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THERAPEUTIC ULTRASOUND AS A TREATMENT APPROACH FOR CARPAL TUNNEL SYNDROME

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ABSTRACT

Introduction: Carpal tunnel syndrome (CTS) is a common compression neuropathy causing pain, paresthesia and impaired hand function. Conservative management includes activity modification, splinting, pharmacotherapy and physical modalities; surgical decompression is indicated for refractory or severe cases. Therapeutic ultrasound (US) is a widely used conservative modality that may exert thermal and non - thermal effects potentially reducing inflammation, promoting tissue repair and improving nerve conduction in CTS.
Aim: To review current clinical evidence on the use of therapeutic ultrasound for the management of mild to moderate carpal tunnel syndrome, with emphasis on clinical outcomes, electrophysiological changes, treatment parameters and study quality.
Review Methods: A focused literature search of PubMed and Google Scholar was performed using combinations of the following keywords: “therapeutic ultrasound”, “ultrasonography therapy”, “phonophoresis”, “underwater ultrasound”, “carpal tunnel syndrome”, “conservative treatment”, and “randomized trial”. Randomized controlled trials, sham-controlled studies, and comparative clinical studies were prioritized.
Conclusion: Therapeutic ultrasound demonstrates potential as a conservative treatment for mild - moderate CTS: several randomized and controlled trials report improvements in pain, symptom severity and certain electrophysiological measures, while other studies show comparable clinical benefit in sham or splint-only groups. Heterogeneity in US dose, mode (continuous vs pulsed), frequency, treatment schedule, concomitant therapies (notably splinting) and short follow - up periods limits firm conclusions. Standardized treatment protocols and larger, well - powered randomized trials with longer follow-up are needed to define optimal parameters and to clarify whether therapeutic ultrasound confers clinically meaningful benefits beyond placebo or standard conservative care.

KEYWORDS

Therapeutic Ultrasound, Carpal Tunnel Syndrome, CTS, Treatment, Pathophysiology

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Introduction:

Carpal tunnel syndrome (CTS) represents the most frequently occurring and extensively researched type of nerve compression disorder. It develops when the median nerve is subjected to pressure at the wrist while traversing a confined osteofibrous passage. (1) This passage, referred to as the the carpal tunnel is a confined, non-distensible osteofibrous canal on the volar aspect of the wrist. Its roof is formed by the transverse carpal ligament (TCL; central thickness 2-4 mm) and its floor by the concave volar surface of the carpus; the radial and ulnar limits are formed by the scaphoid-trapezium and pisiform - hook of hamate eminences, respectively. Extending from the volar wrist crease to Kaplan’s cardinal line at the hook of the hamate, the tunnel contains the median nerve and nine flexor tendons. The median nerve supplies the thenar muscles and lateral lumbricals and continues as the common and proper palmar digital nerves; its palmar cutaneous branch typically arises 6 cm proximal to the TCL and runs superficially, thus remaining outside intratunnel pressure. Patients commonly exhibit characteristic signs, including numbness, tingling, nighttime paresthesia, and neuropathic “pins and needles” sensations affecting the radial 3.5 fingers. (2) Variations in carpal tunnel anatomy partly explain the variable clinical picture of CTS. For example, a bifid median nerve sometimes accompanied by a persistent median artery or an accessory flexor tendon occurs in about 1-3% of individuals. The motor (thenar) branch demonstrates several courses: extraligamentous (46%), subligamentous (31%) and transligamentous (23%), with the thenar fascicles occupying different positions within the nerve. The palmar cutaneous branch usually originates 4-7 cm proximal to the wrist crease, courses briefly alongside the median nerve, and may pass either ulnar to the nerve or traverse the transverse carpal ligament. In rare cases the ulnar nerve lies within the tunnel, which can produce mixed median - ulnar symptoms. In addition, wrist posture and movement markedly influence tunnel dimensions and intracarpal pressure - flexion and extension reduce the tunnel's cross - sectional area and raise pressure. The transverse carpal ligament, a dense fibrous band approximately 2-4 mm thick, is a major structural determinant of these biomechanical changes. (3) Multiple physical examination maneuvers can assist in diagnosing CTS, but no single test is sufficient on its own to establish the diagnosis. The reference standard remains nerve conduction studies, although these tests can yield both false-positive and false-negative results. Therefore, an accurate diagnosis of CTS should be based on a combination of patient history, clinical examination, and electrophysiological findings. (4) Therapeutic ultrasound is an emerging, non - invasive modality that can modulate soft-tissue biology and local microcirculation, making it a logical candidate for adjunctive therapy in common compression neuropathies. Given the high prevalence and substantial functional impact of carpal tunnel syndrome, expanding conservative management options is clinically valuable. Incorporating therapeutic ultrasound alongside established measures (such as splinting, activity modification and rehabilitation) may offer clinicians an additional tool to tailor treatment to individual patients, potentially improving symptom control and functional recovery while preserving a low barrier to implementation in routine practice.

Methodology:

This article is a literature review focused on the use of therapeutic ultrasound in the management of carpal tunnel syndrome (CTS). A comprehensive search of the PubMed and Google Scholar databases was conducted to identify relevant research published in English. The search strategy employed combinations of the following keywords: "carpal tunnel syndrome", "therapeutic ultrasound", "ultrasound therapy," "conservative treatment", and "rehabilitation". Articles were selected based on their relevance to the topic, methodological quality, and accessibility of full text. Both randomized controlled trials and review papers were included to ensure a balanced overview of the current evidence. Data from the selected studies were analyzed descriptively to summarize treatment outcomes, compare ultrasound parameters, and assess the overall efficacy of therapeutic ultrasound in CTS management.

Pathophysiology and risk factors of carpal tunnel syndrome:

Entrapment neuropathy results from a combination of compressive and traction forces. Compression and tensile stress disrupt intraneural microcirculation, damage myelin sheaths and axons, and provoke remodeling of the supporting connective tissue. Entrapment occurs when a peripheral nerve traverses an anatomical compartment that has become restricted, producing dysfunction localized to the site of compression and extending proximally and distally. Median nerve entrapment at the carpal tunnel is the prototypical example. Pathogenesis in CTS is multifactorial, involving elevated tunnel pressure, microvascular injury, compression of perineural connective tissues and synovial hypertrophy. (5) The principal sites vulnerable to entrapment are the tunnel outlet beneath the flexor retinaculum and the region adjacent to the hamulus of the hamate. Increased intratunnel pressure most commonly arises from synovial hypertrophy surrounding the flexor tendons, a response to overuse, wrist trauma, or inflammatory disease. Sustained wrist flexion and repetitive loading raise intratunnel fluid pressure and may precipitate ischemic injury. Comparable ischemic effects can follow disruption of the blood - nerve barrier creating a local microcompartment syndrome, fibrotic changes within the intraneural vasculature, or microvascular dysfunction with resultant intraneural edema. Traumatic obstruction of the canal is an additional mechanism. (6) Objective evidence demonstrates structural and functional consequences of compression. The median nerve commonly becomes enlarged in CTS, reflecting hyperemia and edema secondary to impaired blood flow and mechanical entrapment; this enlargement is quantifiable by ultrasound as an increased cross-sectional area (CSA). A CSA threshold at the pisiform level (commonly cited >9 mm²) or a swelling ratio >1.3 has diagnostic utility. Surgical decompression produces progressive reduction in CSA over weeks, consistent with resolution of edema. Histopathology shows focal deformation of the nerve (flattening), displacement of myelin lamellae near the entrapment edge and features of chronic fibrosis - findings that support the fundamentally mechanical nature of the neuropathy. Biomechanically, interaction among the flexor tendons, median nerve and transverse carpal ligament intensifies with wrist flexion and forceful grip, which explains the association between certain postures/activities and symptom generation, as well as the characteristic nerve flattening observed in affected patients. (7) The epidemiology of carpal tunnel syndrome demonstrates clear sex and age patterns: most studies report a higher incidence among women (approximately 1.5 versus 0.5 per 1,000 person-years), with female incidence peaking between 45 and 54 years, whereas male incidence tends to rise progressively with age; hormonal states such as pregnancy, lactation, the perimenopausal period, and exogenous hormone use have all been associated with increased risk, while oophorectomy appears to reduce risk. In addition to these individual predispositions, elevated body mass index is a strong and consistent predictor of CTS (each 1 unit increase in BMI raising risk by roughly 8%), and a minority of excess cases are attributable to endocrine disorders (e.g. hypothyroidism, acromegaly, diabetes); structural narrowing of the tunnel from trauma or inflammatory arthropathies further increases susceptibility. (2,8) Over the past decades occupational epidemiology has identified forceful exertion, high repetition, and hand–arm vibration as major work-related risk factors, with high - risk jobs including meat and fish processing, chainsaw forestry and electronic assembly; quantitative exposure thresholds reported in pooled analyses include average hand force >4 kg, repetition cycles <10 seconds or >50% cycle time spent performing the same movement, and substantial daily vibration exposure (Energy - equivalent acceleration 3.9 m/s^2). Meta - analytic estimates indicate large effects for vibration, high hand force and repetition, and roughly a doubling of risk with increased exposure to wrist flexion/extension. Although the evidence for routine computer keyboard/mouse use as a primary cause of CTS is weak, particular task circumstances may elevate risk. Finally, psychosocial workplace factors (e.g., high job strain or psychological demand) have been implicated as potential modifiers of risk in some cohort data, but the overall evidence remains less definitive and warrants further targeted study. (9)

Treatment:

A range of therapeutic options is available for carpal tunnel syndrome (CTS), reflecting the multifactorial nature of the condition and the absence of a single universally superior intervention. Management is conventionally divided into conservative and surgical approaches. Conservative measures including wrist splinting, activity modification, oral or injected anti - inflammatory agents, physiotherapy and other adjunctive modalities - often provide symptomatic relief for mild to moderate CTS and are typically attempted first. (10) Surgical decompression by division of the transverse carpal ligament (open or endoscopic carpal tunnel release) is indicated for patients with severe or progressive sensory/motor impairment, thenar atrophy, or when conservative treatment fails to deliver lasting benefit. Treatment selection should be individualized, taking into account symptom severity, electrophysiological findings, patient comorbidities and preferences. (11)

Pharmacology:

Pharmacologic treatment serves mainly as supportive therapy in conservative management of carpal tunnel syndrome (CTS). Short courses of systemic corticosteroids can provide temporary symptom relief in mild to moderate cases, while NSAIDs and other oral analgesics may help reduce pain without offering long - term functional benefit. (12) Topical agents are used for local relief, though their efficacy remains uncertain. Local corticosteroid injection into the carpal tunnel is a well - established intervention that can deliver notable short - term improvement in pain and paresthesia. It may be applied as an initial treatment or to postpone surgery. Evidence shows that local injections outperform oral corticosteroids for up to three months but have comparable outcomes to NSAID use combined with splinting in the short term. Although generally safe, potential complications include transient injection pain, skin changes, and rare nerve injury, highlighting the need for proper technique and patient selection. (13)

Wrist immobilization:

Splinting is considered a first - line therapy for mild to moderate carpal tunnel syndrome due to its ease of use, affordability, and good patient tolerance. (14) A Cochrane review from 2012 demonstrated that nocturnal wrist splinting provides greater symptom relief than placebo, though there was insufficient evidence to favor any specific splint design or to determine its superiority over other conservative treatments. One study indicated that patients using a neutral wrist splint experienced twice the symptom improvement compared with those using an extension splint. (15)

Physiotherapy for carpal tunnel syndrome

Neurodynamic techniques (NT) aim to restore median-nerve excursion and thereby optimize impulse transmission, while tendon-gliding exercises (TGE) are intended to break intracanalar soft-tissue adhesions and improve relative nerve mobility. (16) Clinical studies report that TGE facilitates sliding of the median nerve within the tunnel and that both NT and carpal-bone mobilization techniques (CBMT) produce symptom relief, with some trials showing greater benefit versus control and comparable effects when NT and CBMT are directly compared. Trials that combined TGE with NT or CBMT suggest a potential synergistic effect: addressing adhesions with TGE may enhance the mechanical efficacy of neural gliding and joint - mobilization maneuvers, and thus improve clinical outcomes in chronic CTS. Taken together, these data support a multimodal physiotherapy strategy in which targeted exercises (TGE) are used to address tissue mobility, and manual neurodynamic or joint mobilization techniques are applied to restore nerve mechanics and reduce symptoms. (17)

Physical modalities and complementary therapies

A broad array of physical modalities and complementary therapies is used as part of conservative management for carpal tunnel syndrome (CTS), including thermotherapy, acupuncture and other adjunctive approaches.

Thermotherapy more generally refers to controlled application of heat or cold (packs, paraffin, towels) to modulate pain, muscle tension and local circulation; heat tends to improve perfusion and muscle relaxation, whereas cold (cryotherapy) primarily reduces nociception and tissue swelling. Cryotherapy - one of the oldest therapeutic techniques - is commonly applied to reduce pain, inflammation and swelling; its analgesic effects are mediated by decreased sensitivity of free nerve endings, slowed synaptic transmission and raised firing thresholds, while vasoconstriction limits local edema beyond the period of direct application. (18) Complementary techniques such as acupuncture are also employed in CTS management as minimally invasive adjuncts. Clinical reports indicate that acupuncture may reduce symptom severity and improve function, and that its effects can be enhanced when combined with conventional measures (e.g. splinting or exercise); however, reported outcomes vary and benefit appears to be modality- and protocol-dependent. Overall, physical and complementary modalities can provide symptomatic relief and support rehabilitation in selected patients with CTS, but heterogeneity of techniques and inconsistent methodological quality across studies limit definitive conclusions; therefore these interventions are best considered as components of a multimodal, individualized treatment strategy pending higher-quality comparative data. (19)

Surgical treatment

Surgical decompression remains the definitive treatment for severe or progressive CTS, achieved by dividing the transverse carpal ligament to increase tunnel volume and reduce median nerve pressure. Randomized trials have not demonstrated clear superiority of alternative techniques over standard open carpal tunnel release (OCTR) with respect to long-term symptom relief, although endoscopic carpal tunnel release (ECTR) is consistently associated with faster return to work and reduced early postoperative morbidity (on the order of 1 week). (20) Traditional OCTR has evolved from a long palmar incision to a 2 - 3 cm palmar approach in routine practice; adjunctive procedures such as epineurotomy or internal neurolysis are reserved for selected cases with marked epineurial thickening or intraneural scarring. ECTR - performed via single- or two-portal techniques - divides the ligament from within the tunnel, preserving overlying tissues and potentially shortening recovery. Choice of technique is therefore individualized, taking into account surgeon expertise, patient preference, and specific anatomical or pathological findings. (21)

Principles and mechanisms of therapeutic ultrasound:

Therapeutic ultrasound (US) is a widely used adjunct in musculoskeletal practice that converts electrical energy into acoustic waves which, as they traverse tissues of differing impedance, produce both thermal and non-thermal biological effects. Clinically, US has been reported to reduce local edema, provide analgesia and to accelerate tissue repair; these effects are thought to result from enhanced tissue perfusion and metabolism, increased capillary permeability, and improved extensibility of fibrous tissues, with thermal mechanisms also raising pain thresholds. The precise cellular and molecular mechanisms remain incompletely defined, but the modality's combined mechanical and thermal actions plausibly underlie its clinical effects. Therapeutic ultrasound can be delivered in continuous mode, which emphasizes thermal effects, or in pulsed mode, which is intended to maximize non - thermal, reparative actions. (1,22)

Therapeutic ultrasound for carpal tunnel syndrome:

Therapeutic ultrasound (US) is a minimally invasive adjunctive modality that has been applied in the conservative management of carpal tunnel syndrome (CTS) with the aim of reducing pain, limiting edema and improving nerve mobility and tissue healing. (1) Clinically, US is attractive because it is readily delivered in outpatient physiotherapy settings, is well tolerated, and may be combined with splinting, exercise or other conservative measures for a multimodal approach. (3) Although mechanistic rationale supports its use, clinical trials to date vary in methodology and outcomes; therefore a focused review of randomized trials and systematic reviews is required to determine the magnitude, duration and clinical relevance of any benefit in CTS. (6)

In a placebo-controlled randomized trial, Armagan et al. investigated the efficacy of therapeutic ultrasound in combination with night splinting among 46 patients with mild to moderate idiopathic carpal tunnel syndrome. Participants were randomly assigned to one of three groups: night splinting plus sham ultrasound, continuous ultrasound at 1.0 W/cm², or pulsed ultrasound at 1:4 with the same intensity, administered over 15 sessions within a three-week period. All treatment arms demonstrated significant post-treatment improvements in pain intensity, symptom severity, and functional capacity scores, suggesting that both splinting and adjunctive ultrasound contributed to short - term symptom relief. However, objective neurophysiological parameters, including sensory nerve conduction velocities and distal motor latencies, improved only in the groups receiving active ultrasound. Despite these measurable electrophysiological gains, no statistically significant superiority in patient reported outcomes was observed compared with the sham-ultrasound group receiving splinting alone. The authors note that the small sample and short follow-up limit conclusions and call for larger standardized trials. (22)

Bagçaci et al. conducted a randomized, sham-controlled trial in 75 patients (114 hands) with mild-moderate CTS, comparing underwater pulsed ultrasound plus night splinting, sham ultrasound plus night splinting, and night splinting alone. Although all groups demonstrated clinical improvement, the underwater pulsed ultrasound arm showed significantly greater pain reduction (VAS - Visual Analog Scale, PQAS - Pain Quality Assessment Scale) and grip-strength gains at 2 and 12 weeks, and was the only group to exhibit meaningful electrophysiological improvement (median motor latency and sensory conduction). The study's limitations - short follow-up, no continuous US arm and omission of the BCTQ (Boston Carpal Tunnel Questionnaire) - prompt the authors to recommend further RCTs directly comparing underwater ultrasound with splinting alone. (23)

In a randomized trial, Bakhtiary et al. compared pulsed therapeutic ultrasound (1 MHz, 1.0 W/cm², 1:4 duty, 15 min/session) with low-level laser therapy (830 nm, 9 J at five points) in 50 patients (90 wrists) with EMG - confirmed mild - moderate CTS over 15 sessions with a 4-week follow-up. Both groups improved, but ultrasound produced significantly greater gains in pain relief, pinch and grip strength, motor and sensory distal latencies, and motor/sensory action-potential amplitudes (effects persisted at four weeks); for example, motor latency and pinch strength favored ultrasound with clinically meaningful differences. The authors conclude that pulsed ultrasound was more effective than low-level laser in this cohort and suggest further research into combined or comparative protocols. (24)

In a prospective randomized controlled study, Baysal et al. investigated the effectiveness of three conservative treatment combinations for bilateral carpal tunnel syndrome (CTS) in 28 female patients (56 wrists). The study compared splinting with exercise, splinting with ultrasound therapy, and a combination of splinting, exercise, and ultrasound. All groups completed a three-week treatment protocol with an eight-week follow-up. Significant improvements were observed in pain, functional status, Tinel's and Phalen's signs, as well as grip and pinch strength across all groups. Electroneurography revealed a decrease in median sensory distal latency in the splinting plus exercise group and the combined therapy group, while median motor distal latency remained unchanged in all groups. Patient satisfaction was highest in the combined therapy group, suggesting that integrating splinting, exercise, and ultrasound may provide superior symptomatic relief in CTS. (25)

Bilgici et al. randomized 34 patients (49 hands; 45 hands analyzed per protocol) to therapeutic ultrasound or to local corticosteroid injection plus night splinting, and followed outcomes at 4 and 8 weeks. Both treatments produced significant reductions in pain and symptom-severity/functional scores (BCTQ), with improvements in sensory conduction velocity and decreased motor distal latency observed in both arms; grip strength improved only in the injection group. There were no significant between-group differences for most clinical or electrophysiological measures, and adverse events were limited to transient injection pain. The study's interpretability is constrained by small sample size, inclusion of only mild – moderate CTS and short follow - up, but the authors conclude that ultrasound yields comparable short-term clinical and neurophysiological benefits to steroid injection plus splinting and may represent a safe non - invasive alternative in selected patients. (26)

Dincer et al. carried out a randomized, assessor-blinded, parallel-group trial enrolling 60 female patients (120 wrists) with electrophysiologically confirmed mild to moderate CTS, who were assigned to night splinting alone, splinting combined with therapeutic ultrasound, or splinting combined with low level laser (LLL) therapy, and assessed outcomes at 1 and 3 months (blinded follow-up assessment and ENMG performed). All groups improved versus baseline, but both adjunctive therapies (US and LLL) produced significantly greater gains in symptom severity, functional status, pain (VAS) and electrophysiological measures than splinting alone, with the LLL arm demonstrating the largest improvements and higher patient-satisfaction rates; by 3 months the proportions of electrodiagnostically normal hands were 14.7% (splint), 46.7 % (splint + US) and 52.7% (splint + LLL). Effect-size analyses confirmed clinically meaningful advantages for the combined treatments. The authors note heterogeneity in dosing and protocols across studies and emphasize that, while LLL and US appear beneficial when added to splinting, larger trials with standardized regimens and longer follow-up are required to define optimal parameters and durability of effect. (27)

Yildiz et al. conducted a randomized, sham-controlled, blinded trial including 51 patients (76 median nerves) with electrophysiologically confirmed mild to moderate CTS. Patients were assigned to night-and-day neutral wrist splinting combined with either sham ultrasound, pulsed therapeutic ultrasound (1 MHz, 1.0 W/cm², 15 min/session), or ketoprofen phonophoresis (2.5% ketoprofen gel with identical ultrasound parameters). Clinical and electrophysiological outcomes were evaluated at baseline, after 2 weeks of treatment, and at 8-week follow - up. All groups demonstrated significant improvement compared to baseline; however, ketoprofen phonophoresis led to greater pain reduction at 8 weeks, while therapeutic ultrasound showed no significant advantage over sham. Treatments were well tolerated with no major adverse events. Study limitations included the relatively small sample size, short follow-up, and lack of a splint - only control group. (28)

Ebenbichler et al. evaluated pulsed therapeutic ultrasound (1 MHz, 1.0 W/cm², 20 sessions) versus sham in a double-blind, randomized trial at a tertiary rehabilitation clinic; of 45 patients (90 wrists) enrolled, 34 patients (34 active and 34 sham - treated wrists) completed the protocol. Active ultrasound produced substantially greater and sustained symptomatic benefit: 68% of actively treated wrists achieved satisfactory improvement or remission at end of treatment versus 38% with sham ($P<0.001$), increasing to 74% vs 20% at 6 months ($P<0.001$). Objective neurophysiological measures mirrored clinical gains motor distal latency decreased and sensory conduction velocity increased significantly after active treatment but remained essentially unchanged with sham and both grip and pinch strength improved only in the ultrasound arm. Dropouts (largely early non - attendance or treatment-related pain) and modest baseline imbalances temper interpretation, yet the magnitude and durability of effect support therapeutic ultrasound as an effective non-invasive option for mild-moderate idiopathic CTS. (29)

Fazal-ur-Rehman Saeed et al. randomized 100 patients with electrophysiologically confirmed unilateral CTS to receive either low-level laser therapy (n=50; 9 J/session, 830 nm, 20 sessions over 4 weeks) or therapeutic ultrasound (n=50; 1 MHz, 1.0 W/cm², 20 sessions over 4 weeks). Baseline characteristics were comparable between groups (mean age about 35.6 years; 55% female). Both modalities produced significant symptomatic and functional improvement (VAS, Symptom Severity Scale, Functional Status Scale), but pain reduction was greater in the ultrasound arm and only the ultrasound group demonstrated significant improvements in electrophysiological parameters (distal motor and sensory latencies; $p<0.001$). The authors conclude that both laser and ultrasound are effective conservative options for mild - moderate CTS, with ultrasound showing superior neurophysiological gains; they recommend further studies to define optimal dosing, combinations (with splints), and longer-term outcomes. (30)

Nighat Ansar et al. performed a randomized clinical trial in 60 patients (30 subjects in every group) with electrophysiologically confirmed mild to moderate CTS to compare therapeutic ultrasound versus a single local steroid injection, each delivered together with a standardized exercise program (median - nerve flossing and wrist ROM exercises). The ultrasound arm received 8 sessions over 4 weeks (1 - 3 MHz, 1.5 W/cm², 5 min/session, twice weekly), while the injection arm received one depot steroid injection (40 mg methylprednisolone) plus local anesthetic. Outcomes (numeric pain rating, Boston Carpal Tunnel Questionnaire: Symptom Severity and Functional Status) were measured at baseline and after 4 weeks. Both interventions produced statistically significant improvements in pain, symptom severity and functional scores versus baseline; pain scores improved to a similar extent in both groups. Patients in the injection group showed slightly better gains in functional status, while the ultrasound group despite having worse baseline symptom severity achieved comparable symptom reduction after treatment. The study is limited by short follow-up, small sample size, single-center recruitment and concurrent use of exercise in both arms (which prevents isolation of modality-specific effects). Overall, the trial supports therapeutic ultrasound as a viable, non-invasive alternative to local steroid injection for short-term symptom relief in mild-moderate CTS, but longer, larger trials are required to establish comparative durability and optimal protocols. (31)

In a controlled clinical study, Oztas et al. investigated the effects of therapeutic ultrasound on patients with clinically and electrophysiologically confirmed carpal tunnel syndrome (CTS). The study enrolled 18 women (30 affected hands) aged 37 - 66 years, diagnosed according to the American Academy of Neurology criteria. Participants received ultrasound therapy at intensities of 0.8 W/cm² and 1.5 W/cm², compared with a sham placebo group. After treatment, all groups demonstrated statistically significant clinical improvement in symptom severity; however, there were no significant differences between groups. Electrophysiological outcomes, including median motor distal latency and conduction velocity, showed only minor, non-significant changes in the ultrasound groups relative to placebo. The authors concluded that while ultrasound may yield subjective symptom relief, its measurable neurophysiological benefits remain inconclusive. (32)

Chang et al. conducted a randomized clinical trial to compare the effectiveness of therapeutic ultrasound and paraffin therapy, both administered alongside wrist orthoses, in patients with carpal tunnel syndrome. Initially, 78 participants were screened, but 18 were excluded due to not meeting inclusion criteria or declining participation, resulting in 60 patients who were randomized into two groups. Ultimately, 47 participants completed the full 8-week treatment protocol. Both groups demonstrated significant post-treatment reductions in symptom severity, yet improvements in functional status and pain intensity were observed only in the ultrasound group, with moderate effect sizes (0.38 and 0.74, respectively). Furthermore, ultrasound therapy enhanced palmar pinch strength, while paraffin treatment improved sensory function in the monofilament test. Despite these clinical benefits, no significant changes were noted in electrophysiological measures for either group. The authors concluded that ultrasound therapy may provide superior functional and symptomatic improvement compared to paraffin therapy, though its effects on nerve conduction remain inconclusive. (33)

In a randomized clinical trial conducted by Nazarian et al., 48 patients with carpal tunnel syndrome were allocated to either a therapeutic ultrasound group or a nerve-gliding exercise group. The ultrasound treatment was administered at 1 MHz frequency and 1 W/cm² intensity for 5 minutes per session, while the nerve-gliding group performed ten sessions over three weeks. Clinical outcomes were assessed using the Visual Analogue Scale (VAS) for pain, the Boston Carpal Tunnel Questionnaire (BCTQ) for symptom severity and function, and EMG-NCS for electrophysiological evaluation. Both groups demonstrated significant post-treatment improvements in pain and functional scores ($P < 0.001$). However, only the ultrasound group exhibited a significant reduction in sensory and motor median nerve latency ($P < 0.001$ and $P = 0.001$, respectively). The authors concluded that both ultrasound therapy and nerve-gliding techniques are effective short-term interventions for symptom relief in CTS, with ultrasound offering additional electrophysiological benefits. (34)

Page et al. conducted a systematic review of 11 RCTs involving 414 participants to evaluate the effectiveness of therapeutic ultrasound for CTS compared with placebo, other non-surgical interventions, or as part of multi-component treatments. Results were heterogeneous, with low- to very-low-quality evidence suggesting that therapeutic ultrasound may provide short-term symptom improvement in some cases, particularly when combined with splinting. No consistent differences were found between different ultrasound regimens, and overall effects on functional and neurophysiological parameters were minimal. Adverse events were rarely reported. The authors conclude that current evidence is insufficient to firmly support therapeutic ultrasound over placebo or other non-surgical therapies, emphasizing the need for more rigorous trials with standardized protocols. (35)

Conclusions

Carpal tunnel syndrome (CTS) is a prevalent entrapment neuropathy that considerably affects hand function and quality of life. Among conservative treatment methods, therapeutic ultrasound has emerged as a promising, non-invasive intervention aimed at reducing inflammation, alleviating pain, and improving nerve conduction parameters. Evidence from randomized controlled trials suggests that ultrasound therapy can yield significant symptomatic and functional improvement in patients with mild to moderate CTS, often comparable to, or in some aspects exceeding, the effects of low-level laser therapy or local corticosteroid injections. Despite these encouraging findings, the available studies are limited by small sample sizes, short follow-up periods, and heterogeneous treatment parameters. To establish standardized therapeutic protocols and confirm the long-term efficacy of ultrasound therapy in CTS management, further large-scale, well-designed randomized clinical trials are required.

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