Retrospective Study

A Retrospective Study on the Therapeutic Effect of Low-Temperature Plasma Ablation for Postherpetic Neuralgia with Different Disease Durations

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Background: Postherpetic neuralgia (PHN) is a challenging and persistent neuropathic pain condition that is often unresponsive to standard pharmacological treatments. Minimally invasive interventional therapies for PHN have been increasingly adopted in clinical practice. In recent years, low-temperature plasma ablation (LTPA) has demonstrated potential advantages and promising applications for managing chronic neuropathic pain. However, few studies have explored the use of LTPA in treating PHN.

Objectives: To evaluate the effectiveness and safety of LTPA in treating PHN, with a focus on differences in outcomes among patients with varying durations of the disease.

Study Design: Retrospective cohort study.

Setting: Department of Pain Management, Xuanwu Hospital, Capital Medical University.

Methods: A retrospective analysis was conducted on 109 PHN patients treated with LTPA in our department from January 2023 to March 2024. Patients were categorized into 2 groups based on the duration of their disease: Group A (disease duration < 3 months) and Group B (disease duration ≥ 3 months). Pre-treatment pain levels were assessed using a Numeric Rating Scale (NRS), as were pain levels at one month and 3 months after treatment. Sleep quality was measured using the Medical Outcomes Study Sleep Scale (MOS-SS). Treatment efficacy was evaluated by comparing pre- and post-treatment data, with a reduction of at least 50% in NRS scores at 3 months after treatment considered the criterion for treatment success. The effective rates between the 2 groups were compared. Adverse events were recorded to assess the safety of the procedure.

Results: At all follow-up time points, NRS scores in both groups were significantly lower than pre-treatment scores ($P < 0.05$). At one and 3 months after treatment, Group A had significantly lower NRS scores (2.85 ± 1.89 and 2.74 ± 2.08) than did Group B (3.77 ± 1.91 and 3.71 ± 2.03, respectively; $P < 0.05$). The treatment success rate at 3 months after the treatment was significantly higher in Group A (78.72%) than in Group B (59.68%; $P < 0.05$). Both groups showed significant improvements from the pre-treatment MOS-SS sleep scores (in sleep disturbance [SLPD], sleep adequacy [SLPA], sleep quality [SLPQ], and comprehensive sleep disorder index [9-items]) at the one-month and 3-month follow-up points ($P < 0.05$), with no significant differences between the 2 groups at any time point after treatment. No severe adverse events were reported in either group during treatment or follow-up.

Limitations: The single-center setting, relatively small number of patients, short duration of the review of medical records, and retrospective nature of the study.

Conclusions: LTPA offers effective and sustained pain relief and sleep quality improvements for PHN patients and has a favorable safety profile.

Key words: Postherpetic neuralgia, minimally invasive interventional therapy, low-temperature plasma ablation

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Herpes zoster (HZ) is a disease caused by the varicella zoster virus (VZV). After an initial infection, the virus invades the spinal or cranial nerve sensory ganglia along sensory nerves and remains latent. When the immune system is compromised, the latent virus reactivates, replicates extensively, and spreads along sensory nerve fibers to the dermatomes it innervates, resulting in zoster-associated pain (ZAP). HZ represents a significant global health burden, with an incidence rate of 3-5‰, which increases sharply in individuals over 50 years old (1,2).

Postherpetic neuralgia (PHN) is the most common complication of HZ and is defined as pain lasting for ≥ one month after the resolution of HZ-caused skin lesions. PHN typically manifests as severe intermittent or persistent burning, stabbing, or needle-like pain that can persist for years or even a lifetime. This condition often leads to anxiety, depression, and significantly impaired sleep quality, profoundly affecting patients' quality of life (3,4). A cross-sectional study conducted across 24 hospitals in 7 cities in China reported prevalence rates of 7.7% (95% CI: 7.5-8.0) for HZ and 2.3% (95% CI: 2.2-2.5) for PHN, with 29.8% of HZ patients developing PHN (5). Advanced age is the most significant risk factor for the progression from HZ to PHN, with approximately 65% of HZ patients aged 60 years and above developing PHN. This rate increases to 75% for those at least 70 years of age. Other notable risk factors include severe acute-phase pain and extensive skin lesions (6,7).

The treatment of PHN remains a clinical challenge. Current management strategies rely primarily on oral medications, including gabapentin, pregabalin, tricyclic antidepressants, tramadol, and opioids. However, many PHN patients experience insufficient pain relief and often encounter drug-related side effects. For patients who do not achieve satisfactory results with pharmacological treatments, minimally invasive interventional therapies are an alternative (8-10).

Pulsed radiofrequency (PRF) is one such minimally invasive technique that has gained traction for the treatment of chronic pain. PRF uses intermittent electrical currents generated by radiofrequency electrodes to modulate neuronal activity, alter neuronal excitability, and influence synaptic transmission and neurotransmitter release, thereby alleviating pain (11,12). PRF has shown increasing clinical utility and recognition for managing various chronic pain conditions (13-16), including PHN, for which it has demonstrated efficacy in pain relief, durability, and quality-of-life improvement (17-20). However, as a relatively new modality, minimally invasive interventional technologies like PRF are still in the exploratory phase. Challenges such as unsatisfactory outcomes and high recurrence rates persist. For instance, Luo et al reported recurrence rates of 37.31% within 3 months and 44.78% overall in a cohort of 67 PHN patients treated with PRF (21). Heavner et al found that protein denaturation during PRF occurs only when the temperature reaches 60°C (22). These findings highlight the need for a more effective alternative in minimally invasive treatments for HZ-associated pain.

Low-temperature plasma ablation (LTPA) is a novel electrosurgical technique that has gained popularity recently. By generating a thin plasma field at relatively low temperatures, LTPA disrupts molecular bonds, facilitating tissue cutting or ablation (23,24). LTPA has been applied successfully to treat various chronic pain conditions, including discogenic pain, cervicogenic headaches, trigeminal neuralgia, and cluster headaches, with notable analgesic effects (25-28). Studies suggest that LTPA can reduce PHN-related pain significantly, improve patients' quality of life, and maintain a high safety profile (29).

Despite these promising findings, research on the use of LTPA for PHN patients remains limited, particularly regarding its efficacy across different disease durations. To address this gap, we conducted a retrospective study to evaluate the effectiveness of LTPA in PHN treatment and to compare the outcomes of this procedure among patients with varying disease courses. Our aim is to provide more robust evidence to guide future clinical practice.

Methods

Study Design

This retrospective study was approved by the Institutional Review Board of Xuanwu Hospital, Capital Medical University (Clinical Research and Examination [2024] No. 164-002). Data were collected through historical medical records, medical reports, and telephone follow-ups to analyze the effectiveness and safety of this procedure.

Patients

We retrospectively analyzed PHN patients treated with LTPA in the Department of Pain Management, Xuanwu Hospital, Capital Medical University, between January 2023 and March 2024. Patients were catego-

rized into 2 groups based on disease duration: Group A (disease duration < 3 months) and Group B (disease duration ≥ 3 months).

Inclusion Criteria:

- Diagnosed with PHN and treated with LTPA.
- Numeric Rating Scale (NRS) score ≥ 5.
- Age ≥ 18 years.
- Poor response to traditional drug therapies.

Exclusion Criteria:

- Presence of comorbidities that could affect efficacy evaluation, such as severe cardiovascular or cerebrovascular diseases or mental illnesses.
- An unwillingness to complete follow-ups.

LTPA Treatment Procedure

The surgical procedure was performed in a sterile operating room. Each patient was placed in the lateral position, with the affected side on top. The affected nerve segment was identified based on the skin lesion area and pain distribution, roughly located using bony surface landmarks, and confirmed with C-arm fluoroscopy. After localization, ultrasound guidance was used for puncture. Bone structures, muscles, fasciae, blood vessels, nerves, and nearby organs were identified to determine the safest puncture path. For example, during thoracic nerve root treatment, the transverse process and ribs of the corresponding segment were located using ultrasound. Moving the probe downward revealed the lamina, pleura, and thoracic paravertebral safety triangle (Fig. 1).

A specialized puncture cannula needle (Metal, Sotid, Integrated, 16G, 80 mm, Innosys Co., Ltd.; Uijeongbu, Gyeonggi-do, Korea) was inserted under ultrasound guidance after local anesthesia with 0.5% lidocaine, ensuring the needle was parallel to the pleura to avoid damage (Fig. 2). The needle tip's position in the upper third of the intervertebral foramen, near the target nerve root, was verified using C-arm fluoroscopy. After confirming that no blood, gas, or cerebrospinal fluid appeared upon aspiration, a plasma ablation wand (Innosys Co., Ltd) was inserted, and its position was rechecked (Fig. 3).

When treating postherpetic neuralgia in the cervical segment, we performed LTPA therapy only on the C2 and C3 nerve roots. Under ultrasound, the C2 nerve root needs to be located first by searching for the obliques capitis inferior muscle, which is like a "small boat." Deep within it, the vertebral artery and the C2

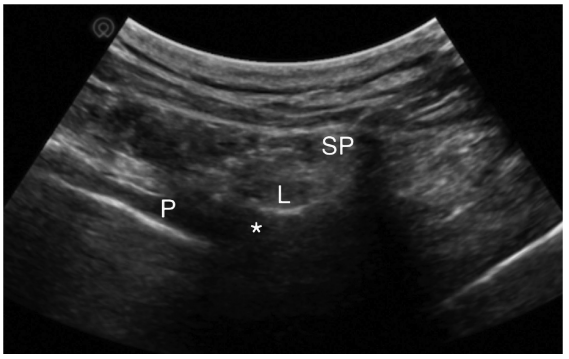

Fig. 1. *Axial ultrasound image of the target nerve root.*
SP: spinous process; P: pleura; L: lamina; *: location of thoracic nerve root

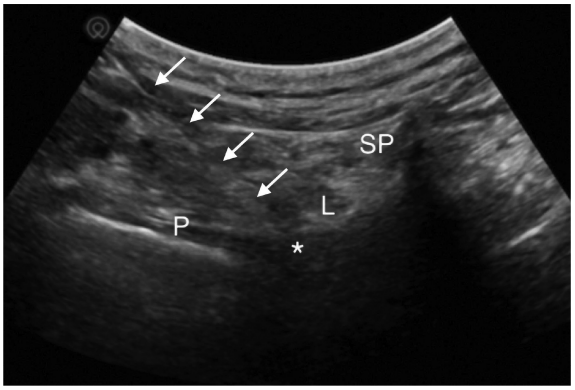

Fig. 2. *Ultrasound image showing the puncture needle reaching the target nerve.*
SP: spinous process; P: pleura; L: lamina; *: location of thoracic nerve root; white arrow: puncture needle

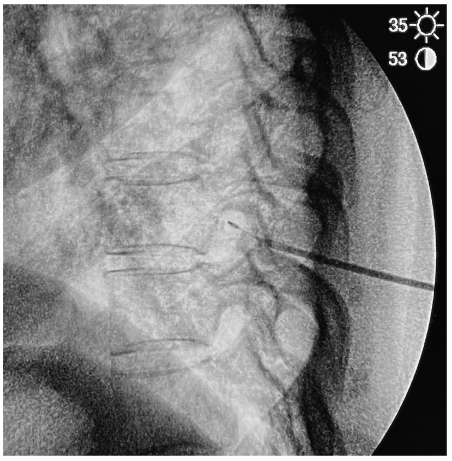

Fig. 3. *Lateral fluoroscopy image after the plasma cutter head is inserted.*

nerve root can be observed to be located on each side of the atlantoaxial joint, and near the C2 nerve root, the spinal cord can be observed (Fig. 4).

The aforementioned ablation wand had a flexible tip, allowing directional adjustments and rotation without altering the puncture needle's position. This approach minimized tissue damage and patient discomfort from repeated punctures (Fig. 5).

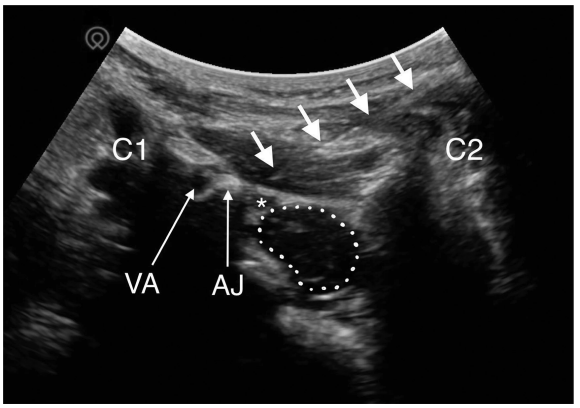

Fig. 4. *Ultrasound image showing the puncture needle reaching the target nerve (C2).*
C1: C1 ransverse process; C2: C2 spinous process; VA: vertebral artery; AJ: atlantoaxial joint; *:nerve root; dashed area: spinal cord; white arrow: puncture needle

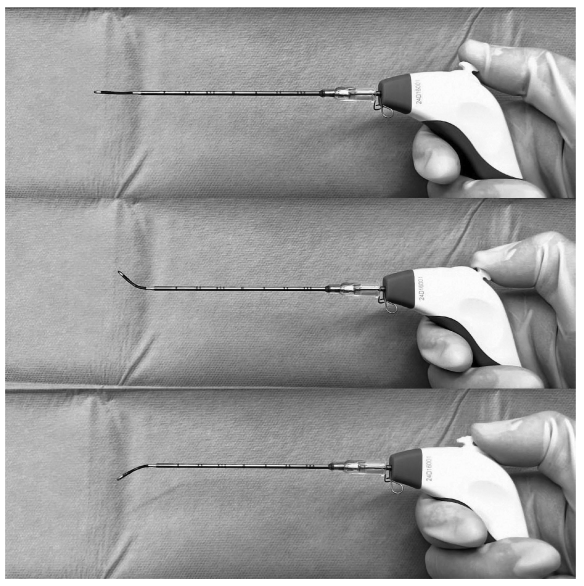

Fig. 5. *Adjustable plasma cutter head with directional flexibility.*

With a 0.5-second stimulation on coag mode one, the placement of the wand was tested. Induced sensations of pain, heat, or abnormality in the original pain area confirmed proximity to the nerve, and ablation was initiated. If the test was unsatisfactory, the needle position was adjusted until an appropriate response was achieved. The ablation was conducted in 3 steps using ablation mode: first gear for 30 seconds, second gear for 30 seconds, and third gear for 30 seconds. For patients who exhibited strong reactions to the stimulation, 3 mL of 0.5% lidocaine was administered at the nerve root for analgesia.

Data Collection

Basic patient information, including age, gender, pain location, nature and severity of pain, and sleep status, was collected upon admission. Patients' pain (evaluated on the NRS) and sleep status (evaluated on the Medical Outcomes Study Sleep Scale [MOS-SS]) were reassessed at preoperative baseline and at one and 3 months after treatment. Pain severity was evaluated using the NRS, which rates pain from 0 (no pain) to 10 (severe pain), with one-3 indicating mild pain, 4-7 moderate pain, and 8-10 severe pain. Sleep status was assessed using the MOS-SS across 4 dimensions: sleep disturbance (SLPD), sleep adequacy (SLPA), sleep quantity (SLPQ), and the comprehensive sleep disorder index (9-items).

Treatment efficacy was compared between the groups at 3 months, with a ≥ 50% reduction in baseline pain scores considered clinically effective (30). Adverse reactions and complications, such as infections, pneumothorax, and skin numbness, were recorded during and after treatment.

Statistical Analysis

Data were analyzed using SPSS 19.0. Measurement data were expressed as mean ± SD ($\bar{x} \pm s$), and differences between groups were compared using the independent sample t-test. Trends across time points within groups were analyzed using repeated measures ANOVA. Count data were presented as cases or percentages (%) and compared using the chi-square test. Statistical significance was set at $P < 0.05$.

Results

General Information

Based on the inclusion and exclusion criteria, 138 patients were initially included in the study, compris-

ing 64 patients with a disease duration of fewer than 3 months and 74 patients with a disease duration exceeding 3 months. Of those patients, 29 missed follow-up data. One hundred nine patients were followed up successfully. Group A included 47 patients with a disease duration of fewer than 3 months, and Group B included 62 patients with a disease duration of more than 3 months.

The distribution of nerve involvement was as follows: cervical segment in 18 cases and thoracic segment in 91 cases. Disease durations ranged from one month to 10 years. Patient characteristics and demographics, including age, gender, involved nerve segment, NRS score, and MOS-SS scores, were recorded. No significant differences in those variables were observed between the 2 groups (Table 1). Table 2 presents affected nerve segments in both patient groups.

Table 1. *Patients' demographics, pain characteristics, and comparison of variables.*

Feature	Group A (n = 47)	Group B (n = 62)	*P* value
Age (years, mean ± SD)	67.09 ± 8.82	69.11 ± 9.23	0.25
Gender (male, %)	23 (48.94)	26 (41.94)	0.467
Segment (thoracic, %)	39 (82.98)	51 (82.26)	0.922
NRS (mean ± SD)	7.28 ± 0.93	7.18 ± 1.17	0.622
SLPD (mean ± SD)	62.53 ± 10.24	64.02 ± 11.22	0.477
SLPA (mean ± SD)	35.43 ± 11.30	32.02 ± 13.48	0.164
SLPQ (mean ± SD)	5.09 ± 0.95	5.00 ± 1.19	0.688
9-items (mean ± SD)	58.33 ± 7.40	59.19 ± 7.78	0.561

Table 2. *Affected nerve segments in the 2 patient groups.*

Segment	Group A (n = 47)	Group B (n = 62)
C2	6	6
C3	2	5
T1	1	3
T2	5	2
T3	4	7
T4	6	9
T5	5	9
T6	1	5
T7	3	5
T8	4	1
T9	3	3
T10	3	5
T11	4	2
T12	0	0

Efficacy Evaluation

Pain Level

At one month and 3 months after operation, the NRS scores of both groups were significantly lower than their pre-treatment scores ($P < 0.05$). Moreover, the reduction in NRS scores was more pronounced in Group A than in Group B at all follow-up time points ($P < 0.05$) (Fig. 6).

Treatment Success Rate

Three months after treatment, 74 patients (67.89%) across both groups achieved a ≥ 50% reduction in NRS scores, including 37 patients (78.72%) in Group A and 37 patients (59.68%) in Group B. The success rate in Group A was significantly higher than in Group B ($P < 0.05$) (Table 3).

Sleep Quality

At both post-treatment time points, both groups showed significant improvements in the MOS-SS scores for SLPD, SLPA, SLPQ, and 9-items from the pre-treatment scores ($p < 0.05$). However, no significant differences were observed between the groups at any time point after treatment (Table 4).

Adverse Events

No serious complications occurred during treatment. Transient pain stimulation during the procedure led to temporary increases in blood pressure and heart rate, which were managed effectively with symptomatic treatment.

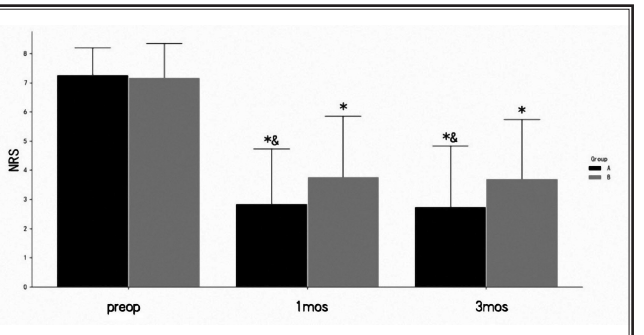

Fig. 6. *Comparison of numerical rating scale (NRS) results before treatment and at 2 follow-up time points (mean ± SD).*
NRS: Numerical Rating Scale; Prep: before treatment; mos: months.
*$P < 0.05$: comparison of each follow-up time point with baseline.
&$P < 0.05$: comparison between Group A and Group B.

Similarly, no serious post-treatment complications, such as infection, pneumothorax, or damage to critical tissues, were reported. A total of 27 patients (24.77%) reported numbness in the nerve innervation area one month after treatment, with 13 patients (11.93%) experiencing discomfort due to numbness. At 3 months after treatment, 20 patients (18.35%) still reported numbness, and 9 patients (8.26%) experienced mild discomfort; however, these outcomes did not affect sleep or quality of life (Table 5).

Discussion

Among HZ patients, nearly 30% develop PHN, enduring severe and persistent pain often accompanied by anxiety, depression, and sleep disturbances. These symptoms profoundly impact patients' quality of life and impose a significant societal burden (31,32). The complex pathogenesis of PHN—encompassing peripheral and central sensitization, inflammatory responses, and deafferentation mechanisms (33)—has made the treatment of the condition a persistent medical challenge. Oral and topical medications form the cornerstone of PHN management. Treatments include topical lidocaine and capsaicin, as well as systemic drugs such as anticonvulsants (e.g., gabapentin, pregabalin), tricyclic antidepressants (e.g., amitriptyline, nortriptyline, desipramine), and opioids (e.g., tramadol, morphine, oxycodone) (34). However, many patients, particularly the elderly, experience limited efficacy, dependency, and significant side effects from these treatments (35). For PHN cases refractory to conservative therapy, minimally invasive interventional treatments are commonly employed in addition to pharmacotherapy. These techniques include nerve blocks, neuromodulation, and neurodestructive methods (19,36,37). Despite the utility of these modalities, each one has limitations, underscoring the challenges in treating PHN.

Current research highlights PRF as a promising approach for PHN treatment, offering the advantage of preserving nerve function. However, PRF is limited by inconsistent efficacy, a lack of durable results, and high recurrence rates (22). The effectiveness of the treatment may also decline in patients with a longer disease duration. A 2017 retrospective study by Kim et al reported that the efficacy rate for PRF was 82.7% in patients with a disease course of < 3 months but that only 17.2% of patients with a disease course > 3 months achieved > 50% pain relief (38).

Radiofrequency thermocoagulation (RFT), which employs higher temperatures to destroy nerve tissue and block pain transmission, has demonstrated superior efficacy to and longer-lasting effects than PRF when used to treat PHN (39). However, RFT is associated with unavoidable complications, such as long-term numbness and abdominal distension in the innervated area (40,41). These findings emphasize the need for interventional techniques that balance pain relief efficacy with minimized side effects.

In this study, 109 patients with PHN refractory to basic drug therapy were treated with LTPA. Both groups demonstrated significant pain reduction and improvements in sleep quality after LTPA. Three months after treatment, 67.89% of the patients achieved at least a 50% reduction in pain, confirming LTPA's effectiveness in reducing PHN-related pain without a gradual decline

Table 3. *Comparison of treatment success rates between groups 3 months after treatment (%), based on results of chi-square (χ^2) analysis.*

Outcome	Group A (%)	Group B (%)	Total (%)	χ^2	*P* value
Ineffective	10 (21.28%)	25 (40.32%)	35 (32.11%)	4.449	0.035*
Effective	37 (78.72%)	37 (59.68%)	74 (67.89%)		
Total	47	62	109		

* $P < 0.05$

Table 4. *Comparison of MOS-SS scores before and after treatment (mean ± SD).*

Group	Sample Size	Time	SLPD	SLPA	SLPQ	9-items
A	47	Before	62.53 ± 10.24	35.43 ± 11.30	5.09 ± 0.55	58.33 ± 7.40
	47	One month	44.86 ± 12.49*	49.14 ± 12.75*	6.18 ± 1.03*	44.06 ± 9.89*
	47	3 months	45.12 ± 12.49*	51.10 ± 14.08*	6.10 ± 1.08*	44.55 ± 8.32*
B	62	Before	64.02 ± 11.22	32.02 ± 13.48	5.00 ± 1.19	59.19 ± 7.78
	62	One month	45.98 ± 13.19*	47.58 ± 15.12*	6.18 ± 1.03*	48.40 ± 11.49*
	62	3 months	48.66 ± 15.17*	47.85 ± 15.12*	6.03 ± 1.17*	47.62 ± 11.95*

SLPD: sleep disturbance; SLPA: sleep adequacy; SLPQ: sleep quantity; 9-items: comprehensive sleep disturbance index.
*$P < 0.05$: comparison of post-treatment time points with baseline.

in efficacy. Furthermore, no serious complications, such as infection, bleeding, pneumothorax, or spinal cord injury, were observed. While 13 patients (11.93%) reported mild numbness in the nerve innervation area at one month after treatment, this figure reduced to 9 cases (8.26%) at 3 months, with no impact on patients' quality of life. These results underscore LTPA's efficacy and safety in treating PHN.

LTPA employs bipolar radiofrequency to generate a 0.2 mm plasma field, which vaporizes and ablates target tissues at 40-70°C. This technique enables precise nerve ablation at lower temperatures, effectively blocking pain transmission while minimizing thermal damage to nerves (23,42,43). Due to its minimally invasive, safe, and effective nature, LTPA has been used successfully to treat various chronic pain conditions, including cervicogenic headaches, trigeminal neuralgia, cervical disc herniation, phantom limb pain, and cluster headaches (26-28,44-46). LTPA demonstrates advantages in the minimally invasive management of chronic pain and has promising clinical applications. Yang et al reported that 80% of patients with thoracic neuralgia, including PHN, achieved > 50% pain relief after LTPA, with sustained benefits observed 6 months after treatment, while mild numbness in the nerve innervation area was the only adverse reaction noted (47). Similarly, Luo et al followed up with 77 thoracic PHN patients treated with LTPA and reported that > 70% achieved at least 50% pain relief and significant quality-of-life improvements at one, 3, and 6 months after treatment, with no severe adverse events (48). Recent studies further demonstrate LTPA's ability to reduce thoracic PHN-related pain and medication dependency, with an impressive treatment efficacy rate of 76.27% at 24 months after treatment (49). To our knowledge, this outcome is the longest-lasting effect of LTPA in the treatment of PHN reported to date. These findings highlight LTPA's long-lasting effects, setting this form of therapy apart as a superior treatment modality for PHN.

Our study further revealed the association between treatment efficacy and disease duration. The effective rates of LTPA in Group A (disease duration < 3 months) and Group B (disease duration ≥ 3 months) were 78.2% and 59.68%, respectively, showing significant differences. This finding indicates a close relationship between the effectiveness of PHN treatment and the duration of the disease. A review of medical records revealed that among the 62 patients in Group B, 51.6% had a disease duration exceeding one year, 25.81% had a duration exceeding 2 years, and the longest duration was up to 10 years. The pathogenesis of PHN involves both the central and peripheral nervous systems and may include central nervous system remodeling (50-52). For patients with longer disease durations, VZV may invade the dorsal root ganglia and spinal cord levels. When the central nervous system is involved, the efficacy of treatments that target peripheral nerves may decrease. However, in this study, the effective rate for patients with a disease duration ≥ 3 months was close to 60%, which is still a satisfactory result. This finding demonstrates that LTPA is also an effective treatment option for PHN patients with longer disease durations, suggesting that future research should focus more on treatment strategies and their outcomes across different disease stages. We should balance effectiveness and side effects, weigh the pros and cons, and explore optimal treatment plans for PHN patients while emphasizing the necessity of early intervention.

Table 5. *Number of patients reporting numbness and discomfort in the nerve innervation area after treatment.*

Follow-Up Time	Group A	Group B	Total
One month	6 (12.77%)	7 (11.29%)	13 (11.93%)
3 months	4 (8.51%)	5 (8.06%)	9 (8.26%)

This study has several limitations. Because of the study's nature as a retrospective analysis based on historical medical records, information bias may be present. The relatively small sample size limits the generalizability and statistical power of the findings, and the follow-up period is relatively short. Future studies should employ multicenter, prospective, randomized controlled trials with larger sample sizes and longer follow-up periods to validate LTPA's efficacy and safety.

Conclusion

In conclusion, LTPA is a safe and effective treatment for PHN, applicable to patients with various disease durations. LTPA provides long-lasting pain relief and improves sleep quality, making the procedure a valuable addition to the therapeutic options for PHN.

Supplemental material is available at www.painphysicianjournal.com

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