Journal of Pain Research

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Treatment of Painful One Level Schmorl's Nodes Using Percutaneous Endoscopic Lumbar Discectomy: A Clinical Evaluation

Zihao Ding[1,*], Jie Wang[1,*], Li Guan[1], Yuzeng Liu[1], Yaoshen Zhang[1], Yong Hai[1–4]

[1]Department of Orthopedic Surgery, Beijing Chao-Yang Hospital, Capital Medical University, Beijing, People's Republic of China; [2]Joint Laboratory for Research & Treatment of Spinal Cord Injury in Spinal Deformity, Capital Medical University, Beijing, People's Republic of China; [3]Laboratory for Clinical Medicine, Capital Medical University, Beijing, People's Republic of China; [4]Clinical Center for Spinal Deformity, Capital Medical University, Beijing, People's Republic of China

*These authors contributed equally to this work

Correspondence: Yong Hai; Yaoshen Zhang, Email yong.hai@ccmu.edu.cn; zhangyaoshen08@163.com

Introduction: Herniations of the intervertebral disc into the vertebral body, known as Schmorl's nodes (SNs), are frequently associated with degenerative disc disease (DDD). Painful SNs can contribute to discogenic lower back pain associated with DDD. Studies show that percutaneous endoscopic lumbar discectomy (PELD) yields favorable treatment outcomes for degenerative spinal diseases. This study retrospectively evaluated the efficacy of PELD in treating painful SNs.

Objective: To evaluate the clinical efficacy and safety of PELD in treating patients with painful SNs.

Methods: From February 1, 2020, to February 1, 2023, 13 patients with discogenic back pain from painful SNs (confirmed via intraoperative discography) who underwent single-level PELD at the index SN level were enrolled in the current study. Clinical data were retrospectively analyzed. Outcome measures, including the visual analog scale (VAS) for back pain and the Oswestry Disability Index (ODI), were recorded preoperatively and at 1 day, 6 months, and 12 months postoperatively. MRI scans of the lumbar region for all patients were evaluated preoperatively and again at the one-month follow-up.

Results: All 13 patients were successfully treated with percutaneous endoscopic lumbar discectomy (PELD), showing significant post-operative improvements in VAS and ODI scores. Postoperative lumbar MRI revealed degenerative disc material in the SN cavities, which was removed using PELD. No surgical issues such as infections or nerve root damage, were noted.

Conclusion: Postoperative MRI confirmed the removal of degenerative disc material, reinforcing PELD's efficacy in treating the pathological changes associated with painful SNs. No surgical complications, such as infections or nerve root damage, were seen, underscoring the safety of PELD. This study demonstrates that PELD effectively manages discogenic lower back pain caused by SNs.

Plain Language Summary:

New knowledge added by this study

- This study presents preliminary evidence supporting a minimally invasive surgery called PELD for painful Schmorl's nodes.
- By using postoperative MRI, this study is the first to confirm that the damaged disc material can be removed through this method.
- The study also provides early evidence of symptom relief lasting up to 27 months.

Implications for clinical practice or policy

- PELD may be a safe and effective option for patients with Schmorl's node-related back pain who do not improve with other treatments.
- MRI and discography can help identify patients who may benefit from this approach.
- These findings may support wider use of PELD and reduce the need for open surgery in select cases.

Keywords: percutaneous endoscopic lumbar discectomy, PELD, Schmorl's Nodes, SNs, discogenic lower back pain

Received: 10 May 2025
Accepted: 17 September 2025
Published: 26 September 2025

Introduction

Lower back pain is a widespread and significant clinical issue, with an approximate incidence of 80% in adults.[1] Multiple studies have established that degenerative disc disease (DDD) and lumbar disc herniation are among the most prevalent causes of lower back pain.[2,3]

In 1927, Christian Georg Schmorl first described Schmorl's nodes (SNs) as the protrusion of disc material past the endplate into the vertebral body. SNs are benign lesions with prevalence rates ranging from 2% to 76%.[4,5]

Although Schmorl's nodes (SNs) are commonly asymptomatic incidental findings, their association with back pain remains controversial.[6,7] Recent studies suggest that symptomatic SNs are often accompanied by MRI-detectable features such as adjacent bone marrow edema and Modic-type endplate changes.[8–10] These pathological findings may reflect subchondral endplate microfractures and local inflammation, activating nociceptors and contributing to discogenic lower back pain.[11] Previous studies have indicated an association between the presence of SNs and DDD, potentially leading to discogenic lower back pain. However, the exact correlation between radiographic alterations and spinal pathology remains contentious.[12,13] Discogenic lower back pain originates from degenerative disc material produced by internal disc disruption. Neural ingrowth into the nucleus pulposus occurs through radial fissures in the degenerated disc. This process is accompanied by the release of pain-related inflammatory mediators and cytokines, including tumor necrosis factor (TNF), substance P, and interleukins.[14,15] Studies have suggested that endplate impairment by SNs is an important cause of discogenic pain.[16]

Discography is the definitive method for diagnosing discogenic lower back pain, with positive discography eliciting concordant lower back pain by injecting a contrast agent into the disc.[17] Discogenic lower back pain associated with sacral nerves is highly suspected when magnetic resonance imaging (MRI) reveals Modic-I changes—characterized by reduced signal intensity on T1-weighted images (T1WI) and increased signal intensity on T2-weighted images (T2WI) in the endplate adjacent to the SNs. This suspicion is further confirmed when discography elicits concordant lower back pain in the index segment containing the SNs.[18]

SNs can cause a unique discogenic back pain that is refractory to conservative treatment for at least 3 months, and surgical interventions are required. Improvements have been reported for SNs using surgical treatment, including lumbar interbody fusion, spinal decompression, and disc block, but all were limited to small sample sizes or case reports.[19,20]

Minimally invasive procedures have demonstrated that percutaneous endoscopic lumbar discectomy (PELD) offers superior treatment outcomes compared to open surgery for degenerative spinal disease.[21,22] To date, only a few studies have reported on the use of minimally invasive surgeries for painful SNs. Therefore, the aim of this study was to evaluate the clinical efficacy and safety of PELD in the treatment of discogenic lower back pain caused by painful SNs confirmed by intraoperative discography and MRI findings.

Materials and Methods

Patient Population

A retrospective assessment was performed on 13 patients with problematic sacral nerve roots who had single-level percutaneous endoscopic lumbar discectomy utilizing the Yeung Endoscopic Spine System (Joimax GmbH Instrument Co.) from February 1, 2020, to February 1, 2023. (Figures 1–3).

Ethics Approval

The study and the protocol were approved by the Ethics Committee of Beijing Chao-Yang Hospital, Capital Medical University (2024-5-16-3) on May 16, 2024. The requirement for individual informed consent was waived due to the retrospective nature of the study and the use of anonymized patient data. All patient information was handled in accordance with the principles of the Declaration of Helsinki and institutional data protection policies to ensure confidentiality.

Inclusion and Exclusion Criteria

Criteria for participation in the study were as follows: (1) patients with back pain unresponsive to conservative treatment for at least 3 months; (2) patients with a visual analog scale (VAS) score of 7 or higher; (3) Spine MRI demonstrates a spinal neoplasm in the lumbar vertebral body, exhibiting low signal intensity at the endplate on T1-weighted imaging and high signal

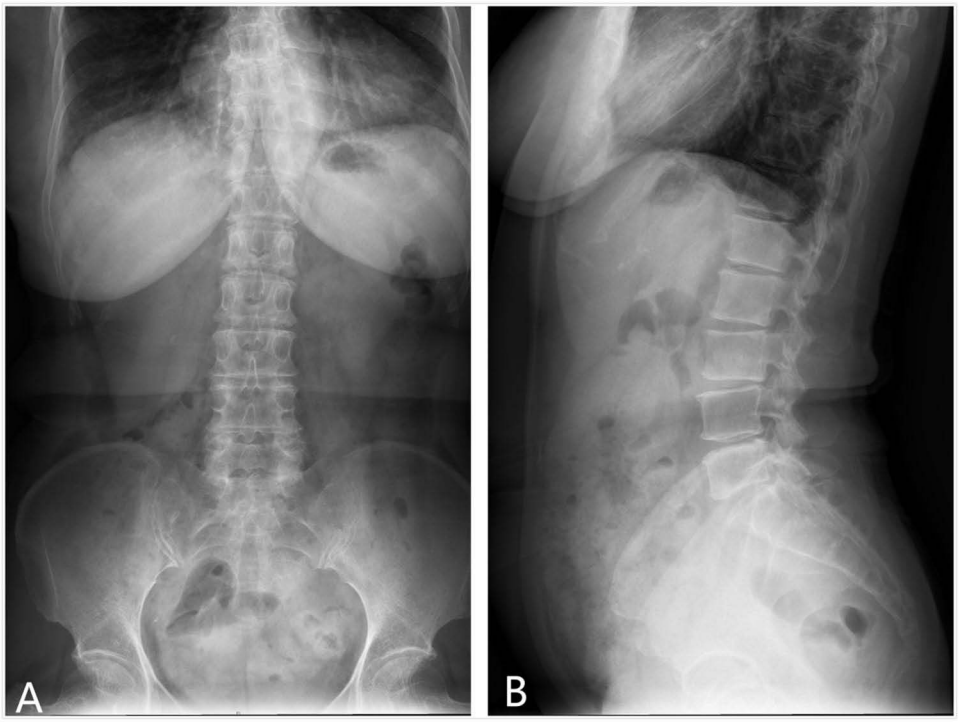

Figure 1 Preoperative anteroposterior plain (**A**) and lateral plain (**B**) X-rays of the lumbar spine showed lumbar degenerative changes and features of Baastrup's disease.

intensity on T2-weighted imaging in the endplate; (4) preoperative lumbar computed tomography (CT) showing an SN located in the posterior one-third of the endplate in the lumbar spine; (5) treatment involving PELD alone; (6) discography confirming concordant pain at the index level with the SN; (7) systematic post-discharge follow-ups.

The exclusion criteria were delineated as follows: (1) multilevel DDD with discogenic back pain, confirmed by spine MRI and discography; (2) spinal CT and MRI revealing an alternative cause of lower back pain, including lumbar spinal stenosis, spinal disc herniation, spinal fractures, or malignant spinal lesions; (3) spondylolisthesis, scoliosis, and other spinal deformities; and (4) discography showing negativity at the index level.

Surgical Procedure

Patients suspected of having discogenic back pain caused by painful SNs underwent initial discography. Patients with positive discography findings proceeded to surgery. All surgical procedures were performed by a proficient spinal surgeon. The patients were positioned in a prone orientation on a Jackson table using the Yeung Endoscopic Spine System for PELD. The surgical site was sterilized and appropriately draped. The entry point was located 8–13 cm lateral to the spinal midline, with an entry angle of 20°–30° from the horizontal plane. The specific distance and entry angle depended on the patient's size, surgical level, and preoperative radiographic examination. Lidocaine (0.5%) was administered subcutaneously and into the musculoaponeurotic layer. After injecting the local anesthetic, an 18-gauge spinal needle was introduced through the fibrous annulus into the nucleus pulposus under fluoroscopic supervision. Discography was performed using contrast media. A positive result on discography was defined as an examination that reproduced concordant lower back pain (Figure 4).

Patients with positive discography results underwent PELD. A guidewire was introduced through an 18-gauge spinal needle into the disc material, targeting the SN. The spinal needle was subsequently withdrawn, and a minor skin incision was made. A series of four obturators was introduced over the guidewire at the incision site. The local anesthetic of the facet joint was injected with 10 mL of lidocaine (0.5%). A tapered, cannulated obturator was subsequently inserted along the guidewire, targeting the disc material near the SN, and a portion of the articular process was excised using the tapered edge of the obturator. Upon insertion of the obturator into the disc and alignment with the SN cavity, a bevel-ended, oval-

 https://doi.org/10.2147/JPR.S538503

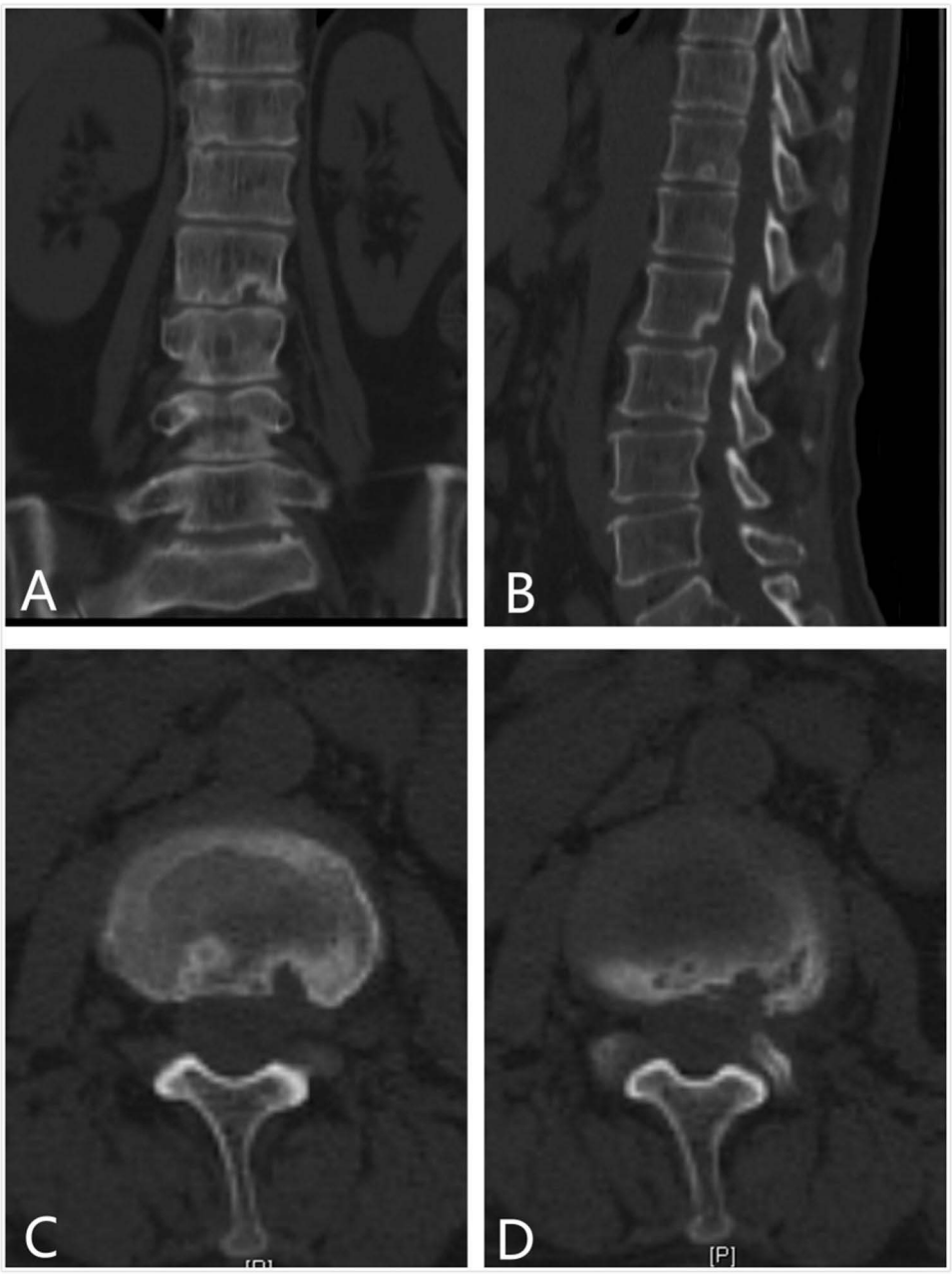

Figure 2 Preoperative coronal (**A**), sagittal (**B**), and axial (**C** and **D**) plain CT images of the lumbar spine showed SNs in the posterior third of the superior endplate of L2.

shaped working cannula was introduced alongside the obturator, and an endoscope was inserted via the cannula. With the assistance of endoscopic instruments and bipolar radiofrequency, the blue-stained intervertebral disc material inside and around the SN cavity was removed. Once the disc material was completely removed, bipolar radiofrequency ablation (RFA) was performed on the vertebral endplate surrounding the SN to achieve denervation. A bipolar radiofrequency probe (MC301, BONSS) was used with a power setting of 23 W in COAG mode for 3–4 seconds per target site. The endoscope was then removed, and an intradiscal block was performed by administering 0.5% lidocaine and betamethasone through the working channel toward the disc. The working channel was withdrawn, and the incision was sutured.

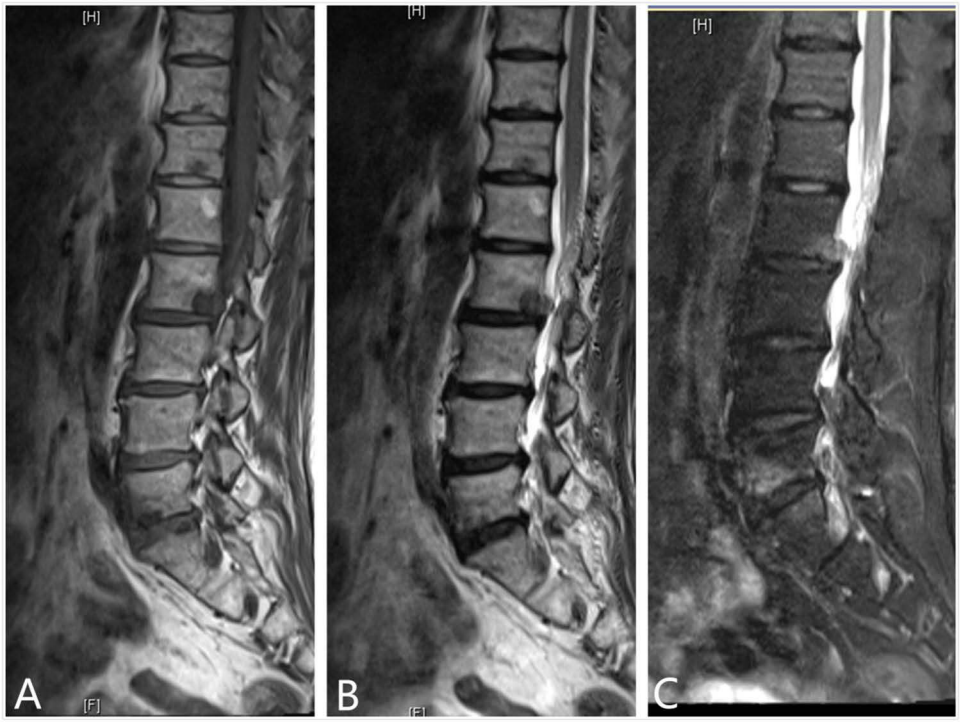

Figure 3 Pre-operation sagittal MRIs showed a large SN at the superior endplate of L2 on T1WI, T2WI, and fat-suppression sequences (**A**–**C**) with abnormal signal intensity.

Clinical Evaluation

Most patients were encouraged to initiate ambulation under lumbar orthosis support 4–6 h after surgery. Ambulation was deferred to the second postoperative day in elderly individuals, those with significant comorbidities (eg, diabetes mellitus or cardiovascular disease), or those exhibiting delayed postoperative recovery. All patients achieved an uneventful recovery without major complications and were discharged within 24–48 h post-operatively. VAS scores for lower back pain, ODI scores, and Modified MacNab criteria were recorded preoperatively, postoperatively, and at follow-up intervals (day 1; months 1, 6, and 12; and final follow-up) via outpatient clinic visits and telephone questionnaires. All patients underwent lumbar MRI before surgery and during the one-month follow-up to verify that the degenerative disc material within and around the cavity of the SNs was predominantly excised (Figure 5).

Data Analysis

The evaluation of clinical data was conducted utilizing SPSS software (version 23.0, SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as the mean ± standard deviation (SD), whereas categorical data were shown as frequencies (%). To compare the VAS and ODI values across different time intervals (both pre- and postoperatively), a paired *t*-test was employed. A p-value of less than 0.05 was considered statistically significant.

Result

Baseline Data

From February 2020 to February 2023, a total of 13 individuals (5 males and 8 females) suffering from discogenic lower back pain attributed to SNs and who had undergone single-level PELD were included in the study. The mean age of the patients during the surgical procedure was 52.54 years, varying between 43 and 66 years, and the average follow-up period lasted 20.62 months, with a range from 15 to 27 months.

https://doi.org/10.2147/JPR.S538503

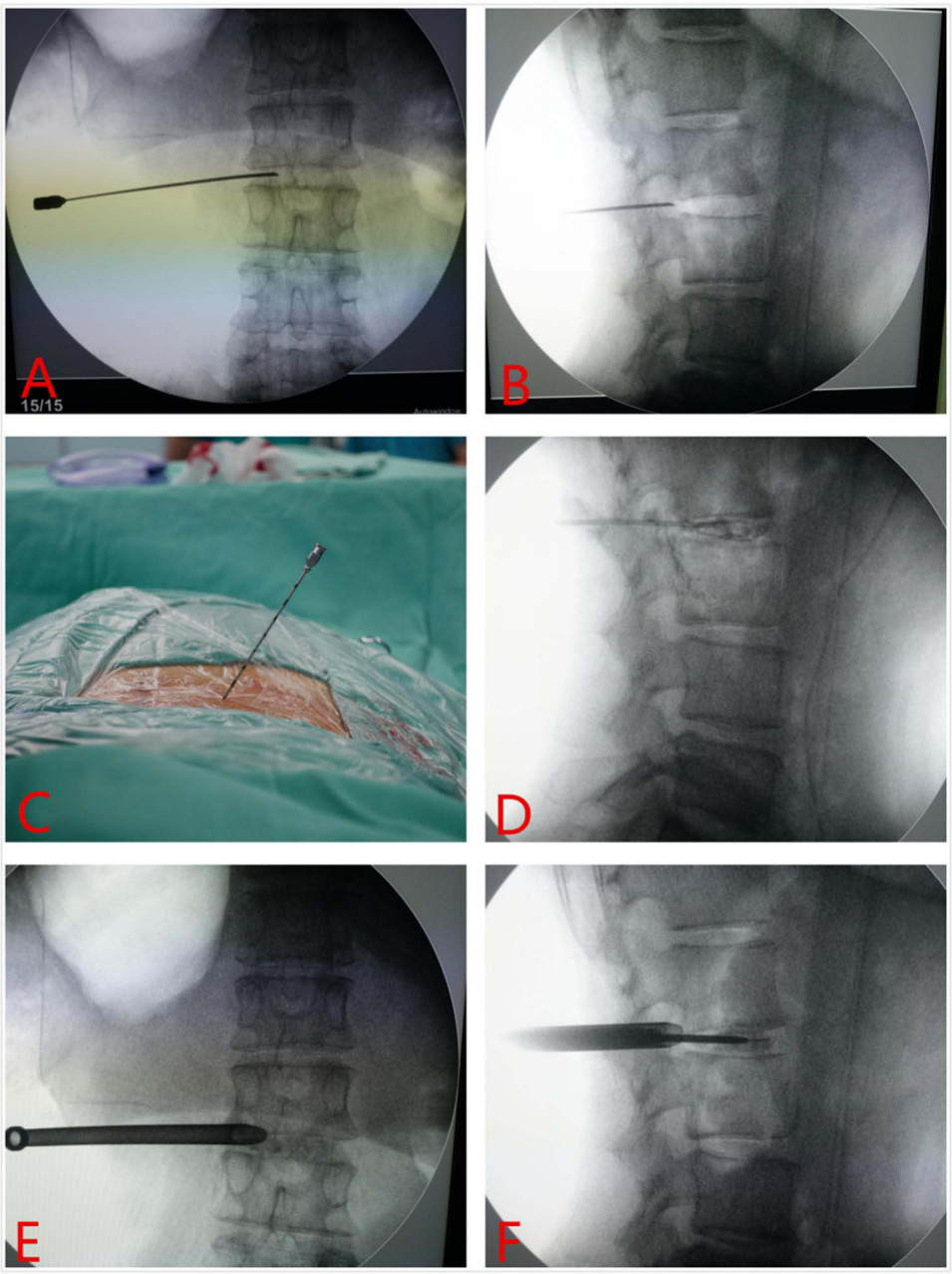

Figure 4 Intra-operation anterior-posterior and lateral plane X-rays taken by C-arm fluoroscopy (**A** and **B**). First, an 18-gauge spinal needle was inserted into the fiber annulus (**C**). Discography was performed with contrast agents injected into the disc space (**D**). For patients with positive discography, a tapered, cannulated obturator was inserted at SN, and endoscopic discectomy was performed (**E** and **F**).

Surgical Dates

All patients were treated by an experienced surgeon, with a mean surgical duration of 61 minutes (range 45–85 minutes). For all surgical levels, PELD was performed 3 times at L2-3, 3 times at L3-4, five times at L4-5, and two times at L5-S1 (Table 1).

Of the 13 included patients, one (7.7%) underwent revision surgery 13 months postoperatively. The patient complained of lower back pain without significant relief after the primary PELD. MRI at 13 months postoperatively showed an increase in the size and signal intensity of the SNs on T2-weighted imaging (T2WI). In this case, lower back pain was relieved after a secondary posterior lumbar interbody fusion (PLIF). No infections, recurrent lumbar disc herniation (LDH), nerve root injuries, or other complications were observed.

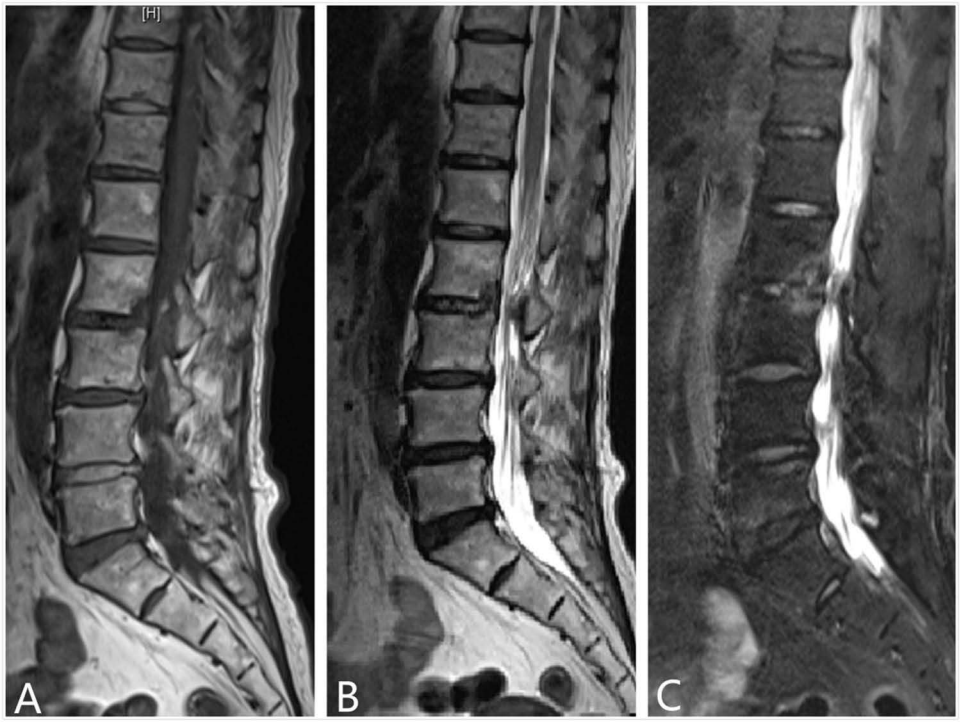

Figure 5 Sagittal MRI of the lumbar spine shows normal signal intensity in T1WI (**A**) and T2WI (**B**) sequences, the increased signal intensity around SN at L2 endplates (**B**), and fat-suppression sequences at 1 month post-operation (**C**).

Clinical Evaluation

Patients showed significant clinical improvement after surgery, with an average follow-up duration of 21 months. VAS and ODI scores showed significant improvement at 1 month, 6 months, 1 year, and the final follow-up after PELD (Table 2). The

Table 1 Clinical Features of the Patients ($\bar{x}$ ± SD)

Clinical Features	
Variation	**Value**
n of cases	13
Baseline Date	
Male	N=5(38.5%)
Female	N=8(61.5%)
Age	52.54±7.276
Follow-up (month)	20.62±3.618
Surgical Level	
L2-3	N=3(23.1%)
L3-4	N=3(23.1%)
L4-5	N=5(38.5%)
L5-S1	N=2(15.4%)

(*Continued*)

https://doi.org/10.2147/JPR.S538503

Table 1 (Continued).

Clinical Features	
Variation	**Value**
Surgical Procedure	
Duration of Operation (minutes)	61.00±24.152
Macnab Score	
7 (Excellent)	N=8(61.6%)
3 (Good)	N=3(23.1%)
2 (Fair)	N=2(15.4%)
1 (Poor)	N=0(0%)
Complications	
Reoperation	N=1(7.7%)

Table 2 Comparison of VAS and ODI Scores of Patients with Lower Back Pain Pre- and Post-Operation ($\bar{x}$ ± SD)

	VAS Score	**P-value**
Pre-operation	8.31±1.109	
Post-operation (1d)	2.46 ±0.877	<0.001
Post-operation (1m)	3.54±0.967	<0.001
Post-operation (6m)	2.92±0.954	<0.001
Post-operation (12m)	2.08±0.862	<0.001
Post-operation (last FU)	1.77±0.832	<0.001
	ODI Score	**P-value**
Pre-operation	67.08±6.563	
Post-operation (1m)	30.38±6.862	<0.001

Abbreviations: VAS, visual analog scale; ODI, Oswestry Disability Index; FU, follow-up.

modified MacNab scores were assessed 6 months postoperatively, and eight cases were evaluated as excellent (4 points), three cases as good (3 points), two cases as fair (2 points), and none as poor (1 point) (Figure 6).

Discussion

Various hypotheses have been proposed regarding SN etiology, including developmental factors, degenerative conditions, a history of trauma, and necrosis beneath the endplate. However, no consensus has been reached.[23–25] Also, while various mechanisms have been proposed, including disc degeneration and endplate trauma, the link between SNs and low back pain remains controversial.[23,24] SNs may result from subchondral endplate osteonecrosis. This process leads to herniation of disc material into the vertebral body via annular fissures, a common feature of degenerative disc diseases.[21] Another study assumed that the development of SNs was related to the abnormal presentation of vertebral body vessels.[26]

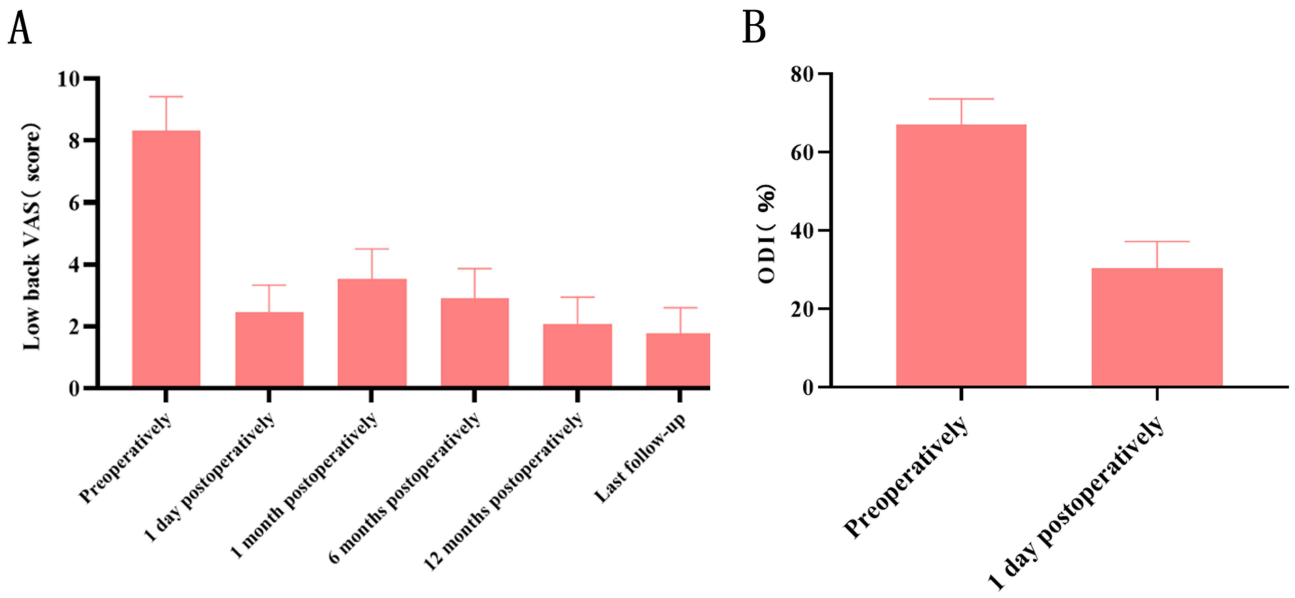

Figure 6 Comparison of lower back VAS (**A**), ODI (**B**) preoperatively and postoperatively.

Although the majority of SNs are asymptomatic and do not require surgical intervention, certain subtypes of SNs may be associated with lower back pain via several pathophysiological mechanisms.[20,27] For all 13 patients enrolled, intraoperative discography confirmed herniation of disc material into the vertebral body and reproduced concordant back pain. Based on these results, we postulate that lower back pain in these patients may be generated from degenerative disc material around the SNs, which we considered a unique type of lower discogenic pain.

The precise pathophysiological origin of lower back pain in patients with painful SNs remains unclear. Previous studies have shown that certain subgroups of patients with SNs exhibiting Modic-I changes are associated with an increased risk of lower back pain. Modic-I changes in the endplate are frequently associated with internal disc disruption and the acute phase of vertebral endplate osteitis and bone marrow edema.[27] Cartilage endplates impaired by SNs with acute bone marrow edema are a critical cause of discogenic pain because they are commonly considered a component of intervertebral disc material.[28] These factors may collectively contribute to the development of a unique form of discogenic lower back pain.

Surgical procedures should be considered for individuals with painful SNs who are unresponsive to conservative care for a minimum of 3 months. Posterior lumbar interbody fusion, nerve block, posterior decompression, and disc block have shown favorable outcomes in the treatment of painful SNs.[28–30] In 2004, Hasegawa et al reported significant postoperative improvement in women with severe chronic back pain due to symptomatic SNs. The study found that lumbar interbody fusion using autogenous iliac bone grafts and Z-plates on the lateral vertebral body effectively alleviated pain. Lower back discomfort was alleviated postoperatively, with fusion achieved at the L2-L3 segment at the final follow-up at two years. Based on these case reports, Hasegawa advocated discography to diagnose painful SNs.[29] Peng et al reported positive outcomes for 21 patients with painful SNs following anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), or posterolateral lumbar interbody fusion, depending on the position of the sacral nerves. In this case series, the fusion rate was 86% at the final follow-up. This indicates that the density of the endplate nerves is comparable to that of the annulus fibrosus nerves, implying that cartilage endplates affected by SNs may contribute to discogenic lower back pain in symptomatic patients.[28] Neves et al reported cases of painful SNs successfully treated with intradiscal decompression without fusion or instrumentation.[31] The intervertebral disc and vertebral bodies are innervated by nerve plexuses, which are connected by branches of the rami communicantes. Jang et al reported improved symptoms when the ramus communicans was blocked using a mixture of mepivacaine and contrast medium in patients with painful SNs.[30] These cases are summarized in comparison with the current study in Table 3.

https://doi.org/10.2147/JPR.S538503

Table 3 Comparison of the Current Study with Similar Case Reports

	Current Study	**Hasegawa et al[29]**	**Peng et al[28]**	**Neves et al[31]**	**Jang et al[30]**
Study Type	Retrospective evaluation	Case report	Case series	Case report	Case report
Surgical Method	Percutaneous Endoscopic Lumbar Discectomy (PELD)	Lumbar interbody fusion	Anterior, posterior, or posterolateral lumbar interbody fusion	Intradiscal decompression	Rami communicans nerve block
Diagnostic Method	Intraoperative discography and MRI	Discography	Not explicitly mentioned, but likely used discography	Not explicitly mentioned	Not explicitly mentioned
Sample Size	13 patients	1 patient	21 patients	1 patient	1 patient
Treatment Goal	Removal of degenerative disc material and endplate denervation	Vertebral body fusion	Vertebral body fusion	Intradiscal decompression	Rami communicans nerve blockade
Contribution	First study to report the effective use of PELD to treat painful SNs. First to confirm removal of degenerative disc material using postoperative MRI.	Advocated the use of discography for diagnosing painful SNs.	Reported outcomes of fusion surgery for painful SNs.	Reported intradiscal decompression without fusion for painful SNs.	Reported on a ramus communicans nerve block for painful SNs.

Chronic back pain associated with symptomatic SNs may represent a distinct form of discogenic pain, requiring different surgical strategies from typical DDD. Innovations in minimally invasive techniques and tools have shown that percutaneous endoscopic lumbar discectomy (PELD) produces treatment results similar to those of open surgery for degenerative spinal conditions or even achieves a better quality of life.[32–34] Initially, a painful sacral nerve (SN) with DDD was identified by Modic type I changes in the surrounding SNs. Additionally, preoperative lumbar CT revealed that the SN was positioned in the posterior third of the endplate, facilitating the establishment of a working channel with the disc material encircling the SN. Removal of degenerated tissue and endplate denervation is thought to alleviate SN-related back pain. During the surgical procedure, the working channel should be placed towards the SN for optimal removal of the disc tissue. To our knowledge, this is the first study to report the effective use of PELD to treat painful SNs.

One of the limitations of this study is the small sample size. Given the rarity of symptomatic SNs that meet strict diagnostic criteria (positive discography, consistent MRI features) and the need to maintain cohort homogeneity, only a small number of patients were included. Although no formal power analysis was conducted, the uniformity of the patient population and consistent surgical technique support the internal validity of the findings. Additionally, the follow-up duration, although reaching up to 27 months in some cases, remains limited for assessing the durability of outcomes. Future prospective, randomized, and multicenter studies with larger samples are needed to validate and expand upon these findings.

Conclusion

This study preliminarily evaluated the clinical efficacy and safety of PELD in treating discogenic lower back pain caused by painful Schmorl's nodes. All enrolled patients experienced significant and sustained improvement in pain and functional disability, with no major surgical complications observed. These results suggest that PELD is a promising minimally invasive surgical approach for selected patients with symptomatic SNs who do not respond to conservative treatment.

Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Beijing Chao-Yang Hospital, Capital Medical University (2024-5-16-3).

Acknowledgments

We would like to thank Dr. Aixing Pan for his help in the methodology review.

Funding

None.

Disclosure

The authors declare that they have no conflicts of interest in this work.

References

1. Kabeer AS, Osmani HT, Patel J, Robinson P, Ahmed N. The adult with low back pain: causes, diagnosis, imaging features and management. *Br J Hosp Med*. 2023;84(10):1–9. doi:10.12968/hmed.2023.0063
2. Zhang AS, Xu A, Ansari K, et al. Lumbar disc herniation: diagnosis and management. *Am J Med*. 2023;136(7):645–651. doi:10.1016/j.amjmed.2023.03.024
3. Kirnaz S, Capadona C, Wong T, et al. Fundamentals of intervertebral disc degeneration. *World Neurosurg*. 2022;157:264–273. doi:10.1016/j.wneu.2021.09.066
4. Kyere KA, Than KD, Wang AC, et al. Schmorl's nodes. *Eur Spine J*. 2012;21(11):2115–2121. doi:10.1007/s00586-012-2325-9
5. Azzouzi H, Ichchou L. Schmorl's nodes: demystification road of endplate defects-a critical review. *Spine Deform*. 2022;10(3):489–499. doi:10.1007/s43390-021-00445-w
6. Park HJ, Lee J, Jo HJ, Choi SS, Lee CH. Percutaneous vertebroplasty in a patient with chronic back pain caused by multiple schmorl's nodes: a case report. *Medicina*. 2023;59(10):1839. doi:10.3390/medicina59101839
7. Wei B, Wu H. Study of the distribution of lumbar modic changes in patients with low back pain and correlation with lumbar degeneration diseases. *J Pain Res*. 2023;16:3725–3733. doi:10.2147/jpr.S430792
8. Firanescu CE, de Vries J, Lodder P, et al. Vertebroplasty versus sham procedure for painful acute osteoporotic vertebral compression fractures (VERTOS IV): randomised sham controlled clinical trial. *BMJ*. 2018;361:k1551. doi:10.1136/bmj.k1551
9. Heggli I, Laux CJ, Mengis T, et al. Modic type 2 changes are fibroinflammatory changes with complement system involvement adjacent to degenerated vertebral endplates. *JOR Spine*. 2023;6(1):e1237. doi:10.1002/jsp2.1237
10. Wei Q, Huang W, Yanling C, Yi Z, Kebing Y, Shaoping W. Retrospective comparative study of lumbar spine MRI texture analysis in diagnosing bone marrow edema lesions in ankylosing spondylitis and non-ankylosing spondylitis. *BMC Musculoskeletal Disorders*. 2025;26(1):163. doi:10.1186/s12891-025-08413-5
11. Wang D, Lai A, Gansau J, et al. Lumbar endplate microfracture injury induces Modic-like changes, intervertebral disc degeneration and spinal cord sensitization - an in vivo rat model. *Spine J*. 2023;23(9):1375–1388. doi:10.1016/j.spinee.2023.04.012
12. Ekşi M, Turgut VU, Berikol G, et al. Schmorl's nodes could be associated with intervertebral disc degeneration at upper lumbar levels and endplate disease at lower lumbar level in patients with low back pain. *J Clin Neurosci*. 2022;100:66–74. doi:10.1016/j.jocn.2022.04.004
13. Teraguchi M, Hashizume H, Oka H, et al. Prevalence and distribution of Schmorl node and endplate signal change, and correlation with disc degeneration in a population-based cohort: the Wakayama Spine Study. *Eur Spine J*. 2024;33(1):103–110. doi:10.1007/s00586-023-08009-4
14. Jha R, Bernstock JD, Chalif JI, et al. Updates on pathophysiology of discogenic back pain. *J Clin Med*. 2023;12(21):6907. doi:10.3390/jcm12216907
15. Lorio MP, Beall DP, Calodney AK, Lewandrowski K-U, Block JE, Mekhail N. Defining the patient with lumbar discogenic pain: real-world implications for diagnosis and effective clinical management. *J Personalized Med*. 2023;13(5):821. doi:10.3390/jpm13050821
16. Lawan A, Crites Videman J, Battié MC. The association between vertebral endplate structural defects and back pain: a systematic review and meta-analysis. *Eur Spine J*. 2021;30(9):2531–2548. doi:10.1007/s00586-021-06865-6
17. Remotti E, Nduaguba C, Woolley PA, et al. Review: discogenic back pain: update on treatment. *Orthop Rev*. 2023;15:84649. doi:10.52965/001c.84649
18. Wu HT, Morrison WB, Schweitzer ME. Edematous Schmorl's nodes on thoracolumbar MR imaging: characteristic patterns and changes over time. *Skeletal Radiol*. 2006;35(4):212–219. doi:10.1007/s00256-005-0068-y
19. He SC, Zhong BY, Zhu HD, et al. Percutaneous vertebroplasty for symptomatic Schmorl's Nodes: 11 cases with long-term follow-up and a literature review. *Pain Physician*. 2017;20(2):69–76.
20. Liu J, Hao L, Zhang X, et al. Painful Schmorl's nodes treated by discography and discoblock. *Eur Spine J*. 2018;27(1):13–18. doi:10.1007/s00586-017-4996-8
21. Li T, Zhang J, Ding Z, Jiang Q, Ding Y. Percutaneous endoscopic lumbar discectomy versus open fenestration discectomy for lumbar disc herniation: a retrospective propensity score-matched study with more than 5 years of follow-up. *J Orthop Surg Res*. 2024;19(1):753. doi:10.1186/s13018-024-05239-0
22. Li X, Bai J, Hong Y, et al. Minimum seven-year follow-up outcomes of percutaneous endoscopic lumbar discectomy for lumbar degenerative disease. *Int J Gen Med*. 2021;14:779–785. doi:10.2147/ijgm.S293400
23. Williams FM, Manek NJ, Sambrook PN, Spector TD, Macgregor AJ. Schmorl's nodes: common, highly heritable, and related to lumbar disc disease. *Arthritis Rheum*. 2007;57(5):855–860. doi:10.1002/art.22789

24. Hilton RC, Ball J, Benn RT. Vertebral end-plate lesions (Schmorl's nodes) in the dorsolumbar spine. *Ann Rheumatic Dis*. 1976;35(2):127–132. doi:10.1136/ard.35.2.127
25. Peng B, Wu W, Hou S, Shang W, Wang X, Yang Y. The pathogenesis of Schmorl's nodes. *J Bone Joint Surg Br Vol*. 2003;85(6):879–882.
26. Nachemson A, Lewin T, Maroudas A, Freeman MA. In vitro diffusion of dye through the end-plates and the annulus fibrosus of human lumbar inter-vertebral discs. *Acta Orthop Scand*. 1970;41(6):589–607. doi:10.3109/17453677008991550
27. Takahashi K, Miyazaki T, Ohnari H, Takino T, Tomita K. Schmorl's nodes and low-back pain. Analysis of magnetic resonance imaging findings in symptomatic and asymptomatic individuals. *Eur Spine J*. 1995;4(1):56–59. doi:10.1007/bf00298420
28. Peng BG, Wu WW, Kuang ZD, Li ZZ, Guo JD, Hou SX. Diagnosis and surgical treatment of back pain originating from endplate. *Zhonghua Wai Ke Za Zhi [Chinese Journal of Surgery]*. 2007;45(20):1401–1404.
29. Hasegawa K, Ogose A, Morita T, Hirata Y. Painful Schmorl's node treated by lumbar interbody fusion. *Spinal Cord*. 2004;42(2):124–128. doi:10.1038/sj.sc.3101506
30. Jang JS, Kwon HK, Lee JJ, Hwang SM, Lim SY. Rami communicans nerve block for the treatment of symptomatic Schmorl's nodes -A case report. *Kor J Pain*. 2010;23(4):262–265. doi:10.3344/kjp.2010.23.4.262
31. Neves NS, Ribeiro da Silva M, Cacho Rodrigues P, Silva ML, Matos R, Pinto R. Symptomatic giant Schmorl's node treated by a decompression procedure. *Orthop Traumatol Surg Res*. 2013;99(3):371–374. doi:10.1016/j.otsr.2013.01.004
32. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. *Spine*. 2008;33(9):931–939. doi:10.1097/BRS.0b013e31816c8af7
33. Kim CH, Chung CK, Park CS, Choi B, Kim MJ, Park BJ. Reoperation rate after surgery for lumbar herniated intervertebral disc disease: nationwide cohort study. *Spine*. 2013;38(7):581–590. doi:10.1097/BRS.0b013e318274f9a7
34. Apaydin AS, Bozyiğit B, Koç-Apaydin Z, Güneş M, Yana M. Efectos de diferentes tratamientos quirúrgicos sobre el dolor, la discapacidad, la ansiedad y la calidad de vida en la hernia de disco lumbar [Effects of different surgical treatments on pain, disability, anxiety and quality of life in lumbar disc herniation]. *Cir Cir*. 2024;92(1):39–45. doi:10.24875/ciru.23000415