Prospective Study

Percutaneous Intradiscal Radiofrequency Thermocoagulation Combined with Sinuvertebral Nerve Ablation for the Treatment of Discogenic Low Back Pain

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Background: Percutaneous intervertebral radiofrequency thermocoagulation (PIRFT) and sinuvertebral nerve ablation (SVNA) are commonly used clinical treatments for discogenic low back pain (DLBP). However, they have been reported to have low efficacy rates of approximately 16.5%-26.5%, especially in the medium to long term.

Objectives: To investigate whether PIRFT combined with SVNA can reduce pain and improve clinical outcomes in patients with DLBP.

Study Design: This is a prospective study.

Setting: All data were from Honghui Hospital in Xi'an.

Methods: Following the inclusion and exclusion criteria, 195 patients were enrolled in this study and randomly divided into 3 groups of 65 patients each and treated with PIRFT+SVNA, PIRFT, or SVNA. Postoperative follow-ups were done at one week, one month, 3 months, 6 months, and 12 months. The demographic characteristics, relevant surgical information, and observed complications of all groups were recorded. The efficacy of the surgeries was evaluated using the visual analog scale (VAS), Oswestry disability index (ODI), and modified Macnab criteria.

Results: In total, 167 patients, comprising 81 men and 86 women (aged 28–75 years), were included in this study and completed postoperative follow-ups. There were 54 patients in the combined PIRFT and SVNA (PIRFT+SVNA) group, 58 patients in the PIRFT group, and 55 patients in the SVNA group. All groups were comparable because there were no significant differences in gender, age, disease duration, follow-up time, surgical segments and presence of high-intensity zones of the groups ($P > 0.05$). In addition, the efficacy of the PIRFT+SVNA group was significantly higher than that of the PIRFT and SVNA groups as assessed by the modified Macnab criteria ($P = 0.032$). Surgery was successfully completed in all 3 groups, and VAS and ODI improved at all postoperative time points in all 3 groups compared to the preoperative scores. The differences between the VAS and ODI scores preoperation and 12 months postoperation were not statistically significant between all 3 groups. However, at one week, one month, 3 months, and 6 months after surgery, the VAS and ODI scores were lower in the PIRFT+SVNA group compared to the PIRFT and SVNA groups. The difference in VAS scores among the 3 groups was most significant at one week postoperation, and the difference in ODI scores was most significant at one month postoperation. The VAS and ODI improvement rates of the 3 groups showed significant improvement at one week, one month, 3 months, and 6 months postoperation ($P < 0.05$). There was no significant difference among the 3 groups at 12 months postoperation ($P > 0.05$)

Limitations: This study was limited by its small sample size in a single-center study.

Conclusions: In DLBP, the sinuvertebral nerve (SVN) is the main nerve involved in the lumbar disc pain signaling pathway, and compared with PIRFT and SVNA alone, combined PIRFT and SVNA treatment may provide more satisfactory pain relief and functional improvement at an early stage.

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Discogenic low back pain (DLBP) is a common type of chronic low back pain and a leading cause of disability in the adult population (1). DLBP is caused by degeneration of the intervertebral disc structure, including disc degeneration and/or the rupture of the annulus fibrosus, with or without disc herniation (2). DLBP mostly occurs in the lumbar girdle region, with pain which typically does not extend beyond the thoracolumbar junction and radiation in the distal region which typically does not extend beyond the knee (3). The main symptoms of DLBP are chronic, recurrent, and persistent low back pain and lower-extremity pain with or without nerve root involvement (4). Thus, patients experience considerable pain, and their quality of life is severely impaired, which also burdens the family of the patient and the society.

Percutaneous intervertebral radiofrequency thermocoagulation (PIRFT) is a cost-effective and safe treatment for DLBP, offering numerous benefits including reduced trauma to the patient and improved visualization (5). PIRFT uses a radiofrequency tip to treat the diseased intervertebral discs to shrink tissue through thermal damage, which in turn reduces inflammation and internal pressure. By using high temperature to repair the torn annulus fibrosus, PIRFT inactivates the sensory nerve endings that transmit pain. PIRFT is designed to eliminate pain mediators, inflammatory agents, and newly formed nerve fibers in the annulus fibrosus (6). However, studies have reported that 16.5%–26.5% of patients experience poor clinical outcomes following PIRFT (7,8).

The sinuvertebral nerve (SVN) is the primary nerve responsible for the transmission of lumbar disc pain-related signals (9,10). As the SVN is present in the outer layers of the disc fibrous annulus, the posterior longitudinal ligament, and the ventral aspect of the dura, it is important to maximize its denervation for effective and minimally invasive treatment of DLBP (11). Theoretically, radiofrequency ablation of the annulus fibrosus rupture alone cannot block pain stimulation from the sensory nerves in the dura mater, posterior longitudinal ligament, and annulus fibrosus along the spinal canal. However, the lumbar SVN typically traverses the spinal nerve root at a fixed location, located medially along the edge of the ganglion and at the beginning of the gray communicating branch (12). Thus, the combination of PIRFT with SVN ablation (SVNA) may block both the source of pain and the pain transduction pathway. This study aimed to evaluate if combining PIRFT with SVNA can reduce pain and improve clinical outcomes in patients with DLBP.

Methods

Study Patients

Between January 2021 and June 2022, participating spine surgeons screened outpatients with DLBP and identifyied patients eligible for the trial. Preoperative lumbar spine x-ray, computed tomography (CT), and magnetic resonance imaging (MRI) were routinely performed on the patients. The inclusion criteria for patients were as follows: 1) clinical manifestations include low back pain with or without lower limb pain and numbness, pain usually not radiating beyond the knee, and unbearable pain when sitting; 2) onset time of >3 months; 3) x-ray shows no obvious lumbar instability and CT shows no obvious lumbar degeneration and hyperplasia; 4) Single-segment disc degeneration with or without a high-intensity zone on the MRI (Fig. 1); 5) lesioned segment with or without paravertebral muscle or spinous process tenderness; 6) the patient's complete lumbar spine imaging data is present. The exclusion criteria for patients were as follows: 1) low back pain due to conditions such as lumbar spine tumor, infection, and fracture; 2) history of lumbar spine surgery in the suspected diseased segment; 3) MRI showing significant disc herniation which compresses nerve roots; 4) presence of severe lumbar spine stenosis, instability or slippage, ligament injury, lumbar facet joint dysfunction, and other nonintervertebral lumbar spine pain; 5) Grade I on the Weishaupt grading of articular synovial

joints and Grade II on the Goutallier grading of lumbar paraspinal muscles; 6) comorbid psychiatric or other cognitive disorders affecting the patient's functional assessment. Based on these criteria, 195 patients were included in this study. The patients were randomly divided into 3 groups of 65 patients each and treated with both PIRFT and SVNA (PIRFT+SVNA), only PIRFT, or only SVNA. This prospective study was approved by the Medical Ethics Committee of the Xi'an Honghui Hospital.

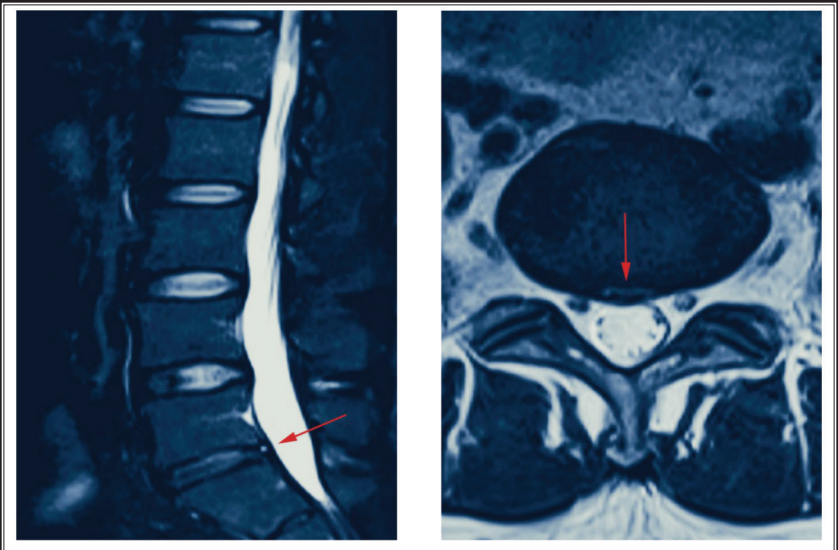

Fig. 1. *Lumbar DLBP. MRI T2-weighted image of a high-intensity zone in the annulus fibrosus (indicated by arrows) showing a tear in the annulus fibrosus. A) Sagittal plane. B) Transverse plane.*

Surgical Procedures

The patients were positioned face down on the spine surgical bed and a CT-guided puncture was performed to access the specific target site previously identified during preoperative planning. The PIRFT target was located at the mid-posterior 1/3 intersection of the disc in the sagittal plane, with the puncture needle tip located at the medial border of the lesser tuberosity in the anteroposterior projection and at the mid-posterior 1/3 of the disc space in the lateral projection (Fig. 2). The SVNA target was located at the junction of the posterior margin of the annulus fibrosus and the posterior longitudinal ligament in the sagittal plane. Here, the tip of the puncture needle was positioned in the region where the line connecting the lateral margins of the upper and lower pedicles met the projection of the intervertebral disc under orthogonal fluoroscopy. It was also located in the ventral side of the superior articular eminence and at the posterior margin of the disc under lateral fluoroscopy (Fig. 3). And the PIRFT+SVNA targets were the same as the PIRFT and SVNA targets described above (Fig. 4). The appropriate disc and puncture sites were identified and anesthetized with a local injection of 1% lidocaine. This study used a 20G*150 mm*5 mm bare-tip radiofrequency puncture needle. After the puncture position was satisfactorily secured, radiofrequency electrodes, with an electrode impedance between 150 and 300 Ω, were placed to indicate whether the needle tip was in or near the disc, and sensory and motor nerve stimulation tests were performed with currents of 2.0 V, 50 Hz and 2.0 V, 2 Hz, respectively. If no abnormalities were found after the preliminary examination, the temperature test was started at 60°C to determine the optimal temperature for the radiofrequency treatment. The temperature was gradually increased, starting at 65°C with a 5°C increase every 30 seconds for each radiofrequency. Throughout the process, the subjective feelings of the patients were frequently assessed, including

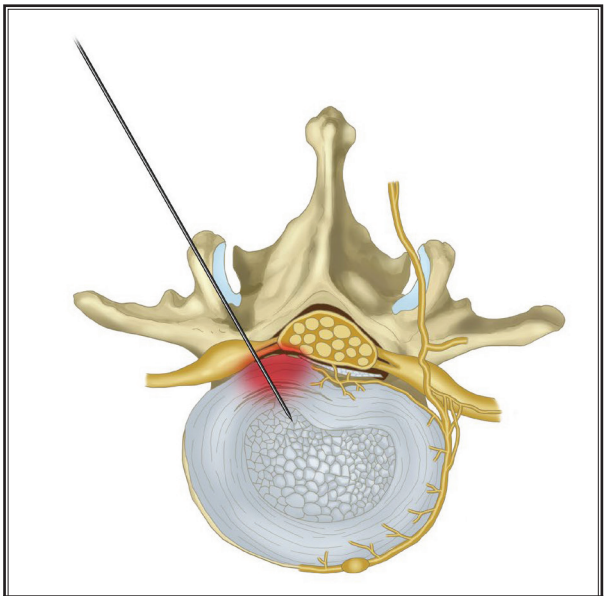

Fig. 2. *Schematic diagram of the PIRFT procedure. The tip of the puncture needle is located in the middle posterior 1/3 of the disc.*

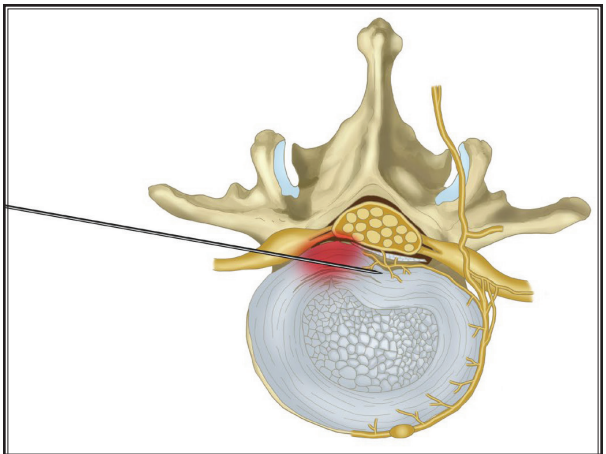

Fig. 3. *Schematic diagram of the SVNA procedure. The tip of the puncture needle is located at the junction of the posterior edge of the fibrous ring and the posterior longitudinal ligament.*

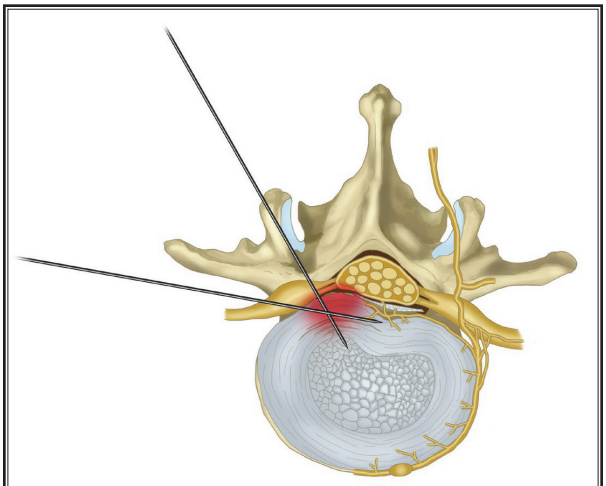

Fig. 4. *Schematic diagram of the PIRFT+SVNA procedure. The PIRFT and SVNA surgical puncture needles were in the same position as above.*

any pain, discomfort, or radiating pain in their lower limbs. The temperature was adjusted to reach the maximum tolerable level for the patient, ideally providing warmth at the original site of the pain.

The PIRFT treatment involved heating to the maximum tolerated temperature of 90°C for 120–240 seconds, whereas the SVNA treatment involved radiofrequency heating to the maximum tolerated temperature of 80°C for 60 seconds. After the treatments, the electrodes were removed and the needles were slowly withdrawn. Patients were then asked about any pain or soreness they were experiencing at the site of their preoperative pain. The position of the needle tip was adjusted based on the response of the patient. Sensorimotor testing was repeated to determine optimal temperature tolerance. The SVNA treatment was then performed at different target sites. At the L3/4 and L4/5 levels, the primary branch of the lumbar SVN runs immediately adjacent to the disc toward the spinal canal, and the secondary branch crosses the disc or posterior margin of the vertebral body at the posterior lateral margin of the disc. At the L5/S1 level, the SVN enters the spinal canal immediately adjacent to the disc. If the patient experienced pain, numbness, abnormal motor function, or radiating pain in their lower extremities during the radiofrequency treatment, it was imperative to stop the procedure and reposition the patient.

Postoperative Management and Follow-ups

Patients were placed on strict bed rest for 24 hours after the operation, after which they could wear a waist cuff to get out of bed appropriately. Patients were prescribed antibiotics for 3 days to prevent infection, and one week post-operation they began lumbar and dorsal muscle functional exercises. Patients were also instructed to wear waist cuffs for one month, and avoid lumbar weight-bearing and strenuous exercises for 6 months post-operation. Baseline and operative data was obtained from the electronic medical record system of the hospital, and the post-operative data was collected by telephone follow-ups and outpatient reviews. At one week, one month, 3 months, 6 months, and 12 month post-operative follow-up visits, the back pain of patients was assessed using the visual analog scale (VAS), and improvement in spinal dysfunction was assessed using the Oswestry disability index (ODI). The VAS and ODI improvement rate was calculated as follows: VAS and ODI improvement rate (%) = (preoperative score – follow-up score)/preoperative score × 100. At the final follow-up, the prognoses of patients were assessed based on the modified Macnab criteria.

Statistical Analyses

Statistical analyses were performed using the statistical software SPSS 26.0 (IBM). Mean ± SD was used to present quantitative variables. Repeated-measure analysis of variance (ANOVA) was performed for intragroup comparisons, and a one-way ANOVA was performed for intergroup comparisons. Countable variables were expressed as the number of cases (%), and intragroup comparisons were performed through the chi-squared

test. A P value of < 0.05 was considered statistically significant.

Results

A total of 167 patients (81 men and 86 women) between the ages of 28 and 75 participated in all the postoperative follow-ups, of which 54 patients were in the PIRFT + SVNA group, 58 patients were in the PIRFT group, and 55 patients were in the SVNA group (Fig. 5). Twenty-eight patients who did not respond to the diagnostic block did not receive surgical treatment for DLBP. There was no significant difference in the positive rates among the 3 groups (χ^2 = 1.084, P = 0.582). The surgical procedures were successfully completed in all groups, with no intraoperative sharp nerve injury, vascular rupture, or organ injury. There were no significant differences in the distribution of gender, age, disease duration, follow-up time, surgical segments and the presence of high-intensity zones between patients in the 3 groups (P > 0.05). The demographic characteristics and surgical information of all groups are summarized in Table 1. Most patients in all groups presented with favorable clinical outcomes. However, the efficacy rate evaluated using the modified Macnab criteria was significantly higher in the PIRFT+SVNA group (47, 87.0%) compared to the PIRFT group (40, 69.0%) and the SVNA group (37, 67.3%) (χ^2 = 6.866, P = 0.032). All patients completed at least 12 months of postoperative follow-ups without complications such as disc inflammation, infection, and vascular or nerve root injury.

The VAS and ODI scores of the 3 groups during the preoperative and 12-month follow-up period showed no statistically significant differences (P > 0.05). All groups showed significant decreases in VAS and ODI scores at 12 months after the surgical treatment compared to those before the surgery (P < 0.001). The greatest variation in the VAS score between the 3 groups was observed at one week post-operation (P < 0.001) (Fig. 6), and the greatest variation in the ODI score was observed at one month post-operation (P < 0.001) (Fig. 7). The postoperative VAS and ODI scores in the PIRFT + SVNA group were consistently lower than those in the PIRFT and SVNA groups (Tables 2 and 3). The VAS and ODI improvement rates of the 3 groups showed significant improvement at one week, one month, 3 months, and 6 months post-operation (P < 0.05). There was no significant difference between the improvement rates of the 3 groups at 12 months post-operation (P > 0.05) (Tables 4 and 5).

Discussion

DLBP is the most common form of chronic low back pain, accounting for approximately 40% of all chronic low back pain cases (13). The etiology of DLBP is not fully understood, with different studies categorizing its cause as mechanical or chemical mechanisms (9,10,14-16). The mechanical mechanism results from disc degeneration, which destabilizes the disc, inducing mechanical stimulation of pain at the sensory nerve endings during lumbar motion (16). The chemical mechanism involves degeneration-induced inflammatory factors that act on

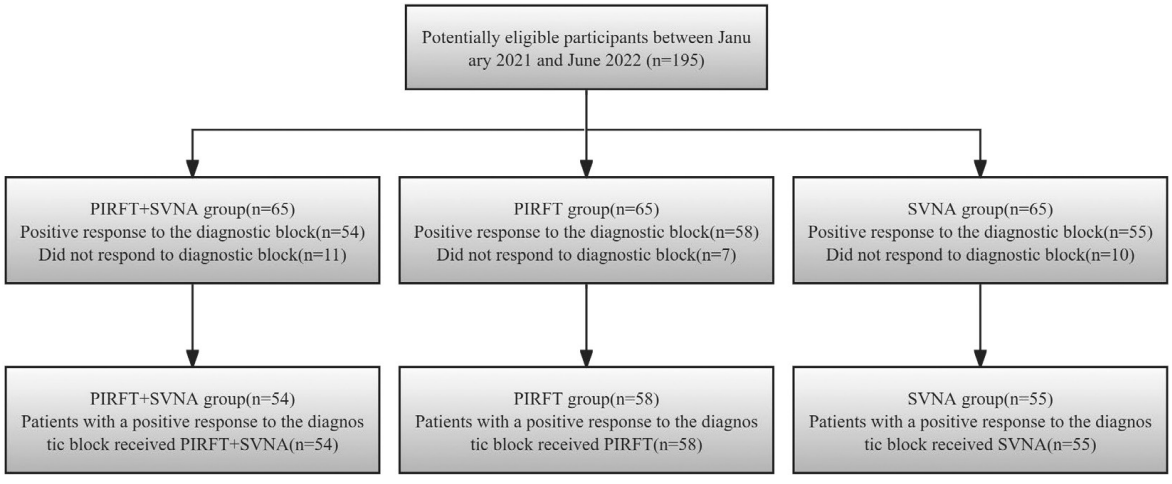

Fig. 5. *Flow chart of this study.*

the nerve endings distributed in the disc or endplate and produce the sensation of pain (9,10). The SVN penetrates the fibrous ring to a greater depth in patients with DLBP, making them more susceptible to pain (17). Thus, both the mechanical and chemical mechanisms of SVN transmission and hypersensitivity play a critical role in manifesting the pain experienced by patients with DLBP.

Herein, 167 patients diagnosed with DIBP were treated with both PIRFT and SVNA, only PIRFT or only SVNA. The baseline characteristics of the 3 groups were comparable. No serious complications occurred during the follow-up period, however, some patients presented with lumbar pain and swelling that was resolved shortly. The VAS and ODI scores showed that postoperative pain and lumbar function of DLBP patients were significantly improved after PIRFT and SVNA, PIRFT or SVNA treatment compared to the preoperative scores ($P < 0.05$). Within 6 months after surgery, patients in the PIRFT+SVNA group showed a significant decrease in the VAS and ODI scores compared to those in the PIRFT group and the SVNA group. The evaluation of the clinical efficacy of the treatments based on the modified Macnab criteria showed that the PIRFT+SVNA group exhibited a higher rate of improvement compared with that of the PIRFT, and SVNA groups. These findings

Table 1. *Comparison of general information and clinical results of the 3 groups.*

Variable	PIRFT+SVNA (n = 54)	PIRFT (n = 58)	SVNA (n = 55)	F/χ^2	*P* value
Gender (men/women)	30/24	25/33	26/29	1.786	0.409
Age (years)	55.7 ± 10.5	54.2 ± 10.2	55.3 ± 10.1	0.321	0.726
Disease duration (months)	21.6 ± 9.1	18.5 ± 8.2	17.5 ± 8.9	3.235	0.042
Follow-up time (months)	17.4 ± 3.7	18.1 ± 3.8	17.3 ± 3.8	0.722	0.488
Surgical segments (n and %)					
L3/4	3 (5.6%)	4 (6.9%)	5 (9%)	1.656	0.799
L4/5	46 (85.2%)	45 (77.6%)	44 (80%)		
L5/S1	5 (9.3%)	9 (15.5%)	6 (11%)		
High intensity zone (n and %)	46 (85.2%)	48 (82.8%)	45 (81.8%)	0.236	0.889
MacNab's criteria (n and %)					
Fair	7 (13.0%)	18 (31.0%)	18 (32.7%)	7.503	0.112
Good	32 (59.3%)	30 (51.7%)	25 (45.5%)		
Excellent	15 (27.8%)	10 (17.2%)	12 (21.8%)		

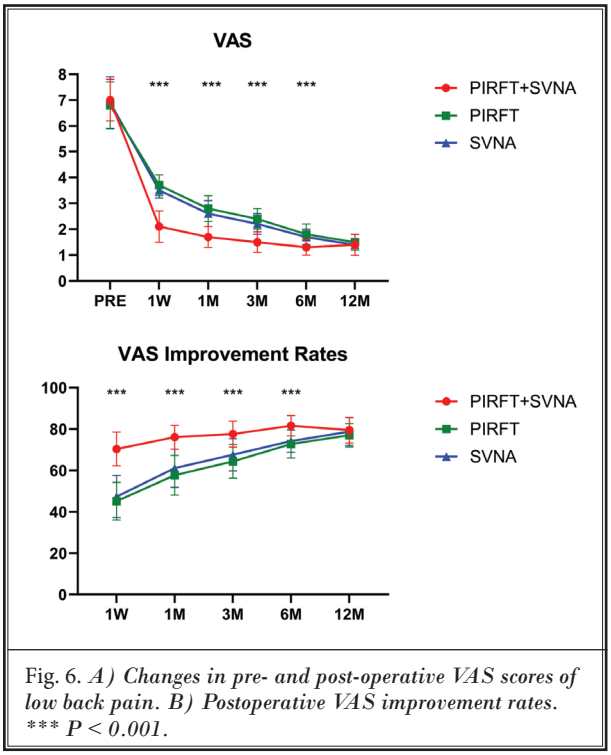

Fig. 6. *A) Changes in pre- and post-operative VAS scores of low back pain. B) Postoperative VAS improvement rates. *** P < 0.001.*

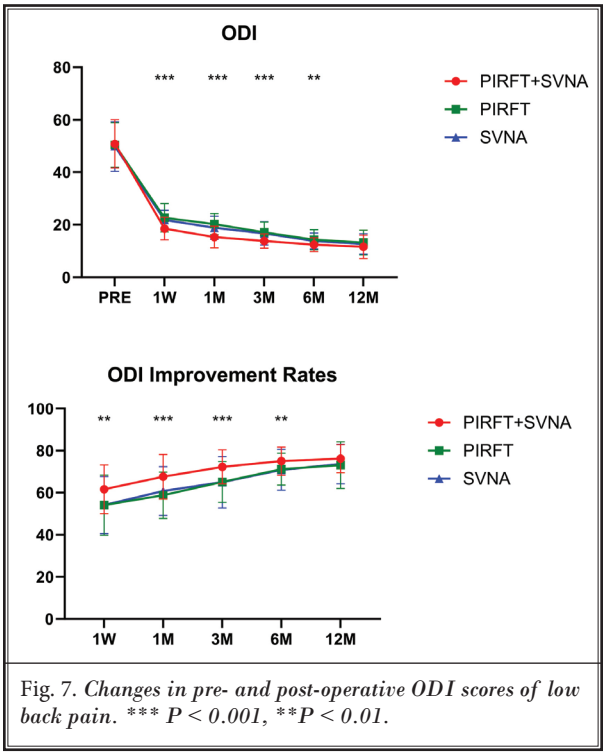

Fig. 7. *Changes in pre- and post-operative ODI scores of low back pain. *** P < 0.001, **P < 0.01.*

Table 2. *Changes in pre- and post-operative VAS scores for low back pain (mean ± SD)*

Group	Preoperation	1 week postoperation	1 month postoperation	3 months postoperation	6 months postoperation	12 months postoperation
PIRFT+SVNA	7.0 ± 0.8	2.1 ± 0.6	1.7 ± 0.4	1.5 ± 0.4	1.3 ± 0.3	1.4 ± 0.4
PIRFT	6.8 ± 0.9	3.7 ± 0.4	2.8 ± 0.5	2.4 ± 0.4	1.8 ± 0.4	1.5 ± 0.3
SVNA	6.9 ± 1.0	3.5 ± 0.3	2.6 ± 0.5	2.2 ± 0.4	1.7 ± 0.3	1.4 ± 0.4
F value	0.693	223.112	95.615	72.264	42.338	2.129
P value	0.501	0.000*	0.000*	0.000*	0.000*	0.122

Notes: One-way ANOVA was used to compare the measured values among the 3 groups. *$P < 0.05$ was considered to indicate significant difference. Data is presented as mean ± SD.
Abbreviations: VAS, visual analog scale; PIRFT, percutaneous intervertebral radiofrequency thermocoagulation; SVNA, sinuvertebral nerve ablation.

Table 3. *Changes in pre- and post-operative ODI scores for low back pain (mean ± SD)*

Group	Preoperation	1 week postoperation	1 month postoperation	3 months postoperation	6 months postoperation	12 months postoperation
PIRFT+SVNA	50.8 ± 9.1	18.8 ± 4.2	15.9 ± 3.7	13.5 ± 2.4	12.3 ± 2.4	11.8 ± 2.9
PIRFT	50.4 ± 8.5	22.5 ± 5.4	20.2 ± 4.0	17.1 ± 3.9	14.2 ± 3.3	13.1 ± 4.6
SVNA	49.8 ± 9.5	21.8 ± 3.7	18.8 ± 4.4	16.7 ± 4.4	13.8 ± 3.0	12.7 ± 3.9
F value	0.193	10.140	16.516	15.571	6.332	1.655
P value	0.825	0.000*	0.000*	0.000*	0.002*	0.194

Notes: One-way ANOVA was used to compare the measured values among the 3 groups. *$P < 0.05$ was considered to indicate significant difference. Data is presented as mean ± SD.
Abbreviations: ODI, Oswestry disability index; PIRFT, percutaneous intervertebral radiofrequency thermocoagulation; SVNA, sinuvertebral nerve ablation.

Table 4. *Postoperative VAS improvement rates. (mean ± SD)*

Group	1 week postoperation	1 month postoperation	3 months postoperation	6 months postoperation	12 months postoperation
PIRFT+SVNA	70.4 ± 8.1	76.1 ± 5.8	77.6 ± 6.3	81.6 ± 4.9	79.5 ± 6.2
PIRFT	45.2 ± 9.1	57.7 ± 9.6	64.4 ± 8.1	72.8 ± 6.8	77.0 ± 5.6
SVNA	47.4 ± 10.2	61.1 ± 9.2	67.6 ± 7.8	74.2 ± 5.3	78.8 ± 6.7
F value	126.087	75.281	46.803	36.794	2.511
P value	0.000*	0.000*	0.000*	0.000*	0.084

Notes: One-way ANOVA was used to compare the measured values among the 3 groups. *$P < 0.05$ was considered to indicate significant difference. Data is presented as mean ± SD.
Abbreviations: VAS, visual analog scale; PIRFT, percutaneous intervertebral radiofrequency thermocoagulation; SVNA, sinuvertebral nerve ablation.

Table 5. *Postoperative ODI improvement rates. (mean ± SD)*

Group	1 week postoperation	1 month postoperation	3 months postoperation	6 months postoperation	12 months postoperation
PIRFT+SVNA	61.6 ± 11.6	67.6 ± 10.6	72.3 ± 8.1	75.0 ± 6.7	76.2 ± 6.7
PIRFT	54.1 ± 14.3	58.8 ± 11.0	65.1 ± 9.7	71.2 ± 7.6	73.1 ± 11.1
SVNA	54.1 ± 13.6	60.8 ± 11.6	65.0 ± 12.2	70.9 ± 9.7	73.6 ± 9.4
F value	5.918	9.579	9.282	4.231	1.702
P value	0.003	0.000*	0.000*	0.016*	0.185

Notes: One-way ANOVA was used to compare the measured values among the 3 groups. *$P < 0.05$ was considered to indicate significant difference. Data is presented as mean ± SD.
Abbreviations: ODI, Oswestry disability index; PIRFT, percutaneous intervertebral radiofrequency thermocoagulation; SVNA, sinuvertebral nerve ablation.

indicate that, for DLBP patients, the efficacy of the combined PIRFT and SVNA treatment exceeds that of the PIRFT or SVNA treatment alone. Twelve months post-operation, there was no statistically significant difference in the VAS and ODI scores among the 3 groups, probably because physicians typically individualize treatment according to patient characteristics in the postoperative period, thus eliminating differences produced by the varying treatments. and the variability of the patient cohort due to the small sample size. The postoperative ODI improvement rate was not as significant as that of the VAS scores, partly because all 3 treatments reduced pain symptoms and dysfunction by reducing the pain signaling caused by DLBP, despite using different modalities and target sites to do so. Other factors, such as assessment methods, individual variances, and overlapping indications, could also have contributed to the results. Therefore, in future studies clinicians should conduct adequate follow-up and evaluations to optimize treatment efficacy.

Previous studies have shown inconsistent results regarding the efficacy of PIRFT (7,18,19). After reviewing the history of PIRFT, we hypothesized that different puncture sites may be contributing to the inconsistent results of PIRFT. Originally, the earliest intradiscal radiofrequency treatments required the tip of the puncture needle to reach the central nucleus pulposus, but subsequent findings revealed that this region is devoid of nerve endings and cannot sense or respond to inflammatory stimuli or pain (7). The efficacy of thermal coagulation and decompression for pain relief was also inconclusive (20). Since then, studies have focused on placing electrodes in the annulus fibrosus, a procedure known as radiofrequency annuloplasty, which can reduce intradiscal pressure, disrupt pain transmission, and repair torn annulus fibrosus tissue (21). Subsequently, the concept of "disc target radiofrequency" was proposed, and most researchers referred to the "target" as the portion of the intervertebral disc that extends beyond the vertebral body margins, where the radiofrequency needle is inserted into the protruding nucleus pulposus to relieve pain through ablation, which reduces mechanical compression (22). As the technique for PIRFT developed, the position of the needle tip changed from the center of the nucleus pulposus to the annulus fibrosus and then to the protruding nucleus pulposus, gradually indicating the importance of SVNA (23). For PIRFT, the presently recommended puncture site is the posterior 1/3 of the disc where the annulus fibrosus is ruptured. While the radiofrequency treatment is beneficial for repairing the ruptured annulus fibrosus and alleviating intradiscal pressure, it has a limited effect on SVN pain transmission interference.

The SVN is morphologically slender, has inconsistent and anastomotic branches in different segments, and there is no consensus on its anatomical orientation, because of which accurate localization of the SVN during denervation remains difficult (11,12,24). Recently, the development of visualized endoscopic techniques has facilitated the microscopy-based search of SVN. While Kim et al (11) have performed endoscopic denervation of the SVN with satisfactory results, damage to the disc tissue, ligaments, synovial processes, and other structures is unavoidable during the endoscopic placement and exposure of the SVN. Therefore, SVNA using radiofrequency therapeutic instruments under x-ray or CT guidance is less damaging, inexpensive, can reduce the surgical pain of patients, resulting in faster recovery (25). In degenerative disc disease, hypersensitivity of the SVN and the basivertebral nerve is closely associated with epidural neovascular adhesions and pathologic pain pathways (9,10). Thus, radiofrequency ablation of epidural neovascular adhesions is effective in treating DLBP and induces relief of paravertebral muscle spasms (26).

Presently, SVNA is based on anatomical landmarks for the selection of the approximate surgical area in the SVN pathway. In recent years, SVN block or disruption has been performed near the pedicle notch, ventral to the dural sac, or at the junction of the posterior longitudinal ligament of the annulus fibrosus (27). In contrast, SVNA has a limited effect in intradiscal treatment because it primarily reduces the mechanical stress and chemical reactions to repair the ruptured annulus fibrosus. However, the growth of SVNs in the disc is related to the location and degree of the annulus fibrosus tear, and it is not guaranteed that sufficient SVNs will be distributed around the puncture target. Therefore, theoretically, combining SVNA with conventional disc repair and mechanical decompression should provide more significant pain relief in DLBP.

Notably, SVN is widely distributed in the annulus fibrosus and the posterior longitudinal ligament of the intervertebral disc, and its anatomical characteristics make it difficult to accurately select a target site for SVNA (28). The reported SVNA surgeries have been based on the pain response of patients after intraoperative stimulation of the corresponding areas, and multiple SVNA have been performed to produce a sufficient therapeutic effect (11,29). Herein, when the puncture needle reached the posterior longitudi-

nal ligament area of the fibrous ring and the patient complained of considerable lumbar soreness, radiofrequency treatment was performed. After completion, the needle was gradually withdrawn from the patient, and the radiofrequency treatment was performed again in the area where the patient felt pain replication or lumbar soreness. Thus, this method expanded the scope of SVNA through radiofrequency treatment at multiple sites. Although the treatment of the PIRFT + SVNA group was more thorough than that of the PIRFT or SVNA group, it inevitably produced a larger number of SVNAs and puncture injuries. There was no significant difference in the occurrence of complications among the 3 groups during the follow-up period, but any potential long-term risks are unknown.

Theoretically, any patient with DLBP can be considered suitable for PIRFT treatment, or an SVN block can be performed to determine the responsible segment. However, in patients with joint process hypertrophy and a high iliac crest, placement of the puncture needle in the ideal puncture target is highly difficult. The clinical causes of low back pain are complex, and patients with chronic low back pain usually present with multiple sources of pain that are often associated with changes in various lumbar spinal structures (30). In this study, only patients who were punctured via the posterior–lateral approach were included to reduce bias, and the target points were selected flexibly based on the anatomical characteristics of the patients undergoing the treatment.

Conclusions

Compared with PIRFT or SVNA alone, PIRFT + SVNA treatment provided more pain relief and functional improvement, suggesting that it is a more effective treatment for DLBP. Furthermore, both PIRFT and SVNA are not likely to induce serious complications, which makes this combination treatment safer and more reliable. Additionally, PIRFT + SVNA is more suitable for DLBP patients since it is a minimally invasive treatment which is less damaging to the patient, not difficult to manage intraoperatively, and has a cost-effective and shorter treatment course, provided the indications are strictly controlled.

Authors' Contributions

Qingda Li and Junsong Yang drafted the manuscript. Tuanjiang Liu and Yayi Xia conceived the study design. Botao Lu, Datong Li, Wangli Huang and Bin Geng supervised the data collection and literature review. Dingjun Hao and Baorong He are responsible for this article.

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