

Research Article

Minimally Invasive Interventional Therapy in the Standardization and Individualization of Postherpetic Neuralgia Management

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Abstract

Minimally invasive interventional therapy for postherpetic neuralgia (PHN) faces a critical challenge in balancing standardized protocols with individualized patient needs. Current limitations include insufficient evidence-based guidance for optimal technique selection (e.g., pulsed radiofrequency [PRF] parameters, nerve blockade timing, spinal cord stimulation [SCS] modes) and over-reliance on simplified approaches like routine epidural blockade, neglecting potential synergies of multimodal strategies. Significant heterogeneity exists regarding PRF efficacy (high-voltage vs. standard, influenced by comorbidities like diabetes) and the optimal intervention window for nerve blockade (acute vs. subacute phase). While novel SCS modalities (high-frequency, burst, DRG stimulation) offer promise, especially for allodynia, robust validation is lacking. Furthermore, standardized protocols inadequately address individual anatomical variations (e.g., ganglion morphology) and physiological factors (e.g., reduced thermal tolerance in diabetes), compounded by guideline gaps in stage-specific (acute inflammatory vs. chronic remodeling) and parameter-specific recommendations. To reconcile standardization with individualization, a stratified treatment pathway ("pharmacotherapy → minimally invasive interventional techniques → combined therapy") tailored to pain intensity, duration, and comorbidities is proposed: SCS is recommended first-line for severe cases with significant comorbidities or extensive lesions, while PRF combined with epidural blockade may suit others. Integrating machine learning to analyze patient data and procedural parameters for complication risk prediction offers a pathway towards optimized efficacy and safety. Urgent guideline refinements incorporating stratified recommendations, parameter rationales, and individual variability are essential for advancing precise PHN management.

Keywords

Herpes Zoster-associated Pain, Minimally Invasive Interventional Therapy, Postherpetic Neuralgia, Standardization, Personalization

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1. The Conflict Between Lack of Standardization and Need for Personalization

1.1. Absence of Evidence-based Guidelines for Technology Selection

Minimally invasive interventional techniques, such as pulsed radiofrequency (PRF), nerve blockade, and spinal cord stimulation (SCS), constitute a multimodal technical system for PHN treatment. However, the indications and operational parameters for these core technologies lack robust evidence-based medical support, resulting in significant heterogeneity in clinical decision-making.

PRF modulates abnormal neural signaling via pulsed electric fields, yet the selection of stimulation patterns remains controversial. For instance, efficacy differences exist between high-voltage PRF and standard PRF. Evidence indicates [1, 2] that patients treated with high-voltage PRF exhibited significantly lower visual analogue scale (VAS) scores at 12 weeks post-treatment compared to standard PRF recipients. Conversely, other researchers [3] argue that while high-voltage PRF benefits PHN patients with diabetes, its efficacy is inferior in non-diabetic PHN patients. These inconsistencies suggest that treatment strategies require stratification based on nerve injury severity and pain phenotype. The optimal timing for nerve blockade is similarly debated. Some studies support early intervention (within 72 hours) to interrupt neural sensitization cascades and mitigate chronic pain risk. In contrast, other scholars propose that intervention during the subacute phase (2–4 weeks) may prove more effective, as inflammatory responses stabilize, enabling more accurate nerve injury assessment, avoiding overtreatment, and reducing blockade-related complications (e.g., inadvertent vascular puncture or nerve root injury). This perspective contrasts with early intervention strategies focused primarily on chronic pain prevention.

SCS is typically reserved for patients refractory to conservative treatments; however, achieving long-term, stable pain relief in PHN through SCS parameter modulation remains challenging, with no consensus on optimal stimulation modes. A systematic evaluation [4] compared traditional SCS with emerging strategies for PHN, highlighting the potential of high-frequency SCS, burst stimulation, and dorsal root ganglion (DRG) stimulation. While traditional SCS demonstrates efficacy, newer modes may offer superior therapeutic outcomes while avoiding paraesthesia commonly associated with conventional SCS. These approaches may be particularly suitable for PHN patients experiencing allodynia. Nevertheless, despite promising preliminary safety and efficacy data, large-scale randomized controlled trials are warranted to confirm the clinical applicability of these novel technologies.

1.2. Over-reliance on Uniform and Simplified Surgical Techniques

Clinical practice reveals significant "therapeutic inertia" in PHN interventions, leading to undertreatment of complex cases and overtreatment of simple ones. This reflects limitations in standardized pathways for addressing individualized patient needs [5, 6].

In most institutions, epidural drug infusion remains the routine minimally invasive intervention for PHN [7]. The potential synergistic benefits of combined therapies, such as PRF combined with intrathecal drug delivery, are often overlooked in complex PHN management. This oversimplified approach fails to meet the diverse needs of patient populations. Multimodal techniques may achieve superior outcomes through synergistic mechanisms. Studies demonstrate that combined epidural blockade and nerve blockade regimens significantly outperform epidural blockade alone in relieving pain, improving sleep quality, and enhancing overall quality of life in PHN patients.

However, combined therapy application is constrained by concerns regarding technical complexity and safety. Consequently, many institutions and physicians default to familiar, relatively simple epidural blockade techniques, potentially depriving patients of optimal therapeutic benefits [8, 9]. Although epidural blockade provides effective analgesia, its effects are often transient, with a high recurrence rate. For patients with severe or protracted pain, single-modality blockade may be inadequate. In such cases, combined therapies hold promise for enhancing efficacy and improving patient satisfaction.

2. Controversial Issues and the Clinical Significance of Individualized Treatment

2.1. Insufficiency and Lag of Evidence-based Clinical Guidelines

Currently, while minimally invasive interventions for PHN feature in multiple clinical guidelines, standardization of specific technical pathways remains inadequate. For example, the "Expert Consensus on Comprehensive Management of Herpes Zoster-Related Pain (2021 Edition)" [10] broadly recommends considering "minimally invasive interventions when standardized pharmacotherapy fails to provide adequate analgesia," yet it omits specifics on technique selection, procedural parameters, or stage-based intervention strategies. Consequently, clinical practice relies heavily on physician experience, resulting in significant variability in treatment efficacy and safety.

Notably, PHN progression exhibits distinct phase-specific characteristics: the acute phase (<1 month) is predominantly inflammation-driven, while the chronic phase (>3 months)

features maladaptive neural remodeling. However, existing guidelines lack stratified interventional recommendations aligned with these stages. For instance, acute-phase interventions should primarily target anti-inflammatory and analgesic effects, such as local glucocorticoid injection or PRF. Conversely, chronic-phase management should emphasize neural function restoration, including SCS or intrathecal drug delivery. Furthermore, technical parameters remain poorly defined. PRF energy settings (e.g., temperature, duration) lack clear biophysical justification, contributing to significant outcome variability.

2.2. The Challenge of Reconciling Personalized Treatment with Standardized Protocols

Individual anatomical variations pose significant challenges to standardized protocols. Human ganglion anatomy exhibits considerable inter-individual variability; some patients present with positional deviations or irregular morphology. Standardized puncture templates, typically based on normative anatomy, prove difficult to apply effectively in these patients, potentially increasing puncture failure rates.

Personalized imaging-guided technologies, such as 3D ultrasound combined with CT navigation, enable precise ganglion localization and real-time puncture guidance, improving procedural success. However, many primary institutions rely on conventional techniques and lack the capability to adapt precisely to anatomical variations. Consequently, technical limitations preclude effective treatment for certain patients.

Additionally, patients exhibit marked variability in tolerating treatment-related complications. Diabetic patients, for example, generally demonstrate reduced tolerance to thermal ablation compared to non-diabetic individuals. During thermal ablation procedures, diabetics are more susceptible to nerve injury from excessive heat accumulation, potentially leading to sensory deficits and motor dysfunction. Nevertheless, current expert consensus guidelines inadequately incorporate individual factors such as metabolic status. Consequently, clinicians lack specific, actionable guidance for special populations, hindering the optimal balance between effective analgesia and complication avoidance. This exacerbates the conflict between individualized needs and standardized pathways, limiting the efficacy and safety of interventions in special populations.

3. Strategies for Resolution and Authors' Perspectives

We propose establishing a three-tiered treatment pathway: "pharmacotherapy → minimally invasive intervention → combined therapy", with stratified recommendations based on pain intensity, disease duration, and comorbidities.

1) For patients with severe pain, advanced age (>60 years),

significant comorbidities (e.g., diabetes, cardiovascular/cerebrovascular disease, renal insufficiency, malignancy), or extensive skin lesions, neuromodulation techniques—particularly SCS—are recommended as first-line therapy.

2) For other patients, PRF combined with epidural blockade may be preferred.

Based on clinical experience:

1) For mild acute-phase PHN pain, epidural blockade combined with local corticosteroid or bupivacaine infusion within 72 hours effectively reduces neural sensitization and alleviates pain.

2) For severe acute-phase pain, PRF or short-term SCS can be considered; short-term SCS demonstrates superior analgesic efficacy and safety compared to PRF.

3) During subacute and chronic phases, SCS or radiofrequency ablation may be continued; however, SCS provides more durable and stable analgesia and should be prioritized.

Furthermore, integrating machine learning to analyze patient baseline data (age, comorbidities), procedural parameters (energy, duration), and imaging characteristics could facilitate complication risk scoring models. Utilizing artificial intelligence to process large-scale clinical datasets enables more accurate complication risk prediction, providing clinicians with critical decision-support tools for proactive preventive measures, thereby reducing complication incidence and enhancing treatment safety and reliability.

4. Conclusion

The field of minimally invasive intervention for PHN urgently requires guideline updates and refinements. This includes developing stratified, stage-specific technical recommendations, clarifying parameter-setting rationales, and fully accounting for individual anatomical and physiological variations. Achieving seamless integration of standardization and individualization will optimize treatment efficacy, improve patient outcomes, and advance the field towards more precise, efficient, and safe therapeutic approaches.

Abbreviations

PHN	Postherpetic Neuralgia
PRF	Pulsed Radiofrequency
SCS	Spinal Cord Stimulation
VAS	Visual Analogue Scale
DRG	Dorsal Root Ganglion

Author Contributions

Yifan Jia is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declare no financial or personal relationships with any individuals or organizations that could inappropriately influence or bias the content of this work.

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Biography

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Research Field

Yifan Jia: Mechanisms of neuropathic pain and neural functional rehabilitation; Neuromodulation therapy.