

# CURRENT TREND OF INSTRUMENTAL FUSION SURGERY IN THE TREATMENT OF DEGENERATIVE DISEASES OF THE LUMBOSACRAL SPINE

## Súčasný trend inštrumentovaných fúzných operácií v liečbe degeneratívnych ochorení driekovokrížovej chrbtice

Roman KALINA

Neurosurgical Clinic, F.D Roosevelt University Hospital with Polyclinic, Banská Bystrica, Head MUDr. J. Šulaj, PhD.

### Abstract

Review article about the current minimally invasive surgical options of fusion operations in the treatment of degenerative diseases of lumbosacral region. The aim of this article is to provide an overview of different minimally invasive surgical techniques and determine suitable patients for each type of surgery. Fusion has been the gold standard in the treatment of degenerative diseases in the lumbosacral region for almost 100 years. The current trend is minimally invasive surgery. Practically all so-called open techniques today have a minimally invasive variant. The goal remains the same, only the method of achieving it has changed dramatically. There are several types of fusion operations. Transforaminal lumbar interbody fusion, Unilateral lumbar interbody fusion, Anterior lumbar interbody fusion, Anterior approach in lateral position, Lateral lumbar interbody fusion, Posterior lumbar interbody fusion, Midline lumbar fusion, Axial lumbar interbody fusion, endoscopy. Indications for surgery are degenerative disc disease, spondylolisthesis, spinal canal stenosis and discogenic instability. The advantages of MIS techniques are mini-invasiveness, lower blood loss, faster recovery and earlier return to work, while the risk of complications is low and comparable to conventional open methods of surgery (Tab. 1, Fig. 9, Ref. 76). Text in PDF [www.lekarsky.herba.sk](http://www.lekarsky.herba.sk).

**KEY WORDS:** minimally invasive surgery, interbody lumbar fusion, endoscopy, degenerative disc disease, stenosis, discogenic instability.

Lek Obz 2025, 75 (3): 113-119

### Abstrakt

Prehľadový článok o súčasných minimálne invazívnych fúzných chirurgických operáciách pri liečbe degeneratívnych ochorení lumbosakrálnej oblasti. Cieľom tohto článku je ukázať rôzne mimimálne invazívne chirurgické techniky a určiť vhodných pacientov pre každý typ operácie. Fúzia je zlatým štandardom v liečbe degeneratívnych ochorení v lumbosakrálnej oblasti už takmer 100 rokov. Súčasným trendom je minimálne invazívna chirurgia. Prakticky všetky takzvané otvorené techniky dnes majú minimálne invazívny variant. Cieľ zostáva rovnaký, len spôsob jeho dosiahnutia sa dramaticky zmenil. Existuje niekoľko typov fúzných operácií. Transforaminálna bedrová medzitelová fúzia, jednostranná bedrová medzitelová fúzia, predná bedrová medzitelová fúzia, predný prístup v laterálnej polohe, bočná bedrová medzitelová fúzia, zadná bedrová medzitelová fúzia, stredová bedrová medzitelová fúzia, axiálna bedrová medzitelová fúzia, endoskopia. Indikáciami na operáciu sú degeneratívne ochorenie platničky, spondylolistéza, stenóza miechového kanála a diskogénna nestabilita. Výhodou techník MIS je miniinvazívnosť, nižšia strata krvi, rýchlejšie zotavenie a skorší návrat do práce, pričom riziko komplikácií je nízke a porovnateľné s konvenčnými otvorenými chirurgickými metódami (tab. 1, obr. 9, lit. 76). Text v PDF [www.lekarsky.herba.sk](http://www.lekarsky.herba.sk).

**KLÚČOVÉ SLOVÁ:** minimálne invazívna chirurgia, medzitelová drieková fúzia, endoskopia, degeneratívne ochorenie platničky, stenóza, diskogénna nestabilita.

Lek Obz 2025, 75 (3): 113-119

### Introduction

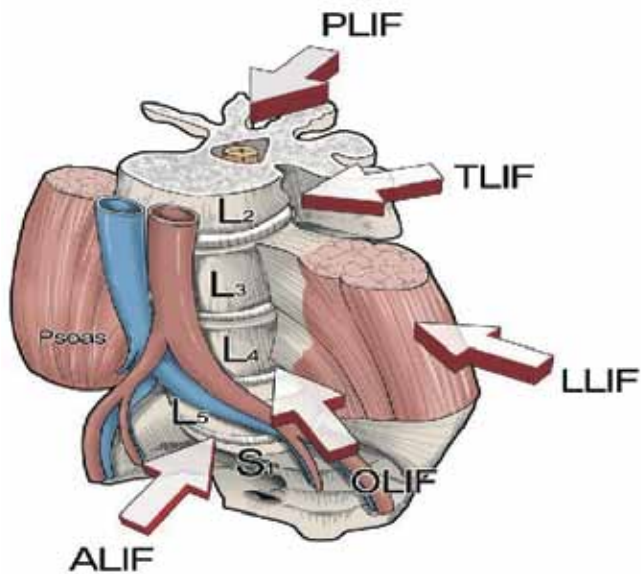
More than 80% of people experience back pain during their lifetime (1, 4). This represents a serious societal problem with significant economic consequences. Lumbar interbody fusion (LIF) is an effective and popular surgical procedure for the management of various spinal pathologies, especially degenerative diseases. This work focuses on current minimally invasive techniques of instrumented fusion operations and discusses

individual types used in treating degenerative spine diseases.

### Surgical Techniques

Nowadays, there are various types of surgical fusion techniques. Some of them are shown in Figure 1.

**Figure 1. Different types of fusion techniques, Posterior lumbar interbody fusion PLIF, Anterior ALIF, Lateral LLIF, Oblique OLIF, Transforaminal TLIF** (source: Lumbar Interbody Fusion: Techniques, Pearls and Pitfall (44)).



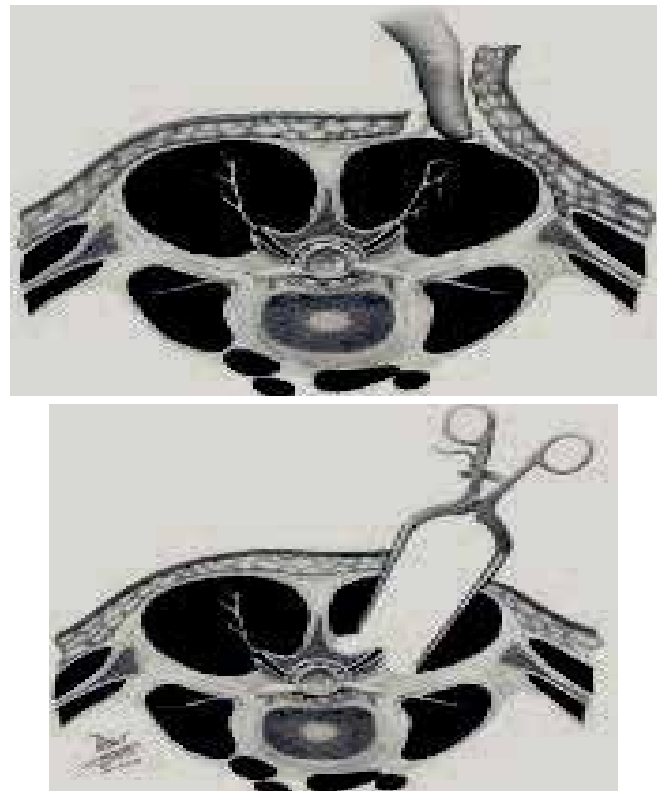
### Minimally invasive transforamina lumbar interbody fusion

Minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) is just one of the ways to achieve the required fusion of a damaged or unstable segment. The term TLIF was first used in 1982, when Harms and Rolinger (5, 6) presented the use of bone graft in a titanium cage, which was inserted transforaminally into the disc space. In the same year, Magerl mentioned percutaneous screw insertion (7). The term minimally invasive surgery (MIS) reflects a procedure that is less invasive than open technique while achieving the same goal. The term was first used by Wickham in 1987 for procedures that cause minimal damage to biological tissue at the instrument entry site (4). The MIS TLIF technique was first presented by authors Foley and Lefkowitz in 2002 (6). Generally, we can define MIS TLIF technique as a unilateral approach with complete or partial removal of the facet joint on the pathology side or approach side, using a special tubular retractor for minimally invasive technique through the paraspinous space (Wiltse approach), disc replacement /graft, spacer, cage/ inserted from one side obliquely, this part of the operation under microscope or with glasses and percutaneously bilaterally inserted screws (2, 3, 5, 6, 9-11). Figure 2 shows the mentioned plane between muscles.

Indications for MIS TLIF are patients with low back pain (LBP) with or without root irritation, where conservative therapy fails. Conditions that lead to clinical presentation are mainly degenerative disc disease (DDD), disc herniation and recurrent symptomatic disc herniation, canal stenosis, segment instability including iatrogenic discogenic instability (DI) and spondylolisthesis. We perform this procedure routinely. In the postoperative period (follow-up), we monitor the patients at 6

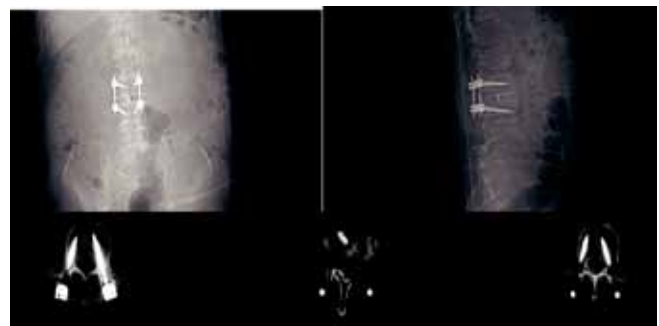
weeks, 6 months, 1 year, and 2 years after surgery, using Visual analogue scale VAS separately for back pain VAS BP and for leg pain VAS LP, Oswestry disability index ODI scoring system, Patient satisfaction rate PSR and complication rate in percentage. We evaluate fusion on X-ray or CT. An example of a patient operated on using this technique with X-ray and CT is shown in Figure 3.

**Figure 2. Wiltse approach** (source: MIS TLIF Sales Brochure, Medtronic, Inc. (2010)).



**Figure 3. Patient operated on using MIS TLIF technique, postoperative X-ray anteroposterior and lateral view and CT axial sections at the level of pedicles and replacement** (source: author's archive).

We evaluate fusion using Bridwell criteria (Bridwell interbody fusion system, Table 1), with grades 1 and 2 of the rating scale considered as fusion.



**Table 1. Bridwell's criteria for interbody fusion.**

Signs of fusion, bone remodelling, trabeculae.
Graft intact, not fully remodelled and incorporated, no lucent zones.
Graft intact, lucent zones present on upper and lower edge of graft.
No fusion, collapse/resorption of graft.

### Unilateral lumbar interbody fusion

Unilateral lumbar interbody fusion (UNILIF) is one of the most modern variants of minimally invasive fusion technique, mainly used in Asia. It was first presented in 2006. It involves implanted material, replacement and screws only from one side, unilateral pedicle screws UPS (3, 14-17. Indications are similar like for MIS TLIF or MIS PLIF techniques. Follow-up is the same as in MIS TLIF. We also use this technique. Figure 4 shows state after unilif surgery.

**Figure 4. Status after UNILIF surgery with cage L5/S1 and unilaterally inserted screws** (source: author's archive).



### Anterior lumbar interbody fusion

Anterior lumbar interbody fusion (ALIF), has been a standard surgical technique since 1983 when it was presented by O'Brien. Classical transperitoneal approaches are now history. Minimally invasive ALIF from retroperitoneal approach dominates, or alternatively the laparoscopic variant (18-24, 52-58). We also use ALIF techniques and perform the procedure in cooperation with a vascular surgeon using a minimally invasive retroperitoneal approach. Relatively the newest variation of ALIF is Anterior lumbar interbody fusion in the lateral decubitus position (XALIF). Anterior approaches allow access to the discs from the front of the spine and do not require muscle stripping. By placing the patient in the lateral decubitus position for this approach, the surgeon is able to decrease the length of surgery and improve recovery times over traditional supine (lying face up) positioning, and gravitation helps to surgeon to make approach to the retroperitoneal space (25, 26) (Fig. 5).

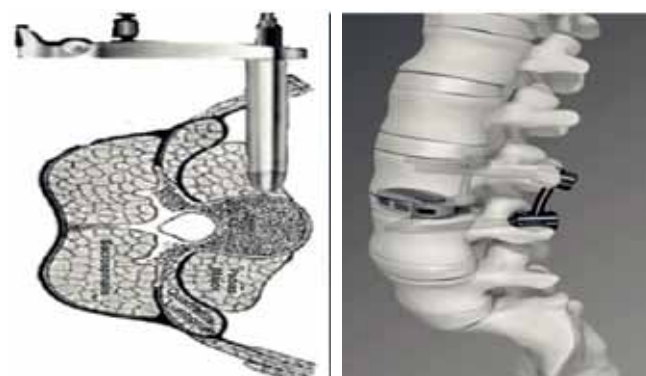
### Lateral lumbar interbody fusion

Lateral lumbar interbody fusion (XLIF, LLIF, DLIF), is another minimally invasive technique, first introduced by Pimenta et al. in 2001, gained greater popularity in 2006 by Ozgur et al. (45). The XLIF is a safe and effective alternative to anterior or posterior approach, without the need for an access surgeon, where the approach to the spine is from the lateral side through the psoas muscle, transpsoatic approach. The corridor for XLIF is limited superiorly by the 11th or 12th rib and inferiorly by the iliac crest, so the access is possible at from L1-2 to L4-5 (45) (Fig. 6).

**Figure 5. Status after ALIF stand alone, Synfix implant** (source: author's archive).

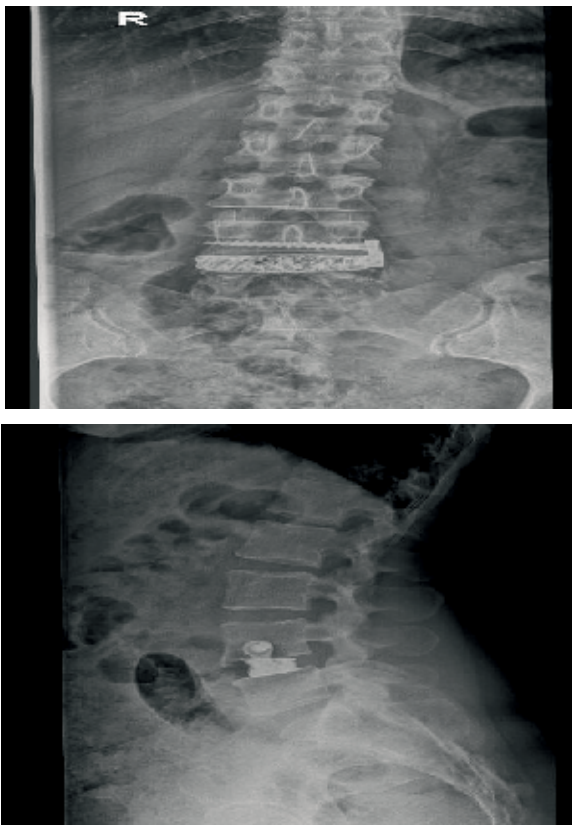


**Figure 6. Schematic procedure for XLIF, transpsoas approach + schematic result of XLIF** (source: XLIF Sales Brochure, Nuvasive, Inc. (2019).



We use this technique routinely with neuromonitoring. For some surgeons, monitoring is mandatory to avoid damage of plexus lumbalis. The technique is not suitable for the L5/S1 segment and low-lying L4/5 segment and for a higher degree of stenosis of the spinal canal, because we can only achieve indirect decompression (27, 28, 30,32,33, 59-64 ). Here, oblique lumbar interbody fusion (OLIF) can be an alternative. In **OLIF** we access the intervertebral disc space between the psoas muscle and the aorta/inferior vena cava (IVC) to reduce the risk of injury to muscle and lumbar plexus (29, 31, 44). OLIF surgery was first described by Mayer in 1997 and became more popular after a larger series by Silvestre et al in 2012. OLIF operations allow access to L1-S1 while remaining anterior to the psoas muscle, prepsoatic approach. Figure 7 shows patient operated by XLIF technique.

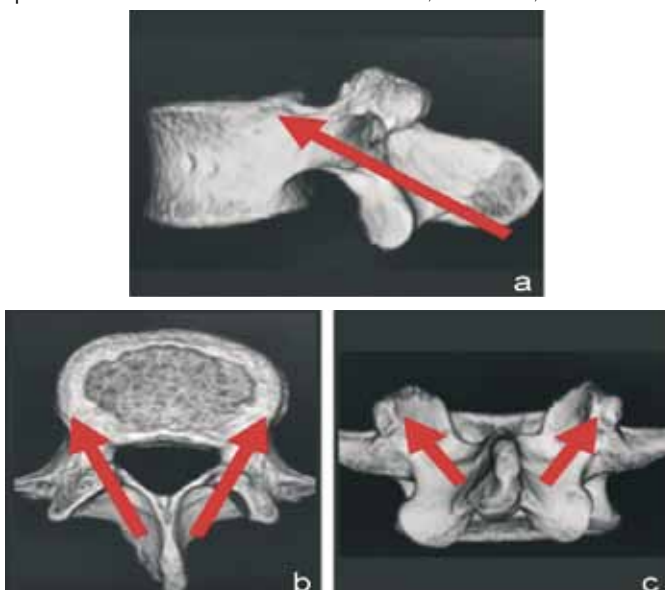
**Figure 7. Status post XLIF procedure, Modulus implant with plate, Globalmed company** (source: author's archive).



### Midline lumbar interbody fusion

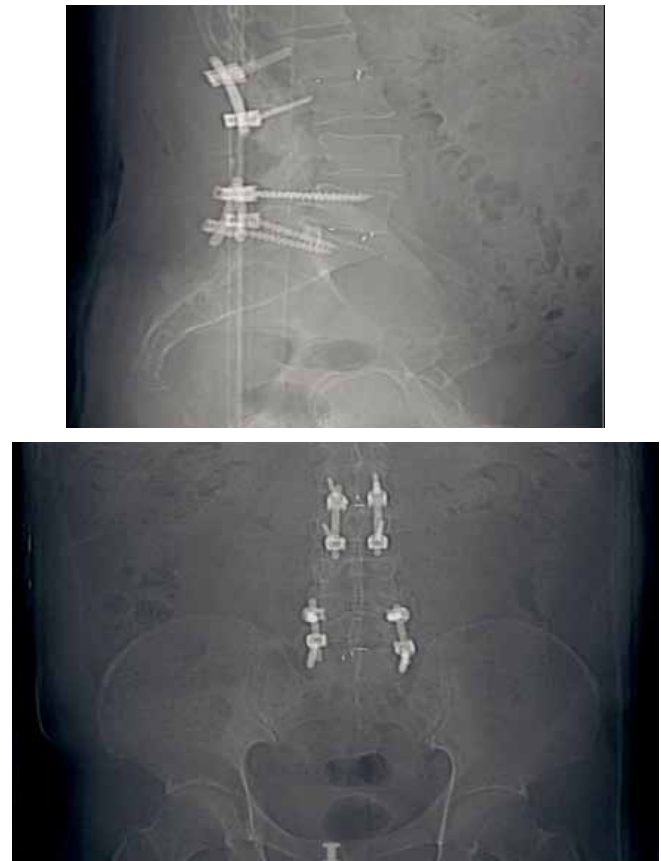
In 2009, Santoni presented another alternative fusion technique using the classic posterior approach, but with a shorter incision and screws inserted in a so-called cortical trajectory (CBT) - see Figure 8. The technique names Midline lumbar fusion (MIDLF), (34-35).

**Figure 8. Trajectory of cortical bone screw.** a: In sagittal plane, caudal to cranial direction of screw, b: medial to lateral trajectory of screw in axial plane, c: CBT screw through the cortical bone of lamina and pedicle. CBT. (source: MIDLF Sales Brochure, Medtronic, Inc. (2011).



The difference in entry points and screw trajectory compared to classic transpedicular screws provides potential benefits in less dissection of adjacent soft tissues, of course less blood loss, better wound healing, as well as lower risk of infection. Figure 9 shows a patient from our clinic, operated on using this technique at L2/3, and at L5/S1 with MIS PLIF technique after some time.

**Figure 9. MIDLF and MIS PLIF** (source: author's archive).



### Posterior lumbar interbody fusion

Posterior lumbar interbody fusion (PLIF) and MIS variant remains the most widely used fusion technique in the world. In our clinic, we almost use the MIS or mini PLIF as a minimally invasive variant, which involves inserting replacements of intervertebral disc through windows uni or bilaterally, without laminectomy, under microscope. We dominantly use only one cage from one side and it is inserted from medial side-similar approach like in microdissectomy. (36-39, 65-75).

### Axial lumbar interbody fusion

Axial lumbar interbody fusion (AXIALIF) is minimally invasive technique for treating L5/S1 pathology. It is percutaneous pre-sacral approach for L5/S1 fusion. (40,41) This technique was first described in 2004. We do not use this technique.

### Endoscopy

There are few studies and articles about the intervertebral disc space replacement by endoscopy through

endoscopic working channel, so called Endo-lumbar interbody fusion (endo LIF) (42,43, 46-51). With both the advancement of minimally invasive technology and anatomical understanding (i.e., Kambin's triangle), the endoscopic spine surgery has emerged. The most common and well-described endoscopic LIF is the TLIF. We currently use endoscopy only for microdiscectomy, but endoscopic assisted fusion seems to be a future of fusion surgery.

### Discussion and conclusion

Low back pain (LBP) is a worldwide problem, „civilization disease“. Current statistical data show that 90% of patients with first occurrence of radiculopathy are treated conservatively (1). For the remaining 10%, in whom problems persist, or even accelerate into neurological deficit, surgical treatment needs to be considered (1). Fusion is still the gold standard in many degenerative diseases of lumbosacral region and it will be the same in future. But so called open methods with serious adverse effects led to the development of minimally invasive techniques. It is important for patients, that in almost all degenerative conditions, where fusion operation is indicated, we can realize MIS surgery with excellent results, minimal complications, rapid recovery and faster integration into normal working life. We discuss about different surgical options and suitable patients. In our clinic we perform almost the whole spectrum of these procedures and the results are very encouraging and promising and the future will be in the sign of MIS. For me, UNILIF is very promising method and maybe endoscopy and robotic spinal neurosurgery will dominate in the future. The most optimistic visions for patients are about stopping disc degeneration, or the possibility of its regeneration. This would mean, that many degenerative conditions would not need to be operated on at all.

In this review, we have discussed current possibilities of minimally invasive surgical fusion techniques in treating degenerative diseases in the lumbosacral region. Minimally invasive techniques in general are associated with lower incidence of complications, earlier recovery, lower analgesic consumption, less blood loss, lower economic costs (5,6, 11-14, 17-19, 23-26,38, 40-43, 54-62). The enormous expansion of minimally invasive techniques has mainly occurred in the last 10 years. It should be realized that minimally invasive techniques have clear advantages and justification over classic open techniques. Currently, there exists a minimally invasive variant for every open technique, which is less burdensome for the patient, is associated with lower morbidity, low risk of complications, and good clinical and radiological results. Less blood loss, faster recovery, faster return to work are just some of the advantages. Disadvantages such as reported longer operation time, longer learning curve, or higher radiation exposure are relative and can be eliminated with increasing numbers of operated patients. Among the mentioned techniques, we most frequently use MIS PLIF and MIS TLIF. To ob-

jectify the data, we have published a prospective randomized controlled study comparing patients operated on using MIS TLIF technique and modified open TLIF via Wiltse approach in Polish Journal of neurology and neurosurgery. UNILIF appears to us as the most promising for the future, where the advantages of minimally invasive techniques will be fully manifested. We have completed our first patients and we are working on retrospective analysis to compare patients operated with UNILIF and MIS TLIF technique. Results so far are very encouraging. Whether we have taken the right direction will be shown in the future and, of course, with more operated patients.\*

\***Conflict of interest:** None declared.

**Ethical approval:** Not necessary for the preparation of this article.

### Literature

1. RUDINSKÝ B, KOLEJÁK K. Degeneratívne ochorenie driekovej chrbtice - možnosti chirurgickej liečby. *Neurol prax* 2008, 3: 135 - 141.
2. HARI A, KRISHNA M, RAJAGANDHI S, RAJAKUMAR DV. Minimally Invasive Transforaminal Lumbar Interbody Fusion-Indications and Clinical Experience. *Neurol India* 2016, 64 (3): 444-454.
3. Unilateral versus Bilateral Pedicle Screw Fixation of Minimally Invasive Transforaminal Lumbar Interbody Fusion: a Meta-Analysis of Randomized Controlled Trials. *BMC Surg* 2014, 14: 87. Doi 10.1186/1471-2482-14-87.
4. McCULLOCH JA, YOUNG PH. *Essentials of spinal microsurgery*. Philadelphia: Lippincott-Raven 1998.
5. HARMS J, ROLLINGER H. A one-stage procedure in operative treatment of spondylolistheses: traction-reposition and anterior fusion. *Z Orthop ihre Grenzgeb* 1982, 120: 343-347.
6. FOLEY KT, LEFKOWITZ MA. Advances in minimally invasive spine surgery. *Clin Neurosurg* 2002. 49: 499-517.
7. MAGERL F. External skeletal fixation of the lower thoracic and lumbar spine. In Uhntoff HK, Stahl E (eds): *Current concepts of external fixation of fractures*. New York: Springer-Verlag 1982: 353-366.
8. CLARK C, BOHL M, TUMIALÁN LM. Evolution of Minimally Invasive Transforaminal Lumbar Interbody Fusion: Improving Patient Safety and Outcomes. *Barrow Quarterly* 2016, 26 (1).
9. WILTSE L, SPENCER CW. New uses and refinements of the paraspinous approach to the lumbar spine *Spine (Phila Pa 1976)* 1988, 13 (6): 696-706.
10. QIN R, ZHOU P, YAO Y, et al. Minimally Invasive Versus Traditional Open Transforaminal Lumbar Interbody Fusion for the Treatment of Single-Level Spondylolisthesis Grades 1 and 2: A Systematic Review and Meta-Analysis. *World Neurosurg* 2019, 122: 180-189. Doi10.1016/j.wneu.2018.10.202.
11. NAYAR G, BLIZZARD DJ, WANG TY, et al. Pedicle Screw Placement Accuracy Using Ultra-Low Radiation Imaging with Image Enhancement versus Conventional Fluoroscopy in Minimally Invasive Transforaminal Lumbar Interbody Fusion: an internally randomized controlled trial.
12. BAEK OK, LEE SH. Extraforaminal lumbar interbody fusion for the treatment of isthmic spondylolisthes *J Spinal Disord Tech* 2009, 22 (3): 219-227. Doi 10.1097/BSD.0b013e3181761528.

13. Arche DR, Druschel C, FAYADA P, VINIKOFF L, DISCH AC. Unilateral Extraforaminal Lumbar Interbody Fusion (ELIF): Surgical Technique and Clinical Outcome in 107 Patients. Doi 10.1097/BSD.0000000000000125
14. HAMEL Q, PREBET R, LUCAS O, et al. Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation (UNILF): outcomes at 7 years. *Eur Spine J* 2024, 33 (1): 356-360. Doi 10.1007/s00586-023-07946-4.
15. GIORGI H, PREBET R, ANDRIANTSIMIYAVONA R, et al. Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation (UNILF): morbidity, clinical and radiological 2-year outcomes of a 66-patient prospective series. *Eur Spine J* 2018, 27 (8): 1933-1939. Doi 10.1007/s00586-017-5452-5.
16. CHEN C, CAO X, ZOU L, HAO G, ZHOU Z, ZHANG G. Minimally invasive unilateral versus bilateral technique in performing single-segment pedicle screw fixation and lumbar interbody fusion. *J of Orthopaedic Surgery and Research* 2015, 10 (112).
17. DEUTSCH H, MUSACCHIO MJ, Jr. Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation. *Neurosurg Focus* 2006, 20 (3): E10. Doi 10.3171/foc.2006.20.3.11
18. KAIN CH, GIESLER B, HOCHSCHULER SH. Anterior lumbar interbody fusion: lumbar approach, complications, and their prevention. *Operative Techniques in Orthopaedics* 1993, 3: 225-231. Doi.org/10.1016/S1048-6666(06)80046-7
19. TAY BB, BERVEN S. Indications, techniques, and complications of lumbar interbody fusion. *Semin Neurol* 2002, 22 (2): 221-230. Doi 10.1055/s-2002-6545.
20. TANG SJ, JIN HB, WANG ZB, MIAO J, ZHONGGUO GS. Progress of anterior lumbar interbody fusion in clinical application. *Am Surg* 2008, 21 (1): 72-75.
21. BEGLAIBTER N, ZAMIR O, MILGRUM M, et al. Laparoscopic anterior lumbar interbody spinal fusion. *Am Surg* 2003, 142 (5): 326-328.
22. INAMASU J, GUIOT BH. Laparoscopic anterior lumbar interbody fusion: a review of outcome studies. *Minim Invasive Neurosurg* 2005, 48 (6): 340-347. Doi 10.1055/s-2005-915634.
23. DEWALD CJ, MILLIKAN KW, HAMMERBERG KW, DOOLAS A, DEWALD RL. An open, minimally invasive approach to the lumbar spine. *Am Surg* 1999, 65 (1): 61-68.
24. SHU-JIE T, HONG-BIN J, ZHI-BIN W, JUN M. Progress of anterior lumbar interbody fusion in clinical application. *Affiliations expand PMID: 19102289.*
25. MALHAM GM, WAGNER TP, CLAYDON MH. Anterior lumbar interbody fusion in a lateral decubitus position: technique and outcomes in obese patients. *J Spine Surg* 2019, 5 (4): 433-442. Doi 10.21037/jss.2019.09.09
26. BUCKLAND A J, LEON C, ASHAYERI K, et al. Spinal exposure for anterior lumbar interbody fusion (ALIF) in the lateral decubitus position: anatomical and technical considerations. *Eur Spine J* 2022, 31 (9): 2188-2195. Doi 10.1007/s00586-022-07227-6.
27. BJERKE B. Extreme Lateral Interbody Fusion (XLIF). *Conditions & Treatments. UCSF Health XLIF: Lumbar Spinal Fusion. Spine-health.*
28. BERJANO P, GAUTSCHI O P, SCHILS F, TESSITORE E. Extreme lateral interbody fusion (XLIF): how I do it. *Acta Neurochir (Wien)* 2015, 157 (3): 547-551. Doi 10.1007/s00701-014-2248-9.
29. MEHREN C, MAYER HM, ZANDANELL C, SIEPE CJ, KORGE A. The Oblique Anterolateral Approach to the Lumbar Spine Provides Access to the Lumbar Spine With Few Early Complications. *Clin Orthop Relat Res* 2016, 474 (9): 2020-2027. Doi 10.1007/s11999-016-4883-3.
30. NARITA W, TAKATORI R, ARAI Y, et al. Prevention of neurological complications using a neural monitoring system with a finger electrode in the extreme lateral interbody fusion approach. *Neurosurg Spine* 2016, 25 (4): 456-463. Doi 10.3171/2016.1.SPINE151069.
31. PHAN K, MAHARAJ M, ASSEM Y, MOBBS RJ. Review of early clinical results and complications associated with oblique lumbar interbody fusion (OLIF). *J Clin Neurosci* 2016, 31: 23-29. Doi 10.1016/j.jocn.2016.02.030.
32. BINA RW, ZOCCALI C, SKOCH J, BAAJ AA. Surgical anatomy of the minimally invasive lateral lumbar approach. *J Clin Neurosci* 2015, 22 (3): 456-459. Doi 10.1016/j.jocn.2014.08.011.
33. MEADE MH, LEE Y, BRUSH PL, LAMBRECHTS MJ, et al. Lateral approach to the lumbar spine: The utility of an access surgeon. *J Craniovertebr Junction Spine* 2023, 14 (3): 281-287. Doi 10.4103/jcvjs.jcvjs\_78\_23.
34. MIZUNO M, KURAISHI K, UMEDA Y, SANOT T, TSUJIM M, SUZUKI H. Midline Lumbar Fusion with Cortical Bone Trajectory Screw. *Neurol Med Chir (Tokyo)* 2014, 54 (9): 716-721. Doi 10.2176/nmc.st.2013-0395
35. HUANG HM, CHEN CHH, LEE HC, et al. Minimal invasive surgical technique in midline lumbar inter-body fusion: A technique note. *J Clin Neurosci* 2018, 55: 103-108. Doi 10.1016/j.jocn.2018.06.033.
36. FOGEL GR, TOOHEY JS, NEIDRE A, BRANTIGAN JW. Is one cage enough in posterior lumbar interbody fusion: a comparison of unilateral single cage interbody fusion to bilateral cages. *J Spinal Disord Tech* 2007, 20 (1): 60-65. Doi 10.1097/01.bsd.0000211251.59953.a4.
37. MOLINARI RW, SLOBODA J, JOHNSTONE FL. Are 2 cages needed with instrumented PLIF? A comparison of 1 versus 2 interbody cages in a military population. *Am J Orthop (Belle Mead NJ)* 2003, 32 (7): 337-343.
38. BINGQIAN CH, FENG X, XIAOWEN S, ET AL. Modified posterior lumbar interbody fusion using a single cage with unilateral pedicle screws: a retrospective clinical study. *Journal of Orthopaedic Surgery and Research* 2015, 10 (98): 52-56. Doi 10.14245/kjs.2014.11.2.52.
39. LEE SK, KIM SW, JU CI, LEE SM, KIM MH. Posterior lumbar interbody fusion using an unilateral cage: a prospective study of clinical outcome and stability. Doi 10.14245/kjs.2014.11.2.52
40. Spinal fusion: Axial lumbar Interbody Fusion. *Mayfield Brain & Spine, Cincinnati, Ohio (mayfieldclinic.com).*
41. ŠTULÍK J, ADÁMEK S, BARNA1 M, KASPŘÍKOVÁ N, POLANECKÝ O, KRYL J. Axiální lumbální meziobratlová fúze – AxiaLIF: prospektivní monocentrická studie. *Acta chirurgiae orthopaedicae et traumatologiae čechosl* 2014, 81: 203-211.
42. ZHENG B, SHAAYA E, FELER J. Endoscopic Techniques for Lumbar Interbody Fusion: Principles and Context. *Biomed Res Int* 2022, 2022: 4979231. Doi 10.1155/2022/4979231
43. PHOLPRAJUG P, KOTHEERANURAK V, LIU Y, SUNG J. The Endoscopic Lumbar Interbody Fusion: A Narrative Review, and Future Perspective. *Kim Neurospine* 2023, 20 (4): 1224-1245. Doi 10.14245/ns.2346888.444
44. YOUNG HK, KEE YH, KEE WR, et al. Lumbar Interbody Fusion: Techniques, Pearls and Pitfalls. *Asian Spine J* 2020, 14 (5): 730-741. Doi.org/10.31616/asj.2020.0485
45. OZGUR BM, ARYAN HE, PIMENTA L, TAYLOR WR. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J* 2006, 6: 435-443
46. KIM JE, CHOI DJ, PARK EJ, et al. Biportal endoscopic spinal surgery for lumbar spinal stenosis. *Asian Spine J* 2019, 13: 334-342.

47. KAPETANAKIS S, GKANTSINIKOUDIS N, THOMAIDIS T, et al. The role of percutaneous transforaminal endoscopic surgery in lateral recess stenosis in elderly patients. *Asian Spine J* 2019, 13: 638-647.
48. HEO DH, HONG YH, LEE DC, CHUNG HJ, PARK CK. Technique of biportal endoscopic transforaminal lumbar interbody fusion. *Neurospine* 2020, 17 (Suppl 1): S129-137.
49. HEO DH, SON SK, EUM JH, PARK CK. Fully endoscopic lumbar interbody fusion using a percutaneous unilateral biportal endoscopic technique: technical note and preliminary clinical results. *Neurosurg Focus* 2017, 43: E8.
50. BRUSKO GD, WANG MY. Endoscopic lumbar interbody fusion. *Neurosurg Clin N Am* 2020, 31: 17-24.
51. LEE SH, ERKEN HY, BAE J. Percutaneous transforaminal endoscopic lumbar interbody fusion: clinical and radiological results of mean 46-month follow-up. *Biomed Res Int* 2017, 2017: 3731983.
52. CHOI J, RHEE I, RUPAREL S. Assessment of great vessels for anterior access of L5/S1 using patient positioning. *Asian Spine J* 2020, 14: 438-444.
53. BAKER JF, CHAN JC, MOON BG, ROBERTSON PA. Relationship of aortic bifurcation with sacropelvic anatomy: application to anterior lumbar interbody fusion. *Clin Anat* 2020. Doi org/10.1002/ca.23598.
54. LIU L, LIANG Y, ZHOU Q, et al. Study on the anatomy of the lumbosacral anterior great vessels pertinent to L5/S1 anterior interbody surgery with computer tomography angiography. *Acta Orthop Belg* 2014, 80: 537-543.
55. BRIDWELL KH, GUPTA M. Bridwell and DeWald's textbook of spinal surgery. 4th ed. Philadelphia (PA): Wolters Kluwer Health 2019.
56. SASSO RC, KENNETH BURKUS J, LEHUEC JC. Retrograde ejaculation after anterior lumbar interbody fusion: transperitoneal versus retroperitoneal exposure. *Spine (Phila Pa 1976)* 2003, 28: 1023-1026.
57. GUMBS AA, BLOOM ND, BITAN FD, HANAN SH. Open anterior approaches for lumbar spine procedures. *Am J Surg* 2007, 194: 98-102.
58. LOLIS E, PANAGOULI E, VENIERATOS D. Study of the ascending lumbar and iliolumbar veins: surgical anatomy, clinical implications and review of the literature. *Ann Anat* 2011, 193: 516-529.
59. LAWS CJ, COUGHLIN DG, LOTZ JC, SERHAN HA, HU SS. Direct lateral approach to lumbar fusion is a biomechanically equivalent alternative to the anterior approach: an in vitro study. *Spine (Phila Pa 1976)* 2012, 37: 819-825.
60. TABA HA, WILLIAMS SK. Lateral lumbar interbody fusion. *Neurosurg Clin N Am* 2020, 31: 33-42.
61. PARK HY, KIM YH, HA KY, et al. Minimally invasive lateral lumbar interbody fusion for clinical adjacent segment pathology: a comparative study with conventional posterior lumbar interbody fusion. *Clin Spine Surg* 2019, 32: E426-33.
62. RABAU O, NAVARRO-RAMIREZ R, AZIZ M, et al. Lateral lumbar interbody fusion (LLIF): an update. *Global Spine J* 2020, 10 (2 Suppl): 17S-21S.
63. LIMTHONGKULW, TANASANSOMBOONT, YINGSAKMONGKOL W, et al. Indirect decompression effect to central canal and ligamentum flavum after extreme lateral lumbar interbody fusion and oblique lumbar interbody fusion. *Spine (Phila Pa 1976)* 2020, 45: E1077-1084.
64. WALKER CT, FARBER SH, COLE TS, et al. Complications for minimally invasive lateral interbody arthrodesis: a systematic review and meta-analysis comparing prepsoas and transpsoas approaches. *J Neurosurg Spine* 2019: 1-15.
65. OPPENHEIMER JH, DECASTRO I, MCDONNELL DE. Minimally invasive spine technology and minimally invasive spine surgery: a historical review. *Neurosurg Focus* 2009, 27: E9.
66. ECK JC, HODGES S, HUMPHREYS SC. Minimally invasive lumbar spinal fusion. *J Am Acad Orthop Surg* 2007, 15: 321-329.
67. DIPAOLO CP, MOLINARI RW. Posterior lumbar interbody fusion. *J Am Acad Orthop Surg* 2008, 16: 130-139.
68. GARFIN SR, EISMONT FJ, BELL GR, et al. Rothman-Simeone and Herkowitz's the spine. 7th ed. Philadelphia (PA): Elsevier 2018.
69. LESTINI WF, FULGHUM JS, WHITEHURST LA. Lumbar spinal fusion: advantages of posterior lumbar interbody fusion. *Surg Technol Int* 1994, 3: 577-590.
70. KIM KT, LEE SH, LEE YH, BAE SC, SUK KS. Clinical outcomes of 3 fusion methods through the posterior approach in the lumbar spine. *Spine (Philadelphia 1976)* 2006, 31: 1351-1357.
71. FAN SW, HU ZJ, FANG XQ, ZHAO FD, HUANG Y, YU HJ. Comparison of paraspinal muscle injury in onelevel lumbar posterior inter-body fusion: modified minimally invasive and traditional open approaches. *Orthop Surg* 2010, 2: 194-200.
72. OKUDA S, MIYAUCHI A, ODA T, HAKU T, YAMAMOTO T, YOUNG-HOON KIM, et al. *Asian Spine J* 2020, 14 (5): 730-741.
73. IWASAKI M. Surgical complications of posterior lumbar interbody fusion with total facetectomy in 251 patients. *J Neurosurg Spine* 2006, 4: 304-309.
74. KRISHNA M, POLLOCK RD, BHATIA C. Incidence, etiology, classification, and management of neuralgia after posterior lumbar interbody fusion surgery in 226 patients. *Spine J* 2008, 8: 374-379.
75. HUMPHREYS SC, HODGES SD, PATWARDHAN AG, et al. Comparison of posterior and transforaminal approaches to lumbar interbody fusion. *Spine (Phila Pa 1976)* 2001, 26: 567-571.
76. ZHANG Q, YUAN Z, ZHOU M, LIU H, XU Y, REN Y. A comparison of posterior lumbar interbody fusion and transforaminal lumbar interbody fusion: a literature review and meta-analysis. *BMC Musculoskelet Disord* 2014, 15: 367.

Do redakcie došlo 20.1.2025.

**Adresa pre korešpondenciu:**  
**Roman KALINA, MD**  
 Podlipa 27  
 Ľubietová, 976 55  
 E-mail: romankalina4@gmail.com