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Current options for nonsurgical management of carpal tunnel syndrome

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Abstract

Carpal tunnel syndrome (CTS) is the most common of the entrapment neuropathies. Surgical decompression is commonly performed and has traditionally been considered the defnitive treatment for CTS. Conservative treatment options include physical therapy, bracing, steroid injections and alternative medicine. While CTS is often progressive, patients may get better without formal treatment. The resolution of symptoms is not necessarily related to the severity of the clinical findings and self-limited activity is common. The current literature suggests that bracing and corticosteroid injections may be useful in the nonsurgical treatment of CTS, although the benefits may be short term. There is limited evidence regarding the efficacy of other treatments, such as therapy, exercise, yoga, acupuncture, lasers and magnets, and further studies are needed. Surgery is recommended for progressive functional deficits and significant pain.

Keywords

alternative therapy; braces; carpal tunnel syndrome; conservative treatment; corticosteroid injection; exercise; treatment outcome

Overview

Carpal tunnel syndrome (CTS) is the most common of the entrapment neuropathies [1]. While the published incidence and prevalence of CTS is variable and complicated by the method of diagnosis, various investigations have produced estimates of population incidence ranging from 0.125 to 1% [2].

Carpal tunnel syndrome represents the compression of the median nerve within the carpal tunnel. The borders of the carpal tunnel are wrist carpal bones on the medial, lateral and dorsal aspect and the transverse carpal ligament on the volar aspect. The median nerve and nine of the finger and thumb flexor tendons pass through this space. CTS is characterized by symptoms of numbness, tingling and paraethesias, which are not always limited to the median nerve distribution. Individuals with CTS tend to initially present with intermittent symptoms that may be worse at night or with repetitive upper-extremity activity. The symptoms may improve with splinting, repositioning or vigorous shaking of the hand [3–6].

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Physical examination findings in more involved cases may present with neurologic deficits, including impaired sensation, two-point discrimination in the median nerve distribution or thenar weakness. Milder cases may only present with positive carpal tunnel provocative maneuvers (e.g., with Phalen's test and Tinel's sign) with normal neurologic examination findings. Nerve conduction studies (NCS) are frequently performed for confirming the diagnosis of CTS. Conservative treatment may include physical therapy, bracing, steroid injections and alternative therapies. However, surgical decompression (carpal tunnel release) is often elected.

While the reported incidence and prevalence of CTS varies widely based on the diagnostic criteria and study methods, it does appear that repetitive trauma disorders and CTS are increasing [1]. Prevalence of CTS in the general population can be difficult to estimate and is frequently reported in specific groups [7]. A Swedish study found that 3.8% of the population have a clinical diagnosis of CTS, and 4.9% have electrophysiologic evidence. A total of 2.7% of the population were found to have both [7]. CTS of a severity indicating surgery has been found in 0.7% of a general population [8]. In the general population, CTS prevalence has been estimated at 3.72% in the USA and 5.8% in The Netherlands [1,9].

The incidence of CTS in The Netherlands has been reported at 1.8 per 1000 people, with a female:male ratio of 3:1 and the highest rates in the 45–64-year-old age group [10]. Women are susceptible to the syndrome, and have been demonstrated to progress differently from males [11]. Blue-collar workers and housewives have been demonstrated to have an increased risk of CTS requiring surgery [12]. Manual labor, exposure to vibratory tools and repetitive flexion and extension of the wrist combined with gripping have been reported as risk factors for CTS, while the risk from using a computer mouse or keyboard is unclear [13–15].

Surgical decompression has traditionally been considered the definitive treatment for CTS. The most common hand surgery in the USA is carpal tunnel release, with 200,000 procedures carried out each year [16]. Surgical treatment appears to be more effective for the symptoms of CTS than splinting, which has been the mainstay of conservative treatment [17]. In order to evaluate the effectiveness of nonsurgical treatments for CTS, an understanding of the efficacy of surgical treatment, as well as the natural progression of untreated CTS, is beneficial.

Natural history

The course of untreated CTS is not completely established [18]. The natural history and progression of CTS has been most thoroughly described in medical literature with respect to the clinical presentation of symptoms. While these symptoms may affect the patient and give the physician an indication of the impairment, they are subjective, difficult to quantify and challenging to follow over time. Electrophysiologic measurements are an integral component of the diagnosis of CTS and provide an objective measurement of the function of the studied nerve. The progression of electrophysiologic characteristics of the median nerve in CTS has had limited investigation with varied results [11].

The initial severity of carpal tunnel symptoms is not a reliable predictor of continued progression. Studies have had varied results when individuals are stratified into groups based on the severity of their symptoms at the initial evaluation. Padua *et al.* prospectively followed 274 untreated hands for 10–15 months with patient-oriented evaluations as well as electrodiagnostic evaluations. They investigated several different outcome measures, including pain, clinical history and physical exam, self-reported symptoms and electrophysiologic findings [19]. Approximately a quarter of cases improved, a quarter worsened and half stayed the same. There was a tendency for those with initially mild symptoms to deteriorate, while severe cases improved over the course of observation. Spontaneous improvement was noted

with shorter duration of symptoms and in younger subjects. Poorer outcomes were found in those with bilateral symptoms and a positive Phalen's test [19].

Karsidag *et al*. followed 28 hands, with varying degrees of CTS. Evaluations by NCS were performed every 12 weeks for 1 year. All subjects received conservative therapy (bracing) during the trial. Mild cases saw no change, moderate cases saw significant improvements and the severe cases were too few in number to make relevant comparisons [11].

A retrospective review of nonsurgical NCS-confirmed CTS cases followed 261 hands. The average follow-up time was 47 months. The majority of the group had progression of their symptoms (54.9%), while a notable percentage improved (34.3%), and only a few were stable (10.8%) [20].

A total of 157 subjects with CTS with positive electrodiagnostic findings were reviewed retrospectively. Of the 72 subjects without surgery, 32% showed improvement compared with 86% of the 85 subjects that improved with carpal tunnel release [21]. A total of 132 subjects with CTS were followed for an average of 2 years and were treated without surgery, injections or braces. Upon evaluation, 47.6% improved with respect to history and examination findings, and 25% improved with respect to NCS. Only 23.4% clinically and 7.6% electrophysiologically worsened [22].

In many of these studies, it is unclear how much of the 'natural history' is actually the self-imposed intervention of activity modification secondary to CTS symptoms. Padua *et al*. monitored hand stress, which was defined as activities with repetitive hand–wrist action, hard manual work, sporadic hand stress or trauma. They found that 68% of subjects decreased their hand stress and 32% altered their work or hobby hand activities after the diagnosis of CTS [19].

Nonsurgical management

Bracing

Splinting is commonly prescribed as a relatively inexpensive, nonoperative treatment for CTS. As CTS has been associated with forceful, repetitive hand and wrist activities [14,23], one purpose of splinting is to minimize motion at the wrist and subsequently decrease symptoms of pain and/or numbness. Splinting may also be helpful for the common symptom of nocturnal paresthesias by limiting prolonged periods of excessive wrist flexion or extension during sleep. Positions of wrist flexion and extension have been demonstrated to cause increased pressure within the carpal tunnel, similar to the findings of increased pressure in the carpal tunnel with CTS [24], and is associated with changes in nerve structure [25].

While immobilizing the wrist with a splint to prevent extremes of flexion and/or extension is a common practice in treating CTS, it is unclear as to which specific type of wrist splint to use. Often, neutral wrist splints are recommended. Neutral wrist position results in lower carpal tunnel pressures compared with flexion or extension [26,27]. However, studies also suggest that flexion of the metacarpophalangeal joints increase carpal tunnel pressure by migration of the lumbricals into the carpal tunnel [28,29]. Soft hand splints have been designed to splint the metacarpophalangeal joint in extension in order to decrease carpal tunnel pressures [30].

We reviewed the literature for recent randomized, controlled trials involving braces/splints for CTS (Ovid MEDLINE® search, 1996 to present). Manente *et al*. studied a total of 83 subjects with CTS diagnosed by history, physical examination and electrodiagnostic studies. Subjects were randomized to a treatment group that wore a soft hand splint at night for 4 weeks, or to an untreated control group. The splinted group had decreased self-reported CTS symptoms and

functional limitations, although there was no significant difference in the electrophysiologic data [30]. DeAngelis *et al*. compared a soft hand splint to a more traditional wrist splint for CTS. A total of 120 subjects with CTS based on history, physical examination and electrodiagnostic studies were randomized into treatment with a soft hand splint or a wrist splint to be worn at night for 3 months. Both groups had decreased symptoms and functional limitations at 3 months, although these results had attenuated at 9 months. No significant differences between the splints were noted [31].

Gerritsen *et al*. compared splinting with surgery for CTS. A total of 176 subjects with clinical and electrodiagnostical CTS were randomized to night-time splints for 6 weeks versus carpal tunnel release. While both groups improved, surgery was found to be more effective than splinting over both the short term and long term [32]. A randomized, controlled trial to compare neutral wrist/metacarpophalangeal extension splinting versus wrist extension splinting demonstrated that the neutral wrist position was more effective in decreasing symptoms [33]. Systematic reviews of conservative treatment suggest splinting is effective over the short term in decreasing CTS symptoms [34,35]. Over the long term, surgery appears to be better than splinting for relieving symptoms, and may be more cost effective [17,36–38].

Injections

Corticosteriod injections are frequently used to treat CTS, and are considered to be both safe and effective for short-term management [39]. Pathology specimens from carpal tunnel release have revealed chronic synovial inflammation, and it is suggested that corticosteroid injections are effective by decreasing the swelling of the flexor synovialis [40,41]. A common belief is that corticosteroid injections can relieve the early symptoms of CTS [42], and that the response to a corticosteroid injection may predict the response to carpal tunnel release [40,42]. There is not a consensus on dose or type of corticosteroid injected, and methylprednisolone, triamcinolone and β-methasone are commonly used [42].

Intracarpal corticosteroid injections have been compared with intracarpal placebo injections, as well as to oral NSAIDs, in prospective, randomized trials.

In a double-blinded, placebo-controlled, randomized clinical trial, Armstrong *et al*. compared intracarpal corticosteriod and lidocaine injection to placebo (saline) and lidocaine in 81 subjects with CTS refractory in order to investigate nonsurgical management. The corticosteroid group had significantly greater symptom relief, based on a symptom satisfaction scale, compared with the placebo group; however, the results were temporary [39].

In a prospective, randomized clinical trial, Gurcay *et al*. compared intracarpal corticosteroid injections to oral NSAIDs in 32 subjects with CTS. Both groups comcomitantly used wrist splints. Outcomes were assessed using a functional status scale and a hand dexterity scale, as well as electrophysiologic findings. Dexterity scores improved in the injection group at 3 months compared with baseline; however, the oral nonsteroidal anti-inflammatory group also had improvements in parameters of dexterity compared with baseline. The functional states scores improved in both groups at month 3 compared with baseline, with no difference between the groups. At month 3, there were no significant differences for electrophysiologic parameters between groups [43].

Both clinical and electrophysiologic parameters may be improved over the short term with carpal tunnel corticosteroid injections, although clinical improvements appear to be more prominent than electrophysiologic improvements, and these improvements decrease as the severity of carpal tunnel increases [44]. However, while some patients may have relatively long-term relief of carpal tunnel symptoms with a corticosteroid injection, it appears that patients become refractory to repeated corticosteroid injections, and that many patients will

proceed to carpal tunnel release despite having had corticosteroid injections [39]. While corticosteroid injections for CTS have been described as safe [39,44], there are several reports of median nerve injury with carpal tunnel corticosteroid injections [45–50]. In order to avoid nerve injury, injection of the carpal tunnel medial to the palmaris longus tendon has been recommended, or injection in line with the ring finger if no palmaris longus tendon is present [45,47,48]. If paresthesias are experienced, the needle should be withdrawn and redirected in an ulnar direction [45]. It is unclear as to whether surgery is superior to corticosteroid injections and further studies are needed [17].

Hand/occupational therapy

Hand therapy is a form of rehabilitation that utilizes different therapeutic interventions to restore functional use of the upper extremities. Using specialized skills to assess and evaluate each person, interventions are then chosen depending on symptom severity, patient needs and goals, comorbidities and doctor referral. TABLE 1 outlines the articles referenced in the following sections.

Modalities

Iontophoresis and ultrasound are modalities often used in hand therapy clinics. These modalities are used to treat hand and upperextremity conditions such as CTS. A limited amount of literature on iontophoresis exists. An article published in the *Cochrane Database of Systematic Reviews* [34] was chosen for discussion in this paper, as well as an article published in the *Journal of Hand Therapy* [51]. Iontophoresis is a method of transdermal administration of ionized drugs in which electrically charged molecules are propelled through the skin by an external electrical field [52]. Advantages of steroid iontophoresis include being painless, noninvasive, sterile and providing local and little systemic concentration of the drug [52].

In a prospective, nonrandomized study utilizing a standardized 3-week protocol, iontophoresis was successful in 58% of those that failed splints and ibuprofen at 6-month follow-up. No adverse effects of the treatment, including significant elevation of serum glucose in insulin-dependent diabetics, occurred [52]. A study comparing local corticosteroid injection and iontophoresis of dexamethasone sodium phosphate in CTS revealed success of both treatments, but symptom relief was greater at 2 and 8 weeks with injection of corticosteroids [53]. In addition to splinting and ibuprofen, iontophoresis may be a safe and effective alternative to surgery for treating early CTS, particularly in those patients that may not tolerate corticosteroid injections [52,53].

Therapeutic ultrasound is a modality that produces acoustical high-frequency vibrations with both thermal and nonthermal effects [54]. Deep, pulsed ultrasound over the carpal tunnel for 15 min for 20 treatments decreases pain and paresthesia symptoms, reduces sensory loss, and improves median nerve conduction and strength when compared with sham ultrasound [34, 51,55]. Ultrasound treatment can also provide a positive effect on sensation and patient-reported symptoms. The average difference in symptom severity between ultrasound and placebo groups at 6 months was reported to be almost two points on a visual analog scale [55]. While superficial, continuous ultrasound in ten treatments for 5 min each time decreased pain, it was found to be no more effective than sham ultrasound and did not improve median nerve conduction [55,56].

Exercise

Mobilization exercises (e.g., tendon gliding and nerve gliding) are commonly employed for symptoms of CTS and are felt to improve axonal transport and nerve conduction [57]. Tendon and nerve gliding exercises may maximize the relative excursion of the median nerve in the carpal tunnel and the excursion of the flexor tendons relative to one another [58].

The effectiveness of neural mobilization exercises specifically for the treatment of CTS is not well documented in randomized, controlled studies. A study published by Heebner and Roddney compared standard of care (i.e., splinting and tendon gliding) with standard of care in addition to neural mobilization (i.e., nerve gliding). **At 6 months, results showed better** self-reported function in the control group (bracing, education and tendon gliding group) than that of the nerve gliding group. The investigators cited numerous reasons as to why the nerve gliding group had nonsignificant findings, including large attrition rates (50% lost to follow-up), which are common in community hospital settings, poor self-reported exercise compliance and symptom severity [59].

In another prospective, randomized trial, nerve gliding, tendon gliding and splinting was compared with splinting alone for a period of 4 weeks [60]. Statistically significant improvement was attained in all parameters in both groups. While the improvement in the mobilization group was slightly greater, the difference between the groups was not significant with the exception of lateral pinch strength [60]. In light of more current research exploring the treatment of CTS with mobilization techniques, more prospective, controlled trials are needed in order to identify populations that may benefit from this treatment.

In addition to neural mobilization, carpal bone mobilization is also widely utilized in the treatment of CTS; however, there is limited evidence of its efficacy. Although not statistically significant (due to low sample size), Tal-Akabi and Rushton found that carpal bone mobilization improved CTS symptoms when applied over the course of 3 weeks [61]. Although their study had high quality diagnostic criteria for CTS, there also existed a high risk of selection and performance bias [34]. It is evident that further investigation with larger sample sizes is necessary to support any future treatment guidelines.

C-TRAC is a custom pneumatic and dynamic hand traction device designed to increase the area of the carpal tunnel through a progressive stretching program. When the device is on the hand and the air bladder is inflated, a ‘three-point’ action force is exerted on the hand. This provides a stretching force, along the transverse carpal ligament. X-rays taken with and without the C-TRAC in place showed an increase in the distance between the trapezium and the hook of hamate and between the scaphoid and pisiform bones up to 3 mm [62]. No NSAIDs, splints or injections were used while patients used the C-TRAC device. At the 4-week follow-up, there were no reported side effects or complications in all patients. Results demonstrate a reduction in symptoms at both 4 and 7 months of follow-up. At the 7-month follow-up, eight of the 18 patients had no symptom recurrence, and ten had minor symptom recurrence. A total of 12 of the 18 patients reported the need to use the device an average of once every 2 months to manage the symptoms.

Comparison of other treatments, such as splinting and cortisone injections with this device, may be beneficial for future research [62]. Limitations of this study include no control group and a low number of subjects.

Further studies considering patient characteristics, such as age, duration of symptoms, general health and exercise regime, symptom severity, occupation and other comorbidites, are needed.

Alternative therapies

Approximately 38% of adults in the USA turn to alternative therapies for pain control [63]. Four alternative therapies (e.g., acupuncture, low-level laser, yoga and static magnetic field therapy) have limited evidence that supports safety and suggests possible therapeutic effectiveness for treating symptoms of CTS. See TABLE 2 for a list of recent studies investigating these and other alternative therapies.

Acupuncture

A 1997 NIH consensus statement concluded that acupuncture may be useful as an adjunct treatment or an acceptable alternative for managing CTS [64]. Needles and low-level lasers can both be used to stimulate acupuncture points. Yang *et al*. compared acupuncture needling of two acupoints (PC 5 and PC 6) during eight treatment sessions over 4 weeks, to 4 weeks of oral prednisolone (20 mg daily for 2 weeks, followed by 10 mg for 2 weeks) and found these treatments to be equally effective for improving symptoms [65]. The only between-group difference was in nocturnal awakening, a symptom that improved more in the acupuncture group ($p = 0.03$) compared with the prednisolone group. No changes in nerve conduction parameters occurred in either group and neither group experienced any serious side effects. Two other acupuncture studies evaluated low-level laser acupuncture in combination with micro-amp transcutaneous electrical nerve stimulation (TENS) [66,67]. All patients in Branco's uncontrolled pre- to post-treatment comparison had previously failed standard medical or surgical treatments. At the end of treatment, participants reported either no pain, or pain reduction of over 50% in 33 out of 36 hands [66]. Naeser *et al*. compared low-level laser acupoint stimulation and microamp TENS to sham treatment in a randomized crossover design. The interventions were administered over 3–4 weeks [67]. Real treatments consisted of applying red-beam laser (continuous wave, 15 mW and 632.8 nm) to shallow acupuncture points on the affected hand, infrared laser (pulsed, 9.4 W and 904 nm) to deeper points on the upper extremity and cervical paraspinal areas, and microamps TENS to the affected wrist. After the real treatment series, significant decreases in the McGill Pain Questionnaire score, median nerve sensory latency, and Phalen and Tinel signs were demonstrated, with no change after the sham treatment series.

Laser

Seven trials assessed the effects of low-level laser applied along the course of the median nerve, rather than at specific acupuncture points (TABLE 2) [68–74]. An uncontrolled study that assessed the safety and effectiveness of laser exposure in 30 hands reported complete symptom resolution in 77% of hands and improvement in motor distal latency in 11 hands, with no adverse events [68]. Padua confirmed Weintraub's findings in 17 hands and found improvements in nocturnal complaints that persisted for up to 1 year [71]. Laser therapy was also compared with three different control interventions (surgery, ultrasound and sham). In one study, low-level laser therapy was found to be as effective as surgery in 60 patients with mild-to-moderate CTS [69]. Significant symptomatic and electrophysiologic pre- to post-changes were observed in an ultrasound/ low-level laser comparison in 50 hands, with slightly greater improvement in the group that received ultrasound than those who received laser therapy [70]. However, when low-level laser therapy was compared with sham laser by Irvine *et al*., equally significant symptomatic improvement was reported in both groups, suggesting a possible placebo effect [72]. Two later sham-controlled trials yielded different results. Shooshtari *et al*. evaluated 80 CTS patients and found symptomatic and electrophysiologic improvement in the treatment group, but not in the sham control group [73]. While Chang *et al*. compared sham with active laser treatment in 36 patients and reported symptomatic improvement, no changes in median NCS were included [74].

Yoga

A single pre–post, within-group, randomized, controlled trial compared the effects of yoga with wearing a wrist splint [75]. The yoga program consisted of 1–1.5 h sessions practiced twice per week for 8 weeks, with a focus on upper body postures and awareness of proper structural alignment. A total of 42 participants with electrophysiologically confirmed CTS completed the study. Participants in the yoga group experienced significant improvement in strength and pain reduction while no significant changes were reported in the wrist splint group.

There was no significant impact on night-time waking between groups. Further limitations of this study include a high bias rating and minimal data on participant compliance or the occurrence of adverse events [76].

Magnetic field therapy

Static magnetic field (SMF) therapy involving heterogenous SMF dosing regimens for CTS were evaluated in three studies (TABLE 2). Carter *et al*. applied a 1000 Gauss (G) SMF for 45 min to 30 wrists with 'presumed diagnosis of CTS' and found symptomatic improvement in the control and active groups, but no between-group differences [77]. In a smaller crossover design study, a 350 G flexible magnet was applied to eight wrists continuously for 30 days [78]. This regimen resulted in significant clinical and electrodiagnostic improvement during the real versus sham magnet exposure. In a dose comparison study, Colbert *et al*. compared two different strength SMFs (150 or 450 G) with a nonmagnetized aluminum disk, in 60 participants [Colbert *et al*., Manuscript under review at *Archives of Physical Medicine and Rehabilitation*]. The devices were applied during the hours of sleep for 6 weeks. All three groups demonstrated pre- to post-statistically significant and clinically meaningful improvements on the Boston Carpal Tunnel Questionnaire, but no between-group differences. Pre- to post-NCS demonstrated no differences within or between groups. No adverse events were reported.

In a randomized, double-blinded, placebo-controlled trial, Weintraub and Cole observed 31 hands wearing a patented wristwatch-like device combining SMFs and dynamic magnetic fields for 4 h per day over the course of 2 months. The device contained a rotating 1150 G permanent magnet, producing biaxial magnetic rotation and oscillating polarities up to 1200 rpm, 20 times per second. At 2 months, composite neuropathy pain scale scores showed statistically significant pain reduction in the magnetic treatment group versus the sham. Alternatively, when comparing visual analog pain scale scores, sleep scores and nerve conduction, no significant between-group differences were found [79].

Conclusion

Carpal tunnel syndrome is a common source of pain and impaired function throughout the population and across the spectrum of occupational and recreational pursuits. While surgery is generally thought to be the defnitive treatment for CTS, some people improve spontaneously and this may relate to activity modification. Nonsurgical interventions are frequently used for CTS and include splinting, medications, exercises, modalities and alternative therapies. The currently available literature suggests that splinting and oral or injected corticosteroids may be effective for the symptoms of CTS, although they often only provide short-term relief [35, 37,76]. At this time, no definitive conclusions can be made with regard to the efficacy of the other commonly utilized nonsurgical interventions for CTS owing to the paucity of trials, the small number of participants in each trial, the heterogeneity of dosing regimens, the few sham-controlled studies and insufficient long-term follow-up. Effective conservative treatment and activity modification for CTS is reasonable to pursue in the patient with tolerable symptoms and the absence of progressive neurologic or functional deficits.

Future perspective

In the future, a better understanding of the risk factors for CTS and the characteristics that predict improvement, as well as stronger evidence with respect to the conservative treatment options, will assist with the management decisions for these patients.

Executive summary

- Carpal tunnel syndrome:
  - Careful history and physical examination are used for diagnosis.
  - Electrodiagnostic studies are used for confirmation.
- Natural history:
  - Resolution of symptoms is not necessarily related to severity.
- Self-imposed activity modification is common.
- Nonsurgical management:
  - Bracing and injections appear helpful.
- Limited evidence of efficacy with other conservative treatments:
  - Surgery recommended for progressive neurologic deficits/significant pain.

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Table 1

Hand therapy studies from 1994 to 2008

Study	Number of hands	Diagnostic criteria	Study design	Dosing regimen	Comparison group	Outcomes	Study limitations	Ref.
Iontophoresis								
Banta (1994)	23	Symptoms and NCS	Prospective, Nonrandomized trial	40–45 mA/min every other day for 1 week	No comparison	Successful in 58% of those that failed splints and ibuporofen treated with 3 week protocol, at 6-month follow-up. Shortcoming: small sample size, lack of randomization and blinding, and no use of sham iontophoresis group	Nonrandomized, no control group	[52]
Gokoglu *et al*. (2005)	48 Median nerves	Symptoms and NCS	Prospective, Randomized trial	40–45 mA/min for 20 min every other day for 1 week	Cortisone injection	Significant improvement of SSS and FSS scores in both groups at 2 and 8 weeks compared with baseline; however, significant better mean SSS and FSS scores are found at week 2 and week 8 for the injection group compared with iontophoresis group	Unblinded	[53]
Ultrasound								
Ebenbichler *et al*. (1998)	90	Symptoms and NCS	RCT	Daily five times/week for 2 weeks 15 min each, 20 treatments total	Sham ultrasound	Treatment > control at 2 weeks, 7 weeks and 6 months; Sensory loss treatment < control at 2 weeks, 7 weeks and 6 months; NCS treatment > control at 2 weeks, 7 weeks and 6 months	-	[55]
Oztas *et al*. (1998)	30	Symptoms and NCS	RCT	Five times/week 5 min, ten treatments for 2 weeks.	Sham ultrasound	Within groups: –Treatment 1: reduced pain, reduced night pain and reduced waking; – Treatment 2: reduced pain, reduced night pain and reduced waking; – Control: reduced pain, reduced night pain and reduced waking; Between groups: no significant differences	-	[56]
Carpal bone mineralization versus nerve gliding								
Tal-Akabi and Rushton (2000)	21	Symptoms and NCS	Comparative investigation	Mobilization grade dependent on symptoms	No treatment	Within group: – Treatment group 1: reduced pain, increased active motion flexion and extension – Treatment group 2: reduced pain and increased motion in extension Between groups: pain relief: – Treatment group 1 > control – Treatment group 2 > control – Treatment group 1 = treatment group 2	Participants not blinded	[61]

Study	Number of hands	Diagnostic criteria	Study design	Dosing regimen	Comparison group	Outcomes	Study limitations	Ref.
Carpal ligament traction								
Porrata *et al.* (2007)	19	Symptoms and NCS	-	Three times per day for 5 min sessions for 4 weeks	No control	4-week follow-up: average pain reduced from 8.52 to 1.05; tingling reduced from 8.15 to 0.95; numbness reduced from 8.47 to 0.95; average times patients woke per night (due to carpal tunnel syndrome) reduced from 3.05 to 0.10 7-month follow-up: (visual analog scale) average max pain was 0.65; tingling 0.4/10; numbness 1.7/10; none woke from sleep	No control group	[62]
Nerve mobilization								
Heebner *et al.* (2008)	60	Symptoms and NCS	Prospective, randomized	Both groups wore splints at night and during heavy lifting Tendon gliding ten repetitions, three to five times per day; group 2: additionally instructed in median nerve gliding ten repetitions, hold stretch for 5 s, three- to five-times daily	Splint, tendon gliding and modification of activities of daily living	At 1-month follow-up: – Group 1: eight patients failed to show up – Group 2: seven patients failed to show up – Group 1: 20 participants remained – Group 2: 25 patients At 6-month follow-up: – 15 subjects in group 1 – Group 2: 14 patients At 6 months: – Group 1 had statistically better function than group 2 – There appeared to be no other differences in outcomes	Unblinded	[59]
Nerve and tendon gliding exercise								
Akalin *et al.* (2002)	36	Symptoms and NCS	Prospective, randomized	Treatment group: tendon gliding exercises and nerve gliding exercises and splinting	Treatment group: tendon gliding (five exercises), nerve gliding (six exercises holding each for 5 s), each ten repetitions, five times per day for 4 weeks.	Within group: – Treatment group: reduced Phalen's and Tinel's sign, improved two patients. Discrimination, increased grip and pinch strength, reduced symptom severity and increased function – Control: reduced Phalen's and Tinel's sign, increased grip and pinch strength, reduced symptoms severity and increased function Between group: pinch strength improvement treatment	No control, unblinded, limited study size	[60]

FSS: Functional status scale; NCS: Nerve conduction studies; RCT: Randomized, controlled trial; SSS: Symptoms severity scale.

Table 2

Alternative therapy studies from 1998 to 2009.

Study	Number of hands	Diagnostic criteria	Study design	Dosing regimen	Comparison group	Outcomes	Study limitations	Ref.
Acupuncture (needle)								
Yang *et al*. (2009)	77	Symptoms and NCS	RCT	Two treaments/ week for 4 weeks	Prednisolone	Acupuncture and prednisolone equally effective	Participants not blinded	[65]
Acupuncutre (laser)								
Branco and Naeser (1999)	36	Symptoms	Pre–post evaluation	Three treatments/ week for 4–5 weeks	No control or comparison group	Post treatment pain reduced significantly	Case series	[66]
Low-level laser								
Naeser *etal*. (2002)	11	Symptoms and NCS	RCT crossover	Three treaments/ week for 3–4 weeks	Sham laser and sham microamp TENS	Decreased pain and median sensory latency after active treatment only	No between-group analyses	[67]
Weintraub (1997)	30	Symptoms and NCS	Pre–post evaluation	15 treatment visits	No control group	Complete resolution of symptoms in 77% of cases	Case series	[68]
Padua *etal.* (1998)	17	Symptoms and NCS	Pre–post evaluation	10 min session three times weekly for 2 weeks	No control group	Significant benefit in NCS and BCTQ with maximum effect 15 days	Case series	[71]
Elwakil *etal*. (2007)	60	Symptoms and NCS	Controlled trial	Two treatments/ week for 6 weeks	Open carpal tunnel release	Significant symptom and NCS improvement in both groups	Not randomized, participants not blinded, no between-group analyses	[69]
Evcik *etal*. (2007)	81	Symptoms and NCS	RCT	Five treaments/ week for 2 weeks	Sham laser	Significant pre–post improvements in VAS, pinch grip and functional capacity measurement in both groups. Significant improvements in sensory nerve velocity, and sensory and motor distal latencies in the laser group only	No between–group analyses	[80]
Bakhtiary *et al.* (2004)	90	Symptoms and NCS	RCT	Five treatments/ week for 3 weeks	Ultrasound	Significantly greater symptomatic and NCS changes in ultrasound than laser group	Participants not blinded, no between-group analyses	[70]
Irvine *et al* (2004)	15	Symptoms and NCS	RCT	Three treatments/ week for 3 weeks	Sham laser	Significant symptomatic improvement in both groups with no between-group	-	[72]

Study	Number of hands	Diagnostic criteria	Study design	Dosing regimen	Comparison group	Outcomes	Study limitations	Ref.
						differences		
Ekim *et al*. (2007)	19	Symptoms and NCS	RCT	Five treatments/ week for 2 weeks	Sham laser	Significant improvement in pain score and functional status in active laser group compared with sham laser group. No improvement in NCS	-	[81]
Shoostari *et al.* (2008)	80	Symptoms and NCS	RCT	Five treatments/ week for 3 weeks	Sham laser	Significant pre–post improvement in clinical symptoms and hand grip in active laser group only. Proximal median sensory latency, distal median motor latency and median sensory	No between-group analyses	[73]
Chang *et al*. (2008)	36	Symptoms and NCS	RCT	Five treatments/ week for 2 weeks	Sham laser	VAS scores significantly lower in the laser group compared with the placebo group after treatment and at follow-up. No significant NCS differences between groups after treatment.	-	[74]
Low-level laser plus splinting								
Yagci *et al.* (2009)	45	Symptoms and NCS	RCT	Ten sessions of laser therapy over 3 months	Wrist splints alone	Pre–post significant improvements on both clinical and NCS parameters in splints plus laser group only	-	[82]
Low-level laser plus splinting compared with US plus splinting or splinting alone								
Dincer *et al*. (2009)	100	Symptoms and NCS	RCT	-	-	The combinations of US or LLL therapy with splinting were more effective than splinting alone; however, LLL therapy plus splinting was more advantageous than US therapy plus splinting, especially for wrist splints	-	[83]
Yoga								
Garfinkel *et al.* (1998)	42	Symptoms and NCS	RCT	Two sessions/week for 8 weeks	Wrist splints	Significant pre–post symptomatic improvement in yoga group but not in wrist splint group	No between-group analyses	[75]
Static magnetic field therapy								
Weintaub and Cole (2000)	8	Symptoms and NCS	Crossover	24 h/day magnet wear for 1 month	Sham magnet	Pre–post symptomatic improvement in four out of eight hands during active magnet wear. Significant pre–post NCS improvement in five out of eight hands	Inadequate statistical analyses	[78]

Study	Number of hands	Diagnostic criteria	Study design	Dosing regimen	Comparison group	Outcomes	Study limitations	Ref.
Carter *et al.* (2002)	30	Symptoms	RCT	Single 45-min treatment	Sham magnet	Significant pre–post symptomatic improvement in both groups. No between-group differences	-	[77]
Colbert *et al.* (under review)	60	Symptoms and NCS	RCT	Nightly magnet wear for 6 weeks	Two different strength magnets versus sham magnet	Significant pre–post symptomatic improvement in all three groups. No between-group differences. No change in NCS	-	
Pulsed electromagnetic field therapy								
Weintraub and Cole (2008)	31	Symptoms and NCS	RCT	Wrist device worn for 2 h twice daily for 2 months	Sham device not described	Significant pre–post improvement in mean pain score in active magnet group, not in sham group. No significant change in NCS in inadequate statistical analyses	nadequate statistical analyses	[79]
Traditional cupping of related shoulder/next zones								
Michalsen *et al.* (2009)	52	Symptoms and Neurological examination	RCT	Single application wet cupping	Local application of heat	Significant between group improvement in average symptom score, BCTQ and DASH at 1-week follow-up	Participants not blinded	[84]

BCTQ: Boston Carpal Tunnel Questionnaire; DASH: Disabilities of the arm, shoulder and hand; LLL: Low-level laser; NCS: Nerve conduction studies; RCT: Randomized, controlled trial; TENS: Transcutaneous electrical nerve stimulation; US: Ultrasound; VAS: Visual analog scale.