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Clinical Research Article

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Evaluation of the efficacy of unipolar and bipolar spinal dorsal root ganglion radiofrequency thermocoagulation in the treatment of postherpetic neuralgia

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Background: Different views have been proposed on the radiofrequency treatment modes and parameters of radiofrequency thermocoagulation of the spinal dorsal root ganglion for the treatment of postherpetic neuralgia (PHN). It is urgent to identify a more effective therapy for patients with PHN.
Methods: Patients who underwent radiofrequency thermocoagulation therapy for PHN were retrospectively reviewed and were divided into a radiofrequency thermocoagulation (CRF) and double neddles radiofrequency thermocoagulation (DCRF). The pain scores (numerical rating scale, NRS) were evaluated at the following time points: before the operation, 1 day, 3 months, 6 months, 1 year, and 2 years after operation. The incidence of complications and the degree of pain relief were evaluated. The *in vitro* ovalbumin experiment was used to indicate the effects of radiofrequency thermocoagulation.
Results: Compared with the preoperative NRS scores, the postoperative NRS scores decreased significantly; the NRS scores of the DCRF group was lower than that of the CRF group at all time points from 6 months to 2 years following the operation. The total effective rate of the DCRF group was significantly higher than that of the CRF group at 2 years following the operation. The incidence of numbness in the DCRF group was higher than that noted in the CRF group. The ovalbumin experiments *in vitro* indicated that the effects of radiofrequency thermocoagulation were optimal when the distance between the two needles was 5 mm.
Conclusions: DCRF with a 5 mm spacing exhibits a longer duration and higher effective rate in the treatment of PHN and is worth promoting.

Key Words: Chronic Pain; Electrocoagulation; Ganglia, Spinal; Herpes Zoster; In Vitro Techniques; Incidence; Needles; Neuralgia, Postherpetic; Ovalbumin; Pain Management; Radiofrequency Therapy; Spine.

INTRODUCTION

Herpes zoster is caused by the varicella-zoster virus, which infects the dorsal root ganglion (DRG) or cerebral nerve [1,2]. It is common in middle-aged and elderly people with impaired immunity. The main risk factors include woman gender, family history, and autoimmune diseases [3]. Although the herpes zoster vaccine has been widely used in certain countries [2,4,5], recent studies have shown that the prevalence rate of this virus continues to rise and that

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the age of the disease exhibits a downward trend [6,7]. When the cellular immune function of the host is low, the virus is activated again, causing inflammation and necrosis of the ganglia. Concomitantly, the activated virus can move along the peripheral nerve fibers to the skin to develop herpes, which is associated with pain [1]. Its severity usually depends on the presence of pain before the formation of the rash, the severity of the rash, sex, age, and impaired immune function [8-10].

Radiofrequency therapy of the spinal DRG is considered to be one of the most effective intervention methods for the treatment of postherpetic neuralgia (PHN) due to its small trauma, effective control, high safety, optimal accuracy, and reliable repeatability. This method has been widely used previously [11,12]. Pulsed radio frequency (PRF) is considered to regulate only the nerve and therefore causes almost no nerve damage [13]. Radiofrequency thermocoagulation is considered to cause nerve damage, resulting in side effects, such as hypoesthesia and decreased muscle strength [13]. However, the effective rate of PRF alone in the clinical treatment is low and its effective time is short [14].

Unipolar radiofrequency means that a single radio frequency puncture needle reaches the operation site, and the other electrode is attached to the body surface, thus forming a large, closed loop. When the radio frequency needle encounters the impedance of human tissue, it produces heat energy and achieves the effect of radiofrequency thermocoagulation. Bipolar radio frequency means that two radio frequency puncture needles reach the operation site and form a small, closed loop in the operation area. According to the impedance of human tissue between the two needles, heat energy is generated to achieve the effect of radiofrequency thermocoagulation. The main difference between the two patterns is that in the unipolar radiofrequency the current passes through the skin tissue where it is lost mainly in the form of radiation heating; while in the bipolar radiofrequency, the current is relatively more concentrated between the needles in the form of linear heating.

Therefore, it is urgent to seek a newer and more effective radiofrequency therapy for patients with PHN. The purpose of this study was to compare the effective rate, effective maintenance time and complications of bipolar and unipolar radiofrequency thermocoagulation of the spinal DRG in the treatment of PHN, so as to guide clinical practice.

MATERIALS AND METHODS

1. Clinical data

A total of 60 patients that underwent radiofrequency thermocoagulation therapy for PHN in the Pain Department of the Affiliated Houspital of Jiaxing University from January 2013 to November 2017 were retrospectively reviewed. Among them, 34 males and 26 females were present, aged from 49 to 93 years, with an average age of 72.5 ± 9.4 years. Radiofrequency thermocoagulation of the spinal DRG was performed by the same doctor with sufficient clinical pain management experience. All patients signed an informed consent form, and our study was conducted in accordance with the Declaration of Helsinki. Moreover, this study was examined and approved by the Ethics Committee of the First Hospital of Jiaxing (LS-2010-119).

2. Inclusion and exclusion criteria

1) The following inclusion criteria were used: (1) The subjects met the clinical diagnostic criteria of post-herpetic neuralgia; (2) The age of the subjects was higher than and/or equal to 18 years; (3) The diseased region of the herpes zoster only involved the unilateral trunk nerve, that is, the thoracic 1-12 nerve; (4) The subjects' numerical rating scale (NRS) score was higher than 4 when they were admitted to the hospital; (5) The course of the herpes zoster disease was ≥ 3 months; (6) The subjects underwent radiofrequency thermocoagulation (CRF) or double neddles radiofrequency thermocoagulation (DCRF); (7) All the subjects agreed and received follow-up by telephone.

2) The following exclusion criteria were used: (1) Patients with a history of malignant tumors; (2) Patients that had received immunosuppressive therapy; (3) Uncooperative patients with mental illness, mental retardation, or confusion; (4) Patients with severe liver, kidney, heart, and lung diseases; (5) Patients that had received a history of invasive treatment prior to operation; (6) Patients that withdrew from the operation due to lack of cooperation with the surgeon during the procedure; (7) Patients that had received other invasive treatment or other surgeries following the operation; (8) Patients with herpes zoster at the lumbar segmental level; (9) Patients that lacked basic information and could not be followed up following the operation.

The patients were selected according to the inclusion and exclusion criteria and all patients were divided into the bipolar group (DCRF group, n = 24) and the unipolar group (CRF group, n = 36) by reviewing their intraoperative imaging data.

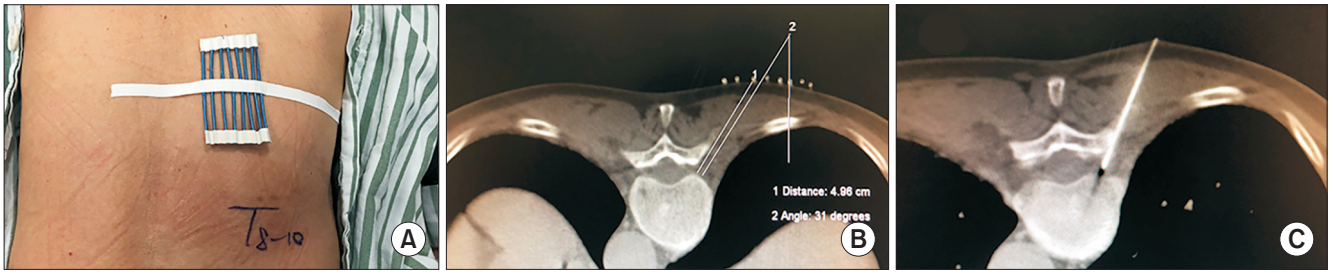

Fig. 1. Surgical procedure of radiofrequency thermocoagulation. (A) Place positioning mark. (B) Design the puncture route. (C) Puncture to predetermined position.

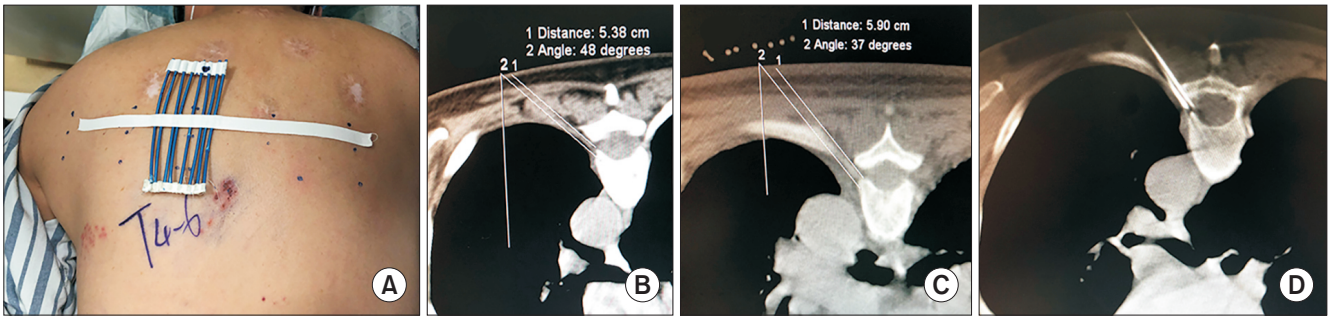

Fig. 2. Surgical procedure of double neddles radiofrequency thermocoagulation. (A) Place positioning mark. (B, C) Design the puncture route. (D) Puncture to predetermined position.

3. Surgical methods

The patients entered the computed tomography (CT) treatment room and laid in a prone position on the treatment bed. A positioning grid was placed at the patient's preoperative mark and fixed with adhesive tape (**Fig. 1A, 2A**). Then, with the help of CT software, the puncture target was pre-designed, and the puncture depth and angle were calculated (**Fig. 1B, 2B, 2C**). After that, local infiltration of anesthesia was performed with 2% lidocaine (Hubei Tianyao Pharmaceutical Co., Ltd., Xiangyang, Hubei, China) at a volume of 0.5 mL. Under the guidance of CT (Siemens SomatomEmotion system - Siemens HealthCare, Malvern, PA), the puncture needle (Inomed Health Ltd, Hopwood Lane, Halifax, Germany) was used to create a puncture following the preset angle and the path to the specified position. In the CRF group, a single puncture needle was used to puncture a pre-designed target (**Fig. 1C**). In the DCRF group, two puncture needles were inserted from different angles towards the pre-designed target (**Fig. 2D**).

Following completion of the initial puncture, a CT scan was performed again to confirm the needle placement. Further adjustment of the direction of the needle was performed to the outlet of the nerve root at the ventral superior edge of the intervertebral foramen in the affected area. Then the radiofrequency (RF) device (Baylis Medical Company Inc., Toronto, ON, Canada) was connected and the following tests were performed: (1) The sensory stimulation was carried out under 50 Hz and 0.1 ms and the current threshold inducing abnormal pain sensation was observed to judge the accuracy of the puncture site and record the current (mA) at this time. (2) The motor stimulation was carried out under 2 Hz and 1.0 ms in order to observe the current threshold that could make the muscle beat in the area, which was innervated by the DRG, and to record the current (mA) at the same time. Subsequently, the tip position was adjusted again until the movement and sensation areas were completely covered, without affecting the normal area. Finally, the radio frequency parameters were set. The parameters of the patients in the CRF and DCRF groups were both 95°C and 300 seconds [15,16]. During the operation, patients didn't receive any additional blocks, the reaction of the patients was observed, and the incidence of the complications was assessed. A record from all the patients was made.

4. Observation and follow-up

The preoperative data included age, sex, pain course, pain location, and preoperative pain NRS score [17], as well as the NRS score 1 day following the operation. The postoperative data included the NRS score, pain relief, operative complications, and side effects at 3 months, 6 months, 1 year, and 2 years, all of which were evaluated by telephone

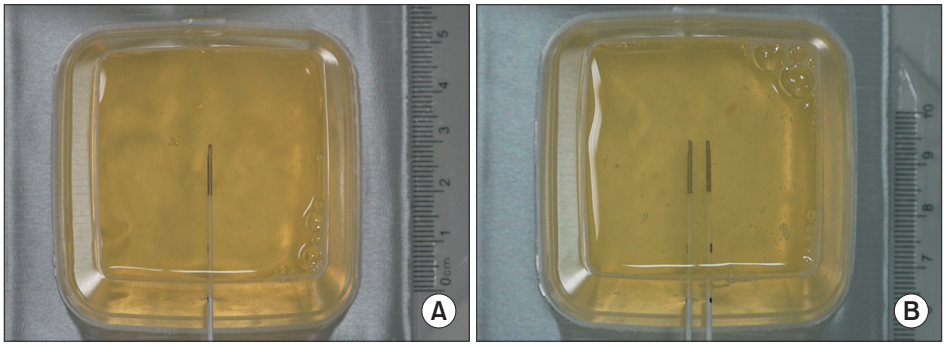

Fig. 3. The active tip of the needle was wrapped by ovalbumin in CRF group (A) and DCRF (B). CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation.

follow-up. The medical staff in the non-operation group followed up the patients by telephone.

Pain was measured with a pain NRS score, ranging from 0 (no pain) to 10 (the most unbearable pain). The degree of pain relief was evaluated according to the curative effect of the patient 2 years following the operation. The curative effect was divided into 4 grades (a, b, c, d) according to the ratio of (the difference between preoperative NRS and postoperative NRS scores)/preoperative NRS score × 100%. The following grades were defined as follows [18,19]: (a) complete relief (CR), pain relief more than 75%; (b) partial relief (PR), pain relief 50 to 75%; (c) mild relief (MR), pain relief 25 to 50%; and (d) unresponsive relief, pain relief less than 25%. The total effective rate (%) was defined by the following equation: [(CR + PR + MR)/n] × 100% and the marked rate (%) = [(CR + PR)/n] × 100%.

In addition, the incidence of the complications, including short-term pneumothorax, such as hematoma, infection and spinal cord injury, and the long-term complications, such as numbness in the corresponding innervated areas and abdominal dilatation were recorded. Moreover, the incidence of numbness and abdominal distension was calculated in the affected area.

5. Power of the study

The analysis of the clinical data of the patients suggested that the marked rate of 2 years after the surgery was 53.33% in the CRF group and 94.74% in the DCRF group. The power of the study was estimated at 90%, with a 95% confidence interval and a 2-sided type I error of 5%. Therefore, the present study required 19 patients in each treatment arm. To compensate for patients who may have been lost to follow-up, 60 patients were reviewed for the two groups. Among them, 36 patients were included in the CRF group and 24 patients in the DCRF group.

6. Ovalbumin *in vitro* test

In the *in vitro* ovalbumin test, the puncture needle and radio frequency electrode used in the clinic were completely immersed in the culture medium, so that the active tip of the needle was wrapped by ovalbumin (**Fig. 3**). In the CRF group and DCRF group, the electrodes were placed in parallel and connected to the output socket of the radio frequency generator. However, in the DCRF group, the distance between the two electrodes was gradually adjusted according to the experimental requirements. When the radio frequency generator was operating, the tip temperature was kept at the target temperature of 95°C. The image of the thermal coagulation of ovalbumin was obtained directly on the side and directly above the active tip of the puncture needle. A measuring ruler was placed for reference (**Subsidiary Video 1, 2**). In the DCRF group, the distance between the two electrodes was set at 2, 3, 4, 5, 6, 7, and 8 mm. The length, width, height, and final weight of the thermal coagulation in the CRF and DCRF groups were recorded by manual measurement of thermal coagulation at different intervals and different time points (**Fig. 4**). Therefore, the effects of the bipolar distance and heating time on the size of coagulation were analyzed further.

7. Statistical analysis

The SPSS ver. 25.0 (IBM Co., Armonk, NY) was used for statistical analysis. The frequency was used as the main variable for the classification of the groups. The normality of the distribution was tested by the Kolmogorov–Smirnov test. The variables of the non-normal distribution were presented by the median (quartile spacing) and were compared by the Mann–Whitney *U*-test. The variables of the normal distribution were analyzed and compared by one-way analysis of variance, and the values were expressed as mean ± standard deviation. Multiple comparisons were made using the Bonferroni correction and after adjusting the significance, a corrected α of 0.0033 was obtained. The analysis was performed using the Pearson's chi-squared on the pain relief degree. A bilateral $P < 0.05$ indicated that the differences were statistically significant.

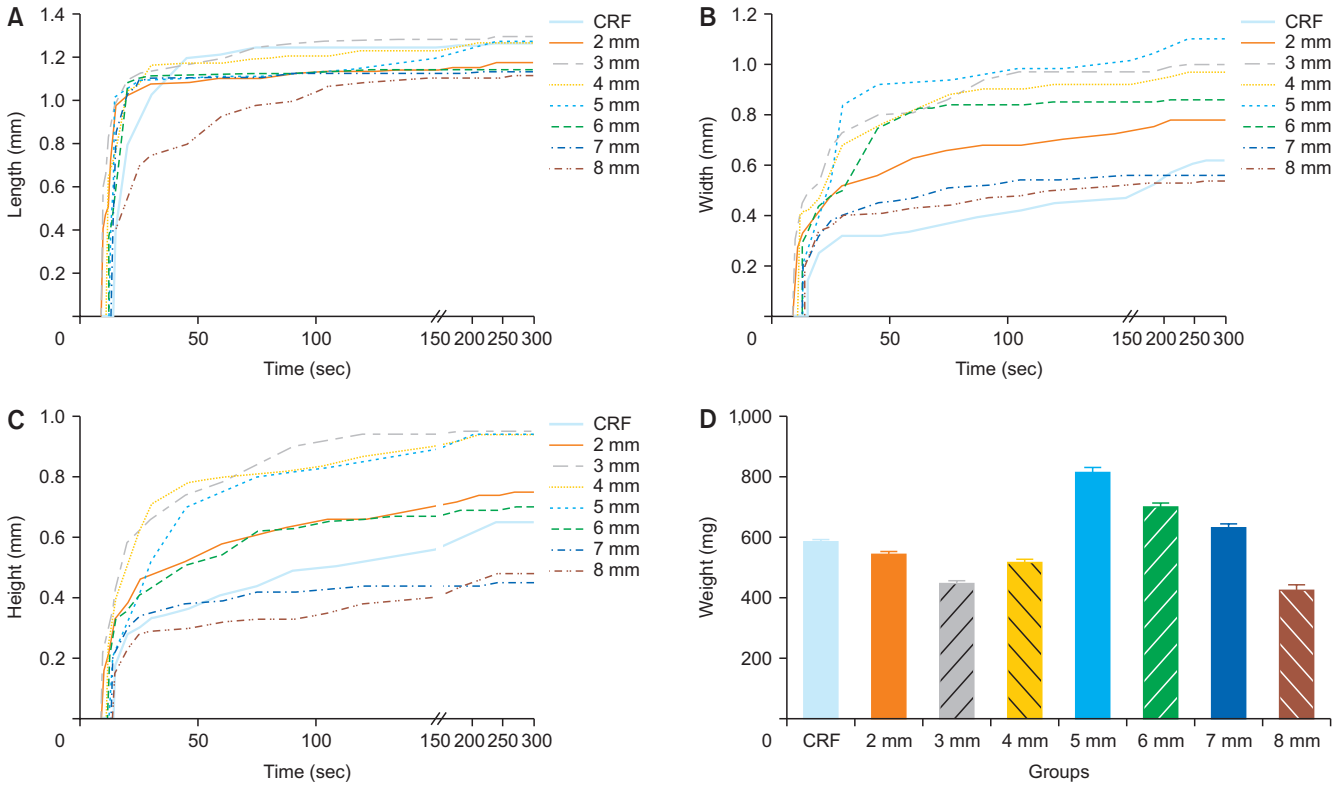

Fig. 4. The length (A), width (B), height (C) and weight (D) of coagulum in each group. CRF: radiofrequency thermocoagulation.

RESULTS

1. Analysis of clinical characteristics of patients

The comparison of the basic demographic and clinical data of the two groups prior to the operation indicated no significant differences between the two groups in terms of sex, age, course of pain, location of pain and, NRS score prior to the operation (**Table 1**).

Table 1. Clinical characteristics of patients

Variable	CRF	DCRF	*P* value
Age	70.8 ± 10.2	72.7 ± 8.0	0.147
Sex			0.933
Male	17	11	
Female	13	8	
Incidence of painful area (%)			
T1	1	0	
T2	3	4	
T3	5	6	
T4	5	7	
T5	11	4	
T6	14	4	
T7	17	3	
T8	14	6	
T9	8	3	
T10	5	7	
T11	3	6	
T12	2	6	
The length of painful time (mo)	10.7 ± 17.5	8.6 ± 6.8	0.228
NRS score before surgery	5.5 ± 1.0	5.3 ± 0.7	0.083

Values are presented as mean ± standard deviation or number only.
CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation, NRS: numerical rating scale.

2. Assessment of the success of surgical puncture

The results of the electrophysiological test indicated that the sensory test of the CRF group was 0.39 ± 0.12 (mA), whereas the DCRF group was 0.36 ± 0.11 (mA), $P = 0.390$; The exercise test of the CRF group was 0.41 ± 0.14 (mA) and the DCRF group was 0.34 ± 0.11 (mA), $P = 0.071$. The difference was not significant (**Table 2**).

3. Pain scores (NRS)

1) Comparative analysis of NRS scores prior to and following operation in the CRF group

The preoperative NRS scores and the postoperative scores at 1 day, 3 months, 6 months, 1 year, and 2 years in the CRF group are shown in **Table 3**. The postoperative NRS score at each time point was lower than that prior to the operation. The difference was significant (**Table 3**).

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2) Comparative analysis of NRS scores prior to and following operation in the DCRF group

The preoperative NRS scores, and scores at postoperative day 1, 3 months, 6 months, 1 year, and 2 years in the DCRF group are shown in **Table 3**. The postoperative NRS score at each time point was lower than that prior to the operation and the difference was statistically significant (**Table 3**).

Table 2. Electrophysiological results of the CRF group and the DCRF group

Group	Sensory test (mA)	Exercise test (mA)
CRF	0.39 ± 0.12	0.41 ± 0.14
DCRF	0.36 ± 0.11	0.34 ± 0.11
P value	0.39	0.07

Values are presented as mean ± standard deviation.
CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation.

3) Comparative analysis of NRS scores prior to and following operation between the CRF and DCRF groups

No significant differences were noted in the NRS score between the DCRF and CRF groups prior to the operation and at day 1 and 3 months following the operation. However, at 6 months following the operation, the NRS score of the DCRF group was significantly lower than that of the CRF group. This effect was noted for the first time. Subsequently, at all the time points from 6 months to 2 years following the operation, the NRS score of the DCRF group was significantly lower than that of the CRF group (**Table 3**).

4. Pain relief degree

From the follow-up, at 2 years following the operation, the marked rate of the CRF group (53.33%) was significantly lower than that of the DCRF group (94.74%). This was our primary outcome. No significant differences were noted in the marked rate at other time points. The total effective rate of the CRF and DCRF groups at each time point fol-

Table 3. Analysis of numerical rating scale before and after surgery in different treatment groups

Group	Before surgery	Time after surgery				
		1 day	3 mo	6 mo	1 yr	2 yr
Comparison within groups						
CRF	5.3 ± 0.7	1.8 ± 0.6	2.5 ± 1.3	2.6 ± 1.3	2.7 ± 1.2	2.6 ± 1.1
P value		0.001	0.001	0.001	0.001	0.001
DCRF	5.5 ± 1.0	2.0 ± 0.5	2.2 ± 0.8	2.1 ± 0.9	2.2 ± 1.0	2.0 ± 0.8
P value		0.001	0.001	0.001	0.001	0.001
Comparison between groups						
CRF	5.3 ± 0.7	1.8 ± 0.6	2.5 ± 1.3	2.6 ± 1.3	2.7 ± 1.2	2.6 ± 1.1
DCRF	5.5 ± 1.0	2.0 ± 0.5	2.2 ± 0.8	2.1 ± 0.9	2.12 ± 1.0	2.0 ± 0.8
P value	0.401	0.522	0.254	0.024	0.041	0.050

Values are presented as mean ± standard deviation.
CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation.

Table 4. Analysis of pain relief degree

Degree	Postoperative 3 mo		Postoperative 6 mo		Postoperative 1 yr		Postoperative 2 yr	
	CRF	DCRF	CRF	DCRF	CRF	DCRF	CRF	DCRF
CR	8	4	7	6	4	6	3	7
PR	10	12	11	10	15	10	13	11
MR	9	3	8	3	8	2	10	1
NR	3	0	4	0	3	1	4	0
The marked rate (%)	60.00	84.21	60.00	84.21	63.33	84.21	53.33	94.74
P value	0.073		0.073		0.115		0.002	
The total effective rate (%)	90.00	100	86.67	100	90.00	94.74	86.67	100
P value	0.273		0.148		0.999		0.148	

The marked rate (%) = [(CR + PR)/n] × 100%. The total effective rate (%) = [(CR + PR + MR)/n] × 100%.
CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation, CR: complete relief, PR: partial relief, MR: mild relief, NR: unresponsive relief.

Table 5. Comparisons of long-term postoperative complications between CRF and DCRF

Complication	Postoperative 3 mo		Postoperative 6 mo		Postoperative 1 yr		Postoperative 2 yr	
	CRF	DCRF	CRF	DCRF	CRF	DCRF	CRF	DCRF
Numbness								
Yes	19	17	18	17	16	16	8	13
No	11	2	12	2	14	3	22	6
Incidence rate (%)	63.33	89.48	60.00	89.48	53.33	84.21	26.67	68.42
P value	0.043		0.026		0.027		0.004	
Abdominal distension								
Yes	21	12	16	9	13	7	9	6
No	9	7	14	10	17	12	21	13
Incidence rate (%)	70.00	63.33	53.33	47.37	43.33	36.84	30.00	31.58
P value	0.619		0.684		0.652		0.907	

Significant differences were noted in the incidence of numbness at each time point between the two groups, $P_{(3month)} = 0.043$, $P_{(6month)} = 0.026$, $P_{(1\ year)} = 0.027$, $P_{(2\ year)} = 0.004$. Whereas no significant difference was noted in the incidence of abdominal distension between the two groups, $P_{(3month)} = 0.619$, $P_{(6month)} = 0.684$, $P_{(1\ year)} = 0.652$, $P_{(2\ year)} = 0.907$.
CRF: radiofrequency thermocoagulation, DCRF: double neddles radiofrequency thermocoagulation.

lowing the operation is shown in **Table 4**. No significant differences were noted between the two groups (**Table 4**).

5. Operative complications

The main operative complications were pneumothorax, spinal cord injury, hematoma, infection, numbness, and abdominal distension. The review of the disease history of the patients demonstrated no intraoperative complications in the aforementioned two groups.

No short-term postoperative complications were noted in both groups. However, observation of long-term postoperative complications demonstrated that all patients exhibited varying degrees of skin numbness in the corresponding innervation area, whereas certain patients had abdominal distension. No other serious or permanent complications and side effects were observed during the follow-up period. The statistical results of the incidence of long-term postoperative complications are shown in **Table 5**. Significant differences were noted in the incidence of numbness at each time point between the two groups, whereas no significant difference was noted in the incidence of abdominal distension between the two groups (**Table 5**).

6. Analysis of ovalbumin *in vitro* test

1) The length, width, and height of coagulation at different time points during the ovalbumin *in vitro* test in each group were measured as shown in **Fig. 4A-C**. The results of the length measurement indicated no difference in the final length of each group, while the width and height of each group indicated that the width and height of the 5 mm group was the widest and highest (**Fig. 4A-C**).

2) The final coagulant weight of each group in the ovalbumin *in vitro* test is shown in **Fig. 4D**. When the distance of the two electrodes was 5 mm, the thermal solidification effect was the best and the weight of the coagulum was the highest, reaching 818.57 ± 26.02 mg (**Fig. 4D**).

Based on the above experimental results of the ovalbumin *in vitro* test, it is inferred that when the distance of the two electrodes was 5 mm, the effects of the radiofrequency thermocoagulation were optimal. This finding has instructive significance for radiofrequency thermocoagulation of the bipolar spinal DRG in the treatment of PHN.

DISCUSSION

In recent years, radiofrequency therapy has been widely recognized due to its high success rate, optimal efficacy, high safety, and high patient satisfaction. It has gradually become one of the mainstream methods for the treatment of neuralgia. Previous research studies on its mechanism have been carried out gradually.

Previous studies have shown that PRF can regulate the synaptic plasticity of nerve cells through *in vivo* experiments and have speculated that the analgesic effect of PRF may be achieved through neuro-regulation [13]. CRF produces high-frequency current, induces ion oscillation in tissues, heats up tissues, increases local temperature, and inactivates hypersensitive nerve endings caused by pathological changes through thermal effect, so as to achieve the purpose of the treatment. At present, it is believed that the analgesic effect of PRF may be due to the temporary blocking of neural signals by neurons through the nerve conduction pathway, while the analgesic effect of CRF may be through the permanent blocking of neural signals through the neural pathway [13].

At present, in the clinic, radio frequency current is used

to treat neuralgia [14] and has been used extensively, such as in cases of paroxysmal collective headache [20], primary trigeminal neuralgia [15,21-23], glossopharyngeal neuralgia [24], PHN [11,12,25,26], chronic knee pain [27], and postherpetic trigeminal neuralgia [28]. In addition, certain studies on the use of different radio frequency modes for the treatment of neuralgia have been carried out consecutively. Previous studies have shown that the effect of simple pulsed radiofrequency is not successful, whereas the therapeutic effect of pulsed radiofrequency combined with radiofrequency thermocoagulation is suitable for its clinical use [22,23]. In the comparative study of unipolar and bipolar groups, it has been found that the bipolar group exhibited more advantages in pain relief and functional recovery [15,27].

In the clinical treatment of PHN, discussion and research on unipolar and bipolar radiofrequency have not been reported. In the present study, an electrophysiological test was used to evaluate whether the puncture was in the correct place for clinical applications. The data demonstrated that when the electrophysiological test results were within 1.0 mA, the puncture needle was close to the target ganglion, suggesting that the puncture was in the correct place.

Moreover, the incidence of numbness in the DCRF group was higher than that in the CRF group at each time point. It is interesting to note that certain patients had abdominal distension following the operation. Therefore, we conducted follow-up statistics on this initial result. The results indicated no significant differences in the incidence of abdominal distension between the two groups. However, the association between this phenomenon and the procedure's curative effects requires further investigation.

Previous studies have suggested that the extension of the time of radiofrequency exposure is not an effective method for the treatment of neuropathic pain and excessive exposure is associated with increased neuronal damage [13,29]. In order to assess the optimal thermal coagulation effect in the bipolar procedure more clearly, we explored the radio frequency duration and bipolar distance in the ovalbumin *in vitro* test [30]. The *in vitro* ovalbumin model is often used to simulate the internal environment of the human body [15,31]. The results of the ovalbumin *in vitro* test indicated a difference in the effects of radiofrequency thermocoagulation between the bipolar and unipolar groups. When the distance of the two electrodes was 5 mm, the effects of the radio frequency thermocoagulation was optimal. It is even more surprising that when the bipolar radio frequency reached approximately 120 seconds, the coagulation volume of ovalbumin remained constant with time. It is uncertain whether the RF time can be reduced to 120 seconds for the patients in a clinical setting.

Through the above research, it was found that if the radio frequency time is prolonged as much as possible, which means increasing the degree or extent of damage, there would not be more complications or more harm to patients. In the future, in order to achieve better clinical treatment results, we will try to further increase the scope of surgical damage, in order to achieve better clinical treatment results. In the end, we want to do a single treatment which is permanently effective.

The present study exhibits certain shortcomings. First of all, it is a single-center study with relatively limited clinical samples. Secondly, we followed-up the subjects to a maximum time duration of 2 years after the operation. Therefore, we may need to increase the follow-up time to further clarify the curative effect, such as at 3 years and 5 years after the operation. Furthermore, in the ovalbumin *in vitro* test, we did not further explore the spatial position and temperature gradient of the electrode, such as crossover, tip adjacency, or tail adjacency in the three-dimensional space. The aforementioned shortcomings will be improved and optimized in future research.

To sum up, radiofrequency thermocoagulation of the bipolar DRG exhibited a longer duration in the treatment of PHN and the effects of radiofrequency thermocoagulation were optimal when the distance between the two electrodes was 5 mm, which is helpful in guiding clinical work and providing more effective treatment for patients.

In summary, bipolar spinal DRG radiofrequency thermocoagulation has a long duration and high rate of effectiveness in the treatment of PHN. DCRF with a 5 mm spacing exhibits a longer duration and higher rate of effectiveness in the treatment of PHN. Therefore, it may be a new choice for the clinical treatment of PHN.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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