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RESEARCH ARTICLE

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Efficacy of percutaneous endoscopic lumbar discectomy (PELD) combined with sinuvertebral nerve ablation versus PELD for low back pain in lumbar disc herniation

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Abstract

Background Percutaneous endoscopic lumbar discectomy (PELD) has demonstrated variable efficacy in alleviating low back pain (LBP) associated with lumbar disc herniation (LDH). Sinuvertebral nerve ablation (SNA), which targets the nociceptive pathway implicated in discogenic LBP pathogenesis, has emerged as a potential adjunctive therapy. The efficacy of endoscopic radiofrequency ablation in enhancing PELD for the treatment of LBP in patients with LDH remains unclear.

Methods A retrospective cohort study was conducted on LDH patients with concomitant LBP treated at the Spinal Surgery Department, China-Japan Friendship Hospital, from June 2020 to June 2023. Participants were categorized into two groups: PELD combined with SNA ($n=51$) and PELD alone ($n=46$). Primary outcome measures included the Visual Analog Scale (VAS) for pain, the Japanese Orthopaedic Association (JOA) score, and the Oswestry Disability Index (ODI) at baseline and 1-, 3-, and 6-month follow-ups.

Results Both groups exhibited significant improvements in VAS, JOA, and ODI scores for LBP and leg pain postoperatively compared to preoperative assessments. Notably, the PELD combined with SNA group demonstrated statistically significant superior outcomes in VAS, JOA, and ODI scores specifically for LBP compared to the PELD group.

Conclusion The combination of PELD with SNA significantly improves LBP outcomes compared to PELD alone in LDH patients. While the observed improvements did not reach the minimal clinically important differences (MICD), these findings suggest that SNA may enhance the efficacy of PELD in LBP management.

Keywords Low back pain, Sinuvertebral nerve, Lumbar disc herniation, Percutaneous endoscopy, Case series

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Introduction

Low back pain (LBP) is a prevalent health condition affecting the majority of individuals at some point in their lives (80%) [1]. Intervertebral disc degeneration is a primary cause of LBP, responsible for 26-42% of cases [2]. Lumbar disc herniation (LDH), a degenerative condition of the lumbar spine, has an annual prevalence of approximately 0.1-0.5% and a lifetime incidence of 1-2% [3]. LDH manifests with various symptoms, including sciatica, LBP, leg discomfort, and reduced mobility, which can significantly compromise quality of life and impose economic burdens [4].

Extensive research has investigated the association between LBP and disc herniation. LDH is recognized as a major contributor to LBP through physical compression, relief, and increased production of inflammatory cytokines [5]. LBP onset is linked to intervertebral disc aging and reduced water content [6, 7]. Chronic inflammation plays a key role, with inflammatory mediators weakening the disc structure and potentially leading to annular fibrous rupture [8]. Neovascularization, neoinnervation, and nociceptive sensitization contribute to pain signal transmission [9]. Anatomical studies have highlighted the crucial role of sinuvertebral nerves in LBP conduction [10]. These nerves are abundant in the intervertebral disc and surrounding tissues and are believed to be the primary mediators of LBP [11].

Contemporary therapeutic strategies for LDH encompass a range of interventions, including bed rest, physical rehabilitation, pharmacotherapy, and additional modalities [12]. However, the efficacy of these approaches frequently falls short of expectations. In this context, spinal endoscopy has emerged as a rapidly advancing field that presents a promising option for the management of intervertebral disc disorders [13]. A pivotal advancement in this area has been the delineation of the "Kambin triangle," along with the influential publication of Kambin's seminal work on endoscopic lumbar discectomy in 1991, which established a standardized technique for spinal endoscopic surgery [14].

Percutaneous endoscopic lumbar discectomy (PELD) is specifically designed to alleviate conditions such as sciatica and cauda equina syndrome [15], both of which stem from nerve root compression resulting from herniated disc material [16, 17]. Nonetheless, follow-up studies have documented variable outcomes concerning the effectiveness of PELD. For instance, a study by Xu et al. involving 113 patients reported no residual leg pain two years postoperatively; however, 32 patients continued to experience LBP [18]. Similarly, Zhong et al. assessed 355 patients and identified varying degrees of postoperative LBP in 130 individuals [19]. A further retrospective analysis of 88 patients undergoing PELD revealed a postoperative LBP incidence of 21.6% [20].

While PELD effectively excises the protruding nucleus pulposus, alleviating the mechanical compression on adjacent nerve roots and thereby reducing leg pain, it is important to acknowledge that intervertebral disc degeneration is an irreversible process. The ongoing inflammatory response may further exacerbate the condition, as inflammatory mediators stimulate the sinuvertebral nerves located on the surface of the intervertebral disc, leading to pain conduction. This persistent inflammation may contribute to the phenomenon of residual LBP. Therefore, the integration of radiofrequency ablation targeting the sinuvertebral nerve alongside percutaneous endoscopic techniques may enhance treatment outcomes and offer a more comprehensive approach to the management of LBP.

Our previous study introduced PELD combined with sinuvertebral nerve ablation (SNA) as a novel therapeutic approach [21], with promising results. However, the comparative efficacy of this combined modality has not been directly assessed. This study aims to directly compare the efficacy of PELD combined with SNA for LBP in LDH.

Methods

Study design and study population

This retrospective analysis included patients with LBP who underwent percutaneous endoscopic surgery at the Spinal Surgery Department of the China-Japan Friendship Hospital between June 2020 and June 2023. The study protocol was conducted in accordance with the ethical standards set forth in the Declaration of Helsinki and approved by the Clinical Research Ethics Committee of the China-Japan Friendship Hospital (2022-KY-104). Written informed consent was obtained from all patients.

Inclusion criteria were as follows: (i) adult patients; (ii) presenting with typical symptoms of nerve root compression or cauda equina syndrome; (iii) with corresponding segmental disc herniation confirmed by imaging studies; (iv) experiencing typical dull LBP or lumbosacral pain; and (v) demonstrating lack of improvement after three months of conservative treatment (including pharmacotherapy, rest, physical therapy, and muscle exercises). Exclusion criteria included patients with other spinal diseases, LBP from other etiologies, surgery for more than 1 segment, surgical contraindications, refusal to undergo surgery, or loss to follow-up. The flowchart for the inclusion of patients in the study is shown as Fig. 1.

There are the same indications for PELD and PELD+SNA. There was no specific preference for the choice of surgery in either group of surgeries. PELD surgery is performed by multiple senior surgeons, and PELD+SNA surgery is performed by only one of these surgeons.

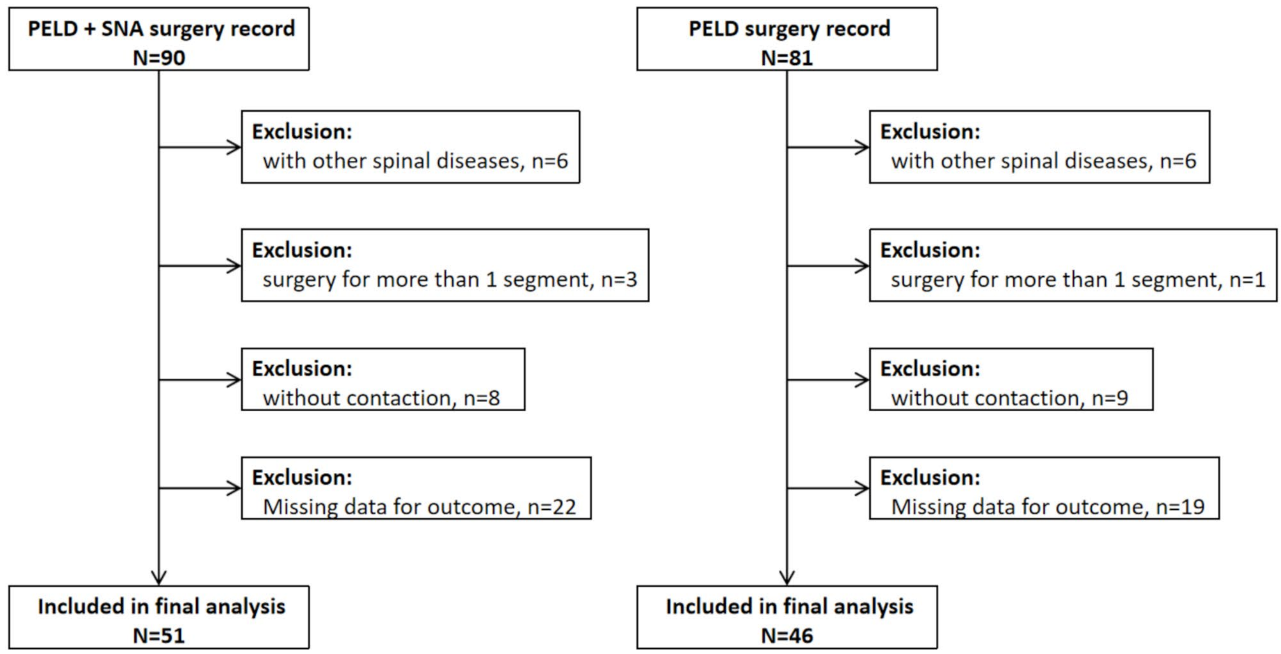

Fig. 1 Flowchart for the inclusion of patients in two groups

Assessment criteria

Patient-reported outcomes were assessed using the Visual Analog Scale (VAS), Japanese Orthopaedic Association (JOA) score, and Oswestry Disability Index (ODI) preoperatively and postoperatively at one-, three-, and six-month follow-up intervals. Treatment efficacy was evaluated at the final follow-up using the modified MacNab criteria. The duration of surgery and perioperative complications were also counted.

Surgical procedure

Senior doctors at the China-Japan Friendship Hospital who were skilled in percutaneous endoscopic procedures carried out every surgery. Thirty minutes before to surgery, antibiotics were given as part of an infection prevention strategy. Patients of both groups underwent local anesthesia with moderate sedation, in prone position on Wilson frame over a radiolucent table. A spinal endoscope (Joimax, Karlsruhe, Germany) and bipolar radiofrequency electrode (Trigger-Flex Bipolar System; Elliquence, New York, NY, USA) were used throughout the procedure.

The entry point was determined to be 8–13 cm from the midline to acquire 45ο from the horizontal line. The 18 gauge endoscopy needle was inserted from the entry point until reached the lateral aspect of the superior articular process (SAP). The needle tip was inserted into the foramen and slid along the ventral part of the facet joint. Needle entry into the intervertebral disc should be more internal than the medial line of the cranial and caudal pedicles in the A-P and lateral views.

PELD

1. Cannula placement: the needle was replaced with a guidewire, and an approximately 1 cm incision was made at the entry point. A pencil dilator was then inserted along the guidewire. Then, A bevel-type cannula (7.5 mm working channel)(Guanlong, Shandong, China) was inserted using a pencil dilator. The cannula position is approved if it lies at the centre of the disc parallel to the endplates and the tip positioned at the medial pedicle line in AP view and posterior vertebral line in the lateral view. Finally, the endoscope was introduced.
2. Discttomy: initially Triggerflex radio frequency probe is used to achieve hemostasis and delineate the anatomical structures. Intradiscal disc fragments are removed with a rongeur. Annular release is done by cutting the posterior part of annulus - PLL complex with a punch forceps. Herniated fragments are then removed. Endoscope is levered upwards to inspect the ventral epidural space and the traversing nerve root. Any free fragments visualised are removed under direct vision. Decompression of the nerve root is confirmed.

PELD + SNA

1. Foraminoplasty and cannula placement: following a dilatior along the guide wire, the working cannula (8.4 mm) and endoscopic trephine (7.5 mm)

(Guanlong, Shandong, China) was placed, which were located at the exterior margin of the superior articular process (SAP) from anteroposterior view and at the tip of the superior articular process from later fuoroscopic view. Then, the endoscope (6.3 mm) (Joimax, Karlsruhe, Germany) was introduced and inserted into the working cannula. Under endoscopic direct vision, the soft tissue around the peripheral facet joint was ablated by the bipolar radiofrequency electrode (Trigger-Flex Bipolar System; Elliquence, New York, NY, USA), and the ventral superior articular process was partially resected to enlarge the intervertebral foramen, using the endoscopic trephine .

2. Discectomy and SNA: after foraminoplasty was concluded, the foramina zone was exposed. Under endoscopic and fluoroscopic guidance, soft tissues were removed using a bipolar radiofrequency electrode (Trigger-Flex Bipolar System; Elliquence, New York, NY, USA) and forceps to expose the surface of disc.The working cannula and endoscope were further pushed toward the lumbar canal, during the intervertebral disc exposure, flexible bipolar radiofrequency is used to clean the sinus vertebral nerve distribution from the outside to inside. The scope of ablation (Fig. 2): centered on the intervertebral disc, the outer edge of the intervertebral foramina on the outside, the midline of the vertebral body on the inner boundary, the upper boundary 3 mm above the lower end plate of the upper vertebral body, and the lower boundary 3 mm below the upper end plate of the lower vertebral body. The working retractor is in place to protect the nerve component. After resection of the nucleus pulposus and satisfactory nerve decompression, the radiofrequency is again administered to the radiofrequency area from the inside out with the withdrawal of the working cannula. Finally, the endoscope is withdrawn, the working channel is removed, and the incision is sutured in layers. For specifics during the course of treatment, please see Fig. 3.

Postoperatively, patients receive symptomatic therapy for pain management, infection prophylaxis, edema reduction, and neurotrophic support. Patients are advised to ambulate with a lumbar support device from the first postoperative day for a duration of four weeks. A progressive rehabilitation regimen is implemented, focusing on strengthening the lumbar musculature.

Statistical analysis

RStudio (version 2022.07.1 Build 554) and R (version 4.2.1) were used for data analysis. The standard deviation (SD) of normally distributed continuous data is shown as mean ±, whereas percentages are used to depict categorical variables. The independent sample t-test was employed to evaluate differences in continuous data, while the chi-square test was used to compare differences between categorical variables. A *P*-value with two tails less than 0.05 was deemed statistically significant.

Results

The study sample comprised 97 patients, 51 of whom underwent PELD with SNA, while 46 underwent PELD alone. Table 1 presents the baseline characteristics of

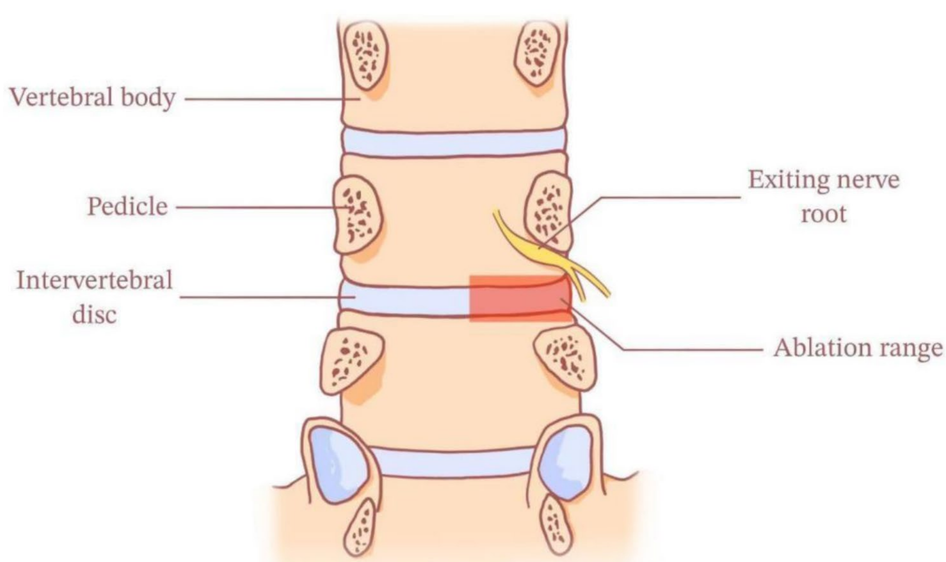

Fig. 2 Visual depiction; the range of ablation is the highlight

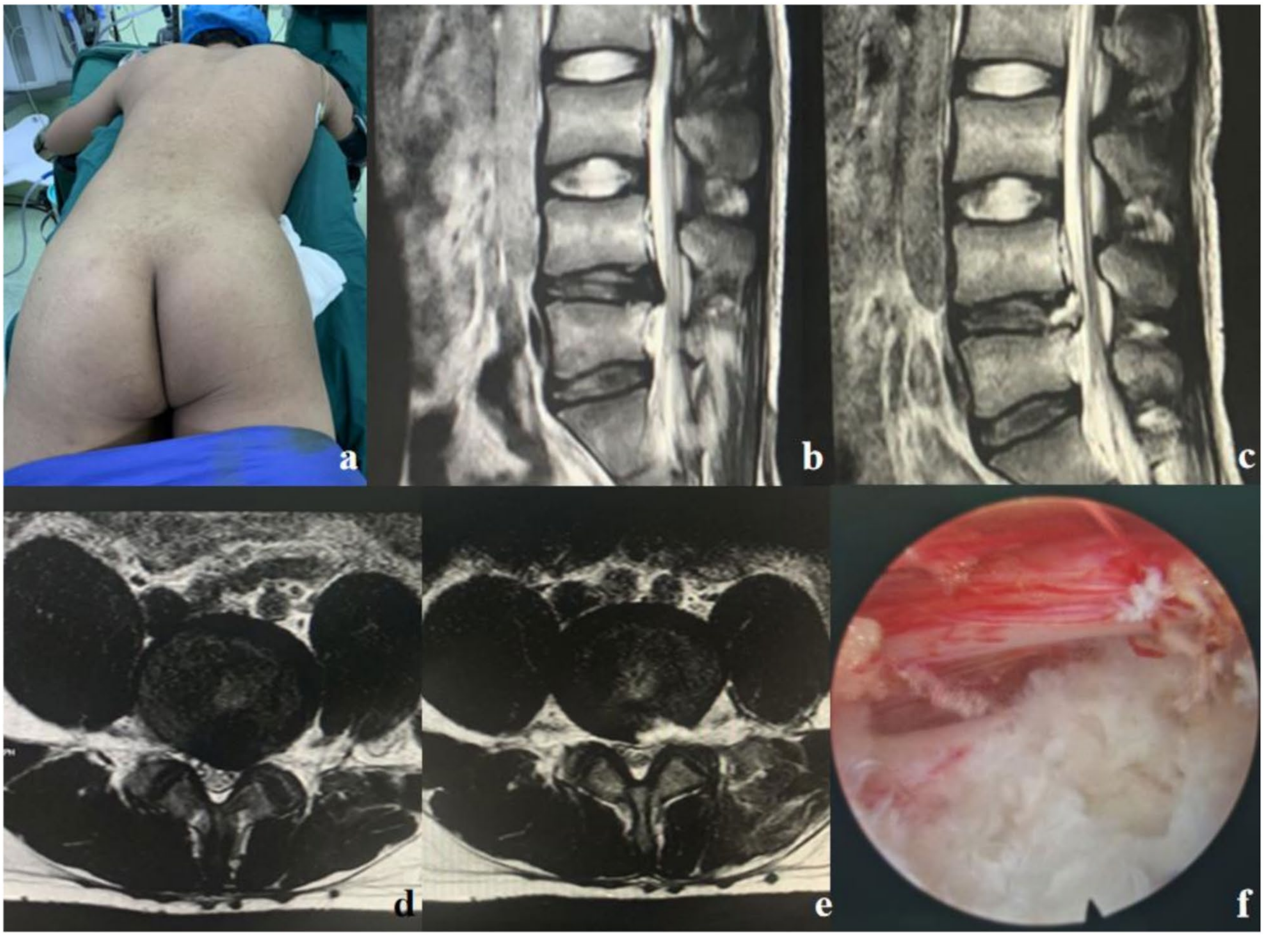

Fig. 3 Photographs throughout treatment: (**a**) the patient positioned before surgery, had compensatory posture due to LBP; (**b**) herniated intervertebral disc of L4/5 segment can be seen in the preoperative T2-weighted MRI; (**c**) the herniated intervertebral disc was removed, compared to preoperative; (**d**) the L4/5 segment before surgery, the horizontal plane of the T2-weighted MRI; (**e**) the L4/5 segment after surgery, the range of ablation was visible; (**f**) the view under the spinal endoscopy showed the ventral dura during the surgery

Table 1 Baseline characteristics of patients with LDH

Characteristic	PELD with SNA (*n* = 51)	PELD (*n* = 46)	*P* Value
Age, years	46.9 ± 16.2	47.2 ± 15.7	0.532
Sex			0.631
Male	30 (58.8%)	28 (60.9%)	
Female	21 (41.2%)	18 (39.1%)	
LDH segment distribution			0.564
L3/4	3 (5.9%)	3 (6.5%)	
L4/5	44 (86.3%)	40 (87.0%)	
L5/S1	4 (7.8%)	3 (6.5%)	
Lesion site			0.936
Central	11 (21.6%)	9 (19.6%)	
Left paracentral	19 (37.3%)	18 (39.1%)	
Right paracentral	21 (41.2%)	17 (33.3%)	
Physical examination			0.999
Lasegue sign positive	37 (72.5%)	33 (71.7%)	
Lower limb hypesthesia	22 (43.1%)	20 (43.5%)	

the two groups, including age, sex, disc herniation level, lesion location, and physical examination findings. Statistical analysis revealed no significant differences in baseline characteristics between the groups ($p > 0.05$).

Patients were followed for a minimum of six months. At baseline and at one-, three-, and six-month intervals postoperatively, back and leg pain VAS scores, JOA scores, and ODI scores were assessed. Treatment efficacy was evaluated at the final follow-up visit using the modified MacNab criteria. Table 2 displays the outcomes. Figure 4 shows the results as a visual representation.

Baseline VAS scores for leg and LBP, JOA scores, and ODI scores were comparable between the groups ($p > 0.05$). At one-, three-, and six-month follow-ups, patients who underwent combined PELD and SNA exhibited significantly lower VAS scores for LBP compared to those who underwent PELD alone ($p < 0.05$). No significant differences were observed in VAS scores for leg pain ($p > 0.05$). The JOA scores were significantly

Table 2 Outcomes of accessment

Parameter	PELD with SNA (n=51)	PELD (n=46)	*P* Value
Low back-VAS			
Pre-operation	6.21 ± 1.32	6.14 ± 1.29	0.821
1 month after operation	1.59 ± 1.64	2.47 ± 1.98	**0.041**
3 month after operation	1.36 ± 1.42	2.22 ± 1.83	**0.027**
6 month after operation	1.31 ± 1.38	2.16 ± 1.91	**0.034**
Leg-VAS			
Pre-operation	7.45 ± 1.15	7.53 ± 1.21	0.684
1 month after operation	1.22 ± 1.24	1.19 ± 1.26	0.571
3 month after operation	1.08 ± 1.07	1.14 ± 1.04	0.739
6 month after operation	1.01 ± 1.09	1.03 ± 1.01	0.927
JOA			
Pre-operation	13.92 ± 5.43	14.61 ± 5.61	0.492
1 month after operation	24.35 ± 4.94	22.07 ± 4.86	**0.039**
3 month after operation	26.42 ± 5.03	24.23 ± 5.52	**0.044**
6 month after operation	27.12 ± 5.38	24.97 ± 6.02	**0.048**
ODI			
Pre-operation	59.12 ± 10.38	57.74 ± 8.92	0.416
1 month after operation	20.10 ± 5.37	24.38 ± 4.89	**0.049**
3 month after operation	17.93 ± 5.12	22.15 ± 5.27	**0.048**
6 month after operation	17.01 ± 5.35	21.60 ± 5.94	**0.043**
Mac Nab criteria			0.484
Excellent	27 (52.9)	19 (41.3)	
Good	18 (35.3)	19 (41.3)	
Fair	6 (11.8)	8 (17.4)	
Surgery time (minutes)	83.7 ± 9.8	80.9 ± 14.2	0.346

higher in the PELD + SNA group compared to the PELD-only group at one-, three-, and six-month follow-ups ($p < 0.05$). Similarly, ODI scores were significantly lower in the PELD + SNA group compared to the PELD-only group at all follow-up time points ($p < 0.05$). Finally, the modified MacNab criteria revealed a higher proportion of excellent outcomes in the PELD + SNA group compared to the PELD-only group, statistically significance ($p > 0.05$). The operation time was longer in the PELD + SNA group, but it was not statistically significant ($P > 0.05$).

No severe vascular and neurological complications occurred during the perioperative period. There were 2 cases of dural tears in the PELD + SNA group and 1 case in the PELD group. All three patients were asymptomatic. There was 1 case of neural irritation in each group. Neural irritation mainly refers to the transient neural symptoms after surgery, which are characterized by decreased sensation and normal strength in the lower extremities. Fortunately, these 2 patients improved with conservative treatment. Neither recurrence nor reoperation occurred during the follow-up period.

Discussion

Our findings indicate that PELD, whether administered as a solitary intervention or in conjunction with SNA, represents a viable approach for the treatment of LDH. Postoperatively, patients in both cohorts experienced statistically significant enhancements in quality of life, alongside reductions in lower back and leg pain. Specifically, the integration of PELD with SNA was associated with a more substantial alleviation of LBP, thereby enhancing overall patient well-being.

Although PELD is perceived to provide limited relief for sciatica and leg pain, its effectiveness in LBP management has been noted in recent literature. For example, a study involving 249 patients reported a 63.1% decrease in the average VAS score for LBP four weeks post-surgery [22]. Additionally, a separate investigation with 56 patients indicated a 60.1% reduction in VAS scores for LBP one year following the procedure [23]. Cao et al. analyzed 167 patients and documented a 66% reduction in VAS scores for LBP two years after surgery [24]. Consistent with this body of evidence, our analysis of 46 patients who underwent PELD revealed a 64.8% decrease in VAS scores for LBP six months postoperatively. Notably, our findings suggest a correlation between preoperative LBP severity and postoperative VAS scores, indicating that more pronounced preoperative symptoms may be associated with higher post-surgical scores.

The efficacy of treating the sinuvertebral nerve in mitigating LBP has been established by prior studies. For instance, Kim et al. demonstrated that radiofrequency ablation of the sinuvertebral nerves resulted in a 73% reduction in average VAS scores for LBP at six months post-procedure, with a remarkable success rate of 93% [25]. Liu et al. similarly reported a significant reduction in average VAS scores for LBP from 5.75 to 2.5, and a notable decrease in the ODI from 32.59 to 17.28, three days after intervention [26]. Koreckij et al. found that radiofrequency ablation of the basivertebral nerve, a branch of the sinuvertebral nerve, resulted in pain relief for 31% of patients, with over 50% experiencing pain reductions exceeding 72.4% two years post-treatment [27].

Previous literature has highlighted minimal clinically important differences (MCID) in spinal rating scales, yet precise values remain contentious. Refer to relevant research [28], we initially set the MCID for VAS to be 2, for the JOA score to be 2.5, and for ODI to be 8. Our study found that SNA significantly decreased measures of back pain and ODI while improving JOA scores; however, these changes, while statistically significant, did not achieve the thresholds of MCID.

The sinuvertebral nerve is a complex anatomical structure that arises from the ventral spinal nerve root and traverses the intervertebral foramina to re-enter the spinal canal. It innervates the posterior aspect of the

Fig. 4 VAS, JOA, and ODI scores at each follow-up time

intervertebral disc, the posterior longitudinal ligament, vertebral bodies, pedicles, and adjacent soft tissues of the anterior intervertebral foramen and spinal canal [29]. Dual innervation from both somatic and sympathetic nerve sources, derived from the spinal nerve and gray communicating branches respectively, characterizes the sinuvertebral nerve [30]. At the lateral outer surface of the intervertebral disc, the nerve bifurcates into a main stem and collateral branches, with the latter primarily supplying the lower edge of the pedicle and the lateral outer portion of the intervertebral disc. The main trunk descends beneath the pedicle and divides into ascending, transverse, descending, and spinal canal branches within the intervertebral foramen, effectively covering nearly all regions of the spinal canal, save for the inner disc surface [10]. Mechanical or chemical stimulation of the sinuvertebral nerve transmits pain signals to the central nervous system, where the cerebral cortex typically localizes the sensation to the lower back, potentially explaining the observed limited efficacy of sinuvertebral ablation on leg pain. Ablation of the sinuvertebral nerve branches interrupts the afferent pain transmission pathway.

Locating the diminutive sinuvertebral nerve can prove challenging, even with endoscopic techniques. Therefore, we implemented an anatomical localization strategy to ascertain the extent of radiofrequency ablation based on existing literature. By targeting both the primary trunk and collateral branches of the sinuvertebral nerve simultaneously, we removed tissue from the surface of the intervertebral disc, its adjacent regions, and the inner periphery of the nerve root. Care was taken to avoid damaging critical structures such as ganglia and arteries, thereby minimizing potential complications. Figure 2 provides a graphic illustration of the extent of ablation performed.

To enhance the management of low back pain in patients with LDH, we have integrated SNA into PELD, resulting in a control group characterized by comparable baseline attributes. Nevertheless, several limitations must be acknowledged. First, we implemented a unilateral block of the sinuvertebral nerve; given that the anastomotic ramus facilitates the transmission of pain to the contralateral side, a bilateral approach may yield greater clinical benefit. Second, as previously noted [31], the surgical excision of osseous, muscular, ligamentous, and fascial tissue can contribute to postoperative discomfort in the lumbar region. Additionally, potential bias may arise from differing surgical teams operating on the respective groups. Our follow-up period was relatively brief, postoperative disc degeneration, recurrent symptoms and reoperation were not documented during the follow-up. However, the combination of PELD and SNA may elevate the risk of recurrent disc herniation owing to annular detachment or compromised mechanical integrity. Finally, the retrospective design of this study may introduce recall bias, and the relatively small sample size underscores the need for larger prospective studies to conclusively address these limitations. Furthermore, exploring alternative strategies for alleviating discogenic low back pain, such as combining PELD with thermal cycloplasty, epidural steroid injections, or spinal cord stimulation, merits investigation; we plan to pursue these avenues in future research initiatives.

Conclusion

Our research indicates that the combination of PELD and SNA leads to significantly greater alleviation of LBP compared to PELD alone. While the observed improvements did not reach MCID, the efficacy of this combined approach suggests that patients suffering from LDH accompanied by LBP may derive substantial benefit from this therapeutic option.

Author contributions

Yanjun Huang contributed to the study's concept and design, methodology, data interpretation, formal analysis, writing the original draft, reviewing and editing the manuscript. Shangshu Wei contributed to the data cleaning and analysis, data interpretation and drafting of the manuscript. Yanjun Huang and Shangshu Wei contributed equally to this work.Shuyue Yang contributed to the visualization and drafting of the manuscript.Yanzhu Shen contributed to method development and data cleaning.Haoning Ma contributed to reviewing and editing the manuscript.Ping Yi contributed to reviewing and editing the manuscript.Xiangsheng Tang contributed to supervision, concept and design, investigation, validation, reviewing and editing the manuscript, and funding acquisition.

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethical approval

The study declares that all protocols were conducted in accordance with the ethical standards set forth in the Declaration of Helsinki and received approval from the Clinical Research Ethics Committee of the China-Japan Friendship Hospital (2022-KY-104). We declare that written informed consent was obtained from all participating patients.

Competing interests

Yanjun Huang, Shangshu Wei, Shuyue Yang, Yanzhu Shen, Ping Yi and Xiangsheng Tang state that they don't have any conflicting interests.

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