Provocative Motor Nerve Conduction Testing in Presumptive Carpal Tunnel Syndrome Unconfirmed by Traditional Electrodiagnostic Testing

Jeffrey Bronson, MD, John Beck, MD, James Gillet, CNP,
San Diego, CA

In this controlled prospective study 22 consecutive surgical candidates with clinically diagnosed CTS and negative findings on median nerve–sensory and motor-conduction velocity tests in both hands were reexamined with a protocol incorporating 5 specific positions of the wrist. Four of the 5 positions represented maximum physiologic ranges of motion for the patient. These positions were neutral (unstressed), extension, flexion, radial deviation and ulnar deviation. Motor latency was recorded in each of the 5 positions using otherwise standard technique. The least latency value in the test sequence was subtracted from the greatest to yield a value called differential latency. Thirty-two control studies were obtained on both hands of 16 normal volunteers and were used to establish a control differential latency which was seen to have a mean of .13 ms. A 2 standard deviation z value of .11 ms was calculated, giving an upper limit of normal (control) differential latency of .24 ms. Preoperative studies yielded an average differential latency of .44 ms, with 20 of 22 patients having differential latency values of greater than .24 ms. Evaluations of these same patients 3 months after surgery showed differential latency values within the same range as those of the control group. Simple modification of standard nerve testing techniques to include positional variation increased the yield of positive test results in 20 of 22 patients with CTS whose electrodiagnostic tests otherwise produced negative findings. (J Hand Surg 1997;22A:1041–1046.)

Various objective tests have been used for the assessment of carpal tunnel syndrome (CTS), including motor nerve–conduction velocities (NCVs),[1] sensory NCVs,[2] electromyography (EMG),[3,4] magnetic resonance imaging,[5] and thermography.[6] Nevertheless, objective tests are accepted to have major shortcomings. Wright reported 90% sensitivity and 60% specificity of electrophysiologic studies in patients clinically diagnosed with CTS.[7] In 1980, Rosen and Warner reported that forceful supination of the forearm caused an increase in latency of .5 ms or more of the posterior interosseus nerve in 28 patients with symptomatic lateral epicondylitis.[8] Olehnik et al. commented that normal NCV was present in a large number of patients with pronator syndrome who had benefitted from surgical decompression.[9] They speculated that nerve compression was actually intermittent and depended on the position of the elbow and/or rotation of the forearm. Phalen reported inducing symptoms by stress-testing the wrist in flexion in patients with CTS.[10] Yoshioka et al. commented on changes in the shape of the carpal

From the Harbor-ucla Medical Center, San Diego, CA.

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Reprint requests: John Beck, MD, 2810 Camino Del Rio South, Suite 203, San Diego, CA 92108.

tunnel in various wrist positions and how that might induce symptomatic response.[11] Gelberman et al. reported on changes in Wick catheter pressures within the carpal tunnel in various wrist positions.[12] These reports led us to postulate that positional changes of the wrist influence the NCVs of peripheral nerves. We extrapolated that such changes might better demonstrate more subtle pathologies, such as abnormalities of neural excursion or intermittent local ischemia.

Since 1989, we have used perioperative nerve monitoring in conjunction with positional variation in over 350 surgeries for peripheral nerve entrapments. Initially, the justification for this monitoring was based on the fact that 85% of our cases involve peripheral nerve syndromes and 15%–20% involve nerve reoperations. Nerve monitoring provided us with information about the integrity of the nerve during surgery and showed us immediate correlation of latency changes with surgical release of observed entrapments. It was our impression from this monitoring that statistically significant variations in latency could be seen from provocative positioning of an extremity. Additionally, we observed that delayed positional latencies did not always occur in expected provocative positions. In carpal tunnel releases, some patients demonstrated visible traction of the nerve, along with prolonged latency, in provocative wrist positions other than extension or flexion. We sometimes observed maximum latencies in radial or ulnar deviation, usually in association with synovial adhesions or hypertrophy. The relevance of this is that multiple stress positions are necessary to encompass the various causes of CTS. On the basis of these experiences, we designed a protocol of 5 specific positions to test patients with CTS. We report here the results obtained in a controlled prospective study that used this protocol in 22 patients for whom the criteria of clinical CTS and negative findings on traditional electrodiagnostic tests were met.

Materials and Methods

Clinical Criteria for Test Subject Selection

All test subjects considered for inclusion in either the control group or the patient group were rated on a clinical point scale. A point was assigned for each positive response. Four history points were possible:

- Numbness and tingling in the median distribution of the hand
- Pain in the wrist or fingers or along the course of the median nerve
- Pain, numbness, or tingling at night
- Symptoms aggravated by repetitive hand activities

Six points were available from clinical examination:

- Decreased overall sensation and response to pinprick and light touch in the median distribution
- Positive Tinel sign at the carpal tunnel
- Positive Phalen sign
- Thenar weakness
- Pain aggravated by direct compression of the median nerve at the wrist
- Pain in the median distribution of the hand caused by application of a forearm tourniquet

A medical history was taken to exclude from both groups those with diabetes, rheumatoid arthritis, hypothyroidism, or cervical spine disease or those who were pregnant. Cervical radiculopathy, when appropriate, was screened with evoked potentials or EMG.

Control Subject Selection

Control subjects were chosen only when they had a positive Tinel sign on examination and no subjective complaints on the above lists. Sixteen test subjects (32 hands) were selected. Standard sensory and motor NCVs were recorded and had to be normal to allow control subjects' inclusion. Group members' ages ranged from 21 to 44 years (average, 29.5 years). Forty-four percent were men and 56% were women. No control subject had previous upper-extremity trauma or physical complaints.

Surgical Subject Selection

The decision to operate was based not on the score on our clinical point scale but rather on traditional clinical indications, as judged by the physicians. On average, patients in this group met 2 subjective and 3 objective points on our scale, however. The 22 surgical candidates were selected as follows: over an 18-month prospective period, all candidates were seen and underwent NCV testing. If a patient's latency was more than 4 ms, a value that is considered abnormal in our laboratory, or if the patient's EMG findings were positive, he or she was considered to have traditional CTS and was excluded from this study. Surgery candidates were between 21 and 59 years old (average age, 34.4 years). Twenty-seven percent were men and 73% women. There was no

indication, on the basis of symptomatology alone, prior to actual testing as to whether an individual's latency would fall above or below our cutoff of 4 ms. All patients who underwent surgery had symptoms for at least 6 months and had received conservative care for 3-6 months.

Testing Technique

A standard Kimura technique[13] for carpal tunnel motor testing was used. All tests were performed by the same neurologic technician. The recording electrode was placed over/in the abductor pollicis brevis, the reference electrode was placed 3 cm distally over the thumb metacarpophalangeal joint, and a grounding electrode was placed within 3 cm of the recording electrode on the dorsum of the thumb web. A supramaximal stimulus was introduced 8 cm proximal to the recording electrode over the course of the median nerve. Pre- and postoperative testing was performed with surface electrodes, and perioperative tests were done with sterile platinum needle electrodes. All testing was done with a Nicolet CA2000 and/or a Viking II electrophysiological monitor (Nicolet Instrument Corp., Madison, WI). Room temperature was constant within 2°C.

Derivation of the Differential Latency Value

Each patient and control subject in this study had normal standard motor and sensory latencies. Differential latency is a value proposed to be more sensitive than traditional sensory latency. The positions selected for testing were:

At rest, wrist in standard neutral position
Maximum wrist extension
Maximum flexion
Maximum radial deviation
Maximum ulnar deviation

For testing, the forearm was positioned in supination with the fingers free and the examiner grasping the patient's palm to control the wrist. After the 5 tests were performed the absolute greatest and least latencies were noted, regardless of the positions in which they were recorded, and the difference between them was calculated. The intermediate 3 latencies or duplicate values were discarded. The resulting difference was termed the differential latency value, reported in milliseconds. The results reported in this study are expressed as differential latency values.

Definition of Statistical Terms

Specific elements of statistical methods used in this study were the *z*-test, the *t*-test, the p test, and multiple regressive analysis. The *z*-test measures multiple observations and defines how many standard deviations (SDs) an observation is above the mean. It is calculated by subtracting the observation value from the mean and dividing by the SD. The *t* value is a test for the mean of a small population. It is defined as (d/SD/N)0.5, where d is the difference, SD is standard deviation of the difference, and N is the number of observations. A p value is a probability value that is never negative or zero; however, p values of .001, for example, reflect an extremely high level of confidence that a given factor is valid. Regressive analysis is a test used to define if 2 operative variables in a small population group are statistically relevant to another group or if the differences make the groups incomparable. Regressive analysis is conducted using a partial regressive coefficient and a standard error coefficient.

Results

Results of Statistical Analysis

The *z*-test was used in this study in the evaluation of the 32 control subjects' examination findings to define the control differential latency with a 95% confidence level. The mean value for the 32 studies was .13 ms, with a *z* value of ± .11 ms. This yields an upper limit of control differential latency of .24 ms.

The *t*-test was used in our study to compare the pre- and postoperative findings for the surgical group with findings for the control group. Prior to surgery, the *t*-test findings indicated that the patient group and the control group were significantly different. After surgery, the *t*-test findings demonstrated a statistically high level of confidence that latency values for the patient group then fell within the range of those for the control group.

Probability was used to compare the preoperative patient group with the control group to determine that these were distinctly different groups. The p value was .0001, indicating that this was the case. Probability was recalculated 3 months after surgery; the p value was .0001, confirming with a high level of confidence that the patient group values then fell within those of the control group.

Multiple regressive analysis was performed by a statistician to determine the significance of age and sex differences between the patient and control pop-

ulations. Age and gender differences were found not to be factors affecting the differences observed between the 2 populations.

Control Group Evaluation. Thirty-two examinations yielded a mean differential latency of .13 ms. (2 SD, + .11 ms) (Fig. 1). The upper limit of control differential latency used in this study was therefore .24 ms.

Surgical Group—Preoperative Evaluation. Twenty-two patients were evaluated. The mean differential latency was found to be .44 ms (Fig. 2). One patient had a differential latency below control value. Overall, statistical analysis expressed a high level of confidence that this was a distinct and separate group from controls.

Surgical Group—Evaluation 3 Months After Surgery. Repeat nerve testing 3 months after surgery showed that the mean differential latency for this group had become .08 ms. Statistical analysis confirmed with a high level of confidence that these patients' latencies had changed enough to fall within those of the control group (Fig. 3).

Clinical Results

At 3 months after surgery, no patient in the surgical group had more than 2 of the 10 objective and subjective complaints on our clinical scale. In addition, every patient in the group had returned to his or her usual occupation.

Discussion

Patients with clinically diagnosed CTS and negative findings on electrodiagnostic tests present a common clinical problem. For this prospective controlled study, we developed a different method of provocative testing using standard equipment and procedures. The patient's wrist is placed in 5 different provocative positions during the test. By subtracting the shortest latency value from the longest, one can obtain a final value called differential latency. By this method, we obtained positive electrodiagnostic test results in 91% of patients with CTS whose previous tests yielded negative results.

Several criticisms of this study can be made. First, provocative positioning of the wrist varies the length of the skin and the nerve, making testing inaccurate. This was considered to be taken into account by the acceptable variation in latency as defined by the control differential latency value of .24 ms obtained with 95% certainty using this method and equipment. Second, the fact that the length of time that a provocative position was maintained in this study was not stan-

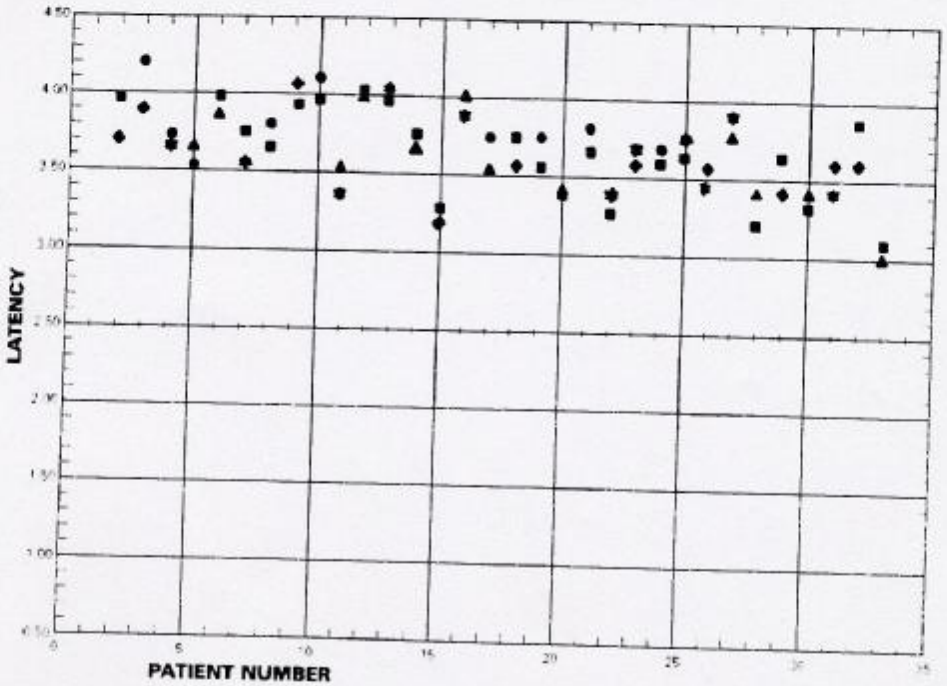

Figure 1. The longest and shortest latencies for each subject in the control group. The differential latency value is the difference between these 2 values. Mean control differential latency, .13 ms. ◆, neutral; ■, extension; ▲, flexion; ●, radial; ★, ulnar.

dardized might influence results. Our extensive experience with perioperative nerve monitoring, however, indicates otherwise. Latency changes, if present, are invariably immediate on positioning and not time dependent. Finally, one might question whether the differential latency correlates with clinical significance in CTS. Our excellent postoperative results in this study would tend to suggest that differential latency has clinical usefulness. Provocative nerve-conduction testing is a useful and simple addition to the overall evaluation of patients with CTS, particularly those with otherwise normal findings on traditional electrodiagnostic studies.

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