Retrospective Study

Ultrasound- Versus Computed Tomography-Guided Cervical Dorsal Root Ganglia Pulsed Radiofrequencies via Intervertebral Foramen for the Treatment of Postherpetic Neuralgia: A Retrospective Cohort Study

Ran Wang, MD, Tong Zhu, MD, and Ying Han, MD

From: Department of Pain Management, Nanjing Drum Tower Hospital, The Affiliated Hospital of Nanjing University Medical School, Nanjing, China

Address Correspondence:
Ying Han, MD
Department of Pain Management
Nanjing Drum Tower Hospital
The Affiliated Hospital of Nanjing University Medical School
Zhongshan Road 321
Nanjing, China
E-mail: hanying@njglyy.com

Disclaimer: There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 10-29-2022
Revised manuscript received: 01-22-2023
Accepted for publication: 01-31-2023

Free full manuscript: www.painphysicianjournal.com

Background: Pulsed radiofrequency (PRF) treatment of the dorsal root ganglia (DRG) has recently been used as an important option for postherpetic neuralgia (PHN) patients who do not respond well to drugs. This procedure is commonly guided by computed tomography (CT) or fluoroscopy, but they cannot be performed in real time and are associated with radiation exposure. Ultrasound (US) is a potential alternative option, but no reliable method of US-guided DRG PRF treatment has been reported.

Objectives: The goal of this study was to propose a method for performing US-guided transforaminal PRF on cervical DRG. By comparing the results with those of CT guidance, we also sought to assess the accuracy, safety, and efficacy of this new approach in the treatment of PHN.

Study Design: A retrospective cohort study.

Setting: The study took place at the department of pain management of a single academic medical center.

Methods: The data of 73 PHN patients receiving 2 sessions of US-guided (US group, n = 26) or CT-guided (CT group, n = 47) cervical DRG PRF were reviewed. US-guided DRG PRF was performed using our proposed protocol. The one-time success rate was used to assess accuracy. The average radiation dose, the number of scans per operation, and the rate of complications were recorded for safety assessment. For the evaluation of pain amelioration, a Numeric Rating Scale (NRS-11), the daily sleep interference score (SIS), and oral medication (i.e., anticonvulsants and analgesics) usage 2 weeks, 4 weeks, 12 weeks, and 24 weeks after treatment were compared to the baseline values and between groups.

Results: The one-time success rate in the US group was significantly higher than that in the CT group ($P < 0.05$). Compared those of the CT group, the mean radiation dose and number of scans per operation were both obviously lower in the US group ($P < 0.05$). The average operation time was also shorter in the US group ($P < 0.05$). No obvious serious complications occurred in either group. No obvious between-group difference was found in the NRS-11 score, daily SIS, or rate of oral medications at any of the time points ($P > 0.05$). The NRS-11 score and SIS significantly decreased after treatment at each follow-up time point ($P < 0.05$) in both groups. Compared with those at baseline, the use rate of anticonvulsants and analgesics obviously decreased 4 weeks, 12 weeks, and 24 weeks after treatment ($P < 0.05$).

Limitations: This study was limited by its nonrandomized and retrospective design.

Conclusions: US-guided transforaminal DRG PRF is a safe and effective method for the treatment of cervical PHN. It is a reliable alternative option to the CT-guided procedure, demonstrating great advantages in reducing radiation exposure and the operation time.

Key words: Ultrasound, pulsed radiofrequency, dorsal root ganglion, postherpetic neuralgia, transforaminal

Pain Physician 2023: 26:E171-E179

Postherpetic neuralgia (PHN) is one of the most complex and refractory forms of neuropathic pain resulting from peripheral nerve damage during a herpes zoster attack (1). PHN seriously interferes with the daily life of patients and causes a heavy health care burden (2,3). However, treatment for PHN is challenging, and drug therapy alone is often insufficient or ineffective. Among patients with PHN lasting more than one year, oral medication is only effective in producing recovery or controlling the condition in only 50% of cases (4). Pulsed radiofrequency (PRF) has recently been used as an important option for PHN patients who do not respond well to drug treatment (5). PRF treatment of the dorsal root ganglia (DRG) can achieve an ideal therapeutic effect in terms of pain alleviation without destruction of the nerve (6,7).

PHN involving the cervical nerves may present with stubborn pain in the neck and upper extremities, which often leads to an inability to work and perform activities of daily living. When performing PRF on cervical DRGs, the adjacent vertebral artery and spine may be accidentally injured, greatly increasing the risk of surgical complications. Computed tomography (CT) and fluoroscopy are common instruments for guiding the cervical DRG puncture. However, because the 2 tools cannot provide real-time guidance, there is still a risk of vascular and spinal cord injury due to the possible error in the actual puncture angle and depth. Puncture adjustment requires repeated radiological scanning, which increases radiation exposure and potentially harms the patient's immune system. In recent years, ultrasound (US) has been applied to PRF for the treatment of refractory cervical radicular pain. However, the PRF target was set as the extraforaminal nerve root, not the DRG, due to the difficulty in puncturing the DRG under US guidance (8,9). As the DRGs are the main targets in a herpes zoster attack, it is commonly believed that PRF on the DRGs may be superior to PRF on the anterior branch of the spinal nerve (10). Therefore, while US-guided PRF on the extraforaminal nerve roots is suitable for PHN treatment, it may be inferior to DRG PRF guided by CT or fluoroscopy in terms of pain alleviation.

Furthermore, due to its imaging properties, CT or fluoroscopy cannot provide clear images of the cervical DRGs directly and therefore relies on the localization of bony anatomical structures, including the transverse process (TP), intervertebral foramen (IVF), and the zygapophyseal joint to perform DRG PRF (11-13). These structures, however, can be located with US. Therefore, in this study, we proposed a method for performing US-guided transforaminal PRF on cervical DRGs. By comparing its results with those of conventional CT guidance, we assessed the accuracy, safety, and efficacy of this new approach for the treatment of PHN.

Methods

Study Design

This was a single-center retrospective cohort study conducted at Nanjing Drum Tower Hospital, The Affiliated Hospital of Nanjing University Medical School. PHN patients receiving US-guided or CT-guided cervical DRG PRF, from January 1, 2017 to March 31, 2021, were reviewed. The study was approved by the Ethics Committee of Nanjing Drum Tower Hospital, The Affiliated Hospital of Nanjing University Medical School (2022-442-01). The need for signed informed consent was waived.

Patients

PHN patients who were > 18 years old and received cervical DRG PRF (C3-C7) twice during hospitalization were enrolled and divided into the US group or CT group depending on the guidance methods used. All procedures were conducted twice by the same doctor (YH), a deputy chief physician skilled in performing DRG PRF. The exclusion criteria were as follows: (1) incomplete medical records or follow-up data; (2) missing records on CT scanning times and radiation doses; and (3) receipt of minimally invasive interventional therapy other than PRF during hospitalization and by 24 weeks of follow-up.

Procedure

All procedures were conducted in a CT room. Patients were placed in the lateral position with the surgical side upward. Blood pressure, pulse rate, and pulse oxygen saturation were continuously monitored. The DRGs of the 2 main affected segments were selected as PRF targets. For puncture guidance, the CT (Philips Brilliance 16 CT scanner, Netherlands) exposure voltage was set to 90 kV, the current to 50 mA, and the thickness to 2 mm. For each scan, the scan range was set to the smallest applicable range. A 21-G RF needle with a 5 mm working tip was used in the treatment and prebent approximately 30° for convenient adjustment of the puncture direction.

The CT-guided cervical DRG puncture in the CT

group was conducted with conventional methods (14) (Fig. 1). After a lead positioning grid plate was placed on the neck, a preoperative scan was made to obtain CT scan images of the targeted cervical vertebra. The upper one-third level of the cervical IVF was identified, and the puncture path along the anterior edge of the facet joint (FJ) into the foramen was drawn. The insertion point was then marked, and the insertion angle and depth were also measured. After disinfection and local anesthesia, a needle was inserted along the planned trajectory. A CT scan and needle adjustment could be made, if necessary, until the needle tip reached the IVF and a sensory test (50 Hz < 0.3 V) was successfully performed (13).

DRG puncture in the US group was guided with US, and the surgery preparation, position, and target selection were the same as those in the CT group. A short-axis US scan was performed, and the C7 cervical spine segments were first confirmed according to the structural characteristics of the C6 and C7 TPs (15). The probe was then moved to the head side. After the targeted anterior rami of the spine nerve root and tubercle of the TP were identified, the probe was further moved toward the head to the TP of the upper segment (TP view, Fig. 2A). Then, the probe was slowly moved caudally until the echo of the TP or the posterior tubercle of the TP disappeared, where the IVF view could be obtained (Fig. 2B). The echo of the centrum/intervertebral disc and the FJ constitute the medial and lateral edges of the IVF, and the vertebral artery and veins can be identified against the medial side of the IVF with Doppler ultrasonography (Fig. 2C). The prebent needle could then be inserted with in-plane or out-of-plane approaches. With the in-plane approach, the needle was first inserted into the anterior edge of the FJ with the tip bent toward the ventral side and then further inserted approximately 5 mm ahead with the tip bent toward the dorsal side to the anteromedial edge of the FJ (Fig. 2D, Fig. 3). When inserting the needle with the out-of-plane technique, the insertion point was placed at the caudal side of the probe. The needle was first inserted into the anterior edge of the FJ with the tip bent toward the lateral side and then further inserted approximately 5 mm ahead with the tip bent toward the medial side to the anteromedial edge of the FJ (Figs. 2E, 2F). After the puncture was completed, a sensory test (50 Hz < 0.3 V) was conducted to confirm the location of the working tip close to the DRG (13). If the sensory test failed, adjustments toward the head or caudally could be made until the sensory test was successfully performed. Finally, a one-time CT scan was performed to confirm the correct location of the needle tip in the IVF. Figure 4 showed the process of C4 and C5 DRG punctures through C3-C4 and C4-C5

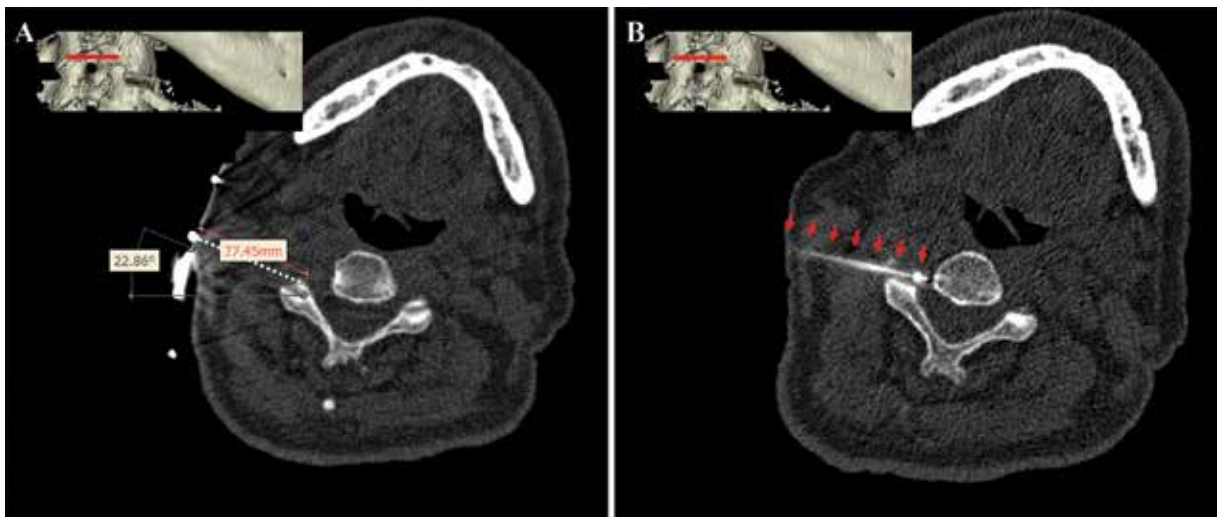

Fig. 1. *CT-guided transforaminal cervical DRG puncture. After preoperative scan with a lead positioning grid plate on the neck, the upper one-third level (red line in the 3D image) of the cervical IVF was identified. The puncture path (dotted line) along the anterior edge of the FJ into the IVF was drawn and the insertion angle and depth were also measured (A). Image B showed the CT scan confirming the final needle (arrow) place.*
CT, computed tomography; DRG, dorsal root ganglia; 3D, 3-dimensional; IVF, intervertebral foramen; FJ, facet joint.

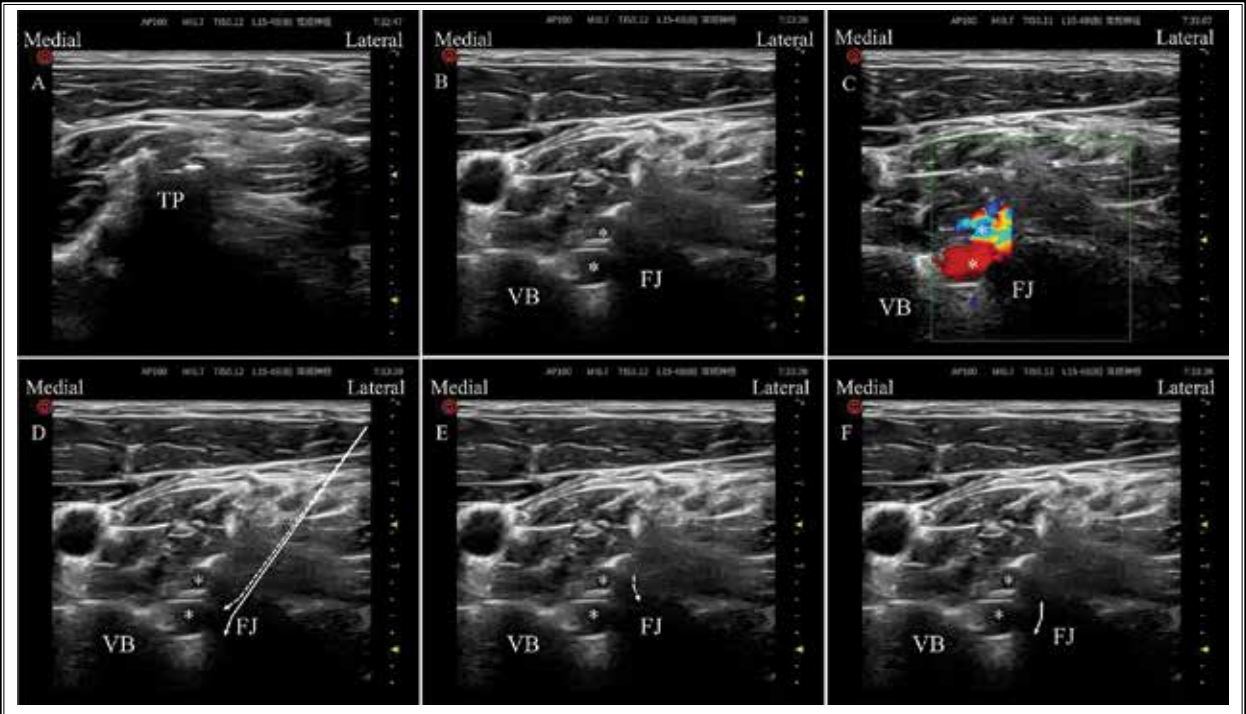

Fig. 2. *US scan of the C4-C5 IVF and puncture path design. C4 TP with anterior and posterior tubercles was shown on a short-axis US scan (A). Then, the high-frequency probe was moved caudally until the TP echo disappears and the IVF echo appears (B). The echo of the VB and FJ constitute the medial and lateral edges of the IVF, respectively, and the vertebral artery and veins* can be identified against the medial side of the IVF with Doppler ultrasonography (C). With the in-plane approach, the prebent needle was planned to first reach the anterior edge of the FJ (dashed arrow) and then inserted inward into the IVF against the anteromedial edge of the FJ with the needle tip bent toward the dorsal side (solid arrow) (D). When inserting with the out-of-plane technique, the needle was first inserted into the anterior edge of the FJ with the tip bent toward the lateral side (dashed arrow) (E) and then further inserted approximately 5 mm ahead with the tip bent toward the medial side to the anteromedial edge of the FJ (solid arrow) (F). IVF, intervertebral foramen; TP, transverse process; VB, vertebral body; FJ, facet joint.*

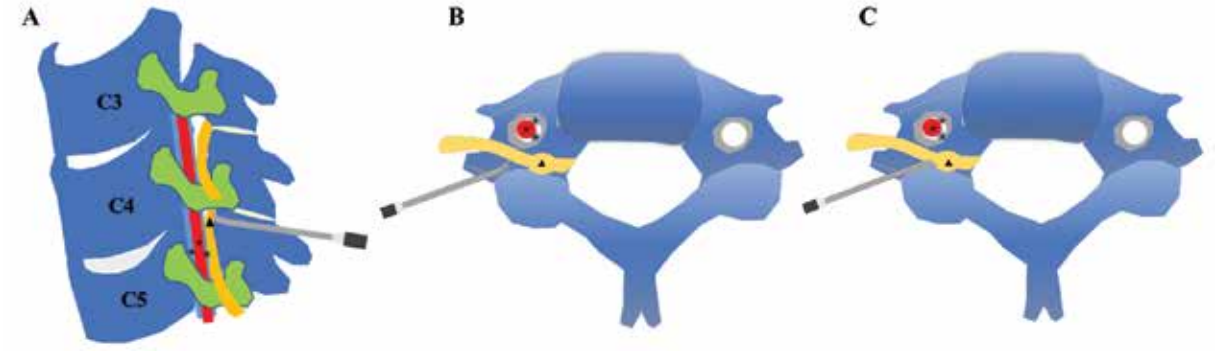

Fig. 3. *Schematic diagram of the transforaminal cervical DRG puncture technique with a prebent needle. The prebent needle was first inserted into the anterior edge of the FJ with the tip bent toward the ventral side and then inserted inward into the IVF against the anteromedial edge of the FJ with the needle tip bent turned toward the dorsal side. DRG, dorsal root ganglia; FJ, facet joint; IVF, intervertebral foramen; *vertebral artery and veins; arrowhead, nerve root*

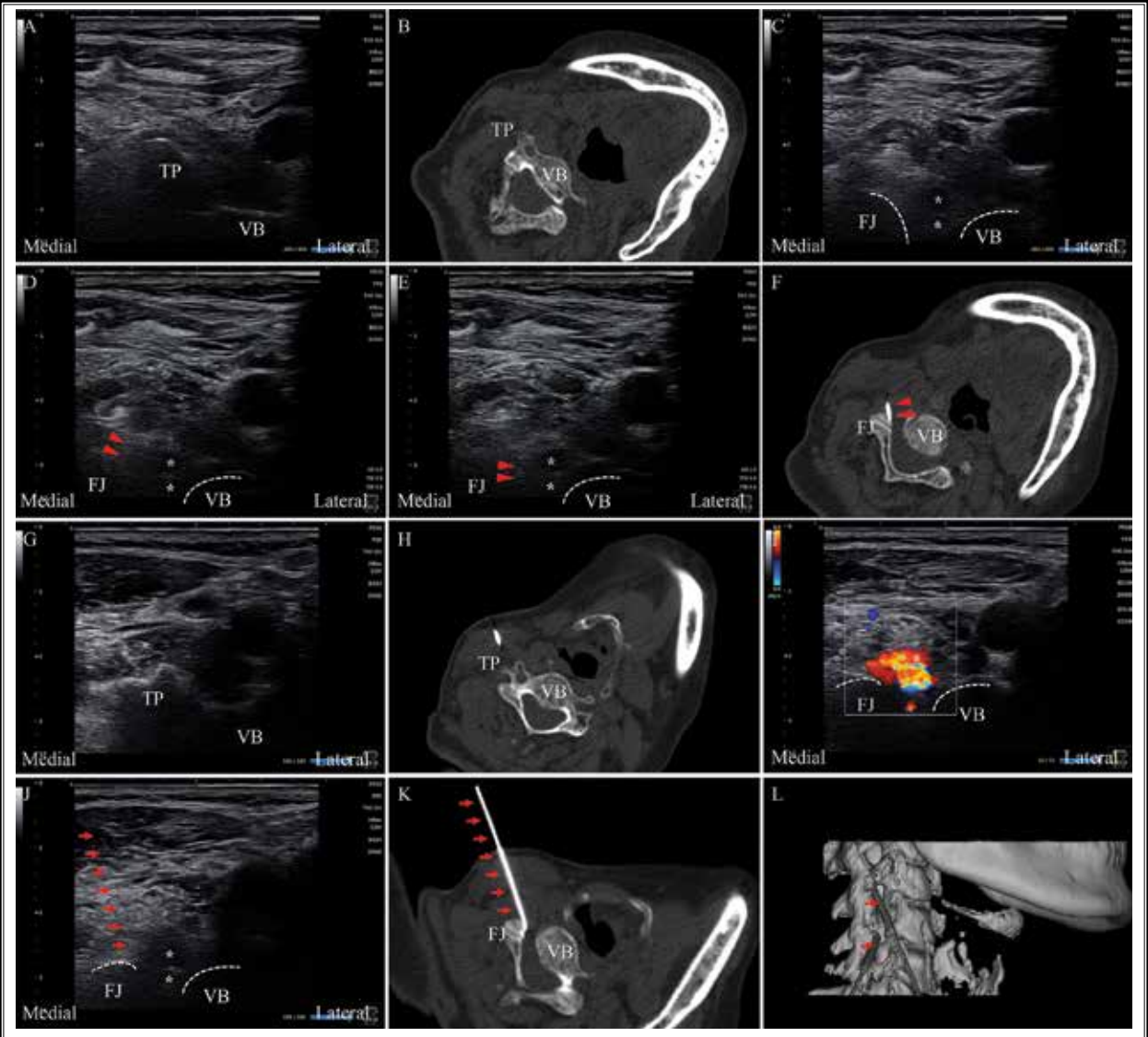

Fig. 4. *One case of transforaminal C4 DRG puncture with the out-of-plane technique and C5 DRG puncture with the in-plane technique. Images A, C, D, and E showed the process of US scan and puncture of C3-C4 IVF with the out-of-plane technique. Images B and F showed counterpart CT images of C3 TP view (A) and final needle location of C3-C4 IVF puncture (E). Images G, I, and J showed the process of US scan and puncture of C4-C5 IVF with the in-plane technique. Images H and K showed counterpart CT images of C4 TP view (G) and final needle location of C4-C5 IVF puncture (J). Image L showed the 3D CT image of final needle location of C3-C4 and C4-C5 IVF puncture. DRG, dorsal root ganglia; US, ultrasound; IVF, intervertebral foramen; CT, computed tomography; TP, transverse process; 3D, 3-dimensional; *vertebral artery and veins; arrowhead, needle tip; arrow, needle.*

IVFs with out-of-plane and in-plane approaches. When the sensory test could not be successfully performed consistently or the CT scan confirmed that the working tip was not in the IVF, the US-guided puncture was converted to a conventional CT-guided puncture.

After sensory testing and CT scan confirmation, PRF was conducted with an RF Generator (Cosman Medical, Burlington, MA). The working temperature was set to 45 °C, the pulse width to 20 milliseconds, the frequency to 2 HZ, the voltage to 80-100 V, and the treatment duration to 600 seconds.

Assessment

One-time success was defined as successful DRG

PRF with a single confirmatory CT scan. One-time success rate was calculated and compared between groups. The average radiation dose and the number of scans per operation were calculated for assessing radiation damage. Complications were recorded, including bleeding, local hematoma, epidural hematoma, infection, nerve injury, spinal cord injury, and pneumothorax. For evaluating pain amelioration, the Numeric Rating Scale (NRS-11) score, daily sleep interference score (SIS), and oral medication use were also recorded before treatment and 2 weeks, 4 weeks, 12 weeks, and 24 weeks after therapy. The NRS-11 score, daily SIS, and the rates of anticonvulsant and analgesic use were compared with baseline and between groups at each time point (Table 1).

Statistical Analysis

SPSS Version 24.0 software (IBM Corporation, Armonk, NY) was used for statistical analysis. Measurement data with a normal distribution are expressed as the mean ± standard deviation. Comparisons between groups and within groups were analyzed by the t test and analysis of variance for repeated measures. Measurement data with a skewed distribution are expressed as median (interquartile distance), and comparisons between groups were analyzed by the Wilcoxon rank-sum test. The rates of oral medication usage and complications are expressed as frequencies (percentages), and the chi-square test was used for comparisons between groups. When $P < 0.05$, the difference was considered statistically significant (Table 1).

Results

Patient Demographics

At baseline, no significant differences between the US group and the CT group were found in age, gender, body mass index, side, disease course, NRS-11 score, affected DRG segments, and accompanying disease ($P > 0.05$) (Table 2). All patients used anticonvulsants (i.e, pregabalin or gabapentin) and analgesics (i.e., oxycodone hydrochloride or tramadol) for pain management.

Table 1. *Use rate of oral medications.*

Follow-up	Use Rate of Anticonvulsants		Use Rate of Analgesics	
	US Group (n = 26)	CT Group (n = 47)	US Group (n = 26)	CT Group (n = 47)
Baseline	26 (100%)	47 (100%)	26 (100%)	47 (100%)
2 weeks	26 (100%)	47 (100%)	22 (84.6%)	40 (85.1%)*
4 weeks	16 (61.5%)*	31 (66.0%)*	7 (26.9%)*	13 (27.7%)*
12 weeks	8 (30.8%)*	15 (31.9%)*	3 (11.5%)*	6 (12.8%)*
24 weeks	5 (19.2%)*	10 (21.3%)*	3 (11.5%)*	5 (10.6%)*

Abbreviations: US, ultrasound; CT, computed tomography.
* compared with baseline, $P < 0.05$.

Radiation Exposure, Operation Time, and Complications

A total of 46 and 94 procedures were performed in the US group and CT group, respectively, of which 46 (100%) in the US group and 11 (11.7%) in the CT group were conducted successfully with only one-time scanning (CT confirmation). The one-time success rate was obviously higher in the US group than in the CT group ($P < 0.05$). Compared with those of the CT group, the mean radiation dose and number of scans per operation, including CT confirmation scans, were both obviously lower in the US group ($P < 0.05$). The average operation time was also shorter in the US group (Table 3). No obvious bleeding, local hematoma, epidural hematoma, infection, nerve injury, spinal cord injury, or pneumothorax occurred in either group.

NRS-11 Score and SIS

No significant interaction between the follow-up time and the group was found in the NRS-11 score ($F = 1.385$, $P = 0.239$) or SIS ($F = 0.778$, $P = 0.540$). Additionally, no obvious between-group difference was found in the NRS-11 score ($F = 0.006$, $P = 0.969$) or SIS ($F = 0.144$, $P = 0.705$), while the in-group difference in the NRS-11 score ($F = 215.456$, $P < 0.001$) and SIS ($F = 251.913$, $P < 0.001$) was significant. The NRS-11 score and SIS significantly decreased after treatment at each follow-up time point ($P < 0.05$) (Fig. 5).

Oral Medications

The oral medication usage of the 2 groups is shown in Table 1. No significant between-group difference was found in the use rate of anticonvulsants and analgesics at any time point ($P > 0.05$). Compared with that at baseline, the use rate of anticonvulsants and analgesics obviously decreased at 4 weeks, 12 weeks, and 24 weeks after treatment ($P < 0.05$).

Discussion

When observing the cervical spine in a horizontal view, the DRGs are always located against the medial surface of the superior articular process. On sagittal view, the DRGs are located at the upper part and against the dorsal edge of the IVF (16). Based on the

Table 2. *Baseline characteristics*.

	US Group (n = 26)	CT Group (n = 47)	Test Value (t/Z/χ^2)	*P* value
Age	70.1 ± 10.6	71.7 ± 11.1	-0.593	0.555
Gender (men:women)	15:11	26:21	0.038	0.845
Disease Course (month)	2 (1, 4)	2 (1, 3)	-0.528	0.597
NRS-11 Score	6.5 (6, 7)	6 (6, 7)	-0.896	0.370
BMI	22.3 ± 3.7	23.3 ± 3.9	-1.071	0.288
Side (left:right)	15:11	17:30	3.149	0.076
DRG Segment			7.566	0.109
C3	7 (13.46%)	22 (23.40%)		
C4	11 (21.15%)	30 (31.91%)		
C5	12 (23.08%)	20 (21.28%)		
C6	15 (28.85%)	17 (18.09%)		
C7	7 (13.46%)	5 (5.32%)		
Accompanying Disease				
Hypertension	7 (26.92%)	18 (38.30%)	0.962	0.327
Type 2 Diabetes	4 (15.38%)	9 (19.15%)	0.162	0.687
Malignant Tumor	1 (3.85%)	0	-	0.356
Immune System Disease	2 (7.69%)	3 (6.38%)	< 0.000	1.000

Abbreviations: US, ultrasound; CT, computed tomography; NRS-11, Numeric Rating Scale; BMI, body mass index; DRG, dorsal root ganglion.

Table 3. *Radiation exposure and operation time between the 2 groups*.

	US Group (n = 26)	CT Group (n = 47)	Test Value (t/Z)	*P* value
Radiation Dose (mGy x cm/operation)	5.3 ± 0.4	20.8 ± 7.4	-20.309	< 0.001
Number of Scans	1 (1, 1)	4 (3, 5)	-10.321	< 0.001
Operation Time (min/operation)	19.4 ± 2.7	27.4 ± 9.5	-7.586	< 0.001

Abbreviations: US, ultrasound; CT, computed tomography.

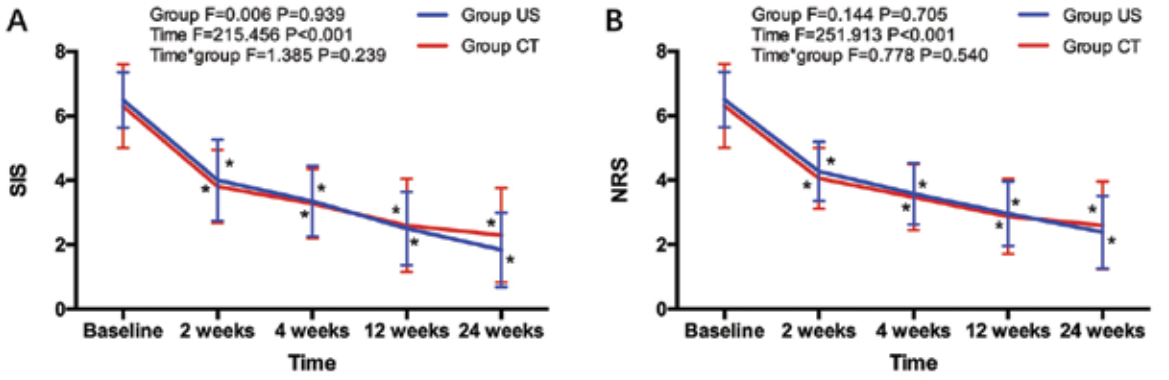

Fig. 5. *Fig. 5. NRS-11 score (A) and SIS (B) of the 2 groups before and after treatment. No significant interaction between follow-up time and group was found in the NRS-11 score (F = 1.385, P = 0.239) or SIS (F = 0.778, P = 0.540). Furthermore, no obvious between-group difference was found in either the NRS-11 score (F = 0.006, P = 0.969) or SIS (F = 0.144, P = 0.705). The NRS-11 score and SIS significantly decreased after treatment at each follow-up time point (P < 0.05). NRS-11, Numeric Rating Scale; SIS, sleep interference score.*

anatomical locations described above, CT-guided PRF on DRGs relies on the localization of only bony anatomical structures without the need for clear DRG imaging (11,17). The puncture target is set at the dorsal point of IVF at the upper one-third level, which is also the medial surface of the superior articular process. The puncture path is often set from anterolateral to posteromedial (11,17). Therefore, the possibility of the DRG puncture guided by US should not be negated due to the inability to visualize the DRGs. As the bony structures of the cervical spine are superficial and can be located well with US, it is possible for US to replace CT in guiding DRG PRF.

In our study, we first present a method for US-guided transforaminal PRF on cervical DRGs, for which the following operational details should be noted. 1) The cervical IVF was scanned on the short axis toward the caudal side. On US, the view at which the TP or the posterior tubercle of the TP of the upper segment just disappeared was considered located at the upper level of the IVF, where the puncture was subsequently conducted. Because the TP of the cervical spine is tilted outward and downward, the axis view determined with the above method may identify the lower part of the IVF in a few patients. To fix this error, adjustments can be made by slightly withdrawing and rotating the prebent needle tip cephalad or caudally and reinserting it. 2) When puncturing with the out-of-plane technique, the needle should be inserted on the caudal side of the probe, with an automatically generated, slight cephalic angle; this can also compensate for the above errors to a certain extent. 3) On horizontal view, the needle is also inserted from anterolateral to posteromedial as designed in the CT-guided method. After reaching the front edge of the FJ, the needle can then be inserted into the IVF against the anteromedial edge of the FJ using the prebent needle tip. The trajectory against the FJ may reduce the damage to the vertebral vessels. 4) When entering the IVP, the needle tip cannot be imaged clearly. Considering that the depth of the IVF is approximately 5-6 mm (width of the pedicle) (18,19), the maximum penetration depth along the anteromedial edge was set as approximately 5 mm to reduce the risk of spinal cord injury.

In the current study, all procedures were conducted successfully with guidance of US, which was comparable to guidance of CT. In both groups, pain intensity significantly decreased after PRF treatment, leading to improvement in sleep and oral medication usage. As previously reported, CT- or fluoroscopy-guided DRG PRF has shown good therapeutic effects on various types of cervical radicular pain, including PHN (11,13,20). It is thought that DRG PRF relieves neuropathic pain through the modulation of chemokine expression, central nerve inflammation, and glial cell dysfunction (21-24). Our results on the analgesic effect of DRG PRF are consistent with existing clinical evidence. Although the analgesic effect was comparable between the 2 groups, US guidance significantly reduced the radiation exposure and shortened the operation time without increasing surgical risk. Considering the above advantages, US guidance may be an alternative to CT guidance in cervical DRG PRF for PHN treatment.

Our innovative method was different from other US-guided approaches for cervical nerve root PRF. Lee et al (8,9) reported the application of US-guided PRF in the treatment of refractory cervical radicular pain, but they targeted the extraforaminal nerve root, not the DRGs. Huang et al (10) reported a superior therapeutic effect of PRF on the DRGs than on the anterior branch of the spinal nerve. Therefore, although Lee et al's (8,9) method of US-guided PRF is safe and easy to perform, it is still not comparable to the CT-guided treatment. In our new method, the target was set as the DRGs in the IVF, the same as in the CT-guided method. The same RF targets may be the basis for comparable analgesic effects of our approach to CT guidance in PRF on cervical DRG for PHN treatment.

Limitations

This study had the following limitations: 1) The nonrandomized design and retrospective nature of the research produces selection bias; 2) US-guided operations require rich operational experience. All procedures in our study were conducted by one physician (YH) at a single center, which may have caused operator-related bias. In the future, prospective, randomized and controlled studies with operators from multiple centers should be conducted for further confirmation of our findings. The number of patients enrolled in the study should also be increased.

Conclusions

US-guided transforaminal DRG PRF is a safe and effective method for the treatment of cervical PHN. It is a reliable alternative option to the CT-guided procedure that produces substantial advantages in reducing radiation exposure and operation time.

References

1. Johnson RW, Rice AS. Clinical practice. Postherpetic neuralgia. *N Engl J Med* 2014; 371:1526-1533.
2. Drolet M, Brisson M, Levin MJ, et al. A prospective study of the herpes zoster severity of illness. *Clin J Pain* 2010; 26:656-666.
3. Harvey M, Prosser LA, Rose AM, Ortega-Sanchez IR, Harpaz R. Aggregate health and economic burden of herpes zoster in the United States: Illustrative example of a pain condition. *Pain* 2020; 161:361-368.
4. Watson PN. Postherpetic neuralgia. *BMJ Clin Evid* 2010; 2010:0905.
5. Dworkin RH, O'Connor AB, Kent J, et al. Interventional management of neuropathic pain: NeuPSIG recommendations. *Pain* 2013; 154:2249-2261.
6. 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.
7. 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.
8. Lee SH, Choi HH, Roh EY, Chang MC. Effectiveness of ultrasound-guided pulsed radiofrequency treatment in patients with refractory chronic cervical radicular pain. *Pain Physician* 2020; 23:E265-E272.
9. Lee SH, Choi HH, Chang MC. Comparison between ultrasound-guided monopolar and bipolar pulsed radiofrequency treatment for refractory chronic cervical radicular pain: A randomized trial. *J Back Musculoskelet Rehabil* 2022; 35:583-588.
10. 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.
11. Ma L, Yao M. Safety and efficacy of CT-guided pulsed radiofrequency combined with steroid and ozone injection-treated cervical 3-8 herpes zoster neuralgia using a posterior and upper quarter of the cervical foramina puncture approach. *J Pain Res* 2022; 15:23-32.
12. Yang S, Chang MC. Effect of bipolar pulsed radiofrequency on chronic cervical radicular pain refractory to monopolar pulsed radiofrequency. Ann Palliat Med 2020; 9:169-174.
13. Choi GS, Ahn SH, Cho YW, Lee DG. Long-term effect of pulsed radiofrequency on chronic cervical radicular pain refractory to repeated transforaminal epidural steroid injections. *Pain Med* 2012; 13:368-375.
14. Du X, Zhao W, Xu L, et al. Clinical observation of CT-guided intervertebral foramen puncture and radiofrequency thermocoagulation for the treatment of refractory PHN in the superior thoracic segment. *Pain Physician* 2022; 25:E767-E775.
15. Chang KV, Wu WT, Özçakar L. Ultrasound-guided interventions of the cervical spine and nerves. *Phys Med Rehabil Clin N Am* 2018; 29:93-103.
16. Kitamura K, Yamamoto M, Hirota Y, et al. Cervical nerve roots and the dural sheath: A histological study using human fetuses near term. *Anat Cell Biol* 2020; 53:451-459.
17. Lin H, Cao G, Yang Z, et al. Computed tomography-guided radiofrequency ablation of the cervical dorsal root ganglia in 27 patients with cervical and occipital postherpetic neuralgia. *Med Sci Monit* 2021; 27:e932612.
18. Uğur HC, Attar A, Uz A, et al. Surgical anatomic evaluation of the cervical pedicle and adjacent neural structures. *Neurosurgery* 2000; 47:1162-1168; discussion 1168-1169.
19. Chen X, Yang Q, Kalisi K, et al. Comparison of morphometric measurements of traditional posterior cervical screw and paravertebral foramen screw in Chinese population. *Spine (Phila Pa 1976)* 2021; 46:E443-E449.
20. Choi GS, Ahn SH, Cho YW, Lee DK. Short-Term effects of pulsed radiofrequency on chronic refractory cervical radicular pain. *Ann Rehabil Med* 2011; 35:826-832.
21. Park HW, Ahn SH, Kim SJ, et al. Changes in spinal cord expression of fractalkine and its receptor in a rat model of disc herniation by autologous nucleus pulposus. *Spine (Phila Pa 1976)* 2011; 36:E753-E760.
22. Das B, Conroy M, Moore D, Lysaght J, Mccrory C. Human dorsal root ganglion pulsed radiofrequency treatment modulates cerebrospinal fluid lymphocytes and neuroinflammatory markers in chronic radicular pain. *Brain Behav Immun* 2018; 70:157-165.
23. 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 β-catenin in chronic constriction injury rats. *Reg Anesth Pain Med* 2019; 44:742-746.
24. 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.