Predictors of Normal Electrodiagnostic Testing in the Evaluation of Suspected Carpal Tunnel Syndrome

Jeffrey Watson · Meijuan Zhao · David Ring

Received: 11 July 2010 / Accepted: 15 August 2010 / Published online: 19 October 2010
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Abstract Electrodiagnostic studies (electromyography and nerve conduction velocity; EMG/NCV) are used to confirm the diagnosis of carpal tunnel syndrome (CTS) and to evaluate its severity. We investigated the hypothesis that normal electrodiagnostic median nerve testing is predicted by 1) Physician pre-test confidence in the diagnosis of CTS, and 2) Puzzling patient factors. One hundred and forty consecutive patients who underwent electrodiagnostic testing to evaluate for possible CTS were reviewed retrospectively. Both physician confidence in the diagnosis of CTS and puzzling patient factors (heightened illness concern, disproportionate complaints, and vague/nonanatomical/non-characteristic symptoms) were recorded. Electrodiagnostic testing was used as the reference standard for diagnosis of CTS. Electrodiagnostic testing confirmed CTS in 115 patients and was within normal limits in 25 patients. Low physician confidence in the diagnosis of CTS was highly predictive of a normal electrodiagnostic test ($p < 0.001$), with high sensitivity (97%), moderate specificity (40%), and high overall accuracy (87%). Puzzling patient factors were moderately predictive of normal electrodiagnostic

testing ($p < 0.001$), with low sensitivity (16%), high specificity (96%), and high overall accuracy (81%). The best multivariable model retained younger age, negative Phalen's test, and low physician confidence as the best predictors of normal electrodiagnostic testing and explained 35% of the variation in test results. A model with low confidence alone explained 19% of the variation in test results. Physician intuition as recorded in the medical record in terms of puzzlement and low confidence are very specific and accurate predictors of normal electrodiagnostic testing in the setting of suspected carpal tunnel syndrome.

Keywords Carpal tunnel syndrome · Electromyography · Nerve conduction velocity · Diagnosis

Introduction

Carpal tunnel syndrome (CTS) is the most common peripheral mononeuropathy of the upper extremity [1–3]. The diagnosis of carpal tunnel syndrome can be verified objectively using electrodiagnostic testing, although the symptoms and signs of carpal tunnel syndrome are so characteristic (either intermittent numbness in the distribution of the median nerve particularly prominent during sleep and relieved by wrist splinting or, when more advanced, static numbness, atrophy, and weakness) that this is not routinely done in all settings. The concept of electrodiagnostically normal carpal tunnel syndrome is controversial—at worst this would represent very mild carpal tunnel syndrome, but might be better considered as

Type of Study: Diagnostic

Level of Evidence: Level II

J. Watson · M. Zhao · D. Ring (✉)
Orthopaedic Hand and Upper Extremity Service,
Massachusetts General Hospital,
Yawkey Center, Suite 2100, 55 Fruit Street,
Boston, MA 02114, USA
e-mail: dring@partners.org

“suspected” carpal tunnel syndrome. When electrodiagnostic testing is normal the diagnosis remains in doubt.

It is our impression that the diagnosis of electrodiagnostically normal carpal tunnel syndrome is most often applied in the context of chronic pain rather than numbness. The debate regarding electrodiagnostically normal carpal tunnel syndrome is intensified by the puzzlement and shortcomings of the treatment of chronic arm pain. The risk in this setting is that if chronic pain complaints are inappropriately ascribed to electrodiagnostically normal carpal tunnel syndrome, than an unnecessary surgery may be performed for a diagnosis that is not objectively testable or verifiable [4–8].

The aim of this study was to determine if there are differences notable prior to electrodiagnostic testing between patients that eventually have normal tests and those in whom a diagnosis of carpal tunnel syndrome is eventually confirmed. In other words, are patients with normal tests different in some clinically important and meaningful ways from patients with positive tests. Nonspecific and unverifiable diagnoses characteristically feature complaints that are vague, disproportionate, or non-anatomical and they have been associated with thought patterns that amplify the experience of pain, including depression, heightened illness concern, and pain catastrophizing [9–13].

We investigated the hypothesis that the physician’s pre-test confidence in the diagnosis of CTS and pre-test assessment of health anxiety, disproportionate complaints, and nonanatomical/noncharacteristic complaints are associated with normal electrodiagnostic testing.

Materials and Methods

Patients

The Human Research Committee at our institution reviewed and approved this investigation. We reviewed the records of 149 consecutive patients who underwent first-time electrodiagnostic testing for CTS evaluation over an 18-month period at our institution. Inclusion criteria included suspected idiopathic carpal tunnel syndrome. Exclusion criteria included systemic inflammatory illness or recent trauma. Nine total patients were excluded: three patients who had rheumatoid arthritis and six patients who had suffered a distal radius fracture to the ipsilateral limb within 6 months prior to electrodiagnostic testing.

The final cohort consisted of 140 patients. Eighty-five of the patients were female (61%) and 55 were male (39%). The average age (and standard deviation) of all patients was 56.4 ± 15.4 years (range, 21–87).

The medical record was reviewed retrospectively by an independent observer to determine physician pre-test confidence in the diagnosis of CTS and the presence of

puzzling patient factors (vague/nonanatomical symptoms, health anxiety, or disproportionate complaints). There were two classes of pre-test confidence in the diagnosis: 1) Confident diagnosis, planning potential surgery and 2) Likely not CTS and just doing the test to exclude it from the differential diagnosis.

Electrodiagnostic testing was the reference standard for diagnosis of CTS in this study. Electrodiagnostic test parameters for normal electrodiagnostic testing were: a) Median distal sensory latency less than 3.6 ms, b) Median-ulnar mixed nerve latency difference less than 0.4 ms, or c) Sensory amplitude greater than 20 μ V. Test values outside these parameters were classified as abnormal. All electrodiagnostic testing was performed using TECA Synergy N2 EMG, by Oxford Instruments Medical, Inc. The median sensory conduction was performed across the wrist with a conduction distance of 13 cm. The median nerve was stimulated at the wrist, and the antidromic sensory nerve action potentials were recorded from in the index finger. The median motor conduction was recorded from Abductor Pollicis Brevis and stimulated at the wrist 7 cm proximal to the recording electrodes.

Statistical Analysis

We evaluated the influence of the following factors in predicting electrodiagnostic test results: age, occupation, marital status, physician confidence in CTS diagnosis, presence of puzzling complaints, Tinel’s test, Phalen’s test, Durkan’s pressure provocation test, static numbness, thenar atrophy, and weakness of palmar abduction. In univariate analysis, Student’s *T*-test was used to compare the ages of patients with positive vs. normal electrodiagnostic test results. A chi-square test was used to determine whether each of the categorical independent variables was significantly associated with electrodiagnostic test results and whether puzzling patient factors were associated with diminished physician confidence in making the diagnosis of CTS. All dichotomous categorical variables were analyzed using Fisher’s exact test. Two-tailed values of $p < 0.05$ were considered statistically significant.

Backward conditional multiple logistic regression analysis was performed to identify the best predictors of normal electrodiagnostic testing. Variables achieving two-tailed *p*-values less than 0.10 in bivariate analysis were included in the multivariable models. Models achieving *p*-values less than 0.05 were considered significant.

Results

Electrodiagnostic testing confirmed CTS in 115 patients (82%) and was normal in 25 patients (18%). In bivariate

analysis, significant determinants of normal electrodiagnostic test results included younger age ($p<0.001$), negative Phalen's test ($p=0.03$), low physician pre-test confidence ($p<0.001$), and puzzling patient factors ($p=0.05$).

Low physician confidence in the diagnosis of CTS was highly predictive of a normal electrodiagnostic test result (NPV=77%), and was highly sensitive (97%), moderately specific (40%), and highly accurate (87%).

The presence of puzzling patient factors was moderately predictive of a normal electrodiagnostic test result (PPV of detecting electrodiagnostically normal patients=44%). Puzzling patient factors predicted electrodiagnostically normal test results with low sensitivity (16%), high specificity (96%), and high overall accuracy (81%). The combination of puzzling factors and low physician confidence predicted normal test results with low sensitivity (16%), high specificity (98%), and high overall accuracy (84%).

Factors not significantly predictive of normal electrodiagnostic test results included: sex ($p=0.50$), occupation ($p=0.68$), marital status ($p=0.24$), Tinel's test ($p=0.13$), Durkan's pressure provocation test ($p=0.19$), static numbness ($p=0.10$), light touch sensation ($p=0.34$), thenar atrophy ($p=0.19$), and weakness of palmar abduction ($p=0.20$).

The variables included in the backward conditional multiple logistic regression analysis included age, Phalen's test, physician confidence, and puzzlement. The best-fit model retained younger age, negative Phalen's test, and low physician confidence (r-squared=0.35, $p<0.001$).

Discussion

The current investigation supports the hypothesis that low physician pre-test confidence in the diagnosis of carpal tunnel syndrome is highly predictive of normal electrodiagnostic testing. Despite the variable predictive utility of physical examination findings in this and numerous prior studies [14–16], the data demonstrate that physicians to a large degree know who has CTS prior to electrodiagnostic testing. This is of particular importance among patients with normal electrodiagnostic testing, in whom the interpretation of both the clinical and electrodiagnostic findings remains a subject of debate.

A community-based epidemiological sample showed that up to 44% of patients referred for electrophysiologic testing for possible carpal tunnel syndrome have normal test results [17]. This retrospective analysis demonstrated that half of these patients may not receive a discrete diagnosis to explain their hand and wrist symptoms even after electrophysiologic testing [17]. It is not clear from the paper whether the chief complaint was pain or numbness, but it is probably safe to assume that it was more often pain

than numbness that went unexplained. Scientific investigations regarding carpal tunnel syndrome should make clear distinction between numbness (which is generally straightforward to work out) and pain (which is often puzzling).

The current investigation demonstrates that physician puzzlement (which has been shown in other studies [9, 10, 17–19] to associate with health anxiety, disability disproportionate to impairment, and non-specific complaints) was moderately accurate in predicting normal electrodiagnostic tests. These findings are consistent with prior work by Eisen et al., that found that 53.3% of patients who were noted to have vague clinical complaints prior to electrodiagnostic testing had a normal electrodiagnostic result [18]. Crossman et al. have also noted prominent psychological correlates of normal electrodiagnostic test results [19], including greater depression and pain related disability than patients with tests consistent with CTS [19]. Furthermore, Crossman et al. demonstrated that depression, patient-reported disability, and effectiveness ratings predicted electrodiagnostic test results 82% of the time [19].

Even when electrodiagnostic testing is abnormal there may be limited correlation with symptoms. Some authors reported a very strong association between symptoms and test results [20, 21] whereas others report no association whatsoever [22–24]. Again, a better distinction between pain and numbness might resolve this issue, because many patients with disabling chronic arm pain may also have underlying carpal tunnel syndrome (a very common condition), but the relationship between the two is debatable.

This study should be interpreted in light of its limitations. There is a spectrum bias in that a large number of patients that were confidently diagnosed with mild or moderate CTS did not have electrodiagnostic testing and therefore were not included in the study. As is the nature of retrospective investigation, the level of confidence or puzzlement of the physician referring for electrodiagnostic studies could only be recorded to the level of precision with which it was documented in the medical record. There was variation in the frequency with which different physicians documented elements of the patient presentation that we have here grouped together as “puzzling” patient factors. This may have influenced the results regarding the predictive ability of puzzlement and it is possible that puzzlement was under-reported in both the electrodiagnostically normal and abnormal patients. Additionally, the choice to group together a variety of symptoms and presentation features into a “puzzlement” category does not allow for subgroup analysis of patients with particular presentation features. As such, the study should be considered more preliminary and hypothesis generating. A study is currently underway to prospectively evaluate physician pre-test confidence and puzzlement, as well as

measures of depression, pain catastrophizing, and heightened illness concern as predictors of electrodiagnostic test results.

The observation that low physician confidence and puzzling patient factors are very specific for normal electrodiagnostic testing should engender caution and respect for the cognitive/behavioral aspects of arm illness. Both diagnoses and treatments have the potential to cause harm and an understanding of factors contributing to unexplained pain may help to minimize referral for diagnostic investigations that are unlikely to lead to improvements in a patients health [9, 25]. Although there are those who advocate operative intervention in electrodiagnostically normal patients and justify this approach based on improvement in symptoms [4–8, 26], caution is warranted in the setting of unverified speculative pathology, a risk of operative complications, and absence of data to demonstrate that the release of the carpal ligament rather than a placebo response or regression to the mean mitigates the relief of pain. We advocate an honest assessment of the patient with an empathic and hopeful discussion of uncertainty in modern medicine and the myriad opportunities for improving health status that arise from an appreciation of the role of psychosocial factors in both symptoms and disability [10]. In other words, when there is no identifiable or measurable pathophysiology, use nonspecific diagnoses and avoid invasive treatments.

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