generally, median DML of APB and the DSL of the index finger are widely accepted as the standard and conventional electrophysiological parameters for diagnosing and assessing the function of the median nerve in CTS.[2,5–8] However, Nobuta et al. reported that the DML and the DSL were often unrecordable in severe CTS with marked thenar atrophy.[2] Therefore, they considered that only a DML or DSL was insufficient for the diagnosis and prediction of clinical results for wrist splint therapy in CTS.[2] Additionally, some studies showed the 2L-INT LD to be an accurate and reliable technique, especially in patients with severe CTS, when the standard DML and the DSL studies failed.[5,7] In the present study, the recordable rates of three electrophysiological studies (DML, DSL, and 2L-INT LD) were 96.2%, 79.2% and 99.1%, respectively. Especially, 2L-INT LD was unrecordable in only one severe hand among all hands. Several authors stated the rate of recordability in the 2L-INT LD was higher than those of both the DML and the DSL, similar to our findings. Inukai et al. reported that the rates of recordability on electrodiagnostic studies for CTS were 74% in DML, 48% in DSL, and 88% in 2L-INT LD.[5] Kodama et al. also described that the ratio of absent DSL, DML and second lumbrical-compound motor action potential (2L-CMAP) was 28%, 7% and 0%, respectively, and that 2L-CMAP could be obtained in all of CTS hands.[6]

Padura et al. have classified the CTS patients into five degrees by the electrophysiological severity: extreme, severe, moderate, mild, and minimal CTS.[18] Their classifications were as follows: the DML could not detect the mild CTS (abnormal DSL, normal DML) or sometimes could not detect the severe CTS (absence of sensory response, abnormal DML) with severe APB atrophy. Moreover, they showed that the DSL sometimes could not detect the moderate CTS (abnormal DSL, abnormal DML) or could not detect the severe CTS, although it could detect the mild CTS.[18] Conversely, the comparative test, i.e. the 2L-INT LD in this study, could detect from the minimal (normal both DSL and DML) to extreme CTS (absence of median motor and sensory response), that is to all grades of CTS. In addition, many authors reported the high comparable sensitivity and high specificity of the electrophysiological diagnostic studies for CTS.[1,6,7,16] They stated that the sensitivity of the DML, the DSL, and the 2L-INT LD was 54–70%, 67–83%, and 85.6–95.0%, respectively. The specificity was 97%, 97% and 97% in the same order. Most of the reports have described that the sensitivity and the detective ratio of the 2L-INT LD were higher than those of the DML and the DSL.[6,7] According to the American Association of Electrodiagnostic Medicine,[15] the 2L-INT LD was recommended as the standard level, together with the DML. Several authors described that the 2L-INT LD had higher sensitivity for diagnosis of CTS, and it was a more accurate and reliable technique than both the DML and the DSL in patients with various degrees of CTS.[5,7,16] Furthermore, Meena et al. reported that the advantages of the 2L-INT LD study were as follows: 1. Both the second lumbrical muscle and the interosseous muscle can be easily tested from the same recording electrode in mid-lateral proximal palm. 2. The temperature is comparable for each distal nerve segment and muscle. 3. Identical distances to each muscle are used, allowing direct comparison of distal motor latencies. 4. It results in an ideal internal control for median motor studies.[7] Some authors also described that the second lumbrical fibers were less severely affected than the thenar motor fibers in CTS, because fascicles from the second lumbrical fibers were in a more dorsal location than the thenar motor fibers and were possibly better protected against the transverse carpal ligament.[2,5] Therefore, we assessed the value of the 2L-INT LD in the electrodiagnosis of the CTS comparing with other conventional median motor and sensory studies, and evaluated the predictive efficacy of the 2L-INT LD in CTS, in order to determinate whether effective or not for indicating splint therapy.

Presently, there have been only a few studies evaluating prognostic indicators of splint treatment success in CTS patients. Electrophysiological study is helpful to forecast prognosis of CTS by the wrist therapy. However, there is uncertainty as to which electrophysiological severity of CTS should receive splinting. Gelberman et al. reported that poor results were seen in the cases with delayed DML of more than 6 ms and absence of sensory response.[19] Nobuta et al. stated that the patients with DML less than 8 ms had good clinical results by splinting.[2] In the present study, three electrophysiological parameters were examined statistically to determine whether they predicted clinical results. Consequently, the significant correlations between each electrophysiological parameter and clinical results were detected. The ratio of excellent or good results in category (DML < 6.5 ms, DSL < 5.7 ms, or 2L-INT LD < 2.5 ms) was significantly large compared with that in category (DML ≥ 6.5 ms, DSL ≥ 5.7 ms, or 2L-INT LD ≥ 2.5 ms) ($P < 0.01$) for predicting clinical results in CTS patients. Therefore, this information suggested that the indication of the wrist splint therapy for CTS was DML < 6.5 ms, DSL < 5.7 ms, or 2L-INT LD < 2.5 ms, which would predict a good prognosis. These values of three parameters were considered as prognostic indicators for good clinical results. Moreover, the odds ratio of the 2L-INT LD was higher than that of the DML or the DSL. In contrast to other studies on the DML as an indication for splinting, few studies have yet addressed the 2L-INT LD to provide an indicator of the efficacy of splinting. We considered that the 2L-INT LD would be the most useful parameter for predicting the efficacy of splinting for CTS among the three electrophysiological studies.

Conclusions

This study showed that wrist splint therapy could bring about significant improvement in the clinical symptoms of mild or moderate CTS. In addition, we found that there was a statistically significant relationship between electrophysiological studies and clinical results using splinting. Especially, CTS patients with DML less than 6.5 ms, DSL less than 5.7 ms, or 2L-INT LD less than 2.5 ms could bring about significantly good clinical results. From this finding these values of three parameters were considered as prognostic indicators for the good clinical results. Notably, the current study demonstrated the 2L-INT LD could be the most appropriate indicator for predicting the efficacy and clinical results using a wrist splint for all grades of CTS. Consequently, this electrophysiological information can be useful in further improvement of accurate diagnosis and objective evaluation of the severity for CTS. It could also help in the assessment of appropriate candidates for treatment for CTS with wrist splinting.

Limitation

The present study had several limitations. First, the follow-up period of this study was comparatively short. A longer follow-up period may provide more definitive conclusions to our findings with regard to the electrophysiological studies. Second, this study included the lack of comparison of the wearing other type splints differing in angles of the wrist joint. Further evaluation concerning this issue could elucidate the most effective method for wrist splinting in detail and improve the clinical results. These remain for future studies.

Conflicts of Interest Disclosure

None.

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