



CT-Guided Radiofrequency Ablation Targeting the Herniation Edge of the Cervical Disc for the Treatment of Neck Pain: A Retrospective Study

Nannan Zhang · Jiaqi Hu · Wenjun Cai · Wenlong Liu ·
Shun Li · Bin Ru

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ABSTRACT

Introduction: Sinuvertebral nerve overactivation is one of the mechanisms of neck pain caused by cervical disc herniation. Radiofrequency ablation (RFA) of sinuvertebral nerves has shown efficacy for the treatment of discogenic low back pain. However, relatively few studies evaluated the efficacy of RFA of sinuvertebral nerves for the treatment of chronic neck pain caused by cervical disc herniation.

Methods: Clinical data were retrospectively collected from 168 patients diagnosed with cervical disc herniated neck pain from January 1, 2019, to September 1, 2022, who were treated with computed tomography (CT)-guided cervical disc RFA of at the Pain Medicine Center of Zhejiang Provincial People's Hospital. A 22-G RFA needle (Inomed, Emmendingen, Germany)

was inserted between the carotid artery and trachea to the intervertebral disc under the direction of CT the scanner. Depending on the position of the protruding nucleus pulposus or the rupture of the annulus fibrosus, the needle was inserted into the posterior side of the intervertebral disc until the tip of the needle reached the target position. The numeric rating scale (NRS) score, pain relief and appearance of complications after RFA were evaluated.

Results: A total of 168 patients underwent CT-guided RFA for cervical disc herniation. The average duration of pain was 67.07 ± 70.42 months. At 6 months of follow-up, the median preoperative NRS score decreased significantly from preoperative 5.41 ± 1.08 to postoperative 1.341 ± 1.25 at 1 month, 1.4 ± 1.38 at 3 months and 1.72 ± 1.41 at 6 months after RFA ($p < 0.01$). The numbers of patients with $\geq 50\%$ of their neck pain relieved were 84% (141/168), 87% (147/168), 87% (147/168) and 79% (133/168) at 1 day, 1 month, 3 months and 6 months after RFA, respectively. No serious complications related to treatment or long-term complications were observed.

Conclusions: This study highlights that CT-guided RFA targeting the edge of cervical disc herniation to destroy the sinuvertebral nerves can effectively relieve neck pain, and the computed tomography (CT)-guided RFA treatment strategy has the advantages of having few complications.

Nannan Zhang and Jiaqi Hu contributed equally to this work.

N. Zhang · J. Hu · W. Cai · W. Liu · S. Li (✉) ·
B. Ru (✉)

Center for Rehabilitation Medicine, Department of Pain Management, Zhejiang Provincial People's Hospital, Affiliated People's Hospital, Hangzhou Medical College, Hangzhou 330004, Zhejiang, China
e-mail: 13732208930@163.com

B. Ru
e-mail: 1148449287@qq.com

Keywords: Radiofrequency ablation; Sinuvertebral nerve; Chronic neck pain; Cervical disc herniation

Key Summary Points

Why carry out this study?

Chronic neck pain has clinical manifestations of pain in the head, neck, shoulder and upper limbs as well as pain associated with numbness

Neck pain seriously affects physical and mental health as well as quality of life of patients and increases health care costs

The purpose of this study was to evaluate pain relief and the occurrence of complications of CT-guided radiofrequency ablation (RFA) targeting the edge of herniation of the cervical disc to destroy the sinuvertebral nerves for the treatment of cervical pain

What was learned from the study?

This study highlights that CT-guided RFA targeting the edge of cervical disc herniation to destroy the sinuvertebral nerves can effectively relieve neck pain

The overactivation of sinuvertebral nerves is one of the mechanisms of neck pain caused by herniated cervical disc. RFA of sinuvertebral nerves has shown efficacy for the treatment of discogenic low back pain

INTRODUCTION

Neck pain is a chronic pain with clinical manifestations of pain in the head, neck, shoulder and upper limbs as well as pain associated with numbness [1–4]. Neck pain seriously affects physical and mental health as well as the quality of life of patients and increase health care costs [5–8]. Chronic neck pain leads to

functional abnormalities in sensorimotor processing, emotion, cognition and memory. Neck pain has a global prevalence of 3551 people and 352 years lived with disability per 100,000 people [9]. Cervical intervertebral disc herniation is one of the most common causes of neck pain [10–14].

Despite such a high prevalence, the relationship between cervical disc herniation and clinical pain and neuropathology is still unclear. Previous studies have shown that neck pain and low back pain induced by disc herniation may be due to stimulation of the sinuvertebral nerves located on the posterolateral edge of intervertebral discs, which produces aseptic inflammation within the annulus of degenerative discs and induced pain [15–19].

Radiofrequency ablation (RFA) is an interventional therapy for the treatment of specific pain syndromes. There are studies that have evaluated the RFA of the sinuvertebral nerve for the treatment of low back pain with good effect; however, due to surgery-related anatomic limitations and the risk of thermal injury associated with the technique to the cervical nerve root [18, 20], few studies have evaluated the RFA of the sinuvertebral nerve for the treatment of neck pain.

In the present study, we retrospectively analyzed the efficacy and safety of a new approach of computed tomography (CT)-guided RFA of the herniated edge of cervical discs to destroy the sinuvertebral nerve for the treatment of neck pain without radiculopathy.

METHODS

Study Participants

This study was approved and waived the requirement for informed consent by the Ethics Committee of the Zhejiang Provincial People's Hospital. This study was designed as a retrospective clinical trial conducted from January 1, 2019, to September 30, 2022. The electronic medical records of patients treated with CT-guided cervical disc RFA at the Pain Medicine Center of Zhejiang Provincial People's Hospital were reviewed. Patients were included only

when they met all the following criteria: (1) chronic axial or referred neck pain; (2) cervical magnetic resonance imaging showed mild cervical disc herniation consistent with patient symptoms; (3) failure of conservative treatments; (4) underwent magnetic resonance imaging (MRI) of the brain prior to treatment. Patients who had: (1) pain intensity (numeric rating scale [NRS] score) was < 4 ; (2) with radiculopathy, spinal cord compression and/or myelopathy; (3) duration of the pain was < 6 months; (4) previous cervical spine surgery at the same cervical level was excluded in this study.

All included patients were discussed before surgery by senior pain physicians who considered neck pain caused by cervical disc herniation. Consent was obtained from all patients.

Surgical Procedures

The procedures were performed by two senior pain physicians (Shun Li and Bin Ru).

The enrolled patients underwent preoperative cervical spine MRI examinations. Based on symptoms and MRI results, senior pain physicians determined on which disc to operate. When the patient's MRI showed that there was only a single plane of disc herniation, we only performed radiofrequency ablation of the intervertebral disc of the corresponding plane; however, when the patient's MRI showed a multiplane disc herniation, we performed a sensory test on this herniated disc, and when the sensory test could induce the patient's usual symptoms, we performed radiofrequency ablation of the intervertebral disc of that plane. The patients were placed in the supine position on the CT gantry table. A wide piece of tape was applied to secure the head to prevent head movement during the operation. Heart and respiratory rate, three-lead electrocardiography and fingertip digital oximetry were monitored throughout the surgical procedure. The sagittal CT image was used to locate the target position (Fig. 1a). The axial CT image was used to determine the puncture approach (Fig. 1b). After identifying the target point (Fig. 1c, d), the carotid arteries and trachea were pushed to the

sides to avoid injury, and then the skin and subcutaneous soft tissue were locally anesthetized with 0.5 ml of 1% lidocaine (Tiancheng Co., Hebei, China). A 22-G RFA needle (Inomed, Emmendingen, Germany) was then inserted between the carotid artery and the trachea to the intervertebral disc (Fig. 1e). After puncture of the intervertebral disc, the position of the needle tip was checked again on the axial CT image. Next, depending on the position of the protruding nucleus pulposus or the rupture of the annulus fibrosus, we proceeded to insert the needle into the posterior side of the intervertebral disc until the tip of the needle reached the target position (Fig. 1f). The schematic diagram of RFA is shown in Fig. 2.

The RFA procedure was performed using the R-2000B radiofrequency lesion generator (Beiqi, Beijing, China). Sensory tests were performed at 50 Hz and < 1.5 V before applying RFA. If pre-operative pain or tingling occurred under simulation, called a positive sensory test, and there was no simultaneous abnormal sensation in the extremities, the placement of the needle tip was considered appropriate and safe. After the sensory test, motor stimulation was performed at 2 Hz and up to 2 V. If there was no abnormal response in the limbs, called a negative motor test, it indicated that there was still a safe distance between the tip of the needle and the cervical spinal cord, which reconfirmed that the tip was in a safe position. Patients with positive sensory test and negative motor test received temperature step-up RFA at 50 °C, 60 °C, 70 °C and 80 °C for 15 s followed by RFA for 180 s at 85 °C. If the patient reported any discomfort during the RFA process, the physician immediately stopped the operation and reconfirmed the position of the needle tip by CT scanner.

The treating physician visited in person 2 h after surgery, the interventional radiology nurse followed up by phone 3–4 days after the RFA surgery, and the treating physician followed up in person or by phone from 1 day to 6 months.

Outcome Analysis

The primary outcome included the mean difference in baseline pain intensity levels at 1 day,

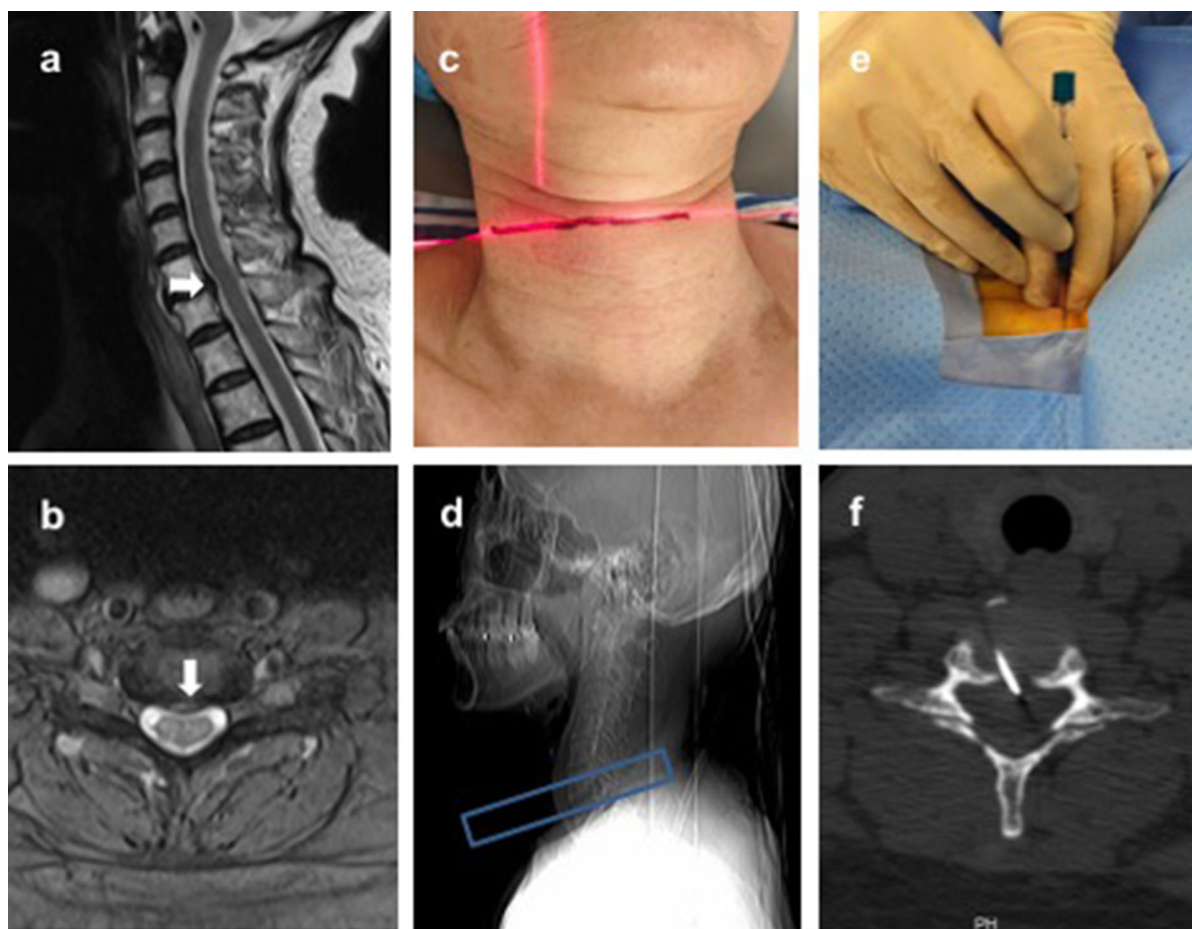


Fig. 1 Radiofrequency ablation (RFA) of cervical intervertebral discs guided by computed tomography (CT). **a**, **b** Magnetic resonance imaging before RFA surgery showed mild central cervical disc herniation (white arrow) at C6–7. **c**, **d** CT scanner guidance was used to locate the target plane for cervical puncture. Blue box, scanning area.

e After the surgeon has pushed the carotid artery and trachea to the sides, the radiofrequency needle is inserted into the intervertebral disc. **f** Under the guidance of CT, the radiofrequency needle reaches the position of the intervertebral disc herniation

1, 3 and 6 months after RFA treatment measured using an 11-point NRS. Pain relief rate was measured during 6 months of follow-up to assess functional status. Complications such as bleeding, paresthesia, and infection were recorded.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 23 (INM Corp., Armonk, NY, USA).

Before statistical analysis, the Kolmogorov-Smirnov test was used to determine the normality of the data distribution. Continuous data following a normal distribution are expressed as mean \pm standard deviation (SD) and were compared between groups using an independent *t*-test. Nonnormally distributed data were described by median (interquartile range [IQR]). Descriptive statistics are shown as mean, SD, median and interquartile range, or numbers. To detect a statistically significant change in the value of the NRS score value in the posttreatment period compared to the pretreatment period, we used the Wilcoxon signed rank test.

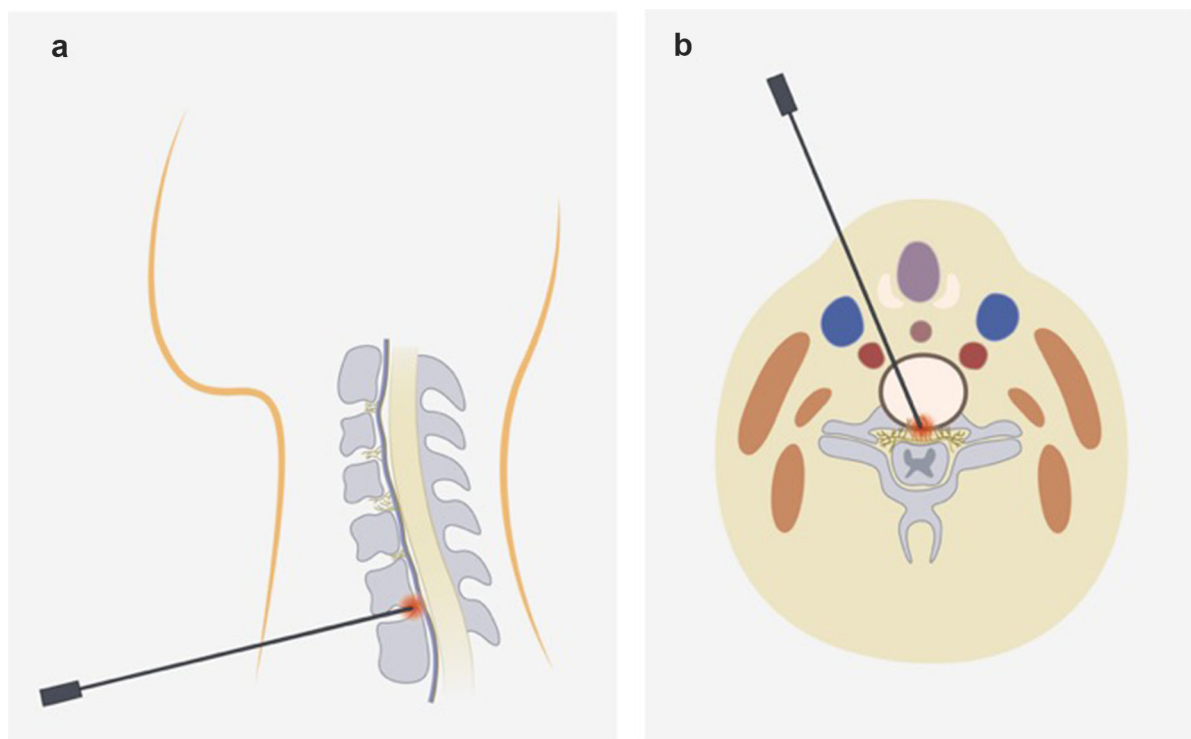


Fig. 2 Scheme illustration of radiofrequency ablation (RFA) for cervical intervertebral disc herniation target. **a** Sagittal view; **b** Axial view

A two-tailed $p < 0.05$ was considered statistically significant.

RESULTS

Patient Characteristics

From January 2019 to September 2022, a total of 213 patients were treated with CT-guided cervical disc RFA at Zhejiang People's Hospital. Twelve patients had a previous cervical spine surgical history, five patients with a neck pain duration < 6 months, six patients with baseline NRS scores < 4 , and five patients with radiculopathy, spinal cord compression or myelopathy, and two patients with intracranial space-occupying lesions were excluded from this study. Therefore, 183 patients with chronic neck pain caused by cervical disc herniation underwent RFA treatment for cervical disc herniation targets under the guidance of CT. However, 15 patients were subsequently

excluded from this study because of loss to follow-up. Finally, 168 patients remained in this study for analysis (Fig. 3; Table 1).

Pre- and Postoperative NRS Scores

The mean preoperative NRS score was 6 (4, 6), and the median NRS scores (IQR) were 2 (1, 3), 1 (0, 2), 1 (0, 2) and 1 (1, 3) at 1 day, 1 month, 3 months and 6 months after RFA surgery treatment (Table 2). The NRS score within 6 months after RFA was significantly lower than before RFA surgery ($p < 0.001$) (Table 2, Fig. 4). Most patients experienced significant relief from neck pain after RFA treatment. In particular, according to the pain relief evaluation, the pain relief rate was 84% (141/168), 87% (147/168), 87% (147/168), and 79% (133/168) at 1 day, 1, 3 and 6 months after RFA treatment, respectively (Table 2).

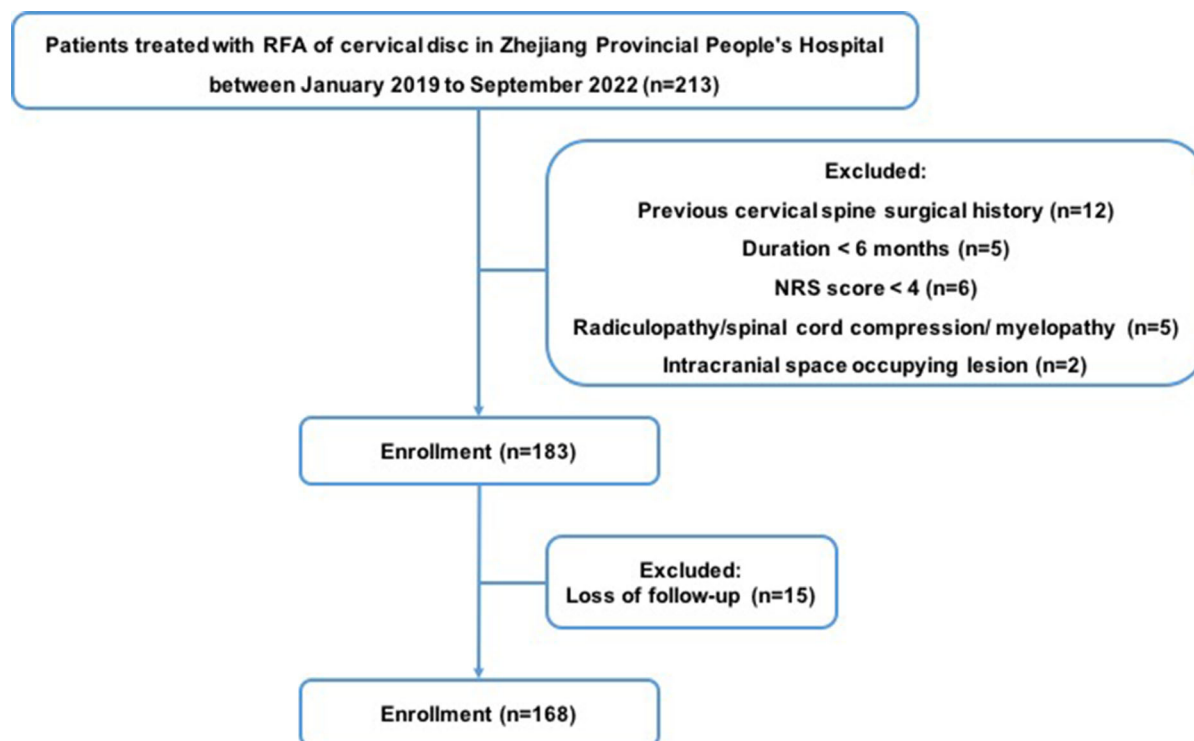


Fig. 3 Flow diagram of patients in this study. *NRS* numeric rating scale, *RFA* radiofrequency ablation

Complications

A total of 18 patients reported soreness at the needle insertion site, but this disappeared 2 weeks after surgery, suggesting that it was not associated with nerve root injury. This complication may be due to repeated punctures for the RFA operations. In the present study, there were no serious complications related to RFA treatment, such as bleeding, paresthesias or infection, in this study.

DISCUSSION

In the present study, we observed the excellent therapeutic efficacy of CT-guided cervical disc RFA for the treatment of neck pain induced by cervical disc herniation, suggesting that method may be a promising treatment. To our knowledge, this is the first report of CT-guided RFA therapy for cervical disc herniation aimed at relieving neck pain by destroying sinuvertebral nerves, and the results showed that this

treatment strategy is promising. Although the study was retrospective, the inclusion of > 160 patients makes the results even more convincing.

Cervical disc herniation is one of the most common causes of neck pain [21]. Current clinical treatment includes conservative treatment (medication and physical therapy), epidural injections (interlaminar or transforaminal), minimally invasive techniques and classical surgery (anterior cervical surgery, cervical disc replacement, anterior cervical fusion surgery or artificial cervical intervertebral disc replacement). In most cases, nonoperative treatment is effective. However, some patients do not respond to conservative treatment. For patients with cervical disc herniation, minimally invasive techniques are the preferred choice to reduce risk and reduce hospital stay. Intervertebral discectomy under intervertebral foramen endoscope is widely used for the treatment of patients with cervical disc herniation complicated with radiculopathy, spinal cord compression and/or myelopathy by

Table 1 Demographics and characteristics of the included patients

Variable	Value
Number of patients	168
Age [years, mean (SD)]	51.92 (10.81)
Gender (male/female), <i>n</i> (%)	49 (29)/119 (71)
Medical records, <i>n</i> (%)	
Migraine	17 (10)
Hypertension	39 (23)
Hyperlipidemia	3 (2)
Osteoporosis	10 (6)
Diabetes mellitus	21 (12)
Neck pain duration (months)	66.55 (66.73)
Location of pain	
Neck	12 (7)
Neck base shoulder top	101 (59)
Neck and head	29 (17)
Neck, shoulder and head	29 (17)
Previous conservative treatment, (%)	
Analgesics, <i>n</i> (%)	152 (90)
Physiotherapy, <i>n</i> (%)	72 (43)
Intervention, <i>n</i> (%)	15 (9)
Duration of operation [mean (SD)]	50.83 (10.2)

SD standard deviation

removing the source of spinal cord compression, resulting in rapid relief of symptoms of axial neck pain and radiculopathy or myelopathy simultaneously. Although for most patients, the intervertebral foramen endoscope strategy is safe and effective, it can induce complications such as scar adhesion and decreased vertebral stability in the long term due to disc destruction and spine structure.

For patients with mild cervical intervertebral disc herniation, the intervertebral foramen endoscope is not the first choice. Many efforts have been made to develop more minimally invasive surgery. Cervical percutaneous discectomy by chemonucleolysis is one of the effective percutaneous disc treatments that aims to partially dissolve the nucleus pulposus, decrease intradiscal pressure and induce disc shrinkage with the advantages of shorter hospitalization, less tissue disruption, less risk, less or no post-operative adhesions, no skin scar, no risk of instability and shorter recovery period. However, chymopapain may induce an anaphylactic reaction [13], and pure ethanol had a short-lived effect with rapid leakage [22].

Cervical discs receive innervation posteriorly from sinuvertebral nerves, laterally from the vertebral nerve and anteriorly from sympathetic trunks [16, 23].

According to anatomy textbooks, the sinuvertebral nerve arises bilaterally from the ventral ramus of each spinal nerve just distal to the dorsal root ganglia, supplying both proprioceptive and nociceptive fibers. It is formed by the union of a somatic root from the ventral

Table 2 Evaluation of pain relief in patients with neck pain caused by cervical disc herniation after RFA treatment

	Pre RFA (baseline)	1 day after RFA	1 month after RFA	3 months after RFA	6 months after RFA	<i>p</i>
NRS scores, median (IQR)	6 (4, 6)	2 (1, 3)	1 (0, 2)	1 (0, 2)	1 (1, 3)	< 0.001
Pain relief after RFA						
< 50%		27 (16)	21 (13)	21 (13)	35 (21)	
≥ 50%		141 (84)	147 (87)	147 (87)	133 (79)	
= 100%		27 (16)	50 (30)	51 (30)	37 (22)	

IQR interquartile range, *NRS* numeric rating scale, *RFA* radiofrequency ablation

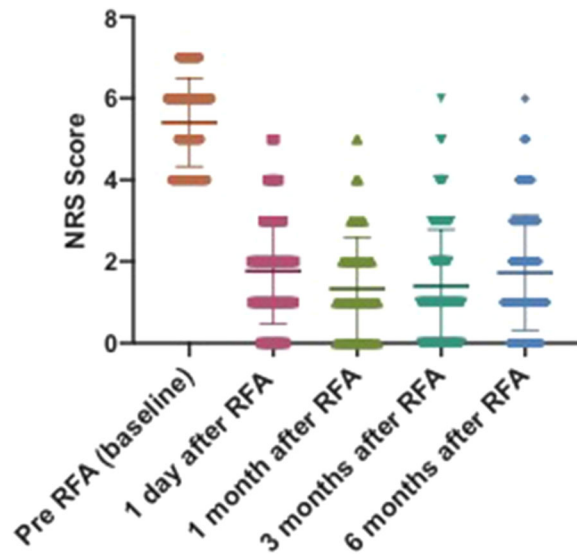


Fig. 4 Numeric rating scale (NRS) scores of patients at varying time intervals as indicated. RFA: radiofrequency ablation

ramus and an autonomic root provided by the gray ramus (A). The sinuvertebral nerve takes a recurrent course and reenters the spinal canal through the intervertebral foramen. Kojima et al. reported that the nerve divides into superficial and deep networks around the longitudinal posterior ligament, providing sensation to the posterior annulus [24]. In healthy patients, the sinuvertebral nerves are located in the three outer layers of the annulus fibrosus, penetrating about 3 mm through the anulus [25, 26]. However, in degenerative discs, sinuvertebral nerves penetrate into the inner one third layer of the annulus fibrosus, even the nucleus pulposus [1, 27]. Sinuvertebral nerves have been found to be associated with discogenic low back pain in most previous research [18, 19]. In recent years, researchers have found that sinuvertebral nerves were associated with cervicogenic headaches [28, 29].

RFA, known as radiofrequency ablation, was first described by Kirschner in the early 1930s with thermocoagulation of the Gasserian ganglion for the treatment of trigeminal neuralgia [30]. The continuous radiofrequency current created a focal thermal lesion in a neural pathway with the goal of interrupting nociception. RFA has been widely applied for the treatment

of specific pain syndromes. For example, Lord et al. demonstrated that percutaneous radiofrequency neurotomy could be used successfully for chronic cervical zygapophyseal joint pain [31]. RFA is also used for the treatment of back pain induced by degenerative disc disease. Kim et al. reported that RFA of the sinuvertebral nerves relieved paravertebral muscle spasms in patients with chronic discogenic back pain.

Compared to interventions for lumbar back pain treatment, neck pain treatment is challenging because of surgically related anatomic limitations and the risk of technique-associated thermal injury to the cervical nerve root [18, 20]. With the development of the image, CT guidance provides a clear review of the vessels and intervertebral discs, allowing for precise and safe positioning of a needle tip during the RFA procedure. The application of CT-guided interventional therapy for the treatment of neck pain induced by cervical disc degeneration has been widely accepted. However, few studies have evaluated the pain relief and complications of CT-guided RFA by targeting sinuvertebral nerves for the treatment of neck pain induced by cervical disc herniation.

Complications such as nerve root injury during the procedure were the major concern regarding its application at the cervical level. In the present study, none of the patients showed signs of nerve root injury symptoms during or after RFA treatment. A total of 18 patients reported soreness at the needle insertion site, but it disappeared 2 weeks postoperatively, suggesting that it is not associated with nerve root injury. Some limitations of the study need to be acknowledged. First, we only followed up all patients for a 6-month postoperative period, so we cannot claim that the technique was effective at relieving this kind of pain for a much longer period. Second, although the NRS score pain rating system was widely used as a gauge, we cannot eliminate the subjective preference of patients for their own pain ratings.

CONCLUSIONS

In summary, CT-guided RFA targeting the edge of the herniated cervical disc to destroy the sinuvertebral nerves can effectively relieve neck pain, and the CT-guided RFA treatment strategy has the advantages of having few complications. However, due to the limitations of this study, multicenter, prospective and randomized controlled trials are necessary to confirm these results.

Medical Writing/Editorial Assistance Nannan Zhang completed to the writing of the manuscript under the guidance of Bin Ru. During the writing of this manuscript, American Journal Experts (AJE; part of Springer Nature) was used to edit the language of this manuscript. The authors funded the AJE service.

Author Contributions. BR and SL brought forward the subject of this study and guided the writing; NZ, JH, WC and WL were significant contributors to data acquisition and manuscript writing. All authors read and approved the final manuscript.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Nannan Zhang, Jiaqi Hu, Wenjun Cai, Wenlong Liu, Shun Li and Bin Ru have declared that no competing interest exists.

Ethical Approval. This study was approved, and the requirement for informed consent was

waived by the Ethics Committee of Zhejiang Provincial People's Hospital.

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