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ORIGINAL RESEARCH

Targeted Decompression Under Local Anesthesia versus Extensive Decompression Under General Anesthesia for Octogenarians with Lumbar Degenerative Diseases: A Real-World Propensity Score-Matched Analysis

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Background: Surgical management of lumbar degenerative diseases (LDD) in octogenarians requires balancing effective neural decompression against diminishing physiological reserves. While general anesthesia (GA)-based endoscopic techniques (ENDO-GA) are highly effective, they often impose excessive systemic stress on frail patients. Conversely, percutaneous endoscopic lumbar discectomy under local anesthesia (PELD-LA) provides targeted decompression while mitigating these GA-associated risks. Given the scarcity of direct comparisons in this fragile population, this study evaluates the safety and efficacy of PELD-LA versus ENDO-GA.

Methods: We retrospectively analyzed 100 consecutive octogenarians treated for LDD between January 2021 and December 2024. Patients were stratified into two specific surgical strategy groups: targeted decompression via PELD-LA (n=54) and extensive decompression via ENDO-GA (utilizing UBE or Delta techniques, n=46). To minimize selection bias, a 1:1 Propensity Score Matching (PSM) was conducted using specific covariates (age, sex, comorbidities, and ASA classification), yielding 39 matched pairs (n=78). Primary outcomes assessed perioperative safety and recovery efficiency (complications, PONV, ambulation time, and length of hospital stay).Secondary outcomes evaluated postoperative clinical efficacy (VAS and ODI at 3 months, and modified MacNab criteria at 12 months postoperatively).

Results: After propensity score matching, baseline characteristics were well-balanced between the two groups. Perioperatively, the PELD-LA group exhibited significantly shorter operative times (97 vs 150 min, P<0.001), earlier ambulation (48 vs 72 h, P<0.001), and reduced length of hospital stay (9 vs 14 days, P<0.001) compared to the ENDO-GA group. Clinically, despite a smaller "targeted" decompression range, PELD-LA achieved long-term efficacy (MacNab criteria: 94.9% vs 94.9%, P=1.000) comparable to extensive decompression, while demonstrating superior early pain relief and functional improvement (VAS and ODI) at 3 months postoperatively (P<0.01). Crucially, the overall complication rate was significantly lower in the PELD-LA group (30.8% vs 82.1%, P<0.001), primarily driven by a marked reduction in postoperative nausea and vomiting (PONV) (23.1% vs 66.7%, P<0.001).

Conclusion: Within our short-to-medium-term observation period, PELD-LA delivered clinical efficacy comparable to GA-based endoscopic procedures for octogenarians, while significantly reducing perioperative complications and accelerating recovery. Crucially, we do not assert that PELD-LA is universally superior; rather, we emphasize the importance of tailored patient selection. For frail patients with limited physiological reserve, PELD-LA serves as a physiologically rational strategy, balancing targeted decompression with the preservation of systemic stability.

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Introduction

With the rapid acceleration of population aging, the prevalence of lumbar degenerative diseases (LDD) among octogenarians has risen dramatically. For this demographic, symptoms such as neurogenic intermittent claudication and radiculopathy are more than quality-of-life issues; they are primary drivers of immobility. Prolonged immobility can precipitate a rapid decline in physiological reserve, exacerbating frailty and increasing mortality risk.[1] Due to decreased organ reserve function, this vulnerable population is extremely sensitive to perioperative stressors. Historically, the significant risks associated with open decompression surgery and general anesthesia have often deterred surgical intervention.[2]

The evolution of Minimally Invasive Spine Surgery (MISS) has transformed the clinical treatment landscape. Techniques such as Percutaneous Endoscopic Lumbar Discectomy (PELD), alongside the increasingly popular Unilateral Biportal Endoscopy (UBE) and large-channel endoscopic systems (eg, Delta), allow surgeons to achieve neural decompression with reduced tissue disruption.[3,4] However, these endoscopic techniques differ fundamentally in their underlying principles. PELD approaches the intervertebral foramen obliquely from the posterolateral side via Kambin's triangle; by bypassing the paraspinal muscles and the interlaminar space, it achieves "targeted decompression" by exclusively removing the herniated nucleus pulposus. Conversely, UBE and large-channel techniques essentially function as endoscopic simulations of open surgery; they necessitate muscle stripping through the interlaminar space and partial laminectomy to establish a larger working cavity, aiming for an anatomically "extensive decompression." This divergence in surgical scope directly dictates the difference in anesthetic management: UBE and large-channel systems typically rely on high-flow saline irrigation and a greater degree of muscle manipulation, requiring General Anesthesia (GA) with muscle relaxation. In contrast, transforaminal PELD, due to its muscle-sparing nature, is uniquely suited for Local Anesthesia (LA) combined with conscious sedation.[5]

For robust, younger patients, the choice between these anesthetic modalities may be inconsequential. However, for octogenarians with diminished physiological reserve, general anesthesia poses a significant physiological challenge and markedly compounds the systemic burden, thereby elevating the overall surgical risk.[6] This raises a critical clinical dilemma: for this specific demographic, should surgeons prioritize targeted decompression, or strive for anatomically perfect decompression at the cost of greater perioperative risks? Emerging evidence suggests that hemodynamic fluctuations and pharmaceutical burdens associated with general anesthesia can lead to perioperative complications and delayed recovery in the elderly.[7] Therefore, the definition of "minimally invasive" for this specific cohort should arguably extend beyond the size of the skin incision to encompass the invasiveness of the anesthetic management.[8]

Currently, high-quality evidence-based studies guiding the selection of clinical surgical strategies for this specific population remain scarce. In this study, we retrospectively analyzed the clinical outcomes of octogenarians undergoing endoscopic decompression, aiming to compare the safety and efficacy of a local anesthesia strategy (PELD-LA) versus a general anesthesia strategy (ENDO-GA). Our objective was to evaluate whether prioritizing minimal anesthetic interference via PELD yields superior perioperative safety for super-elderly patients compared to standard general anesthesia-based endoscopic approaches.

Materials and Methods

Study Design and Participants

This retrospective cohort study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Yichang Central People's Hospital (Approval No. 2025-535-01). Written informed consent was obtained from all patients. We reviewed 100 consecutive octogenarian patients (aged $\geq$ 80 years) who underwent endoscopic lumbar decompression between January 2021 and December 2024.

The inclusion criteria were: (1) Age ≥ 80 years; (2) Symptomatic lumbar spinal stenosis or lumbar disc herniation confirmed by MRI and CT; (3) Refractory to conservative therapy for at least 6 weeks; and (4) Single- or double-level decompression. Exclusion criteria included spinal instability requiring fusion, infection, tumor, or previous surgery at the same level.

Clinical Decision-Making and Group Allocation

Given the retrospective nature of this study, treatment allocation was non-randomized. The choice of surgical technique and anesthetic modality was determined by a risk-stratified clinical protocol balancing systemic physiological reserve against local pathological complexity (Figure 1). This protocol prioritized patient safety as follows:

Physiological Priority (The "Safety-First" Pathway)

Patients with limited physiological reserve (ASA grade ≥ III) or severe cardiopulmonary comorbidities (eg, COPD, heart failure) were preferentially assigned to the PELD-LA group.[9] For these patients, avoiding the hemodynamic stress of general anesthesia was considered the primary safety objective, even if the pathology was complex.[10]

Anatomical Priority (The "Efficacy-First" Pathway)

Patients presenting with complex anatomical features requiring extensive bony resection (eg, severe central stenosis with ossified ligamentum flavum, degenerative spondylolisthesis ≥ Grade I) were assigned to the ENDO-GA group.[11,12] The general anesthesia provided necessary muscle relaxation and immobilization to ensure surgical safety during wide decompression.

Contraindications for LA

Patients unable to cooperate intraoperatively due to cognitive impairment (eg, Alzheimer's disease), severe deafness, or extreme anxiety were mandatorily assigned to the ENDO-GA group.[13]

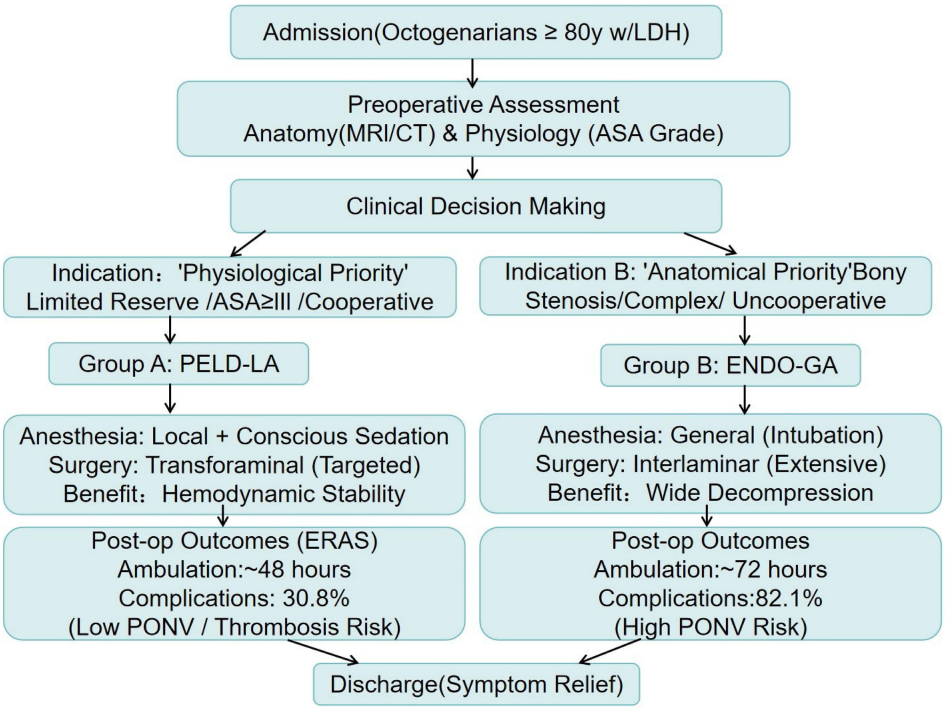

Figure 1 Flowchart of the risk-stratified clinical decision-making protocol and surgical strategy allocation. Patients were stratified into the PELD-LA group (Physiological Priority) or ENDO-GA group (Anatomical Priority) based on their physiological reserve (ASA grade) and anatomical complexity. The diagram illustrates the specific indications, anesthetic modalities, and perioperative outcomes for each pathway.

Abbreviations: ASA, American Society of Anesthesiologists; PELD-LA, Percutaneous Endoscopic Lumbar Discectomy under Local Anesthesia; ENDO-GA, Endoscopic Decompression under General Anesthesia; PONV, Postoperative Nausea and Vomiting.

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Surgical and Anesthetic Procedures

Patients were stratified into two groups based on the executed strategy:

Group A: PELD Under Local Anesthesia (PELD-LA, n=54)

Surgeries were performed via the transforaminal approach using the PELD system. Anesthesia was achieved using local infiltration (1% lidocaine + 0.25% ropivacaine) combined with targeted conscious sedation (dexmedetomidine). Patients remained awake and responsive to provide real-time feedback regarding nerve root irritation. The surgical goal was "targeted decompression"—specifically removing the herniated disc or osteophytes compressing the nerve root, rather than extensive "unroofing" of the spinal canal (Supplementary Figure S1).

Group B: Endoscopic Decompression Under General Anesthesia (ENDO-GA, n=46)

This group included patients treated with Unilateral Biportal Endoscopy (UBE) or Large-channel Interlaminar Endoscopy (Delta). Procedures were performed under general anesthesia with tracheal intubation and muscle relaxation. This modality allowed for wide laminectomy and bilateral decompression via a unilateral approach, utilizing high-pressure saline irrigation.

Outcome Measures

Safety Outcomes

The primary endpoint was the incidence of perioperative complications. To ensure clinical relevance, strictly defined criteria were applied to exclude minor, self-limiting events. Specifically regarding Postoperative Nausea and Vomiting (PONV), we did not record transient mild nausea. A PONV event was documented as a complication only if it met the following criteria: (1) severe symptoms causing significant distress; (2) confirmation through consultation with an anesthesiologist or gastroenterologist; (3) requirement for antiemetic pharmacotherapy or other medical interventions. For octogenarians, such clinically significant PONV poses substantial risks; therefore, these confirmed events were weighted as major complications in our analysis, alongside delirium and thromboembolic events.

Recovery Efficiency

Assessed by time to ambulation (hours from surgery to first standing/walking) and Length of Hospital Stay (LOS).

Clinical Efficacy

Functional outcomes were evaluated using Visual Analog Scale (VAS) scores for back pain and the Oswestry Disability Index (ODI). Long-term satisfaction was assessed using modified MacNab criteria at the final follow-up.

Statistical Analysis and Propensity Score Matching

Statistical analysis was performed using SPSS software (Version 21.0; IBM Corp., Armonk, NY, USA), and data visualization was generated using GraphPad Prism 9 (GraphPad Software, San Diego, CA, USA).

Descriptive Statistics and Univariate Analysis

Continuous variables were first assessed for normality using the Shapiro–Wilk test. Given the non-normal distribution observed in this geriatric cohort, continuous data are presented as medians with interquartile ranges (IQR) and were compared between groups using the Mann–Whitney *U*-test. Categorical variables are expressed as frequencies and percentages (n, %) and were analyzed using the Chi-square test or Fisher's exact test, as appropriate.

Propensity Score Matching (PSM)

As described in the allocation protocol, the PELD-LA group initially comprised patients with significantly higher physiological risks (higher ASA grades and comorbidities). To minimize this selection bias and ensure a comparable physiological baseline for safety evaluation, a Propensity Score Matching (PSM) analysis was performed.

A 1:1 nearest-neighbor matching algorithm was applied with a caliper width of 0.2 times the logit of the standard deviation. The propensity score was calculated based on the following covariates: age, gender, comorbidities (hypertension, diabetes mellitus, coronary heart disease), and ASA classification. This rigorous matching process was intended to

isolate the impact of the anesthetic/surgical strategy by balancing the confounding demographic and health status variables.A two-sided P-value of <0.05 was considered statistically significant for all analyses.

Results

Demographic Characteristics and Propensity Score Matching

The study initially enrolled 100 consecutive octogenarian patients. In the unmatched cohort, the PELD-LA group (n=54) exhibited a significantly higher burden of comorbidities compared to the ENDO-GA group (n=46), particularly regarding ASA classification and the prevalence of hypertension. To mitigate selection bias and ensure rigorous comparison, 1:1 Propensity Score Matching (PSM) was performed based on age, gender, and comorbidities. After matching, 39 pairs (n=78) were retained for the final analysis. As shown in Table 1, there were no statistically significant differences in baseline demographics, comorbidities, or preoperative functional scores between the two groups (P>0.05), indicating a well-balanced cohort. The assessment of covariate balance is visualized in Figure 2.

Perioperative Efficiency

The PELD-LA protocol demonstrated distinct advantages in surgical efficiency and postoperative mobilization. Statistical analysis revealed that the median operative time in the PELD-LA group (97 [70, 126] min) was significantly shorter than that in the ENDO-GA group (150 [120, 195] min, P<0.001)(Figure 3). Regarding postoperative recovery, patients in the PELD-LA group achieved significantly earlier mobilization. The median time to ambulation was 48 (24, 48) hours for the PELD-LA group, compared to 72 (48, 72) hours for the ENDO-GA group (P<0.001). Driven by the

Table 1 Baseline Characteristics of the Study Population Before and After Propensity Score Matching

	Before Matching		*Z/X²*	*P*	*SMD*	After Matching		*Z/X²*	*P*	*SMD*
	GA Group (n=46)	**LA Group (n=54)**				**GA Group (n=39)**	**LA Group (n=39)**			
Age (years)	81(80,82)	82(81,84)	−2.287	0.022	0.477	81(80,83)	81(80,83)	−1.017	0.309	0.227
Sex (%)			0.288	0.592	0.107			0.000	1.000	0.000
Male	18(39.13)	24(44.44)				16(41.03)	16(41.03)			
Female	28(60.87)	30(55.56)				23(58.97)	23(58.97)			
Hypertension (%)			4.486	0.034	0.430			0.834	0.361	0.205
No	15(32.61)	29(53.7)				15(38.46)	19(48.72)			
Yes	31(67.39)	25(46.3)				24(61.54)	20(51.28)			
Diabetes mellitus (%)			5.587	0.018	0.483			1.156	0.282	0.242
No	31(67.39)	47(87.04)				28(71.79)	32(82.05)			
Yes	15(32.61)	7(12.96)				11(28.21)	7(17.95)			
Coronary Artery disease (%)			1.513	0.219	0.246			0.626	0.429	0.178
No	38(82.61)	39(72.22)				31(79.49)	28(71.79)			
Yes	8(17.39)	15(27.78)				8(20.51)	11(28.21)			
ASA classification (%)			4.81	0.09	0.315			0.752	0.687	0.041
II	17(36.96)	17(31.48)				13(33.33)	14(35.9)			
III	26(56.52)	25(46.3)				23(58.97)	20(51.28)			
IV	3(6.52)	12(22.22)				3(7.69)	5(12.82)			
Pre-op VAS	8(8,8)	8(8,9)	−1.347	0.178	0.266	8(8,8)	8(8,9)	−0.724	0.469	0.174
Pre-op ODI	80(80,80)	80(80,85)	−1.481	0.139	0.342	80(80,85)	80(80,85)	−0.415	0.678	0.138

Notes: Values are presented as median (interquartile range) for continuous variables and number (percentage) for categorical variables. P values were calculated using the Mann–Whitney *U*-test for continuous variables and the Chi-square test for categorical variables.

Abbreviations: GA, General Anesthesia; LA, Local Anesthesia (PELD-LA); ASA, American Society of Anesthesiologists; VAS, Visual Analog Scale; ODI, Oswestry Disability Index; SMD, Standardized Mean Difference.

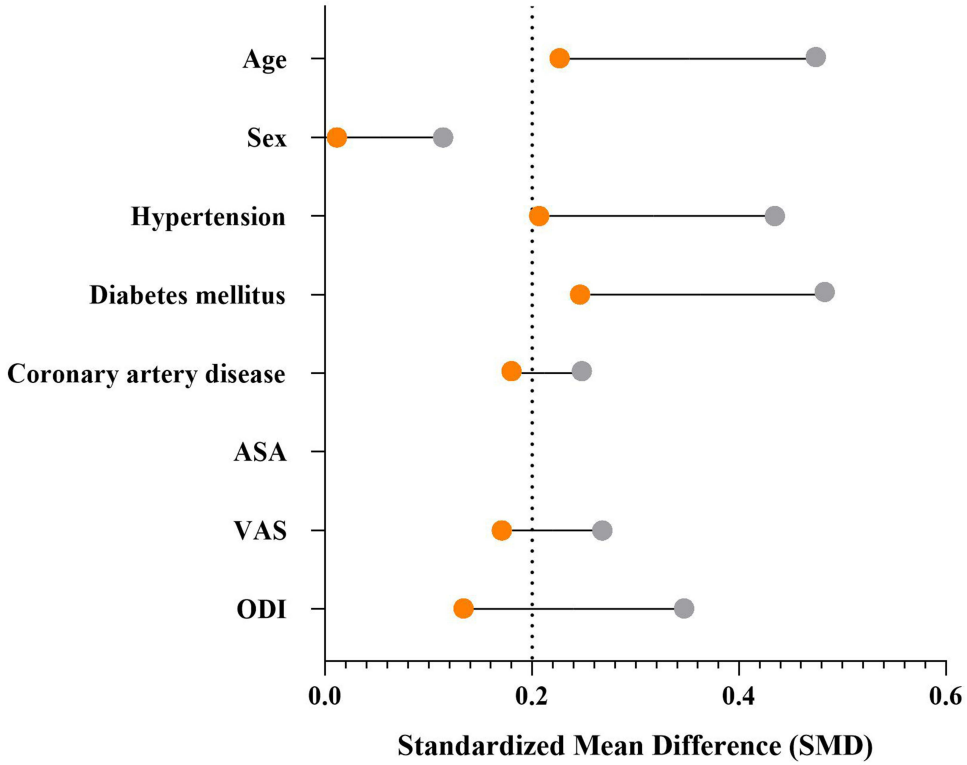

Figure 2 Assessment of covariate balance before and after Propensity Score Matching. The Love plot illustrates the absolute Standardized Mean Differences (SMD) for baseline characteristics between the PELD-LA and ENDO-GA groups. The Orange dots represent the unmatched cohort, showing larger disparities, while the grey dots represent the matched cohort. The vertical dotted lines indicate the threshold for balance (SMD < 0.2). After matching, all covariates (including Age, Sex, Comorbidities, ASA grade, VAS, and ODI) fell within the accepted range, indicating a well-balanced cohort with minimized selection bias.
Abbreviations: SMD, Standardized Mean Difference; ASA, American Society of Anesthesiologists; VAS, Visual Analog Scale; ODI, Oswestry Disability Index.

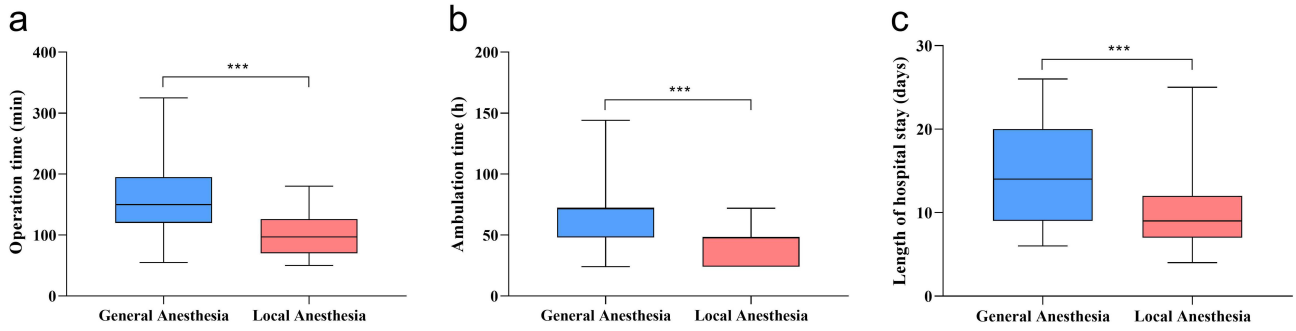

Figure 3 Comparison of perioperative efficiency outcomes between groups. The box-and-whisker plots display the distribution of (**a**) Operation time, (**b**) Ambulation time, and (**c**) Length of hospital stay (LOS). The central horizontal line represents the median, the box represents the interquartile range (IQR), and the whiskers represent the range (min-max). The PELD-LA group demonstrated significantly shorter operative times and faster recovery compared to the ENDO-GA group. In accordance with standard statistical graphing conventions, the "***" symbol denotes a statistically significant difference between the two groups (***P < 0.001, Mann–Whitney *U*-test).

efficient surgical process and early ambulation, the median length of hospital stay (LOS) was significantly reduced in the PELD-LA group (9 days vs. 14 days, P<0.001)(Table 2).

Clinical Outcomes

Both groups showed significant improvement in pain (VAS) and functional disability (ODI) compared to preoperative baselines (P<0.05). Inter-group comparison indicated that the PELD-LA group exhibited a superior early postoperative recovery trajectory. At all early time points (Post-op Day 1, Week 1, and Month 3), the VAS scores and ODI indices were significantly lower in the PELD-LA group compared to the ENDO-GA group (P<0.05)(Figure 4), and patient satisfaction

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Table 2 Comparison of Perioperative Efficiency and Safety Outcomes Between the Matched Groups

Variables	GA Group (n=39)	LA Group (n=39)	X^2/t value	*P* value	SMD/OR (95% CI)
Operative time (min)	150(120,195)	97(70,126)	−4.441	<0.001	1.146
Ambulation time (h)	72(48,72)	48(24,48)	−5.236	<0.001	1.367
Length of hospital stay (days)	14(9,20)	9(7,12)	−3.619	<0.001	0.888
Complications (n(%))	32(82.05)	12(30.77)	20.856	<0.001	0.097 (0.034–0.282)

Notes: Values are presented as median (interquartile range) or number (percentage). P < 0.05 indicates a statistically significant difference.
Abbreviations: GA, General Anesthesia; LA, Local Anesthesia; CI, Confidence Interval; OR, Odds Ratio; SMD, Standardized Mean Difference.

scores were higher (Table 3). However, long-term outcomes converged over time. At the 12-month follow-up, there was no statistically significant difference in the modified MacNab criteria (Excellent/Good rate) between the two groups (94.87% for both, P=1.000). This suggests that while the invasiveness differs, PELD-LA provides targeted decompression sufficient to resolve pathological symptoms in complex octogenarian patients.

Safety and Complications

Postoperative complications served as the core metric for evaluating perioperative safety. While surgical success rates were comparable, the ENDO-GA group had a significantly higher overall complication rate of 82.05%, compared to only 30.77% in the PELD-LA group (P<0.001)(Table 4 and Figure 5). Further analysis revealed that this disparity was primarily driven by the high incidence of Postoperative Nausea and Vomiting (PONV). The rate of PONV was 66.67% in the ENDO-GA group versus 23.08% in the PELD-LA group (P<0.001). Additionally, although not statistically significant due to sample size, the incidence of thrombotic events was numerically lower in the PELD-LA group (7.69% vs. 15.38%), aligning with the benefits of early ambulation.

Discussion

This study retrospectively compared the clinical outcomes of local anesthesia micro-endoscopic surgery (PELD-LA) versus general anesthesia endoscopic surgery (ENDO-GA) in a highly specific cohort: octogenarians (≥ 80 years) with high-risk comorbidities. The results clearly demonstrate that for this vulnerable population, PELD-LA provides perioperative safety superior to that of ENDO-GA while achieving comparable clinical efficacy.

Validity of Clinical Efficacy: Targeted Decompression is Sufficient

In this study, both patient groups showed significant improvement in VAS and ODI scores compared to baseline, confirming that spinal endoscopic surgery—whether via PELD, UBE, or the Delta system—is highly effective for

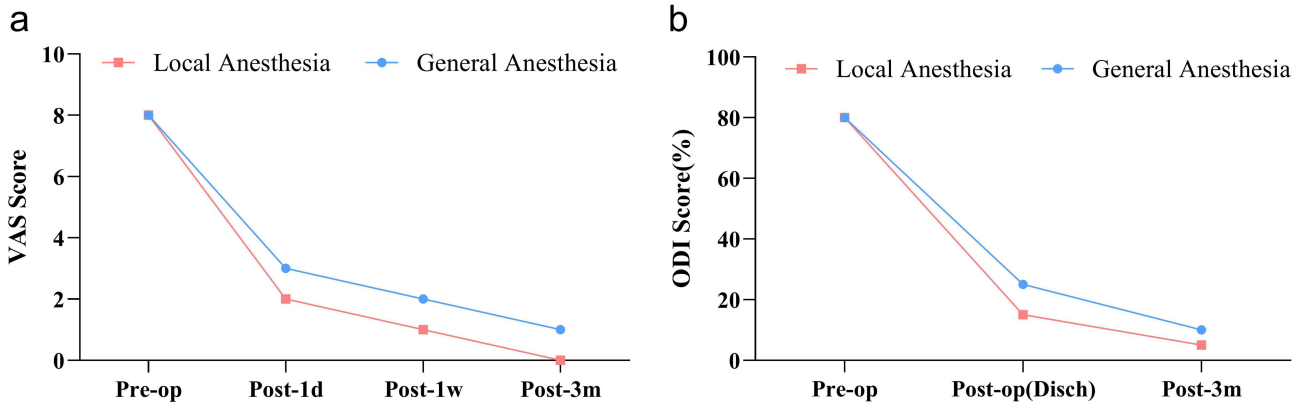

Figure 4 Postoperative trends in clinical outcomes. The line graphs illustrate the changes in (**a**) Visual Analog Scale (VAS) scores for pain and (**b**) Oswestry Disability Index (ODI) scores from preoperative baseline to 3 months postoperatively. The PELD-LA group (red line) exhibited a steeper recovery trajectory with significantly lower pain and disability scores at Post-op Day 1, Week 1, and Month 3 compared to the ENDO-GA group (blue line).
Abbreviations: VAS, Visual Analog Scale; ODI, Oswestry Disability Index.

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Table 3 Comparison of Postoperative Clinical Outcomes Between the Matched Groups

Variables	GA Group (n=39)	LA Group (n=39)	X^2/t value	*P* value	SMD/OR (95% CI)
Post-op VAS Score					
Post-op 1 day	3(2,4)	2(2,3)	−2.335	0.020	0.509
Post-op 1 week	2(1,3)	1(1,2)	−3.443	0.001	0.738
Post-op 3 months	1(0,2)	0(0,1)	−2.811	0.005	0.641
Post-op ODI Index (%)					
Early Post-op (Discharge/1 week)	25(20,35)	15(10,20)	−4.608	<0.001	1.131
Post-op 3 months	10(5,15)	5(3,7)	−3.385	0.001	0.770
MacNab Good/Excellent Rate at 12 months (Good/Exc.)	37(94.87)	37(94.87)	0.000	1.000	1.000 (0.134–7.480)
Patient Satisfaction at 12 months (0–10 points)	10(8,10)	10(10,10)	−2.717	0.007	0.610

Notes: Clinical scores (VAS, ODI, Satisfaction) are presented as median (interquartile range). The modified MacNab criteria are presented as the number of patients achieving an "Excellent" or "Good" outcome (percentage).
Abbreviations: GA, General Anesthesia; LA, Local Anesthesia; VAS, Visual Analog Scale; ODI, Oswestry Disability Index; SMD, Standardized Mean Difference; OR, Odds Ratio.

Table 4 Comparison of Perioperative Complications Between the Matched Groups

Complication Category	GA Group (n=39)	LA Group (n=39)	X^2/t value	*P* value	OR (95% CI)
Postoperative Nausea and Vomiting (PONV)	26(66.67)	9(23.08)	14.978	<0.001	0.150(0.055–0.407)
Thrombotic events	6(15.38)	3(7.69)	0.502	0.478	0.458(0.106–1.982)
CNS symptoms/Delirium (CNS/Delirium)	4(10.26)	0(0.00)	2.372	0.124	–
Cardiovascular	2(5.13)	0(0.00)	0.513	0.474	–
Infection/Fever	1(2.56)	2(5.13)	0.000	1.000	2.054 (0.179–23.632)
Neurological symptoms (Neuro/Pain)	1(2.56)	0(0.00)	–	1.000	–

Notes: Values are presented as number (percentage). P values were calculated using the Chi-square test or Fisher's exact test (for cells with expected counts < 5).
Abbreviations: GA, General Anesthesia; LA, Local Anesthesia; PONV, Postoperative Nausea and Vomiting; CNS, Central Nervous System; OR, Odds Ratio; CI, Confidence Interval.

treating degenerative lumbar disease in the elderly. However, a persistent debate in the field concerns the trade-off between the extent of decompression and the physiological cost required to achieve it.[14] Critics often argue that compared to procedures performed under general anesthesia (such as UBE or Delta), which allow for extensive "unroofing", PELD-LA is constrained by a narrower operative window and a limited range of decompression.[15] While this observation is anatomically accurate, our data suggest that such extensive decompression is often unnecessary.

Despite the limited visualization, PELD-LA achieved long-term clinical success rates identical to the more invasive ENDO-GA group (MacNab scores: 94.9% vs. 94.9%). Furthermore, regarding short-term efficacy, the PELD-LA group demonstrated lower pain scores at 1 week (VAS: 1 vs 2, P<0.001) and 3 months postoperatively (VAS: 0 vs 1, P<0.001), as well as superior functional status at 3 months (ODI: 5 vs 10, P<0.001). Therefore, for patients over 80, the primary therapeutic goal is to eliminate severe pain caused by nerve root compression; the focus should be on symptom relief rather than the pursuit of anatomically "perfect" decompression. PELD-LA provides precise decompression while effectively minimizing the disruption of spinal stability and avoiding the systemic additional physiological burden associated with general anesthesia.These findings underscore the concept that precise nerve root decompression is the key to pain relief. For many elderly patients, the targeted approach of PELD is sufficient to alleviate symptoms, thereby circumventing the need for more complex and invasive endoscopic procedures under general anesthesia.

Within the 12-month follow-up of this study, none of the 100 patients in either the LA or GA cohort required revision surgery for recurrent neural compression. However, this does not imply that endoscopic targeted decompression is a definitive, "once-and-for-all" cure. We must objectively acknowledge the inherent risks associated with a targeted approach, particularly the potential for "missing culprit segments" or the subsequent development of adjacent segment degeneration (ASD), both of which could lead to secondary surgeries. This highlights the critical need for surgeons to

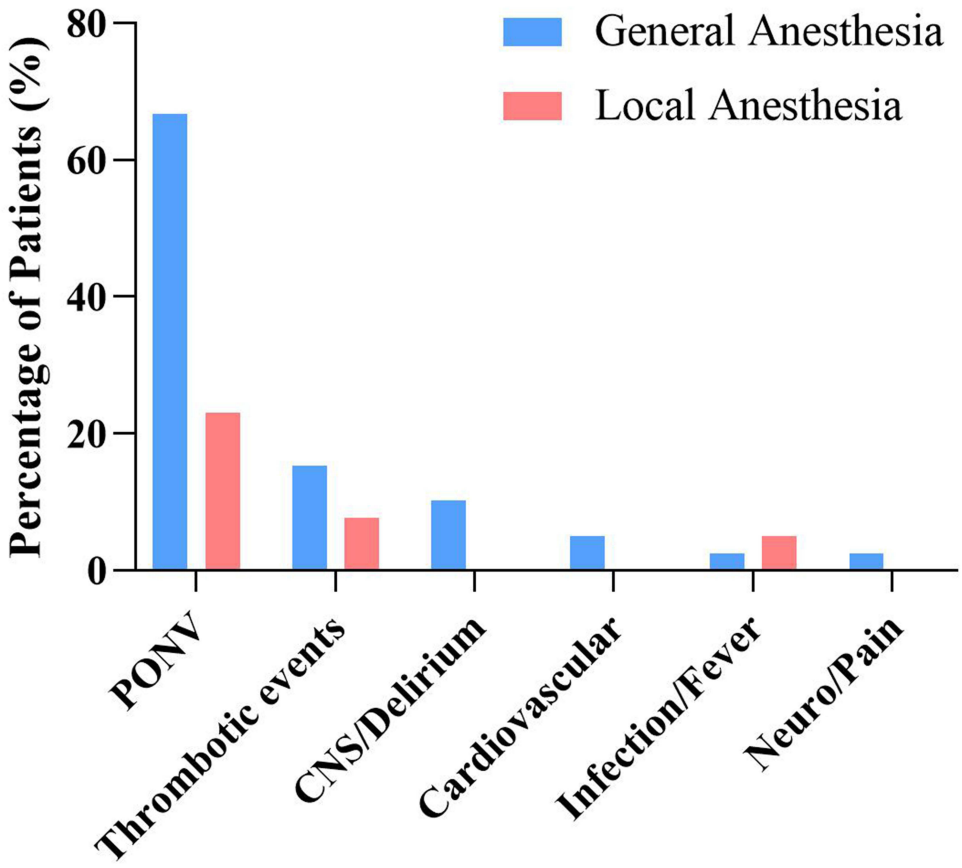

Figure 5 Comparison of specific perioperative complications between groups. The bar chart details the incidence of adverse events in the General Anesthesia (blue bars) and Local Anesthesia (red bars) groups. The ENDO-GA group exhibited a significantly higher rate of Postoperative Nausea and Vomiting (PONV) and a higher trend in thrombotic events and CNS symptoms compared to the PELD-LA group.
Abbreviations: PONV, Postoperative Nausea and Vomiting; CNS, Central Nervous System.

perform meticulous preoperative clinical and radiological correlations, and underscores the necessity for larger-scale retrospective studies to properly evaluate long-term reoperation rates.

Anesthesia Selection and Physiological Impact: Avoiding the "Secondary Physiological Insult"

In this study, the core divergence between the PELD-LA and ENDO-GA groups lies not merely in the method of anesthesia, but in the intrinsic causal relationship between the surgical approach and the anesthetic requirement. This distinction is of decisive significance for octogenarians with extremely fragile physiological reserves.

First, General Anesthesia is not a benign "harmless sleep" for the elderly; it imposes a substantial cumulative physiological stress following the surgical trauma.[16] Established literature indicates that due to poor vascular compliance and weak autonomic nerve regulation in octogenarians, drastic hemodynamic fluctuations during the induction and emergence phases of elderly spinal surgery are frequent precursors to severe postoperative cardiovascular and cerebrovascular complications.[17,18] In our study, the prolonged average operative time in the GA group (up to 150 minutes) meant that patients were exposed to anesthetic agents and mechanical ventilation for an extended period, which undoubtedly increased the risk of circulatory system instability. Conversely, PELD-LA leverages the patient's clear-headed physiological autoregulation, maintaining hemodynamic stability throughout the perioperative period.

Second, the trauma profile of the surgical technique dictates the choice of anesthesia. The reliance of UBE and Delta systems on General Anesthesia, compared to the feasibility of Local Anesthesia for PELD, is rooted in anatomical logic. UBE and large-channel techniques essentially function as endoscopic simulations of open surgery, necessitating the

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stripping of muscle through the interlaminar space to establish a large working cavity.[19] This process is often accompanied by high irrigation pressure and muscle traction; if performed under local anesthesia, patients would be prone to severe pain and agitation, thereby increasing the risk of intraoperative injury.[20] In contrast, PELD utilizes the natural "Kambin's triangle" safety zone, expanding soft tissue via puncture rather than dissection.[21] This "micro-invasive" approach minimizes nociceptive stimuli, making local anesthesia a feasible and humane option.

Finally, PELD-LA offers a unique "tolerance advantage" in this geriatric population. Compared with intraoperative neurophysiological monitoring (IONM), real-time verbal feedback serves as a more immediate and sensitive modality for preventing nerve root injury.[22,23] For octogenarians who cannot tolerate endotracheal intubation or suffer from severe cardiopulmonary diseases, PELD-LA is not just a technical alternative but a physiologically rational strategy. Our study confirms that this strategy maximizes the safety of vital signs while ensuring effective neural decompression, as evidenced by a 94.87% Excellent/Good rate in MacNab criteria.

Safety and Complications Analysis

As the primary target population of this study was super-elderly patients aged ≥ 80 years, surgery-related complications were our pivotal metrics for assessing safety.

CNS and Delirium

Postoperative Delirium (POD) and delayed emergence are among the most perilous complications in elderly patients, not only prolonging hospital stay but also correlating closely with long-term cognitive decline.[24] In this study, although the POD incidence in the ENDO-GA group (10.26%) did not show a statistically significant difference from the PELD-LA group (0%) ($P>0.05$), the clinical trend is highly consistent with existing literature. The pathophysiological mechanism likely stems from two factors. First is the direct neurotoxicity and metabolic burden of anesthetic agents. As Zhang et al pointed out in a comparative study of elderly lumbar surgery, general anesthetic agents (especially inhalational anesthetics and opioids) act directly on central nervous system receptors and require hepatic and renal metabolism.[25] These agents easily accumulate in octogenarians with declining organ function, leading to delayed emergence and mental confusion. In contrast, the PELD-LA strategy adopted in this study effectively reduces this risk through "awake anesthesia". Second is the impact of intraoperative hemodynamic stability on cerebral perfusion. A recent prospective study on delayed neurocognitive recovery (dNCR) in elderly patients indicated that intraoperative blood pressure fluctuation is an independent risk factor for postoperative cognitive dysfunction.[26] Hypotensive events during the induction and maintenance of general anesthesia may cause transient cerebral hypoperfusion, which is particularly devastating for octogenarians with impaired cerebrovascular regulation.[26] Patients in the PELD-LA group remained awake throughout the procedure, preserving their own vascular tone and maintaining stable cerebral perfusion; furthermore, real-time doctor-patient communication (Verbal Feedback) provided an additional safeguard for the central nervous system. Therefore, we believe that for patients over 80, "non-intubation and non-general anesthesia" is in itself the most effective neuroprotective strategy.

Postoperative Nausea and Vomiting (PONV)

Surgeons often view PONV as a minor, self-limiting inconvenience. In this study, however, we applied specific criteria to distinguish clinically significant events from minor complaints. We excluded transient nausea, recording a complication only if the episode was severe enough to trigger a specialist consultation (anesthesiology or gastroenterology) and required pharmaceutical intervention. We insisted on this high threshold because, for octogenarians, intractable vomiting is a physiological hazard.[27] Unlike in younger patients, the physical stress of retching can rapidly induce electrolyte imbalances (such as hypokalemia) or mechanical trauma like Mallory-Weiss syndrome (esophageal-cardiac mucosal tear).[28,29] Despite these rigorous exclusion criteria, the PONV rate in the ENDO-GA group remained high at 66.67%, compared to 23.08% in the PELD-LA group ($P<0.001$). This gap clearly implicates the anesthetic method. General anesthesia exposes the elderly patient to emetogenic agents—specifically opioids and inhalational gases—that depress gastrointestinal motility long after the surgery ends.[30,31] The clinical consequence was evident in our recovery data: severe nausea prevented early mobilization in the GA group, delaying ambulation to 72 hours and elevating the

thrombosis risk. PELD-LA effectively avoids this cascade, preserving the patient's physiological reserve by eliminating the pharmacological triggers of vomiting.

Early Ambulation and Thrombosis Prevention

For patients over 80, Venous Thromboembolism (VTE) is often fatal. In this study, the incidence of thrombotic events in the ENDO-GA group was 15.38%, far higher than the 7.69% in the PELD-LA group. This difference is primarily attributed to the promotion of "Early Ambulation" by local anesthesia. Time to ambulation is the golden metric for thrombosis prevention.[32] Previous studies on thrombosis risk in spine surgery have clearly indicated that prolonged postoperative immobilization is an independent risk factor for VTE formation[33.] In this study, thanks to the awake state and extremely low PONV incidence, PELD-LA patients were able to ambulate on average 48 hours after surgery, a full day earlier than the general anesthesia group (72 hours). This early postoperative mobilization effectively reduced the thrombotic tendency caused by poor vascular elasticity and high blood viscosity in elderly patients. The impact of anesthesia method on vascular regulation function cannot be ignored either. Large-sample comparative studies of geriatric orthopedic surgery show that local anesthesia significantly reduces the incidence of DVT compared to general anesthesia.[34] Muscle relaxation during general anesthesia leads to lower limb venous dilation and blood stasis, whereas under local anesthesia, patients retain lower limb muscle tone, maintaining basic venous return.[35] Therefore, we consider PELD-LA not just a surgical technique but an active "thrombosis prevention strategy," achieving a more positive and safer preventive effect than anticoagulant drugs by enabling patients to "move as soon as they are awake".

Cost-Effectiveness and Resource Utilization

In the context of increasingly strained global medical resources and intensifying aging, an ideal surgical plan needs to be not only "effective" but also "efficient". In this study, the PELD-LA strategy translated into significant health economic benefits through the accumulation of a series of clinical advantages. First, the "subtraction" of anesthesia and complications directly brought about a reduction in hospitalization costs. This saving is multi-dimensional: it directly saves costs on general anesthesia drugs and intubation consumables; it avoids the occupation of monitoring resources in the Post-Anesthesia Care Unit (PACU); and more critically, the complication rate in the PELD-LA group in this study was only 30.77% (far lower than the 82.05% in the GA group), thereby drastically reducing extra drug expenditures for treating PONV, fluid replacement, and anticoagulation. As Horn et al stated, postoperative complications are the main driver of out-of-control medical spending in spine surgery, and PELD-LA "cuts off" this source of expenditure through high safety.[36]

Second, rapid recovery significantly improved the turnover efficiency of medical resources. In this study, the PELD-LA group had an average hospital stay of only 9 days, 5 days shorter than the ENDO-GA group's average of 14 days. This difference is significant for large medical centers with tight bed capacity. Some scholars believe that local anesthesia endoscopic technology is the core driver promoting the transformation of spine surgery towards "Ambulatory Surgery".[37,38] Although complete day surgery is difficult for 80-year-old patients, the "quasi-day-surgery" recovery speed brought by PELD-LA (average ambulation in 48 hours) allows medical institutions to serve more patients with the same bed resources, maximizing social benefits. However, we must acknowledge that despite the accelerated recovery of PELD-LA, the average hospital stay for both groups still exceeded one week. This is primarily because this specific octogenarian population frequently presents with multiple chronic comorbidities (such as hypertension, diabetes, and coronary heart disease). When treating these highly vulnerable patients, the surgeon's responsibility extends beyond merely alleviating pain caused by neural compression; it necessitates collaboration with other specialists to co-manage these underlying chronic conditions, ultimately aiming to extend the patients' overall life expectancy.

Learning Curve

Although PELD-LA offers significant safety benefits, its clinical uptake is hindered by divergent surgical philosophies. Unlike UBE/Delta techniques, which replicate the visual field of open surgery and fit standard surgical intuition, PELD relies on endoscopic "triangulation," representing a different operative mindset. Additionally, the requirement for awake local anesthesia demands high levels of patience and communication, increasing the surgeon's psychological pressure. As

a result, surgeons often gravitate towards the familiar, stress-free environment of general anesthesia (ENDO-GA), bypassing the PELD-LA option despite its minimal physiological impact on the patient. Overcoming this "technical comfort zone" necessitates specific training programs and a strong commitment to a "patient-first" minimally invasive approach.

Limitations

This study is subject to the limitations inherent in its retrospective design.

First, the patient allocation was non-randomized, which introduced heterogeneity in pathological complexity between the two groups. Guided by our risk-stratification protocol, patients with complex bony stenosis or spondylolisthesis were preferentially assigned to the ENDO-GA group, while the PELD-LA group primarily consisted of patients with localized pathology manageable via a transforaminal approach. Consequently, our findings should be interpreted as a comparison of two distinct clinical strategies—"physiological preservation via targeted decompression" versus "anatomical reconstruction via extensive decompression"—rather than a direct technical comparison of the surgical instruments alone.

Second, while Propensity Score Matching (PSM) effectively balanced the baseline physiological characteristics (such as ASA grade and comorbidities), it could not fully account for the anatomical variations. We acknowledge that a residual selection bias remains regarding anatomical complexity; patients in the ENDO-GA group may have presented with more severe bony stenosis or spondylolisthesis compared to the PELD-LA group. These anatomical factors could inherently prolong operative time and recovery, independent of the anesthetic modality. Crucially, although the PELD-LA group had lower physiological reserves (higher ASA grades), they still achieved significantly lower complication rates. This implies that the selection bias regarding anatomy does not negate our overall conclusions; rather, given the frailty of the PELD-LA cohort, our results may actually underestimate the true protective value of the local anesthesia strategy. Furthermore, the small sample size post-matching (n=39 per group) may result in insufficient statistical power, potentially obscuring differences in low-probability, high-risk complications like thromboembolic events and delirium, which warrants future large-scale systematic studies for verification.

Finally, this was a single-center study with a relatively short follow-up period (12 months). While this duration is sufficient to evaluate our primary endpoints of perioperative safety and early recovery, longer-term follow-up is necessary to confirm whether the "targeted decompression" provided by PELD-LA maintains its efficacy over time compared to the wider decompression of GA-based techniques. Additionally, extended observation is essential to assess long-term structural and clinical indicators, such as postoperative spinal instability, symptom recurrence, or adjacent segment degeneration (ASD).

Conclusion

In conclusion, our results confirm that PELD-LA is a safe and effective option for octogenarians (≥80years). As demonstrated in this study, within our short-to-medium-term observation period (12 months), local anesthesia-based targeted decompression can significantly reduce perioperative physiological interference related to general anesthesia while ensuring clinical efficacy. While it delivers clinical efficacy comparable to general anesthesia-based endoscopic procedures, it also significantly reduces perioperative complications and accelerates recovery. Crucially, we do not assert that PELD-LA is universally superior; rather, we emphasize the importance of tailored patient selection. For frail patients with limited physiological reserve, PELD-LA serves as a physiologically rational strategy, balancing targeted decompression with the preservation of systemic stability.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This study was performed in strict accordance with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Yichang Central People's Hospital, First Clinical Medical College of China Three Gorges

University (Approval No. 2025-535-01). Written informed consent was obtained from all individual participants included in the study.

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