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Unilateral Biportal Endoscopy for Lumbar Disc Herniation and Spinal Stenosis: Clinical Outcomes and Complication Analysis

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ABSTRACT

AIM: To evaluate clinical outcomes, complications, and pathological distribution in patients with lumbar disc herniation (LDH) and/or lumbar spinal stenosis (LSS) undergoing unilateral biportal endoscopic (UBE) surgery.

MATERIAL and METHODS: This retrospective study included 127 patients with LDH and/or LSS who underwent UBE surgery between October 2024 and May 2025. Demographic and operative data were reviewed. Clinical outcomes were evaluated using Visual Analog Scale (VAS) scores at baseline, on postoperative Day 1, and at three months, and by using Oswestry Disability Index (ODI) scores at baseline and at three months. The primary outcome was the change in ODI from baseline to three months. Secondary outcomes included trajectories of VAS-leg/back, operative metrics, and complications.

RESULTS: Of the patients, 58.3% were female and 41.7% were male with a mean age of 49.20±13.92 years. The mean operative time was 48.76±14.18 min, and 94.5% were discharged within one day. The most common pathology was pure disc herniation (63%), predominantly at the L4-L5 level (59.8%). Complication rates were as follow: dural tear in 3.9%, wound discharge in 2.4%, and recurrence in 3.2%. Statistically significant improvements in VAS and ODI scores were observed postoperatively ($p<0.001$). Moreover, minimum clinically important difference (MCID)-based responder rates were high for both disability and pain outcomes at three months, indicating that the improvements were also clinically meaningful.

CONCLUSION: The UBE technique is associated with shorter operative time and length of hospital stay. This finding supports its place as effective and safe minimally invasive treatment for LDH and LSS, facilitating rapid functional recovery and early discharge.

KEYWORDS: Unilateral biportal endoscopy, Lumbar disc herniation, Spinal stenosis, Minimally invasive spine surgery, Outcomes

ABBREVIATIONS: LDH: Lumbar disc herniation, LSS: Lumbar spinal stenosis, UBE: Unilateral biportal endoscopy, VAS: Visual analog scale, ODI: Oswestry disability index, OLM: Open lumbar microdiscectomy, MIS: Minimally invasive surgery, MISS: Minimally invasive spinal surgery

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■ INTRODUCTION

Lumbar disc herniation (LDH) and lumbar spinal stenosis (LSS) are common degenerative spinal pathologies, particularly prevalent in the aging population, and are major contributors to reduced quality of life due to low back pain and radiculopathy (1,8,20,23). Clinically, patients typically present with radicular symptoms, neurological deficits, paresthesia in the lower limbs, low back pain, and neurogenic claudication, primarily due to nerve root compression (8,20). Although conservative treatment is the initial approach, surgical intervention is indicated when symptoms persist or progress despite conservative treatment (1,3,20).

While conventional surgical approaches such as microscopic discectomy and laminectomy can yield successful clinical outcomes, they often involve extensive soft tissue dissection and muscle damage, thereby increasing the risk of long-term complications, including postoperative low back pain, paraspinal muscle atrophy, adjacent segment degeneration, and even failed back surgery syndrome (3,26,29). To address these limitations, minimally invasive surgery (MIS) techniques have been developed (8,10,29).

A key advancement in this field is the integration of microsurgical principles with endoscopic systems (20,21). Unilateral biportal endoscopy (UBE) is a minimally invasive spinal surgery (MISS) technique which utilizes two separate portals to access the spinal canal: one for visualization and another for surgical instruments (12). This method addresses the limitation of uniportal approaches, in which instruments can obstruct the view, thereby providing an advantage for treating pathologies such as LDH and LSS (8,25). The UBE technique offers several benefits, including smaller surgical incisions, reduced postoperative back pain, shorter hospital stays, and minimal damage to soft tissue and bone (21,27,29). Recent meta-analyses have demonstrated that UBE can provide more favorable or comparable short-term pain relief to microdiscectomy (21,27,32). Furthermore, UBE is usually associated with a lower incidence of complications and less intraoperative blood loss compared to microdiscectomy (24).

However, the UBE technique involves a steep learning curve and presents unique practical challenges for surgeons (11). Maintaining stable fluid dynamics within the surgical field is critical for ensuring clear visualization and preventing complications (12). Factors such as the use of a rigid cannula, cannula length, and the patient's body mass index (BMI) can influence the water pressure in the operative field and, consequently, surgical outcomes (12,24).

Review of the literature reveals that there are often no statistically significant long-term differences between UBE and conventional microsurgery in terms of Oswestry Disability Index (ODI) scores and operative time (21,27), suggesting that both methods may yield comparable functional outcomes. However, while some studies report advantages of UBE, such as shorter operative time and reduced intraoperative blood loss (21,32), others show no significant differences (20). These inconsistencies in the current literature highlight the need for further research, particularly larger-scale, randomized-con-

trolled trials, to clarify the clinical role of UBE and define its optimal indications.

In the present study, we aimed to evaluate clinical outcomes, complications, and pathological distribution in patients undergoing UBE surgery.

■ MATERIAL and METHODS

This single-center, retrospective study was conducted at Tokat Erbaa State Hospital, Department of Neurosurgery between October 2024 and May 2025. Initially, a total of 142 consecutive patients who underwent UBE surgery for lumbar degenerative diseases (LDH and/or LSS) were screened for eligibility. Inclusion criteria were as follows: *i)* age ≥ 18 years; *ii)* persistence of symptoms despite at least six months of conservative medical treatment; *iii)* concordance between the patient's symptoms, neurological examination findings, and radiological imaging; and *iv)* a minimum follow-up period of three months. Patients were excluded if they were younger than 18 years or presented with extraforaminal disc herniation, a history of active or previous spinal infection, or radiological evidence of spondylolisthesis or segmental instability. After 15 patients who did not fulfill inclusion criteria were excluded from the study, 127 patients were recruited. The study flowchart is shown in Figure 1. Given the retrospective design of the study, the requirement for informed consent for study participation was waived by the Ethics Committee. All patients had provided written informed consent for the surgical procedure and for the use of their anonymized clinical data for scientific purposes at the time of admission. The study protocol was approved by the Tokat Gaziosmanpasa University Ethics Committee (No: 25-MOBAEK-330). The study was conducted in accordance with the principles of the Declaration of Helsinki.

All surgical procedures were performed by a single neurosurgeon experienced in MISS. Patient data were retrieved from medical records. These included demographic characteristics (age, sex, body mass index [BMI]), clinical features (pathology and its level, history of revision surgery, comorbidities), and surgical parameters (type of anesthesia, operative time, intraoperative complications, change in pre- and postoperative hemoglobin levels), and length of hospital stay. Postoperative wound complications and recurrence rates were also recorded.

Incidental dural tear was defined as any intraoperative breach of the dura mater as confirmed by the surgeon, managed either by primary repair or sealant patch. Wound complications were classified as superficial (discharge requiring dressing changes) or deep (infection requiring debridement/revision). Symptomatic postoperative epidural hematoma was defined as a radiological collection compressing the neural elements necessitating surgical evacuation. Recurrence was defined as radiating pain with radiological confirmation of a new disc herniation at the same level and side during the follow-up period. Re-operation criteria included intractable pain resistant to conservative management, progressive neurological deficit, or cauda equina syndrome.

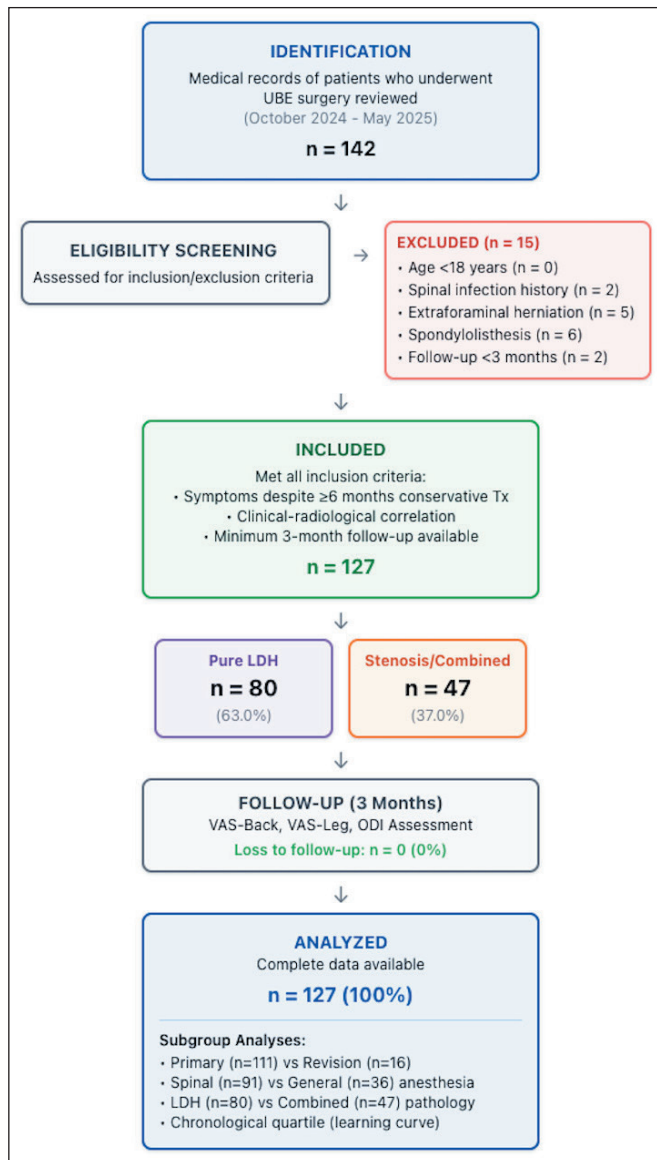


Figure 1: STROBE Flow Diagram showing patient selection and study population.

LDH: Lumbar disc herniation, **UBE:** Unilateral biportal endoscopy, **VAS:** Visual analog scale, **ODI:** Oswestry disability index, **Tx:** Treatment

For the evaluation of clinical outcomes, Visual Analog Scale (VAS) scores (for back and leg pain) were recorded at baseline, on postoperative Day 1, and at three months, while ODI scores were assessed at baseline and at three months. All preoperative assessments were conducted during in-person clinic visits by trained staff using standardized questionnaires. The VAS scores on postoperative Day 1 were obtained during routine ward rounds prior to discharge. The three-month follow-up VAS and ODI scores were collected face-to-face during scheduled outpatient clinic visits. The primary outcome was the change in ODI from preoperative baseline to three months. Secondary outcomes included changes in VAS scores (leg/back) at baseline, postoperative Day 1, and three

months postoperatively; operative time; estimated blood loss/hemoglobin change; length of stay; and complications.

Statistical Analysis

Statistical analysis was performed using the IBM SPSS Statistics for Windows version 20.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were presented in mean±standard deviation (SD) or median (min-max), while categorical variables were presented in number and frequency. The Shapiro-Wilk test was used to assess the normality of data distribution. The Friedman test was used to analyze the changes in VAS scores across three time points (preoperative, postoperative Day 1, and three-month follow-up). If the Friedman analysis revealed a significant difference, *post-hoc* multiple comparison tests were carried out to identify the source of the difference. To evaluate functional improvement, as measured by ODI scores recorded at two time points (*i.e.*, baseline and three months), the Wilcoxon signed-rank test was used. To evaluate the clinical meaningfulness of the surgical outcomes beyond statistical significance, the minimum clinically important difference (MCID) responder rates were also calculated. Based on large-scale registry data, MCID achievement was defined as an improvement of ≥12.8 points for the ODI (2,6). For pain scores, a reduction of ≥2.0 points for VAS back and leg pain was considered the threshold for clinically important improvement (22). The proportion of patients meeting these thresholds at three months of follow-up was calculated. To evaluate the surgical learning curve, operative times between the first and final chronological quartiles were compared using the Mann-Whitney U test. A *p* value of <0.05 was considered statistically significant.

RESULTS

A total of 127 patients were included in this study. Complete follow-up data were available for all 127 patients at all time points, with no loss to follow-up. The mean age of the patients was 49.20±13.92 (range, 22 to 80) years. The study population consisted of 74 (58.3%) females and 53 (41.7%) males. The mean BMI was 28.80±4.45 kg/m². Regarding the distribution of pathologies, 63.0% (n=80) of patients underwent surgery for disc herniation, 19.7% (n=25) for spinal stenosis, and 17.3% (n=22) for a combination of spinal stenosis and disc herniation. The analysis of surgical levels revealed that L4-L5 was the most frequently operated level at 59.8% (n=76), followed by L5-S1 at 30.7% (n=39). Other operated levels included L3-L4 (4.7%, n=6), L3-L4 + L4-L5 (3.1%, n=4), L1-L2 (0.8%, n=1), and L4-L5 + L5-S1 (0.8%, n=1). The majority of patients (87.41%, n=111) underwent primary surgery, while 12.6% (n=16) underwent revision surgery. Spinal anesthesia was administered to 71.7% (n=91) of the patients, and general anesthesia was used in 28.3% (n=36). The mean operative time was 48.76±14.18 min. The mean difference between preoperative and postoperative Day 1 hemoglobin levels was measured as 0.34±0.15 g/dL. The mean length of hospital stay was 1.10±0.30 days. While 94.5% (n=120) of the patients were hospitalized for one day, 5.5% (n=7) stayed for two days. Considering complications, an incidental dural tear was observed in five patients (3.9%), wound discharge oc-

curred in three patients (2.4%), and recurrent disc herniation was detected in four patients (3.2%) during the three-month follow-up period. Additionally, one patient developed transient postoperative visual disturbance, which resolved completely with medical management. Demographic and perioperative characteristics of the patients are summarized in Table I.

Preoperative, postoperative Day 1, and three-month follow-up VAS (back and leg) and ODI scores are presented in Table II. The mean preoperative VAS score for back pain decreased from 7.34 ± 0.70 to 5.35 ± 0.70 on the first postoperative day and further to 2.25 ± 0.64 at three months of follow-up. The reductions at both postoperative Day 1 and three months were statistically significant compared to baseline ($p < 0.001$ for both). Furthermore, the improvement observed at three months was also significant, compared to the score on the first postoperative day ($p < 0.001$). Similarly, the mean preoperative VAS score for leg pain decreased from 7.31 ± 0.77 preoperatively to 3.03 ± 1.02 on postoperative Day 1 and further to 1.84 ± 0.72 at 3 months. Both the postoperative Day 1 and the three-month scores demonstrated highly significant reductions compared to the preoperative period ($p < 0.001$ for both). The scores at the three-month follow-up also showed a significant improvement compared with Day 1 ($p < 0.001$). The mean ODI score, reflecting functional status, improved from a preoperative value of 71.04 ± 7.01 to 7.32 ± 3.19 at the three-month follow-up, indicating statistical significance ($p < 0.001$).

The patients were stratified into two groups based on pathology: pure LDH ($n=80$) and LSS with or without LDH (Stenosis/Combined group) ($n=47$). Subgroup analysis revealed significant differences in operative metrics and specific clinical outcomes between these groups (Table III). Regarding perioperative metrics, the hemoglobin drop was significantly lower in the LDH group (0.29 ± 0.13 vs. 0.40 ± 0.15 g/dL; $p < 0.001$, $r=0.332$). Similarly, the operative time was significantly shorter in the LDH group compared to the Stenosis/Combined group (43.29 ± 9.26 min vs. 57.75 ± 16.24 min; $p < 0.001$, $r=0.450$). However, no significant difference was observed in the length of hospital stay ($p=0.513$). In terms of clinical outcomes, both groups achieved significant improvements. However, the magnitude of improvement varied by symptom type. For leg pain (VAS-Leg), the LDH group demonstrated a significantly greater reduction at three months compared to the Stenosis/Combined group (Δ VAS: -5.82 ± 0.87 vs. -4.89 ± 1.11 ; $p < 0.001$, $r=0.414$). Conversely, for back pain (VAS-Back), the Stenosis/Combined group showed a slightly larger mean reduction

Table I: Demographic and Perioperative Characteristics of the Patients

Characteristic	Value (n=127)
Age (years), Mean $\pm$ SD	49.20 $\pm$ 13.92
Gender, n (%)	
Female	74 (58.3)
Male	53 (41.7)
BMI (kg/m ²), Mean $\pm$ SD	28.80 $\pm$ 4.45
Pathology Type, n (%)	
Pure Disc Herniation (LDH)	80 (63.0)
Stenosis / Combined	47 (37.0)
Surgical Level, n (%)	
L4-L5	76 (59.8)
L5-S1	39 (30.7)
Other (L1-L2, L3-L4, Multi-level)	12 (9.5)
Surgery Type, n (%)	
Primary	111 (87.4)
Revision	16 (12.6)
Anesthesia Type, n (%)	
Spinal	91 (71.7)
General	36 (28.3)
Operative Metrics	
Operative time (min), Mean $\pm$ SD	48.76 $\pm$ 14.18
Hemoglobin drop (g/dL), Mean $\pm$ SD	0.34 $\pm$ 0.15
Length of Stay (days), Mean $\pm$ SD	1.10 $\pm$ 0.30
Complications, n (%)	
Incidental Dural Tear	5 (3.9)
Wound Discharge	3 (2.4)
Recurrent Disc Herniation	4 (3.2)
Transient Visual Disturbance	1 (0.8)

SD: Standard deviation, **BMI:** Body mass index, **Preop:** Preoperative, **Postop:** Postoperative.

Table II: Comparison of Preoperative, Postoperative Day 1, and 3-Month Follow-up ODI and VAS Scores

Score	Preoperative	Postoperative Day 1	Postoperative 3-Month	p-value
VAS Back ^a	7.34 $\pm$ 0.70	5.35 $\pm$ 0.70	2.25 $\pm$ 0.64	<0.001
VAS Leg ^a	7.31 $\pm$ 0.77	3.03 $\pm$ 1.02	1.84 $\pm$ 0.72	<0.001
ODI ^b	71.04 $\pm$ 7.01	—	7.32 $\pm$ 3.19	<0.001

Values are presented as Mean $\pm$ Standard Deviation.

^a Analyzed using Friedman Test (Repeated measures across 3 time points). Post-hoc pairwise comparisons were all significant ($p < 0.001$).

^b Analyzed using Wilcoxon Signed-Rank Test (Paired comparison between baseline and 3-month follow-up).

VAS: Visual analog scale, **ODI:** Oswestry disability index, **SD:** Standard deviation.

Table III: Subgroup Analysis: Comparison of Outcomes by Pathology Type (LDH vs. Combined)

Variable	Pure LDH (n=80)	Stenosis/Combined pathology (n=47)	p-value	Effect Size (r)
Hemoglobin Drop (g/dL)	0.29±0.13	0.40±0.15	<0.001	0.332
Length of Stay (days)	1.09±0.28	1.13±0.33	0.513	0.058
Operative Time (min)	43.29±9.26	57.75±16.24	<0.001	0.450
Clinical Improvement (Δ)				
Δ VAS Back (Preop - 3 Months)	-4.98±0.75	-5.25±0.97	0.019	0.208
Δ VAS Leg (Preop - 3 Months)	-5.82±0.87	-4.89±1.11	<0.001	0.414
Δ ODI (Preop - 3 Months)	-63.82±7.39	-63.54±7.57	0.713	0.033

Values are presented as Mean±Standard Deviation. Comparisons performed using Mann-Whitney U Test.

Δ: Change score (Mean difference between preoperative and postoperative values)

Table IV: Impact of Surgical Factors on Operative Metrics and Clinical Outcomes

Comparison Factor	Outcome Measure	Group 1 (Mean±SD)	Group 2 (Mean±SD)	p-value	Effect Size (r)
Surgical History		Primary (n=111)	Revision (n=16)		
	Operative Time (min)	47.05±14.16	60.63±6.80	<0.001	0.367
	Hemoglobin Drop (g/dL)	0.33±0.16	0.36±0.08	0.280	0.096
	Length of Stay (days)	1.09±0.28	1.19±0.40	0.231	0.106
	Δ ODI (Improvement)	-64.07±7.69	-62.25±4.78	0.065	0.164
Anesthesia Type		Spinal (n=91)	General (n=36)		
	Operative Time (min)	46.78±13.15	53.75±15.60	0.009	0.230
	Hemoglobin Drop (g/dL)	0.34±0.16	0.33±0.11	0.969	0.003
	Length of Stay (days)	1.09±0.28	1.14±0.35	0.395	0.076
	Δ ODI (Improvement)	-64.37±6.81	-62.05±8.70	0.071	0.160
Learning Curve		1st Quartile (Cases 1-32)	4th Quartile (Cases 96-127)		
	Operative Time (min)	51.88±14.68	52.96±13.28	0.780	0.035
Overall Clinical Responsiveness		MCID Threshold	Responder Rate (%)	n / Total	
	ODI (Δ12.8 pts)		98.3%	125 / 127	-
	VAS Leg (Δ 2.0 pts)		96.8%	123 / 127	-
	VAS Back (Δ 2.0 pts)		92.1%	117 / 127	-

Values are presented as Mean±Standard Deviation for continuous variables and percentages for responder rates. Comparisons performed using Mann-Whitney U Test. Statistical significance was set as $p < 0.05$.

MCID: Minimum Clinically Important Difference. Thresholds defined as ≥ 12.8 points for ODI and ≥ 2.0 points for VAS.

Note: Comparison of complication rates between quartiles was not performed due to the low number of events.

at three months (Δ VAS: -5.25±0.97 vs. -4.98±0.75; $p=0.019$, $r=0.208$), likely due to higher baseline back pain scores in the stenosis cohort. Notably, functional recovery as measured by the ODI score improvement was comparable between the two groups (Δ ODI: -63.82 vs. -63.54; $p=0.713$, $r=0.033$).

We further analyzed the impact of surgical history and anesthesia type on operative metrics and clinical outcomes (Table IV). Patients undergoing revision surgery ($n=16$) required sig-

nificantly longer operative times than those in primary cases (60.63±6.80 vs. 47.05±14.16 min; $p<0.001$, $r=0.367$). However, despite the increased surgical complexity, there were no statistically significant differences between the primary and revision groups regarding hemoglobin drop ($p=0.280$), length of hospital stay ($p=0.231$), or clinical improvements in VAS back ($p=0.600$), VAS leg ($p=0.268$), and ODI scores (Δ ODI: -64.07 vs. -62.25; $p=0.065$) at three months of follow-up. Re-

garding anesthesia modality, patients operated under spinal anesthesia ($n=91$) had significantly shorter operative times compared to those under general anesthesia (46.78 ± 13.15 vs. 53.75 ± 15.60 min; $p=0.009$, $r=0.230$). In terms of clinical outcomes, the general anesthesia group showed a statistically greater magnitude of improvement in back pain (Δ VAS-Back) at both postoperative Day 1 ($p=0.026$) and three months ($p=0.017$). However, this difference did not translate into functional recovery, as ODI scores improved similarly in both anesthesia groups ($p=0.0715$).

A substantial proportion of patients achieved the MCID thresholds at three months of follow-up. For functional disability (ODI), 98.3% of the cohort achieved the MCID of ≥ 12.8 points. Similarly, successful pain relief (Δ VAS ≥ 2.0) was achieved in 96.8% of patients for leg pain and 92.1% for back pain (Table IV).

To evaluate the learning curve effect, the patients were divided into chronological quartiles based on the date of surgery. A comparison between the first quartile (first 32 cases) and the last quartile (last 32 cases) revealed no statistically significant difference in the mean operative time (51.88 ± 14.68 min vs. 52.96 ± 13.28 min, $p=0.780$) (Table IV). Due to the low overall incidence of complications (e.g., $n=5$ dural tears), a meaningful statistical subgroup comparison of complication rates across quartiles could not be performed.

DISCUSSION

In the surgical treatment of lumbar degenerative diseases, there has been a dramatic paradigm shift toward MISS techniques (11). This transformation is driven by multiple factors, including an aging patient population with increased comorbidities, evolving patient preferences, and amendments in healthcare reimbursement policies (11). Although traditional open surgical approaches provide favorable outcomes, they are associated with certain disadvantages, such as extensive soft tissue dissection, paraspinal muscle trauma, considerable blood loss, a higher risk of infection, and prolonged hospital stays (16,19). The UBE technique has been developed as a less invasive alternative to overcome these limitations (13,28).

In the present study, we evaluated clinical outcomes, complications, and pathological distribution in patients undergoing UBE surgery. In our study, the mean age of patients was 49.20 ± 13.92 years, with a predominance of female patients (58.3%). This demographic distribution is consistent with other UBE studies in the literature, such as the systematic review by Lin et al. (19), which reported a mean age of 55.8 years and a 53.6% female population, and the study by Kim et al. (16), which reported a mean age of 50.98 ± 18.23 years and a 56.7% female cohort. The distribution of surgical pathologies in our cohort indicated that UBE was primarily used for common lumbar pathologies, most notably disc herniation (63.0%) at the L4-L5 level (59.8%), followed by the L5-S1 level. The majority of our patients (63.7%) presented with left-sided symptoms.

Our clinical outcomes support that UBE significantly reduces back and leg pain (VAS scores) and functional disability

(ODI scores) in the short-term postoperative period. Indeed, our results are corroborated by numerous studies, including a meta-analysis by Xie et al. (28), which showed that postoperative leg and back VAS scores, as well as ODI scores, were statistically significantly lower than preoperative values. Other systematic reviews by Lin et al. and Kwon et al. also reported similar significant improvements in VAS and ODI scores following UBE surgery (18,19). Beyond statistical significance, determining the responder rate is crucial for validating surgical success. In our study, the high responder rates for both ODI and VAS scores were achieved. While our follow-up is relatively short, the magnitude of the observed improvement indicates a clinically meaningful early functional recovery and effective pain relief following UBE decompression.

The mean difference between pre- and postoperative hemoglobin levels in our cohort was only 0.34 ± 0.15 g/dL, supporting the notion that UBE is characterized by minimal blood loss. This finding is consistent with the study by Kim et al. (16), who reported significantly less estimated blood loss in the UBE group (34.67 ± 16.9 mL) than in the open lumbar microdiscectomy (OLM) group (140.05 ± 57.8 mL). Similarly, Lin et al. reported a mean blood loss of 48 mL (19). These advantages are further substantiated by a recent meta-analysis involving 1,001 patients, which confirmed that UBE is associated with significantly shorter hospital stays and lower estimated blood loss than microdiscectomy, despite no significant difference in long-term efficacy (9). The fact that a vast majority of our patients (94.5%) had a hospital stay of only one day aligns with the minimally invasive nature of UBE and supports similar findings in the literature.

In our study, the mean operative time was 48.76 ± 14.18 min. This duration is shorter than that reported in several literature series, such as 70.15 ± 22.0 min by Kim et al. (16), an average of 81.3 min by Lin et al. (19), and an average of 74.4 min by Kwon et al. (18), for their respective UBE groups. In contrast, Jiang et al. found a longer mean operative time in the UBE group (117.54 ± 20.36 min) than in the PELD group (64.63 ± 13.13 min) (13). These discrepancies in the literature can be attributed to factors such as the surgeon's experience, the complexity of the case, and the surgical team's learning curve.

Our subgroup analysis revealed distinct perioperative and clinical profiles for pure LDH and Stenosis/Combined groups. The significantly longer operative times and greater hemoglobin drop in the Stenosis/Combined group reflect the greater technical demand of bony decompression (laminotomy and flavectomy) compared to soft-tissue discectomy. Clinically, the superior leg pain relief observed in the LDH group aligns with the pathophysiological understanding that acute nerve compression (LDH) typically resolves more rapidly than chronic neurogenic claudication (stenosis), where chronic intraneural ischemia may delay neural recovery (17). Conversely, the greater reduction in back pain in the Stenosis/Combined group likely stems from the higher preoperative baseline back pain levels associated with multilevel degeneration and stenosis. Importantly, the comparable functional recovery (Δ ODI) between groups ($p=0.713$) suggests that UBE provides adequate mechanical decompression for both pathologies in the early postoperative period; however, this similarity should be

interpreted with caution, as the short follow-up duration may mask potential long-term divergences in clinical trajectories associated with the chronicity of spinal stenosis.

Furthermore, our analysis of surgical factors provides insights into the versatility of the UBE technique. First, regarding revision surgery, the significantly longer operative time observed in the revision group reflects the technical challenges posed by epidural fibrosis and altered anatomical landmarks. However, the clinical outcomes (VAS and ODI improvement) and complication profile (hemoglobin drop, hospital stay) were statistically comparable to those of the primary cases. This suggests that high-resolution visualization and distinct instrument portal of the UBE may facilitate safe and effective adhesion dissection, supporting its viability as an option for revision cases without compromising short-term clinical success. Second, regarding anesthesia, we observed shorter operative times in the spinal anesthesia group. This may be attributed to the physiological benefits of reduced venous congestion in the epidural space, resulting from lower intrathoracic pressure compared to general anesthesia, which minimizes intraoperative bleeding and maintains a clear endoscopic visual field, thereby reducing the time required for hemostasis. More interestingly, although the general anesthesia group showed statistically greater improvement in back pain scores, this did not translate into superior functional recovery. We speculate that this difference in pain scores may be an artifact of higher baseline pain levels in patients selected for general anesthesia, often those with multilevel or complex pathology, creating a larger potential for mathematical improvement, rather than a direct superiority of the anesthesia type itself. Ultimately, the comparable functional outcomes support the use of spinal anesthesia as a resource-efficient alternative in eligible patients.

The rate of dural tear in our study was 3.9% (n=5), which is comparable to the average rates reported in the literature. Kim et al. reported a rate of 3% (16), a systematic review by Lin et al. found a mean rate of 4.1% (19), and a review by Kwon et al. cited a rate of 3% (18). In a comprehensive systematic review of 20,020 patients, Compagnone et al. reported that, while perioperative complications such as dural tears and transient neurological deficits were the most relevant risks, the overall safety profile remained acceptable when the learning curve was navigated carefully (5). Other complications, such as wound discharge (2.4%), were observed at low rates in our series.

The occurrence of a rare but serious complication, such as the transient visual disturbance observed in one of our patients, highlights the critical importance of managing the pressure of the continuous irrigation fluid used in UBE surgery. It is well-documented that excessive hydrostatic pressure in the lumbar epidural space can be transmitted to the intracranial compartment, potentially raising intracranial pressure (ICP) via the dura mater or Batson's venous plexus and leading to iatrogenic injury (14). Factors such as preoperative anticoagulant use, female sex, advanced age, and the use of an intraoperative water infusion pump have been identified as risk factors (15). Symptoms can range from headache and neck pain to visual disturbances or seizures. To minimize these risks, we adopted a structured safety framework for fluid management

and avoided high-pressure infusion pumps and preferred gravity-assisted irrigation (15). We also ensured the continuous patency of the portal to prevent 'fluid choking,' checking frequently that outflow always exceeds inflow to avoid epidural pressure buildup. Close communication with the anesthesia team was maintained to detect early signs of sympathetic response (e.g., bradycardia or hypertension) indicative of rising ICP. The transient visual symptom observed in our series resolved rapidly with conservative management, confirming its pressure-related etiology rather than direct neural injury.

As with any surgical technique, UBE has been emphasized as having a significant learning curve. Studies by Choi et al. and Demirtaş and Özer examined the relationship between the learning curve and complication rates, indicating that surgeons require time to adapt to the new procedure (4,7). Difficulties may be encountered, particularly in initial cases, with establishing the working space and identifying anatomical structures. This indicates the unmet need for a thorough understanding of the surgical procedure and for practical experience. Interestingly, our chronological analysis did not show a significant reduction in operative time between the initial and final quartiles. A potential explanation for this might be the increasing complexity of cases selected in the later period. As the surgeon's proficiency with the UBE technique grew, more challenging pathologies such as severe stenosis, combined pathologies, or revisions were included, which offset the time gained from technical familiarity.

A comparison of UBE with other MIS techniques is essential to determine its place in the literature. Kim et al. compared UBE with OLM and found less blood loss and shorter hospital stays in the UBE group (16). However, the operative time was longer in the UBE group in the same study. Notably, long-term clinical outcomes (as measured by VAS, ODI, and MacNab criteria) were similar between the two groups. Similarly, Zhou et al. and Zheng et al. demonstrated in their meta-analyses that UBE could provide superior immediate postoperative relief of back pain and reduced levels of inflammatory markers (CRP) compared to microscopic techniques, likely due to less extensive muscle stripping (30,31).

The substantial improvement in ODI scores observed in our study is noteworthy. While the magnitude of this improvement exceeds that of some reported series, it may be attributed to the specific characteristics of our cohort. Our patients had relatively high baseline disability scores, providing a larger window for potential absolute improvement. Also, applying the inclusion criterion of 'failure of at least six months of conservative care' likely isolated the subgroup of patients most prone to benefit dramatically from surgical decompression. However, these promising results must be interpreted in the light of limitations to the study. First, the dramatic improvement in patient-reported outcomes at three months may represent an early "honeymoon period" and could be subject to regression over longer follow-up; therefore, caution is warranted regarding long-term durability of clinical improvements and risk of recurrent herniation over longer periods. The relatively short follow-up period also limits our ability to assess symptomatic restenosis, reoperation rates, adjacent segment degeneration, or late complications. Second, the retrospective design

inherently carries the risk of selection bias. Additionally, the method of outcome collection may introduce recall bias or social desirability bias, particularly if patients felt obligated to report favorable outcomes to their treating surgeons. The lack of a control group (e.g., open microdiscectomy or other MIS techniques) precludes a direct comparative effectiveness assessment. Finally, the study was conducted at a single center by a single surgeon, which may limit generalizability to centers with different levels of UBE experience.

CONCLUSION

In conclusion, this study supports the short-term efficacy and safety of UBE discectomy in the treatment of LDH and/or LSS. Regarding our primary endpoint, our findings demonstrate that UBE surgery provides statistically significant improvements in functional disability, accompanied by significant relief in back and leg pain in the postoperative period. The remarkably short hospital stay and minimal perioperative blood loss (secondary endpoints), reflected in the negligible change in hemoglobin levels, highlight the distinct advantages of its minimally invasive character.

Declarations

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Availability of data and materials: The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Disclosure: The authors have declared that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Study conception and design: AK

Data collection: AK, NB

Analysis and interpretation of results: MIO, NB

Draft manuscript preparation: AK, MIO

Critical revision of the article: MIO, IS

Other (study supervision, fundings, materials, etc.): IS

All authors (AK, MIO, NB, IS) reviewed the results and approved the final version of the manuscript.

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