The Value Added by Electrodiagnostic Testing in the Diagnosis of Carpal Tunnel Syndrome

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The Value Added by Electrodiagnostic Testing in the Diagnosis of Carpal Tunnel Syndrome

By Brent Graham, MD

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Background: There is no clear-cut consensus on the best diagnostic criteria for carpal tunnel syndrome. The objective of this study was to compare the probability of carpal tunnel syndrome being present following electrodiagnostic testing with the probability of it being present after the diagnosis was established on the basis of a clinical evaluation alone.

Methods: The study sample included patients with any peripheral nerve diagnosis who had been referred to the electrodiagnostic laboratory of an academic health-care center. The probability of carpal tunnel syndrome before electrodiagnostic testing (pretest probability) was estimated with use of the CTS-6, a validated clinical diagnostic aid that is used to estimate the probability of carpal tunnel syndrome on the basis of the presence or absence of six clinical findings recorded as part of the history or noted on physical examination. All patients then underwent a standard electrodiagnostic assessment of the median nerve by a neurologist blinded to the result of the CTS-6 evaluation. Sensory nerve conduction velocity was used to classify the result of the electrodiagnostic testing as either positive or negative for carpal tunnel syndrome with use of two different criteria (one stringent and one lax) derived from the literature. The main outcome measure was the difference between the pretest and posttest probabilities of carpal tunnel syndrome.

Results: One hundred and forty-three patients were studied. The pretest probability of carpal tunnel syndrome ranged between 0.10 and 0.99 (mean [and standard deviation], 0.81 ± 0.22). Seventy-three percent of the patients had a pretest probability of at least 0.80. The average change in probability for these patients was 0.02 when the stringent electrodiagnostic criterion was used and 0.06 when the lax criterion was used. With either electrodiagnostic criterion, the majority of the large changes in probability were for patients for whom the pretest probability was ≤0.50. The probability of carpal tunnel syndrome was lowered after the electrodiagnostic testing in most of these cases.

Conclusions: For the majority of patients who are considered to have carpal tunnel syndrome on the basis of their history and physical examination alone, electrodiagnostic tests do not change the probability of diagnosing this condition to an extent that is clinically relevant.

Level of Evidence: Diagnostic Level I. See Instructions to Authors for a complete description of levels of evidence.

Carpal tunnel syndrome remains the most commonly diagnosed compressive neuropathy in the upper extremity. It is diagnosed by a broad spectrum of primary care and specialist physicians and surgeons; however, the importance attributed to the various clinical findings recorded as part of the history and noted on physical examination in the process of establishing the diagnosis varies considerably both within and across medical and surgical specialties. The absence of a clear consensus on the best clinical criteria for the diagnosis of carpal tunnel syndrome probably leads to variations in care, including mistakes in the ordering and interpretation of diagnostic tests as well as in recommending and carrying out treatment.

The reasons why clinicians use varying criteria when making a diagnosis of carpal tunnel syndrome are unknown, but it is likely that this is at least partly due to a general reliance on the absence of a clear consensus on the best clinical criteria for the diagnosis of carpal tunnel syndrome.
on the results of electrodiagnostic tests as a diagnostic gold standard. In many instances, the results of such tests trump a clinical assessment. Although there have been studies suggesting a limited role for electrodiagnostic testing in predicting the outcome of treatment, to my knowledge no one has measured the diagnostic value that electrical testing actually adds to a careful clinical assessment when the diagnosis of carpal tunnel syndrome is under consideration. Standardization of the clinical criteria for diagnosing carpal tunnel syndrome is an important step in the evaluation of the role of electrodiagnostic tests, and a diagnostic scale for carpal tunnel syndrome, the CTS-6, has been recently described. This instrument, which has been validated, is used to estimate the probability of carpal tunnel syndrome on the basis of the presence or absence of six items recorded as part of the clinical history or noted on physical examination that were weighted for their diagnostic importance.

The objective of this study was to determine the degree to which the probability of carpal tunnel syndrome as estimated clinically with use of the CTS-6 is changed by electrodiagnostic testing.

Materials and Methods

The CTS-6 represents a logistic regression model that estimates the probability of carpal tunnel syndrome on the basis of the presence or absence of six clinical findings recorded as part of the history or noted on the physical examination that were weighted for their diagnostic importance. The evaluator determines whether or not each of the findings is present and then can sum up the clinical probability of the diagnosis of carpal tunnel syndrome. Because the components of the scale have differing degrees of diagnostic importance, the specific findings in a given case may have an important influence on the probability of diagnosing carpal tunnel syndrome.

This study was conducted as a prospective, blinded investigation. All patients who had been referred to an electrodiagnostic laboratory in a tertiary care center for the evaluation of any upper-extremity peripheral nerve problem underwent an evaluation for carpal tunnel syndrome with use of the CTS-6. The diagnosis that led to the referral was not used as a criterion for entry into the study. This was a deliberate strategy to determine the discriminating capacity of the diagnostic instrument. If the study were designed to only evaluate individuals with carpal tunnel syndrome, there would be a risk of overestimating the diagnostic value of the CTS-6. Similarly, any additional history related to age, sex, body mass index, history of metabolic dysfunction (e.g., diabetes mellitus or hypothyroidism), or work history was not included in the assessment because these were not part of the clinical diagnostic instrument. A hand therapist, blinded to the suspected diagnosis, carried out the clinical evaluation. The CTS-6 assessment was used to establish a pretest probability of carpal tunnel syndrome. The patients then underwent a standard electrodiagnostic evaluation, recorded by a technician and interpreted by a neurologist, both of whom were blinded to the outcome of the CTS-6 assessment. The electrodiagnostic variable of interest was sensory nerve conduction velocity, which was measured over an 8-cm segment from the proximal edge of the carpal tunnel to the middle finger.

In order to establish the parameters for estimating the posttest probability of carpal tunnel syndrome from the electrodiagnostic test data, the literature was searched for studies describing electrodiagnostic evaluations of patients thought to have carpal tunnel syndrome on clinical grounds. An important starting point for the search was the review of the American Association of Electrodiagnostic Medicine (AAEM) Quality Assurance Committee, which was first published in 1993 and later updated in 2002. These publications established criteria for evaluating studies for methodological quality. Studies that met at least four of these six criteria were reviewed to determine if they contained sufficient data to allow calculation of the sensitivity and specificity for the test conditions reported. These values are required to calculate the positive and negative likelihood ratios for the diagnosis of carpal tunnel syndrome associated with a positive or negative test result. Most papers did not contain enough data to allow a determination of specificity because the electrodiagnostic testing was not carried out in a group of asymptomatic patients who did not have a clinical diagnosis of carpal tunnel syndrome. Only papers that reported on slowing of median nerve sensory conduction velocity were selected because this is the study carried out routinely in most laboratories to evaluate patients for carpal tunnel syndrome. However, a similar analysis could have been carried out with use of any other measure of nerve conduction velocity, such as the difference in latency between median and ulnar nerve-innervated digits or the difference in latency observed in the median nerve in the forearm and across the carpal tunnel.

Although there has been abundant study of a wide variety of electrodiagnostic parameters in carpal tunnel syndrome, very few investigations with sufficient methodological rigor have been published. Only three papers could be found that met the methodological criteria and contained enough information to calculate sensitivity and specificity. Two of these studies were used to establish a "stringent" and a "lax" definition of electrodiagnostic evidence of carpal tunnel syndrome. The outcome of the electrodiagnostic testing was classified as positive or negative with use of these two electrophysiologic definitions of carpal tunnel syndrome. The "stringent" definition of carpal tunnel syndrome was a sensory latency of ≥2.27 msec over an 8-cm interval presumably from the carpal tunnel to the middle finger, although this was not specified in the original paper. The "lax" definition was a sensory latency of >2.0 msec (also over an 8-cm interval). The sensitivity and specificity of this

| Table I: Characteristics of the Selected Electrodiagnostic Criteria |
|------------------|------------------|
| **Sensitivity**  | 0.69             | 0.92             |
| **Specificity**  | 0.97             | 0.63             |
| Positive likelihood ratio | 23 | 2.57 |
| Negative likelihood ratio | 0.32 | 0.13 |
criterion had to be interpolated from figures published in the paper because these characteristics were not specifically reported in the body of the text. The positive and negative likelihood ratios for these two criteria were calculated (Table I).

The likelihood ratio is a reflection of the effectiveness of a test in aiding the evaluation of a condition. The positive likelihood ratio is calculated as: sensitivity/(1 - specificity). The negative likelihood ratio is calculated as: (1 - sensitivity)/specificity.

The posttest probability of carpal tunnel syndrome was calculated for each of the two electrophysiologic criteria with use of the likelihood ratio formulation of the Bayes theorem of conditional probabilities: \( P(D/O) = P/(P + [(1 - P)/LR]) \), where \( P(D/O) \) = posttest probability of disease with a given test outcome, \( P \) = pretest probability, and LR = likelihood ratio. The estimate of the pretest probability of carpal tunnel syndrome based on the CTS-6 and the posttest probability of carpal tunnel syndrome estimated from this equation were correlated with use of the Pearson correlation coefficient.

The hospital institutional review board approved the study protocol. Informed consent to undergo an interview about their medical history and a physical examination for the purpose of deriving a score with the CTS-6 was obtained from all study subjects.

Results

One hundred and forty-three patients were recruited into the study. The pretest probability of carpal tunnel syndrome as estimated with the CTS-6 ranged from 0.10 to 0.99 (mean [and standard deviation], 0.81 ± 0.22). The correlation between the pretest probability estimated with use of the CTS-6 and the posttest probability following electrodiagnostic testing was calculated as: 0.91.

![Graph showing pretest versus posttest probability](image)

**TABLE II Summary of Changes from the Pretest Probability for Carpal Tunnel Syndrome After Electrodiagnostic Testing**

<table>
<thead>
<tr>
<th></th>
<th>Average Change (Standard Deviation)*</th>
<th>Absolute Change (Standard Deviation)†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stringent</td>
<td>Lax</td>
</tr>
<tr>
<td>All patients</td>
<td>−0.06 (0.14)</td>
<td>−0.11 (0.20)</td>
</tr>
<tr>
<td>Pretest probability ≥0.80</td>
<td>−0.02 (0.10)</td>
<td>−0.06 (0.16)</td>
</tr>
<tr>
<td>Pretest probability ≥0.90</td>
<td>−0.02 (0.06)</td>
<td>−0.01 (0.12)</td>
</tr>
</tbody>
</table>

*“Average” refers to the mean of P[posttest] − P[pretest] values. In some cases, this was a negative value, indicating a smaller probability of carpal tunnel syndrome being present after electrodiagnostic testing. In other cases, this value was positive, indicating that the posttest probability of carpal tunnel syndrome was higher than the pretest probability. †“Absolute change” refers to the mean of the absolute value for P[posttest] − P[pretest]. This is a measure of the change in probability in either direction, up or down.
was 0.91 (Fig. 1) when the stringent electrodiagnostic criterion was employed and 0.83 when the lax definition was employed. The majority of patients already had a substantial pretest probability of having carpal tunnel syndrome: 73% had a pretest probability of at least 0.80. The average change in probability for these patients, after the results of electrodiagnostic testing were known, was $-0.02 \pm 0.10$ when the stringent criterion was used and $-0.06 \pm 0.16$ when the lax criterion was used. For 59% of the patients, the pretest probability of carpal tunnel syndrome was at least 0.90 and the change in the posttest probability after electrodiagnostic testing ($-0.02 \pm 0.06$ and $-0.01 \pm 0.12$) was even smaller than that in the group with a pretest probability of at least 0.80.

Electrodiagnostic testing lowered the probability, as compared with the pretest value, in some cases and increased it in others; however, the absolute change in probability in either direction (either increase or decrease) was relatively small ($0.13 \pm 0.10$ when the stringent electrodiagnostic definition was used and $0.17 \pm 0.15$ when the lax definition was used).

The variables to consider in estimating the sample required for a study of this nature are the accuracy of the estimate, in this case the absolute change in probability of carpal tunnel syndrome as a result of electrodiagnostic testing, expressed as a confidence interval, the standard deviation of the estimate, and the confidence level required. For a given confidence level, the sample size increases as the desired confidence interval narrows.

### CTS-6

**A clinical aid for diagnosing carpal tunnel syndrome**

<table>
<thead>
<tr>
<th>Symptoms and history</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbness predominately or exclusively in median nerve territory</td>
<td></td>
</tr>
<tr>
<td>Sensory symptoms are mostly in the thumb, index, middle and/or ring fingers</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nocturnal numbness</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms are prominent when patient sleeps; numbness wakes patient from sleep</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical examination</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thenar atrophy and/or weakness</td>
<td></td>
</tr>
<tr>
<td>The bulk of the thenar area is reduced or manual motor testing shows strength of grade 4 or less</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positive Phalen test</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion of the wrist reproduces or worsens symptoms of numbness in the median nerve territory</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loss of 2 point discrimination</th>
<th>4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A failure to discriminate two points held 5mm or less apart from one another, in the median nerve innervated digits, is a positive test suggestive of CTS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Positive Tinel sign</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light tapping over the median nerve at the level of the carpal tunnel causing radiating paraesthesiae into the median nerve innervated digits (not proximally) is a positive test</td>
<td></td>
</tr>
</tbody>
</table>

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**Fig. 2**

CTS-6 scale in point form for clinical use. The point values are based on the regression coefficients in the logistic regression model (see Appendix).
and as the standard deviation increases: 

$$N = \frac{4z_\alpha S^2}{W^2},$$

where $z_\alpha = \text{standard normal deviate for } \alpha$ (1.96, when $\alpha = 0.05$), $S = \text{standard deviation}$, and $W = \text{width of confidence interval}$. For all participants in the study, the standard deviation for absolute change with use of the stringent criterion was 0.10 (Table II). With a sample size of 143 individuals, the width of the confidence interval, $W$, is 0.03. The conclusion is that, with use of the stringent criterion, there is a 95% likelihood that the true value for the absolute change in probability of carpal tunnel syndrome after electrodiagnostic testing is 0.13 ± 0.03. The 95% confidence interval is 0.17 ± 0.04 when the lax criterion is used.

For the group with a pretest probability of at least 0.80, the absolute change in probability was much smaller than that in the series as a whole when either the stringent criterion (0.08 ± 0.07) or the lax criterion (0.11 ± 0.13) was used. For the group with a pretest probability of at least 0.90, the values were 0.05 ± 0.04 and 0.08 ± 0.10 with use of the stringent and lax criteria, respectively. These data are summarized in Table II.

Discussion

An accurate diagnosis is the basis on which treatment and prognosis are established. The classic approach is to use information from the history and physical examination to determine a number of potential diagnoses and then perform ancillary testing as required to refine the list12. Implicit in that process is an ordering of the possible diagnoses by probability. The role of testing therefore essentially amounts to revising the probability of a diagnosis up or down, depending on the test result. In some instances, when the implication of an error is particularly serious, tests may be done to rule out an unlikely diagnosis. In other cases, testing is done to “confirm” a diagnosis, and again the need for this may be dictated by circumstances such as those around treatment.

In most instances, the value of ancillary testing should be determined by the extent to which it affects the probability of the patient having the diagnosis that had been established clinically. Clearly, there are diagnoses that cannot be well established on the basis of clinical criteria alone and appropriate...
testing may have a substantial impact in these cases. On the other hand, when a diagnosis can be reliably established clinically, testing may simply add inconvenience, delay, discomfort, and expense to the diagnostic process.

The pattern of care of patients with a possible diagnosis of carpal tunnel syndrome may vary considerably depending on the clinical background of the treating physician. Electrodiagnostic testing is almost always performed in some clinical settings and rarely used in others. These variations in the pathway of care may be related in part to the absence of consensus on the best clinical criteria for establishing a diagnosis of carpal tunnel syndrome. The CTS-6 was developed to model the practices of experts in the clinical diagnosis of carpal tunnel syndrome and has been shown to be valid. The output of the instrument reflects the probability of carpal tunnel syndrome being present, so that the clinician can then determine the need for treatment or further evaluation with electrodiagnostic testing. The logistic regression model that is the basis of the instrument can be reformatted into a point system based on the weightings of the variables in the model. That point system may prove to be more user-friendly, although this has not been tested clinically.

The present study showed that the value added by electrodiagnostic testing, in terms of changes in the probability of carpal tunnel syndrome compared with the probability established clinically, was very small for a large majority of patients referred to a tertiary care center. To a certain extent, this was due to the fact that the probability of the condition estimated on a clinical basis alone was already very high in most cases and thus the capacity to increase the probability was limited. When the pretest probability of carpal tunnel syndrome was at least 0.80, even a “negative” finding on electrodiagnostic testing according to either criterion resulted in very small reductions in the probability of carpal tunnel syndrome that would be unlikely, in most cases, to have any impact on decisions regarding treatment. The largest changes in probability were for patients with a pretest probability of approximately ≤0.50, and in almost all cases (81% when the lax criterion was used and 96% when the stringent criterion was used) the posttest probability was even lower. Whether lowering an already low probability of carpal tunnel syndrome has value is determined by the setting, but in most cases it would probably not be necessary.

These findings suggest that the value of electrodiagnostic testing in diagnosing carpal tunnel syndrome is probably much smaller than would be suggested by its current status in most settings in which carpal tunnel syndrome is diagnosed and treated. In fact, the correlation between the pretest probability established with the CTS-6 and the posttest probability calculated from the results of the electrodiagnostic testing was very high (0.91 and 0.83 with use of the stringent and lax criteria, respectively). It is true that, according to the Bayes theorem, the value of the pretest probability has a direct relationship to the posttest probability. However, the strength of the correlation indicates that posttest probabilities can be accurately predicted by pretest probabilities, and this suggests that there may not be a need for electrodiagnostic tests in many, if not most, cases. This is consistent with the data indicating that little value is added, in terms of changes in probability, by performing electrodiagnostic tests in most cases of carpal tunnel syndrome. Decisions regarding treatment and prognosis can likely be safely made on the basis of a clinical assessment alone, although there may be some instances in which a small increase or decrease in probability resulting from the outcome of electrodiagnostic testing may influence a clinical decision. The most valuable role for electrodiagnostic testing seems to be in the evaluation of patients who have a pretest probability of between about 0.60 and 0.80. There were both increases and decreases in probability in that group, although the testing lowered the pretest probability in the majority of cases. It is true that electrodiagnostic tests may indicate the presence of additional peripheral nerve pathology. However, in many instances, coexisting conditions (for example, compressive neuropathy of the ulnar nerve) should also be apparent clinically. The role of electrodiagnostic testing in establishing the severity of nerve compression is also controversial. The results of surgical intervention are not necessarily predicted by the results of preoperative electrical testing. There are also reliable and valid clinical tools for assessing symptom severity in carpal tunnel syndrome.

The main strength of this study was its prospective, blinded design. This minimized the risk of bias, especially on the part of the evaluator using the diagnostic instrument. The electrodiagnostic testing was not performed until after the results of the assessment with the CTS-6 were recorded, and those results were unknown to the neurologist and technicians performing the electrodiagnostic tests. The posttest probability was established from the quantitative measurements of sensory nerve conduction velocity and was not based on any subjective opinion of the neurologist. Furthermore, the use of the sensory nerve conduction velocity to establish the posttest probability may increase the generalizability of the study results since this parameter is commonly measured in electrodiagnostic laboratories in North America. It might be argued that there are electrophysiologic tests that would be considered more sensitive or specific for the diagnosis of carpal tunnel syndrome—for example, a comparison of conduction between the median and ulnar nerves or measurement of the distal motor latency in the median nerve. However, regardless of what electrophysiologic variable is used to define carpal tunnel syndrome, the same Bayesian analysis applies because the most important consideration should be whether the pretest probability is changed to a clinically relevant extent. The study showed that, in all likelihood, the reason why electrophysiologic testing does not change the probability of diagnosing carpal tunnel syndrome to any substantial degree is, in large measure, because the probability estimated clinically with the CTS-6 is already very high. This leads to the conclusion that, no matter what electrophysiologic parameter is considered diagnostic of carpal tunnel syndrome, it is unlikely to make a large difference in the probability that carpal tunnel syndrome is the correct diagnosis. At 0.97, the specificity of the simple criterion used in this study for the stringent definition was already very high. It might also be argued that the global assessment of a neurologist who has knowledge of the electrophysiologic findings may add to the
value of the testing process, but, once again, with a high level of pretest probability this global judgment is unlikely to add materially to the diagnosis. The CTS-6 instrument was based on the judgments of experts from a wide range of clinical backgrounds, including neurology.

The main weakness of this study relates to the setting of the investigation. It is unknown how the sample of patients referred to a tertiary care center for electrodiagnostic tests would compare with a sample referred to a community-based electrodiagnostic laboratory. The sample included all patients referred to the laboratory for testing of a peripheral nerve problem, but the most common disorder appears to have been carpal tunnel syndrome.

A second weakness may be related to the fact that one of two certified hand therapists administered the CTS-6 instrument in all 143 cases. In the original design of the study, it was thought that a hand therapist would be a reasonable surrogate for a primary care physician. This assumption could be questioned, and it is possible that the clinical skill of a hand therapist in applying this instrument may be either superior or inferior to that of the average primary care physician. A similar study to assess the prototype instrument and the point system for use by primary care physicians is currently under development. It can be concluded that certain allied health personnel, such as hand therapists, may be able to effectively screen patients for carpal tunnel syndrome using the CTS-6 and reliably produce results that are highly correlated with the outcome of electrodiagnostic testing. This could have ramifications for the use of the CTS-6 in occupational health settings.

Finally, the CTS-6, a set of clinical criteria for the diagnosis of carpal tunnel syndrome that has been shown to have strong criterion validity by virtue of its correlation with the judgments of clinical experts based on case histories, has now also been shown to be highly correlated with the results of electrodiagnostic testing. These two findings suggest that the CTS-6 could be used to standardize the diagnosis of carpal tunnel syndrome; however, the instrument still has not been independently validated in a clinical setting. This type of standardization is an important first step in evaluating the etiologic role of various exposures, including those in the workplace, in carpal tunnel syndrome. Whether the use of standardized diagnostic criteria to establish the presence of carpal tunnel syndrome and to help guide the need for and interpretation of electrodiagnostic testing would have an impact on outcomes remains to be determined. It seems obvious, however, that an accurate diagnosis is a necessary, although not clearly a sufficient, condition for successful treatment.

Appendix

The logistic regression formula for the model is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on “Supplementary Material”) and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD).

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References


