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Role of surgery in primary lumbar disk herniation: WFNS spine committee recommendations

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ABSTRACT

Objective: To provide the most up-to-date recommendations on the role of surgery in first-time lumbar disk herniations (LDH) in order to standardize surgical management.

Methods: We performed a literature search in PubMed, Scopus, and Embase from 2012 to 2022 using the following keywords: "lumbar disk herniation AND surgery". Our initial search yielded 2610 results, which were narrowed down to 283 papers after standardized screening critera were applied. The data from these 283 papers were presented and discussed at two international meetings of the World Federation of Neurosurgical Societies (WFNS) Spine Committee, where the Delphi method was employed and ten spine experts voted on five final consensus statements.

Results: and Conclusions: The WFNS Spine Committee's guidelines cover four main topics: (1) role and timing of surgery in first-time LDH; (2) role of minimally invasive techniques in LDH; (3) extent of disk resection in LDH surgery; (4) role of lumbar fusion in the context of LDH. Surgery for LDH is recommended for failure of conservative treatment, cauda equina syndrome, and progressive neurological impairment, including severe motor deficits. In the latter cases, early surgery is associated with faster recovery and may improve patient outcomes. Minimally invasive techniques have short-term advantages over open procedures, but there is insufficient evidence to make a recommendation for or against the choice of a specific surgical procedure. Sequestrectomy and standard microdiscectomy demonstrated similar clinical results in terms of pain control, recurrence rate, functional outcome, and complications at short and medium-term follow-up. Lumbar fusion is not recommended as a routine treatment for first-time LDH, although it may be considered in specific patients affected by chronic axial pain or instability.

1. Introduction

Lumbar Disk Herniation (LDH) is a common disease that affects adults worldwide, with a reported incidence of 2–3%.[1] It represents the most common cause of low back and leg pain and may significantly affect a patient's quality of life. While the majority of patients recover with conservative treatment (including medications and physical therapy, which are addressed in a separate WFNS consensus manuscript in this edition), some are refractory to conservative treatment and present persistent, aggravated, or recurrent symptoms. These patients may require surgical intervention to alleviate their short-term symptoms and improve long-term outcomes.[2,3] Multiple surgical techniques are routinely utilized, including the removal of disc fragments only (sequestrectomy) versus a more aggressive removal of disc fragments and disc material in the disc space (conventional microdiscectomy). Either technique may be performed via an open or minimally invasive approach, including either a tubular retractor with a microscope or endoscope.[4,5]

Especially for very common procedures which are performed extensively worldwide, it is important to continuously update our gold standards and to apply the most recent advances and literature to our

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Abbreviations

APLD	Automated Percutaneous Lumbar Discectomy
BP	Bodily Pain Scale
CCT	Controlled Clinical Trials
CES	Cauda Equina Syndrome
CESI	Cauda Equina Syndrome – Incomplete
CESR	Cauda Equina Syndrome – Retention Type
CI	Confidence Interval
CN	Chemonucleolysis
DVT	**Deep Vein Thrombosis**
HR	Hazard Ratio
IL-PED	percutaneous interlaminar endoscopic discectomy
IS	**Interspinous Spacer**
LDH	Lumbar Disk Herniation
LBP	Low Back Pain
LF	Lumbar Fusion
LOE	Level of Evidence
MD	**Microdiscectomy**
MED	Microendoscopic Technique
MID	Minimally Invasive Discectomy
MMT	Manual muscle testing
MRC	Medical Research Council scale for muscular strength
MRI	Magnetic Resonance Imaging
NRPT	Non-Randomized Prospective Trial
OD/OMD	Open discectomy/Open microdiscectomy
ODI	Oswestry Disability Index scale
OR	Odds Ratio
PD	Percutaneous Discectomy
PED	Percutaneous Endoscopic Discectomy
PLDD	Percutaneous Laser Disk Decompression
PTED	Percutaneous Transforaminal Endoscopic Discectomy
PF	Physical Function Scale
PLIF	Posterior Lumbar Intersomatic Fusion
PS	Prospective Study
QRCT	Quasi-Randomized Controlled Trial
RCT	Randomized Controlled Trial
RD	Re-discectomy
rLDH	Recurrent Lumbar Disk Herniation
RS	Retrospective Study
SF	Spinal Fusion
SMD	Standard Mean Difference
TD	Tubular Discectomy
UTI	Urinary Tract Infection
VAS	Visual Analogue Scale
WFNS	World Federation of Neurosurgical Societies

clinical practice. The goal of this manuscript is to provide a comprehensive systematic review regarding the management of first-time LDH and to formulate up-to-date, evidence-based recommendations focused on the role of surgery in LDH, which can be followed by practicing spine surgeons across the globe. The World Federation of Neurosurgical Societies (WFNS) Spine Committee formulated five final consensus statements on the following topics: (1) role and timing of surgery in first-time LDH; (2) role of minimally invasive techniques in LDH; (3) extent of disk resection in LDH surgery; and (4) role of lumbar fusion in the context of LDH.

2. Methods

2.1. Literature review

We performed a systematic literature review in PubMed, Scopus, and Embase from 2012 to 2022 using the following keywords: "lumbar disk herniation AND surgery". This initial search yielded 2610 results. Duplicate articles and those without full text available, not in the English language, clinically non-relevant studies (i.e. very small cohorts and technical notes), non-human studies, and case reports were excluded. Four separate reviewers performed the screening process, resulting in 283 articles that were used in the final analysis. The screening methodology is shown in Fig. 1 and adhered to PRISMA guidelines. Final selection was performed in order of priority based on the analysis of Levels of Evidence. The selected articles were then subdvided according to Level I through IV Evidence andcovering the following topics: (1) role and timing of surgery in first-time LDH; (2) role of minimally invasive techniques in LDH; (3) extent of disk resection in LDH; and (4) role of lumbar fusion in the context of LDH surgery.

2.2. Consensus meetings

These 283 papers provided the foundation for the presentation at two separate international meetings of the World Federation of Neurosurgical Societies (WFNS) Spine Committee, the first held in Karachi, Pakistan in May 2022, and the second held in Istanbul, Turkey, in September 2022. Utilizing the Delphi method, ten international spine surgery experts created, revised, and then voted on five final consensus statements on the role of surgery in LDH. The following Likert scale was used for voting: 1 to 5 (1 = strongly disagree, 2 = disagree, 3 = somewhat agree, 4 = agree, 5 = strongly agree). Responses 1 or 2 were considered disagreement; 3, 4, or 5 were considered agreement. Consensus was achieved when the sum for disagreement or agreement was $\geq$66%.

3. Results and discussion

3.1. Role and timing of surgery in first-time LDH

Many studies show high rates of symptomatic improvement and even complete resolution with conservative treatment of first-time lumbar disc herniations (LDH). A systematic review of 11 cohort studies by Zhong et al reported that 66% of LDH spontaneous resorb.[6] Another systematic review published in 2015 found a rate of spontaneous regression of 96% for disc sequestration, 70% for disc extrusion, 41% for disc protrusion, and 13% for disc bulging. Complete disc resolution was reported for 43% of sequestrated discs and 15% of extruded discs.[7]

In their 2016 *New England Journal of Medicine* article, Deyo and Mirza recommend surgery for first-time LDH if patients have severe or progressive neurologic deficits with congruent clinical and MRI findings and/or if they fail conservative treatment for 6 weeks. The major benefit of surgery is represented by the immediate relief of symptoms, if compared to conservative treatment, and results of early surgery versus prolonged conservative treatment appear similar at 1-year follow-up.[8] Similar conclusions are drawn by Bailey at al, who report that microdiscectomy is superior to non-surgical care in reducing pain intensity at six months, as resulted by their analysis of a 128 patients with sciatica due to LDH cohort.[9] Another study by Gugliotta and colleagues finds faster relief from back pain symptoms in patients treated with surgery as compared to conservative care, but did not show a difference in mid- or long-term outcomes.[10]

The Spine Patient Outcome Research Trial (SPORT) trial is the most rigorous and largest randomized trial addressing the role of surgery for LDH. This study included 501 prospective randomized participants and 743 observational patients treated at 13 United States medical centers with 8 years of follow-up. Eligible patients presented with symptoms of lumbar radiculopathy persisting for at least six weeks, with a disc

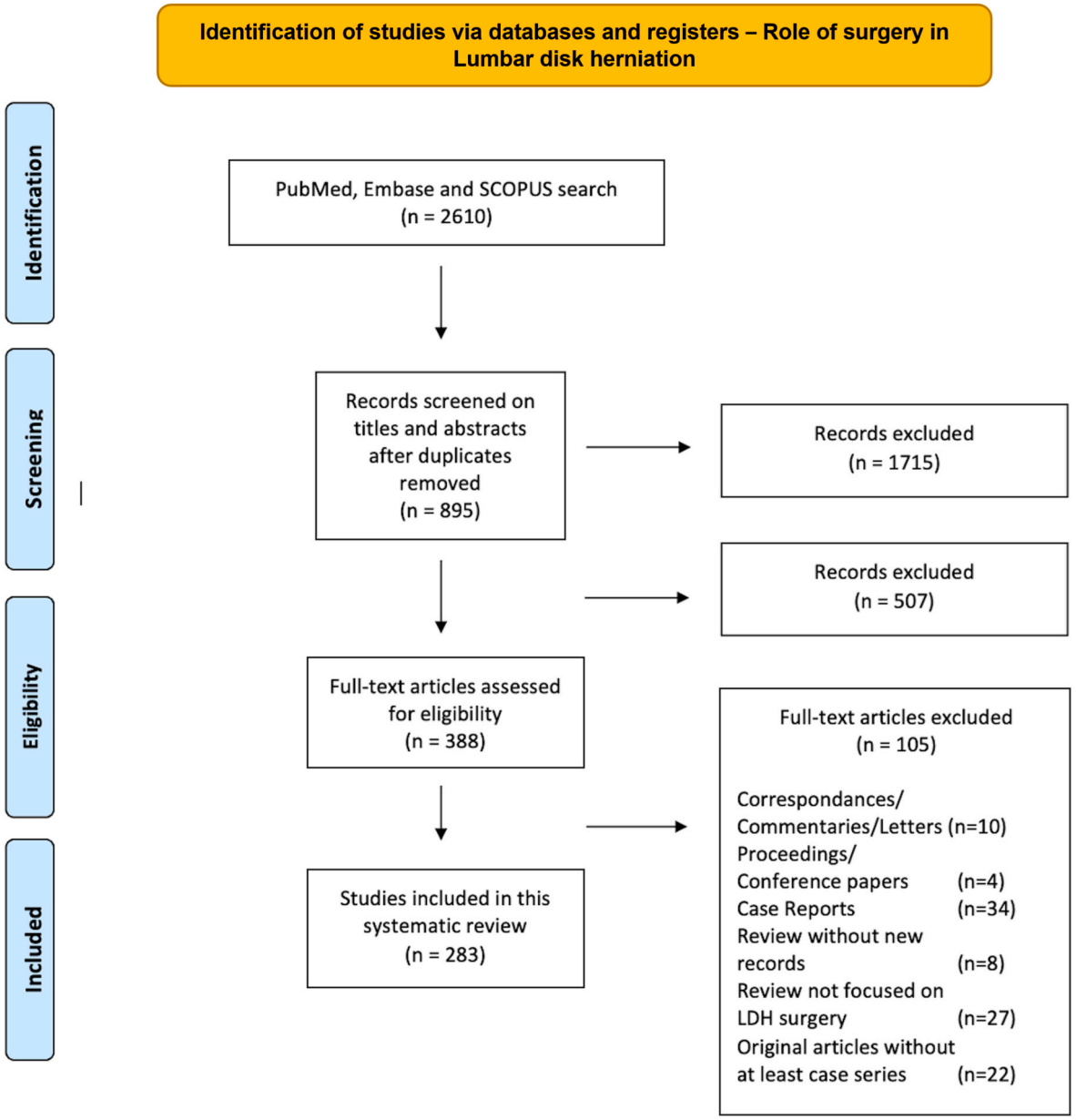

Fig. 1. Flowchart for literature search and article screening process.

herniation at the corresponding level and side on imaging, who were being considered for surgery.[11] The authors concluded that carefully selected patients, who underwent surgical intervention, demonstrated better outcomes if compared to non-operative patients. In the as-treated analysis, the treatment effect for surgery was seen as early as 6 weeks, appearing to reach a maximum by 6 months, persisting forover 8 years. There was little to no degradation of outcomes in either group (operative and non-operative) between 4 and 8 years.

Synthesizing the recently published guidelines (23 recommendations on LDH since 2011)[12–16] surgical intervention with microdiscectomy is recommended when there is a failure of conservative therapy or when progressive/persistent disability is present (see Table 1). This is consistent with the 2014 North America Spine Society guidelines that provide the following grade B recommendation:[15] "*Discectomy is a procedure able to provide more effective symptom relief than medical/-interventional care for patients with LDH with radiculopathy whose symptoms warrant surgical intervention*". Moreover, "*surgical intervention before* 6 months *is suggested in patients with symptomatic lumbar disc herniation whose symptoms are severe enough to warrant surgery. Earlier surgery (within* 6 months *to 1 year) is associated with faster recovery and improved long-term outcomes.*"

In a 2014 review, Balaji et al evaluated the role of surgical treatment for LDH with motor deficit (specifically a Medical Research Council (MRC) grade$\leq$3 out of 5). They found a 6.4% improvement in recovery rate in patients treated operatively for LDH with motor deficit as compared to those treated non-operatively.[17] Subsequent studies further revealed that pre-operative motor strength and time to surgery were the most important predictors of foot drop improvement caused by LDH, and that the median time to foot drop improvement after surgical intervention was 6 weeks.[18,19] Another systematic review and similar works reported that longer symptoms duration pre-operatively adversely impacts post-operative recovery, and suggested that "six months" may represent the cut-off beyond which surgical intervention does not improve functional outcome.[20,21]

The timing of surgery acquires particular importance in the setting of both incomplete and retention-type Cauda Equina Syndrome (CESI and CESR, respectively), which are covered in detail in a separate manuscript within this special edition of *World Neurosurgery X*.

Table 1
Summary of most relevant literature data regarding the role and timing of surgery in LDH. BP: Bodily Pain scale; CES: cauda equina syndrome; CESI: incomplete cauda equina syndrome; CESR: cauda equina syndrome with urinary retention; CI: confidence interval; HR: hazard ratio; LDH: lumbar disc herniation; MMT: manual muscle testing; MRC: Medical Research Council scale for muscular strength; MRI: magnetic resonance imaging; ODI: Oswestry Disability Index scale; PF: Physical Function Scale; RCT: randomized controlled trial.

Authors	Year	Study type	Objective	Level of Evidence	Number of studies included	Number of patients included	Main Result	Conclusions
Zhong et al.[6]	2017	Systematic review of prospective/ retrospective studies	• To analyze the incidence of spontaneous resorption after conservative treatment of LDH using CT and MRI	IIb	11 Prospective/ Retrospective studies	587	• Overall incidence of spontaneous resorption after LDH was 66.66% (95% CI 51%–69%). • Incidence in the United Kingdom was 82.94% (95% CI 63.77%–102.11%), while iincidence in Japan was 62.58% (95% CI 55.71%–69.46%).	• Given high rate of disk spontaneous resorption, conservative treatment may become first choice of treatment for LDH.
Chiu et al.[7]	2015	Systematic review of Prospective/ Retrospective studies	• To determine the probability of spontaneous disc regression among each type of lumbar herniated disc	IIb	31 Prospective/ Retrospective studies	361	The rate of spontaneous regression was found to be: −96% for disc sequestration −70% for disc extrusion −41% for disc protrusion, −13% for disc bulging. The rate of complete resolution of disc herniation was: −43% for sequestrated discs 15% for extruded discs	• There are high rates of spontaneous disc regression with conservative treatment. Patients with disc extrusion and sequestration had a significantly higher possibility of spontaneous regression than those with bulging or protruding discs. Disc sequestration had a significantly higher rate of complete regression than disc extrusion.
Lurie et al.[11]	2014	RCT	• To assess the 8-year outcomes of surgery vs. non-operative care of the SPORT trial	Ib	/	1244 (743 observational cohort, 501 prospective randomized cohort)	• Intent-to-treat analysis showed advantage in all primary and secondary outcomes (including sciatica bothersomeness, satisfaction with symptoms and self-rated improvement; not work status) for surgery versus conservative care. There was significant non- adherence to treatment assignment, however: 49% patients assigned to non-operative therapy ended up receiving surgery versus 60% of patients assigned to surgery. As-treated analysis showed clinically meaningful benefit for surgical treatment for primary outcome measures: Mean change Surgery vs. n Non-operative; treatment effect; 95% CI): Bodily Pain Scale (45.3 vs. 34.4; 10.9; 7.7 to 14); Physical Function Scale (42.2 vs. 31.5; 10.6; 7.7 to 13.5) and Oswestry Disability Index (−36.2 vs. −24.8; −11.2; −13.6 to −9.1).	• Carefully selected patients who underwent surgery for a LDH had better outcomes than conservatively treated patients. No significant change at 4–8 years post-op.
Gugliotta et al.[10]	2016	Prospective cohort study	• To compare short- and long-term effectiveness of surgical	IIb	/	370	• Surgical patients reported less back pain at 6 weeks than	• Compared with conservative therapy, surgical treatment for

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Table 1 (*continued*)

Authors	Year	Study type	Objective	Level of Evidence	Number of studies included	Number of patients included	Main Result	Conclusions
			and conservative treatment in sciatic symptom severity and quality of life in patients with LDH				conservative group (−0.97; 95% CI −1.89 to −0.09), were more likely to report ≥50% decrease in back pain from baseline to 6 weeks (48% vs 17%, risk difference: 0.34; 95% CI 0.16 to 0.47), and reported less physical function disability at 52 weeks (−3.7; 95% CI −7.4 to −0.1). No other significant differences between groups reported.	LDH provided faster relief from back pain symptoms, but did not show a benefit in midterm and long-term follow-up.
Deyo et al.[8]	2016	Review	To provide a review on clinical management and natural history of LDH	III	Not specified	Not specified	Surgery is an option for patients with pain that persists beyond 6 weeks, as long as they have exam findings and MRI congruent with symptoms. Patients and physicians should participate in shared decision making, carefully reviewing potential risks and benefits. Patients should be informed that surgery provides faster relief of leg pain than conservative therapy, but that surgical and conservative outcomes generally do not differ significantly at 1 year.	•Same as Results
Bailey et al.[9]	2020	RCT, single center	• To determine whether diskectomy or a conservative approach is better for sciatica≥4 months	Ib	/	790	• At baseline, mean leg pain intensity score was 7.7 in the surgical group vs 8.0 in the nonsurgical group. The primary outcome of leg pain intensity at 6 months was 2.8 in the surgical group vs 5.2 in the nonsurgical group ($P < 0.001$).	• Microdiscectomy was superior to nonsurgical care in reducing leg pain intensity at 6 month follow-up.
Balaji et al.[17]	2014	Systematic review of Prospective/ Retrospective studies	• To define whether surgical intervention is beneficial in patients with severe motor weakness (defined by MRC grade of 3 or less) due LDH and to understand if time to surgery from onset of motor weakness or other factors influence outcome	IIb	7 (1 RCT, 6 Prospective/ Retrospective studies)	354	• For patients with motor weakness (MRC ≤ 3/5 due to LDH), complete motor recovery was seen in 38.4% of patients following surgery and 32% following nonoperative treatment. Age and grade of motor deficit were identified as significant prognostic factors in some studies.	Future high-quality evidence needed to better address these questions.
Macki et al.[18]	2016	Retrospective study	• To measure prognostic factors and time to foot drop improvement after lumbar decompression	IIIb	/	71	• Dorsiflexion function improved postoperatively in 73.2% ($n = 52$) patients, with mean follow-up of 30.4 months. Median time to surgery from onset of foot drop was 6 weeks, and the median preoperative manual	Preoperative muscle strength and palsy duration were statistically significant predictors of foot drop improvement. Median time to improvement was 6 weeks after surgery.

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Table 1 (*continued*)

Authors	Year	Study type	Objective	Level of Evidence	Number of studies included	Number of patients included	Main Result	Conclusions
							muscle testing strength of patients with foot drop improvement was 3 out of 5. Duration of anterior tibialis and pre-operative muscle strength were significant predictors of foot drop improvement. Median time to foot drop improvement was within 6 weeks of surgical intervention.	
Petr et al.[19]	2019	Retrospective study	To assess the impact of time to surgery in patients with motor deficits motor deficits on their functional outcome.	IIb	/	330 participants	Group I (paresis <48 h, vs. Group II, all patients with paresis >48 h) showed significantly faster recovery of moderate/severe paresis (MRC 0–3) at discharge, and 6-weeks/3-months follow up ($P \leq 0.001$), whereas there were no significant differences in recovery for mild paresis (MRC 4). Sensory deficits also recovered substantially faster in Group I at 6-weeks ($P = 0.003$) and 3-months follow up ($P = 0.045$). Body mass index, preoperative MRC-grade, and duration of MDs were identified as significant predictors for recovery of paresis at all follow ups with substantial impact on patient reported outcomes including sciatica and/or dermatomal sensory deficits.	Given the superior rates of neurological recovery of acute moderate/severe motor deficits, immediate surgery should be the primary option.
Schoenfeld et al.[20]	2015	Systematic review of Prospective/ Retrospective studies	•To determine if symptomatic duration before surgery influence functional recovery after lumbar discectomy and what is the time point for intervention beyond which the extent of postoperative recovery might be compromised	IIb	11 Prospective and Retrospective studies	2949	•Longer symptom duration adversely impacted post-op recovery. There were significant differences among duration reported by individual studies, ranging from 2 to 12 months. Several studies showed that surgery≥6 months after symptom onset may not lead to post-op recovery.	•Longer symptom duration had an adverse impact on post-op outcomes. A possible point beyond which outcomes may be compromised is 6 months after symptom onset.
Siccoli e al.[21]	2019	Prospective study	To quantify the association of time to surgery with leg pain outcome after lumbar discectomy and to identify a maximum time to surgery cutoff anchored to the minimum clinically important difference	IIb	/	372 participants	From a prospective registry, 372 patients who had undergone first-time tubular microdiscectomy were identified; 308 of these patients (83%) obtained a minimum clinically important difference. Attaining such outcome was associated with a shorter time to surgery (HR 0.718, 95% CI 0.546–0.945, p = 0.018), and the optimal maximum time to surgery was estimated at 23.5 weeks based on the AUC,	The study findings suggest that late lumbar discectomy is linked with poorer patient-reported outcomes and that-in accordance with the literature-a maximum time to surgery of 6 months should be aimed for.

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Table 1 (*continued*)

Authors	Year	Study type	Objective	Level of Evidence	Number of studies included	Number of patients included	Main Result	Conclusions
							while the cutoff-specific method suggested 24 weeks. The 24-week cutoff also coincided with the time point after which the specificity for minimum clinically important first drops below 50% and after which the negative predictive value for nonattachment of minimum clinically important difference first surpasses ≥20%.	

4. Role of minimally invasive techniques in LDH

The surgical treatment of LDH has evolved over the past years, with the progressive availability of different minimally invasive techniques (including tubular microscopic, also known as microendoscopic discectomy, and percutaneous endoscopic disectomy) that have been introduced as alternatives to the standard open lumbar discectomy. A 2014 Cochrane review found that leg and back pain relief may be worse in minimally invasive versus open techniques. Furthermore, rehospitalization rates, in particular for discrecurrence, may be higher in minimally invasive techniques, although su ch differences resulted to be very small and may not be clinically meaningful. Potential advantages for minimally invasive techniques include lower risk of surgical site and other infections, as well as shorter hospital stays, but the evidence was inconsistent.[22] Another meta-analysis reported decreased blood loss, shorter hospital stay, and faster return to work in minimally invasive versus open discectomy for LDH.[23] Similarly, the analysis of a total of 1707 patients across 15 RCTsby Alvi and colleagues lead to the conclusion that minimally invasive approaches (specifically, tubular microscopic disectomy and percutaneous endoscopic discectomy) had better ODI scores, shorter length of hospital stay, and less blood loss, but higher rates of dural tears, overall complications, recurrent herniations, and revision LDH surgery than open discectomy.[24] However, other meta-analyses found no significant difference in clinical outcomes between tubular and open discectomy, specifically with regards to re-operation rates, dural tears, VAS score, operative time, or length of hospital stay.[25,26]

In their 2017 meta-analysis including 29 RCTs and 3146 patients, Cai et al suggested that percutaneous endoscopic discectomy may have a higher success rate and lower complication rate than other discectomy techniques, although open discectomy demonstrated the lowest re-operation rate.[27] Similarly, a 2021 meta-analysis of 22 RCTs concluded that percutaneous endoscopic discectomy had the lowest dural tear and intra-op complication rate, as well as the highest rate of pain improvement.[28] These authors argued that endoscopic discectomy demonstrates an excellent safety and efficacy profile, recommending the endoscopic techniquefor LDH management.

Taken together, many recent studies suggest that endoscopic discectomy is a promising minimally invasive technique for treatment of LDH, particularly as it can be done in an outpatient setting with same-day discharge. Outcomes for percutaneous endoscopic discectomy were found to be similar to microendoscopic discectomy in a randomized controlled trial with two-year follow-up.[29] In this particular study, percutaneous endoscopic discectomy was not as effective for median disc herniations, whereas micro-endoscopic discectomy did not appear to be a good option for far lateral disk herniations.[29] In a similar work, the endoscopic techniques resulted to be non-inferior to open microdiscectomy in reduction of leg pain, conversely resulting in more favourable results for self-reported leg pain, back pain, functional status, quality of life, and recovery.[30] Another meta-analysis shows that percutaneous endoscopic discectomy had shorter incision length, less blood loss, shorter post-operative in-bed time, shorter hospital stay, and better VAS back pain scores, while microendoscopic discectomy had less fluoroscopy time/exposure and lower re-operation rates.[30–32] Shorter hospital and in-bed times for percutaneous endoscopic discectomy were confirmed in additional studies.[3,29,33] However, another meta-analysis (Rickers et al, published in 2021 and covering 4877 patients across 32 RCTs) reported worse outcomes in terms of disability scores, pain scores, and re-operation rates for percutaneous endoscopic surgery as compared to open and tubular discectomy approaches.[34]

Given the mixed results offered by recent literature, it is not possible to recommend one type of treatment over the others for first-time LDH. Minimally invasive approaches including microendoscopic disectomy (also referred to as tubular discectomy) and percutaneous endoscopic discectomy appear to permit decreased blood loss, shorter hospital stays, and faster return to work times, but overall functional and pain outcomes are similar and re-operation rates may be higher than standard open discectomy. There is insufficient evidence to make a recommendation for or against a specific surgical approach for treatment of first-time LDH (see Table 2).

4.1. Extent of disk resection in LDH surgery

There is still considerable debate regarding the role of sequestrectomy alone (resection of disc fragments) versus standard discectomy (removal of disc fragments and disc material) for treatment of LDH. The major studies that address this issue are presented in Table 3. In their meta-analysis of one RCT and five non-randomized prospective studies that included 764 patients, Azarhomayoun et al reported less analgesic consumption in the sequestrectomy group, but overall similar pain improvement, disc recurrence rate, functional outcome, and short and medium-term complications in sequestrectomy versus standard discectomy.[35] Similar outcomes between sequestrectomy and standard discectomy were confirmed in multiple other studies.[36–39] However, some suggest that disc recurrence rates may be higher in sequestrectomy as compared to discectomy patients (19% vs 10% in a study of 172 patients).[39] Conversely, a meta-analysis published in 2015 (including one RCT, five prospective, and six retrospective studies) reported less operative time, lower back pain VAS scores, less post-operative pain medication use, and higher patient satisfaction in sequestrectomy as compared to standard discectomy for LDH.[40]

Table 2
Summary of most relevant recent literature data regarding the role of minimally invasive techniques in LDH. APLD: automated percutaneous lumbar discectomy; CN: chemonucleolysis; EDH: extraforaminal disc herniation; IL-PED: interlaminar percutaneous endoscopic discectomy; LBP: low-back pain; LDH: lumbar disc herniation; MD: microdiscectomy; MED: microendoscopic discectomy (introduced by Foley, using a transmuscular approach with advanced optics); MID: minimal invasive discectomy; OD: open discectomy; ODI: Oswestry Disability Index; PED: percutaneous endoscopic discectomy (endoscopic discectomy performed thorugh a percutaneous access); PTED: Percutaneous transforaminal endoscopic discectomy (transforaminal endoscopic discectomy performed thorugh a percutaneous access); PLDD: percutaneous laser disc decompression; QRCT: quasi-randomized controlled trial; RCT: randomized controlled trial; TD: tubular discectomy; VAS: visual analogue score.

Authors	Year	Study type	Objective	Level of Evidence	Number of studies	Number of patients	Results/Conclusions
Rasouli et al.[22]	2014	Review	To compare the benefits and harms of minimally invasive diskectomy versus open discectomy for management of LDH	Ia	11 RCTs/QRCTs (7 with high risk of bias)	1172 participants	Low quality evidence suggests minimally invasive diskectomy is assocated with worse leg pain and LBP than open discectomy, with no significant difference at 1 year. There were no other significant differences between groups in terms of functional disability (ODI) or persistence of motor and sensory deficits. Minimally invasive discectomy had lower surgical site infection and other infection rates, but higher risk of re-hospitalization due to recurrent disk herniation. There were inconsistent results with regards to shorter hospital length of stay in minimally invasive vs open disectomy.
Akinduro et al.[23]	2017	Review and Meta-analysis	To compare open diskectomy vs minimally invasive diskectomy for extraforaminal LDH	IIa	41 Prospective or Retrospective studies	1813 patients	There was no significant difference in complication rate or patient satisfaction in open versus minimally invasive discectomy. Open discectomy group had greater estimated blood loss (MD: 38.6 mL), slightly longer operation time (MD: 12.2 min), longer hospital stay (MD: 30.3 h), and longer return to work time (MD: 3.3 weeks). Tubular discectomies had lower incidence of re-operation compared to open or endoscopic procedures.
Fang et al.[27]	2017	Meta-analysis	To evaluate the clinical results of seven different surgical interventions for the treatment of LDH	Ia	29 RCTs	3146 participants	Success rate (best to worst): Percutaneous endoscopic disectomy (PED) P> standard open discectomy (OD) > standard open microdiscectomy (MD) > chemonucleolysis (CN) > microendoscopic discectomy (MED) > percutaneous laser disc decompression (PLDD) > automated percutaneous lumbar discectomy (APLD) Complication rate (best to worst): PED > MD > OD > MED > PLDD > CN > APLD. Re-operation rate (best to worst): MD > OD > MED > PLDD > PED > CN > APLD. In summary, PED has the highest success rate and lowest complication rate, but MD has lowest re-operation rate. Higher quality RCTs are needed to confirm these results.
Wei et al.[28]	2021	Meta-analysis	To compare the outcomes of different surgical approaches for lumbar disc herniation (LDH).	Ia	22 RCTs	2529 patients	Compared with other approaches used to treat LDH, percutaneous endoscopic disectomy (PED) had the best efficacy, lowest dural tear, intra-operative, and overall complication rate. Tubular decompression (TD) had the lowest re-operation rate. The authors recommend PED for LDH.
Rickers et al.[35]	2021	Meta-analysis	To compare multiple surgical methods for LDH	Ia	32 RCTs	4877 Patients	All treatments (including annular repair and dynamic stabilization devices) were superior to conservative treatment and percutaneous discectomy. There was no significant difference in reoperation rates or change in disability score, regardless of treatment.
Alvi et al.[24]	2018	Meta-analysis	To evaluate outcomes of open versus minimally invasive discectomy apporoaches	Ia	15 RCTs	1707 patients	There were 782 patients undergoing open or microdiscectomy, 199 having tubular disectomy, 199 having percutaneous endoscopic discectomy, and 235 having percutaneous disectomy in this study. Open discectomy had significantly worse ODI, longer operative duration, and

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Table 2 (*continued*)

Authors	Year	Study type	Objective	Level of Evidence	Number of studies	Number of patients	Results/Conclusions
							higher blood loss. Tubular disectomy had greater rate of overall complications (odds ratio [OR] 1.49, $P = 0.002$), greater incidence of dural tears (OR 1.72 P [0.04), and higher rate of recurrent herniation (OR 2.09, $P = 0.0007$). Open diskectomy, however, was associated with significantly lower incidence of revision surgery (OR 0.53, $P = 0.0007$).
Arts et al.[25]	2011	Double-blinded RCT	To evaluate results of tubular discectomy vs conventional microdiscectomy	Ib	1 RCTs	328 patients	Patients undergoing tubular discectomy had more leg pain and lower back pain, although these differences were not clinically meaningful. There was no signfiiant difference in Roland–Morris Disability Questionnaire between the two groups.
Wang et al.[26]	2019	Meta-analysis	To evaluate the efficacy of tubular disectomy (TD) compared to open microdiscectomy (OMD) for LDH	Ia	4 RCTS	610 patients	There was no significant difference in VA scores, dural tear, re-operation, operative time, or hospital stay between tubular discectomy (TD) and open microdiscectomy (OMD). TD had improved ODI at 1 year post-op and lower blood loss, but worse SF-36 values than OMD.
Chen et al.[29]	2020	RCT	To compare clinical outcomes between percutaneous transforaminal endoscopic discectomy (PED) versus microendoscopic disectomy (MED)	Ib	RCT	250 patients	Over 2-year follow-up period, PED and MED had similar clinical outcomes and complication rates. PED had inferior results for median disc herniation, whereas MED did not appear to be the best option for far-lateral disc herniation. There was a higher rate of re-operation for LDH recurrence in the PED vs MED group (8.4% vs 4.1%).
Gadjradj et al[30]	2022	RCT	To assess whether percutaneous transforaminal endoscopic discectomy is non-inferior to conventional open microdiscectomy in reduction of leg pain caused by lumbar disc herniation.	Ib	RCT	613 participants	At 12 months, patients who were randomised to PTED had a statistically significantly lower visual analogue scale score for leg pain (median 7.0, interquartile range 1.0–30.0) compared with patients randomised to open microdiscectomy (16.0, 2.0–53.5). Blood loss was less, length of hospital admission was shorter, and timing of postoperative mobilisation was earlier in the PTED group. Secondary patient reported outcomes such as the Oswestry Disability Index, visual analogue scale for back pain, health related quality of life, and self-perceived recovery, were similarly in favour of PTED. Within one year, nine (5%) in the PTED group compared with 14 (6%) in the open microdiscectomy group had repeated surgery.
Ayer et al.[31]	2022	Systematic Review	To compare outcomes of minimally invasive versus open discectomy	Ib	9 RCTs	N/A	Based on review of the nine included studies, endoscopic discectomy is as effective as other surgical techniques, and has additional benefits of lower complication rate and superior perioperative parameters.
Xu et al.[32]	2020	Meta-analysis	To evaluate the midterm and long-term efficacy of PED versus MED for LDH	Ib	8 non-RCTs, 1 RCT	516 patients	There were no statistically significant differences in operative time, blood loss, leg pain VAS, overall complication rate, LDH recurrence, orre-operation between PED and MED groups. While there were no difference in LBP VAS or ODI within 2 years, PED had superior LBP VAS and ODI score after 2 years post-operatively, as compared to MED. PED group also had shorter length of incision (OR 2.302, 95% CI 2.789 to 1.815, P 1 = 0.000), shorter time in bed after operation (OR 3.060, 95% CI 4.988 to 1.132, $P = 0.002$), and shorter hospital stay (OR 1.041, 95% CI 1.493 to 0.583, $P = 0.000$) compared

(*continued on next page*)

Table 2 (*continued*)

Authors	Year	Study type	Objective	Level of Evidence	Number of studies	Number of patients	Results/Conclusions
							with the MED group. –
Shi et al.[33]	2019	Meta-analysis	To compare the clinical outcomes of PED and MED for the treatment of LDH	Ia	10 non-RCTs, 8 RCTs	2161 patients	There were no statistically significant differences between PED vs MED group for ODI, VAS leg pain, VAS unspecified, excellent/good outcome rate, total complication rate, dural tear rate, residual or recurrence rate, operative time, or total hospital cost. PED group had significantly shorter length of incision (MD − 1.18; 95% CI − 1.39 to − 0.97; $P < 0.00001$), less blood loss (MD − 45.17; 95% CI − 64.74 to − 25.60; $P < 0.00001$), shorter post-operative in-bed time (MD − 59.11; 95% CI − 71.19 to − 47.04; $P < 0.00001$), shorter post-operative hospital stay (MD − 3.07; 95% CI − 4.81 to − 1.33; $P < 0.00001$), shorter total hospital stay (MD − 2.29; 95% CI − 3.03 to − 1.55; $P < 0.00001$), and lower VAS-back pain at last follow-up (MD − 0.77; 95% CI − 1.31 to − 0.24; $P = 0.005$). However, PED had significantly worse fluoroscopy time (MD 7.63; 95% CI 5.25 to 10.01; $P < 0.00001$) and higher re-operation rate (OR, 2.67; 95% CI 1.07 to 6.67; $P = 0.04$) as compared to MED.

4.2. Role of lumbar fusion in the context of LDH surgery

LDH patients typically complain of radicular symptoms due to nerve compression as well as non-specific low back pain (LBP). This LBP is presumably associated with biomechanical alterations due to disc degeneration. As discussed in prior sections, lumbar discectomy is the established procedure to treat symptomatic LDH. Although spinal fusion can be performed for concomitant lumbar instability or severe low-back pain, this increases the complexity of the surgery, prolongs operative time, and potentially increases complication rates. In this analysis, we reviewed 179 papers (summarized in Table 4) specifically covering lumbar fusion in primary lumbar disc herniation herniated, as well as lumbar fusion in LDH recurrence (which is addressed specifically in another manuscript in this *World Neurosurgery X* special edition),

As stated in *the Journal of Neurosurgery: Spine* 2014 Guidelines Update, there are a large number of level I/II studies showing excellent results for patients with primary disc herniations having decompressive surgeries without lumbar fusion (LF).[12] There are low-quality studies (eight manuscripts with level IV/III evidence) concluding that LF is not recommended as a routine treatment following primary disc excision in patients with isolated herniated lumbar discs causing radiculopathy. It is a potential option in patients with chronic axial back pain, who work as manual laborers, have severe degenerative changes, or have spinal instability associated with radiculopathy.

Similar findings were reported in a prospective study of 103 patients that found no significant difference in ODI or VAS back and leg pain between patients undergoing discectomy alone versus discectomy plus interspinous spacer or discectomy plus posterior lumbar interbody fusion. Not surprisingly, the interspinous spacer and fusion groups had higher hospital cost and longer length of stay.[41] Another study reported similar ODI, VAS, recurrence rate, and adjacent segment degeneration in patients receiving interspinous spacer versus discectomy for primary LDH.[42]

In contrast to primary LDH, the role of lumbar fusion in lumbar disc *recurrence* is more controversial. In one study, the re-operation rate for single-level lumbar diskectomy is ~12.2% at four years; of these, greater than one third of re-operated patients require lumbar fusion.[43] A separate manuscript in this edition of *World Neurosurgery X* discusses the data pertaining to treatment of recurrent LDH. To briefly summarize that data here, patients with recurrent LDH and back pain symptoms may benefit from lumbar fusion, although complication rates, hospital stay, and blood loss are higher than discectomy alone.

4.3. WFNS recommendations for role of surgery in LDH

After summarizing and discussing the available literature, as outlined above, the WFNS achieved consensus on the following five statements. Voting for each consensus statement in shown in Table 5.

5. Role and timing of surgery in LDH

1) Surgery for LDH should be individualized. It is recommended for failure of conservative treatment, severe motor deficit, progressive neurological impairment, or cauda equina syndrome.
2) Earlier surgery in LDH is recommended in case of major motor deficit and is associated with faster recovery and potentially better motor outcomes.

6. Role of minimally invasive techniques in LDH

3) Although minimally invasive procedures have short term advantages, there is insufficient evidence to make a recommendation for or against the choice of a specific surgical procedure for LDH.

7. Extent of disc resection in LDH surgery

4) Sequestrectomy and standard microdiscectomy have similar clinical results in terms of pain control, recurrence rate, functional outcome, and short/medium term complications.

8. Role of lumbar fusion in the context of LDH

5) Lumbar fusion is not recommended as a routine treatment for patients with isolated herniated lumbar discs causing radiculopathy. Lumbar fusion may be considered in patients with herniated discs who have evidence of significant chronic axial back pain, have severe

Table 3
Summary of most relevant literature data regarding the extent of disk decompression in LDH. CCT: Controlled clinical Trials; CI: Confidence Interval; LDH: Lumbar Disk Herniation; LoE: Level of Evidence; NRPT: Non-Randomized Prospective Trial; OR: Odds Ratio; PS: Prospective Study, RCT: Randomized Controlled Trial; SMD: Standard Mean Difference; RS: Retrospective Study; VAS: Visual Analog Scale.

Study	Year of Publication	Study Design	Number of Studies Included	Level of evidence	Sample	Objective	Results	Conclusions
Azarhomayoun et al.[36]	2015	Systematic Review	4 Prospective studies and 1 RCT	1a	764 patients	To compare discectomy vs sequestrectomy in the treatment of LDH	There were no significant differences for leg pain, functional outcomes, complications, and hospital stay or recurrence rate for 2 years in sequestrectomy vs discectomy. Sequestrectomy was associated with less analgesic consumption versus discectomy All studies had high bias risk.	No significant difference in outcomes for sequestrectomy vs discectomy.
Fakouri et al.[37]	2015	Systematic Review	2 RCTs and 5 Retrospective studies	1a	7 studies	To compare discectomy vs sequestrectomy in the treatment of LDH	VAS score improvement: 5.6 to 6.5 points in microdiscectomy groups vs 5.5 to 6.6 in sequestrectomy group Re-herniation rate: 2.3%–11.8% in discectomy vs 2%–12.5% in sequestrectomy	Similar VAS score improvements and re-herniation rates were seen in discectomy vs sequestrectomy.
Ran et al.[41]	2015	Systematic Review	16 Prospective studies, 1 RCT, 6 Retrospective studies	1a	1648 patients	To compare discectomy vs sequestrectomy in the treatment of LDH	Sequestrectomy was associated with significantly less operative time ($p < 0.001$), lower VAS for low back pain ($p < 0.05$), less post-operative analgesic usage ($p < 0.05$), and higher patient satisfaction ($p < 0.05$) There was no significant difference in recurrent herniation rate, reoperation rate, intraoperative blood loss, hospitalization duration and VAS for sciatica between sequestrectomy and discectomy.	Sequestrectomy may provide some benefits over discectomy.
Shamji et al.[40]	2014	Retrospective Study	/	3b	172 patients	To compare discectomy vs sequestrectomy in the treatment of LDH	85% patients improved regardless of procedure at 3 months. There was no significant difference in blood loss, operative time, or hospital stay in discectomy vs sequestrectomy. Recurrent herniation at 6 year median follow-up was lower in diskectomy patients. Re-operation rate was higher in sequestrectomy group.	No short-term advantage to sequenstectomy vs discectomy, but lower LDH recurrence and lower re-operation rates seen in disectomy group.
Zhang et al.[39]	2015	Meta-Analysis	4 RCTs and 2 CCT	1a	793 patients	To compare discectomy vs sequestrectomy in the treatment of LDH	Microdisectomy had better improvement in LBP VAS score. There was no significant difference in incidence of re-operation or neuropathic pain between discectomy and sequestrectomy. Sequestrectomy had lower analgesic usage rate.	Same as results.

degenerative changes, or have instability associated with radiculopathy caused by herniated lumbar discs.

Analyzing actual literature, whether the resulting recommendations are appropriate for patients of low- and middle-income countries is not known.

9. Conclusion

There is an ever-increasing body of literature regarding the surgical treatment of LDH. In this manuscript, the WFNS Spine Committee reviews the latest evidence on the surgical treatment of first-time LDH and provides consensus statements to standardize and guide the treatment of LDH for practicing clinicians worldwide. These guidelines should not be

Table 4
Summary of most relevant literature data regarding the role of lumbar fusion in the context of LDH surgery. DVT: Deep vein thrombosis; IS: Interspinous spacer; MD: microdiscectomy; PLIF: Posterior lumbar intersomatic fusion; RD: re-discectomy; rLDH: recurrent lumbar disc herniation; SF: Spinal Fusion; UTI: Urinary tract infection.

Authors	Year	Study type	Objective	Level of Evidence	Number of studies included	Number of patients included	Main Results	Conclusions
Segura-Trepichio et al.[42]	2021	Prospective Study	To compare microdiscectomy combined with interspinous spacer (IS) or posterior lumbar interbody fusion (PLIF) versus microdiscetomy alone.	IIb	/	103	All 3 groups had significant improvement in ODI and VAS back and leg pain. At 1 year, there was no significant difference in ODI, VAS back and legs pain between the 3 groups. IS group had 169% higher total direct inpatient hospital cost, and PLIF group had 287% higher total direct inpatient hospital cost, in relation to microdiscectomy alone ($p < 0.001$). Length of stay was 86% higher in the IS group and 384% longer in the PLIF group compared to microdiscectomy alone ($p < 0.001$). 1-year re-operation rates trended towards higher in the IS and PLIF group, but were not statistically significantly different.	There is no significant clinical benefit to adding IS or PLIF to disckectomy alone for LDH. These are associated with higher cost and longer LOS.
Gu et al.[43]	2018	RCT	To evaluate Wallis interspinous spacer placement vs discectomy in patients with low back pain or sciatica due to LDH	IIb	/	77	At 36 months, both groups showed significant improvement in VAS, JOA, and ODI compared with to baseline ($P < 0.001$). There was no significant difference in primary outcomes (VAS, JOA, ODI) or complication rates at 3 years post-op between the two groups (discectomy vs discectomy + interspinous spacer). Disc height was significantly greater in the interspinous spaer group. Two patients in the interspinous spacer group and three patients in the control group underwent revision surgery for LDH recurrence.	There is no significant difference in clinical outcomes between interspinous spacer and discectomy for LDH at 3 years post-op.

Table 5
Final voting for ten consensus statements on the tole of surgery in primary lumbar disk herniation.

Statement	Voting
(1) Surgery for lumbar disc herniation is individualized. It is recommended for failure of conservative treatment, severe motor deficit, progressive neurological impairment, CES.	7 (78%) strongly agree 1 (11%) agree 1 (11%) disagree
(2) Earlier surgery in lumbar disc herniation is suggested in case of major motor deficit and is associated with faster recovery and might improve motor outcomes.	5 (56%) strongly agree 2 (22%) agree 2 (22%) somewhat agree
(3) Although minimally invasive procedures have short term advantages, there is insufficient evidence to make a recommendation for or against the choice of a specific surgical procedure for LDH.	7 (78%) strongly agree 2 (22%) agree
(4) Sequestrectomy and standard microdiscectomy have similar clinical results in terms of pain control, recurrence rate, functional outcome, and complications at short/medium term.	5 (56%) strongly agree 3 (33%) agree 1 (11%) somewhat agree
(5) Lumbar fusion is not recommended as a routine treatment following primary discectomy in patients with isolated herniated lumbar discs causing radiculopathy. Lumbar fusion may be considered in patients with herniated discs who have evidence of significant chronic axial back pain, have severe degenerative changes, or have instability associated with radiculopathy caused by herniated lumbar discs.	5 (63%) strongly agree 2 (25%) agree 1 (12%) somewhat agree

viewed as "standard of care" or rigid protocols; instead, treatment should be individualized to the patient, provider, and practice setting.

While up to 66% of lumbar disc herniations may resolve spontaneously, surgical treatment for LDH becomes necessary in cases of failed conservative treatment with unrelenting, severe pain or neurologic deficit (including motor deficit or cauda equina syndrome). Although short-term pain control outcomes appear to be better with discectomy, long-term outcomes between surgical and conservative groups are similar. Early surgery for first-time LDH is recommended in cases of motor deficits and CES. Multiple surgical techniques could be employed for LDH, including open discectomy, tubular discectomy, and percutaneous endoscopic discectomy. Although minimally invasive procedures may demonstrate better short-term outcomes (including shorter hospital stay, decreased infection risk, and reduced blood loss), there is insufficient evidence to make a recommendation for or against a specific discectomy technique. There is also insufficient evidence to recommend sequestrectomy (resection of disc fragment alone) versus standard discectomy (resection of disc fragment plus disc material). Lumbar fusion is not recommended as a routine first-line treatment for patients with isolated herniated lumbar discs causing radiculopathy. However, fusion may be considered in LDH patients with significant chronic axial back pain, severe disc degeneration, or spinal instability.

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Research ethics

/

Statement 1. : Surgery for lumbar disc herniation is individualized. It is recommended for failure of conservative treatment, severe motor deficit, progressive neurological impairment, CES (7 out of 9 voted grade 5, with 1 voting 4 and only 1 voting 2).

Statement 2. : Earlier surgery in lumbar disc herniation is suggested in case of major motor deficit and is associated with faster recovery and might improve motor outcomes (5 out of 9 voted grade 5, 2 voted grade

4 and 2 voted grade 3).

Statement 3. : Although minimally invasive procedures have short term advantages, there is insufficient evidence to make a recommendation for or against the choice of a specific surgical procedure for LDH (7 out of 9 voted grade 5, 2 voted grade 4).

Statement 4. : Sequestrectomy and standard microdiscectomy have similar clinical results in terms of pain control, recurrence rate, functional outcome, and complications at short/medium term (5 out of 9 voted grade 5, 3 voted grade 4 and just 1 voted grade 3).

Statement 5. : Lumbar fusion is not recommended as a routine treatment following primary discectomy in patients with isolated herniated lumbar discs causing radiculopathy. Lumbar fusion may be considered in patients with herniated discs who have evidence of significant chronic axial back pain, have severe degenerative changes, or have instability associated with radiculopathy caused by herniated lumbar discs (5 out of 9 voted grade 5, 2 voted grade 4 and just 1 voted grade 3).

CRediT authorship contribution statement

Francesco Costa: Writing – review & editing, Data curation, Conceptualization. **Joachim Oertel:** Writing – review & editing. **Mehmet Zileli:** Writing – review & editing, Data curation, Conceptualization. **Francesco Restelli:** Writing – original draft, Formal analysis, Data curation. **Corinna Clio Zygourakis:** Data curation, Writing – review & editing. **Salman Sharif:** Writing – review & editing, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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