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RESEARCH

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Comparative efficacy of unilateral biportal and percutaneous endoscopic techniques in unilateral laminectomy for bilateral decompression (ULBD) for lumbar spinal stenosis

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Abstract

Background Unilateral laminotomy for bilateral decompression (ULBD) has yielded positive results in the treatment of lumbar spinal stenosis (LSS). Unilateral biportal ULBD (UB-ULBD) and percutaneous endoscopic ULBD (PE-ULBD) are gaining popularity because of the progress that has been made in minimally invasive surgery (MIS). The objective of this study was to evaluate and compare the radiographic and clinical results of UB-ULBD and PE-ULBD.

Methods This study retrospectively enrolled patients who underwent ULBD surgery for LSS. The patients were categorized into two groups on the basis of the surgical method: the UB-ULBD group and the PE-ULBD group. Data on the general demographic data, surgical details, clinical efficacy, radiography and complications were compared between the two groups were compared. The minimum follow-up duration was 12 months.

Results A total of 113 LSS patients who had undergone ULBD at our institution were included, of whom 61 patients underwent UB-ULBD surgery and 52 underwent PE-ULBD surgery. The UB-ULBD group had a significantly shorter operation time ($P < 0.05$). The facet was significantly better preserved in the UB-ULBD group than in the PE-ULBD group, and the angle of ipsilateral facet joint resection in the UE-ULBD group was significantly smaller ($P < 0.05$). The ODI score, VAS score and modified Macnab criteria improved postoperatively in both groups. The UB-ULBD group had a 95.08% rate of excellent or good patient outcomes, whereas the PE-ULBD group had a 92.30% rate.

Conclusion Both UB-ULBD and PE-ULBD can provide favourable clinical outcomes when used to treat LSS. UB-ULBD is beneficial because of its shorter operation time, smaller angle of ipsilateral facet joint resection and better facet preservation, making it a viable and safe option for treating LSS while ensuring spinal stability.

Keywords Lumbar spinal stenosis, Unilateral laminotomy for bilateral decompression, Unilateral biportal endoscopy, Percutaneous endoscopic

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Introduction

Lumbar spinal stenosis (LSS) is a prevalent degenerative disease that affects adults aged 60 years and older and is frequently characterized by intermittent neurological claudication, back pain, and radicular leg pain [1]. Disc degeneration and loss of disc height are the primary causes of spinal canal narrowing and compression of neural structures [2]. For individuals with significant difficulty walking and ongoing radicular pain that does not improve with conservative treatments such as physical therapy, medication, and nerve-block procedures, surgical intervention is recommended. Laminectomy is the standard procedure for surgical decompression [3].

Traditional extensive decompression surgery often involves destruction of the supraspinal/interspinal ligament complex, dissection, and extensive traction of the bilateral paraspinal muscles (especially the multifidus muscles) [4]. Biomechanical studies have shown that the composite structures behind the spine, such as the spinous processes, supraspinous and interspinous ligaments, facet joints, and articular processes, are crucial for maintaining spinal stability [5]. Therefore, minimizing muscle traction damage, avoiding separation of the tendinous structures behind the spine from their bone attachment points, and maintaining the integrity of the lumbar fascia are crucial for maintaining long-term spinal stability [6, 7].

To maintain the midline structure, McCulloch et al. [8]. introduced the microsurgical method known as unilateral laminotomy for bilateral decompression (ULBD), which can fully maintain more than 80% of the degree of spinal stress and reduce facet joints damage [9]. In recent years, the introduction of endoscopes and other related instruments has facilitated the ongoing development of minimally invasive surgery (MIS) for the treatment of LSS.

Several MIS alternatives, notably, percutaneous endoscopy (PE) and unilateral biportal endoscopy (UBE), have been proposed to overcome these problems [10]. However, the learning curve is steep for PE, and the operating equipment is limited by the rigid sleeve, which accounts for the difficulty and high risks associated with bilateral decompression [11]. A previous study revealed that UBE is an effective and safe surgery that can achieve sufficient decompression of lumbar disc herniation with satisfactory early follow-up outcomes [12].

As the latest in endoscopic spine surgeries, PELD-ULBD (PE-ULBD) and UBE-ULBD (UB-ULBD) have distinctive technical characteristics [13]. Nevertheless, only a few comparative studies have assessed the clinical efficacy of PE-ULBD and UBE-ULBD for the treatment of LSS, and these studies are limited by small patient populations and rarely compare the radiological outcomes of the two surgical methods [14, 15]. Therefore, the aim of the present investigation was to compare the clinical and radiological outcomes of PE-ULBD and UB-ULBD for the treatment of LSS, in order to assess their effectiveness and safety.

Methods

Patient population

We retrospectively reviewed the data of hospitalized patients who underwent ULBD surgery by surgeons at a single institution between January 2020 and October 2022. The surgeon explained the advantages and disadvantages of the two surgical methods and the possible complications to the patients before the operation, and the patients chose the surgical method. Patients were divided into two groups according to the surgical method used: the UB-ULBD group and the PE-ULBD group. All patients met the clinical and radiological standards for LSS. The inclusion criteria were as follows: (1) typical intermittent claudication symptoms before surgery (excluding vascular claudication); (2) back pain and neurological symptoms and signs; (3) a diagnosis of single-level LSS on the basis of clinical history, physical examination, and imaging studies; (4) ineffective treatment after 3 months or more of conservative treatment; and (5) at least one year of postoperative follow-up. The exclusion criteria were as follows: (1) a history of previous spinal surgery or signs of lumbar instability or other abnormalities (spinal tumor, bone infection, or progressive neurological deficits); (2) multilevel spinal stenosis; (3) severe internal medical conditions and inability to tolerate surgery in the prone position; and (4) incomplete radiological or treatment information.

Surgical techniques

PE-ULBD

The patient was placed in the prone position, and general anaesthesia or local anaesthesia was induced according to the patient's situation. After successful anaesthesia, fluoroscopy was performed to determine the location and level of the lesion. The puncture point was located 1 cm away from the midline, and the working sleeve was inserted into the posterior ligamentum flavum and intervertebral space to remove soft tissue from the field of view, fully exposing the vertebral plate, facet joints, and base of the spinous process. The radiofrequency probe and arthroscopic forceps were used for ipsilateral partial laminectomy and facetectomy. After confirming that the ipsilateral recess and walking root were fully decompressed, the angle of the endoscope was adjusted, and the junction between the lamina and the spinous process, the bottom of the spinous process base and the ventral side of the opposite lamina were ground step by step. Afterwards, the contralateral compressed nerve root was fully decompressed, and the lateral recess was expanded.

Finally, other narrowing of the bilateral lateral recess and nerve roots was determined (Fig. 1. a-b).

The criteria for conversion from local to general anaesthesia were as follows: (1) inability to tolerate pain; (2) discomfort or excessive agitation; and (3) low level of cooperation with the surgery.

UB-ULBD

The patient was placed in the prone position after general anaesthesia. The lesion site and corresponding intervertebral space were determined via fluoroscopy. The incision was made 1 cm next to the spinous process and 2 cm above and below the intervertebral space with a scalpel, and a continuous dilator was inserted into the vertebral plate. After the dilator was removed, an observation channel and a working channel were established. A radiofrequency probe was used through the working channel to fully peel off the surrounding soft tissue until the margin of the lower lamina was completely exposed. An automated drill and traditional Kerrison punches were used for ipsilateral hemilaminotomy to remove hypertrophic facet joints and lamina and to peel off the ligamentum flavum, which ensured that the ipsilateral dural sac and nerve root were fully decompressed. When contralateral decompression was performed, the fissure in the ligamentum flavum and the lower edge of the spinous process root were first identified, and then part of the basal part of the spinous process was removed. A drill and Kerrison punches were used to remove the ventral part of the contralateral vertebral plate, and if necessary, the inner edge of the contralateral lower articular process was removed to separate the contralateral ligamentum

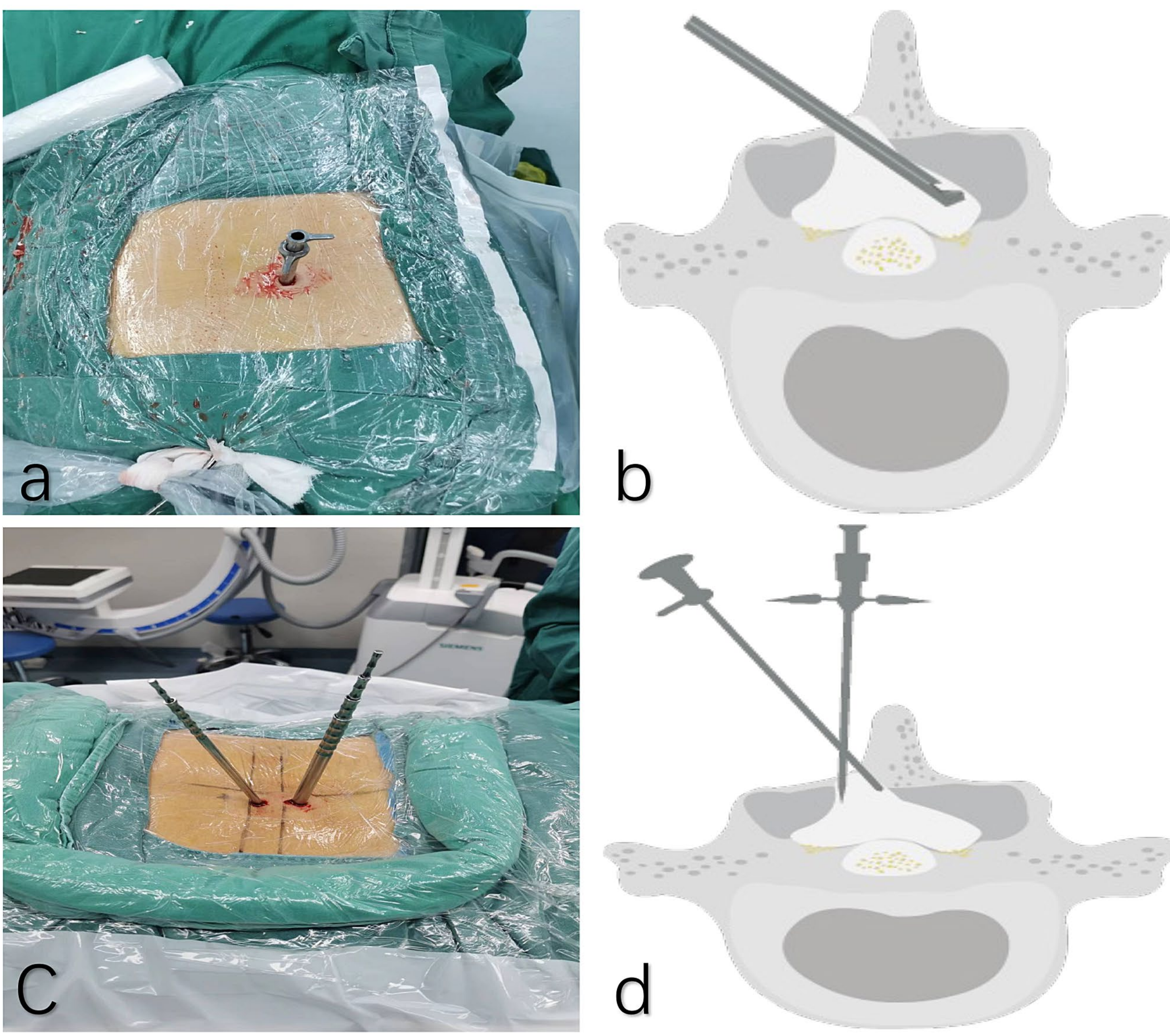

Fig. 1 **a**-**b**) The PE-ULBD; **c**-**d**) The UB-ULBD

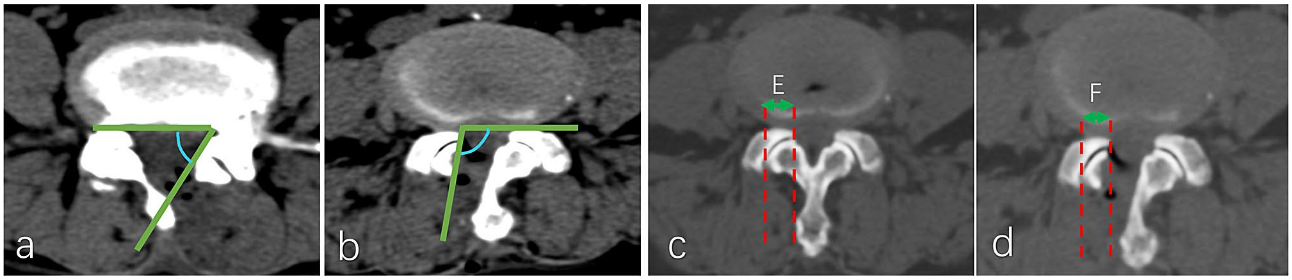

Fig. 2 **a**-**b**) The ipsilateral facet joint resection angle: the angle between the medial and axial horizontal lines of the ipsilateral facet joint resection area on postoperative lumbar CT; **c**-**d**) The facet preservation rate was measured through lumbar CT: facet preservation rate = (E/F) × 100%

flavum from the attachment point of the vertebral plate. Finally, the contralateral dural sac and nerve root were sufficiently decompressed to ensure complete freedom (Fig. 1. c-d).

Clinical evaluation

Patients had scheduled outpatient visits at 3 days and 3 and 12 months after the operation. We recorded and compared basic data such as age, sex, BMI, symptom duration and disc level, as well as all perioperative data, including operating time, estimated blood loss, hospitalization time and complications. To measure the degree of surgical invasiveness, the levels of creatine phosphokinase (CPK) in the serum were assessed both before and one day after surgery. The ratio of postoperative to preoperative CPK levels was used to illustrate the magnitude of change. C-reactive protein (CRP) levels before and 3 days after surgery were used to assess the presence of inflammation in the body. Follow-up clinical assessments involved the use of the visual analogue scale (VAS) to score back and leg pain, along with the Oswestry Disability Index (ODI). Patient satisfaction was represented by modified MacNab scores and was investigated preoperatively and at the postoperative follow-up.

The angle of ipsilateral facet joint resection and the facet preservation rate were obtained from computed tomography (CT) images (Fig. 2). A standardized measurement guide was used, which included identifying and marking the centre of the facet joint, the tips of the superior and inferior articular processes, and the midline of the vertebral body. The angle of ipsilateral facet joint resection and the facet preservation rate were measured on axial CT images at the level at which the facet joint space was maximally visualized. All the measurements were performed independently by two of the participating surgeons who were blinded to each other's assessments. To ensure consistency in the measurements, the participating surgeons received training on the measurement protocol prior to the commencement of the study. In cases of discrepancy between the two observers, a consensus meeting was conducted to reach an agreement. This procedure was facilitated by a third senior surgeon when necessary.

Table 1 The general information of UB-ULBD and PE-ULBD

Characteristics	UB-ULBD($n=61$)	PE-ULBD($n=52$)	*P* value
Age(years)	61.5 ± 7.08	65.3 ± 6.92	0.56
Gender (male/female)	27/34	21/31	0.28
BMI (kg/m^2)	25.16 ± 3.34	24.89 ± 3.06	0.11
Symptom duration (Month)	15.15 ± 2.87	15.30 ± 3.62	0.34
Disc Level			0.27
L3/4	13	11	
L4/5	31	27	
L5/S1	17	14	

Statistical analysis

The data were statistically analysedvia SPSS 22.0 software (IBM Corp, Armonk, New York, USA). Continuous variables are displayed as the means ± standard errors of the means. Demographic characteristics and perioperative outcomes were assessed via independent sample t tests, Fisher's exact tests, or Mann−Whitney U tests. The ODI and VAS score for back and leg pain were compared via repeated measures analysis of variance. A P value less than 0.05 was considered to indicate statistical significance.

Results

Patient characteristics

The data of 113 LSS patients who had undergone ULBD surgery at our institution were collected, of whom 61 underwent UB-ULBD and 52 underwent PE-ULBD. There were no significant differences in basic demographics, including age, sex, BMI, disc level or symptom duration, between the two groups (Table 1).

Surgical outcomes

There were no significant differences in estimated blood loss or hospitalization time between the UB-ULBD group and the PE-ULBD group ($P>0.05$). The operation time of the UE-ULBD group was significantly shorter (59.41 ± 11.22 vs. 63.31 ± 12.97, $P<0.05$). Postoperative changes in the serum CPK level were similar between the two groups. The facet was better preserved in the UB-ULBD group than in the PE-ULBD group (89.9±6.5% vs. 87.4±7.2%, $P<0.05$). Moreover, the angle of ipsilateral facet joint resection in the UE-ULBD group was significantly smaller (86.29±2.15 vs. 91.33±2.88, $P<0.05$) (Table 2; Figs. 3 and 4). Four patients underwent conversion from local anaesthesia to general anaesthesia during surgery because of their anxiety and low level of cooperation with the surgery. After transitioning to general anaesthesia, the surgery went smoothly without any abnormal findings.

Clinical outcomes

The VAS score, ODI score and patient satisfaction score of the two groups were compared. The results revealed improvements in the postoperative VAS and ODI scores in both groups; however, there were no significant differences in the VAS or ODI scores after surgery ($P>0.05$). In terms of the modified MacNab criteria, the UB-ULBD group had a 95.08% rate of excellent or good patient outcomes, whereas the PE-ULBD group had a 92.30% rate (Table 3).

Table 2 Comparison of perioperative date of UB-ULBD and PE-ULBD

Parameter	UB-ULBD($n=61$)	PE—ULBD($n=52$)	*P* value
Operation time (Mins)	59.41 ± 11.22	63.31 ± 12.97	**< 0.05**
Estimated blood loss (mL)	51.55 ± 10.27	49.23 ± 11.83	0.24
Hospitalization time (Day)	3.87 ± 0.88	3.38 ± 0.34	0.76
CPK ratio	1.33 ± 0.06	1.17 ± 0.11	0.44
CRP (mg/L)			
Preoperative	0.10 ± 0.04	0.10 ± 0.03	0.13
Postoperative 3 d	1.18 ± 0.23	0.75 ± 0.15	0.69
Facet preservation (%)	89.9 ± 6.5%	87.4 ± 7.2%	**< 0.05**
Angle of ipsilateral facet joint resection (°)	86.29 ± 2.15	91.33 ± 2.88	**< 0.05**
Complications(%)	1(1.6%)	2(3.8%)	0.97

Complications

During hospitalization, one patient in the UB-ULBD group experienced temporary leg numbness after surgery. In the PE-ULBD group, two patients reported postoperative dural tears. All three patients were cured without any sequelae after conservative treatment, such as bed rest, analgesia, and nutritional therapy.

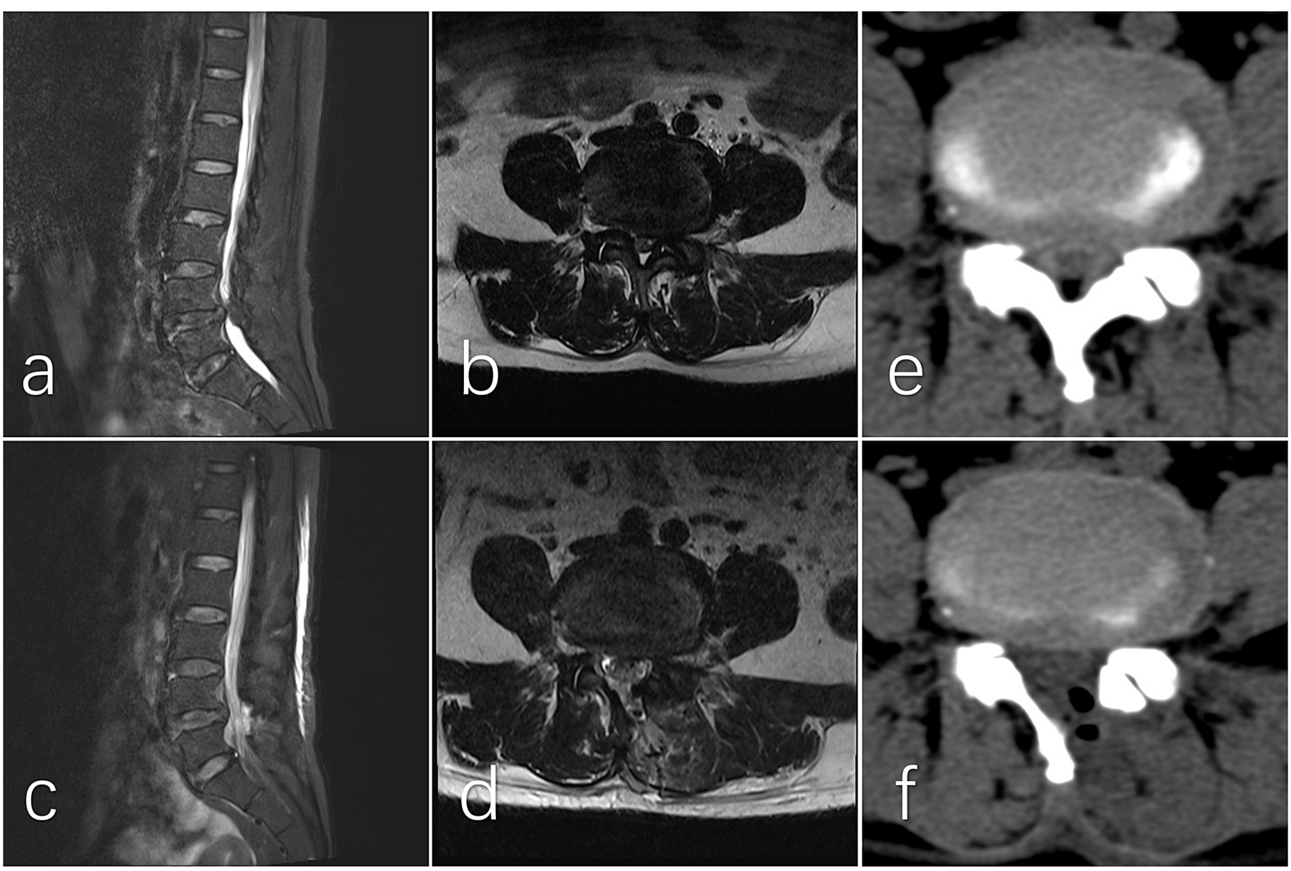

Fig. 3 UB-ULBD: **a**-**b**) Preoperative MRI showed hyperplasia of the ligamentum flavum, resulting in compression of the dural sac and spinal cord; **c**-**d**) Postoperative shows that dural sac and nerve root compression relieving; **e**-**f**) Comparison of preoperative and postoperative CT images show a sufficient bilateral decompression of the lateral recess and partial ipsilateral facet joint destruction

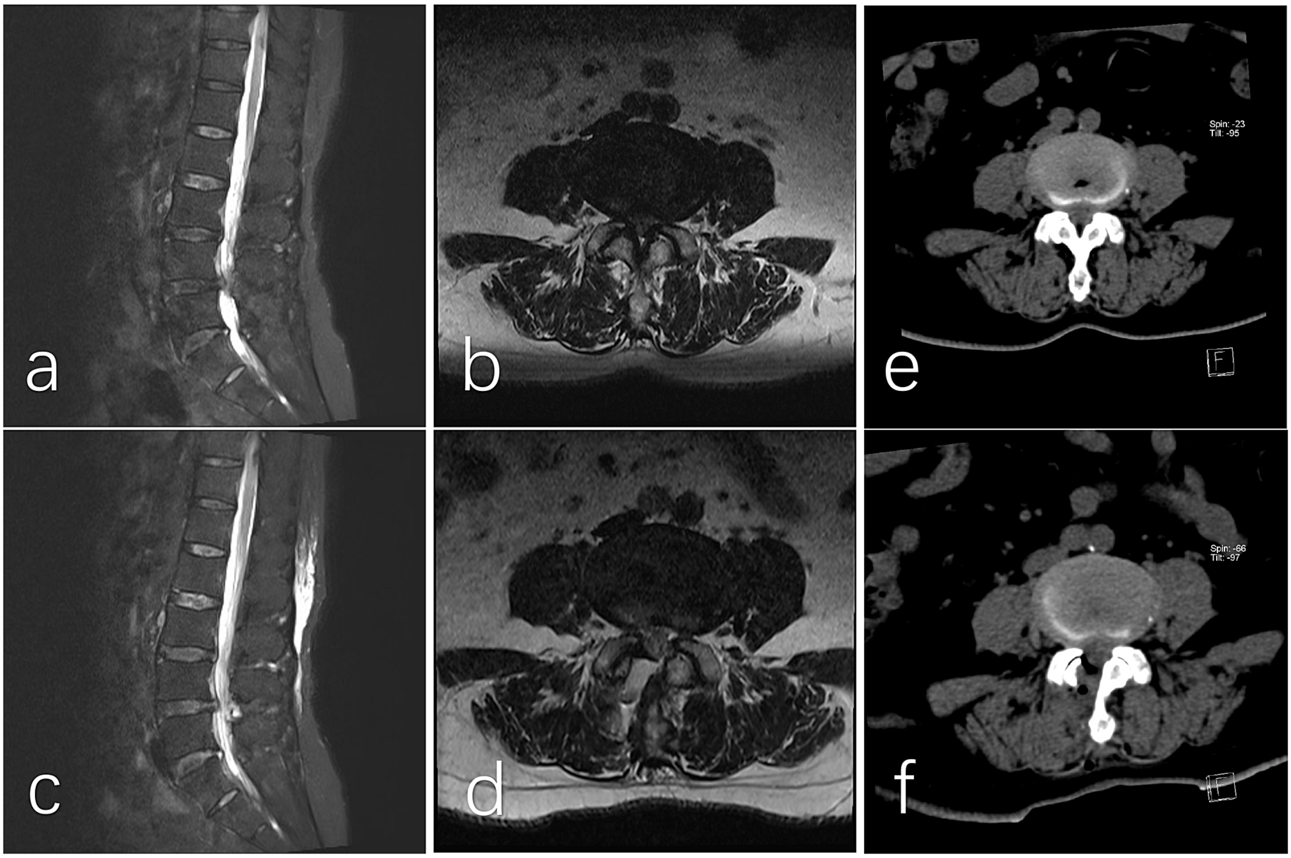

Fig. 4 PE-ULBD: **a**-**b**) Preoperative MRI showed lumbar disc herniation with hyperplasia of the ligamentum flavum, resulting in compression of the dural sac and spinal cord; **c**-**d**) Postoperative shows that dural sac and nerve root compression relieving; **e**-**f**) Comparison of preoperative and postoperative CT images show a sufficient decompression and a bilateral partial facetectomy

Table 3 Comparison of clinical results between the two groups

Parameter	UB-ULBD(*n* = 61)	PE-ULBD(*n* = 52)	*P* value
VAS for LP			
Preoperative	7.02 ± 1.58	7.08 ± 1.34	0.12
Postoperative 3 d	1.89 ± 0.97*	2.01 ± 0.76*	0.47
Postoperative 3 mo	1.67 ± 0.31*	1.81 ± 0.55*	0.33
Postoperative 12 mo	1.65 ± 0.51*	1.76 ± 0.46*	0.13
VAS for BP			
Preoperative	6.84 ± 1.35	6.91 ± 1.38	0.54
Postoperative 3 d	1.91 ± 0.69*	1.73 ± 0.63*	0.22
Postoperative 3 mo	1.75 ± 0.57*	1.73 ± 0.55*	0.34
Postoperative 12 mo	1.69 ± 0.46*	1.71 ± 0.56*	0.91
ODI (%)			
Preoperative	62.71 ± 5.26	62.51 ± 7.21	0.11
Postoperative 3 d	32.18 ± 3.92*	34.47 ± 2.36*	0.98
Postoperative 3 mo	23.98 ± 3.31*	23.11 ± 1.44*	0.41
Postoperative 12 mo	20.21 ± 1.91*	21.11 ± 2.87*	0.55
Modified MacNab			NS
Excellent	31	21	
Good	27	27	
Fair	3	4	
Poor	0	0	
Excellence/good rate	58(95.08%)	48(92.30%)	

*Compared with the preoperative value, $P < 0.05$

Discussion

Currently, the main treatment method for LSS is surgery, and MIS has become the preferred approach in spinal surgery [16–18]. It mainly utilizes small skin incisions to achieve sufficient nerve decompression while preserving soft tissue and bone anatomical structures, reducing muscle traction damage [19, 20]. Compared with traditional surgery, MIS reduces postoperative pain, haemorrhaging and complication rates, and the time required for recovery [21, 22]. Moreover, ULBD can greatly reduce the risk of damage to structures such as facet joints, muscles, and ligaments while fully decompressing the affected nerve [23]. It is currently one of the ideal minimally invasive treatment methods for bilateral lateral recess stenosis with or without central spinal canal stenosis [24]. With the gradual popularization of MIS, the use of the UB-ULBE and PE-ULBD surgical techniques have been widely reported [25, 26]. Nevertheless, few studies have compared the results of the UB-ULBD and PE-ULBD in terms of clinical and radiological outcomes.

Our study revealed that the UE-ULBD group had a shorter surgical time. The possible reason is the restricted view of the surgical field, which has also been reported in related studies [14, 27]. Our data also support the above clinical outcomes. The advantage of UBE is that the endoscope can operate through two channels separately without mutual interference. Moreover, both the endoscope and the working channel can be tilted and moved in any direction, and the field of view will not change when the endoscope is operated through the working channel. These features greatly increase space for the activity and make the surgery more flexible. In contrast, the design of both the endoscope and operating channel in PELD results in an insufficient observation range of the visual field, the need to use small operating tools, a limited range of movement, and relatively low work efficiency. Therefore, the surgery time was shorter in the UB-ULBD group than in the PE-ULBD group.

We measured the average resection angle of the ipsilateral facet joint and the extent of facet preservation in the two groups of patients after surgery. We found that (1) the average resection angle of the ipsilateral facet joint in the UB-ULBD group was significantly smaller than that in the PE-ULBD group and was lower than 90°, and (2) the extent of facet preservation in the UB-ULBD group was greater. This finding indicates that UB-ULBD performs better in terms of ipsilateral facet joint resection and can minimize ipsilateral facet joint damage while fully decompressing the ipsilateral nerve roots. However, PE-ULBD is slightly inadequate in this regard. The possible reasons are the limitations in the types and angles of surgical instruments used for PELD, which require the removal of too many facet joints to achieve sufficient decompression of the ipsilateral nerve roots. In contrast, more conventional surgical instruments can be used for UB-ULBD, especially the 30° arthroscopy system, which can increase the movement angle and range of surgical instruments, increasing the convenience, flexibility, effectiveness, and movement space. These characteristics make it significantly advantageous for removing bony structures and minimizing damage to the ipsilateral facet joints while providing safer and more thorough decompression of the bilateral nerve roots. However, the degree of preservation of facet joints and sufficient decompression of nerve roots are also related to the ability of the surgeons. Another reason for this result may be related to the steep learning curve for PELD, which may limit the widespread adoption of surgery and lead to poor radiological results.

In addition, 3 patients reported postoperative complications, but all the complications spontaneously resolved after conservative therapy without additional intervention. Dural tearing is a common complication of LSS. In this study, two patients in the PE-ULBD group experienced dural tearing as a result of adhesion between the ligamentum flavum and the dural sac. PE-ULBD is a uniportal system, so adhesion between the ligamentum flavum and the dural sac is difficult to detect. Thus, more focus is needed when performing PE-ULBD to treat LSS.

We also compared the clinical outcomes of the two approaches for the treatment of LSS. The postoperative rates of excellent or good patient outcomes were 95.08% in the UE-ULBD group and 92.30% in the PE-ULBD group, surpassing the rates reported in published studies on ULBD surgery for patients with LSS [28]. Our results revealed that the VAS and ODI scores of both groups improved during the follow-up period. Nevertheless, there was no significant difference between the groups in terms of the scoring system used. This outcome could be attributed to the fact that both groups underwent full spine decompression via endoscopic techniques. Moreover, minimizing injury to the multifidus muscle can lead to decreased postoperative back pain and improved functional outcomes. Surgical procedures that cause less muscular damage are associated with reduced atrophy and fatty infiltration. Studies indicate that reduced muscle injury after MIS-ULBD contributes to better long-term clinical results than those observed after traditional open surgery [22, 29]. In our study, both groups presented slight increases in postoperative CPK and CRP levels. The potential explanation lies in the reduced damage caused by the smaller diameter and axial flexibility of endoscopic working cannulas. As a result, the slight difference in leg and back pain between the groups had no significant impact on the functional outcomes or quality of the life of patients.

Our study has several limitations. First, the study design was nonrandomized, which may have introduced sampling bias because it was a single-center retrospective analysis with a relatively small sample size; Second, the follow-up period in this study was limited, which restricts the ability to draw conclusions about the long-term efficacy and impact of the UB-ULBD technique; Third, the long-term spinal stability and lumbar function need further clinical evaluation. Future research with larger sample sizes and extended monitoring is necessary to confirm our findings and to thoroughly evaluate the long-term outcomes.

Conclusions

Both the UB-ULBD and the PE-ULBD can provide good clinical results in the treatment of LSS. The UB-ULBD method offers the benefits of a shorter operation time, a smaller angle of ipsilateral facet joint resection and better facet preservation and may be a practical and safe alternative for treating LSS while maintaining spinal stability.

Abbreviations

LSS	Lumbar spinal stenosis
ULBD	Unilateral laminotomy for bilateral decompression
MIS	Minimally Invasive Surgery
PELD	Percutaneous endoscopic lumbar discectomy

UBE Unilateral Biportal Endoscopy
CPK Creatine phosphokinase
VAS Visual analog scale
ODI Oswestry disability index for disability

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Author contributions
Zhongxin Tang: Data curation, Writing- Original draft preparation; Mingkui Shen: Formal analysis, Investigation; Jun Tan: Supervision; Hejun Yang: Writing - Review & Editing.

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Data availability
The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the the Medical Ethics Committee of the third people's hospital of henan province. All subjects gave written informed consent to participate in the study. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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