Pain Ther
https://doi.org/10.1007/s40122-026-00849-4

SYSTEMATIC REVIEW

Transcutaneous Pulsed Radiofrequency in Chronic Pain: A Systematic Review of Randomized Controlled Trials

Thalis Asimakopoulos · Athanasia Tsaroucha · Martina Rekatsina

Received: April 15, 2026 / Accepted: May 26, 2026

ABSTRACT

***Introduction*:** Transcutaneous pulsed radiofrequency (TcPRF) is a non-invasive neuromodulation technique increasingly investigated for the management of chronic pain. However, its clinical efficacy and safety across different chronic pain conditions remains uncertain.
***Methods*:** A systematic search of PubMed, Scopus, and Google Scholar was performed from database inception to March 2026. Randomized controlled trials (RCTs) evaluating TcPRF in chronic pain conditions were included. Pain intensity, functional outcomes, and safety data were extracted. Risk of bias was assessed using the Cochrane RoB 2 tool.
***Results*:** Eight RCTs were included, encompassing both musculoskeletal and neuropathic pain conditions. TcPRF was associated with reductions in pain intensity in most studies, with more consistent effects observed in sham-controlled trials and at later follow-up time points. Functional outcomes generally improved in parallel with pain, although results varied depending on the outcome measures used. TcPRF was well tolerated, with no serious adverse events reported. However, substantial heterogeneity was noted in patient populations, comparator interventions, treatment protocols, and outcome measures.
***Conclusion*:** TcPRF appears to be a promising non-invasive treatment option for selected chronic pain conditions, particularly when a minimally invasive approach is preferred. Nevertheless, current evidence remains limited by heterogeneity and methodological variability. Further large-scale, well-designed RCTs with standardized treatment protocols and longer follow-up are required to clarify its clinical role.

Keywords: Transcutaneous pulsed radiofrequency; TcPRF; Chronic pain; Neuromodulation; Non-invasive PRF; Randomized controlled trials; Pain management

T. Asimakopoulos (✉) · A. Tsaroucha · M. Rekatsina
1st Department of Anesthesiology and Pain Medicine, Aretaieion University Hospital, National and Kapodistrian University of Athens, Athens, Greece
e-mail: medthalis@gmail.com

Published online: 17 June 2026

Key Summary Points

The efficacy and safety of transcutaneous pulsed radiofrequency (TcPRF) as a non-invasive neuromodulation treatment for chronic pain have not been systematically evaluated.

This systematic review assessed the clinical effects of TcPRF in chronic pain based on randomized controlled trial evidence.

TcPRF improved pain and functional outcomes in several neuropathic and musculoskeletal pain conditions and was well tolerated.

Clinical and methodological heterogeneity limits comparability, underscoring the need for standardized, high-quality trials.

INTRODUCTION

Chronic pain is a major global health challenge, affecting a substantial proportion of the population and significantly impairing quality of life, physical function, and psychological well-being [1]. It is associated with considerable socioeconomic burden due to healthcare utilization, reduced productivity, and long-term disability. Despite advances in pharmacological and interventional therapies, many patients continue to experience inadequate pain relief or develop adverse effects related to therapeutic interventions or long-term treatment [2, 3]. These limitations have fueled interest in novel neuromodulatory approaches that may offer safer and more targeted strategies for pain modulation.

Pulsed radiofrequency (PRF) has emerged over the past two decades as a minimally destructive neuromodulation technique that delivers short bursts of high-frequency electrical current while maintaining tissue temperatures below neurodestructive thresholds [4]. Unlike conventional continuous radiofrequency ablation, PRF is thought to exert its effects primarily through modulation of neural signaling pathways rather than thermal lesioning and therefore does not typically cause permanent thermal damage or Wallerian degeneration to the nerves [5]. Although the analgesic mechanisms of PRF are not yet fully understood, experimental and clinical studies suggest that PRF may influence pain transmission through alterations in synaptic activity, inflammatory mediators, and gene expression within nociceptive pathways [6–10]. In current clinical practice, PRF is typically delivered through needle-based approaches targeting peripheral nerves, dorsal root ganglia, or other anatomical structures under imaging guidance.

More recently, the development of transcutaneous pulsed radiofrequency (TcPRF) has extended this concept further by enabling non-invasive delivery of PRF through the skin (Fig. 1). This approach aims to retain the neuromodulatory properties of PRF without the need for needle placement or invasive procedures, potentially improving safety and accessibility. Early clinical studies have explored the use of TcPRF for a variety of chronic pain conditions, including musculoskeletal and neuropathic pain syndromes [11–18].

However, despite growing clinical interest, the evidence supporting the efficacy of TcPRF remains fragmented. Randomized controlled trials (RCTs) have begun to emerge, yet their findings have not been systematically synthesized. A rigorous evaluation of the growing yet still limited randomized evidence is therefore necessary to clarify the therapeutic potential of this technique and to identify gaps that may guide future investigation. To our knowledge, the present study is the first systematic review of randomized controlled trials evaluating the efficacy of TcPRF for the treatment of chronic pain.

METHODS

Study Design and Protocol Registration

This review was conducted in accordance with the PRISMA 2020 Statement [19] and was registered in PROSPERO, an international prospective register of systematic reviews (protocol registration number: CRD420261331838). This article is based on previously conducted studies and does not contain any new studies with human

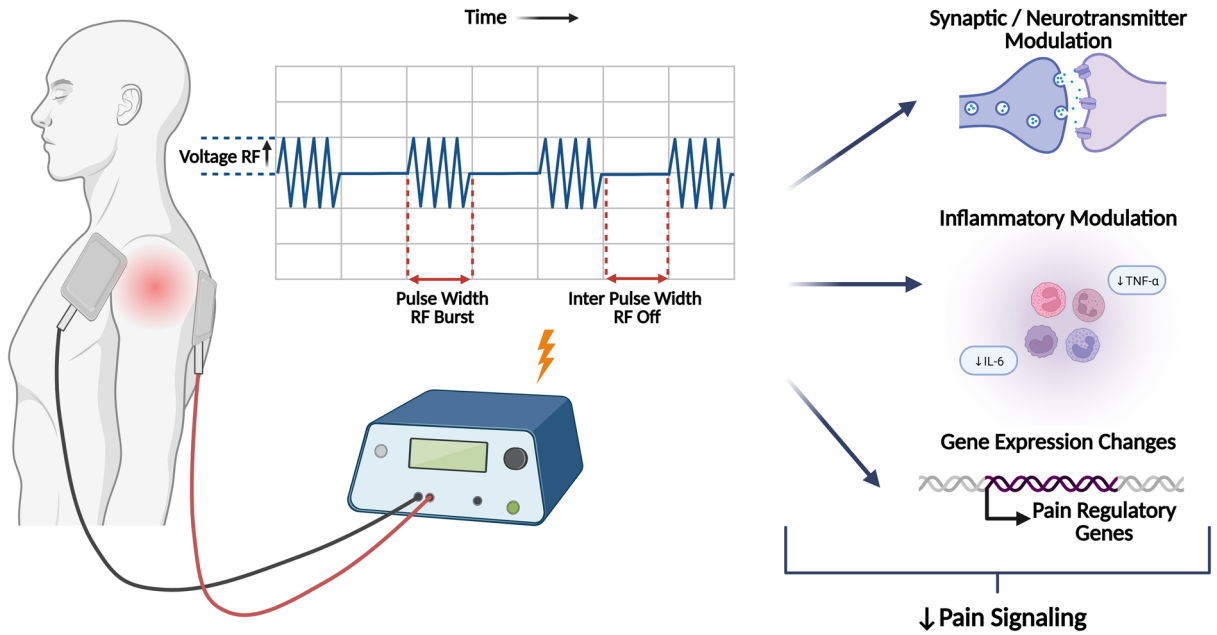

Fig. 1 Overview and proposed analgesic mechanisms of transcutaneous pulsed radiofrequency (TcPRF), which delivers bursts of radiofrequency energy through electrode patches placed over the target painful region. The pulsed waveform consists of brief radiofrequency bursts separated by intervals without energy delivery. Although the precise mechanisms remain incompletely understood, experimental and clinical evidence suggests that PRF may modulate pain signaling through different biological pathways, including alterations in synaptic activity and neurotransmitter release, modulation of inflammatory mediators, and changes in gene expression within nociceptive pathways. Created in BioRender. Asimakopoulos, T. (2026) https://BioRender.com/q1a2ykg

participants or animals performed by any of the authors.

Search Strategy

A systematic literature search was performed in PubMed, Scopus, and Google Scholar from database inception to March 5, 2026. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to transcutaneous pulsed radiofrequency and chronic pain. The following keywords and their combinations were used: “transcutaneous pulsed radiofrequency”, “transcutaneous PRF”, “TcPRF”, and “TPRF”, together with terms related to chronic pain. Additionally, the terms "pulsed radiofrequency”, and “PRF” were combined with modifiers such as "transcutaneous", "non-invasive", and "noninvasive" to capture studies that described “pulsed radiofrequency applied transcutaneously/non-invasively”. Boolean operators (AND, OR) were applied as appropriate. The following search strategy was used in PubMed: [(“pulsed radiofrequency” OR PRF) AND (transcutaneous OR non-invasive OR noninvasive OR wearable OR external)]. Examples of combinations used in Scopus and Google Scholar included: “transcutaneous pulsed radiofrequency” AND chronic pain; “transcutaneous PRF” AND pain; (“pulsed radiofrequency” AND transcutaneous) AND pain; and (“PRF” AND non-invasive) AND chronic pain. Due to the high number of potentially irrelevant results generated by Google Scholar, screening was restricted to results sorted by relevance and limited to the first 10 pages of results. Finally, reference lists of relevant articles were screened to identify additional studies.

Eligibility Criteria

Studies were considered eligible if they were RCTs evaluating the use of transcutaneous pulsed radiofrequency in adult patients with chronic pain of any etiology. Eligible studies were required to include a comparator group, such as sham treatment, placebo, or standard care, and to report pain-related outcomes (e.g., measures of pain intensity). Only studies published in English were included. Studies were excluded if they were observational in design, including retrospective studies, prospective cohort studies, case reports, case series, reviews, editorials, conference papers, animal studies, or studies evaluating invasive pulsed radiofrequency procedures.

Study Selection

After all retrieved records were compiled and prior to screening, duplicate entries were removed. Two reviewers (TA, MR) independently screened titles and abstracts to identify potentially eligible studies. The full texts of selected articles were subsequently assessed for inclusion according to the predefined eligibility criteria. Disagreements between reviewers were resolved through discussion, and, when necessary, a third reviewer (AT) was consulted to reach consensus.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized data collection form. Extracted information included study characteristics such as author, year of publication, and country of origin, as well as clinical characteristics including sample size, pain condition, intervention details, comparator intervention, outcome measures, follow-up duration, and reported adverse events. Any discrepancies in extracted data were resolved through discussion or consultation with a third reviewer. Sample size data visualization was conducted using GraphPad Prism (version 9.1.1; San Diego, CA, USA).

Risk of Bias Assessment

The methodological quality of the included randomized controlled trials was evaluated using the Cochrane Risk of Bias Tool (RoB 2) [20]. This tool assesses potential bias across several domains, including the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of reported results. Each domain was classified as low risk of bias, some concerns, or high risk of bias.

Data Synthesis

A qualitative synthesis of the included studies was conducted. When appropriate, results were summarized across studies to describe patterns in treatment effects, clinical indications, and methodological characteristics of the trials.

RESULTS

Study Selection

The database search identified 511 records. After removal of 24 duplicates, 487 records remained for title and abstract screening. Of these, 445 articles were excluded because they did not meet the objectives of this review. The full texts of 42 articles were assessed for eligibility, of which 34 were excluded after full-text evaluation. The most common reasons for exclusion at this stage were invasive PRF application or studies investigating non-chronic pain conditions. No additional studies were identified through manual screening of the reference lists. Ultimately, eight randomized controlled trials, published between 2010 and 2025, met the inclusion criteria and were included in the qualitative synthesis. A schematic of the study selection process is presented in Fig. 2, following the PRISMA 2020 Statement [19].

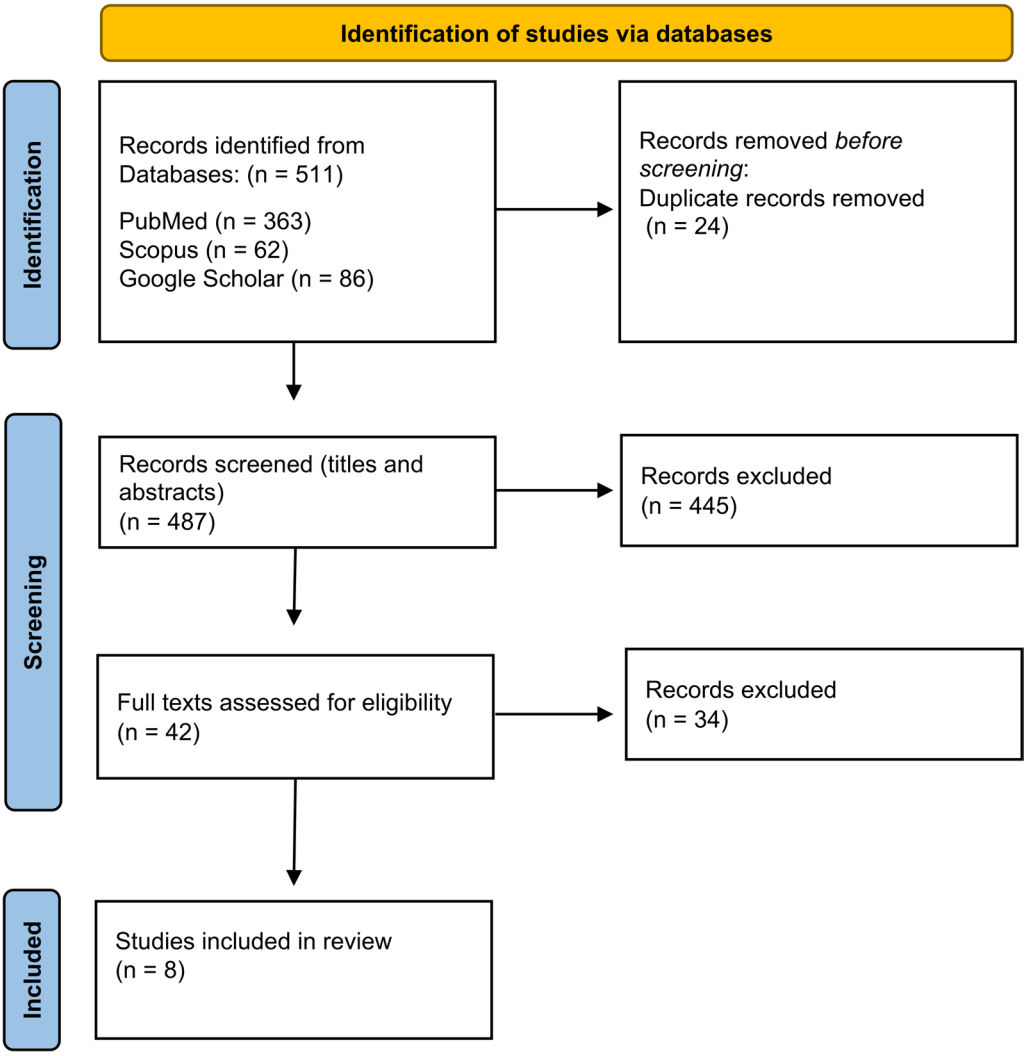

Fig. 2 PRISMA flow diagram of the study selection process, illustrating the identification, screening, eligibility assessment, and final inclusion of studies in this systematic review. Selection was performed in accordance with the PRISMA 2020 Statement [19]

Study Characteristics

Eight RCTs published between 2010 and 2025 were included in this review [11–18]. Across these studies, a total of 467 participants were enrolled, with sample sizes ranging from 50 to 70 patients. The sample size (*n*) of each RCT is presented in Fig. 3.

The studies were conducted in several countries, including Australia, Taiwan, Turkey, and Egypt, and investigated the effects of non-invasive TcPRF across a variety of chronic pain conditions. These included musculoskeletal disorders, such as knee osteoarthritis [17], shoulder pain [13, 16, 18], and lateral epicondylitis [11], as well as neuropathic pain syndromes, including carpal tunnel syndrome (CTS) [14], diabetic neuropathic pain [15], and chronic migraine [12].

Technical parameters of TcPRF varied across studies. Reported pulse widths ranged from approximately 10–50 ms, with low-frequency repetition rates (2–5 Hz) and voltages typically between 80 and 100 V when specified. Treatment duration was most commonly 2 min per

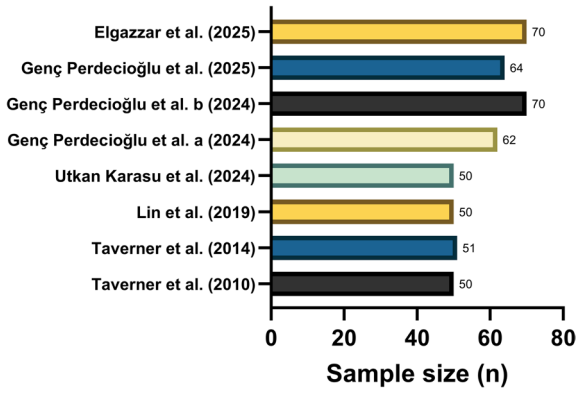

Fig. 3 Sample size distribution of the included randomized controlled trials [11–18]

site, with total session times of approximately 10–15 min. Although most studies reported key technical parameters, variability and occasional incomplete reporting limited reproducibility and comparability across studies. A detailed summary of parameters is provided in Table 1.

Most studies compared TcPRF with sham stimulation [13, 15–17], while others used active comparators, such as transcutaneous electrical nerve stimulation (TENS), corticosteroid injection, or greater occipital nerve block [11, 12, 18]. The number of treatment sessions varied across studies, ranging from a single session to multiple sessions, and follow-up periods ranged from 1 to 12 weeks. Pain intensity was most commonly assessed using the visual analog scale (VAS), while several studies also evaluated functional or disease-specific outcomes using validated instruments, including the Constant–Murley Shoulder Score, Patient-Rated Tennis Elbow Evaluation (PRTEE), Shoulder Pain and Disability Index (SPADI), Self-Leeds Assessment of Neuropathic Symptoms and Signs (S-LANSS), and the Migraine Disability Assessment (MIDAS). A detailed overview of the included studies and their characteristics is presented in Table 2.

Pain Outcomes

Pain intensity was evaluated in all included studies, most commonly using the VAS. One study investigating CTS used the Boston Carpal Tunnel Questionnaire (BCTQ) instead [14]. Another study employed the Pain, Enjoyment of life, and General activity (PEG) scale, a validated three-item measure of pain intensity and interference with function [18]. Across all RCTs, TcPRF offered pain relief at different extents and timepoints.

Table 1 Technical parameters of TcPRF across included studies

Study	Pulse width	Frequency	Voltage	Duration
Taverner et al. 2010 [17]	20 ms	2 Hz	80 V	2 min
Taverner et al. 2014 [16]	10 ms	5 Hz	80 V	2 min
Lin et al. 2019 [18]	50 ms	2 Hz	100 V	NR
Karasu et al. 2024 [13]	10 ms	5 Hz	80 V	2 min
Genç Perdeciolu et al. 2024 (CTS) [14]	20 ms	2 Hz	80 V	8 min
Genç Perdeciolu et al. 2024 (migraine) [12]	20 ms	2 Hz	80 V	8 min
Genç Perdecioğlu et al. 2025 [15]	20 ms	2 Hz	80 V	8 min
Elgazzar et al. 2025 [11]	NR	NR	NR	15 min (session total duration)

NR non-reported parameters

Table 2 Characteristics of included randomized controlled trials evaluating TcPRF for chronic pain

Author	Year	Country	Design	Condition	Sample size	Intervention	Comparator	Sessions	Follow-up	Pain outcome	Functional outcome	Adverse events
Taverner et al. [17]	2010	Australia	Randomized, double-blind, sham-controlled	Chronic knee pain (referred for primary knee replacement)	50	TcPRF	Sham	Single session	1 week, 4 weeks	VAS pain score, at rest and after walking (20m and 400m)	Walking pain assessment (20m and 400m)	None reported
Taverner et al. [16]	2014	Australia	Randomized, double-blind, sham-controlled	Chronic shoulder pain (referred for surgery)	51	TcPRF	Sham	Single session	4 weeks, 12 weeks	VAS pain score (night, rest, activity)	Brief Pain Inventory (BPI), Pain Self-Efficacy Questionnaire, Oxford Shoulder Score, range of motion, Global Perceived Effect	None reported
Lin et al. [18]	2019	Taiwan	Randomized, double-blind, controlled	Chronic shoulder pain/ tendinitis	50	TcPRF	TENS	Three sessions	1 week, 4 weeks, 12 weeks	VAS pain score (within the PED score)	PEG: pain, P (scored by visual analog score "VAS," scored from 0 to 100), enjoyment of life, E (scored from 0 to 100), and general activity, G (scored from 0 to 100), Constant–Murley Shoulder Score (CMS)	None reported

Table 2 continued

Author	Year	Country	Design	Condition	Sample size	Intervention	Comparator	Sessions	Follow-up	Pain outcome	Functional outcome	Adverse events
Karasu et al. [13]	2024	Turkey	Randomized, double-blind, sham-controlled	Chronic shoulder pain / subacromial impingement syndrome (SAIS)	50	TcPRF	Sham	Single session	1 week, 4 weeks, 12 weeks	VAS pain score (activity and resting pain)	SPADI (Shoulder Pain and Disability Index), SF-36 quality of life, Range of motion, Ultrasonographic measures (AHD, supraspinatus thickness)	None reported
Genç Perdeciolu et al. a [14]	2024	Turkey	Randomized, single-blind, controlled	Carpal tunnel syndrome	62	TcPRF	Wrist splint	Two sessions	4 weeks, 12 weeks	BCTQ symptom severity	BCTQ functional score	Mild skin hyperemia (reported in 9 patients)
Genç Perdeciolu et al. b [12]	2024	Turkey	Randomized, single-blind, controlled	Chronic migraine	70 (62 completed)	TcPRF	US-guided greater occipital nerve block	Two sessions	4 weeks (headache diary)	VAS pain score	Headache frequency, MIDAS	Mild erythema (reported in 6 patients in NipRF group, resolved spontaneously)

Table 2 continued

Author	Year	Country	Design	Condition	Sample size	Intervention	Comparator	Sessions	Follow-up	Pain outcome	Functional outcome	Adverse events
Genç Perdeciolu et al. [15]	2025	Turkey	Randomized, single-blind, controlled	Diabetic neuropathic pain	64 (58 completed)	TcPRF	Sham	Two sessions	4 weeks, 12 weeks	VAS pain score	S-LANSS neuropathic pain score	Mild erythema/burning (reported in 7 patients, transient)
Elgazzar et al. [11]	2025	Egypt	Randomized, controlled	Chronic lateral epicondylitis (tennis elbow)	70	TcPRF	Local corticosteroid injection	Single session	2 weeks, 4 weeks, 8 weeks, 12 weeks	VAS pain score	Patient-Rated Tennis Elbow Evaluation (PRTEE) score, quick disabilities of the arm (DASH), Chair test and Thompson test	None reported

Includes year of publication, country of origin, study design, patient population, intervention and comparator, treatment sessions, follow-up duration, pain outcomes, functional outcomes, and adverse events

AHD acromiohumeral distance, *BCTQ* Boston Carpal Tunnel Questionnaire, *BPI* Brief Pain Inventory, *MIDAS* Migraine Disability Assessment, *NiPRF* non-invasive pulsed radiofrequency, *PEG* Pain, Enjoyment of life, and General activity scale, *SLANSS* Self-report Leeds Assessment of Neuropathic Symptoms and Signs, *SPADI* Shoulder Pain and Disability Index, *TcPRF* transcutaneous pulsed radiofrequency, *TENS* transcutaneous electrical nerve stimulation, *VAS* Visual Analog Scale

In patients with painful knee osteoarthritis awaiting surgery, Taverner et al. reported significant reduction in pain scores in the TcPRF group, compared with the sham intervention at the 4-week follow-up assessment [17]. Similarly, in patients with chronic shoulder pain booked for surgery, TcPRF resulted in statistically significant reductions of pain at night (42% reduction compared to sham) and pain with activity (29% reduction compared to sham) at 4 weeks, an effect that was partially sustained at 12 weeks after the treatment session [16].

Among other shoulder pain conditions, a study comparing TcPRF with TENS in patients with chronic shoulder tendinitis showed that both groups improved over time, but TcPRF was associated with lower pain scores. This difference persisted after 3 months, although with a diminishing superiority over time [18]. In patients with subacromial impingement syndrome TcPRF was found to be more effective than sham treatment at the 12-week follow-up visit in lowering rest pain VAS scores but not pain with activity [13]. At other times or for other outcome measures, however, there were no discernible differences between the TcPRF and sham groups [13]. In lateral epicondylitis (tennis elbow syndrome), reported improved pain scores after TcPRF compared with corticosteroid injection over later follow-up timepoints (4, 8, and 12 weeks after treatment), supporting a beneficial and perhaps more robust analgesic effect in this group over time [11].

Favorable pain outcomes were also reported in trials by Genç Perdeciolu et al., involving headache and neuropathic pain conditions [12, 14, 15]. In patients with CTS, TcPRF was associated with significant improvements in BCTQ scores compared with the control intervention (finger splint) at 4- and 12-week follow-up [14]. In migraine, the analgesic efficacy of non-invasive PRF was comparable to that of the occipital nerve block: a notable reduction was observed in the VAS scores of both the block and radiofrequency groups at week 4 relative to the pretreatment baseline scores [12]. Finally, in patients with diabetic neuropathic pain, TcPRF resulted in significantly greater reductions in VAS pain scores compared with sham treatment at 4 and 12 weeks after treatment [15].

Overall, the included trials demonstrated improvements in pain outcomes following TcPRF across both musculoskeletal and neuropathic chronic pain conditions.

Functional Outcomes

Several studies assessed functional or disease-specific secondary outcomes in addition to pain intensity. In shoulder pain conditions, TcPRF was associated with improvement in measures such as the Brief Pain Inventory, Pain Self-Efficacy Questionnaire, Oxford Shoulder Score, Constant–Murley Shoulder Score, and the SPADI, although the extent and persistence of between-group differences varied across trials [13, 16, 18].

In lateral epicondylitis, functional outcomes assessed with the PRTEE and the Quick Disabilities of the Arm, Shoulder and Hand questionnaire favored TcPRF over corticosteroid injection at later follow-up assessments [11]. In CTS, TcPRF was associated with improvement in BCTQ scores [14]. In chronic migraine, headache frequency decreased after treatment, although between-group differences were not statistically significant [12]. In diabetic neuropathic pain, TcPRF was associated with significant improvement in S-LANSS scores compared with sham treatment [15].

Overall, functional and secondary outcomes tended to improve in parallel with pain reduction.

Safety Assessment

Adverse events were infrequently reported across the included trials. No serious complications related to TcPRF were described. Mild and transient local skin reactions were reported in 3 of 8 studies, affecting 22 of 467 participants, and consisted mainly of erythema or hyperaemia at the electrode site, occasionally with mild burning sensation or discomfort [12, 14, 15]. These events resolved spontaneously without treatment. Overall, TcPRF appeared to be safe and well tolerated.

Risk of Bias

Risk of bias (RoB) was assessed using the Cochrane RoB 2 tool [20]. Overall, six studies were judged as having some concerns, while two studies were rated as high risk of bias (Fig. 4). The most common sources of concern were insufficient detail regarding the randomization process, incomplete blinding, and the use of subjective patient-reported outcomes. High risk of bias was identified mainly in studies with substantial missing outcome data or open-label designs that could have influenced outcome assessment. The predominance of studies with some concerns or high risk of bias warrants cautious interpretation of the reported efficacy outcomes. Visualization was generated using the risk of bias visualization (robvis) tool [21].

DISCUSSION

This systematic review of randomized controlled trials suggests that TcPRF may improve pain outcomes across a range of chronic musculoskeletal and neuropathic pain conditions, while maintaining a favorable safety profile. Across the eight included trials [11–18], beneficial effects were reported in conditions such as knee osteoarthritis, chronic shoulder pain, subacromial impingement syndrome, lateral epicondylitis, carpal tunnel syndrome, chronic migraine, and diabetic neuropathic pain. Overall, the direction of effect was generally in favor of TcPRF, although the magnitude and consistency of benefit varied according to the underlying pain condition, comparator intervention, and follow-up duration. The most convincing findings were observed in sham-controlled studies [15–17] and in trials where benefits were sustained at later assessments [11, 15, 16, 18], whereas in some studies the superiority of TcPRF was limited to selected outcomes or specific time points [13]. These findings support the potential role of TcPRF as a non-invasive analgesic strategy, but they should be interpreted cautiously considering the clinical and methodological heterogeneity across the included trials.

While the mechanistic background of PRF-induced analgesia has not been fully elucidated, several hypotheses on cellular and molecular mechanisms of action have been developed [22]. PRF therapy has been shown to influence major components of nociceptive pathways such as pain neurotransmitters, synaptic function, post-synaptic receptors and ion channels, at or below gene expression level [6, 10, 22]. Those alterations potentially explain long-term depression of nociceptive signaling from the peripheral to the central nervous system and enhancement of descending inhibitory pain pathways that are shown after PRF application [7]. On top of its neuromodulatory effects, PRF has been proposed to reduce pain through anti-inflammatory actions, particularly by decreasing pro-inflammatory cytokines and microglial activation as well as altering neuroimmune pathways that contribute to peripheral and central sensitization [8, 9, 23]. This multifaceted mechanism of action may hence explain why TcPRF appeared beneficial across conditions with different pathophysiological backgrounds, including both musculoskeletal and neuropathic pain syndromes. At the same time, the incomplete understanding of its mechanism underscores the need for caution when extrapolating across pain conditions or attempting to define a single unifying mode of action. Importantly, clarifying the key biological pathways involved in PRF's mechanism of action may help identify pain biomarkers that could be used to predict treatment response and to evaluate treatment efficacy [24]. Towards that direction, an earlier randomized study by Lin et al. [25], available only as a conference report and therefore excluded from the present analysis, compared TcPRF with TENS in chronic shoulder pain and demonstrated superior clinical outcomes with TcPRF, accompanied by a significant reduction in cortisol levels, therefore suggesting that cortisol serum levels could represent a potential biomarker of treatment response to TcPRF.

The broader literature also contains other studies that were not included in the present review because they did not meet the predefined eligibility criteria, including promising case series, retrospective analyses, and studies in non-eligible populations [26–29]. In a study on

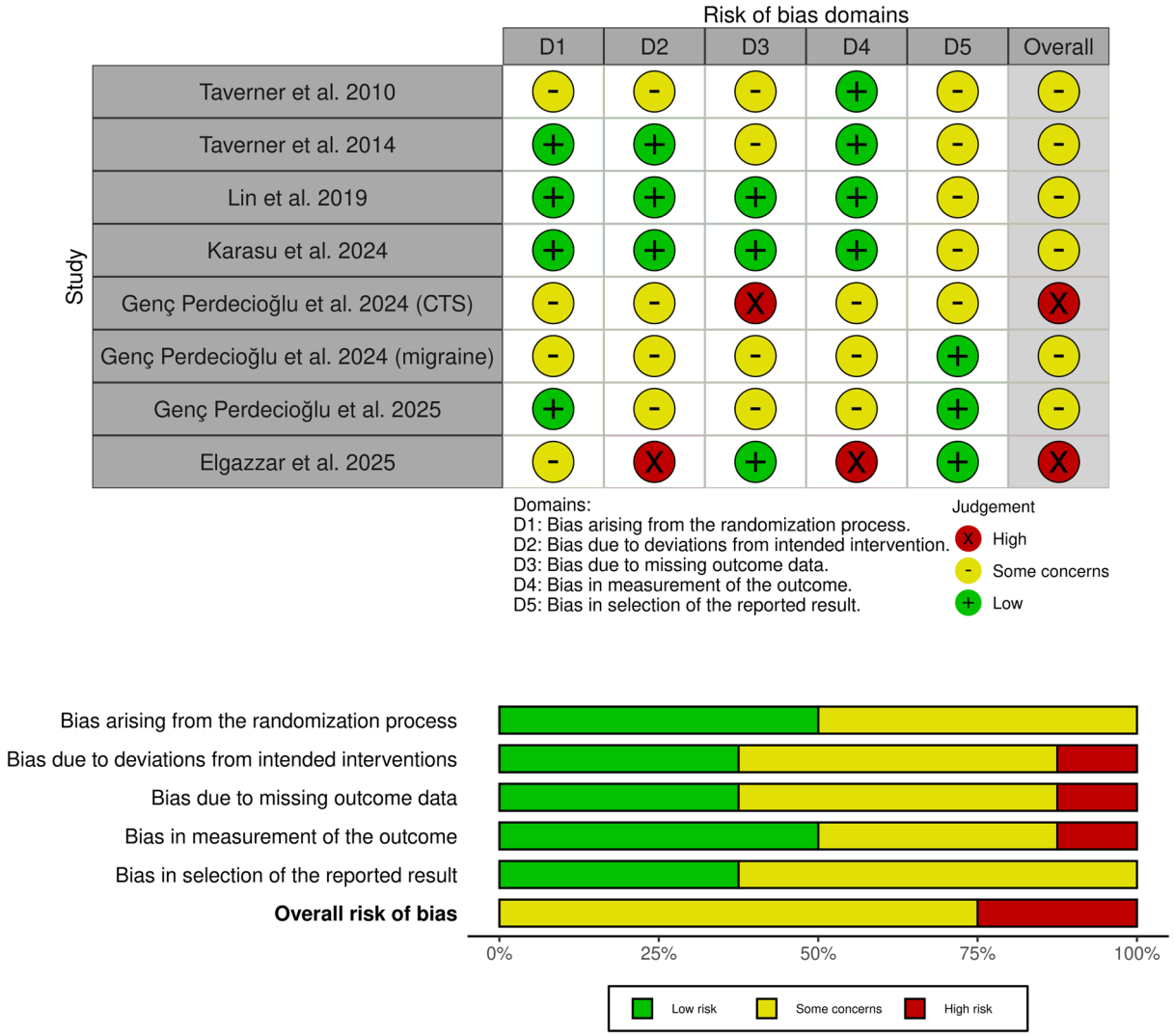

Fig. 4 Traffic-light plot of risk of bias assessment across the included randomized controlled trials. Risk of bias was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool [20]. *Green* indicates low risk of bias, *yellow* indicates some concerns, and *red* indicates high risk of bias. The visualization was generated using the robvis tool [21]

childhood migraine, TcPRF showed comparable short-term efficacy to calcium channel blockers and a safe profile, offering a non-invasive alternative, particularly appealing in the pediatric realm [27]. Current evidence also suggests the potential benefit of TcPRF-STP (Sluijter–Teixeira Pulse) in chronic spinal pain, as a small case series reported marked short-term pain reduction, functional improvement, and even favorable MRI changes in patients with disc herniation, stenosis, and radiculopathy, although the uncontrolled design and very limited sample preclude firm conclusions [28]. Similarly, a retrospective study in patients with osteoarthritis of the upper extremity reported significant short-term improvement in pain scores, without reported adverse events, after TcPRF treatment [26]. Non-invasive wearable PRF devices have been also tested in the acute pain setting in RCTs studying postoperative analgesia, with mixed results, as some studies demonstrated reduced pain scores, whereas others failed to show meaningful analgesic benefit or reduced opioid consumption [30, 31]. Those studies were excluded

to preserve the methodological rigor of RCT-only evidence synthesis. Their existence nevertheless indicates that interest in TcPRF extends beyond the relatively small number of randomized trials currently available and may help guide future hypothesis-generating research.

Safety findings across the included trials were generally reassuring. Adverse events were restricted to mild, temporary, self-resolving local skin reactions, such as erythema or hyperemia, occasionally accompanied by mild burning or discomfort at the electrode site [12, 14, 15]. No significant complications linked to TcPRF were reported. This favorable short-term safety profile is clinically relevant, particularly in comparison with more invasive neuromodulatory or injection-based interventions associated with iatrogenic adverse events [32]. However, the follow-up periods in most studies were relatively short, and conclusions regarding long-term safety or repeated treatment exposure remain limited. We should mention that the minimally invasive nature of this technique makes it particularly appropriate for use in populations that may opt for less interventional options (e.g., children or patients with needle phobia).

Finally, the potential role of TcPRF in other challenging pain conditions warrants consideration; in particular, conditions such as postherpetic neuralgia, where pharmacological management is often insufficient and treatment escalation typically involves invasive procedures [33, 34], may represent promising targets. Pulsed radiofrequency has demonstrated efficacy in these settings when applied using invasive techniques [35, 36], suggesting that a non-invasive approach could offer a safer and more accessible alternative. A similar rationale applies to trigeminal neuralgia and other trigeminal neuropathic pain syndromes, where TcPRF application may be feasible given the superficial anatomical distribution of affected nerves while targeting molecular nodes amenable to neuromodulation, such as ion channels and neuroinflammatory pathways that radiofrequency influences [22, 37, 38]. These observations point to promising directions for future research and potential clinical application.

This review has several strengths [39, 40]. To our knowledge, it is the first systematic review assessing the efficacy and safety of TcPRF in chronic pain. It focused exclusively on RCTs, had a registered protocol, applied a structured risk-of-bias assessment using the RoB 2 tool, and included a broad range of chronic pain conditions, thereby providing a contemporary overview of the highest level of available clinical evidence for TcPRF. All included studies were analyzed thoroughly with close attention to comparator type, follow-up duration, and outcome heterogeneity, which helped avoid overinterpretation of clinically diverse trials.

At the same time, important limitations of current research must be acknowledged. The number of eligible trials was small, sample sizes were generally modest, and follow-up durations were often short. Considerable heterogeneity was present in study populations, outcome measures, treatment protocols, and comparator interventions. These differences are important because superiority over sham is not equivalent to superiority over an established active intervention and makes direct comparison difficult and likely contributed to the inconsistent extent of benefit observed across studies. In addition, minimal clinically important differences were inconsistently reported across studies and varied across outcome measures, limiting assessment of the clinical relevance of the observed improvements. Variability in TcPRF technical parameters, including pulse width, voltage, treatment duration, session number, and electrode positioning, may also have contributed to differences in clinical outcomes and further limited comparability across studies, including quantitative comparison of effect sizes. Finally, most included studies were judged to have either some concerns or high risk of bias, which reduces confidence in the overall body of evidence. The decision not to perform a meta-analysis further reflects the clinical and methodological diversity of the included studies.

CONCLUSION

Transcutaneous pulsed radiofrequency appears to be a promising non-invasive treatment option for selected chronic pain conditions,

particularly when conventional conservative strategies have failed or when a less interventional approach is preferred. However, the current evidence remains limited and insufficient to support firm condition-specific recommendations across all chronic pain syndromes with the predominance of trials with some concerns or high risk of bias. Future randomized trials should include larger sample sizes, multicenter designs, improved blinding strategies, and longer follow-up. Standardization of treatment parameters, electrode positioning, sham protocols, and core outcome measures will be essential to improve comparability between studies and strengthen future evidence syntheses.

Author Contributions. Thalis Asimakopoulos: Conceptualization, methodology, literature search, screening and data extraction, writing—original draft, writing—review and editing, final approval. Athanasia Tsaroucha: Literature review, study selection, writing—review and editing, final approval. Martina Rekatsina: Conceptualization, methodology, supervision, writing—review and editing, final approval.

Funding. No funding or sponsorship was received for this study or publication of this article.

Data Availability. All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declarations

Conflict of Interest. Martina Rekatsina is an Editorial Board member of Pain and Therapy. Martina Rekatsina was not involved in the selection of peer reviewers for the manuscript nor any of the subsequent editorial decisions. All other authors (Thalis Asimakopoulos, and Athanasia Tsaroucha) have nothing to disclose.

Ethical approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

REFERENCES

1. Cohen SP, Vase L, Hooten WM. Chronic pain: an update on burden, best practices, and new advances. The Lancet. 2021;397:2082–97. https://doi.org/10.1016/S0140-6736(21)00393-7.

2. Carr CM, Plastaras CT, Pingree MJ, Smuck M, Maus TP, Geske JR, et al. Immediate adverse events in interventional pain procedures: a multi-institutional study. Pain Med. 2016;17:2155–61. https://doi.org/10.1093/pm/pnw051.

3. Els C, Jackson TD, Kunyk D, Lappi VG, Sonnenberg B, Hagtvedt R, et al. Adverse events associated with medium- and long-term use of opioids for chronic non-cancer pain: an overview of Cochrane reviews. Cochrane Database Syst Rev. 2017. https://doi.org/10.1002/14651858.CD012509.pub2.

4. Byrd D, Mackey S. Pulsed radiofrequency for chronic pain. Curr Pain Headache Rep. 2008;12:37–41. https://doi.org/10.1007/s11916-008-0008-3.

5. Podhajsky RJ, Sekiguchi Y, Kikuchi S, Myers RR. The histologic effects of pulsed and continuous radiofrequency lesions at 42 degrees C to rat dorsal root ganglion and sciatic nerve. Spine (Phila Pa 1976). 2005;30:1008–13. https://doi.org/10.1097/01.brs.0000161005.31398.58.

6. Hagiwara S, Iwasaka H, Takeshima N, Noguchi T. Mechanisms of analgesic action of pulsed

radiofrequency on adjuvant-induced pain in the rat: roles of descending adrenergic and serotonergic systems. Eur J Pain. 2009;13:249–52. https://doi.org/10.1016/j.ejpain.2008.04.013.

7. Park D, Chang MC. The mechanism of action of pulsed radiofrequency in reducing pain: a narrative review. J Yeungnam Med Sci. 2022;39:200–5. https://doi.org/10.12701/jyms.2022.00101.

8. Yuba T, Koyama Y, Uematsu H, Takahashi A, Matsuda Y, Fujino Y, et al. Elucidation of the treatment mechanism of pulsed radiofrequency based on its antiinflammatory effects. Sci Rep. 2025;15:33611. https://doi.org/10.1038/s41598-025-19045-z. (**[Internet]. Nature Publishing Group**).

9. Sluijter ME, Teixeira A, Vissers K, Brasil LJ, van Duijn B. The anti-inflammatory action of pulsed radiofrequency—a hypothesis and potential applications. Medical Sciences. 2023;11:58. https://doi.org/10.3390/medsci11030058. (**[Internet]. Multidisciplinary Digital Publishing Institute**).

10. Vallejo R, Tilley DM, Williams J, Labak S, Aliaga L, Benyamin RM. Pulsed radiofrequency modulates pain regulatory gene expression along the nociceptive pathway. Pain Physician. 2013;16:E601-613.

11. Elgazzar AM, Shalaby OM, Salem AEE, Hamoda NE. A comparative study between transcutaneous pulsed radiofrequency and corticosteroid injections in the management of pain in lateral epicondylitis. Tanta Medical Journal. 2025;53(4):444. https://doi.org/10.4103/tmj.tmj_30_25.

12. Perdecioğlu GRG, Ateş MP, Yürük D, Can E, Yıldız G, Akkaya ÖT. A new neuromodulation method in chronic migraine; non-ınvasive pulsed radiofrequency, a single-blinded, randomised, controlled trial. Ir J Med Sci. 2024;193:1487–93. https://doi.org/10.1007/s11845-023-03598-x.

13. Utkan Karasu A, Kılıç A, Karaoğlan B. Efficacy of transcutaneous pulsed radiofrequency treatment in subacromial impingement syndrome: a randomized controlled study. J Clin Med. 2024;13:7462. https://doi.org/10.3390/jcm13237462.

14. Genç Perdecioğlu GR, Panpallı Ateş M, Yürük D, Akkaya ÖT. Neuromodulation of the median nerve in carpal tunnel syndrome, a single-blind, randomized controlled study. Korean J Pain. 2024;37:34–40. https://doi.org/10.3344/kjp.23232.

15. Genç Perdecioğlu GR. Non-invasive peripheral nerve neuromodulation in diabetic neuropathic pain: a randomised controlled trial. Agri. 2025. https://doi.org/10.14744/agri.2025.28909

16. Taverner M, Loughnan T. Transcutaneous pulsed radiofrequency treatment for patients with shoulder pain booked for surgery: a double-blind, randomized controlled trial. Pain Pract. 2014;14(2):101–8. https://doi.org/10.1111/papr.12059.

17. Taverner MG, Ward TL, Loughnan TE. Transcutaneous pulsed radiofrequency treatment in patients with painful knee awaiting total knee joint replacement. Clin J Pain. 2010;26(5):429. https://doi.org/10.1097/AJP.0b013e3181d92a87.

18. Lin M-L, Chiu H-W, Shih Z-M, Lee P-Y, Li P-Z, Guo C-H, et al. Two transcutaneous stimulation techniques in shoulder pain: Transcutaneous pulsed radiofrequency (TPRF) versus transcutaneous electrical nerve stimulation (TENS): a comparative pilot study. Pain Res Manag. 2019;2019:2823401. https://doi.org/10.1155/2019/2823401.

19. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021. https://doi.org/10.1136/bmj.n71.

20. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ. 2019;366:l4898. https://doi.org/10.1136/bmj.l4898.

21. McGuinness LA, Higgins JPT. Risk-of-bias VISualization (robvis): an R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods. 2021;12(1):55–61. https://doi.org/10.1002/jrsm.1411.

22. Sam J, Catapano M, Sahni S, Ma F, Abd-Elsayed A, Visnjevac O. Pulsed radiofrequency in interventional pain management: cellular and molecular mechanisms of action—an update and review. Pain Phys. 2021;24:525–32.

23. Occhigrossi F, Mosca J, Leoni MLG, Pasqualucci A, Gazzeri R, Cascella M, et al. Role of pulsed radiofrequency on the immunological system in chronic pain patients: a narrative review. Explor Immunol. 2026;6:1003235. https://doi.org/10.37349/ei.2026.1003235.

24. Asimakopoulos T, Tsaroucha A, Kouri M, Pasqualucci A, Varrassi G, Leoni MLG, et al. The role of biomarkers in acute pain: a narrative review. Pain Ther. 2025;14:775–89. https://doi.org/10.1007/s40122-025-00718-6.

25. Lin M-L, Luo Y-J, Hsu Y-M, Guo C-H, Lin S-C, Lin K-Y, et al. Randomized controlled trial comparing of analgesic effectiveness of TPRF and TENs in clinical and endocrinological changes for chronic

shoulder pain. 2015 International Symposium on Bioelectronics and Bioinformatics (ISBB) [Internet]. 2015. p. 23–6. https://doi.org/10.1109/ISBB.2015.7344914

26. Janssens P, Koenraadt-van Oost I, van Boekel L, Eygendaal D, Beumer A, van der Velden M, et al. Transcutaneous pulsed radiofrequency treatment in patients with osteoarthritis of the upper extremity. Anesth Pain Med. 2024;14(4):e146816. https://doi.org/10.5812/aapm-146816.

27. Üstün C, Perdecioğlu GRG, Akkaya ÖT, Yüksel D. A novel neuromodulation method for childhood migraine: comparing noninvasive pulsed radiofrequency therapy with calcium channel blockers, a randomized controlled trial. Pediatr Neurol. 2026;176:41–7. https://doi.org/10.1016/j.pediatrneurol.2025.12.011.

28. de Mf JD, Rohof O, Jorge MBF, Teixeira A, de Oliveira CA, Sobreiro P, et al. A transcutaneous randomized pulsed radiofrequency application for spine pain conditions: a case series. J Funct Morphol Kinesiol. 2025;10:242. https://doi.org/10.3390/jfmk10030242.

29. Karaoğlan M, Takmaz SA. Evaluating the therapeutic impact of transcutaneous radiofrequency therapy on myofascial pain syndrome patients: a clinical study. Ankara Egıtım Arastırma Hastan Tıp Derg. 2024;57:64–8. https://doi.org/10.20492/aeahtd.1430864.

30. Ilfeld BM, Finneran JJ, Said ET, Ball ST, Wallace AM, Broderick RC, et al. Wearable, noninvasive, pulsed shortwave (radiofrequency) therapy for postoperative analgesia: a randomized, double-masked, sham-controlled pilot study. Pain Pract. 2025;25(2):e70007. https://doi.org/10.1111/papr.70007.

31. Rawe IM, Lowenstein A, Barcelo CR, Genecov DG. Control of postoperative pain with a wearable continuously operating pulsed radiofrequency energy device: a preliminary study. Aesthetic Plast Surg. 2012;36:458–63. https://doi.org/10.1007/s00266-011-9828-3.

32. Gharibo C, Drewes AM, Breve F, Rekatsina M, Narvaez Tamayo MA, Varrassi G, et al. Iatrogenic side effects of pain therapies. Cureus. 2026;15:e44583. https://doi.org/10.7759/cureus.44583.

33. Asimakopoulos TA, Gika AA, Kekelos PS, Kouroukli IC. The efficacy of stellate ganglion blockade in herpetic neuralgia: a case report. Cureus. 2023. https://doi.org/10.7759/cureus.43805.

34. Lin C-S, Lin Y-C, Lao H-C, Chen C-C. Interventional treatments for postherpetic neuralgia: a systematic review. Pain Physician. 2019;22:209–28.

35. Wang H, Zhang D, Wang S, Wang H, Nie H. Comparison of the efficacy of pulsed radiofrequency in treating acute herpetic neuralgia and postherpetic neuralgia in the thoracic segment. Front Neurol. 2024. https://doi.org/10.3389/fneur.2024.1425796.

36. Wu C-Y, Lin H-C, Chen S-F, Chang W-P, Wang C-H, Tsai J-C, et al. Efficacy of pulsed radiofrequency in herpetic neuralgia: a meta-analysis of randomized controlled trials. Clin J Pain. 2020;36:887–95. https://doi.org/10.1097/AJP.0000000000000867.

37. Asimakopoulos T, Kourousi M, Varrassi G, Rekatsina M. Piezo channels in migraine and trigeminal pain syndromes: a systematic review of their role in pain pathways. Adv Health Res. 2024;1(1):4. https://doi.org/10.4081/ahr.2024.4.

38. Chua NHL, Halim W, Beems T, Vissers KC. Pulsed radiofrequency treatment for Trigeminal Neuralgia. Anesthesiol Pain Med. 2012;1:257–61. https://doi.org/10.5812/aapm.3493.

39. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143. https://doi.org/10.1186/s12874-018-0611-x.

40. Yuan Y, Hunt RH. Systematic reviews: the good, the bad, and the ugly. Am J Gastroenterol. 2009;104:1086–92. https://doi.org/10.1038/ajg.2009.118.