Chapter 8

Lumbar Disc Surgery Complications and Management, From Recent Literature

Ozan Aydoğdu[1]

Cihan Alp Cihangiroğlu[2]

Abstract

Lumbar disc herniation surgery is generally safe, but intraoperative and postoperative complications still determine functional outcome, medico-legal risk, and patient satisfaction. Over the last decade, the spectrum of techniques—from conventional open and microscopic discectomy to tubular microendoscopic and full-endoscopic procedures—has expanded, as have anesthetic strategies ranging from general anesthesia to spinal and other regional techniques. Recent systematic reviews and large cohort series confirm that overall complication rates are low and broadly comparable across techniques, but the type and timing of complications differ between macroscopic, microscopic, and endoscopic approaches and are modulated by anesthetic choice. This chapter reviews intraoperative and postoperative complications of lumbar disc surgery across open, microscopic, and endoscopic techniques, with emphasis on literature from approximately the last five years and on series including Turkish cohorts. Practical checklists highlight key decision points in preoperative risk stratification, intraoperative prevention, and postoperative surveillance for neurosurgeons.

1 Corresponding Author: MD Specialist Neurosurgeon, Muğla Training and Research Hospital Department of Neurosurgery, E-mail: md.o.aydogdu@gmail.com – ORCID: 0000-0002-5998-2673

2 MD Neurosurgery Resident, Muğla Sıtkı Koçman University Faculty of Medicine Deparment of Neurosurgery, E-mail: doublecihan@gmail.com, ORCID: 0009-0003-4586-1699

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1. INTRODUCTION

Lumbar disc herniation (LDH) is a leading cause of lumbosacral radiculopathy and work disability in adults. When adequate conservative therapy fails, surgical discectomy—traditionally open discectomy (OD) or microscopic discectomy (MD)—offers rapid decompression and durable pain relief for most patients [2,4,11]. Minimally invasive and endoscopic techniques, including microendoscopic discectomy (MED), percutaneous endoscopic lumbar discectomy (PELD), full-endoscopic lumbar discectomy (FELD) with transforaminal (TELD) or interlaminar (IELD) approaches, and unilateral biportal endoscopic (UBE) discectomy, were introduced to reduce approach-related morbidity [1,2,7,12].

Recent network meta-analyses and large systematic reviews report overall complication rates for LDH surgery in the range of 5–20% depending on technique, definition, and follow-up [1,2,4,11]. Typical rates include recurrent disc herniation of about 3–15%, incidental durotomy 1–7%, new or worsened neurological deficit 1–5%, nerve-root injury 0.3–3%, and wound or deep infection 0.1–2.4% [1,2,4]. While PELD and other endoscopic techniques tend to show lower overall complication rates than OD/MD, they may carry slightly higher risks of re-herniation or approach-specific dysesthesia in some series [1,2,13].

Parallel developments have occurred in anesthesia. General anesthesia (GA) remains the dominant modality worldwide, but spinal anesthesia (SA), epidural anesthesia, and local anesthesia with monitored sedation are increasingly used for limited lumbar procedures, particularly MD, MED, and endoscopic discectomy [3,8,14]. Comparative studies and systematic reviews suggest that SA and other regional techniques can reduce intraoperative blood loss, postoperative nausea and vomiting (PONV), and early analgesic requirements but may increase urinary retention and post-dural puncture headache (PDPH) [3,8,14].

For the neurosurgeon, a pragmatic understanding of these complications—rather than a purely technique-driven enthusiasm—is essential, especially as day-case discectomy and outpatient endoscopic surgery become more common. This chapter synthesizes current evidence, highlights data from recent literature, and integrates both single-center and multicenter experiences to form a comprehensive global perspective [5–10,15–18].

Checklist 1. Pre-operative risk stratification in lumbar disc surgery

- Confirm indication: concordant radicular symptoms and imaging, failure of adequate conservative therapy, and realistic patient expectations.
- Review bleeding risk: antiplatelet/anticoagulant therapy, history of VTE, liver disease, systemic steroid use, and planned neuraxial anesthesia.
- Screen for infection risk: diabetes, obesity, smoking, malnutrition, chronic skin disease, and prior wound problems.
- Identify anatomical complexity: highly migrated or sequestered fragment, far-lateral or foraminal herniation, L5–S1 with high iliac crest, congenital anomalies, or prior surgery.
- Stratify patient-related risk factors for complications and recurrence: age >70 years, obesity, diabetes, heavy smoking, advanced Modic changes, and physically demanding work [1,2,6,19].
- Match technique to pathology and surgeon expertise (OD/MD vs MED vs PELD/FELD vs UBE) rather than pursuing the "smallest incision" at all costs [1,2,7,12].
- Discuss with the patient the specific profile of complications (durotomy, infection, recurrence, instability, chronic pain) and the potential need for re-operation.

2. SURGICAL TECHNIQUES AND ANESTHESIA MODALITIES

2.1. Open and microscopic discectomy

Conventional open discectomy with partial laminectomy and MD with microscope-assisted unilateral laminotomy remain benchmark techniques. MD allows smaller incisions and less muscle dissection with excellent visualization and is still regarded as the "gold standard" in many countries [4,11,18]. Large systematic reviews and meta-analyses report overall complication rates around 10–15% for OD/MD, with durotomy 2–4%, neurological complications 2–3%, and infection ~1–2% [1,2,4,11]. Recurrent LDH after MD is typically reported in the 3–10% range over mid-term follow-up [1,6,11,20]. Microdiscectomy series, including cohorts of more than 1000 patients, show comparable recurrence and re-operation rates and emphasize smoking, obesity, and certain radiological features (e.g., larger herniation volume, advanced degeneration) as risk factors for recurrence [6,16,19]. MD therefore remains the most widely used technique in routine neurosurgical practice.

2.2. Microendoscopic discectomy (MED)

MED employs a tubular retractor and endoscope or microscope introduced through a 1.5–2 cm incision, aiming to preserve paraspinal musculature. Comparative trials and meta-analyses have generally shown similar clinical outcomes between MED and MD, with shorter hospital stay and faster early recovery after MED but modestly longer operative times [2,4,11]. Complication patterns are broadly similar, though some series note slightly higher early rates of dural tear or nerve-root irritation during the learning curve [2,11].

2.3. Full-endoscopic lumbar discectomy (PELD, TELD, IELD, UBE)

Full-endoscopic discectomy uses a working-channel endoscope under continuous irrigation via transforaminal (PELD/TELD), interlaminar (IELD), or biportal (UBE) approaches [7,12,13]. Recent systematic reviews and randomized trials confirm non-inferiority of PELD/FELD compared with MD in terms of leg-pain reduction and functional improvement, with equal or lower overall complication rates and shorter hospital stay [1,2,12,13].

A 2022 systematic review of LDH discectomy techniques (Bombieri et al.) reported overall complication rates around 5–8% for PELD compared with 12–17% for OD/MD in pooled RCT and cohort data, although re-herniation rates may be slightly higher after PELD in some series [1]. Network meta-analysis by Chen et al. similarly ranked PELD as the technique with the lowest overall complication rates but noted that re-operation rates were not dramatically different among techniques [2].

Large endoscopic series have reported perioperative complication rates of approximately 5–7%, including durotomy, transient dysesthesia, pudendal neuralgia, infection and epidural hematoma [7,10,13,15]. Many of these complications are transient and improve with conservative management, particularly sensory disturbances related to dorsal-root ganglion (DRG) irritation after transforaminal procedures [7,10,13].

2.4. General versus spinal and other regional anesthesia

Most OD/MD procedures worldwide are still performed under GA. However, numerous prospective comparative series and systematic reviews have evaluated SA and other regional techniques in lumbar spine surgery, including LDH discectomy [3,8,14]. A comparative study by Dagistan et al. reported that MD under SA was associated with shorter total anesthetic time, lower intraoperative blood loss, lower intraoperative mean arterial pressure, and reduced early postoperative analgesic requirement compared with GA, at the cost of higher urinary retention [3]. A broader systematic review of GA versus SA in lumbar surgery found that SA was associated with less PONV, reduced opioid consumption, and shorter length of stay, without major differences in serious neurological or cardiopulmonary events when patients were appropriately selected [8,14].

Regional anesthesia techniques are particularly attractive for endoscopic procedures performed in ambulatory settings, enabling intraoperative patient feedback and early mobilization. However, neuraxial anesthesia is contraindicated or relatively contraindicated in patients with coagulopathy, uncontrolled anticoagulation, or severe spinal canal compromise, and it carries rare but serious risks such as spinal hematoma and cauda equina syndrome [8,14].

Checklist - Choosing Surgical and Anesthetic Technique

- Choose MD as the baseline option when anatomy is straightforward and endoscopic experience is limited.
- Consider MED or full-endoscopic (TELD/IELD/UBE) techniques for young or working patients, obesity and recurrent herniation after prior MD, provided an experienced endoscopic team is available [1,2,7,10,12].
- Use interlaminar endoscopy for large L5–S1 herniations with high iliac crest, and transforaminal endoscopy for foraminal or extraforaminal herniations [7,12,13].
- Prefer GA for anxious patients, prolonged multilevel procedures, or when rapid airway control may be needed.
- Consider SA or other regional techniques for short-segment LDH surgery in stable patients to minimize PONV and facilitate early discharge, while respecting contraindications to neuraxial anesthesia [3,8,14].
- Apply the technique that the surgeon can perform safely and reproducibly, rather than the newest or most minimally invasive option.

3. INTRAOPERATIVE COMPLICATIONS

3.1. Wrong-level Surgery

Wrong-level exposure is an uncommon but serious event, reported in most large LDH series at <1% [1,2,4]. It has been described with open, microscopic, and endoscopic techniques. Risk factors include obesity, transitional vertebrae, scoliosis, and inadequate fluoroscopic imaging. Prevention depends on systematic use of intraoperative fluoroscopy after positioning and before bone removal, careful counting of levels on preoperative MRI and CT, and heightened vigilance when anatomical landmarks are ambiguous.

If wrong-level exposure is recognized intraoperatively, the correct level should be decompressed in the same session whenever possible, with meticulous documentation and transparent postoperative communication. Delayed recognition may contribute to persistent symptoms and medicolegal consequences.

3.2. Incidental Durotomy and Cerebrospinal Fluid (CSF) Leak

Incidental durotomy is among the most frequent intraoperative complications of LDH surgery. Recent systematic reviews and large series report durotomy rates typically between 1% and 7%, varying with pathology, technique, and whether the case is primary or revision [1,2,4,11]. MD and OD series commonly show rates of 2–4%, while experienced endoscopic centers report rates around 1–3%, with the highest risk during early learning phases [1,2,7,10,13].

Risk factors include older age, severe canal stenosis, thickened ligamentum flavum, revision surgery with dense scar, female sex, and antiplatelet or anticoagulant use [1,2,11,19]. Incomplete removal of ossified ligament or aggressive resection in the lateral recess can predispose to tears. Durotomy is independently associated with an increased risk of postoperative infection and readmission [2,11].

Management follows general principles:

- Small, linear tears accessible via the approach should be primarily closed with fine non-absorbable sutures when technically feasible, sometimes augmented with a small autologous fat or muscle graft and fibrin sealant.
- Larger, complex, or ventral tears may require patch techniques and fibrin sealant without complete suturing; in some cases, conversion from endoscopic to microscopic or open exposure is prudent.
- In endoscopic surgery, very small tears can sometimes be managed with hemostatic material and sealant applied via the working channel, with careful observation postoperatively; however, low threshold for conversion is advisable for high-flow leaks.

Postoperatively, patients with durotomy should be observed for orthostatic headache, nausea, clear wound drainage, pseudomeningocele, and meningitis. Conservative management includes short-term supine positioning, adequate hydration, and careful wound care. Persistent high-flow leakage, enlarging pseudomeningocele, or infection usually mandates re-exploration, dural repair, and occasional lumbar drainage [11].

3.3. Nerve-root and Cauda Equina Injury

Iatrogenic nerve-root trauma may arise from excessive retraction, inadvertent instrument contact, or thermal injury from bipolar or radiofrequency devices. In large series, permanent nerve-root injury is rare (approximately 0.3–1.5%), but transient postoperative neurological deficits are more common, particularly after minimally invasive or endoscopic techniques [1,2,4,11]. Microtrauma to the exiting nerve root or DRG is a recognized mechanism of postoperative dysesthesia, particularly after transforaminal PELD [7,10,13].

Prevention emphasizes constant visualization of neural structures before advancing instruments, gentle and intermittent retraction, judicious energy settings, and avoidance of blind disc curettage in the foraminal and extraforaminal zones. New postoperative motor deficits should prompt urgent MRI to exclude compressive lesions such as residual fragment or epidural hematoma. When compression is present, early re-exploration improves neurological prognosis [11].

3.4. Vascular and Visceral Injury

Major vascular or visceral injury during LDH surgery is exceedingly rare but potentially catastrophic. Cases of retroperitoneal hematoma, segmental vessel injury, and visceral perforation have been reported, mostly in association with over-penetration of instruments beyond the anterior annulus or imprecise trajectory during transforaminal approaches [2,4,11]. Prevention requires meticulous fluoroscopic control in anteroposterior and lateral planes, respect for the anterior longitudinal ligament, and a clear understanding of the limits of Kambin's triangle.

Intraoperative hypotension, unexplained blood loss, abdominal distension, or postoperative retroperitoneal pain should raise suspicion and prompt immediate vascular and general-surgical consultation and targeted imaging.

3.5. Epidural Bleeding and Hematoma

Epidural venous bleeding is common, especially in obese patients and those with elevated venous pressure. With appropriate bipolar coagulation, irrigation, and hemostatic agents, it rarely progresses to clinically significant epidural hematoma. However, symptomatic postoperative epidural hematoma, though uncommon (around 0.1–0.4%), may cause rapid neurological deterioration and requires emergency decompression [2,4,11].

Risk factors include uncontrolled hypertension, coagulopathy, continued antithrombotic therapy, extensive decompression, and prolonged surgery. Careful preoperative management of coagulation status, controlled blood pressure, and meticulous hemostasis are essential preventive measures.

3.6. Anesthesia-related Intraoperative Events

Under GA, relevant intraoperative complications include airway difficulties, hypotension, arrhythmia, and positioning-related problems, such as pressure neuropathies and, very rarely, postoperative visual loss in prolonged prone procedures [4,11]. Under SA and other neuraxial techniques, hypotension, bradycardia, high spinal block, and local anesthetic toxicity are the main intraoperative issues, though serious neurological complications are rare in large series and registries [8,14].

A recent systematic review comparing SA and GA in lumbar surgery found that SA was associated with lower intraoperative blood pressure and heart rate, less blood loss, and shorter recovery-room stay, without significant differences in major cardiopulmonary events [8,14]. Dagistan et al. similarly reported lower early postoperative pain scores and reduced opioid requirement with SA in MD, but more frequent urinary retention [3].

Checklist - Intraoperative Prevention of Complications

- Confirm correct level fluoroscopically after positioning and again before bone removal.
- Protect the dura during flavectomy using undercutting techniques and avoiding “blind” rongeur bites.
- Maintain continuous visualization of neural structures; never advance instruments beyond the field of view.
- Minimize root retraction time and force; release retraction regularly.
- Coordinate anticoagulation management with anesthesia; adhere to evidence-based intervals for stopping and restarting agents when neuraxial techniques are used.
- Limit irrigation pressure and procedure time in endoscopic surgery to reduce risk of intracranial pressure elevation and fluid-related complications.
- Ensure the availability of a durotomy-repair set and a standardized algorithm for intraoperative CSF leak management.

4. EARLY POSTOPERATIVE COMPLICATIONS (0–30 DAYS)

4.1. Wound Complications and Infection

Postoperative wound problems range from superficial erythema and seroma to deep infection and spondylodiscitis. Modern series report surgical-site infection (SSI) rates after LDH surgery between 0.1% and 2.4%, with lower rates in minimally invasive and endoscopic procedures than in open approaches [1,2,4,11,13]. Risk factors include diabetes, obesity, smoking, prolonged operative time, revision surgery, durotomy, and CSF leak [2,11,18].

Superficial SSIs may respond to local wound care and short-course oral antibiotics. Deep infections and discitis require MRI confirmation, long-term targeted intravenous antibiotics, and, in selected cases, surgical debridement, drainage, or removal of infected material [11]. Endoscopic debridement has been described as a minimally invasive option for selected infectious complications [13].

4.2. Persistent CSF Leak and Pseudomeningocele

Unrecognized or inadequately treated intraoperative dural tears may manifest in the early postoperative period as clear wound drainage, positional headache, neck pain, or a subcutaneous fluid collection. Small leaks can often be treated conservatively with a brief period of bed rest, compressive dressing, and avoidance of Valsalva maneuvers. Persistent high-flow leakage, enlarging pseudomeningocele, or meningitic signs require imaging and usually surgical revision. In rare refractory cases, shunting procedures may be needed [11].

4.3. Acute Neurological Deterioration

New motor deficit, cauda equina syndrome, or severe recurrent radiculopathy within the first days after surgery should be treated as a neurosurgical emergency. Differential diagnoses include residual or migrated disc fragment, epidural hematoma, compressive seroma, and severe nerve-root edema. Immediate clinical evaluation and urgent MRI are mandatory. When a compressive lesion is identified, prompt re-exploration and decompression offer the best chance for neurological recovery [11].

4.4. Radicular Pain Flare-up, Dysesthesia, and Pudendal Neuralgia

Transient exacerbation of radicular pain and sensory disturbances are well recognized after LDH surgery. In endoscopic transforaminal procedures, DRG irritation can result in burning dysesthesia in the exiting-root distribution, typically improving over weeks with neuropathic pain medication and physiotherapy [7,10,13]. Pudendal neuralgia and perineal dysesthesia have been reported after aggressive retraction or misplaced working channels, but are rare [7,10].

Persistent or worsening symptoms should prompt imaging to exclude residual compression or recurrent herniation. If structural pathology is absent, conservative management with neuropathic pain agents, physical therapy, and occasionally selective nerve-root blocks is usually effective.

4.5. Urinary Retention and Bladder Dysfunction

Urinary retention is common after LDH surgery, particularly under SA, and is generally transient. Contributing factors include neuraxial blockade, perioperative opioids, and longstanding preoperative bladder dysfunction. Routine bladder scanning and intermittent catheterization for retention help prevent over-distension and urinary tract infection. Persistent bladder dysfunction beyond the expected resolution of anesthesia warrants neurological evaluation and repeat imaging to exclude cauda equina syndrome.

4.6. Venous Thromboembolism (VTE) and Systemic Events

Symptomatic VTE after single-level LDH surgery is relatively rare (usually <2–3%), but the consequences can be serious [2,4,11]. Early mobilization, mechanical prophylaxis, and risk-adapted pharmacologic prophylaxis according to standard spine-surgery and thrombosis guidelines are recommended. Elderly and frail patients are at higher risk of medical complications (urinary tract infection, pneumonia, delirium), and proactive geriatric comorbidity management improves outcomes [5,9].

Checklist - Early Postoperative "Red Flags"

- New or progressive motor weakness, saddle anesthesia, or sphincter dysfunction.
- Severe back or leg pain after an initial pain-free interval.
- Fever, wound drainage—especially clear fluid—or severe positional headache.
- Increasing back pain with neurological deterioration suggesting epidural hematoma.
- Persistent urinary retention beyond expected anesthetic effect or new incontinence.
- Dyspnea, chest pain, or tachycardia suggestive of pulmonary embolism.

5. LATE COMPLICATIONS (>30 DAYS)

5.1. Recurrent Lumbar Disc Herniation

Recurrent LDH is usually defined as herniation at the same level (often same side) after a pain-free interval of at least six months. Contemporary series report recurrence in approximately 3–15% of patients following LDH surgery, with most large cohorts clustering around 4–8% [1,2,4,6,19]. Recent Turkish multicenter analysis of more than 1200 microdiscectomy cases found recurrence rates in this range and identified smoking, obesity, Modic changes, and certain disc morphology features as independent risk factors [6,19].

Management depends on symptom severity, neurological status, and radiological findings. A small subset of patients with mild symptoms may respond to renewed conservative therapy, but in most cases with recurrent radicular pain and clear neural compression, surgery is preferred. Both revision MD and full-endoscopic discectomy have shown good outcomes in recurrent LDH, with endoscopic revisional surgery offering the advantage of limited additional tissue damage when performed by experienced surgeons [9,10,15].

5.2. Segmental Instability and Deformity

Because LDH surgery typically involves limited bone removal, clinically significant iatrogenic segmental instability is uncommon. However, extensive facet resection, multilevel decompression, prior laminectomies, and underlying degenerative spondylolisthesis can predispose to progressive mechanical back pain and recurrent radiculopathy [2,11]. Diagnosis relies on standing radiographs (including flexion-extension views) and MRI. Management ranges from physiotherapy and core-stabilization programs to instrumented fusion in selected patients with radiographic instability and persistent disabling symptoms.

5.3. Chronic Pain and Failed Back Surgery Syndrome (FBSS)

Despite technically successful decompression and satisfactory early outcomes, a subset of patients develop chronic pain and disability. Etiologies of FBSS include recurrent or residual disc herniation, epidural fibrosis, facet or sacroiliac joint pain, psychosocial factors, and maladaptive central pain processing [11,21]. Preoperative risk factors include high baseline pain intensity, depression, pain catastrophizing, and work dissatisfaction [21].

Management requires a multimodal approach: detailed reassessment, repeat MRI (often with contrast) to distinguish recurrent herniation from scar, targeted injections, optimization of medical therapy, cognitive-behavioral interventions, and, in refractory cases without compressive pathology, neuromodulation such as spinal cord stimulation [21].

5.4. Endoscopy-Specific Late Complications

Endoscopy-specific late complications are rare but include delayed pseudomeningocele, chronic DRG neuropathy, infection related to retained fragments or foreign material, and symptomatic epidural fibrosis around the endoscopic tract [7,10,13]. Their prevention relies on meticulous technique, adherence to standardized operative steps, and adequate training and supervision during the learning curve.

Checklist - Long-term Follow-up Priorities

- Re-evaluate radicular symptoms and functional scores within the first 6–12 months to detect recurrence early.
- Educate patients regarding realistic expectations, ergonomics, and lifestyle modification (smoking cessation, weight control, core strengthening).
- Use MRI selectively for recurrent or persistent radicular pain and for new neurological deficits.
- Consider targeted pain interventions and multidisciplinary rehabilitation before re-operation when no clear compressive lesion is present.
- Coordinate care with primary physicians and pain specialists for patients at risk of FBSS.

6. COMPARATIVE COMPLICATION PROFILES ACROSS TECHNIQUES AND ANESTHESIA

6.1. Open/Microscopic versus Endoscopic Discectomy

The key question for practicing neurosurgeons is not whether endoscopic techniques “work”—they do—but how their complication patterns differ from MD and how this should influence case selection. The most robust contemporary evidence indicates:

- Overall complication rates are low for all techniques and broadly similar when high-volume, experienced centers are compared [1,2,4,11].
- PELD and other full-endoscopic techniques often show lower overall complication rates than OD/MD in pooled analyses, driven mainly by reduced wound complications and infections [1,2,13].

- Durotomy rates tend to be lowest in well-established endoscopic and MD series and highest in open decompression or complex revision cases [1,2,7,11].
- Neurological complication rates are low across all techniques; minimally invasive and endoscopic approaches may show slightly higher rates of transient dysesthesia or DRG-related neuropathic pain, whereas OD/MD may show slightly higher rates of direct root injury in some older series [1,2,4,7,11].
- Recurrent herniation rates are similar across techniques but may be marginally higher after some PELD protocols, particularly early in the learning curve, and in high-risk patients [1,2,4,6,10,19].

Large comparative studies and RCTs involving TELD/IELD, PELD, UBE, MED, and MD consistently demonstrate non-inferiority in terms of pain relief and disability improvement, with shorter hospital stay and faster early recovery for endoscopic and MED techniques [1,2,7,12,13,17].

6.2. Effect of Anesthetic Technique on Complications

With respect to anesthesia, level-1 evidence directly specific to LDH surgery remains limited, but several comparative trials and systematic reviews in lumbar surgery provide consistent signals [3,8,14]:

- SA and other neuraxial techniques are associated with lower intraoperative blood loss, lower heart rate and blood pressure, less PONV, shorter recovery-room stay, and reduced early opioid requirements compared with GA [3,8,14].
- GA offers superior airway control and is preferred for prolonged procedures, complex deformity and combined anterior–posterior approaches.
- Serious neuraxial complications such as spinal epidural hematoma are rare but potentially devastating; strict adherence to anticoagulation guidelines and meticulous postoperative neurological monitoring are essential when SA/epidural techniques are used [8,14].
- Overall rates of major cardiopulmonary complications and neurological outcomes do not differ significantly between GA and SA when patient selection is appropriate [8,14].

Checklist - Matching Technique and Anesthesia to Patient Risk

- In high bleeding-risk patients (e.g., antithrombotic use, coagulopathy), minimize soft-tissue dissection, optimize coagulation preoperatively, and consider MD or endoscopic approaches with careful hemostasis.
- In high infection-risk patients (e.g., diabetes, obesity, long operative times), favor shorter procedures, meticulous wound care, and early mobilization; treat CSF leaks aggressively.
- In patients with significant cardiopulmonary disease, consider SA or local anesthesia with monitored sedation for short procedures, in close collaboration with anesthesia colleagues, and avoid prolonged GA when possible.
- In complex revision cases or when anatomy is distorted, prioritize the technique with which the surgeon has the greatest experience and control (often MD or UBE) rather than the most minimally invasive option.
- Embed anesthesia choice in a standardized institutional protocol that includes clear thresholds for conversion to GA and documented postoperative neurological checks.

7. REHABILITATION AND PREVENTION OF SECONDARY COMPLICATIONS

Rehabilitation after LDH surgery aims to consolidate neurological recovery, minimize recurrence, and prevent chronic pain. Randomized trials and prospective cohorts support early mobilization and structured core-stabilization programs after discectomy; such programs improve pain and function without increasing re-herniation [11,18,22]. Typical elements include early ambulation, progressive strengthening of trunk and hip musculature, stretching of hamstrings and hip flexors, and graded return to aerobic activity and work tasks.

Patient education is central: instruction in proper lifting techniques, avoidance of extreme flexion/rotation under load, ergonomic optimization at work, and weight management all contribute to long-term success. Patients with psychosocial risk factors for chronic pain benefit from early integration of cognitive-behavioral strategies and multidisciplinary pain management [21,22].

Checklist - Practical postoperative rehabilitation plan

- Mobilize on the day of surgery or first postoperative day whenever medically feasible.
- Begin simple isometric core and lower-limb exercises in the early postoperative period as pain allows.
- Initiate a structured physiotherapy program within 2–6 weeks, focusing on dynamic lumbar stabilization and gradual return to daily activities and work.
- Counsel patients on smoking cessation and weight reduction, particularly in the presence of risk factors for recurrence.
- Screen for psychological distress; involve pain and mental-health specialists early in patients with high pain catastrophizing or poor coping.

8. CONCLUSIONS

Complications of lumbar disc surgery are multifactorial and technique-, patient-, and anesthesia-dependent. Contemporary evidence from the last five years confirms that OD, MD, MED, PELD/FELD, and UBE all achieve high rates of pain relief and functional improvement, with low and broadly comparable overall complication rates when performed in experienced hands [1,2,4,7,11–13]. Endoscopic techniques appear to reduce wound-related morbidity and length of stay but introduce specific neuropathic and technical complications, particularly early in the learning curve. Anesthetic choice modulates perioperative morbidity and recovery profile rather than dramatically changing major surgical complication rates, provided that patient selection and anticoagulation management are appropriate [3,8,14].

For the practicing neurosurgeon, the most effective strategy to reduce complications is not a single "best" technique but rather careful preoperative risk assessment, appropriate matching of technique and anesthesia to patient and pathology, meticulous intraoperative technique, and structured postoperative surveillance and rehabilitation. Incorporating evidence-based checklists and institutional protocols, and learning from national and international registry data—including growing Turkish experience—can further improve safety and outcomes for patients undergoing lumbar disc surgery.

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