Chapter 3. Results

Carpal Tunnel Syndrome

Question #1: What are the most effective methods and approaches for the early identification and diagnosis of carpal tunnel syndrome?

Our response to this question is comprised of a subsection on early diagnosis and a subsection on studies of diagnosis of carpal tunnel syndrome, in general. These two subsections follow our evaluation of the internal validity and generalizability of the available relevant literature. Following these two subsections, is a subsection on screening.

The subsection on early diagnosis is the most direct answer to this question, and in it we examine all articles described by their authors as pertaining to early diagnosis of these conditions. However, there are only a few such articles, and we therefore expand our response to diagnosis in general on the grounds that a "good" diagnostic method may also be a "good" method for making an early diagnosis. Ultimately, though, this reasoning is inferential, and conclusive evidence about whether a "good" diagnostic method is also useful for making an early diagnosis can only be derived by studies that directly address this issue.

The evaluation the diagnostic tests we consider is, as with any such test, greatly complicated by the absence of an independent "gold standard" test for any of the upper extremity disorders we address .[27] With no independent reference standard whose results are definitive, clinical trials of diagnostic tests for these disorders generally report differences in test results between a group of patients believed to have the condition and a group believed not to have it. Because determinations of who has and does not have the disorder are imperfect (for example, persons who do not have CTS may have symptoms of another condition that mimics CTS), it is impossible for such studies to draw accurate conclusions on how well any test performs.

The definitions of the groups being compared in these studies can also affect results by introducing spectrum effects to the study population. Criteria for selecting patients with WRUEDs may result in inclusion of only clear-cut cases of the condition, thus excluding mild cases that would be harder to diagnose. Selection criteria for patients without WRUEDs may result in inclusion of only those in ideal health, excluding those with early-stage cases of an upper extremity disorder. Together, these spectrum effects amplify the differences that are found in these studies. Thus, their results may not be applicable to the population most likely to get a test in routine practice: persons in high risk groups or with questionable symptoms.

A variety of diagnostic modalities have been reported in the carpal tunnel syndrome literature, including clinical signs (Table 7), sensory tests (Table 8), nerve conduction studies (Table 9), and imaging tests (Table 10). Furthermore, within each testing

modality, there are many specific tests and test variations, and there is little consensus about which tests are useful.

Most clinical tests to diagnose CTS (Table 7) involve specific maneuvers that elicit pain, numbness, or tingling in the median-nerve portion of the wrist. For example, in Phalen's test, the patient places both elbows on a horizontal surface with the forearms vertical, and allows the wrists to flex by gravity. If the patient feels numbness or tingling within one minute, the test is positive.[28] In Tinel's test, the examiner taps lightly over the median nerve at the wrist. If the patient feels tingling, the test is considered positive.[29]

Sensory tests for carpal tunnel syndrome (Table 8) typically involve measurement of a patient's threshold for detection of a sensory stimulus. For example, in the Semmes-Weinstein test, the examiner touches the patient with monofilaments, and the test is considered positive if the patient's sensitivity to the monofilaments falls outside normal limits.[30] Another example is the two-point discrimination test in which the examiner touches two closely-spaced prongs to the patient's fingers. The test is considered positive if the patient cannot discriminate the prongs when they are 5 millimeters apart.[31]

Nerve conduction testing for carpal tunnel syndrome can involve several variables (Table 9). Electrodes are placed in two locations along a nerve; the nerve is stimulated from one electrode, and the impulse is recorded from the other electrode. Tests can be performed on either the median nerve, ulnar nerve, or radial nerve, and can assess either motor or sensory function. The placement of electrodes can be either orthodromic (in which stimulating electrodes are placed distal to recording electrodes) or antidromic (in which stimulating electrodes are placed proximal to recording electrodes). Furthermore, many aspects of the nerve impulse can be measured such as latency, amplitude, and velocity.

Some investigators compare two or more nerve conduction tests in an attempt to assist the diagnosis of CTS (e.g., compute a difference between two latencies). We refer to these comparisons as *composite nerve conduction* tests. One potential advantage of composite nerve conduction tests is that they can compare two measurements in the same individual, thereby controlling for the effect of age on single nerve conduction tests.[97]

Imaging tests for carpal tunnel syndrome include radiography (conventional film x-ray), computed tomography (CT) scan, magnetic resonance imaging (MRI), and ultrasound. Using these methods, investigators attempt to measure the size of anatomical features such as the carpal tunnel or the median nerve. Radiologists may also look for qualitative signs of CTS, such as bowing of the flexor retinaculum or a flattened shape of the carpal tunnel.[98] CTS may also manifest itself through changes in the appearance of the image, such as changes MR signal intensity of the median nerve. One cannot generalize that CTS will always be represented by an increase in signal intensity, because the relative contrast of different tissues is a function of the specific MR pulse sequence used.[99] Within a given study, if the same pulse sequence is used, the effect on appearance of normal and abnormal tissue is expected to be consistent.

Many different measurements are possible from a single image. Some of them may be useful in diagnosis of CTS while others are of no use at all. Furthermore, radiologists may take several of these measurements into account when judging an image as positive or negative for CTS. When assessing imaging tests for CTS, one must be specific as to the particular image parameter or combination of parameters being used, and avoid generalization from effectiveness of one imaging measurement to effectiveness of another. Because they were so numerous, we did not tabulate all imaging measurements reported in clinical trial articles, but instead we tabulated the use of each imaging modality (x-ray, CT, MRI, or ultrasound).

Imaging tests, particularly film radiography, may be used to rule out other causes of hand and wrist symptoms, such as fractures or osteoarthritis [100] and thus may have a role in differential diagnosis of CTS, even if they are not themselves tests for CTS.

As noted above, the vast majority of CTS diagnostic trials compared groups of patients with known or suspected disorders and groups of healthy normal controls. Therefore it is worth summarizing the difficulties with such studies:

- Potential spectrum bias because the controls are required to be asymptomatic, and subjects with unrelated upper extremity disorders are excluded. In routine practice, the spectrum of negative cases is likely to include patients with abnormalities that might mimic the condition being tested for, thereby reducing test specificity and positive predictive value.

- Potential spectrum bias when severe or obvious cases are selected for in patient inclusion criteria, and patients with mild disorders are excluded. In routine practice, the spectrum of patients with CTS is likely to include mild cases that may not be detected by the diagnostic test, thereby reducing sensitivity and negative predictive value.

- The converse of the above spectrum bias, where inclusion criteria are designed to study patients with mild disorders. Studies of patients with only mild disease will underestimate test performance.

- Potential age bias arising from selection of young hospital or laboratory workers as controls rather than persons of the same ages as CTS sufferers. Where possible, we recorded mean ages of CTS and control groups in each study, and identified studies in which the mean ages of the groups differed by 5.0 years or more.

Potential sex bias arising from different sex distributions in the patient group and the control group. Where possible, we recorded the sex distributions of CTS and control groups in each study, and identified studies in which the percentage of females differed by 20 percentage points or more.

Table 7. Clinical Signs and Symptoms Used to Diagnose CTS

Test	Definition
Closed fist test[101]	The patient makes a fist. If the patient feels tingling within one minute, the test is positive.
Combined Phalen's and Durkan's test[102]	With the patient's elbow extended, the forearm in supination, and the wrist flexed to 60 degrees, the examiner uses one thumb to apply pressure over the carpal tunnel. If the patient feels tingling or numbness within 30 seconds, the test is positive.
Decreased muscle strength[103]	Maximum force exerted by the patient on a measurement device.
Durkan compression test[104]	This test is also called the carpal compression test. With the patient's wrist in a neutral position and the forearm supinated, the examiner uses his/her thumbs to compress the wrist at the median nerve. If the patient feels numbness or tingling within 30 seconds, the test is positive.
Flick test[105]	The patient is asked: "What do you do with your hands when your symptoms are at their worst?" If the patient shakes or flicks the hands, the test is positive.
Gilliat tourniquet test[106]	The examiner inflates a blood pressure monitor on the patient's arm proximal to the elbow. If the patient feels numbness or tingling within one minute, the test is positive.
Grip strength[107]	Force measured when patient squeezes a measurement device using the whole hand.
Hypesthesia[103]	Also called hypoesthesia. It refers to decreased sensitivity to touch.
Pain on VAS[108]	Pain as measured by a visual analog scale in which the patient rates the subjective degree of pain by placing a mark on a graphical bar.
Paresthesia in APB[109]	Tingling in the abductor pollicus brevis muscle of the hand.
Phalen's test[28]	This test is also called the wrist flexion test. The patient places both elbows on a horizontal surface with the forearms vertical, and allows the wrists to flex by gravity. If the patient feels numbness or tingling within one minute, the test is positive.
Pinch strength[107]	Force measured when patient squeezes a measurement device using the thumb and a finger
Symptoms measured systematically[29]	Any symptoms of carpal tunnel such as pain, tingling, or numbness, as measured by a questionnaire or a hand diagram.
Symptoms during ultrasound[110]	Whether the patient experiences carpal tunnel symptoms when the wrist is stimulated with an ultrasound transducer.
Reverse Phalen's test[111]	This test is also called the wrist extension test. The patient extends both wrists and fingers. If the patient feels numbness or tingling within two minutes, the test is positive.
Thenar atrophy[103]	The degree of wasting in the thenar muscle of the hand.
Thenar weakness[31]	The degree of weakness in the thenar muscle of the hand.
Tinel's test[29]	This test is also called Hoffman-Tinel's test. The examiner taps lightly on the medial aspect of the wrist. If the patient feels tingling, the test is positive.

Sources: Massy-Westrop[112] and ECRI review of clinical trial articles

Table 8. Sensory tests for Diagnosis of CTS

Test	Definition
Current perception[113]	Whether the patient's threshold for perception of electrical current is within normal limits.
Moving two-point discrimination[107]	The examiner touches two closely-spaced prongs to patient's fingers and moves them distally. The test is positive if the patient cannot discriminate the prongs when they are 4-6 millimeters apart.
Object identification[114]	The patient blindly feels wooden shapes and is asked to identify them.
Pinprick sensation[109]	Whether the patient has normal pinprick-induced sensation.
Pressure measurement[115]	Whether the patient's threshold for perception of pressure is within normal limits.
Ridge threshold[116]	The patient places an index finger on a circular disc that has a small ridge. If the patient's threshold for detection of the ridge is abnormal, the test is positive.
Semmes-Weinstein monofilament[30]	This test is also called the von Frey hairs test. The examiner touches the patient with a series of standardized nylon monofilaments, and records the smallest monofilament the patient can detect the presence of.
Static two-point discrimination[31]	The examiner touches two closely-spaced prongs to patient's fingers and holds them still. The test is positive if the patient cannot discriminate the prongs when they are 5 millimeters apart.
Temperature measurement[117]	Whether the patient's threshold for perception of temperature, heat pain or cold pain is within normal limits.
Tuning fork[30]	The examiner hits a metal tuning fork which vibrates, and the patient's threshold for detection of vibration is determined. If the threshold falls outside of normal limits, the test is positive.
Vibrometer[118]	An instrument vibrates at varying frequencies, and the patient's threshold for detection of vibration is determined. If the threshold falls outside of normal limits, the test is positive

Sources: Massy-Westrop[112] and ECRI review of clinical trial articles

Table 9. Definitions of Nerve Conduction Parameters

Test	Definition
Nerves tested	
Median nerve	The central nerve that is believed to be impaired in carpal tunnel syndrome. It innervates the thumb, index, middle, and ring fingers.
Ulnar nerve	The nerve on the medial side of the arm that innervates the ring and little fingers. Some researchers compare median and ulnar nerve conduction tests to diagnose carpal tunnel syndrome.
Radial nerve	The nerve on the lateral side of the arm that innervates the thumb. Some researchers compare median and radial nerve conduction tests to diagnose CTS.
Motor or sensory	Whether the test assesses motor or sensory nerve function.
Orthodromic or antidromic	The relative placement of the stimulating and recording electrodes. If the stimulating electrode is distal to the recording electrode (i.e., the stimulator is further from the torso), the test is orthodromic. Conversely, if the stimulating electrode is proximal to the recording electrode, (i.e., the stimulator is closer to the torso), the test is antidromic. These terms apply to sensory tests but not to motor tests.
Electrode placement sites	
Abductor pollicus brevis muscle (APB)	A muscle in the hand that is used to record median motor parameters.
Abductor digiti minimi (ADM)	A muscle in the hand that is used to record ulnar motor parameters.
Parameters Measured	
Latency	The time in milliseconds (ms) between stimulation and recording of an electrical impulse.
Onset latency	The time in milliseconds (ms) between stimulation and recording of an electrical impulse when measured to the beginning of the action potential.
Peak latency	The time in milliseconds (ms) between stimulation and recording of an electrical impulse when measured to the largest amplitude of the action potential.
Velocity	Speed of nerve conduction in meters per second (m/s)
Amplitude	Size of the action potential in microvolts (uV)
Presence/absence	Whether the nerve action potential was recordable. In severe cases, some action potentials may not be recordable.
Inching test	A series of nerve conduction tests designed to locate specific areas of nerve slowing. It can be performed orthodromically or antidromically. Electrodes are placed in 9-12 locations which are each a small distance (e.g., 1 cm) apart. By stimulating a fixed site (e.g., the middle finger) and recording at several locations (e.g., 9 evenly-spaced locations along the wrist), researchers can measure the nerve latencies and velocities for each segment along the nerve.

Table 10. Imaging Modalities for the Diagnosis of CTS

Test	Definition
Film	Plain film radiograph (x-ray).
CT	Computed tomography scan. No articles reported use of obsolete (first- or second-generation CT scanners).
MRI	Magnetic resonance imaging scan. No articles reported use of obsolete or prototype MR scanners
Ultrasound	Ultrasonic imaging

Evidence Base

Articles were included in this analysis if they reported counts of positive and negative test results for at least one test, and they included ten or more patients. Having sufficient data from each included study to complete the 2 x 2 diagnostic truth table is important, because sensitivity and specificity must be measured simultaneously, using the same diagnostic threshold. Otherwise, the threshold could be shifted to favor the reported statistic at the expense of the unreported one.

Not all of the articles we examined are addressed in this evidence report. However, data from the articles we did not address are provided in the evidence tables in the appendix. We included articles in these evidence tables, regardless of their level of reporting, if their authors described them as screening studies or studies on "early diagnosis" of CTS.

The evidence tables thus list 205 articles that met our *a priori* inclusion criteria. We subsequently excluded 16 of them. Each of these excluded articles is listed in Table 11 along with its reason for exclusion. Some articles were excluded for more than one reason, but only the first reason is listed in the table. Therefore, this table cannot be used to determine what percentage of the literature suffered a specific flaw. The reasons for exclusion of each study in the table were each confirmed by a second analyst. In case of disagreement, the study was not excluded.

After these exclusions, 189 articles remained for analysis, with a total of 38,087 participants in these studies. The majority of studies (110 or 58%) were conducted outside the United States, and almost all of the studies (184 or 97%) were done at a single center.

In order to be included in meta-analyses of diagnostic trial results, articles had to report sufficient data to permit calculation of sensitivity and specificity for the test in question. In other words, counts of positive and negative test results had to be reported, percentages had to be reported with sufficient data on numbers of patients and controls for us to recalculate the 2 x 2 table, or results for each individual patient had to be reported. Patient-level data were reported in 19 of the 189 articles, and counts for at least some patient groups were reported in 131. Only summary statistics (typically group means) were reported in 39 articles. Even though sensitivity and specificity were not reported in

these articles, they were included in the analysis because they met other criteria, such as reporting "early diagnosis" of CTS or an intent to evaluate diagnostic tests in a screening population. In 129 of the articles (68%), it was possible to determine sensitivity and specificity for at least one test from the reported data; in 79 of the articles, the authors themselves reported sensitivity and specificity.

Table 11. Excluded Studies

Author	Reason for Exclusion
Ikegaya[119]	Special patient population (dialysis)
Tackmann[120]	No diagnostic data
Jordan[121]	Reported only statistical significance of results
Sivri[122]	Special patient population (arthritis), only 2 cases of CTS
Stolp-Smith[123]	Special patient population (pregnant women), only 5 cases of CTS
Dlabalová[124]	All patients post-surgery for CTS
Lazaro[125]	All patients post-surgery for CTS
Nakamichi[126]	All patients post-surgery for CTS
Williams[127]	Discrepancies in reported results; 2 x 2 table could not be accurately reproduced by ECRI.
Mossman[128]	Published as letter rather than full paper; 2 x 2 table could not be accurately reproduced by ECRI.
Westerman[129]	Discrepancies in reported number of patients, unexplained exclusions of patients.
Herrick[130]	Combined results from CTS patients and patients with other conditions.
MacDermid[131]	Combined results from CTS patients and patients with other conditions.
Gerrning[132]	Combined results from CTS patients and patients with other conditions.
Byl[133]	Combined results from CTS patients and patients with other conditions.
Palmer[134]	Combined results from CTS patients and patients with other conditions.

Internal Validity of Results

To evaluate the quality of this literature base, we determined what proportion of articles reported various details of study methods or results. Reporting of these details is necessary to verify the internal validity and generalizability of study results. Reporting of characteristics affecting the internal validity of the results (the degree to which the reported results reflect the true performance of the test in the conditions of the particular study) is summarized in Table 12; this table includes all 189 articles on CTS diagnosis that were abstracted into the database. Details of the studies eventually included in quantitative analyses are listed in Table 13.

The design of most studies raised the possibility of age bias in which patients were markedly older than controls. Some nerve conduction measurements become slower as people age,[97] thus if patients are older than controls, the study will overestimate the

effectiveness of some nerve conduction tests. For this analysis, we defined age bias as a difference of five years or more between the mean age of patients and the mean age of controls. If a study reported ages of more than one group of carpal tunnel patients or more than one group of controls, we used the ages that implied the least amount of age bias in the study. This conservative approach tends to underestimate the amount of age bias in the studies.

Of 189 carpal tunnel studies we examined, 35 did not include a separate control group and 65 failed to report mean or median ages for one or both groups. That left 89 studies for which we could determine whether there was an age bias. Of these 89 studies, 52 had no age bias according to our definition. In 36 studies, patients were five years or more older than controls, while in one study[135], controls were five years or more older than patients. In only 12 articles were all patient groups within one year of the controls in mean age. This suggests that there is little use of age-matching to ensure that age bias does not affect results, even though it is known that results of some diagnostic tests are affected by age.

Figure 7 plots each study using the mean age of controls on the horizontal axis and the mean age of patients on the vertical axis. The solid diagonal line represents the points at which patients and controls had the same age. The dashed diagonal lines represent the points at which patients and controls were five years apart. The plot shows that patients tended to be older than controls. Whereas patients were older than controls in 76 studies, the reverse was true in only 11 studies (in the remaining two studies, the group means were the same).

A similar analysis was done for possible sex bias. We arbitrarily defined potential sex bias as a difference of 20 or more percentage points in the proportions of females in the patient group and in the control group. As with the age bias analysis, when a study had more than one carpal tunnel group or more than one control group, we used a conservative approach by selecting groups that minimized potential sex bias. This approach will underestimate the amount of potential sex bias.

Of 189 carpal tunnel diagnostic studies recorded in the database, 35 did not contain a separate control group, and 65 did not report the sex distribution for one or both of the CTS and control groups. There were 89 studies for which we could determine whether there was a sex bias. Note that these were not the same 89 studies for which we could determine age bias; 21 studies reported age but not sex, and 21 studies reported sex but not age.

Of these 89 studies, 65 did not meet our definition of possible sex bias. In 21 studies, the percentage of females in the CTS group was 20 or more percentage points higher than the control group. In 3 studies, the percentage of females in the CTS group was 20 or more percentage points lower than in the control group.

Figure 8 plots the sex distribution of each study, using the percentage of females in the control group on the horizontal axis and the percentage of females in patient group on the

vertical axis. The plot shows that the percentage of females tended to be higher in patient groups than in control groups. The percentage of females in the patient group was greater than the percentage of females in the control group in 63 of the 89 studies. The reverse was true in only 13 studies. There were 13 studies in which the percentages were equal.

We defined studies as sex-matched if the proportion of women in each patient groups differed two percentage points or less from the proportion of women in the control group. Using this definition, 20 of the 89 studies (22%) could be called sex-matched. To the extent that sex affects the diagnostic tests for CTS, there is a potential for sex bias in the results. Despite this possible bias, few studies controlled for differing proportions of men and women in their CTS and control groups. These differences, and age differences in patient and control group, are components of the evaluation of diagnostic clinical trial results.

Other study and patient characteristics that potentially affect diagnostic results are just as poorly reported in the clinical trial articles on CTS diagnosis. Patient inclusion criteria were reported in nearly all studies (98%), but exclusion criteria were reported in less than half (48%, Table 12). Lack of reporting does not necessarily mean that studies are free of selection bias. Patients' comorbidities were reported in only 24% of articles even though some may affect test results. Methods for evaluating the diagnostic tests were also rarely reported.

Blinding of test operators and readers to whether a subject was in the CTS or control group was reported in 7-12% of articles, and only 2 of the 29 articles included in our analyses (7%, Table 12). Blinding protects against the potential for intentional or unintentional bias in performing and interpreting the test. Groups of workers in the same hospital or university as the investigators were often used as a convenient source of asymptomatic control subjects. Without blinding, the persons evaluating those subjects would know that familiar persons from around the institution are likely to be controls who do not have CTS, and could consciously or unconsciously bias their findings toward the negative. While some studies may have used blinding without reporting it, one cannot assume that this is so.

Use of multiple readers was not widely reported, and where there were multiple readers reported, only 4 of 7 articles reported how they arrived at conclusions. This could affect the internal validity of the conclusions in studies where multiple readers interpreted each test and then met with each other to resolve their differences in interpretation. This practice can reduce interobserver variability and thus may overestimate the true performance of tests which normally are interpreted by just one person.

Generalizability

Reporting statistics on characteristics pertaining to the generalizability of each article's results on them are found in Table 14. Details of the studies in the quantitative analyses are reported in Table 15. Some of these characteristics, like age and sex, can affect both internal validity and generalizability. Even if a study is free of age bias (the ages of the

control subjects are similar to the ages of the CTS patients), it is possible that the results may not be generalizable because the ages of the patients in a clinical trial of a test are different from the ages of patients encountered in routine use of the test.

In this literature, reporting of patient comorbidities was particularly bad. Only 46 of the articles (24%) reported any comorbidities at all. Duration of patients' conditions was reported in only 18 studies (10%) even though this variable is an indicator of condition severity.

Ninety-eight CTS diagnostic articles (52%) reported patient selection criteria that had the potential to bias studies towards including more easy cases (e.g. including only cases of severe CTS) or more difficult cases to diagnose (e.g. including only cases where other diagnostic tests were equivocal). These criteria represent potential for bias but not conclusive proof of bias, thus we did not exclude such studies. Instead, we used potential selection bias in our analyses of homogeneity, by separately analyzing the homogeneity of studies with and without these potential biases. Generalizability of study results is also affected by the possible spectrum bias arising from study designs where patients with known CTS are compared to healthy volunteers, and the absence of a "gold standard" test for diagnosis of CTS.

Incomplete reporting of important study design and patient characteristics prevents one from ruling out selection biases and other confounding factors as the cause of clinical trial results. The quality of this evidence base is not sufficient to permit us to draw reliable conclusions from a single study. Meta-analysis and heterogeneity analysis can be used to try and identify the effects of these study variables on study results.

Table 12. Summary of Study Characteristics Affecting Internal Validity

Study characteristic	Number of studies reporting (percentage)	Specifics (percentage)
Whether trial was funded by a for-profit institution	24 (13%)	For-profit funding: 3 (2%) No for-profit funding: 21 (11%)
Was selection of patients prospective or retrospective?	75 (40%)	Prospective: 58 (28%) Retrospective: 17 (9%)
Patient inclusion criteria	185 (98%)	See **Table 46**
Patient exclusion criteria	87 (46%)	See **Table 46**
Was sex distribution of patients reported?	131 (69%)	[a]Percentage female: 61.5%
Was the percentage of females in the patient group within 20 percentage points of the control group?	89 (47%)	Yes: 65 (34%) No, patients were = 20% more female: 21 (11%) No, controls were =20% more female: 3 (2%)
Were patient ages reported?	123 (65%)	[a]Mean age 48.1 years
Was the mean patient age within 5 years of the mean control age?	89 (47%)	Yes: 52 (28%) No, patients were = 5 years older: 36 (19%) No, controls were =5 years older: 1 (1%)
Was duration of patients' condition reported?	18 (10%)	[a, b]Mean duration 28.1 months
Were patient comorbidities reported?	46 (24%)	NA
Was the test operator blinded?	13 (7%)	Yes: 13 (7%)
Was the test reader blinded?	23 (12%)	Yes: 23 (12%)
Were there multiple test readers?	7 (4%)	2 readers: 4 (2%) 3 readers: 2 (1%) 4 readers: 1 (1%)
What was the method for multiple test readers?	4 (57% of studies reporting multiple readers)	Independent: 2 (1%) Mean: 1 (1%) Consensus: 1 (1%)
Was the test compared to an independent reference standard?	38 (20%)	Yes: 38 (20%)
Were all patients given the test and the reference standard?	28 (15%)	Yes: 28 (15%)

Key:
NA—not applicable
[a]Calculated on a per-patient basis (i.e., weighted by number of patients in each study reporting this characteristic)
[b]Studies reporting median duration [109,136,137] were excluded from calculation.

Table 13. Study Characteristics Affecting Internal Validity of Results

Article	Funded by for-profit institution?	Inclusion criteria reported?	Exclusion criteria reported	Method of diagnosis reported	Patient selection	Comorbidity reported	[a]Percent female	Possible sex bias	[a]Mean age	Possible age bias	[a]Mean duration of condition	Test operator blinded	Test reader blinded	Multiple readers	Method for multiple readers	Independent reference standard	Were patients given both test and reference
Distal Motor Latency: Unspecified Diagnosi s Patient Group																	
Rosén, 1993 [138]	NR	Yes	Yes	Yes	NR	NR	75%	P	41	No	NR	NR	NR	NR	NR	No	No
Marin, 1983 [139]	NR	Yes	NR	NR	NR	NR	86%	P	49	P	13	NR	NR	NR	NR	No	No
Kimura, 1979 [140]	NR	Yes	Yes	Yes	NR	NR	75%	No	48	No	NR	NR	NR	NR	NR	No	No
Loong, 1972 [141]	NR	Yes	NR	NR	NR	NR	100%	No	43.7	MNR	12.7	NR	NR	NR	NR	No	No
Plaja, 1971 [142]	NR	NR	Yes	NR	Retrospective	NR	NR	GNR	NR	MNR	NR	NR	NR	NR	NR	No	No
Distal Motor Latency: Symptoms/Presented Patient Groups																	
Murthy, 1999 [143]	NR	Yes	NR	Yes	NR	NR	NR	GNR	NR	ANR	NR	NR	NR	NR	NR	No	No
Atroshi, 1996 [136]	No	Yes	NR	NR	Prospective	Yes	69%	No	52	P	24	NR	NR	NR	NR	No	No
Kuntzer, 1994 [144]	NR	Yes	Yes	NR	Prospective	NR	80%	P	51	P	NR	NR	NR	NR	NR	No	No
Chang, 1991 [145]	NR	Yes	Yes	NR	NR	Yes	79%	GNR	42.3	No	NR	NR	NR	NR	NR	No	No
Cioni, 1989 [146]	NR	Yes	Yes	NR	NR	NR	16%	C	46.4	P	NR	NR	NR	NR	NR	No	No
Messina, 1980 [120]	NR	Yes	NR	NR	NR	NR	NR	GNR	45.1	No	NR	NR	NR	NR	NR	No	No
Melvin, 1972 [147]	NR	Yes	NR	NR	NR	NR	NR	GNR	NR	ANR	NR	NR	NR	NR	NR	No	No
Loong, 1971 [148]	NR	Yes	Yes	NR	NR	Yes	100%	No	NR	ANR	7.6	NR	NR	NR	NR	No	No
Palmar Sensory Latency: Symptoms/Presented Patient Groups																	
Murthy, 1999 [143]	NR	Yes	NR	Yes	NR	NR	NR	GNR	NR	ANR	NR	NR	NR	NR	NR	No	No
Girlanda, 1998 [149]	NR	Yes	Yes	NR	NR	Yes	93%	GNR	39	ANR	48	NR	NR	NR	NR	No	No
Chang, 1991 [145]	NR	Yes	Yes	NR	NR	Yes	79%	GNR	42.3	No	NR	NR	NR	NR	NR	No	No
Jackson, 1989 [150]	No	Yes	Yes	NR	NR	Yes	82%	No	52.6	P	NR	NR	NR	NR	NR	No	No
Escobar, 1985 [151]	NR	Yes	Yes	NR	NR	Yes	70%	No	NR	ANR	NR	NR	NR	NR	NR	No	No

Article	Funded by for-profit institution?	Inclusion criteria reported?	Exclusion criteria reported	Method of diagnosis reported	Patient selection	Comorbidity reported	[a]Percent female	Possible sex bias	[a]Mean age	Possible age bias	[a]Mean duration of condition	Test operator blinded	Test reader blinded	Multiple readers	Method for multiple readers	Independent reference standard	Were patients given both test and reference
Phalen's Maneuver: All Patient Groups																	
Szabo, 1999 [152]	No	Yes	NR	Yes	Prospective	NR	76%	No	NR	ANR	NR	NR	Yes	NR	NR	No	No
Fertl, 1998 [153]	NR	Yes	Yes	Yes	Prospective	NR	83%	P	55.5	P	NR	Yes	Yes	NR	NR	No	No
Gerr, 1998 [31]	NR	Yes	Yes	Yes	NR	NR	72%	No	46.6	P	NR	NR	NR	NR	NR	Yes	No
Ghavanini, 1998 [154]	NR	Yes	Yes	Yes	Prospective	NR	81%	No	40	No	15	NR	NR	NR	NR	No	No
Tetro, 1998 [102]	No	Yes	Yes	Yes	Prospective	NR	64%	No	49.3	No	NR	NR	NR	NR	NR	No	No
González del Pino, 1997 [104]	NR	Yes	NR	Yes	Prospective	NR	81%	No	50	No	37.9	NR	NR	3	NR	Yes	Yes
De Smet, 1995 [101]	NR	Yes	NR	Yes	NR	NR	88%	C	49.2	C	NR	NR	NR	NR	NR	No	No
Werner, 1994 [111]	NR	Yes	NR	Yes	NR	NR	NR	GNR	NR	ANR	NR	NR	NR	NR	NR	No	No
Durkan, 1991 [155]	No	Yes	NR	Yes	NR	NR	NR	GNR	45	ANR	NR	NR	NR	NR	NR	Yes	Yes
Gellman, 1986 [106]	No	Yes	NR	Yes	NR	Yes	74%	GNR	NR	ANR	NR	NR	NR	NR	NR	Yes	Yes
Tinel's Sign: All Patient Groups																	
Szabo, 1999 [152]	No	Yes	NR	Yes	Prospective	NR	76%	No	NR	ANR	NR	NR	Yes	NR	NR	No	No
Gerr, 1998 [31]	NR	Yes	Yes	Yes	NR	NR	72%	No	46.6	P	NR	NR	NR	NR	NR	Yes	No
Ghavanini, 1998 [154]	NR	Yes	Yes	Yes	Prospective	NR	81%	No	40	No	15	NR	NR	NR	NR	No	No
Tetro, 1998 [102]	No	Yes	Yes	Yes	Prospective	NR	64%	No	49.3	No	NR	NR	NR	NR	NR	No	No
González del Pino, 1997 [104]	NR	Yes	NR	Yes	Prospective	NR	81%	No	50	No	37.9	NR	NR	3	NR	Yes	Yes
De Smet, 1995 [101]	NR	Yes	NR	Yes	NR	NR	88%	C	49.2	C	NR	NR	NR	NR	NR	No	No
Durkan, 1991 [155]	No	Yes	NR	Yes	NR	NR	74%	GNR	45	ANR	NR	NR	NR	NR	NR	Yes	Yes
Seror, 1987 [156]	NR	Yes	Yes	Yes	NR	NR	79%	No	56.8	No	NR	NR	NR	NR	NR	No	No
Gellman, 1986 [106]	No	Yes	NR	Yes	NR	Yes	NR	GNR	NR	ANR	NR	NR	NR	NR	NR	Yes	Yes
Gelmers, 1979 [29]	NR	Yes	Yes	Yes	NR	NR	81%	No	57	No	NR	NR	NR	NR	NR	Yes	No
Stewart, 1978 [157]	NR	Yes	Yes	Yes	NR	Yes	81%	No	55	No	NR	NR	NR	NR	NR	Yes	No

Key:

[a]Percent female, mean age, and mean duration of condition for CTS patients

Possible sex bias: No—proportion women in epicondylitis group within 20% of proportion of women in control group; P—Patients were more likely to be female; C—Controls were more likely to be female; GNR—Genders not reported for both groups; NC—Study did not contain a separate control group

Possible age bias: No—mean age of epicondylitis group within 5 years of mean age of control group; P—Patients were older than controls; C—Controls were older than patients; ANR—Ages not reported for both groups; NC—Study did not contain a separate control group

Method for multiple test readers: Indep—Independent

Figure 7. Mean Ages of Patient and Control Groups in CTS Diagnostic Studies

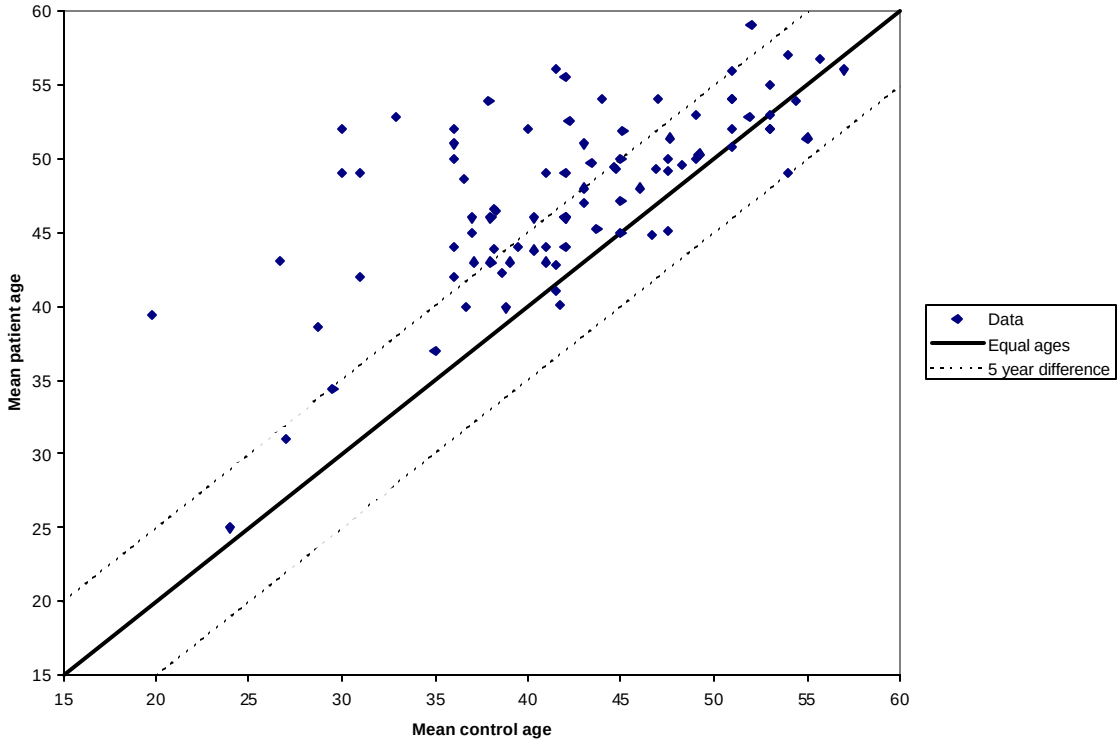


Figure 8. Sex Ratios of Patient and Control Groups in CTS Diagnostic Studies

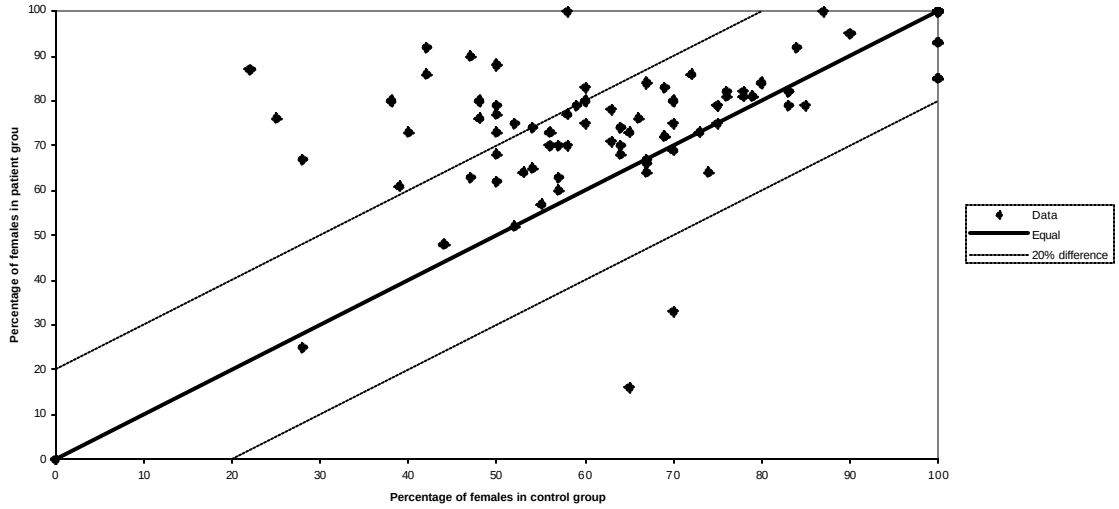


Table 14. Summary of Study Characteristics Affecting Generalizability

Study characteristic	Number of studies reporting (percentage)	Specifics (percentage)
Years in which study was conducted	39 (21%)	NA
Number of centers	189 (100%)	Single: 184 (97%) Multiple (<5): 4 (2%) Multiple (>5): 1 (1%)
Country in which study was conducted	189 (100%)	USA: 79 (42%) Other: 110 (58%)
Patient inclusion criteria	185 (98%)	See **Table 46**
Patient exclusion criteria	87 (46%)	See **Table 46**
Were patient comorbidities reported?	46 (24%)	NA
Was sex distribution of patients reported?	131 (69%)	[a]Percentage female: 61.5%
Were patient ages reported?	123 (65%)	[a]Mean age 48.1 years
Was duration of patients' condition reported?	18 (10%)	[a, b]Mean duration 28.1 months
Did all patients have previous conservative treatment?	1 (1%)	Yes: 1 (1%)
Did any patients have previous surgical treatment?	6 (3%)	Yes: 6 (3%)
Adequate reporting of study's source of patients	29 (15%)	NA
Was there a potential selection bias for easy cases?	58 (31%)	Yes: 58 (31%)
Was there a potential selection bias for hard cases?	40 (21%)	Yes: 40 (21%)

Key:
NA—not applicable
[a]Calculated on a per-patient basis (i.e., weighted by number of patients in each study reporting this characteristic)
[b]Studies reporting median duration [109,136,137] excluded from calculation

Table 15. Study Characteristics Affecting Generalizability of Results

Article	Years in which trial was conducted	Number of centers	Country where trial was conducted	Are patient comorbidity reported?	Percent female	Mean age	Mean duration of condition	Did all patients have previous conservative	Did any patients have previous surgical	Source of patients adequately described and generalizable to broader clinical practice?	Potential selection bias for easy cases?	Potential selection bias for difficult cases?
Distal Motor Latency: Unspecified Diagnosis Patient Group												
Rosén, 1993 [138]	1986-1987	Single	Sweden	No	75%	41	NR	No	No	Yes	No	No
Marin, 1983 [139]	NR	Single	USA	No	86%	49	13	No	No	No	Yes	No
Kimura, 1979 [140]	1978	Single	USA	No	75%	48	NR	No	No	No	No	Yes
Loong, 1972 [141]	NR	Single	Singapore	No	100%	43.7	12.7	No	No	No	No	No
Plaja, 1971 [142]	NR	Single	Spain	No	NR	NR	NR	No	No	No	Yes	No
Distal Motor Latency: Symptoms/Presented Patient Groups												
Murthy, 1999 [143]	NR	Single	India	No	NR	NR	NR	No	No	No	Yes	No
Atroshi, 1996 [136]	NR	Single	Sweden	Yes	69%	52	24	Yes	No	No	Yes	No
Kuntzer, 1994 [144]	NR	Single	Switzerland	No	80%	51	NR	No	No	Yes	No	No
Chang, 1991 [145]	NR	Single	Taiwan	Yes	79%	42.3	NR	No	No	No	No	No
Cioni, 1989 [146]	NR	Single	Italy	No	16%	46.4	NR	No	No	No	No	No
Messina, 1980 [120]	NR	Single	Italy	No	NR	45.1	NR	No	No	No	No	No
Melvin, 1972 [147]	NR	Single	USA	No	NR	NR	NR	No	No	No	No	No
Loong, 1971 [148]	NR	Single	Singapore	Yes	100%	NR	7.6	No	No	No	No	No
Palmar Sensory Latency: Symptoms/Presented Patient Groups												
Murthy, 1999 [143]	NR	Single	India	No	NR	NR	NR	No	No	No	Yes	No
Girlanda, 1998 [149]	NR	Single	Italy	Yes	93%	39	48	No	No	No	No	Yes
Chang, 1991 [145]	NR	Single	Taiwan	Yes	79%	42.3	NR	No	No	No	No	No
Jackson, 1989 [150]	NR	Single	Canada	Yes	82%	52.6	NR	No	No	No	No	No
Escobar, 1985 [151]	NR	Single	USA	Yes	70%	NR	NR	No	No	No	No	No

Article	Years in which trial was conducted	Number of centers	Country where trial was conducted	Are patient comorbidity reported?	Percent female	Mean age	Mean duration of condition	Did all patients have previous conservative	Did any patients have previous surgical	Source of patients adequately described and generalizable to broader clinical practice?	Potential selection bias for easy cases?	Potential selection bias for difficult cases?
Phalen's Maneuver: All Patient Groups												
Szabo, 1999 [152]	1993-1996	Single	USA	No	76%	NR	NR	No	No	No	No	No
Fertl, 1998 [153]	1997	Single	Austria	No	83%	55.5	NR	No	No	Yes	No	No
Gerr, 1998 [31]	NR	Single	USA	No	72%	46.6	NR	No	No	No	No	No
Ghavanini, 1998 [154]	NR	Single	Iran	No	81%	40	15	No	No	No	No	No
Tetro, 1998 [102]	1995-1997	Single	USA	No	64%	49.3	NR	No	No	Yes	No	No
González del Pino, 1997 [104]	1992-1995	Single	Spain	No	81%	50	37.9	No	No	No	Yes	No
De Smet, 1995 [101]	NR	Single	Belgium	No	88%	49.2	NR	No	No	No	No	No
Werner, 1994 [111]	NR	Single	USA	No	NR	NR	NR	No	No	No	No	No
Durkan, 1991 [155]	1987-1990	Single	USA	No	NR	45	NR	No	No	No	No	No
Gellman, 1986 [106]	1982-1984	Single	USA	Yes	74%	NR	NR	No	No	No	Yes	No
Tinel's Sign: All Patient Groups												
Szabo, 1999 [152]	1993-1996	Single	USA	No	76%	NR	NR	No	No	No	No	No
Gerr, 1998 [31]	NR	Single	USA	No	72%	46.6	NR	No	No	No	No	No
Ghavanini, 1998 [154]	NR	Single	Iran	No	81%	40	15	No	No	No	No	No
Tetro, 1998 [102]	1995-1997	Single	USA	No	64%	49.3	NR	No	No	Yes	No	No
González del Pino, 1997 [104]	1992-1995	Single	Spain	No	81%	50	37.9	No	No	No	Yes	No
De Smet, 1995 [101]	NR	Single	Belgium	No	88%	49.2	NR	No	No	No	No	No
Durkan, 1991 [155]	1987-1990	Single	USA	No	74%	45	NR	No	No	No	No	No
Seror, 1987 [156]	NR	Single	France	No	79%	56.8	NR	No	No	No	No	No
Gellman, 1986 [106]	1982-1984	Single	USA	Yes	NR	NR	NR	No	No	No	Yes	No
Gelmers, 1979 [29]	NR	Single	Netherlands	No	81%	57	NR	No	No	No	Yes	No
Stewart, 1978 [157]	NR	Single	Canada	Yes	81%	55	NR	No	No	No	Yes	No

Key:
NR—not reported

Studies of "Early Diagnosis"

Because there is no broad agreement among clinicians of what constitutes and "early" diagnosis of CTS, we accepted any studies so described by their authors as studies of early identification of the condition.

Eighteen studies proposed tests specifically for the early detection of CTS. Table 16 shows the patient selection criteria used in these studies and the authors' proposed methods for early detection. Eleven of the 18 studies (61%) selected patients who had mild CTS as defined by positive symptoms and normal results on commonly-performed nerve conduction tests. None of these eleven studies, however, agreed on the specific kinds of nerve conduction tests and appropriate thresholds.

Thirteen of the 18 studies (72%) proposed sensory nerve conduction test(s) for the early diagnosis of carpal tunnel syndrome. As with the selection criteria, however, there was little agreement regarding test specifics. Two studies by Seror[158,159] each proposed the orthodromic sensory inching test for the early detection of CTS. Two studies by Uncini[160,161] each proposed the difference between median and ulnar orthodromic sensory latencies from the ring finger for the early detection of CTS. None of the other nine studies of sensory nerve conduction proposed the same specific tests or combination of tests. Therefore, studies of the early detection of CTS utilize the same general categories of nerve conduction tests, but there is wide variability in the specific tests employed. Furthermore, there are insufficient studies of any specific test to permit meta-analysis for drawing conclusions on whether it is effective for early identification of CTS. For this reason, we proceed to examine diagnostic tests for carpal tunnel syndrome, in general.

Table 16. Articles Self-Described as "Early Diagnosis" of CTS

Article	Patient selection criteria relevant to early detection	Symptoms and normal NCS?	Authors' proposed method for early detection	Sensory NCS?
Seror, 2000 [158]	Symptoms, but normal needle examination, normal DML (<4 ms) and normal palm-to-wrist orthodromic SCV (>45 m/s).	☑	Orthodromic sensory inching test from the middle finger.	☑
Girlanda, 1998 [149]	Symptoms, but no weakness, no muscle atrophy, and normal DML (<4 ms).	☑	Combination of nerve conduction tests:a) Difference between median and ulnar orthodromic SCV from ring finger to wrist, and b) Ratio of orthodromic SCV from middle finger to palm and orthodromic SCV from palm to wrist	☑
Seror, 1998 [159]	Symptoms, but normal DML (<4 ms) and normal palm-to-wrist orthodromic SCV (>45 m/s).	☑	Orthodromic sensory inching test from the middle finger.	☑
Terzis, 1998 [162]	Symptoms, but normal DML (<4.2 ms)	☑	Combination of orthodromic sensory nerve conduction tests from the ring finger.	☑
Bronson, 1997 [163]	Symptoms, but normal DML (<4 ms) and normal needle examination.	☑	Comparison of DMLs using five different wrist positions.	?
Murata, 1996 [164]	Workers at risk	?	Ratio of:a) Antidromic SCV from wrist to index finger, and b) Antidromic SCV from palm to index finger	☑
Padua, 1996 [165]	Symptoms, but no signs of severe CTS (e.g., absent SNAP at the wrist).	☑	Ratio of:a) Orthodromic SCV from middle finger to palm, and b) Orthodromic SCV from palm to wrist	☑
Young, 1995 [166]	Workers at risk	?	Total score on a grading scale that included seven clinical signs, four symptoms, and DML≥4.45 ms.	?
Johnson, 1993 [167]	Workers at risk	?	Track changes in DML over time	?
Uncini, 1993 [160]	Symptoms, but normal DML (<4.2 ms) and normal SCV from index finger to wrist (>45 m/s)	☑	Difference between: a) Median orthodromic latency between ring finger and wrist, and b) Ulnar orthodromic latency between ring finger and wrist	☑
Jetzer, 1991 [168]	Workers at risk	?	Vibrometry	?
Luchetti, 1991 [169]	Symptoms, but normal motor function, sensory function, quantitative sensory examination, cutaneous trophism, DSL (NR), and DML (NR).	☑	Antidromic inching test to the middle finger	☑

Article	Patient selection criteria relevant to early detection	Symptoms and normal NCS?	Authors' proposed method for early detection	Sensory NCS?
Charles, 1990 [170]	Clinical diagnosis of CTS by referring physician, and at least one of the following: a) DML ≥4.5 ms; b) Orthodromic SCV from index finger <45 m/s; c) Difference ≥0.5 ms between median and ulnar sensory antidromic latencies to the ring finger	?	Difference between: a) Median antidromic latency between ring finger and wrist, and b) Ulnar antidromic latency between ring finger and wrist	☑
Palliyath, 1990 [171]	Symptoms, but "very little electrophysiological changes on routine tests for CTS" (p 307).	☑	Duration of relative refractory period and absolute refractory period.	?
Cioni, 1989 [146]	Symptoms	?	Orthodromic SCV from ring finger to wrist	☑
Jackson, 1989 [150]	Symptoms. Patients were stratified into three groups, and one group represented mild CTS as defined by normal NCS (based on four tests) and normal needle examination.	☑	Combination of two nerve conduction tests: a) Difference between median and radial antidromic sensory latencies from wrist to thumb, and b) Difference between median and ulnar antidromic sensory latencies from wrist to ring finger	☑
Uncini, 1989 [161]	Symptoms, but normal DML (≤4.2 ms) and SNAPs were present with normal amplitude.	☑	Difference between:a) Median orthodromic latency between ring finger and wrist, and b) Ulnar orthodromic latency between ring finger and wrist	☑
Wongsam, 1983 [172]	Symptoms suggesting early CTS.	?	Ratio of:a) Antidromic latency from wrist to middle fingerb) Antidromic latency from palm to middle finger	☑

Key:
DML—Distal motor latency
DSL—Distal sensory latency
ms—Milliseconds
m/s—Meters per second
SCV—Sensory conduction velocity
SNAP—Sensory nerve action potential
NR—Not reported

"Diagnosis Studies"

Our evaluation of methods for diagnosing CTS is primarily meta-analytic. To identify diagnostic tests of CTS for which meta-analyses were appropriate, we performed several tabulations. These tabulations were restricted to studies that met each of the following three criteria: 1) Study included a carpal tunnel syndrome group; 2) Study included a normal group; 3) Study was not a screening study. There were 138 studies that met all of these criteria.

For each test, we determined the number of studies in each of four patient selection categories that reported the test. Within each of these four categories, we also determined the number of studies for which sensitivity and specificity could be derived (based on information provided in the article). These study counts appear in Table 17 through

Table 21. The first number in each cell is the count of all studies in a category, and the second number in each cell is the subset of studies from which we could derive sensitivity and specificity. We coded a study as having derivable sensitivity/specificity if *any* of the tests in that study had derivable sensitivity and specificity. Because this was not necessarily true for all tests in a study, the table's counts for some tests may slightly overestimate the numbers of studies with derivable sensitivity and specificity.

As an initial criterion for conducting meta-analyses, we required that a minimum of 10 studies that reported a specific test in a specific population had derivable sensitivity and specificity. In other words, the second number in the table cell was required to be 10 or more. We adopted this criterion to ensure that our analysis would focus on the diagnostic tests that are the subject of greatest research interest. When there was a minimum of 10 articles, we proceeded with a meta-analysis even if one or more articles were subsequently excluded because it did not report sensitivity and specificity for the particular test being analyzed (or for other reasons discussed below).

Three combinations of test and patient population (see shaded cells in Table 19) met the a priori analysis criterion of at least 10 articles reporting the test and reporting results in sufficient detail that sensitivity and specificity could be calculated. The table entries on level of reporting are based on the highest level for any test reported in the article, and all tests reported were not necessarily reported at the highest level. This was especially true for studies reporting distal motor latency. It may be the case that some investigators reported only summary data for distal motor latency because it was considered a more of a routine test than other reported tests.

Table 17. Numbers of Studies Reporting Signs/Symptoms Tests Across Patient Selection Categories

Legend:
First entry in cell—Total number of articles

Second entry in cell—Number of articles with derivable sensitivity and specificity

Sign/symptom	Complex objective standard	Simple nerve conduction	Symptoms/ presented	Unspecified diagnosis
Closed fist test	0, 0	1, 1	1, 1	0, 0
Combined Phalen's/Durkan test	1, 1	0, 0	0, 0	0, 0
Decreased muscle strength	0, 0	0, 0	1, 1	0, 0
Durkan compression	5, 5	1, 1	3, 3	1, 1
Flick sign	0, 0	0, 0	0, 0	1, 1
Gilliat tourniquet	1, 1	1, 1	1, 1	1, 1
Grip strength	0, 0	0, 0	0, 0	1, 0
Hypesthesia	0, 0	0, 0	1, 1	0, 0
Pain on VAS	0, 0	0, 0	1, 1	1, 1
Paresthesia in APB	0, 0	0, 0	0, 0	1, 1
Phalen's/reverse Phalen's	7, 7	2, 1	6, 6	3, 3
Pinch strength	0, 0	0, 0	0, 0	1, 0
Symptoms measured systematically	3, 3	0, 0	2, 2	1, 0
Symptoms during ultrasound	0, 0	0, 0	1, 1	0, 0
Thenar atrophy	0, 0	0, 0	2, 2	0, 0
Thenar weakness	0, 0	0, 0	1, 1	0, 0
Tinel's	9, 9	2, 1	3, 3	2, 2

Table 18. Numbers of Studies Reporting Sensory Tests Across Patient Selection Categories

Legend:

First entry in cell—Total number of articles

Second entry in cell—Number of articles with derivable sensitivity and specificity

Sensory test	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
Object identification	0, 0	0, 0	0, 0	1, 0
Pinprick sensation	0, 0	0, 0	0, 0	1, 1
Pressure measurement	0, 0	0, 0	1, 1	1, 0
Ridge threshold	0, 0	0, 0	0, 0	1, 0
Semmes-Weinstein filament	1, 1	0, 0	0, 0	4, 1
Temperature measurement	0, 0	0, 0	1, 1	2, 1
Texture discrimination	0, 0	0, 0	0, 0	1, 0
Tuning fork	1, 1	0, 0	1, 1	0, 0
Two-point discrimination (moving or static)	2, 2	0, 0	2, 2	1, 0
Vibrometer	2, 2	0, 0	5, 5	1, 0

Table 19. Numbers of Studies Reporting Nerve Conduction Tests Across Patient Selection Categories

Legend:

Nerve tested: MED–median, RAD–radial, ULN–ulnar
MOT–motor, SEN–Sensory
Configuration (not applicable to motor nerve tests): OR–orthodromic, AN–antidromic
Stimulation electrode placement: ELB–elbow, FOR–forearm, WR–wrist, PAL–palm, TH–thumb, IN–index finger, MI–middle finger, RI–ring finger, LI–little finger, APB–abductor policis brevis, ADM–abductor digiti minimi, OTH–other
Recording electrode placement (see D for abbreviations)
Measured parameter: LAT–latency, PRE–presence/absence of signal, AMP–amplitude, VEL–velocity, INCH–inching, OTH–other
Blank cells—Not reported or not applicable

First entry in cell—Total number of articles

Second entry in cell—Number of articles with derivable sensitivity and specificity

Shaded cells—Ten or more articles reporting sensitivity and specificity.

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
	MOT				LAT	1, 1	0, 0	0, 0	1, 1
	MOT		WR	OTH	LAT	0, 0	0, 0	0, 0	1, 1
	SEN				LAT	1, 1	0, 0	0, 0	1, 1
	SEN	OR	TH	WR	PRE	0, 0	0, 0	1, 1	0, 0
MED					OTH	0, 0	0, 0	2, 2	0, 0
MED	MOT					0, 0	0, 0	0, 0	1, 0
MED	MOT				AMP	0, 0	1, 0	0, 0	0, 0
MED	MOT				LAT	2, 1	1, 0	2, 2	2, 1
MED	MOT				OTH	1, 1	1, 0	2, 1	0, 0
MED	MOT				VEL	0, 0	1, 0	1, 1	1, 0
MED	MOT			APB	AMP	1, 1	0, 0	0, 0	0, 0
MED	MOT			APB	LAT	1, 1	0, 0	0, 0	0, 0
MED	MOT		ELB	APB	AMP	1, 0	0, 0	1, 1	1, 1
MED	MOT		ELB	APB	LAT	1, 1	0, 0	0, 0	1, 1
MED	MOT		ELB	APB	OTH	1, 1	0, 0	1, 1	0, 0
MED	MOT		ELB	APB	VEL	1, 0	0, 0	1, 1	2, 2
MED	MOT		ELB	IN	AMP	0, 0	0, 0	0, 0	1, 1
MED	MOT		ELB	IN	LAT	0, 0	0, 0	0, 0	1, 1
MED	MOT		ELB	IN	VEL	0, 0	0, 0	0, 0	1, 1
MED	MOT		ELB	WR	AMP	1, 0	0, 0	0, 0	0, 0
MED	MOT		ELB	WR	LAT	0, 0	0, 0	0, 0	0, 0
MED	MOT		ELB	WR	VEL	2, 1	0, 0	3, 3	1, 1
MED	MOT		FOR		VEL	1, 1	0, 0	0, 0	1, 1
MED	MOT		FOR	APB	AMP	1, 1	0, 0	0, 0	0, 0

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
MED	MOT		FOR	APB	LAT	1, 1	0, 0	0, 0	0, 0
MED	MOT		FOR	APB	VEL	0, 0	0, 0	1, 1	0, 0
MED	MOT		FOR	PAL	AMP	1, 1	0, 0	0, 0	0, 0
MED	MOT		FOR	PAL	LAT	1, 1	0, 0	0, 0	0, 0
MED	MOT		FOR	WR	VEL	0, 0	0, 0	0, 0	1, 1
MED	MOT		PAL	APB	AMP	1, 1	0, 0	1, 0	2, 1
MED	MOT		PAL	APB	LAT	0, 0	0, 0	0, 0	2, 1
MED	MOT		PAL	IN	AMP	0, 0	0, 0	0, 0	1, 1
MED	MOT		PAL	IN	LAT	0, 0	0, 0	0, 0	1, 1
MED	MOT		PAL	IN	VEL	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR		AMP	0, 0	0, 0	1, 1	0, 0
MED	MOT		WR		LAT	2, 2	1, 0	1, 1	0, 0
MED	MOT		WR		PRE	1, 1	0, 0	0, 0	0, 0
MED	MOT		WR		VEL	1, 1	0, 0	0, 0	0, 0
MED	MOT		WR	APB	AMP	2, 1	0, 0	9, 7	9, 6
MED	MOT		WR	APB	LAT	4, 4	3, 2	21, 17	24, 21
MED	MOT		WR	APB	OTH	2, 1	1, 0	1, 1	2, 2
MED	MOT		WR	APB	PRE	0, 0	0, 0	3, 3	1, 1
MED	MOT		WR	APB	VEL	0, 0	0, 0	2, 1	5, 5
MED	MOT		WR	IN	AMP	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR	IN	LAT	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR	IN	VEL	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR	OTH	AMP	1, 0	0, 0	1, 1	1, 1
MED	MOT		WR	OTH	LAT	1, 1	1, 1	8, 8	3, 3
MED	MOT		WR	OTH	OTH	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR	OTH	VEL	1, 0	0, 0	1, 1	0, 0
MED	MOT		WR	PAL	AMP	0, 0	0, 0	1, 1	0, 0
MED	MOT		WR	PAL	LAT	0, 0	0, 0	1, 1	0, 0
MED	MOT		WR	PAL	OTH	0, 0	0, 0	0, 0	1, 1
MED	MOT		WR	PAL	VEL	0, 0	0, 0	1, 0	0, 0
MED	MOT		WR	TH	LAT	0, 0	0, 0	2, 0	0, 0
MED	MOT		WR	TH	VEL	0, 0	0, 0	1, 1	0, 0
MED	SEN					0, 0	0, 0	0, 0	1, 0
MED	SEN				LAT	3, 2	0, 0	0, 0	1, 0
MED	SEN				OTH	0, 0	0, 0	1, 0	1, 0
MED	SEN				VEL	0, 0	1, 0	0, 0	0, 0
MED	SEN		WR		AMP	1, 1	0, 0	0, 0	0, 0
MED	SEN		WR		LAT	1, 1	0, 0	0, 0	0, 0
MED	SEN	AN			AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	AN			LAT	1, 1	0, 0	1, 1	1, 1
MED	SEN	AN			VEL	1, 1	0, 0	1, 1	0, 0
MED	SEN	AN	ELB	IN	AMP	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	ELB	IN	OTH	0, 0	0, 0	1, 1	0, 0

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
MED	SEN	AN	ELB	MI	VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	AN	ELB	PAL	INCH	0, 0	0, 0	0, 0	1, 1
MED	SEN	AN	ELB	WR	VEL	0, 0	0, 0	2, 2	1, 1
MED	SEN	AN	FOR	IN	LAT	0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	FOR	RI	LAT	0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	FOR	TH	LAT	0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	PAL	IN	AMP	1, 1	0, 0	2, 1	0, 0
MED	SEN	AN	PAL	IN	LAT	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	PAL	IN	PRE	1, 1	0, 0	0, 0	0, 0
MED	SEN	AN	PAL	IN	VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	AN	PAL	MI		0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	PAL	MI	AMP	0, 0	0, 0	2, 1	0, 0
MED	SEN	AN	PAL	MI	LAT	0, 0	0, 0	2, 1	0, 0
MED	SEN	AN	PAL	MI	OTH	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	PAL	MI	VEL	0, 0	0, 0	1, 1	2, 2
MED	SEN	AN	WR		LAT	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	WR	IN	AMP	3, 2	0, 0	6, 5	5, 4
MED	SEN	AN	WR	IN	LAT	1, 1	0, 0	11, 9	5, 3
MED	SEN	AN	WR	IN	OTH	2, 1	0, 0	2, 2	0, 0
MED	SEN	AN	WR	IN	PRE	1, 1	0, 0	2, 2	2, 2
MED	SEN	AN	WR	IN	VEL	0, 0	0, 0	3, 2	0, 0
MED	SEN	AN	WR	MI	AMP	0, 0	0, 0	4, 3	0, 0
MED	SEN	AN	WR	MI	INCH	1, 1	0, 0	1, 1	0, 0
MED	SEN	AN	WR	MI	LAT	0, 0	0, 0	2, 1	0, 0
MED	SEN	AN	WR	MI	PRE	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	WR	MI	VEL	0, 0	0, 0	3, 3	1, 1
MED	SEN	AN	WR	OTH	VEL	0, 0	0, 0	1, 1	0, 0
MED	SEN	AN	WR	PAL	AMP	0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	WR	PAL	LAT	0, 0	1, 0	1, 1	0, 0
MED	SEN	AN	WR	PAL	VEL	0, 0	0, 0	3, 2	2, 2
MED	SEN	AN	WR	RI	AMP	0, 0	0, 0	1, 0	0, 0
MED	SEN	AN	WR	RI	LAT	0, 0	0, 0	3, 2	3, 2
MED	SEN	AN	WR	RI	VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	AN	WR	TH	AMP	1, 1	0, 0	2, 1	0, 0
MED	SEN	AN	WR	TH	LAT	1, 1	0, 0	3, 2	0, 0
MED	SEN	AN	WR	TH	VEL	0, 0	0, 0	1, 1	1, 1
MED	SEN	OR			AMP	0, 0	1, 0	0, 0	0, 0
MED	SEN	OR			LAT	0, 0	1, 0	0, 0	0, 0
MED	SEN	OR		WR	AMP	0, 0	0, 0	2, 2	0, 0
MED	SEN	OR		WR	LAT	0, 0	0, 0	1, 1	2, 2
MED	SEN	OR		WR	VEL	0, 0	0, 0	2, 2	0, 0
MED	SEN	OR	IN		AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	IN		LAT	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	IN		OTH	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	IN		VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	IN	PAL	VEL	0, 0	0, 0	0, 0	1, 1

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
MED	SEN	OR	IN	WR	AMP	4, 3	0, 0	7, 5	2, 2
MED	SEN	OR	IN	WR	LAT	1, 1	0, 0	8, 7	3, 3
MED	SEN	OR	IN	WR	OTH	2, 2	0, 0	2, 1	1, 1
MED	SEN	OR	IN	WR	PRE	1, 1	0, 0	4, 4	0, 0
MED	SEN	OR	IN	WR	VEL	4, 3	1, 1	8, 7	3, 3
MED	SEN	OR	MI		AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI		LAT	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI		OTH	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI		VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI	MI	AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI	MI	VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	MI	PAL	AMP	1, 0	0, 0	0, 0	0, 0
MED	SEN	OR	MI	PAL	VEL	1, 0	0, 0	2, 2	0, 0
MED	SEN	OR	MI	WR	AMP	2, 1	0, 0	3, 3	4, 4
MED	SEN	OR	MI	WR	INCH	1, 1	0, 0	0, 0	2, 2
MED	SEN	OR	MI	WR	LAT	0, 0	0, 0	4, 3	0, 0
MED	SEN	OR	MI	WR	OTH	1, 1	0, 0	1, 1	0, 0
MED	SEN	OR	MI	WR	PRE	1, 1	0, 0	2, 2	1, 1
MED	SEN	OR	MI	WR	VEL	3, 2	0, 0	5, 5	5, 5
MED	SEN	OR	OTH		VEL	1, 1	0, 0	0, 0	0, 0
MED	SEN	OR	OTH	WR	AMP	0, 0	0, 0	1, 1	0, 0
MED	SEN	OR	OTH	WR	LAT	0, 0	0, 0	2, 2	0, 0
MED	SEN	OR	OTH	WR	VEL	0, 0	0, 0	2, 2	1, 1
MED	SEN	OR	PAL	WR	AMP	0, 0	0, 0	2, 2	1, 1
MED	SEN	OR	PAL	WR	LAT	1, 1	1, 1	11, 11	1, 1
MED	SEN	OR	PAL	WR	OTH	0, 0	0, 0	1, 1	0, 0
MED	SEN	OR	PAL	WR	PRE	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	PAL	WR	VEL	0, 0	0, 0	7, 7	7, 6
MED	SEN	OR	RI		AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	RI		LAT	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	RI		OTH	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	RI		VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	RI	WR	AMP	3, 2	0, 0	3, 2	1, 1
MED	SEN	OR	RI	WR	LAT	1, 1	1, 1	4, 3	1, 1
MED	SEN	OR	RI	WR	OTH	1, 1	0, 0	1, 1	0, 0
MED	SEN	OR	RI	WR	PRE	1, 1	0, 0	1, 1	2, 2
MED	SEN	OR	RI	WR	VEL	2, 1	0, 0	3, 3	2, 2
MED	SEN	OR	TH		AMP	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	TH		LAT	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	TH		OTH	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	TH		VEL	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	TH	ELB	PRE	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	TH	MI	VEL	0, 0	0, 0	0, 0	0, 0
MED	SEN	OR	TH	PAL	VEL	0, 0	0, 0	0, 0	0, 0
MED	SEN	OR	TH	WR	AMP	1, 1	0, 0	3, 3	2, 2
MED	SEN	OR	TH	WR	LAT	0, 0	0, 0	3, 3	0, 0
MED	SEN	OR	TH	WR	OTH	1, 1	0, 0	1, 1	0, 0

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
MED	SEN	OR	TH	WR	PRE	1, 1	0, 0	1, 1	1, 1
MED	SEN	OR	TH	WR	VEL	1, 1	0, 0	5, 5	2, 2
MED	SEN	OR	WR	ELB	AMP	2, 1	0, 0	0, 0	1, 1
MED	SEN	OR	WR	ELB	OTH	1, 1	0, 0	0, 0	0, 0
MED	SEN	OR	WR	ELB	PRE	0, 0	0, 0	0, 0	1, 1
MED	SEN	OR	WR	ELB	VEL	2, 1	0, 0	0, 0	1, 1
MED	Transcarpal				AMP	0, 0	0, 0	0, 0	1, 1
MED	Transcarpal				LAT	0, 0	0, 0	0, 0	1, 1
RAD	SEN	AN	FOR	TH	LAT	0, 0	0, 0	1, 0	0, 0
RAD	SEN	AN	WR	TH	AMP	1, 1	0, 0	0, 0	0, 0
RAD	SEN	AN	WR	TH	LAT	1, 1	0, 0	2, 2	2, 0
RAD	SEN	AN	WR	TH	VEL	0, 0	0, 0	0, 0	1, 1
RAD	SEN	OR	TH	WR	AMP	1, 0	0, 0	1, 1	0, 0
RAD	SEN	OR	TH	WR	LAT	0, 0	0, 0	1, 1	0, 0
RAD	SEN	OR	TH	WR	PRE	0, 0	0, 0	1, 1	0, 0
RAD	SEN	OR	TH	WR	VEL	1, 0	0, 0	2, 2	1, 1
ULN	MOT				LAT	0, 0	0, 0	0, 0	1, 1
ULN	MOT				OTH	1, 1	0, 0	1, 0	0, 0
ULN	MOT		ELB	ADM	LAT	1, 1	0, 0	0, 0	0, 0
ULN	MOT		ELB	ADM	OTH	1, 1	0, 0	0, 0	0, 0
ULN	MOT		ELB	OTH	AMP	0, 0	0, 0	0, 0	1, 1
ULN	MOT		ELB	OTH	PRE	0, 0	0, 0	0, 0	1, 1
ULN	MOT		ELB	OTH	VEL	0, 0	0, 0	0, 0	1, 1
ULN	MOT		ELB	WR	VEL	1, 1	0, 0	1, 1	1, 1
ULN	MOT		WR		LAT	1, 1	0, 0	1, 1	0, 0
ULN	MOT		WR		VEL	1, 1	0, 0	0, 0	0, 0
ULN	MOT		WR	ADM	AMP	0, 0	0, 0	1, 0	2, 1
ULN	MOT		WR	ADM	LAT	2, 2	1, 1	4, 2	5, 4
ULN	MOT		WR	ADM	OTH	1, 1	0, 0	0, 0	0, 0
ULN	MOT		WR	ADM	VEL	0, 0	0, 0	1, 0	0, 0
ULN	MOT		WR	APB	LAT	1, 1	0, 0	0, 0	0, 0
ULN	MOT		WR	OTH	AMP	0, 0	0, 0	1, 1	0, 0
ULN	MOT		WR	OTH	LAT	0, 0	1, 1	3, 3	4, 3
ULN	MOT		WR	OTH	PRE	0, 0	0, 0	1, 1	0, 0
ULN	MOT		WR	PAL	AMP	0, 0	0, 0	1, 1	0, 0
ULN	MOT		WR	PAL	LAT	0, 0	0, 0	1, 1	0, 0
ULN	SEN				OTH	0, 0	0, 0	1, 0	0, 0
ULN	SEN		WR		AMP	1, 1	0, 0	0, 0	0, 0
ULN	SEN		WR		LAT	1, 1	0, 0	0, 0	0, 0
ULN	SEN	AN	FOR	LI	LAT	0, 0	0, 0	1, 0	0, 0
ULN	SEN	AN	FOR	RI	LAT	0, 0	0, 0	1, 0	0, 0
ULN	SEN	AN	PAL	LI	LAT	0, 0	0, 0	1, 1	0, 0
ULN	SEN	AN	WR	LI	AMP	0, 0	0, 0	2, 2	1, 1
ULN	SEN	AN	WR	LI	LAT	0, 0	0, 0	2, 2	1, 1
ULN	SEN	AN	WR	LI	VEL	0, 0	0, 0	3, 3	0, 0
ULN	SEN	AN	WR	PAL	LAT	0, 0	0, 0	1, 1	0, 0
ULN	SEN	AN	WR	RI	LAT	0, 0	0, 0	2, 2	4, 2

Nerve Conduction Test						Patient selection type			
Nerve Tested	**Nerve Tested**	**Configuration**	**Stimulation**	**Recording**	**Parameter**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
ULN	SEN	AN	WR	RI	VEL	0, 0	0, 0	0, 0	1, 1
ULN	SEN	OR	LI	WR	AMP	2, 1	0, 0	4, 3	3, 3
ULN	SEN	OR	LI	WR	LAT	1, 1	0, 0	3, 2	1, 1
ULN	SEN	OR	LI	WR	OTH	1, 1	0, 0	1, 0	0, 0
ULN	SEN	OR	LI	WR	PRE	0, 0	0, 0	1, 1	0, 0
ULN	SEN	OR	LI	WR	VEL	2, 1	0, 0	3, 2	3, 3
ULN	SEN	OR	OTH		VEL	1, 1	0, 0	0, 0	0, 0
ULN	SEN	OR	OTH	WR	VEL	0, 0	0, 0	0, 0	1, 1
ULN	SEN	OR	PAL	WR	AMP	0, 0	0, 0	1, 1	0, 0
ULN	SEN	OR	PAL	WR	LAT	0, 0	1, 1	6, 6	0, 0
ULN	SEN	OR	PAL	WR	VEL	0, 0	0, 0	2, 2	1, 1
ULN	SEN	OR	RI	WR	AMP	2, 1	0, 0	2, 1	2, 2
ULN	SEN	OR	RI	WR	LAT	1, 1	1, 1	3, 2	1, 1
ULN	SEN	OR	RI	WR	PRE	0, 0	0, 0	1, 1	1, 1
ULN	SEN	OR	RI	WR	VEL	2, 1	0, 0	2, 2	3, 3
ULN	SEN	OR	WR	ELB	AMP	1, 1	0, 0	0, 0	0, 0
ULN	SEN	OR	WR	ELB	OTH	1, 1	0, 0	0, 0	0, 0
ULN	SEN	OR	WR	ELB	VEL	1, 1	0, 0	0, 0	0, 0

Table 20. Numbers of Studies Reporting Composite Nerve Conduction Tests Across Patient Selection Categories

Legend:

Blank cells—Not reported or not applicable

First entry in cell—Total number of articles

Second entry in cell—Number of articles with derivable sensitivity and specificity

Composite test type					Patient selection group			
Nerve for test 1	**Nerve for test 2**	**Motor or sensory**	**Unit of nerve test**	**Type composite**	**Complex objective standard**	**Simple nerve conduction**	**Symptoms/ presented**	**Unspecified diagnosis**
Median	Median	Motor	Amplitude	Difference	0, 0	0, 0	0, 0	1, 0
Median	Median	Motor	Amplitude	Ratio	1, 1	0, 0	1, 0	0, 0
Median	Median	Motor	Latency	Difference	0, 0	0, 0	2, 2	2, 2
Median	Median	Motor	Latency	Ratio	0, 0	0, 0	0, 0	1, 1
Median	Median	Motor	Velocity	Difference	1, 0	0, 0	0, 0	0, 0
Median	Median	Sensory	Amplitude	Difference	1, 1	0, 0	2, 2	0, 0
Median	Median	Sensory	Amplitude	Ratio	1, 1	0, 0	1, 0	1, 1
Median	Median	Sensory	Latency	Difference	1, 1	0, 0	6, 5	1, 1
Median	Median	Sensory	Latency	Ratio	0, 0	0, 0	0, 0	1, 1
Median	Median	Sensory	Velocity	Difference	0, 0	0, 0	2, 2	1, 1
Median	Median	Sensory	Velocity	Ratio	0, 0	0, 0	4, 4	2, 2
Median	Radial	Sensory	Latency	Difference	1, 1	0, 0	3, 3	2, 0
Median	Radial	Sensory	Velocity	Difference	0, 0	0, 0	0, 0	1, 1
Median	Radial	Sensory	Velocity	Ratio	0, 0	0, 0	1, 1	0, 0
Median	Ulnar	Motor	Latency	Difference	1, 1	2, 2	3, 3	5, 4
Median	Ulnar	Motor	Other	Difference	1, 1	0, 0	0, 0	0, 0
Median	Ulnar	Sensory	Amplitude	Ratio	0, 0	0, 0	2, 2	1, 1
Median	Ulnar	Sensory	Latency	Difference	1, 1	1, 1	10, 9	5, 3
Median	Ulnar	Sensory	Velocity	Difference	0, 0	0, 0	1, 1	1, 1
Median	Ulnar	Sensory	Velocity	Ratio	0, 0	0, 0	1, 1	0, 0
Radial	Median	Sensory	Velocity	Ratio	0, 0	0, 0	1, 1	0, 0
Radial	Radial	Sensory	Latency	Difference	0, 0	0, 0	1, 0	0, 0
Ulnar	Median	Sensory	Velocity	Difference	1, 0	0, 0	0, 0	0, 0
Ulnar	Median	Sensory	Velocity	Ratio	0, 0	0, 0	1, 1	0, 0
				Other Difference	3, 1	0, 0	3, 3	1, 1
				Other Ratio	0, 0	0, 0	3, 2	1, 1
				Other Composite	5, 4	0, 0	9, 8	4, 2

Table 21. Numbers of Articles Reporting Imaging Tests in Patient Selection Categories

Legend:

First entry in cell—Total number of articles

Second entry in cell—Number of articles with derivable sensitivity and specificity

Imaging test	Complex objective standard	Simple nerve conduction	Symptoms/presented	Unspecified diagnosis
CT	0, 0	0, 0	0, 0	2, 0
MRI	2, 0	2, 0	1, 1	5, 2
Ultrasound	1, 0	1, 0	1, 0	3, 3

Summary ROC Meta-Analysis of Diagnostic Test Results

Ideally, a meta-analysis of a test includes only studies that use the same definition of what is to be diagnosed. However, the absence of a gold standard for defining carpal tunnel syndrome resulted in there being as many different definitions of the condition (and therefore of positive cases) as there were studies. Therefore, we could only combine study results by permitting different authors to use different definitions of CTS. Testing for heterogeneity of results helps reduce, but does not eliminate the possibility that different definitions affected study results.

Distal Motor Latency: Patients with Unspecified Diagnosis of CTS v. Normal Controls

While there were 21 studies of distal motor latency (DML) in patient groups coded as "Unspecified diagnosis" that reported some 2 x 2 tables, only five of those studies ultimately could be included in a meta-analysis. Reasons for the exclusion of the others are shown in Table 22. Seven studies did not report any sensitivity or specificity results for the DML measurements, even though they reported them for other tests. Four studies reported sensitivity but not specificity, while one reported specificity but not sensitivity. These studies were excluded because data from both groups are necessary to ensure the validity of the results and because the summary ROC method requires both sensitivity and specificity for each study. The study by Bronson et al.[163] was excluded because DML results were reported for only some of the patients. So et al.[173] combined direct measurement of DML with abnormalities in the difference between median and ulnar latency when reporting their results, and we could not isolate results for DML. Charles et al.[170] was excluded because authors reported use of a mean + 2 SD threshold for defining abnormal latency, but the actual threshold reported (4.5 msec) did not agree with their reported results for their control subjects (mean + 2 SD = 4.0 msec). Since the number of controls with latency = 4.5 msec was not reported, we could not derive an internally-consistent 2 x 2 table from the article, and had to exclude it from analysis. Resende et al.[174] reported patient-level data, but did not report a threshold fordistinguishing normal

from abnormal latency. Because there is no agreement on a standard threshold for DML (and there was no way to objectively choose a threshold), we excluded this study.

Two of the five studies included in the meta-analysis[140,175] did not report counts of normal and abnormal results in the control subjects, but because their thresholds were based on two standard deviations from the mean, we estimated the number of false-positive results by multiplying the number of patients in the control group by the probability that a result would be two or more standard deviations above the mean (0.02275 based on the normal distribution). We also recalculated the results from the study by Rosén[176], which reported a histogram of latency results and did not report a 2 x 2 table for their specified threshold. In the other included articles, there were no discrepancies between the sensitivity and specificity figures reported by the authors and the figures calculated by ECRI and used in the meta-analysis.

Results of each included trial and of the meta-analysis are shown in Table 23 and Figure 9. No statistically significant heterogeneity was found in the results ($Q = 0.33$, $p = 0.99$). The results clustered in a small portion of the graph, suggesting there was good agreement among clinicians in how this test is used and how effective it is. The sensitivity and specificity at mean threshold, our best estimate of the effectiveness of the test, was 57.1% sensitivity, 97.9% specificity.

The section of the summary ROC curve above sensitivity = 70% is an extrapolation from the actual data. It represents thresholds that are much lower than the thresholds used in the published trials and as such, may not represent an accurate description of clinical events.

Table 22. Distal Motor Latency Studies Excluded from Meta-Analysis

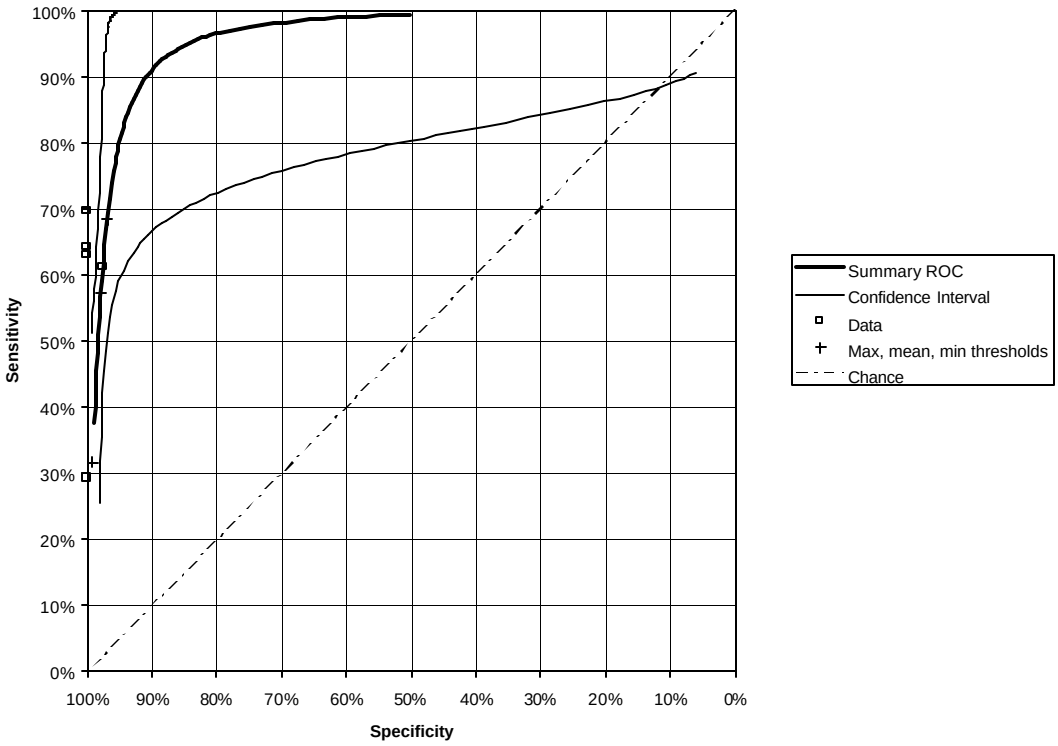
Study	Reason for Exclusion
Pease, 1990 [177]	Did not report sensitivity and specificity for distal motor latency test
Seror, 1998 [159]	Did not report sensitivity and specificity for distal motor latency test
Rossi, 1994 [178]	Did not report sensitivity and specificity for distal motor latency test
Seror, 1995 [179]	Did not report sensitivity and specificity for distal motor latency test
Lang, 1995 [109]	Did not report sensitivity and specificity for distal motor latency test
Tzeng, 1990 [180]	Did not report sensitivity and specificity for distal motor latency test
Mondelli, 2001 [181]	Did not report sensitivity and specificity for distal motor latency test
Simovic, 1997 [182]	Did not report distal motor latency results for control subjects
Simovic, 1999 [183]	Did not report distal motor latency results for control subjects
Resende, 2000 [184]	Did not report distal motor latency results for control subjects
Lauritzen, 1991 [185]	Did not report distal motor latency results for control subjects
Loscher, 2000 [175]	Did not report distal motor latency results for CTS patients
Bronson, 1997 [163]	Selective reporting of distal motor latency results
So, 1989 [173]	Reported combination test of distal motor latency and other nerve conduction measurements
Charles, 1990 [170]	Discrepancy in reported threshold
Resende, 2000 [174]	No diagnostic threshold reported

Table 23. Meta-analysis of Distal Motor Latency Results in Trials With Non-specific Diagnosis of Carpal Tunnel Syndrome Groups

Study	TP	FN	FP	TN	Sen. 95% CI	Spec. 95% CI	PPV 95% CI	NPV 95% CI	Prev.
[a]Kimura[140]	105	67	3	119	61.0% 53.4% 68.2%	97.5% 92.9% 99.2%	97.2% 92.0% 99.1%	64.0% 56.7% 70.7%	58.5%
Marin[139]	9	5	0	12	64.3% 38.3% 83.9%	100% 75.0% 100%	100% 69.2% 100%	70.6% 46.4% 86.9%	53.8%
Loong[141]	17	10	0	30	63.0% 43.9% 78.7%	100% 88.2% 100%	100% 81.0% 100%	75.0% 59.5% 86.0%	47.4%
Plaja[142]	16	7	0	20	69.6% 48.7% 84.6%	100% 83.3% 100%	100% 80.0% 100%	74.1% 54.9% 87.0%	53.5%
[b]Rosén[138]	12	29	0	50	29.3% 17.4% 44.8%	100% 92.6% 100%	100% 75.0% 100%	63.3% 52.0% 73.3%	45.1%
Meta-analysis results (mean threshold)					**57.1%** 49.1% 64.8%	**97.9%** 97.1% 98.5%			

Key:
TP–true positive, FN–false negative, FP–false positive, TN–true negative
Sen.–sensitivity, Spec–specificity, PPV–positive predictive value, NPV–negative predictive value, Prev.–prevalence of CTS
Confidence intervals on sensitivity, specificity, PPV, NPV calculated by Wilson method[96]
[a]Counts for control group (false positive, true negative) estimated by ECRI from threshold reported by authors (mean + 2 SD)
[b]Results calculated by ECRI from published histogram

Figure 9. Meta-analysis of Distal Motor Latency Results in Trials With Non-specific Diagnosis of Carpal Tunnel Syndrome Groups



Distal Motor Latency: Patients with Symptoms of CTS v. Normal Controls

Seventeen studies met the initial criteria for inclusion in a meta-analysis of DML for distinguishing patients with symptoms of CTS from healthy volunteer controls. As with the meta-analysis on patients with unspecified diagnosis of CTS, there were several articles that did not include sufficient data to permit inclusion in the meta-analysis (Table 24). Four articles were excluded because they did not report the number of CTS patients with normal and abnormal DML, and two articles were excluded because they did not report the corresponding data for control subjects. Two articles were excluded due to selection bias: DML was one of their patient selection criteria. Another article was excluded because of discrepancies in the reported results; ECRI could not verify or recalculate the 2 x 2 table.

Eight articles remained after those exclusions (see Table 25). Significant heterogeneity in their results was found by the Q statistic ($Q = 16.7$, $p = 0.019$), with one obvious outlier (Atroshi et al.[136], standardized residual = –3.68). Excluding that study left the remaining results homogeneous ($Q = 3.15$, $p = 0.79$). The meta-analysis was completed both with and without the outlier included, and there was no substantial effect on the results. With the outlier excluded (Figure 10), the sensitivity/specificity at mean threshold was 66.0%/98.3%. Including the outlier changed the results by less than a percentage point: the sensitivity/specificity at mean threshold was 65.0%/97.7%.

The results of this meta-analysis are very similar to the results for the meta-analysis of DML with patient groups with unspecified diagnosis of CTS. The results of both meta-analyses suggest that this test has very high specificity, but only moderate sensitivity.

Table 24. Distal Motor Latency Articles Excluded From Meta-Analysis

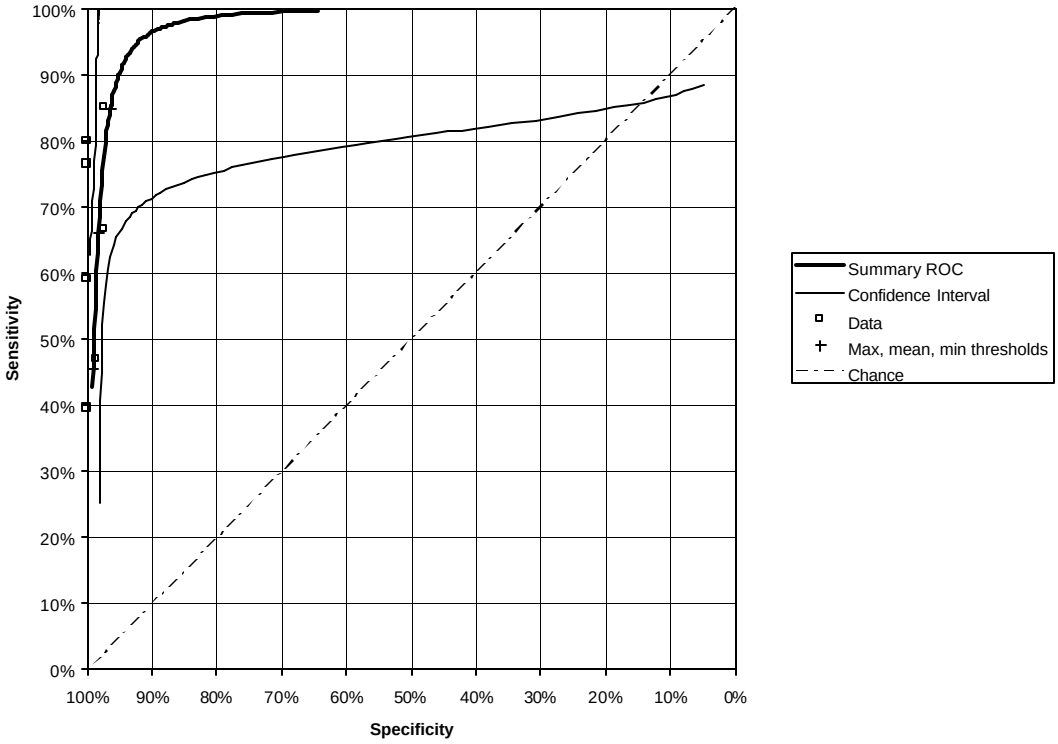
Study	Reason for Exclusion
Jackson, 1989 [150]	Did not report sensitivity and specificity for distal motor latency test
Sener, 2000 [186]	Did not report sensitivity and specificity for distal motor latency test
Schwartz, 1979 [187]	Did not report sensitivity and specificity for distal motor latency test
Escobar, 1985 [151]	Did not report sensitivity and specificity for distal motor latency test
Preston, 1992 [188]	Did not report distal motor latency results for control subjects
Kimura, 1985 [189]	Did not report distal motor latency results for control subjects
Cherniak, 1996 [190]	Used distal motor latency for patient selection
Sheean, 1995 [191]	Used distal motor latency for patient selection
Foresti, 1996 [192]	Discrepancies in reported results

Table 25. Meta-analysis of Distal Motor Latency Results in Trials With Patients Presenting with CTS Symptoms

Study	TP	FN	FP	TN	Sen. 95% CI	Spec. 95% CI	PPV 95% CI	NPV 95% CI	Prev.
[a, b]Chang[145]	17	26	0	40	39.5% 26.1% 54.7%	100% 90.9% 100%	100% 81.0% 100%	60.6% 48.3% 71.7%	51.8%
Kuntzer[144]	47	53	1	69	47.0% 37.3% 56.9%	98.6% 92.1% 99.8%	97.9% 88.8% 99.6%	56.6% 47.5% 65.2%	58.8%
[a]Murthy[143]	38	19	2	72	66.7% 53.5% 77.7%	97.3% 90.5% 99.3%	95.0% 83.2% 98.6%	79.1% 69.5% 86.3%	43.5%
Cioni[146]	300	75	0	56	80.0% 75.6% 83.8%	100% 93.3% 100%	100% 98.7% 100%	42.7% 34.4% 51.5%	87.0%
[b]Messina[120]	34	6	1	39	85.0% 70.6% 93.0%	97.5% 86.8% 99.6%	97.1% 85.1% 99.5%	86.7% 73.5% 93.8%	50.0%
Melvin[147]	13	4	0	24	76.5% 52.2% 90.6%	100% 85.7% 100%	100% 76.5% 100%	85.7% 68.1% 94.4%	41.5%
Loong[148]	13	9	0	60	59.1% 38.4% 77.0%	100% 93.8% 100%	100% 76.5% 100%	87.0% 76.8% 93.1%	26.8%
[c]Atroshi[136]	25	18	8	52	58.1% 43.0% 71.9%	86.7% 75.6% 93.2%	75.8% 58.6% 87.3%	74.3% 62.7% 83.2%	41.7%
Meta-analysis results (mean threshold)					**66.0%** 55.7% 75.0%	**98.3%** 97.4% 98.9%			

Key:
TP–true positive, FN–false negative, FP–false positive, TN–true negative
Sen.–sensitivity, Spec–specificity, PPV–positive predictive value, NPV–negative predictive value, Prev.–prevalence of CTS
Confidence intervals on sensitivity, specificity, PPV, NPV calculated by Wilson method
[a]Counts for control group (false positive, true negative) estimated by ECRI from threshold reported by authors (mean + 2 or 2.5 SD)
[b]Results calculated by ECRI from published graph
[c]Outlier (excluded from meta-analysis results): see text

Figure 10. Meta-analysis of Distal Motor Latency Results in Trials With Patients Presenting with CTS Symptoms



Note:
One outlier[136] was excluded (see text).

Palmar Sensory Latency: Patients with Symptoms of CTS v. Normal Controls

The cross-tabulation found 11 articles that included palmar sensory latency studies and reported some data in the form of a 2 x 2 table. The articles compared patients who presented with suspected CTS or symptoms of CTS to healthy normal controls. As with the other meta-analyses, several studies could not be included in the meta-analysis (Table 26). Five articles did not report sufficient data to allow us to calculate sensitivity and specificity for this particular test. One used palmar sensory latency as a patient selection criterion and was excluded due to selection bias.

After these exclusions, five studies remained in the meta-analysis. There was no statistically significant heterogeneity in their results ($Q = 4.87$, $p = 0.30$). The studies and their results are listed in Table 27 and the summary ROC plot is shown in Figure 11.

Like DML, palmar sensory latency has very high specificity. The normal volunteers studied in these trials rarely had abnormal results. This finding, however, does not reveal the test performance on persons with suspected CTS. To address that issue, a computation of sensitivity is required. The sensitivity/specificity at mean threshold was 75.8%/97.7%, and it is clear that the test has some ability to identify persons with

symptoms of CTS. Although the summary ROC can be extrapolated to a point where sensitivity and specificity are both quite high (i.e., 96%, 96% respectively), in actual practice it is likely that only specificity is so high. Sensitivity was lower than specificity in all five studies.

Table 26. Palmar Sensory Latency Articles Excluded from Meta-analysis

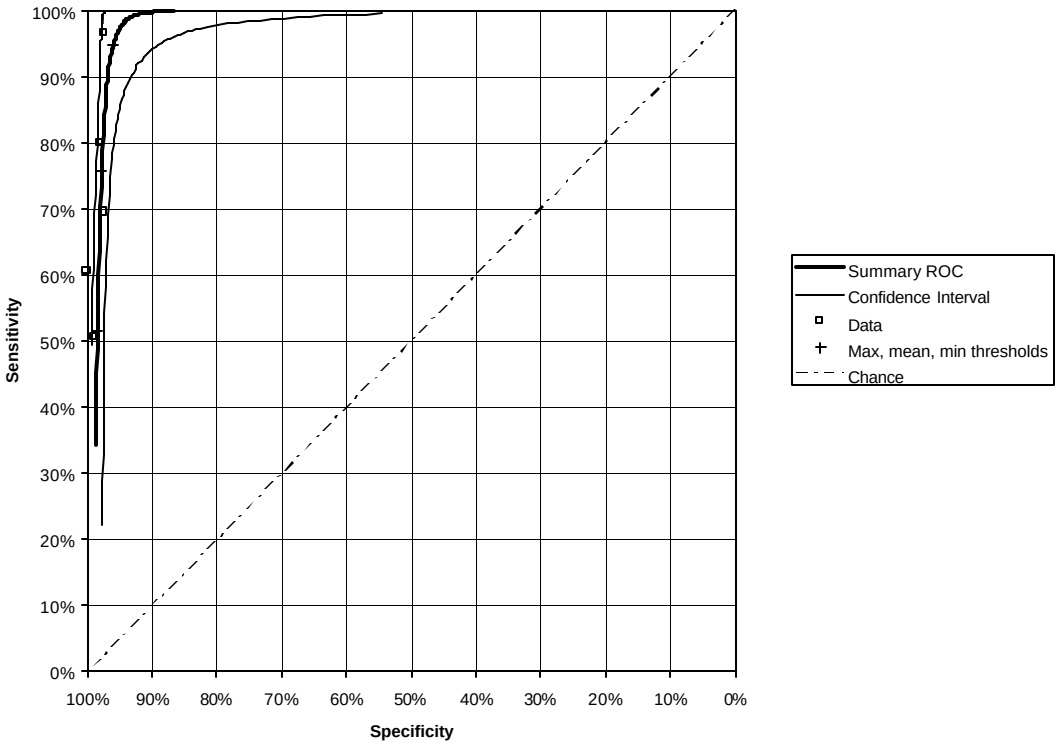
Study	Reason for Exclusion
Gerr, 1998 [31]	Did not report sensitivity and specificity for palmar sensory latency test
Foresti, 1996 [192]	Did not report sensitivity and specificity for palmar sensory latency test
Eisen, 1993 [193]	Did not report sensitivity and specificity for palmar sensory latency test
Mills, 1985 [194]	Did not report sensitivity and specificity for palmar sensory latency test
Kim, 1983 [195]	Did not report sensitivity and specificity for palmar sensory latency test
Andary, 1996 [196]	Palmar sensory latency results used as patient selection criterion

Table 27. Meta-analysis of Palmar Sensory Latency Results

Study	TP	FN	FP	TN	Sen. 95% CI	Spec. 95% CI	PPV 95% CI	NPV 95% CI	Prev.
[a, b]Chang[145]	26	17	0	40	60.5% 45.3% 73.9%	100% 90.9% 100%	100% 86.7% 100%	70.2% 57.1% 80.6%	51.8%
[c]Jackson[150]	91	40	1	37	69.5% 60.9% 76.8%	97.4% 86.2% 99.5%	98.9% 93.9% 99.8%	48.1% 37.0% 59.3%	77.5%
[a]Murthy[143]	55	2	2	72	96.5% 87.8% 99.1%	97.3% 90.5% 99.3%	96.5% 87.8% 99.1%	97.3% 90.5% 99.3%	43.5%
[a]Escobar[151]	32	8	2	102	80.0% 64.9% 89.6%	98.1% 93.1% 99.5%	94.1% 80.5% 98.4%	92.7% 86.1% 96.3%	27.8%
[c]Girlanda[149]	38	37	1	89	50.7% 39.4% 61.9%	98.9% 93.8% 99.8%	97.4% 86.5% 99.6%	70.6% 62.0% 78.0%	45.5%
Meta-analysis results (mean threshold)					75.8% 68.8% 81.6%	97.7% 96.8% 98.4%			

Key:
TP–true positive, FN–false negative, FP–false positive, TN–true negative
Sen.–sensitivity, Spec–specificity, PPV–positive predictive value, NPV–negative predictive value, Prev.–prevalence of CTS
Confidence intervals on sensitivity, specificity, PPV, NPV calculated by Wilson method
[a]Counts for control group (false positive, true negative) estimated by ECRI from threshold reported by authors (mean + 2 or 2.5 SD)
[b]Results calculated by ECRI from published graph
[c]Results calculated by ECRI from published percentages

Figure 11. Meta-analysis of Palmar Sensory Latency Results



Phalen's Maneuver: Combined CTS Groups v. Normal Controls

There were no clinical signs or symptoms for which at least 10 articles reported sensitivity and specificity in a specific patient population. Therefore, we loosened the inclusion criteria by first combining the four patient selection categories, and then requiring a total of 20 or more sensitivity/specificity articles. Because none of the signs and symptoms data met that loosened criterion, we again lowered the threshold to a total of 15 studies or more. Two tests met that criterion: Phalen's maneuver and Tinel's sign. We proceeded to attempt meta-analysis of these data, recognizing that combining patient selection groups could cause heterogeneity of study results that could prevent meta-analysis.

The evidence base on Phalen's maneuver comprised 15 studies. Two of these reported two CTS groups, for a total of 17 entries in the cross-tabulation. For analyzing the two studies with two CTS groups,[101,154] we combined results of all CTS patients. Three articles were excluded because they did not report sufficient data to allow specificity to be calculated. Phalen's maneuver data from the article by Glass and King[28] was excluded because results were reported for only 22 of the 159 hands with CTS, and the authors did not report the reason for this. Finally, we determined while abstracting data that two publications by Gerr[31,197] reported the same controls and likely the same patients. Only the later publication[31] was included in the analysis. Excluded articles are listed in Table 28.

This left a total of 10 articles for meta-analysis (Table 29). We found significant heterogeneity among the studies' results (Q = 71.4, p <0.000001). Six studies selected CTS patients using procedures we categorized as "complex objective standard." Analyzing this subgroup separately did not eliminate the heterogeneity (Q = 59.4, p <0.000001), nor did excluding the one study[111] that used the reverse Phalen maneuver. (Q = 70.8, p <0.000001). There were no obvious outliers to explain the heterogeneity, and grouping studies according to criteria that might affect the validity or generalizability of the results (Table 30) did not reduce heterogeneity to statistically non-significant levels. Thus we could not confidently report a single point as the most likely sensitivity and specificity of the test.

The variability of results is shown in Figure 12; sensitivity/specificity covered a large range. We can only conclude that Phalen's maneuver has some ability to distinguish CTS patients from normal controls; the data are too heterogeneous to estimate sensitivity or specificity.

Table 28. Phalen's Maneuver Articles Excluded from Meta-Analysis

Study	Reason for Exclusion
Koris, 1988 [198]	Did not report specificity of Phalen's maneuver
Brahme, 1997 [199]	Did not report specificity of Phalen's maneuver
Lang, 1995 [109]	Did not report specificity of Phalen's maneuver
Glass, 1995 [28]	Reported results for only 22 of 159 affected hands
Gerr, 1994 [197]	Duplicate publication

Table 29. Diagnostic Trial Results for Phalen's Maneuver

Study	TP	FN	FP	TN	Sen. 95% CI	Spec. 95% CI	PPV 95% CI	NPV 95% CI	Prev.
De Smet[101]	57	9	4	77	86.4% 75.8% 92.7%	95.1% 87.8% 98.1%	93.4% 84.1% 97.5%	89.5% 81.1% 94.5%	44.9%
Durkan[155]	32	14	8	42	69.6% 54.9% 81.1%	84.0% 71.2% 91.8%	80.0% 64.9% 89.6%	75.0% 62.0% 84.6%	47.9%
Gellman[106]	45	18	10	40	71.4% 59.0% 81.3%	80.0% 66.7% 88.9%	81.8% 69.4% 89.9%	69.0% 55.9% 79.6%	55.8%
[a, b]Gerr[31]	48	67	4	119	41.7% 33.0% 51.1%	96.7% 91.8% 98.8%	92.3% 81.5% 97.0%	64.0% 56.7% 70.7%	48.3%
[b]Ghavanini[154]	34	40	17	41	45.9% 34.9% 57.4%	70.7% 57.7% 81.0%	66.7% 52.7% 78.2%	50.6% 39.7% 61.4%	56.1%
González del Pino[104]	174	26	20	180	87.0% 81.5% 91.0%	90.0% 84.9% 93.5%	89.7% 84.5% 93.3%	87.4% 82.0% 91.3%	50.0%
[a]Szabo[152]	65	22	5	95	74.7% 64.4% 82.8%	95.0% 88.7% 97.9%	92.9% 84.1% 97.0%	81.2% 73.0% 87.3%	46.5%
Tetro[102]1	58	37	16	80	61.1% 50.8% 70.4%	83.3% 74.4% 89.6%	78.4% 67.5% 86.4%	68.4% 59.3% 76.2%	49.7%
Fertl[153]	50	23	3	36	68.5% 56.9% 78.2%	92.3% 79.3% 97.4%	94.3% 84.4% 98.1%	61.0% 48.0% 72.6%	65.2%
[c]Werner[111]	17	14	0	20	54.8% 37.5% 71.1%	100% 83.3% 100%	100% 81.0% 100%	58.8% 41.9% 73.9%	60.8%
Meta-analysis results (mean threshold)					**NA**	**NA**			

Key:
TP–true positive, FN–false negative, FP–false positive, TN–true negative
Sen.–sensitivity, Spec–specificity, PPV–positive predictive value, NPV–negative predictive value, Prev.–prevalence of CTS
Confidence intervals on sensitivity, specificity, PPV, NPV calculated by Wilson method
NA—Results not valid because of excessive heterogenity in study results
[a]Results calculated by ECRI from published percentages
[b]Errors in published results corrected by ECRI
[c]Tested reverse Phalen's maneuver

Figure 12. Diagnostic Trial Results for Phalen's Maneuver

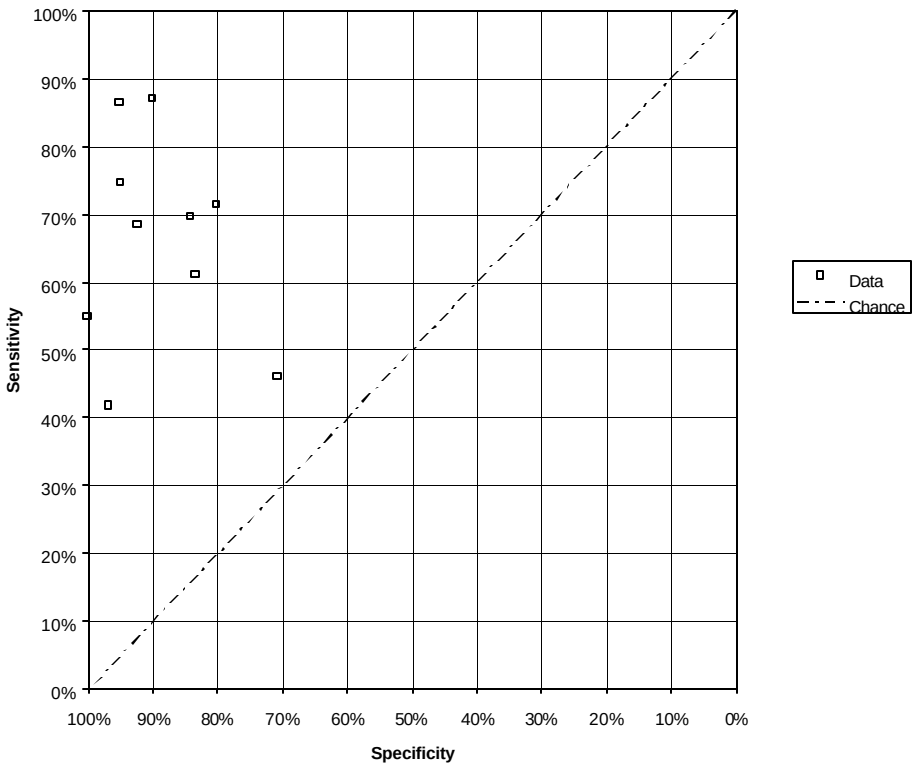


Table 30. Heterogeneity of Diagnostic Trial Results for Phalen's Maneuver

Group	Q (p-value) for larger group
All articles (N = 10)	71.4 (p <0.000001)
Patients selected with complex objective standard (N = 6) v. other selection	59.4 (p <0.000001)
Reverse Phalen's maneuver (N = 1) v. conventional	70.8 (p <0.000001)
Not funded by for-profit device or drug manufacturer (N = 4) v. not reported	58.5 (p <0.000001)
Reported both inclusion and exclusion criteria (N = 4) v. reported only inclusion criteria	20.5 (p = 0.001)
Prospective patient selection (N = 5) v. not reported	58.7 (p <0.000001)
Comorbidity reported (N = 1) v. not reported	69.9 (p <0.000001)
Sex ratios of patients, controls within 20% of each other (N = 5) v. possible sex bias	58.5 (p <0.000001)
Mean ages of patients, controls within 5 years (N = 3) v. possible age bias	15.4 (p = 0.017)
Duration of condition reported (N = 2) v. not reported	48.4 (p <0.000001)
Independent reference standard (N = 4) v. no independent reference standard reported	48.2 (p <0.000001)
Patients given both study test and reference test (N = 3) v. did not do so	49.3 (p <0.000001)
Studies done in USA (N = 6) v. other countries	58.1 (p <0.000001)
Potential selection bias for easy cases (N = 4) v. no bias or not reported	49.3 (p <0.000001)

Q—Q-statistic, with probability that variability in study results [D, logit (sensitivity) + logit (specificity)] is the result of random variability within a homogeneous sample of studies.

Tinel's Sign: Combined CTS Groups v. Normal Controls

The evidence base on Tinel's sign comprised 13 studies; three of these reported two CTS groups, for a total of 16 entries in the cross-tabulation. As mentioned in the meta-analysis of Phalen's maneuver, only the later of the duplicate Gerr publications[31,197] was included in the analysis, and we pooled patient groups in studies with two CTS groups. Two articles were excluded because they did not report specificity. Exclusions are summarized in Table 31

Eleven studies remained for meta-analysis (Table 32). The meta-analysis found significant heterogeneity among the studies' results ($Q = 59.1$, $p < 0.000001$). All but two studies (De Smet et al.[101] and Seror et al.[156]) selected CTS patients using procedures we categorized as "complex objective standard." Excluding those studies from the analysis did not substantially reduce the heterogeneity ($Q = 46.7$, $p < 0.000001$).

The heterogeneity is evident in Figure 13. Sensitivity/specificity results are widely dispersed in the graph, and there is no pattern of results that is obvious on inspection. The data suggest that Tinel's sign has some ability to diagnose CTS, but the sensitivity and specificity of the test are uncertain. However, the sensitivity of the test appears to be low.

To see whether other factors, particularly those relating to the validity or generalizability of results, could explain the observed heterogeneity, we repeated the heterogeneity tests for groups defined by reporting criteria in Table 13 and Table 15. The results of those analyses are shown in Table 33. Significant heterogeneity remained regardless of the criteria used to group trials. Therefore none of these criteria are sufficient to explain the heterogeneity that prevents us from meta-analyzing the results.

Table 31. Tinel's Sign Articles Excluded from Meta-analysis

Study	Reason for Exclusion
Brahme, 1997 [199]	Did not report specificity of Tinel's sign
Lang, 1995 [109]	Did not report specificity of Tinel's sign
Gerr, 1994 [197]	Duplicate publication

Table 32. Diagnostic Trial Results for Tinel's Sign

Study	TP	FN	FP	TN	Sen. 95% CI	Spec. 95% CI	PPV 95% CI	NPV 95% CI	Prev.
De Smet[101]	14	17	0	81	45.2% 28.9% 62.5%	100% 95.3% 100%	100% 77.8% 100%	82.7% 73.8% 89.0%	27.7%
Durkan[155]	26	20	10	40	56.5% 42.0% 70.0%	80.0% 66.7% 88.9%	72.2% 55.7% 84.3%	66.7% 53.8% 77.5%	47.9%
Gellman[106]	29	37	3	47	43.9% 32.4% 56.2%	94.0% 83.5% 98.0%	90.6% 75.4% 96.8%	56.0% 45.1% 66.3%	56.9%
Gelmers[29]	20	27	11	32	42.6% 29.3% 57.0%	74.4% 59.4% 85.2%	64.5% 46.6% 79.1%	54.2% 41.4% 66.5%	52.2%
[a, b]Gerr[31]	8	50	2	121	13.8% 7.1% 25.2%	98.4% 94.1% 99.6%	80.0% 48.4% 94.5%	70.8% 63.4% 77.2%	32.0%
Ghavanini[154]	24	52	9	49	31.6% 22.1% 42.9%	84.5% 72.8% 91.7%	72.7% 55.4% 85.1%	48.5% 38.8% 58.3%	56.7%
González del Pino[104]	42	87	6	194	32.6% 24.9% 41.2%	97.0% 93.5% 98.6%	87.5% 75.0% 94.2%	69.0% 63.3% 74.3%	39.2%
[a]Seror[156]	63	37	18	22	63.0% 53.0% 72.0%	55.0% 39.5% 69.6%	77.8% 67.4% 85.6%	37.3% 25.9% 50.3%	71.4%
Stewart[157]	23	28	15	37	45.1% 32.0% 58.9%	71.2% 57.4% 81.8%	60.5% 44.4% 74.6%	56.9% 44.6% 68.5%	49.5%
[a]Szabo[152]	56	31	1	99	64.4% 53.7% 73.8%	99.0% 94.4% 99.8%	98.2% 90.5% 99.7%	76.2% 68.0% 82.8%	46.5%
[a]Tetro[102]	70	25	9	87	73.7% 63.8% 81.6%	90.6% 82.9% 95.1%	88.6% 79.5% 94.0%	77.7% 68.9% 84.5%	49.7%
Meta-analysis results (mean threshold)					**NA**	**NA**			

TP–true positive, FN–false negative, FP–false positive, TN–true negative

Sen.–sensitivity, Spec–specificity, PPV–positive predictive value, NPV–negative predictive value, Prev.–prevalence of CTS

Confidence intervals on sensitivity, specificity, PPV, NPV calculated by Wilson method

NA—Results not valid because of excessive heterogenity in study results

[a]Results calculated by ECRI from published percentages

[b]Errors in published results corrected by ECRI

Figure 13. Diagnostic Trial Results for Tinel's Sign

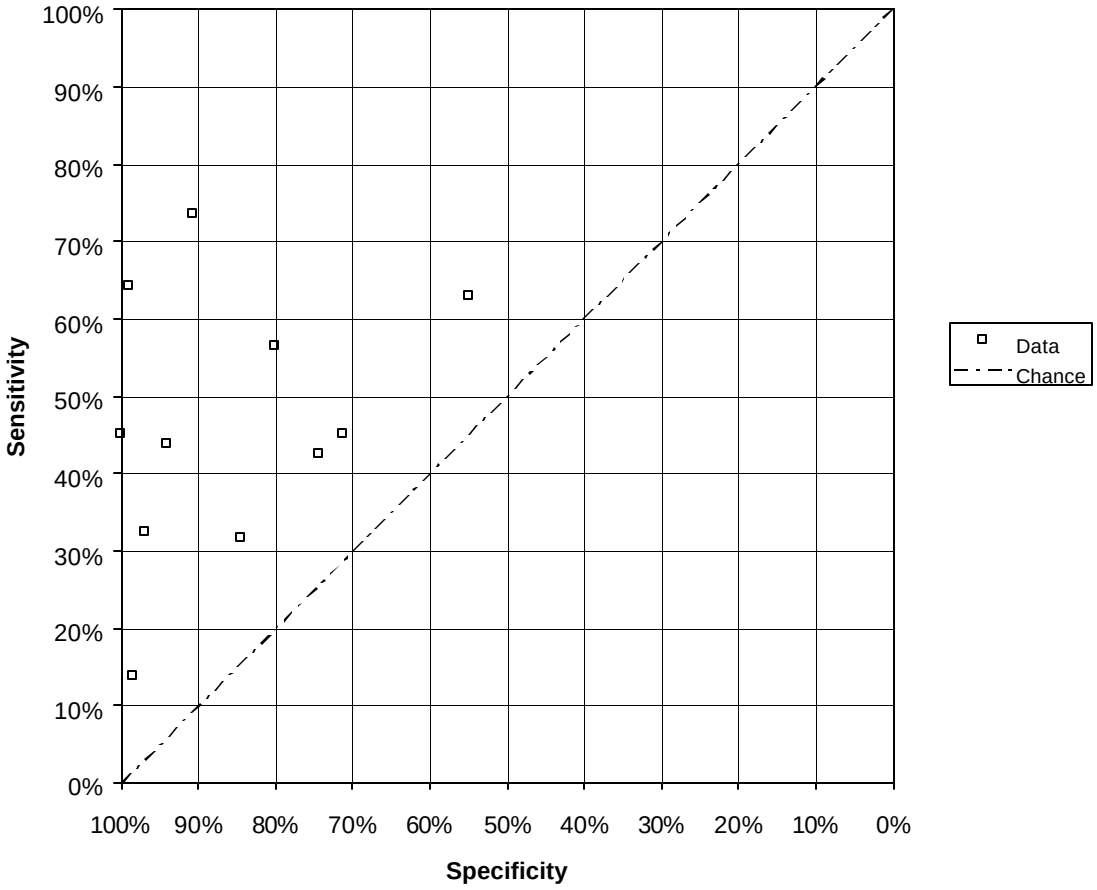


Table 33. Heterogeneity of Diagnostic Trial Results for Tinel's Sign

Group	Q (p-value) for larger group
All articles (N = 11)	59.1 (p <0.000001)
Patients selected with complex objective standard (N = 9) v. other selection	46.1 (p <0.000001)
Not funded by for-profit device or drug manufacturer (N = 5) v. not reported	10.7 (p = 0.057)
Reported both inclusion and exclusion criteria (N = 6) v. reported only inclusion criteria	30.2 (p = 0.000013)
Prospective patient selection (N = 4) v. not reported	16.6 (p = 0.011)
Comorbidity reported (N = 2) v. not reported	51.4 (p <0.000001)
Mean ages of patients, controls within 5 years (N = 6) v. possible age bias	37.8 (p <0.000001)
Possible sex bias (N = 3) vs. sex ratios of patients, controls within 20% of each other (N = 8)	52.8 (p <0.000001)
Duration of condition reported (N = 2) v. not reported	50.6 (p <0.000001)
Independent reference standard (N = 6) v. no independent reference standard reported	16.5 (p = 0.005545)
Patients given both study test and reference test (N = 3) v. did not do so	51.6 (p <0.000001)
Studies done in USA (N = 5) v. other countries	22.3 (p = 0.000454)
Potential selection bias for easy cases (N = 4) v. no bias or not reported	41.9 (p <0.000001)

Q—Q-statistic, with probability that variability in study results [D, logit (sensitivity) + logit (specificity)] is the result of random variability within a homogeneous sample of studies.

Articles on Carpal Tunnel Syndrome Screening

Screening tests are intended to identify persons at risk of developing a condition in the future, not those who already have the condition. Because there is no agreement on what constitutes screening for CTS, we accepted any studies so described by their authors as screening studies. There were 28 articles described by their authors as screening studies. Two (Bland[200] and Rosen[201]) were excluded from this analysis because they required all participants to be symptomatic. Two[202,203] were sequential reports on the same study. Therefore, 25 studies (Table 34) were included in the analysis of screening of carpal tunnel syndrome. Twenty-two of the studies screened workers at risk, and the remaining three studies screened the general population; the table is stratified according to these two categories.

The reported methods of diagnosis in the 28 screening studies appear in Table 35. The most common diagnostic criteria were symptoms (12 studies, 43%) and the difference between median and ulnar sensory tests (9 studies, 32%). Thirteen studies (46%) used both clinical criteria and nerve conduction criteria, three studies (11%) used nerve conduction criteria only, and no studies used clinical criteria only. The table demonstrates the variability in authors' methods for screening for CTS. As with the diagnostic articles on CTS, we tabulated the number of screening articles reporting use of each particular test (Table 36, Table 37, Table 38, Table 39, Table 40). In no case were there sufficient articles reporting a particular test to meet our a priori criteria for meta-analyzing their data.

The presence of symptoms and the presence of a positive nerve conduction test appeared to be independent of each other in the screening studies. Figure 14 plots the prevalence of symptoms on the horizontal axis and the prevalence of positive nerve conduction tests on the vertical axis. We could only plot the 15 studies that reported both variables. The

correlation between symptoms and nerve conduction was 0.21 ($r^2 = 0.04$) and was not statistically different from zero. Because two of the 15 studies screened a general population, we recomputed the correlation after removing these two studies. The correlation was 0.16 ($r^2 = 0.02$) and was not statistically different from zero. The weak association between symptoms and abnormal nerve conduction suggests that a high incidence of CTS symptoms in workers at risk does not necessarily imply that those same workers will have a high incidence of abnormal nerve conduction.

Lack of agreement on what constitutes carpal tunnel syndrome is another obstacle to analyzing these studies. Table 41 lists all the different criteria used to define true cases of CTS in the screening articles. In 13 of the 28 articles (46%), the criteria were not reported at all. The majority of articles that did report criteria (80%) considered both nerve conduction and symptoms; the others used nerve conduction only. In some cases, it was not clearly reported how the elements of the diagnosis were to be combined: whether any sign of CTS would be considered diagnostic for the condition or whether all the criteria must be met.

The ideal study design for evaluating screening tests for WRUEDs would first test a group of at-risk persons, and then perform followup for a period of time to determine whether symptoms develop. Only six articles in our evidence base reported this kind of trial, and two reported on the same trial. The bulk of the "screening" literature was made up of articles intended to diagnose CTS in screening populations (asymptomatic workers presumed to be at risk for CTS). The five longitudinal studies of screening populations are listed in Table 42. The evidence base is small enough that each study will be discussed individually in this report.

Kearns[204] measured nerve conduction in new workers at a pork processing plant. Tests were done before the workers started employment and after two months' employment, though the actual time of the followup test ranged from 42 days to 83 days. Only the nerve conduction tests were done; no symptoms were reported and the authors cautioned that the study was not intended to identify workers who developed CTS. Therefore, this study cannot be used to base conclusions of nerve conduction measurement as a screening test for CTS.

Nathan et al. performed the longest longitudinal study on nerve conduction measurements: 11 years. Two articles[202,203] reported on the same group of subjects: 471 workers from a variety of manufacturing and clerical jobs. Their initial testing was in 1984, with subsequent testing in 1989 (316 subjects followed)[203] and 1994-95 (283 subjects)[202]. Both inching tests and sensory latency measurements were reported in the latest article, though several other nerve conduction tests were also done.

The first followup article reports that there was a statistically significant association between slowing of nerve conduction in 1984 and CTS symptoms in 1989, but did not report sufficient data to allow us to verify these findings or determine the sensitivity and specificity of the test. There were sufficient data of this type reported from the 1994-95 followup to calculate sensitivity and specificity of one nerve conduction test: the

"maximum latency difference" test, which is a variation of the inching test. We reanalyzed this data: the resulting sensitivities and specificities at different threshold values are shown in Table 43 and an ROC curve fitted to the data using the logit regression method is shown in Figure 15. While it is clear that this test had a significant ability to predict future CTS in this screening population, this is just one of several nerve conduction tests done in this study, and the possibility of a chance result cannot be discounted. Independent confirmation of this finding would be necessary for us to conclude that this is an effective predictive test. Reanalysis of the unpublished results from this study could verify whether or not other nerve conduction tests also predict future CTS, and could help clinicians decide which test is most effective.

Table 34. Articles Described as Screening Studies

Article	N	Population	Symptoms	Positive NCS	Symptoms & Positive NCS
Workers-at-risk screening studies for carpal tunnel syndrome					
Kearns, 2000 [204]	45	Pork processors	NR	NR	NR
Missere, 1999 [205]	45	Meat manufacturers	NR	[a] 28.9%	NR
Nathan, 1998 [202]	283	Steel mill workers, food processors, electronics workers, and plastics workers	12.9%	43.0%	8.2%
Tan, 1998 [206]	64	Carpet weavers	NR	NR	NR
Werner, 1998 [207]	119	Automobile parts manufacturers	NR	27%	[b] 20.2%
	98	Furniture manufacturers	NR	26%	[b] 10.2%
	77	Paper containers manufacturers	NR	34%	[b] 14.3%
	64	Automobile parts manufacturers	NR	30%	[b] 17.2%
	164	Clerical insurance workers	NR	15%	[b] 11.0%
	202	Spark plugs manufacturers	NR	28%	[b] 9.4%
Franzblau, 1997 [208]	148	Automobile parts manufacturers	41%	NR	NR
Jeng, 1997 [209]	27	Food processors	48.8%	34.1%	22.0%
Werner, 1997 [210]	59	Manufacturing workers and clerical workers	11.1%	45.4%	5.6%
Bingham, 1996 [211]	1021	Applicants for jobs in meat packers, plastics assemblers, food processors, furniture manufacturers, or grocery warehousing workers	[c] 6.0%	[a] 17.4%	[c] 1.8%
Murata, 1996 [164]	27	Data entry operators	NR	37%	NR
Pierre-Jerome, 1996 [212]	24	Floor cleaners	NR	NR	NR
Werner, 1995 [213]	167	Automobile parts manufacturers	19.8%	24.6%	9.0%
Young, 1995 [166]	157	Poultry processors	70%b	31%	NR
Franzblau, 1994 [113]	84	Automobile parts manufacturers	21.4%	19.3%	8.40%
Kirschberg, 1994 [214]	112	Poultry processors	22.3%	29.5%	17.0%

Article	N	Population	Symptoms	Positive NCS	Symptoms & Positive NCS
Workers-at-risk screening studies for carpal tunnel syndrome					
Nathan, 1994 [215]	101 316	Japanese furniture factory workers Steel mill workers, food processors, electronics workers, and plastics workers	[a, b] 4.5% [a, b] 23.4%	[b] 17.8% [b] 22.0%	[b] 2.0% [b] 8.3%
Nilsson, 1994 [216]	61 58 56	Office workers Truck assemblers Platers	NR NR NR	33% 40% 55%	NR NR NR
Werner, 1994 [217]	130	Automobile parts manufacturers	27.7%	[d] 20.2%	NR
Johnson, 1993 [167]	184	Poultry processors	[a, b] 37.3%	[a, b] 19.2%	[a, b] 6.0%
Nathan, 1993 [218]	737	Steel mill workers, meat/food processors, electronics workers, plastics workers, aluminum reduction workers, and cable plant workers.	[a, b] 51.0%	[a, b] 33.6%	[a, b] 19.8%
Grant, 1992 [219]	63	Manufacturing plant workers	[a] 25.4%	NR	NR
Jetzer, 1991 [168]	39 100 284	Computer assemblers Meat processors Keyboard operators	NR NR NR	NR NR NR	NR NR NR
General population screening studies for carpal tunnel syndrome					
Atroshi, 1999 [220]	2466	General population	14.4%	[c] 22.3%	[c] 6.6%
Ferry, 1998 [221]	648	General population	18.5%	17.4%	7.7%
DeKrom, 1990 [222]	500	General population	13.8%	NR	[c] 7.8%

Key
NR-Not reported
NCS-Nerve conduction studies
[a]Based on hands instead of participants
[b]Calculated by ECRI based on information reported in the article
[c]Estimated by ECRI based on information reported in the article
[d]Prevalence of positive NCS in the study by Werner[217] was based on 129 participants .

Table 35. Definitions of CTS Reported in Screening Articles

Author, Year	Clinical findings			Nerve conduction studies						Comments
	SYM	CLN	OTH CLN	DML	DSL	PAL	SEN DIF	MOT DIF	OTH NCS	
Bland, 2000 [200]	?	?	?	☑	?	?	?	?	☑	If tests equivocal, authors measured sensory potential or inching test
Kearns, 2000 [204]	?	?	?	?	?	?	?	?	?	NR
Atroshi, 1999 [220]	☑	☑	?	?	?	?	☑	?	?	
Missere, 1999 [205]	?	?	?	?	?	?	?	?	☑	
Ferry, 1998 [221]	?	?	?	?	?	?	?	?	?	NR
Nathan, 1998 [202]	☑	?	?	?	☑	☑	?	?	☑	
Rosen, 1998 [201]	?	?	?	?	?	?	?	?	?	NR
Tan, 1998 [206]	?	?	?	?	?	?	?	?	?	NR
Werner, 1998 [207]	☑	?	?	?	?	?	☑	?	?	
Franzblau, 1997 [208]	?	?	?	?	?	?	?	?	?	NR
Jeng, 1997 [209]	☑	?	?	☑	☑	?	☑	?	?	
Werner, 1997 [210]	☑	?	?	?	?	?	☑	?	?	
Bingham, 1996 [211]	?	?	?	?	?	?	?	?	?	NR
Murata, 1996 [164]	?	?	?	?	?	?	?	?	?	NR
Pierre-Jerome, 1996 [212]	?	?	?	?	?	?	?	?	?	NR
Werner, 1995 [213]	☑	?	?	?	?	?	☑	?	?	
Young, 1995 [166]	?	?	?	?	?	?	?	?	?	NR
Franzblau, 1994 [113]	☑	?	?	?	?	?	☑	?	?	
Kirschberg, 1994 [214]	☑	☑	☑	☑	?	☑	☑	?	☑	
Nathan, 1994 [215]	☑	?	?	?	☑	☑	?	?	☑	
Nilsson, 1994 [216]	?	?	?	?	?	?	?	?	?	NR
Werner, 1994 [217]	?	?	?	?	?	?	?	?	?	NR
Johnson, 1993 [167]	?	?	?	?	?	?	?	?	?	NR
Nathan, 1993 [218]	☑	?	?	?	☑	☑	?	?	☑	
Grant, 1992[219]	?	?	?	☑	☑	?	☑	☑	?	

Author, Year	Clinical findings			Nerve conduction studies						Comments
	SYM	CLN	OTH CLN	DML	DSL	PAL	SEN DIF	MOT DIF	OTH NCS	
Jetzer, 1991 [168]	☑	?	?	?	?	?	?	?	?	Or positive NCS (tests not reported)
DeKrom, 1990 [222]	☑	?	?	☑	?	?	☑	?	?	
Welch, 1973 [223]	?	?	?	?	?	?	?	?	?	NR
Totals	12	2	1	5	5	4	9	1	6	

Key
SYM—Were positive symptoms included in the author's method of diagnosis?
CLN—Was a positive clinical exam included in the author's method of diagnosis?
OTH CLN—Were other clinical findings included in the author's method of diagnosis?
DML—Was distal motor latency included in the author's method of diagnosis?
DSL—Was distal sensory latency included in the author's method of diagnosis?
PAL—Was palmar sensory latency included in the author's method of diagnosis?
SEN DIF—Was the difference between median and ulnar sensory studies included in the author's method of diagnosis?
MOT DIF—Was the difference between median and ulnar motor studies included in the author's method of diagnosis?
OTH NCS—Were other nerve conduction studies included in the author's method of diagnosis?
NR—Method of diagnosis was not reported

Figure 14. Association of Symptoms with Positive NCS Findings in Screening Studies

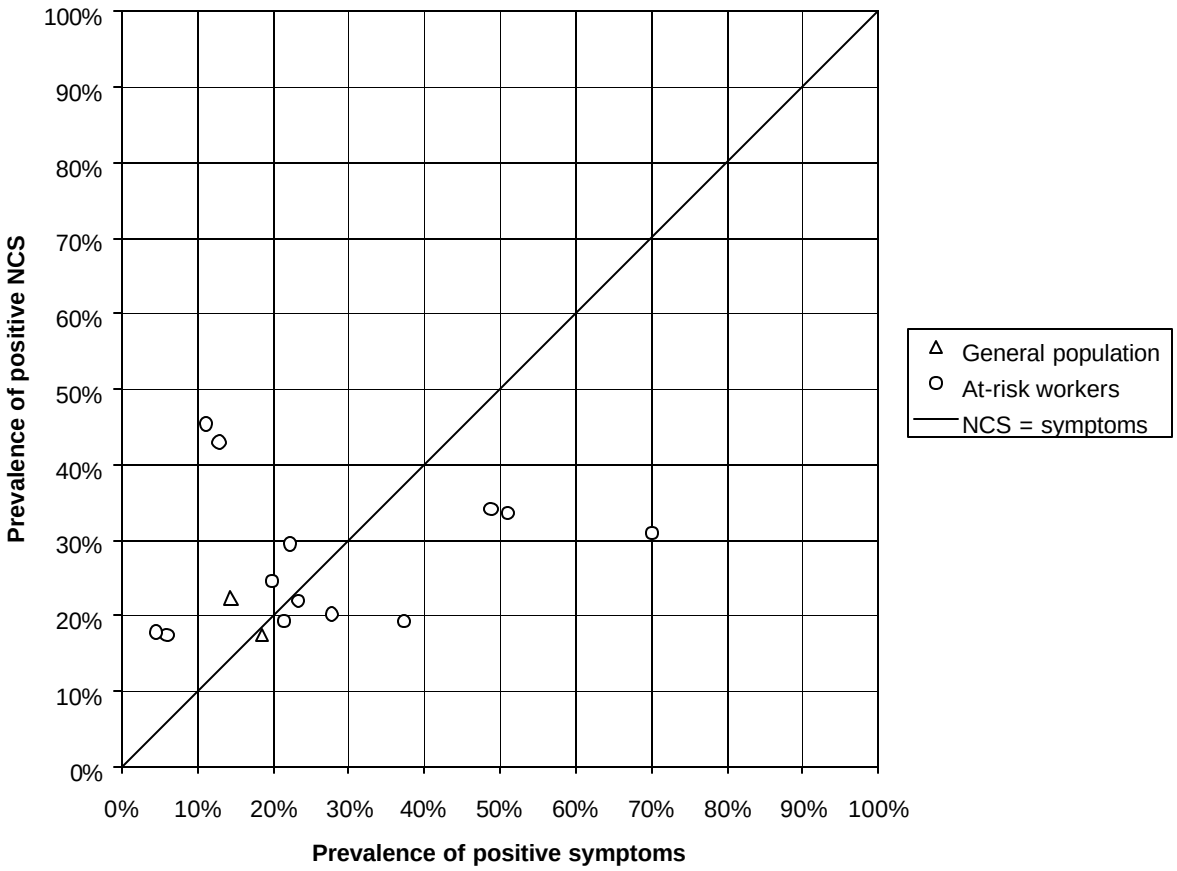


Table 36. Signs and Symptoms Reported in Screening Articles

Legend:
First entry in cell—Total number of articles
Second entry in cell—Number of articles with derivable sensitivity and specificity

Sign/symptom	Number of articles reporting
Clinical exam and history	1, 0
Durkan compression	1, 1
Flick sign	1, 1
Flick: Does shaking alleviate night symptoms?	1, 1
Gilliat tourniquet	1, 1
Grip strength	2, 0
Hypalgesia	1, 0
Hyperpathia	1, 0
Lateral pinch strength	1, 0
Luthy's test	1, 1
Night symptoms	1, 1
Opponens pollicus weakness	1, 1
Phalen's/reverse Phalen's	3, 2
Right or left hand worse? Or bilateral?	1, 1
Signs	1, 0
Symptoms measured systematically	15, 7
Symptoms	2, 0
Symptoms and signs	1, 0
Thenar atrophy	1, 1
Thenar weakness	1, 1
Three-point pinch strength	1, 0
Tinel's	3, 2
When are symptoms worse?	1, 1
Which fingers are worst affected?	1, 1

Table 37. Sensory Tests Reported in Screening Articles

Legend:
First entry in cell—Total number of articles
Second entry in cell—Number of articles with derivable sensitivity and specificity

Sensory test	Number of articles reporting
Current perception	1, 1
Gap detection test	1, 1
Semmes-Weinstein monofilament	1, 0
Tactile discrimination	1, 1
Vibrometer	6, 3

Table 38. Nerve Conduction Tests Reported in Screening Articles

Legend:

Nerve tested: MED–median, RAD–radial, ULN–ulnar
Nerve tested: MOT–motor, SEN–Sensory
Configuration (not applicable to motor nerve tests: OR–orthodromic, AN–antidromic
Stimulation/measurement sites: ELB–elbow, FOR–forearm, WR–wrist, PAL–palm, IN–index finger, MI–middle finger, RI–ring finger, LI–little finger, APB–abductor policis brevis, ADM–abductor digiti minimi, OTH–other
Measured parameter: LAT–latency, AMP–amplitude, VEL–velocity, INCH–inching, OTH–other
Blank cells—characteristic not reported
First entry in cell—Total number of articles
Second entry in cell—Number of articles with derivable sensitivity and specificity
Numeric entries—Total number of articles, articles from which sensitivity and specificity can be calculated

Nerve tested		Configuration	Stimulation site	Measurement site	Parameter measured	Number of articles reporting
MED	MOT				LAT	2, 0
MED	MOT		FOR	APB	LAT	1, 1
MED	MOT		WR	APB	LAT	4, 2
MED	MOT		WR	APB	VEL	1, 1
MED	MOT		WR	OTH	AMP	1, 0
MED	MOT		WR	OTH	LAT	3, 2
MED	MOT		WR	OTH	VEL	1, 0
MED	SEN				AMP	1, 0
MED	SEN				LAT	4, 0
MED	SEN				OTH	1, 1
MED	SEN	AN			LAT	1, 1
MED	SEN	AN	PAL	IN	VEL	1, 1
MED	SEN	AN	PAL	MI	AMP	1, 1
MED	SEN	AN	PAL	MI	VEL	1, 1
MED	SEN	AN	WR	IN	AMP	2, 2
MED	SEN	AN	WR	IN	LAT	5, 3
MED	SEN	AN	WR	IN	VEL	1, 1
MED	SEN	AN	WR	MI	AMP	1, 1
MED	SEN	AN	WR	MI	INCH	3, 1
MED	SEN	AN	WR	MI	VEL	1, 1
MED	SEN	AN	WR	OTH	LAT	3, 1
MED	SEN	AN	WR	PAL	VEL	2, 2
MED	SEN	AN	WR	RI	LAT	1, 1
MED	SEN	OR	IN	WR	LAT	1, 1
MED	SEN	OR	IN	WR	VEL	1, 0
MED	SEN	OR	PAL	WR	LAT	5, 2
MED	SEN	OR	WR	ELB	VEL	1, 1
ULN	MOT				LAT	1, 0
ULN	MOT		WR	ADM	LAT	1, 0
ULN	SEN				LAT	2, 0
ULN	SEN	AN			LAT	1, 1
ULN	SEN	AN	WR	LI	AMP	2, 2
ULN	SEN	AN	WR	LI	LAT	4, 2
ULN	SEN	AN	WR	RI	LAT	1, 1
ULN	SEN	OR	LI	WR	LAT	1, 0
ULN	SEN	OR	LI	WR	VEL	1, 0
ULN	SEN	OR	PAL	WR	LAT	3, 2

Table 39. Composite Nerve Conduction Tests Reported in Screening Articles

Legend:
Nerves: MED—median, ULN—Ulnar
Measured parameter: LAT–latency, VEL–velocity
First entry in cell—Total number of articles
Second entry in cell—Number of articles with derivable sensitivity and specificity

First nerve	Second nerve	Motor or Sensory	Parameter Measured	Combination	Number of articles reporting
MED	MED	SEN	VEL	Ratio	1, 1
MED	ULN	MOT	LAT	Difference	2, 0
MED	ULN	SEN	LAT	Difference	11, 6
ULN	MED	SEN	LAT	Difference	1, 0
				Other composite	7, 3

Table 40. Imaging Tests Reported in Screening Articles

Legend:
First entry in cell—Total number of articles
Second entry in cell—Number of articles with derivable sensitivity and specificity

Imaging modality	Number of articles reporting
CT	1, 0
MRI	1, 0
Ultrasound	1, 1

Table 41. Definitions of CTS Reported in Screening Articles

Article	Method of diagnosis used to determine patient condition
Bland, 2000 [200]	Median and ulnar sensory conduction (velocity?), DML to APB. Sensory potential or segmental study of conduction used if previous tests equivocal. Threshold 2.5 SD from the mean.
Kearns, 2000 [204]	Not reported
Atroshi, 1999 [220]	Two definitions: 1) Symptoms and positive clinical exam. Symptoms were pain, numbness and/or tingling in 2 or more of the first 4 fingers at least twice weekly during the preceding 4 weeks, as stated on a questionnaire. Clinical exam required the presence of nocturnal and/or activity-related numbness and/or tingling involving the palmar aspects of at least 2 of the first 4 fingers. The presence of median nerve sensory and/or motor deficit was supportive of the diagnosis but not necessary. 2) Symptoms and positive clinical exam and positive nerve conduction. Included the same definitions as above, and in addition required a difference of 0.8 ms or more between the median sensory latency (middle finger to wrist) and the ulnar sensory latency (little finger to wrist).
Missere, 1999 [205]	SCV <42.5 m/s as measured by the nerve conduction inching test.
Ferry, 1998 [221]	Not reported
Nathan, 1998 [202]	Symptoms and abnormal nerve conduction. Symptoms defined as positive when the patient has either one of two sets of symptoms: 1) Two or more specific CTS symptoms such as numbness, tingling, nocturnal awakening occurring at least twice per month in the median nerve distribution. 2) One specific CTS symptoms and two or more nonspecific symptoms such as pain, tightness, clumsiness occurring at least twice per month in the median nerve distribution. NCS was defined as abnormal when a patient had any of the following three abnormalities: 1) Maximum latency difference = 0.4 ms in the orthodromic inching test. 2) Antidromic wrist-to-digit sensory latency >3.6 ms. 3) Orthodromic palm to wrist sensory latency >2.2 ms
Rosen, 1998 [201]	Not reported
Tan, 1998 [206]	Not reported
Werner, 1998 [207]	Nerve conduction abnormality defined as a difference >0.5 ms between median and ulnar antidromic sensory latencies to index and little fingers, respectively. Symptom abnormality defined as numbness, tingling, burning, or pain in the wrist, fingers, or hand.
Franzblau, 1997 [208]	Not reported
Jeng, 1997 [209]	Two definitions: One required both symptoms and abnormal conduction, and the other required either symptoms or abnormal nerve conduction :Symptoms: tingling, numbness, pain, perceived weakness, and clumsiness.Nerve conduction was abnormal on any of the following three tests: 1) DML >4.5 ms. 2) Antidromic sensory latency from index finger >3.7 ms. 3) Difference between median palm-to-wrist latency and ulnar palm-to-wrist latency >0.5 ms.
Werner, 1997 [210]	Difference between median and ulnar sensory latency >0.5 ms, and symptoms.
Bingham, 1996 [211]	Not reported
Murata, 1996 [164]	Not reported
Pierre-Jerome, 1996 [212]	Not reported
Werner, 1995 [213]	Symptoms and abnormal NCS. Positive symptoms were defined as any of the following: numbness, tingling, buning, pain, or nocturnal paresthesia in the hand. Abnormal CTS was defined as a difference greater than 0.5 ms between the median and ulnar sensory antidromic latencies.
Young, 1995 [166]	Not reported

Article	Method of diagnosis used to determine patient condition
Franzblau, 1994 [113]	Symptoms and abnormal nerve conduction. Positive symptoms was defined as having both 1) numbness, tingling, burning, or pain in the fingers, hand, wrist, or forearm and 2) nocturnal occurrence of above symptoms. Abnormal nerve conduction was defined as a difference >0.5 between median sensory antidromic wrist-to-index latency and ipsilateral ulnar sensory antidromic wrist-to-little-finger latency.
Kirschberg, 1994 [214]	Clinical CTS: One or more of the following 7 findings: 1) nocturnal paresthesia of the hand, relieved by shaking; 2) sensory symptoms in the specific distribution of the median nerve; 3) specific median nerve sensory loss; 4) positive Phalen's sign; 5) Positive Tinel's sign; 6) Thenar atrophy; 7) Thenar weakness. Electrodiagnostic CTS (using Mayo Clinic criteria) involved any of the following 4 findings: 1) Median DML >4.6 ms; 2) Median palmar sensory latency >2.2 ms; 3) Difference >0.2 ms between median and ulnar palmar latencies; 4) Difference >1.8 ms between median and ulnar latencies.
Nathan, 1994 [215]	Symptoms and abnormal nerve conduction. Symptoms defined as positive when the patient has either one of two sets of symptoms: 1) Two or more specific CTS symptoms such as numbness, tingling, nocturnal awakening occurring at least twice per month in the median nerve distribution 2) One specific CTS symptom and two or more nonspecific symptoms such as pain, tightness, clumsiness occurring at least twice per month in the median nerve distribution. NCS was defined as abnormal when a patient had any of the following three abnormalities: 1) Maximum latency difference = 0.4 ms in the orthodromic inching test. 2) Antidromic wrist-to-digit sensory latency >3.6 ms 3) Orthodromic palm to wrist sensory latency >2.2 ms
Nilsson, 1994 [216]	Not reported
Werner, 1994 [217]	Not reported
Johnson, 1993 [167]	Not reported
Nathan, 1993 [218]	Symptoms and abnormal nerve conduction. Symptoms defined as positive when the patient has either one of two sets of symptoms: 1) Two or more specific CTS symptoms such as numbness, tingling, nocturnal awakening occurring at least twice per month in the median nerve distribution 2) One specific CTS symptoms and two or more nonspecific symptoms such as pain, tightness, clumsiness occurring at least twice per month in the median nerve distributionNCS was defined as abnormal when a patient had any of the following three abnormalities: 1) Maximum latency difference = 0.4 ms in the orthodromic inching test. 2) Antidromic wrist-to-digit sensory latency >3.6 ms 3) Orthodromic palm to wrist sensory latency >2.2 ms
Grant, 1992 [219]	Median DML >4.5 ms or median DSL >3.5 ms or median-ulnar DML difference >1.2 ms or median-ulnar DSL difference >0.5 ms
Jetzer, 1991 [168]	Symptoms and either positive EMG or recent prior carpal tunnel surgery.
DeKrom, 1990 [222]	Nocturnal paresthesia at least twice a week and either DML >4.5 ms or a difference >0.4 ms between median and ulnar antidromic latencies to the ring finger.
Welch, 1973 [223]	Not reported

Table 42. Screening Articles Reporting Longitudinal Results

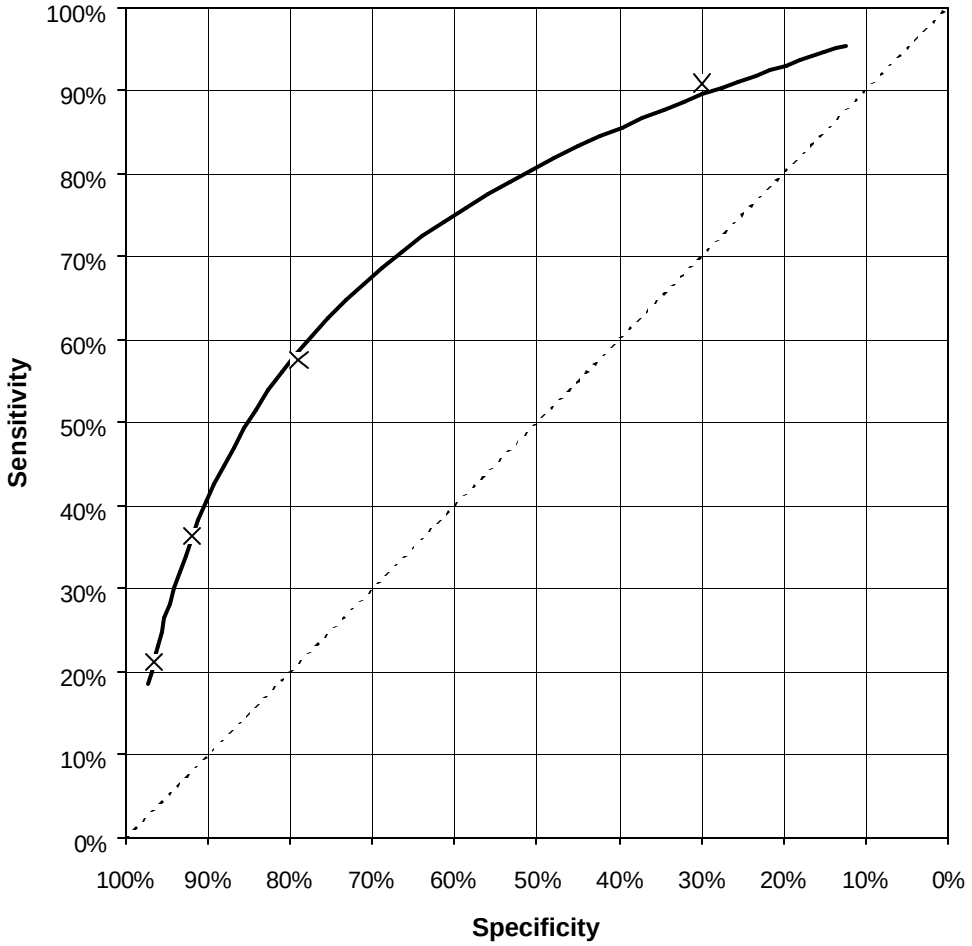
Article	N	Population	Selection	Followup
Kearns, 2000 [204]	45	Porkprocessors	Starting employment	42-83 days, mean 64
Nathan, 1998 [202] [203] [218]	283	Various manufac-turing and clerical	Randomly-selected workers	11 years
Werner, 1997 [210]	NR, though over 700	Various manufac-turing and clerical	NCS positive workers and matched controls	10 to 24 months
Johnson, 1993 [167]	184	Meat processors	Mostly new employees	Not reported, but few followed more than 3 months

Table 43. Prediction of Future CTS by Maximum Latency Difference

MLD result	Future CTS	No CTS	Threshold	Sensitivity	Specificity	PPV	NPV
<0.28 ms	3	129	0.28 ms	90.9% 76.1% 96.9%	29.9% 25.7% 34.5%	9.0% 6.4% 12.7%	97.7% 93.4% 99.2%
0.28–0.35 ms	11	211	0.36 ms	57.6% 40.5% 73.0%	78.9% 74.7% 82.5%	17.3% 11.2% 25.6%	96.0% 93.4% 97.7%
0.36–0.43 ms	7	56	0.44 ms	36.4% 22.0% 53.7%	91.9% 88.8% 94.1%	25.5% 15.1% 39.8%	95.0% 92.4% 96.7%
0.44–0.51 ms	5	20	0.52 ms	21.2% 10.5% 38.1%	96.5% 94.3% 97.9%	31.8% 16.1% 53.1%	94.1% 91.5% 96.0%
>0.51 ms	7	15					

Data from Nathan et al., 1998 [202]
Future CTS—Patients developed CTS during the 11-year followup periof
No CTS—Patients did not develop CTS during followup period.

Figure 15. Prediction of Future CTS by Maximum Latency Difference



Data from Nathan et al.[202]

Conclusions

The evidence base on most individual diagnostic tests for carpal tunnel syndrome is small, even though the total number of articles on CTS diagnosis is large (Table 19). This is because there are so many different tests that have been reported. Nerve conduction tests are most frequently reported in the literature, but there is great diversity in their methods, and one cannot conclude that one of these tests is effective based on clinical trial results for another test.

The most frequently reported nerve conduction tests were distal motor latency and palmar sensory latency. There were sufficient clinical trial articles available for us to meta-analyze their results and obtain estimates of their sensitivity sensitivities and specificites. For both tests, clinicians chose thresholds that yielded high specificity (a low incidence of false-positive results). ECRI's meta-analyses of distal motor latency studies found the sensitivity of the test to be 57% to 66% and the specificity to be 98%. The meta-analysis of palmar sensory latency studies found a sensitivity of 76% and a specificity of 98%.

Because all of the trials in these analyses used healthy asymptomatic persons as controls, the results of these analyses may overestimate the specificity of nerve conduction measurements in typical practice, where the test would be used on workers believed to be at risk for CTS or persons suspected of having CTS. There are not enough data to permit us to test the hypothesis that high specificity may be an effect of selection criteria for the control groups creating a control population unrepresentative of the population the test would be used on in routine practice: patients with suspected CTS.

Clinical signs and symptoms are also used in the diagnosis of CTS. The evidence base on these tests was smaller than the evidence base on nerve conduction measurement. Like nerve conduction tests, there were many different signs and symptoms reported in the literature, and one cannot infer a test's effectiveness based on the effectiveness of other tests. We attempted to use our meta-analysis techniques to obtain summary values for the sensitivity and specificity of Tinel's sign and Phalen's maneuver. In both cases, there was heterogeneity in the published results that could not be explained by differences in patient selection or by single outlier studies. Therefore, we did not calculate summary measurements for sensitivity or specificity. The sensitivity of Phalen's maneuver was lower than its specificity, and two trials reported sensitivity of 80% to 90%. All of the studies of Tinel's sign found that its sensitivity was lower than its specificity, and none found a sensitivity of 75 percent or greater. There was too much heterogeneity in the results for us to conclude that one test was superior to the other, or to compare these tests to nerve conduction testing.

Regarding sensory tests, composite nerve conduction tests, and imaging tests, there was insufficient evidence for us to perform meta-analyses of clinical trial results.

Analysis of tests for CTS screening and for early diagnosis of CTS is hampered by the lack of agreement by investigators on what those terms mean. We identified 28 articles described by their authors as "screening" studies, but only five of these studies provided longitudinal data. Most employed cross-sectional designs in which the authors evaluated the ability of other tests to identify subjects with abnormal nerve conduction.

One well-designed study by Nathan et al[202] suggests that nerve conduction measurement may be able to identify some workers at risk of developing CTS in the future. By itself, this evidence is not sufficient for us to conclude that nerve conduction screening for CTS is effective, but there could be sufficient unpublished results from this study to confirm the findings of the one reported test.

Table 44. Carpal Tunnel Syndrome–Study Design

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Finsen, 2001 [224]	☑	☐	☐	☑	☐	☐	Single	1	68	0	0	Prospective	Counts	No: thresholds not reported
Mondelli, 2001 [181]	☐	☐	☑	☐	☐	☑	Single	1	20	1	19	Not reported	Counts	Calculated by ECRI
Atroshi, 2000 [225]	☐	☐	☑	☐	☐	☐	Single	1	262	1	125	Prospective	Summary	No: only summary statistics reported
Bland, 2000 [200]	☑	☐	☐	☐	☐	☑	Single	1	8223	1	3533	Retrospective	Counts	Reported by authors
Cuturic, 2000 [226]	☐	☐	☑	☐	☐	☑	Single	1	19	1	16	Prospective	Patient level	Calculated by ECRI
Kearns, 2000 [204]	☐	☐	☑	☑	☐	☐	Single	1	45	0	0	Prospective	Summary	No: only summary statistics reported
Loscher, 2000 [175]	☐	☐	☑	☑	☐	☐	Single	2	NR	1	87	Prospective	Counts	Reported by authors
Montagna, 2000 [227]	☐	☐	☐	☐	☐	☑	Single	1	30	1	15	Not reported	Counts	Reported by authors
Nakamichi, 2000 [228]	☐	☐	☑	☐	☑	☐	Single	1	125	1	200	Not reported	Summary	No: only summary statistics reported
Raudino, 2000 [229]	☑	☐	☐	☐	☐	☐	Single	1	83	0	0	Not reported	Counts	Reported by authors
Resende, 2000 [184]	☐	☐	☑	☑	☐	☐	Single	1	32	1	20	Not reported	Patient level	Calculated by ECRI
Resende, 2000 [174]	☐	☐	☑	☐	☐	☐	Single	1	20	1	20	Not reported	Patient level	Calculated by ECRI
Sener, 2000 [186]	☑	☐	☑	☐	☐	☑	Single	1	31	1	21	Not reported	Counts	Calculated by ECRI
Seror, 2000 [158]	☐	☐	☑	☑	☐	☐	Single	1	20	1	20	Not reported	Counts	Reported by authors
Stalberg, 2000 [230]	☐	☐	☐	☑	☐	☐	Single	1	136	1	32	Not reported	Counts	Reported by authors
Weber, 2000 [108]	☑	☑	☐	☑	☐	☐	Single	1	53	1	26	Not reported	Counts	Reported by authors
Atroshi, 1999 [220]	☑	☐	☑	☑	☐	☐	Single	1	2466	0	0	Prospective	Counts	No: only one patient group
Burke, 1999 [231]	☑	☐	☑	☑	☐	☐	Multiple (<5)	1	186	0	0	Prospective	Counts	Calculated by ECRI
Duncan, 1999 [232]	☐	☐	☐	☐	☑	☐	Single	1	68	1	36	Prospective	Counts	Reported by authors
Kabiraj, 1999 [233]	☐	☐	☑	☑	☐	☐	Single	1	31	1	38	Not reported	Counts	Calculated by ECRI
Lee, 1999 [234]	☐	☐	☐	☐	☑	☐	Single	1	50	1	28	Prospective	Counts	Reported by authors
Missere, 1999 [205]	☐	☐	☑	☐	☑	☐	Single	1	45	0	0	Not reported	Counts	Reported by authors
Mongale, 1999 [235]	☐	☐	☐	☐	☑	☐	Single	1	8	2	16	Not reported	Summary	No: only summary statistics reported

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Murthy, 1999 [143]	☐	☐	☑	☑	☐	☑	Single	1	84	1	37	Not reported	Counts	Reported by authors
Rudolfer, 1999 [236]	☐	☐	☐	☑	☐	☐	Single	1	937	0	0	Retrospective	Counts	Calculated by ECRI
Sander, 1999 [237]	☐	☐	☑	☑	☐	☑	Single	1	59	1	34	Prospective	Counts	Reported by authors
Simovic, 1999 [183]	☐	☐	☑	☑	☐	☐	Single	2	66	1	19	Prospective	Counts	Reported by authors
Szabo, 1999 [152]	☑	☑	☑	☐	☐	☑	Single	1	50	2	100	Prospective	Counts	Reported by authors
Thonnard, 1999 [117]	☐	☑	☑	☑	☐	☑	Single	1	11	1	10	Prospective	Summary	No: only summary statistics reported
Wang, 1999 [238]	☐	☐	☑	☑	☐	☐	Single	1	12	1	12	Prospective	Summary	No: only summary statistics reported
Aurora, 1998 [239]	☐	☐	☑	☐	☐	☐	Single	1	19	1	20	Not reported	Summary	No: only summary statistics reported
Ferry, 1998 [221]	☑	☐	☑	☑	☐	☐	Single	1	648	0	0	Prospective	Counts	Reported by authors
Fertl, 1998 [153]	☑	☐	☑	☐	☐	☑	Single	1	47	1	20	Prospective	Counts	Reported by authors
Gerr, 1998 [31]	☑	☑	☑	☑	☐	☑	Single	1	60	1	59	Not reported	Counts	Reported by authors
Ghavanini, 1998 [154]	☑	☑	☑	☐	☐	☐	Single	1	74	1	58	Prospective	Counts	Reported by authors
Girlanda, 1998 [149]	☑	☐	☑	☑	☐	☐	Single	1	41	1	45	Not reported	Counts	Reported by authors
Kabiraj, 1998 [240]	☐	☐	☑	☑	☐	☐	Single	1	72	1	65	Retrospective	Summary	No: only summary statistics reported
Kleindienst, 1998 [241]	☐	☐	☐	☐	☑	☐	Single	1	77	1	18	Prospective	Summary	No: only summary statistics reported
Luchetti, 1998 [242]	☐	☐	☐	☐	☐	☑	Single	1	39	1	12	Not reported	Summary	No: only summary statistics reported
Nathan, 1998 [202]	☑	☐	☑	☑	☐	☐	Single	1	283	0	0	Prospective	Counts	No: only one patient group
Rosen, 1998 [201]	☐	☑	☐	☐	☐	☐	Single	2	34	1	60	Prospective	Counts	Reported by authors
Scelsa, 1998 [243]	☐	☐	☑	☐	☐	☐	Single	2	63	1	25	Prospective	Counts	Reported by authors
Seror, 1998 [159]	☐	☐	☑	☐	☐	☐	Single	1	85	1	80	Not reported	Counts	Reported by authors
Smith, 1998 [244]	☐	☐	☑	☐	☐	☐	Single	1	82	0	0	Prospective	Counts	Calculated by ECRI
Tan, 1998 [206]	☐	☐	☑	☐	☑	☐	Single	1	64	1	56	Not reported	Summary	No: only summary statistics reported
Terzis, 1998 [162]	☐	☐	☑	☐	☐	☐	Single	1	72	1	43	Not reported	Counts	Reported by authors
Tetro, 1998 [102]	☑	☑	☑	☐	☐	☑	Single	1	64	1	50	Prospective	Counts	Reported by authors
Werner, 1998 [207]	☑	☐	☑	☑	☐	☐	Multiple (>5)	1	727	0	0	Prospective	Counts	No: only one patient group
Wilson, 1998 [245]	☐	☐	☑	☑	☐	☐	Single	1	23	1	14	Not reported	Summary	No: only summary statistics reported
Bak, 1997 [246]	☐	☐	☐	☑	☑	☐	Single	1	20	0	0	Prospective	Counts	No: no control group
Brahme, 1997 [199]	☑	☐	☐	☐	☑	☐	Single	1	20	1	15	Prospective	Counts	Reported by authors

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Bronson, 1997 [163]	☐	☐	☑	☑	☐	☐	Single	1	22	1	16	Prospective	Patient level	Calculated by ECRI
Del Pino, 1997 [104]	☑	☐	☐	☐	☐	☐	Single	1	180	1	100	Prospective	Counts	Reported by authors
Dellon, 1997 [107]	☑	☑	☐	☐	☐	☐	Single	1	72	2	94	Not reported	Counts	No: inconsistent thresholds
Franzblau, 1997 [208]	☑	☐	☐	☐	☐	☐	Single	1	148	0	0	Prospective	Summary	No: only summary statistics reported
Guglielmo, 1997 [247]	☐	☐	☑	☑	☐	☐	Single	1	198	1	69	Prospective	Summary	No: only summary statistics reported
Gunnarsson, 1997 [248]	☑	☐	☑	☑	☐	☐	Single	1	100	0	0	Prospective	Counts	Reported by authors
Horch, 1997 [249]	☐	☐	☐	☐	☑	☐	Single	1	19	1	17	Not reported	Summary	No: only summary statistics reported
Jeng, 1997 [209]	☑	☑	☑	☑	☐	☑	Single	1	27	0	0	Prospective	Counts	Reported by authors
Kaneko, 1997 [250]	☐	☐	☑	☑	☐	☐	Single	1	15	3	66	Not reported	Summary	No: only summary statistics reported
King, 1997 [114]	☐	☑	☐	☐	☐	☐	Single	1	29	1	100	Not reported	Summary	No: only summary statistics reported
Pierre-Jerome, 1997 [251]	☐	☐	☑	☐	☑	☐	Single	1	27	1	28	Prospective	Summary	No: only summary statistics reported
Radack, 1997 [252]	☐	☐	☐	☐	☑	☐	Single	1	161	1	NR	Retrospective	Counts	Reported by authors
Rosecrance, 1997 [253]	☐	☐	☐	☑	☐	☑	Single	1	28	1	25	Not reported	Summary	No: only summary statistics reported
Simovic, 1997 [182]	☐	☐	☑	☑	☐	☐	Single	1	107	1	15	Retrospective	Counts	Reported by authors
Werner, 1997 [210]	☐	☐	☑	☑	☐	☐	Single	2	108	0	0	Retrospective	Counts	No: incomplete reporting
Andary, 1996 [196]	☐	☐	☑	☑	☐	☐	Single	1	81	1	17	Prospective	Counts	Reported by authors
Atroshi, 1996 [136]	☐	☐	☑	☐	☐	☐	Single	1	36	2	60	Prospective	Counts	Reported by authors
Bingham, 1996 [211]	☑	☐	☑	☑	☐	☐	Single	1	1021	0	0	Prospective	Counts	No: only one patient group
Checkosky, 1996 [254]	☐	☑	☐	☐	☐	☐	Single	1	24	1	20	Not reported	Patient level	Reported by authors
Cherniak, 1996 [190]	☐	☑	☑	☑	☐	☑	Single	1	49	1	10	Not reported	Counts	Reported by authors
Foresti, 1996 [192]	☐	☐	☑	☑	☐	☐	Single	1	100	1	25	Prospective	Counts	Reported by authors
Ghavanini, 1996 [255]	☐	☐	☑	☑	☐	☐	Single	1	50	1	50	Not reported	Summary	No: only summary statistics reported
Kleindienst, 1996 [256]	☐	☐	☐	☐	☑	☐	Single	1	55	1	18	Not reported	Counts	Reported by authors
Murata, 1996 [164]	☑	☐	☑	☑	☐	☐	Single	1	27	1	19	Not reported	Counts	Calculated by ECRI

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Padua, 1996 [165]	☐	☐	☑	☑	☐	☐	Single	1	43	1	36	Not reported	Counts	Reported by authors
Pierre-Jerome, 1996 [212]	☑	☐	☑	☐	☑	☐	Single	1	24	1	19	Prospective	Summary	No: only summary statistics reported
Britz, 1995 [257]	☑	☐	☑	☑	☑	☑	Single	1	32	1	5	Prospective	Patient level	No: results not reported for controls
De Smet, 1995 [101]	☑	☐	☐	☐	☐	☐	Single	2	50	2	55	Not reported	Counts	Reported by authors
Gerr, 1995 [118]	☐	☑	☐	☐	☐	☐	Single	2	60	1	59	Not reported	Counts	Reported by authors
Glass, 1995 [28]	☑	☐	☑	☐	☐	☐	Single	1	82	1	24	Not reported	Counts	Calculated by ECRI
Golovchinsky, 1995 [258]	☐	☐	☑	☑	☐	☑	Single	1	571	0	0	Retrospective	Counts	Reported by authors
Hamanaka, 1995 [259]	☐	☐	☑	☑	☐	☑	Single	2	647	1	31	Retrospective	Counts	Calculated by ECRI
Hansson, 1995 [137]	☐	☐	☑	☑	☐	☐	Single	2	30	1	10	Not reported	Counts	Reported by authors
Kothari, 1995 [260]	☐	☐	☑	☐	☐	☐	Single	1	59	1	30	Not reported	Summary	No: only summary statistics reported
Lang, 1995 [109]	☑	☑	☑	☐	☐	☑	Single	1	23	1	16	Prospective	Counts	Reported by authors
Lesser, 1995 [261]	☐	☐	☑	☑	☐	☑	Single	1	45	1	20	Not reported	Counts	Reported by authors
Nakamichi, 1995 [262]	☐	☐	☐	☐	☑	☐	Single	1	15	1	15	Not reported	Patient level	Calculated by ECRI
Seradge, 1995 [263]	☐	☐	☐	☐	☐	☑	Single	1	72	1	21	Not reported	Summary	No: only summary statistics reported
Seror, 1995 [179]	☐	☐	☑	☑	☐	☐	Single	3	75	1	40	Not reported	Counts	Reported by authors
Shafshak, 1995 [264]	☐	☐	☑	☐	☐	☑	Single	2	36	2	36	Not reported	Counts	No: no diagnostic results reported
Sheean, 1995 [191]	☐	☐	☑	☑	☐	☐	Single	1	49	1	NR	Not reported	Counts	Calculated by ECRI
Tassler, 1995 [115]	☐	☑	☐	☑	☐	☐	Single	1	14	1	13	Retrospective	Counts	Reported by authors
Valls-Sole, 1995 [265]	☐	☐	☑	☑	☐	☐	Single	1	18	1	15	Prospective	Summary	No: only summary statistics reported
Werner, 1995 [213]	☑	☑	☑	☑	☐	☐	Single	1	167	0	0	Not reported	Counts	Reported by authors
Young, 1995 [166]	☑	☑	☑	☐	☐	☐	Single	1	157	0	0	Prospective	Counts	No: only one patient group
Clifford, 1994 [266]	☐	☐	☑	☑	☐	☐	Single	1	20	1	10	Not reported	Summary	No: only summary statistics reported
Durkan, 1994 [267]	☑	☐	☐	☐	☐	☐	Single	1	30	1	25	Not reported	Counts	Calculated by ECRI
Franzblau, 1994 [113]	☑	☑	☑	☑	☐	☐	Single	1	83	0	0	Prospective	Counts	Reported by authors
Gerr, 1994 [197]	☑	☑	☐	☐	☐	☐	Single	2	NR	1	NR	Not reported	Counts	Reported by authors

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Kirschberg, 1994 [214]	☑	☐	☑	☑	☐	☐	Single	1	112	0	0	Retrospective	Counts	No: only one patient group
Kuntzer, 1994 [144]	☐	☐	☑	☑	☐	☑	Single	1	100	1	70	Prospective	Counts	Reported by authors
Nathan, 1994 [215]	☑	☐	☑	☑	☐	☐	Multiple (<5)	2	417	0	0	Retrospective	Counts	No: no control subjects
Nilsson, 1994 [216]	☐	☐	☑	☐	☐	☐	Single	3	175	0	0	Prospective	Counts	Reported by authors
Para, 1994 [103]	☑	☐	☑	☑	☐	☑	Single	2	51	1	12	Not reported	Counts	Reported by authors
Rossi, 1994 [178]	☐	☐	☑	☑	☐	☐	Single	1	62	1	27	Not reported	Counts	Reported by authors
Werner, 1994 [217]	☑	☑	☑	☑	☐	☐	Single	1	130	0	0	Prospective	Counts	Calculated by ECRI
Werner, 1994 [111]	☑	☐	☑	☑	☐	☐	Single	1	31	1	20	Not reported	Counts	Calculated by ECRI
Eisen, 1993 [193]	☐	☐	☑	☑	☐	☐	Single	1	NR	1	NR	Not reported	Counts	Reported by authors
Johnson, 1993 [167]	☑	☐	☑	☐	☐	☐	Single	1	184	0	0	Prospective	Summary	No: only summary statistics reported
Nakamichi, 1993 [268]	☐	☐	☐	☐	☑	☐	Single	1	128	0	0	Not reported	Counts	No: only one patient group
Nathan, 1993 [218]	☑	☐	☑	☑	☐	☐	Single	2	1125	1	45	Prospective	Counts	Reported by authors
Rodriquez, 1993 [269]	☐	☐	☑	☐	☐	☑	Single	1	10	1	8	Prospective	Patient level	Calculated by ECRI
Rosen, 1993 [270]	☐	☑	☑	☐	☐	☐	Single	2	62	2	71	Not reported	Counts	Calculated by ECRI
Rosén, 1993 [138]	☐	☐	☑	☑	☐	☐	Single	1	28	3	86	Not reported	Counts	Calculated by ECRI
Uncini, 1993 [160]	☐	☐	☑	☑	☐	☐	Single	1	70	1	47	Not reported	Counts	Reported by authors
Buchberger, 1992 [271]	☐	☐	☐	☐	☑	☐	Multiple (<5)	1	18	1	NR	Not reported	Counts	Reported by authors
Grant, 1992 [219]	☐	☑	☑	☐	☐	☐	Single	1	22	1	47	Not reported	Counts	Calculated by ECRI
Imaoka, 1992 [272]	☐	☐	☑	☐	☐	☐	Single	1	42	1	32	Not reported	Counts	Calculated by ECRI
Kindstrand, 1992 [273]	☐	☐	☐	☐	☐	☑	Single	1	94	1	127	Prospective	Patient level	Calculated by ECRI
Preston, 1992 [188]	☐	☐	☑	☑	☐	☐	Single	1	8	1	NR	Not reported	Counts	Calculated by ECRI
Tchou, 1992 [274]	☐	☐	☐	☐	☐	☑	Single	1	61	1	40	Not reported	Patient level	Reported by authors
Buchberger, 1991 [275]	☐	☐	☐	☐	☑	☐	Single	1	25	1	14	Not reported	Summary	No: only summary statistics reported

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Chang, 1991 [145]	☐	☐	☑	☑	☐	☐	Single	1	43	1	40	Not reported	Counts	Calculated by ECRI
Durkan, 1991 [155]	☑	☐	☐	☐	☐	☐	Single	1	31	1	50	Not reported	Counts	Reported by authors
Jetzer, 1991 [168]	☑	☑	☐	☐	☐	☑	Single	3	323	1	284	Prospective	Counts	No: no control subjects
Katz, 1991 [276]	☑	☑	☑	☑	☐	☑	Single	1	78	0	0	Not reported	Counts	Reported by authors
Lauritzen, 1991 [185]	☐	☐	☑	☑	☐	☑	Single	1	38	1	23	Not reported	Counts	Calculated by ECRI
Luchetti, 1991 [169]	☑	☐	☑	☑	☐	☐	Single	1	14	0	0	Retrospective	Patient level	No: only one patient group
Radwin, 1991 [116]	☐	☑	☐	☐	☐	☐	Single	1	12	1	15	Not reported	Patient level	No: no diagnostic threshols used
Charles, 1990 [170]	☐	☐	☑	☑	☐	☐	Single	1	158	2	90	Not reported	Counts	Reported by authors
De Krom, 1990 [222]	☑	☐	☑	☑	☐	☐	Single	1	50	0	0	Prospective	Counts	Calculated by ECRI
Fitz, 1990 [277]	☐	☐	☑	☑	☐	☐	Single	1	36	1	44	Not reported	Counts	Calculated by ECRI
Gilliatt, 1990 [278]	☐	☐	☑	☑	☐	☐	Single	1	10	1	15	Not reported	Counts	Calculated by ECRI
MacDonell, 1990 [90]	☐	☐	☑	☐	☐	☐	Single	1	34	1	12	Not reported	Counts	Reported by authors
Merchut, 1990 [279]	☐	☑	☑	☐	☐	☐	Single	1	23	1	54	Not reported	Counts	Reported by authors
Palliyath, 1990 [171]	☐	☐	☑	☐	☐	☐	Single	1	10	1	11	Not reported	Summary	No: only summary statistics reported
Pease, 1990 [177]	☐	☐	☑	☐	☐	☐	Single	1	21	1	16	Not reported	Counts	Calculated by ECRI
Rojviroj, 1990 [280]	☐	☑	☐	☐	☐	☐	Single	1	33	1	16	Prospective	Counts	Reported by authors
Tzeng, 1990 [180]	☐	☐	☑	☐	☐	☐	Single	1	84	1	50	Not reported	Counts	Calculated by ECRI
Uncini, 1990 [135]	☐	☐	☑	☑	☐	☐	Single	1	35	1	39	Not reported	Summary	No: only summary statistics reported
Winn, 1990 [281]	☐	☑	☐	☐	☐	☐	Single	2	61	0	0	Prospective	Summary	No: only summary statistics reported
Braun, 1989 [282]	☑	☑	☐	☐	☐	☐	Single	1	40	0	0	Not reported	Counts	No: no diagnostic thresholds reported
Cioni, 1989 [146]	☐	☐	☑	☑	☐	☐	Single	1	307	1	54	Not reported	Counts	Reported by authors
Jackson, 1989 [150]	☐	☐	☑	☑	☐	☑	Single	1	123	1	38	Not reported	Counts	Reported by authors
Meyers, 1989 [283]	☐	☐	☐	☐	☐	☑	Single	1	14	1	19	Not reported	Counts	Calculated by ECRI
So, 1989 [173]	☐	☐	☑	☐	☐	☑	Single	1	22	2	35	Not reported	Counts	Reported by authors
Szabo, 1989 [284]	☐	☑	☐	☐	☐	☐	Single	1	22	0	0	Not reported	Summary	No: only summary statistics reported
Uncini, 1989 [161]	☐	☐	☑	☑	☐	☐	Single	1	32	1	33	Not reported	Summary	No: only summary statistics reported
De Léan, 1988 [285]	☐	☐	☑	☐	☐	☐	Single	1	150	0	0	Not reported	Counts	Calculated by ECRI

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Koris, 1988 [198]	☑	☑	☐	☐	☐	☐	Single	1	21	1	15	Prospective	Counts	Reported by authors
Molitor, 1988 [110]	☑	☐	☐	☐	☐	☑	Single	1	19	1	NR	Not reported	Counts	Calculated by ECRI
Mortier, 1988 [286]	☐	☐	☑	☑	☐	☐	Single	1	116	1	102	Retrospective	Counts	Reported by authors
Pease, 1988 [287]	☐	☐	☑	☑	☐	☐	Single	1	25	1	23	Not reported	Summary	No: only summary statistics reported
Carroll, 1987 [288]	☐	☐	☑	☑	☐	☐	Single	1	101	1	50	Not reported	Counts	Reported by authors
Jessurun, 1987 [289]	☐	☐	☐	☐	☑	☐	Multiple (<5)	1	24	1	10	Not reported	Summary	No: only summary statistics reported
Johnson, 1987 [290]	☐	☐	☑	☑	☐	☐	Single	1	20	1	78	Not reported	Counts	Calculated by ECRI
Liang, 1987 [291]	☐	☐	☐	☐	☑	☐	Single	1	68	2	139	Not reported	Summary	No: only summary statistics reported
Macleod, 1987 [292]	☑	☐	☑	☐	☐	☐	Single	1	111	1	125	Not reported	Summary	No: only summary statistics reported
Seror, 1987 [156]	☑	☐	☐	☐	☐	☐	Single	1	62	1	20	Not reported	Counts	Reported by authors
Borg, 1986 [293]	☑	☑	☑	☐	☐	☐	Single	1	22	0	0	Not reported	Counts	Calculated by ECRI
Gellman, 1986 [106]	☑	☐	☑	☑	☐	☐	Single	1	NR	2	NR	Not reported	Counts	Reported by authors
Escobar, 1985 [151]	☐	☐	☑	☐	☐	☐	Single	1	23	1	55	Not reported	Counts	Calculated by ECRI
Kimura, 1985 [189]	☐	☐	☑	☑	☐	☑	Single	1	438	1	148	Not reported	Counts	Reported by authors
Mills, 1985 [194]	☐	☐	☑	☑	☐	☐	Single	1	47	2	49	Not reported	Counts	Calculated by ECRI
Borg, 1984 [294]	☐	☑	☐	☐	☐	☐	Single	3	45	0	0	Prospective	Patient level	Calculated by ECRI
Pryse-Phillips, 1984 [105]	☑	☐	☐	☐	☐	☐	Single	1	212	4	184	Retrospective	Counts	Reported by authors
Satoh, 1984 [295]	☑	☐	☑	☐	☐	☐	Single	1	14	0	0	Retrospective	Patient level	No: only one patient group
Szabo, 1984 [30]	☑	☑	☐	☐	☐	☐	Single	1	20	0	0	Prospective	Counts	No: only one patient group
Goddard, 1983 [296]	☐	☐	☑	☐	☐	☐	Single	1	24	1	49	Not reported	Counts	Calculated by ECRI
Kim, 1983 [195]	☐	☐	☑	☑	☐	☐	Single	1	39	1	33	Not reported	Counts	Reported by authors
Marin, 1983 [139]	☐	☐	☑	☑	☐	☐	Single	1	14	1	12	Not reported	Counts	Calculated by ECRI
Wongsam, 1983 [172]	☐	☐	☑	☐	☐	☐	Single	1	15	2	56	Not reported	Summary	No: only summary statistics reported
Johnson, 1981 [297]	☐	☐	☑	☑	☐	☐	Single	1	18	1	37	Not reported	Summary	No: only summary statistics reported

Article	SGN	SEN	NCS	CMP	IMG	OTH	Centers	CTS groups	CTS pts.	Neg. groups	Neg. subjects	Prospective or retrospective	Level of reporting	Could sensitivity & specificity be determined?
Dekel, 1980 [21]	☐	☐	☐	☐	☑	☐	Single	1	26	1	33	Prospective	Patient level	No: could not extract 2 x 2 counts from graph
Messina, 1980 [120]	☐	☐	☑	☑	☐	☐	Single	1	40	1	40	Not reported	Counts	Reported by authors
Gelmers, 1979 [29]	☑	☐	☑	☑	☐	☐	Single	1	47	1	43	Not reported	Counts	Reported by authors
Kimura, 1979 [140]	☐	☐	☑	☑	☐	☐	Single	1	105	1	61	Not reported	Counts	Calculated by ECRI
Schwartz, 1979 [187]	☐	☐	☑	☑	☐	☐	Single	1	20	1	10	Not reported	Counts	Calculated by ECRI
Stewart, 1978 [157]	☑	☐	☐	☐	☐	☐	Single	1	37	1	38	Not reported	Counts	Reported by authors
Eisen, 1977 [298]	☐	☐	☑	☑	☐	☐	Single	1	30	3	101	Not reported	Patient level	Calculated by ECRI
Sedal, 1973 [299]	☐	☐	☑	☐	☐	☐	Single	1	214	1	34	Retrospective	Counts	Reported by authors
Welch, 1973 [223]	☐	☑	☐	☐	☐	☐	Single	1	428	1	111	Not reported	Summary	No: only summary statistics reported
Casey, 1972 [300]	☐	☐	☑	☐	☐	☐	Single	1	16	2	112	Not reported	Patient level	Calculated by ECRI
Loong, 1972 [141]	☐	☐	☑	☑	☐	☐	Single	1	18	1	30	Not reported	Patient level	Calculated by ECRI
Melvin, 1972 [147]	☐	☐	☑	☐	☐	☐	Single	1	17	1	24	Not reported	Counts	Calculated by ECRI
Buchthal, 1971 [301]	☐	☐	☑	☐	☐	☑	Single	1	22	1	10	Not reported	Counts	Calculated by ECRI
Loong, 1971 [148]	☐	☐	☑	☑	☐	☐	Single	1	15	1	30	Not reported	Patient level	Calculated by ECRI
Plaja, 1971 [142]	☐	☐	☑	☐	☐	☑	Single	1	56	1	20	Retrospective	Counts	Reported by authors

Table 45. Carpal Tunnel Syndrome–Patient Groups

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Finsen, 2001 [224]	CTS	Unspecified diagnosis	68	74	48	21	86				Yes
Mondelli, 2001 [181]	Normal	Healthy volunteers	19	NR	51.9	31	72				No
Mondelli, 2001 [181]	CTS	Unspecified diagnosis	20	80	52.8	35	75				No
Atroshi, 2000 [225]	CTS	Symptoms/ presented	262	57	52						No
Atroshi, 2000 [225]	Normal	Healthy volunteers	125	55	51						No
Bland, 2000 [200]	CTS	Complex objective standard	4690	65	57						No
Bland, 2000 [200]	CTS	Symptoms/ presented	8223	66	53	10	98				No
Bland, 2000 [200]	Normal	Other	3533	67	49						No
Cuturic, 2000 [226]	CTS	Unspecified diagnosis	19	0	43	29	62				No
Cuturic, 2000 [226]	Normal	Healthy volunteers	16	0	41	26	58				No
Kearns, 2000 [204]	CTS	Workers at risk	45	4							Yes
Loscher, 2000 [175]	Normal	Healthy volunteers	87	NR	47	15	86				No
Loscher, 2000 [175]	CTS	Unspecified diagnosis		NR							No
Loscher, 2000 [175]	CTS	Other		NR							No
Montagna, 2000 [227]	Cubital tunnel syndrome	Unspecified diagnosis	10	NR							No
Montagna, 2000 [227]	Normal	Healthy volunteers	15	NR							No
Montagna, 2000 [227]	CTS	Unspecified diagnosis	30	NR							No
Nakamichi, 2000 [228]	CTS	Simple nerve conduction	125	100	56	40	70				No
Nakamichi, 2000 [228]	Normal	Healthy volunteers	200	NR	57	40	70				No
Raudino, 2000 [229]	CTS	Complex objective standard	83	82	48.9	19	82	26.9	1	180	Yes
Resende, 2000 [174]	CTS	Unspecified diagnosis	20	NR							No
Resende, 2000 [174]	Normal	Healthy volunteers	20	NR		21	55				No
Resende, 2000 [184]	Normal	Healthy volunteers	20	100	36	20	54				No
Resende, 2000 [184]	CTS	Unspecified diagnosis	32	100	44	25	59				No
Sener, 2000 [186]	CTS	Symptoms/ presented	31	NR	46	26	70				Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Sener, 2000 [186]	Normal	Healthy volunteers	21	NR	38	18	60				Yes
Seror, 2000 [158]	Normal	Healthy volunteers	20	75	43	20	67				No
Seror, 2000 [158]	CTS	Complex objective standard	20	75	47	32	76				No
Stalberg, 2000 [230]	CTS	Symptoms/ presented	136	NR							No
Stalberg, 2000 [230]	Normal	Healthy volunteers	32	NR		21	62				No
Weber, 2000 [108]	CTS	Symptoms/ presented	53	79	45						No
Weber, 2000 [108]	Normal	Healthy volunteers	26	85	37						No
Burke, 1999 [231]	CTS	Symptoms/ presented	186	NR							No
Atroshi, 1999 [220]	Normal	Other	2466	NR							No
Duncan, 1999 [232]	CTS	Complex objective standard	68	74	54						Yes
Duncan, 1999 [232]	CTS	Complex objective standard		NR							Yes
Duncan, 1999 [232]	Normal	Healthy volunteers	36	64	44						Yes
Kabiraj, 1999 [233]	Normal	Healthy volunteers	38	50		20	79				No
Kabiraj, 1999 [233]	CTS	Complex objective standard	31	68		28	85				No
Lee, 1999 [234]	Normal	Healthy volunteers	28	54		22	47				No
Lee, 1999 [234]	CTS	Unspecified diagnosis	50	74		32	81				No
Missere, 1999 [205]	CTS	Workers at risk	45	0	37.7						No
Mongale, 1999 [235]	Normal	Healthy volunteers	9	100	39	26	50				No
Mongale, 1999 [235]	Normal	Healthy volunteers	7	0	39	27	58				No
Mongale, 1999 [235]	CTS	Unspecified diagnosis	8	100	43	24	54				No
Murthy, 1999 [143]	CTS	Symptoms/ presented	84	NR							No
Murthy, 1999 [143]	Normal	Healthy volunteers	37	NR							No
Rudolfer, 1999 [236]	CTS	Symptoms/ presented	937	NR							No
Sander, 1999 [237]	Normal	Healthy volunteers	34	NR	41	26	71				No
Sander, 1999 [237]	CTS	Complex objective standard	59	NR	49	29	73				No
Simovic, 1999 [183]	CTS	Other	12	NR							Yes
Simovic, 1999 [183]	Normal	Healthy volunteers	19	63	40	25	68				Yes
Simovic, 1999 [183]	CTS	Unspecified diagnosis	54	NR							Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Szabo, 1999 [152]	Normal	Healthy volunteers	50	66		18	59				No
Szabo, 1999 [152]	CTS	Complex objective standard	50	76		20	73		2	240	No
Szabo, 1999 [152]	Unrelated disease	Other	50	80		28	72		0	180	No
Thonnard, 1999 [117]	CTS	Unspecified diagnosis	11	73	52						No
Thonnard, 1999 [117]	Normal	Healthy volunteers	11	73	53						No
Wang, 1999 [238]	CTS	Complex objective standard	12	92	46	30	65				No
Wang, 1999 [238]	Normal	Healthy volunteers	12	42	37	28	59				No
Aurora, 1998 [239]	CTS	Symptoms/ presented	19	NR	52.8						No
Aurora, 1998 [239]	Normal	Healthy volunteers	20	NR	32.9						No
Ferry, 1998 [221]	Normal	Other	648	56	46.9						No
Fertl, 1998 [153]	Normal	Healthy volunteers	20	60	42	25	77				No
Fertl, 1998 [153]	CTS	Symptoms/ presented	47	83	55.5	21	78				No
Gerr, 1998 [31]	Normal	Healthy volunteers	59	69	38.2						No
Gerr, 1998 [31]	CTS	Symptoms/ presented	60	72	46.6						No
Ghavanini, 1998 [154]	CTS	Complex objective standard	26	100	37	20	50	9	1	36	No
Ghavanini, 1998 [154]	CTS	Symptoms/ presented	74	81	40	20	50	15	1	60	No
Ghavanini, 1998 [154]	Normal	Healthy volunteers	58	76	36.7	20	50				No
Ghavanini, 1998 [154]	CTS	Complex objective standard	26	69	41	20	50	19.4	1	48	No
Ghavanini, 1998 [154]	CTS	Complex objective standard	22	73	42	30	50	19	4	60	No
Girlanda, 1998 [149]	CTS	Symptoms/ presented	41	93	39	24	65	48	1	180	Yes
Girlanda, 1998 [149]	Normal	Healthy volunteers	45	NR							Yes
Kabiraj, 1998 [240]	CTS	Symptoms/ presented	72	NR							No
Kabiraj, 1998 [240]	Normal	Healthy volunteers	65	45	39.8	20	75				No
Kleindienst, 1998 [241]	CTS	Complex objective standard		NR							No
Kleindienst, 1998 [241]	CTS	Other		NR							No
Kleindienst, 1998 [241]	CTS	Complex objective standard		NR							No
Kleindienst, 1998 [241]	CTS	Other		NR							No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Kleindienst, 1998 [241]	Normal	Healthy volunteers	18	83	51	43	59				No
Kleindienst, 1998 [241]	CTS	Complex objective standard		NR							No
Kleindienst, 1998 [241]	CTS	Unspecified diagnosis	77	82	54	22	79				No
Luchetti, 1998 [242]	CTS	Unspecified diagnosis	39	79	31	26	45				No
Luchetti, 1998 [242]	Normal	Healthy volunteers	12	83	27	24	36				No
Nathan, 1998 [202]	CTS	Workers at risk	283	45	35.2						No
Rosen, 1998 [201]	Normal	Healthy volunteers	60	NR							No
Rosen, 1998 [201]	CTS	Workers at risk	20	5	46	26	65				No
Rosen, 1998 [201]	CTS	Unspecified diagnosis	14	100	53	33	78				No
Scelsa, 1998 [243]	CTS	Other	21	48	46	10	69				No
Scelsa, 1998 [243]	CTS	Unspecified diagnosis	42	76	50	25	85				No
Scelsa, 1998 [243]	Normal	Healthy volunteers	25	44	42	23	63				No
Seror, 1998 [159]	CTS	Unspecified diagnosis	85	74	46	25	83				No
Seror, 1998 [159]	Normal	Healthy volunteers	80	64	42	22	68				No
Smith, 1998 [244]	CTS	Symptoms/ presented	82	61	44	17	88	14	1	120	No
Tan, 1998 [206]	CTS	Workers at risk	64	63		22	28				No
Tan, 1998 [206]	Normal	Healthy volunteers	56	57		21	29				No
Terzis, 1998 [162]	CTS	Unspecified diagnosis	72	92	49.6						No
Terzis, 1998 [162]	Normal	Healthy volunteers	43	84	48.3						No
Tetro, 1998 [102]	Normal	Healthy volunteers	50	74	46.9	22	79				No
Tetro, 1998 [102]	CTS	Complex objective standard	64	64	49.3	21	83				No
Werner, 1998 [207]	CTS	Workers at risk	727	54	42	25	69				Yes
Wilson, 1998 [245]	Normal	Healthy volunteers	14	NR	52	33	76				No
Wilson, 1998 [245]	CTS	Complex objective standard	23	NR	59	24	76				No
Bak, 1997 [246]	CTS	Symptoms/ presented	20	55							Yes
Brahme, 1997 [199]	CTS	Unspecified diagnosis	20	90	37	21	61				No
Brahme, 1997 [199]	Normal	Healthy volunteers	15	47	35	22	60				No
Bronson, 1997 [163]	Normal	Other	16	56	29.5	21	44				Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Bronson, 1997 [163]	CTS	Unspecified diagnosis	22	73	34.4	21	59				Yes
Del Pino, 1997 [104]	Normal	Healthy volunteers	100	78	49	37	67				No
Del Pino, 1997 [104]	CTS	Complex objective standard	180	81	50	16	84	37.9	1	216	No
Dellon, 1997 [107]	CTS	Unspecified diagnosis	72	NR							Yes
Dellon, 1997 [107]	Cubital tunnel syndrome	Unspecified diagnosis	42	NR							Yes
Dellon, 1997 [107]	Normal	Other	52	62							Yes
Franzblau, 1997 [208]	CTS	Workers at risk	148	57	44.2						Yes
Guglielmo, 1997 [247]	CTS	Symptoms/ presented	198	60	46	13	84				No
Guglielmo, 1997 [247]	Normal	Healthy volunteers	69	57	40.3	20	86				No
Gunnarsson, 1997 [248]	CTS	Symptoms/ presented	100	NR							No
Horch, 1997 [249]	Normal	Healthy volunteers	17	71	43.4	24	58				No
Horch, 1997 [249]	CTS	Simple nerve conduction	19	63	49.7	25	67				No
Jeng, 1997 [209]	CTS	Workers at risk	27	52	40.2	23	57				No
Kaneko, 1997 [250]	CTS	Unspecified diagnosis	15	87		40	54				Yes
Kaneko, 1997 [250]	Normal	Healthy volunteers	46	22		25	45				Yes
Kaneko, 1997 [250]	Cubital tunnel syndrome	Unspecified diagnosis	10	20		45	56				Yes
Kaneko, 1997 [250]	Combined WRUEDs	Unspecified diagnosis	10	50		40	62				Yes
King, 1997 [114]	CTS	Unspecified diagnosis	29	62							No
King, 1997 [114]	Normal	Healthy volunteers	100	50							No
Pierre-Jerome, 1997 [251]	Normal	Healthy volunteers	28	100	45.1	26	67				No
Pierre-Jerome, 1997 [251]	CTS	Simple nerve conduction	27	100	51.9	16	78	36	12	72	No
Radack, 1997 [252]	CTS	Complex objective standard		NR							No
Radack, 1997 [252]	Normal	Unrelated disease		NR							No
Radack, 1997 [252]	CTS	Symptoms/ presented	161	53	37.4	13	86				No
Rosecrance, 1997 [253]	CTS	Complex objective standard	20	70	41.5			[a]32			No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Rosecrance, 1997 [253]	CTS	Complex objective standard	10	60	39.9			[a]14			No
Rosecrance, 1997 [253]	Normal	Healthy volunteers	25	28	38.8						No
Rosecrance, 1997 [253]	CTS	Complex objective standard	28	NR							No
Simovic, 1997 [182]	Normal	Healthy volunteers	15	NR		18	70				No
Simovic, 1997 [182]	CTS	Unspecified diagnosis	107	61	51	19	86				No
Werner, 1997 [210]	CTS	Workers at risk	59	64	40.1						No
Werner, 1997 [210]	Normal	Simple nerve conduction	49	67	41.7						No
Andary, 1996 [196]	Normal	Healthy volunteers	17	NR	36						No
Andary, 1996 [196]	CTS	Symptoms/ presented	81	NR	42						No
Atroshi, 1996 [136]	Normal	Healthy volunteers	30	57	36	25	62				Yes
Atroshi, 1996 [136]	CTS	Symptoms/ presented	36	69	52	20	87	[a]24	1	120	Yes
Atroshi, 1996 [136]	Normal	Healthy volunteers	30	70	40	19	65				Yes
Bingham, 1996 [211]	CTS	Workers at risk	1021	29	30.1	17	60				No
Checkosky, 1996 [254]	Normal	Healthy volunteers	10	70		25	44				No
Checkosky, 1996 [254]	Normal	Healthy volunteers	20	75		25	67				No
Checkosky, 1996 [254]	CTS	Symptoms/ presented	12	83		45	70				No
Checkosky, 1996 [254]	CTS	Symptoms/ presented	24	79	46.7	27	70				No
Checkosky, 1996 [254]	Normal	Healthy volunteers	10	80		46	67				No
Checkosky, 1996 [254]	CTS	Symptoms/ presented	12	75		27	45				No
Cherniak, 1996 [190]	Normal	Healthy volunteers	10	70	37.1	26	52				No
Cherniak, 1996 [190]	CTS	Symptoms/ presented	49	33	43	19	71				No
Foresti, 1996 [192]	Normal	Healthy volunteers	25	28	42	18	69				Yes
Foresti, 1996 [192]	CTS	Symptoms/ presented	100	25	49	27	78				Yes
Ghavanini, 1996 [255]	CTS	Unspecified diagnosis	50	82	38.6	27	59				Yes
Ghavanini, 1996 [255]	Normal	Healthy volunteers	50	78	28.7	20	42				Yes
Kleindienst, 1996 [256]	CTS	Other	55	82	54						No
Kleindienst, 1996 [256]	Normal	Healthy volunteers	18	83	51						No
Murata, 1996 [164]	Normal	Healthy volunteers	19	100	24	19	31				Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Murata, 1996 [164]	CTS	Workers at risk	27	100	25	19	37				Yes
Padua, 1996 [165]	Normal	Healthy volunteers	36	69	43.7	19	79				No
Padua, 1996 [165]	CTS	Symptoms/ presented	43	72	45.2	23	80	27	2	48	No
Pierre-Jerome, 1996 [212]	CTS	Workers at risk	24	100	44	26	59				Yes
Pierre-Jerome, 1996 [212]	Normal	Other	19	100	39.5	25	44				Yes
Britz, 1995 [257]	CTS	Unspecified diagnosis	32	NR							No
Britz, 1995 [257]	Normal	Healthy volunteers	0	NR							No
De Smet, 1995 [101]	CTS	Simple nerve conduction	10	70	42.8	22	53				No
De Smet, 1995 [101]	Normal	Healthy volunteers	46	100	51	34	76				No
De Smet, 1995 [101]	Normal	Other	9	100							No
De Smet, 1995 [101]	CTS	Symptoms/ presented	40	93	50.8	23	77				No
Gerr, 1995 [118]	Symptomatic /normal NCS	Complex objective standard	30	60	43.9						No
Gerr, 1995 [118]	CTS	Complex objective standard	30	83	50.1						No
Gerr, 1995 [118]	Normal	Healthy volunteers	59	69	38.2						No
Glass, 1995 [28]	CTS	Symptoms/ presented	82	77		23	69				No
Glass, 1995 [28]	Normal	Contralateral arm	26	NR							No
Glass, 1995 [28]	Normal	Healthy volunteers	24	58		24	69				No
Golovchinsky, 1995 [258]	Combined WRUEDs	Unspecified diagnosis	571	49	45.2	22	86				No
Hamanaka, 1995 [259]	CTS	Unrelated disease	31	39	37.9	18	67				Yes
Hamanaka, 1995 [259]	CTS	Unspecified diagnosis	647	61	53.9	21	87				Yes
Hansson, 1995 [137]	CTS	Symptoms/ presented	20	95	45	31	60	[a]9	2	120	Yes
Hansson, 1995 [137]	Normal	Healthy volunteers	10	90	45	26	65	[a]9	2	120	Yes
Hansson, 1995 [137]	CTS	Complex objective standard	10	100	57	41	79	[a]9	2	120	Yes
Kothari, 1995 [260]	CTS	Symptoms/ presented	59	75	50	22	91				No
Kothari, 1995 [260]	Normal	Healthy volunteers	30	70	36	21	70				No
Lang, 1995 [109]	CTS	Unspecified diagnosis	23	78	51.4			[a]36	12	420	No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Lang, 1995 [109]	Normal	Healthy volunteers	16	63	55						No
Lesser, 1995 [261]	Normal	Healthy volunteers	20	40	36	22	50				No
Lesser, 1995 [261]	CTS	Complex objective standard	45	73	52	27	79				No
Nakamichi, 1995 [262]	CTS	Unspecified diagnosis	15	100	53.9	50	58				Yes
Nakamichi, 1995 [262]	Normal	Healthy volunteers	15	100	54.4	50	58				Yes
Seradge, 1995 [263]	CTS	Unspecified diagnosis	72	75	45.6	18	80				No
Seradge, 1995 [263]	Normal	Unrelated disease	21	52		20	74				No
Seror, 1995 [179]	Normal	Healthy volunteers	40	70	53						No
Seror, 1995 [179]	CTS	Unspecified diagnosis	25	80	56						No
Seror, 1995 [179]	CTS	Unspecified diagnosis	25	84	52						No
Seror, 1995 [179]	CTS	Unspecified diagnosis	25	84	55						No
Shafshak, 1995 [264]	CTS	Complex objective standard	25	52		22	40				Yes
Shafshak, 1995 [264]	Other	Other	11	27		23	51				Yes
Shafshak, 1995 [264]	Normal	Healthy volunteers	25	52	42	18	57				Yes
Shafshak, 1995 [264]	CTS	Unspecified diagnosis	11	100		27	53				Yes
Sheean, 1995 [191]	CTS	Symptoms/ presented	49	71	56.2	29	84				No
Sheean, 1995 [191]	Normal	Healthy volunteers		NR		22	59				No
Tassler, 1995 [115]	Cubital tunnel syndrome	Unspecified diagnosis	13	NR							Yes
Tassler, 1995 [115]	CTS	Unspecified diagnosis	14	NR							Yes
Valls-Sole, 1995 [265]	CTS	Complex objective standard	18	100		34	53		6	144	No
Valls-Sole, 1995 [265]	Normal	Healthy volunteers	15	87		25	51				No
Werner, 1995 [213]	CTS	Workers at risk	167	NR							No
Young, 1995 [166]	CTS	Workers at risk	157	82	39.9	20	64				No
Clifford, 1994 [266]	CTS	Symptoms/ presented	20	100	43.1						No
Clifford, 1994 [266]	Normal	Healthy volunteers	10	NR	26.7						No
Durkan, 1994 [267]	CTS	Unspecified diagnosis	30	43	52	21	88				No
Durkan, 1994 [267]	Normal	Healthy volunteers	25	NR							No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Franzblau, 1994 [113]	CTS	Workers at risk	83	53	33.8						No
Gerr, 1994 [197]	Normal	Healthy volunteers		NR	38						No
Gerr, 1994 [197]	CTS	Complex objective standard		NR	43						No
Gerr, 1994 [197]	CTS	Complex objective standard		NR	50						No
Kirschberg, 1994 [214]	CTS	Workers at risk	112	85	33.3						No
Kuntzer, 1994 [144]	Normal	Healthy volunteers	70	60	43	25	70				No
Kuntzer, 1994 [144]	CTS	Symptoms/ presented	100	80	51	26	85				No
Nathan, 1994 [215]	CTS	Workers at risk	316	47	40.4						No
Nathan, 1994 [215]	CTS	Workers at risk	101	26	38.6						No
Nilsson, 1994 [216]	CTS	Workers at risk	58	0	24.6						No
Nilsson, 1994 [216]	CTS	Workers at risk	61	0	37.4						No
Nilsson, 1994 [216]	CTS	Workers at risk	56	0	32.4						No
Para, 1994 [103]	CTS	Symptoms/ presented	24	71	51.6	26	62				No
Para, 1994 [103]	CTS	Symptoms/ presented	27	70	48.6	28	60				No
Para, 1994 [103]	Normal	Healthy volunteers	12	58	36.6	17	55				No
Rossi, 1994 [178]	CTS	Unspecified diagnosis	62	84	49.4	22	63				No
Rossi, 1994 [178]	Normal	Healthy volunteers	27	67	44.6	22	62				No
Werner, 1994 [217]	CTS	Workers at risk	130	56	34						No
Werner, 1994 [111]	CTS	Symptoms/ presented	31	NR							No
Werner, 1994 [111]	Normal	Healthy volunteers	20	NR							No
Eisen, 1993 [193]	CTS	Symptoms/ presented		NR							Yes
Eisen, 1993 [193]	Normal	Healthy volunteers		NR							Yes
Johnson, 1993 [167]	CTS	Workers at risk	184	NR							No
Nakamichi, 1993 [268]	CTS	Unspecified diagnosis	128	74	54	33	86				No
Nathan, 1993 [218]	Normal	Healthy volunteers	45	47	19.8						No
Nathan, 1993 [218]	CTS	Workers at risk	388	63	39.4						No
Nathan, 1993 [218]	CTS	Workers at risk	737	28	42.4						No
Rodriquez, 1993 [269]	Normal	Healthy volunteers	8	38	40.3	23	82				No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Rodriquez, 1993 [269]	CTS	Unspecified diagnosis	10	80	43.8	22	83				No
Rosen, 1993 [270]	Normal	Healthy volunteers	21	48	33.6	20	50				No
Rosen, 1993 [270]	Normal	Healthy volunteers	50	0	41.5	27	63				No
Rosen, 1993 [270]	CTS	Symptoms/ presented	47	0	42.8	23	63				No
Rosen, 1993 [270]	CTS	Symptoms/ presented	15	80	37.9	26	53				No
Rosén, 1993 [138]	Normal	Healthy volunteers	15	60	34	21	46				No
Rosén, 1993 [138]	Normal	Other	50	0	41.5	27	63				No
Rosén, 1993 [138]	CTS	Unspecified diagnosis	28	75	41	26	77				No
Rosén, 1993 [138]	Normal	Healthy volunteers	21	48	33.6	20	50				No
Uncini, 1993 [160]	Normal	Healthy volunteers	47	72	44.7	18	78				No
Uncini, 1993 [160]	CTS	Simple nerve conduction	70	86	49.3	26	78				No
Buchberger, 1992 [271]	Normal	Healthy volunteers		NR							No
Buchberger, 1992 [271]	CTS	Unspecified diagnosis	18	78	57	23	82				No
Grant, 1992 [219]	CTS	Complex objective standard	22	NR		22	71				Yes
Grant, 1992 [219]	Normal	Healthy volunteers	47	100		16	65				Yes
Grant, 1992 [219]	CTS	Workers at risk		NR							Yes
Grant, 1992 [219]	CTS	Symptoms/ presented		NR							Yes
Imaoka, 1992 [272]	CTS	Unspecified diagnosis	42	79	50.3	20	76				Yes
Imaoka, 1992 [272]	Normal	Healthy volunteers	32	59	49.2	24	76				Yes
Kindstrand, 1992 [273]	Normal	Other	127	65	47.5	15	84				Yes
Kindstrand, 1992 [273]	CTS	Complex objective standard	94	73	50	19	95		1	121	Yes
Preston, 1992 [188]	Normal	Healthy volunteers		NR	31	18	50				Yes
Preston, 1992 [188]	CTS	Other	8	NR							Yes
Preston, 1992 [188]	CTS	Symptoms/ presented		NR	49	21	98				Yes
Tchou, 1992 [274]	CTS	Unspecified diagnosis	61	NR							No
Tchou, 1992 [274]	Normal	Healthy volunteers	40	50		22	45				No
Buchberger, 1991 [275]	Normal	Healthy volunteers	14	64							No
Buchberger, 1991 [275]	CTS	Symptoms/ presented	25	68	61	38	85				No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Chang, 1991 [145]	Normal	Healthy volunteers	40	NR	38.6	22	60				Yes
Chang, 1991 [145]	CTS	Symptoms/ presented	43	79	42.3	25	64				Yes
Durkan, 1991 [155]	CTS	Complex objective standard	31	74	45	22	79				No
Durkan, 1991 [155]	Normal	Healthy volunteers	50	NR							No
Jetzer, 1991 [168]	CTS	Workers at risk	100	NR							No
Jetzer, 1991 [168]	CTS	Workers at risk	284	NR							No
Jetzer, 1991 [168]	CTS	Workers at risk	39	NR							No
Jetzer, 1991 [168]	Normal	Healthy volunteers	284	NR							No
Katz, 1991 [276]	CTS	Symptoms/ presented	78	63	43.4						Yes
Lauritzen, 1991 [185]	CTS	Unspecified diagnosis	38	68	53						Yes
Lauritzen, 1991 [185]	Normal	Healthy volunteers	23	NR							Yes
Luchetti, 1991 [169]	CTS	Unspecified diagnosis	14	93	41	21	64	31.3	2	120	Yes
Radwin, 1991 [116]	CTS	Unspecified diagnosis	12	58		29	60				No
Radwin, 1991 [116]	Normal	Healthy volunteers	15	NR	34.5	25	67				No
Charles, 1990 [170]	Other	Other	30	60	45.5	25	63				Yes
Charles, 1990 [170]	Normal	Healthy volunteers	60	80	45	23	76				Yes
Charles, 1990 [170]	CTS	Unspecified diagnosis	158	84	47.1	20	64				Yes
De Krom, 1990 [222]	Normal	Other	50	86							No
Fitz, 1990 [277]	Normal	Healthy volunteers	44	NR	30	22	66				No
Fitz, 1990 [277]	CTS	Complex objective standard	36	NR	52	25	88				No
Gilliatt, 1990 [278]	CTS	Unspecified diagnosis	10	NR	44						No
Gilliatt, 1990 [278]	Normal	Healthy volunteers	15	NR	42						No
MacDonell, 1990 [90]	CTS	Complex objective standard	34	NR	44	29	67				No
MacDonell, 1990 [90]	Normal	Healthy volunteers	12	NR	41	26	61				No
Merchut, 1990 [279]	Normal	Healthy volunteers	54	NR	53						No
Merchut, 1990 [279]	CTS	Symptoms/ presented	23	87	53	25	74				No
Palliyath, 1990 [171]	Normal	Healthy volunteers	11	NR	31						No
Palliyath, 1990 [171]	CTS	Unspecified diagnosis	10	NR	42	30	50				No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Pease, 1990 [177]	Normal	Healthy volunteers	16	NR		21	63				No
Pease, 1990 [177]	CTS	Unspecified diagnosis	21	NR							No
Rojviroj, 1990 [280]	CTS	Complex objective standard	33	76	46.5	19	67	19	1	120	No
Rojviroj, 1990 [280]	Normal	Healthy volunteers	16	25							No
Tzeng, 1990 [180]	CTS	Unspecified diagnosis	84	70	48	21	67				No
Tzeng, 1990 [180]	Normal	Healthy volunteers	50	56	46	20	65				No
Uncini, 1990 [135]	Normal	Healthy volunteers	39	NR	54	16	81				No
Uncini, 1990 [135]	CTS	Complex objective standard	35	80	49	28	68			8	No
Winn, 1990 [281]	CTS	Other	34	NR							No
Winn, 1990 [281]	CTS	Symptoms/ presented	27	NR							No
Braun, 1989 [282]	CTS	Symptoms/ presented	40	80	38						Yes
Cioni, 1989 [146]	Normal	Healthy volunteers	54	65	38.3	18	68				No
Cioni, 1989 [146]	CTS	Symptoms/ presented	307	16	46.4	20	72				No
Jackson, 1989 [150]	CTS	Symptoms/ presented	123	82	52.6	21	85				Yes
Jackson, 1989 [150]	Normal	Healthy volunteers	38	76	42.2	21	66				Yes
Meyers, 1989 [283]	Normal	Healthy volunteers	19	53	36	22	60				No
Meyers, 1989 [283]	CTS	Unspecified diagnosis	14	64	51	36	68				No
So, 1989 [173]	Normal	Healthy volunteers	20	NR							No
So, 1989 [173]	Cubital tunnel syndrome	Unspecified diagnosis	15	NR							No
So, 1989 [173]	CTS	Unspecified diagnosis	22	NR							No
Szabo, 1989 [284]	CTS	Unspecified diagnosis	22	73	51	24	79	29	7	120	Yes
Uncini, 1989 [161]	CTS	Symptoms/ presented	32	NR							No
Uncini, 1989 [161]	Normal	Healthy volunteers	33	55		16	81				No
De Léan, 1988 [285]	CTS	Simple signs/symptoms	150	73	47.6	18	84	31	1	144	Yes
Koris, 1988 [198]	CTS	Unspecified diagnosis	21	86	60	28	85		1	120	Yes
Koris, 1988 [198]	Normal	Healthy volunteers	15	NR		28	40				Yes
Molitor, 1988 [110]	CTS	Symptoms/ presented	19	NR							No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Molitor, 1988 [110]	Normal	Healthy volunteers		NR	49	23	79				No
Mortier, 1988 [286]	CTS	Simple nerve conduction	116	67	49.2	20	82				No
Mortier, 1988 [286]	Normal	Healthy volunteers	102	67	47.5	22	86				No
Pease, 1988 [287]	Normal	Healthy volunteers	23	NR		21	62				No
Pease, 1988 [287]	CTS	Unspecified diagnosis	25	NR							No
Carroll, 1987 [288]	CTS	Symptoms/ presented	101	76	44.8	22	82				No
Carroll, 1987 [288]	Normal	Healthy volunteers	50	48	46.7	16	82				No
Jessurun, 1987 [289]	Normal	Healthy volunteers	10	50							No
Jessurun, 1987 [289]	CTS	Unspecified diagnosis	24	88							No
Johnson, 1987 [290]	Normal	Healthy volunteers	78	NR		20	79				Yes
Johnson, 1987 [290]	CTS	Complex objective standard	20	NR							Yes
Liang, 1987 [291]	CTS	Other	10	100							No
Liang, 1987 [291]	CTS	Unspecified diagnosis	68	79	50	24	73				No
Liang, 1987 [291]	Normal	Contralateral arm	39	67							No
Liang, 1987 [291]	Normal	Healthy volunteers	100	50	45	20	69				No
Liang, 1987 [291]	CTS	Other	28	82							No
Liang, 1987 [291]	CTS	Other	20	90							No
Liang, 1987 [291]	CTS	Other	20	65							No
Liang, 1987 [291]	CTS	Other	58	76							No
Macleod, 1987 [292]	CTS	Simple nerve conduction	111	NR							No
Macleod, 1987 [292]	Normal	Healthy volunteers	26	58	39	17	63				No
Macleod, 1987 [292]	Normal	Healthy volunteers	125	52	41	17	82				No
Seror, 1987 [156]	CTS	Symptoms/ presented	62	79	56.8	29	85				No
Seror, 1987 [156]	Normal	Healthy volunteers	20	75	55.7	34	79				No
Borg, 1986 [293]	CTS	Symptoms/ presented	22	82	45.5			33			No
Gellman, 1986 [106]	CTS	Complex objective standard		NR							Yes
Gellman, 1986 [106]	Normal	Healthy volunteers		NR							Yes
Gellman, 1986 [106]	Other	Other		NR							Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Escobar, 1985 [151]	CTS	Symptoms/ presented	23	70		22	55				Yes
Escobar, 1985 [151]	Normal	Healthy volunteers	55	64		20	70				Yes
Kimura, 1985 [189]	Normal	Healthy volunteers	148	54	47.6	20	81				No
Kimura, 1985 [189]	CTS	Symptoms/ presented	438	65	51.4	18	85				No
Mills, 1985 [194]	CTS	Symptoms/ presented	47	77		29	74		0	60	No
Mills, 1985 [194]	Normal	Healthy volunteers	29	45		19	63				No
Mills, 1985 [194]	Normal	Other	20	50		19	75				No
Borg, 1984 [294]	CTS	Unspecified diagnosis	21	NR							No
Borg, 1984 [294]	CTS	Other	12	NR							No
Borg, 1984 [294]	CTS	Unspecified diagnosis	12	NR							No
Pryse-Phillips, 1984 [105]	Other	Complex objective standard	44	NR							No
Pryse-Phillips, 1984 [105]	Cubital tunnel syndrome	Complex objective standard	67	NR							No
Pryse-Phillips, 1984 [105]	CTS	Complex objective standard	212	NR							No
Pryse-Phillips, 1984 [105]	Other	Complex objective standard	41	NR							No
Pryse-Phillips, 1984 [105]	Other	Complex objective standard	32	NR							No
Satoh, 1984 [295]	CTS	Complex objective standard	14	100							No
Szabo, 1984 [30]	CTS	Unspecified diagnosis	20	50		32	81		2	180	No
Goddard, 1983 [296]	CTS	Unspecified diagnosis	24	NR							No
Goddard, 1983 [296]	Normal	Healthy volunteers	49	NR							No
Kim, 1983 [195]	Normal	Healthy volunteers	33	NR	41.3	20	68				No
Kim, 1983 [195]	CTS	Symptoms/ presented	39	NR							No
Marin, 1983 [139]	CTS	Unspecified diagnosis	14	86	49	23	79	13	1	24	No
Marin, 1983 [139]	Normal	Healthy volunteers	12	42	30	22	48				No
Wongsam, 1983 [172]	DM with peripheral neuropathy	Unrelated disease	6	NR							No
Wongsam, 1983 [172]	CTS	Symptoms/ presented	15	NR							No

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Wongsam, 1983 [172]	Normal	Healthy volunteers	50	56		20	68				No
Johnson, 1981 [297]	CTS	Unspecified diagnosis	18	NR							No
Johnson, 1981 [297]	Normal	Healthy volunteers	37	49							No
Dekel, 1980 [21]	Normal	Healthy volunteers	33	58	40.3						No
Dekel, 1980 [21]	CTS	Unspecified diagnosis	26	100							No
Messina, 1980 [120]	CTS	Symptoms/ presented	40	NR	45.1	19	67				No
Messina, 1980 [120]	Normal	Healthy volunteers	40	NR	47.5						No
Gelmers, 1979 [29]	Normal	Healthy volunteers	43	79	54	26	74				No
Gelmers, 1979 [29]	CTS	Complex objective standard	47	81	57	29	78				No
Kimura, 1979 [140]	CTS	Unspecified diagnosis	105	70	48	20	78				No
Kimura, 1979 [140]	Normal	Unrelated disease	61	57	43	15	50				No
Schwartz, 1979 [187]	CTS	Symptoms/ presented	20	85	52	27	77				No
Schwartz, 1979 [187]	Normal	Healthy volunteers	10	100		20	28				No
Stewart, 1978 [157]	CTS	Complex objective standard	37	81	55	36	84				Yes
Stewart, 1978 [157]	Normal	Healthy volunteers	38	79	53	30	84				Yes
Eisen, 1977 [298]	Cubital tunnel syndrome	Complex objective standard	18	NR	51.7	26	65				No
Eisen, 1977 [298]	Normal	Healthy volunteers	60	NR	41.5	11	74				No
Eisen, 1977 [298]	Combined WRUEDs	Other	23	NR	50	7	68				No
Eisen, 1977 [298]	CTS	Complex objective standard	30	NR	56.1	21	76				No
Sedal, 1973 [299]	Normal	Healthy volunteers	34	NR	47	18	77				Yes
Sedal, 1973 [299]	CTS	Complex objective standard	214	56	54	19	87				Yes
Welch, 1973 [223]	Other	Other	111	NR							No
Welch, 1973 [223]	Combined WRUEDs	Workers at risk	428	81							No
Casey, 1972 [300]	CTS	Unspecified diagnosis	16	94	55.9	35	70				Yes
Casey, 1972 [300]	Other	Other	18	33	53.5	30	77	178	72	444	Yes

Article	Disorder type	Patient selection	N patients	% female	Mean age	Age of youngest	Age of oldest	Duration of condition before treatment (months)	Shortest duration (months)	Longest duration (months)	Are patient comorbidities reported?
Casey, 1972 [300]	Normal	Healthy volunteers	94	NR	51	20	80				Yes
Loong, 1972 [141]	Normal	Healthy volunteers	30	100		30	60				No
Loong, 1972 [141]	CTS	Unspecified diagnosis	18	100	43.7	31	60	12.7	1	48	No
Melvin, 1972 [147]	CTS	Symptoms/ presented	17	NR							No
Melvin, 1972 [147]	Normal	Healthy volunteers	24	NR							No
Buchthal, 1971 [301]	Normal	Healthy volunteers	10	50		32	57				No
Buchthal, 1971 [301]	CTS	Other	22	73		29	67			360	No
Loong, 1971 [148]	Normal	Healthy volunteers	30	100		30	60				Yes
Loong, 1971 [148]	CTS	Symptoms/ presented	15	100		31	60	7.6	1	24	Yes
Plaja, 1971 [142]	Normal	Healthy volunteers	20	NR							No
Plaja, 1971 [142]	CTS	Unspecified diagnosis	56	NR							No

[a]Reported median age instead of mean age
CTS—Carpal tunnel syndrome
DM—Diabetes mellitus

Table 46. Carpal Tunnel Syndrome–Reported Inclusion and Exclusion Criteria

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Finsen, 2001 [224]	Positive clinical diagnosis of carpal tunnel syndrome	Patients for whom the clinical diagnosis was considered equivocal. If more than one hand was treated, only the first was included.
Mondelli, 2001 [181]	Idiopathic CTS with reduction of distal conduction velocity of the median nerve. Unilateral CTS.	None reported
Atroshi, 2000 [225]	Respondents to a random survey who reported numbness and/or tingling in at least two radial fingers at least twice a week for previous four weeks	Previous CTS surgery, resolution of symptoms, symptoms not consistent with CTS, unwilling to take test
Bland, 2000 [200]	All patients in county referred for NCS with suspected CTS, also patients with other referrals who then had a positive NCS	None (authors report 100% inclusion)
Cuturic, 2000 [226]	Sensory symptoms and abnormal NCS, limited to mild or moderate disease	Certain EMG abnormalities (authors do not specify that these were in fact exclusion criteria--just that no patients had them)
Kearns, 2000 [204]	Pork processing employees who had worked for at least 2 months.	Pre-existing CTS or diabetes.
Loscher, 2000 [175]	Referred to the laboratory for neurophysiological assessment of median nerve	Traumatic nerve lesions
Montagna, 2000 [227]	Diagnosed with carpal tunnel syndrome or cubital tunnel syndrome.	None reported
Nakamichi, 2000 [228]	DML >4.2 ms and SCV >45 m/s	None reported
Raudino, 2000 [229]	Referred to lab. All were complaining of discomfort, paresthesias, or weakness in the territory of the median nerve occurring especially at night or after repetitive actions and relieved by changes in posture or shaking hands. Abnormal nerve conduction test as defined by one of the following three abnormalities: 1) DML >4 ms; 2) antidromic DSL to index finger >3 ms; wrist-to-palm sensory latency >1.8 ms for patients <45 years old or >2 ms for patients older than 45.	Metabolic diseases, radiculopathies, polyneuropathies, concomitant pathologies.
Resende, 2000 [184]	Clinical diagnosis of carpal tunnel syndrome and abnormal conventional motor and sensory conduction studies	None reported
Resende, 2000 [174]	Diagnosed with carpal tunnel syndrome by clinical and electrophysiological methods with conventional techniques. Normal bilateral sensory conduction studies of the ulnar nerve.	None reported
Sener, 2000 [186]	Symptoms and clinical signs suggesting carpal tunnel syndrome.	Peripheral nerve dysfunction or peripheral neuropathy other than CTS
Seror, 2000 [158]	Diagnosis of mild CTS	None reported
Stalberg, 2000 [230]	Patients referred to the lab with the presumptive diagnosis of carpal tunnel syndrome.	None reported
Weber, 2000 [108]	Suspected of having carpal tunnel syndrome.	None reported

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Atroshi, 1999 [220]	Randomly selected from the population of Sweden.	Did not respond to mailed questionnaire, did not attend clinical exam, previous carpal tunnel surgery, declined nerve conduction testing, neurologic disease
Burke, 1999 [231]	Referred for splinting	None reported
Duncan, 1999 [232]	Positive NCS (decreased median SCV or prolonged DML) or two physicians agreeing that the symptoms and history are consistent with CTS. Did not give specific criteria for either.	Previous surgery or anatomic variation in the median nerve
Kabiraj, 1999 [233]	DML >4.02 m/sec [sic] (mean + 2 SD), MCV <47.57 m/s (mean – 2 SD), CMAP decreased by 1 SD, prolonged or absent median sensory action potential. Painful paresthesia with night worsening, appropriate distribution, thenar weakness, positive Tinel, positive Phalen.	None reported
Lee, 1999 [234]	Clinical diagnosis of CTS.	None reported
Missere, 1999 [205]	Male workers in a meat processing plant	None reported
Mongale, 1999 [235]	Diagnosed with carpal tunnel syndrome via NCS.	None reported
Murthy, 1999 [143]	Referred for electrodiagnostic evaluation for paresthesia	None reported
Rudolfer, 1999 [236]	Patients in database referred to electromyographer.	Non-CTS abnormality.
Sander, 1999 [237]	Both clinical and electrophysiological diagnosis of carpal tunnel. 1) Clinical: Two or more of the following primary symptoms in a median nerve distribution: numbness, tingling, clumsiness, or nocturnal symptom exacerbation. If only one of these symptoms was present, two of the following secondary symptoms were required: burning/cold, tightness, sore/ache/discomfort, or puffiness. 2) Electrodiagnostic confirmation: one of the following three abnormalities: A) an absent median palm-wrist mixed nerve action potential latency. B) a median palm-wrist mixed nerve action potential latency >1.7ms, C) if this same latency exceed the ipsilateral ulnar palm-wrist latency by more than 0.3ms.	Carpal tunnel patients: excluded if a history or physical exam suggestive of a neuromuscular disorder other than carpal tunnel syndrome.
Simovic, 1999 [183]	Referred to laboratory with hand or arm complaints including but not limited to numbness, tingling, or pain	Diabetes or the clinical or electrophysiological suggestion of a concomitant peripheral nerve disorder
Szabo, 1999 [152]	Diagnosed CTS	None reported
Thonnard, 1999 [117]	Severe CTS: small or absent sensory amplitude, DSL and DML >5 ms, and evidence of denervation in APB	Other (non-CTS) electrodiagnostic abnormalities

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Wang, 1999 [238]	Symptoms and at least 2 of the following 5 NCS criteria: 1) DML >4.2 ms 2) DSL to index >3.5 ms 3) Difference between median and ulnar mixed nerve latencies = 0.4 ms 4) Difference between median and ulnar sensory latency to ring finger = 0.5 ms 5) Difference between median motor latency to 2nd lumbrical and ulnar motor latency to first palmar interosseous = 0.5 ms	Additional neuromuscular disease, polyneuropathy, cervical radiculopathy, severe CTS, atypical histories.
Aurora, 1998 [239]	Referred to lab with clinically definite carpal tunnel syndrome.	None reported
Ferry, 1998 [221]	All participants were registered to receive primary care at a local general practice.	None reported
Fertl, 1998 [153]	Referred with pain	Polyneuropathy, ulnar nerve lesion, radiculopathy, arthropathy
Gerr, 1998 [31]	Any patient 18-70 years old with symptoms of pain, weakness, numbness, or tingling in the cutaneous distribution of the median nerve	Electrophysiological tests positive for a disorder other than CTS.
Ghavanini, 1998 [154]	Symptoms of CTS	Conditions other than CTS
Girlanda, 1998 [149]	Symptomatic hands with clinical evidence of idiopathic CTS. Examples of symptoms: nocturnal or activity-related pain and paresthesia in the hand, Phalen's, hypaesthesia limited to the distribution of the median nerve. Mild CTS required: No weakness or muscle atrophy present, DML in all patients was never slower than 4.0 ms which represented 2.5 SD below mean of controls in this laboratory.	Known causes of entrapment neuropathies or systemic diseases. Cervical radiculopathy, brachial plexopathy, thoracic outlet syndrome, multi-polyneuropathies.
Kabiraj, 1998 [240]	Patients had the following symptoms and signs: history of pain, numbness, paresthesia, nocturnal awakening due to pain and weakness with or without atrophy, decreased sensations, Tinel's signs and wrist flexion Phalen's signs	Evidence of peripheral neuropathy other than median nerve dysfunction
Kleindienst, 1998 [241]	Clinical diagnosis of CTS	None reported
Luchetti, 1998 [242]	Idiopathic CTS, defined as night pain and/or paresthesia, and median nerve sensory deficits. Motor deficits not required.	Diabetes, uremia, polyneuropathy, history of wrist trauma
Nathan, 1998 [202]	Industrial workers in four industries: steel mill workers, food processors, electronics workers, and plastics workers.	Previous carpal tunnel release surgery.
Rosen, 1998 [201]	Carpal tunnel patients: Clinically diagnosed. Vibration-exposure patients Symptomatic, with exposure to hand-held vibrating tools.	None reported
Scelsa, 1998 [243]	Clinically definite CTS as defined by: symptoms of numbness, paresthesia or pain in median nerve distribution and at least one of the following: hand clumsiness, nocturnal hand symptoms, sensory loss, weakness on exam in an appropriate median nerve distribution. Normal ulnar sensory and motor conduction studies	Cervical radicular pain or objective signs of cervical radiculopathy, or clinical evidence of polyneuropathy, or electrophysiological evidence of ulnar neuropathy

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Seror, 1998 [159]	Intermittent symptoms of burning, tingling, and paresthesia in the radial digits especially at night or upon awakening. Also patients had normal classical electrodiagnostic tests, i.e., DML to APB <4ms and palm-to-wrist orthodromic sensory conduction velocity >45m/s	None reported
Smith, 1998 [244]	Referred with suspected CTS	None reported
Tan, 1998 [206]	Working as carpet weaver	None reported
Terzis, 1998 [162]	CTS patients: Median distal motor latency required to be less than 4.2 ms. 18 months after the study, confirmation of CTS by sensory nerve latency on either digit 2 or digit 3 of >3ms.	Any history of peripheral nerve problems. Any other pathology, screened out by ulnar nerve and palmar stimulation studies
Tetro, 1998 [102]	CTS symptoms including median distribution of pain and paresthesia. Positive NCS including abnormal DML or DSL or DML 1.0 ms more than contralateral or DSL 0.5 ms more than contralateral	Proximal entrapment symptoms, thoracic outlet syndrome, acute CTS, paralysis, negative NCS (n = 7)
Werner, 1998 [207]	Workers were selected to be representative of a range of jobs typically found in contemporary manufacturing and clerical sites.	None reported
Wilson, 1998 [245]	Presence of carpal tunnel syndrome	History of significant hand trauma, or peripheral neuropathy, or radiculopathy, or Martin-Gruber anastomosis
Bak, 1997 [246]	Suspected CTS	Diabetes, severe renal disease, pregnancy within the last year, previously treated CTS, contraindications to MRI, polyneuropathy.
Brahme, 1997 [199]	Diagnosed by hand surgeon with work-related dynamic carpal tunnel syndrome (indicating that symptoms only occurred during repetitive motion).	None reported
Bronson, 1997 [163]	Patients: Pre-surgery, DML <4 ms, normal needle EMG of APB. Included in this group based on traditional clinical indications, as judged by physicians. Controls: positive Tinel's sign, but no symptoms. Negative on standard sensory and motor nerve conduction tests.	Diabetes, rheumatoid arthritis, hypothyroidism, cervical spine disease, pregnancy, cervical radiculopathy.
Del Pino, 1997 [104]	All of the following three criteria for diagnosis of CTS: 1) Symptoms of CTS, consisting of pain predominantly at night, paresthesias and dysaesthesias, numbness, sensory deficit in the territory of the median nerve, and weakness of the APB; 2) Abnormal sensitivity in the median nerve distribution compared to the ulnar territory of the same hand and/or cutaneous territory of the contralateral median nerve in cases of unilateral involvement; 3) Complete relief of pain and paresthesias within 15 days of open surgical release of the carpal tunnel.	None reported

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Dellon, 1997 [107]	Already diagnosed with either carpal tunnel syndrome or cubital tunnel syndrome. Diagnosis was based on the clinical history and physical examination, which included positive provocative testing, positive Tinel's sign at the wrist or elbow, abnormal tuning fork perception.	Cervical radiculopathy, diabetes, thoracic outlet syndrome, thyroid disease, collagen vascular disease, using narcotics or antidepressants.
Franzblau, 1997 [208]	At least 6 months' tenure in jobs at a spark plug manufacturing plant	None reported
Guglielmo, 1997 [247]	Typical signs and symptoms of carpal tunnel syndrome (based on American Academy of Neurology Quality Standards Subcommittee)	None reported
Gunnarsson, 1997 [248]	Referred to lab with suspected CTS	Neuropathies
Horch, 1997 [249]	Surgical candidates with symptoms of CTS and median motor latency >4 ms	None reported
Jeng, 1997 [209]	Volunteers from food processing plant.	History of peripheral neuropathy, fractures, severe burns, arthritis, diabetes, carpal tunnel surgery
Kaneko, 1997 [250]	Group 01: Coexisting entrapment neuropathy and cervical cord compression demonstrated by MRI. Group 02: Diagnosed with carpal tunnel syndrome. Group 03: Diagnosed with cubital tunnel syndrome. Group 04: Control group, no subjective symptoms or neurologic findings associated with peripheral or central lesions.	None reported
King, 1997 [114]	CTS as confirmed by EMG or NCS. New referrals.	None reported
Pierre-Jerome, 1997 [251]	Typical signs and symptoms, DML >4.5 ms or sensory velocity <45 m/s	Previous surgery, comorbidity with "somatic connective tissue diseases" (radiculopathy?), alcoholism
Radack, 1997 [252]	All wrist MRI examinations, regardless of indication	None
Rosecrance, 1997 [253]	Recent (within two weeks) numbness and tingling, or one of those plus any two of: burning/cold, tightness, pain, symptoms worsening at night. Must have involved median nerve distribution (thumb to medial aspect of ring finger).	Disorders with similar presentation to CTS.
Simovic, 1997 [182]	1) Referral to laboratory for possible carpal tunnel syndrome; and 2) Completion of a median motor study including distal and proximal stimulation, sensory antidromic median conduction to the index finger, and mixed nerve median and ulnar conduction studies with palmar stimulation	1) Clinical symptoms or signs of other peripheral nerve disorders of the same limb. 2) Diabetes mellitus 3) Insufficient chart data
Werner, 1997 [210]	DSL prolonged by 0.5 ms or more, but asymptomatic	None reported
Andary, 1996 [196]	Referred to lab because of pain or numbness in the hand and wrist with histories and physical exam consistent with the possible diagnosis of CTS. Median antidromic sensory latency to index finger was required to be <4.0 ms to rule out "clear cut" CTS. Other nerve conduction tests (unspecified), however, were required to be positive.	None reported

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Atroshi, 1996 [136]	Symptoms and signs consistent with carpal tunnel syndrome. Unsuccessful prior nonoperative treatment.	None reported
Bingham, 1996 [211]	All new applicants who had been offered jobs at meat packing, plastics assembly, food processing, furniture manufacturing, or grocery warehousing in a 17 county area in the southeastern US over an 18 month period. Applicants had worked for an average of 4.4 years in various settings.	None reported
Checkosky, 1996 [254]	Physician-diagnosed CTS	None reported
Cherniak, 1996 [190]	Referred to lab.	None reported
Foresti, 1996 [192]	Patients with suspected carpal tunnel referred to the laboratory	Other pathologies potentially causing polyneuropathy such as diabetes, iperuremia, acromegaly, etc.
Ghavanini, 1996 [255]	Paresthesia or numbness in fingers, and nocturnal hand pain or paresthesia, and excessive hand sweating or coldness, and positive Tinel sign or Phalen sign.	Diabetes, rheumatoid arthritis, thyroid dysfunction, history of trauma to neck or hands, cervical spondylosis, pregnancy, hand edema, obesity
Kleindienst, 1996 [256]	Pre-operative	None reported
Murata, 1996 [164]	Data entry operators.	None of the patients complained of nocturnal awakening with paresthesia or pain in hands, none had positive Tinel's sign or positive Phalen's sign. Also excluded prior pregnancy, occupational exposure to neurotoxic substances, endocrine disorders, neurological disorders, diabetes, acromegaly, myxedema, lupus, amyloidosis, rheumatoid arthritis, alcoholic dependency, hand injury, forearm injury.
Padua, 1996 [165]	Paresthesia, pain, hypotrophy of thenar eminence	Other neuropathies or signs of severe CTS (i.e., absence of SNAP at wrist).
Pierre-Jerome, 1996 [212]	Cleaners: Worked for at least three consecutive years and at least 19 hours a week.	Systemic diseases and psychiatric disorders including alcoholism.
Britz, 1995 [257]	select group of patients who had been clinically diagnosed as having CTS	None reported
De Smet, 1995 [101]	Presented as surgical candidate	None reported
Gerr, 1995 [118]	Age 18-70 with any hand symptoms	None reported
Glass, 1995 [28]	CTS symptoms	None reported
Golovchinsky, 1995 [258]	Referred to lab with complaints of neck pain and/or pain, numbness, or weakness in upper extremities.	Obvious injuries of the wrist, diabetes, hypothyroidism, renal failure.
Hamanaka, 1995 [259]	Clinical diagnosis of CTS based on symptoms, sensory disturbance of the median nerve distribution area, Tinel's sign, Phalen's sign, manual muscle testing, and APB atrophy. Carpal canal pressure in resting position >15 mm Hg or carpal canal pressure in power active flex >135 mmHg.	None reported

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Hansson, 1995 [137]	Typical history (defined by sensory or motor symptoms like intermittent paresthesias, numbness, pain and weakness in the domain of the median nerve)	Diabetes, polyneuropathy, or rheumatic disease
Kothari, 1995 [260]	Clinical diagnosis of CTS, including arm or wrist pain, paresthesia or other median distribution symptoms, weakness, Tinel's, or Phalen's and positive NCS	Signs or symptoms of neuropathy
Lang, 1995 [109]	1) CTS-typical signs and symptoms; 2) DML >4.5 ms or orthodromic SCV palm-to-wrist <45 m/s 3) planned surgical treatment	Previous surgery on the same hand
Lesser, 1995 [261]	Typical signs and symptoms of carpal tunnel syndrome, AND one or more of the following: 1) median distal motor latency >4.4ms, 2)median sensory antidromic latency to peak >3.5ms, 3) median sensory palm to wrist latency at least 0.4ms longer than that latency for the analogous segment of the ulnar nerve.	Peripheral neuropathy or multiple mononeuropathy
Nakamichi, 1995 [262]	Clinical and electrophysiological diagnosis of bilateral CTS. Clinical evaluation included the presence of typical sensory symptoms, Phalen's test, two-point discrimination, muscle testing, and thenar atrophy. Electrophysiological criteria were either DML >4.2 ms or SCV <45 m/s.	Rheumatoid arthritis, chronic renal failure under hemodialysis, endocrine or metabolic disorders including diabetes, gout, amyloidosis, or hypothyroidism, Colles fracture, ganglion, calcium deposition, and osteoarthritis.
Seradge, 1995 [263]	None reported	None reported
Seror, 1995 [179]	Referred to lab based on a clinical diagnosis of carpal tunnel syndrome: Intermitted paresthesia, numbness, tingling, or hypoesthesia in the median nerve distribution, with nocturnal aggravation, with or without pain in the hand, wrist, and forearm, and rarely for thenar muscle atrophy.	None reported
Shafshak, 1995 [264]	Group 001: Positive Phalen's, positive Tinel's, DSL >4 ms, DML >4.7 ms, but normal ulnar nerve conduction studies Group 002: Definite polyneuropathy, DML >4.7 ms, slowed MCV at the forearm. Group 003: Severe unilateral CTS based on clinical findings, and unobtainable DML and DSL, but normal ulnar nerve conduction.	None reported
Sheean, 1995 [191]	Referred to lab based on suspected CTS.	None reported
Tassler, 1995 [115]	Symptomatic patients who had been diagnosed, had not been cured by nonoperative methods, and later received surgery for the condition.	Diabetes, alcoholism, other toxicity.
Valls-Sole, 1995 [265]	Referred to lab, and all of the following:1) Slowing of MCV in wrist to palm and normal DML to thenar and normal CV elbow to wrist2) Normal CMAP amplitude from wrist or elbow stimulation3) Slow median SCV from palm to wrist, but no reduced SNAP amplitude4) Normal ulnar SCV5) No significant limitation of joint movement because of pain, skin or joint diseases or fat.	None reported

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Werner, 1995 [213]	Employees at an automobile parts manufacturing plant and a furniture assembly plant in southern Michigan.	None reported
Young, 1995 [166]	Workers at a poultry processing plant.	None reported
Clifford, 1994 [266]	Referred to lab from family physicians, rheumatologists, and neurologists. Symptoms of CTS (e.g. pain, numbness, tingling). Screening history and physical exam to ensure the referring diagnosis of CTS was warranted.	Peripheral neuropathy, or obvious entrapment other than the median nerve.
Durkan, 1994 [267]	Symptoms of CTS, particularly in median nerve distribution	None reported
Franzblau, 1994 [113]	Full-time employees of an automobile parts manufacturing plant which had reported problems with upper extremity cumulative trauma disorders.	None reported
Gerr, 1994 [197]	Referred to lab, age 18-70 with symptoms of pain, weakness, numbness, or tingling that involved either hand.	None reported
Kirschberg, 1994 [214]	Employees in repetitive jobs in the poultry industry who were referred to a neurologist with pain, numbness, or tingling.	None reported
Kuntzer, 1994 [144]	If patient reported a combination of hand and arm symptoms suggestive of CTS, with numbness, tingling, pins and needles, "sleeping" of the hands and fingers, nocturnal symptoms or clumsiness, weakness, puffiness, swelling, tightness, joint pain or aching of the hand or fingers.	Patients: Two were excluded due to absent distal reflexes in the lower extremities. Controls: Two were excluded due to presence of symptoms of CTS, or pregnancy.
Nathan, 1994 [215]	Japanese furniture factory workers. American workers from four industries.	None reported
Nilsson, 1994 [216]	Currently working as a platers, truck assembler, or office worker. Male, age <54, randomly selected from larger groups for participation in the study. Platers were required to be currently exposed to vibration, and were selected for nerve conduction based on consecutive cases.	None reported
Para, 1994 [103]	Paresthetic CTS: Has CTS, has normal distal motor latency. Slight CTS: Has CTS, has abnormal distal motor latency. Controls: no current or past subjective complaints about upper extremities and an entirely normal neurological exam.	None reported
Rossi, 1994 [178]	History and symptoms typical of idiopathic CTS. Reduction of median nerve SCV in one or more of the digit-wrist segments studied, with normal values of ulnar and radial nerve sensory conduction.	Working at manual jobs. None had signs or history of cervical radiculopathy or peripheral neuropathy.
Werner, 1994 [217]	Employees at an automobile parts manufacturing plant that had reported a significant problem with CTS. Consent to testing.	Significant exposures to vibration or low temperature.
Werner, 1994 [111]	Referred for evaluation of CTS, must have median nerve symptoms	None reported

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Eisen, 1993 [193]	One of three groups: 1) Clinical for CTS. Symptoms and clinical signs. Examinations included Tinel's and Phalen's, but these were not required for diagnosis of CTS; 2) Historical for CTS. Sympto ms: pain, sensory discomfort, or numbness in the hand, nocturnal awakening because of hand pain, clumsiness and loss of dexterity; 3) Uncertain. Vague complaints without nocturnal awakening and no loss of hand dexterity, and normal neurological exam.	1) Clinical or electrophysiological evidence of other upper limb neuropathy such as proximal median neuropathy, ulnar neuropathy, or cervical radiculopathy. 2) Historical or clinical evidence of systemic disease such as diabetes or alcoholism. 3) Prior treatment with a wrist splint or carpal tunnel surgical release. 4) Inability to obtain a median CMAP elicited by stimulating the median nerve at the wrist or inability to obtain median or ulnar SNAPs by palmar stimulation
Johnson, 1993 [167]	Employees at one of six poultry processing plants.	None reported
Nakamichi, 1993 [268]	Diagnosed with carpal tunnel syndrome based on clinical signs and NCS tests. Clinical evaluation included the presence of typical sensory symptoms, Phalen's and Tinel's tests, sensory testing by 2-point discrimination on the middle finger, muscle testing, and thenar atrophy. NCS was abnormal if either DML >4.2 ms or SCV <45 m/s.	None reported
Nathan, 1993 [218]	Industrial workers from six industries: steel mill, meat/food processing, electronics, plastics, aluminum reduction, and cable plant. Workers' compensation patients had upper extremity complaints, primarily related to suspected CTS.	None reported
Rodriquez, 1993 [269]	History and physical, and abnormal NCS	Peripheral neuropathy, cervical radiculopathy, other entrapments
Rosen, 1993 [270]	Workers: Complaints of numbness and paresthesia and sometimes pain after long term exposure to vibrating tools. Carpal tunnel syndrome patients: Diagnosed with carpal tunnel syndrome, symptoms typical of CTS (numbness and paresthesia of radial fingers aggravated at night), not exposed to vibration	None reported
Rosén, 1993 [138]	Referred for diagnosis of suspected CTS. All had numbness and paresthesia that worsened at night	Any other explanation for symptoms, such as radiculopathy or polyneuropathy
Uncini, 1993 [160]	Clinical signs and symptoms suggestive of CTS, DML <4.2 ms (normal), SCV index-to-wrist >45 m/s (normal).	None reported
Buchberger, 1992 [271]	Patients with carpal tunnel syndrome. All had pain and sensory impairment in the distribution of the median nerve. All had prolonged DML (unspecified threshold).	None reported
Grant, 1992 [219]	Symptomatic: tingling, numbness, or decreased sensation in at least two fingers. Diagnosed: symptoms plus abnormal NCS	Arthritis, broken bones in hand/wrist, Raynaud's syndrome, previous wrist surgery, diabetes, kidney or metabolic disorders, heart or other circulatory disorders, pregnancy, use of OCs or hormones, history of heavy alcohol or tobacco use

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Imaoka, 1992 [272]	Any sensory disorder in the median nerve region, and either nocturnal acroparesthesia or positive Phalen's sign.	Marked atrophy of APB, peripheral nerve disorders, diabetes, or other polyneuropathies.
Kindstrand, 1992 [273]	NCS-confirmed CTS	None reported
Preston, 1992 [188]	Symptoms of CTS, "proven to have electrophysiologic CTS by standard nerve conduction criteria." Plus eight patients with possible CTS (symptomatic, but normal standard median studies, and at least one additional abnormal test)	None reported
Tchou, 1992 [274]	Referred to lab with symptoms and clinically diagnosed CTS, and confirmation of diagnosis via established criteria for nerve conduction studies. Developed symptoms within three months preceding examination.	None reported
Buchberger, 1991 [275]	Symptoms of CTS.	Unrelieved or recurrent CTS after surgical treatment.
Chang, 1991 [145]	History of carpal tunnel syndrome, with intermittent paresthesia occurring spontaneously at night or after repetitive use of the affected hand	Diabetes
Durkan, 1991 [155]	Suspected carpal tunnel syndrome based on pain, numbness, and paresthesias in the distribution of the median nerve. Either abnormal motor latency or sensory latency.	None reported
Jetzer, 1991 [168]	One of four different groups: computer assemblers, meat processors, keyboard workers, controls.	None reported
Katz, 1991 [276]	Pain or paresthesia in the upper extremity who were referred to the lab, and whose symptoms were caused by work.	Patients whose symptoms were not caused by work.
Lauritzen, 1991 [185]	Symptoms and signs compatible with CTS, and slowing of SCV along the median nerve from digit 1 or 3,or both, to the wrist, and prolonged DML from wrist to APB.	None reported
Luchetti, 1991 [169]	Nocturnal paresthesia in the median nerve territory. Normal motor function, sensory function, quantitative sensory examination, cutaneous trophism, distal sensory latency, distal motor latency.	Polyneuropathy, metabolic diseases with involvement of peripheral nerves.
Radwin, 1991 [116]	Diagnosis of CTS. Sensory complaints including tingling or numbness in the thumb, index, or middle finger and nocturnal exacerbation of the paresthesias. Either positive Tinel's sign, positive Phalen's sign, or positive Semmes-Weinstein monofilaments test.	Polyneuropathy, evidence of Raynaud's phenomenon.
Charles, 1990 [170]	For carpal tunnel syndrome patients: Clinical diagnosis of CTS by referring physician, and at least one of the following: 1) DML = 4.5 ms; 2) median orthodromic sensory nerve conduction in the second finger <45 m/s; 3) difference between median and ulnar orthodromic distal sensory latencies in the ring finger = 0.5ms.	For controls: Diabetes, peripheral neuropathy, no symptoms suggestive of CTS For the cervical spondylitic radiculopathy group: hand paresthesia mainly in the second and third fingers
DeKrom, 1990 [222]	Randomly selected from the general population of Maastricht (The Netherlands) and surrounding villages.	None reported

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Fitz, 1990 [277]	APB motor latency = 4.2 ms, or digit 1 radial sensory latency = 3.1 ms, or median sensory latency = 3.2 ms or difference = 0.5 ms or similar abnormalities on digit 3	None reported
Gilliatt, 1990 [278]	Patients had carpal tunnel syndrome	None reported
MacDonell, 1990 [90]	Patients had at least two of five criteria: 1) DML >4.2ms; 2) SNAP amplitude <10µV; 3) SNAP conduction velocity <40m/s; 4) SNAP amplitude less than that of the ipsilateral ulnar nerve at the wrist; 5) median motor or sensory latencies at the wrist more than 0.5 ms longer than opposite hand	Normal ulnar nerve motor and sensory conduction studies in both arms
Merchut, 1990 [279]	Symptomatic CTS referred to the lab. Electrophysiological confirmation via at least one of four NCS tests: 1) Prolonged sensory latency; 2) Prolonged DML; 3) Slowed median SCV; 4) prolonged difference between median sensory latency from ring finger and ulnar sensory latency from ring finger.	Excluded if any clinical signs, symptoms, or EMG findings suggested the possibility of another cause of paresthesia or numbness in their hands such as polyneuropathy, radiculopathy, or CNS lesion.
Palliyath, 1990 [171]	Symptoms of CTS, but little change on routine NCS	None reported
Pease, 1990 [177]	Symptoms and abnormal nerve conduction testing (vague).	Abnormalities or radial or ulnar nerves. Abnormal EMG of any muscle except the thenar muscles.
Rojviroj, 1990 [280]	Symptoms, positive Phalen's and positive Tinel's, and carpal tunnel was confirmed by DSL >3.5 ms or DML >4.5 ms or both.	None reported
Tzeng, 1990 [180]	Diagnosed by both clinical and electromyographic findings	None reported
Uncini, 1990 [135]	Typical CTS symptoms but normal DML and normal or borderline SCV	None reported
Winn, 1990 [281]	Responded to ad on bulletin board	None reported
Braun, 1989 [282]	Symptoms of dynamic carpal tunnel syndrome.	Evidence of long-standing fixed compression neuropathy or with contributory diseases such as rheumatoid arthritis. Thenar atrophy or profound fixed anesthesia.
Cioni, 1989 [146]	Signs and symptoms suggestive of carpal tunnel syndrome. Referred to laboratory for electrophysiological confirmation of carpal tunnel syndrome.	History or physical evidence of peripheral neuropathy or cervical radiculopathy.
Jackson, 1989 [150]	Referred to the lab for symptoms of CTS.	Peripheral neuropathy, or obvious entrapment other than median nerve.
Meyers, 1989 [283]	History and physical consistent with CTS, characteristic electrophysiologic abnormalities	None reported

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
So, 1989 [173]	Patients were selected from referrals to the lab. Carpal tunnel syndrome: Confident clinical diagnosis based on history of pain and paresthesias in the hand and fingers, and physical findings that localized the pathology to the median nerve, e.g. sensory alteration or weakness in a median nerve distribution, Tinel's, or Phalen's. Cubital tunnel syndrome: Confident clinical diagnosis based on paresthesias or numbness in an ulnar nerve distribution, usually accompanied by weakness in ulnar-innervated muscles. In those patients without weakness on examination, the diagnosis of ulnar neuropathy at the elbow was not made unless there was percussion sensitivity at the cubital tunnel or the ulnar groove, or exacerbation of symptoms with elbow flexion.	None reported
Szabo, 1989 [284]	CTS patients about to have carpal tunnel release surgery. Clinical and electrophysiological evidence of CTS. Electrophysiological evidence based on either DML >4.5 ms or DSL >3.5 ms.	None reported
Uncini, 1989 [161]	Symptoms and signs of carpal tunnel syndrome	Severe carpal tunnel (DML >4.2 ms or SNAPs were absent or SNAPs were very low amplitude)
De Léan, 1988 [285]	Paresthesia in median nerve distribution, regardless of Tinel's or Phalen's signs	Polyneuropathy, medicolegal cases, workers' comp
Koris, 1988 [198]	Accepted signs and symptoms including paresthesia, but did not have to be limited to the median nerve distribution	None reported
Molitor, 1988 [110]	Referred to lab for the diagnosis of carpal tunnel.	None reported
Mortier, 1988 [286]	Prolonged distal motor latency of median nerve or prolonged distal sensory latency of median nerve	Generalized peripheral neuropathy, other peripheral entrapment neuropathies, cervical radiculopathy.
Pease, 1988 [287]	Diagnosed with CTS based on clinical and electrodiagnostic findings	None reported
Carroll, 1987 [288]	Referred to lab, symptoms suggestive of CTS	Abnormal ulnar sensory amplitude or latency.
Jessurun, 1987 [289]	Suffering from primary CTS	None reported
Johnson, 1987 [290]	Antidromic DSL to middle finger >4 ms and DML >4.3 ms.	None reported
Liang, 1987 [291]	None reported	None reported
Macleod, 1987 [292]	Symptomatic NCS confirmed with abnormal sensory latency	Signs of other neurologic disorder
Seror, 1987 [156]	Pathological wrists	Radicular signs
Borg, 1986 [293]	Referred to lab with suspicion of CTS. Patients had digital paresthesias.	None reported

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Gellman, 1986 [106]	Carpal tunnel group syndrome: Three requirements: 1) Symptoms indicative of median-nerve compression in the carpal canal; 2) Either positive Semmes-Weinstein test or positive two-point discrimination test; 3) Positive nerve conduction results as indicated by any of four abnormalities: A) DML >4.5 ms B) DML on symptomatic hand more than 1 ms slower than DML on asymptomatic hand C) Sensory latency >3.5 ms D) Sensory latency on symptomatic hand more than one millisecond slower than on asymptomatic hand. Diverse lesion group: Abnormal results on clinical sensibility testing other than carpal tunnel syndrome	None reported
Escobar, 1985 [151]	Patients: Referred to lab for evaluation of numbness, tingling, weakness, and/or pain in the hand or arm. Controls: DSL <3.7 ms.	Endocrine disorders or peripheral nerve disease.
Kimura, 1985 [189]	Referred to lab with frank clinical signs and symptoms suggestive of CTS	Other disease that predispose toward peripheral neuropathy.
Mills, 1985 [194]	Tentative diagnosis of CTS	None reported
Borg, 1984 [294]	Patients with CTS. Some patients' conditions had been neurophysiologically confirmed (undefined).	None reported
Pryse-Phillips, 1984 [105]	Group 01: Carpal tunnel syndrome: Symptoms of paresthesia, numbness and/or weakness in the hand in digits I-II or I-V, with or without hand and arm pain, usually with nocturnal or early morning accentuation, ± clinical signs of thenar motor or median nerve territory sensory deficit. DML >4.5 ms or a difference of 1 ms between right and left or 1.5 median/ulnar difference. Median SNAP amplitude <ulnar or <10 μV or latency to onset >3.5 ms. Group 02: Cubital tunnel syndrome: Symptoms of hand weakness, ± digit V (IV) hypoesthesia, not extending into palm: and/or electrical signs of interosseous or hypothenar wasting, with proportionate weakness. Eisen score (undefined) greater than 5/10. Group 03: Other median nerve pathologies: Digital neuropathy affecting digits I-III or arm pain/paresthesia without nocturnal predominance, or clinically apparent weakness of long forearm flexors, ± palmar hypoesthesia. EMG evidence of acute/chronic denervation in forearm flexor muscles, ± delay in motor conduction across the point above the wrist with absence of electrical evidence of median nerve compression at the carpal tunnel. Group 04: Thoracic outlet syndrome. Group 05: Cervical radiculopathy	Carpal tunnel syndrome: Martin-Gruber anastomosis, other median nerve pathologies: cases of anterior interosseous syndrome
Satoh, 1984 [295]	No symptoms, normal ulnar sensory and motor conduction and one of three nerve conduction abnormalities: 1) orthodromic SCV digit-to-palm <42 m/s; 2) terminal latency >4.2 ms; 3) absent SNAP and absent CMAP.	None reported

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Szabo, 1984 [30]	Patients with objectively proved abnormalities of median nerve conduction who had carpal tunnel release surgery.	None reported
Goddard, 1983 [296]	Diagnosed with CTS and referred to the department	None reported
Kim, 1983 [195]	Signs and symptoms highly suggestive of CTS but with borderline or normal DSL.	None reported
Marin, 1983 [139]	Patients had previously undergone routine NCS studies for carpal tunnel syndrome	None reported
Wongsam, 1983 [172]	Symptoms suggesting early CTS	None reported
Johnson, 1981 [297]	Diagnosed CTS: history and NCS	None reported
Dekel, 1980 [21]	Diagnosed with carpal tunnel using history, clinical exam, and nerve conduction studies.	Any of the recognized diseases associated with carpal tunnel syndrome.
Messina, 1980 [120]	Signs and symptoms suggestive of CTS	None reported
Gelmers, 1979 [29]	Diagnosis of carpal tunnel based on three findings: 1) Acroparesthesia in the distribution of the median nerve; 2) Thenar muscle wasting or weakness or failure to detect an action potential of the thenar muscles by needle electromyography; 3) Prolongation of distal latency of the median nerve to more than 4.7 ms, or a difference in distal latency of more than 1 ms between symptomatic and asymptomatic hands, even though both latencies were within normal limits	Signs of generalized neuropathy
Kimura, 1979 [140]	Clinical impression (history and symptoms, not NCS), relatively mild symptoms	Polyneuropathy
Schwartz, 1979 [187]	Referred to lab based on sensory symptoms in a median distribution.	Generalized neuropathy
Stewart, 1978 [157]	In addition to ipsilateral ulnar sensory amplitude = 8.5 μV and ulnar sensory latency <2.8 ms, three or more of the following were required: 1) Sensory signs in the distribution of the median nerve.; 2) Thenar wasting or weakness; 3) DML >4.5 ms; 4) sensory onset latency >2.7 ms; 5) Sensory amplitude <8.6 μV	Diabetes, peripheral neuropathy. CTS secondary to trauma or other localized or generalized disease.

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Eisen, 1977 [298]	Carpal tunnel patients: Sensory symptoms limited to one or both hands, normal ulnar sensory latency (<2.8 ms), normal ulnar sensory amplitude (>8.4 μV), and at least three of the following five criteria: 1) Sensory signs restricted to median distribution; 2) Weakness or wasting of the APB muscle; 3) Median DML >4.5 ms; 4) Median DSL >2.7 ms; 5) Median SNAP amplitude <8.6 μV or median SNAP duration >2.4 ms. Cubital tunnel patients: Sensory symptoms limited to one or both hands, normal median sensory latency (<2.7 ms), normal median sensory amplitude (>8.6 μV), and at least three of the following six criteria: 1) Sensory signs restricted to ulnar distribution; 2) Weakness or wasting of the ulnar-innervated muscles of the hand; 3) Ulnar DML >4.0 ms; 4) Ulnar proximal motor latency (stimulation just above the elbow) >8.9 ms; 5) Ulnar DSL >2.8 ms; 6) Ulnar SNAP amplitude <8.4 μV or ulnar SNAP duration >2.1 ms. Patients with proximal lesions: Sensory symptoms limited to one or both hands, but did not meet criteria for either carpal tunnel or cubital tunnel.	Subjects were excluded from the control group if there was neuromuscular disease, diabetes, alcoholism, peripheral neuropathy, or systemic dysfunction.
Sedal, 1973 [299]	Presented as idiopathic carpal tunnel.	Excluded if CTS was an incidental finding in the investigation of a generalized peripheral neuropathy, OR if they had diabetes or alcoholism or chronic renal disease, or if there was clinical evidence of either radial or nerve lesions
Welch, 1973 [223]	Workers at a factory employed on repetition work producing domestic appliances. The other group consisted of job applicants who had not yet started work.	None reported
Casey, 1972 [300]	Carpal tunnel syndrome: Classical symptoms. Also 10 of the 16 patients had hypalgesia in the fingers of the involved hand supplied by the median nerve. Abnormal (or at the lower limit of normal) median SNAP recorded at the wrist after digital stimulation. Diabetics: Reflex changes and distal sensory abnormalities in the lower limbs, consisting of pain and paresthesia with sensory loss. In addition, 10 of the 18 diabetics had sensory changes in the upper limbs	None reported
Loong, 1972 [141]	Clinical diagnosis of CTS with typical history of intermittent paresthesia at night or after use.	None reported
Melvin, 1972 [147]	Referred to the laboratory as possible cases of carpal tunnel syndrome.	None reported
Buchthal, 1971 [301]	None reported	Normal ulnar SCV and latency to ADM to exclude generalized neuropathy

Article	Reported Patient Inclusion Criteria	Reported Patient Exclusion Criteria
Loong, 1971 [148]	Referred to lab with clinical diagnosis of carpal tunnel syndrome. Typical history of the syndrome with intermittent paresthesia occurring spontaneously at night or after use of the affected hand.	Diabetes
Plaja, 1971 [142]	None reported	"We excluded misleading diagnosis by controlling at the same time different levels and nerve trunks."

Question #2: What are the specific indications for surgery for carpal tunnel syndrome?

Published evidence does not directly address the specific indications for surgery for carpal tunnel syndrome. Therefore, we describe the reported characteristics of patients who have received surgery for carpal tunnel syndrome in published studies. The extent to which these patients represent typical surgical candidates is not certain. Patients included in published studies of a procedure are frequently a subset of patients who are candidates for that procedure. They may represent an unusual group of interest, or a group thought most likely to benefit from the procedure. Therefore, the data presented here, while informative, may not accurately reflect the overall patient population. It does, however, represent the best data available, and is the most comprehensive description of those carpal tunnel syndrome patient characteristics who receive surgery that has yet been compiled.

Evidence Base

To answer this question, we examined 141 studies (controlled trials and case series) describing a total of 15,993 patients.

Age

Patients who received surgery for carpal tunnel syndrome were predominantly of middle age. The mean of mean ages from the 124 studies that reported this information was 50.5 years, with a standard deviation of 5.7. Ages of individual patients ranged from 17 to 100 years. Mean ages and ranges from individual studies are given in Table 47, and are depicted in Figure 16. The vertical line in Figure 16 represents the mean age for all studies.

Very few studies (4%) reported that patients were excluded on the basis of age. Two studies excluded patients under the age of 18,[302,303] and one excluded patients under 16.[304] In contrast, one excluded patients over the age of seventy,[305] and another excluded patients over 75.[306]

Sex

Patients receiving surgery for carpal tunnel syndrome were more likely to be female than male, as can be seen in Figure 17. One hundred twenty eight studies provided sufficient information to calculate the male-to-female patient ratio. The average study reported that 73% of patients were female, with a standard deviation of 0.2. Patients in two studies were 100% female, and 100% male in one study. Numbers of male and female patients in individual studies are reported in Table 47.

No study reported sex to be a criterion for exclusion or inclusion. However, both studies in which men were the majority recruited their patients from male-majority populations. One recruited exclusively from a veteran's hospital population,[307] and one

recruited patients who worked with heavy, vibrating machinery.[308] These patients do not represent typical carpal tunnel syndrome patients.

Signs and Symptoms

Signs and symptoms of carpal tunnel syndrome among patients receiving surgery for carpal tunnel syndrome were incompletely reported. This is illustrated by Figure 18, which depicts the percentage of studies reporting the number of patients with an individual sign or symptom. This percentage never exceeds 15% of all studies. Rather than report the number of patients with a given sign or symptom, the common practice among studies of carpal tunnel syndrome is to report that patients had one or more symptoms from a given list. Some studies that included patients with bilateral carpal tunnel syndrome report symptoms per affected hand rather than per patient, reflecting the fact that the same patient can have different symptoms in each hand. The number and percent of patients reporting each sign or symptom is given in Table 48. These data are summarized in Figure 19. "Error" bars in Figure 19 represent the range of percentages reported by individual studies. Because so few (always less than 15%) studies reported this information, the extent to which the available data reflect the signs and symptoms of typical patients receiving surgery cannot be determined.

Eight studies excluded patients with thenar atrophy, while four included only patients with thenar atrophy. Seven studies required their patients to have Tinel's sign, Phalen's sign or both, and an indeterminate number included tests for these signs as part of their diagnostic procedure. The exact number of such studies can not be determined because some describe their patients as having "signs and symptoms of carpal tunnel syndrome" without providing further description or enumeration. The extent to which use of these criteria influence the overall description of the typical patient with carpal tunnel syndrome cannot be determined, because it is unclear whether or to what extent criteria for surgery may differ from criteria for study inclusion.

The duration of symptoms prior to surgery was reported by 35 studies (24% of total). These are listed in Table 49. The mean of means among these 35 studies was 29.9 months, with a standard deviation of 16.5 and a range of zero to 480 months. The means and ranges of individual studies are depicted in Figure 20. The vertical line in Figure 20 represents the mean of means.

Neuroelectrical characteristics

Of the 145 studies that reported on surgery for carpal tunnel syndrome and met inclusion criteria, 83 stated that electrodiagnostic tests were part of their inclusion criteria, but did not provide any further information as to the nature of these tests. An additional 26 did not provide any diagnostic information. Eleven studies did not include electrodiagnostic studies in their description of their diagnostic and inclusion criteria, and two specifically stated that electrodiagnostics were not part of their diagnostic protocol. Electrodiagnostic criteria in the remaining studies are reported in Table 50. Because the majority of studies excluded some patients based on their

neuroelectrical characteristics without providing information as to which patients were excluded or why, the impact of these exclusion criteria on the characteristics of the patients described in these studies cannot be determined.

Employment Characteristics

Of the 145 studies describing patients receiving surgery for carpal tunnel syndrome that met inclusion criteria, only 20 (14%) reported data on the types of employment of their patients. The occupations of patients receiving surgery for carpal tunnel syndrome and the percent of patients in each study possessing that occupation are given in Table 51.

No consistent categorization was used in these studies. The distinction between groups may be unclear. For example, the study by Worseg, et al. distinguished between "Workers" and "Employees".[44] The difference between the two groups was not described. As a result, it is difficult to make generalizations about typical characteristics of patients with carpal tunnel syndrome. The number of studies reporting each occupational category is given in Figure 21, and the percent of patients with each occupation among studies reporting that occupation is given in Figure 22.

Comorbidities

The number of patients with comorbidities is incompletely reported in published studies of surgical treatment for carpal tunnel syndrome, as can be seen in Figure 23. The number of studies reporting the presence of a given comorbidity never exceeds 20% of the available studies. Further confounding analysis is the fact that many studies excluded patients with comorbidities, and not all studies reported a precise list of excluded comorbidities. Because comorbidities are underreported and because patients with them are frequently excluded, it is difficult to draw conclusions about the presence of comorbidities among patients receiving surgery for carpal tunnel syndrome or how these comorbidities affect whether a patient is a candidate for surgery.

Conclusions

Patients who have undergone surgery for carpal tunnel syndrome are predominantly middle aged and female. Because of underreporting, no firm evidence-based conclusions can be drawn regarding the signs, symptoms, neuroelectrical characteristics and comorbidities of these patients.

Table 47. Age and sex of patients receiving surgery for carpal tunnel syndrome

Trial	Number of patients	Number of males	Number of females	Percent female	Age reported as mean or median?	Age	Age of youngest patient	Age of oldest patient
Finsen, 2001 [224]	79	18	61	77.2%	Median	48	21	86
Mondelli, 2001 [181]	28	4	24	85.7%	Mean	52.8	35	75
Avci, 2000 [309]	25	1	24	96.0%	Mean	43	21	72
Khan, 2000 [310]	44	11	33	75.0%	Mean	55	29	88
Mondelli, 2000 [311]	110	13	97	88.2%	Mean	56	20	82
Muller, 2000 [312]	148	28	120	81.1%	Mean	51.8	NR[a]	NR
Porras, 2000 [313]	85	8	77	90.6%	Mean	52	18	81
Vartimidis, 2000 [314]	15	6	9	60.0%	Mean	52	28	75
Alderson, 1999 [315]	26	5	21	80.8%	Mean	44.4	22	79
Braun, 1999 [316]	225	36	189	84.0%	Mean	41.0	NR	NR
Chen, 1999 [317]	948	212	736	77.6%	Mean	48	21	79
Erhard, 1999 [318]	124	15	109	87.9%	Mean	54.3	19	84
Finsen, 1999 [319]	82	22	60	73.2%	Mean	49.4	21	86
Hasegawa, 1999 [320]	82	0	82	100.0	Mean	54.1	NR	NR
Hirooka, 1999 [321]	37	4	33	89.2%	Mean	58	40	78
Lindau, 1999 [322]	140	17	123	87.9%	Mean	55.4	NR	NR
Olney, 1999 [323]	211	46	165	78.2%	Mean	44.8	NR	NR
Senda, 1999 [324]	26	1	25	96.2%	Mean	56.8	19	93
Straub, 1999 [305]	67	47	20	29.9%	Median	40	19	70
Vartimidis, 1999 [325]	22	8	14	63.6%	Mean	52	21	77
Atroshi, 1998 [326]	103	35	68	66.0%	Mean	52	21	88
Aulisa, 1998 [327]	45	8	37	82.2%	Mean	47	26	68
Buckhorn 1998 [328]	50	21	29	58.0%	Mean	51.3	27	61
Choi, 1998 [329]	154	6	148	96.1%	Mean	52	30	82
Davies, 1998 [330]	239	NR	NR	NR	Mean	43.5	20	82
Lee, 1998 [331]	525	134	391	74.5%	Mean	50.7	21	88
Nakamichi, 1998 [332]	130	16	114	87.7%	Mean	58	35	85

Trial	Number of patients	Number of males	Number of females	Percent female	Age reported as mean or median?	Age	Age of youngest patient	Age of oldest patient
Papageorgiou, 1998 [333]	76	18	58	76.3%	Mean	48	NR	NR
Schuind. 1998 [334]	13	6	7	53.8%	Mean	47	45	77
Tomaino, 1998 [335]	29	6	23	79.3%	Mean	52	28	82
Armstrong, 1997 [336]	176	35	141	80.1%	Mean	50.5	30	86
Atroshi, 1997 [337]	204	56	148	72.5%	Mean	49.3	19	94
Baguneid, 1997 [338]	75	11	64	85.3%	Mean	56	24	85
Chia, 1997 [339]	62	13	49	79.0%	Mean	47.7	29	73
Citron, 1997 [340]	47	8	39	83.0%	Mean	52.1	26	80
Higgs, 1997 [341]	93	30	63	67.7%	Mean	43	23	69
Karlsson, 1997 [48]	74	15	59	79.7%	Median	54.5	24	88
Katz, 1997 [302]	135	42	93	68.9%	NR	NR	NR	NR
Leinberry, 1997 [342]	44	18	26	59.1%	Mean	64.9	38	100
Rosen, 1997 [343]	102	18	84	82.4%	Mean	51.0	24	82
Serra, 1997 [344]	112	16	96	85.7%	Mean	47	31	70
Stahl, 1997 [345]	50	16	34	68.0%	Mean	49.5	NR	NR
Tucci, 1997 [346]	27	6	21	77.8%	Mean	48.6	NR	NR
Weber, 1997 [347]	74	26	48	64.9%	Median	41.4	26	80
Wheatly, 1997 [307]	126	114	12	9.5%	NR	NR	NR	NR
Cobb, 1996 [348]	235	44	191	81.3%	Mean	51	20	79
Elmaraghy. 1996 [349]	69	21	48	69.6%	Mean	51	24	97
Franzini, 1996 [350]	50	11	39	78.0%	Mean	52	32	60
Gibbs, 1996 [351]	46	16	30	65.2%	Mean	56.2	31	86
Glowacki, 1996 [352]	167	35	132	79.0%	Mean	42	17	84
Jacobsen, 1996 [353]	32	9	23	71.9%	Mean	44.9	24	59
Kluge. 1996 [354]	66	18	48	72.7%	Mean	51	36	93
Lee, 1996 [355]	275	76	199	72.4%	Mean	50.7	21	88
Mclaughlin, 1996 [356]	102	26	76	74.5%	Mean	52	NR	NR
Nagle, 1996 [357]	506	134	372	73.5%	Mean	48	13	91
Nygaard, 1996 [306]	29	7	22	75.9%	Mean	53	32	75
Okutsu, 1996 [41]	43	2	41	95.3%	Mean	55.1	31	87

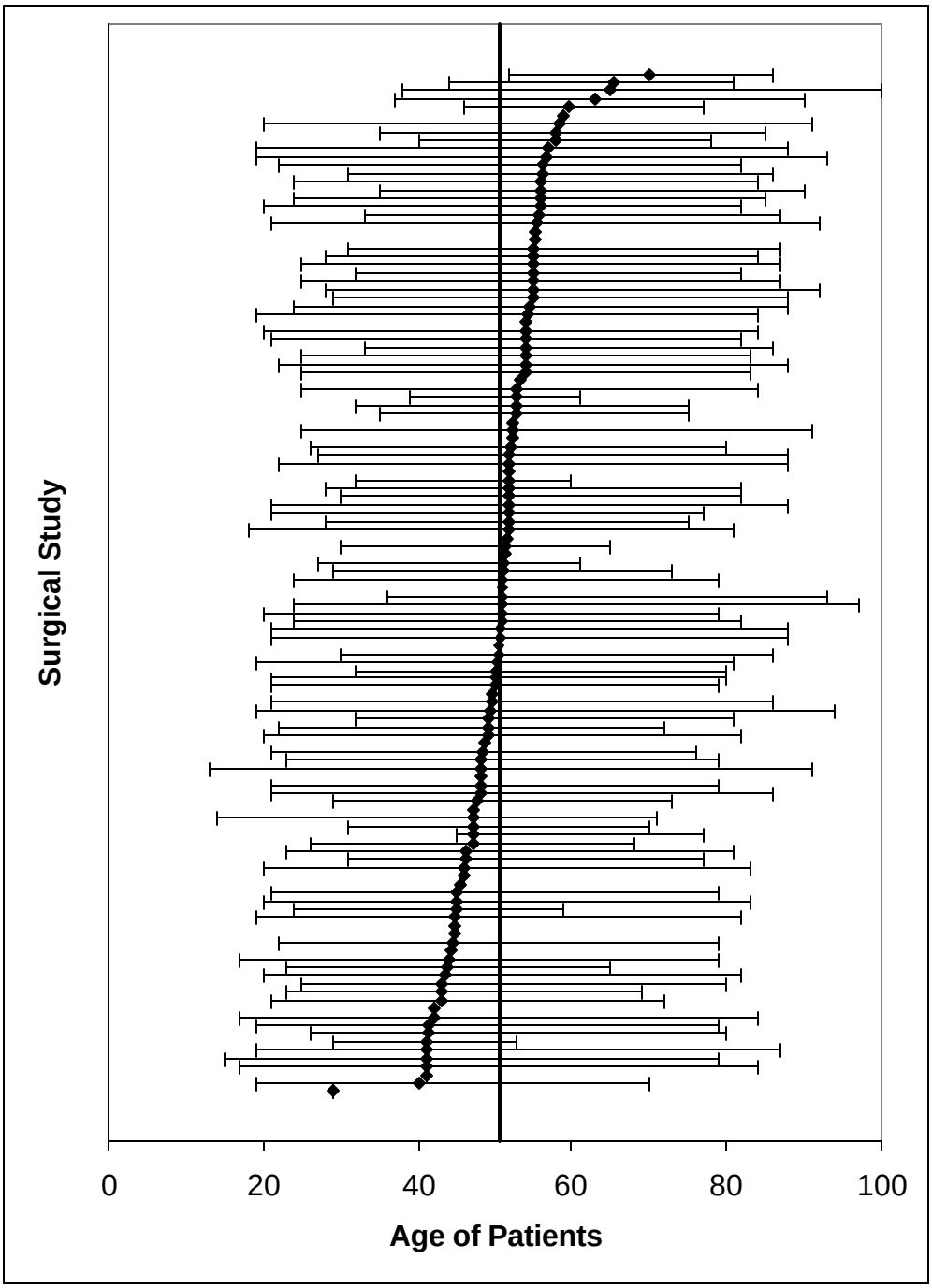
Trial	Number of patients	Number of males	Number of females	Percent female	Age reported as mean or median?	Age	Age of youngest patient	Age of oldest patient
Padua, 1996 [358]	33	7	26	78.8%	Mean	47.2	NR	NR
Pennino, 1996 [359]	124	NR	NR	NR	Mean	55	28	92
Povlsen, 1996 [360]	51	23	28	54.9%	NR	NR	NR	NR
Strickland, 1996 [361]	62	16	46	74.2%	Mean	52	22	88
Wintman, 1996 [362]	50	NR	NR	NR	Mean	54	25	83
Worseg, 1996 [44]	126	38	88	69.8%	Mean	56.0	35	90
Abdullah, 1995 [363]	100	19	81	81.0%	Mean	41.4	19	79
Bury, 1995 [364]	43	4	39	90.7%	Mean	52.3	NR	NR
Dumontier, 1995 [365]	96	11	85	88.5%	Mean	41.1	29	53
El-Zahaar, 1995 [43]	41	12	29	70.7%	Mean	53	39	61
Futami, 1995 [366]	10	1	9	90.0%	Mean	51	NR	NR
Gross, 1995 [367]	44	16	28	63.6%	Mean	44.2	NR	NR
Hallock, 1995 [368]	100	26	74	74.0%	Mean	59	NR	NR
Katz, 1995 [369]	50	6	44	88.0%	Mean	51.4	NR	NR
Lang, 1995 [109]	23	5	18	78.3%	Mean	53	25	84
LoVerme, 1995 [370]	42	4	38	90.5%	Mean	29	NR	NR
Mirza, 1995 [371]	236	74	162	68.6%	Mean	44	17	79
Nancollas, 1995 [372]	93	17	76	81.7%	Mean	52.5	NR	NR
Sennwald, 1995 [373]	47	12	35	74.5%	Mean	54	22	88
Shinya, 1995 [374]	88	16	72	81.8%	Mean	49	20	82
Al-Qattan, 1994 [375]	112	28	84	75.0%	Mean	54	25	83
Chow, 1994 [42]	815	289	526	64.5%	NR	NR	NR	NR
Erdmann, 1994 [304]	96	26	70	72.9%	Mean	53.4	NR	NR
Foulkes, 1994 [376]	33	16	17	51.5%	Mean	45.4	NR	NR
Katz, 1994 [377]	104	31	73	70.2%	Mean	55	25	87
Kelly, 1994 [378]	69	16	53	76.8%	Mean	50	21	79
Kerr, 1994 [379]	85	37	48	56.5%	Mean	44.8	19	82
Menon, 1994 [380]	87	28	59	67.8%	Mean	48.3	21	76

Trial	Number of patients	Number of males	Number of females	Percent female	Age reported as mean or median?	Age	Age of youngest patient	Age of oldest patient
Pascoe, 1994 [381]	28	12	16	57.1%	Mean	55	32	82
Payne, 1994 [382]	16	6	10	62.5%	NR	NR	NR	NR
Roth. 1994 [383]	94	35	59	62.8%	Mean	52.4	25	91
Singh, 1994 [384]	357	56	301	84.3%	NR	NR	NR	NR
Skoff, 1994 [385]	1994	NR	NR	NR	Mean	56.0	24	84
Slattery, 1994 [40]	215	69	146	67.9%	Mean	41	17	84
Strasberg, 1994 [386]	45	16	29	64.4%	Mean	50.6	NR	NR
Wolson, 1994 [387]	30	10	20	66.7%	Mean	47	14	71
Biyani, 1993 [388]	56	7	49	87.5%	Mean	65.4	44	81
Brown, 1993 [45]	145	46	99	68.3%	Mean	55	25	87
Chang, 1993 [389]	30	6	24	80.0%	Mean	46.2	31	77
Feinstein, 1993 [390]	55	21	34	61.8%	Mean	45	21	79
Jiminez, 1993 [391]	24	6	18	75.0%	Mean	46	NR	NR
Leach, 1993 [392]	25	11	14	56.0%	Mean	43	25	80
Levine, 1993 [393]	39	17	22	56.4%	Median	57	19	88
Nakamichi, 1993 [394]	41	8	33	80.5%	Mean	54	33	86
Nathan, 1993 [395]	238	80	158	66.4%	Mean	41	15	79
Okutsu, 1993 [396]	27	0	27	100.0%	Mean	55.9	33	87
Palmer, 1993 [397]	173	73	100	57.8%	Mean	44.9	20	83
Waegeneers, 1993 [398]	76	21	55	72.4%	Mean	54	21	82
Nolan, 1992 [399]	22	7	15	68.2%	Mean	70	52	86
Pagnanelli, 1992 [400]	228	65	163	71.5%	Mean	55.2	NR	NR
Viegas, 1992 [401]	71	17	54	76.1%	Mean	48	23	79
Young, 1992 [402]	21	NR	NR	NR	Mean	49	22	72
Yu, 1992 [403]	53	22	31	58.5%	Median	46	20	83
Flaschka, 1991 [404]	99	18	81	81.8%	Mean	56.4	22	82
Foucher, 1991 [405]	83	17	66	79.5%	Mean	59.6	46	77
Hagberg, 1991 [308]	41	41	0	0.0%	Mean	42.0	NR	NR

Trial	Number of patients	Number of males	Number of females	Percent female	Age reported as mean or median?	Age	Age of youngest patient	Age of oldest patient
Jakab, 1991 [406]	73	25	48	65.8%	Mean	52	27	88
Mackimmon, 1991 [407]	59	11	48	81.4%	Mean	58.5	20	91
Resnick, 1991 [408]	65	17	48	73.8%	Mean	46.2	23	81
Schuind, 1990 [409]	21	2	19	90.5%	Mean	49	32	81
Gellman, 1989 [410]	21	2	19	90.5%	Mean	51.5	30	65
Okutsu, 1989 [411]	45	15	30	66.7%	Mean	51.1	29	73
Richman, 1989 [412]	12	6	6	50.0%	NR	NR	NR	NR
Seiler, 1989 [413]	10	2	8	80.0%	Mean	43.6	23	65
Seradge, 1989 [414]	500	218	282	56.4%	Median	41	19	87
Szabo, 1989 [284]	22	6	16	72.7%	Mean	51	24	79
Gelberman, 1987 [415]	29	17	12	41.4%	Mean	55	28	84
Holmgren, 1987 [416]	48	15	33	68.8%	Mean	50	21	80
Gartsman, 1986 [417]	50	14	36	72.0%	NR	NR	NR	NR
Kulick, 1986 [418]	167	30	137	82.0%	Mean	55.5	21	92
Leblhuber , 1986 [419]	47	10	37	78.7%	Mean	50.2	19	81
Shurr, 1986 [420]	36	8	28	77.8%	Mean	44.6	NR	NR
Wadstroem, 1986 [421]	36	10	26	72.2%	Mean	50	32	80
Rhodes, 1985 [422]	32	21	11	34.4%	Mean	63	37	90
Litchman, 1984 [423]	135	28	107	79.3%	Mean	54	20	84
van Rossum, 1980 [424]	37	6	31	83.8%	NR	NR	NR	NR

a: Not reported

Figure 16. Distribution of patient ages in studies of surgical treatment for carpal tunnel syndrome



The solid vertical line denotes the mean age for all studies

Figure 17. Sex distribution in surgical trials of surgical treatment for carpal tunnel syndrome

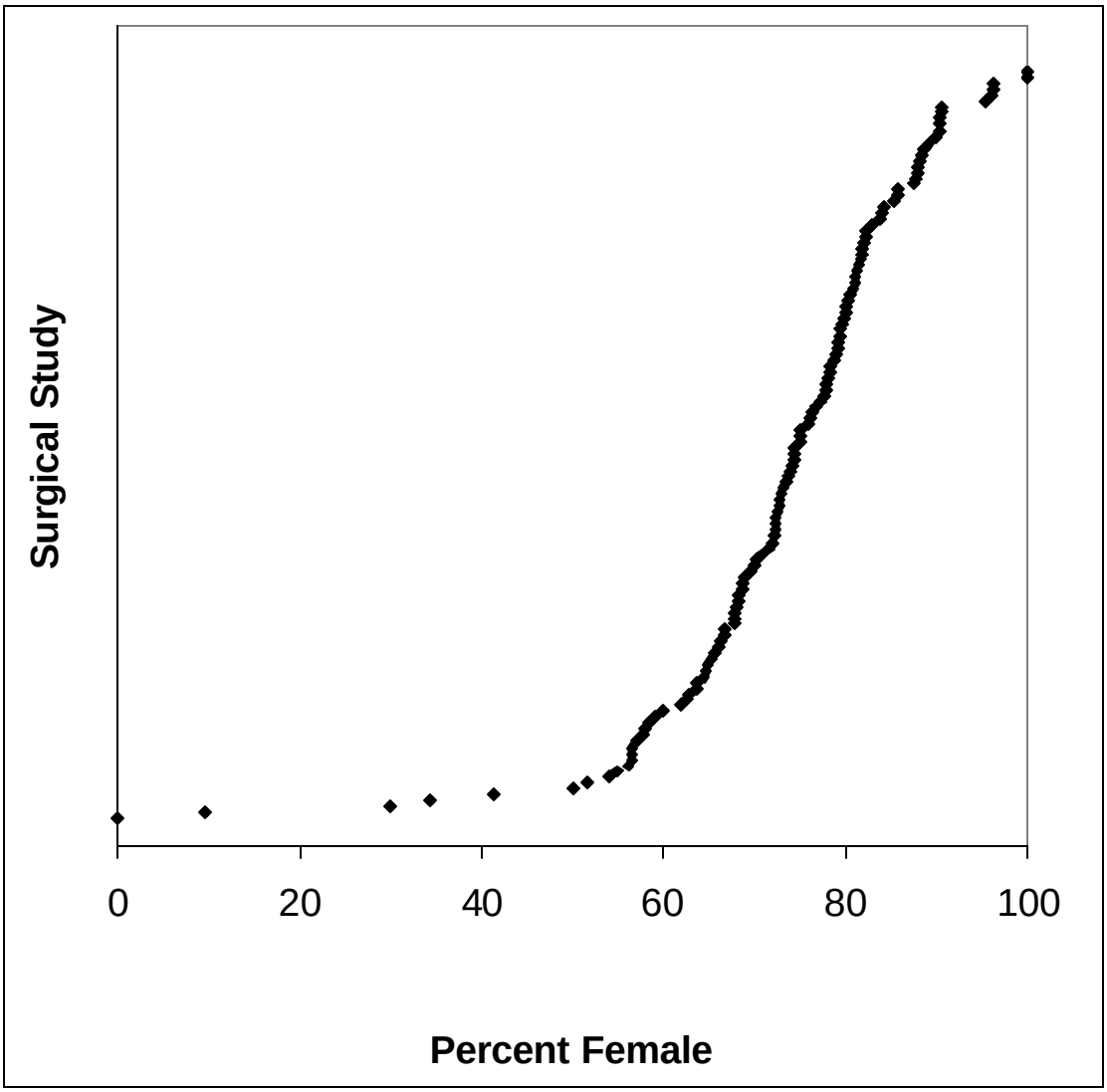


Figure 18. Reporting of symptoms in studies of surgical treatment for carpal tunnel syndrome

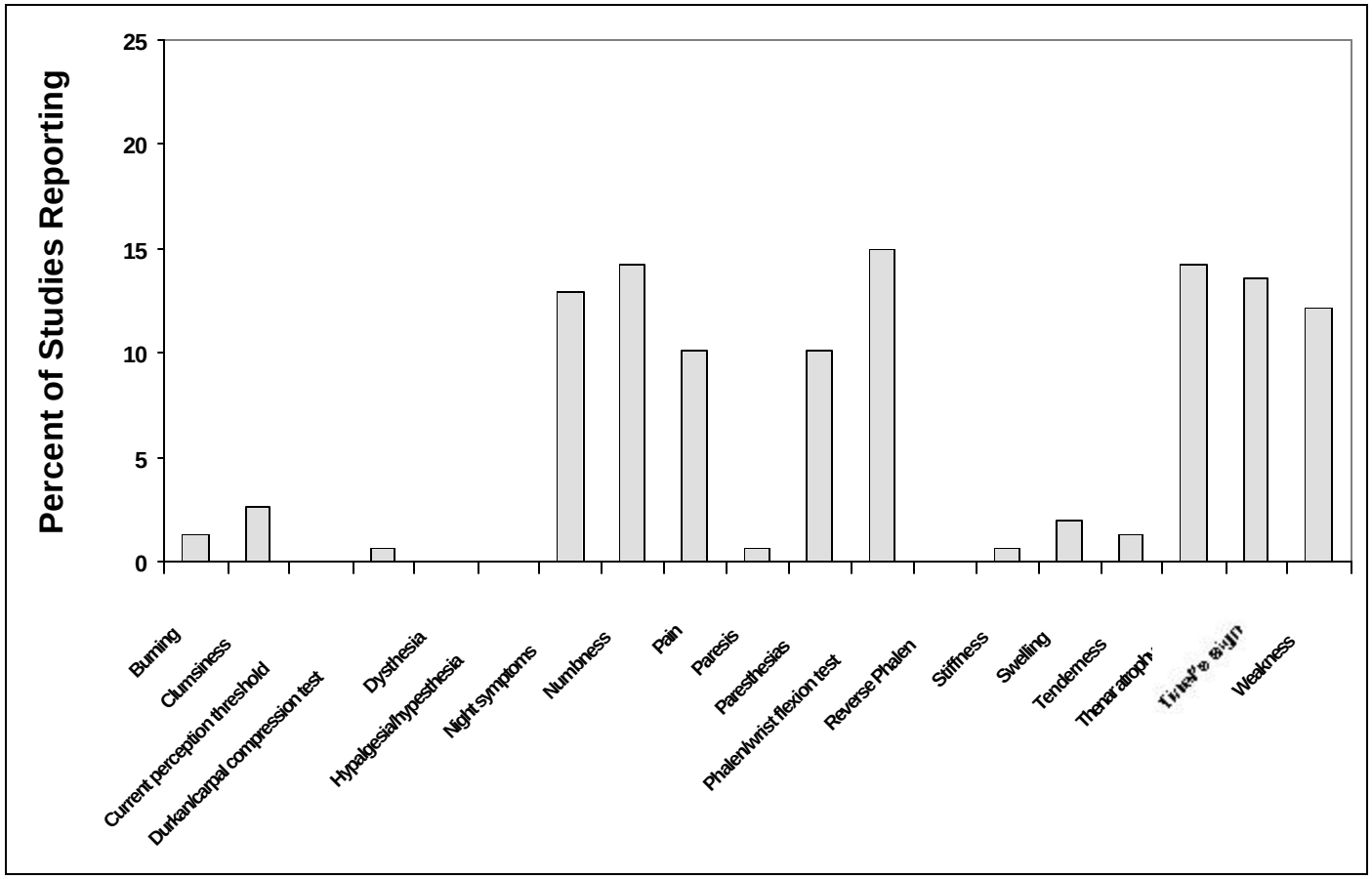


Table 48. Symptoms of patients treated with surgery for carpal tunnel syndrome

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
McLaughlin, 1996 [356]	102	Burning	70	68.6%
Mirza, 1995 [371]	56	Burning	6	10.7%
Finsen, 2001 [224]	79	Clumsiness	42	53.2%
Atroshi, 1997 [337]	255 Hands	Clumsiness	155	60.8%
Cobb, 1996 [348]	235	Clumsiness	81	34.5%
Lee, 1996 [355]	275 Hands	Clumsiness	207	75.3%
Lascar, 2000 [425]	71	Clumsiness	6	8.5%
Porras, 2000 [313]	85	Durkan/carpal compression test	50	58.8%
Finsen, 2001 [224]	79	Night symptoms	56	70.9%
Straub, 1999 [305]	100 Hands	Night symptoms	93	93.0%
Aulisa, 1998 [327]	45	Night symptoms	44	97.8%
Buchhorn, 1998 [328]	50	Night symptoms	50	100.0%
Atroshi, 1997 [337]	255 Hands	Night symptoms	237	92.9%
Cobb, 1996 [348]	235	Night symptoms	71	30.2%
Elmaraghy, 1996 [349]	69	Night symptoms	56	81.2%
Glowacki, 1996 [352]	167	Night symptoms	114	68.3%
Kluge, 1996 [354]	66	Night symptoms	50	75.8%
Lee, 1996 [355]	275 Hands	Night symptoms	226	82.2%
McLaughlin, 1996 [356]	102	Night symptoms	78	76.5%
Nygaard, 1996 [306]	29	Night symptoms	20	69.0%
Strickland, 1996 [361]	58	Night symptoms	58	100%
Worseg, 1996 [44]	126	Night symptoms	111	88.1%
Singh, 1994 [384]	357	Night symptoms	104	29.1%
Palmer, 1993 [397]	173	Night symptoms	148	85.5%
Pagnanelli, 1992 [400]	456 Hands	Night symptoms	424	93.0%
Resnick, 1991 [408]	75 Hands	Night symptoms	66	88.0%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Freshwater, 1978 [426]	22	Night symptoms	22	100%
Provinciali, 2000 [427]	100	Numbness	62	62.0%
Vartimidis, 2000 [314]	15	Numbness	15	100.0%
Straub, 1999 [305]	100 Hands	Numbness	71	71.0%
Aulisa, 1998 [327]	45	Numbness	7	15.6%
Armstrong, 1997 [336]	208 Hands	Numbness	160	76.9%
Atroshi, 1997 [337]	255 Hands	Numbness	178	69.8%
Blair, 1996 [428]	75	Numbness	71	94.7%
Cobb, 1996 [348]	235	Numbness	88	37.4%
Elmarghy, 1996 [349]	69	Numbness	68	98.6%
Kluge, 1996 [354]	66	Numbness	35	53.0%
Lee, 1996 [355]	275 Hands	Numbness	240	87.3%
McLaughlin, 1996 [356]	102	Numbness	71	69.6%
Futami, 1995 [366]	10	Numbness	10	100%
LoVerme, 1995 [370]	42	Numbness	28	66.7%
Mirza, 1995 [371]	56	Numbness	53	94.6%
Singh, 1994 [384]	357	Numbness	283	79.3%
Strasberg, 1994 [386]	45	Numbness	45	100.0%
Waegeneers, 1993 [398]	100 Hands	Numbness	28	28.0%
Pagnanelli, 1992 [400]	456 Hands	Numbness	264	57.9%
Wadstroem, 1986 [421]	36	Numbness	25	69.4%
Freshwater, 1978 [426]	11	Numbness	11	100%
Provinciali, 2000 [427]	100	Pain	80	80.0%
Vartimidis, 2000 [314]	15	Pain	15	100%
Armstrong, 1997 [336]	208 Hands	Pain	185	88.9%
Atroshi, 1997 [337]	255 Hands	Pain	198	77.6%
Blair, 1996 [428]	75	Pain	67	89.3%
Cobb, 1996 [348]	131	Pain	80	61.1%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Elmaraghy, 1996 [349]	69	Pain	59	85.5%
Lee, 1996 [355]	275 Hands	Pain	232	84.4%
Mirza, 1995 [371]	56	Pain	46	82.1%
Strasberg, 1994 [386]	45	Pain	39	86.7%
Waegeneers. 1993 [398]	100 Hands	Pain	96	96.0%
Nolan, 1992 [399]	22	Pain	11	50.0%
Richman, 1989 [412]	12	Pain	10	83.3%
Lowry, 1988 [429]	50	Pain	47	94.0%
Freshwater, 1978 [426]	22	Pain	6	27.3%
Nygaard, 1996 [306]	29	Paresis	8	27.6%
Provinciali, 2000 [427]	100	Paresthesias	82	82.0%
Straub, 1999 [305]	100 Hands	Paresthesias	100	100%
Buchholm, 1998 [328]	50	Paresthesias	49	98.0%
Armstrong, 1997 [336]	208 Hands	Paresthesias	195	93.8%
Atroshi, 1997 [337]	255 Hands	Paresthesias	242	94.9%
Cobb, 1996 [348]	235	Paresthesias	82	34.9%
Elmaraghy, 1996 [349]	69	Paresthesias	59	85.5%
Kluge, 1996 [354]	66	Paresthesias	3	4.5%
Lee, 1996 [355]	275 Hands	Paresthesias	233	84.7%
Worseg, 1996 [44]	126	Paresthesias	120	95.2%
Mirza, 1995 [371]	56	Paresthesias	56	100%
Palmer, 1993 [397]	173	Paresthesias	171	98.8%
Waegeneers, 1993 [398]	100 Hands	Paresthesias	99	99.0%
Pagnanelli, 1992 [400]	456 Hands	Paresthesias	424	93.0%
Wadstroem, 1986 [421]	36	Paresthesias	32	88.9%
Finsen, 2001 [224]	79	Phalen's sign	58	73.4%
Porras, 2000 [313]	85	Phalen's sign	64	75.3%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Straub, 1999 [305]	100 Hands	Phalen's sign	87	87.0%
Aulisa, 1998 [327]	45	Phalen's sign	32	71.1%
Atroshi, 1997 [337]	255 Hands	Phalen's sign	214	83.9%
Serra, 1997 [344]	112	Phalen's sign	98	87.5%
Glowacki, 1996 [352]	167	Phalen's sign	115	68.9%
McLaughlin, 1996 [356]	102	Phalen's sign	90	88.2%
Nygaard, 1996 [306]	29	Phalen's sign	22	75.9%
Strickland, 1996 [361]	62	Phalen's sign	45	72.6%
Worseg, 1996 [44]	126	Phalen's sign	74	58.7%
Bury, 1995 [364]	43	Phalen's sign	43	100.0%
Futami, 1995 [366]	10	Phalen's sign	10	100.0%
Lang, 1995 [109]	23	Phalen's sign	19	82.6%
Erdmann. 1994 [304]	96	Phalen's sign	80	83.3%
Payne, 1994 [382]	16	Phalen's sign	16	100.0%
Roth, 1994 [383]	94	Phalen's sign	94	100.0%
Palmer, 1993 [397]	211 Hands	Phalen's sign	196	92.9%
Waegemeers, 1993 [398]	100 Hands	Phalen's sign	84	84.0%
Resnick, 1991 [408]	75 Hands	Phalen's sign	69	92.0%
Richman, 1989 [412]	12	Phalen's sign	10	83.3%
Freshwater, 1978 [426]	22	Phalen's sign	17	77.3%
Armstrong, 1997 [336]	208 Hands	Stiffness	174	83.7%
Lascar, 2000 [425]	71	Stiffness	7	9.9%
Aulisa, 1998 [327]	45	Swelling	27	60.0%
Mirza, 1995 [371]	280	Swelling	3	1.1%
Freshwater, 1978 [426]	22	Swelling	0	0.0%
Strickland, 1996 [361]	58	Tenderness	54	93.1%
Pagnanelli, 1992 [400]	456 Hands	Tenderness	18	3.9%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Porras, 2000 [313]	85	Thenar atrophy	15	17.6%
Aulisa, 1998 [327]	45	Thenar atrophy	3	6.7%
Buchhorn, 1998 [328]	50	Thenar atrophy	11	22.0%
Atroshi, 1997 [337]	255 Hands	Thenar atrophy	36	14.1%
Serra, 1997 [344]	112	Thenar atrophy	16	14.3%
McLaughlin, 1996 [356]	102	Thenar atrophy	16	15.7%
Nygaard, 1996 [306]	29	Thenar atrophy	8	27.6%
LoVerme, 1995 [370]	42	Thenar atrophy	8	19.0%
Singh, 1994 [384]	357	Thenar atrophy	110	30.8%
Waegeneers, 1993 [398]	100 Hands	Thenar atrophy	8	8.0%
Nolan, 1992 [399]	22	Thenar atrophy	11	50.0%
Pagnanelli, 1992 [400]	456 Hands	Thenar atrophy	112	24.6%
Foucher, 1991 [405]	83	Thenar atrophy	83	100.0%
Mackimmon, 1991 [407]	59	Thenar atrophy	41	69.5%
Resnick, 1991 [408]	75 Hands	Thenar atrophy	12	16.0%
Richman, 1989 [412]	12	Thenar atrophy	3	25.0%
Gelberman, 1987 [415]	61	Thenar atrophy	38	62.3%
Kulick, 1986 [418]	167	Thenar atrophy	20	12.0%
Leblhuber, 1986 [419]	55 Hands	Thenar atrophy	14	25.5%
Wadstroem, 1986 [421]	36	Thenar atrophy	17	47.2%
Freshwater, 1978 [426]	22	Thenar atrophy	2	9.1%
Finsen, 2001 [224]	79	Tinel's sign	46	58.2%
Porras, 2000 [313]	85	Tinel's sign	51	60.0%
Straub, 1999 [305]	100 Hands	Tinel's sign	73	73.0%
Buchhorn, 1998 [328]	50	Tinel's sign	46	92.0%
Atroshi, 1997 [337]	255 Hands	Tinel's sign	176	69.0%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Serra, 1997 [344]	112	Tinel's sign	5	4.5%
Glowacki, 1996 [352]	96	Tinel's sign	66	68.8%
McLaughlin, 1996 [356]	102	Tinel's sign	69	67.6%
Nygaard, 1996 [306]	29	Tinel's sign	9	31.0%
Strickland, 1996 [361]	62	Tinel's sign	45	72.6%
Worsegm 1996 [44]	126	Tinel's sign	100	79.4%
Futami, 1995 [366]	10	Tinel's sign	10	100.0%
Lang, 1995 [109]	23	Tinel's sign	7	30.4%
Erdmann, 1994 [304]	96	Tinel's sign	74	77.1%
Roth, 1994 [383]	94	Tinel's sign	94	100.0%
Palmer, 1993 [397]	211	Tinel's sign	181	85.8%
Waegeneers, 1993 [398]	100 Hands	Tinel's sign	77	77.0%
Resnick, 1991 [408]	75 Hands	Tinel's sign	57	76.0%
Richman, 1989 [412]	12	Tinel's sign	7	58.3%
Freshwater, 1978 [426]	22	Tinel's sign	15	68.2%
Provinciali, 2000 [427]	100	Weakness	75	75.0%
Straub, 1999 [305]	100 Hands	Weakness	63	63.0%
Aulisa, 1998 [327]	45	Weakness	9	20.0%
Armstrong, 1997 [336]	208 Hands	Weakness	156	75.0%
Atroshi, 1997 [337]	255 Hands	Weakness	79	31.0%
Cobb, 1996 [348]	235	Weakness	97	41.3%
Elmaraghy, 1996 [349]	69	Weakness	35	50.7%
Kluge, 1996 [354]	66	Weakness	5	7.6%
Lee, 1996 [355]	275 Hands	Weakness	220	80.0%
McLaughlin, 1996 [356]	102	Weakness	17	16.7%
Singh, 1994 [384]	357	Weakness	120	33.6%
Strasberg, 1994 [386]	45	Weakness	42	93.3%

Study	Number of patients (or hands)	Sign or symptom	Number of patients with sign or symptom	Percent of patients (or hands)
Palmer, 1993 [397]	173	Weakness	152	87.9%
Waegeneers, 1993 [398]	100 Hands	Weakness	43	43.0%
Pagnanelli, 1992 [400]	456 Hands	Weakness	210	46.1%
Richman, 1989 [412]	12	Weakness	7	58.3%
Kulick, 1986 [418]	167	Weakness	20	12.0%
Freshwater, 1978 [426]	22	Weakness	17	77.3%

Figure 19. Symptoms of patients with carpal tunnel syndrome

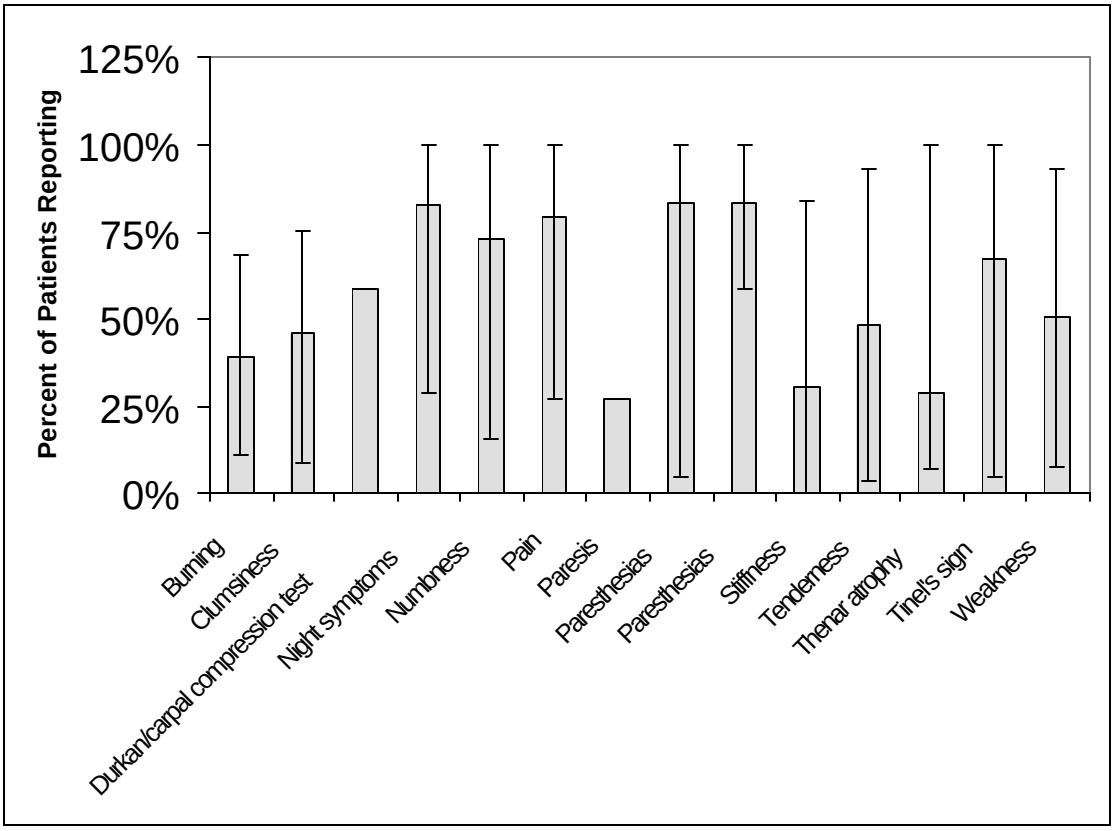
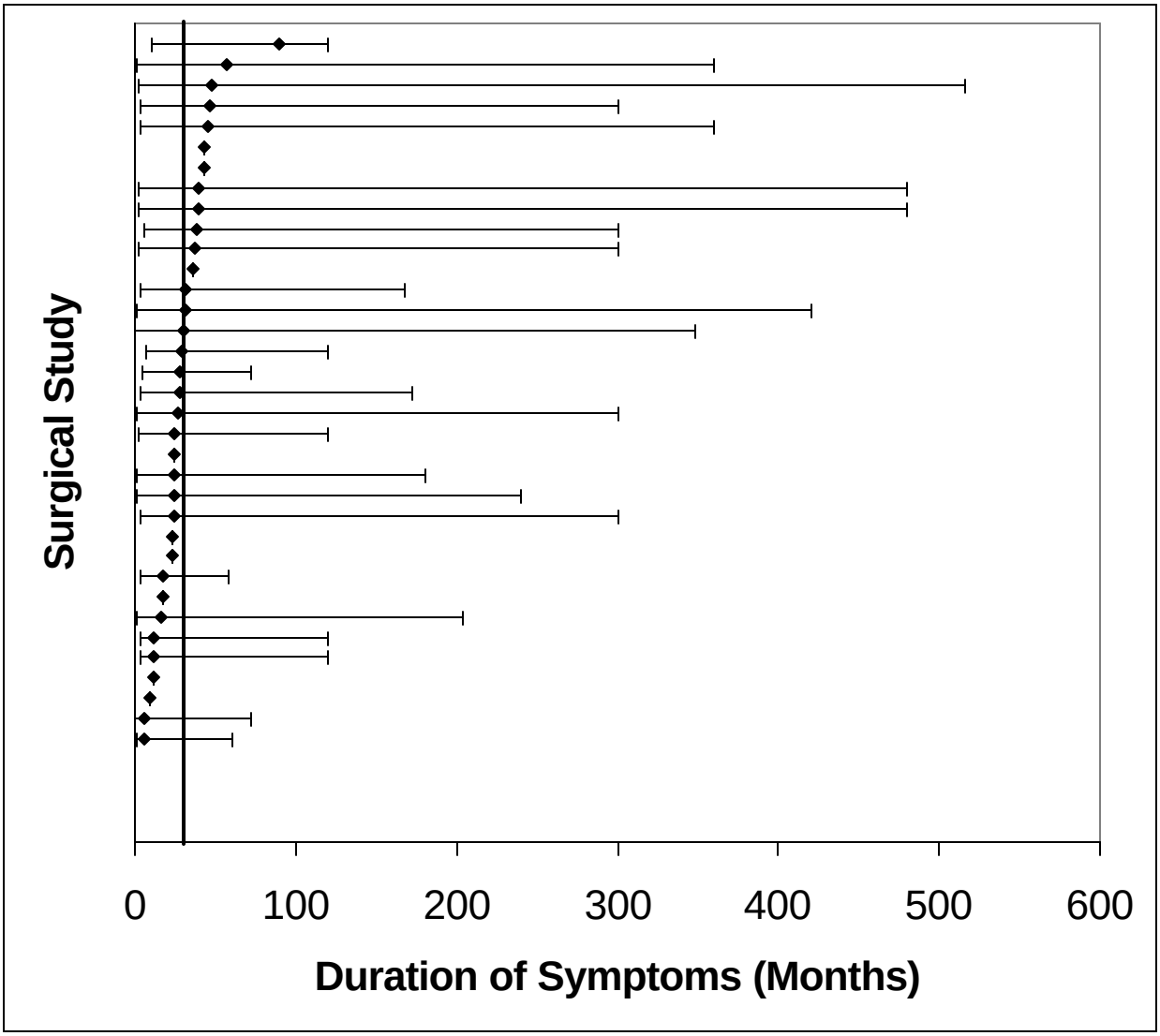


Table 49. Duration of symptoms among patients treated with surgery for carpal tunnel syndrome

Trial	N	Is duration of condition reported as Mean or Median?	Duration of condition before treatment (months)	Shortest period of duration before treatment (months)	Longest period of duration before treatment (months)
Porras, 2000 [313]	85	Mean	39	6	300
Straub, 1999 [305]	67	Median	24	3	300
Buchhorn, 1998 [328]	50	Mean	43	Not reported	Not reported
Lee, 1998 [331]	525	Mean	40.1	2	480
Atroshi, 1997 [337]	204	Mean	24	1	240
Karlsson, 1997 [48]	74	Median	6	1	60
Leinberry, 1997 [342]	44	Mean	31.8	3	168
Wheatly, 1997 [307]	126	Mean	90	10	120
Gibbs, 1996 [351]	46	Mean	57.0	1	360
Glowacki, 1996 [352]	96	Mean	17.8	Not reported	Not reported
Lee, 1996 [430]	525	Mean	40.1	2	480
Nagle, 1996 [357]	506	Mean	31	1	420
Wintman, 1996 [362]	50	Mean	28	3	173
Worseg, 1996 [44]	126	Mean	23.4	Not reported	Not reported
Mirza, 1995 [371]	236	Mean	23	Not reported	Not reported
Nancollas, 1995 [372]	93	Mean	26.5	1	300
Sennwald, 1995 [373]	47	Mean	9.2	Not reported	Not reported
Erdmann, 1994 [304]	96	Mean	24.1	Not reported	Not reported
Roth, 1994 [383]	94	Mean	46.8	4	300
Brown, 1993 [45]	145	Mean	25	2	120
Clarke, 1993 [431]	37	Mean	37	2	300
Levine, 1993 [393]	39	Median	18	3	58
Palmer, 1993 [397]	173	Mean	35.6	Not reported	Not reported
Pagnanelli, 1992 [400]	228	Mean	45.6	3	360
Yu, 1992 [403]	53	Median	6	0	72

Trial	N	Is duration of condition reported as Mean or Median?	Duration of condition before treatment (months)	Shortest period of duration before treatment (months)	Longest period of duration before treatment (months)
Flaschka, 1991 [404]	99	Mean	24	1	180
Hagberg, 1991 [308]	41	Mean	43.6	Not reported	Not reported
Jakab, 1991 [406]	73	Mean	48	2	516
Resnick, 1991 [408]	65	Mean	16.8	1	204
Richman, 1989 [412]	12	Mean	28	5	72
Szabo, 1989 [284]	22	Mean	29	7	120
Kulick, 1986 [418]	167	Mean	30	0	348
Shurr, 1986 [420]	36	Mean	12	Not reported	Not reported
Freshwater, 1978 [426]	11	Mean	12	3	120

Figure 20. Duration of symptoms in studies of surgery for carpal tunnel syndrome



Solid vertical line denotes the mean duration of symptoms

Table 50. Electrodiagnostic criteria among patients treated with surgery for carpal tunnel syndrome

Trial	Electrodiagnostic criteria
Hasegawa, 1999 [320]	Patients with grade I (mild) symptoms were accepted for surgery if they also had distal motor latency >7.1ms or distal motor latency >5.2ms and 3 months of failed conservative treatment
Hirooka, 1999 [321]	Patients with grade 1 (mild) symptoms received surgery only if they had a distal motor latency of at least 7.0 ms.
Aulisa, 1998 [327]	Patients fit into one of the following categories: Mild: Sensory conduction velocity, first digit to wrist <42m/s, third digit to wrist <44m/s Moderate: Sensory conduction velocity as in mild, plus median distal motor latency >4ms Severe: Absent sensory or motor median response.
Jacobsen, 1996 [353]	Patients fit into one of the following categories: Slight CTS: >3 sensory responses delayed 2-4 standard deviations (SD). Intermediate CTS: All sensory responses delayed >3SD+decreased sensory amplitudes. Pronounced CTS: Several or all sensory responses lacking and rest are delayed >4SD with low amplitudes, motor delay >4SD with low amplitude or no motor response. The "normal" values to which these diagnostics were compared, and the size of a standard deviation were not reported.
Cook, 1995 [432]	Distal motor latency >4.5 ms and/or sensory antidromic latency >3.5 ms.
Lang, 1995 [109]	Either distal motor latency >4.5 ms or orthodromic sensory conduction velocity palm-to-wrist <45 m/s
Foulkes, 1994 [376]	Distal sensory latency of at least 3.6ms or motor latency of 4.4ms were considered supportive of diagnosis.
Pascoe, 1994 [381]	Difference between median and palmar sensory latency of more than 0.4ms
Brown, 1993 [45]	Electrophysiological confirmation was established when distal motor latency was 4.5 ms or there was a difference of 1 ms or more between the affected and unaffected hand or sensory latency was more than 3.5 ms or there was a difference of more than 0.5 ms between the affected and unaffected hand.
Nakamichi, 1993 [394]	Distal motor latency >4.2ms or sensory nerve conduction velocity <45ms
Hagberg, 1991 [308]	A positive phalen test or distal motor latency of at least 4.5
Schuind, 1990 [409]	Distal motor latency >4ms or distal sensory latency >3.5ms
Richman, 1989 [412]	Distal motor latency >4.5ms or distal sensory latency >3.5ms
Szabo, 1989 [284]	Distal motor latency >4.5 ms or distal sensory latency >3.5 ms.
Lowry, 1998 [429]	Distal antidromic sensory latency >5ms or unobtainable at 13cm.
Holmgren-Larssen, 1985 [433]	Sensory nerve conduction velocity <50 ms and distal latency >4.5 ms.
Rhoades, 1985 [422]	Fibrillations in the abductor pollicis or opponens pollicis muscles detectable by EMG.
Van Rossum, 1980 [424]	Distal motor latency >4.5 ms
Freshwater, 1978 [426]	No patients had normal motor latency (4.5ms or less), but this was not stated to have been an inclusion criterion.

Table 51. Reported occupations of patients receiving surgery for carpal tunnel syndrome

Study	Occupation	Number of Patients	Number of patients with occupation	Percent of patients with occupation
Mirza, 1995 [371]	Blue Collar	56	9	16.1%
Olney, 1999 [323]	Clerical	211	89	42.2%
Weber, 1997 [347]	Clerical	74	29	39.2%
Cobb, 1996 [348]	Clerical	235	38	16.2%
Mirza, 1995 [371]	Clerical	56	6	10.7%
Kelly, 1994 [378]	Clerical	69	10	14.5%
Palmer, 1993 [397]	Clerical	173	35	20.2%
Pagnanelli, 1992 [400]	Clerical	228	71	31.1%
Dumontier, 1995 [365]	Clerical, unoccupied or retired	96	47	49.0%
Wintman, 1996 [362]	Disabled	50	1	2.0%
Worseg, 1996 [44]	Employee	126	19	15.1%
Buchhorn, 1998 [328]	Employee- average work	50	21	42.0%
Olney, 1999 [323]	Factory	211	30	14.2%
Nagle, 1996 [357]	Heavy work	506	27	5.3%
Yu, 1992 [403]	Heavy work	53	23	43.4%
Porras, 2000 [313]	High manual activity	85	14	16.5%
Kelly, 1994 [378]	High manual activity	69	7	10.1%
Cobb, 1996 [348]	Homemaker	235	19	8.1%
Wintman, 1996 [362]	Homemaker	50	12	24.0%
Worseg, 1996 [44]	Homemaker	126	8	6.3%
Mirza, 1995 [371]	Homemaker	56	5	8.9%
Chow, 1994 [42]	Homemaker	815	63	7.7%
Kelly, 1994 [378]	Homemaker	69	14	20.3%
Yu, 1992 [403]	Homemaker	53	3	5.7%
Palmer, 1993 [397]	Industrial	173	90	52.0%
Katz, 1997 [302]	Laborer/machine operator	135	25	18.5%
Nagle, 1996 [357]	Light work	506	72	14.2%
Buchhorn, 1998 [328]	Light work	50	16	32.0%
Yu, 1992 [403]	Light work	53	8	15.1%
Wintman, 1996 [362]	Light labor with repetitive tasks or clerical work	50	15	30.0%
Nagle, 1996 [357]	Light-repetitive work	506	42	8.3%
Porras, 2000 [313]	Low manual activity	85	37	43.5%
Kelly, 1994 [378]	Low manual activity	69	21	30.4%
Katz, 1997 [302]	Management	135	22	16.3%
Weber, 1997 [347]	Management	74	14	18.9%
Lindau, 1999 [322]	Manual Worker	140	29	20.7%
Buchhorn, 1998 [328]	Manual Worker	50	8	16.0%
Weber, 1997 [347]	Manual Worker	74	25	33.8%
Cobb, 1996 [348]	Manual Worker	235	60	25.5%
Dumontier, 1995 [365]	Manual Worker	96	45	46.9%
Erhard, 1999 [318]	Manual worker- heavy lifting	124	12	9.7%
Olney, 1999 [323]	Manual worker- heavy lifting	211	40	19.0%

Study	Occupation	Number of Patients	Number of patients with occupation	Percent of patients with occupation
Buchhorn, 1998 [328]	Manual worker- heavy lifting	50	5	10.0%
Wintman, 1996 [362]	Manual worker- heavy lifting	50	5	10.0%
Chow, 1994 [42]	Manual worker- heavy lifting	815	322	39.5%
Pagnanelli, 1992 [400]	Manual worker- heavy lifting	228	60	26.3%
Erhard, 1999 [318]	Manual worker- light lifting	124	12	9.7%
Chow, 1994 [42]	Manual worker- light lifting	815	215	26.4%
Pagnanelli, 1992 [400]	Manual worker- light lifting	228	97	42.5%
Olney, 1999 [323]	Meat packing	211	15	7.1%
Palmer, 1993 [397]	Medical	173	7	4.0%
Porras, 2000 [313]	Medium manual activity	85	35	41.2%
Nagle, 1996 [357]	Medium work	506	46	9.1%
Yu, 1992 [403]	Medium strenuous work	53	13	24.5%
Lindau, 1999 [322]	Nonmanual worker	140	41	29.3%
Chow, 1994 [42]	Other	815	68	8.3%
Katz, 1997 [302]	Other	135	81	60.0%
Cobb, 1996 [348]	Other	235	14	6.0%
Worseg, 1996 [44]	Other	126	3	2.4%
Kelly, 1994 [378]	Other	69	1	1.4%
Palmer, 1993 [397]	Other	173	15	8.7%
Wintman, 1996 [362]	Professional	50	6	12.0%
Mirza, 1995 [371]	Professional	56	11	19.6%
Palmer, 1993 [397]	Professional	173	16	9.2%
Palmer, 1993 [397]	Education	173	8	4.6%
Lindau, 1999 [322]	Retired	140	21	15.0%
Weber, 1997 [347]	Retired	74	6	8.1%
Wintman, 1996 [362]	Retired	50	7	14.0%
Worseg, 1996 [44]	Retired	126	60	47.6%
Hallock, 1995 [368]	Retired	100	15	15.0%
Mirza, 1995 [371]	Retired	56	5	8.9%
Strasberg, 1994 [386]	Retired	45	4	8.9%
Yu, 1992 [403]	Retired	53	6	11.3%
Palmer, 1993 [397]	Retired or Homemaker	173	40	23.1%
Olney, 1999 [323]	Retired or light employment	211	57	27.0%
Chow, 1994 [42]	Retired or unemployed	815	147	18.0%
Kelly, 1994 [378]	Retired or unemployed	69	16	23.2%
Erhard, 1999 [318]	Sedentary	124	18	14.5%
Nagle, 1996 [357]	Sedentary	506	69	13.6%
Strasberg, 1994 [386]	Student	45	2	4.4%
Wintman, 1996 [362]	Unemployed	50	4	8.0%
Worseg, 1996 [44]	Unemployed	126	19	15.1%
Strasberg, 1994 [386]	Unemployed	45	28	62.2%
Worseg, 1996 [44]	Worker	126	17	13.5%

Figure 21. Number of studies reporting occupations of patients receiving surgery for carpal tunnel syndrome

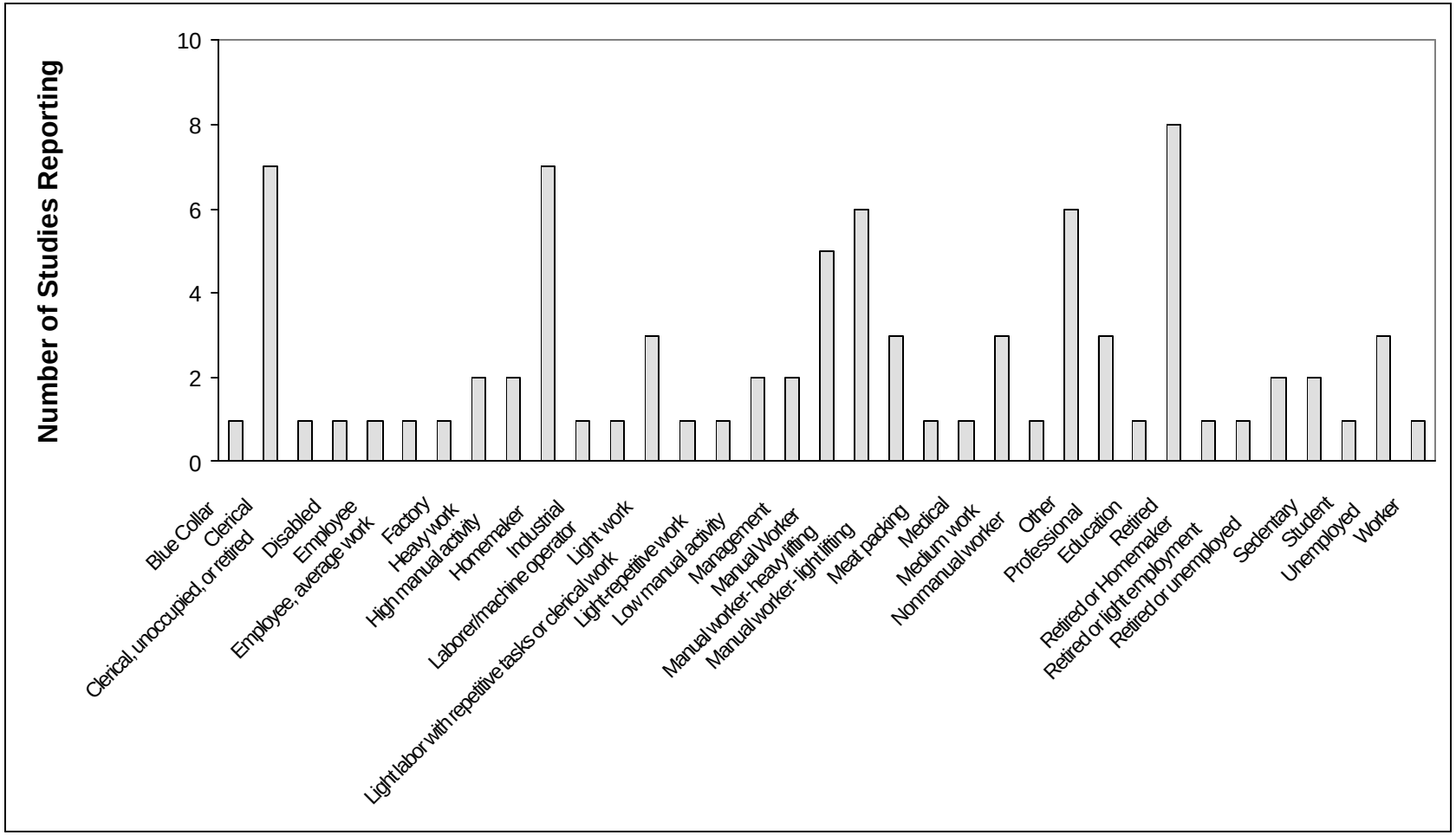


Figure 22. Percent of patients with reported occupations receiving surgery for carpal tunnel syndrome

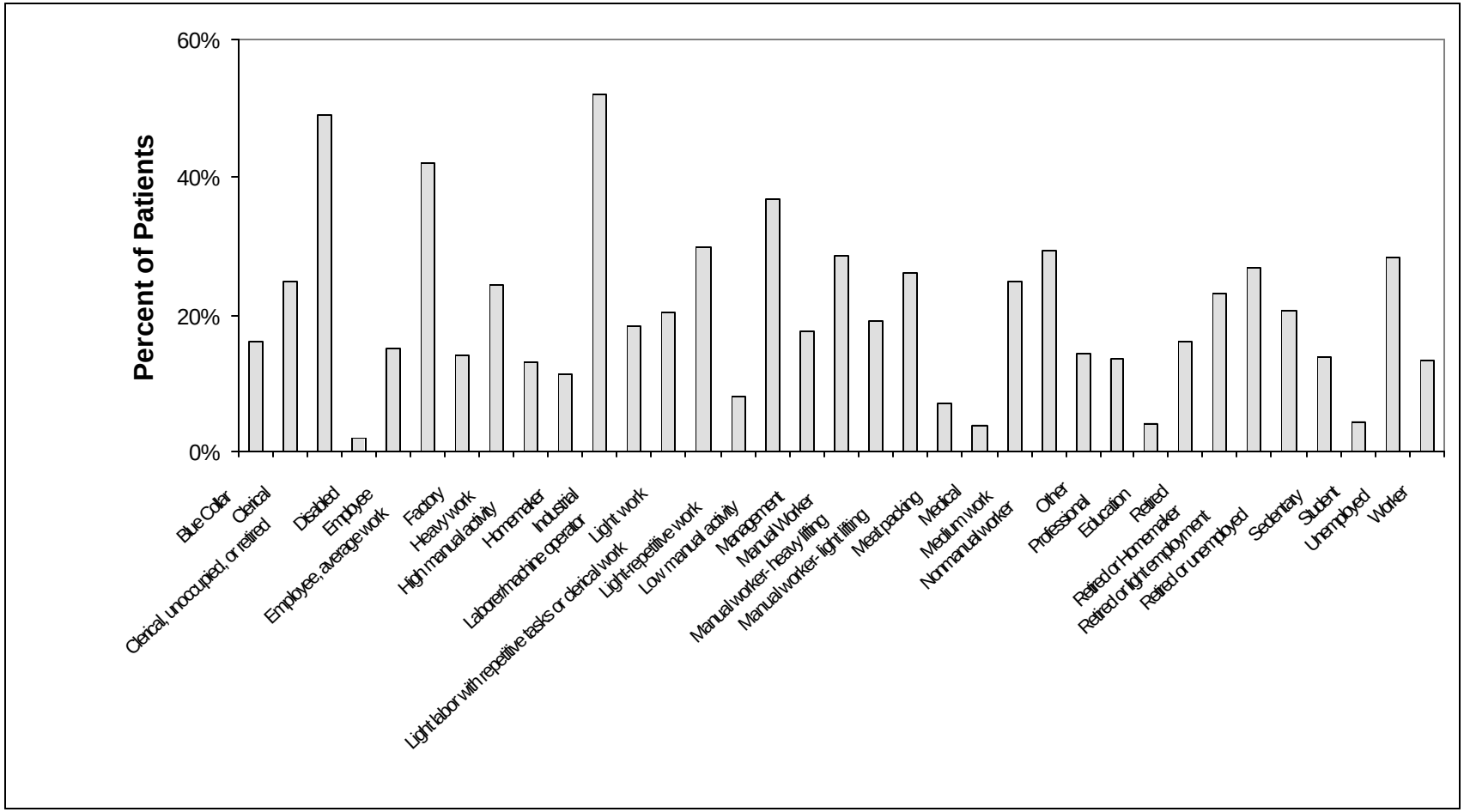
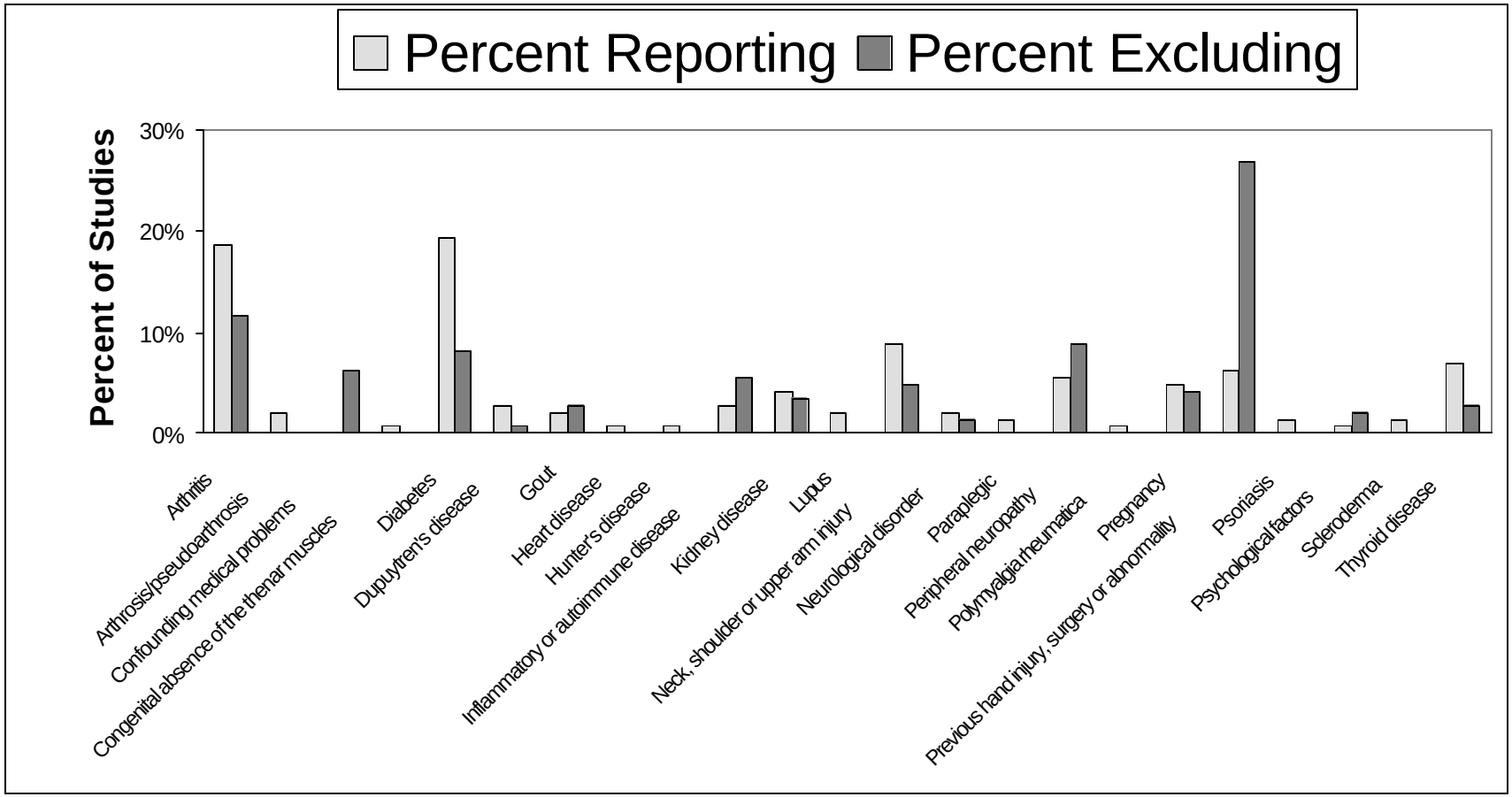


Figure 23. Percent of studies reporting and excluding comorbidities



Question #3: What are the relative benefits and harms of various surgical and nonsurgical interventions for persons with carpal tunnel syndrome?

Evidence Base

In addressing this question, we consider only data from controlled trials. Controls are needed to account for changes that can occur over time that are not due to treatment. These changes could be caused by rest, changes in patient activity, or other factors. CTS is often a progressive disease, but remissions occur, even in untreated patients.[434]

As described in the methodology section of this evidence report, we only evaluate patient-oriented outcomes. These are the outcomes of primary interest to the patient. They include pain, functional activity, quality of life, return to work, and global measures of treatment outcome such as patient satisfaction and overall relief of symptoms. Functional activity includes the measures of functional ability as well as measures of activities of daily living (ADL), including time to return to ADL. Outcomes that are not directly experienced by the patient, such as change in nerve conduction velocity, are not assessed. Surrogate outcomes, such as two-point discrimination or grip strength, are important only to the extent that they correlate with patient-oriented outcomes. Because no measures of correlation between changes in surrogate outcomes and changes in patient-oriented outcomes have been published, we did not analyze surrogate outcomes.

To determine the benefits and harms of various treatments for carpal tunnel syndrome, we retrieved 58 controlled trials. Seventeen of these were excluded for reasons stated in Table 52, leaving 41 studies to be assessed. Four (10%) of these trials were multicenter, 27 (66%) were randomized, and 34 (83%) were prospective. Sixteen (39%) of the studies were double or single blinded and 16 (39%) either used intent-to treat analysis to account for patients lost to followup or had no reported loss to followup.

No published trials compared surgery to no treatment or placebo, making it difficult to determine, in strict scientific terms, whether surgery benefits patients. Although absence of evidence is not evidence of absence of efficacy, the lack of trials that incorporate these controls complicates evaluation of the effectiveness of surgery. However, differences between the effects of various surgical treatments can in some cases be assessed. The existence of differences in effect size between treatments may itself constitute evidence that some treatments are, to some extent, effective.

The 41 studies are divided below into groups of studies comparing similar treatments. Internal validity and generalizability are discussed separately for each group of studies. The former term describes the potential for bias in the studies. Randomization and blinding help to eliminate potential sources of bias, providing stronger evidence that any observed differences between groups are the result of differences in treatment. Patient attrition and threats to statistical validity may also affect internal validity.

Generalizability refers to the extent to which the results of a trial may be applied to the overall population of candidates for treatment. If the patients described in a trial are unusual or specialized, the generalizability of the trial is limited. The results of a study that includes only elderly patients, for example, may not be generalizable to a population of younger patients.

Table 52. Excluded trials

Study	Reason for Exclusion
Todnem, 2000 [435]	Retrospective comparison of operated and nonoperated patients. Groups were significantly different in several electrodiagnostic parameters prior to surgery.
Atherton, 1999 [436]	Did not report any patient characteristics or patient-oriented outcomes.
Brüser, 1999 [437]	A single study comparing two very similar treatments.
Davis, 1998 [438]	Utilized a combination of treatments, rendering it impossible to determine the effect of a single treatment.
Ebenbichler, 1998 [439]	There were significant differences between groups at baseline. Although patients were described as having bilateral carpal tunnel syndrome, five patients in the treated group and seven in the placebo group had no wrist complaints.
Garfinkel, 1998 [440]	The treatment received by the control group was not standardized and was not described.
Netscher, 1998 [47]	Did not report any patient-oriented outcomes.
Rozmaryn, 1998 [32]	Patients received an assortment of nonstandardized treatments in addition to the experimental treatment.
Braithwaite, 1997 [441]	Compares minor variations in surgical technique. No patient-oriented outcome measures were reported other than perioperative pain. No patient characteristics were reported.
Jones, 1997 [442]	A single study comparing two very similar treatments.
Monge, 1995 [443]	No patient-oriented outcomes were reported for the controls; only for treated patients. Reported no information on the source of control data or the comparability of controls and treated patients.
Bande, 1994 [444]	Groups were not comparable. Patients with comorbidities (e.g. synovitis, diabetes, rheumatoid arthritis) were all placed in the open release group. There was no indication as to how many such patients were included.
Biyani, 1993 [388]	A single study comparing two very similar treatments.
Nathan, 1993 [395]	A single study comparing two very similar treatments.
Spooner, 1993 [445]	Did not report any patient-oriented outcomes.
Groves, 1989 [446]	Compared outcomes at two separate clinics. There was no indication that the patient populations treated by the two clinics were comparable. This study had no internal validity.
Wolaniuk, 1983 [447]	Did not report any patient-oriented outcomes.
Ellis, 1979 [447]	Describes a double-blind crossover study of a single patient.

What are the relative benefits and harms of open and endoscopic carpal tunnel release for persons with carpal tunnel syndrome?

Seventeen published controlled trials addressing this question met inclusion criteria. These trials described a total of 2,598 patients.

Internal validity

Six of these trials were randomized; two of which were blinded. One RCT was incompletely randomized, as some patients with bilateral CTS requested endoscopic release for their second procedure after undergoing endoscopic release in the initial hand.[46] Blinding of patients and posttreatment examiners in trials of surgical treatments is often impractical, if not impossible. In the two blinded studies, only raters and not patients were blinded. In addition to the prospective trials, there were four retrospective comparisons between patient groups. Patient attrition ranged from zero to more than 80%. No studies with patient attrition performed intent-to-treat analyses performed. In at least two reports, investigators had a financial stake in the results of their studies. Neither of these studies were blinded. Study characteristics affecting internal validity are listed in Table 53.

Randomization is necessary to ensure that patients in the different groups of a study are as similar as possible. One particularly important feature of randomization is that important but unknown patient characteristics are equally distributed among groups. Finally, randomization reduces the chance of bias being introduced as a result of the personal preferences or expectations of the patient or the physician. Similarly, lack of blinding can introduce bias.

Patient attrition may skew the results of a study in the direction of seeming more favorable toward a treatment, because patients who are dissatisfied with their treatment may be less likely to return for followup examinations. Wherever possible, we have recalculated data from studies with patient attrition. In doing so, we apply the conservative assumption that treatment failed for all patients lost to followup. If statistical significance is obtained under this assumption, one can be more confident that the effect of patient attrition is not severe enough to overturn a statistically significant result.

An additional threat to internal validity common in studies of carpal tunnel syndrome is the presence of bilateral procedures. Carpal tunnel syndrome often occurs in both hands, leading some researchers to report outcome data per procedure rather than per patient. Using procedures rather than patients as the unit of analysis violates statistical assumptions of independence between and within groups and compromises the statistical validity of the study if more than one procedure is performed on a single patient. Four studies included patients with bilateral procedures, but did not violate assumptions of independence between groups because all patients had the same procedure in each hand.[351,368,379,448] An additional study implied, but did not explicitly state, that no patient underwent both open and endoscopic release.[317] Two studies included patients with

bilateral procedures, but analyzed their data using the Wilcoxon rank-sum test, which does not assume independence between groups.[304,353] The study by Sennwald also analyzed some data by this method, but did not specify which comparisons utilized this test.[373] In all cases, assumptions of independence within groups were violated.

Violating the assumption of independence within groups leads to underestimation of standard errors and spurious statistically significant results (Type I errors). Four studies had no bilateral procedures and therefore did not violate the independence assumption. Among the remaining studies, the extent of the violation depends on the percentage of patients with bilateral procedures. The more bilateral patients, the more severe the violation. To guage the severity of this violation, we note the percentage of patients on whom bilateral procedures were performed for each study. Four of the studies (Chen, Gibbs, Futami and Erdman) had a fairly high percentage of patients who received bilateral procedures (>30%), and are particularly prone to statistical biases in their results.

The power of a statistical test to detect differences between groups is also an internal validity issue. However, statistical power is different for each outcome. Therefore, power is addressed as part of the discussion of each outcome, below.

Generalizability

The average age of patients in the 13 studies that provided this information is 49.0 years. Mean ages ranged from 44 to 56 years, while individual ages ranged from 19 to 90 years. The majority of patients (56% to 100%) were female. This is consistent with available epidemiological data on carpal tunnel syndrome,[22,25] as well as with data on surgical patients compiled in answer to question 2 of this evidence report. This indicates that the results of these studies are broadly generalizable to the overall carpal tunnel population. These and other patient characteristics are listed in Table 54.

The presence of various comorbidities associated with CTS is incompletely reported in these studies. Some studies excluded patients with some comorbidities, indicated in Table 54 by a zero under that comorbidity. This somewhat limits the generalizability of these studies, as comorbidities are not exclusion criteria for surgery. An exception is rheumatoid arthritis, which can sometimes interfere with endoscopic carpal tunnel release. Five studies excluded patients with severe CTS. While this exclusion may limit our ability to generalize to other severe CTS patients, it may render the results more generalizable to average patients. Eight studies excluded patients with mild CTS. The effect of this exclusion on generalizability is unknown, because we do not know whether the criteria applied were unique to these studies or if they are normally applied to surgical candidates in general clinical practice.

Patient employment characteristics (Table 55) are incompletely reported in these studies. Therefore, the extent to which the employment characteristics of these patients may be generalized to the overall CTS patient population cannot be determined from the information available.

Table 53. Internal validity of studies comparing open and endoscopic carpal tunnel release

Study	Number of patients	Percent of patients with bilateral procedures	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?
Concannon, 2000 [449]	191	NR[a]	Single	Not reported	Retro	No	0	Yes
Chen, 1999 [317]	948	At least 34.8%[b]	Single	Not reported	Retro	No	24	No
Hasegawa, 1999 [320]	82	2.4%	Single	Not reported	Retro	No	0	Yes
Povlsen, 1997 [450]	120	0%	Multiple (<5)	Not reported	CT	No	4	No
Gibbs, 1996 [351]	46	23.9%	Single	Not reported	Retro	No	3	No
Jacobsen, 1996 [353]	29	10.3%	Single	Not reported	RCT	Rater	0	Yes
Worseg, 1996 [44]	126	0%	Single	Not reported	CT	No	0	Yes
Dumontier, 1995 [365]	103	0%	Single	Not reported	RCT	No	83	No
Futami, 1995 [366]	10	100%	Single	Not reported	CT	No	0	Yes
Hallock, 1995 [368]	96	37%	Single	Not reported	CT	No	0	No[c]
Sennwald, 1995 [373]	47	0%	Single	Not reported	RCT	No	0	Yes
Erdmann, 1994 [304]	71	47.9%	Single	Not reported	RCT	No	0	Yes
Kerr, 1994 [379]	157	At least 17.4%[b]	Single	Not reported	CT	No	13	No
Brown, 1993 [45]	151	13.2%	Multiple (<5)	No	RCT	Rater	22	No
McDonough, 1993 [448]	88	23.5%	Single	Yes	Retro	No	7	No
Palmer, 1993 [397]	211	29.4%	Single	No	CT	No	0	Yes
Agee, 1992 [46]	122	20.5%	Multiple (>5)	Yes	RCT	No	NR	No

[a]: This report describes the results of 191 procedures. The number of patients was not reported.
[b]: The number of bilateral procedures among those patients who underwent open procedures was not reported.
[c]: Four patients whose endoscopic procedures were, for various technical reasons, converted to open procedures, are included in the Open group.

Table 54. Generalizability of studies comparing open and endoscopic carpal tunnel release

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Concannon, 2000 [449]	191	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	No	No
Chen, 1999 [317]	948	48 (21-79)	78.5	NR	0.6	2.4	0	NR	0	0.3	0	Yes	No
Hasegawa, 1999 [320]	82	54.1	100	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Povlsen, 1997 [450]	120	NR	NR	NR	NR	NR	NR	NR	0	NR	NR	No	No
Gibbs, 1996 [351]	46	56.2 (31-86)	89.1	57.0 (1-360)	0	0	NR	0	NR	NR	NR	No	No
Jacobsen, 1996 [353]	29	(24-59)	NR	NR	NR	NR	NR	NR	NR	NR	NR	Yes	Yes
Worseg, 1996 [44]	126	56.0 (35-90)	69.8	23.4	NR	0	NR	NR	0	NR	NR	Yes	Yes
Dumontier, 1995 [365]	103	52.3	82.5	NR	NR	NR	NR	NR	NR	NR	NR	No	No
Futami, 1995 [366]	10	53 (39-61)	90.0	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Hallock, 1995 [368]	96	44.2	77.1	NR	NR	NR	0	NR	NR	NR	NR	No	No
Sennwald, 1995 [373]	47	52.5	80.9	9.2	0	0	NR	NR	NR	NR	NR	No	Yes
Erdmann, 1994 [304]	71	53.4	98.6	27.3	2.8	28.2	0	NR	NR	NR	NR	Yes	No
Kerr, 1994 [379]	157	44.8 (19-82)	56.5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Brown, 1993 [45]	151	55 (25-87)	65.6	25 (2-120)	NR	0	NR	NR	0	0	NR	No	No
McDonough, 1993 [448]	88	46.0 (21-79)	62.5	35.6	NR	NR	NR	NR	NR	NR	NR	No	Yes
Palmer, 1993 [397]	211	44.9 (20-83)	65.4	35.7	1.4	0	NR	NR	NR	NR	NR	No	Yes

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Agee, 1992 [46]	122	NR	NR	NR	0	0	0	NR	0	NR	0	Yes	Yes

Table 55. Patient employment characteristics in studies comparing open and endoscopic carpal tunnel release

Study	Number of patients	% Patients employed	% Patients receiving workers' compensation	% Patients retired	% Patients Homemakers	Reported occupations
Concannon, 2000 [449]	191	Not reported	44.0	Not reported	Not reported	Not reported
Chen, 1999 [317]	948	Not reported	Not reported	Not reported	Not reported	Not reported
Hasegawa, 1999 [320]	82	Not reported	Not reported	Not reported	Not reported	Not reported
Povlsen, 1997 [450]	120	Not reported	Not reported	Not reported	Not reported	Not reported
Gibbs, 1996 [351]	46	84.8	15.2	Not reported	Not reported	16 Retired, homemaker or unemployed
Jacobsen, 1996 [353]	29	100	0	0	0	Not reported
Worseg, 1996 [44]	126	31.0	87.3	47.6	6.3	19 Employee 17 Worker 60 Retired 19 Unemployed 8 Homemaker 3 Other
Dumontier, 1995 [365]	103	89.3	Not reported	Not reported	Not reported	45 Manual workers 47 Clerical, unoccupied or retired
Futami, 1995 [366]	10	Not reported	Not reported	Not reported	Not reported	Not reported
Hallock, 1995 [368]	96	Not reported	54.2	15.6	Not reported	Not reported
Sennwald, 1995 [373]	47	Not reported	Not reported	Not reported	Not reported	Not reported
Erdmann, 1994 [304]	71	Not reported	Not reported	Not reported	Not reported	Not reported
Kerr, 1994 [379]	157	Not reported	Not reported	Not reported	Not reported	Not reported
Brown, 1993 [45]	151	53.6	4.6	Not reported	Not reported	41 Professional, management or business 29 Clerical or technical support 11 Manual labor
McDonough, 1993 [448]	88	Not reported	27.3	Not reported	Not reported	Not reported

Study	Number of patients	% Patients employed	% Patients receiving workers' compensation	% Patients retired	% Patients Homemakers	Reported occupations
Palmer, 1993 [397]	211	73.9	57.8	Not reported	Not reported	8 Education 90 Industrial 7 Medical 16 Professional 35 Clerical 40 Retired or Homemaker 15 Other
Agee, 1992 [46]	122	Not reported	Not reported	Not reported	Not reported	Not reported

Results

Global outcome

A global outcome is any score that attempts to encompass the overall success or failure of the treatment. It may be a numerical rating of overall symptom relief or patient satisfaction, a categorical rating such as excellent, good, fair or poor, or a dichotomous rating such as the answer to the question "Would you undergo this procedure again?." Such outcomes were reported in seven controlled trials, two of which were randomized and two of which were retrospective. The results are presented in Table 56.

Five studies reported sufficient data for an effect size to be calculated. This number was sufficient for us to perform a meta-analysis. In this analysis, a positive effect size indicates that the study favors endoscopic release over open release, and a negative effect size indicates the converse. The results of the meta-analysis of the five studies are summarized in Table 57.

The combined fixed effect size from the meta-analysis is modest ($d = 0.19$), but statistically significant. The individual and combined effect sizes are illustrated in Figure 24. The magnitude of the effect size is further illustrated in Figure 25 which demonstrates that there is a high degree (85.7%) of overlap in the global outcome scores of the two treatment groups.

Four of the five studies were neither randomized nor blinded. Two were retrospective. Although there is a trend in favor of endoscopic release, the suboptimal quality of the studies incorporated into this analysis means that these results are suggestive rather than definitive. In addition, the difference is not robust. The incorporation of a single study showing no difference between groups into the meta-analysis would render the overall effect size nonsignificant. On the other hand, the two studies reporting global outcomes that were not incorporated into the meta-analysis all found slightly more favorable results in the endoscopic groups. Addition of these studies would likely reduce the impact of a "no-effect" study on the summary effect size. Therefore, our analysis suggests that although there may be a difference in the global outcome of patients who receive open surgery and those who receive endoscopic surgery, any such difference is small, and its exact value is uncertain.

Table 56. Global outcome in patients treated with open or endoscopic carpal tunnel release

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Hasegawa et al., 1999 [320]	40 Open 42 Endoscopic	Global outcome rating at 12 Months 28 Excellent 8 Good 3 Fair 1 Poor 29 Excellent 13 Good 1 Fair 1 Poor	Not significantly different by chi square test conducted by ECRI, p = 0.57
Gibbs et al., 1996 [351]	43 Open 14 Endoscopic (Hands)	Mean change in symptom severity score 3-33 Months -12.5±5.6 -12.2±5.3	Not significantly different by t-test conducted by ECRI, p = 0.86
Worseg et al., 1996 [44]	62 Open 64 Endoscopic	Mean symptom rating, verbal scale This outcome was reported using a 3-dimensional graph, making it difficult to estimate values.	Scores were not significantly different between groups at any time point (p >0.05, Wilcoxon rank sum test)
Futami 1995 [366]	10 Open 10 Endoscopic (Hands of 10 patients)	Weeks until relief of symptoms 2.5 Weeks 2.4 Weeks	Not reported
Hallock 1995 [368]	71 Open 66 Endoscopic (Hands)	Number of hands with complete relief of symptoms (Time not reported) 63 61	Not significantly different by chi square test conducted by ECRI, p = 0.46
Erdmann, 1994 [304]	52 Open 53 Endoscopic	Days until relief of symptoms 1.75 Days 1.1 Days	Not significantly different by Mann-Whitney test. The p value determining significance was not reported.
Brown, 1993 [45]	82 Open 78 Endoscopic (Hands)	Mean patient satisfaction rating, 0-100 84 Days: 84±26 84 Days: 89±18	Not significantly different by t-test conducted by ECRI, p = 0.15

Table 57. Results of meta-analysis of the effect of open or endoscopic treatment on global outcome

Author	Year	N	Effect Size	95% CI	p-value	Standardized Residual	Outlier by Std Resid?
Hasegawa [320]	1999	82	0.362	-0.07-0.80	0.105	0.83	No
Gibbs [351]	1996	57	-0.054	-0.66-0.55	0.862	-0.84	No
Worseg [44]	1996	126	0.12[a]	-0.23-0.41.	0.502	-0.49	No
Hallock [368]	1995	137	0.240	-0.41-0.89	0.466	0.15	No
Brown [45]	1993	160	0.222	-0.09-0.53	0.163	-0.22	No
			Summary Effect Size	**95% CI**	**p-value**	**Q Statistic**	**p of Q**
Fixed Effects Model			0.19	0.01-0.38	0.041	1.44	0.838

a: Estimated from published data by assuming that the p-value of the Wilcoxon test was 0.5

Figure 24. Results of meta-analysis of effect of treatment on global outcome

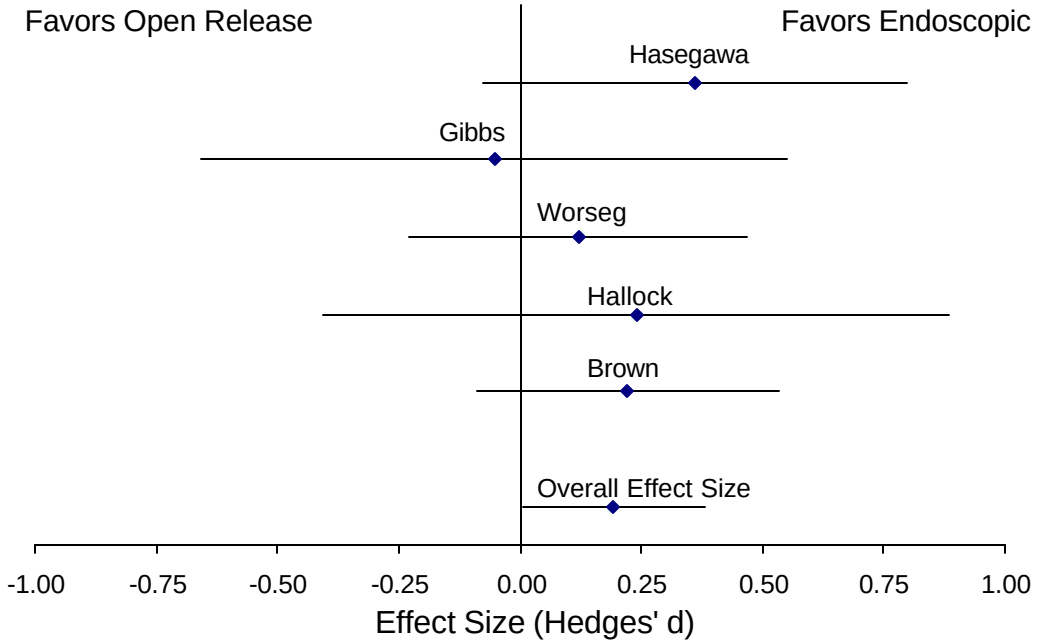
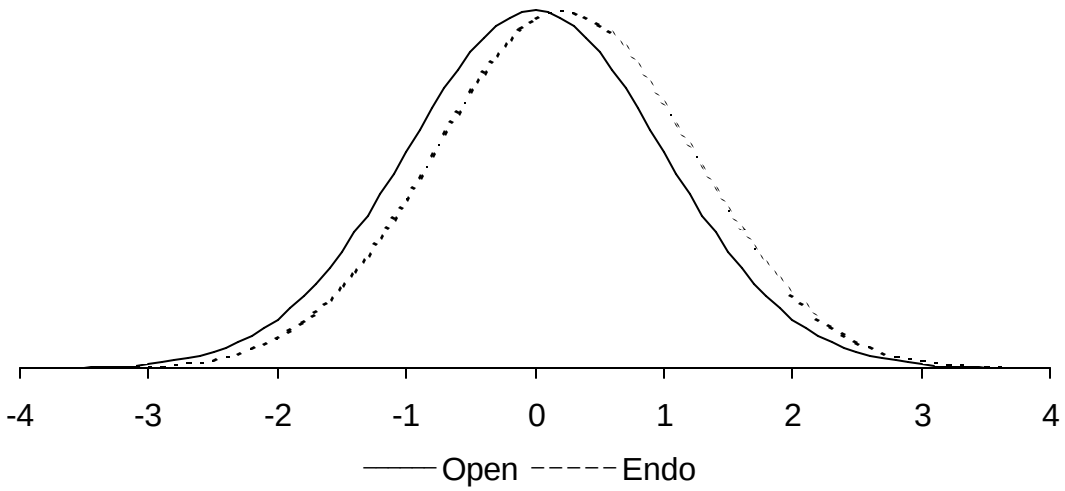


Figure 25. Degree of overlap between outcomes



Return to work

Return to work was reported in 12 controlled trials, six of which were randomized and two of which were retrospective. Only two studies reported sufficient data for an effect size to be calculated. Results from such a small fraction (16.7%) of the available studies do not constitute a sufficient sampling of the available information. For this reason, we did not perform a meta-analysis on these data. The results of the trials are given in Table 58. Data are reported as means plus or minus standard deviations (when available) unless otherwise stated.

Table 59 summarizes return to work data by indicating whether patients treated with endoscopic or open carpal tunnel release had a faster reported return to work, and whether that difference was statistically significant. As can be seen in Table 59 and Figure 26, only one trial found that patients receiving open release returned to work faster than those receiving endoscopic release, and that difference was not statistically significant. Examination of the study designs, patient and employment characteristics (Table 53, Table 54, and Table 55) does not suggest a reason why this study found a trend opposite that observed in the other studies. In contrast, 11 trials found that endoscopic release led to faster return to work. This difference was statistically significant in six trials.

Table 59 also indicates the power of each study to detect differences between groups. In all three of the studies for which power could be calculated, there was insufficient power to detect small (less than 10%) differences between groups. Two of the studies that did not detect a significant effect lacked the power to detect moderate (less than 25%) differences. The addition of more patients to these studies might have increased the statistical power to detect differences between groups enough so that the detected differences would have become statistically significant.

Effect sizes (Hedges' d) could be calculated for only two studies. These are given in Table 59 and Figure 27.

Because no meta-analysis could be conducted on the available studies, we base our conclusions on a semi-quantitative analysis. Data from 11 of 12 trials suggest that patients undergoing endoscopic surgery show a tendency toward faster return to work than patients who have open surgery. However, because no quantitative analysis was possible, no reliable conclusions can be drawn as to how much faster they may return.

Table 58. Time to return to work in patients treated with open or endoscopic surgery

Study	n (units)	Time Until Return to Work	Statistical Significance of Difference Between Groups
Gibbs, 1996 [351]	Open Endoscopic Total N = 28 Group n not reported	Time at which 50% of patients had returned to work 4 Days (Range 1->1003)[a] 14 Days Range (1-91)	Groups were not significantly different by log rank test , p = 0.63
Jacobsen, 1996 [353]	16 Open 16 Endoscopic (Hands)	Open 18.94±10.25 Days (Range 0-42) Endoscopic 17.06±9.11 Days (Range 0-31)	Groups not significantly different, p >0.05, Fisher Exact test
Dumontier, 1995 [365]	Open Endoscopic Numbers of patients not reported	Percent of patients returning to work within: 2 Weeks: 29%; 1 Month: 70%; 3 Months: 89%[b] 2 Weeks: 30%; 1 Month 45%; 3 Months 70%	Groups were not significantly different at any time by chi square test . At 1 month, p = 0.13. p-values were not reported for the other two time points.
Futami, 1995 [366]	Open 3 Endoscopic 3	7 Weeks 6 Weeks	Not reported
Hallock, 1995 [368]	Open 39 Endoscopic 25	46.3±36.9 Days[c] 39.8±19.3 Days	Groups were not significantly different, p = 0.373. The test used was not reported.
Sennwald, 1995 [373]	22 Open 25 Endoscopic (Patients)	41.95±13.18 Days[d] 24.13±7.69 Days	Groups were significantly different by t-test calculated by ECRI, p = 0.000001
Erdmann, 1994 [304]	23 Open (Patients) 27 Open (Hands)[e] 23 Endoscopic (Patients) 28 Endoscopic (Hands)	39 Days Open 14 Days Endoscopic	Groups were significantly different, p <0.005 unpaired Mann-Whitney U test

Study	n (units)	Time Until Return to Work	Statistical Significance of Difference Between Groups
Kerr, 1994 [379]	72 Open 72 Endoscopic	Patients treated endoscopically returned to work 10.6 days sooner than those treated openly.	Groups were significantly different by paired t-test (p = 0.0015)
Brown, 1993 [45]	85 Open 84 Endoscopic (Hands)	Median 28 Days Open[a] Median 14 Days Endoscopic	Groups were statistically significant, p <0.05, log-rank test
McDonough, 1993 [448]	28 Open 27 Endoscopic (Patients)	50.4 Days (Range 11-103) 28.5 Days (Range 4-67)	Not reported
Palmer, 1993 [397]	Open Endoscopic-Agee method Endoscopic-Chow method n not reported	44.1±37.3 20.7±12.8 27.9±16.9	Open was significantly different from the other two groups by t-test, p <0.05
Agee, 1992 [46]	30 Open 49 Endoscopic (Patients)	Median 46.5 Days[a] Median 25 Days	Statistically significant difference between groups, p <0.01, survival analysis version of the Wilcoxon test

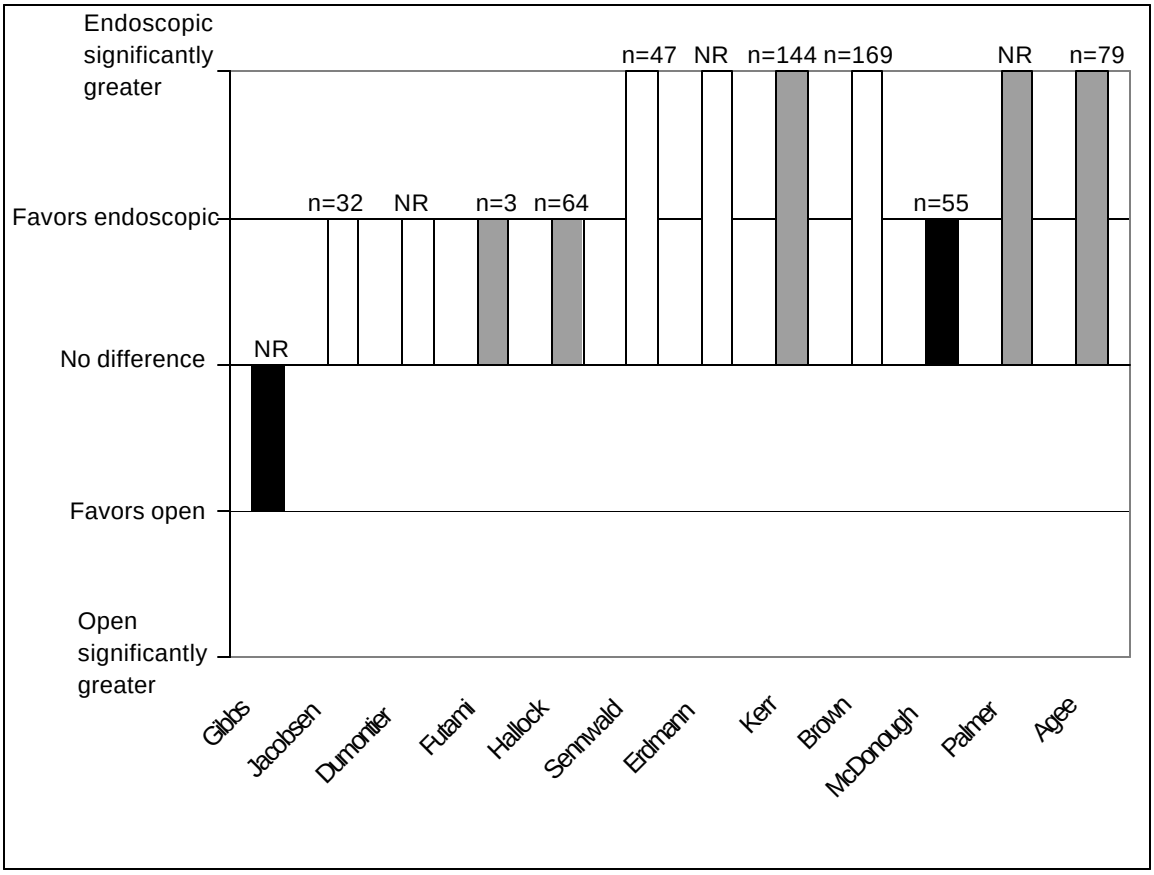
a: Calculated by Kaplan-Meier survival analysis
b: Percentages estimated from a published chart. They cannot be converted to numbers of patients because it is unclear whether they are percentages of all patients or of patients employed prior to surgery.
c: Some patients in each group did not return to work. The numbers reported therefore do not constitute an accurate representation of time to return to work.
d: Estimated by ECRI from a published chart.
e: Unclear whether data is reported per patient or per treated hand. Therefore, we did not calculate an effect size for this study.

Table 59. Summary of effect of treatment type on return to work

Study	Which Procedure Yielded Faster Return to Work?	Was the Difference Statistically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Gibbs, 1996 [351]	Open	No	Not calculable	Not calculable
Jacobsen, 1996 [353]	Endoscopic	No	25%	0.19 (-0.51 – 0.88)
Dumontier, 1995 [365]	Endoscopic at 2 weeks Open at 1 month and 3 months	No	Not calculable	Not calculable
Futami, 1995 [366]	Endoscopic	No	Not calculable	Not calculable
Hallock, 1995 [368]	Endoscopic	No	32.6%	Not calculable
Sennwald, 1995 [373]	Endoscopic	Yes	15.1%	1.65 (0.99 –2.31)
Erdmann, 1994 [304]	Endoscopic	Yes	Not calculable	Not calculable
Kerr, 1994 [379]	Endoscopic	Yes	Not calculable	Not calculable
Brown, 1993 [45]	Endoscopic	Yes	Not calculable	Not calculable
McDonough, 1993 [448]	Endoscopic	Not reported	Not calculable	Not calculable
Palmer, 1993 [397]	Endoscopic	Yes	Not calculable	Not calculable
Agee, 1992 [46]	Endoscopic	Yes	Not calculable	Not calculable

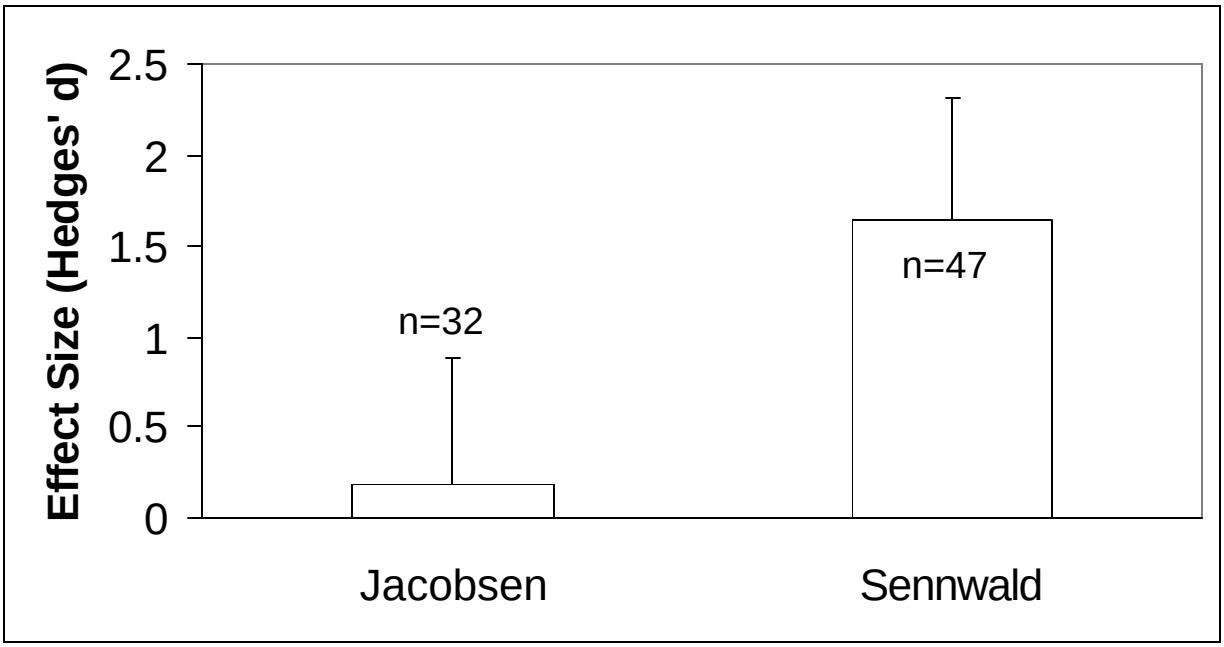
[a]: Calculated by ECRI

Figure 26. Summary of effect of treatment on return to work



An open bar denotes an RCT, a striped bar a CT, and a filled bar a retrospective trial.
NR indicates that the authors did not report the number of patients for whom this outcome was recorded.

Figure 27. Calculable effect sizes for effect of treatment type on return to work



Time to return to activities of daily living

This outcome was reported in five controlled studies, three of which were randomized. Data from these studies are presented in Table 60. Unless otherwise stated, data are presented as mean times to return to activities of daily living (ADLs). Only one study reported sufficient data for a valid effect size to be calculated. Therefore, no meta-analysis could be performed. Instead, Table 61 summarizes trends in the data available from the controlled trials.

Four trials found a faster return to daily activities in the group treated with endoscopic release. Three of these found the difference to be statistically significant. A chi square test conducted by ECRI found that in the study by Brown, the difference between groups at 84 days was statistically significant despite the fact that it was reported as insignificant.[45] The effect size calculated from the same data was significantly different from zero. The study that did not favor endoscopic release was the only retrospective study. It found that both groups returned to daily activities in the same amount of time. This is illustrated in Figure 28.

The amount of time required for return to ADLs varies among studies. Futami reported that all patients treated with endoscopic release returned to daily activities "with full use of the hand" within 18 days, while Brown reported that only a fraction of endoscopic patients (11%) returned to ADLs within 21 days. Gibbs reported that half of the patients in the endoscopic group returned to work in 21 days, while Agee reported a median of 9 days. The reasons for these differences are unknown.

As was the case for return to work, the data show a trend toward faster return to daily activities for patients treated with endoscopic carpal tunnel release than with open surgery. However, because one cannot perform a meta-analysis on the data, the magnitude of the difference cannot be precisely determined.

Table 60. Time to return to activities of daily living in patients treated with open or endoscopic surgery

Study	Number of Patients	Time to Return to Activities of Daily Living	Statistical Significance of Difference Between Groups
Gibbs, 1996 [351]		Time until 50% of patients had returned to ADL[a]	Groups not significantly different by log-rank test
	43 Open	21 Days (Range 1->911)	
	14 Endoscopic	21 Days (Range 7->425)	
Futami, 1995 [366]	10 Open[b]	41 Days (Range 28-51)	Groups significantly different by t-test, p <0.01
	10 Endoscopic	12 Days (Range 4-18)	
Erdmann, 1994 [304]	23 Open (Patients)		Groups significantly different (p <0.005, Mann-Whitney test)
	27 Open (Hands)	39 Days	
	23 Endoscopic (Patients)[c]	14 Days	
	28 Endoscopic (Hands)		
Brown, 1993 [45]	21 Days, N = 149 Hands Group n not reported[d]	Number of patients (hands) with no impairment of ADL	
	Open	3 (5)	Groups were not significantly different by Kaplan-Meier survivorship analysis.
	Endoscopic	8 (8)	
	42 Days, N = 147 Hands		
	Open	(12)	Groups were not significantly different by Kaplan-Meier survivorship analysis.
	Endoscopic	(14)	
	84 Days, N = 160 Hands		
	82 Open	28 (29)	Groups were not significantly different by Kaplan-Meier survivorship analysis. However, they were significantly different by chi square test conducted by ECRI, p = 0.019
	78 Endoscopic	39 (42)	

Study	Number of Patients	Time to Return to Activities of Daily Living	Statistical Significance of Difference Between Groups
Agee, 1992 [46]	63 Open 81 Endoscopic (Hands)	Median 13 Days, estimated by Kaplan-Meier Median 9 Days, estimated by Kaplan-Meier	Groups not significantly different according to a survival analysis version of the Wilcoxon test.

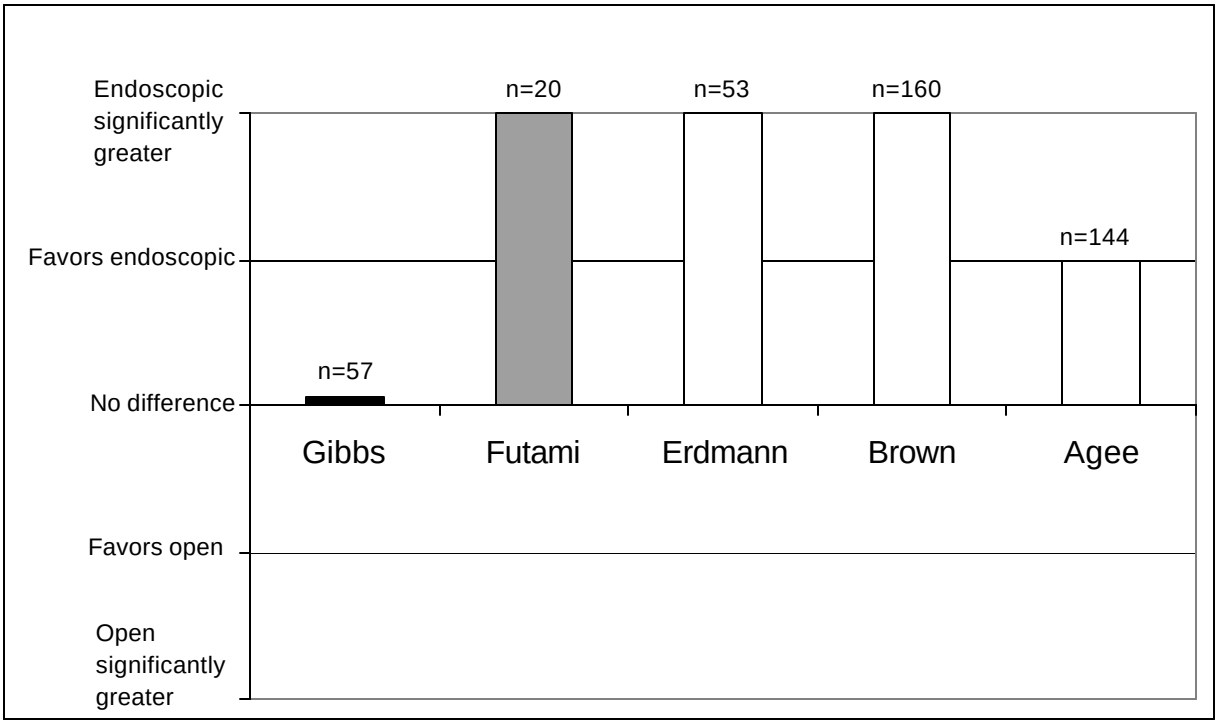
[a]: Calculated by Kaplan-Meier survival analysis
[b]: 20 hands in 10 patients
[c]: Unclear whether means were calculated as per patient or per hand.
[d]: Sum of group ns calculated by ECRI from published data did not match reported total Ns.

Table 61. Summary of effect of treatment (open or endoscopic) on time to return to ADLs

Study	Which Procedure Yielded Faster Return to Daily Activities?	Was the Difference Statistically Significant?	Power (Minimum percent difference detectable[a]	Effect Size (95% Confidence Interval)[a]
Gibbs, 1996 [351]	Both groups were equal	No	Not calculable	Not calculable
Futami, 1995 [366]	Endoscopic	Yes	Not calculable	Not calculable
Erdmann, 1994 [304]	Endoscopic	Yes	Not calculable	Not calculable
Brown, 1993 [45]	Endoscopic	21 days: No 42 days: No 84 days: Yes	21 days: Not calculable 42 days: Not calculable 84 days: 18.3%	21 Days: Not calculable 42 days: Not calculable 84 days: 0.42 (0.065-0.77)
Agee, 1992 [46]	Endoscopic	No	Not calculable	Not calculable

[a]: Calculated by ECRI

Figure 28. Summary of effect of treatment on return to ADLs



Open bars represent RCTs, striped bars CTs, and dark bars retrospective trials.

Pain

In this question, we address pain as a symptom of carpal tunnel syndrome, distinct from postsurgical pain, scar tenderness or pillar pain. This outcome was reported in four controlled trials, two of which were randomized. Again, because effect sizes could be calculated for only two studies, we did not perform a meta-analysis. Therefore, we examine the data for trends. Data describing the relative effect of open and endoscopic treatment on pain are presented in Table 62.

To address this outcome, we perform three separate analyses. First, we assess differences between patient groups prior to treatment. If there are differences in pain prior to treatment, this may influence whether there are differences after treatment. In randomized controlled trials, the process of randomization is used to eliminate this concern.

The second analysis we performed is a comparison of short-term results. This is because the rationale behind endoscopic treatment is that it is less invasive, leading to faster recovery. Whether this also means faster relief of symptoms has not been determined. For this analysis, we are defining short-term results to be those obtained one month or less after surgery. Finally, in our third analysis, we evaluated long-term (longer than one month) results.

Data relevant to these three analyses are summarized in Table 63. There were no statistically significant differences between groups before treatment. All three studies reporting pain at early (1 month or less) times after treatment found less pain in the endoscopic groups, with one RCT finding a statistically significant difference. At later time points, all but the one retrospective study found less pain in the endoscopic groups. However, none of the differences were statistically significant.

The statistically nonsignificant results may indicate that these studies were too small (i.e., underpowered to detect differences. Only Gibbs provided sufficient data for power to be calculable. After treatment, the study only had the power to detect large (>40%) differences between groups. If the true difference between groups is less than this, the study is uninformative. However, the two calculable post-treatment effect sizes are not large (See Figure 31), suggesting that low power is not exclusively responsible for these non-significant results.

The data show a trend toward greater pain relief for patients treated with endoscopic carpal tunnel release at both early and later times after surgery (See Figure 29, Figure 30, and Figure 31). However, there is some circumstantial evidence to suggest that the effect is not large at both early and late followup times. At early followup times, only one of three studies found a statistically significant effect, despite all three studies being of reasonable size (>100 patients). At later followup times, no studies found a statistically significant effect. Similarly, the only calculable effect size from a prospective trial (an RCT) was not large. Thus, while the precise effect size cannot be calculated, evidence suggests it is small.

Table 62. Symptomatic pain in patients treated with open or endoscopic carpal tunnel release

Study	Number of Hands	Pain	Statistical Significance of Difference Between Groups
Gibbs, 1996 [351]	43 Open 14 Endoscopic	Pain rating Preop:: 3.3±1.0 18.9 Months: 1.2 ±0.52 Preop: 3.3±0.87 16 Months: 1.5±0.96	Groups not significantly different before or after treatment by t-test, p = 0.78 and 0.21 respectively.
Erdmann, 1994 [304]	52 Open 53 Endoscopic	Mean VAS, 0-10 Scale[a] Preop: 5.6; 1 Week: 3.9 1 Year: 0.95 Preop, 5.7; 1 Week: 2.4 1 Year: 0.1	Groups significantly different at 1 week only (Mann-Whitney test, p <0.05)
Palmer, 1993 [397]	42 Patients, 49 Hands Open 70 Patients, 90 Hands Endoscopic (Agee method) 62 Patients, 72 Hands Endoscopic (Chow method)	Percent of patients[b] reporting nocturnal pain Preop: 88.7% 2 Weeks: 23.3% 6 Months: 25.0% Preop: 80.0% 2 Weeks: 16.7% 6 Months: 12.5% Preop: 89.8% 2 Weeks: 21.7% 6 Months: 28.9%	Groups not significantly different at any time point by chi square test, p >0.05
Agee, 1992 [46]	65 Open 82 Endoscopic	Percent of patients[b] with symptomatic pain Preop: 89; 1 Week: 59 26 Weeks: 27 Preop: 85; 1 Week: 43 26 Weeks: 25	Not reported

a: Estimated by ECRI from a published chart
b: The report states that outcomes are reported as percent of patients. However, as some patients had a different procedure in each hand, it is likely that the outcome is actually percent of hands. Thus, the true n is unclear.

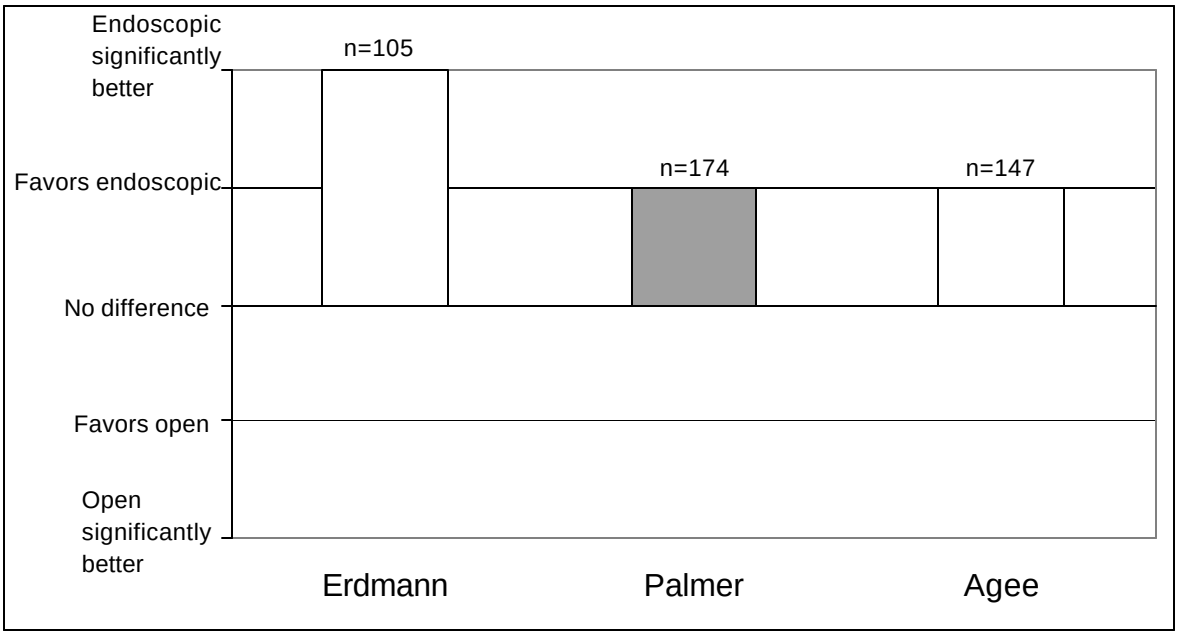
Table 63. Summary of effect of treatment (open or endoscopic) on pain

Study	Which Procedure Had Less Pain?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable 80% of the time)[a]	Effect Size (95% Confidence Interval)[a]
Gibbs, 1996 [351]	Preop: No difference Early: Not reported Late: Open	Preop: No Early: Not reported Late: No	Preop: 17.5% Early: Not reported Late: 40.0%	Preop: 0.0 (-0.60–0.60) Early: Not reported Late: -0.45 (-1.06-0.15)
Erdmann, 1994 [304]	Preop: Open Early: Endoscopic Late: Endpscopic	Preop: No Early: Yes Late: No	Not calculable	Preop: Not calculable Early: 0.39 (0.00-0.77)[b] Late: Not calculable
Palmer, 1993 [397]	Preop: Endoscopic Early: Endoscopic Late: Endoscopic	Preop: No Early: No Late: No	Not calculable	Not calculable
Agee, 1992 [46]	Preop: Endoscopic Early: Endoscopic Late: Endoscopic	Preop: Not reported Early: Not reported Late: Not reported	Not calculable	Not calculable

a: Calculated by ECRI

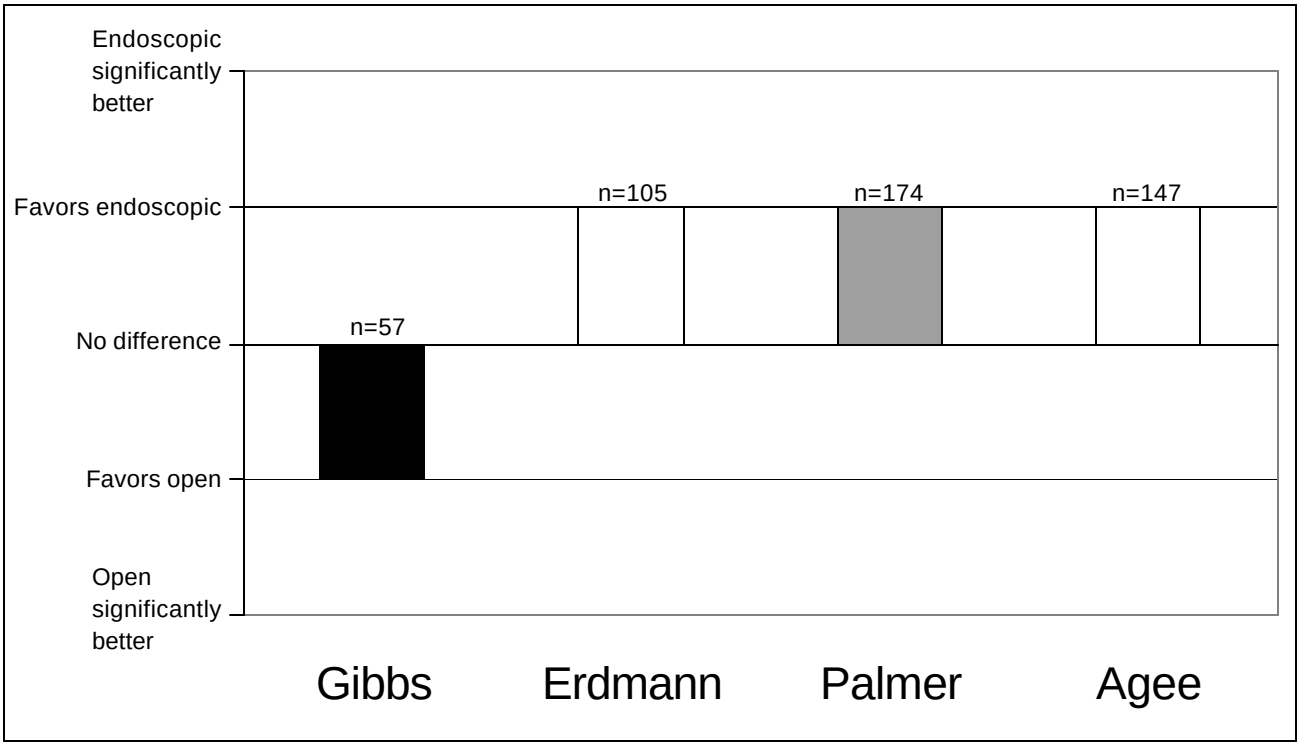
b: Calculated by ECRI based on the conservative assumption that p = 0.049)

Figure 29. Summary of the effect of treatment on pain at early time points



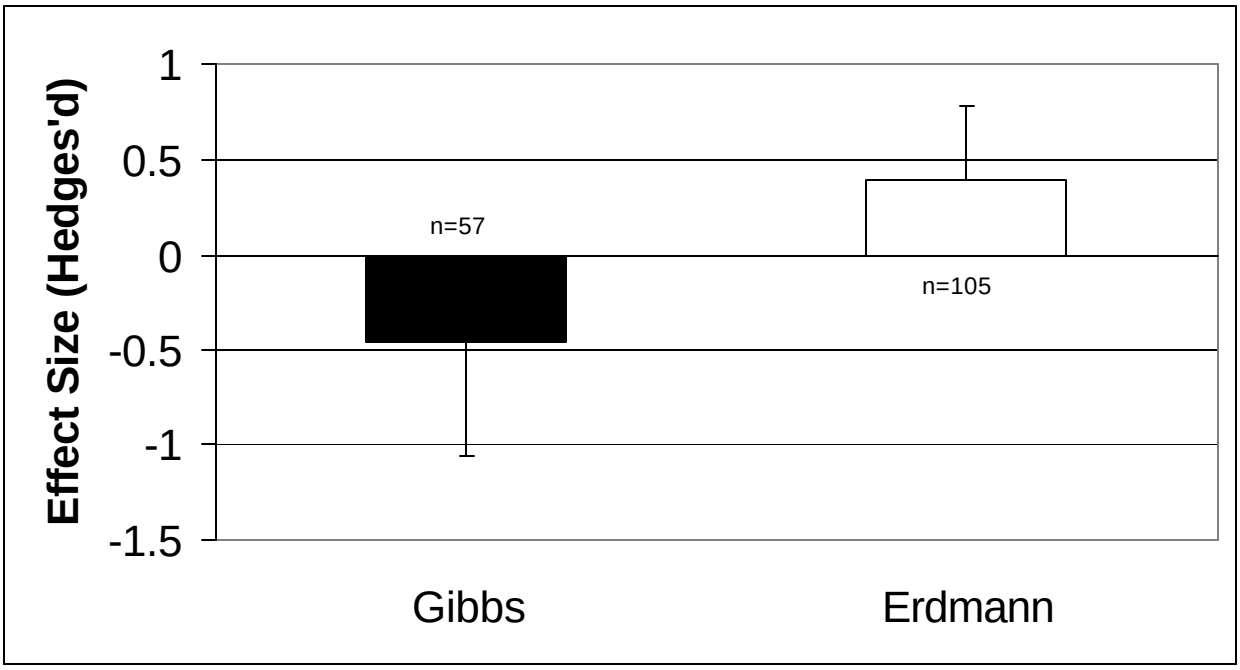
An open bar indicates an RCT, a striped bar a CT. The study by Gibbs does not appear because it did not report early time ponts.

Figure 30. Summary of the effect of treatment on pain at late time points



An open bar indicates an RCT, a striped bar a CT, and a dark bar a retrospective study.

Figure 31. Calculable effect sizes for pain



An open bar indicates an RCT and a dark bar a retrospective study.

Function

Function refers to the ability of the patient to perform various tasks and activities with their affected limb(s). It is measured using any of a number of tests.

Only one nonrandomized controlled trial, that by Worseg, reported a measure of function. This outcome is described in Table 64 and summarized in Table 65. Worseg's global function was the mean of the difficulty ratings (scale of 1-5) of eight individual activities (writing, buttoning clothes, holding a book, gripping a telephone, opening jars, household chores, carrying a grocery bag, and bathing and dressing).

The endoscopic group experienced superior function one week after surgery, but there were no statistically significant differences in the long term. This is consistent with the idea that the less invasive treatment leads to more rapid recovery. Because, however, function was examined in only one study (which was not randomized), it is difficult to draw firm evidence-based conclusions about the relative effects of open and endoscopic surgery on function.

Table 64. Function in patients treated with open or endoscopic carpal tunnel release

Study	Number of Patients	Function	Statistical Significance of Difference Between Groups
Worseg et al., 1996 [44]		Mean of function scores[a]	Between group differences were significant at 1 Week only (p <0.05, Wilcoxon rank sum test).
	Open 62	Preop: 3.14 ; 1 Week: 3.33; 24 Weeks: 1.29	
	Endoscopic 64	Preop: 3.16 ; 1 Week: 2.29; 24 Weeks: 1.20	

a: Lower score indicates superior function

Table 65. Summary of the effect of treatment on function

Study	Which Procedure Had Superior Function at Followup?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Worseg, 1996 [44]	Endoscopic	At 1 week only	Not calculable	Preop: 0.12 (-0.23 – 0.47)[b] 1 Week: 0.35 (0.00 – 0.70) 24 Weeks: 0.12 (-0.23 – 0.47)

a: Calculated by ECRI
b: Calculated by ECRI based on the conservative assumption that p = 0.49 at one week and p = 0.50 at the other time points.

Quality of Life

No studies reported this outcome.

Harms

Analysis of differences in incidence of adverse events between endoscopic and open surgery is hindered by incomplete reporting. Figure 32 shows the percent of studies reporting each adverse effect. Only one complication, transient sensory disturbance, was reported by more than half of the studies. It is not possible to determine whether in the remaining studies complications did not occur or were not reported in the remaining studies. Six studies did not report any complications. A complete listing of reported complications may be found in Evidence Table 12.

The following analysis is based on the assumption that major, severe complications are more likely to be reported than minor ones. This analysis is therefore limited to reports of the accidental severing of a nerve, tendon or blood vessel. This type of injury requires repair and is presumably serious enough to warrant mention. Incidence of accidental laceration is reported in Table 66.

Incomplete transection of the carpal ligament is a technical failure that can lead to recurring or continuing symptoms of carpal tunnel syndrome and may require reoperation. The number of incomplete transections reported in studies comparing open and endoscopic carpal tunnel release are presented in Table 67.

Ten studies reporting on 490 open releases reported one nerve injury. Among 1,774 Endoscopic releases, there were five nerve, tendon or blood vessel lacerations. The difference between groups was not statistically significant by a chi square test ($p=0.767$) conducted by ECRI.

An incomplete transection of the carpal ligament is unlikely when performing open release, because the ligament is fully visualized. Since the rate of incomplete release is essentially zero when performing open release, the rate for endoscopic release (9 incomplete transections in 378 procedures) is higher. Endoscopic release may therefore have a higher reoperation rate than open release.

Figure 32. Studies reporting minor complications

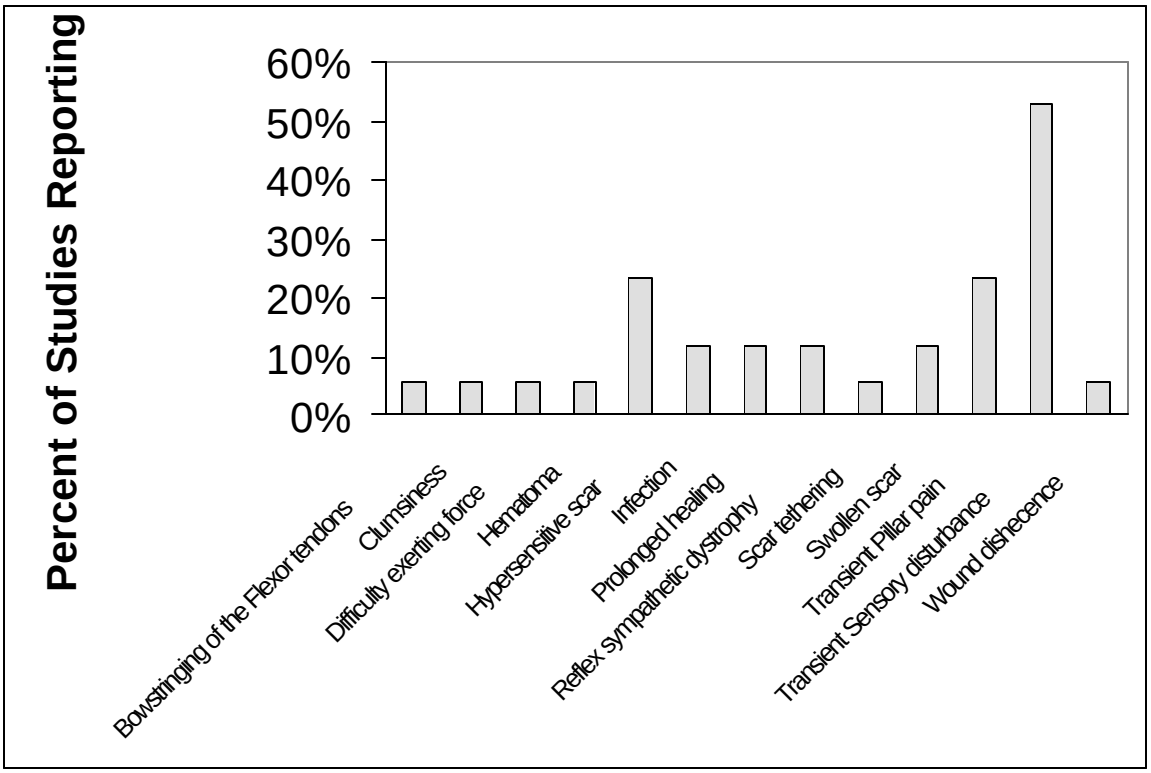


Table 66. Blood vessel, nerve and tendon lacerations during open and endoscopic carpal tunnel release

Study	Procedures	Endoscopic Lacerations	Open Lacerations
Chen, 1999 [317]	Open 64 Endo 1214	1 Motor nerve	0
Povlsen, 1997 [450]	Open 50 Endo 50	0	0
Jacobsen, 1996 [353]	Open 16 Endo 16	0	0
Worseg, 1996 [44]	Open 62 Endo 64	1 Transection of the superficial palmar arch	0
Dumontier, 1995 [365]	Open 40 Endo 56	1 Ulnar artery injury	0
Sennwald, 1995 [373]	Open 22 Endo 25	0	0
Erdmann, 1994 [304]	Open 52 Endo 53	0	1 Palmar cutaneous nerve
Brown, 1993 [45]	Open 85 Endo 84	1 Superficial palmar arch	0
McDonough, 1993 [448]	Open 50 Endo 50	1 Digital tendon	0
Palmer, 1993 [397]	Open 49 Endo (Agee) 90 Endo (Chow) 72	0	0
Total		1774 Procedures 5 Lacerations	490 Procedures 1 Laceration

Table 67. Incomplete transections of the carpal ligament

Study	Procedures	Endoscopic Incomplete Transections	Open Incomplete Transections
Concannon et al., 2000 [449]	Open 103 Endo 88	5	0
Sennwald and Benedetti, 1995 [373]	Open 22 Endo 25	0	0
Erdmann, 1994 [304]	Open 52 Endo 53	1	0
McDonough et al., 1993 [448]	Open 50 Endo 50	1	0
Palmer et al., 1993 [397]	Open 49 Endo (Agee) 90 Endo (Chow) 72	1 Agee 1 Chow	0
Total		378 Procedures 9 Incomplete transections	276 Procedures 0 Incomplete transections

Conclusions

Endoscopic release allows faster return to work and to activities of daily living. In addition, it leads to superior global outcome and reduced pain. However, the effects on pain and global outcome may be small. Presently available data do not allow one to reach firm evidence-based conclusions about the relative effect of open and endoscopic surgery on function. Because of incomplete transection of the transverse carpal ligament, endoscopic release has a higher rate of reoperation. Although there is insufficient data to draw firm conclusions, endoscopic release may also have a higher complication rate.

What are the relative benefits and harms of open carpal tunnel release with and without neurolysis for persons with carpal tunnel syndrome?

Eight published studies comparing open carpal tunnel release with carpal tunnel release combined with neurolysis met the inclusion criteria. These studies enrolled a total of 494 cases. One of these, the study by Gelberman et al.,[415] compared their data to an earlier case series, that of Rhodes et al.[451] Therefore, the study of Rhodes et al. may be considered an historical control for the study by Gelberman et al. Six of the remaining trials are prospective, randomized controlled trials. Four are single- or double-blinded. One is double-blinded, but not randomized.[426] Long-term outcomes for one study are reported in a separate publication.[416,433]

Internal validity

Factors affecting internal validity of controlled trials of neurolysis are described in Table 68. Three studies had no attrition, and the remaining five had attrition ranging from 6% to 50%. None of the studies with patient attrition reported results on an intent-to-treat basis. Wherever possible, we compensated for attrition using the conservative assumption that treatment had failed for all patients not accounted for. All but one of the studies violated statistical assumptions of independence by including patients with bilateral CTS.[433] The impact of this violation in terms of the number of times an erroneous conclusion of statistical significance was drawn is unknown, but it does affect one's confidence in the results of our analyses.

Generalizability

The average age of the patients in the five studies reporting mean ages was 55.7, with a range of 20-100. This is consistent with the reported epidemiology of CTS as well as with the ages observed under question 2 of this evidence report. Two of the studies included somewhat fewer than 50% female patients, but this percentage is not so low that it would greatly limit the generalizability of the data reported. These and other patient characteristics are listed in Table 69.

Except in cases where patients with comorbidities were excluded (noted in Table 69 by a zero under the comorbidity), patient comorbidities were not described in these studies. Similarly, employment characteristics are not described, as can be seen in Table 70. No conclusions about the generalizability of these results to the general CTS population is possible.

One study (Leinberry, et al.) included only patients with severe disease.[342] It may therefore be inappropriate to combine the study by Leinberry with the remaining studies, and this study may not be generalizable to the CTS population at large. All but one of the studies excluded patients with mild disease.[426] The extent to which this criterion differs from criteria for surgical candidates in ordinary clinical practice is not known. Therefore, the impact of this exclusion on generalizability is not known.

Table 68. Internal validity of studies comparing open carpal tunnel release with and without neurolysis

Study	Number of patients	Percent of patients with bilateral procedures	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?
Leinberry, 1997 [342]	44	13.6%	Single	No	RCT	Rater	0	Yes
Blair, 1996 [428]	117	36.0%	Single	No	RCT	Rater	42	No
Foulkes, 1994 [376]	46	8.7%	Single	No	RCT	Rater	23	No
Mackinnon, 1991 [407]	59	6.8%	Single	No	RCT	Double	20	No
Lowry, 1988 [429]	50	22.0%	Single	Not reported	RCT	Double	3	No
Gelberman, 1987 [415]	61	13.1%	Multiple (<5)	No	Retro	No	0	Yes
Holmgren-Larsson, 1985 [433] Holmgren, 1987 [416]	48	0.0%	Single	Not reported	RCT	No	7	No
Freshwater, 1978 [426]	22	18.2%	Single	Not reported	CT	Double	0	Yes

Table 69. Generalizability of studies comparing open carpal tunnel release with and without neurolysis

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Leinberry, 1997 [342]	44	65 (38-100)	59.1	31.8 (1-360)	6.8	NR	NR	NR	NR	NR	NR	No	Yes
Blair, 1996 [428]	86	49 (23-82)	72.1	NR	NR	NR	NR	0	0	NR	NR	No	Yes
Foulkes, 1994 [376]	46	NR	37.0	NR	NR	NR	NR	NR	NR	0	NR	No	Yes
Mackinnon, 1991 [407]	79	58.5 (20-91)	60.8	NR	0	NR	0	0	0	NR	NR	No	Yes
Lowry, 1988 [429]	50	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Gelberman, 1987 [415]	61	59.2 (28-90)	37.7	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Holmgren, 1987 [416]	48	50 (21-80)	68.8	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Holmgren-Larsson, 1985 [433]	48	50 (21-80)	68.8	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Freshwater, 1978 [426]	22	NR; (32-74)	NR	12 (3-120)	NR	0	NR	NR	NR	NR	NR	NR	NR

Table 70. Patient employment characteristics in studies comparing open carpal tunnel release with and without neurolysis

Study	Number of patients	% Patients employed	% Patients receiving workers' compensation	% Patients retired	% Patients Homemakers	Reported occupations
Leinberry, 1997 [342]	44	Not reported	Not reported	Not reported	Not reported	Not reported
Blair, 1996 [428]	86	Not reported	Not reported	Not reported	Not reported	Not reported
Foulkes, 1994 [376]	46	Not reported	Not reported	Not reported	Not reported	Not reported
Mackinnon, 1991 [407]	79	Not reported	12.7	Not reported	Not reported	Not reported
Lowry, 1988 [429]	50	Not reported	Not reported	Not reported	Not reported	Not reported
Gelberman, 1987 [415]	61	Not reported	Not reported	Not reported	Not reported	Not reported
Holmgren, 1987 [416]	48	Not reported	Not reported	Not reported	Not reported	Not reported
Holmgren-Larsson, 1985 [433]	48	Not reported	Not reported	Not reported	Not reported	Not reported
Freshwater, 1978 [426]	22	Not reported	Not reported	Not reported	Not reported	Not reported

Results

Global outcome

This outcome was reported by all eight controlled trials, six of which were randomized and one of which was retrospective. Of the six randomized trials, five were blinded. Data from these trials are summarized in Table 71. The study by Blair employed three different measures of global outcome.[428] We did not consider patient perceptions about symptom relief because these authors presented their results in a manner that is difficult to quantify. For example, they reported that some patients experience permanent partial relief while others experienced temporary total relief. It is difficult to determine which of these outcomes the patients considered superior.

Of the remaining two outcomes in the report by Blair et al., both could be used to calculate an effect size. The number of patients stating they would have surgery again gave an effect size of d = 0.067, while the number of patients happy or satisfied with their treatment led to an effect size of d = 0.94. It is unclear which of these is the more accurate measure of global effect. We chose to use the smaller effect size in our meta-analysis. This conservative approach, which is biased against finding a significant effect, adds credibility to the resulting significant effect.

The report by Foulkes [376] provided two measures of global outcome, only one of which could be used to calculate an effect size. We were able to compensate for 13 of the 27 hands lost to followup by using the conservative assumption that they were unimproved at followup. The remaining 14 hands could not be accounted for because their group assignment was not reported. Similarly, the 42 hands not reported in the study by Blair and twenty in the study by Mackinnon could not be accounted for because their group assignment was not reported.

The report by Holmgren et al. is a long-term followup of Holmgren-Larsson et al. that does not account for five patients (10.4%) who did not return for followup examinations.[416,433] Because the original report by Holmgren-Larsson did not report the number of patients assigned to each group, the group assignments of these five patients is not known. Thus, these patients cannot be accounted for when calculating effect sizes. The two patients known to have died were not included in our calculations. Three patients were not accounted for in the study by Lowry. Two of them were in the no neurolysis group and one in the neurolysis group. We accounted for them using the conservative assumption that treatment had failed for all of them.

Eight studies provided sufficient data for meta-analysis. The results may be found in Table 72. The calculated effect sizes are not heterogenous (Q = 5.20; p = 0.64) and the overall effect size is significantly different from zero (d = 0.27, 95% C.I. = 0.003-0.537; p = 0.047). The lack of heterogeneity suggests that although the study by Leinberry incorporated patients who may have had more severe CTS than those in the other studies,[342] its results were not derived from a different population than the results of other studies. It was therefore statistically valid to combine this study with the others for

meta-analysis. The effect sizes of the individual studies as well as the overall effect size, and their 95% confidence intervals are depicted graphically in Figure 33. Although the difference between groups is statistically significant, there is still considerable (80.6%) overlap between the global outcome scores of the two groups, as can be seen in Figure 34.

One difficulty in interpreting this meta-analysis comes from the large rate of patient attrition. Of the 494 cases treated in these studies, results were not reported for 99. Two of these had died, and an additional 16 could be accounted for by assuming that treatment had failed for them. This leaves a total of 81 (16.4%) patients unaccounted for. The existence of a large number of treated patients whose outcomes are not known may undermine the confidence with which these results are interpreted.

For three of the studies in this meta-analysis, more than one effect size could be calculated depending on the assumptions made about the data. In all cases, we chose the most conservative assumption. However, because of the distribution of patients between groups, the most conservative assumption did not always lead to the smallest possible effect size. In the study by Foulkes, there were 11 patients missing from the neurolysis group and only two from the no neurolysis group. Assuming that treatment had failed for all of these patients leads to a larger effect size (favoring no neurolysis) than either applying the anti-conservative assumption that treatment had succeeded for these patients or not attempting to account for missing patients at all. Thus, application of this assumption may have lead to an erroneous result. The effect of making conservative or anticonservative assumptions, or of not attempting to account for missing patients by recalculating data is summarized in Table 73.

As can be seen in Table 73, consistently applying either the conservative or the anti-conservative assumptions to the data leads to a statistically significant effect. Anti-conservative in this instance means assuming that treatment was successful for all missing patients, and using the larger of the two effect sizes calculable from the data of Blair. The fact that the results significantly favor no neurolysis regardless of whether conservative or anticonservative assumptions are applied strengthens our confidence in the results of our analysis.

When the data from the studies by Foulkes and Lowry were not recalculated to account for missing patients, the meta-analytic summary statistic was statistically significant only when the larger effect size from the study by Blair was used. This later meta-analysis, however, was only marginally nonsignificant ($p = 0.052$), and could be overturned by future studies. This result, however, does not establish that there is a benefit derived from performing neurolysis. To the contrary, if the true effect size is nonsignificant, this indicates that there is no effect of neurolysis on global outcome. The lack of a statistically significant effect of neurolysis does not arise because we included non-randomized and non-blinded studies in our meta-analysis. Removal of such studies again yielded a non-significant meta-analytic summary statistic ($d = 0.18$, 95% CI –0.7-0.42, $p=0.154$.

The results of our conservative meta-analysis suggest that in a typical case of carpal tunnel syndrome, there is no benefit from performing neurolysis along with surgical release of the carpal tunnel. When statistical assumptions are consistently applied while performing meta-analysis, results suggest that patients report superior global effect of surgery when neurolysis is not performed. The results of this meta-analysis become statistically nonsignificant when analysis is restricted to the results of blinded RCTs. Removal of studies, however, reduces the statistical power of the meta-analysis, and it may be this loss of power, rather than any bias in the non-blinded studies that causes the analysis to become non-significant. That there is no marked bias in these studies is suggested by the lack of heterogeneity, which, in turn, indicates that all eight studies in the meta-analysis measure the same population parameter. There is insufficient evidence to reach an evidence-based conclusion about whether neurolysis is of benefit in atypical cases, such as when there is marked scarring or neural adhesion.

Table 71. Effect of neurolysis on global outcome

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Leinberry, 1997 [342]		Number of hands with no symptoms	Not significantly different, test not reported
	Open Release 25	12 Months: 15	
	Release and Neurolysis 25	12 Months: 14	
	(Hands)		
Blair, 1996 [428]		Patients stating they would have surgery again	Not reported
	Open Release 27	26	
	Release and Neurolysis 48	46	
	(Hands)	Patient perceptions about relief of symptoms	
	Open Release 27	Permanent total: 13 Permanent partial: 12 Temporary total: 2	
	Release and Neurolysis 48	Permanent total: 31 Permanent partial:15 Temporary total: 2	
		Patient satisfaction	
	Open Release 27	Happy/very happy: 19 Satisfied, with reservations: 8 Disappointed/ very disappointed: 0	
	Release and Neurolysis 48	Happy/very happy: 35 Satisfied, with reservations: 9 Disappointed/ very disappointed: 4	

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Foulkes, 1994 [376]		Improvement at 29 Months	Not reported
	Open Release 8	Normal 2 Improved 6 Unimproved 0	
	Release and Neurolysis 15	Normal 5 Improved 9 Unimproved 1	
	Recalculated: Open Release 10[a]	Recalculated: Normal 2 Improved 6 Unimproved 2	Not reported
	Release and Neurolysis 26	Normal 5 Improved 9 Unimproved 12	
	(Hands)	Symptom severity score	
	Open Release 8	Preop: 2.5; 29 Months: 0.4 Recalculated to account for patient attrition:	
	Open Release 10	Preop: 2.5; 29 Months: 0.82	
	Release and Neurolysis 15	Preop 2.9; 29 Months: 0.3 Recalculated to account for patient attrition:	
	Release and Neurolysis 26	Preop: 2.9; 29 Months: 1.4	
	(Hands)		
Mackinnon 1991 [407]		Symptom rating at 12 months.	Not reported
	Open Release 32	Relief of all or most symptoms 28 Unimproved 4 Worse 0	
	Release and neurolysis 31	Relief of all or most symptoms 25 Unimproved 5 Worse 1	
	(Hands)		

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Lowry, 1988 [429]		3 Months	Not reported
	Open Release 23	Excellent 7 Good 8 Fair 6 Poor 2	
	Release and Neurolysis 24	Excellent 4 Good 12 Fair 7 Poor 1	
		Recalculated[b]:	
	Open Release 25	Excellent 7 Good 8 Fair 6 Poor 4	
	Release and Neurolysis 25	Excellent 4 Good 12 Fair 7 Poor 2	
Gelberman,1987 [415]; Rhodes, 1985 [451]		Number of patients with complete resolution of signs and symptoms	Significantly different ($p < 0.05$, chi square)
	Open Release: 29	Complete resolution: 18 Mean followup time: 16 Months	
	Release and Neurolysis 32	Complete resolution: 10 Mean followup time: 18 Months	

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Holmgren-Larsson, et al. 1985 [433] Holmgren, 1987 [416]	48 Patients; Number in each group not reported. Open Release Release and Neurolysis Open Release 20 Release and Neurolysis 23	Percent of patients reporting themselves symptom-free at 6 months 89% 89% 3-4 Years: Totally restituted: 12 Improved: 4 Dead: 1 Did not respond: 3 Totally restituted: 18 Improved: 3 Dead: 1 Did not respond: 1	Not reported
Freshwater, 1978 [426]	Open Release 12 Release and Neurolysis 14	Number of patients with no symptoms at 2 years 11 12	Not significantly different by chi square test conducted by ECRI, p = 0.64

[a]: Two hands were lost to followup in the open release group and eleven in the neurolysis group. These hands were conservatively assumed to be unimproved. The significant loss to followup, as well as the fact that loss was not evenly distributed between groups, may render these data unreliable. This recalculation does not account for the additional 13 patients (14 hands) who were lost to followup for whom the group assignment was not reported.

[b]: Recalculated to account for patient attrition using the conservative assumption that treatment had failed for the two patients missing from the open release group and the one patient missing from the release and neurolysis group.

Table 72. Results of conservative meta-analysis of global outcome among patients treated with neurolysis for carpal tunnel syndrome

Author	Year	N	Effect Size	95% CI	p-value	Standardized Residual	Outlier by Std Residual?
Leinberry, [342]	1997	50	0.089	-0.53-0.78	0.778	-0.64	No
Blair, [428]	1996	75	0.067	-1.28-1.42	0.923	-0.30	No
Foulkes, [376]	1994	36	0.432	-0.30-1.17	0.250	0.46	No
Mackinnon, [407]	1991	63	0.282	-0.48-1.04	0.465	0.03	No
Lowry, [429]	1988	50	0.140	-0.41-0.70	0.615	-0.52	No
Gelberman, [415]	1987	61	0.697	0.11-1.28	0.019	1.61	No
Holmgren, [416]	1987	41	-0.741	-2.04-0.56	0.263	-1.56	No
Freshwater, [426]	1978	26	0.324	-1.08-1.72	0.650	0.08	No
			Fixed effects model:				
			Overall Effect Size	95% CI	p-value of E.S.	Q	p-value of Q
			0.27	0.003-0.537	0.047	5.20	0.636

Figure 33. Results of meta-analysis of the effect of neurolysis on global outcome

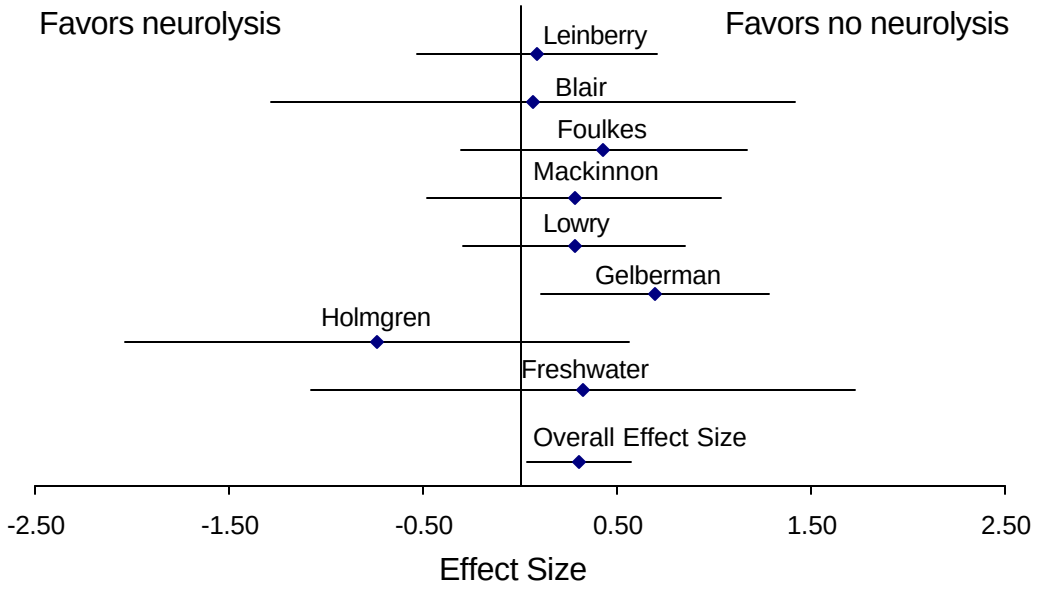


Figure 34. Overlap between effects of neurolysis and no neurolysis

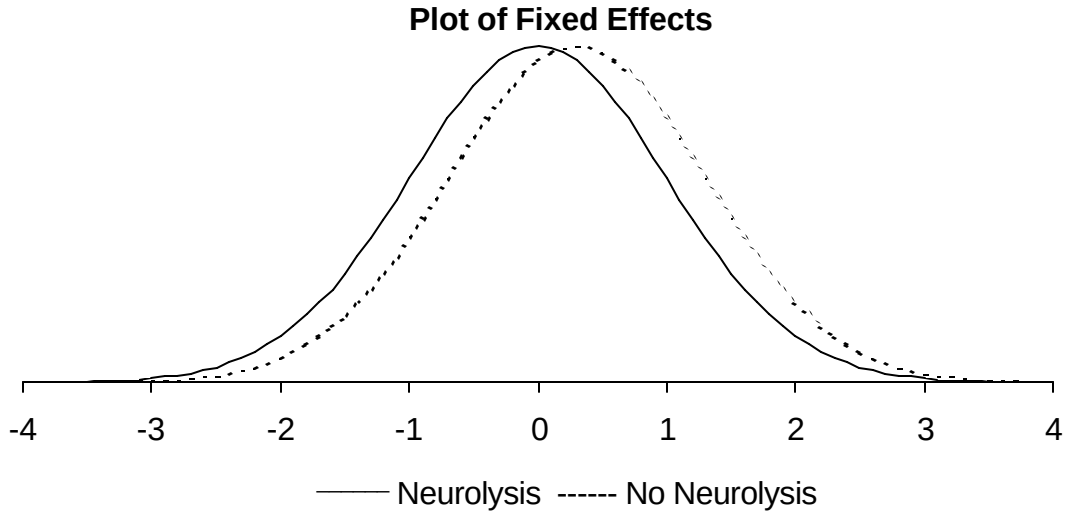


Table 73. Effect sizes of individual studies according to the assumptions used to calculate them

Study	Assumption used to calculate Hedges' d		
	Conservative	No Recalculation	Anti-conservative
Blair [428]	0.067 (-1.28-1.42)	N/A[a]	0.94 (-0.70-2.57)
Foulkes [376]	0.43 (-0.30-1.17)	0.30 (-1.53-2.13)	0.11 (-1.69-1.92)
Lowry [429]	0.14 (-0.41-0.70)	0.28 (-0.30-0.85)	0.37 (-0.19-0.93)
Overall Effect Size	0.27 (0.003-0.537)	0.29 (0.01-0.97)[b] 0.28 (-0.01-0.57)[c]	0.31 (0.03-0.59)

[a]: N/A; Not applicable. Data from this study were not recalculated.
[b]: If the anticonservative effect size from the study by Blair is used.
[c]: If the conservative effect size from the study by Blair is used.

Table 74. Effects of assumptions about individual studies on the overall effect size

Study			Is the overall effect size significantly different from zero?
Blair	Foulkes	Lowry	
Conservative	Conservative	Conservative	Yes
Conservative	No Recalculation	No Recalculation	No
Conservative	Anti-conservative	Anti-conservative	No
Anti-conservative	Conservative	Conservative	Yes
Anti-conservative	No Recalculation	No Recalculation	Yes
Anti-conservative	Anti-conservative	Anti-conservative	Yes

Return to work

Two controlled trials, one of which was randomized, reported some information describing return to work. Both included patients who received bilateral procedures, and one had high (36%) attrition. Results are presented in Table 75 and summarized in Table 76. Neither study reported the number of patients who were working or on sick leave prior to treatment, so the number of patients returning to work could not be determined. As can be seen in Table 76 and Figure 35, both studies favor release without neurolysis, with the difference achieving statistical significance in one study. Because of incomplete reporting, no meta-analysis or power analysis was possible.

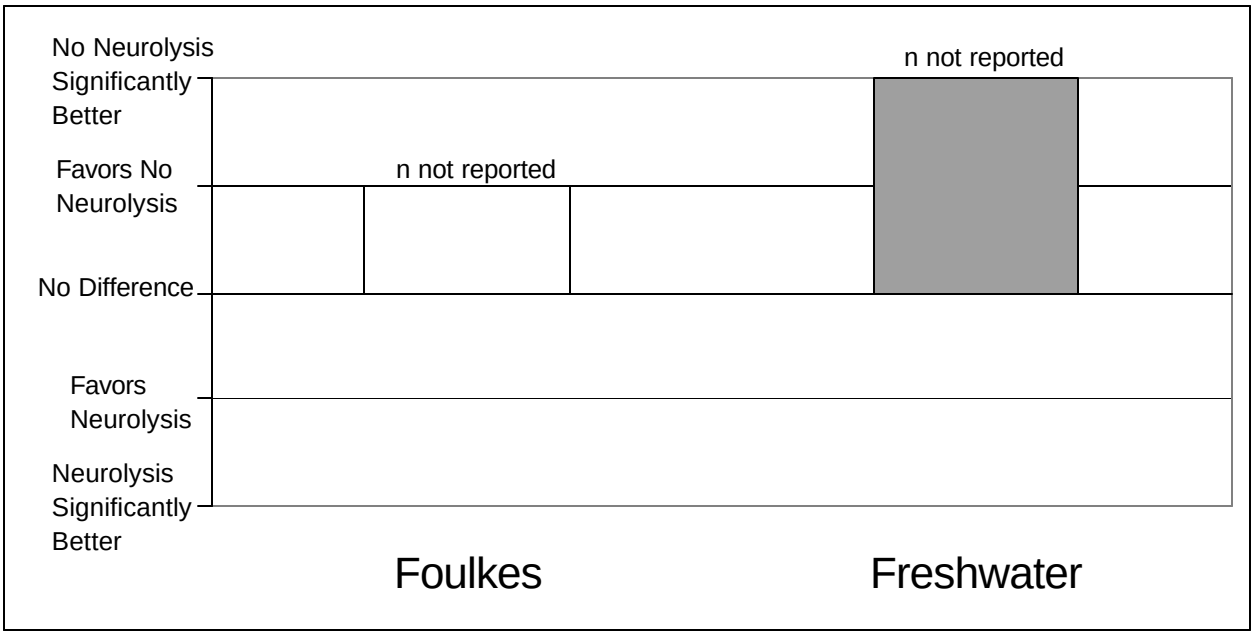
Table 75. Effect of neurolysis on return to work

Study	Number of Patients	Time to Return to Work	Statistical Significance of Difference Between Groups
Foulkes, 1994 [376]	Open Release Release and Neurolysis N not reported	Median 53 Days (Range 1-180) Median 59 Days (Range 14-120)	Not significantly different, statistical test not reported.
Freshwater, 1978 [426]	N not reported	Stated only that patients receiving open release without neurolysis returned to work more quickly than those who received neurolysis.	This difference was statistically significant by the Mann-Whitney U test ($p < 0.01$).

Table 76. Summary of the effect of neurolysis on return to work

Study	Which Procedure Had Faster Return to Work?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)	Effect Size (95% Confidence Interval)
Foulkes, 1994 [376]	No neurolysis	No	Not calculable	Not calculable
Freshwater, 1978 [426]	No neurolysis	Yes	Not calculable	Not calculable

Figure 35. Summary of the effect of neurolysis on return to work



An open bar indicates an RCT, while a striped bar indicates a CT.

Return to Activities of Daily Living

No studies reported this outcome.

Pain

Three controlled trials, two of which were randomized, compared pain in patients who received surgery with and without neurolysis. Results are presented in Table 77. The study by Freshwater and Arons found no statistically significant differences between groups in incidence of night pain and tenderness.[426] Too few patients (6, or 23%) had wrist pain prior to treatment for any statistical analysis of differences in pain between groups to be made. The study by Blair shows a trend toward superior results from neurolysis, but the difference between groups is not significant (chi square test conducted by ECRI, p = 0.106). Given the 36% loss to followup in the study, as discussed above, its results are not conclusive. If only the more successful candidates returned for followup, this would bias the results. Holmgren-Larssen et al.[433] found that the patients treated with neurolysis had a resurgence in pain at 6-month followup, while the patients with no neurolysis did not. The statistical significance of this trend cannot be determined, however, because they did not report the number of patients in each group.

These results are summarized in Table 78 and Figure 36. Calculable effect sizes are presented in Figure 37. The available data are of insufficient quality and quantity to allow one to reach n evidence-based conclusion about whether there is a difference in symptomatic pain resulting from performing or not performing neurolysis.

Table 77. Effect of neurolysis on carpal tunnel pain

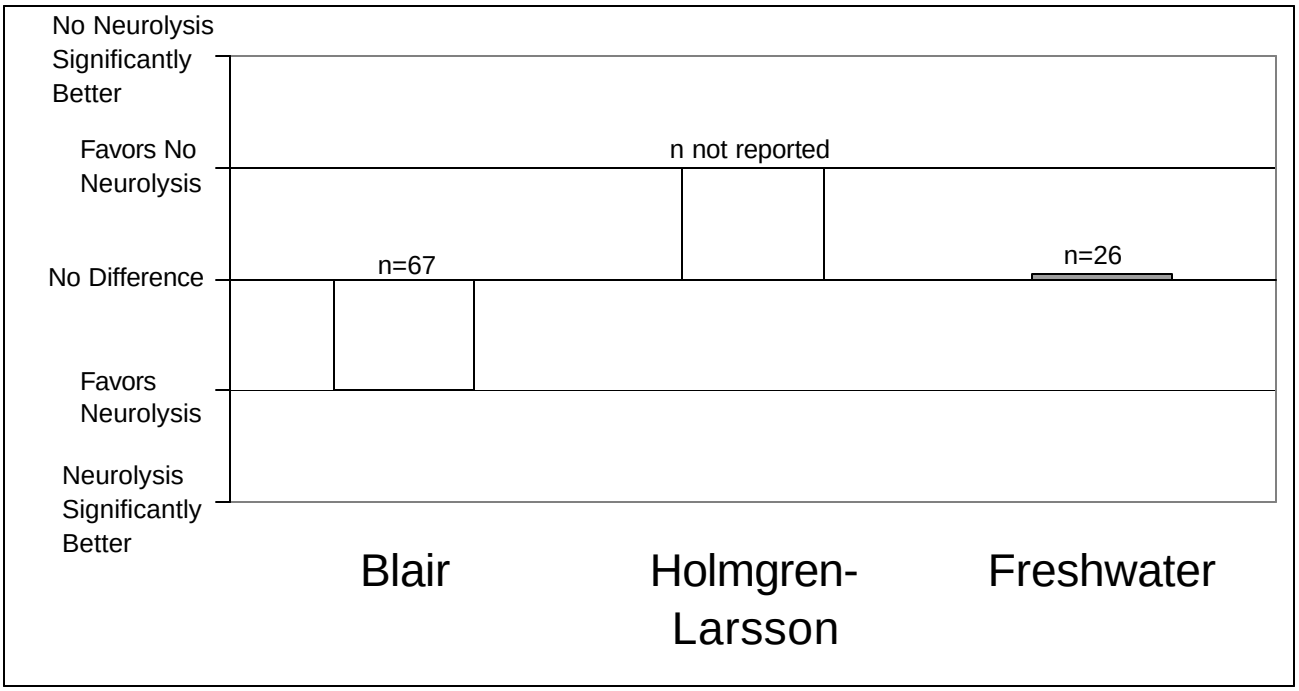
Study	Number of Hands	Pain	Statistical Significance of Difference Between Groups
Blair, 1996 [428]	Open Release 27 Release and Neurolysis 48 (Hands)	Preop: 25 had pain Unimproved: 0 Improved: 8 (32%) No Pain: 17 (68%) Preop: 42 had pain Unimproved: 1 (2.4%) Improved: 5 (12%) No Pain: 36 (86%)	Not significantly different by chi square test conducted by ECRI, p = 0.11
Holmgren-Larsson, 1985 [433]	48 Hands total; number in each group not reported. Open release Preop. 3-4 Weeks 6 Months Release and neurolysis Preop. 3-4 Weeks 6 Months	Percent of patients reporting pain 78 0 0 85 4 13	Not reported
Freshwater, 1978 [426]	 Open Release 12 Release and Neurolysis 14 Open Release 12 Release and Neurolysis 14	Patients with wrist pain: Preop: 2; Postop: 1 Preop 4; Postop: 1 Patients with night-waking pain and tenderness: Preop: 12; Postop: 0 Preop: 14; Postop: 0	Not significantly different by chi square test conducted by ECRI, p = 0.91 Not significantly different by chi square test conducted by ECRI, p = 0.97

Table 78. Summary of the effect of neurolysis on pain

Study	Which Procedure led to less pain?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Blair, 1996 [428]	Neurolysis	No	28%	-0.57 (-1.23-0.10)
Holmgren-Larsson, 1985 [433]	No Neurolysis	No	Not calculable	Not calculable
Freshwater, 1978 [426]	No difference	No	Not calculable	0.08 (-2.12-2.28)

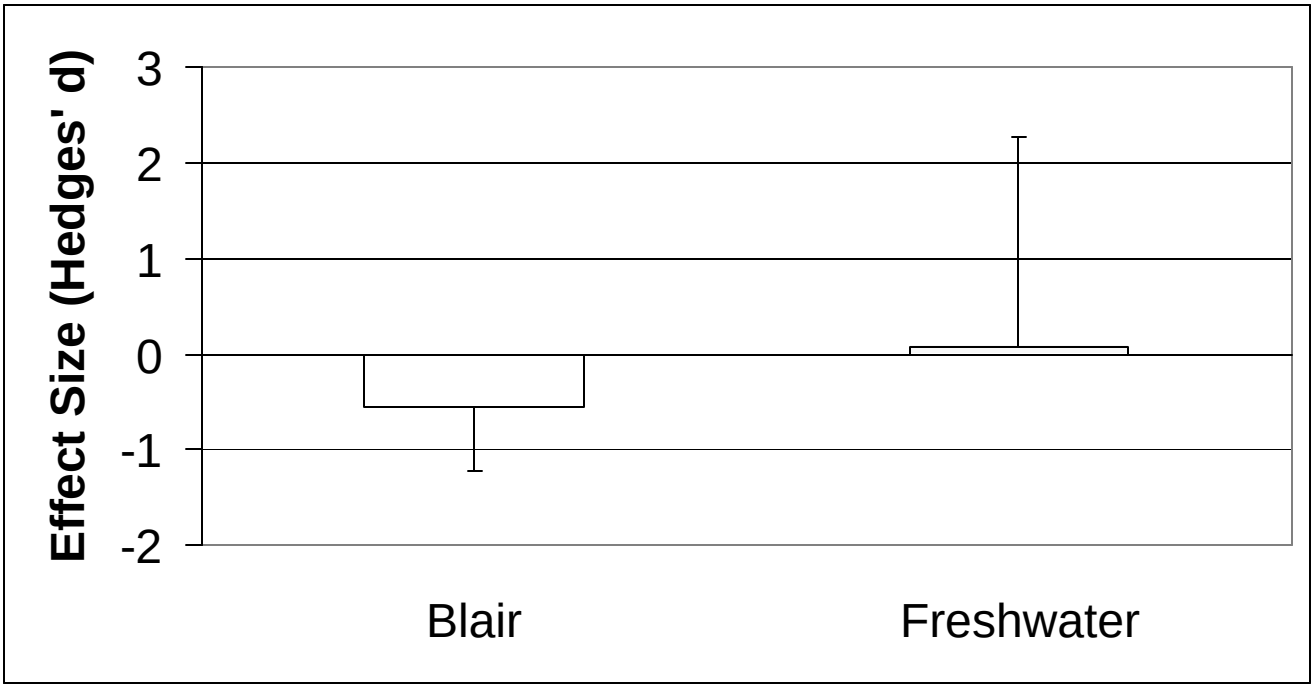
a: Calculated by ECRI

Figure 36. Summary of effect of neurolysis on pain



An open bar indicates an RCT, a striped bar indicates a CT.

Figure 37. Size of effect (Hedges' d) of neurolysis on pain



Function

Two randomized controlled trials of carpal tunnel release with or without neurolysis reported measures of function. Both included patients treated for bilateral CTS, and both had high (36%-50%) rates of attrition. Their results can be found in Table 79. Foulkes et al. asked patients to rate their hand function on a scale of 0-100, while Blair et al. reported the number of patients having difficulty in three specific activities. As can be seen in Table 80 and Figure 38, neither study found a statistically significant difference between groups, and no clear trends can be observed favoring one group or the other. Differences between groups are small, and, in the case of Blair, would have to be large (at least 44%) before the study would have the statistical power to find them significant.

Table 79. Effect of neurolysis on hand function

Study	Number of Patients	Function	Statistical Significance of Difference Between Groups
Blair et al., 1996 [428]		Patients having difficulty:	There were no significant differences between groups before or after treatment (test not reported)
		Screwing Lids:	
	Open Release 27	Preop: 25 (92.5%) 24 Months: 11 (40.7%)	
	Release and Neurolysis 48	Preop: 41 (85.4%) 24 Months: 15 (31.3%)	
		Picking up small objects:	
	Open Release 27	Preop: 18 (66.7%) 24 Months: 10 (37.0%)	
	Release and Neurolysis 48	Preop: 27 (56.3%) 24 Months: 9 (18.8%)	
		Lifting:	
	Open Release 27	Preop: 15 (55.6%) 24 Months: 7 (25.9%)	
	Release and Neurolysis 48	Preop: 25 (52.1%) 24 Months: 9 (18.8%)	
	(Hands)		
Foulkes et al., 1994 [376]		Function rating (0-100)	Not reported
	Open Release 8	Preop: 41 29 Months: 89	
	10	Recalculated[a]: 79.4	
	Release and Neurolysis 15	Preop: 34 29 Months: 88	
	26	Recalculated: 65.2	

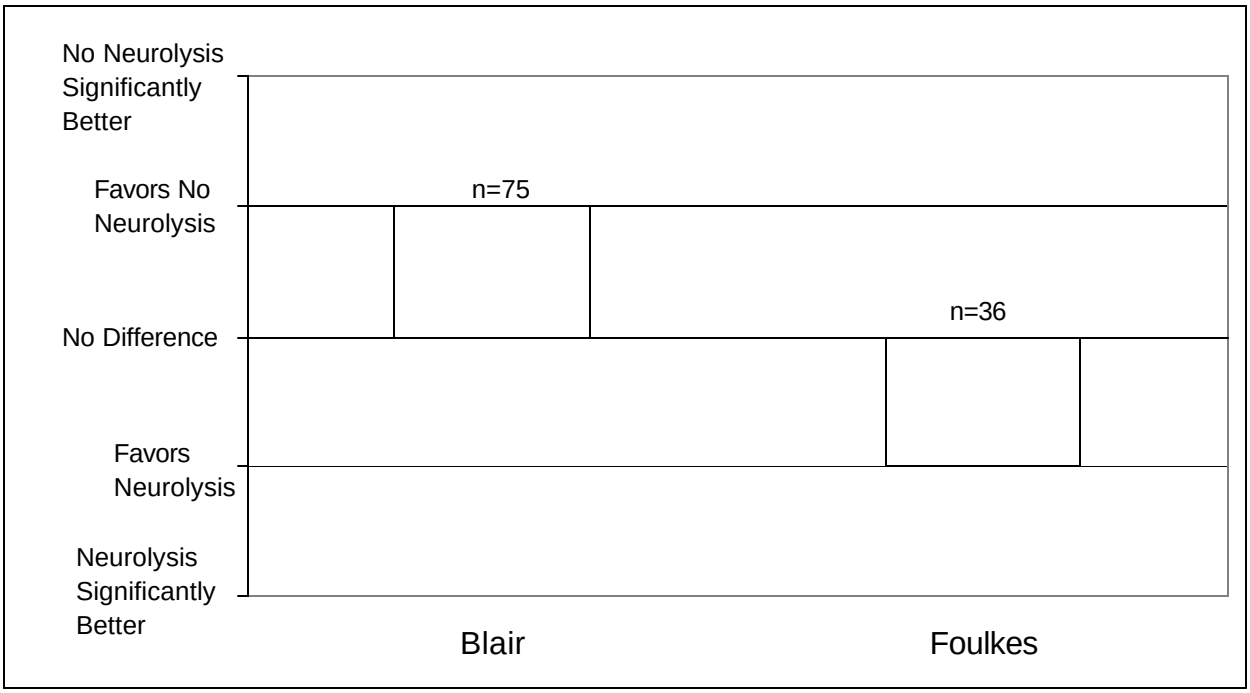
[a]: Recalculated by ECRI according to intent to treat principles by making the conservative assumption that the two patients lost to followup in the open release group had function ratings of 41 at 29 months, and the 11 lost to followup in the neurolysis group had function ratings of 34.

Table 80. Summary of effect of neurolysis on hand function

Study	Which Procedure led to superior function?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)
Blair, 1996 [428]	Neurolysis	No	Screwing Lids: 62% Picking up objects: 57% Lifting: 44%	Not calculable
Foulkes, 1994 [376]	Open release	Not reported	Not calculable	Not calculable

a: Calculated by ECRI

Figure 38. Summary of effect of neurolysis on hand function



Quality of Life

No studies reported on this outcome.

Harms

Only two randomized controlled trials reported on complications and adverse effects among patients receiving neurolysis. One of these had 50% attrition.[376] These trials are listed below in Table 81. One controlled trial and one retrospective trial reported that there were no complications.[415,426] There are insufficient data to allow one to reach an evidence-based conclusion.

Table 81. Complications in controlled trials of neurolysis for patients with carpal tunnel syndrome

Study	Group n	Complication	Number of patients reporting
Foulkes, 1994 [376]	No Neurolysis 8 Hands	Infection	0
	Neurolysis 15 Hands	Infection	2
Lowry, 1988 [429]	No Neurolysis 23	Persistent incisional pain	3
		Hand swelling	0
		Causalgia	1
	Neurolysis 24	Persistent incisional pain	4
		Hand swelling	1
		Causalgia	0

Conclusion

The available evidence suggest there is little or no benefit from performing neurolysis along with surgical release of the carpal tunnel. Meta-analysis of global outcomes demonstrates a benefit from not performing neurolysis that was not apparent from examination of the individual studies. Available return to work data also shows a trend toward an advantage of not performing neurolysis. There are insufficient data to allow one to reach an evidence-based conclusion, on the effect of neurolysis on pain or function. The possibility remains that neurolysis may be helpful is special cases, such as in the presence of marked scarring or neural adhesion, but no available evidence specifically documents the benefits and harms of neurolysis among such patients.

What are the relative benefits and harms of steroid injection into the carpal tunnel for persons with carpal tunnel syndrome?

Four prospective, randomized controlled trials describing 261 patients reported on the effect of steroid injections into the carpal tunnel.

Internal Validity

Three studies of steroid injections were double-blinded,[36,452,453] and one was unblinded.[427] Three studies assessed only one hand per patient, while Girlanda et al. assessed 53 hands in 32 patients.[36] This study therefore violated the statistical principle of independence between subjects. All four studies had no attrition and full compliance. Data on study internal validity may be found in Table 82.

Generalizability

None of the studies reported patient comorbidities, except when some comorbidities were excluded, as indicated by a zero in Table 83. Dammers, et al. excluded patients with mild disease.[452] Results in this study may therefore be different from results in others. None of the studies provided information about patient employment characteristics.

Table 82. Internal validity of studies of steroid injection for carpal tunnel syndrome

Study	Number of patients	Percent of patients with bilateral CTS	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
O'Gradaigh, 2000 [454]	123	0%	Single	Not reported	RCT	No	0	Yes	100
Dammers, 1999 [452]	60	0%	Single	No	RCT	Double	0	Yes	100
Girlanda, 1993 [36]	32	65.6%	Single	Not reported	RCT	Double	0	Yes	100
Ozdogan, 1984 [453]	37	0%	Single	Not reported	RCT	Double	0	Yes	100

Table 83. Generalizability of studies of steroid injection for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
O'Gradaigh, 2000 [454]	123	NR	NR	NR	NR	NR	0	NR	NR	NR	NR	No	No
Dammers, 1999 [452]	60	52	83.3	29	NR	NR	NR	NR	NR	NR	NR	No	Yes
Girlanda, 1993 [36]	32	45.5	81.3	53.5 (1-240)	0	0	NR	0	0	NR	0	No	No
Ozdogan, 1984 [453]	37	47.0	100	45.6	0	0	0	NR	NR	NR	0	No	No

Global outcome

One study compared steroid injection with no treatment,[454] two compared steroid injection with placebo (saline or lidocaine),[36,452] and one compared carpal tunnel injection with intramuscular injection.[453] Two therefore controlled for a possible placebo effect, while one is considered a comparison of treatments, as intramuscular steroid injection may exert an effect.

The results of the four trials may be found in Table 84. Because effect sizes could only be calculated for three studies, we did not perform a meta-analysis. After treatment, global outcomes were significantly higher in all treated groups (as compared to untreated) in the study by O'Gradaigh et al., but were not significantly different from each other at 6 weeks or 6 months (chi square tests conducted by ECRI). The difference from untreated remained statistically significant after applying the Bonfferoni correction for multiple statistical tests (critical $p = 0.004$).

Similarly, Dammers found that treated groups were significantly different from placebo groups at both time points reported,[452] while Girlanda reported global scores favoring steroid injection over placebo, but did not report on the statistical significance of this difference. The results of the four trials are summarized in Table 85 and Figure 39.

Both studies that reported longer followup times (>6 months) found that the effect of steroid injection declined over time. The period of relief that can be expected by the average patient cannot be determined from the available data.

The differences in effect sizes between studies may be explained by the differences in the groups to which steroid injection into the carpal tunnel is being compared. The largest effect sizes, ranging from 1.62 to 2.11, are found in the study by O'Gradaigh, who compared steroid injection to no treatment. The next largest (1.40-1.44) are in the study by Dammers, who compared steroid injection to placebo injection. If the placebo exerted a placebo effect, the difference between groups, and thus the effect size, would be smaller than that found in a study comparing treated and untreated groups. The smallest effect sizes (0.25-0.28) are found in the study by Ozdogan, who compaired steroid injection into the carpal tunnel with another active treatment, intramuscular steroid injection. Ozdogan thus tests not whether steroid injection into the carpal tunnel is effective, but whether it exerts an effect superior to that of intramuscular injection.

Table 84. Effect of steroid injection on global outcome

Study	Number of Patients		Global Outcome	Statistical Significance of Difference Between Groups
O'Gradaigh, 2000 [454]			Patients showing improvement of symptoms	Treatments were superior to controls at either time point by chi square test, p <0.05
			6 Weeks:	Treatments were not significantly different from each other at either time point by chi square test, p >0.05.
	No Injection	20	1 (5.0%)	
	20 mg Triamcinolone	18	13 (72.2%)	
	25 mg Hydrocortisone	32	21 (65.6%)	
	100 mg Hydrocortisone	53	34 (64.1%)	
			6 Months:	
	No Injection	20	0 (0%)	
	20 mg Triamcinolone	18	8 (44.4%)	
	25 mg Hydrocortisone	32	14 (43.8%)	
	100 mg Hydrocortisone	53	17 (32.1%)	
Dammers, 1999 [452]			Patients with No symptoms or minor symptoms	Treatments were significantly different at both time points (p = 0.000011 and 0.0002 respectively, chi square test conducted by ECRI)
			1 Month	
	Placebo (10 mg Lignocaine)	30	6 (20.0%)	
	10 mg Lignocaine and 40 mg Methylprednisone	30	23 (76.7%)	
			12 Months	
	Placebo (10 mg Lignocaine)	30	2 (6.7%)	
	10 mg Lignocaine and 40 mg Methylprednisone	30	15 (50.0%)	
Girlanda, et al., 1993 [36]			Mean symptom score (0-10)	Not reported
			Pretreatment:	
	Placebo (Saline)	26	9	
	15 mg Methylprednisone	27	8	
			1 Week	
	Placebo (Saline)	26	7	

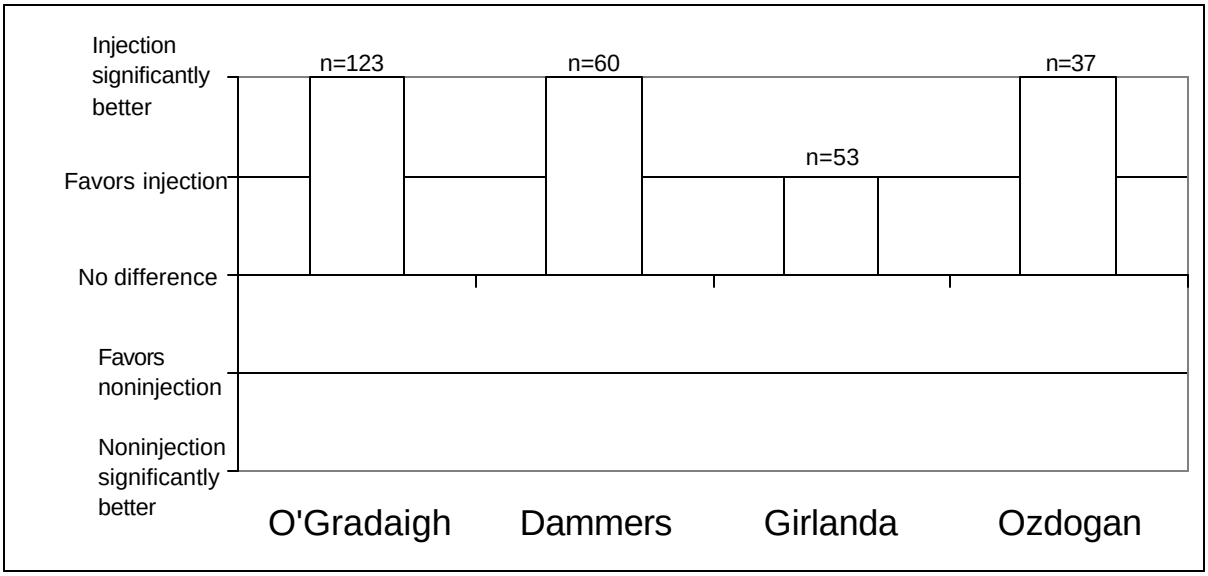
Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
	15 mg Methylprednisone 27	3	
		2 Months	
	Placebo (Saline) 26	8	
	15 mg Methylprednisone 27	1.5	
Ozdogan and Yazici, 1984 [453]		Pretreatment::	
	1.5mg Betamethasone in the deltoid muscle 19	Severe 13 Moderate 4 Minimal 2 No Symptoms 0	Groups were not significantly different, p = 0.83, chi square test conducted by ECRI
	1.5mg Betamethasone in the carpal tunnel 18	Severe 11 Moderate 6 Minimal 1 No Symptoms 0	
		1 Week:	
	1.5mg Betamethasone in the deltoid muscle 19	Severe 5 Moderate 2 Minimal 8 No Symptoms 4	Groups were not significantly different, p = 0.25, chi square test conducted by ECRI.
	1.5mg Betamethasone in the carpal tunnel 18	Severe 2 Moderate 3 Minimal 8 No Symptoms 5	
		1 Month:	
	1.5mg Betamethasone in the deltoid muscle 19	Severe 8 Moderate 8 Minimal 2 No Symptoms 1	Groups were significantly different, p = 0.009, chi square test conducted by ECRI
	1.5mg Betamethasone in the carpal tunnel 18 18	Severe 6 Moderate 3 Minimal 0 No Symptoms 9	

Table 85. Summary of effect of steroid injection on global outcome

Study	Which Procedure led to Superior Global Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
O'Gradaigh, 2000 [454]	Injection	Yes	20 mg Triamcinolone 22% 25 mg Hydrocortisone 18% 100 mg Hydrocortisone 17%	20 mg Triamcinolone 6 Weeks: 2.11 (0.86 – 3.35) 6 Months: 1.89 (0.27 – 3.52) 25 mg Hydrocortisone 6 Weeks: 1.95 (0.77 - 3.13) 6 Months: 1.88 (0.29 – 3.48) 100 mg Hydrocortisone 6 Weeks: 1.92 (0.77 – 3.07) 6 Months: 1.62 (0.05 – 3.20)
Dammers, 1999 [452]	Injection	Yes	16%	1 Month: 1.40 (0.720-02.08) 12 Months: 1.44 (0.55 – 2.32)
Girlanda, 1993 [36]	Injection	Not reported	Not calculable	Not calculable
Ozdogan, 1984 [453]	Injection	At 1 month only	Not calculable	1 Week: 0.25 (-0.39 – 0.90) 1 Month: 0.28 (-0.37 – 0.40)

[a]: Calculated by ECRI

Figure 39. Summary of effect of injection on global outcome



Return to Work

No studies reported this outcome.

Return to Activities of Daily Living

No studies reported this outcome.

Pain

No studies reported this outcome.

Function

No studies reported this outcome.

Quality of Life

No studies reported this outcome.

Harms

No side effects or complications were described by any of the reports. This does not necessarily indicate that there were no such occurrences. Only Dammers et al. specifically stated that there were no side effects.[452]

Conclusions

The results of these four studies indicate that injection of steroid into the carpal tunnel yields superior global outcomes than no treatment or placebo. Although the short-term (1 week) effect of carpal tunnel injection was not superior to intramuscular injection in the trial by Ozdogan and Yazici, the effects of injection may last longer.[453] Carpal tunnel injection was significantly better than intramuscular injection at a longer (1 month) followup time. Because no further time points were reported, we are unable to determine whether this difference persists beyond this time.

There are no data available that indicate whether any type of steroid may be superior to any other, or whether any particular dose is optimum. Although it is clear that the effects of steroid injection wear off after time, there is no information indicating the expected duration of relief for the average patient, or whether any patients can expect to experience permanent relief.

What are the relative benefits and harms of oral medications for persons with carpal tunnel syndrome?

Oral medications, including steroids, nonsteroidal anti-inflammatory drugs (NSAIDs) and diuretics have been used to treat carpal tunnel syndrome.

Internal Validity

Two prospective, double-blinded randomized controlled trials describing 109 patients reported the effects of oral medications on carpal tunnel syndrome.[35,455] Study characteristics affecting internal validity are listed in Table 86.

All results were reported per patient, rather than per hand. Therefore, there was no violation of the statistical assumption of independence. Both reports described only patients who completed the treatment. There was a 20% attrition before final followup in the study by Chang, including 7 patients who underwent carpal tunnel surgery during the course of the study. The study by Herskovitz reported a 16.7% attrition rate, including two patients from the prednisone group and one from the placebo group. This attrition may have resulted in an increase in the apparent effectiveness of the drugs, as patients who are unsatisfied with their treatment may have been more likely to drop out of the study. The seven patients described by Chang et al. who underwent surgery were clearly unsatisfied with the results of their medication. Neither trial provided a measure of patient compliance. Therefore it is unknown whether or how often the patients took their medication.

Generalizability

Patients were middle-aged (mean 46.3 years) and predominantly female (58%-80%). Both excluded patients with mild and severe CTS. Herskovitz included patients with diabetes and arthritis, while these patients were excluded from the study by Chang. This exclusion limits both the generalizability of the study and the extent to which the results of the two studies can be compared and combined. Patient characteristics from the two studies are presented in Table 87. Neither study described patient employment characteristics.

One trial compared oral prednisone with placebo,[455] while the other compared prednisolone, tenoxicam, trichlormethiazide and placebo.[35] These drugs and dosages are described in Table 88. The two studies tested different drugs. However, both report the effects of an anti-inflammatory steroid, and these results are to some extent comparable.

Table 86. Internal validity of studies of oral medication for carpal tunnel syndrome

Study	Number of patients	Percent of patients with bilateral CTS	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Chang, 1998 [35]	91	0%	Single	Not reported	RCT	Double	18	No	NR
Herskovitz, 1995 [455]	18	0%	Single	Not reported	RCT	Double	3	No	NR

Table 87. Generalizability of studies of oral medication for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Chang, 1998 [35]	91	45.7	58.2	NR	0	0	NR	NR	0	0	NR	Yes	Yes
Herskovitz, 1995 [455]	18	49.6	80.0	20.6	6.6	6.6	NR	0	0	NR	NR	Yes	Yes

Table 88. Oral drugs used to treat carpal tunnel syndrome in controlled studies

Drug	Dose	Description
Prednisone	20mg/day for 1 week, then 10mg/day for 1 week	An anti-inflammatory steroid
Prednisolone	20mg/day for 2 weeks, then 10mg/day for 2 weeks	An anti-inflammatory steroid
Tenoxicam	20mg/day for 4 weeks	A nonsteroidal anti-inflammatory drug (NSAID)
Trichlormethiazide	2mg/day for 4 weeks	A diuretic, used to reduce swelling and lower carpal tunnel pressure

Results

Global outcome

Both studies reported global symptom scores. This was the mean of five symptom severity ratings on a scale of zero to ten. The symptoms rated were pain, numbness, paresthesia, weakness/clumsiness and nocturnal awakening. These data are summarized in Table 89. As can be seen in Table 90 and Figure 40, both reports found statistically significant decreases in symptom scores among patients treated with steroids compared to placebo controls. However, Herskovitz et al. reported that symptoms returned after the cessation of treatment. In neither study did symptom scores approach zero, indicating that although there was some relief, symptoms were still present. Chang et al. reported a 64% mean decrease in global symptom scores, while Herskovitz et al reported a 68% decrease. Neither paper indicated whether the patients were satisfied with their level of symptom relief.

When the data were recalculated to account for patient attrition, the steroid groups in both studies still showed a greater than 50% reduction in global symptom scores. However, because we are unable to accurately estimate the standard deviations around the recalculated means, we are unable to determine whether the difference remains statistically significant. The number of patients reporting symptom relief in the report by Herskovitz is not statistically significantly different between groups once we attempted to compensate for patient attrition by assuming that patients for whom there was no data did not improve.

In the study by Chang, neither the diuretic nor the NSAID caused statistically significant symptom relief compared to placebo control. However, a single small trial with high loss to followup is not sufficient proof that these agents have no effect. Moreover, only a single dosage of each drug was tested. There are no published data on the effectiveness of these agents at other dosages. The power of the study by Chang was sufficient to detect medium-sized (20-30%) differences between groups. The differences between placebo and steroid were greater than this, while the differences between the other groups and placebo were too small to be statistically significant with the available power.

The study by Herskovitz had fewer patients than the study by Chang. Although the statistical power of this study to detect differences in global symptom score could not be calculated, it was likely lower than that of Chang. The study by Herskovitz had the power to detect only a large (49%) difference between number of improved patients in each group. Because of this low power and high attrition, we are unable to determine whether oral steroids lead to a statistically significant improvement in global outcome.

Table 89. Effect of oral medications on global outcome of carpal tunnel syndrome

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Chang, et al., 1998 [35]		Mean global symptom score[a]	
	Placebo 16	Baseline: 22.9±5.9 2 Weeks: 21.6±6.4 4 Weeks: 20.8±6.6	Symptom reduction among patients receiving steroid was significantly greater at 2 weeks than among patients in the other three groups (F = 7.37, p = 0.0002) Symptom reduction among patients receiving steroid was significantly greater at 4 weeks than among patients in the other three groups (F = 10.7, p = 0.0001) NSAID and diuretic groups were not significantly different from placebo at either time point.
	Diuretic 16	Baseline: 26.0±3.8 2 Weeks: 22.3±5.5 4 Weeks: 21.6±6.3	
	NSAID 18	Baseline: 29.7±8.4 2 Weeks: 24.7±8.6 4 Weeks: 24.0±9.7	
	Steroid 23 (Prednisolone)	Baseline: 27.9±6.9 2 Weeks: 15.0±6.8 4 Weeks: 10.0±7.5	
	Recalculated[b]	Recalculated[b]	
	Placebo 23	Baseline: 22.9 2 Weeks: 22.0 4 Weeks: 21.4	
	Steroid 26	Baseline: 27.9 2 Weeks: 16.5 4 Weeks: 12.1	
Herskovitz, et al., 1995 [455]		Mean global symptom score[a]	
	Placebo 9	Baseline: 23 2 Weeks: 19 4 Weeks: 17 8 Weeks: 16.5	Groups were significantly different only at 2 weeks (p <0.05, t-test)

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
	Steroid 6 (Prednisone)	Baseline: 25 2 Weeks: 8 4 Weeks: 11 8 Weeks: 20	
	Recalculated[b]	Recalculated[b]	
	Placebo 10	Baseline: 23 2 Weeks: 19.4 4 Weeks: 17.6 8 Weeks: 17.2	
	Steroid 8	Baseline: 25 2 Weeks: 12.3 4 Weeks: 14.5 8 Weeks: 21.3	
		Number of patients reporting improvement in symptoms:	Numbers were the same for all time points, and were significantly different between groups (p = 0.02, test not reported)
	Placebo 9	3	Improvement rates were no longer statistically significant if the two patients from the steroid group and one from the placebo group who were not reported on were assumed not to have improved, p = 0.058 by chi square test conducted by ECRI.
	Steroid 6 (Prednisone)	6	

a: The sum of severity ratings (scale 0-10) for 5 symptoms: pain, numbness, paresthesia, weakness/clumsines s, and nocturnal wakening

b: Recalculated to account for patient attrition using the conservative assumption that patients for whom no data was provided had scores equal to the mean baseline score for that group.

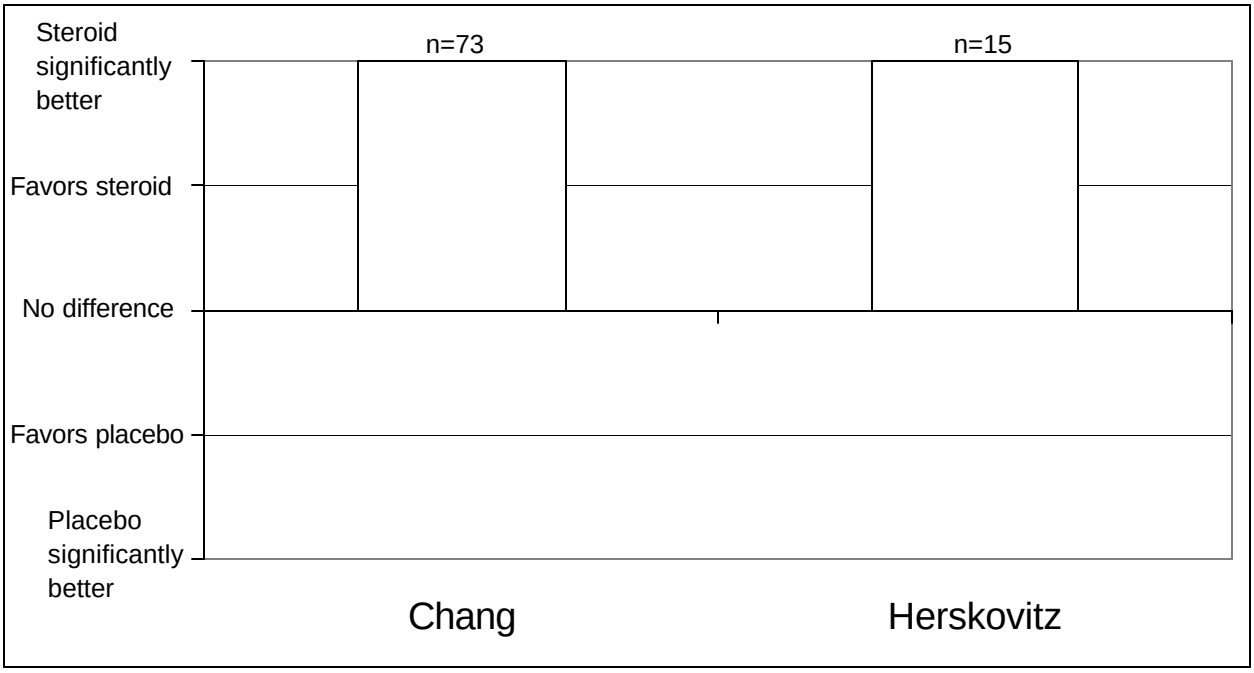
Table 90. Summary of effect of oral medications on global outcome of carpal tunnel syndrome

Study	Which Medication led to Superior Global Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Chang, 1998 [35]	Steroid	Yes	Diuretic 2 Weeks: 20.0% 4 Weeks: 22.4% NSAID 2 Weeks: 24.6% 4 Weeks: 27.9% Steroid 2 Weeks: 20.2% 4 Weeks: 22.4%	Diuretic 2 Weeks: -0.11 (-0.81 – 0.58) 4 Weeks: -0.12 (-0.81 – 0.57) NSAID 2 Weeks: -0.40 (-1.08 – 0.28) 4 Weeks: -0.37 (-1.05 – 0.31) Steroid 2 Weeks: 0.97 (0.30 – 1.65) 4 Weeks: 1.48 (0.76 – 2.20)
Herskovitz, 1995 [455]	Steroid	Yes	Global Symptom Score Not calculable Number of Patients Improved 49%	Global Symptom Score 2 Weeks: 1.08 (-0.03 – 2.18)[b] Number of Patients Improved 1.65 (-0.09 – 3.39)

a: Calculated by ECRI

b: Estimated by ECRI based on the conservative assumption that p = 0.049.

Figure 40. Summary of effect of oral steroids on global outcome



Return to Work

Neither study reported this outcome.

Return to Activities of Daily Living

Neither study reported this outcome.

Pain

Because the study by Chang did not report this outcome, only the effect of oral steroids can be considered. Herskovitz et al. reported that improvement in pain scores was significantly greater in the steroid group than the control ($p = 0.07$, 0.03 and 0.008 at 2, 4, and 8 weeks, respectively by t-test). Because the raw were not reported, no analysis is possible. Although the differences may be statistically significant, without information regarding their magnitude (effect size), we are unable to determine whether they are clinically significant. Further, the results of a single small trial are insufficient evidence for conclusions to be drawn.

Function

Neither study reported this outcome.

Quality of Life

Neither study reported this outcome.

Harms

Chang et al. reported the number of patients experiencing nausea and epigastric pain, while Herskovitz et al. reported the number experiencing any perceived effect. These results are presented in Table 91. In both studies, numbers of patients reporting side effects were not significantly different between treated groups and placebo groups by chi square test conducted by ECRI ($p > 0.3$). However, there are too few studies to allow one to reach a firm evidence-based conclusion about the side effects experienced by patients with carpal tunnel syndrome who are given oral medications.

Table 91. Side effects of oral medications for carpal tunnel syndrome

Study	Group	Complication	Number of patients experiencing complication
Chang, et al., 1998 [35]	Placebo 16	Nausea Epigastric pain	1 2
	Diuretic 16	Nausea Epigastric pain	0 2
	NSAID 18	Nausea Epigastric pain	3 3
	Steroid 23 (Prednisolone)	Nausea Epigastric pain	3 2
Herskovitz, et al., 1995 [455]	Placebo 9	Nausea/abdominal discomfort, constipation, insomnia, headache, dysuria, and burning nostrils	3
	Prednisone 6	Nausea/abdominal discomfort, constipation, dysgeusia, mild hypoglycemia	3

Conclusions

Two double-blinded randomized controlled trials suggest that oral steroids may lead to a reduction in symptoms of CTS. A single published randomized controlled trial indicates that oral tenoxicam and trichlormethiazide do not reduce the symptoms of CTS under the dosing regimens described. The effects of oral steroids are short-lived and may not be sufficient for patient satisfaction. There are no published controlled trials describing the effects of higher doses or longer treatment regimens.

What are the relative benefits and harms of oral and locally injected corticosteroids for persons with carpal tunnel syndrome?

A single randomized, double-blinded trial of 60 patients compared oral steroids with a single injection of steroid into the carpal tunnel. Patients in the steroid injection group received a single injection of 15mg methylprednisolone acetate directly into the carpal tunel and instructed to take placebo pills daily for 10 days. The oral steroid group received an injection of saline into the carpal tunnel, and took 25 mg of prednisolone daily for 10 days.

Internal Validity

Factors affecting internal validity are listed in Table 92. Although 14 patients had bilateral CTS, all results are reported per patient, rather than per effected hand. Therefore, there is no violation of the statistical assumption of independence. Whether patients with bilateral CTS received injections into both wrists was not reported. The effect of bilateral CTS on a patient's global symptom score (the only outcome measure reported) is not known. Patients with bilateral CTS may rate themselves as having more severe CTS than patients with only one arm affected. Bilateral patients were evenly distributed between groups by chi square test conducted by ECRI ($p = 0.54$). There was no patient attrition. Therefore, there was no violation of the intent-to-treat principle. However, the rate at which patients complied with instructions and took their oral medications was not reported.

Generalizability

Patient age and sex was consistent with the overall population of CTS patients as described in the introduction under Epidemiology. However, this study excluded patients with comorbidities, those with severe disease, and those with mild disease. These exclusions may limit the generalizability of the results of this study. Patient characteristics affecting generalizability are listed in Table 93.

Table 92. Internal validity of the study comparing oral and injected steroids

Study	Number of patients	Percent bilateral patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Wong, 2001 [456]	60	23.3%	Single	Not Reported	RCT	Double	0	Yes	NR

Table 93. Generalizability of the study comparing oral and injected steroids for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Wong, 2001 [456]	60	49	88.3%	NR	0	0	0	0	0	0	0	Yes	Yes

Results

Global Outcome

The outcome measure was global symptom score, the sum of ratings (0 to 10) of pain, numbness, paresthesia, weakness/clumsiness and nocturnal awakening. These scores are given in Table 94, and the results are summarized in Table 95. This outcome was statistically significantly different between groups at 8 weeks and 12 weeks. The difference between groups at two weeks was smaller than the study had the power to detect.

Table 94. Relative effect of steroid injection and oral steroids on global outcome of CTS

Study	Number of Patients	Global Symptom Score	Statistical Significance of Difference Between Groups
Wong, 2001 [456]	Injection 30		Groups were significantly different at 8 weeks and 12 weeks by t-test conducted by ECRI.
	Pretreatment	25.00±6.41	
	2 Weeks	13.57±7.47	
	8 Weeks	13.67±8.27	
	12 Weeks	14.30±8.42	
	Oral 30		
	Pretreatment	25.73±8.31	p = 0.705
	2 Weeks	17.77±9.98	p = 0.070
	8 Weeks	20.83±8.73	p = 0.0019
	12 Weeks	21.40±9.64	p = 0.0036

Table 95. Summary of the relative effect of steroid injection and oral steroids on global outcome of CTS

Study	Which Procedure led to Superior Global Outcome?	Was the Difference Statiscally Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Wong, 2001 [456]	2 Weeks: Injection	No	21%	0.47 (-0.09-1.03)
	8 Weeks: Injection	Yes	21%	0.831. (0.25-1.41)
	12 Weeks: Injection	Yes	22%	0.77 (0.20-1.35)

a: Calculated by ECRI

Return to Work

This study did not report this outcome.

Return to Activities of Daily Living

This study did not report this outcome.

Pain

This study did not report this outcome.

Function

This study did not report this outcome.

Quality of Life

This study did not report this outcome.

Harms

Harms reported among the two groups are given in Table 96. Steroid and placebo injection led to injection pain in two patients each. All other side effects were reported to have been experienced by the oral steroid group only. The difference in occurrence of side effects between groups was statistically significant by chi square test conducted by ECRI ($p = 0.0195$).

Table 96. Reported harms of injected and oral steroids

Study	Group	Complication	Number of patients experiencing complication
Wong, 2001[456]	Injected 30	Injection pain	2
		Increased appetite	0
		Bloating	0
		Insomnia	0
	Oral 30	Injection pain	2
		Increased appetite	3
		Bloating	2
		Insomnia	2

Conclusions

Although only a single study, this study had high internal validity, providing evidence that, under the conditions of the experiment, steroid injection leads to greater reduction of symptoms with fewer side effects than oral steroid. The experiment is short-term (12 weeks) and does not address the issue of whether the effect of injection remains effective at longer time points. Further, it does not address whether continued treatment with oral steroids leads to further benefits or harms to the patient.

What are the relative benefits and harms of physical therapy for persons with carpal tunnel syndrome?

Two randomized controlled trials describing 121 patients reported on the effects of various forms of physical therapy. Tal-Akabi and Rushton compared groups receiving nerve mobilization, groups receiving bone mobilization and a no-treatment control group.[457] Provinciali et al. compared a program of physical therapy including strengthening exercises, massage, gliding exercises and sensory re-training to instruction in a program of home-based strengthening exercises.[427]

Internal Validity

The study by Provinciali was rater-blinded, while the other was unblinded. Trial characteristics affecting internal validity are listed in Table 97. Neither study had any reported attrition, and neither reported on patient compliance.

Generalizeability

In both studies, patients were predominantly middle-aged (mean 54.8 years) and female (67%-82%), as reported in Table 98. This is consistent with the overall population with CTS as described in the introduction under Epidemiology. Tal-Akabi excluded patients with comorbidities, while Provincialli did not report comorbidities. Both studies excluded patients with mild disease. This may limit generalizability, as patients with mild disease are more likely to receive noninvasive treatments such as physical therapy than patients with severe disease, who may be candidates for surgery. Neither study reported patient employment characteristics.

Table 97. Internal validity of studies of physical therapy for carpal tunnel syndrome

Study	Number of patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Provinciali, 2000 [427]	100	Single	Not reported	RCT	Rater	0	Yes	NR
Tal-Akabi, 2000 [457]	21	Not Reported	Not reported	RCT	No	0	Yes	NR

Table 98. Generalizability of studies of physical therapy for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Provincialli, 2000 [427]	100	56.45 (24-86)	82.0	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes
Tal-Akabi, 2000 [457]	21	47.1 (29-85)	66.6	27.6 (12-36)	0	0	0	0	0	0	NR	No	Yes

Results

Global Outcome

Global outcome was assessed in the study by Tal-Akabi and Rushton as the number of patients who did or did not go on to receive surgery after treatment. All patients had been drawn from a waiting list for surgery, which may eliminate factors such as economic status that might have influenced the patients' willingness to undergo surgery. Results are presented in Table 99, and summarized in Table 100. Outcomes of the two treated groups were not significantly different from each other ($p = 0.51$ by chi square test conducted by ECRI), but both the neurodynamic and carpal bone mobilization groups had significantly fewer patients going on to surgery than control ($p = 0.03$ and 0.008, respectively). Although differences between the treated groups and the control group were large enough to be statistically significant, the study lacks the statistical power required to demonstrate significant differences between-treatment groups. With only seven patients per group, a statistically significant effect can be detected only when there is at least a 50% difference between groups.

Table 99. Global outcome of physical therapy for carpal tunnel syndrome

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Tal-Akabi and Rushton, 2000 [457]		Global Score (Number of patients going on to receive surgery)	The two treated groups were not significantly different from each other (p = 0.51 by chi square test conducted by ECRI); both were significantly different from control (p = 0.03 and 0.008, respectively).
	Neurodynamic mobilization 7	2	
	Carpal Bone mobilization 7	1	
	No treatment (Control) 7	6	

Table 100. Summary of Global outcome of physical therapy for carpal tunnel syndrome

Study	Which Procedure led to Superior Global Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Tal-Akabi, 2000 [457]	Carpal bone mobilization	Yes	50%	Neurodynamic mobilization 1.40 (-0.08 – 2.87) Carpal bone mobilization 1.85 (0.20 – 3.50) Difference between-treatment groups 0.45 (-1.42-1.93)

[a]: Calculated by ECRI

Return to work

A single study reported time to return to work. Provincialli et al. reported that patients receiving physical therapy returned to work earlier than patients assigned to home exercise.[427] As can be seen in Table 101, the difference was statistically significant, but the number of patients for whom this measurement was taken was not reported. Further, it is unclear exactly what was measured. These numbers are described both as time to return to daily activities and time to return to work. These ambiguities render it difficult to draw conclusions from these data.

Table 101. Time to return to work after physical therapy for carpal tunnel syndrome

Study	Number of Patients	Days until Return to Activities of Daily Living	Statistical Significance of Difference Between Groups
Provincialli et al., 2000 [427]	Physical Therapy Home Exercise Number of patients is unknown because patients receiving workers' compensation were excluded. The number of such patients was not reported.	32.16±10.72 42.55±13.39	Difference was statistically significant by ANOVA (p <0.006)

Return to Activities of Daily Living

This outcome was not reported by either study.

Pain

Both studies reported pain scores. Tal-Akabi and Rushton also reported pain relief scores. These data are given in Table 102. Provincialli et al. found no statistically significant difference between the program of physical therapy and home exercise instructions. Tal-Akabi and Rushton found that one treatment, carpal bone mobilization, but not the other treatment, neurodynamic modulation, led to pain scores statistically significantly lower than those in the control group (p = 0.003 and 0.35 respectively). The two treatment groups were not significantly different from each other (p = 0.18). The study lacked the statistical power to detect the difference between these groups. Only large between-group differences (>50%) could be detected in this study, as can be seen in Table 103. While the differences between carpal bone mobilization and control are large enough to be detected, other between-group differences are not. The fact that carpal bone mobilization led to a statistically significant effect while neurodynamic mobilization did not suggests, but does not prove, that carpal bone manipulation is the superior treatment for pain. Further study is necessary to test the differences between these therapies.

Although pain ratings in the VAS group were not significantly different from control after treatment, differences between pain relief scores were statistically significant. It is unclear which is the superior measure of pain.

Table 102. Effects of nerve and bone mobilization on pain from carpal tunnel syndrome

Study	Number of Patients	Pain	Statistical Significance of Difference Between Groups
Provinciali, 2000 [427]	Physical Therapy 50 Pretreatment 1 Month 2 Months Home Exercise 50 Pretreatment 1 Month 2 Months	Sum of patients' pain ratings (scale not reported) 149 55 50 145 54 50	Groups were not significantly different by chi square test (p >0.001; p-level required for significance adjusted by Provinciali using the Bonferroni correction related to 40 comparisons)
Tal-Akabi, 2000 [457]	Neurodynamic mobilization 7 Carpal Bone mobilization 7 No treatment (Control) 7 Neurodynamic mobilization 7 Carpal Bone mobilization 7 No treatment	Pain (VAS, 0-10) Baseline 2.42±1.51 3 Weeks 1.57±1.4 Baseline 2.29±0.95 3 Weeks 0.71±0.76 Baseline 2.0±1.29 3 Weeks 2.14±0.69 Pain Relief Rating 3.14±1.35 3.71±0.95 0±0	After treatment, the carpal bone mobilization group was significantly different from control by t-test conducted by ECRI (p = 0.003), but the neurodynamic mobilization group was not significantly different from control (p = 0.35) or from carpal bone mobilization (p = 0.18) Not significantly different between the two treated groups (p = 0.38), but both the neurodynamic mobilization group and the carpal bone mobilization group were significantly different from control (p = 0.00005 and 0.0000002, respectively)

Study	Number of Patients	Pain	Statistical Significance of Difference Between Groups
	(Control) 7		

Table 103. Summary of effects of nerve and bone mobilization on pain from carpal tunnel syndrome

Study	Which Procedure led to Less Pain?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Provinciali, 2000 [427]	No difference	No	Not calculable	Not calculable
Tal-Akabi, 2000 [457]	Carpal bone mobilization	Yes	Neurodynamic mobilization: 60% Carpal bone mobilization: 54%	VAS Neurodynamic mobilization 0.48 (-0.62 – 1.58) Carpal bone mobilization 1.84 (0.59 – 3.10) Pain Relief Rating Neurodynamic mobilization 3.08 (1.53 – 4.63) Carpal bone mobilization 5.17 (2.99 – 7.35)

[a]: Calculated by ECRI

Function

In the study by Provincialli, function was measured using a nine-hole peg test. Function scores were not significantly different between groups at any time point.[427] In the study by Tal-Akabi and Rushton, functional scores were based on the impairment rating of the patient's most impaired activity.[457] Thus, a lower score indicates superior function. These scores were not significantly different before treatment. Results are presented in Table 104. After treatment, functional scores in the carpal bone mobilization group were significantly lower than those of the control group ($p = 0.01$), while those of the neurodynamic mobilization group were not ($p = 0.09$). The two treatment groups were not significantly different from each other ($p = 0.57$). As presented in Table 105, the study only had the power to detect large (>50%) differences between groups. Only the difference between carpal bone mobilization and control was large enough to be found statistically significant.

Table 104. Effect of physical therapy on function

Study	Number of Patients	Function	Statistical Significance of Difference Between Groups
Provinciali et al. 2000, [427]	Physical Therapy 50 Pretreatment 12 Days 1 Month 2 Months Home Exercise 50 Pretreatment 12 Days 1 Month 2 Months	Time (units not stated) to complete nine-hole peg test 22.35±5.14 23.8[a] 20.5 19.5 22.38±3.23 20.5 20.5 19	Groups were not significantly different by t-test (p >0.001; p-level required for significance adjusted by Provinciali using the Bonnferoni correction related to 40 comparisons
Tal-Akabi and Rushton, 2000 [457]	Neurodynamic mobilization 7 Carpal Bone mobilization 7 No treatment (Control) 7	Function Score (Range 0-4) Baseline 2.0±1.41 3 Weeks 1.14±1.35 Baseline 2.0±1.41 3 Weeks 0.71±0.76 Baseline 2.42±1.27 3 Weeks 2.42±1.27	After treatment, carpal bone mobilization group was significantly different from control group (p = 0.01) neurodynamic mobilization group was not (p = 0.09). The two treatment groups were not significantly different from each other (p = 0.57). t-tests conducted by ECRI.

[a]: Estimated by ECRI from a published chart

Table 105. Summary of the effect of physical therapy on function

Study	Which Procedure led to Superior Function?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Provinciali, 2000 [427]	No difference	No	Not calculable	Not calculable
Tal-Akabi, 2000 [457]	Carpal bone mobilization	Yes	Neurodynamic mobilization 63% Carpal bone mobilization 50%	Neurodynamic mobilization 0.91 (-0.21 – 2.19) Carpal bone mobilization 1.53 (0.34 – 2.72)

[a]: Calculated by ECRI

Quality of Life

This outcome was not reported by either study.

Harms

No harms were reported by either study.

Conclusions

Manual therapy may have some use in the treatment of carpal tunnel syndrome. A single study suggests that carpal bone mobilization provides pain relief, improves function, and delays or eliminates the need for surgery among patients with carpal tunnel syndrome.[457] Results from neurodynamic mobilization show a similar trend, but because of a lack of statistical power one cannot conclude that this trend is real. For the same reason, differences in effectiveness between these two treatment groups cannot be determined. The study was not placebo-controlled and was not blinded. The observed effects may have been influenced by a placebo effect or rater bias.

A larger, more statistically powerful study found no difference between the effects of a physical therapy program and home exercise instructions on pain or function. However, patients receiving physical therapy returned to work faster than those instructed to exercise at home.

Although these studies indicate a trend toward physical therapy having an effect on carpal tunnel syndrome, they are too small and inconclusive for one to reach a firm evidence-based conclusion.

What are the relative benefits and harms of ultrasound for persons with carpal tunnel syndrome?

One patient-blinded randomized controlled trial describing 18 patients reported on the effects of ultrasound.[33] This study compared two different levels of intensity of ultrasound to placebo.

Internal Validity

Factors affecting the internal validity of this study are listed in Table 106. The data are reported in terms of the number of hands, rather than number of patients, and among the 18 patients, 30 hands were treated. This violates statistical assumptions of independence.

Generalizability

As can be seen in Table 107, the 18 patients were middle-aged (range 37-66), and all were female. Patients with comorbidities were excluded, as were patients with very mild or severe CTS. These exclusions may limit the generalizability of the trial's results, especially given the fact that only a single trial has been published.

Table 106. Internal validity of the study of ultrasound for carpal tunnel syndrome

Study	Number of patients	Percent bilateral patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Oztas, 1998 [33]	18	66.7%	Single	No	RCT	Patient	0	Yes	NR

Table 107. Generalizability of the study of ultrasound for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Oztas, 1998 [33]	18	51.6 (37-66)	100	84 (6-240)	0	0	0	0	0	0	0	Yes	Yes

Results

Because this is a single trial describing only two outcomes, we discuss the results together. Return to work, return to ADLs, function, quality of life and harms were not described. The results of the trial are presented in Table 108 and summarized in Table 109. There were no differences between groups. Moreover, the sham-treated group showed a statistically significant effect of treatment for both pain and global outcome.[33] This may indicate that some patients were incorrectly diagnosed, that patients were receiving additional treatments that were exerting an effect, or they were experiencing a placebo effect.

Pain scores, but not global outcome ratings, were lower in the group treated with 1.5 W/cm^2 ultrasound than in the control group. However, the difference was not statistically significant. The study had the statistical power to detect only large (49-52%) differences between groups. It is unknown whether a more powerful study would have found the difference between groups to be statistically significant.

Interpretation of these results is further complicated by the fact that VAS scores were higher in the placebo-treated group prior to treatment than in either of the treated groups. This may indicate that the randomization procedure in this study was ineffective. The decrease in both VAS and global symptom score after treatment was also greater among placebo-treated hands than among hands receiving ultrasound. This may have been simply because the higher initial scores allowed greater room for improvement, or the improvement may have been the result of regression to the mean.

Table 108. Effects of ultrasound on carpal tunnel syndrome

Study	Number of Hands[a]	Outcome	Statistical Significance of Difference Between Groups
Oztas, et al., 1998 [33]		Pain (VAS, 0-10)	
	1.5 W/cm^2 10	Baseline 6.10±2.50 Posttreatment[b] 2.90±1.69	All posttreatment scores were significantly different from baseline ($p < 0.05$, t-test). There were no significant differences between groups ($p > 0.05$, 1-way ANOVA).
	0.8 W/cm^2 10	Baseline 7.10±2.38 Posttreatment 3.60±1.90	
	0 W/cm^2 (Placebo) 10	Baseline 7.90±1.80 Posttreatment 4.00±2.40	
		Global Outcome (Mean of a categorical symptom rating, 0-3 scale)	
	1.5 W/cm^2 10	Baseline 2.30±0.68 Posttreatment 1.40±0.52	
	0.8 W/cm^2 10	Baseline 2.60±0.70 Posttreatment 1.70±0.82	
	0 W/cm^2 (Placebo) 10	Baseline 2.60±0.69 Posttreatment 1.40±0.97	

[a]: Eighteen patients with a total of 30 affected hands were treated.
[b]: Followup time was five days after two weeks of treatment

Table 109. Summary of effects of ultrasound on carpal tunnel syndrome

Study	Which Procedure led to Superior Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Oztas, 1998 [33]	No differences	No	Pain 49% Global Outcome 52%	Pain 1.5 W/cm^2 0.51 (-0.38 – 1.40) 0.8 W/cm^2 0.18 (-0.70 – 1.06) Global Outcome 1.5 W/cm^2 0 (-0.88 – 0.88) 0.8 W/cm^2 -0.32 (-1.20 – 0.56)

[a]: Calculated by ECRI

Conclusions

Only one study meeting inclusion criteria addresses the use of ultrasound for carpal tunnel syndrome. Because of this, and because its design and analysis difficulties, one cannot reach a firm evidence-based conclusion.

What are the relative benefits and harms of full-time and nighttime-only splint use for persons with carpal tunnel syndrome?

A single unblinded randomized trial of 21 patients compared the effects of nighttime-only and full-time splint use.[34]

Internal Validity

Study characteristics related to internal validity are presented in Table 110. This study reported a 20% loss to followup. Of those patients who returned for followup, there was considerable noncompliance. Only 85% of the nighttime-only group reported complete or nearly complete nighttime splint use. Twenty-three percent of this group also reported some daytime use, despite instructions to wear the splint only at night. Complete or nearly-complete daytime use was reported by only 27% of patients instructed to wear the splints full-time. Nearly 43% of the patients had bilateral CTS, and results were reported per hand rather than per patient. This, combined with the loss to followup and noncompliance issues, raises serious doubts as to the reliability of the results of this study.

Generalizability

Patients were middle age (mean 60 years) and predominantly male. This distinguishes them from the majority of CTS patients, who are usually female. Patient characteristics are listed in Table 111. No information about comorbidities or employment characteristics was reported, except that 57.1% of patients were employed (Table 112).

Table 110. Internal validity of the study of full-time and nighttime-only splint use for carpal tunnel syndrome

Study	Number of patients	Percent of bilateral patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Walker, 2000 [34]	21	42.9%	Single	Not reported	RCT	No	4	No	14

Table 111. Generalizability of the study of full-time and nighttime-only splint use for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Walker, 2000 [34]	21	60	3.0	28.5	NR	NR	NR	NR	NR	NR	NR	No	Yes

Table 112. Patient employment characteristics in the study of full-time and nighttime-only splint use for carpal tunnel syndrome

Study	Number of patients	% Patients employed	% Patients receiving workers' compensation	% Patients retired	% Patients Homemakers	Reported occupations
Walker, 2000 [34]	21	57.1	Not reported	Not reported	Not reported	Not reported

Results

Because there is only a single study reporting two outcomes, we discuss the results together. No results were described for return to work, return to ADLs, pain, quality of life or harms. Reported results can be found in Table 113. There were no statistically significant differences between groups in global outcome or functional ability, as can be seen in Table 114. However, the study lacked the statistical power to detect small differences between groups. Only medium (28%-33%) or larger differences would have been statistically significant.

Table 113. Results of comparison between full-time and part-time splint wear for carpal tunnel syndrome

Study	Number of Hands	Outcome	Statistical Significance of Difference Between Groups
Walker et al., 2000 [34]		Global outcome (Symptom severity)	Change from pre to post was not significantly different between groups by t-test. p-values were not reported.
	Nighttime-only 13		
	Pretest	2.89±0.96	
	Posttest	2.30±0.93	
	Full-time 11		
	Pretest	2.79±0.69	
	Posttest	2.09±0.62	
		Functional (Levine) score	Change from pre to post was not significantly different between groups by t-test. p-values were not reported.
	Nighttime-only 13		
	Pretest	2.75±1.01	
	Posttest	2.14±0.87	
	Full-time 11		
	Pretest	2.27±1.03	
	Posttest	1.93±0.77	

Table 114. Summary of comparison between full-time and part-time splint wear for carpal tunnel syndrome

Study	Which Procedure led to Superior Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Walker et al., 2000 [34]	Full-time use	No	Global outcome 29% Functional (Levine) score 33%	Global outcome 0.25 (-0.55 – 1.06) Functional (Levine) score 0.25 (-0.56 – 1.05)

a: Calculated by ECRI

Conclusions

Splint use was addressed only by a single trial that had design difficulties. Because of this, one cannot reach an evidence-based conclusion about splint use.

What are the relative benefits and harms of open carpal tunnel release with ligament reconstruction for persons with carpal tunnel syndrome?

One non-blinded, retrospective controlled trial reported on the effects of ligament lengthening or reconstruction.[48]

Internal Validity

The study did not include patients with bilateral CTS, meaning that there were no violations of the assumption of statistical independence. There was no attrition. Therefore intent-to-treat principles were followed. Study characteristics related to internal validity are listed in Table 115.

Generalizability

Patients were predominantly female and the reported range of ages (24-88 years) is broadly similar to that of the overall CTS population. The trial did not describe patient comorbidities or employment characteristics.[48] Patient characteristics are presented in Table 116.

Table 115. Internal validity of studies of open carpal tunnel release with and without ligament reconstruction

Study	Number of patients	Percent of bilateral patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?
Karlsson, 1997 [48]	74	0%	Single	Not reported	Retro	No	0	Yes

Table 116. Generalizability of studies of open carpal tunnel release with and without ligament reconstruction

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Karlsson, 1997 [48]	74	NR; (24-88)	59.6	[Median) 6 (1-60)	NR	NR	NR	NR	NR	NR	NR	No	No

Results

Time to return to work among patients treated with open release or ligament reconstruction is reported in Table 117. No other patient-oriented outcomes were reported.

Patients who received ligament reconstruction were statistically significantly slower to return to work than those who received open release without ligament reconstruction. The effect size was statistically significantly different from zero (d = 0.65, 95% C.I. = 0.15 – 1.15).

Table 117. Effect of ligament reconstruction on time to return to work

Study	Number of Patients	Weeks until Return to Work	Statistical Significance of Difference Between Groups
Karlsson et al., 1997 [48]	Open release 50 Release and reconstruction 24	4.5 (Range 1-12) 6.0 (Range 3-24)	Groups were significantly different ($p < 0.01$, t-test.).

Conclusions

The results of one study suggest that suboptimal outcomes are obtained when patients receive ligament reconstruction. However, this trial was neither randomized nor blinded, so one cannot draw firm evidence-based conclusions from it.

What are the relative benefits and harms of open carpal tunnel release with early or late mobilization for persons with carpal tunnel syndrome?

Three prospective, randomized controlled trials describing 171 patients compared early and late mobilization (removal of cast or splint) after open carpal tunnel release.

Internal Validity

None of these trials were blinded. Study characteristics related to internal validity are presented in Table 118. Only one study had patient attrition, and two reported results of bilateral patients as per hand rather than per patient. One study had a high (92.7%) rate of compliance, while the other two did not report compliance.

Generalizability

Patient characteristics are reported in Table 119. The studies by Finsen and Bury included predominantly female, middle-aged patients, while Cook did not report these characteristics. The studies differed in their inclusion/exclusion criteria, with Bury et al excluding patients with mild carpal tunnel syndrome,[458] Cook et al. excluding both the most mild and the most severe cases,[432] and Finsen et al. not excluding according to severity.[319] Finsen and Cook excluded patients with comorbidities, while Bury included patients with other nerve impingement conditions. These differences may make it less valid to compare or combine the results of these studies.

Employment characteristics were under-reported in all three studies, as can be seen in Table 120.

Table 118. Internal validity of studies of splinting after carpal tunnel release

Study	Number of patients	Percent bilateral patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Finsen, 1999 [319]	74	10.8%	Single	Not reported	RCT	No	0	Yes	92.7
Bury, 1995 [364]	47	7.5%	Single	Not reported	RCT	No	7	No	NR
Cook, 1995 [432]	50	0%	Single	Not reported	RCT	No	0	Yes	NA

Table 119. Generalizability of studies of splinting after carpal tunnel release

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Finsen, 1999 [319]	74	54.7 (21-86)	81.1	NR	0	0	0	0	0	0	0	No	No
Bury, 1995 [364]	47	41.4 (19-79)	83.0	13 (5-36)	NR	NR	NR	7	NR	NR	NR	No	Yes
Cook, 1995 [432]	50	NR	NR	NR	0	NR	0	NR	0	0	0	Yes	Yes

Table 120. Patient employment characteristics in studies of splinting after carpal tunnel release

Study	Number of patients	% Patients employed	% Patients receiving workers' compensation	% Patients retired	% Patients Homemakers	Reported occupations
Finsen, 1999 [319]	74	63.5	Not reported	Not reported	Not reported	Not reported
Bury, 1995 [364]	47	Not reported	Not reported	Not reported	Not reported	Not reported
Cook, 1995 [432]	50	Not reported	16.0	Not reported	Not reported	Not reported

Results

Global Outcome

Effects of splinting after surgery on global outcome can be seen in Table 121. In the study by Bury et al., the number of patients said to be cured does not equal the number said to be symptom-free.[364] The reason for this discrepancy is not clear. Results are summarized in Table 122 and Figure 41. Both Bury and Cook found that superior global outcomes were obtained in the absence of splinting, with the difference statistically significant only in the study by Cook.

Table 121. Effect of splinting after surgery on global outcome

Study	Number of Patients	Global Outcome	Statistical Significance of Difference Between Groups
Bury et al., 1995 [364]		Global score (Scale not reported)	Not reported
	No splint 17	8.0	
	2 week splint 26	8.1	
		Number of patients symptom-free	Not significantly different by chi square test conducted by ECRI, p = 0.85.
	No splint 17	9	
	2 week splint 26	13	
		Categorical rating	Not significantly different by chi square test conducted by ECRI, p = 0.68.
	No splint 17	Cured: 8 Improved: 9 Unchanged: 0 Worse: 0	Not significantly different when data is collapsed into a dichotomous outcome (number cured or improved) by chi square test conducted by ECRI, p = 0.15
	2 week splint 26	Cured: 12 Improved: 11 Unchanged: 1 Worse: 2	
Cook et al., 1995 [432]		14 Days:	
	No splint 25	Excellent 9 Good 9 Fair 7	Significantly different by chi square test conducted by ECRI, p = 0.018.
	2 week splint 25	Excellent 1 Good 14 Fair 10	
		1 Month:	
	No splint 25	Excellent 12 Good 10 Fair 3	Significantly different by Chi square test conducted by ECRI, p = 0.007.
	2 week splint 25	Excellent 2 Good 18 Fair 5	

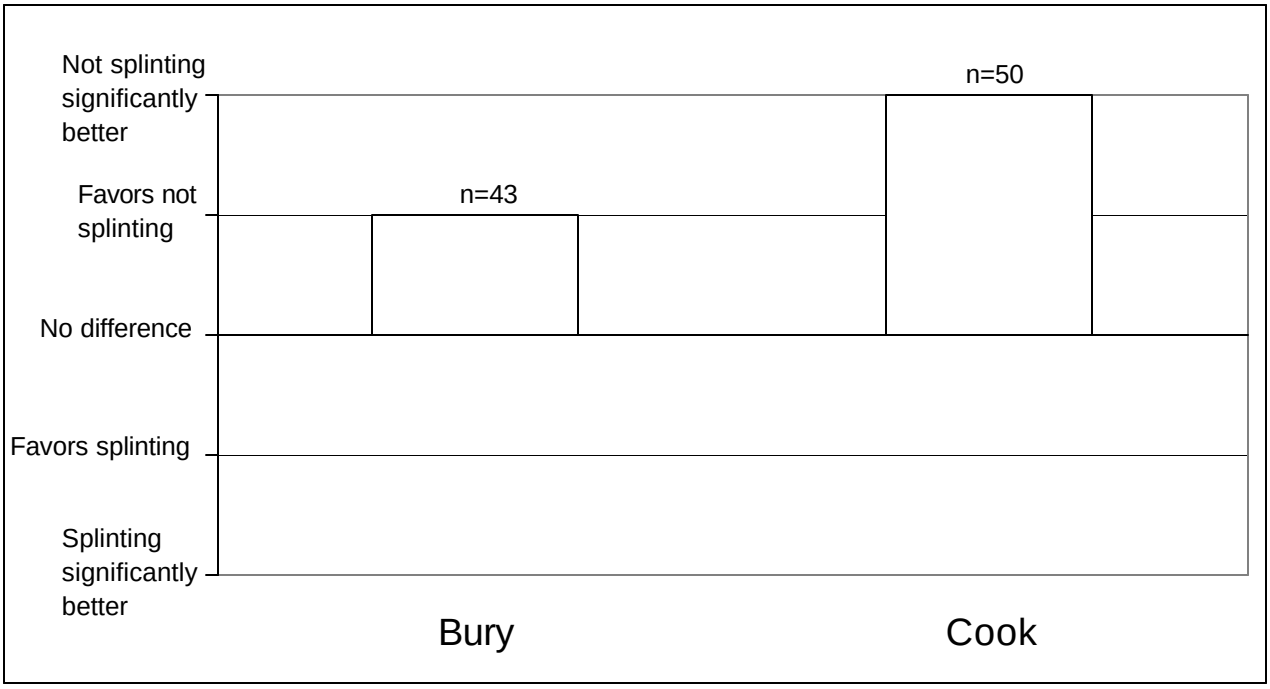
Table 122. Summary of effect of splinting after surgery on global outcome

Study	Which Procedure led to Superior Global Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Bury, 1995 [364]	No Splint	No	Number symptom-free 28% Categorical rating[b] 29%	Number symptom-free 0.06 (-0.61 – 0.72) Categorical rating[b] 0.89 (-0.78-2.56)
Cook, 1995 [432]	No Splint	Yes	Not calculable	14 Days 0.38 (-0.18-0.94) 1 Month 0.86 (0.28-1.44)

a: Calculated by ECRI

b: Calculated by ECRI by collapsing the categorical rating into a dichotomous one: number cured or improved.

Figure 41. Effect of splinting after surgery on global outcome



Return to work

All three trials reported on return to work. These results are presented in Table 123. As can be seen in Table 124 and Figure 42, two studies show a trend toward favoring no splint, with the difference becoming statistically significant in the study by Cook. In contrast, the study by Finsen shows no difference between groups.

Table 123. Effect of splinting after surgery on return to work

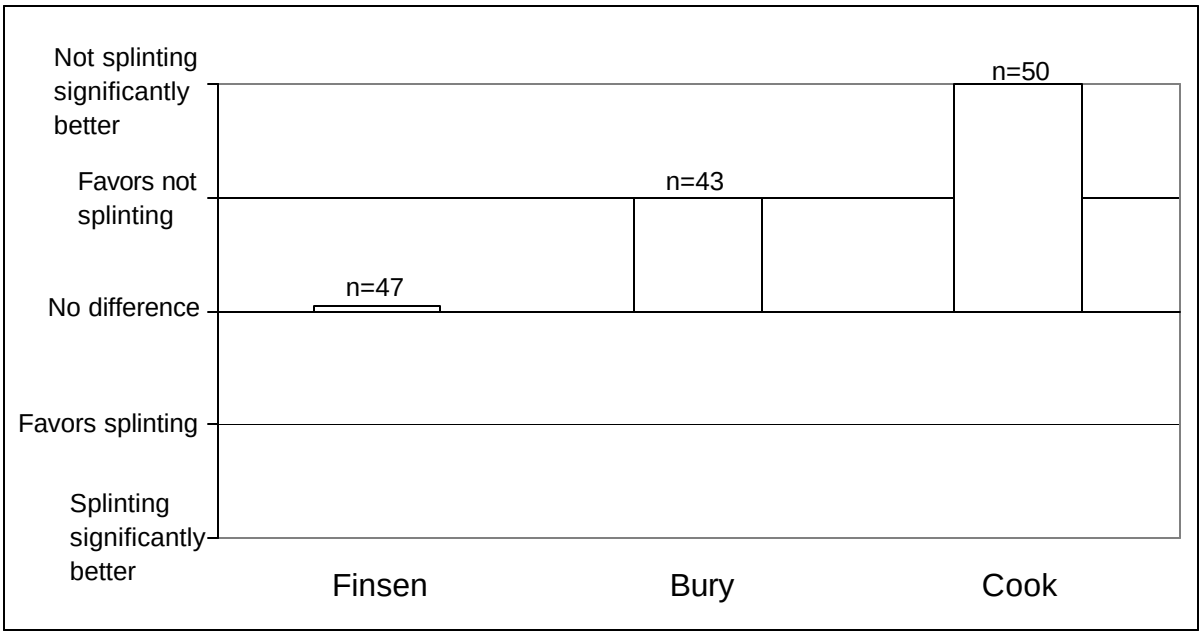
Study	Number of Patients	Return to work	Statistical Significance of Difference Between Groups
Finsen, 1999 [319]		Median time to return to work	Not reported
	No splint 28	6 Weeks (95% CI 5-6 Weeks)	
	4 week splint 19	6 Weeks (95% CI 4-7 Weeks)	
Bury, 1995 [364]		Number[a] of patients who had not returned to work at last followup (Mean 5.7 Months)	Not significantly different by chi-square test conducted by ECRI, p = 0.23
	No splint 17	2	
	2 week splint 26	7	
Cook, 1995 [432]		Time to return to work	Significantly different by t-test (Light duty p = 0.01; Full duty p = 0.005)
	No splint 25	Light duty: 15 Days Full duty: 17 Days	
	2 week splint 25	Light duty: 24 Days Full duty: 27 Days	

a: Calculated by ECRI from a published percentage

Table 124. Summary of effect of splinting after surgery on return to work

Study	Which Procedure led to Superior Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Finsen, 1999 [319]	No difference	No	Not calculable	Not calculable
Bury, 1995 [364]	No Splint	No	24%	0.55 (-0.39 – 1.49)
Cook, 1995 [432]	No Splint	Yes	Not calculable	Light duty: 0.75 (0.17 – 1.32) Full duty: 0.82 (0.24-1.40)

Figure 42. Effect of splinting after carpal tunnel surgery on return to work



Return to Activities of Daily Living

One study of 50 patients reported on time to return to activities of daily living. The results are presented in Table 125. These results show a statistically significant advantage to not splinting.[432] The effect size is significantly different from zero (d = 1.06, 95%C.I. 0.47 – 1.65).

Table 125. Effect of splinting after surgery on time to return to activities of daily living

Study	Number of Patients	Return to Activities of Daily Living	Statistical Significance of Difference Between Groups
Cook, 1995 [432]		Time to return to activities of daily living	Significantly different by t-test, p = 0.0004.
	No splint 25	6 Days	
	2 week splint 25	12 Days	

Pain

Two studies reported on pain. The results are presented in Table 126. Finsen et al. found no statistically significant differences between groups.[319] Cook et al. found statistically significant differences between groups at 2 weeks and 4 weeks. These differences were stated to be no longer significant at 3 and 6 months, but no data were reported. In this study, it is unclear whether the pain described after treatment is pain from carpal tunnel syndrome, pain resulting from surgery, or both. As can be seen in Table 127 and Figure 43, the results of the two studies show opposite trends, and as noted above, it is unclear whether the patients in these two studies are comparable.

Table 126. Effect of splinting after surgery on pain

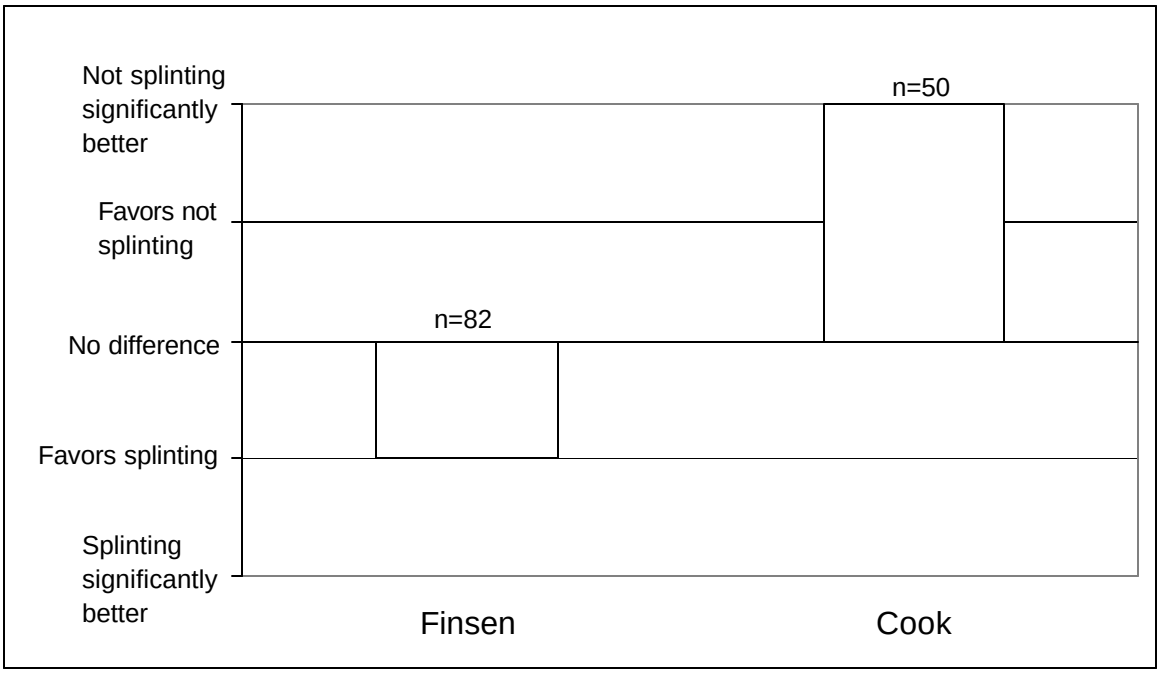
Study	Number of Patients	Pain	Statistical Significance of Difference Between Groups
Finsen, et al., 1999 [319]		Median VAS (0-100)	Not significantly different (p >0.05; test not reported)
	No splint 45		
	Preop	56 (Range 46-65)	
	2 Weeks	6 (Range 4-17)	
	6 Months	3 (Range 2-8)	
	4 week splint 37		
	Preop	51 (Range 38-57)	
	2 Weeks	5 (Range 2-11)	
	6 Months	2 (Range 0-4)	
Cook et al., 1995 [432]		Verbal Scale (1-10)	Significantly different at both time points (p = 0.001 and 0.01 respectively by t-test)
	No splint 25		
	14 Days	0.9	
	1 Month	0.5	
	2 week splint 25		
	14 Days	2.4	
	1 Month	1.5	

Table 127. Summary of effect of splinting after surgery on pain

Study	Which Procedure led to Superior Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Finsen, et al., 1999 [319]	Splinting	No	Not calculable	Not calculable
Cook et al., 1995 [432]	No Splint	Yes	Not calculable	14 Days: 0.98 (0.39 – 1.56) 1 Month: 0.75 (0.17 – 1.32)

a: Calculated by ECRI

Figure 43. Summary of effect of splinting after surgery on pain



Harms

All three studies reported harms, but as listed in Table 128, none reported the same harms. Although all reported harms occurred in the unsplinted group, both the numbers of patients and the numbers of harms are too small to demonstrate significant differences between groups. No evidence-based conclusions can be drawn as to whether splinting after surgery prevents complications.

Table 128. Reported harms in studies of splinting after carpal tunnel surgery

Study	Patients per group	Complication	Number reporting
Finsen, 1999 [319]	No splint 45	Superficial Hematoma Wound discharge	1 1
	2 Week splint 36	Superficial Hematoma Wound discharge	0 0
Bury, 1995 [364]	No splint 17	Persistent symptoms requiring reoperation	1
	2 week splint 26	Persistent symptoms requiring reoperation	0
Cook, 1995 [432]	No splint 25 2 week splint 25	Reported that there were no wound complications or bowstringing tendons	0

Conclusions

The three studies examining whether there was an advantage to splinting after carpal tunnel surgery have yielded fairly consistent results within each study. Cook, et al found a statistically significant advantage to not splinting for reduced pain, faster return to work and daily activities, and superior global outcome.[432] Bury also found that not splinting led to better global outcome and faster return to work, but neither of these effects was statistically significant.[364] This study lacked the statistical power to detect small (<20%) differences between groups. In contrast, Finsen et al. found a small and statistically nonsignificant trend advantage for the effect of splinting on pain, while times to return to work were the same for both groups. The reasons for the differences between studies is not readily apparent from an examination of the study or patient characteristics. There may be conditions under which splints offer an advantage and conditions under which they do not. Further studies are necessary before a conclusion may be reached.

What are the relative benefits and harms of vitamin B therapy for persons with carpal tunnel syndrome?

One trial of 17 patients examining the effect of vitamin B_6 therapy on carpal tunnel syndrome met exclusion criteria.[459]

Internal Validity

This was a small (n = 15) randomized controlled trial. There was 13% attrition, and compliance was not reported. Study characteristics affecting internal validity are listed in Table 129.

Generalizability

This study did not report patient characteristics except that patients with mild disease were excluded, so no discussion of its generalizability is possible.

Table 129. Internal validity of studies of vitamin B therapy for carpal tunnel syndrome

Study	Number of patients	Number of centers	Funded by a for-profit stakeholder?	Study design	Blinding	Total Patient Attrition (all patient groups)	Intent to treat analysis?	% Compliance
Stransky, 1989 [459]	15	Single	Not reported	RCT	Double	2	No	NR

Table 130. Generalizability of studies of vitamin B therapy for carpal tunnel syndrome

Study	Number of patients	Mean age and range	% Female	Mean Duration (Months) of condition and range	% Patients with diabetes	% Patients with arthritis	% Patients with previous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Excluded severe disease?	Excluded mild disease?
Stransky, 1989 [459]	15	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	No	Yes

Results

This trial reported a single patient-oriented outcome (global outcome expressed as number of patients improved after treatment). A summary of the effect of vitamin B_6 therapy in this study is shown in Table 131. There was no statistically significant difference in percent of patients improved between-treatment groups. This study had few patients and very low power. Only large (46-48%) differences between groups were would have been statistically significant.

Table 131. Global outcome in patients treated with vitamin B therapy

Study	N (units)	Global outcome - number (%) patients improved	Statistical significance of difference between groups
Stransky et al. 1989 [459]	Vitamin B_6 6 Placebo 5 Untreated Control 4	3 (50) 4 (80) 3 (75)	Vitamin B_6 was not significantly different from placebo or control by chi-square test conducted by ECRI (p = 0.30 and 0.42, respectively)

Table 132. Summary of effect of vitamin B therapy on symptoms of carpal tunnel syndrome

Study	Which Treatment led to Superior Global Outcome?	Was the Difference Stastically Significant?	Power (Minimum percent difference detectable)[a]	Effect Size (95% Confidence Interval)[a]
Stransky et al. 1989 [459]	Placebo	No	Vitamine vs. Placebo 46% Vitamine vs. No treatment 48%	Vitamine vs. Placebo -0.55 (-1.86 – 0.75) Vitamine vs. No treatment -0.42 (-1.76 – 0.91)

[a]: Calculated by ECRI

Conclusions

Although the low power of the study prevents any solid conclusion from being drawn, the trend toward a greater percentage of improved patients in the placebo group does not support the therapeutic effectiveness of Vitamin B_6.

Question #4: Is there a relationship between specific clinical findings and specific treatment outcomes among patients with carpal tunnel syndrome?

In addressing this question, we consider whether published literature suggests that there are clinical findings that predict positive or negative outcomes after treatment for carpal tunnel syndrome. The studies we considered all attempted to identify predictors by using regression techniques or by comparing outcomes in different groups of patients with different pre-treatment clinical findings.

Excluded studies

As discussed in the Methods section, we retrieved articles identified by our literature searches according to certain *a priori* criteria. However, not all of the retrieved studies met our more specific inclusion criteria for this question. These latter studies, and the reason we did not consider them for this question are shown in Table 133.

Table 133. Excluded studies

Author	Reason for exclusion
Walker (2000) [34]	Stratified study that did not examine any correlations that were also examined by at least two other studies
Hasegawa (1999) [34]	Stratified study that did not examine any correlations that were also examined by at least two other studies
Olney (1999) [323]	Stratified study that did not examine any correlations that were also examined by at least two other studies
Rosen (1997) [343]	Stratified study that did not examine any correlations that were also examined by at least two other studies
LoMonaco (1996) [358]	Stratified study that did not examine any correlations that were also examined by at least two other studies
Padua (1996) [358]	Stratified study that did not examine any correlations that were also examined by at least two other studies
Wintman (1996) [362]	Stratified study with no clinical finding/outcome comparisons reported by at least three studies
Chang and Dellon (1993) [389]	Stratified study that did not examine any correlations that were also examined by at least two other studies

Evidence base

After these exclusions, there remained 12 studies with a total of 1723 patients.

Study quality

The evaluation of the quality of literature for this question differs from quality evaluations of studies of treatments. This is because, for the present question, the RCT is not necessarily the “gold standard”. Case series data, if appropriately analyzed, can also yield valid information. Consequently, the method of data analysis plays a prominent role when considering the quality of the studies relevant to this question.

One valid way to analyze these data is to use multiple regression techniques. These techniques allow construction of a regression equation (or model) consisting of one or more predictor variables. The advantage of multiple regression is that the predictive ability of any given variable is adjusted for any other predictor variables in the equation.

Another valid way to analyze these data involves stratifying patients along some clinical variable. For example, in a stratified study one might compare the outcomes of patients with severe disease to those with mild disease. In a stratified study, the predictive ability of the variable of interest is not adjusted for any other predictor variables. Therefore, the magnitude of a variable's ability to predict future outcomes may be misestimated in stratified studies. For this reason, one can consider the results of stratified studies to be somewhat less reliable than those studies that employed regression techniques. However, an important advantage of stratified studies is that studies that have stratified patients into two groups have more statistical power than studies that used regression analysis.

Another aspect of study quality pertinent to the present question is whether the study was performed prospectively or retrospectively. Patients in retrospective studies may not be representative of the population of patients with carpal tunnel syndrome. This means that the generalizability of the results of retrospective studies is unknown. It also means that the patients in retrospective studies may be more homogeneous than the population of patients with carpal tunnel syndrome. If this were the case, then the magnitude of a clinical finding's ability to predict future outcome would be misestimated. In the extreme case, the artificial homogeneity of patients in a retrospective study could lead to "range restriction". This, in turn, could lead to the inability to detect important predictors of outcome. For these reasons, one can consider the results of prospective studies as stronger than those of retrospective studies.

Table 134 shows relevant quality characteristics of studies that met the inclusion criteria for this question.

Table 134. Study quality

Author/year	Prospective?	Methods used to identify predictor variables
Finsen and Russwurm (2001) [224]	Yes	Stratification
Shin (2000) [460]	No	Multiple logistic regression
Straub (1999) [305]	Yes	Stratification
Atroshi (1998) [461]	Yes	Multiple linear regression
Choi and Ahn (1998) [329]	No	Stratification
Katz (1998) [462]	Yes	Multiple logistic regression
Higgs (1997) [341]	No	Stratification
Glowacki (1996) [352]	No	Stratification
Jacobsen and Rahme (1996) [353]	Yes	Multiple regression[a]
Al-Qattan (1994) [375]	No	Stratification
Nathan (1993) [395]	Partly[b]	Multiple regression
Yu (1992) [403]	No	Stratification

aIndependent analysis of individual patient data conducted by ECRI
bPatients entering the study after a certain date were studied prospectively; patients who had treatment prior to that date were studies retrospectively.

Results

Table 135 shows the relationship of specific clinical findings to treatment outcomes in those studies that used regression to identify predictor variables. In the table, clinical variables are indicated by boldface type. There are five such studies with a total of 932 patients. Also presented in this table are non-clinical variables (e.g. age, gender) to show all of the variables used in each multiple regression.

No study that employed regression analysis reported statistically significant correlations between two-point discrimination or grip strength and any outcomes. However, three out of four studies that examined the "predictability" of electrodiagnostic tests reported statistically significant correlations between electrodiagnostic test results and various outcomes. Two of the studies that found a statistically significant relationship were prospective.

The outcomes predicted by electrodiagnostic test results in the three "significant" studies were odds of obtaining disability payment, patient satisfaction with surgery, and number of sick leave days. Odds of obtaining disability payment were higher in patients diagnosed with CTS (mild, moderate, or severe) compared to those with normal electrodiagnostic findings.[460] Another study found patient satisfaction with surgery was lower among patients with a better electrodiagnostic test (distal motor latency) before surgery.[461] Analysis of individual patient data from a third study revealed that number of sick leave days was higher among patients with a pre-surgical electrodiagnostic test indicating slight or intermediate CTS as opposed to pronounced CTS.[353] In the fourth

study, the relationship between electrodiagnostic test results and return to work was not statistically significant.[395] Electrodiagnostic test result was the only variable shown to predict treatment outcome in more than one of the studies that employed multiple regression.

We attempted to confirm the relationship between electrodiagnostic test results and patient outcomes by examining the results of studies that stratified according to the electrodiagnostic test results (Table 136). There were seven such studies, two of which were prospective. All studies evaluated surgical procedures. Six (85.7%) of the studies did not find a statistically significant relationship between electrodiagnostic test results and global outcomes. The remaining study (which was retrospective) found that patients with normal/near normal nerve deficit before treatment had a significantly better global outcome after treatment.

Table 135. Relationship between specific clinical findings and treatment outcomes among patients with Carpal Tunnel Syndrome (Multiple regression analysis)

Author	N	Treatment	Outcomes	Variables examined by at least two studies (significant correlation with outcome?)									Unique study variables
				Age	Gender	Treatment	Hand dominance	Insurance type	Employment status	**Two-point discrimination[d]**	**Electrodiagnostic test**	**Grip strength**	
Shin (2000) [460]	210	Conservative treatments Surgery[a]	Odds of obtaining employment disability	NS	NS	NS	–	–	–	–	Sig	–	Mechanism of injury (NS)
Atroshi (1998) [461]	140	Surgery[b]	Global outcome (patient dissatisfaction)	Sig	NS	–	NS	–	NS	NS	Sig	NS	Vibration exposure (sig), ADL score (NS), **thenar atrophy** (NS), **pinch strength** (NS), **tinel sign** (NS), **phalen sign** (NS)
Katz (1998) [462]	315	Surgery and conservative treatments (not described)	Work absence (18 months after treatment)	NS	NS	NS	–	NS[e]	NS	–	–	NS	Occupation (NS), baseline function (sig), function at 6 months (sig), hired attorney (sig), work absence at enrollment (NS), work absence at 6 months (sig), mental health status (NS), physical and clerical self-reported exposure scales
Jacobsen and Rahme (1996) [353]	29 (32 hands)	Surgery[c]	Number of sick days after surgery	NS	NS	NS	NS	–	–	NS	Sig	–	None
Nathan (1993) [395]	238	Surgery[a]	Return to work	NS	NS	–	NS	Sig	NS	–	NS	–	Laterality (NS), year of study (NS), referral source (NS), incision length (NS), occupational hand use (NS), **diabetes** (NS),

Author	N	Treatment	Outcomes	Variables examined by at least two studies (significant correlation with outcome?)									Unique study variables
				Age	Gender	Treatment	Hand dominance	Insurance type	Employment status	**Two-point discrimination**[d]	**Electrodiagnostic test**	**Grip strength**	
													rheumatoid arthritis (NS), number and density of hand therapy sessions/ week (NS)

aOpen release
bUnilateral endoscopic release
cOpen and endoscopic release
dVariables in boldface represent clinical findings
dIn a related publication, surgical patients alone were analyzed and insurance type significantly correlated with work absence 6 months post-surgery.[302]
NS – Not significant

Table 136. Stratified studies (global outcome)

Study	N	Treatment	Global outcome measure	Stratification variable
				Electrodiagnostic nerve deficit
Finsen and Russworm (2001) [224]	79	Surgery (open release)	VAS for pain and discomfort	NS
Straub (1999) [305]	100	Surgery (endoscopic release)	Satisfactory/unsatisfactory result	NS (but trend toward more success in abnormal sensory/ normal motor nerve conduction group)
Choi and Ahn (1998) [329]	154	Surgery (open release)	Patient satisfaction (poor, fair, good, or excellent)	NS
Higgs (1997)	93	Surgery (open release)	Improved/not improved	Sig (normal/near normal)
Glowacki (1996) [352]	167	Surgery (open release)	Symptoms resolved, improved, or same or worse	NS
Al-Qattan (1994) [375]	112	Surgery (open release)	Satisfactory/poor outcome	NS
Yu (1992) [403]	53	Surgery (open release)	Good/fair/poor result	NS

NS – Not signficant

Conclusions

Studies that searched for relationships between clinical findings and treatment outcomes did so by using multiple regression analysis or stratified patient groups. Among studies that used regression analysis, the only clinical finding variable shown by more than one study to significantly predict treatment outcomes was electrodiagnostic testing. This finding was statistically significant in three of the four studies that examined it. The outcomes predicted by these three studies were patient satisfaction with surgery, odds of obtaining disability payment, and number of sick days after surgery. Odds of obtaining disability payment were higher in patients diagnosed with CTS (mild, moderate, or severe) compared to those with normal electrodiagnostic findings. Another study found patient satisfaction with surgery was lower among patients with a better electrodiagnostic test results (distal motor latency) before surgery. Analysis of individual patient data from a third study revealed that number of sick leave days was higher among patients with a pre-surgical electrodiagnostic test indicating slight or intermediate CTS as opposed to pronounced CTS. The fourth study of electrodiagnostic tests found no statistically significant relationship between electrodiagnostic test results and return to work. This apparent lack of consistency of results could indicate that, although the relationship between electrodiagnostic tests and treatment outcomes is statistically significant, it may not be substantial. The possibility that this relationship is small is supported by the results of stratified studies that examined the relationship between electrodiagnostic test results and global outcomes. Six of seven studies did not find a statistically significant relationship.

Question #5: Is there a relationship between duration of symptoms and specific treatment outcomes among patients with carpal tunnel syndrome?

In addressing this question, we consider whether published literature suggests that duration of symptoms predicts positive or negative outcomes after treatment for carpal tunnel syndrome. The studies we considered all attempted to identify predictors by using regression techniques or by comparing outcomes in different groups of patients with different duration of symptoms.

Excluded studies

As discussed in the Methods section, we retrieved articles identified by our literature searches according to certain *a priori* criteria. However, not all of the retrieved studies met our more specific inclusion criteria for this question. These latter studies, and the reason we did not consider them for this question are shown in Table 137.

Table 137. Excluded studies

Author	Reason for exclusion
Wintman (1996) [362]	Stratified study with no duration of symptoms/outcome comparisons reported by at least three studies

Evidence base

After this exclusion, there remained six studies with 984 patients.

Study quality

The criteria used to evaluate study quality were identical to those described for Question 4. One prospective study and one retrospective study conducted a multiple regression analysis, while four studies performed stratifications (Table 138). Only one of the four stratified studies was prospective in design.

Table 138. Study quality

Author/year	Prospective?	Methods used to identify predictor variables
Straub (1999) [305]	Yes	Stratification
Atroshi (1998) [461]	Yes	Multiple linear regression
Choi and Ahn (1998) [329]	No	Stratification
DeStefano (1997) [463]	No	Multivariable proportional hazards regression
Al-Qattan (1994) [375]	No	Stratification
Yu (1992) [403]	No	Stratification

Results

Table 139 shows the relationship between duration of symptoms and treatment outcomes in the only study that used regression to adjust for the effects of other predictor variables. All other variables used in this regression are also presented in the table. Atroshi et al. (1998) found that duration of symptoms was not a statistically significant predictor of patient dissatisfaction at three or six months following surgery.[461] The range of duration of symptoms was not reported in this study. DeStefano et al. (1997) found that duration of symptoms was a statistically significant predictor of symptom resolution among surgical patients (symptom duration <3 years correlated with greater likelihood of symptom resolution) but not among non-surgical patients.[463] They did not report the specific range of duration of symptoms, except that it ranged from <2 months to >3 years.

We searched further for a relationship between duration of symptoms and patient outcomes by examining the results of studies that stratified according to duration of symptoms (Table 140). There were four such studies, one of which was prospective. All studies evaluated the effects of surgical procedures, and all contained patients with a duration of symptoms ranging from weeks to years. Three out of four studies found no statistically significant relationship between duration of symptoms and global outcomes. The fourth study found a statistically significant correlation between shorter duration of symptoms and improved global outcome.

Table 139. Relationship between duration of symptoms and treatment outcomes among patients with Carpal Tunnel Syndrome.

Author	N	Treatment	Outcomes	Duration of symptoms – significance (duration associated with better outcome)	Other variables examined
Atroshi (1998) [461]	140	Surgery (unilateral endoscopic release)	Global outcome (patient dissatisfaction)	NS	Age (sig), sex (NS), hand dominance (NS), unemployment (NS), vibration exposure (sig), ADL score (NS), DML (sig), surgeon (NS), subjective weakness (NS), type of work (NS), type of symptoms (NS), Tinel sign (NS), Phalen's test results (NS), thenar atrophy (NS), two-point discrimination (NS), grip strength (NS), pinch strength (NS)
DeStefano (1997) [463]	425	Non-surgical (oral meds, oral steroids, steroid injections, splints) Surgical (carpal tunnel release)	Global outcome (symptom resolution)	NS (non-surgical patients) Sig (surgical patients, <3 years)	Age (NS), sex (NS), carpal tunnel syndrome category (NS), hand involved (NS), arthritis (NS), pregnancy (NS), injury (NS), diabetes or hypothyroidism (sig for surgical patients)

Table 140. Stratified studies (global outcome)

Study	N	Treatment	Global outcome measure	Duration of symptoms – significance (duration associated with better outcome)
Straub (1999) [305]	100	Surgery (endoscopic release)	Satisfactory/unsatisfactory result	NS
Choi and Ahn (1998) [329]	154	Surgery (open release)	Patient satisfaction (poor, fair, good, or excellent)	Sig (shorter duration, <3 months)
Al-Qattan (1994) [375]	112	Surgery (open release)	Satisfactory/poor outcome	NS
Yu (1992) [403]	53	Surgery (open release)	Good/fair/poor result	NS, but trend toward more success in ≥6 month group

NS – Not signficant

Conclusions

The majority of available evidence is less than optimal because it consists primarily of retrospective studies. The highest quality study (prospective with multiple regression analysis) suggested that there was no statistically significant correlation between duration of symptoms and global outcome after surgery. One prospective and two retrospective stratified studies found similar results. Two retrospective studies (one performing multiple regressions, one stratified) found a statistically significant relationship between shorter duration of symptoms and symptom resolution or patient satisfaction after surgery. The retrospective nature of these trials could have created bias that influenced these findings. An additional high quality prospective study is needed before firm conclusions can be reached.

Question #6: Is there a relationship between factors such as patients' age, gender, socioeconomic status and/or racial or ethnic grouping and specific treatment outcomes among patients with carpal tunnel syndrome?

In addressing this question, we consider whether published literature suggests that there are demographic variables that predict positive or negative outcomes after treatment for carpal tunnel syndrome. The studies we considered all attempted to identify predictors by using regression techniques or by comparing outcomes in different groups of patients with different pre-treatment demographic characteristics.

Excluded studies

As discussed in the Methods section, we retrieved articles identified by our literature searches according to certain *a priori* criteria. However, not all of the retrieved studies met our more specific inclusion criteria for this question. These latter studies, and the reason we did not consider them for this question are shown in Table 141.

Table 141. Excluded studies

Author	Reason for exclusion
Walker (2000) [34]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Braun (1999) [316]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Hasegawa (1999) [34]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Higgs (1997) [341]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Rosen (1997) [343]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Padua (1996) [358]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Wintman (1996) [362]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Nancollas (1995) [464]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Chang and Dellon (1993) [389]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies
Feinstein (1993) [390]	Data presentation did not allow determination of correlation
Hagberg (1991) [308]	Stratified study with no demographic variables/outcome comparisons reported by at least three studies

Evidence base

After these exclusions, there remained 22 studies with a total of 3616 patients.

Study quality

The criteria used to evaluate study quality were identical to those described for Question 4 of our section on carpal tunnel syndrome. Table 142 shows the 22 included studies and the relevant study design and quality characteristics. Six studies used multiple regression and 16 used stratifications to identify correlations between demographic variables and treatment outcomes. Of the six studies utilizing regression, three were prospective, one was partially prospective, and two were retrospective. Of the 16 stratified studies, eight were prospective.

Table 142. Study quality

Author/year	Prospective?	Methods used to identify predictor variables
Shin (2000) [460]	No	Multiple logistic regression
Olney (1999) [323]	No	Stratification
Straub (1999) [305]	Yes	Stratification
Atroshi (1998) [461]	Yes	Multiple linear regression
Davies (1998) [330]	No	Stratification
Katz (1998) [462]	Yes	Multiple logistic regression
DeStefano (1997) [463]	No	Multivariable proportional hazards regression
Elmaraghy and Hurst (1996) [349]	Yes	Stratification
Glowacki (1996) [352]	No	Stratification
Jacobsen and Rahme (1996) [353]	Yes	Multiple regression
Lee and Jackson (1996) [355]	No	Stratification
Nagle (1996) [357]	Yes	Stratification
Strickland (1996) [361]	No	Stratification
Wintman (1996) [362]	Yes	Stratification
Hallock and Lutz (1995) [368]	Yes	Stratification
Mirza (1995) [371]	Unknown	Stratification
Al-Qattan (1994) [375]	No	Stratification
Roth (1994) [383]	Yes	Stratification
Nathan (1993) [395]	Partly[a]	Multiple regression
Palmer (1993) [397]	Yes	Stratification
Agee (1992) [46]	Yes	Stratification
Yu (1992) [403]	No	Stratification

WC – Workers' compensation
bPatients entering the study after a certain date were studied prospectively; patients who had treatment prior to that date were studies retrospectively

Results

Table 143 shows the relationship of specific demographic variables to treatment outcomes in those studies that used regression to identify predictor variables (demographic variables are shown in bold type). There are six such studies with a total of 1357 patients. Also presented in this table are non-demographic variables (e.g. grip strength) to show all of the variables used in each multiple regression.

Gender, employment status, and hand dominance did not correlate significantly with any treatment outcomes in any of these studies. Two studies found that insurance type (workers' compensation vs non-workers' compensation) correlated significantly with treatment outcomes (work absence and return to work) after surgical treatment.[302,395] One of these studies was a subgroup analysis derived from a larger study that analyzed surgical and non-surgical patients together.[462] When data from these patients were combined, the correlation between insurance type and treatment outcome was not statistically significant. Although one out of five studies found age to be significantly correlated with patient satisfaction,[461] the reported odds ratio was close to 1. Two studies evaluated diabetes as a potential predictor variable. One retrospective study found it to have a statistically significant relationship with symptom resolution, but only among surgical patients.[463] The other study (partly retrospective, partly prospective) found no statistically significant relationship between diabetes and return to work among surgical patients.[395]

Table 144 and Table 145 summarize the results of studies that conducted stratification and outcome comparisons (e.g. stratification by age, evaluated by patient satisfaction) that were reported by at least three studies. The only two outcomes reported by at least three studies were global outcome (Table 144) and return to work (Table 144), and the only stratifications reported by at least three studies were insurance type and job category. All of these studies evaluated the effectiveness of various surgical procedures.

Of the four stratified studies that attempted to correlate workers' compensation status with global outcomes, three found that non-workers' compensation patients had significantly better global outcomes after treatment.[330,352,375] These were the three largest studies that examined this relationship, but all were retrospective. The remaining study, which was prospective but slightly smaller, found a non-significant trend toward a better global outcome in the non-workers' compensation group.[305] Of three studies that attempted to correlate job category with global outcomes, two (one of which was prospective) found that patients with jobs that were not physically strenuous had significantly better global outcomes after treatment.[375,403] The remaining study found no statistically significant difference among job categories as measured by global outcome.[305]

Of studies that examined return to work as an outcome measure, 11 studies stratified patients by workers' compensation status, and 10 (six of which were prospective) found a significantly quicker return to work after treatment in the non-workers' compensation group. The remaining study showed a significantly quicker return to work among non-workers' compensation patients only in the subgroup of manual workers.[361]

Table 143. Relationship between demographic factors and treatment outcomes among patients with Carpal Tunnel Syndrome (multiple regression analysis)

Author	N	Treatment	Outcomes	Variables examined by at least two studies (significant correlation with outcome?)									Unique study variables
				Age[d]	**Gender**	**Treatment**	**Hand dominance**	**Insurance type**	**Employment status**	Two-point discrimination	Electrodiagnostic test	Grip strength	
Shin (2000) [460]	210	Conservative treatments Surgery[a]	Odds of obtaining employment disability	NS	NS	NS	–	–	–	–	Sig	–	Mechanism of injury (NS)
Atroshi (1998) [461]	140	Surgery[b]	Global outcome (patient dissatisfaction)	Sig	NS	–	NS	–	NS	NS	Sig	NS	**Vibration exposure** (sig), ADL score (NS), thenar atrophy (NS), pinch strength (NS), tinel sign (NS), phalen sign (NS)
Katz (1998) [462] [302]	315	Surgery and conservative treatments (not described)	Work absence (18 months after treatment)	NS	NS	NS	–	NS (all patients)[e] Sig (surgery patients)	NS	NS	–	NS	**Occupation** (NS), **baseline function** (sig), function at 6 months (sig), **hired attorney** (sig), work absence at enrollment (NS), work absence at 6 months (sig), mental health status (NS), physical and clerical self-reported exposure scales
DeStefano (1997) [463]	425	Conservative treatments Surgery (carpal tunnel release)	Global outcome (symptom resolution)	NS	NS	Sig	NS	–	–	Sig (surgical patients only)	–	–	–

Author	N	Treatment	Outcomes	Variables examined by at least two studies (significant correlation with outcome?)									Unique study variables
				Age[d]	**Gender**	**Treatment**	**Hand dominance**	**Insurance type**	**Employment status**	Two-point discrimination	Electrodiagnostic test	Grip strength	
Jacobsen[e] and Rahme (1996) [353]	29 (32 hands)	Surgery[c]	Number of sick days after surgery	NS	NS	NS	NS	–	–	NS	Sig	–	None
Nathan (1993) [395]	238	Surgery[a]	Return to work	NS	NS	–	NS	Sig	NS	–	NS	–	**Laterality** (NS), **year of study** (NS), **referral source** (NS), **incision length** (NS), **occupational hand use** (NS), diabetes (NS), rheumatoid arthritis (NS), number and density of hand therapy sessions/ week (NS)

aOpen release
bUnilateral endoscopic release
cOpen and endoscopic release
dVariables in boldface represent demographic characteristics
eIn a related publication, surgical patients alone were analyzed and insurance type significantly correlated with work absence 6 months postsurgery.[302]
eMultiple regression performed independently by ECRI from individual patient data presented in this study
NS – Not significant

Table 144. Stratified studies (global outcome)

Study	N	Treatment	Global outcome measure	Stratification variable	
				Workers' compensation (WC) status	Job category
Straub (1999) [305]	100	Surgery (endoscopic release)	Satisfactory/unsatisfactory result	NS (but trend toward more success in non-WC group)	NS
Davies (1998) [330]	239	Surgery (endoscopic release)	Patient satisfaction/dissatisfaction	Sig (non-WC)	–
Glowacki (1996) [352]	167	Surgery (open release)	Symptoms resolved, improved, or same or worse	Sig (non-WC)	–
Al-Qattan (1994) [375]	112	Surgery (open release)	Satisfactory/poor outcome	Sig (non-WC)	Sig (not physically strenuous)
Yu (1992) [403]	53	Surgery (open release)	Good/fair/poor result	–	Sig (not physically strenuous)

NS – Not significant

Table 145. Stratified studies (return to work)

Study	N	Treatment	Stratification variable
			Workers' compensation (WC) status
Olney (1999) [323]	211	Surgery (open or endoscopic release)	Sig (non-WC and non-contested WC)
Davies (1998) [330]	239	Surgery (endoscopic release)	Sig (non-WC)
Elmaraghy and Hurst (1996) [349]	75	Surgery (endoscopic release)	Sig (non-WC)
Lee and Jackson (1996) [355]	237	Surgery (limited incision release using carposcope)	Sig (non-WC)
Nagle (1996) [357]	291	Surgery (endoscopic release)	Sig (non-WC)
Strickland (1996) [361]	62	Surgery (hypothenar fat pad flap for patients who received unsuccessful open release)	NS, except for manual labor subgroup (non-WC)
Hallock and Lutz (1995) [368]	96	Surgery (open or endoscopic release)	Sig (non-WC)
Mirza (1995) [371]	236	Surgery (endoscopic release)	Sig (non-WC)
Roth (1994) [383]	95	Surgery (endoscopic release)	Sig (non-WC)
Palmer (1993) [397]	163	Surgery (open or endoscopic release)	Sig (non-WC)

Study	N	Treatment	Stratification variable
			Workers' compensation (WC) status
Agee (1992) [46]	122	Surgery (open or endoscopic release)	Sig (non-WC)

NS – Not significant

Conclusions

The available evidence suggests that patients who are not receiving workers' compensation tend to return to work faster than those receiving such compensation. This is suggested by one of two "multiple regression" studies of this relationship and by a combination of 10 prospective and retrospective stratified studies. Some evidence also suggests that patients who are not receiving workers' compensation have better global outcomes, but this evidence is derived exclusively from retrospective studies. Therefore, these latter findings require confirmation. In any event, one cannot ascribe causal relationships to these correlations.

Available evidence suggests that there is no strong relationship between gender, employment status, or hand dominance and return to work or global outcomes. There is insufficient evidence to arrive at a firm evidence-based conclusion on the relationship between type of work, diabetes, or age and patient outcomes.

Question #7: What are the surgical and nonsurgical costs or charges for treatment of carpal tunnel syndrome?

According to the Medicare Provider Analysis and Review (MEDPAR) database, which covers hospital inpatient services, average total charges per patient for the DRG (diagnosis-related group) of carpal tunnel release are $8,185.24 (calculated by dividing total charges by number of discharges). This DRG includes open and endoscopic release. The Median Costs for Hospital Outpatient Services Dataset contains median costs for services that are reimbursed under Medicare for the hospital outpatient prospective payment system. The reported median cost for endoscopic release of the transverse carpal ligament is $849.84 (cost of open release was not reported by this database). The reported median cost for application of a short arm static splint is $72.69.

Question #8: For persons who have had surgery for carpal tunnel syndrome, what are the most effective methods for preventing the recurrence of symptoms, and how does this vary depending on subject characteristics or other underlying health problems?

This question distinguishes symptom recurrence from continued symptoms after treatment. The latter may be caused by incomplete sectioning of the transverse carpal ligament, damage to the median nerve during the operation, initial misdiagnosis of carpal tunnel syndrome, or the presence of additional compressive nerve injuries.[465-467] Recurrence of carpal tunnel syndrome after initial relief of symptoms may be caused by compression of the medial nerve due to fibrosis, hematoma, neuroma, scarring, or re-injury.[465,466,468]

Techniques that have been recommended to prevent recurrence include changing work habits, use of ergonomic equipment, and other forms of occupational therapy.[469] Careful surgical technique to prevent excessive scarring,[468] and physical therapy to prevent formation of adhesions may also have some utility.[32,466] However, no controlled trials have been published that report on the efficacy or effectiveness of any technique for the prevention of recurrence of carpal tunnel syndrome. Controlled trials are necessary so that incidence of recurrence among patients for whom measures have been taken to prevent recurrence may be compared with recurrence among patients for whom no such measures have been taken, drawn from the same population. Controls enable one to distinguish treatment effects from effects due to population differences, changes in behavior, and/or medications (including over-the-counter drugs, and other, unknown factors that may influence recurrence rates. In the absence of controlled trials, no analysis may be performed and no evidence-based conclusions may be drawn.

Question #9: What instruments, if any, can accurately assess functional limitations in an individual with carpal tunnel syndrome?

Instruments have been developed that allow patients to self-report their degree of functional impairment. Self-administered questionnaires require few personnel to adminster and are a low-cost way to collect information, especially of data for which the patient's self-report is the only possible source. However, such instruments tend to suffer from certain biases caused by basic human psychological tendencies. These biases are listed in Table 146. The effect of these biases on the results of assessment instruments can be reduced by careful instrument design, but never completely eliminated. Because these biases can distort the results of assessment instruments, each assessment instrument must be evaluated as to its usefulness and accuracy.

Evaluating the usefulness and accuracy of functional assessment instruments is difficult because there is no "gold standard" against which to compare the results. However, these instruments can be evaluated according to three key components: internal reliability, test-retest reliability, and validity of results. If there is a treatment available for the disorder causing the functional impairment, instruments are also evaluated as to their ability to respond to changes in function caused by treatment.[470]

Internal reliability, or internal consistency, refers to the degree to which scores on subsections of the test correlate with scores from other subsections. For example, if a subject has significant functional impairment in the use of the hands, it is likely that the subject will score as impaired on questions about both work activities and home activities.

Test-retest reliability means that the score of a test depends solely on the impairments of the individual taking the test, not on factors such as the time of day the test is administered, or who is administering the test. Test-retest reliability is usually measured by having the subject take the test several times under different conditions.

Evaluating the validity of an assessment instrument can be difficult. Content validity, which refers to whether the test questions reflect the functions required to perform the task(s) in question, is largely a theoretical concept and cannot be directly measured.[89] Concurrent validity refers to the way a test's scores correlate with other measurements of what the test is purported to assess.[89] However, findings on clinical examinations often do not correlate well with functional impairment and thus can be problematic when used to validate functional assessment instruments.[471-473] Predictive validity refers to a test's ability to reflect future performance, i.e., if a subject's scores predict little functional impairment and the subject soon returns to full work, the test may be said to have predictive validity.[89]

We define an instrument that can accurately assess functional limitations in an individual with carpal tunnel syndrome as one that has been shown to have: test-retest reliability, internal reliability, concurrent validity, predictive validity, and responds to treatment.

Table 146. Potential biases in assessment instruments[a]

Bias	Definition
Yea-saying	The tendency to always agree with yes-no questions.
End aversion	The tendency to use middle values rather than the end points of analog scales
Question framing	The tendency for the wording of a question to affect the response.
Motivation to seem better	Patients want to subconsciously please their health-care providers by responding to treatment and are embarrassed to complain about problems.
Motivation to seem worse	Can occur if patients will lose services or benefits if they improve.
Response shifts	The tendency of patients to modify their internal standards of evaluation so that their current level of functioning is seen as normal.
Memory failure	Difficulty in remembering past function may influence assessment of current function.
Leading the patient	The tendency of the questionnaire itself to change the way the patient assesses functioning.

a Adapted from Gotay 1996[474]

Evidence base

Eight studies met the inclusion criteria (see the section Inclusion Criteria). They are listed in Table 147. The functional assessment instruments evaluated by the studies that met the inclusion criteria are listed in Table 148.

Table 147. Trials of functional assessment instruments that met the inclusion criteria

Study	Instruments evaluated[a]	N subjects	Outcome measurements
Vaile 1999 [475]	NHP, SF-36, mSHAQ, V-VAS	27	Response to treatment
Alderson 1999 [315]	AMHFQ	26	Validity Test-retest reliability
Atroshi 1998 [326]	SF-36 and CTS-I	102	Test-test comparison Test-retest reliability Response to treatment
Pransky 1997 [476]	UEF	165	Validity Test-test comparison
Atroshi 1997 [477]	SF-36 and CTS-I	277	Validity
Katz 1994 [377]	Global score	104	Validity
Katz 1994 [303]	CTS-I and K-ADL	74	Response to treatment
Levine 1993 [393]	CTS-I	67	Validity Test-retest reliability Response to treatment

a The full names of the instruments and descriptions of the instruments are given in

.

Table 148. Instruments evaluated to measure functional limitations associated with carpal tunnel syndrome

Instrument	Abbreviation	First described by	Scoring system	Subjects covered	Extent of use[a]
Alderson-McGall Hand Function Questionnaire	AMHFQ	Alderson and McGall 1999[318]	Functional difficulty categories	Common tasks performed with the hands	Not widely used
Calculated Global Score	Global Score	Katz 1994[377]	VAS	Grip strength, numbness, pain, parethesia	Not widely used
Carpal Tunnel Syndrome Instrument	CTS-I	Levine 1993[393]	Functional difficulty categories/ symptom severity categories	Eight ADL, and severity of symptoms	Widely used
Katz Activities of Daily Living	K-ADL	Katz 1994[303]	Functional difficulty categories	Ten ADL	Not widely used
Medical Outcomes Study 36-Item Short-Form Health Survey	SF-36	Ware 1992[478]	Categories	Impact of health on physical activities, social activities, activities of daily living, pain, psychological distress, emotional health, and energy	Extensively used
Modified Stanford Health Assessment Questionnaire	mSHAQ	[479]	Categories	ADL	Widely used
Nottingham Health Profile	NHP	Hunt 1985[480]	Categories	Pain, energy, emotional reactions, sleep problems, social isolation, physical mobility, employment, hobbies, sex life, personal relationships, and holiday	Widely used
Upper Extremity Function Scale	UEF	Pransky 1997[476]	Functional difficulty categories	Eight ADL	Not widely used
Vaile Visual Analog Scales	V-VAS	Vaile 1999[475]	VAS	Impact of CTS on well being, discomfort, activities	Not widely used

[a]Extent of use was determined by searching Medline for manuscripts that used the assessment instrument.
Not widely used = 3 or fewer studies. Widely used= four to ten studies. Extensively used= more than ten studies.

Study quality

Internal validity

Studies evaluating instruments need not include a separate control group, because each patient acts as his/her own control. The patient's score on the assessment instrument can be directly compared to the patient's score on the parameter against which the test is being measured. All of the studies included in this section are single-arm prospective cohort studies. Factors relating to the quality of the studies are shown in Table 149. Five of the eight studies administered and scored the instruments with evaluators who were blinded to the identity, history, and other test scores of the patients. Studies that did not use blinded evaluators may have been subject to bias.

Table 149. Details of study design

Study	Number of patients	Number of centers	Funded by a for-profit agency?	Study design	Prospective	Blinding	% Attrition	Intent to treat analysis	% Compliance
Vaile 1999 [475]	27	2	NR	Cohort	Yes	No	0	Yes	NA
Alderson 1999 [315]	26	1	NR	Cohort	Yes	Rater	34	No	NA
Atroshi 1998 [326]	102	1	No	Cohort	Yes	Rater	0	Yes	NA
Pransky 1997 [476]	165	1	No	Cohort	Yes	No	44.8	No	NA
Atroshi 1997 [477]	277	3	No	Cohort	Yes	No	23.4	No	NA
Katz 1994 [377]	104	4	No	Cohort	Yes	Rater	0	Yes	NA
Katz 1994 [303]	74	4	NR	Cohort	Yes	Rater	NR	No	NA
Levine 1993 [393]	67	2	No	Cohort	Yes	Rater	0	No	NA

Generalizability

It is important for studies that evaluate assessment instruments to enroll patients who are representative of the population of interest. Information about patients enrolled in the studies addressing this question are shown in Table 150. All eight studies recruited populations that appear to be "typical" of patients presenting with carpal tunnel syndrome as has been established by epidemiology studies (See the Introduction). The patient groups are predominantly female and middle aged. Few of the studies reported on the presence of co-morbid conditions that may have contributed to functional limitations. The occupations and employment status of the patients are shown in Table 151. The two studies by Katz recuited patients from the same large randomized controlled trial, a trial that was comparing different methods of surgically treating carpal tunnel syndrome.

Table 150. Study generalizability: patient characteristics

Study	Number of patients	Mean age and range	% female	Duration of conditon mean and range months	% Patients with diabetes	% Patients with arthritis	% Patients with prevous relevant injuries	% Patients with other relevant nerve impingement conditons	% Patients with peripheral neruopathy	% Patients pregnant	% Patients on kidney dialysis	Did the study exclude patients with severe disease?	Did the study exclude patients with mild disease?
Vaile 1999 [475]	27	57 (29-84)	81.4	NR	NR	55.5	NR	NR	NR	NR	NR	No	No
Alderson 1999 [315]	26	44.4 (22-79)	70.5	(3-48)	NR	0	NR	NR	NR	NR	NR	No	No
Atroshi 1998 [326]	102	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Pransky 1997 [476]	165	46 (19-65)	67	NR	NR	NR	NR	NR	NR	NR	NR	No	No
Atroshi 1997 [477]	277	46.6 (13-91)	77.8	NR	NR	NR	NR	NR	NR	NR	NR	No	No
Katz 1994 [377]	104	55 (25-87)	70	NR	NR	NR	NR	NR	NR	NR	NR	No	No
Katz 1994 [303]	74	55 (25-87)	70	NR	NR	0	NR	0	0	0	NR	No	No
Levine 1993 [393]	67	57 (19-88)	75	18 (3-58)	NR	NR	NR	NR	NR	NR	NR	NR	No

Table 151. Generalizability: employment status and occupations

Study	Number of patients	% Patients employed	% Patients on Workers Compensation	% Patients retired	% Patients homemakers	Reported Occupations
Vaile 1999 [475]	27	NR	0	NR	NR	NR
Alderson 1999 [315]	26	NR	35	NR	5.6%	Business-17.6% Sciences-5.9% Health-11.8% Education-5.9% Recreation-5.9% Sales-11.8% Trades and Transport-5.9% Industry-5.9% Manufacturing-23.5%
Atroshi 1998 [326]	102	NR	NR	NR	NR	NR
Pransky 1997 [476]	165	89	10	NR	NR	NR
Atroshi 1997 [477]	277	NR	28.8	NR	NR	NR
Katz 1994 [377]	104	NR	8	NR	NR	NR
Katz 1994 [303]	74	NR	8	NR	NR	NR
Levine 1993 [393]	67	NR	13	NR	NR	NR

Results

Test-retest reliability

Two studies have reported that two tests, the CTS-I and the AMFHQ, give similar results when administered twice to the same subject. The correlation coefficients describing the test-retest reliability are shown in Table 152.

Table 152. Results of test-retest reliability tests

Study	Number of patients	Tests evaluated	Time between test administrations	Type of statistical comparison being made	Was the instrument reliable?
Alderson 1999 [315]	26	AMFHQ	NR	Intraclass correlation coefficient Reported to be consistent	Yes
Atroshi 1998 [326]	22	CTS-I	24 hours	Correlation coefficient r = 0.71	Yes
Levine 1993 [393]	67	CTS-I	24 hours	Pearson's correlation coefficient r = 0.93	Yes

Internal reliability

None of the studies reported on this aspect of instrument evaluation.

Response to treatment

Four studies have reported the ability of six different assessment instruments to respond to changes in subjects treated for carpal tunnel syndrome. For the purposes of answering this question, studies that analyzed the test scores of patients who were successfully treated separately from those patients who failed treatment are superior. If the test scores of patients who failed treatment are included with those who were successfully treated, the results will be biased towards finding that the assessment instrument cannot detect a response to treatment. None of the studies separately analyzed data from successfully treated patients and data from unsuccessfully treated patients. The studies by Vaile 1999 and Katz 1995 included only patients who had been successfully treated. The results of the response to treatment evaluations are summarized in Table 153.

Because there are three or fewer studies evaluating each test, we did not perform a meta-analysis. We scored an instrument as being responsive to treatment if there was a statistically significant difference in the effect sizes determined from the pre-treatment and post-treatment scores. By this criterion, the mSHAQ and NHP were not responsive to treatment, while the V-VAS and the K-ADL were responsive to treatment. Three studies evaluated the CTS-I; all three found the instrument to be responsive to treatment. Two studies reported that the SF-36 was not responsive to treatment.

In summary, the more general instruments were not found to be responsive to treatment for carpal tunnel syndrome (NHP, SF-36, mSHAQ). Instruments designed to evaluate carpal tunnel syndrome were found to respond to treatment for carpal tunnel syndrome (CTS-I, K-ADL, V-VAS).

Table 153. Results of response to treatment tests

Study	Number of patients	Test evaluated	Treatment	Time of testing months	Effect size hedges' d (95% CI)[a]	Was the instrument responsive to treatment?
Vaile 1999 [475]	27	mSHAQ	Injection of corticosteroids	0 - - - - - - - - 1	0.31 (-0.23 to 0.85)	No
		SF-36	Injection of corticosteroids	0 - - - - - - - - 1	-0.29 (-0.82 to 0.24)	No
		NHP	Injection of corticosteroids	0 - - - - - - - - 1	0.38 (-0.16 to 0.91)	No
		V-VAS	Injection of corticosteroids	0 - - - - - - - - 1	1.58 (0.97 to 2.19)	Yes
Atroshi 1998 [326]	102	CTS-I	Carpal tunnel release surgery	0 - - - - - - - - 3	0.78 (0.50 to 1.07)	Yes
	48	SF-36	Carpal tunnel release surgery	0 - - - - - - - - 3	-0.052 (-0.45 to 0.35)	No
Katz 1994 [303]	43	CTS-I	Carpal tunnel release surgery	0 - - - - - - - - 3	1.08 (0.63 to 1.53)	Yes
	55	K-ADL	Carpal tunnel release surgery	0 - - - - - - - - 3	1.32 (0.91 to 1.73)	Yes
Levine 1993 [393]	38	CTS-I	Carpal tunnel release surgery	0 - - - - - - - - 14 mean	0.97 (0.50 to 1.45)	Yes

a calculated by ECRI

Validity

The validity tests performed on the instruments evaluated are summarized in Table 154. The validity tests can be separated into two groups: those measuring predicitive validity, and those measuring concurrent validity.

Predictive validity

Atroshi 1997 compared the test scores of those receiving Workers' Compensation to the scores of those not receiving Workers' Compensation. Atroshi 1997 found no statistically significant differences between the two groups in their scores on either the SF-36 or the CTS-I. Workers' Compensation is paid to only those with injuries so severe that they cannot work. Thus, the results of this study suggest that either the SF-36 and the CTS-I are not valid tests for functional limitations, or that Workers' Compensation is not a valid measure of the severity of functional limitations. Due to a lack of reported data, we were unable to verify that the study by Atroshi 1997 had sufficient statistical power to be able to detect a statistical significance between the two groups if one had existed.

Pransky 1997 compared test scores on the UEF of those working and those not working. However, instead of calculating the correlation between the individual scores and work status, Pransky 1997 compared the mean scores of the two groups of patients. There was a statistically significant difference between the means of the two groups for both a mixed population of upper extremity disorders and a population with carpal tunnel syndrome. Comparing the means suggests that the UEF can discriminate between subjects who are working and not working, but provides little information as to whether an individual score on the test can be used to predict an individual's ability to work.

Katz 1994 tested individuals shortly after surgery for carpal tunnel syndrome and found a statistically significant correlation between the Global Score and time to return to work for those treated with open tunnel release surgery, but not for those treated with endoscopic tunnel release surgery. This finding can be explained by the fact that one of the measurements that contributes to the Global Score is the amount of pain the individual experiences at the site of surgery. Thus it is likely that the Global Score is not a particularly valid measurement of functional limitations related to the WRUEDs.

In summary, none of the instruments have been reported to have predictive validity as measured by the ability to work. None of the instruments were evaluated as to predictive validity as measured by the ability to perform activities of daily living.

Concurrent validity

The clinical examination results used to validate the instruments consist of measurements of hand grip strength, and measurements of hand sensory function or nerve conduction speed. One study per test has reported a weak correlation (see Table 154 for the values of the correlation coefficients) between scores on the AMHFQ, the UEF, and the CTS-I and hand grip strength. This suggests that all three tests may have concurrent validity as measured by hand grip strength.

Alderson 1999 reported no statistically significant correlation between scores on the AMHFQ and measurements of hand sensory capability. Levine 1993 reported a weak correlation between hand sensory capability and scores on the CTS-I. Pransky 1997 and Levine 1993 reported no statistically significant correlation between nerve conduction speed tests and scores on the UEF and CTS-I. These results indicate that the instruments cannot be used to predict sensory/nerve function.

In summary, the AMHFQ, the UEF, and the CTS-I may all be concurrently valid as measured by hand grip strength, but not of hand sensory ability.

Table 154. Results of validity tests

Study	Number of patients	Test evaluated	Type of statistical comparison being made	Validated against	Was the instrument valid by this measurement?
Alderson 1999 [315]	26	AMHFQ	Pearson's correlation coefficient	pinch strength r = 0.295	Yes, but the r value is low
				grip strength r = 0.3867	Yes, but the r value is low
				two-point discrimination r = -0.127	No
Atroshi 1997 [477]	102	SF-36	ANOVA	On workers comp. vs. not on workers comp. p = 0.5	No
		CTS-I	ANOVA	On workers comp. vs. not on workers comp p = 0.07	No
Pransky 1997 [476]	165	UEF	Difference between two means with t-test	working vs. not working p <0.001	Yes
				normal Phalen's test vs. abnormal Phalen's test p <0.05	Yes
			Pearson's correlation coefficient	nerve conduction speed test p >0.05	No
				pinch strength p <0.001	Yes
				grip strength p <0.001	Yes
Katz 1994 [377]	104	Global score	Pearson's correlation coefficient	time to return to work- treated with open release surgery r = 0.67	Yes
				time to return to work- treated with endoscopic release surgery r = 0.2	Yes, but the r value is low
Levine 1993 [393]	67	CTS-I	Spearmann's correlation coefficient	Semmes-Weinstein monofilament testing r = 0.24	Yes, but the r value is low
				two-point discrimination test r = 0.42	Yes
				pinch strength r = 0.60	Yes
				grip strength r = 0.50	Yes
				median nerve sensory conduction velocity r = 0.12	No

Test-test comparisons

One study compared the scores of the same patients on different tests (Table 155). Atroshi 1998 compared the CTS-I and the SF-36 tests on patients with carpal tunnel syndrome. Before treatment of the carpal tunnel syndrome, the test scores correlated fairly well, but the correlation dropped after treatment. This change may be attributed to the finding, discussed previously, that the CTS-I instrument is responsive to treatment while the SF-36 is not.

Table 155. Results of test-test comparisons

Study	Tests being compared	Type of statistical comparison being made	Value of comparison r	Were the tests consistent?
Atroshi 1998 [326]	CTS-I and SF-36, pre-treatment	Spearmann's correlation coefficient	0.62	Yes
	CTS-I and SF-36, post-treatment	Spearmann's correlation coefficient	0.56	Yes

Conclusion

Eight studies evaluated the ability of nine different instruments as ways to measure functional limitations of patients with carpal tunnel syndrome. Of the available instruments, only two were evaluated by more than one trial. The two instruments that were evaluated by three and four trials, respectively, were the SF-36 and the Levine CTS-I.

It can be tentatively concluded that the SF-36 is not a useful instrument for assessing functional limitations in individuals with carpal tunnel syndrome. The SF-36 was reported to not be responsive to treatment and to not be able to predict ability to work.

It can be tentatively concluded that the Levine CTS-I may be a useful instrument for assessing functional limitations in individuals with carpal tunnel syndrome. This instrument was reported to be responsive to treatment, and to have concurrent validity as measured by grip and pinch strength. However, the Levine CTS-I was not evaluated by the studies included in the answer to this question for internal reliability, or prediction of the ability to perform activities of daily living. In addition, the Levine CTS-I has been reported by one study to not be able to predict ability to work.

It is difficult to reach an evidence-based conclusion as to the usefulness of the other instruments evaluated in this report due to the limited evidence base.

Question #10: What are the functional limitations for an individual with carpal tunnel syndrome before treatment?

This question inquires about the functional limitations of an individual before they have received conservative or surgical treatment for carpal tunnel syndrome. In addressing it, our objective is to catalogue these limitations, and not to address the effectiveness of these treatments. We address the effectiveness of conservative and surgical treatments in Question 3.

The available literature governs our approach to the present question. Hence, we address functional status rather than functional limitations, because no published studies specifically addressed the latter. In addition, the only available data operationally defines functional status in terms of scores on certain written tests. Hence, we also address functional status in these terms. The validity and reliability of these written tests is discussed in Question 9. Study inclusion criteria are described under Methods (section).

Excluded studies

As discussed in the Methods section, we retrieved articles identified by our literature searches according to certain *a priori* criteria. However, not all of the retrieved studies met our more specific inclusion criteria for this question. These latter studies, and the reason we did not consider them for this question are shown in Table 156.

Table 156. Excluded studies

Author	Reason for exclusion
Sefcovic (2000) [481]	Some patients had prior treatment (including surgery), some did not, but all were analyzed together.
Davis (1998) [438]	Used CTOA-I scale that has not been validated against accepted functional scales for carpal tunnel syndrome

There were also nine studies wherein functional status was reported for patients prior to receiving surgical treatment.[44,311,313,326,428,476,482-484] These patients generally had received prior conservative treatment that had been ineffective at relieving symptoms (or had not provided enough relief). Because patients who eventually receive surgery may have more severe pre-treatment symptoms than non-surgical patients, these nine studies do not address the question and are not considered further.

Evidence Base

Two studies (with a total of 51 patients) remained that addressed this question after the above exclusions.

Internal validity

Aspects of study quality that are most relevant to the present question are shown in Table 157. Because we are cataloging functional status rather than using it to compare treatments, randomization and the use of control groups are not of paramount importance here. Therefore, Table 157 does not depict these aspects of study design. However, the following variables are particularly important: attrition rates, whether the trial was prospective, and whether the raters of functional status (in this case the patients) were blinded to the treatment the patient received.

One study reported no patient attrition, the other reported an attrition rate of 19 percent. This latter study did not perform an intent-to-treat analysis.[34] Both studies were prospective, but neither employed blinding. Because it is difficult to blind patients to the treatment received, we are considering unblinded studies to be of acceptable quality for this question.

Table 157. Internal validity

Author	Number of patients	Number of centers	Funded by a for-profit agency?	Prospective	Blinding	% Attrition	Intent to treat analysis	% Compliance
Walker (2000) [34]	21	1	No	Yes	No	19.0	No	92
Vaile (1999) [485]	30	2	NR	Yes	No	0	Yes	NR

NR – Not reported

Generalizability

Selected patient characteristics are presented in Table 158. Both studies reported mean patient age and percentage of female patients. For the remaining categories, one study reported combidities,[485] and neither study reported duration of symptoms or selection of patients based on severity of disease. In one study (Walker et al., 2000), the percent of female patients was much lower than that found in a typical population of carpal tunnel patients. This study examined a population of Veteran's Administration patients, of which men comprise an overwhelming majority.[34] Although Vaile et al. (1999) did not report a mean age, the range suggests that the mean age is probably consistent with epidemiologic studies (see Introduction section, carpal tunnel syndrome, subheading epidemiology, as well as Question two for CTS).

Only one study reported any information relating to patient employment or occupation. Vaile et al. (1999) reported that there were no patients receiving workers' compensation (Table 159).[485] Because there were only two studies, and they incompletely presented information on occupation-related variables, one cannot determine how generalizable these studies are to the greater population of patients with carpal tunnel syndrome.

Table 158. Patient characteristics

Author	Number of patients	Mean age (range)	% female	Duration of condition mean and range (months)	% Patients with diabetes	% Patients with arthritis	% Patients with prevous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Did the study exclude patients with severe disease?	Did the study exclude patients with mild disease?
Walker (2000) [34]	21	60 (44-81)	4.8	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Vaile (1999) [485]	30	(29-84)	81.5	NR	NR	55.6	NR	7.4	NR	NR	NR	NR	NR

NR – Not reported

Table 159. Patient occupation

Author	Number of patients	% Patients employed	% Patients on Workers Compensation	% Patients retired	% Patients homemakers	Reported Occupations
Walker (2000) [34]	21	NR	NR	NR	NR	NR
Vaile (1999) [485]	30	NR	0	NR	NR	NR

NR – Not reported

Results

Table 160 shows the reported functional status of patients with carpal tunnel syndrome who had no prior treatment. Since each study used a different scale to measure functional status, the scores are not directly comparable. The two studies suggested that untreated patients on average score in the middle range (the 30-65% level) of functional status scales, suggesting mild to moderate difficulty with functional activities.[34,485]

Table 160. Studies with patients who had no prior treatment

Study	N	Future treatment	Scale	Range of scale	Overall mean pre-treatment functional status score	% of maximum score
Walker (2000) [34]	21	Non-surgical (splints)	CTS-I	1-5	Splint (night only): 2.75 (1.01) Splint (full-time): 2.27 (1.03)	43.8 31.8
Vaile (1999) [485]	30	Non-surgical (steroid injections)	Vaile VAS	0-100	64.2 (24.0)	64.2

CTS-I – Carpal Tunnel Syndrome Instrument
VAS – Visual Analog Scale

Conclusions

There is some evidence to suggest that most untreated patients with carpal tunnel syndrome have mild to moderate functional difficulties before treatment. However, this evidence is derived from only two studies comprised of a total of 51 patients. This is too few patients and too few studies to allow one to reach a firm evidence-based conclusion.

Question #11: What are the functional limitations of an individual with carpal tunnel syndrome after treatment?

This question inquires about the functional limitations of an individual after they have received conservative or surgical treatment for carpal tunnel syndrome. Our objective is as described in Question 10 for carpal tunnel syndrome. As also discussed in Question 10, our approach is governed by the available literature. We refer the reader to that question for additional details.

Excluded studies

As discussed in the Methods section, we retrieved articles identified by our literature searches according to certain *a priori* criteria. However, not all of the retrieved studies met our more specific inclusion criteria for this question. Table 161 shows these latter studies and the reason we did not consider them for this question.

Table 161. Excluded studies

Author	Reason for exclusion
Provinciali (2000) [427]	Used Jebsen-Taylor test to measure functional limitation. The test is not validated for carpal tunnel syndrome
Atroshi (1999) [486]	Study group overlaps with Atroshi et al.[326]
Bessette (1998) [487]	Used SF-36 scale that is not accurate for carpal tunnel syndrome (see Question 9 for carpal tunnel syndrome)
Davis (1998) [438]	Used CTOA-I scale that has not been validated against accepted functional scales for carpal tunnel syndrome
Katz (1998) [462]	Study group contains an unspecified number of the same patients evaluated in Katz et al.[482]
Atroshi (1997) [483]	Lack of information about treatment status of the study group
Katz (1996) [488]	Study group contains an unspecified number of the same patients evaluated in Katz et al.[482]
Katz (1994) [303]	Biased post-hoc selection of patients for analysis

Evidence base

Twelve studies (with a total of 1567 patients) that addressed this question remained after the above exclusions.

Internal Validity

Aspects of study quality that are most relevant to the present question are shown in Table 162. Because we are cataloging functional status rather than using it to compare treatment, randomization and the use of control groups are not of paramount importance here. Therefore, Table 162 does not depict these aspects of study design. However, the

following variables are particularly important: attrition rates, whether the trial was prospective, and whether the raters of functional status (in this case the patients) were blinded to the treatment the patient received.

None of the studies that reported attrition performed an intent-to-treat analysis. Four studies reported an attrition rate that exceeded 20 percent. This is sufficient attrition to cast doubt on the internal validity of the studies. Nine of 12 studies were prospective. In another study, some, but not all, patients were prospectively enrolled. No studies employed blinding of patients to the treatment they received. Because it is difficult to blind patients to the treatment received (especially surgical treatments), we are considering unblinded studies to be of acceptable quality for this question.

Table 162. Study quality

Author	Number of patients	Number of centers	Funded by a for-profit agency?	Prospective	Blinding	% Attrition	Intent to treat analysis	% Compliance
Mondelli (2000) [311]	110	1	No	NR	No	15.5	No	NA
Porras (2000) [313]	85	1	NR	Yes	No	0	Yes	NA
Walker (2000) [34]	21	1	No	Yes	No	19.0	No	92
Vaile (1999) [485]	30	2	NR	Yes	No	0	Yes	NR
Atroshi (1998) [326]	111	1	No	Yes	No	8.1	No	NA
Katz (1998) [482]	429	26	No	Yes	No	21 (6 months) 28 (18 months) 31 (30 months)	No	NR
Atroshi (1997) [477]	277	1	No	NA	NA	24	No	NR
Pransky (1997) [476]	165	1	No	Yes	No	13 37 (18 months)	No	NR
Amadio (1996) [484]	22	1	No	Yes	No	0	Yes	NA
Blair (1996) [428]	86	1	No	Yes	Single (partly)	11.8	No	NA
Worseg (1996) [44]	126	1	No	Yes	No	0	Yes	NA
Levine (1993) [393]	105	1	No	Yes (partly)	No	Not clear	Yes	NR

NR – Not reported

Generalizability

Selected patient characteristics are presented in Table 163. Ten of 12 studies (83.3%) reported mean patient age and all studies reported percentage of female patients. The mean ages of patients in surgical studies (53.4 years) was similar to that reported in epidemiological studies (see Introduction section, subheading epidemiology) and the average obtained from the 124 surgical studies (50.5 years) that were evaluated for any question in this document (see Question 2). The percentage of female patients in surgical studies was generally similar to that observed when compared to all surgical studies. The

non-surgical study by Walker et al. (2000) reported a low percentage of females (4.8%) compared to the typical carpal tunnel population.[34] This study examined Veterans Administration patients, a population that is overwhelmingly male.

For the remaining categories, two studies reported duration of symptoms, zero to three studies reported specific comorbidities, and no studies reported selection of patients based on severity of disease.

Few studies reported information on patient employment or occupation (Table 164). Two of 12 studies (16.7%) reported percentage of patients employed, six of 12 (50%) reported percentage on workers' compensation, two of 12 (16.7%) reported specific patient occupations, and only one study (8.3%) reported percentage of patients retired or homemakers. There is not enough information in epidemiological studies to determine the relative generalizability of these studies regarding patient occupation. Likewise, there were too few studies in the larger group of 124 surgical studies that reported this type of information to determine generalizability.

Table 163. Patient characteristics

Author	Number of patients	Mean age (range)	% female	Duration of condition mean and range (months)	% Patients with diabetes	% Patients with arthritis	% Patients with prevous relevant injuries	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Did the study exclude patients with severe disease?	Did the study exclude patients with mild disease?
Mondelli (2000) [311]	110	56 (20-82)	86.0	NR	5.4	0	4.3	NR	1.1	NR	0	NR	NR
Porras (2000) [313]	85	52 (18-81)	90.6	39 (6-300)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Walker (2000) [34]	21	60 (44-81)	4.8	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Vaile (1999) [485]	30	(29-84)	81.5	NR	NR	55.6	NR	7.4	NR	NR	NR	NR	NR
Atroshi (1998) [326]	111	52 (21-88)	65.7	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Katz (1998) [482]	429	NR	74.2	NR	NR	NR	NR	NR	NR	0	NR	NR	NR
Atroshi (1997) [477]	277	WC: 41 (25-62) Non-WC: 49 (13-91)	77.8	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Pransky (1997) [476]	165	46 (22-80)	67	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Amadio (1996) [484]	22	60 (33-80)	59.1	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Author	Number of patients	Mean age (range)	% female	Duration of condition mean and range (months)	% Patients with diabetes	% Patients with arthritis	% Patients with prevous relevant injurie	% Patients with other relevant nerve impingement conditions	% Patients with peripheral neuropathy	% Patients pregnant	% Patients on kidney dialysis	Did the study exclude patients with severe disease?	Did the study exclude patients with mild disease?
Blair (1996) [428]	86	49 (23-82)	82.7	NR	NR	NR	NR	NR	0	NR	NR	NR	NR
Worseg (1996) [44]	126	56 (35-90)	69.8	23.4	NR	NR	NR	NR	0	NR	NR	NR	NR
Levine (1993) [393]	105	58 (19-88)	74.3	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

NR – Not reported

Table 164. Patient occupation

Author	Number of patients	% Patients employed	% Patients on Workers Compensation	% Patients retired	% Patients homemakers	Reported Occupations
Mondelli (2000) [311]	110	NR	NR	NR	NR	NR
Porras (2000) [313]	85	NR	NR	NR	NR	Homemaker, low functional demand, cleaners, keyboard workers, heavy work, assembly line
Walker (2000) [34]	21	NR	NR	NR	NR	NR
Vaile (1999) [485]	30	NR	0	NR	NR	NR
Atroshi (1998) [326]	111	NR	NR	NR	NR	NR
Katz (1998) [482]	429	NR	38.2	NR	NR	NR
Atroshi (1997) [477]	277	NR	28.8	NR	NR	NR
Pransky (1997) [476]	165	89	10	NR	NR	NR
Amadio (1996) [484]	22	63.6	0.9	NR	NR	NR
Blair (1996) [428]	86	NR	NR	NR	NR	NR
Worseg (1996) [44]	126	NR	NR	47.6	6.3	Retired, employee, worker, unemployed, homemaker, other
Levine (1993) [393]	105	NR	12.4	NR	NR	NR

NR – Not reported

Results

Table 165 shows the results of the two nonsurgical studies of post-treatment functional limitations in patients with carpal tunnel syndrome. Since these studies used different scales to measure functional status, their scores are not directly comparable. Both studies suggested that after nonsurgical treatment, patients score, on average, in the lower range (the 20-30% level) of functional status scales.[34,485] However, it is unclear whether the results of these two studies are generalizable to the larger patient population.

Table 165. Studies with patients who had no prior treatment

Study	N	Treatment	Scale	Range of scale	Overall mean post-treatment functional status score (± SD)	% of maximum score
Walker (2000) [34]	21	Non-surgical (splints)	CTS-I	1-5	Splint (night only): 2.14 (0.87) Splint (full-time): 1.93 (0.77)	28.5 23.3
Vaile (1999) [485]	30	Non-surgical (steroid injections)	Vaile VAS	0-100	23.8 (26.2)	23.8

CTS-I – Carpal Tunnel Syndrome Instrument
VAS – Visual Analog Scale

Table 166 shows the results of the two surgical studies that reported individual functional activity mean scores using the CTS-I scale. Lower scores on this scale indicate less functional limitation. Table 167 shows the number of patients for each level of the scale in the surgical study of Atroshi et al. (1998).[326]

Table 168 shows the results of a third surgical study, performed by Blair et al.[428] Although these latter authors did not use a specific scale, they did report the number of patients who had difficulty with specific functional activities. Both of these studies suggest that patients have relatively mild functional limitations following surgery, and the study by Blair et al. suggests that the majority of patients do not have any noticeable difficulty with certain functional activities after surgery.

Seven studies reported overall mean functional activity scores on the CTS-I scale prior to surgery (Table 169). Four out of seven studies did not describe the surgical procedure, so no evidence-based conclusions can be reached concerning functional limitations after specific surgical procedures. However, one can make some broad conclusions about functional limitations after surgical procedures as a group. These studies suggested that most patients report no-to-moderate difficulty with functional activities (mean 1.4-2.6 on CTS-I) after surgery. Although there were no statistically significant posttreatment differences between specific patient groups, in two studies there was a trend toward more difficulty with functional activities among patients receiving workers' compensation.

The utility of functional status scales would be enhanced if they could be shown to predict work-related outcomes. The relevance of the CTS-I scale in relating functional limitation to work-related outcomes was examined by the Maine Carpal Tunnel Study (Katz et al.).[462] Results of this study suggest that patients with functional difficulty at six months after treatment have greater odds of being absent from work at 18 months post-treatment (odds ratio 3.3, 95% CI 1.5-6.9, $p = 0.002$). This odds ratio, as determined by logistic regression was per one unit change on the CTS-I scale. However, the available data were insufficient to allow an estimation of the percentage of patients with a particular score who were absent from work.

Table 166. Studies with post-treatment functional limitation data for patients with carpal tunnel syndrome (individual functional activities – mean scores from CTS-I)

Study	N	Treatment	Range of scale	Writing	Holding a book	Buttoning clothes	Gripping the telephone	Opening jars	Performing household chores	Carrying a grocery bag	Bathing and dressing
Atroshi (1998) [326]	111	Endoscopic release	1-5	1.5	1.7	1.7	1.5	2.1	1.7	2.1	1.3
Worseg (1996) [44]	126	Endoscopic release	1-5	1.0 (0.2)[a]	1.0 (0.1)	1.0 (0.1)	1.0 (0.1)	1.6 (0.7)	1.4 (0.8)	1.4 (0.8)	1.2 (0.4)
		Open release		1.0 (0.2)	1.0 (0.2)	1.2 (0.4)	1.1 (0.2)	1.9 (0.8)	1.2 (0.4)	1.7 (0.8)	1.2 (0.4)

[a]Numbers in parentheses indicate standard deviations

Table 167. Studies with post-treatment functional limitation data for patients with carpal tunnel syndrome (individual functional activities – number of patients)

Study	N	Score	Number of patients in each CTS-I Functional Status category (%)							
			Writing	Holding a book	Buttoning clothes	Gripping the telephone	Opening jars	Performing household chores	Carrying a grocery bag	Bathing and dressing
Atroshi (1998) [326]	111	1	69 (70.4)	59 (60.2)	59 (59.6)	69 (72.6)	42 (42.4)	56 (56.6)	41 (42.3)	77 (77)
		2	17 (17.3)	21 (21.4)	19 (19.2)	12 (12.6)	26 (26.3)	21 (21.2)	25 (25.8)	18 (18)
		3	6 (6.1)	9 (9.2)	15 (15.2)	7 (7.4)	13 (13.1)	16 (16.2)	16 (16.5)	3 (3)
		4	6(6.1)	9 (9.2)	2 (2.0)	4 (4.2)	14 (14.1)	4 (4.0)	12 (12. 4)	2 (2)
		5	0 (0)	0 (0)	4 (4.0)	3 (3.2)	4 (4.0)	1 (1.0)	3 (3.1)	0 (0)

Table 168. Studies with post-treatment functional limitation data for patients with carpal tunnel syndrome (individual functional activities – number of patients)

Study	Treatment	Difficulty	Self-described difficulty in performing selected activities of daily living after carpal tunnel release (% of patients)		
			Screwing lids	Picking up small objects	Lifting
Blair (1996) [428]	Open release plus epineurotomy (n = 48)	Yes	15 (31.3)	9 (18.8)	9 (18.8)
		No	33 (68.8)	39 (81.3)	39 (81.3)
	Open release without epineurotomy (n = 27)	Yes	11 (40.7)	10 (37.0)	7 (25.9)
		No	16 (59.3)	17 (63.0)	20 (74.1)

Table 169. Studies with post-treatment functional limitation data for patients with carpal tunnel syndrome (mean function score on CTS-I)

Study	N	Treatment	Study Design	Range of scale	Followup time	Overall mean post-treatment functional status score (SD)	% of maximum score
Mondelli (2000) [311]	110	Surgical (open release)	Prospective case series	1-5	1 month	2.0 (0.7)	25
					6 months	1.5 (0.6)	12.5
Porras (2000) [313]	85	Surgical (open release)	Prospective case series	1-5	6 months	1.4 (range 1-4.2)	10
Atroshi (1998) [326]	111	Surgical (endoscopic release)	Prospective case series	1-5	3 months	1.7 (range 1.6-1.9)	17.5
Katz (1998) [482]	429	Surgical (n = 270, procedures not described) Non-surgical (n = 125) (34 patients who crossed over to surgery were not evaluated)	Prospective case series (stratified)	1-5	6 months	Surgical patients: >55 years: 1.7 (0.9) ≤55 years, WC non-recipient:: 1.6 (0.7) ≤55 years, WC recipient: 2.1 (0.9)	17.5 15 27.5
						Non-surgical patients: >55 years: 2.6 (0.8) ≤55 years, WC non-recipient:: 1.9 (0.9) ≤55 years, WC recipient: 2.2 (0.7)	40 22.5 30
					18 months	Surgical patients: >55 years: 1.6 (0.7) ≤55 years, WC non-recipient: 1.6 (0.7) ≤55 years, WC recipient: 2.2 (0.9)	15 15 30

Study	N	Treatment	Study Design	Range of scale	Followup time	Overall mean post-treatment functional status score (SD)	% of maximum score
						Non-surgical patients: >55 years: 2.3 (0.9) ≤55 years, WC non-recipient:: 2.0 (1.0) ≤55 years, WC recipient: 2.4 (0.7)	32.5 25 35
					30 months	Surgical patients: >55 years: 1.6 (0.9) ≤55 years, WC non-recipient: 1.6 (0.7) ≤55 years, WC recipient: 2.2 (1.0)	15 15 30
						Non-surgical patients: >55 years: 2.2 (0.8) ≤55 years, WC non-recipient:: 2.0 (0.9) ≤55 years, WC recipient: 2.2 (0.8)	30 25 30
Atroshi (1997) [477]	277	Surgical or non-surgical (or both) (procedures not described)	Cross-sectional study	1-5	6-20 months	WC patients: 2.5 (95% CI: 2.2-2.7) Non-WC patients: 2.2 (2.0-2.4)	37.5 30
Amadio (1996) [484]	22	Surgical (not described)	Prospective case series	1-5	3 months	1.77 (0.68)	19.3

Study	N	Treatment	Study Design	Range of scale	Followup time	Overall mean post-treatment functional status score (SD)	% of maximum score
Levine (1993) [393]	67	Surgical or non-surgical (not described)	Prospective case series	1-5	3 months	Prospective: 2.1 (1.1)	27.5
	38	Surgical (not described)	Retrospective case series		Median: 14 months	Retrospective: 2.0 (1.1)	25

WC – Workers' Compensation

Table 170. Studies with post-treatment functional limitation data for patients with carpal tunnel syndrome (summary function score on UEFS)

Study	N	Treatment	Study Design	Range of scale	Followup time	Overall summary post-treatment functional status score (SD)	% of maximum score
Pransky (1997) [476]	108	Surgical or non-surgical (not described)	Prospective case series	1-10	Mean: 18 months	25.4 (18.1)* Note: this study also had a case series of mixed upper extremity disorders (UEDs)	17.1

Conclusions

Although studies of non-surgical therapies suggested that most patients experience only mild difficulty with functional activities after treatment, it is unclear whether the results of these two studies are generalizable to the larger patient population. Studies with surgical outcomes suggested that most patients report no-to-moderate difficulty with functional activities (mean 1.4-2.6 on CTS-I) after surgery. Although there were no statistically significant differences between specific patient groups, in two studies there was a trend toward more difficulty with functional activities among workers' compensation patients. Decreased functional ability on the CTS-I scale shows a strong correlation with work absence. The available data are insufficient to determine a cutoff point on measuring scales above which patients are unable to work.