Retrospective Study

Clinical Observation of CT-Guided Intervertebral Foramen Puncture and Radiofrequency Thermocoagulation for the Treatment of Refractory PHN in the Superior Thoracic Segment

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Background: Post-herpetic neuralgia (PHN) is a typical neuropathic pain. Conventional oral analgesics and nerve block therapy can only obtain temporary analgesia in many cases. This study summarized the clinical effect of CT-Guided intervertebral foramen puncture and radiofrequency thermocoagulation through the superior margin of costotransverse joint for the treatment of refractory PHN in the superior thoracic segment.

Objectives: To observe the efficacy of CT-Guided intervertebral foramen puncture and radiofrequency thermocoagulation (RFT) treatment of refractory PHN in the T1 ~ T3 spinal innervation area.

Study Design: A retrospective, observational study.

Setting: Pain department, Jiaxing and Hangzhou, China.

Methods: Thirty-six patients with intractable superior thoracic PHN were admitted to the Pain Department. After the positioning image of CT was taken by prone, the upper thoracic segment was scanned in axial position with the layer thickness of 3 mm of spinal model.The puncture path was designed by selecting the slice of the foramen and costotransverse joint from the obtained images. The needle was inserted to the corresponding foramen. After confirmation by high and low frequency current stimulation tests, the RFT was performed at 90°C for 180s. A numeric rating scale (NRS) for pain was recorded before surgery, 2 hours, 1 week, 4 weeks and 8 weeks after surgery and the mental state was assessed with the SF-36 clinical questionnaire before surgery, 4 weeks and 8 weeks after surgery.

Results: Following RFT intervention the measured pain NRS significantly decreased after 2 hours, 1 week, 4 weeks and 8 weeks ($P < 0.01$). SF-36 scores in all categories increased 4 and 8 weeks after the operation ($P < 0.01$). No serious adverse effects were reported during the study period and no hypoxemia was found under intraoperative nasal catheter oxygen inhalation.

Limitations: Limitations of this study include the small sample size, and nonrandomized retrospective design.

Conclusion: CT-Guided intervertebral foramen puncture and RFT through the superior margin of the costotransverse joint can effectively improve refractory PHN in the superior thoracic segment with good safety.

Key words: Neuralgia; Post-herpetic; Electrocoagulation; Thermocoagulation; CT-Guided Neuralgia; prevention

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Post-herpetic neuralgia (PHN) is a typical neuropathic pain most commonly originating as a complication of herpes zoster (1). The current standard of care includes conventional oral analgesics and nerve block therapy (2) which only provide temporary pain relief. Pulsed radiofrequency modulation (PRF) can improve patient condition and keep longer pain relief. Previous research (3) has shown PRF applied to the dorsal root ganglia (DRG) to be efficacious for treatment-resistant cases of herpes zoster and PHN, and should be considered for pain control and prevention of PHN. However, severe and protracted pain is still found in some patients. Chronic pain can seriously affect the daily life of patients and their families. The treatment of PHN of the superior thoracic segment is relatively difficult to perform due to the structural characteristics of the small vertebral body. This study summarized the clinical effect of computed-tomography (CT)-guided intervertebral foramen puncture and radiofrequency thermocoagulation (RFT) for the treatment of refractory PHN in the superior thoracic segment from January 2018 to December 2020.

Methods

Study Design

A total of 36 patients (15 men and 21 women, aged 42-92 years) with refractory PHN in the superior thoracic segment received CT-guided trans-costotransverse joint puncture and RFT in the Pain Department, Zhejiang Hospital of Integrated Traditional Chinese and Western Medicine and affiliated Hospital of Jiaxing University, from January 2018 to December 2020. The medical history of herpes zoster was 8 ~ 24 months, with the original shingles rash located around the chest, back and armpit (T1-T3 spinal innervation segments) including 19 cases on the left and 17 cases on the right sides. Figure 1 shows representative patient case.

Inclusion Criteria

Inclusion criteria for this retrospective study include: ① presentation of upper thoracic postherpetic neuralgia; ② reported persistent pain with a numeric rate scale (NRS) value ≥ 5 following application of oral analgesics or nerve block therapy with PRF modulation; ③ description of pain as having a knife cutting or burning sensation which is predominantly intermittent and spontaneous; ④ provided consent for the treatment plan.

Exclusion Criteria

Exclusion criteria included ① skin damage and infection at the puncture site; ② bleeding and coagulation disorders; ③ severe cardiovascular and cerebrovascular diseases; ④ severe organ failure; ⑤ mental disorders and communication difficulties.

Preoperative Preparation

All procedure patients were asked to fast 4 to 6 h prior to the procedure. Upon being admitted to the hospital patient puncture contraindications were first excluded via chest CT. Electrocardiograph (ECG), blood biochemistry, as well as routine blood and coagulation function tests were then performed. Patients and their family were informed of the operating process, expected effect, and possible complications before consenting to be included in the observational study.

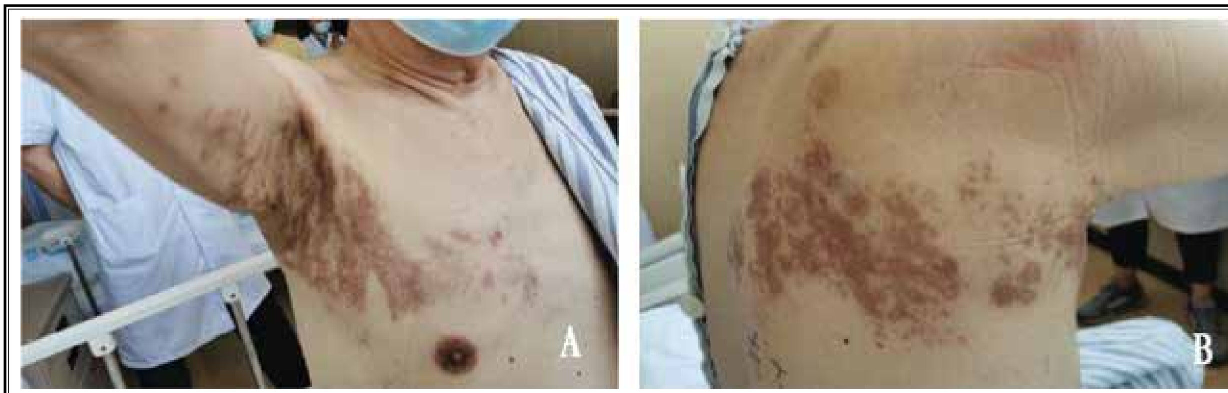

Fig. 1. *Lesions in patients with refractory superior thoracic postherpetic neuralgia before treatment.*

An intravenous indwelling trocar was then fixed to the patient. The PRF therapeutic apparatus (RFG-18 therapeutic apparatus produced by COSMAN, USA) was prepared along with the monitoring and rescue equipment and drugs. The vertebral foramen closest to the skin lesion and pain site was identified as the puncture therapeutic target.

Procedure

In preparing for the CT-guided intervention, the patient was placed prone on the CT table with a thin pillow under the chest with oxygen administered via a nasal catheter. Blood pressure, heart rate and pulse oxygen saturation were monitored continuously. A positioning grid was placed on the patient's back followed by a preliminary scan to position the upper thoracic segment of the spine in the scanner field-of-view. Then an axial scan of the upper thoracic spine was performed to plan the interventional procedure using acquisition and reconstruction settings optimized for the spine including a 3 mm slice thickness. From this planning scan the slice containing the intervertebral foramen with the target spinal nerve root was first localized and used to define the puncture path. Using a built-in ruler tool on the scanner, the puncture path was drawn to connect the upper 1/3 of the target intervertebral foramen to the upper edge of the corresponding costotransverse joint (Fig. 2). The puncture entry point was then defined as the intersection of the puncture path and the skin. This planning scan was also used to measure the required needle penetration depth, entry angle, and safety margin required for the first needle entry.

Local anesthesia was then performed on the skin of the puncture site with 1% lidocaine, and the corresponding puncture target was punctured with a radiofrequency needle along the determined puncture path. A sterilized 16-gauge piercing needle was first inserted at the puncture point. A smaller 22-gauge RF ablation needle was pre-bent based on the required geometry determined from the planning scan (4) and threaded through the initial piercing needle. A secondary CT scan was performed to ensure the RF needle insertion had not exceeded the predetermined safety margin and confirm the puncture angle was consistent with the set puncture path angle. Needle position adjustments were made if necessary and then the RF needle was further inserted until the tip reached each puncture

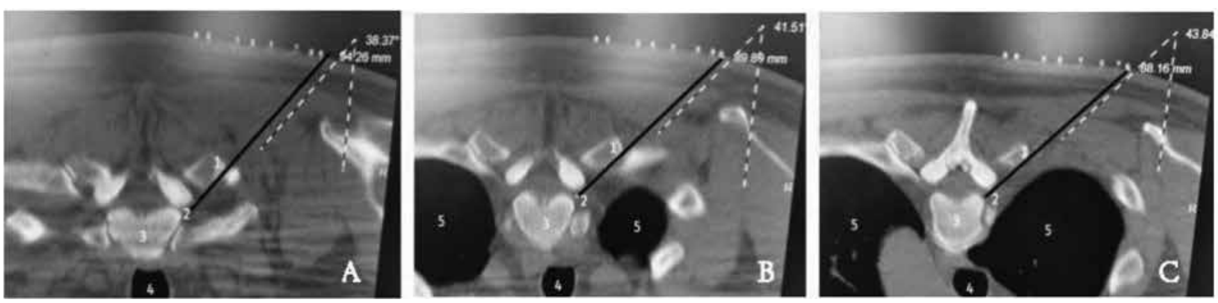

Fig. 2. *Planning diagram before puncture.*

Fig. 3. *Actual puncture diagram.*

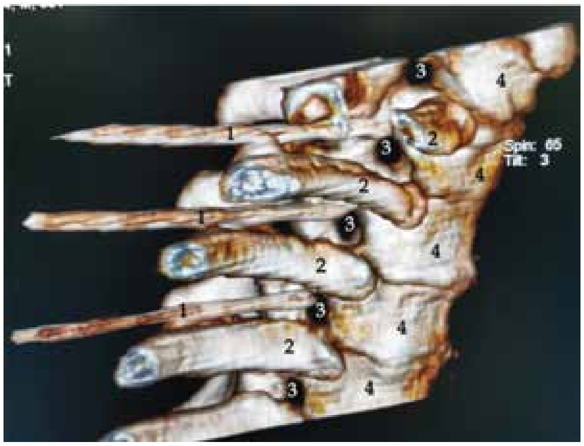

Fig. 4. *Three-dimensional CT reconstruction after successful puncture.*

target at the upper 1/3 of the intervertebral foramen and below the superior inferior pedicle notch (Fig. 3). Three-dimensional reconstruction was performed to confirm needle placement (Fig. 4). With the RF needle in place, a high frequency (50 Hz, 500 μs width, < 0.2 volts) sensory stimulation test and low frequency (2 Hz, 1000 μs width, < 0.5 volts) motor stimulation test were performed. Following intravenous injection of fentanyl (0.03 ~ 0.05 mg) RFT was performed at 90°C for 180s. This RFT procedure was repeated until numbness and loss of pain sensation in the original pain region following application of currents 0.1-0.5 mA (5). After treatment, another CT scan of the chest was performed and viewed in a lung display window to check for pneumothorax. Patient heart rate, blood pressure, pulse oxygen saturation and other vital signs were monitored continuously during treatment. If blood pressure exceeded 20% of the patient baseline or more than 180/100 mmHg, 12.5~50.0mg urapidil was administered to control hypertension. In case of pneumothorax, when lung compression exceeded 25%, closed thoracic drainage on the affected side would be performed. If lung compression was ≤ 25%, the patient would be return to the ward for monitoring and then treated accordingly.

Assessments

NRS: NRS score was evaluated before surgery as well as 1 week, 4 weeks, and 8 weeks post-surgery. An NRS score of 0 indicates no pain whereas 10 is unbearable pain with higher scores signifying more severe pain.

Survival Quality Scores, SF-36: The Medical Outcomes Study 36-Item Short Form (SF-36) (6) was used to assess health quality of life prior to surgery as well as 4 and 8 weeks after surgery. The survey included the following items: physical functioning (PF: 10 items), role physical (RP: 4 items), general health (GH: 5 items), mental health (MH, 5 items), vitality (VT, 4 items), role emotional (RE, 3 items), bodily pain (BP; 2 items) and social functioning (SF, 2 items). Scores for the 8 scales ranged from 0 (worst) to 100 (best) (7) with higher score indicating improved quality of life.

Clinical efficacy evaluation: NRS weighted value (NRS-WV) was used as the index to evaluate the efficacy(8), NRS-WV = (A-B)/A, where A is the preoperative NRS and B is the NRS score one week after surgery. Efficacy was classified into four types: NRS-WV ≥ 75% was classified as "cured", 50% ≤ NRS-WV < 75% was "significantly effective", 30% ≤ VAS-WV < 50% was "effective", and VAS-WV < 30% was "ineffective". The overall effective rate summarized the overall proportion of cases classified as "effective" or better, overall effective rate = ("cured" + "significantly effective" + "effective")/ (total number of observed cases).

Side effects: In the event of side effects to the procedure, every reported adverse event would be recorded, including type of event, time of onset, duration, and severity.

Ethical Statement

This study was reviewed and approved by the Ethics Committee of Zhejiang Chinese Medicine and Western Medicine Integrated Hospital and the First Hospital of Jiaxing (LS2018-141 and 2020 Expedited Review 57), and all subjects are given and signed the informed consent.

Statistical Analysis

The SPSS 23.0 statistical software was used for analysis. The results of NRS and SF-36 scores in all groups showed a positive distribution by the Shapiro-Wilk positive test, which was expressed as mean ± standard deviation, for mean value $\bar{x}$ and standard deviation s, and was compared with pre-intervention scores using a t-test. Enumeration data were expressed as frequency, and χ^2 test was used for comparison before and after treatment. $P < 0.05$ was considered statistically significant.

Results

Operation

All 36 patients were inserted the puncture needle to the target (the superior third of the foramen at T1, T2, and T3) according to the designed path under the guidance of CT localization, and stimulated with electrical high and low frequency electrical stimulation between 0.1 - 0.5 mA. Initial sensation and motor stimulation tests confirmed patient skin numbness in the original pain area and corresponding intercostal muscle twitching function. Following one round of RFT treatment 28 patients developed skin numbness and pain relief in the original pain area. Another 8 patients developed no obvious skin numbness in the original lesion area. Following readjustment of the needle tip position, patient sensory and motor function was retested and RFT was repeated until the treatment endpoint was reached. CT scans following the intervention confirmed no pneumothorax had occurred. No patients experienced hypoxemia under intraoperative nasal catheter oxygen inhalation. Twelve patients experienced hypertension during the procedure and urapidil was administered to return blood pressure to nominal values. No cardiovascular or cerebrovascular accidents occurred.

Comparison of NRS before and after Surgery

Patients reported a reduction in pain NRS 2 hours, 1 week, 4 weeks, and 8 weeks compared following the procedure ($P < 0.01$). (Table 1, Fig. 5).

Clinical Efficacy

Using the NRS-WV scores to classify clinical efficacy, one week after the operation 0 cases were ineffective (0%), 10 cases were effective (27.78%), 25 cases were significantly effective (69.44%), and 1 case was cured (1.92%). Aggregated together these cases yielded an overall effective rate of 100% (36 / 36). Of the 36 cases, 2 cases had NRS scores of 4 and 5 one-week after the operation and were retreated with RFT. Following this second round of treatment their NRS decreased to 2 and considered effective. All patients were contacted by telephone every month to inquire about NRS scores, sleep status, as well as work and life status among other potential complications.

Comparison of Changes in Quality of life (SF-36) Before and After Treatment

Compared with preoperative, the scores of all categories of SF-36 increased by 4 and 8 weeks following the intervention ($P<0.01$) (Table 2, Fig. 6).

Adverse Effects

After 8 weeks of follow-up, all patients had no obvious sleep disorders and could keep normal working and living. Among them, 2 cases had tight sensation in the innervated segment of RF injury. The curative effect of other patients was satisfactory and there were no obvious other adverse reactions.

Discussion

When the host is immunocompromised the varicella-zoster virus can become reactivated and proliferate potentially damaging the neuronal cell bodies of the DRG of spinal nerves. After the initial skin lesions have healed, neurons or nerve fibers can become demyelinated due to inflammation. Electrical excitation studies have shown this demyelination can produce a cascade burst of “wind-up” effects due to interactions between mixed transmission or reentrant circuits causing hyperalgesia and hypersensitivity (9). Some patients experience intractable pain due to poor nerve envelope repair. Such cases can be difficult to treat, especially around the upper thoracic segment of the spine due to proximity to the lungs and spinal nerves.

I. Radiofrequency Therapy for Refractory PHN

The dorsal root ganglion of spinal nerve plays an important role in the occurrence of PHN and is the main treatment target (9). A consensus of pain department experts have recommended radiofrequency therapy of the spinal nerve root for treating of PHN (10,11) It is considered that for intractable PHN, RFT is preferred over pulse radiofrequency yielding longer lasting pain relief (12). To better ablate the responsible nerve, the research team adopted 90°C and 180 s RTF parameters resulting in more effective treatment

Table 1: *The comparison of NRS(n = 36).*

Observation Indicators	Pre-operation	2h post-operation	1w post-operation	4w post-operation	8w post-operation
NRS	5.861 ± 0.899	2.625 ± 0.740	2.569 ± 0.709	2.389 ± 0.494	1.667 ± 0.478
t	—	20.888*	20.922*	18.802*	24.268*
P	—	0.000*	0.000*	0.000*	0.000*

Note: Compared with pre-operation *$P<0.01$

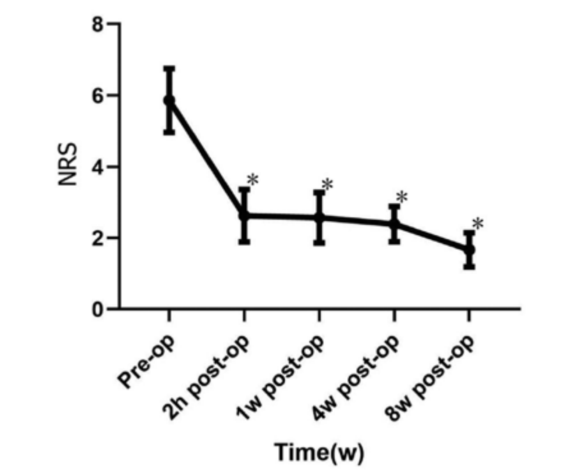

Fig. 5. *The comparison of NRS.*

Table 2. *The comparison of SF-36 scale (n = 36).*

Observation Indicators	Pre-operation	4w post-operation	8w post-operation
Physical function (PF)	29.03 ± 10.75	57.64 ± 16.58*	66.67 ± 17.07*
Role physical(RP)	18.75 ± 16.23	59.72 ± 14.97*	78.47 ± 14.82*
Bodily pain (BP)	28.92 ± 13.08	66.53 ± 12.21*	81.28 ± 8.87*
General health (GH)	35.58 ± 11.35	56.39 ± 10.38*	65.78 ± 11.51*
Vitality (VT)	31.94 ± 13.95	57.36 ± 15.97*	68.75 ± 17.17*
Social function (SF)	36.11 ± 17.62	69.51 ± 14.13*	77.85 ± 14.60*
Role emotional (RE)	25.91 ± 18.01	56.49 ± 22.30*	71.31 ± 22.76*
Mental health, (MH)	35.11 ± 11.91	59.00 ± 16.74*	70.03 ± 15.43*

Note: Compared with pre-operation *$P < 0.01$

of the cervical nerve root, extracranial non meniscus node and other nerve lesions (13). Although different from the temperature parameter recommended by the above expert consensus, the expert consensus also points out the appropriate RTF temperature can be selected according to the purpose of treatment (10). The patients in this study are mainly intractable upper thoracic PHN patients. While increasing temperature can better ablate the nerve to ensure therapeutic effect, there is an associated higher risk of damaging motor branches of the upper thoracic spinal nerve which innervate the internal and external intercostal muscles and play a role in assisting breathing. However, these nerves have compensatory mechanisms. If three or fewer nerve on one side are damaged there is no impairment on physiological function. Thus if too much consideration is given to protecting motor function, the sensory branches may not be completely ablated, which increases the likelihood of recurrent pain and treatment dissatisfaction. These high temperature can yield severe local pain during the procedure which can be controlled with intravenous analgesics. From the group of patients observed in this study RTF treatment yielded robust therapeutic effect, significantly reducing pain with minimal adverse reactions such as dyspnea.

II. Difficulties in Radiofrequency Puncture for Superior Thoracic PHN

The puncture treatment is difficult to perform due to the small superior thoracic vertebral body compared to the large vertebral plate. As a result the curved needle technique (4) is required to deliver the needle tip into the foramen, which is time-consuming and laborious. For the puncture at T1, the study team also explored and succeeded in the lateral position (14), but it was not applicable below T2 because it could not avoid the lung tissue. We found the upper edge of the corresponding costotransverse joint more suitable for puncture of the upper thoracic intervertebral foramen. The position of the upper thoracic intervertebral foramen is mostly flat or slightly lower than the level of the upper edge of the corresponding costotransverse joint (Fig. 2). Horizontally puncture paths through the upper margin of the costal-transverse joint to the intervertebral foramen (Fig. 3) can be used to successfully avoid the obstruction of the lamina and reach the intervertebral foramen, as shown in the three-dimensional reconstruction (Fig. 4) and schematic diagram (Fig. 7).

III. Prevention from Complications of Radiofrequency Puncture for Superior Thoracic PHN

1. Prevention of Pneumothorax:

Intraprocedural complications to the lungs such as pneumothorax can be prevented by planning a safe puncture path and safe needle depth and angle with the help of built-in CT scanner treatment planning tools. The shortest distance from the puncture point to the pulmonary pleura can be used to define a safety margin during the procedure (15). If the puncture depth does not exceed this safe distance during the first puncture risks of rupturing the pulmonary pleura and pneumothorax can be minimized. Another best practice for a safe procedure is the principle of "only advance" (16), that is the puncture needle can only be allowed to enter and stop, but not be withdrawn. If the needle tip is withdrawn potential punctures to the pleura cannot be easily seen as the needle is no longer in the image during subsequent scans. Finally after the procedure is complete the absence of pneumothorax can be confirmed with a CT scan viewed in lung window display settings.

2. Maintaining Stability of Circulatory System:

Treatment should be carried out under oxygen inhalation and close monitoring wih vasoactive drugs and rescue equipment on standby. Any cerebrovascular accidents during the procedure should be treated immediately (17).

IV. Attention to the Negative Emotions caused by Patient's Pain during the Treatment of PHN

This study found that PHN, especially the stubborn PHN patients with unsatisfactory effects of various treatment methods, have negative emotions and even psychological depression. This results in a reduction in quality of life due to impaired social communication (18), lack of confidence, and even suicidal thoughts (19,20). Thus, a timely and effec-

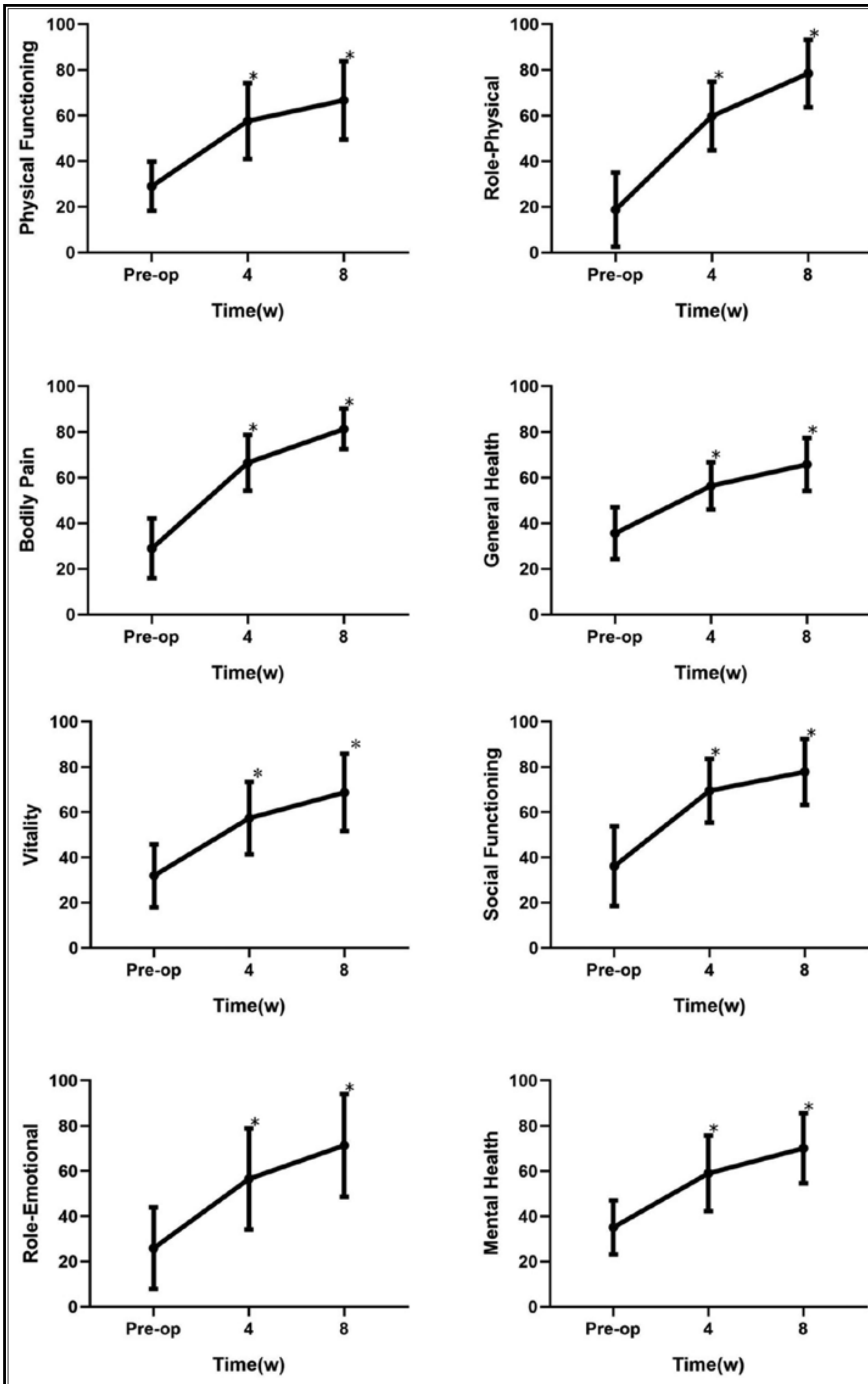

Fig. 6. *The comparison of SF-36 scale*

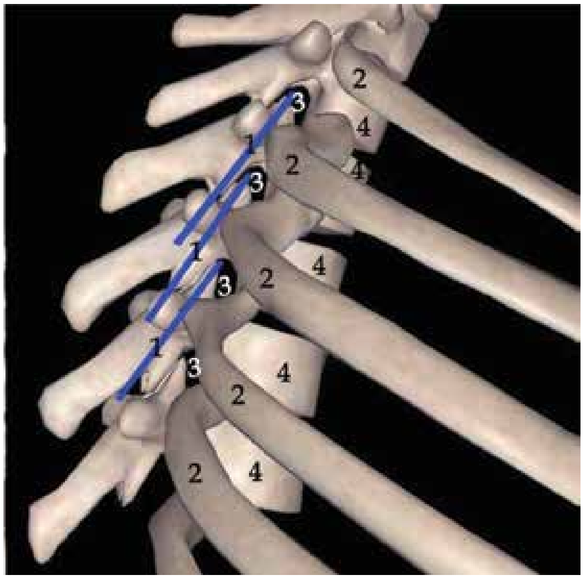

Fig. 7. *Puncture diagram.*

tive treatment can correct this cascade of progressive negativity of emotions potentially avoiding malignant events. In this study, the RFT through the superior margin of the costo-transverse joint significantly improved intractable superior thoracic PHN and played a positive role in the mental health of patients.

Limitations

Limitations of this study include the nonrandomized design with no control arm and small sample size. Additionally the single-center and retrospective nature of the review produces moderate selection bias. Future multicenter, randomized, and controlled studies prospectively evaluating a larger number of patients would address these sources of bias.

Conclusion

In summary, CT-guided RFT through the superior margin of the costal-transverse joint is effective in the treatment of intractable PHN in the superior thoracic segment, which can effectively improve the patients' depression and quality of life. However, the treatment of PHN must still follow the sequential treatment principles of herpes zoster neuralgia and carry out the stepped comprehensive treatment according to the severity and stage of the disease (24).

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