



Original Research Article

Preliminary Clinical and Radiological Outcomes of Trans–Superior Articular Process Endoscopic Lumbar Discectomy

Article History:

Name of Author:

Hoang Huu Duc¹, Dinh Ngoc Son^{1*}, Le Van Binh¹, Tran Thai Hung¹, Nguyen Viet Luc², Le Thanh Dung²

Affiliation: ¹ Hanoi Medical University, Hanoi, Vietnam

² Viet Duc University Hospital, Hanoi, Vietnam

Corresponding Author:

Dinh Ngoc Son

Received: 12-11-2025

Revised: 10-12-2025

Accepted: 15-12-2025

Published: 18-12-2025

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-Noncommercial-Share Alike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

Abstract: Objective: To prospectively evaluate the clinical, radiological, and perioperative outcomes of full-endoscopic lumbar discectomy using the trans–superior articular process (Trans-SAP) approach in patients with lumbar disc herniation treated at a tertiary referral center in Vietnam. **Methods:** A prospective observational study was conducted on 62 consecutive patients with single-level lumbar disc herniation who underwent Trans-SAP full-endoscopic lumbar discectomy between June 2023 and September 2024. Clinical outcomes were assessed using the Visual Analog Scale (VAS) for leg pain, the Oswestry Disability Index (ODI), and the modified MacNab criteria. Radiological outcomes were evaluated by postoperative magnetic resonance imaging. Perioperative parameters, complications, reoperation rate, hospital stay, cost, and return-to-work time were recorded. **Results:** The mean VAS score for leg pain significantly decreased from 6.87 ± 0.76 preoperatively to 1.98 ± 1.09 at final follow-up ($p < 0.001$), while the ODI improved from $57.0 \pm 7.7\%$ to $11.1 \pm 5.5\%$ ($p < 0.001$). Excellent or good outcomes according to the MacNab criteria were achieved in 88.5% of patients. Adequate radiological decompression was confirmed in 93.4% of cases. Complications occurred in 6.6% of patients, and the reoperation rate was 1.6%. The mean hospital stay was 1.1 ± 0.3 days, and most patients returned to work within 2–6 weeks.

Conclusion: Full-endoscopic lumbar discectomy via the Trans-SAP approach is a safe and effective technique for lumbar disc herniation, including anatomically complex cases. It provides significant pain relief, functional recovery, high rates of radiological decompression, and favorable perioperative outcomes, supporting its broader application in routine clinical practice.

Keywords: Lumbar disc herniation, Full-endoscopic lumbar discectomy, Trans–superior articular process approach, Minimally invasive spine surgery, Clinical outcomes.

INTRODUCTION

Lumbar disc herniation is a leading cause of low back pain and sciatica, imposing a substantial burden on quality of life and healthcare systems worldwide [1-3]. It results from displacement of nucleus pulposus material through the annulus fibrosus, leading to neural compression and radicular symptoms, and affects approximately 12% to 40% of adults, with peak incidence between 30 and 50 years of age and a higher prevalence in men [1, 2, 4-6]. Established risk factors include age, obesity, smoking, cardiovascular comorbidities, and occupational lumbar loading, while pathological forms range from disc bulge and protrusion to extrusion and sequestration [4, 6, 7]. Although conservative management remains effective for many

patients, surgical intervention is required in refractory cases, with minimally invasive endoscopic techniques increasingly favored due to clinical outcomes comparable to open microdiscectomy and the advantages of reduced tissue injury, shorter hospitalization, and faster recovery [5, 7-9]. Accumulating evidence from randomized trials and meta-analyses demonstrates that both approaches provide comparable clinical outcomes, patient satisfaction, and overall recall or complication rates [10-13]. Nevertheless, important technical differences have been reported. The interlaminar approach is consistently associated with shorter operative times and lower radiation exposure, particularly at the L5–S1 level, whereas the transforaminal approach often requires greater technical expertise and increased

fluoroscopic guidance. Although both techniques show low rates of dural tears and reherniation, some studies suggest a slightly higher incidence of dural injury and persistent muscle weakness with the transforaminal route [11, 13].

Anatomical variations of the superior articular process (SAP) present a significant challenge to standard transforaminal endoscopic access, especially in patients with foraminal narrowing or SAP hypertrophy. To address these limitations, modified techniques such as the transfacet and trans-superior articular process approaches have been introduced, allowing safe endoscopic access while maintaining spinal stability [14, 15]. Recent systematic reviews and treatment algorithms emphasize that selection of the endoscopic route should be individualized based on disc herniation morphology, spinal level, and patient-specific anatomy. While the transforaminal approach is generally preferred for foraminal or extraforaminal herniations and upper lumbar levels, the interlaminar route is favored for central or subarticular herniations at L4–L5 and L5–S1, particularly in the presence of a high iliac crest or SAP hypertrophy. In this context, the trans-SAP approach represents an important technical adaptation that expands the indications of endoscopic discectomy in anatomically complex cases [11, 12, 15].

Despite the growing global adoption of endoscopic lumbar discectomy and the increasing refinement of techniques such as the trans-SAP, evidence from Southeast Asia, and particularly from Vietnam, remains limited. Differences in patient characteristics, spinal anatomy, disease presentation, surgeon experience, and healthcare systems underscore the need for region-specific data to validate the safety, feasibility, and effectiveness of advanced endoscopic approaches in routine clinical practice. Therefore, the objective of this study was to prospectively evaluate the clinical, radiological, and perioperative outcomes of full-endoscopic lumbar discectomy using the Trans-SAP approach in patients with lumbar disc herniation treated at a tertiary referral center in Vietnam, with particular attention to its applicability in anatomically challenging cases involving foraminal or migrated disc herniations.

MATERIALS AND METHODS

Study Design and Patients

This prospective observational study included 62 consecutive patients diagnosed with lumbar disc herniation who underwent full-endoscopic lumbar discectomy using the Trans-superior articular process (Trans-SAP) approach at the Department of Spine Surgery, Viet Duc University Hospital, Hanoi, Vietnam, between June 2023 and September 2024. All surgical procedures were performed by the same specialized endoscopic spine surgery team to ensure

procedural consistency and minimize operator-related variability. The study protocol was reviewed and approved by the Institutional Ethics Committee of Hanoi Medical University, and written informed consent was obtained from all participants prior to enrollment.

Eligible patients met predefined inclusion criteria, which comprised a single-level lumbar disc herniation confirmed by magnetic resonance imaging, accompanied by unilateral or bilateral radicular leg pain consistent with imaging findings. Imaging evidence was required to demonstrate disc herniation corresponding to the clinical radicular symptoms, with or without associated foraminal stenosis caused by factors such as facet hypertrophy, disc protrusion, or ligamentous thickening. In addition, all patients had failed to achieve sufficient clinical improvement after at least six weeks of conservative treatment.

Patients were excluded if they presented with multilevel disc herniation or coexisting spinal instability or spondylolisthesis. Other exclusion criteria included a high iliac crest at the L5–S1 level that prevented endoscopic access, cauda equina syndrome, severe chronic nerve root injury associated with muscle atrophy, spinal infection, tumor, or other space-occupying lesions. Patients with severe systemic comorbidities, such as advanced hepatic or renal failure, coagulopathy, or active systemic infection, as well as those with congenital or acquired spinal deformities in the lumbosacral region, were also excluded.

Surgical Considerations

The Trans-SAP approach was performed under general anesthesia with the patient placed in the prone position, in accordance with standard principles of endoscopic lumbar discectomy. As the technical aspects of the Trans-SAP technique have been extensively described in previous studies, they are not reiterated in detail here. Instead, the present study emphasizes several practical intraoperative observations related to anatomical orientation that were found to be particularly relevant during the early adoption phase of this technique.

One of the most common intraoperative challenges encountered during Trans-SAP endoscopy is loss of anatomical orientation when localizing the superior articular process, especially in patients with facet hypertrophy or atypical bony anatomy. Misidentification of the superior articular process may result in incorrect drilling direction, insufficient decompression, or excessive resection of the facet joint. Based on accumulated intraoperative experience, several consistent anatomical landmarks were identified as reliable indicators for confirming the superior articular process and defining safe working boundaries.

The first key landmark is the attachment of the

ligamentum flavum. The ligamentum flavum firmly attaches to the apex of the superior articular process, forming a clear anatomical boundary between the facet joint and the spinal canal. Under endoscopic visualization, this ligament can be observed running along the medial edge of the superior articular process. Careful dissection and incision of the ligament at its attachment point not only aid in confirming the medial border of the superior articular process but also facilitate exposure of the exiting nerve root and expansion of the working corridor.

The second important landmark is the natural anterior space represented by the intervertebral foramen, which lies immediately anterior to the superior articular process. When the superior articular process is correctly identified, the area in front of it appears as a natural cavity rather than solid bone. Recognition of this space helps define the anterior boundary of the superior articular process and reduces the risk of unintentional injury to the exiting nerve root.

The third anatomical cue is the bony arch formed by the superior articular process and the pedicle.

Together, these structures create an arch-shaped osseous configuration that marks the inferior boundary of the operative field. As the endoscope is advanced caudally, visualization of this dense bony arch signals the lower limit of safe drilling. Accurate identification of this structure helps prevent excessive bone removal into the pedicle and minimizes the risk of foraminal nerve injury.

Once the superior articular process was clearly identified, limited bone resection was performed along its anterior aspect, following the attachment line of the ligamentum flavum. High-speed diamond burrs were used to gradually thin the cortical bone until a characteristic arched configuration, formed by the remaining superior articular process and pedicle, became visible. This configuration opened the pathway toward the lateral recess and served as a critical orientation reference throughout the decompression process.

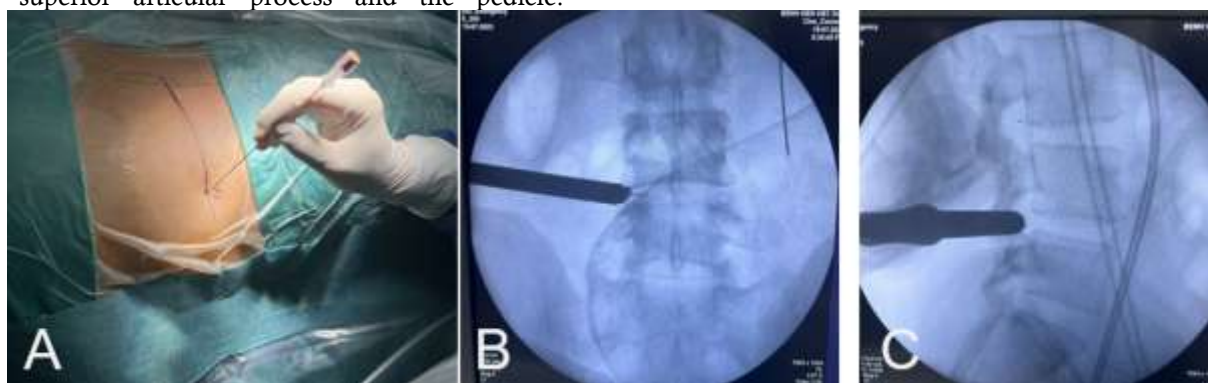


Figure 1. (A) Identification and marking of the skin incision site. **(B)** Introduction and positioning of the needle followed by working tube under fluoroscopic guidance (anteroposterior view). **(C)** Confirmation of the working tube position under fluoroscopic guidance (lateral view).

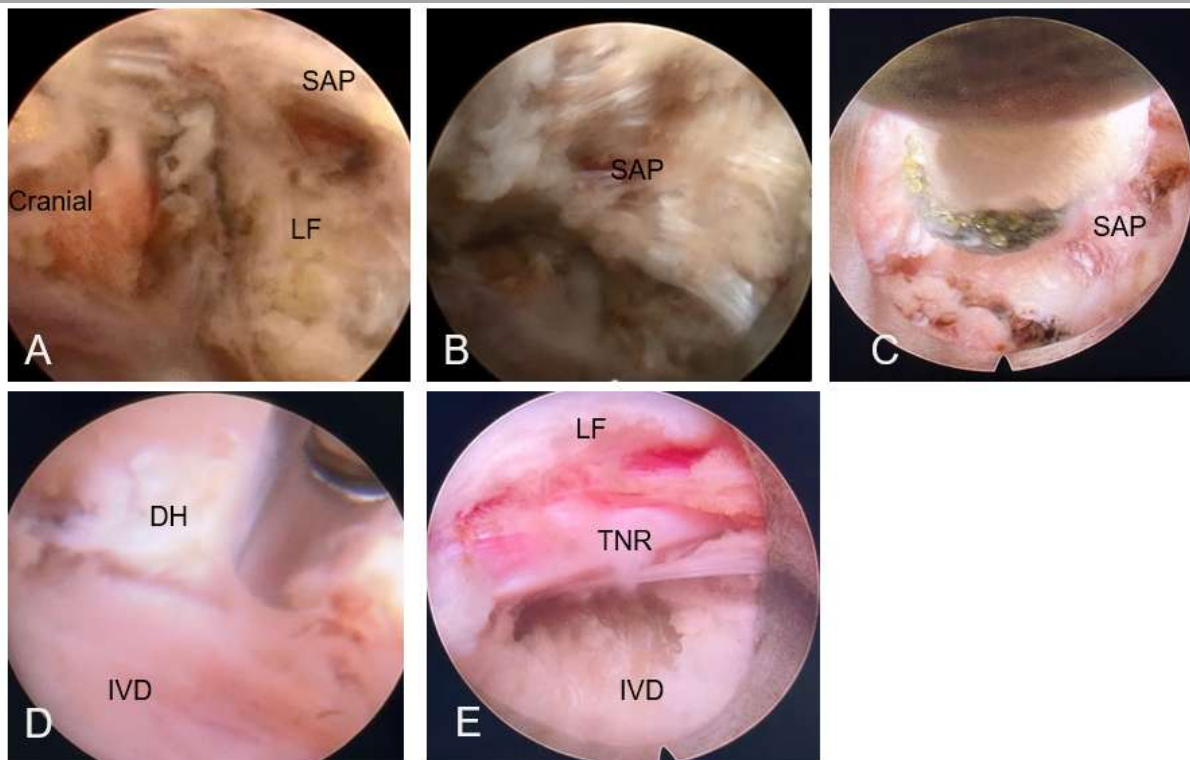


Figure 2. Main surgical procedures under endoscopy.

(A, B) Exposure of the superior articular process (SAP) and identification of the ligamentum flavum (LF) attachment at the apex of the SAP. (C) Partial resection of the SAP using a high-speed burr to enlarge the intervertebral foramen. (D) Removal of the herniated disc fragment causing nerve root compression. (E) Adequate decompression with a freely mobilized transversing nerve root (TNR) after removal of the herniated disc. DH: disc herniation, IVD: intravertenral disc.

Outcome Measures

Clinical outcomes were evaluated using standardized and validated assessment tools. Pain intensity was measured using the Visual Analog Scale for both leg pain and back pain. Functional disability was assessed using the Oswestry Disability Index, while overall patient satisfaction was evaluated according to the modified MacNab criteria at the final follow-up.

Radiological outcomes were assessed using magnetic resonance imaging performed both preoperatively and postoperatively to confirm adequate neural decompression and to identify the absence of residual or recurrent disc fragments. Intraoperative and perioperative parameters, including operative time, length of hospital stay, and procedure-related complications, were systematically recorded.

Economic feasibility was also assessed by documenting the total surgical cost after

reimbursement by the national health insurance system. In addition, the time required for patients to return to work was recorded for each case, based on postoperative recovery status and occupational demands.

Follow-up

All patients were evaluated by the same surgical team throughout the follow-up period to ensure consistency in clinical assessment. Scheduled follow-up visits were conducted at 1 day, 1 month, 6 months, and at least 12 months postoperatively. At each visit, patients underwent clinical evaluation including Visual Analog Scale and Oswestry Disability Index scoring, as well as a detailed neurological examination to detect any sensory or motor deficits.

Final follow-up data obtained at 12 months or later were used for the primary outcome analysis. Postoperative magnetic resonance imaging was performed either during a scheduled follow-up visit or immediately in cases where new or recurrent symptoms were reported, in order to confirm adequate neural decompression and exclude residual or recurrent disc herniation. All adverse events and postoperative complications, such as dural tears, transient dysesthesia, or infections, were documented and analyzed.

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS software version 20 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean values with corresponding standard deviations, while categorical variables were presented as percentages. Comparisons between preoperative and postoperative Visual Analog Scale and Oswestry Disability Index scores were conducted using the paired t-test for normally distributed data or the Wilcoxon signed-rank test for non-normally distributed data. A p-value of less than 0.05 was considered to indicate statistical significance. Subgroup analyses were additionally performed to compare clinical outcomes between patients with and without migrated or foraminal disc herniations, in order to further evaluate the effectiveness of the Trans-SAP approach in these more complex clinical scenarios.

RESULTS

Table 1 summarizes the baseline demographic and clinical characteristics of the 61 patients included in the study. The mean age was 48.8 ± 15.3 years (range, 20–80), with a predominance of male patients (63.9%). The most commonly operated level was L4–L5 (62.3%), followed by L5–S1 (26.2%) and L3–L4 (11.5%). Contained disc herniation accounted for 64.0% of cases, while migrated or foraminal herniations comprised 36.0%. The mean operative time was 74.5 ± 18.6 minutes, with an estimated blood loss of 29 ± 15 mL and an average hospital stay of 1.1 ± 0.3 days. All patients had a minimum follow-up duration of 12 months (range, 12–18). Complications occurred in 6.6% of patients, including two dural tears and two cases of transient dysesthesia, and the reoperation rate was 1.6%. The mean total treatment cost was approximately 50 million VND (about USD 1,900–2,000).

Table 1. Baseline Demographic and Clinical Characteristics of Patients (n = 61)

Characteristics	Group	Frequency	Percent (%)
Sex	Male	39	63.9
	Female	22	36.1
Age (years)	mean $\pm$ SD (range)	48.8 ± 15.3 (20–80)	
Operated level	L3–L4	7	11.5
	L4–L5	38	62.3
	L5–S1	16	26.2
Type of herniation	Contained	39	64.0
	Migrated / Foraminal	22	36.0
Operative time (min)	mean $\pm$ SD (range)	74.5 ± 18.6	
Estimated blood loss (mL)	mean $\pm$ SD (range)	29 ± 15	
Hospital stay (days)	mean $\pm$ SD (range)	1.1 ± 0.3	
Complications	Any complication	4	6.6
	Dural tear	2	3.3
	Transient dysesthesia	2	3.3
Reoperation	Yes	1	1.6

Table 2 and Figure 1 presents the clinical and radiological outcomes of the study. The mean Visual Analog Scale score for leg pain decreased from 6.87 ± 0.76 preoperatively to 2.10 ± 1.21 at postoperative day 1 and further to 1.98 ± 1.09 at the final follow-up (≥ 12 months), with a statistically significant difference ($p < 0.001$). The Oswestry Disability Index improved from $57.0 \pm 7.7\%$ before surgery to $11.1 \pm 5.5\%$ at the final follow-up ($p < 0.001$). According to

the modified MacNab criteria, 88.5% of patients achieved excellent or good outcomes. Adequate radiological decompression on postoperative magnetic resonance imaging was observed in 93.4% of cases. Residual asymptomatic disc herniation was detected in 4.9% of patients, while recurrent herniation occurred in 1.6%. Most patients returned to light work within 2–3 weeks and to heavy work within 4–6 weeks after surgery.



Table 2. Clinical and Radiological Outcomes (n=61)

Outcome measure	Preoperative	Postoperative (1 day)	Postoperative (≥ 12 months)	p-value
VAS (leg pain), mean ± SD	6.87 ± 0.76	2.10 ± 1.21	1.98 ± 1.09	< 0.001
ODI (%), mean ± SD	57.0 ± 7.7	—	11.1 ± 5.5	< 0.001
MacNab outcome (Excellent/Good), n (%)	—	—	54 (88.5)	—
Adequate radiological decompression on MRI, n (%)	—	—	57 (93.4)	—
Residual disc herniation, n (%)	—	—	3 (4.9)*	—
Recurrent disc herniation, n (%)	—	—	1 (1.6)	—

Values are presented as mean ± standard deviation unless otherwise indicated; VAS, Visual Analog Scale; ODI,

Oswestry Disability Index; *Asymptomatic residual disc fragments detected on follow-up MRI.



Figure 3. Postoperative MRI demonstrating complete neural decompression after Trans-SAP endoscopic lumbar discectomy. Note: (A), (B): Pre-operative; (C), (D): Post-operative

DISCUSSION

This prospective study demonstrates that full-endoscopic lumbar discectomy using the trans-superior articular process approach provides effective symptom relief, reliable neural decompression, and an acceptable safety profile in patients with lumbar disc herniation, including anatomically complex cases. Overall, the procedure resulted in substantial clinical improvement, low complication and reoperation rates, short hospitalization, and favorable economic feasibility in a Vietnamese tertiary-care setting.

The Trans-SAP approach achieved marked and sustained improvements in pain and functional status, which are consistent with outcomes reported for full-endoscopic transforaminal lumbar discectomy in the international literature. Multiple studies have demonstrated significant reductions in VAS scores for leg pain, with mean values decreasing from approximately 7.0–7.6 preoperatively to below 1.0 at long-term follow-up, including outcomes at 5 years [13, 16–18]. Improvements in functional disability have been similarly robust, with Oswestry Disability Index scores commonly declining from around 60–70% before surgery to approximately 10% at mid- and long-term follow-up [9, 16, 19–21]. High patient satisfaction rates, with 93–94% of patients reporting excellent or good outcomes, have also been consistently reported after endoscopic discectomy [10, 13], supporting the clinical relevance of the improvements observed in the present cohort.

Radiological outcomes in this study further support the technical effectiveness of the Trans-SAP approach. Adequate neural decompression was achieved in more than 90% of cases on postoperative magnetic resonance imaging, despite a substantial proportion of patients presenting with migrated or foraminal disc herniations. These morphologies are widely recognized as technically demanding for standard transforaminal endoscopic access due to superior articular process hypertrophy or foraminal narrowing [19, 21, 22]. Reported recurrence rates following endoscopic lumbar discectomy typically range from 2% to 8% in large series [16, 18, 23], and the low rates of residual and recurrent disc herniation observed in this study are comparable with these benchmarks, suggesting that SAP-assisted access provides sufficient working space and visualization for effective decompression.

The perioperative safety profile observed in this cohort aligns with published data on the feasibility of endoscopic lumbar discectomy. Complication and reoperation rates reported in the literature are generally low and comparable to those of open microdiscectomy, typically ranging between 2% and 8% [9, 10, 13, 24]. Although a learning curve has been described for percutaneous endoscopic techniques, with proficiency often achieved after approximately 27–36 cases [21], outcomes from experienced centers consistently demonstrate low rates of neurological injury and revision surgery. The favorable safety outcomes in this study support the view that careful anatomical orientation and limited

resection of the superior articular process can mitigate procedure-related risks, even in complex anatomical settings.

The minimally invasive nature of the Trans-SAP technique is further reflected in its perioperative and recovery-related advantages, which have been widely documented. Endoscopic lumbar discectomy is associated with smaller incisions, minimal blood loss, and shorter hospital stays, typically ranging from 1 to 4 days, when compared with open surgery [13, 16, 19, 22]. These features facilitate early mobilization and rapid return to work, contributing to favorable functional and socioeconomic outcomes. From an economic perspective, although endoscopic procedures may involve higher upfront costs related to specialized equipment and training, cost-utility analyses indicate lower overall societal costs and favorable quality-adjusted life year outcomes compared with microdiscectomy [9, 18]. Together, these findings support the Trans-SAP approach as a clinically effective, safe, and economically reasonable extension of endoscopic lumbar discectomy.

The results of this study support the Trans-SAP endoscopic approach as an effective extension of standard endoscopic lumbar discectomy techniques. It appears particularly useful for patients with foraminal stenosis, migrated disc herniation, or superior articular process hypertrophy, in whom conventional transforaminal access may be restricted. Adoption of this technique may expand the indications for endoscopic surgery while maintaining favorable clinical, radiological, and economic outcomes.

This study has several limitations. The single-center design and lack of a comparative control group limit direct comparison with interlaminar, standard transforaminal, or open surgical approaches. The sample size was moderate, and although all patients were followed for at least 12 months, longer-term data are needed to assess spinal stability and late recurrence. Additionally, outcomes may reflect the experience of a specialized endoscopic surgical team, which may limit generalizability to lower-volume centers.

CONCLUSION

Full-endoscopic lumbar discectomy via the trans-superior articular process approach is a safe and effective surgical option for lumbar disc herniation, including cases with challenging anatomy. The technique provides significant pain relief, meaningful functional recovery, high rates of radiological decompression, and low complication and reoperation rates, with the added benefits of rapid recovery and economic feasibility. Further multicenter and comparative studies are warranted to validate these findings and refine patient selection criteria.

REFERENCES

1. Chen Z, Zhao J, Wang L, Shao H, Cao L, He X, et al. Prevalence of lumbar disc herniation and its associated factors: A cross-sectional study in Gansu. *PLOS ONE*. 2024;19. doi: 10.1371/journal.pone.0310550.
2. Hincapié C, Kroismayr D, Hofstetter L, Kurmann A, Cancelliere C, Rampersaud R, et al. Incidence of and risk factors for lumbar disc herniation with radiculopathy in adults: a systematic review. *European Spine Journal*. 2024;34:263-94. doi: 10.1007/s00586-024-08528-8.
3. Qin X, Sun K, Xu W, Gao J, Jiang H, Chen W, et al. An evidence-based guideline on treating lumbar disc herniation with traditional Chinese medicine. *Journal of Evidence-Based Medicine*. 2024;17:187-206. doi: 10.1111/jebm.12598.
4. La Rocca G, Galieri G, Mazzucchi E, Pignotti F, Orlando V, Pappalardo S, et al. The Three-Step Approach for Lumbar Disk Herniation with Anatomical Insights Tailored for the Next Generation of Young Spine Surgeons. *Journal of Clinical Medicine*. 2024;13. doi: 10.3390/jcm13123571.
5. Duceac M, Guțu C, Pleșea-Condratovici A, Duceac L, Eva L, Dabija M, et al. A Retrospective Study of Lumbar Disk Herniation: An Analysis of Clinical Cases and Treatment Plans. *Journal of Clinical Medicine*. 2025;14. doi: 10.3390/jcm14113952.
6. Lee JS, Lee S-B, Kang K-Y, Oh SH, Chae D-S. Review of Recent Treatment Strategies for Lumbar Disc Herniation (LDH) Focusing on Nonsurgical and Regenerative Therapies. *Journal of Clinical Medicine*. 2025;14. doi: 10.3390/jcm14041196.
7. Melhat AE, Youssef A, Zebdawi M, Hafez M, Khalil L, Harrison D. Non-Surgical Approaches to the Management of Lumbar Disc Herniation Associated with Radiculopathy: A Narrative Review. *Journal of Clinical Medicine*. 2024;13. doi: 10.3390/jcm13040974.
8. Choueiri JE, Pellicano F, Caimi E, Laurelli F, Di Cosmo L, Rada AD, et al. Advancements in Spinal Endoscopic Surgery: Comprehensive Techniques and Pathologies Addressed by Full Endoscopy Beyond Lumbar Disc Herniation. *Journal of Clinical Medicine*. 2025;14. doi: 10.3390/jcm14113685.
9. Lee C-C, Lin R-M, Juan W-S, Chuang H-Y, Lin H-L, Cheng C-H, Yao C-H. Comparing Clinical Outcomes of Microdiscectomy, Interspinous Device Implantation, and Full-Endoscopic Discectomy for Simple Lumbar Disc Herniation. *Journal of Clinical Medicine*. 2025;14. doi: 10.3390/jcm14061925.
10. Nie H-F, Zeng J, Song Y, Chen G, Wang X-D, Li Z, et al. Percutaneous Endoscopic Lumbar Discectomy for L5-S1 Disc Herniation Via an

Interlaminar Approach Versus a Transforaminal Approach: A Prospective Randomized Controlled Study With 2-Year Follow Up. *SPINE*. 2016;41. doi: 10.1097/brs.0000000000001810.

11. Chen K-T, Tseng C, Sun L-W, Chang K-S, Chen C-M. Technical Consideration of Interlaminar Approach in the Lumbar Disc Herniation. *World neurosurgery*. 2020. doi: 10.1016/j.wneu.2020.06.211.

12. Jitpakdee K, Liu Y, Kotheeranurak V, Kim J-S. 362 Transforaminal Versus Interlaminar Endoscopic Lumbar Discectomy for Lumbar Disc Herniation: a Systematic Review and Meta-Analysis. *Neurosurgery*. 2023;69:60-1. doi: 10.1227/neu.0000000000002375_362.

13. Jamaledine Y, Hussein AH, Afyouni A, Mayta Z, Ayoubi LME, Salameh P, et al. Effect of Patient's Characteristics and Surgical Technique on the Patient Outcomes and Satisfaction After Endoscopic Lumbar Discectomy—A Long-Term Retrospective Study. *Journal of Clinical Medicine*. 2025;14. doi: 10.3390/jcm14051411.

14. Ning C, Wang Y, Xu F, Zhang W, Liu W, Lv Z, et al. Percutaneous endoscopic lumbar discectomy by transfacet joint approach. *Medicine*. 2018;97. doi: 10.1097/md.00000000000013373.

15. Yu Z, Lu Y, Li Y, An Y, Wang B. A one-step foraminoplasty via a large trephine in percutaneous endoscopic transforaminal discectomy for the treatment of lumbar disc herniation. *PLOS ONE*. 2022;17. doi: 10.1371/journal.pone.0268564.

16. Ahn Y, Lee U, Kim W-K, Keum H. Five-year outcomes and predictive factors of transforaminal full-endoscopic lumbar discectomy. *Medicine*. 2018;97. doi: 10.1097/md.00000000000013454.

17. Chen Z, Zhang L, Dong J, Xie P, Liu B, Wang Q-Y, et al. Percutaneous Transforaminal Endoscopic Discectomy Versus Microendoscopic Discectomy for Lumbar Disc Herniation: Two-Year Results of a Randomized Controlled Trial. *Spine*. 2019. doi: 10.1097/brs.0000000000003314.

18. Gadjradj P, Harhangi B, Amelink J, Van Susante J, Kamper S, Van Tulder M, et al. Percutaneous Transforaminal Endoscopic Discectomy Versus Open Microdiscectomy for Lumbar Disc Herniation. *Spine*. 2020;46:538-49. doi: 10.1097/brs.0000000000003843.

19. Chen C-M, Sun L-W, Tseng C, Chen Y-C, Wang G-C. Surgical outcomes of full endoscopic spinal surgery for lumbar disc herniation over a 10-year period: A retrospective study. *PLOS ONE*. 2020;15. doi: 10.1371/journal.pone.0241494.

20. Qian Y, Chen Z, Zhang G, Wang X, Liu J, Yang A, et al. Transforaminal endoscopic lumbar discectomy using a 45° puncture angle and foraminotomy versus traditional THESYS for L5/S1 lumbar disc herniation: a prospective randomized controlled trial. *European spine journal : official publication of the European Spine Society, the*

European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2024. doi: 10.1007/s00586-023-08117-1.

21. Qiao H, Haijun, Shen M, Tan J. Unilateral biportal endoscopic discectomy versus percutaneous endoscopic lumbar discectomy in the treatment of far-lateral lumbar disc herniation. *Neurosurgical review*. 2025;48 1:588. doi: 10.1007/s10143-025-03748-y.

22. Zhao X-M, Chen A, Lou X-X, Zhang Y-G. Comparison of Three Common Intervertebral Disc Discectomies in the Treatment of Lumbar Disc Herniation: A Systematic Review and Meta-Analysis Based on Multiple Data. *Journal of Clinical Medicine*. 2022;11. doi: 10.3390/jcm11226604.

23. Krishnan A, Murugan C, Panthackel M, Anil A, Degulmadi D, Mayi S, et al. "Transforaminal endoscopic ventral stenosis decompression in calcified lumbar disc herniation: A long term outcome in 79 patients". *World neurosurgery*. 2024. doi: 10.1016/j.wneu.2024.03.104.

24. Ruetten S, Komp M, Merk H, Godolias G. Full-Endoscopic Interlaminar and Transforaminal Lumbar Discectomy Versus Conventional Microsurgical Technique: A Prospective, Randomized, Controlled Study. *Spine*. 2008;33:931-9. doi: 10.1097/brs.0b013e31816c8af7.