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Do Electrodiagnostic Variables Correlate with Functional Outcomes in Carpal Tunnel Syndrome?

Donald Kasitinon[1], **Thiru M. Annaswamy**[2*], **Alexandru Anastase**[3], **Tong Zhu**[4], **Hai-Yan Li**[5] **and Samuel M. Bierner**[6]

[1]*UT Southwestern Medical Center, Dallas, TX, USA*

[2]*PM & R Service, VA North Texas Health Care System and UT Southwestern Medical Center, Dallas, TX, USA*

[3]*Select Rehabilitation Hospital, Denton, TX, USA*

[4]*St. Louis, MO, USA*

[5]*Scripps Clinic Medical Group, San Diego, CA, USA*

[6]*MRM, University of Nebraska Medical Center, Omaha, NE, USA*

[*]**Corresponding author:** Thiru M. Annaswamy, PM & R Service, VA North Texas Health Care System and UT Southwestern Medical Center, Dallas, TX, USA, Tel: 214-857-0273; Fax: 214-857-1281; E-mail: thiru.annaswamy@va.gov

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Abstract

Background: The most common entrapment neuropathy seen in electrodiagnostic (EDX) laboratories is carpal tunnel syndrome (CTS). The diagnostic value of EDX with regard to CTS is well-established, but EDX's predictive value is unclear. To date, only one study has attempted to establish a relationship between EDX findings and a patient's clinical status pre- and post-treatment, and there was no significant relationship found.

Objective: To establish a relationship between EDX variables and clinical severity assessment with Disabilities of the Arm, Shoulder, and Hand (DASH) scores at a single point in time and over a period of time.

Methods: The study was a prospective single group cohort. 41 patients referred to an EDX clinic with suspected diagnoses of CTS were enrolled. Patients underwent EDX studies and completed DASH questionnaires at initial and follow-up visits at 8-month to 12-month intervals. Data collected included median sensory, mixed, and motor latencies, amplitudes, conduction velocities, and needle electromyography (EMG). Correlation coefficients were determined between EDX data variables and severity assessment (independent variables) and patients' DASH questionnaire measures (dependent variables) at initial and follow-up assessments.

Results: Change in DASH score over time positively correlated with left distal median motor latency (DMML) decrement and right transcarpal median sensory conduction block and negatively correlated with left median sensory nerve action potential (SNAP) amplitude decrement percentage, right needle EMG motor unit morphology abnormality, and right median forearm motor conduction velocity increment. The correlations observed are of unclear significance since the DASH scores themselves did not change significantly over time.

Conclusions: Objective EDX data coupled with patient-reported outcome (PRO) measures such as the DASH score may be more meaningful in directing clinical care than either of them alone.

Keywords: Carpal tunnel syndrome; Outcome assessment; Correlation study; Neural conduction; Electromyography; Electrodiagnosis

Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy seen in most electrodiagnostic (EDX) laboratories. It is brought on by compression of the median nerve as it travels through the carpal tunnel. The patient with classic CTS presents with paraesthesia's in the median nerve territory, which typically includes the first three digits and the radial half of the fourth digit [1].

History and physical examination (H & P) is sufficient to make a presumptive diagnosis of CTS in a majority of cases, but EDX helps to confirm or rule out other conditions mimicking CTS such as polyneuropathy, plexopathy, and radiculopathy. The primary intention of every EDX study is to localize the disorder, and EDX in combination with the clinical examination can typically provide a diagnosis of CTS accurately [2]. Although the diagnostic value of EDX is unequivocal, EDX's value in predicting outcomes is unclear [3-6]. Standardized patient-reported outcome (PRO) measures such as the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire are more commonly used in clinical evaluation of CTS over EDX because of better clinical relevance. Common reasons cited for not routinely performing EDX prior to surgical release of the carpal tunnel include "The EDX data doesn't correlate with our clinical assessment," and "The results don't help me decide what to do with the patient." Other reasons include additional expense, delays in initiating care, unneeded inconvenience, discomfort to the patient, and subjectivity involved in severity assessment on the part of the electrodiagnostician. Additionally, the use of the DASH questionnaire allows clinicians to follow patient changes over time and therefore evaluate the efficacy of treatment interventions [7].

The clinician, however, must keep in mind that the DASH questionnaire is subjective. A patient's self-report may be unable to differentiate between patients with true pathology and patients with potential secondary gains related to workers' compensation, disability determinations, or other medico-legal issues. This is where the importance of EDX comes into play. The objectivity of EDX testing is extremely valuable since it removes the need to rely solely on patient's subjective reports [8]. A previous study reported that if a patient has an abnormal hand diagram indicating median nerve distribution paraesthesia's, positive Phalen's test, positive carpal compression test, and night pain, the probability that CTS will be correctly diagnosed is 86% [9]. However, it is not often that a patient will present with all four of these findings. EDX testing can potentially improve the sensitivity of diagnosing CTS when added to a standard H & P, minimizing the subjectivity involved in patient questionnaire assessments such as the DASH [10].

EDX findings have been positively correlated with patient symptom severity and negatively correlated with functional status [11,12]. One study, however, reported a negative correlation between EDX data and development of symptoms and diagnosis of CTS in industrial workers followed prospectively [13]. Preoperative EDX data has been predictive of and well-correlated with subjective patient outcome measures and symptom scores after surgery and other treatment approaches [14,15]. Other studies have reported poor or no association between surgical outcomes and preoperative EDX findings [4,16].

Severity assessment is included in most electro diagnosticians' reports. There is no universally accepted standard in classification of severity assessment of CTS. However, several electro diagnosticians use the AANEM minimonograph as their guideline [12,17]. In a previous study, clinical and EDX changes after surgery were evaluated in patients with "severe" CTS, and severity was defined based on EDX data [18]. However, it wasn't based on any standard or widely accepted norm. A 6-point severity scale [5] and a 7-point neurophysiologic grading scale [3] have also been used. Significant correlations between these classification systems with H & P findings and the Boston Carpal Tunnel Questionnaire have been reported [19], and statistically significant differences have been reported when using the 7-point scale in a large retrospective cohort [3]. However, these scales have neither been widely used nor adequately validated.

Classification of severity or grading any medical condition should be based not only on an ordinal ranking, but should also be clinically relevant in reflecting prognosis and predicting outcomes with various treatment choices. Most importantly, severity classification should be strongly associated with a patient's functional status. A good classification system would greatly facilitate comparison of the severity of CTS across varied patient groups and practice settings. EDX findings and severity classification have not been well-correlated with symptom severity, functional status, or surgical outcomes, thereby limiting their utility to some extent.

A previous study looked at the relationship between EDX findings and patient symptom severity and found them to be independent measures [20], but to date, only one study has attempted to establish a relationship between EDX findings and PRO measures pre- and post-treatment. Although there was improvement in EDX and PRO measures post-surgically, there was no significant relationship established between the EDX findings and PRO measures themselves in both the pre- and post-treatment period [21]. Additionally, it is unclear how clinically relevant a summative assessment of severity of CTS based on EDX is in reflecting prognosis or predicting outcome after treatment [12,14,16]. Studies addressing these unanswered questions will provide further clarification and guidance regarding optimal conservative and surgical management of CTS [22].

We conducted a clinical investigation with the objectives of correlating EDX variables and summative severity assessment with DASH scores and measuring changes over time in the EDX variables and severity assessment with corresponding changes in DASH scores. We hypothesized that:

1. There are statistically significant correlations between a) various EDX data variables, b) electro diagnostician's severity assessments, and c) PRO measures in patients with CTS.

2. Changes in EDX data variables and severity assessments with treatment are predictive of similar changes in PRO measures in patients with CTS regardless of treatment/s instituted.

Methods

Study design

This study was a prospective, single group cohort with a pre-post design.

Participants

Consecutive patients referred to an outpatient Veterans Affairs hospital-based EDX clinic for EDX evaluation of their upper limbs with suspected diagnoses of CTS were included in the study. All required institutional review board (IRB) approvals were obtained to conduct this study, and all patients provided written informed consent.

Study protocol

Once the patient provided consent to participate in the study, a standard H&P was performed. Key information such as duration of symptoms, presence or absence of nocturnal paraesthesia's, distribution of sensory symptoms, comorbid medical conditions, past surgical history, and information regarding any previous EDX testing for CTS were obtained in the history. Physical examination included a detailed neuromuscular exam of the subject's hands and special tests including Tinel's test, Phalen's test, reverse Phalen's test, and carpal compression test. Clinical diagnosis of CTS was made based on the above according to the current consensus criteria for CTS [6].

Electrodiagnostic evaluation

Once the patient met study criteria, EDX testing was performed on the affected upper extremity/ies based on the guidelines outlined in the AANEM practice parameter for EDX studies in CTS [1]. One of the study investigators directly supervised all the EDX studies. During the EDX study, surface temperature was measured continuously and maintained above 32°C at all times. Disposable surface electrodes were used for the NCS portion, and disposable concentric needle electrodes were used for the needle electromyography (EMG) portion of the study. The EDX study obtained the data variables as detailed in Tables 1 and 2.

Inclusion	Exclusion
Proper execution of informed consent.	- Patient didn't provide consent.
Clinical evaluation (H & P) consistent with diagnosis of CTS.	- Clinical evaluation (H & P) not consistent with diagnosis of CTS.
	- Serious cardiac disease, pulmonary disease, cancer, or renal disease.
	- Previous history of carpal tunnel release surgery.
	- Previous EDX evaluation confirming diagnosis of CTS.
	- Peripheral neuromuscular disorders such as myopathy or neuromuscular junction disorders.

Table 1: Study criteria.

After the study, an EDX report was generated that included the diagnosis, type of nerve injury, and severity assessment on a 3-point scale: 1) mild, 2) moderate, and 3) severe (Table 3). Severity assessment was based on published guidelines [17]. However, a contingent modification was made to the severity rating: if there was presence of a transcarpal median motor conduction block (TMMCB), mild severity was upgraded to moderate severity.

Study questionnaire and follow-up

After completion of the EDX study, each patient completed the DASH questionnaire. Follow-up evaluations were performed at 8-month to 12-month intervals after the initial visit following treatment (included both non-surgical and surgical treatments based on referring physician).

Conventional Variables
- Wrist median motor latency
- Wrist median compound muscle action potential amplitude (CMAP)
- Wrist-elbow motor conduction velocity
- Wrist median sensory latency
- Wrist median sensory nerve action potential amplitude (SNAP)
- Median mixed nerve action potential (NAP) latency
- Median mixed NAP amplitude
- Ulnar mixed NAP latency
- Median to ulnar mixed NAP latency difference
- Denervation potentials on needle EMG of APB/OP
Additional Variables
- Palmar median CMAP
- Palmar median motor latency
- Transcarpal median motor conduction velocity
- Transcarpal median motor conduction block

Table 2: EDX variables.

If the patient was seen in person, evaluation consisted of focused neuromuscular examination of the affected extremity/ies and completion of the DASH questionnaire by the patient. Patients who returned for this visit also underwent a focused, repeat EDX study to obtain median nerve conduction studies and EMG assessment of the abductor pollicis brevis (APB) muscle/opponens pollicis (OP) muscle.

Mild	Prolonged sensory or mixed NAP distal latency +/- SNAP amplitude below the lower limit of normal.
Moderate	Abnormal median sensory latency as above AND prolonged median motor distal latency.
Severe	Prolonged median motor and sensory distal latency, with either an absent SNAP or mixed NAP, or low amplitude/absent thenar CMAP AND needle EMG displaying abnormal spontaneous activity, reduced recruitment and/or abnormal motor unit morphology.

Table 3: EDX classification of CTS Severity (AANEM Guidelines) Modified severity rating: If patient had a transcarpal median motor conduction block (TMMCB), mild severity was upgraded to moderate severity. Otherwise, severity assessment remained unchanged.

For those who were found to have bilateral CTS on the initial study, both upper extremities were tested again, and for those who were found only to have unilateral CTS on the initial study, only the affected upper extremity was evaluated again. During each assessment, information on change in medical status including interventions started and on-going since the previous evaluation for treatment of CTS (particularly any surgical intervention) was also obtained. Other appropriate work, pertinent social history, and any adverse events were recorded as well.

	N	Mean	Standard Deviation

Age	41	54.34	12.142
Entry DASH	41	36.3780	18.50241
Final DASH	28	35.3043	21.12358
Left Median CMAP	36	7.4306	2.68230
Right Median CMAP	34	7.3618	2.95451

Table 4: Descriptive statistics.

Statistical analysis

Correlation coefficients were determined between EDX data variables and severity assessment, which served as the independent variables, and patients' DASH questionnaire measures, which served as the dependent variables, at initial and follow-up assessments. EDX data obtained at the follow-up visit were compared to the initial EDX data variables, and changes in EDX data were correlated to the changes in DASH questionnaire scores.

Results

The goal of this study was to determine if there is a relationship between objective EDX variables and clinical severity assessment with subjective PRO measures pre- and post-treatment. 41 subjects (35 male and 6 female) enrolled in the study. 12 had mild CTS, 23 had moderate CTS, and 6 had severe CTS according to AANEM guidelines [17]. The mean initial age of the subjects was 54.3 with a standard deviation of 12.1, and the mean initial DASH score was 36.4 with a standard deviation of 18.5. Of the 41 initial subjects, only 28 returned for their repeat study, and the mean final DASH score was 35.3 with a standard deviation of 21.1 (Table 4).

To assess whether there is a relationship between subjective PRO measures and objective severity assessment, we looked at changes in DASH score over time and relationships between DASH score and EDX severity. There was no significant change between the initial and final DASH scores (t=0.293, df=27, p=0.77), but there was a significant positive correlation between the two (r =0.63; p<.01) (Table 5), even when controlling for age (r=0.59; p<.01). However, neither the initial nor final DASH scores had a significant correlation with EDX severity (original or modified severity on each side and overall) (Table 6).

		DASH (initial)	DASH (final)	Left DMML	Right DMML	Left Median CMAP	Right Median CMAP	Patient Severity Initial
Correlation	DASH (initial)	1.00	*0.63	-0.06	-0.05	-0.08	-0.07	-0.10
	DASH (final)	0.63	1.000	-0.33	-0.25	0.11	0.31	*-0.41
	Left DMML	-0.06	-0.33	1.000	*0.61	*-0.36	-0.34	*0.72
	Right DMML	-0.05	-0.25	0.61	1.000	*-0.38	*-0.57	*0.75
	Left Median CMAP	-0.08	0.11	-0.36	-0.38	1.000	*0.56	*-0.56
	Right Median CMAP	-0.07	0.31	-0.34	-0.57	0.56	1.000	*-0.59
	Severity Initial	-0.10	-0.41	0.72	0.75	-0.56	-0.59	1.000

Table 5: Correlation matrix (Spearman's Rho) *Significant Correlation Established (p<0.05); **DMML**=Distal Median Motor Latency; **CMAP**=Compound Muscle Action Potential).

In order to determine whether patients in different EDX severity classifications experience significantly different levels of improvement in PRO measures, we compared changes in DASH score pre- and post-treatment within mild, moderate, and severe cases of CTS. Not all mild and moderate CTS cases returned for follow-up study, but all severe CTS cases did return. Interestingly, the mean DASH score for those diagnosed with mild CTS and moderate CTS increased from 39.9 to 46.6 and 34.7 to 37.7, respectively, while the mean DASH score for those diagnosed with severe CTS in the initial study decreased from 35.8 to 19.0 (Table 7).

Control Variables		DASH (I)	DASH (F)	Initial Severity (L)	Initial Severity (R)	Initial Modified Severity (L)	Initial Modified Severity (R)	Initial Patient Severity	Initial Modified Patient Severity
Age	DASH (I)	1.00	*0.59	0.22	0.11	0.25	0.16	0.09	0.25
	DASH (F)	0.59	1.00	0.37	-0.13	0.24	-0.22	-0.11	-0.14

	Initial Severity (L)	0.22	0.37	1.00	0.32	*0.65	0.29	*0.59	0.31
	Initial Severity (R)	0.11	-0.13	0.32	1.00	0.21	*0.89	*0.78	*0.70
	Initial Modified Severity (L)	0.25	0.24	0.65	0.21	1.00	0.29	0.34	*0.49
	Initial Modified Severity (R)	0.16	-0.22	0.29	0.89	0.29	1.00	*0.74	*0.81
	Initial Patient Severity	0.09	-0.11	0.59	0.78	0.34	0.74	1.00	*0.79
	Initial Modified Patient Severity	0.25	-0.14	0.31	0.70	0.49	0.81	0.79	1.00

Table 6: EDX severity Correlations when Age is Control Variable (Spearman's Rho; N=22) *Significant Correlation Established (p<0.05). **Note:** DASH (Initial or Final) did not correlate with any EDX severity measure (see rows 1 and 2).

The initial DASH score showed a significant negative correlation with age (r=-.379, p<.05) but no significant correlation with time interval between measurements (r=.047, p=.82). Additionally, age positively correlated with EDX severity assessment (r=0.615; p<0.001) and EDX modified severity assessment (r=0.666; p<0.001).

DASH (initial)				**DASH (final)**			
Severity	Mean	N	Std. Deviation	Severity	Mean	N	Std. Deviation
Mild CTS	39.9067	12	16.7579	Mild CTS	46.578	5	16.1755
Moderate CTS	34.6843	23	17.681	Moderate CTS	37.7335	17	20.9994
Severe CTS	35.8133	6	26.4937	Severe CTS	19.0267	6	17.999
Total	36.378	41	18.5024	Total	35.3043	28	21.1236

Table 7: Relationship of initial and final dash to initial EDX severity assessment.

To establish relationships between various EDX variables and PRO measures, we compared initial DASH, final DASH, and change in DASH scores with various EDX variables. Principal component analysis was used to reduce the large number of EDX variables, which accounted for 73.5% of the cumulative variance. Initial patient severity demonstrated significant negative correlations with the final DASH score and left and right median compound muscle action potentials (CMAP) and significant positive correlations with left and right distal median motor latencies (DMML) (Table 5). Change in DASH score over time was found to have significant positive correlations with left DMML decrement and right transcarpal median sensory conduction block (>50% decrement) and significant negative correlations with left median sensory nerve action potential (SNAP) amplitude decrement percentage, right needle EMG motor unit morphology abnormality, and right median forearm motor conduction velocity increment (Table 8).

Outcome Variable	**Independent Variable**	**N**	**Mean or (Median)**	**Standard Deviation or (Range)**	**Spearman's Correlation**	**P-Value**
Initial DASH	Initial L Median NAP Latency (ms)	29	(2.5)	(1.8 to Absent)	-0.38	.04
	Initial R Long Segment Median Sensory CV (m/s)	34	(42.5)	(28 to Absent)	0.39	.02
Final DASH	Final L EMG Reduced Recruitment	16	(Normal)	(Normal to Abnormal)	-0.65	.01
	Final L Median Mixed NAP Latency (ms)	21	(2.8)	(2.0 to No Response)	-0.51	.02
	Final L Transcarpal Median Sensory Conduction Block (>50% decrement)	16	(No CB)	(No CB to CB)	-0.55	.03
	Final R Median Mixed NAP Amplitude (mcv)	17	(21)	(5.0 to No Response)	0.51	.04
DASH Difference	L DMML Difference (ms)	21	-0.09	1.21	0.47	.03

	L SNAP % Difference	11	-0.11	0.43	-0.62	.04
	R EMG Motor Unit Morphology Diff	12	(Normal)	(Normal to Abnormal)	-0.65	.02
	R Forearm Motor CV Diff (m/s)	17	3.76	9.6	-0.58	.01
	R Transcarpal Median Sensory Conduction Block (>50% decrement)	10	(No CB)	(No CB to CB)	0.72	.02

Table 8: Significant (p<.05) Correlations of DASH with Other EDX Variables (Spearman's Rho).

Discussion

This prospective cohort study attempted to examine the influence of EDX parameters on PRO scores using the DASH instrument. Our study methods were similar to Bulut et al.'s study which also attempted to examine functional measures pre- and post-treatment. Both studies used severity classifications based on AANEM guidelines. However, pertinent differences include: a.) all patients in Bulut et al.'s study were treated surgically with the mini incision technique while those in our study included patients undergoing both non-surgical and surgical treatments, b.) Bulut et al.'s study used the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ) as the PRO measure while our study used the DASH, and c.) needle EMG was not performed in Bulut et al.'s study [21]. The DASH was chosen over the BCTQ in our study because although not as specific for CTS as the BCTQ, DASH is a more widely accepted and clinically used questionnaire among the hand surgery colleagues in our community and in the orthopaedic literature. The DASH questionnaire was developed by the American Academy of Orthopedic Surgeons in collaboration with the Council of Musculoskeletal Specialty Societies and the Institute for Work and Health (Toronto, Ontario) [23].

Our results showed no significant average change in DASH score over time. The study was hindered by a significant drop-out (2nd visit), which reduced its power to detect a meaningful difference and to perform multivariate regression analysis. This may have been due to selection bias because patients who did not get better agreed to come back for repeat testing while those who did get better refused repeat testing. Additionally, within the mild and moderate cases, there was an increase in mean DASH scores from the initial visit to the follow-up, which may be partially explained by the fact that those that improved did not return for follow-up as mentioned above as well as increased expectations for relief post-treatment. Counterintuitively, there was a decrease in mean DASH scores from initial visit to follow-up within severe cases, which may be due to more aggressive treatment and/or acclimation to the condition in its most severe form. This result differs from that of the Bulut et al.'s study, which found that there was significant improvement in clinical scores in all the preoperative severity classifications except the moderate grades [21].

The change in DASH score over time was positively correlated with worsening left median motor latency and increasing incidence of right transcarpal median sensory conduction block and negatively correlated with change in left median SNAP decrement, increasing incidence of right EMG motor unit morphology abnormality, and change in right median forearm motor conduction velocity. However, since the DASH scores did not change significantly over time, these correlations are of unclear significance. This finding is similar to Bulut et al.'s study in which no relationship was found between EDX severity assessment and clinical results in both pre- and post-treatment periods [21]. A study with a larger number of patients and better follow-up in the future may rectify this lack of significance and thus provide good EDX predictors for patients.

Interestingly, DASH scores showed a significant negative correlation with age of subject, but when age was controlled, no significant correlation was noted between EDX severity and DASH score. This surprising result suggests that older patients with CTS may under-report their functional difficulties due to CTS or younger patients with CTS may over-report their functional difficulties due to CTS (or a combination of both).

Our study focused on the predictive value of changes in EDX variables and severity assessments in patient outcomes regardless of treatment/s instituted (which were determined by a referring physician on a case by case basis). A future study stratifying the different treatments would be of value to identify any specific variables' predictive value to guide decisions on treatment. Taking hand dominance into account would also be helpful as it can affect a patient's perceived clinical status. Additionally, our study was limited by the typical Veterans Affairs hospital patient population (male and Caucasian dominant). A study involving a more diverse population in terms of gender and race would be useful for results to be more applicable to the general CTS population.

Conclusion

This study revealed that EDX data and severity assessment in CTS individually do not correlate with standardized PRO scores. There was also no clear predictive value of changes in EDX data and severity assessments for changes in PRO measures. Thus, objective EDX data in combination with PRO scores may be more meaningful in directing clinical care than either of them alone.

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