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GUIDELINES

The Leiden–Nice Consensus (2024–2025)—Technical Standardization and Clinical Algorithms for Pulsed Radiofrequency for Chronic Pain

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ABSTRACT

Pulsed radiofrequency (PRF) has emerged as a safe, minimally invasive clinical strategy for the management of acute and chronic pain syndromes. Over the past two decades, its range of clinical applications has expanded across spinal, peripheral nerves, and intra-articular interventions. Despite the growing evidence supporting the clinical efficacy of PRF, two major challenges remain: (a) the lack of standardized technical parameters and the absence of structured clinical algorithms guiding physicians in selecting the targets and therapeutic strategies. In April 2024, an international panel of pain specialists convened in Leiden, the Netherlands to propose standardized technical guidelines for PRF procedures, resulting in the Leiden Consensus 2024, which focuses on reproducible parameters such as voltage, exposure time, electrode configuration, and procedural technique. Subsequently, during expert consensus discussions held in Nice, France, in 2025, the same international workgroup addressed a second critical gap in the field: clinical decision-making

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in interventional pain management. The Nice 2025 Consensus therefore developed practical diagnostic and therapeutic algorithms for common chronic pain conditions, including cervical facet pain, shoulder pain, knee osteoarthritis, sacroiliac pain, hip pain, thoracic pain, and central sensitization syndromes. This integrated consensus manuscript combines both initiatives into a comprehensive clinical framework. The Leiden Consensus proposes reproducible technical standards for PRF procedures, while the Nice Consensus provides stepwise clinical pathways emphasizing diagnosis-driven interventions and prioritizing nondestructive neuromodulation strategies. A central principle of the consensus is that PRF may be considered the first-line interventional treatment for peripheral nerve-related chronic noncancer pain, reserving ablative radiofrequency techniques for cases that are refractory to neuromodulation. The present document represents a living consensus intended to guide clinical practice worldwide while stimulating future research and evidence generation in the rapidly evolving field of PRF pain therapy.

Keywords: Pulsed radiofrequency; Chronic pain; Interventional pain management; Neuromodulation; Consensus guideline

Key Summary Points

An international workgroup panel proposed standardized technical parameters for pulsed radiofrequency (PRF) procedures to address methodological heterogeneity.

A subsequent international workgroup panel expanded the framework to include structured clinical algorithms to standardize clinical decision-making.

The consensus provides an integrated document that standardizes voltage, exposure time, electrode configuration, and impedance parameters in PRF procedures. Furthermore, it provides structured stepwise algorithms for cervical, thoracic, lumbar, shoulder, knee, hip, sacroiliac joint pain, and central sensitization. Overall, this consensus guideline proposes a safety-first neuromodulation approach and proposes intraoperative PRF as an emerging frontier.

This document should be considered a living document, with future updates expected as new clinical evidence, randomized trials, and mechanistic studies further clarify the use of PRF in interventional pain medicine.

INTRODUCTION

At the close of the twentieth century, the field of interventional pain saw a drastic change with the introduction of pulsed radiofrequency (PRF) by Prof. Dr. Menno E. Sluijter in 1998 [1]. Since then, PRF has been increasingly adopted by pain specialists as a new treatment strategy against chronic pain by delivering high-intensity electrical fields without producing neural thermal lesions like PRF's precursor—continuous radiofrequency (CRF) [2].

According to a PubMed search (National Library of Medicine, performed 18 December 2025), annual publications on the use of PRF techniques in pain centers have been increasing, with a marked growth in the past decade (since 2015) [3]. Despite the increasing amount of scientific output, adherence to structured reporting that ensures reproducibility remains limited in the field of interventional pain, including above-mentioned publications regarding PRF procedures [4]. Irreproducible data not only hamper scientific progress and clinical translation but also create heterogeneity of treatment in clinical practice [5, 6].

Clinical reports on the use of PRF suggest that the technique is safe—owing to a negligible rate of adverse events—and offers long-term

positive clinical outcomes for a wide-range of chronic pain conditions, such as shoulder pain, spinal conditions, and neuropathic and non-neuropathic pain [7–10]. Although the existing data are promising, the majority remain preliminary and warrant validation in larger trials with more structured and reproducible reporting [9].

Performing a procedure with PRF entails the selection of a protocol. This includes anatomical landmarks, needle positioning, and a set of electrophysiological parameters that contribute to more effective pain relief. For example, Teixeira and Sluijter (2006) suggested that voltage (i.e., PRF intensity) and tissue impedance (i.e., resistance to the flow of an electric field [11]) are tightly correlated and their dependency is essential to achieve a biological effect within the target tissue—with the aim of generating a very strong electric field during the active phase of the PRF stimulation [12]. The authors continued by suggesting that, while most clinical outcomes are already achieved with short exposure times of 2 min, there may be clinical cases where a longer exposure time results in improved outcomes in specific PRF procedures (e.g., PRF for low-back disc versus discogenic pain, PRF for dorsal root ganglion (DRG) versus postherpetic neuralgia, and PRF for pudendal nerve versus pudendal neuralgia) [12–14]. Furthermore, while anatomical landmarks have dictated the sizing and gauges of needles—with thinner and shorter needles for cervical structures and high-risk procedures—the milestone publication by Cosman (2005) also uncovered the tight dependency of electrode tip shape and length in modulating the geometry of the delivered PRF electric field [15]. Beyond these technical determinants, emerging experimental and translational evidence suggests that PRF-induced electric fields may exert their effects through a combination of neuroinflammatory modulation, regulation of voltage-gated sodium channels (including Nav1.7 and Nav1.8), activation of microglial autophagy pathways, normalization of the descending inhibitory control, and dynamic central–peripheral crosstalk along the neuraxis. Together, these biological mechanisms, interacting with the physical characteristics of the electric field, provide a plausible framework linking PRF parameter selection to neuromodulatory efficacy [15–21].

In recent years, to further the knowledge on the mechanisms of action of PRF along with the need to improve clinical outcomes, there has been renewed interest within the pain field in formulating standardized PRF parameters [22–24]. However, the scientific literature—along with real-life world scenarios within clinical practices—suggest that there is still not a standard consensus on the selection of parameters [25]. Although proficiency and experience facilitate the selection of PRF parameters, physicians may encounter initial challenges during clinical decision-making, particularly when identifying the pain source and selecting the most appropriate interventional strategy. To address these limitations, an international panel of experts in the PRF field—anesthesiologists, orthopedists, and pain specialists and researchers—stipulated the 2024 Leiden Consensus—a technical guideline of PRF parameters, followed by the 2025 Nice Consensus—a clinical treatment algorithm for chronic pain. The objective of the present manuscript is to integrate these efforts into a unified framework for clinical practice, with the aim of generating data homogeneity in scientific publications, as well as improved patients' outcomes within clinical practice.

MATERIALS AND METHODS

On the occasion of the 3rd Symposium on the Evolution of PRF (Leiden, the Netherlands), the group convened to develop and draft the 2024 Leiden Consensus. The panel of experts was appointed with the aim of creating a clinically relevant guideline on the standardized use of PRF technical parameters for a wide range of applications, with the aim of fostering methodological homogeneity. In 2025, on the occasion of the 4th Symposium on the Evolution of PRF (Nice, France), it became evident that a greater challenge faced by clinicians lies in clinical decision-making rather than PRF device technical programming. During the preparation of the Nice Consensus, the expert meeting expanded on the existing framework to include structured

clinical algorithms. In both instances, the symposia preceding the workgroup were approved by the London Pain Forum, in 2024 and 2025. The workgroup convened the following day and comprised six internationally recognized specialists in interventional pain management and neuromodulation, representing different geographic regions and clinical practice environments. Four members participated in both consensus initiatives, providing conceptual continuity and integration between the two guidelines: Dr. Daniel de Moraes Ferreria Jorge (Brazil), Dr. Alexandre Teixeira (Portugal), Dr. Olav Rohof (the Netherlands), and Dr. Luis Josino Brasil (Brazil). Two additional rotating specialists participated in the consensus meeting and broadened the diversity of clinical perspectives and international representation. Across both consensus initiatives, all recommendation statements were reviewed, discussed, and voted upon by the full expert panel during structured consensus sessions.

In both instances, a structured process was developed, incorporating elements of both the Delphi methodology and a modified nominal group technique (NGT). Questions and formats were drafted in advance by the workgroup chair and subsequently refined during the meeting together with the workgroup on the basis of available evidence and expert clinical practice. Examples of consensus questions included the role of intra-articular versus suprascapular PRF as the initial intervention for shoulder pain, the sequencing of intra-articular and genicular nerve PRF for knee pain, and standardization of each individual PRF parameter for DRG, medial branch, intra-articular, sacroiliac, sacral, and intradiscal procedures. All contributing authors participated in the discussion and review of each statement. Recommendations were evaluated through an open yes–no voting process involving all panel members. A priori, consensus was defined as unanimous agreement (100% affirmative votes from all participating experts). Statements that failed to achieve unanimous agreement underwent further discussion, revision, and subsequent voting rounds until consensus was achieved. The final recommendations therefore represent statements that achieved unanimous agreement following iterative rounds of discussion, modification, and voting. While the process incorporated key principles of the NGT, including structured discussion, equal participation, iterative refinement, and formal voting, it did not employ anonymous voting or formally record individual response distributions. Consequently, the methodology should be regarded as a modified NGT-based expert consensus process rather than a formal Delphi study. The multidisciplinary workgroup further established that all literature searches would be conducted using the National Center for Biotechnology Information (NCBI) PubMed database, focusing on English-language full-text studies published within the previous 5 years, from January 2020 to November 2025. Irrespective of clinical outcomes, papers were selected and evaluated solely on methodological design and technical PRF parameters. An initial query search was used to select the most reported PRF interventions. Eligible publications included clinical trials, observational studies, and case reports on both human and animal studies. Title and abstracts were screened for relevance, followed by methodology review of selected articles. Scientific publications reporting neuroablative techniques were excluded, giving priority to neuromodulatory treatments.

Keywords for parameters were selected and included in accordance with the literature on PRF procedures, such as “electrode type/tip,” “PRF mode,” “exposure time,” “voltage,” “impedance,” and “needles.” For the Leiden workgroup, clinical procedures of interest such as “dorsal root ganglion (DRG),” “medial branch (at cervical, thoracic, and lumbar level),” “intra-articular (at small and large joints),” “peripheral nerve,” “SI joint,” “sacral PRF,” and “disc” were selected to formulate standardized protocols. For the 2025 Nice workgroup, relevant keywords for clinical decision-making were selected, such as “central sensitization,” “cervical facet pain,” “shoulder pain,” “knee osteoarthritis,” “hip pain,” “SI joint pain,” and “thoracic pain.” All keywords mentioned above and the reported literature were used to tailor individual questions and formulate guideline topics; where high-quality evidence was limited, expert clinical experience supported further refinement of consensus statements and algorithms. Supporting

evidence identified through the literature review is reported in Supplementary Tables S1-S6.

The present manuscript integrates both of these consensus efforts into a single clinical framework. While the 2024 Leiden Consensus provides the technical procedural standards for PRF, the 2025 Nice Consensus proposed diagnostic and therapeutic decision pathways guiding the clinical application of such procedures. Together, these complementary initiatives aim to provide physicians with standardized technical parameters and clinical algorithms, answering respectively the questions of how to perform PRF procedures and when and/or where to apply PRF, both of which are summarized in Tables 1 and 2. Below, the manuscript follows the chronological order of consensus efforts, progressing from the selection of procedural parameters (Leiden 2024) to the identification of diagnosis and treatment (Nice 2025). Note that

Table 1 Overview of the 2024 Leiden Consensus guidelines with regards to PRF parameters in clinically relevant procedures by anatomical target

Anatomical landmark	Electrode length–tip length	PRF mode*	Exposure time	Voltage	Impedance
DRG	10–10 (lumbar) 6–10 (cervical)	STP, 3 Hz or 5 Hz, 5 ms	6 min	35 V	200–400 Ω
Medial branch	6–10 (cervical) 10–10 (thoracic) 10–10 (lumbar)	STP, 3 Hz or 5 Hz, 5 ms	4 min	40 V	200–400 Ω
Intra-articular	6–5 (small) 10–10 (large)	STP, 3 Hz or 5 Hz, 5 ms	8 min 12 min	40 V	200–400 Ω
SI joint	10–10	STP, 3 Hz or 5 Hz, 5 ms	12 min	40 V	200–400 Ω
Sacral PRF	10–10 or 15–15	STP, 3 Hz or 5 Hz, 5 ms	10–20 min (depending on tenderness)	45 V	200–400 Ω
Disc	15–15	STP, 3 Hz or 5 Hz, 5 ms	15 min	40 V	120–250 Ω Sensory testing, when 1.5 V and sensitive, positive indication When injection of disc antibiotics prophylactic is used

*3 Hz or 5 Hz, 5 ms are the recommended parameters to ensure that the maximum duty cycle remains safely below 25 ms/s. The maximum duty cycle is calculated as the selected frequency (*f*) multiplied by the length of the pulse width (ms)

Needles: 20–23-gauge invasive PRF is performed monopolar (exception for pacemaker)

The area to be treated between the needle tip and dispersive/directional plate

Needle close to the nerve (stimulation at < 0.5 V)

Corticosteroids: no

Local anesthetics: yes (1 ml; 10–20 mg/ml lidocaine)

STP, Sluijter–Teixeira–Poisson; SI, sacroiliac; PRF, pulsed radiofrequency

Table 2 Overview of the 2025 Nice Consensus guidelines with regards to clinical algorithms for PRF applications

Pain condition/ clinical scenario	Patient selection or diagnostic pathway	First-line intervention	Escalation/adjunctive strategies	Key remarks
Central sensitization	Chronic pain > 3 months; diffuse spinal tenderness; normal MRI	Sacral PRF via sacral hiatus	Ongoing search for primary nociceptive trigger	Consider central sensitization when structural pathology is absent
Cervical pain	Clinical examination → MRI → exclusion of surgical pathology	PRF of cervical medial branches	PRF of corresponding DRG if pain persists	Stepwise escalation from facet to segmental modulation
Shoulder pain	Clinical diagnosis of shoulder-joint-related pain	Intra-articular PRF	PRF of suprascapular nerve if incomplete relief	Addresses intra- and extra-articular pain generators
Knee pain	Degenerative or chronic knee pain	Intra-articular PRF ± viscosupplementation	PRF of genicular nerves (superior medial, superior lateral, and inferior medial)	Inferior lateral genicular nerve generally avoided owing to fibular nerve proximity
Hip pain	Clinical and imaging-based diagnosis of hip joint pain	PENG block combined with PRF	Targeting femoral, obturator, and accessory obturator nerves	Reflects complex hip joint innervation
Sacroiliac joint pain	Clinical diagnosis ± confirmatory imaging or blocks	PRF neuromodulation	L5 medial branch treatment; intra-articular injection	Ablative RF reserved for refractory cases
Thoracic pain	Clinical assessment of thoracic pain generators	PRF of medial branches and/or intercostal nerves	DRG PRF; ESP block as adjunct	ESP block recognized as a safe adjunctive technique
Future applications	Perioperative and preventive pain strategies	Intraoperative PRF	–	Potential to reduce postoperative pain, facilitate rehabilitation, and lower opioid use

ESP, erector spinae plane; PENG, pericapsular nerve group; PRF, pulsed radiofrequency; MRI, magnetic resonance imaging

the recommendations are presented in a manner that may not be consistent with a real-world clinical workflow from diagnosis and clinical indications to intervention.

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.

RESULTS

Literature Search

A comprehensive literature search was undertaken to identify studies focusing on the application of pulsed radiofrequency (PRF) in the management of spinal pain conditions. The search strategy was intentionally broad and initially conducted without anatomical restriction to ensure a wide capture of relevant evidence. Subsequently, the identified studies were stratified according to their anatomical target, which included disc, sacroiliac joint, medial branch including facet joint, and dorsal root ganglion (DRG). The combined search across all categories yielded a total of 196 records, distributed as follows: 31 studies related to discogenic pain, 15 to sacroiliac joint pain, 40 to medial-branch-related pain (21 of which related to facet joint procedures), and 111 to DRG interventions. After compiling the search results, duplicate records were systematically removed. Duplicates were identified both within individual categories and across different anatomical categories, an occurrence attributable to overlapping indexing of PRF studies (for example, some DRG studies were retrieved under disc, facet, or medial branch searches).

Following deduplication, the remaining unique records advanced to the screening phase. Owing to the presence of cross-categorical duplication and repeated indexing, it was not possible to allocate each unique record to a single anatomical category at this stage; thus, these records were managed collectively during screening, consistent with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. During abstract screening, records were excluded on the basis of predefined criteria. Exclusion reasons included narrative reviews, systematic reviews, consensus statements, studies not involving PRF, radiofrequency ablation without PRF neuromodulation, nonspinal targets, and clearly irrelevant indications. Full-text articles were then retrieved for those studies meeting initial criteria and assessed for methodological eligibility. Further exclusions at this stage were applied if the following criteria were met: (a) absence of full-text access, (b) duplicate publication of an already included study, (c) review articles identified after abstract screening, (d) lack of reported PRF procedural parameters, and (e) PRF applied to an anatomical target different from that indexed.

Across all anatomical targets, the most frequent reasons for full-text exclusion were missing methodological details, publications limited to reviews, or misclassification of anatomical targets (such as DRG studies appearing in disc or facet search results). Following this multistage screening process, the studies included by PRF anatomical targets were: 4 studies for discogenic pain, 1 for sacroiliac joint pain, 6 for medial-branch-related pain (medial branch or facet joint access), 71 for dorsal root ganglion interventions, 36 for peripheral nerves, and 19 for intra-articular procedures. Because the literature review was conducted as a narrative, consensus-guided process rather than a formal systematic review, the study selection flow is reported descriptively without a PRISMA diagram. The aim of the review was not to formally grade evidence quality but rather to identify commonly reported technical parameters and clinical applications to inform consensus discussion.

THE 2024 LEIDEN CONSENSUS—TECHNICAL PRF PARAMETERS

Workgroup recommendation—2024 Leiden Consensus guideline on PRF DRG procedures:

DRG procedures for the management of chronic pain are a commonly used PRF approach

against a range of pain conditions, such as chronic radicular pain [26], neuropathic pain syndromes (i.e., post-herpetic neuralgia [27]), and complex regional pain syndromes [18]. Owing to its key role in pain transmission and its anatomical configuration, the DRG is usually favored over other targets—it allows for easy access and for segment-specific targeting with a favorable safety profile [28].

Results of the literature review on DRG procedures are summarized in Supplementary Table S1, demonstrating efficacy and safety of PRF DRG procedures in an ample range of clinical cases. While the terminology used across publications appears to be in agreement, there is inconsistent reporting on methodological descriptors, which weakens comparability across studies. Despite the gap in reporting, there is fair homogeneity and adequate description of electrode types, gauges, exposure times, voltages, and tests across the available publications on PRF DRG.

On the basis of the literature search and clinical knowledge of the workgroup, the workgroup formulated guidelines regarding PRF DRG procedures, which are incorporated into the Leiden Consensus summary (Table 1). DRG procedures can be performed at 35 V (intensity of PRF electric field), for 6 min, as long as the tissue impedance of the target area is maintained between the recommended range of 200 to 400O h ms. As mentioned above, the anatomical structures around the DRG are easy to access but may vary at the spinal level; as a result, it is important to use a 6-cm electrode type for cervical procedures and a 10-cm electrode type for lumbar procedures, with a 10-mm active tip.

Workgroup recommendation—Leiden Consensus guideline on medial branch procedures:

Several publications continue to report the use of continuous (ablative) radiofrequency for the treatment of lumbar medial branch nerves, with evidence suggesting longer-lasting outcomes and faster pain relief. However, it is important to recognize that these sensory nerves also contribute to the innervation and maintenance of intrinsic paraspinal muscles. Ablation of these structures may therefore predispose patients to future intrinsic muscle weakness—an especially relevant concern given the well-known difficulty of restoring muscle mass and achieving effective spinal stabilization once muscle degeneration occurs [29, 30]. Recent studies demonstrating favorable outcomes with PRF for the treatment of medial branch nerves deserve attention. As a nondestructive technique, PRF offers the potential for effective pain relief while minimizing the risks of muscle denervation, deafferentation pain, granuloma formation, and unintended thermal injury associated with the high temperatures of continuous radiofrequency.

PRF has been reported to be as effective and safe in patients suffering facet joint pain (cervical, thoracic, and lumbar) and lower back pain [31, 32]. As a result, while the initial literature review included only medial branch procedures, the workgroup decided to expand the search by including a new keyword—"facet joint." The outcome of this second search is summarized in Supplementary Table S2. The heterogeneity in methodology reporting indicates that it remains unclear which PRF parameters yield the most favorable clinical outcomes during medial branch procedures—despite being one of the most frequently performed PRF techniques.

For medial branches, the workgroup formulated the guideline on the basis of anatomical region (cervical, thoracic, and lumbar), as reported in Table 1. The medial branch is always approached using a 10-mm active tip electrode, with either a 6-cm (cervical) or 10-cm (thoracic, lumbar) needle length. The recommended PRF intensity is 40V , with a shorter exposure time than DRG of 4 min—as long as the tissue impedance of the target area is maintained in the recommended range.

Workgroup recommendation—Leiden Consensus guideline on intra-articular procedures:

A subset of chronic pain conditions involves small and large joints (i.e., knee, shoulder, and hip), as a result of aging, degenerative osteoarthritis, and rheumatoid arthritis. Given that continuous radiofrequency induces ablation through heat generation, its application in proximity to chondral tissue should be avoided owing to the potential risk of aggravating cartilage damage and joint deterioration. As part of standard of care, intra-articular PRF is considered safe and effective, and can be performed with or without the injection of viscosupplementation

and even orthobiologics products [33–36]. Supplementary Table S3 presents a comprehensive summary of the literature collected during the workgroup's search pertaining to the use of intra-articular PRF for the management of shoulder or knee pain. The substantial range of PRF parameters presented makes it challenging to establish a definitive conclusion regarding optimal clinical practice.

The biological composition of a joint space makes it necessary to extend the exposure time to 8 min for smaller joints and up to 12 min for large joints. Furthermore, although larger joints allow for a standard 10-cm-long, 10-mm active electrode tip, the anatomical geometry of a small joint requires the use of a shorter active tip (5 mm) such that the needle's active tip is fully within the joint, ensuring optimal therapeutic outcomes. A summary of technical recommendations from this consensus on intra-articular procedures is incorporated into the Leiden Consensus (Table 1).

Workgroup recommendation—Leiden Consensus guideline on peripheral nerve procedures

PRF is generally well tolerated and considered nondestructive, minimizing thermal injury risk relative to continuous RF, and nerve injury is widely recognized as challenging to treat and may predispose patients to complex pain syndromes and long-term sensory or motor impairments. Accordingly, PRF may represent an effective treatment option in carefully selected cases [25].

For any peripheral nerve application, the workgroup collected a literature review (Supplementary Table S4)and formulated a guideline (Table 1), agreeing to a 4-min exposure time and 40 V for peripheral target points, with electrode length type based on the location of the nerve: 6 cm for superficial nerves and 10 cm for deeper regions.

Workgroup recommendation—Leiden Consensus guideline on sacroiliac joint procedures

The etiology of pain from the sacroiliac (SI) joint ranges from strain or degeneration to malignancy or infection [37]. SI joint pain occurs in around 15–30% of cases of patients with low-back pain with no radicular involvement. Owing to its complex anatomy (a ligament-rich region, innervated by a cluster of nerves including lumbosacral branches) and its morphological diversity across individuals, SI joint procedures present challenges [38]. The available literature is summarized in Supplementary Table S5.

While proper diagnosis and patient selection are known to be factors influencing the outcomes of SI joint procedures, the workgroup proposed a sequence of the most optimal parameters, as summarized in Table 1. Similar to other larger joints, the exposure time is 12 min, with a 10-cm-long, 10-mm active electrode tip.

Workgroup recommendation—Leiden Consensus guideline on disc procedures:

Pain originating from the spine is heterogeneous and may result from trauma (i.e., strain), degenerative processes, or structural abnormalities. Among these etiologies, disc herniation, annular fissuring, and internal disc disruption represent common sources of chronic axial mechanical back pain, accounting for approximately 40% of cases [31].

Intradiscal PRF has emerged as a minimally invasive therapeutic option, with multiple prospective cohorts demonstrating consistent reductions in pain and improvements in function. Studies by Fukui et al. (2012 and 2013) and Rohof (2011), encompassing a combined sample of 145 patients with discogenic low-back pain, reported significant decreases in Numeric Rating Scale (NRS) scores and improvements in disability measures following PRF delivered at 60 V for 12–15 min using 150–200-mm electrodes. Pain relief was sustained across follow-up periods ranging from 3 to 12 months, supporting the potential role of intradiscal PRF in the management of chronic discogenic pain [39–42]. While short- to mid-term outcomes appear promising, data on long-term structural effects on the intervertebral disc remain limited. Further studies are needed to evaluate durability of clinical benefit and potential effects on disc integrity. The studies identified during the literature review on discal pulsed radiofrequency are summarized in Supplementary Table S6.

The consensus guideline for discal PRF proposes the use of a 15-cm-long, 15-mm active electrode tip to approach the spine—close to the target point or the disc from the referred area of pain. A traditional pressure discogram, as a way

of confirming the disc as pain generator, is commonly performed with the use of contrasting agents. An alternative method, first described by Dr. Menno Sluijter and recommended by this workgroup, is the use of sensory testing at 1.5 V. If any indications suggest that the needle has entered intradiscally, it is recommended to start antibiotic prophylaxis. Fluoroscopic imaging together with a low impedance (<200 Ω) are standardized tools to confirm the exact needle location during disc procedures. As suggested in Table 1, a 15-min exposure time at 40 V is the recommendation for the most optimal clinical outcome.

Workgroup recommendation—Leiden Consensus guideline on sacral PRF:

Building on the above-mentioned clinical framework for identifying central sensitization, this section focuses on the technical and procedural recommendations for sacral PRF as a neuromodulatory intervention. As a promising interventional approach for central sensitization in pain management, sacral PRF is a technique in which the electrode tip is introduced via the sacral hiatus in a richly vascularized region of the sacrum, in close proximity to multiple dorsal root and parasympathetic ganglia.

The workgroup formulated clinical guidelines regarding the sacral PRF procedure, with an emphasis on the importance of accurate diagnosis. Physical examination—by means of testing the presence of tenderness over spinous processes in prone position—is key for proper indication, assuming presence of central sensitization. Following confirmation of tenderness, sacral PRF can be performed at 45 V, with a 10-cm-long (or 15-cm-long) and 10-mm (or 15-mm) active electrode tip for a period of 15–20 min—depending on the severity of the tenderness at intake. The dispersive plate is placed at the high thoracic or low cervical spine for propagation of the electromagnetic PRF field along the spinal structures.

Overall recommendations—Leiden Consensus guideline:

An overview of the 2024 Leiden Consensus guideline is presented in Table 1. The recommendations reflect expert consensus and are not graded according to formal evidence quality systems.

PRF is generally performed using a monopolar approach, except in patients with pacemakers, for whom alternative approaches may be necessary. Additionally, exceptions to this monopolar approach may apply in patients with obesity, where technical considerations could influence procedural choices.

While electrode and active tip length, electrode type, exposure time, and voltage are all parameters that are highly dependent on the anatomical landmark and selected procedure, one standard parameter across procedures remains the PRF mode—commonly reported in the scientific literature in terms of frequency (Hz) and pulse width (ms). As the literature suggests, common PRF modes include either 2Hz, 20 ms (n = 69 papers) or 5 Hz, 5 ms (n = 5 papers), and although there is a good amount of evidence investigating the clinical effects of the 2 Hz, 20 ms modality, the workgroup suggests the use of 3 or 5 Hz,with a 5-ms width setting, at least 10 mm or less, which allows for more frequent electric excitations as well as lower peak thermal accumulation per burst. According to Prof. Dr. Menno E. Sluijter, the inventor of PRF, the accumulated thermal peak experienced when using a 20-ms pulse width is only a side effect. Therefore, the strength of the electric field in V/m when using 5 Hz, 5 ms favors an amount of neuromodulatory effects preventing ablation.

While selecting optimal PRF parameters, a strategy to consider is the so-called duty cycle (measured in ms/s): for example, 2 Hz × 20 ms gives a duty cycle of 0.04, 5 Hz × 5 ms gives a duty cycle of 0.025, and 3 Hz × 5 ms gives a duty cycle 0.015, while the average duty cycle for the PRF STP mode is slightly below 0.015. Probes with shorter active tip lengths, less than 10 mm, tend to produce fewer heat spikes, and when using a 5mm (active tip length) probe, no such temperature effects occur. The recommended duty cycle value below 0.025 is optimal to prevent heat spikes and ablation, along with the use of a 5mm probe to bring the therapeutic focus on immune- and neuromodulatory effects.

Another important point to highlight here is the relationship between the cannula, which acts as an active pole, and the dispersive plate, which in the PRF technique acts as a passive pole, receiving the electromagnetic field

produced by the cannula at its active tip. As illustrated schematically in Fig. 1a, the interaction between the active canula and dispersive plate defines the electromagnetic field distribution; therefore, the placement of the plate on the patient in PRF should be as close as possible to the application site, while maintaining a safe, sterile area for asepsis and antisepsis. This differs from what occurs in continuous RF, where the effects are all concentrated solely at the active tip of the cannula (as illustrated in Fig. 1b), and the plate serves merely as a ground plate to maintain contact. For this reason, we suggest that the term "ground plate" no longer be used in the context of PRF; instead, "dispersive plate" seems much more appropriate to us. It is interesting to note how similar techniques, owing to differences in the format of energy delivery, can have such distinct applications and modes of use, and it is important that all of this be clear to the scientific community.

Furthermore, the guideline explicitly advises against the use of corticosteroids in conjunction with PRF procedures, since corticosteroids have an immune-suppressive effect and could counteract the expected immune-stimulating response.

A step deeper toward understanding the potential relevance of pulse pattern in PRF mode is the Sluijter–Teixeira–Poisson (STP) mode—a conceptual framework that excludes thermal mechanisms and introduces the nonlinear and probabilistic nature of neural responses to PRF stimulation. Following a Poisson-like distribution of pulses, the STP mode may provide a biologically effective interaction between the PRF-generated electric fields and (neural) tissues and occurs in a stochastic (random and independent) rather than deterministic fashion (predictive cumulative dosing of standard 2 Hz, 20 ms or 5 Hz, 5 ms), as shown schematically in Fig. 2.

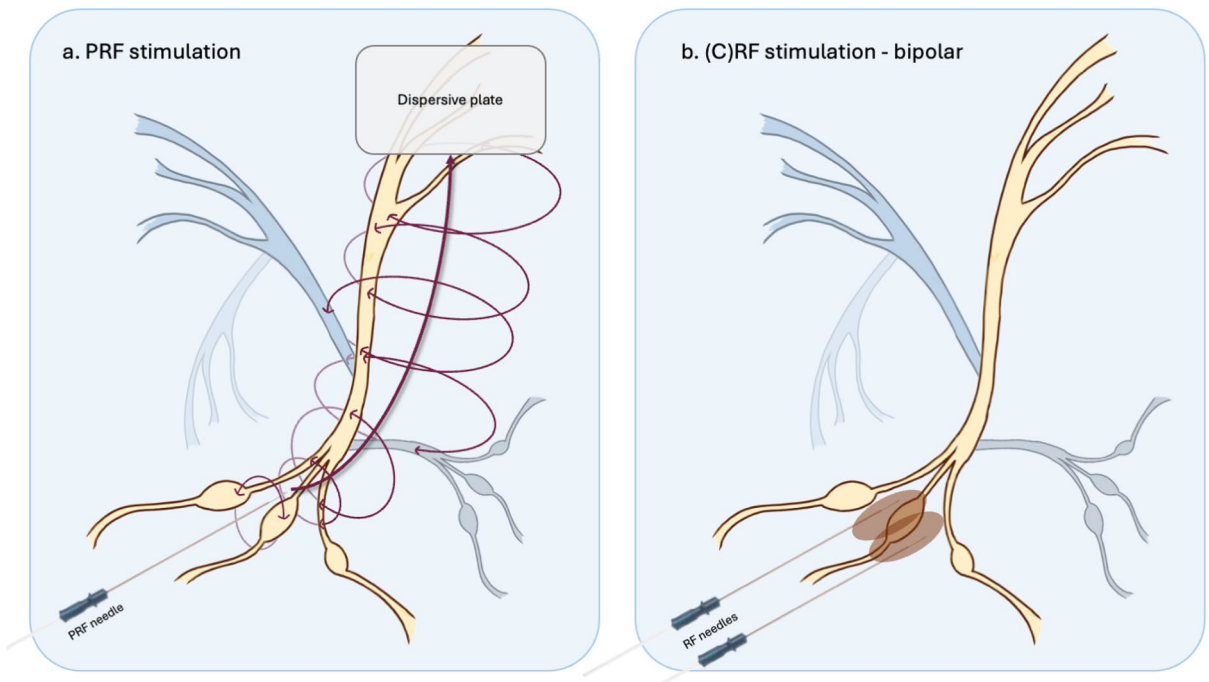

Fig. 1 Schematic representations of radiofrequency energy delivery modes, not based on quantitative experimental modeling: (**a**) pulsed radiofrequency (PRF) in monopolar configuration, illustrating the active cannula tip and the dispersive plate acting as a passive electrode, with the electromagnetic field distributed between them and minimal thermal effect at the target site; (**b**) continuous radiofrequency (CRF) in bipolar configuration, when energy is confined locally between the active electrodes, resulting in focal tissue heating and lesion formation for ablative purposes

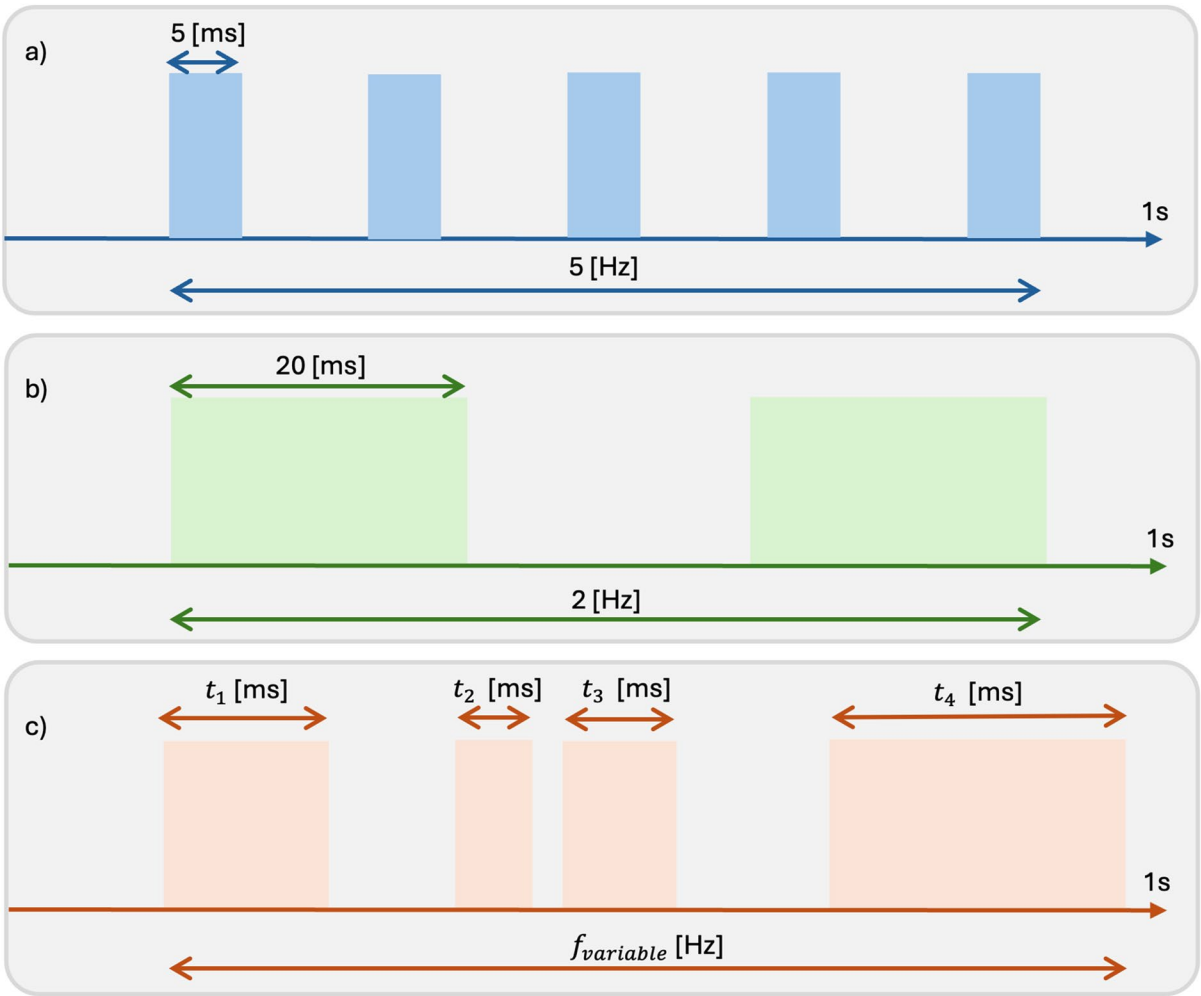

Fig. 2 Schematic comparison of pulse patterns used in PRF stimulation: (**a**) standard PRF waveform with a pulse width of 5 ms at a frequency of 5 Hz; (**b**) standard PRF waveform with a pulse width of 20 ms at a frequency of 2 Hz; (**c**) Sluijter–Teixeira–Poisson (STP) mode, illustrating a stochastic, Poisson-like distribution of pulses. Unlike in standard mode, during STP mode, the pulse duration (t_1, t_2, t_3, t_4) and frequency (f_{variable}) vary through the intervention

The workgroup collective acknowledged that the limited body of literature on STP mode is largely attributable to the methodological challenges inherent in demonstrating the superiority of one PRF modality over another. These challenges include the difficulty of designing adequately powered randomized controlled trials, the need for large and clinically homogeneous cohorts to reach statistical significance, and the intrinsic variability and subjectivity of pain-related outcome measures. In the absence of definitive comparative evidence, the workgroup's recommendation toward STP mode is therefore primarily informed by expert experience and theoretical consideration rather than robust literature evidence, but consistent with the observation of clinical successes across centers and expert consensus.

The consensus also recognizes a nonnegligible technical challenge during PRF procedures: ensuring an optimal spatial relationship among the needle tip, the target, and the dispersive plate. Effective targeting is achieved when the needle tip is positioned in close proximity to the

intended tissue, as confirmed through sensory stimulation testing (50 Hz, <0.5 V). Equivalently, positioning the target between the active tip and the dispersive plate ensures that the generated electric field adequately encompasses the intended (neural) structures. Misalignment or suboptimal placement may result in inadequate field coverage, reducing effects and potentially compromising clinical outcomes.

THE 2025 NICE CONSENSUS—CLINICAL ALGORITHM

The workgroup reached consensus on a pragmatic, diagnosis-driven framework for the application of PRF across a range of spinal and peripheral pain conditions. These recommendations emphasize careful patient selection, structured escalation of interventions, and the integration of PRF as a neuromodulatory strategy within a broader multimodal pain management approach. For ease of interpretation, the main clinical outcomes associated with each algorithm are summarized in Table 2.

Workgroup recommendation—Nice Consensus guideline on central sensitization:

Central sensitization is a clinical phenomenon observed across multiple chronic pain conditions, including post-herpetic neuralgia, fibromyalgia, osteoarthritis, postoperative spinal pain syndrome (PSPS), cancer-related pain, and other persistent pain states. Although its etiology remains incompletely understood, central sensitization is thought to be driven primarily by neuroinflammatory processes involving both the peripheral and central nervous systems, with activation of pro-inflammatory cytokines and chemokines. Owing to its multifactorial nature, diagnosis is challenging and typically requires a multidisciplinary approach integrating clinical assessment, the central sensitization inventory, imaging, and, where available, quantitative sensory testing and functional magnetic resonance imaging (MRI).

Within the consensus framework, central sensitization was identified as a potential contributing mechanism in patients presenting with chronic pain lasting longer than 3 months, diffuse spinal tenderness on physical examination, and the absence of significant structural abnormalities on magnetic resonance imaging. However, the workgroup acknowledges that central sensitization is a complex, multidimensional biopsychosocial phenomenon. In this subgroup, pain is unlikely to be adequately explained by isolated peripheral or structural pathology alone. Accurate diagnosis typically requires the integration of clinical assessment, validated questionnaires, psychological factors, and, where available, quantitative sensory testing. The clinical indicators described in this manuscript should therefore not be used as unique diagnostic criteria but rather as preliminary signals prompting further evaluation.

From an interventional perspective, sacral PRF delivered via the sacral hiatus is proposed as a neuromodulatory strategy aimed at influencing central pain processing; however, the supporting evidence in the literature remains limited, and this application should be considered exploratory. Importantly, the workgroup emphasized that sacral PRF should not be considered as a standalone intervention. In parallel, clinicians should continue to identify and, where possible, address the primary nociceptive driver that may have initiated or is perpetuating the sensitized pain state.

Workgroup recommendation—Nice Consensus guideline on cervical pain:

For cervical pain, the workgroup proposed a stepwise algorithm beginning with thorough clinical examination and magnetic resonance imaging, followed by explicit exclusion of surgical pathology. Once surgical indications have been ruled out, PRF of the cervical medial branches may be considered as the first interventional step, targeting facet-mediated pain mechanisms. In cases of persistent or insufficient pain relief, escalation to PRF of the corresponding dorsal root ganglion (DRG) is advised. This sequential approach reflects the need to progress from peripheral nociceptive modulation to more targeted segmental neuromodulation when initial interventions fail to achieve adequate clinical benefit.

Workgroup recommendation—Nice Consensus guideline on shoulder pain:

In patients with shoulder pain, intra-articular PRF was recommended as the first-line intervention, particularly in the context of degenerative or inflammatory joint-related pain. When intra-articular treatment results in incomplete or suboptimal pain relief, PRF of the suprascapular nerve is advised as a second step. This strategy allows for both intra-articular and extra-articular pain generators to be addressed in a structured manner.

Workgroup recommendation—Nice Consensus guideline on knee pain:

For knee pain, particularly in degenerative conditions, the workgroup endorsed a two-step approach. Initial management consists of intra-articular PRF, with or without the addition of viscosupplementation, depending on the clinical context. If pain persists, PRF of the genicular nerves can be considered, specifically targeting the superior medial, superior lateral, and inferior medial branches. The inferior lateral genicular nerve should generally be avoided owing to its close anatomical relationship with the common fibular nerve, which increases the risk of unintended neural injury. This recommendation underscores the importance of anatomical precision and risk mitigation in interventional pain procedures.

Workgroup recommendation—Nice Consensus guideline on hip pain:

In hip pain, the workgroup suggests a pericapsular nerve group (PENG) block combined with PRF as the preferred interventional strategy. The targeted neural structures include the femoral nerve, obturator nerve, and accessory obturator nerve. This approach reflects the complex innervation of the hip joint and aims to provide comprehensive neuromodulation of both anterior and medial articular branches.

Workgroup recommendation—Nice Consensus guideline on sacroiliac joint pain:

For sacroiliac joint pain, PRF neuromodulation was recommended as the first-line interventional treatment. Adjunctive options include treatment of the L5 medial branch and intra-articular sacroiliac joint injections, which may be used to enhance clinical outcomes. The workgroup agreed that ablative radiofrequency techniques may be considered for refractory cases, after failure of neuromodulatory approaches, because of the more destructive nature of neurotomy.

Workgroup recommendation—Nice Consensus guideline on thoracic pain:

Thoracic pain management should initially focus on PRF of the medial branches and/or intercostal nerves, depending on the suspected pain generator. In patients with persistent symptoms, PRF of the DRG represents a second-line option. Additionally, the erector spinae plane (ESP) block was recognized as a safe and useful adjunctive technique, particularly in complex or multifactorial thoracic pain presentations.

Workgroup recommendation—Nice Consensus guideline on future applications:

Finally, the workgroup identified several emerging applications of PRF, with particular interest in its intraoperative use. The application of PRF during orthopedic procedures, such as joint arthroplasty, may contribute to reduced postoperative pain, facilitate early rehabilitation, and decrease opioid requirements. While these applications remain investigational and supported by limited clinical evidence, they represent a promising extension of PRF to chronic pain management into perioperative and preventive analgesia strategies.

Overall recommendations:

Diagnosis precedes intervention: A thorough and systematic clinical examination remains the cornerstone for effective pain management interventions. The process begins with careful evaluation of the patient's history, symptoms, and physical presentation, ensuring that the underlying pain source is accurately identified. This diagnostic approach is critical, as it guides the selection of appropriate treatment strategies, including procedural interventions such as PRF. By prioritizing comprehensive clinical examination, practitioners are equipped to exclude potential surgical indications, assess systemic factors contributing to pain, and tailor interventional procedures to individual patient needs. Meticulous diagnosis through physical examination is fundamental to ensuring the success of subsequent therapeutic choices. This approach enhances patient outcomes in interventional pain medicine, highlighting the importance of clinical expertise in identifying the underlying pain source. The next step in the

diagnostic workflow involves reviewing imaging studies, including MRI and computed tomography (CT) scans. The complementary information provided by diagnostic imaging supports the physician in excluding surgical indications and offers insight into systemic factors that contribute to the patient's pain experience. During the consensus discussion, the principle of "put your finger before the needle" was emphasized, underscoring the necessity of performing physical examination prior to any interventional procedure.

PRF as first-line intervention over RF neuroablation: PRF can be considered as the first-line interventional treatment for patients experiencing chronic noncancer pain mediated by peripheral nerves. The use of ablative radiofrequency (RF) procedures is considered for cases where pain remains refractory despite prior interventions, for advanced degenerative conditions, or in the presence of oncologic pain syndromes. This stepwise approach ensures that more destructive procedures are only considered when less invasive options have been exhausted. It is particularly important to exercise caution in younger patients, as destructive RF lesions may result in joint instability or long-term neuromuscular dysfunction. By prioritizing PRF, clinicians aim to minimize potential adverse outcomes and preserve joint and neuromuscular integrity, especially in those at greater risk for complications.

A systematic and stepwise approach is proposed for the management of chronic pain, ensuring that each patient receives interventions tailored to their individual clinical presentation. The escalation pathway begins with a thorough diagnosis (step A), which includes careful evaluation to identify any red flags that may suggest underlying serious pathology. Accurate diagnosis is fundamental for selecting appropriate subsequent interventions and for excluding conditions that may require urgent attention.

Once diagnosis is complete, conservative management strategies (step B) are prioritized. These may include physical therapy, pharmacological treatments, and lifestyle modifications, all aimed at addressing pain while minimizing procedural risks. If conservative therapies do not provide sufficient relief, neuromodulatory techniques such as PRF (step C) are considered. PRF offers a nondestructive option for pain modulation, particularly in cases mediated by peripheral nerves. For patients whose pain persists despite neuromodulation, more focused interventions targeting specific peripheral nerves (step D) may be warranted. These approaches are tailored to the patient's unique pain pattern and anatomy. Ablative procedures (step E) are reserved for cases where other interventions have been exhausted or are unsuitable. These techniques are considered when pain is refractory, progressive degenerative changes are present, or in selected oncologic pain syndromes, with careful attention to patient risk profiles and potential adverse outcomes.

DISCUSSION

To date, heterogeneity in the methodological reporting of PRF procedures has continued to limit the comparability of clinical data on PRF efficacy for chronic pain and contributes to inconsistencies in real-world practice across pain centers. The 2024 Leiden Consensus sought to address this issue by prioritizing uniformity and homogeneity in the selection and reporting of PRF parameters, thereby improving the comparability of clinical outcomes and facilitating international collaboration. Building upon this foundation, the 2025 Nice Consensus focused on addressing the critical gap related to clinical decision-making, contributing structured treatment algorithms to support physicians in selecting appropriate PRF applications across diverse pain conditions. The integration of the Leiden 2024 and Nice 2025 guidelines therefore provides a comprehensive framework that combines technical PRF standardization with practical clinical pathways. This dual approach aims to resolve two longstanding limitations in interventional pain medicine: (1) the lack of reproducible procedural parameters and (2) the absence of structured clinical decision-making. Many of the perceived limitations of PRF reflect variability in diagnosis, target selection, and parameter implementation rather than inherent shortcomings of the technique itself,

underscoring the importance of structured clinical algorithms and reproducible technical standards. By emphasizing neuromodulation over neuroablation, the consensus promotes safer and more biologically rational treatment strategies focusing on *functional restoration strategies* for chronic pain. As emerging evidence from future clinical, mechanistic, and multicenter studies becomes available, this consensus will continue to evolve as a living document guiding the responsible and evidence-aligned use of PRF in pain care.

Limitations

It is important to emphasize that the majority of the recommendations presented in this manuscript are based on expert consensus supported by available literature, rather than high-quality comparative evidence. These recommendations should therefore be interpreted as guidance rather than definitive standards.

Given the evolving evidence surrounding PRF, the panel recognizes that these recommendations should be considered a living document, with future updates expected as new clinical evidence, randomized trials, and mechanistic studies further clarify the mode of action of PRF in interventional pain medicine. The current work represents a collaborative effort among experienced researchers, anesthesiologists, orthopedists, and pain specialists, relying on their collective clinical expertise with PRF techniques. The included studies were not evaluated on the basis of the quality of their evidence, as the focus of this work was restricted to methodological reporting. While this rating approach may assist future work by the group in better assessing correlations between parameter selection and clinical outcomes, the present consensus does not provide guidance on patient selection nor account for individual variability across clinical scenarios. Moreover, the consensus is primarily grounded in expert opinion supported by the available literature rather than large, well-designed randomized controlled trials. To strengthen the evidence base and enhance the precision of future recommendations, multicenter studies are needed to validate treatment algorithms, evaluate long-term outcomes, and standardize the reporting of PRF parameters.

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Declarations

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