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ORIGINAL RESEARCH

Percutaneous Endoscopic Decompression versus Non-Operative Care for Radicular Pain in the Oldest-Old with Lumbar Stenosis: A Target Trial Emulation Focusing on Pain Relief and Deprescribing

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Objective: To emulate a target trial comparing percutaneous transforaminal endoscopic decompression (PTED) versus non-operative care for older patients with unilateral radicular pain due to lumbar spinal stenosis (LSS), focusing on comprehensive treatment failure and deprescribing.

Design: Retrospective cohort study using a Target Trial Emulation Framework.

Setting: Single academic spine center.

Participants: 143 consecutive patients aged ≥80 years with unilateral radicular symptoms and imaging-confirmed LSS (February 2022–October 2024). All underwent confirmatory diagnostic nerve root block.

Interventions: PTED under local anesthesia (n=75) versus structured non-operative care (n=68).

Main Outcome Measures: Primary outcome was 90-day comprehensive treatment failure (unplanned rehospitalization or treatment escalation due to uncontrolled pain or serious complication). Secondary outcomes were Oswestry Disability Index (ODI) and polypharmacy at 12 months.

Results: PTED group had significantly lower primary outcome incidence (16.0% vs 44.1%). After multivariable adjustment and inverse probability weighting, PTED was associated with markedly lower odds of comprehensive treatment failure (adjusted odds ratio [aOR] 0.18, 95% CI 0.07–0.47), primarily driven by pain-related failure (aOR 0.06; number needed to treat = 3.7). Complication-related failure did not differ significantly between groups, yielding a favorable benefit-risk ratio of 6.6:1. Subgroup analyses confirmed treatment effect consistency across key patient characteristics. At 12 months, PTED patients demonstrated greater ODI improvement (adjusted difference –8.92 points) and significantly lower polypharmacy prevalence (aOR 0.14), indicating sustained "deprescribing" benefit.

Conclusion: In this emulated target trial, PTED was associated with reduced 90-day treatment failure and benefits at 12 months in pain relief and polypharmacy reduction among carefully selected oldest-old patients with LSS. These findings support PTED's potential in this population and justify the need for a prospective randomized trial.

Keywords: percutaneous transforaminal endoscopic decompression, lumbar spinal stenosis, oldest-old, target trial emulation, comprehensive treatment failure, polypharmacy

Introduction

Symptomatic lumbar spinal stenosis (LSS) is a leading cause of pain and functional disability in the rapidly growing population of adults aged 80 years and older.[1] While these patients often present with substantial symptom burden and a strong desire for improved mobility, therapeutic decision-making is frequently complicated by concerns over chronological age, multimorbidity, and polypharmacy.[2] This clinical dilemma creates a tendency towards therapeutic inertia or

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undermanagement, leaving a critical need for evidence-based strategies that effectively balance efficacy with procedural risk in this vulnerable demographic.

Current treatment paradigms offer limited guidance. Structured non-operative care, including physical therapy and pharmacotherapy, is commonly initiated but is supported by low-quality evidence specifically in the oldest-old,[3] with its true failure rate and risk-benefit profile poorly quantified. Although open surgical decompression can be effective, its association with general anesthesia and significant tissue dissection raises justifiable concerns about perioperative complications in frail patients.[4] Percutaneous transforaminal endoscopic decompression (PTED) has emerged as a minimally invasive alternative, performed under local anesthesia.[5] Through a transforaminal approach, PTED allows targeted resection of hypertrophic ligamentum flavum and partial undercutting of the facet joint, thereby indirectly decompressing the central spinal canal while directly addressing lateral recess and foraminal stenosis. However, its purported advantages for the oldest-old remain inadequately evaluated. Existing studies are predominantly single-arm or use historical controls,[6–8] lacking rigorous contemporaneous comparison against a systematic non-operative regimen. Consequently, the comparative effectiveness, safety, and comprehensive value of PTED as an initial treatment option for octogenarian and nonagenarian patients with LSS are still unestablished.

To address this evidence gap, we designed a Target Trial Emulation Framework—a methodological approach that uses observational data to approximate a randomized controlled trial when one is not available. We aimed to directly compare the outcomes of PTED versus a structured non-operative protocol in consecutive patients aged 80 years or older with symptomatic LSS. Our primary focus was a patient-centered composite endpoint of 90-day comprehensive treatment failure. Furthermore, we evaluated sustained functional improvement and the novel outcome of "deprescribing"—the reduction in polypharmacy burden at one year—to capture the broader health impact of effective pain source treatment. This study seeks to determine whether PTED offers a superior benefit-risk profile and should thus be considered a first-line therapeutic option for carefully selected patients in this age group.

Methods

Study Design and Patient Population

This single-center retrospective cohort study consecutively enrolled patients aged ≥80 years with symptomatic lumbar spinal stenosis treated at our institution from February 2022 to October 2024.

Inclusion criteria were: (1) age ≥80 years; (2) radiologically confirmed lumbar spinal stenosis on magnetic resonance imaging (MRI); (3) unilateral lower limb radicular pain as the dominant complaint; (4) failure of at least 3 months of structured conservative management; and (5) completion of an ultrasound-guided diagnostic nerve root block to identify the symptomatic level.

Exclusion criteria included: (1) previous lumbar spine surgery; (2) acute spinal pathology (fracture, infection, malignancy); (3) concomitant neurological conditions that could confound symptom assessment; (4) severe hip or knee osteoarthritis based on radiographic evaluation; (5) negative response to the diagnostic nerve root block; (6) American Society of Anesthesiologists physical status classification ≥4; (7) documented cognitive impairment; and (8) incomplete 90-day follow-up data.

All patients were required to meet all eligibility criteria at a uniformly defined time zero, which was the date following a confirmatory diagnostic nerve root block that resulted in effective pain relief. Treatment strategies were identified based on the care pathway initiated from this point, and all follow-up for outcomes began at time zero.

Diagnostic and Assessment Protocols

Imaging-based Stenosis Grading: All baseline MRI evaluations were independently performed by two radiologists blinded to the clinical data and treatment allocation. The severity of central canal and lateral recess stenosis was graded according to the comprehensive MRI classification system proposed by Spinnato et al[9] while foraminal stenosis was assessed using the same system, which provides defined grades for each region and specifies the primary etiologies.

Ultrasound-guided Diagnostic Nerve Root Block: To accurately identify the pain-generating level, all patients underwent a diagnostic selective nerve root block under ultrasound guidance. The procedure followed the standardized protocol described by Wang et al[10] using a convex array transducer to identify lumbar levels from the sacrum, with the

needle advanced toward the posterior aspect of the intervertebral foramen under real-time guidance. A positive response (typically defined as >50% pain reduction) was a mandatory prerequisite for study inclusion and subsequent treatment allocation.

Treatment Strategies and Standardized Protocols

Eligible patients were allocated to one of two groups based on a shared decision-making process involving clinical evaluation and patient preference:

PTED Group: Patients underwent Percutaneous Transforaminal Endoscopic Decompression. The procedure was performed by experienced spinal surgeons following the standardized PTED technique under local anesthesia, as previously described in detail by Yang et al[11] Representative intraoperative endoscopic images are provided in Supplementary Figure 1.

Non-operative Treatment Group: Patients received structured non-operative care. This multimodal regimen was centered on supervised rehabilitation therapy (typically including a standardized protocol of supervised physical therapy, pharmacologic management with NSAIDs or neuropathic pain agents as tolerated, and the diagnostic/therapeutic nerve root block), consistent with the moderate-quality evidence for its efficacy, as synthesized by Ammendolia et al[12] For patients in this group, the diagnostic selective nerve root block also served as an initial therapeutic intervention within their comprehensive care plan. Pharmacologic management was provided as an adjunctive therapy based on clinical need.

Outcome Measures

The primary outcome measure was 90-day comprehensive treatment failure (CTF), a composite endpoint defined as meeting at least one of the following criteria:

Pain-related treatment failure (PRTF): Unplanned rehospitalization or escalation of care due to inadequate control of persistent or recurrent radicular pain in the index limb. This includes rehospitalization for intensified non-operative management, or any surgical reintervention primarily intended to address unresolved or recurrent radicular symptoms (eg., conversion from non-operative to operative treatment, or a repeat decompression procedure).

Complication-related treatment failure (CRTF): Unplanned rehospitalization or reoperation within 90 days due to a serious adverse event related to the initial treatment, including but not limited to deep vein thrombosis, pulmonary infection, surgical site infection, urinary tract infection, or gastrointestinal hemorrhage.

Rationale for the Composite Endpoint: The composite endpoint of "comprehensive treatment failure" was adopted to provide a holistic assessment of initial treatment success from both efficacy and safety perspectives, reflecting real-world clinical decision-making. This approach increases the statistical power to detect an overall difference between treatment strategies, which is particularly relevant given the multifactorial nature of treatment failure in the geriatric population, where pain, functional decline, and complications are often interlinked.[13] To ensure clinical interpretability and address the distinct etiologies of its components, we conducted and present separate analyses for pain-related failure and complication-related failure alongside the primary composite analysis.

Secondary outcomes included functional improvement (change in Oswestry Disability Index score) and polypharmacy status at the 12-month follow-up.

Target Trial Emulation Framework and Statistical Analysis

Target Trial Protocol: We explicitly specified the protocol of a hypothetical pragmatic randomized controlled trial (the target trial) that we aimed to emulate. Key components were: (1) Eligibility criteria identical to Study Design and Patient Population, assessed at a uniformly defined time zero (the date following a confirmatory diagnostic nerve root block with effective pain relief). (2) Treatment strategies of (A) PTED and (B) structured non-operative care. (3) Treatment assignment by randomization at time zero. (4) Outcomes of 90-day comprehensive treatment failure, and 12-month ODI and polypharmacy status. (5) Follow-up starting at time zero. (6) Analysis following the intention-to-treat principle.

Emulation Using Observational Data: In our emulation, treatment assignment was not randomized but determined by the strategy actually initiated after time zero, reflecting real-world clinical decision-making. To address the confounding arising from this non-randomized assignment and approximate the comparability intended by randomization, we used

inverse probability of treatment weighting (IPTW), in addition to multivariable adjustment. All other protocol elements (eligibility, time zero, outcomes, follow-up, ITT analysis) were adhered to as specified.

Baseline characteristics are presented as mean (standard deviation) or number (percentage). Between-group comparisons were performed using independent samples *t*-test, chi-square test, or Fisher's exact test. The standardized mean difference (SMD) was calculated to quantify baseline imbalance, with an absolute value <0.1 indicating good balance.

First, univariate logistic regression analyses ($P < 0.05$ significance threshold) identified candidate variables. The final multivariable logistic regression model was constructed based on clinical relevance and avoiding multicollinearity. Given conceptual overlap, only polypharmacy was selected from correlated variables (frailty index, Charlson Comorbidity Index, polypharmacy, ASA grade) representing "overall vulnerability". The final model included treatment strategy, foraminal stenosis severity, pretreatment polypharmacy, and ADL score.

Model performance was assessed using the area under the receiver operating characteristic curve (AUC) and the Hosmer-Lemeshow goodness-of-fit test. Internal validation was performed using non-parametric bootstrap resampling with 200 replicates.

Inverse probability of treatment weighting (IPTW) was used to address selection bias. Propensity scores were estimated from eight covariates (age, gender, central canal stenosis, foraminal stenosis, pretreatment polypharmacy, ADL score, Charlson Comorbidity Index, and frailty index), and balance was assessed using standardized differences (target <0.1).

Robustness was further verified via sensitivity analysis comparing models of varying complexity (minimal, main, and full models), calculation of absolute risk reduction (ARR), number needed to treat (NNT), and number needed to harm (NNH), and subgroup analysis for treatment effect consistency. Subgroup interactions were tested using likelihood ratio tests.

Long-term outcomes at 12 months were analyzed under the intention-to-treat principle. For the 12-month ODI analysis, a conservative baseline observation carried forward (BOCF) approach was applied for patients who met the comprehensive treatment failure endpoint within 90 days. The 12-month ODI score was analyzed using linear regression, adjusted for baseline ODI, age, and gender. The outcome of persistent polypharmacy at 12 months was analyzed using logistic regression, adjusted for baseline polypharmacy status, age, gender, Charlson Comorbidity Index, and frailty index.

All analyses used Stata/MP 18.0; $P < 0.05$ was considered statistically significant. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

Results

Patient Enrollment Flow and Baseline Characteristics

The patient selection process is detailed in Figure 1. Of 562 screened patients, 143 were included (75 PTED, 68 Non-operative), with a 95.3% follow-up rate. Baseline characteristics were well-balanced for most demographics, comorbidities, and functional scores (Table 1). However, the PTED group had a higher prevalence of severe lateral recess stenosis (96.0% vs. 82.4%; SMD = −0.447) and severe central stenosis (61.3% vs. 45.6%; SMD = −0.317).

Univariate Analysis and Multivariable Model Construction

Univariate logistic regression analysis (Supplementary Table 1) identified several factors significantly associated with 90-day comprehensive treatment failure ($P < 0.05$). Treatment with PTED demonstrated a strong protective effect. Notably, four conceptually related variables representing general medical condition—frailty index, Charlson Comorbidity Index, polypharmacy, and ASA grade—all showed significant associations. Correlation analysis (Supplementary Table 2) confirmed substantial to high multicollinearity among these variables (correlation coefficients range: 0.55–0.78), validating our strategy to include only "polypharmacy" as a representative variable in the final model to avoid multicollinearity.

Primary Multivariable Model and Performance

The final multivariable model included four variables: treatment strategy, foraminal stenosis severity, pretreatment polypharmacy, and ADL score. As presented in Table 2 and visualized in Figure 2, PTED treatment was a strong independent protective factor against treatment failure (aOR = 0.18, 95% CI: 0.07–0.47). Severe foraminal stenosis (aOR = 2.99) and

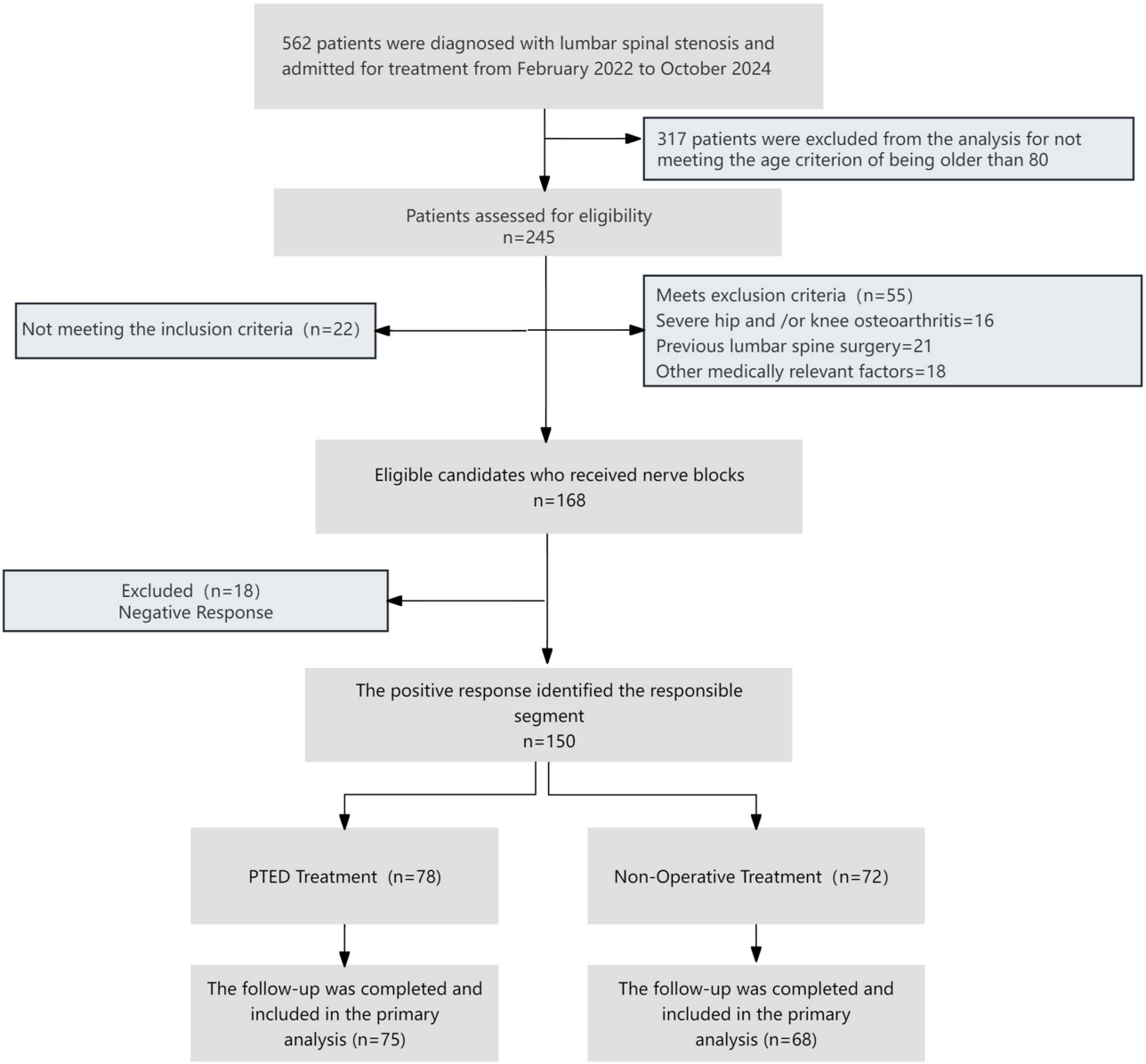

Figure 1 Patient Selection Flowchart. This diagram illustrates the process for screening, enrolling, and allocating the study participants.

pretreatment polypharmacy (aOR = 6.51) were identified as significant risk factors, while a higher baseline ADL score was protective (aOR = 0.89 per point).

This primary model demonstrated excellent predictive performance. It showed outstanding discrimination for predicting treatment failure, with an area under the receiver operating characteristic curve of 0.88 (95% CI: 0.82–0.94) (Figure 3A). The calibration plot showed high agreement between predicted probabilities and observed outcomes, indicating good model calibration (Hosmer-Lemeshow goodness-of-fit test, $P = 0.333$) (Figure 3B).

Robustness Validation and Component Analysis

We employed multiple methods to validate the robustness of our primary findings. First, as shown in Table 2, the Inverse Probability of Treatment Weighting (IPTW) analysis, which achieved excellent covariate balance (all SMDs <0.04), yielded consistent results, with PTED remaining a significant protective factor (IPTW-adjusted OR = 0.33, 95% CI: 0.11–0.98). It is noteworthy that the association between severe foraminal stenosis and treatment failure, while still

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Table 1 Baseline Characteristics of Patients by Treatment Strategy

Characteristic	Non-operative Treatment (N=68)	PTED (N=75)	P-value	Standardized Mean Difference (SMD)
Demographics				
Age, mean (SD)	82.87 (2.88)	82.91 (3.61)	0.94	−0.012
Female, No. (%)	45 (66.2%)	43 (57.3%)	0.47	−0.120
BMI, mean (SD)	23.55 (3.06)	22.91 (3.35)	0.24	0.200
Comorbidity Status				
CCI, mean (SD)	8.53 (2.25)	7.83 (2.14)	0.058	0.320
ASA III, No. (%)	40 (58.8%)	41 (54.7%)	0.62	0.083
Frail (Score >4), No. (%)	16 (23.5%)	19 (25.3%)	0.85	0.009
Pretreatment Polypharmacy, No. (%)	37 (54.4%)	37 (49.3%)	0.54	0.101
Anatomical & Pathological Features				
Index Level, No. (%)			0.15†	——
L4/5	56 (82.4%)	65 (86.7%)		
L5/S1	12 (17.6%)	7 (9.3%)		
L3/4	0 (0.0%)	3 (4.0%)		
Symptomatic Side, No. (%)			0.79	0.044
Right	36 (52.9%)	38 (50.7%)		
Left	32 (47.1%)	37 (49.3%)		
Severe Central Stenosis, No. (%)	31 (45.6%)	46 (61.3%)	0.059	−0.317
Severe Lateral Recess Stenosis, No. (%)	56 (82.4%)	72 (96.0%)	0.008	−0.447
Severe Foraminal Stenosis, No. (%)	21 (30.9%)	24 (32.0%)	0.89	−0.024
Piffman Classification, No. (%)			0.32	——
Grade 3	14 (20.6%)	23 (30.7%)		
Grade 4	31 (45.6%)	33 (44.0%)		
Grade 5	23 (33.8%)	19 (25.3%)		
Scoliosis, No. (%)	24 (35.3%)	30 (40.0%)	0.56	−0.097
Kyphosis, No. (%)	20 (29.4%)	16 (21.3%)	0.27	0.185
Pedicle Rotation, No. (%)	22 (32.4%)	22 (32.4%)	0.15	−0.240
Baseline Functional & Pain Scores				
Pretreatment Leg VAS, mean (SD)	6.38 (0.52)	6.51 (0.50)	0.15	−0.243
Pretreatment Back VAS, mean (SD)	3.43 (0.70)	3.67 (0.47)	0.017	−0.402
Pretreatment ODI, mean (SD)	66.73 (7.99)	68.31 (7.79)	0.23	−0.200
Pretreatment ADL, mean (SD)	55.96 (8.07)	55.67 (6.75)	0.82	0.039

Notes: 1.Data are presented as mean (SD) for continuous variables and No. (%) for categorical variables. 2.P-values were derived from independent samples *t*-test for continuous variables and Chi-square test for categorical variables, unless otherwise specified. (†P-value for Index Level was derived from Fisher's exact test due to an expected cell count <5). 3.The Standardized Mean Difference (SMD) quantifies the balance between groups, with an absolute value <0.1 indicating negligible imbalance. SMD is not presented for multi-category variables (Index Level, Piffman Classification) as a single summary measure is not appropriate. 4.The PTED group had a higher prevalence of severe lateral recess stenosis (SMD = −0.447) and severe central stenosis (SMD = −0.317). These imbalances were adjusted for in the subsequent multivariable logistic regression and inverse probability of treatment weighting (IPTW) analysis.

Abbreviations: PTED, Percutaneous Transforaminal Endoscopic Decompression; SD, Standard Deviation; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; ASA, American Society of Anesthesiologists; VAS, Visual Analog Scale; ODI, Oswestry Disability Index; ADL, Activities of Daily Living.

suggesting increased risk, was attenuated and lost statistical significance in the IPTW model (OR = 2.56, 95% CI: 0.88–7.50) compared to the primary multivariable model. This may reflect the adjustment for a broader set of covariates in the propensity score or potential interactions. Second, sensitivity analysis demonstrated the stability of the PTED effect across models of varying complexity (Supplementary Tables 3 and 4). Finally, bootstrap internal validation confirmed the excellent stability of the final model, with minimal estimation bias for all key predictors (Supplementary Table 5).

We further deconstructed the primary outcome through component analysis (Table 3). The protective effect of PTED was primarily driven by a profound reduction in pain-related treatment failure (3 [4.0%] vs. 23 [33.8%]; aOR = 0.06), while it showed no significant effect on complication-related treatment failure (10 [13.3%] vs. 6 [8.8%]; aOR = 2.44).

Table 2 Comparison of Treatment Effect Estimates: Multivariable Regression vs. Inverse Probability Treatment Weighting

Variable	Category	Multivariable Analysis	IPTW Analysis	Balance Diagnostics
		OR (95% CI)	OR (95% CI)	Standardized Difference
Treatment				
PTED	Operative vs Non-operative	**0.18 (0.07–0.47)**	**0.33 (0.11–0.98)**	—
Clinical Predictors				
Foraminal stenosis	Severe vs Non-severe	2.99 (1.12–8.01)	2.56 (0.88–7.5)	0.011
Pre-treatment polypharmacy	Yes vs No	**6.51 (2.25–18.88)**	**6.39 (2.06–19.82)**	0.004
ADL score	Per 1-point increase	**0.89 (0.82–0.96)**	**0.91 (0.83–0.99)**	0.037
Covariates For Balancing				
Age	Per 1-year increase	—	—	−0.022
Gender	Male vs Female	—	—	−0.037
Central canal stenosis	Severe vs Non-severe	—	—	−0.006
CCI index	Per 1-point increase	—	—	0.015
Frailty index	Per 1-level increase	—	—	0.013

Notes: Boldface indicates statistical significance ($P < 0.05$). The multivariable model was prioritized for primary inference due to its clinical interpretability and optimal model fit statistics (see Supplementary Table 4). The IPTW analysis is presented as a complementary approach to address potential selection bias. The multivariable regression model included 4 clinically selected predictors (treatment, foraminal stenosis, pretreatment polypharmacy, and ADL score) based on a variable selection process. The IPTW analysis used propensity scores estimated from 8 covariates to balance the treatment groups: age, gender, central canal stenosis, CCI index, frailty index, as well as the three clinical predictors (foraminal stenosis, pretreatment polypharmacy, and ADL score). Balance was achieved for all covariates (all standardized differences < 0.04).
Abbreviations: IPTW, Inverse Probability Treatment Weighting; OR, odds ratio; CI, confidence interval; ADL, Activities of Daily Living; CCI, Charlson Comorbidity Index.

Benefit-Risk Profile and Subgroup Analysis

The benefit-risk assessment (Figure 4) quantified these component effects. PTED demonstrated an absolute risk reduction of 29.8% for pain-related failure, corresponding to a number needed to treat (NNT) of 3.7. For safety outcomes, PTED

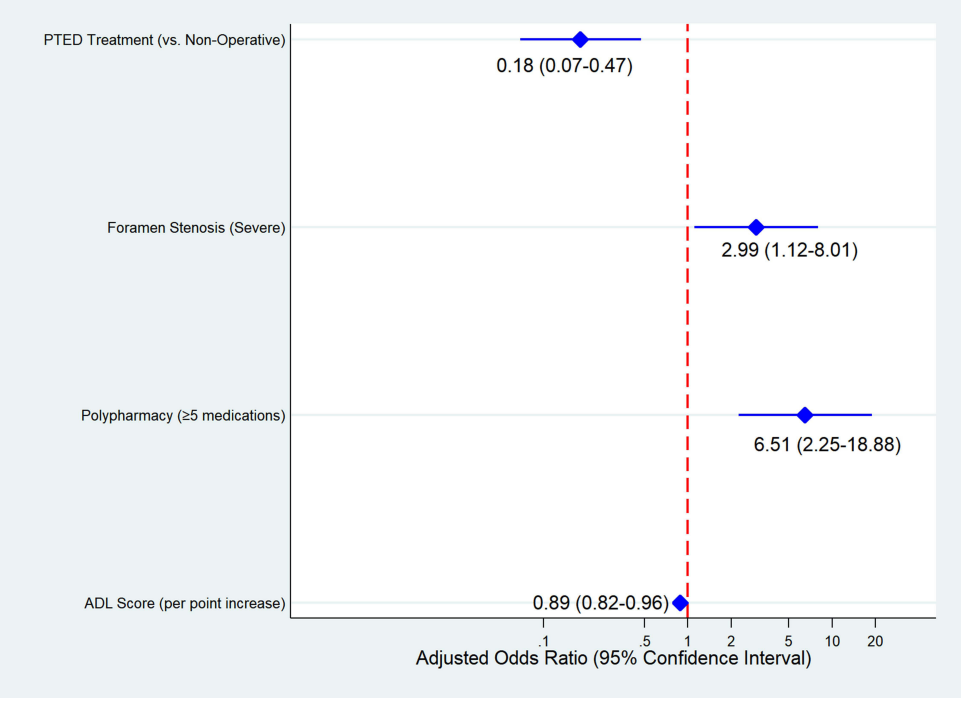

Figure 2 Multivariable Analysis of Factors Associated with 90-Day Comprehensive Treatment Failure. Forest plot displaying adjusted odds ratios (ORs) and 95% confidence intervals for all variables included in the multivariable logistic regression model.
Abbreviations: PTED, percutaneous transforaminal endoscopic decompression; ADL, activities of daily living.

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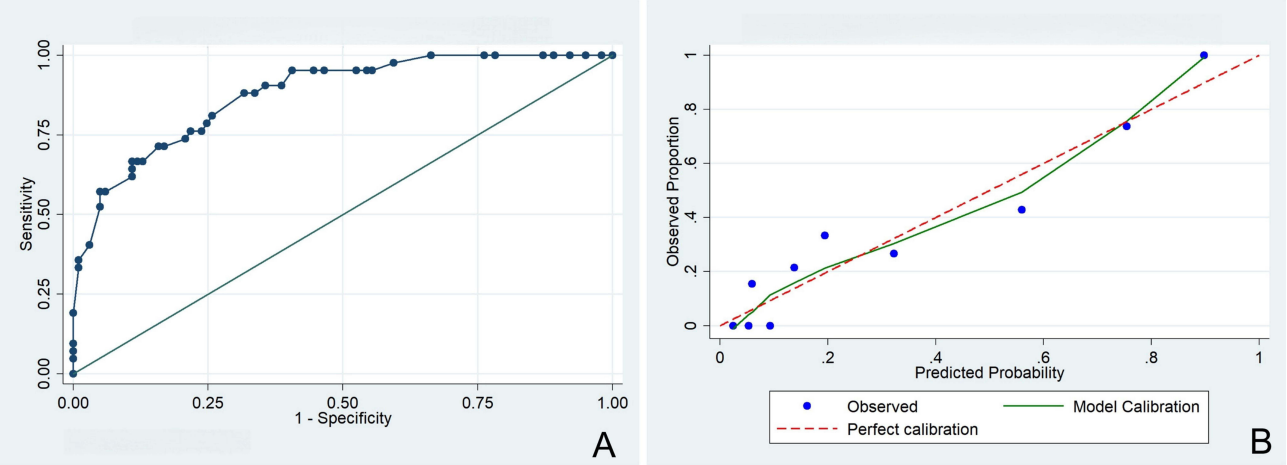

Figure 3 Performance of the Primary Multivariable Logistic Regression Model for Predicting 90-Day Comprehensive Treatment Failure. (**A**) Receiver operating characteristic (ROC) curve. The solid green line represents the reference line (no discrimination). The blue connected dots form the ROC curve for the primary multivariable model (including treatment, foraminal stenosis, polypharmacy, and ADL score), with each dot representing sensitivity and 1-specificity at various risk thresholds. The model demonstrated excellent discriminative ability, with an area under the curve (AUC) of 0.88 (95% CI: 0.82–0.94). (**B**) Calibration plot. The plot shows the agreement between predicted probabilities and observed frequencies of treatment failure. Blue dots represent observed event rates by decile of predicted risk; the solid green line is the locally smoothed (Lowess) calibration curve; the diagonal dashed red line indicates perfect calibration. Calibration was assessed with the Hosmer-Lemeshow goodness-of-fit test (p = 0.333).

was associated with an absolute risk increase of 4.5% for complication-related failure, yielding a number needed to harm (NNH) of 26. This translates to a favorable benefit-risk ratio of 6.6:1.

Subgroup analyses demonstrated a consistent protective effect of PTED across all predefined patient characteristics (Figure 5). Formal tests for interaction revealed no statistically significant effect modification by frailty status (P for interaction = 0.346), central canal stenosis severity (P = 0.648), baseline leg pain intensity (P = 0.797), or age group (P = 0.945). Notably, the point estimates favored PTED treatment in every subgroup analyzed, with odds ratios ranging from 0.14 to 0.26.

Long-Term Outcomes at 12 Months

Long-term outcomes at the 12-month follow-up are summarized in Table 4. The intention-to-treat analysis showed that the improvement in ODI score was significantly greater in the PTED group than in the non-operative treatment group (adjusted between-group difference: −8.92 points). Furthermore, the proportion of patients with polypharmacy at 12 months was significantly lower in the PTED group (16.0% vs. 47.1%), with an adjusted odds ratio of 0.14, indicating a substantially reduced risk.

Table 3 Treatment Effects on Comprehensive and Component Outcomes

Outcome	Events, n (%)		Unadjusted OR (95% CI)	Multivariable Adjusted OR (95% CI)
	Non-operative	PTED		
Comprehensive Treatment Failure	30 (44.1)	12 (16.0)	0.24 (0.11–0.52)	0.18 (0.07–0.47)*
Component Analysis				
Pain-Related Failure	23 (33.8)	3 (4.0)	0.08 (0.02–0.27)	0.06 (0.02–0.25)†
Complication-Related Failure	6 (8.8)	10 (13.3)	1.59 (0.56–4.47)	2.44 (0.69–8.68)‡

Notes: Component analyses are presented to clarify the drivers of the composite outcome. Different adjustment sets were used for each component model to reflect their distinct presumed etiology. *Adjusted for foraminal stenosis, polypharmacy, and ADL score. †Adjusted for foraminal stenosis, polypharmacy, ADL score, age, and gender. ‡Adjusted for age, gender, polypharmacy, Charlson Comorbidity Index (CCI), and frailty index.

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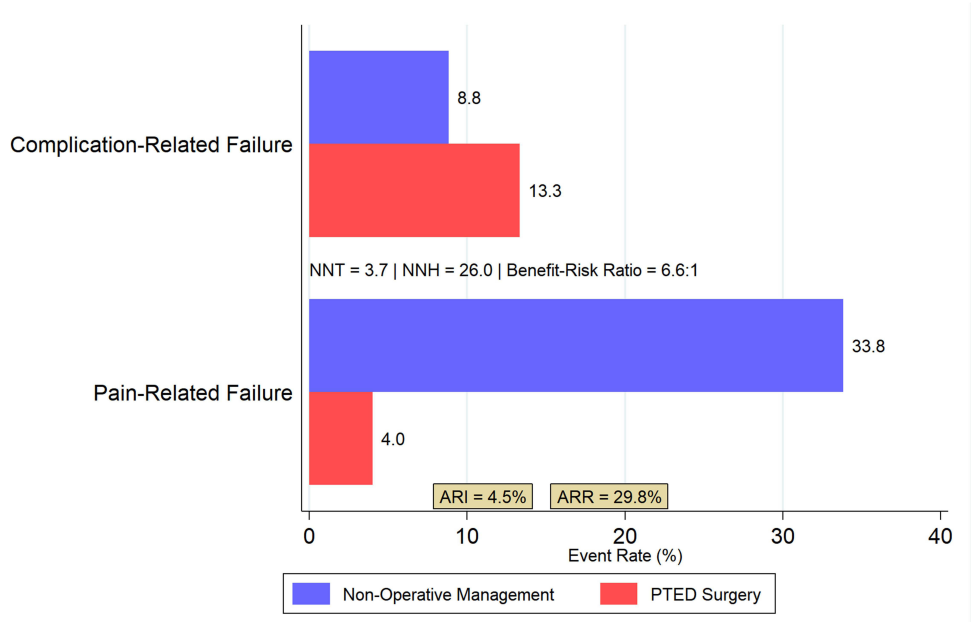

Figure 4 Benefit-Risk Profile of PTED Versus Non-Operative Treatment. Butterfly plot comparing event rates for key outcomes between treatment groups. PTED demonstrated substantial benefit in reducing pain-related treatment failure (absolute risk reduction 29.8%) with a comparatively smaller increase in complication-related failure (absolute risk increase 4.5%). The number needed to treat (NNT) of 3.7 and number needed to harm (NNH) of 26.0 yield a favorable benefit-risk ratio of 6.6:1. non-operative treatment included pharmacologic management and nerve blocks.
Abbreviations: ARR, absolute risk reduction; ARI, absolute risk increase.

Discussion

Determining the optimal treatment strategy for the oldest-old patients with lumbar spinal stenosis (LSS) necessitates a delicate balance between therapeutic efficacy and procedural risk. Traditionally, clinical decision-making has often leaned towards conservatism due to a lack of high-quality comparative evidence.[12] This study utilized a composite endpoint of "comprehensive treatment failure", a design informed by the clinical reality in which pain, frailty, functional decline, and polypharmacy are intricately linked in the geriatric population.[2,14] This approach aims to more comprehensively capture the overall effectiveness of an intervention in a real-world setting. By employing a Target Trial Emulation Framework,[15] we provide novel and methodologically rigorous comparative evidence, with rigorous adjustment for confounders, in this critical area. In this study, treatment with percutaneous transforaminal endoscopic decompression (PTED) was associated with a significantly lower odds of 90-day comprehensive treatment failure compared to a structured non-operative protocol, after adjusting for key confounders. This association was primarily driven by a reduction in pain-related failures and was sustained at 12 months, alongside observed reductions in polypharmacy and greater functional improvement. These findings suggest that PTED may offer a valuable outcome profile for selected patients, supporting a more nuanced consideration of minimally invasive options beyond generalized concerns about age and frailty.

This study primarily addresses a persistent evidence gap. Previous reports on PTED have largely been single-arm studies using pre-post designs.[7,16] While consistently reporting favorable outcomes, the absence of control groups and insufficient adjustment for confounding factors have limited the ability to accurately assess its incremental value compared to standard non-operative care. Our head-to-head analysis positions PTED against a structured non-operative protocol within the same evaluative framework. The results reveal a 44.1% rate of comprehensive failure within 90 days for non-operative management, objectively highlighting the limitations of current conservative strategies in this severely affected cohort. In contrast, PTED was independently associated with an 82% reduction in the risk of comprehensive treatment failure (aOR 0.18). Its exceptional efficacy is reflected in a Number Needed to Treat (NNT) of only 3.7. This striking figure provides a clear, intuitive quantitative tool for shared decision-making, helping to advance the expectation of therapeutic benefit from vague experiential descriptions towards concrete probabilistic assessment.

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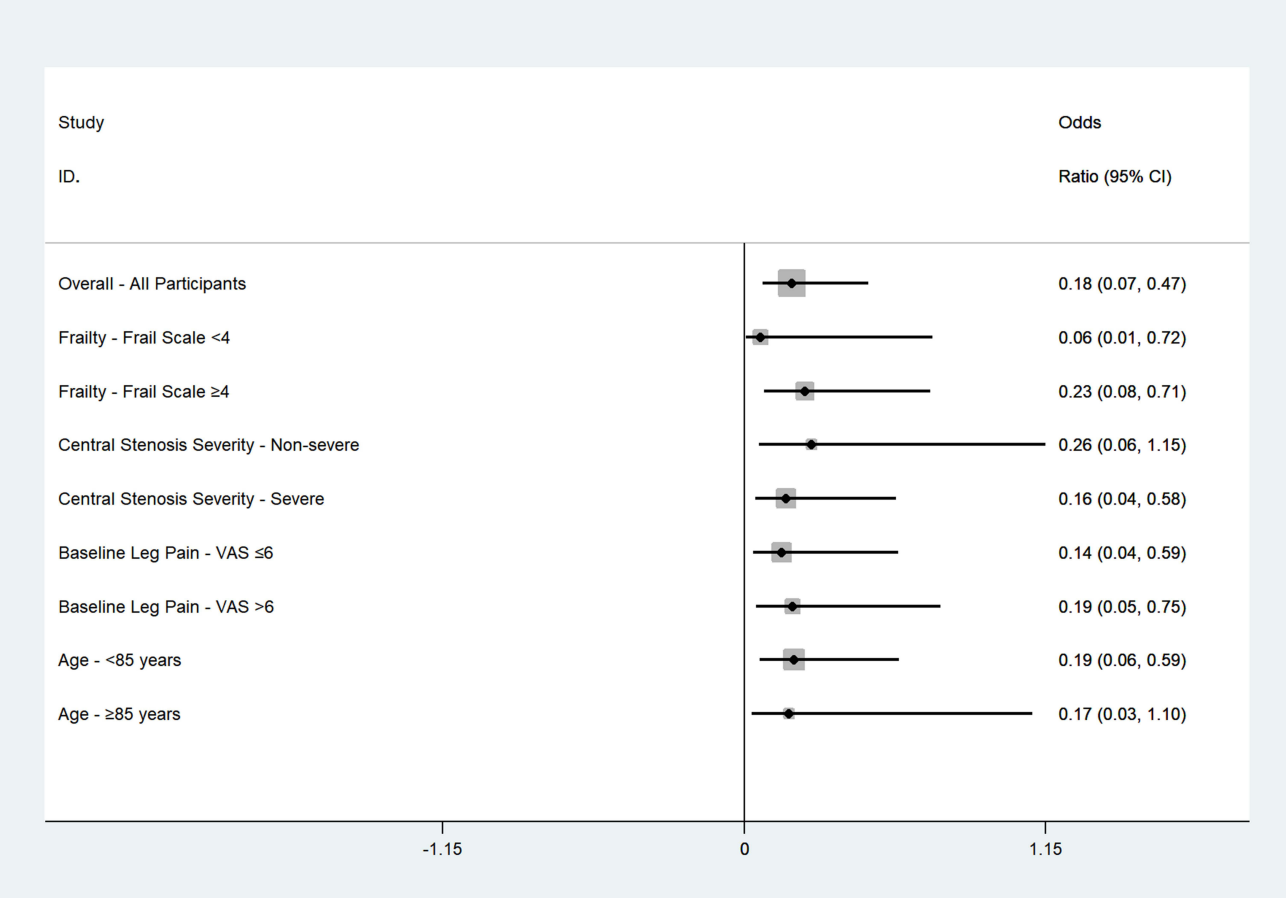

Figure 5 Subgroup Analysis of the Treatment Effect of PTED. The protective effect of PTED was consistent across all predefined patient subgroups. No statistically significant interactions were observed (all P for interaction > 0.05), indicating that the treatment benefit did not differ significantly based on these patient characteristics.

The mechanism underlying PTED's marked efficacy is rooted in its precise targeting of the disease's core element: mechanical compression of the nerve root.[17] All patients in the PTED group underwent strict screening via diagnostic selective nerve root block, ensuring surgical intervention was precisely directed at the symptomatic level. This validates and reinforces the principle that "accurate diagnosis is the prerequisite for accurate treatment" as central to geriatric spine surgery.[18] Consequently, PTED's technical efficacy can be attributed to its fundamental mechanism: direct endoscopic visualization and decompression of the compromised neural structures. The pronounced reduction in pain-related failure indicates that the benefit of PTED stems primarily from adequate decompression of the neuroforamen and lateral recess

Table 4 Long-Term Outcomes at 12-Month Follow-Up: Intention-to-Treat Analysis

Outcome	Non-operative (n=68)	PTED (n=75)	Unadjusted Analysis	Adjusted Analysis	P-value
ODI Score					
Baseline	66.73 ± 7.99	68.31 ± 7.79	—	—	—
12-Month	37.16 ± 9.00	28.78 ± 8.17	—	—	—
Change from baseline	29.57 ± 9.87	39.52 ± 9.73	9.95 (6.71, 13.20)	−8.92 (−11.68, −6.16)*	<0.001
Polypharmacy Status	**n (%)**	**n (%)**	**OR (95% CI)**	**OR (95% CI)**	
12-Month polypharmacy	32 (47.1%)	12 (16.0%)	0.21 (0.10, 0.47)	0.14 (0.06, 0.37)†	<0.001

Notes: Analysis was performed on the intention-to-treat population. In the Adjusted Analysis column, data represent the coefficient from linear regression* or the odds ratio (OR) from logistic regression†. Specifically: * Coefficient from linear regression of 12-month ODI, adjusted for baseline ODI, age, and gender. † Odds ratio from logistic regression of 12-month polypharmacy, adjusted for baseline polypharmacy status, age, and gender.

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(key pain-generating zones),[19] rather than from a primary pursuit of complete radiological normalization of the central canal.[20] This perspective is supported by evidence indicating that the severity of central canal stenosis alone is a poor predictor of surgical outcome. Our adopted strategy of unilateral, symptom-targeted decompression aligns with high-level evidence; for instance, the recent NORDSTEN-SST trial clearly demonstrated that additional decompression of radiographically stenotic but asymptomatic adjacent levels conferred no additional clinical benefit over surgery directed solely at the symptomatic level.[21] In contrast, while non-operative management employs a multimodal approach, its capacity to modify the fundamental etiology of such clear-cut anatomical compression is limited, which partly explains the differential effectiveness.

A nuanced interpretation of the final multivariable model provides a practical framework for risk stratification. Severe foraminal stenosis was identified as a significant risk factor (aOR 2.99), which is anatomically logical as the neuroforamen is the critical exit zone for the nerve root. Severe stenosis here poses a direct and recalcitrant mechanical challenge to the root,[22] constituting a hurdle for both non-operative management (relying on medication and rehabilitation) and PTED, which aims for sufficient decompression. Conversely, a higher baseline Activities of Daily Living (ADL) score (indicating greater physiological reserve) served as a protective factor (aOR 0.89 per point increase), underscoring the importance of pre-treatment functional status.[23] We speculate that a lower ADL score may signify diminished physiological reserve and tolerance, which could increase the technical challenge of achieving adequate decompression during awake surgery, potentially impacting early pain control. This mechanistic hypothesis warrants further investigation with detailed intraoperative metrics.

Regarding safety, our findings refine the notion[24] that "advanced age" is synonymous with "high surgical risk". PTED's core advantage lies in its ability to achieve precise decompression of the culprit lesion while avoiding the greater physiological insult associated with general anesthesia and open fusion procedures. This strategy initiates a beneficial causal chain. First, effective pain control reduces analgesic use. The resulting decrease in medication burden directly lowers the risk of adverse drug events,[25] such as gastrointestinal bleeding or falls. Furthermore, the minimally invasive nature of PTED itself, along with facilitated early mobilization, reduces the incidence of immobility-related complications like deep vein thrombosis and pulmonary infection. This study must emphasize that ineffective pain control, regardless of the treatment path chosen, can exacerbate polypharmacy. "Pretreatment polypharmacy" was confirmed as the strongest independent risk factor (aOR 6.51), warning that failure to adequately control pain often leads to intensification of polypharmacy, creating a vicious cycle[14,25,26] of "pain-medication escalation-adverse events-functional decline". Therefore, proactive management of polypharmacy should be a central component of caring for these patients. In this study, PTED was not associated with a significant increase in complication-related failure, resulting in a favorable benefit-risk ratio of 6.6:1, which epitomizes the clinical manifestation of the aforementioned mechanistic chain.

Subgroup analysis demonstrated that the benefit of PTED was consistent across patients with varying degrees of frailty, age strata, central canal stenosis severity and comorbidity burden. This finding carries significant clinical implications, suggesting that static labels such as chronological age or frailty scores should not serve as automatic contraindications to effective minimally invasive treatment.[23] Clinical decision-making should focus more on a dynamic "risk-benefit" analysis, for which "severe foraminal stenosis" and "baseline polypharmacy" constitute two powerful, actionable predictive coordinates.

These short- to mid-term follow-up further corroborated the durability of this beneficial mechanistic chain. At the 12-month follow-up, the prevalence of polypharmacy was significantly lower in the PTED group (aOR 0.14). This "deprescribing" effect is crucial, as it extends the impact of treatment from the nervous system alone to the patient's overall health ecosystem.[25] For the oldest-old patients with multimorbidity entrenched in the "polypharmacy dilemma", the breadth and depth of health gains from this chain reaction may rival those achieved by addressing the local spinal pathology itself.[27] Thus, PTED transcends its role as a specialized technical procedure, evolving into a levered intervention strategy capable of optimizing a patient's overall medication management and health, fully aligning with the "patient-centered" value-based care paradigm.

Strengths and Limitations

The strengths of this study include the use of a Target Trial Emulation Framework to enhance causal thinking, a consecutively enrolled cohort with high follow-up, comprehensive adjustment and multiple sensitivity analyses, and the assessment of a novel patient-centered outcome (deprescribing).

However, several important limitations must be acknowledged. First, despite our analytical efforts, the observational design means that residual confounding by unmeasured factors (eg., patient preferences, specific physical therapy regimens, or social support) cannot be ruled out. Second, the composite primary outcome, while designed to capture overall treatment burden, combines etiologically distinct components (pain and complications); we addressed this by presenting component analyses. Third, the single-center setting and modest sample size may affect generalizability and the precision of subgroup estimates. Fourth, imaging follow-up was not systematically collected; therefore, we could not assess long-term morphological correlates. We acknowledge this as an important direction for future research. Most importantly, the non-randomized treatment allocation limits the strength of causal inference; our findings should therefore be interpreted as generating strong hypotheses rather than providing definitive evidence of superiority.

Concurrently, in-depth health economic evaluations are needed to quantify the full-cycle value of PTED, derived from reducing rehospitalizations and lowering long-term medication and care dependency, which will provide vital information for healthcare resource allocation.[28]

Conclusion

In conclusion, this study provides consistent associative evidence linking PTED to lower odds of short-term treatment failure and reduced polypharmacy at 12 months compared to non-operative care in carefully selected oldest-old patients with LSS. The reproducibility of this association across multiple analytical approaches enhances the reliability of the findings. These results support the therapeutic potential of PTED in this population and provide a strong rationale for further investigation. They underscore the imperative for a prospective, randomized controlled trial to conclusively determine the comparative effectiveness and safety of this treatment approach.

Research Ethics

This study was approved by the Ethics Committee of Suining Central Hospital (Approval No.: KYLLKS20250202), and all procedures complied with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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References

1. Dorsi MJ, Buchanan P, Vu C, et al. Pacific Spine and Pain Society (PSPS) evidence review of surgical treatments for lumbar degenerative spinal disease: a narrative review. *Pain Ther*. 2024;13(3):349–390. doi:10.1007/s40122-024-00588-4
2. Zhang Y, Wu Q, Han M, et al. Frailty is a risk factor for postoperative complications in older adults with lumbar degenerative disease: a prospective cohort study. *Clin Interv Aging*. 2024;19:1117–1126. doi:10.2147/CIA.S462731
3. Kwon JW, Suk KS, Moon SH, et al. Lumbar spinal stenosis: current concept of management. *Asian Spine J*. 2025;19:687–688. doi:10.31616/asj.2025.0394.r2

4. Wang SK, Wang QJ, Wang P, et al. The impact of frailty on clinical outcomes of older patients undergoing enhanced recovery after lumbar fusion surgery: a prospective cohort study. *Int J Surg*. 2024;110(8):4785–4795. doi:10.1097/JS9.0000000000001594
5. Telfeian AE, Sastry R, Oyelese A, et al. Awake, transforaminal endoscopic lumbar spine surgery in octogenarians: case series. *Pain Physician*. 2022;25(2):E255–E262.
6. Ahn Y, Keum HJ, Son S. Percutaneous endoscopic lumbar foraminotomy for foraminal stenosis with postlaminectomy syndrome in geriatric patients. *World Neurosurg*. 2019;130:e1070–e1076. doi:10.1016/j.wneu.2019.07.087
7. Chen X, Qin R, Hao J, et al. Percutaneous endoscopic decompression via transforaminal approach for lumbar lateral recess stenosis in geriatric patients. *Int Orthop*. 2019;43(5):1263–1269. doi:10.1007/s00264-018-4051-3
8. Xie P, Feng F, Chen Z, et al. Percutaneous transforaminal full endoscopic decompression for the treatment of lumbar spinal stenosis. *BMC Musculoskelet Disord*. 2020;21(1):546. doi:10.1186/s12891-020-03566-x
9. Spinnato P, Petrera MR, Parmeggiani A, et al. A new comprehensive MRI classification and grading system for lumbosacral central and lateral stenosis: clinical application and comparison with previous systems. *Radiol Med*. 2024;129(1):93–106. doi:10.1007/s11547-023-01741-3
10. Wang B, Sun Y, Zhang J, Meng H, Zhang H, Shan L. Ultrasound-guided versus fluoroscopy-guided lumbar selective nerve root block: a retrospective comparative study. *Sci Rep*. 2024;14(1):3235. doi:10.1038/s41598-024-53809-3
11. Yang J, Wu H, Kong Q, et al. Full endoscopic transforaminal decompression surgery for symptomatic lumbar spinal stenosis in geriatric patients. *World Neurosurg*. 2019;127:e449–e459. doi:10.1016/j.wneu.2019.03.171
12. Ammendolia C, Hofkirchner C, Plener J, et al. Non-operative treatment for lumbar spinal stenosis with neurogenic claudication: an updated systematic review. *BMJ Open*. 2022;12(1):e057724. doi:10.1136/bmjopen-2021-057724
13. Wang S, Wang P, Han D, Chen X, Lu S. The combined effect of nutritional status and body mass index on 90-day adverse events following long-segments fusion for adult spinal deformity: a propensity score-matched analysis. *Eur Spine J*. 2025;34(7):2865–2874. doi:10.1007/s00586-025-08865-2
14. Kawabata S, Michikawa T, Nagai S, et al. Possible negative impact of polypharmacy on surgical outcomes in older patients with lumbar spinal stenosis. *Geriatr Gerontol Int*. 2025;25(1):31–37. doi:10.1111/ggi.15026
15. Hernan MA, Wang W, Leaf DE. Target trial emulation: a framework for causal inference from observational data. *JAMA*. 2022;328(24):2446–2447. doi:10.1001/jama.2022.21383
16. Ahn Y, Jung JH. Transforaminal endoscopic lumbar lateral recess decompression for octogenarian patients. *J Clin Med*. 2024;13(2):515. doi:10.3390/jcm13020515
17. Crock HV. Normal and pathological anatomy of the lumbar spinal nerve root canals. *J Bone Joint Surg Br*. 1981;63B(4):487–490. doi:10.1302/0301-620X.63B4.7298672
18. Ko S, Jun C, Min WK, et al. Pain relief after selective nerve root block as a predictor of postoperative functional outcome in patients with degenerative lumbar spinal stenosis patients undergoing decompressive surgery. *Spine*. 2022;47(9):666–671. doi:10.1097/BRS.0000000000004216
19. Genevay S, Atlas SJ. Lumbar spinal stenosis. *Best Pract Res Clin Rheumatol*. 2010;24(2):253–265. doi:10.1016/j.berh.2009.11.001
20. Hermansen E, Myklebust TA, Weber C, et al. Postoperative dural sac cross-sectional area as an association for outcome after surgery for lumbar spinal stenosis: clinical and radiological results from the NORDSTEN-spinal stenosis trial. *Spine*. 2023;48(10):688–694. doi:10.1097/BRS.0000000000004565
21. Hermansen E, Franssen E, Myklebust TA, et al. No long term benefit of decompression of a borderline lumbar spinal stenosis level adjacent to a more stenotic index level. *Eur Spine J*. 2025;34:5715–5724. doi:10.1007/s00586-025-09113-3
22. Aaen J, Banitalebi H, Austevoll IM, et al. Is the presence of foraminal stenosis associated with outcome in lumbar spinal stenosis patients treated with posterior microsurgical decompression. *Acta Neurochir*. 2023;165(8):2121–2129.
23. Saleh A, Thirukumaran C, Mesfin A, Molinari RW. Complications and readmission after lumbar spine surgery in elderly patients: an analysis of 2,320 patients. *Spine J*. 2017;17(8):1106–1112. doi:10.1016/j.spinee.2017.03.019
24. Baek W, Park SY, Kim Y. Impact of frailty on the outcomes of patients undergoing degenerative spine surgery: a systematic review and meta-analysis. *BMC Geriatr*. 2023;23(1):771.
25. Nagai S, Inagaki R, Michikawa T, et al. Efficacy of surgical treatment on polypharmacy of elderly patients with lumbar spinal canal stenosis: retrospective exploratory research. *BMC Geriatr*. 2023;23(1):169.
26. Saraiva MD, Suzuki GS, Lin SM, de Andrade DC, Jacob-Filho W, Suemoto CK. Persistent pain is a risk factor for frailty: a systematic review and meta-analysis from prospective longitudinal studies. *Age Ageing*. 2018;47(6):785–793.
27. Pergolizzi JV, Ma L, Foster DR, et al. The prevalence of opioid-related major potential drug-drug interactions and their impact on health care costs in chronic pain patients. *J Manag Care Spec Pharm*. 2014;20(5):467–476. doi:10.18553/jmcp.2014.20.5.467
28. Shah D, Allen L, Zheng W, et al. Economic burden of treatment-resistant depression among adults with chronic non-cancer pain conditions and major depressive disorder in the US. *Pharmacoeconomics*. 2021;39(6):639–651. doi:10.1007/s40273-021-01029-2