

# Extracorporeal Shock Wave Therapy and Radial Pressure Wave Therapy in Carpal Tunnel Syndrome: A Narrative Review of Clinical Outcomes and Therapeutic Implications

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## Abstract

**Introduction:** Carpal tunnel syndrome (CTS) is the most common peripheral entrapment neuropathy and a frequent cause of pain, functional impairment, and reduced quality of life. Although conservative management remains the first-line approach for mild-to-moderate disease, optimal non-invasive treatment strategies continue to be investigated. Extracorporeal shock wave therapy (ESWT) and radial pressure wave therapy (RPWT) have emerged as potential therapeutic alternatives due to their biological effects on nerve regeneration, inflammation, and tissue healing.

**Objective:** The objective of the study is to synthesize and critically evaluate the current evidence regarding the efficacy and safety of ESWT and RPWT in the management of CTS.

**Materials and Methods:** A narrative review of the literature was conducted using PubMed, Scopus, and Web of Science databases. Studies evaluating the effects of ESWT and RPWT in patients with CTS were included, encompassing randomized controlled trials, observational studies, and systematic reviews. Outcomes of interest included pain intensity, functional status, and electrophysiological parameters.

**Results:** The available evidence suggests that ESWT and RPWT are associated with significant improvements in pain relief, functional outcomes, and nerve conduction parameters in patients with mild-to-moderate CTS. Both ESWT and RPWT modalities demonstrated clinical benefits, with improvements observed in Visual Analog Scale scores, Boston Carpal Tunnel Questionnaire outcomes, and electrophysiological measures. Across studies, ESWT and RPWT were generally well tolerated, with minimal and transient adverse effects. Comparisons with conventional treatments, including splinting and corticosteroid injection, indicate comparable or superior outcomes for ESWT and RPWT in selected patient populations.

**Conclusion:** ESWT and RPWT represent promising non-invasive treatment options for CTS, offering meaningful clinical benefits with a favorable safety profile. Although current evidence supports their use in mild-to-moderate disease, further high-quality randomized controlled trials are warranted to establish optimal treatment parameters and long-term efficacy.

**Keywords:** Carpal Tunnel Syndrome; Extracorporeal Shock Wave Therapy; Radial Pressure Wave Therapy; Median Nerve.

## Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper limb and constitutes a leading cause of pain, functional impairment, and work-related disability worldwide. It predominantly affects women and older adults and is frequently associated with repetitive manual activities and metabolic conditions such as diabetes mellitus [1, 2, 3]. Beyond its clinical impact, CTS imposes a substantial socioeconomic burden, reflected in increased

healthcare utilization, reduced work productivity, and absenteeism [4].

The pathophysiology of CTS is multifactorial and primarily involves mechanical compression of the median nerve within the carpal tunnel, resulting in ischemia, impaired axonal transport, and progressive neural dysfunction. Persistent increased intracarpal pressure leads to venous congestion, reduced intraneural blood flow, and subsequent demyelination and axonal injury [1, 5, 6, 7]. In addition,

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histopathological studies have demonstrated thickening and fibrosis of the subsynovial connective tissue, microvascular alterations, and inflammatory changes that further contribute to nerve dysfunction [2]. Collectively, these mechanisms explain the development and progression of the clinical manifestations observed in CTS.

Beyond mechanical compression, increasing evidence supports the role of neuroinflammation and microvascular dysregulation in the pathogenesis of CTS. Elevated levels of inflammatory mediators, vascular endothelial growth factor, and neuropeptides have been identified in affected tissues, suggesting that CTS represents a dynamic neuropathic process rather than a purely structural entrapment [1, 8]. These findings help explain the heterogeneity of clinical presentation and the persistence of symptoms in some patients despite mechanical decompression.

Clinically, CTS is characterized by paresthesia, numbness, and pain in the median nerve distribution, frequently worsening at night and during repetitive hand activities. As the condition progresses, patients may develop motor deficits, including reduced grip strength and thenar muscle atrophy. Diagnostic evaluation typically combines clinical assessment with electrodiagnostic studies and, increasingly, high-resolution ultrasonography. Ultrasonographic measurement of median nerve cross-sectional area and assessment of intraneural morphology have emerged as valuable, non-invasive tools that complement nerve conduction studies and improve diagnostic accuracy [1, 2, 9].

Management strategies for CTS range from conservative approaches such as splinting, activity modification, pharmacologic therapy, and physical modalities to surgical decompression in refractory or severe cases. While surgery remains effective for advanced disease, it carries inherent risks and variable functional outcomes. Consequently, growing attention has been directed toward non-invasive and minimally invasive therapies that target the underlying pathophysiological mechanisms of CTS. Among these, extracorporeal shock wave therapy (ESWT) and radial pressure wave therapy (RPWT) have emerged as promising options due to their potential effects on angiogenesis, neuroregeneration, inflammation modulation, and tissue remodeling.

Understanding the biological rationale and clinical evidence supporting ESWT and RPWT is therefore essential for defining their role in the management of CTS. This review aims to synthesize current knowledge regarding the pathophysiology of CTS and critically examine the emerging evidence supporting the use of ESWT and RPWT as therapeutic strategies for this prevalent and disabling condition.

### **CTS: Epidemiology and risk factors**

CTS is the most prevalent entrapment neuropathy of the upper limb and constitutes a major source of pain, functional impairment, and work-related disability worldwide. The estimated prevalence in the general population ranges between 1% and 5%, with substantially higher rates reported in specific occupational groups and among individuals with predisposing systemic conditions [1, 2, 4]. CTS affects women more frequently than men, and its incidence increases with age, particularly during the fifth and sixth decades of life.

The development of CTS is multifactorial and has been consistently

associated with a combination of occupational, systemic, and anatomical risk factors. Repetitive hand movements, sustained or extreme wrist postures, forceful gripping, obesity, diabetes mellitus, hypothyroidism, pregnancy, and inflammatory or degenerative disorders have all been implicated in increasing susceptibility to median nerve compression. Occupational exposure involving repetitive manual tasks has been particularly associated with a higher risk in industrial and healthcare settings. In addition, anatomical factors such as reduced carpal tunnel volume, tenosynovial thickening, and elevated intracarpal pressure may further contribute to the pathophysiology of CTS [1, 2, 10].

The multifactorial nature of CTS underscores the complexity of its pathogenesis, which involves not only mechanical compression but also metabolic, vascular, and inflammatory mechanisms. These interacting factors contribute to the heterogeneous clinical presentation and variable disease progression observed among affected individuals.

### **Pathophysiology and diagnostic considerations**

The pathophysiology of CTS is characterized by increased pressure within the carpal tunnel, leading to impaired microcirculation, ischemia, and progressive dysfunction of the median nerve. Prolonged compression results in intraneural edema, demyelination, and, in more advanced cases, axonal degeneration. Histopathological studies have demonstrated thickening and fibrosis of the subsynovial connective tissue, which contributes to elevated intracarpal pressure and compromised nerve mobility [1, 2, 5, 6, 11].

In addition to mechanical compression, inflammatory and vascular mechanisms play a significant role in the development and progression of CTS. Increased expression of inflammatory mediators and alterations in microvascular perfusion have been reported, supporting the concept that CTS represents a dynamic neuropathic process rather than a purely mechanical entrapment. These mechanisms help explain the variability in symptom severity and response to treatment among patients with similar anatomical findings [8, 12].

Diagnosis of CTS is primarily clinical, based on characteristic symptoms such as nocturnal paresthesia, hand numbness, and weakness in the median nerve distribution. Physical examination maneuvers, including Tinel's and Phalen's tests, can support the diagnosis but lack sufficient sensitivity and specificity when used in isolation. Electrodiagnostic studies remain the reference standard for confirming the diagnosis and grading disease severity, as they provide an objective assessment of sensory and motor nerve conduction abnormalities. In recent years, ultrasonography has emerged as a valuable complementary tool, allowing direct visualization of median nerve morphology, assessment of cross-sectional area, and detection of structural abnormalities within the carpal tunnel [1, 2, 6, 11].

### **Conservative management and rationale for ESWT and RPWT**

Conservative management represents the first-line approach for patients with mild-to-moderate CTS. Traditional non-surgical interventions include activity modification, wrist splinting, nonsteroidal anti-inflammatory drugs, local corticosteroid injections, and physical therapy modalities. While these treatments may provide

symptomatic relief, their effects are often temporary, and recurrence of symptoms is common, particularly in chronic or progressive cases.

In this context, ESWT and RPWT have emerged as promising non-invasive alternatives. ESWT delivers acoustic waves that induce mechanical and biological effects at the tissue level, including increased angiogenesis, modulation of inflammatory pathways, and stimulation of nerve regeneration. These mechanisms align closely with the pathophysiological processes implicated in CTS, providing a strong biological rationale for its therapeutic use [12, 13].

Clinical studies have demonstrated that both ESWT and RPWT can lead to significant improvements in pain intensity, functional outcomes, and electrophysiological parameters in patients with CTS. The non-invasive nature of ESWT and RPWT, combined with their favorable safety profile, positions it as an attractive option for patients who are unsuitable for surgery or who prefer conservative management strategies. Furthermore, ESWT and RPWT may serve as an intermediate therapeutic option between conventional conservative measures and surgical decompression, particularly in patients with mild-to-moderate disease severity.

### Materials and Methods

This narrative review was conducted to synthesize and critically analyze the available scientific evidence regarding the use of ESWT and RPWT in the management of CTS. A comprehensive literature search was performed to identify relevant studies published up to December 2024. The electronic databases PubMed/MEDLINE, Scopus, and Web of Science were systematically searched using combinations of medical subject headings and free-text terms, including but not limited to “carpal tunnel syndrome,” “median nerve,” “extracorporeal shock wave therapy,” “shock wave therapy,” “focused shock wave,” “radial pressure wave therapy,” and “nerve conduction.” Additional articles were identified through manual review of reference lists from relevant reviews and original studies to ensure completeness of the search.

This review was conducted in accordance with general recommendations for narrative reviews. The selection process focused on studies evaluating the effects of ESWT and RPWT in adult patients diagnosed with CTS. Eligible studies included randomized controlled trials, prospective and retrospective clinical studies, and systematic reviews that assessed clinical, functional, or electrophysiological outcomes following ESWT and/or RPWT. Studies involving animal models, in vitro experiments, case reports, conference abstracts, or publications lacking sufficient methodological detail were excluded. Articles not published in English or without accessible full texts were also excluded from the analysis.

After the initial screening of titles and abstracts, potentially relevant articles were reviewed in full text to determine eligibility. Data extraction was conducted manually and focused on study design, sample size, patient characteristics, diagnostic criteria for CTS, type of therapy used (ESWT or RPWT), treatment parameters (energy flux density [EFD], number of sessions, frequency, and application technique), comparator interventions, outcome measures, and duration of follow-up. Primary outcomes of interest included pain intensity, functional status, and electrophysiological parameters such

as nerve conduction velocity and distal motor latency. Secondary outcomes included safety profiles, adverse events, and overall clinical improvement.

Given the heterogeneity of study designs, treatment protocols, and outcome measures, a qualitative synthesis approach was adopted rather than a quantitative meta-analysis. The findings were synthesized narratively, emphasizing patterns of efficacy, consistency of results across studies, and potential mechanisms of action. Particular attention was paid to differences between ESWT and RPWT modalities, as well as to comparisons with other conservative treatment strategies such as splinting, pharmacological therapy, and local corticosteroid injections.

This methodological approach was chosen to provide a comprehensive and clinically meaningful overview of the current evidence supporting the use of ESWT and RPWT in CTS, while acknowledging the heterogeneity and limitations inherent in the existing literature.

## Results

### Study selection and characteristics

The literature search identified a substantial number of publications evaluating the use of ESWT and RPWT in patients with CTS. The selected studies included randomized controlled trials, prospective clinical studies, and systematic reviews encompassing patients with predominantly mild-to-moderate disease severity. Across studies, sample sizes ranged from small single-center cohorts to larger controlled trials, with follow-up periods varying from 4 weeks to 12 months [12, 13, 14].

Both ESWT and RPWT modalities were represented, with heterogeneity in treatment parameters such as EFD, number of sessions, and treatment intervals. Outcome assessment commonly included patient-reported measures, functional scales, and electrophysiological testing. The main characteristics of the most relevant randomized controlled trials evaluating ESWT and RPWT in CTS and related conditions are summarized in Table 1.

### Effects of ESWT on pain and functional outcomes

Consistent improvements in pain intensity and functional status were reported across the majority of included studies. Reductions in pain scores, measured using the Visual Analog Scale or Numeric Rating Scale, were observed shortly after treatment and persisted throughout follow-up periods of several weeks to months [14, 15, 16]. Functional outcomes assessed using the Boston Carpal Tunnel Questionnaire demonstrated significant improvements in both symptom severity and functional status domains.

Several randomized controlled trials reported that ESWT and RPWT yielded comparable or superior improvements relative to conventional conservative treatments such as wrist splinting or pharmacological therapy. In some studies, ESWT and RPWT demonstrated outcomes comparable to local corticosteroid injection, particularly in short- to mid-term follow-up, with the additional advantage of fewer reported adverse effects [13, 17, 18].

### Effects on nerve conduction parameters

Electrophysiological assessments revealed that ESWT and RPWT

**Table 1: Selected clinical studies evaluating extracorporeal shock wave therapy and radial pressure wave therapy in carpal tunnel syndrome and related conditions**

First author (year)	Study design	Population/clinical context	ESWT modality and protocol	Comparator/co-interventions	Outcomes and follow-up	Main findings
Koçak Ulucaköy (2020)	Double-blind, prospective, randomized, placebo-controlled trial	n=189 (168 completed); Mild-to-moderate CTS (conservative treatment)	RPWT (Vibrolith®); 3 weekly sessions; 1,000 shocks/session, 0.05 ml/mm <sup>2</sup> , 5 Hz; Ultrasound-guided application at the proximal carpal tunnel (pisiform level)	Wrist splint alone; splint+ESWT; ESWT alone; splint+sham ESWT	VAS, BCTQ, finger pinch strength, LANSS, electrophysiology; baseline, 1 and 3 months	All groups improved; greater functional and electrophysiological improvement observed in the splint+ESWT group; ESWT was safe with no reported adverse effects (Koçak Ulucaköy.)
Sağlam	Randomized controlled trial	125 wrists/95 patients; Mild-to-moderate CTS	RPWT (Masterpuls® mp200); 3 weekly sessions; 2,000 impulses, 4 bar, 5 Hz; applied 2 cm proximal to the median nerve, diffusely over the pisiform	Splint+home exercise (control); PT modalities (paraffin, ultrasound, TENS)+splint+exercise	VAS, BCTQ, LANSS, sensory nerve conduction velocity; baseline, 3 and 12 weeks	RPWT and PT were effective; rESWT produced significantly greater improvement in pain, function, and neuropathic symptoms compared with PT and splint/exercise alone (Sağlam)
Menekşeoğlu (2023)	Double-blind, prospective, randomized, placebo-controlled trial	66 wrists/45 participants (55 wrists completed); Mild-to-moderate CTS	RPWT (Vibrolith®); 3 weekly sessions; 2,000 shocks/session, 1.6 bar, 6 Hz; Ultrasound-guided application at median nerve and proximal carpal tunnel	Sham RPWT; all participants received night splint+tendon/nerve gliding exercises	VAS, BCTQ, LANSS, electrophysiology; baseline and 1 month	RPWT significantly improved pain, function, sensory and motor distal latency, and sensory conduction velocity compared with sham (Menekşeoğlu.)
Habibzadeh (2022)	Randomized clinical trial (three-arm)	n=60; Mild-to-moderate CTS	RPWT (Masterplus® MP100); 4 sessions; 1,500 shocks/session, 1.5 bar, 6 Hz; Point (carpal tunnel) versus Sweep (median nerve pathway) application	Conventional physiotherapy (TENS, ultrasound, splinting, vitamin B1) in all groups	Pain, paresthesia, BCTQ, sensory and motor distal latency; baseline, 1 and 4 weeks	RPWT groups showed greater clinical and electrophysiological improvement than physiotherapy alone; no difference between point and sweep techniques (Habibzadeh.)
Turgut (2021)	Double-blind, randomized, sham-controlled trial	n=60; Pillar pain after open carpal tunnel release (post-operative condition)	ESWT (Storz Medical AG); 3 weekly sessions; 2,000 pulses/session, 4 bar, 5 Hz; EFD starting at 0.03 ml/mm <sup>2</sup> , increased according to tolerance; applied to painful scar tissue	Sham ESWT	VAS, Michigan Hand Outcomes Questionnaire; baseline, 3 weeks, 3 months, 6 months	ESWT significantly reduced pain and improved hand function compared with sham; benefits sustained up to 6 months (Turgut)

CTS: Carpal tunnel syndrome, ESWT: Extracorporeal shock wave therapy, RPWT: Radial pressure wave therapy, VAS: Visual Analog Scale, BCTQ: Boston carpal tunnel questionnaire, LANSS: Leeds assessment of neuropathic symptoms and signs, NCS: Nerve conduction studies, PT: Physical therapy, TENS: Transcutaneous electrical nerve stimulation, EFD: Energy flux density. Koçak Ulucaköy., Sağlam et al., Menekşeoğlu, and Habibzadeh et al. Evaluated ESWT as a conservative treatment for primary mild-to-moderate CTS, whereas Turgut. investigated ESWT for post-operative pillar pain following carpal tunnel release. ESWT and RPWT protocols varied across studies with respect to energy parameters, number of sessions, and application technique

were associated with measurable improvements in nerve conduction parameters. Multiple studies reported significant reductions in distal sensory latency and improvements in sensory nerve conduction velocity following treatment. Improvements in motor nerve conduction parameters, including distal motor latency and compound muscle action potential amplitude, were also observed, although findings were less consistent across studies [12, 14].

Meta-analytic evidence further supports the positive effect of ESWT and RPWT on peripheral nerve physiology, particularly with respect to sensory nerve recovery. These findings suggest that ESWT may exert neuromodulatory effects beyond symptomatic relief, potentially facilitating functional recovery at the neural level [19].

### Comparison between ESWT and RPWT

Both ESWT and RPWT demonstrated clinical efficacy in the management of CTS. ESWT, characterized by deeper tissue penetration and higher energy concentration, was more frequently associated with improvements in electrophysiological outcomes and longer-lasting symptom relief. In contrast, RPWT showed consistent benefits in pain reduction and functional improvement, particularly in patients with mild-to-moderate disease severity [15, 20, 21, 22, 23].

Although direct head-to-head comparisons remain limited, available evidence suggests that treatment selection should consider disease severity, target tissue depth, and therapeutic goals rather than a clear superiority of one modality over the other.

### Safety and adverse events

Across all included studies, ESWT and RPWT demonstrated a favorable safety profile. Reported adverse events were mild and transient, consisting mainly of localized discomfort, erythema, or transient pain at the treatment site. No serious adverse events or permanent neurological complications were reported. These findings support the overall safety of ESWT as a non-invasive therapeutic modality for patients with CTS.

### Discussion

This review provides an updated and comprehensive overview of the current evidence regarding the use of ESWT and RPWT in the management of CTS. The findings suggest that ESWT and RPWT represent promising non-invasive therapeutic options, particularly for patients with mild-to-moderate disease who are either poor surgical candidates or seek alternatives to invasive interventions.

Across the analyzed studies, ESWT and RPWT demonstrated consistent benefits in reducing pain intensity and improving functional outcomes, as measured by validated clinical instruments such as the Visual Analog Scale and the Boston Carpal Tunnel Questionnaire. In addition, several investigations reported favorable changes in electrophysiological parameters, including sensory nerve conduction velocity and distal motor latency, supporting a potential biological effect beyond symptomatic relief. These findings are clinically relevant, as improvements in nerve conduction parameters may reflect underlying neurophysiological recovery rather than transient analgesia.

The mechanisms by which ESWT and RPWT exert their therapeutic effects appear to be multifactorial. Experimental and clinical data

suggest that shock waves may promote angiogenesis, enhance microcirculation, and modulate inflammatory pathways through the release of nitric oxide and growth factors. Furthermore, ESWT and RPWT have been associated with neuromodulatory effects that may facilitate nerve regeneration and reduce nociceptive signaling. These mechanisms provide a plausible biological rationale for the observed improvements in both symptoms and functional outcomes among patients with CTS.

When compared with conventional conservative treatments, such as splinting or pharmacological therapy, ESWT and RPWT demonstrate comparable or superior clinical benefits, particularly in terms of pain reduction and functional recovery. Importantly, several studies suggest that ESWT and RPWT may offer outcomes similar to corticosteroid injections while avoiding the potential risks associated with repeated steroid exposure. Although surgical decompression remains the definitive treatment for severe cases, ESWT and RPWT may represent a valuable intermediate option within the therapeutic continuum, especially for patients with mild-to-moderate disease severity.

Despite these encouraging findings, the existing literature presents notable heterogeneity in study design, patient selection, treatment protocols, and outcome measures. Variations in EFD, number of sessions, treatment intervals, and type of mechanical waves (ESWT versus RPWT) limit direct comparisons across studies and preclude definitive recommendations regarding optimal treatment parameters. In addition, long-term outcomes beyond 6–12 months remain insufficiently explored, underscoring the need for well-designed prospective trials with extended follow-up.

Overall, the current evidence supports the clinical utility of ESWT and RPWT as safe and effective modalities for managing CTS. However, further high-quality randomized controlled trials are necessary to establish standardized treatment protocols, clarify patient selection criteria, and determine the long-term benefits of this intervention.

### Conclusion

ESWT and RPWT represent promising, non-invasive therapeutic options for the management of CTS. Available evidence indicates that ESWT and RPWT can effectively reduce pain, improve functional outcomes, and enhance nerve conduction parameters, particularly in patients with mild-to-moderate disease. Its favorable safety profile and noninvasive nature make it an attractive alternative or adjunct to conventional conservative treatments.

Although current data support the clinical usefulness of ESWT and RPWT, further high-quality studies are required to define optimal treatment protocols, determine long-term efficacy, and clarify its role relative to other therapeutic modalities. Future research should focus on standardized treatment parameters, comparative effectiveness studies, and long-term follow-up to better delineate the position of ESWT and RPWT within the comprehensive management of CTS. Future well-designed randomized controlled trials are warranted to further define optimal treatment protocols and long-term outcomes.

**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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