A new provocative test for carpal tunnel syndrome

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To establish the value of median nerve compression with wrist flexion as a provocative test for carpal tunnel syndrome (CTS), we performed a prospective study of 64 patients (95 hands) with CTS confirmed by electrodiagnostic studies and 50 normal subjects (96 hands). We recorded results for the common provocative tests (Tinel’s percussion test, Phalen’s wrist flexion test and the carpal compression test) and the new test which combines wrist flexion with median nerve compression.

Using a receiver operator characteristic curve (ROC) technique, we found that the optimal cut-off time for the wrist-flexion and median-nerve compression test was 20 s, giving a sensitivity of 82% and a specificity of 99%. These results were significantly better than for Phalen’s wrist flexion test (61% and 83%, respectively) and for the sensitivity of Tinel’s test (74%). The positive predictive values of the wrist flexion and median-nerve compression test, which is more important clinically, were 99%, 95% and 81% at population prevalences of 50%, 20% and 5%, respectively. These were significantly better than those of the three other provocative tests at each prevalence.

Electrodiagnostic studies have significant false-positive and false-negative rates in CTS, and therefore provocative tests remain important in its diagnosis. We have shown that wrist flexion combined with the median-nerve compression test at 20 s, is significantly better than the other methods, and may thus be clinically useful.

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The clinical diagnosis of carpal tunnel syndrome (CTS) is usually made on the history, physical signs and one or more positive provocative tests. The sensitivities of Phalen’s wrist flexion and Tinel’s percussion tests vary from 44% to 75% with specificities of 70% to 100%,\(^1\) and positive predictive values (PPV) of 21% to 53%.\(^5,6\)

For cubital tunnel syndrome, a combined flexion-compression test for ulnar nerve compression has been shown to increase diagnostic sensitivity, specificity and predictive value.\(^7,8\) The mechanism of the improvement is probably an increase in local neural ischaemia, which exacerbates the symptoms.\(^8\)

We hypothesised that the combination of wrist flexion with direct pressure over the median nerve would increase local ischaemia to more than either wrist flexion or nerve compression alone, and provide rapid and reproducible symptoms. We have evaluated this test by comparing it with other commonly used tests in a prospective clinical study.

Patients and Methods

From December 1995 to March 1997, 71 patients presented with clinical symptoms of median nerve compression at the carpal tunnel, giving typical histories of pain or paraesthesiae in the distribution of the median nerve, often worse at night and related to activity. Patients were excluded if they had symptoms or signs of entrapment of the proximal median nerve, cervical root pain, thoracic outlet syndrome, acute CTS, or a history of paralysis with the use of a wheelchair or walking aids. All had nerve-conduction tests and the criteria for a positive result were delay in the median nerve motor or sensory distal latency above normal limits, a distal median motor latency of 1 ms, or a distal median sensory latency of 0.5 ms more than the contralateral side.
Of the 71 patients, seven (eight wrists) with negative nerve-conduction studies were excluded leaving 23 men (30 wrists) and 41 women (65 wrists) in the study. Their mean age was 49.3 years ± 14.6 (SD) (21.5 to 83.9). The control group of 50 normal subjects (96 wrists) was either hospital personnel (25) or asymptomatic visitors (25), all with no history of nerve entrapment in the proximal or distal arm. There were 13 men and 37 women with a mean age of 46.9 ± 15.0 years (22 to 79.5). Four had intermittent paraesthesiae, and therefore only 96 hands were assessed. Electrophysiological studies were not performed on the normal subjects.

Both the clinical and control groups had a static two-point discrimination test, using a dull-pointed calliper in the axis of the finger without blanching the skin.\(^9\)-\(^11\) Abductor pollicis brevis was tested manually and graded as Medical Research Council power 0 to 5. The provocative tests were performed in random order, with one-minute intervals between tests. Tinel’s test was by gentle tapping over the median nerve at the wrist in the neutral position, and recorded as positive if the patient experienced paraesthesiae or dysaesthesia in the distribution of the median nerve.\(^12\) For Phalen’s test the patient was actively placed in complete unforced flexion, and a positive result recorded for paraesthesiae in the median nerve or exacerbation of existing paraesthesiae within 60 s.\(^13\),\(^14\) For the carpal compression test, the examiner placed two fingers or a finger and thumb over the median nerve at the carpal tunnel,\(^2\) with the wrist in the neutral position. Even, constant pressure was applied for up to 30 s, and the test was recorded as positive when it produced numbness, pain or paraesthesiae.\(^5\),\(^15\)-\(^17\)

The new test was performed with the elbow extended, the forearm in supination and the wrist flexed to 60°. Even, constant digital pressure was then applied with one thumb over the median nerve at the carpal tunnel. The time before development of paraesthesiae or numbness in the distribution of the median nerve was recorded, and the test was considered positive if symptoms occurred within 30 s.

Data analysis used contingency tables to determine the sensitivity and specificity of each test. Both positive and negative predictive values depend on the disease prevalence in the population,\(^18\) and were calculated for each provocative test for three different populations.\(^18\) A disease prevalence of 5% (0.50) represents that in a specialised hand surgery clinic, while 20% (0.20) aimed to represent patients with hand pain seen in an occupational medicine clinic or by a general practitioner. A prevalence of 5% (0.05) was chosen to reflect screening in an active working population.

We used the McNemar test to compare the sensitivity and specificity of the provocative tests, with statistical significance at \(p < 0.05\).\(^19\) We also calculated confidence intervals (CI) for positive and negative predictive values for each hypothetical population.\(^19\)

**Results**

Details of the two groups are given in Table I. In the patient group, 18 hands showed increased two-point discrimination (>6 mm) and 17 had some weakness of the abductor pollicis brevis. Five wrists in four patients had a completely negative series of provocative tests despite positive clinical histories and electrodiagnostic studies. The other 90 wrists of the 60 patients had at least one positive provocative test. In the normal group, 20 wrists in 17 subjects had at least one positive provocative test. All wrists with a positive wrist flexion-nerve compression test also had a positive carpal-compression test.

The sensitivity of the wrist flexion-nerve compression test (86%) was significantly better than that of Phalen’s test (61%; \(p < 0.0001\)), Tinel’s test (74%; \(p < 0.05\)) and the carpal-compression test (75%; \(p < 0.005\)) (Table II). The specificity of the new test (95%) was statistically significantly greater than that of Phalen’s test (83%; \(p < 0.005\)), but not significantly different from that of Tinel’s test (91%) and the carpal-compression test (93%).

In a hypothetical population with a CTS prevalence of 50%, the PPV of the new test (94%) was significantly better than that of the wrist flexion test alone (79%), but not statistically different from that of Tinel’s test and carpal compression. The NPV for this population showed a significant difference between the new test (87%) and

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**Table I.** Details of the 64 patients in the study group and the 50 normal subjects in the control group

<table>
<thead>
<tr>
<th></th>
<th>Study</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (range) in years</td>
<td>49.3 (21.5 to 83.9)</td>
<td>46.9 (22.0 to 79.5)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>41</td>
<td>37</td>
</tr>
<tr>
<td>Female</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Total wrists</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>Static two-point discrimination (&gt;6 mm)</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Weakness of abductor pollicis brevis muscle</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Mean (±SD) distal motor latency (ms)</td>
<td>5.0 ± 1.8 (92 of 95 positive)</td>
<td>N/A</td>
</tr>
<tr>
<td>Mean (±SD) distal sensory latency (ms)</td>
<td>4.9 ± 1.4 (92 of 95 positive)</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Phalen’s test (68%), but no statistically significant difference from the carpal-compression (79%) or Tinel’s tests (78%).

With a disease prevalence of 20%, the PPV of the wrist flexion-nerve compression test (81%), the carpal-compression (72%), and Tinel’s test (66%) were all significantly better than that of Phalen’s test (48%), but not from each other. The NPVs of the provocative tests were all statistically similar, ranging from 90% to 97%.

With a prevalence rate set at 5%, the NPVs of all the provocative tests were very similar (98% to 99%), but the PPV of the wrist flexion-nerve compression test (47%) was significantly better than that for both the wrist-flexion test (16%) and Tinel’s test (29%).

Both Phalen’s test and the wrist flexion-nerve compression test require a defined ‘cut-off’ time to classify the result as normal or pathological; we chose 30 or 60 s arbitrarily. We used receiver-operator characteristic (ROC) curves to show graphically the trade-off between sensitivity and specificity at different cut-off times (Figs 1 and 2).

### Table II. The sensitivity, specificity, PPV and NPV of the four provocative tests. For each PPV and NPV the associated disease prevalence of the hypothetical population was used to determine their corresponding values.

<table>
<thead>
<tr>
<th></th>
<th>Percussion (Tinel’s)</th>
<th>Wrist flexion (Phalen’s)</th>
<th>Carpal compression</th>
<th>Wrist flexion and median nerve compression (30 s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity (%) (95% CI)</td>
<td>74 (66 to 81)*</td>
<td>61 (53 to 69)*</td>
<td>75 (67 to 82)*</td>
<td>86 (80 to 92)</td>
</tr>
<tr>
<td>Specificity (%) (95% CI)</td>
<td>91 (86 to 95)</td>
<td>83 (77 to 89)*</td>
<td>93 (88 to 97)</td>
<td>95 (91 to 99)</td>
</tr>
<tr>
<td>PPV (%) (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevalence rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50</td>
<td>89 (83 to 94)</td>
<td>79 (71 to 87)</td>
<td>91 (87 to 96)</td>
<td>94 (90 to 98)†</td>
</tr>
<tr>
<td>0.20</td>
<td>66 (58 to 74)</td>
<td>48 (38 to 57)</td>
<td>72 (64 to 80)</td>
<td>81 (74 to 88)†</td>
</tr>
<tr>
<td>0.05</td>
<td>29 (21 to 37)</td>
<td>16 (9 to 23)</td>
<td>35 (26 to 44)</td>
<td>47 (38 to 56)†‡‡</td>
</tr>
<tr>
<td>NPV (%) (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevalence rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50</td>
<td>78 (71 to 84)</td>
<td>68 (61 to 75)</td>
<td>79 (72 to 85)</td>
<td>87 (82 to 93)†</td>
</tr>
<tr>
<td>0.20</td>
<td>93 (89 to 97)</td>
<td>90 (85 to 94)</td>
<td>94 (90 to 97)</td>
<td>97 (94 to 100)</td>
</tr>
<tr>
<td>0.05</td>
<td>99 (97 to 100)</td>
<td>98 (95 to 100)</td>
<td>99 (97 to 100)</td>
<td>99 (98 to 100)</td>
</tr>
</tbody>
</table>

* statistical significance in relation to wrist flexion test  
† statistical significance in relation to wrist flexion test, percussion test and carpal compression test  
‡‡ statistical significance in relation to wrist flexion with median nerve compression test at 30 s
test shows improved sensitivity as the cut-off time is extended from 5 to 20 s (Fig. 1), but after 20 s, small gains in sensitivity are accompanied by losses in specificity. This suggests that 20 s is the optimal cut-off time. This duration, rather than 30 s, at 20% and 5% prevalence (PPV of 95% and 81%, respectively) improved the PPV significantly (Table III).

Phalen's test is also timed and can be analysed by an ROC curve. Using intervals of 5 s, the optimal positive determinant was at 40 s. Compared with 60 s, this decreased the sensitivity (61% to 57%; p > 0.10) but significantly increased the specificity (83% to 94%; p < 0.005). The use of 40 s increased the PPV at each disease prevalence, but made little difference to the NPV. (Fig. 3).

**Discussion**

CTS is a most common compression neuropathy; recent studies suggest that it is due to reduced microvascular perfusion of the median nerve.\textsuperscript{20-22} External pressures of 20 to 30 mmHg have been shown to impair venous blood flow and retard axonal transport, while pressures of 130 to 150 mmHg cause a conduction block.\textsuperscript{22} Resting carpal canal pressures in patients with CTS are higher (32 mmHg) than in normal subjects (2.5 mmHg) and rise significantly (94 mmHg) with 90° wrist flexion.\textsuperscript{20} An externally applied pressure of 90 mmHg over a normal carpal tunnel has been shown to induce a complete sensory block,\textsuperscript{21,22} but the pathological changes of chronic compression make a nerve more susceptible to external pressure. The combination of wrist flexion and median nerve compression has not previously been described as a provocative test, and reports of a new test for the cubital tunnel syndrome led us to postulate that wrist flexion and median nerve compression would create a rapid rise in pressure and a quicker onset of sensory symptoms.

Our findings for the sensitivity and specificity of Tinel's and the wrist flexion tests were consistent with previous reports\textsuperscript{1-4,23,24} as were those for the carpal-compression test.\textsuperscript{2,15,17} Wrist flexion with nerve compression at 20 s showed sensitivity (82%) and specificity (99%) similar to the best reported results for other provocative tests.

All provocative tests aim to predict whether a particular patient has CTS, and the predictive values vary with the pretest probability of disease, so that any assessment of PPV and NPV requires knowledge of sensitivity, specificity and also disease prevalence in the population being studied. This will vary with the selection bias that occurs at referral. The prevalence of CTS may be as high as 50% in patients referred to a hand surgeon. The annual incidence of CTS is about 125 cases per 100 000 person years\textsuperscript{25,26} with prevalence rates of up to 5% in adult women\textsuperscript{27} and up to 15% in some occupational groups.\textsuperscript{5,6} Many reports of provocative tests for carpal tunnel syndrome reported high sensitivities and specificities, with good PPVs and NPVs,\textsuperscript{17} but the data may be misleading since they rarely consider different prevalences of disease. The use of a disease prevalence table offers more insight into the value of provocative tests.
Our use of ROCs allowed us to determine the optimum timing for PPV and NPV. For wrist flexion and nerve compression the use of 20 s significantly increased the specificity from 95% for 30 s to 99%. The PPV of the other provocative tests decreased significantly with decreasing disease prevalence, but the new test showed a PPV of over 80%, even at 0.05 prevalence.

Hypothetically, a group of patients referred to a hand surgeon with complaints of pain and paraesthesiae may have a CTS prevalence of 50% or higher. At this level all provocative tests have a PPV of 79% or greater, but a 20 s wrist-flexion and nerve compression test PPV is significantly better at 99%. The value of a positive wrist-flexion and nerve-compression test is more apparent at a lower CTS prevalence. At 5% prevalence, positive Phalen’s, Tinel’s, and carpal-compression tests are poorly predictive. Only one person in six with a positive Phalen’s test has CTS, but four in five with a positive wrist-flexion and nerve-compression test will have CTS.

ROC may be applied to any continuously measured variable, such as time. Phalen decided that his wrist-flexion test was positive if symptoms were reproduced within 60 s, but the optimal time has not been studied before. Using ROC theory, we found that Phalen’s test at 40 s had significantly improved specificity and PPV, although it was not as valuable as wrist flexion with nerve compression.

Eight wrists which were not included in our study had positive clinical histories and provocative tests, but negative electrodiagnostic studies. This emphasises the significant limitations, with false-positive and false-negative results, of electrodiagnosis for CTS. Redmond and Rivner reported electrodiagnostic studies in 50 normal asymptomatic subjects with 46% false-positive results for CTS, and the best electrodiagnostic studies report a sensitivity and specificity of 86% and 83%, respectively. It seems likely that no electrodiagnostic test can correctly identify all patients with CTS, and Katz et al considered that the clinical judgement of an experienced neurologist was best as a final determinant.

Our study has some limitations. First, our use of electrodiagnostically proven cases excluded some patients with firm clinical diagnoses of CTS. This may have led to underestimation of the true statistical values of some tests. Secondly, there is some sampling (spectrum) bias in the study group because all the patients had been referred with a suspicion of CTS. Other more obscure presentations of CTS may have given different results, and the performance characteristics of the new test in patients with less severe symptoms are yet to be determined. In addition, the lack of blinding to the subject’s symptoms could have introduced an observer bias. Finally, the study of 95 wrists in 64 patients and 96 wrists in 50 control subjects meant that there was no true independence of all variables. Findings for one wrist only would have had little significant effect on the calculated results but would have decreased the study size and slightly changed the confidence limits.

Carpal tunnel syndrome should be diagnosed clinically, and although electrodiagnostic studies are a standard method of confirmation, they have limitations. Clinical diagnostic skill must be emphasised, and the new wrist-flexion and nerve-compression test, with a cut-off at 20 s, appears to be a valuable provocative test.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


