RELATIONSHIPS BETWEEN CLINICAL SCALES ON SEVERITY OF SYMPTOMS AND ELECTRODIAGNOSTIC MEASURES ON ABNORMALITY OF NERVE CONDUCTION IN CARPAL TUNNEL SYNDROME

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This study examined the severity of carpal tunnel syndrome symptoms in relation to nerve conduction measures of the median nerve. The symptom scales include (1) numbness, (2) tingling, (3) nocturnal symptoms, (4) pain, (5) weakness, and (6) clumsiness; the nerve conduction measures are (1) peak amplitude and (2) peak latency of the sensory action potential, (3) conduction velocity of the sensory nerve fibers, (4) peak amplitude and (5) onset latency of the motor action potential. The symptom severity and nerve conduction impairment were evaluated for 34 affected hands of 24 patients (6 males and 18 females) by using a questionnaire developed by Levine et al. and an electromyographic instrument, respectively. Significant relationships identified among the clinical scales resulted in a dichotomous symptom classification scheme with a criterion of the relatedness to nerve damage: primary and secondary symptoms. Correlation analysis on the symptom and electrodiagnostic measures showed both the severity scales for the primary and all the symptoms had higher correlations with the extent of the nerve injury than that for the secondary symptoms. These results demonstrated a biological significance of the clinical scales, which can be used in evaluating the outcome of treatments and developing a model for exposure-severity relationship.

INTRODUCTION

Carpal tunnel syndrome (CTS), the focal neuropathy of the median nerve at the wrist, has been a major problem in industries especially involving repetitive use of the hand due to its work relatedness, significant incidence rate, and high cost (Hagberg et al., 1995). To detect this nerve injury in an individual, two or all of the following manifestations should be considered to reduce the possibility of false diagnosis: clinical symptoms, physical signs, and nerve conduction abnormalities. The first two clinical conditions can be identified through responses of a patient, while the last by use of an electromyographic instrument. A diagnosis of the disorder based only on symptoms and/or signs may be questionable because other common disorders such as tendonitis and cervical radiculopathy cause similar responses (AAEM et al., 1993), thus an electrophysiologic test on the lesion is employed to confirm the clinical diagnosis.

Along with diagnosis on the presence of CTS, assessment of the severity of symptoms is of valuable use in evaluating the outcome of treatments and developing an exposure-severity relationship for the disorder. When a CTS patient being treated with a conservative (immobilization of the affected hand or medication) or surgical (carpal tunnel release) care, the underlying condition of symptoms should be assessed appropriately to identify the effectiveness of the treatment with respect to recuperation of the impaired nerve. Also for a better understanding of the effect of risk exposures on the severity of the disorder, a symptom assessment tool having a biological significance is needed. Although electrophysiologic test has been accepted as a standard for the diagnosis of CTS over the other criteria, no tool quantifying the severity of symptoms has been standardized so far.

Levine et al. (1993) developed a self-administered questionnaire for assessing the severity of CTS symptoms, but found an insignificant correlation between the overall severity scale for all symptoms and conduction velocity of the sensory nerve. This questionnaire comprises 11

questions for six typical symptoms: numbness, tingling, nocturnal symptoms, pain, weakness, and clumsiness. Nathan and Keniston (1993) classified the first three as major CTS symptoms and the last three as minor CTS symptoms. Levine et al. determined the overall severity as an average of all the symptom severity scores, and then related this to the nerve conduction measure. Based on a weak relationship between the scales (r = -0.11), they concluded severity of symptoms could not be estimated by nerve conduction measurement, indicating no significant relationships exist between the clinical and electrodiagnostic criteria. However, a strong relationship may still be found between a subgroup of the symptoms and the other electrodiagnostic measures. Furthermore, they did not include an analysis on the relationships between individual symptoms, which may be of value in understanding their characteristics prior to drawing any conclusion.

The purpose of this study is to examine the relationships between the clinical symptoms and electrodiagnostic measures in median nerve impairment and to understand a biological significance (reflecting the integrity of the median nerve) between these two measures.

MATERIALS AND METHODS

Symptom Severity Questionnaire

The assessment questionnaire developed by Levine et al. (1993) was utilized to evaluate the severity of each of the six typical CTS symptoms (pain, weakness, clumsiness, numbness, tingling, and nocturnal awakening) for the affected hand. The questionnaire uses the metrics of 1 (no symptom) to 5 (most severe) with respect to the magnitude, frequency, or duration of an episode, as illustrated in Figure 1. The symptom assessment was conducted on each patient soon after that a nerve conduction study confirmed the presence of the disorder. This was designed so as to avoid any effect of a treatment following the test to response on the symptom severity.

Figure 1. Example of symptom severity questions for carpal tunnel syndrome

2. **How often** do you have hand or wrist **pain during the daytime**?

Left Hand	Right Hand
☐ Never	☐ Never
☐ Once or twice a day	☐ Once or twice a day
☐ Three to five times a day	☐ Three to five times a day
☐ More than five times a day	☐ More than five times a day
☐ The pain is constant throughout the day	☐ The pain is constant throughout the day

Nerve Conduction Study

Nerve conduction studies on the median nerve include the following three sensory- and two motor-nerve measures:

(1) baseline to peak amplitude of the sensory nerve action potential (S-AP),
(2) peak latency of the sensory nerve action potential (S-LT),
(3) conduction velocity of the sensory nerve fibers (S-CV),
(4) baseline to peak amplitude of the compound muscle action potential (M-AP), and
(5) onset latency of the compound muscle action potential (M-LT).

The sensory nerve responses were measured at the index finger with ring electrodes and the motor responses (compound muscle action potential) over the abductor policis brevis muscle with surface electrodes, respectively, while the median nerve was stimulated percutaneously at the wrist using a constant current stimulator. Supramaximal stimulations were used in all cases, with skin temperature at 32° C or greater.

Participant Composition

Twenty-four patients (6 males and 18 females) diagnosed with unilateral or bilateral CTS at the Electromyography Laboratory in Penn State Geisinger Hershey Medical Center participated in the study, providing informed written consent. The average age was 47.0 years (standard deviation (s.d.) = 10.6, range (R) = 24 to 65); the average body mass index (BMI), a ratio of weight to height squared, an index of obesity for the body, was 30.2 (s.d. = 6.8, R = 21.0 to 44.4), corresponding to

'obese' level (BMI > 30.0) (Werner et al., 1994). A comparison of individual characteristics of the participants to those of 149 CTS patients for the year 1997 diagnosed at the laboratory found no significant difference in gender ($\chi^2(1) = 0.04$, p = 0.83), age ($t(21) = 0.17$, p = 0.86), and obesity ($t(24) = -0.51$, p = 0.62) at $\alpha = 0.05$.

RESULTS

Relationships between Symptom Severity Scales and Development of Symptom Classification Scheme

Strongly significant correlations ($p < 0.01$) were obtained for all the relationships within each of the following two symptom groups: (1) numbness, tingling, and nocturnal symptoms, and (2) pain, weakness, and clumsiness; however, only one-third of the relationships between the symptom groups was significant at $\alpha = 0.05$ (see Table 1). These relationship patterns indicate the six symptom scales could be classified into two groups, providing a better interpretation with the symptoms.

Table 1. Pearson's correlation coefficients for symptom severity scales

	Numbness	Tingling	Nocturnal symptoms	Pain	Weakness	Clumsiness
Numbness	1					
Tingling	0.71 ‡	1				
Nocturnal symptoms	0.53 †	0.47 †	1			
Pain	0.25	0.31	0.42 *	1		
Weakness	0.34 *	0.29	0.18	0.61 ‡	1	
Clumsiness	0.44 *	0.27	0.23	0.51 †	0.61 ‡	1

* p < 0.05; † p < 0.01; ‡ p < 0.001

To explore underlying variables that explain the interrelationships among the clinical symptom scales. factor analysis was conducted by selecting the principal components method for factor extraction and the varimax procedure for factor rotation, respectively. The estimates of the factor loadings shown in Table 2 indicate that factor 1 relates to numbness, tingling, nocturnal symptoms, which are typical symptoms from nerve damage, and factor 2 corresponds to pain, weakness, and clumsiness, which are symptoms from damage in the body tissues including tendon, muscle, and nerve. Accordingly, in light of the relatedness of nerve damage, factor 1 designates primary (major) symptoms and factor 2 does secondary (minor) symptoms for CTS, respectively. The two rotated factors together explain 72% of the total variance of the six symptom scales.

Table 2. Varimax rotated factors for symptom scales

	Factor Loadings		
Symptoms	Factor 1	Factor 2	Communality
Numbness	0.86	0.23	0.79
Tingling	0.85	0.16	0.76
Nocturnal symptoms	0.76	0.15	0.61
Pain	0.23	0.79	0.68
Weakness	0.12	0.88	0.79
Clumsiness	0.20	0.81	0.70
Variance explained	2.15	2.16	4.31
Percentage	35.8 %	36.0 %	71.8 %

Relationships between Nerve Conduction Measures

All the nerve conduction measures were significantly interrelated to each other in a desirable direction (see Table 3). The highest correlation was obtained in the relationship between sensory peak latency and sensory conduction velocity. This is

Table 3. Pearson's correlation coefficients for nerve conduction measures

	S-AP	S-LT	S-CV	M-AP	M-LT
Sensory Amplitude (S-AP)	1				
Sensory Latency (S-LT)	- 0.74 ‡	1			
Sensory Conduction Velocity (S-CV)	0.76 ‡	- 0.94 ‡	1		
Motor Amplitude (M-AP)	0.35 *	- 0.39 *	0.40 *	1	
Motor Latency (M-LT)	- 0.58 ‡	0.82 ‡	- 0.78 †	- 0.62 ‡	1

* p < 0.05; † p < 0.01; ‡ p< 0.001

natural because the conduction velocity is determined by the distance between stimulating and recording sites and onset latency of the sensory action potential, which is closely related to the peak latency. The relatively low correlations between motor amplitude and the other nerve conduction measures indicate that the use of motor amplitude may yield different results in the diagnosis of CTS from those based on the other measures. The strong correlation (r = 0.82) between sensory peak and motor onset latency measures is noteworthy because they are widely used for electrodiagnosis of the disorder (Eversmann, 1993).

Relationships between Symptom Severity Scales and Nerve Conduction Measures

The present study hypothesizes that the severity scale for the primary symptoms, closely related to nerve damage, would have higher correlations with the nerve conduction measures than that for the secondary symptoms or all the symptoms. The estimates of the correlation coefficients displayed in Table 4 confirmed that the primary symptom scale is more closely related, in general, to the nerve conduction measures than the secondary symptom scale. However, the dominance of the primary symptom scale in relation to the lectrodiagnostic measures was not revealed when comparing with the overall symptom scale. Instead, the overall symptom scale had better relationships to both sensory and motor latency measures, widely used in the diagnosis of CTS, than the primary symptom scale. Lastly, no symptom scales had a significant relationship at $\alpha = 0.05$ with peak amplitude of the motor nerve action potential, which reduces usefulness of the nerve conduction measure.

Table 4. Pearson's correlation coefficients between symptom severity scales and nerve conduction measures

Nerve Conduction Measures	Symptom Severity Scales: Primary Symptom	Secondary Symptom	Overall Symptom
Sensory Amplitude (S-AP)	- 0.60 ‡	- 0.23	- 0.48 †
Sensory Latency (S-LT)	0.48 †	0.42 †	0.54 ‡
Sensory Conduction Velocity (S-CV)	- 0.45 †	- 0.34 *	- 0.47 †
Motor Amplitude (M-AP)	- 0.33	- 0.20	- 0.30
Motor Latency (M-LT)	0.35 *	0.47 †	0.50 †

* p < 0.05; † p < 0.01; ‡ p < 0.001

DISCUSSION

This study had five major findings. First, analyzing the relationships between the clinical scales, the present study provides a dichotomous classification scheme for symptoms of CTS: primary and secondary symptoms. The primary symptoms (numbness, tingling, and nocturnal symptoms) are those usually considered to be more specific for nerve injury, while the secondary symptoms (pain, weakness, and clumsiness) are those commonly found in soft tissue injuries and other musculoskeletal disorders. The weak relationships between the two symptom groups support the necessity of the dichotomous categorization. Interestingly, the categorization scheme is similar to the one (major and minor symptoms) used by Nathan and Keniston (1993) when defining probable CTS. Nathan and Keniston did not discuss the relevance of the symptom classification in detail.

Second, this study identifies strong relationships among the nerve conduction measures studied except for the motor amplitude, signifying a high probability of establishing a consistent result in the diagnosis of CTS when different electrodiagnostic measures are considered. The high correlation of the sensory and motor latency measures especially supports the prevalent use of the two measures in establishing the electrodiagnosis of the disorder. Also the significant relationships between the sensory and motor nerve conduction measures indicates that all

the nerve fibers in the median nerve are usually impaired simultaneously.

Third, in contrast to Levine et al. (1993), we found significant relationships between the clinical scales and nerve conduction measures. In the present study, a relatively high and significant correlation ($r = -0.47$) between the overall symptom scale and sensory nerve conduction velocity was obtained, in contrast to the poor correlation in the study of Levine et al. ($r = -0.11$). This may be due to the difference in study protocol rather than in participant group. In this study, the symptom severity survey was conducted following the nerve conduction studies before treatment. Levine et al. did not provide details on the timing of symptom assessment. Also, this study collected data for each affected hand, not for each patient, to exclude the effect of the healthy hands to response on the symptom severity. Levine et al. did not give any indication on whether data were collected for only the hands diagnosed with CTS. Overall symptom severity appeared to similar in our study and theirs when contrasting the overall severity scores (average = 3.0, s.d. = 1.0) of their patient group with those of the present patient group (average = 2.9, s.d. = 0.7); significant difference in overall severity level between the two patient groups was not found ($t(48.36) = 0.28$, $p = 0.78$).

Fourth, the present study indicates that the severity scale for the primary symptoms is more closely related to the nerve conduction measures than that for the secondary symptoms. We expect that use of only the primary symptoms, which may better reflect nerve injury, would be more meaningful for developing a symptom assessment tool having biological significance for impairment of the median nerve than use of all symptoms.

Lastly, this study indicates that the clinical scales probably have a relationship with biological/structural abnormalities of the median nerve. The symptom severity scales are simple and non-invasive in measurement and related to the magnitude of electrophysiologic abnormality of the median nerve. Thus, such scales may contribute to early detection of CTS at the work place, and may be useful in the study of exposure-severity relationships for CTS and in the evaluation of outcomes of CTS treatment.

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