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International Practice Patterns in the Surgical Management of Primary Lumbar Disc Herniation: An AO Spine Cross-Sectional Study

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Objective: This study aimed to characterize international practice patterns in the surgical management of primary lumbar disc herniation (LDH) among AO Spine surgeons.
Methods: A cross-sectional online survey was distributed in September 2024 to AO Spine members. The questionnaire collected detailed information on demographic characteristics, surgical indications, preferred techniques, and approaches for primary LDH treatment. Data on specialty, practice setting, fellowship training, and surgical case volume were analyzed using univariate and multivariate logistic regression to identify significant associations between surgeon characteristics and treatment preferences.
Results: A total of 714 surgeons participated, representing diverse regions: North America (9.0%), Latin America (18.7%), Europe & Southern Africa (34.7%), Middle East & Northern Africa (12.8%), and Asia Pacific (24.8%). Neurological status was the most critical factor influencing early operative treatment in nonurgent cases, while bladder/bowel dysfunction and severe motor deficits were the primary indications in urgent scenarios. The majority of respondents (54.2%) preferred a mini-open technique—using either a surgical microscope or loupes—with partial laminotomy (58.1%) and partial discectomy (63.2%) being the most frequently performed procedures. Regional variations and differences in surgeon training were significantly associated with the choice of surgical approach and overall case volume.
Conclusion: The findings reveal substantial variability in the surgical management of primary LDH across regions and specialties. This comprehensive dataset underscores the need for standardized, evidence-based guidelines to harmonize treatment strategies and optimize patient outcomes.

Keywords: Lumbar disc herniation, Discectomy, Sequestrectomy, Survey, Spine, Surgery

INTRODUCTION

Lumbar disc herniation (LDH) is among the most prevalent spinal disorders encountered in clinical practice, frequently resulting in significant morbidity and imposing substantial socioeconomic burdens worldwide.[1] Despite considerable advancements in diagnostic imaging and surgical interventions over recent decades, there is no universal consensus on the optimal management strategy for LDH. This ongoing debate is reflective of the diverse array of clinical presentations leading to different treatment modalities offered to patients, from conservative approaches, such as physical therapy and pharmacological management, to more invasive options, including various surgical techniques.[2,3] The latter are particularly required when nonsurgical treatments fail or in case of worsening neurological deficits.[4]

The heterogeneity in treatment approaches can be attributed to multiple factors, including differences in surgeon training, regional medical practices, and, primarily, the variable natural history of the disease.[5,6] Indeed, most LDHs tend to regress naturally through resorption mechanisms, raising questions regarding the appropriateness of invasive treatments in some cases.[7] However, early surgery is advised in severe symptomatic cases due to better neurological prognosis[8] and decreased healthcare costs.[9] Additionally, the evolution of minimally invasive surgical techniques and improvements in perioperative care have further diversified the spectrum of interventions, making it increasingly challenging to establish standardized treatment guidelines.[10] In this context, understanding the contemporary practice patterns among spine surgeons is crucial for benchmarking current clinical practices and identifying gaps in knowledge and areas of controversy that warrant further investigation.

In this study, we conducted a comprehensive survey of AO Spine surgeons to examine current treatment strategies for primary LDH. This cross-sectional study aimed to identify the key factors influencing clinical decision-making, including treatment modalities, indications, and preferred surgical approaches, while also exploring the rationale behind these choices. A deeper understanding of current practice patterns would encourage the development of more standardized, evidence-based treatment protocols for patients with LDH.

MATERIALS AND METHODS

1. Study Participants

The AO Spine Knowledge Forum Degenerative developed an online questionnaire to assess the practice patterns related to the treatment of LDH. This study did not require formal Institutional Review Board approval. The survey was distributed by AO Spine to its registered membership in September 2024. AO Spine's membership includes clinicians, researchers, therapists and other allied professionals; based on AO Spine internal estimates, approximately 6,000 members are practicing surgeons. Because the distribution was made to the full AO Spine membership (not only surgeons) and the authors do not have access to the AO Spine membership counts and invitation-delivery logs by region, precise invitation denominators or formal response rates by region could not be calculated. All participants provided digital informed consent and agreed to the use of their anonymized responses for research purposes.

2. Study Questionnaire

The questionnaire collected demographic information about the participating surgeons, including their country and AO Spine region of practice, specialty, practice focus (e.g., degenerative, deformity, trauma/spinal cord injury, tumor, other), practice setting, spine surgery fellowship experience, overall spine surgery volume, and LDH case volume. Subsequently, surgical indications, preferred surgical approaches, disc space approaches, and discectomy techniques for primary LDH surgeries, early recurrences (< 3 months), and late recurrences (> 3 months) were investigated. Surgical approaches were defined as follows: open: posterior midline exposure with no surgical magnification; mini-open: posterior midline exposure using loupe or microscope magnification but without use of tubular retractors; tubular retractor: use of a tubular dilator system to create a working corridor for microscopic discectomy; transforaminal full-endoscopic: percutaneous approach through the foramen using a working channel endoscope to access and remove herniated fragments from the foraminal region; interlaminar full-endoscopic: interlaminar endoscopic access through a posterior interlaminar window for central or paracentral herniations using a working channel endoscope; unilateral biportal endoscopy: a 2-portal endoscopic technique using separate viewing and working portals. Disc space approach referred to surgical techniques used to access the spinal canal and disc space after muscle dissection. These included: laminectomy, involving complete lamina removal; partial laminotomy, which is limited lamina removal for exposure of the ligamentum flavum and dural sac; hemilaminotomy, in which the ipsilateral half of the lamina is removed; and transforaminal endoscopic methods that use an endoscope to access the foramen without lamina removal. Eventually, indications for fusion, prescription of postoperative lumbar braces,

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postoperative activity limitations, length of hospital stay, and postoperative medication protocols were assessed. The present study focuses exclusively on responses related to indications for primary LDH surgery, preferred surgical techniques, preferred disc space approaches, and discectomy techniques. For several items the questionnaire included an "other (please specify)" free-text option. Free-text responses indicating specific techniques were reviewed and coded into predefined categories. The full questionnaire is available in the Supplementary Material.

3. Statistical Analysis

Categorical data were shown as absolute counts (n) and relative (%) frequencies. The Friedman test was employed to analyze the ranked data collected from respondents regarding their rationale for direct surgical treatment of patients diagnosed with LDH without an indication for urgent surgery. Each respondent ranked five rationale categories (1 = most important, 5 = least important), and the Friedman test determined whether statistically significant differences existed in the median ranks assigned to these categories. The Dunn multiple comparisons test was performed to compare mean ranks of the most important category (i.e., mean value closer to 1) with all the other ones. The main indications for early surgery (within 48 hours), surgical approaches for primary LDH surgery, and discectomy techniques were analyzed using the Chi-squared test. Multiple logistic regression was conducted to examine the associations between surgeon characteristics (i.e., specialty, fellowship training, spine surgery case volume, number of LDH patients seen per month, and number of LDH surgeries performed per year) and variables including AO region, hospital setting, community setting, practice focus (i.e., degenerative, deformity, trauma/spinal cord injury, tumor), main indication for elective surgery, preferred surgical technique, preferred disc space approach, and preferred discectomy technique. Covariates entered into each multiple logistic regression model were selected based on significance in univariate analyses ($p < 0.10$) and clinical relevance. Reference levels were selected based on their frequency or their relevance per each independent covariate. For clarity, reference categories for categorical variables are reported here and in each table footnote. Where applicable the following reference levels were used: AO Spine Region — Europe & Southern Africa (reference); Preferred surgical approach — Mini-open (reference); Preferred disc space approach — Partial laminotomy (reference); Preferred discectomy technique — Partial discectomy (reference); Specialty — Orthopaedics (reference). Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each reference category. Statistical significance was set at $p < 0.05$. Formal analysis was performed using Prism 10 (v. 10.4.1, GraphPad Software, USA).

RESULTS

1. Participants' Demographics

A total of 714 surgeons completed the survey. Participants resided in North America (9.0%), Latin America (18.7%), Europe & Southern Africa (34.7%), Middle East & Northern Africa (12.8%), and Asia Pacific (24.8%). Most respondents were orthopedic surgeons (60.9%). Among participants, 38.1% of surgeons practiced in an academic hospital, 29.8% in a private setting, and 29.1% in a public hospital. Most of the participants completed a spine surgery fellowship (63.3%) and the vast majority of surgeons (95.3%) operated on degenerative cases. The complete demographic characteristics of included respondents are shown in Table 1. On a monthly basis, the surgeons reported seeing an average of < 10 (9.6%), 10–20 (35.9%), 20–30 (19.6%), 30–40 (12.8%), 40–50 (6.0%), or > 50 (15.8%) LDH cases in their offices. Participants performed a mean of 1–20 (28.7%), 20–50 (38.2%), 50–100 (18.6%), or > 100 (14.4%) LDH surgeries per year, including primary, revision, and multilevel procedures.

2. Indications and Approaches for Primary LDH Surgery

When considering surgical indication for nonurgent LDH cases, the most important reason for early operative treatment was neurological status ($p < 0.001$) (Fig. 1), followed by debilitating pain, failed conservative treatment, and failed epidural steroid injection(s). In this scenario, patient's willingness to undergo surgery was rated as the least relevant factor ($p < 0.001$). In urgent cases, the most important indications for surgery were bladder and/or bowel dysfunction (93.8%) and severe and/or progressive motor deficit (90.5%), followed by intractable pain (37.0%) and sensory loss (17.4%). These differences were statistically significant ($p < 0.001$).

For primary LDH surgeries, the most preferred surgical approach was through a mini-open technique, by either use of a surgical microscope or loupes (54.2%), followed by a conventional open approach (19.0%), tubular retractors (14.8%), full-endoscopic approach (8.4%), unilateral biportal endoscopic spine surgery (2.7%) or others (0.8%). These differences were statistically significant ($p < 0.001$). Among surgical approaches, partial laminotomy was the most common (58.1%), followed by hemilaminotomy (24.0%), laminectomy (8.7%), transforaminal en-

Table 1. Demographic characteristics of included participants (n = 714)

Characteristic	No. (%)
AO Spine region	
Europe & Southern Africa	248 (34.7)
Asia Pacific	177 (24.8)
Latin America	134 (18.7)
Middle East & Northern Africa	91 (12.8)
North America	64 (9.0)
Specialty	
Orthopaedics	435 (60.9)
Neurosurgery	271 (37.9)
Other	8 (1.2)
Practice focus	
Degenerative	681 (95.3)
Deformity	354 (49.5)
Trauma/spinal cord injury	498 (69.7)
Tumor	361 (50.5)
Infection	17 (2.3)
Other	20 (2.8)
Hospital setting	
Public hospital or government/military hospital	208 (29.1)
Private practice	213 (29.8)
Academic/university affiliate	272 (38.1)
Other	21 (2.9)
Community setting	
Urban	557 (78.0)
Suburban	128 (17.9)
Rural	29 (4.1)
Completed spine fellowship?	
Yes	452 (63.3)
No	262 (36.7)
Time since completion of spine fellowship (yr)	
< 5	93 (20.6)
5–10	98 (21.7)
11–15	83 (11.6)
16–20	61 (18.4)
> 20	117 (25.9)
Spine surgical case volume (n)	
< 10	28 (3.9)
11–25	42 (5.9)
26–50	80 (11.2)
51–100	175 (24.5)
> 100	389 (54.5)

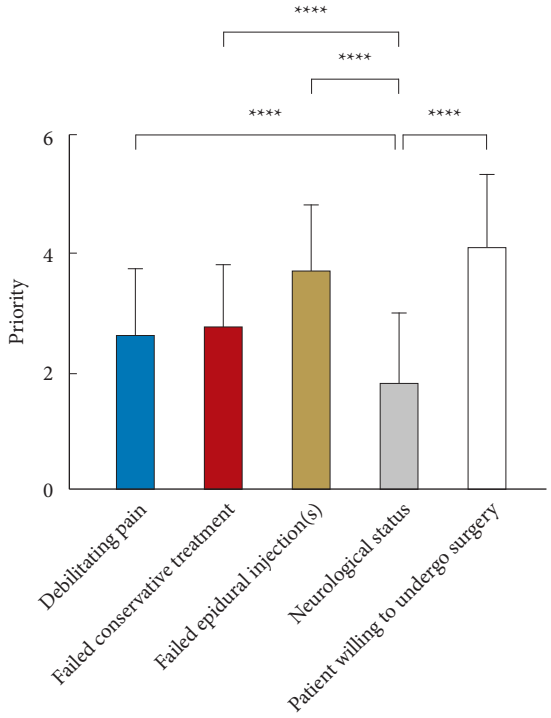


Fig. 1. Priority of reasons for direct surgery in nonurgent lumbar disc herniation cases, ranging from 1 (top priority) to 5 (low priority). Friedman test with *post hoc* Dunn; data were compared to "neurological status" as the most relevant reason for surgery among respondents (n = 712). ****p < 0.0001.

doscopic approach (4.1%), interlaminar endoscopic approach (2.2%), or others (5.0%) (p < 0.001). In terms of the extent of disc removal, most adopted partial discectomy (63.2%), defined as removal of the herniated fragment, annulotomy, and curettage of the disc space with the removal of loose pieces, followed by sequestrectomy (removal of free fragments only) in 25.2% of cases. The remaining participants (9.9%) performed radical discectomy, defined as removal of the herniated fragment, annulotomy, removal of as much disc material as possible, and endplate curettage, while 1.7% of surgeons performed fusion at the time of primary surgery. Again, these differences were statistically significant (p < 0.001).

3. Multivariate Logistic Regression

Compared to neurosurgeons, orthopedic surgeons were more frequently located in the Asia Pacific area (OR, 2.85; 95% CI, 1.76–4.66; p < 0.001), were less subspecialized in the care of spinal tumors (OR, 0.24; 95% CI, 0.16–0.34; p < 0.001), performed a lower number of LDH surgeries per year (OR, 0.45; 95% CI, 0.30–0.66; p < 0.001), and were less likely to operate on patients willing to undergo surgery (OR, 0.40; 95% CI, 0.17–0.91; p = 0.031).

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Table 2. Multivariate logistic regression model showing the association between respondents' specialty and study covariates

Covariate	OR	95% CI	p-value
AO Spine region			
Europe & Southern Africa (reference)			
Asia Pacific	2.85	1.76–4.66	< 0.001*
Latin America	1.19	0.72–1.96	0.509
North America	1.74	0.90–3.43	0.104
Middle East & Northern Africa	1.37	0.76–2.50	0.299
Subspecialty†			
Degeneration	0.96	0.32–2.57	0.938
Deformity	0.97	0.69–1.38	0.877
Tumor	0.24	0.16–0.34	< 0.001*
Community			
Urban (reference)			
Suburban	1.36	0.83–2.26	0.230
Rural	1.51	0.56–4.62	0.438
Spine surgical volume			
≤ 50 cases/yr (reference)			
> 50 cases/yr	0.99	0.59–1.63	0.957
LDH surgery cases			
≤ 50 cases/yr (reference)			
> 50 cases/yr	0.45	0.30–0.66	< 0.001*
Main indication for elective surgery			
Failed conservative treatment (reference)			
Patient willing to undergo surgery	0.40	0.17–0.91	0.031*
Neurological status	0.78	0.45–1.33	0.374
Debilitating pain	1.02	0.52–1.99	0.951
Failed epidural steroid injection(s)	0.61	0.22–1.71	0.347
Preferred surgical approach			
Mini-open (e.g., microscopic, loupe-assisted; reference)			
Open	2.46	1.39– 4.48	0.003*
Tubular retractor	1.26	0.77– 2.08	0.359
UBE	0.96	0.33–2.95	0.938
Full-endoscopic (e.g., TELD, IELD)	0.82	0.38–1.80	0.616
Preferred disc space approach			
Partial laminotomy (reference)			
Laminectomy	1.84	0.76–4.84	0.190
Hemilaminotomy	1.31	0.85–2.02	0.218
Transforaminal endoscopic	1.63	0.60–4.75	0.353

Orthopedics was set as a positive outcome.
OR, odds ratio; CI, confidence interval; LDH, lumbar disc herniation; UBE, unilateral biportal endoscopy; TELD, transforaminal endoscopic lumbar discectomy; IELD, interlaminar endoscopic lumbar discectomy.
*$p < 0.05$, statistically significant differences. †Being a subspecialist in a specific spine field (i.e., having answered "yes") was set as the reference.

Table 3. Multivariate logistic regression model showing the association between fellowship training and study covariates

Covariate	OR	95% CI	p-value
AO Spine region			
Europe & Southern Africa (reference)			
Asia Pacific	3.16	1.98–5.11	< 0.001*
Latin America	3.31	1.97–5.67	< 0.001*
North America	14.02	5.36–48.46	0.003*
Middle East & Northern Africa	2.35	1.35–4.15	< 0.001*
Subspecialty†			
Degeneration	0.66	0.27–1.57	0.346
Deformity	1.13	0.80–1.58	0.487
Hospital setting			
Academic/university hospital (reference)			
Private practice	0.99	0.64 1.55	0.974
Public hospital or government/ military hospital	0.61	0.40–0.91	0.017*
Spine surgical volume			
≤ 50 cases/yr (reference)			
> 50 cases/yr	2.10	1.36–3.26	0.001*
Preferred surgical approach			
Mini-open (e.g., microscopic, loupe-assisted; reference)			
Open	0.62	0.37–1.03	0.065
Tubular retractor	1.11	0.66–1.88	0.701
UBE	4.10	1.08–27.06	0.071
Full-endoscopic (e.g., TELD, IELD)	0.85	0.40–1.85	0.680
Preferred disc space approach			
Partial laminotomy (reference)			
Laminectomy	0.57	0.28–1.17	0.128
Hemilaminotomy	1.12	0.73–1.73	0.615
Transforaminal endoscopic	0.86	0.32–2.37	0.758
Preferred discectomy approach			
Partial discectomy (reference)			
Sequestrectomy	1.03	0.69–1.55	0.885
Radical discectomy	0.65	0.36–1.15	0.138
Fusion on primary surgery	3.00	0.77–13.27	0.123

OR, odds ratio; CI, confidence interval; UBE, unilateral biportal endoscopy; TELD, transforaminal endoscopic lumbar discectomy; IELD, interlaminar endoscopic lumbar discectomy.
*$p < 0.05$, statistically significant differences. †Being a subspecialist in a specific spine field (i.e., having answered "yes") was set as the reference.

Additionally, orthopedic spine surgeons used more frequently open approaches (OR, 2.46; 95% CI, 1.39–4.48; $p = 0.003$) (Table 2).

When considering fellowship training as the dependent variable, fellowship-trained surgeons tended to be based in AO Spine regions other than Europe & South Africa (Asia Pacific: OR, 3.16; 95% CI, 1.98–5.11; p < 0.001; North America: OR, 14.02; 95% CI, 5.36–48.46; p < 0.001; Middle East & Northern Africa: OR, 2.35; 95% CI, 1.35–4.15; p = 0.003; Latin America: OR, 3.31; 95% CI, 1.97–5.67; p < 0.001). Furthermore, they were less frequently working in public or government/military hospitals (OR, 0.61; 95% CI, 0.40–0.91; p = 0.017), and presented a higher volume of spine surgical cases yearly (OR, 2.10; 95% CI, 1.36–3.26; p = 0.001) (Table 3).

Surgeons with a high overall spine case volume were less often based in the Asia Pacific (OR, 0.40; 95% CI, 0.21–0.75; p = 0.005), the Middle East & Northern Africa (OR, 0.24; 95% CI, 0.12–0.50; p < 0.001), and Latin America regions (OR, 0.31; 95% CI, 0.16–0.59; p < 0.001). They were more frequently subspecialized in spine degeneration (OR, 5.27; 95% CI, 2.06–13.98;

Table 4. Multivariate logistic regression model showing the association between overall spine case volume and study covariates

Covariate	OR	95% CI	p-value
AO Spine region			
Europe & Southern Africa (reference)			
Asia Pacific	0.40	0.21–0.75	0.005*
Latin America	0.31	0.16–0.59	< 0.001*
North America	3.02	0.90–14.03	0.104
Middle East & Northern Africa	0.24	0.12–0.50	< 0.001*
Specialty			
Orthopedics (reference)			
Neurosurgery	1.63	0.96–2.81	0.072
Subspecialty†			
Degeneration	5.27	2.06–13.98	0.001*
Deformity	0.81	0.52–1.25	0.338
Trauma/spinal cord injury	0.55	0.32–0.92	0.026*
Tumor	2.10	1.28–3.48	0.003*
Community			
Urban (reference)			
Suburban	0.59	0.34–1.05	0.071
Rural	0.69	0.25–2.03	0.487
Fellowship training‡	2.82	1.74–4.60	< 0.001*
LDH surgery cases			
≤ 50 cases/yr (reference)			
> 50 cases/yr	8.41	4.26–18.01	< 0.001*
Main indication for elective surgery			
Failed conservative treatment (reference)			
Patient willing to undergo surgery	0.95	0.34–2.69	0.918
Neurological status	1.64	0.85–3.09	0.131
Debilitating pain	1.16	0.54–2.50	0.670
Failed epidural steroid injection(s)	1.71	0.48–7.05	0.425
Preferred discectomy approach			
Partial discectomy (reference)			
Sequestrectomy	0.98	0.57–1.70	0.930
Radical discectomy	0.21	0.11–0.41	< 0.001*
Fusion on primary surgery	0.25	0.06–1.10	0.060

OR, odds ratio; CI, confidence interval; LDH, lumbar disc herniation. *p < 0.05, statistically significant differences. †Being a subspecialist in a specific spine field (i.e., having answered "yes") was set as the reference. ‡Having undergone fellowship training (i.e., having answered "yes") was set as the reference.

Table 5. Multivariate logistic regression model showing the association between number of yearly LDH surgeries (> 50/yr) and study covariates

Covariate	OR	95% CI	p-value
AO Spine region			
Europe & Southern Africa (reference)			
Asia Pacific	1.26	0.77–2.09	0.359
Latin America	0.50	0.28–0.90	0.021*
North America	0.77	0.37–1.53	0.104
Middle East & Northern Africa	1.04	0.56–1.95	0.899
Specialty			
Orthopedics (reference)			
Neurosurgery	2.05	1.36–3.09	< 0.001*
Subspecialty†			
Degeneration	0.66	0.19–1.95	0.478
Tumor	0.93	0.62–1.39	0.710
Hospital setting			
Academic/university hospital (reference)			
Private practice	1.24	0.77–1.98	0.377
Public hospital or government/ military hospital	1.21	0.76–1.92	0.429
Spine surgical volume			
≤ 50 cases/yr (reference)			
> 50 cases/yr	7.36	3.89–15.08	< 0.001*
LDH cases seen in the office			
≤ 30 cases/mo (reference)			
> 30 cases/mo	6.33	4.32–9.37	< 0.001

OR, odds ratio; CI, confidence interval; LDH, lumbar disc herniation. *p < 0.05, statistically significant differences. †Being a subspecialist in a specific spine field (i.e., having answered "yes") was set as the reference.

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p = 0.001) and tumors (OR, 2.10; 95% CI, 1.28–3.48; p = 0.003) and less commonly in trauma and spinal cord injury (OR, 0.54; 95% CI, 0.32–0.92; p = 0.026). Additionally, these respondents were more frequently fellowship-trained (OR, 2.82; 95% CI, 1.74–4.60; p < 0.001), performed a higher number of LDH surgeries (OR, 8.41; 95% CI, 4.26–18.01; p < 0.001), and were less likely to perform a radical discectomy (OR, 0.25; 95% CI, 0.06–1.10; p < 0.001) (Table 4).

Surgeons performing a higher number of LDH surgeries were less frequently based in Latin America (OR, 0.50; 95% CI, 0.28–0.90; p = 0.021) and were more often neurosurgeons (OR, 2.05; 95% CI, 1.36–3.09; p = 0.001). Furthermore, these surgeons also tended to have a generally higher spine surgical volume (OR, 7.36; 95% CI, 3.89–15.08; p < 0.001) and to see a greater number of patients with LDH per month (OR, 6.33; 95% CI, 4.32–9.37; p < 0.001) (Table 5).

DISCUSSION

This study provides a comprehensive international perspective on current practice patterns among AO Spine members regarding the surgical management of primary LDH. Our findings highlight significant variability in decision-making processes, including indications for surgery, preferred surgical techniques, and approaches, which reflect differences in regional practices and surgeon training. Our results indicate that neurological status was the most influential factor in deciding surgical intervention in nonurgent LDH cases. This finding aligns with existing literature emphasizing the importance of preserving neurological function in surgical decision-making.[1] Debilitating pain and failed conservative treatment also ranked highly, underscoring the role of symptom severity in determining the need for surgery.[2] Interestingly, patient preference to undergo surgery was the least significant factor, suggesting that clinical necessity primarily drove treatment decisions rather than patient demand. In urgent cases, bladder and/or bowel dysfunction and severe progressive motor deficits were the dominant indications for immediate surgery, consistent with established guidelines for emergent intervention in case of cauda equina syndrome.[11]

The study reveals a preference for mini-open techniques, utilizing either a surgical microscope or loupes, as the most common approach for primary LDH surgery. This trend reflects the shift toward less invasive procedures that balance adequate visualization with minimal tissue disruption.[12] Conventional open surgery remains a common approach, likely due to surgeon familiarity and perceived reliability. Endoscopic approaches accounted for approximately 11% of the reported preferred surgical approaches in our cohort; while emerging,[13] they remain a minority technique within AO Spine respondents and warrant dedicated studies to characterize adoption barriers and outcomes. Regarding disc space approaches, partial laminotomy was the most frequently reported technique, followed by hemilaminotomy and laminectomy. These preferences reflect a tendency toward procedures that provide sufficient decompression while maintaining spinal stability. In most cases of LDH, a complete laminectomy is unnecessary, whereas partial laminotomy has been linked to lower rates of iatrogenic instability and improved clinical outcomes.[14] Similarly, partial discectomy emerged as the most commonly performed discectomy technique, aligning with evidence suggesting comparable reherniation rates to more aggressive disc excision, which has been linked to increased risks of chronic low back pain and segmental degeneration.[15]

Our multivariate logistic regression analysis identified significant variations in practice patterns based on regionality and surgeon characteristics. Orthopedic surgeons were more commonly based in the Asia Pacific region, and demonstrated a lower tendency to perform high-volume LDH surgeries than neurosurgeons. This trend was reported in a large database study, which found that neurosurgeons performed 70.6% of discectomies, while orthopedic surgeons accounted for the remaining 29.4%. Several factors may contribute to this difference, including variations in surgical indications, patient demographics, and case mix.[16] Furthermore, orthopedic surgeons preferred open surgical techniques, whereas neurosurgeons were more inclined toward minimally invasive approaches. This may be attributed to neurosurgeons' general familiarity with surgical microscopes and microsurgical techniques. Fellowship-trained surgeons were more commonly found outside Europe and Southern Africa, especially in North America and Asia Pacific regions. This regional disparity may reflect global differences in post-residency training patterns, as North American surgeons are more likely to complete a structured educational program including a spine fellowship as part of their training compared to healthcare and academic systems in other regions of the world.[17] Fellowship-trained surgeons also reported higher spine surgery volumes and were less likely to practice in public or government hospitals, suggesting that specialized training may be associated with higher procedural caseloads and greater involvement in private or academic settings.

The observed heterogeneity in surgical management strategies in this and other studies underscores the need for continued efforts to develop standardized, evidence-based guidelines

for LDH treatment. While variations in practice may be influenced by resource availability, training background, and healthcare system structures, identifying best practices through high-quality comparative studies could help harmonize decision-making globally.[10] Future research should focus on long-term outcomes associated with different surgical techniques, particularly the impact of minimally invasive versus open approaches on reherniation rates, recovery times, and patient-reported outcomes. Although multiple meta-analyses suggest that novel minimally invasive techniques yield outcomes that are comparable or slightly superior to conventional methods, the existing evidence is often subject to significant bias. This limitation may obscure the true magnitude of any potential benefits, underscoring the need for high-quality, more rigorous studies.[15,18] Additionally, our findings emphasize the importance of surgeon education and training in shaping practice patterns. Expanding access to advanced surgical training programs, particularly in regions with limited exposure to newer techniques, may help bridge the gap between traditional and evolving surgical paradigms.

This study has several limitations. First, the questionnaire was circulated to all AO Spine surgical members, and we do not have access to AO Spine's regional membership counts or invitation-delivery logs; therefore, precise response rates and formal measures of sampling representativeness by region cannot be calculated from the data available to the authors. Indeed, some regions, especially North America, were particularly underrepresented compared to others, such as Europe & Southern Africa and Asia Pacific. The limited number of responses from these regions might have skewed the results toward the small sample of practitioners who answered the survey. The reliance on self-reported survey data introduces the potential for response bias. While efforts were made to include a diverse global sample, the results may not fully represent all spine surgeons' practice patterns. Additionally, variations in regional healthcare infrastructure and access to surgical technologies were not explicitly analyzed, which may also influence treatment preferences. While endoscopic approaches are increasingly discussed in the literature, in our sample they represent a minority (11%) of the reported preferred approaches. Therefore, dedicated investigations are needed to clarify adoption trends, training needs, and barriers to implementation among AO Spine practitioners.

CONCLUSION

The findings of this study highlight the diverse factors influencing surgical decision-making, including neurological status, pain severity, and failed conservative treatment. While mini-open techniques and partial discectomy remain the preferred approaches, there is growing adoption of minimally invasive strategies. Significant regional and training-related variations exist, underscoring the need for standardized guidelines and further research to optimize patient outcomes.

NOTES

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