Retrospective Study

High-voltage, Long-duration Pulsed Radiofrequency to the Dorsal Root Ganglion Provides Improved Pain Relief for Herpes Zoster Neuralgia in the Subacute Stage

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Background: Postherpetic neuralgia (PHN) is pain persisting beyond 3 months from rash onset and is the most common complication of herpes zoster (HZ); it is commonly refractory to medication treatment. Available evidence indicates that high-voltage, long-duration pulsed radiofrequency (PRF) to the dorsal root ganglion (DRG) is a novel and effective treatment for this complication. Nevertheless, the effects of this intervention on refractory HZ neuralgia less than 3 months have not been evaluated.

Objective: The objective of this study was to assess the therapeutic efficacy and safety of high-voltage, long-duration PRF to the DRG for patients with subacute HZ neuralgia compared with that of patients with PHN.

Study Design: A retrospective comparative research.

Setting: Hospital department in China.

Methods: Sixty-four patients with HZ neuralgia in different stages receiving high-voltage, long-duration PRF to the DRG were included. According to the days from zoster onset to PRF implementation, they were divided into the subacute (one to 3 months) or PHN group (more than 3 months). The therapeutic effect was evaluated by pain relief using the Numeric Rating Scale at one day, one week, one month, 3 months, and 6 months post-PRF. The five-point Likert scale measured patient satisfaction. Post-PRF side effects were also recorded to determine the safety of the intervention.

Results: The intervention significantly reduced pain in all patients, but pain relief at one month, 3 months, and 6 months post-PRF was better in the subacute group than in the PHN group. Furthermore, the success rate of PRF was significantly increased in the subacute group compared with the PHN group (81.3% vs 56.3%, $P = 0.031$). There was no significant difference in patient satisfaction at 6 months between groups.

Limitations: This is a single-center retrospective study with a small sample size.

Conclusions: High-voltage, long-duration PRF to the DRG is effective and safe for HZ neuralgia in different stages, and can provide an improved pain relief for HZ neuralgia in the subacute stage.

Key words: Pulsed radiofrequency, dorsal root ganglion, subacute herpes zoster neuralgia, postherpetic neuralgia

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Herpes zoster (HZ), commonly known as shingles, results from reactivation of the dormant varicella zoster virus and is typically characterized by painful dermatomal vesicular rash (1-3).

Postherpetic neuralgia (PHN) is the most common complication of HZ. It is generally defined as pain that persists beyond 3 months from the onset of eruption of the herpes zoster rash (4,5). PHN incidence varies from 5% to more than 30% (6), and increases with age

(4,7). The available evidence indicates that PHN occurs in more than 50% of patients with HZ who are more than 60 years old (8). As an intractable pain disease, PHN can affect a patient's mood and quality of life, probably leading to insomnia, anxiety, depression, and other complications (9-14).

It is generally believed that PHN is commonly refractory to pharmacological therapies, including topical lidocaine, antiepileptics, antidepressants, analgesics, and others (15). Interventional treatments, such as nerve root block, paravertebral injection, epidural nerve block, and stimulating electrodes implantation, have been used for treating PHN in clinical practice, but they have various drawbacks, including partial pain relief, serious side effects, a long treatment time, and high costs (16,17). Pulsed radiofrequency (PRF), which is generated by short bursts of high-frequency current, is a novel and minimally invasive therapeutic method for treating PHN (18). PRF has been shown as an effective and safe method of pain relief for patients with PHN (18), but its therapeutic strategies are not uniform in clinical practice, including single target PRF (19), multiple targets PRF (20), ganglion PRF (21), peripheral nerve PRF (22), low output voltage PRF (23), high output voltage PRF (24), and different-duration PRF (25).

As the dermatome originally affected by HZ and the adjacent dermatomes are commonly involved, PHN may influence more than one dermatome (26-28). Furthermore, intervention of one segmental dorsal root ganglion (DRG) can result in the electrophysiological changes of the neighboring DRGs, which contributes to hyperalgesia and allodynia (29). Thus, the implementation of PRF to a DRG responsible for HZ and the neighboring ones have been reported by Ding et al (20) and Han et al (24).

The DRG, composed of primary afferent neurons, is considered as an important structure in pain transduction and the persistence of neuropathic pain (30). Regarding HZ, the latent varicella zoster virus typically begins reactivating in the sensory ganglia, such as the gasserian ganglion and DRG. Therefore, the DRG is commonly regarded as the target of PRF for treatment of HZ neuralgia involving the spinal nerves (19,21,23,31,32). PRF to peripheral nerves has been applied for treatment of PHN in several studies (22,33,34), but the efficacy of PRF to a DRG is superior to that on an intercostal nerve in older patients with PHN (35). This suggests that the DRG has a high priority as the target of PRF for HZ neuralgia.

In previous works regarding PRF to a DRG for treatment of PHN (19-21,23,24), a low output voltage (45 V - 65 V) is often used. A retrospective analysis demonstrated that the therapeutic effect of PRF was positively correlated to the output voltage, indicating that the therapeutic effect can be improved by elevating the output voltage (36). Furthermore, the efficacy of high-voltage (maximal and bearable in conscious patients) PRF has been reported to be superior to that of low-voltage (45 V) PRF in treating neuropathic pain involving the trigeminal nerve (37,38). Recently, high-voltage PRF has been safely applied to a DRG in patients with PHN, and represents effective treatment for PHN (25). However, there has been no study assessing the therapeutic effect of high-voltage PRF to a DRG for refractory HZ neuralgia experienced for less than 90 days (acute or subacute phase). Hence, the present study retrospectively compared the efficacy of high-voltage, long-duration PRF to a DRG in outpatients with HZ neuralgia in different stages (subacute stage [one month to 3 months]) and the PHN stage (20,39).

Methods

Patients

After the protocols of this retrospective study were approved by the Ethics Committee of the Beijing Friendship Hospital (MR-11-22-006904), medical records of 94 patients undergoing PRF to a DRG due to HZ neuralgia beyond one month from January 2021 through May 2022 in our pain clinic were reviewed.

Inclusion Criteria

Eligible patients were those whose HZ neuralgia lasted more than one month and was refractory to conventional therapy.

Exclusion Criteria

Exclusion criteria were as follows: insufficient medical records; those who had received trigeminal nerve PRF; those lost to follow-up or died of other diseases; a history of systemic immune diseases, organ transplantation, or cancers; or those who received other invasive treatments, such as spinal cord stimulation.

Procedure for PRF to the DRG

In this study, all procedures were carried out by the same experienced physician (Dr. Xiuliang Li). At first, the target segment of the DRG was confirmed by cutaneous pigmentation resulting from HZ and the region of pain, commonly along with allodynia. PRF was used

for the target DRG and 2 adjacent DRGs. For example, if the T5 DRG was identified as the target segment, T4, T5 and T6 DRGs were chosen to receive PRF.

Patients were placed prone for PRF to a thoracic or lumbosacral DRG, while patients who underwent PRF to the cervical DRG were placed in a lateral decubitus position. During the procedure, blood pressure, heart rate, electrocardiogram and pulse blood oxygen saturation were continuously monitored, and the C-arm was set in pulsed mode.

After local anesthesia was performed at the puncture site, under fluoroscopic guidance, 3 straight, sharp RF cannulas (Inomed Medizintechnik) with an exposed tip were inserted into the sites close to the DRGs.. A 20G cannula, 150 mm long, was used for the lumbosacral segment and a 22G cannula, 100 mm long, for other segments. The needle tip position was adjusted using fluoroscopic guidance until it was located in the posterocranial quadrant of the intervertebral foramen in the lateral view and positioned downwards to the vertebral pedicle in the anteroposterior view (Fig. 1).

Subsequently, the stylet was withdrawn, and the radiofrequency electrode (CD2282 for cervical DRG and thoracic DRG; CD2213 for lumbosacral DRG; Beijing Neo Science Co.) was inserted. In order to ensure the needle tip was adjacent to the DRG, 50 Hz of sensory stimulation with a voltage less than 0.5 V should cause a tingling sensation in the involved dermatomes. Two Hz of motor stimulation with a voltage less than 0.5 V was performed to ensure there was no muscle fibrillation and pulsation in the innervated area during stimulation.

Once the needle tip position was confirmed, PRF was carried out using a radiofrequency generator (R-2000BA1, Beijing Neo Science Co., Ltd). The generator's manual mode was used with the settings of 42°C, 20 milliseconds, 2 Hz, and 15 minutes. The output voltage of PRF was gradually increased from 45 V to maximal voltage (endurable without pain). The maximal output voltages during PRF were recorded.

Data Collection

Preoperative and postoperative data were collected from medical records. The preoperative data included gender, age, height, weight, underlying diseases, affected side, involved dermatome, disease course (days from zoster onset to PRF), and pain level. The postoperative data mainly were pain levels at one day, one week, one month, 3 months, and 6 months postprocedure. Preoperative and postoperative pain levels were evaluated by the 11-point Numerical Rating Scale (NRS-11), in which 0 means no pain at all and 10 means the most serious pain imaginable. At 6 months postprocedure, the 5-point Likert scale was used to evaluate patient satisfaction (Table 1) (24).

Efficacy and Safety Evaluation

The eligible patients were divided into subacute and PHN groups. In the subacute group, PRF was performed from one to 3 months after the onset of zoster rash; for the PHN group, PRF was carried out beyond 3 months after zoster onset.

Both the NRS-11 score and Likert scale score were used to evaluate the therapeutic effect of PRF to the DRG. The success of the PRF intervention was defined as more than a 50% reduction in NRS-11 score at 6 months postprocedure compared to the preoperative pain NRS-11 score (32).

Statistical Analysis

Data analysis was carried out using IBM SPSS Statistics 20.0 statistical software (IBM Corp.). Normally distributed data were expressed as mean ± standard deviation and between-group comparisons were performed using Student's t test. Nonnormally distributed

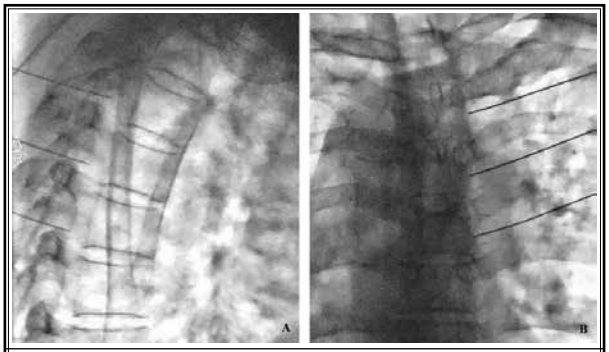

Fig. 1. *Fluoroscopic images of PRF to DRG in lateral view (A) and anteroposterior view (B).*

Table 1. *Likert Scale*

Score	Would you please assess the therapeutic effect after PRF?
1	Very dissatisfied
2	Dissatisfied
3	Same as before
4	Satisfied
5	Very satisfied

data were presented as median and interquartile range (IQR) and between-group comparisons were carried out using the Mann–Whitney U test. Intragroup comparisons for NRS-11 score changes over time were done by repeated measures analysis of variance. The χ^2 test or Fisher's exact test was used for categorical data. A *P* value < 0.05 was considered statistically significant.

Results

A total of 94 patients who received PRF due to HZ neuralgia were screened. Of them, 2 had insufficient medical records, 10 received PRF to peripheral nerves or the gasserian ganglion of the trigeminal nerve, and 5 were lost to follow-up or died of other diseases before 6 months post-PRF. Furthermore, 12 patients were excluded because of systemic immune diseases, organ transplantation, cancers, or receiving other treatments (e.g., spinal cord stimulation) within 6 months postprocedure.

Sixty-four patients were included in the study and their data were analyzed. Of the 64 included patients, 32 received PRF to the DRG in the subacute stage (subacute group), and the other 32 patients received this intervention in the PHN stage (PHN group). The flow chart of included and excluded patients is shown in Fig. 2.

There were no significant differences between groups in the demographic data, including gender, age, height, weight, history of underlying disease, and involved dermatome (Table 2). Furthermore, maximal output voltages during PRF were 95 V (IQR, 95-95) and 95 V (IQR, 95-95) in the subacute and PHN groups, respectively, without a significant difference between groups (*P* = 0.739).

Preoperative and postoperative pain levels are shown in Fig. 3. Preoperative NRS-11 scores were not significantly different between groups (*P* > 0.05). After the PRF intervention, NRS-11 scores reduced obviously with time in the 2 groups; NRS-11 scores at one day and one week postprocedure were not significantly different between groups (*P* > 0.05). Nevertheless, NRS-11 scores at one month, 3 months and 6 months post-PRF were markedly lower in the subacute group than in the PHN group (*P* < 0.05). The success rate of the PRF intervention was 81.3% (26/32) and 56.3% (18/32) in the subacute and PHN groups, respectively, with a significant difference between groups (*P* = 0.031).

The median Likert scale scores were 4.5 (IQR, 4.0 - 5.0) and 4.0 (IQR, 3.0 - 4.8) in the subacute and PHN groups, respectively, without a significant difference between groups (*P* = 0.076). The percentage of patients with very satisfied or satisfied with the therapy was greater in the subacute group than in the PHN group (78.1% vs 62.5%), but a significant statistical difference was not achieved (*P* > 0.05).

A pneumothorax occurred in one patient who rapidly recovered after bed rest. No postoperative neurological complication, pain exacerbation, infection, or other serious side effects were noted in any patient.

Discussion

Our retrospective study aimed to compare the effectiveness of high-voltage, long-duration PRF to the

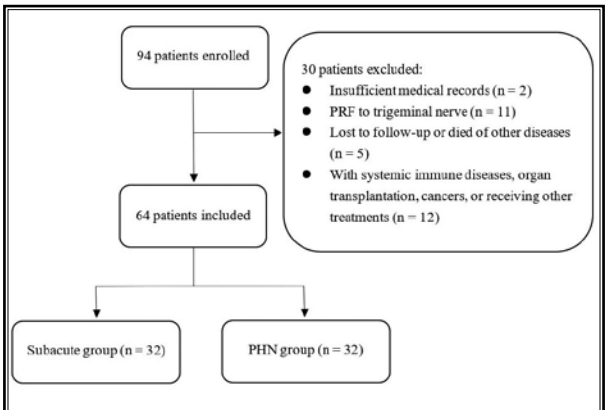

Fig. 2. *The flow chart of included and excluded patients.*

Table 2. *Patient demographic data.*

	Subacute group	PHN group	*P* values
Gender (men/women)	12/20	11/21	0.794
Age (years)	66.5 ± 1.5	70.1 ± 1.3	0.077
Height (cm)	163.8 ± 1.3	162.8 ± 1.4	0.571
Weight (kg)	64.5 ± 1.9	65.5 ± 1.5	0.668
Underlying diseases			
Diabetes mellitus	4	1	0.298
Hypertension	10	11	
Diabetes mellitus and hypertension	1	4	
None	17	16	
Affected side (left/right)	14/18	9/23	0.193
Involved dermatome			
Cervical	4	2	0.596
Thoracic	25	28	
Lumbosacral	3	2	

Categorical variables are expressed as number, and continuous variables as mean ± SD.

DRG on HZ neuralgia in both subacute and PHN stages. Our results show that NRS-11 scores were reduced over time after PRF intervention in both groups, but improved pain control was obtained in the subacute group compared to the PHN group at one month, 3 months and 6 months post-PRF intervention.

Applying PRF to the DRG is a novel interventional treatment for neuropathic pain, including PHN. Conventionally, 45 V is recommended as the standard voltage for PRF to the DRG (19,32,35). However, accumulating evidence demonstrates that PRF using a high output voltage is effective for painful conditions, and even improved pain relief is likely to be achieved through elevating the output voltage of PRF. In 2006, Teixeira and Sluijter (40) found that 60 V high-voltage PRF evidently alleviated discogenic pain. Furthermore, it has been reported that PRF with a 65 V output to the peripheral nerve or ganglion is an effective and safe treatment alternative for PHN (25,41).

In a retrospective analysis using PRF to treat idiopathic trigeminal neuralgia, the output voltage of PRF was also found to be significantly higher in the effective group compared to the ineffective group (39 ± 6 V vs 35 ± 4 V) (36). Subsequently, it was reported that the effectiveness of high-voltage PRF was superior to standard voltage PRF in treating idiopathic trigeminal neuralgia (71.5 ± 8.0 V vs 36.3 ± 5.6 V) (37,38) and neuralgia of the infraorbital nerve (96 ± 9 V vs 50 ± 10 V) (37,38). In addition, the maximum output voltage, which was bearable without causing pain in conscious patients, was used during PRF (37,38). Han et al (24) retrospectively compared the effectiveness of PRF to the DRG at 3 different voltages for patients with PHN. They showed that 65 V PRF was superior to 45 V or 55V PRF, and 55 V PRF resulted in more significant pain relief than 45 V PRF. According to the findings of the above studies, we have reason to believe that the effectiveness of using PRF to relieve neuropathic pains, including PHN, may be positively correlated to the output voltage.

In the present study, PRF to a DRG was applied with the maximum output voltage that patients could tolerate. Our results demonstrate that after a PRF intervention, NRS-11 scores were reduced over time in the both the subacute and the PHN groups. This is in line with findings of Wan et al's study (25), in which pain levels at all observed points after high-voltage PRF to a DRG in patients with PHN were significantly decreased. In a study concerning the efficacy of PRF with different voltages (45 V, 55 V and 65 V) to a DRG for PHN (24), the pain level at each observed point after relatively high-voltage PRF (65 V) was significantly lower than before PRF, which was in agreement with our results.

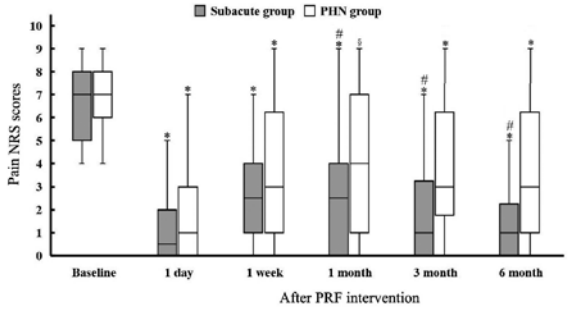

Fig. 3. *The pain levels of both groups before and after PRF intervention.*
Data are shown as median (horizontal line), interquartile range (box) and range (whiskers).
*$P < 0.001$ versus pain levels before PRF. §$P < 0.05$ versus pain levels before PRF. #$P < 0.05$ versus the PHN group.

In 2017, Kim et al (32) pioneered the application of standard-voltage PRF to a DRG in patients with acute HZ and showed that pain level was significantly reduced by PRF intervention. In the patients with HZ-related pain less than 3 months (acute stage and subacute stage), Ding et al (32) demonstrated that pain level at each observed point was significantly reduced after standard-voltage PRF. Additionally, it has been reported that prolonged duration of PRF intervention can attenuate mechanical allodynia induced by resiniferatoxin in rats (42). In our research, a prolonged duration of PRF intervention (15 minutes) was performed in all patients. A literature search of PubMed for articles published before September 30, 2022 shows that our study is the first to evaluate clinical efficacy of high-voltage, long-duration PRF to a DRG in patients with HZ neuralgia in the subacute stage.

An important finding of our study was that high-voltage, long-duration PRF to a DRG produced improved pain relief at one month, 3 months and 6 months postintervention in the subacute group compared to the PHN group, i.e., a more significant pain relief was obtained in the subacute group beyond one month. Moreover, PRF's success rate in the PHN group was inferior to the subacute group (56.3% vs 81.3%), though a significant statistical difference was not achieved. It is generally believed that PHN can result in structural reorganization in the spinal dorsal horn (43,44), which accounts for a poor clinical outcome for PRF in patients with PHN.

Since all of the patients included in our study were

refractory to conventional pharmacological therapies, such as antiepileptic agents (pregabalin or gabapentin) and analgesics, a better therapeutic efficacy for PRF in the subacute group may be because that HZ is at the early recovery period of its natural course. This suggests that early implementation of a PRF intervention to a DRG in the patients in the subacute stage may impede or decrease the development of serious neuropathic conditions such as PHN.

It must be noted that mechanisms of using PRF to relieve neuropathic pain, including HZ neuralgia, are not fully understood. Typically, PRF intervention is regarded as a neuromodulation therapy for neuropathic pain. It is shown that activation of spinal mitogen-activated protein kinases (MAPKs) can induce the releases of proinflammatory cytokines including IL(interleukin)-1β, IL-6 and tumor necrosis factor (TNF)-α, which are involved in the development of inflammatory or neuropathic pain (45). In animals, PRF intervention to a DRG has been shown to decrease the pain signal transmission to the central nervous system by modulating C-fiber signal transduction (46) and suppressing the activation of spinal MAPKs (46-49). This technique is able to improve neuropathic pain and reduce peripheral levels of proinflammatory cytokines in rats with chronic constriction injury (50). Moreover, PRF has also been demonstrated to affect a variety of different biological pathways modulating neuropathic pain (51). Luo et al (52) reported that PRF to a DRG could alleviate neuropathic pain by suppressing the P2X3 receptor expression in a DRG and spinal dorsal horns of rats with chronic constriction injury. Thus, the pain due to acute nerve injury can be alleviated and the development of neuropathic pain is probably impeded. Most important, clinical evidence indicates that early effective interventional therapies are capable of decreasing the severity and duration of HZ neuralgia, and consequently the risk of developing PHN is lowered (16,20).

Our study shows that high-voltage, long-duration PRF to a DRG is also useful for PHN lasting more than 3 months, because more than 60% of our patients with PHN were satisfied or very satisfied with this intervention according to the Likert scale. Because our sample size is small and the study is retrospective, however, patient satisfaction was not significantly different between the subacute and PHN groups. Despite that, these results at least suggest that high-voltage, long-duration PRF to DRG is able to improve the life quality of life of patients with PHN.

It is generally believed that PRF is a type of non-destructive interventional therapy. Actually, however, this technique is a modification of radiofrequency thermocoagulation in which pulsed-wave radiofrequency power is used to ensure the target issue exposed to a temperature under 42°C (53). Nevertheless, Cosman et al (54) found that PRF was capable of generating heat spikes beyond 45°C - 50°C, leading to destructive heat injuries. Thus, it is best to describe PRF as "minimally destructive" rather than nondestructive, because destructive effects may occur at a cellular and even subcellular level (46). However, it is reported that egg white fails to be coagulated with PRF at 42°C (55). Thus, PRF at this temperature may avoid protein coagulation and thermal destruction of nervous tissue. In our retrospective analysis, no neurological or other complications associated with PRF were identified, except for a case of pneumothorax by puncture. Moreover, Wan et al (25) reported that no serious adverse events, including neurological complications, were observed after high-voltage, long-duration PRF to a DRG in patients with PHN. All of this evidence suggests that high-voltage, long-duration PRF to a DRG is safe, especially in the reduction or avoidance of nerve injuries.

Limitations

It must be pointed out that the main limitations of our study are its retrospective nature, single-center design, small sample size, short follow-up, and others. These factors can not only introduce the influences of unknown confounding factors on study outcomes, but also may decrease the generalization of study findings. Thus, further prospective controlled trials with enough power and long follow-up are needed to validate our findings. If further studies show a consistent beneficial effect for high-voltage, long-duration PRF to a DRG for HZ neuralgia in the subacute stage, we believe the implications for practice are immense.

Conclusions

In summary, this retrospective study demonstrates that high-voltage, long-duration PRF to a DRG is an effective and safe interventional therapy for patients with HZ neuralgia refractory to conservative therapies in different stages, and can provide improved pain relief for HZ neuralgia in the subacute stage.

Author Contributions

Chen-Li Sun contributed considerably to the design of the research, data collection and analysis, and drafted the manuscript. Fu-Shan Xue and Jie Zhang equally

contributed to the design and critically revised the manuscript, and are the co-authors responsible for this manuscript. Xiu-Liang Li, Cheng-Wen Li and Nong He participated substantially in the design of the research, data collection and analysis, and manuscript revision. All authors read and approved the final manuscript.

References

1. Massengill JS, Kittredge JL. Practical considerations in the pharmacological treatment of postherpetic neuralgia for the primary care provider. *J Pain Res* 2014; 7: 125-132.
2. Yawn BP, Gilden D. The global epidemiology of herpes zoster. *Neurology* 2013; 81:928-930.
3. Klompas M, Kulldorff M, Vilk Y, et al. Herpes zoster and postherpetic neuralgia surveillance using structured electronic data. *Mayo Clin Proc* 2011; 86:1146-1153.
4. Forbes HJ, Thomas SL, Smeeth L, et al. A systematic review and meta-analysis of risk factors for postherpetic neuralgia. *Pain* 2016; 157:30-54.
5. Johnson RW, Rice AS. Clinical practice. Postherpetic neuralgia. *N Engl J Med* 2014; 371:1526-1533.
6. Kawai K, Gebremeskel BG, Acosta CJ. Systematic review of incidence and complications of herpes zoster: Towards a global perspective. *BMJ Open* 2014; 4:e004833.
7. Kost RG, Straus SE. Postherpetic neuralgia--pathogenesis, treatment, and prevention. *N Engl J Med* 1996; 335:32-42.
8. Feller L, Khammissa RAG, Fourie J, et al. Postherpetic neuralgia and trigeminal neuralgia. *Pain Res Treat* 2017; 2017:1681765.
9. Gauthier A, Breuer J, Carrington D, et al. Epidemiology and cost of herpes zoster and post-herpetic neuralgia in the United Kingdom. *Epidemiol Infect* 2009; 137:38-47.
10. Gialloreti LE, Merito M, Pezzotti P, et al. Epidemiology and economic burden of herpes zoster and post-herpetic neuralgia in Italy: A retrospective, population-based study. *BMC Infect Dis* 2010; 10: 230.
11. Chen MH, Wei HT, Su TP, et al. Risk of depressive disorder among patients with herpes zoster: A nationwide population-based prospective study. *Psychosom Med* 2014; 76:285-291.
12. Yang F, Yu S, Fan B, et al. The epidemiology of herpes zoster and postherpetic neuralgia in China: Results from a cross-sectional study. *Pain Ther* 2019; 8:249-259.
13. Mallick-Searle T, Snodgrass B, Brant JM. Postherpetic neuralgia: Epidemiology, pathophysiology, and pain management pharmacology. *J Multidiscip Healthc* 2016; 9:447-454.
14. Drolet M, Brisson M, Schmader KE, et al. The impact of herpes zoster and postherpetic neuralgia on health-related quality of life: A prospective study. *CMAJ* 2010; 182:1731-1736.
15. Song D, He A, Xu R, et al. Efficacy of pain relief in different postherpetic neuralgia therapies: A network meta-analysis. *Pain Physician* 2018; 21:19-32.
16. Shrestha M, Chen A. Modalities in managing postherpetic neuralgia. *Korean J Pain* 2018; 31:235-243.
17. Lin CS, Lin YC, Lao HC, et al. Interventional treatments for postherpetic neuralgia: A systematic review. *Pain Physician* 2019; 22:209-228.
18. Shi Y, Wu W. Treatment of neuropathic pain using pulsed radiofrequency: A meta-analysis. *Pain Physician* 2016; 19:429-444.
19. Liu B, Yang Y, Zhang Z, et al. Clinical study of spinal cord stimulation and pulsed radiofrequency for management of herpes zoster-related pain persisting beyond acute phase in elderly patients. *Pain Physician* 2020; 23:263-270.
20. Ding Y, Li H, Hong T, et al. Efficacy and safety of computed tomography-guided pulsed radiofrequency modulation of thoracic dorsal root ganglion on herpes zoster neuralgia. *Neuromodulation* 2019; 22:108-114.
21. Ke M, Yinghui F, Yi J, et al. Efficacy of pulsed radiofrequency in the treatment of thoracic postherpetic neuralgia from the angulus costae: A randomized, double-blinded, controlled trial. *Pain Physician* 2013; 16:15-25.
22. Li D, Sun G, Sun H, et al. Combined therapy of pulsed radiofrequency and nerve block in postherpetic neuralgia patients: A randomized clinical trial. *PeerJ* 2018; 6:e4852.
23. Kim ED, Lee YI, Park HJ. Comparison of efficacy of continuous epidural block and pulsed radiofrequency to the dorsal root ganglion for management of pain persisting beyond the acute phase of herpes zoster. *PLoS One* 2017; 12:e0183559.
24. Han Z, Hong T, Ding Y, et al. CT-guided pulsed radiofrequency at different voltages in the treatment of postherpetic neuralgia. *Front Neurosci* 2020; 14:579486.
25. Wan CF, Liu Y, Dong DS, et al. Bipolar high-voltage, long-duration pulsed radiofrequency improves pain relief in postherpetic neuralgia. *Pain Physician* 2016; 19:E721-E728.
26. Sampathkumar P, Drage LA, Martin DP. Herpes zoster (shingles) and postherpetic neuralgia. *Mayo Clin Proc* 2009; 84:274-280.
27. Philip A, Thakur R. Post herpetic neuralgia. *J Palliat Med* 2011; 14:765-773.
28. Gross GE, Eisert L, Doerr HW, et al. S2k guidelines for the diagnosis and treatment of herpes zoster and postherpetic neuralgia. *J Dtsch Dermatol Ges* 2020; 18:55-78.
29. Ma C, Shu Y, Zheng Z, et al. Similar electrophysiological changes in axotomized and neighboring intact dorsal root ganglion neurons. *J Neurophysiol* 2003; 89:1588-1602.
30. Esposito MF, Malayil R, Hanes M, et al. Unique characteristics of the dorsal root ganglion as a target for neuromodulation. *Pain Med* 2019; 20:S23-S30.
31. Kim YH, Lee CJ, Lee SC, et al. Effect of pulsed radiofrequency for postherpetic neuralgia. *Acta Anaesthesiol Scand* 2008; 52:1140-1143.
32. Kim K, Jo D, Kim E. Pulsed radiofrequency to the dorsal root ganglion in acute herpes zoster and postherpetic neuralgia. *Pain Physician* 2017; 20:E411-E418.
33. Ding Y, Li H, Hong T, et al. Efficacy of pulsed radiofrequency to cervical nerve root for postherpetic neuralgia in upper extremity. *Front Neurosci* 2020; 14:377.
34. Zhu J, Fei Y, Deng J, et al. Application and therapeutic effect of puncturing of the costal transverse process for pulsed radiofrequency treated T1-T3 herpes zoster neuralgia. *J Pain Res* 2020; 13:2519-2527.
35. Huang X, Ma Y, Wang W, et al. Efficacy and safety of pulsed radiofrequency

modulation of thoracic dorsal root ganglion or intercostal nerve on postherpetic neuralgia in aged patients: a retrospective study. *BMC Neurol* 2021; 21:233.

36. Luo F, Meng L, Wang T, et al. Pulsed radiofrequency treatment for idiopathic trigeminal neuralgia: A retrospective analysis of the causes for ineffective pain relief. *Eur J Pain* 2013; 17:1189-1192.
37. Fang L, Tao W, Jingjing L, et al. Comparison of high-voltage- with standard-voltage pulsed radiofrequency of gasserian ganglion in the treatment of idiopathic trigeminal neuralgia. *Pain Pract* 2015; 15:595-603.
38. Luo F, Wang T, Shen Y, et al. High voltage pulsed radiofrequency for the treatment of refractory neuralgia of the infraorbital nerve: A prospective double-blinded randomized controlled study. *Pain Physician* 2017; 20:271-279.
39. Liang L, Li X, Zhang G, et al. Pregabalin in the treatment of herpetic neuralgia: Results of a multicenter Chinese study. *Pain Med* 2015; 16:160-167.
40. Teixeira A, Sluijter ME. Intradiscal high-voltage, long-duration pulsed radiofrequency for discogenic pain: A preliminary report. *Pain Med* 2006; 7:424-428.
41. Li H, Ding Y, Zhu Y, et al. Effective treatment of postherpetic neuralgia at the first branch of the trigeminal nerve by high-voltage pulsed radiofrequency. *Front Neurol* 2021; 12:746035.
42. Tanaka N, Yamaga M, Tateyama S, et al. The effect of pulsed radiofrequency current on mechanical allodynia induced with resiniferatoxin in rats. *Anesth Analg* 2010; 111:784-790.
43. Fields HL, Rowbotham M, Baron R. Postherpetic neuralgia: Irritable nociceptors and deafferentation. *Neurobiol Dis* 1998; 5:209-227.
44. Bennett GJ, Watson CP. Herpes zoster and postherpetic neuralgia: Past, present and future. *Pain Res Manag* 2009; 14:275-282.
45. Ji RR, Gereau RWt, Malcangio M, et al. MAP kinase and pain. *Brain Res Rev* 2009; 60:135-148.
46. Huang RY, Liao CC, Tsai SY, et al. Rapid and delayed effects of pulsed radiofrequency on neuropathic pain: Electrophysiological, molecular, and behavioral evidence supporting long-term depression. *Pain Physician* 2017; 20:E269-E283.
47. Lin ML, Lin WT, Huang RY, et al. Pulsed radiofrequency inhibited activation of spinal mitogen-activated protein kinases and ameliorated early neuropathic pain in rats. *Eur J Pain* 2014; 18:659-670.
48. Chen KH, Yang CH, Juang SE, et al. Pulsed radiofrequency reduced complete Freund's adjuvant-induced mechanical hyperalgesia via the spinal c-Jun N-terminal kinase pathway. *Cell Mol Neurobiol* 2014; 34:195-203.
49. Chua NH, Vissers KC, Sluijter ME. Pulsed radiofrequency treatment in interventional pain management: Mechanisms and potential indications-A review. *Acta Neurochir (Wien)* 2011; 153:763-771.
50. Jiang R, Li P, Yao YX, et al. Pulsed radiofrequency to the dorsal root ganglion or the sciatic nerve reduces neuropathic pain behavior, decreases peripheral pro-inflammatory cytokines and spinal beta-catenin in chronic constriction injury rats. *Reg Anesth Pain Med* 2019; 44:742-746.
51. Sam J, Catapano M, Sahni S, et al. Pulsed radiofrequency in interventional pain management: Cellular and molecular mechanisms of action - An update and review. *Pain Physician* 2021; 24:525-532.
52. Fu M, Meng L, Ren H, et al. Pulsed radiofrequency inhibits expression of P2X3 receptors and alleviates neuropathic pain induced by chronic constriction injury in rats. *Chin Med J* 2019; 132:1706-1712.
53. Wu CY, Lin HC, Chen SF, et al. Efficacy of pulsed radiofrequency in herpetic neuralgia: A meta-analysis of randomized controlled trials. *Clin J Pain* 2020; 36:887-895.
54. Cosman ER, Jr., Cosman ER, Sr. Electric and thermal field effects in tissue around radiofrequency electrodes. *Pain Med* 2005; 6:405-424.
55. Heavner JE, Boswell MV, Racz GB. A comparison of pulsed radiofrequency and continuous radiofrequency on thermocoagulation of egg white in vitro. *Pain Physician* 2006; 9:135-137.