PREDICTORS OF INDIRECT DECOMPRESSION IN PATIENTS WITH MONOSEGMENTAL LUMBAR SPINAL STENOSIS

I.D. Isakov, A.J. Sanginov, E.A. Mushkachev, A.V. Peleganchuk
Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia

Objective. To identify predictors of indirect decompression of spinal nerve roots in patients with degenerative monosegmental central spinal canal stenosis in the lumbar spine after isolated direct lateral interbody fusion (XLIF).

Material and Methods. This prospective study analyzes the treatment outcomes of 80 patients with multisegmental central degenerative spinal stenosis associated with instability of the spinal motion segment. All patients underwent single-level XLIF without additional posterior fixation. Based on early postoperative data, patients were divided into groups with no positive dynamics in neurological status ($n = 58$) and with positive dynamics in the form of a decrease in the lower extremity pain to 1 point on the VAS ($n = 22$). All patients underwent preoperative MRI, MSCT, lumbar spine radiography, and VAS questionnaire survey. Postoperatively, they underwent MRI and MSCT of the lumbar spine, and VAS questionnaire survey. The prognostic significance of the studied factors for treatment outcomes was determined using logistic regression analysis.

Results. Factor analysis revealed significant prognostic factors for the effectiveness of indirect decompression of spinal nerve roots in the spinal canal after XLIF: lateral recess depth greater than 3.75 mm and body mass index greater than 35.97 kg/m^2. According to a single-factor model, it was revealed that the higher Hounsfield (HU) values in the bodies of adjacent vertebrae, a lower intervertebral disc, the presence of laterospondylolisthesis, intervertebral disc degeneration (Pfirrmann grades 4, 5), endplate changes of grades 4, 5, 6 according to Toshiba Endplate Scoring (TEPS) and the clinical picture of dynamic compression are moderate prognostic factors for successful indirect decompression of the nerve roots in the spinal canal after XLIF for degenerative central stenosis associated with instability of the spinal motion segment.

Conclusion. Further studies are required to validate the identified prognostic criteria, as well as other possible prognostic indicators — the timing of bone block formation in the surgical area, the frequency of implant subsidence and its clinical significance in the long-term period, the long-term effect of indirect decompression, and the results of the ODI and SF-12 survey in the late postoperative period.

Key Words: central degenerative spinal canal stenosis; direct lateral fusion; indirect decompression; predictors of indirect decompression; LLIF (lateral lumbar interbody fusion); DLIF (direct lumbar interbody fusion), ELIF; XLIF (extreme lumbar interbody fusion); ID (indirect decompression).

Please cite this paper as: *Isakov ID, Sanginov AJ, Mushkachev EA, Peleganchuk AV. Predictors of indirect decompression in patients with monosegmental lumbar spinal stenosis. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2025;22(4):56–65. In Russian. DOI: http://dx.doi.org/10.14531/ss2025.4.56-65*

Currently, decompression as well as decompression and stabilization surgeries are the standard treatment options for patients with degenerative spinal canal stenosis in cases of nonsurgical treatment failure [1]. If instability of the spinal motion segment is detected or there is a high probability of its development, it is required to perform spinal fusion after decompression. Decompression of the spinal nerve roots can be direct (microsurgical) or indirect (an increase in the reserve spaces of the spinal canal without contact with neurovascular structures, for example, by restoring the height of the interbody space and changing the positions of adjacent vertebrae after placing an interbody implant through an anterior approach) [2–11]. Indirect decompression of the spinal nerve roots in the intervertebral foramen after isolated direct lateral interbody fusion (XLIF) is a rather predictable outcome [12–16].

An isolated direct lateral interbody fusion (DLIF) as a decompression and stabilization surgical procedure is a treatment technique in demand, since indirect decompression is equal with direct decompression in efficiency and significantly reduces the risk of injury to the dura mater, retraction injury to the spinal cord roots, and eliminates the formation of peridural fibrosis [17].

Indirect decompression of the spinal nerve roots in the spinal canal after isolated direct lateral fusion is not always successful in patients with degenerative spinal canal stenosis [18]. It is currently impossible to predict the outcome of indirect decompression at the surgical planning stage. Several studies have been published on the identification of predictors of indirect decompression, but they either involve heterogeneous patient groups, a small number of patients, or lack a clear description of the surgical technique and little information about a patient.

Identifying predictors of indirect decompression of spinal nerve roots will help to develop a personalized approach to the extent of surgery and improve the clinical outcomes for patients with central degenerative spinal stenosis.

The objective is to identify predictors of indirect decompression of spinal nerve roots in patients with degenerative monosegmental central spinal canal stenosis in the lumbar spine after isolated direct lateral interbody fusion (XLIF).

Material and Methods

Study design: a prospective open-label non-randomized cohort study with 80 participants.

An analysis was conducted of early (up to 7 days) postoperative outcomes in 80 patients with single-level central degenerative spinal canal stenosis, clinical signs of neural compression (radicular syndrome, compression-ischemic radiculopathy, neurogenic claudication), and instability of the spinal motion segment at the level of spinal canal stenosis. From 2018 to 2024, patients in the neurosurgery unit No. 2 of the Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan underwent isolated XLIF with cages 45 and 50 mm wide, 9 to 15 mm high, and with a lordotic angle of 8°. In 2006, Ozgur et al. published a description of the surgical technique [12].

Inclusion criteria:

1) single-level central degenerative stenosis of the spinal canal in the lumbar spine, corresponding to types B, C, and D as described by Schizas et al. [19];

2) levels of stenosis: L2–L3, L3–L4, L4–L5;

3) instability of the spinal motion segment, corresponding to disc angulation of more than 10° and translation of the superjacent vertebra by 3 mm or more [20];

4) ineffective conservative treatment for 1.5 months;

5) clinical signs of compression of the spinal nerve roots, including neurogenic intermittent claudication, radicular syndrome, and compression-ischemic radiculopathy;

6) surgery performed using XLIF without additional fixation.

Ineligibility criteria:

1) central degenerative stenosis of the spinal canal, corresponding to type A according to Schizas, and isolated foraminal stenosis with compression of the spinal nerve roots;

2) previous spinal surgery at the level of stenosis, as well as at the site of surgical approach for direct lateral interbody fusion;

3) degenerative pathomorphological substrate at two or more levels;

4) congenital abnormalities, infectious and traumatic injuries and their consequences, space-occupying processes, including the presence of an intraspinal synovial cyst in the lumbar spine, spinal injuries associated with autoimmune diseases (rheumatoid arthritis, etc.);

5) scoliotic deformity of the lumbar spine (Cobb angle ⩾20°);

6) pathology of the lower extremities with length discrepancy;

7) presence of a spinal cord neurostimulator.

Patients included in the study were mobilized on the first day after surgery. Seven days after isolated XLIF, they were divided into two groups: Group 1 included 58 (72.5%) patients without effective indirect decompression of the spinal nerve roots, and Group 2 included 22 (27.5%) patients with effective indirect decompression. Patients in Group 1 underwent the second stage of surgery involving direct decompression (total unilateral facetectomy with microsurgical decompression of the spinal nerve roots) and transpedicular fixation of the spinal motion segment. There were no cases of implant migration during the follow-up period.

The criterion for indirect decompression of the spinal nerve roots was pain relief in the lower extremities to one point within seven days after XLIF, without the need for analgesics; one point was considered acceptable if the patient experienced pain in the lower extremity on the side of approach in the early postoperative period.

The following data points were analyzed: gender, age, surgical approach side, spinal canal stenosis according to the Schizas classification (pre- and postoperative), level of surgical intervention, presence of dynamic neural compression [21], patient body mass index (BMI), preoperative VAS score for back and leg pain, presence of anterolisthesis, severity of spondyloarthrosis according to Grogan et al. [22], intervertebral disc height measured on preoperative anterior, middle, and posterior lumbar MSCT [23], adjacent vertebral body changes according to Modic et al. [24], degree of intervertebral disc degeneration according to Pfirrmann et al. [25], presence of lateral recess stenosis, lateral recess angle and depth [26], segmental angle and vertebral translation measured on lumbar spine anteroposterior and lateral radiographs, presence of lateral and retrolisthesis, pre- and postoperative spinal canal cross-sectional area, pre- and postoperative ligamentum flavum thickness, pre- and postoperative dimensions (height and width) of the intervertebral foramina, condition of the adjacent vertebral endplates assessed with the TEPS classification [27], fatty degeneration of paraspinal muscles according to Goutallier et al. [28, 29], spinal sagittal balance parameters (LL, PI, PT, SS) measured on lateral spine radiographs in the STEP mode [23], vertebral bone density measured in Hounsfield units (HU) [30] in the adjacent vertebral bodies, as well as the dimensions (height and width) of the implants.

The main characteristics of the patients and their comparison are shown in Table 1.

Empirical data distributions were evaluated for conformity with the normal distribution law using the Shapiro–Wilk test.

In order to compare continuous data between groups, the nonparametric Mann–Whitney *U* test was used, since, according to the Shapiro–Wilk test, only 17% of the distribution indicators could be considered normal. The median [first quartile; third quartile] (Me [Q1; Q3]) was used as the main descriptive characteristic of continuous data, with the mean ± standard deviation ($M \pm SD$) and minimum and maximum values (min–max) also provided. Categorical and binary data are reported as number (*n*) and frequency (%), compared using Fisher's exact test, and Wilson's formula was used for binary data to calculate a 95% confidence interval for frequencies

(95% CI). Only two-tailed comparison criteria were used.

Univariate and multivariate logistic regression models were used to identify predictors of indirect decompression of spinal nerve roots. Using ROC analysis, maximizing the Youden's index, the best threshold for indirect decompression prediction was defined for the multivariate logistic regression model, for which the predictive indicators of sensitivity, specificity, and diagnostic accuracy were calculated with 95% CI. The Hosmer–Lemeshow test was used to verify the calibration of the multivariate model with the observed indirect decompression data.

If the significance value was $p < 0.05$, the differences and predictors were considered statistically significant.

The data were statistically processed using R scripts, version 4.4.2 (2024-10-31 ucrt) in the RStudio software (version 2025.05.0 Build 496).

Results

The patient gender, the side of the surgical approach, the type of spinal canal stenosis according to Schizas, the level of degenerative stenosis, and the VAS score in the lower extremities before surgery did not differ significantly between the groups.

The comparative analysis of MRI, MSCT, and radiological characteristics revealed that Group 2 primarily consisted of patients with a lower intervertebral disc height (anterior disc height: $p = 0.028$, middle: $p = 0.046$, posterior: $p = 0.013$), more degenerated discs according to the Pfirrmann grading system (Grades 4 and 5: 39.7% in Group 1 vs. 68.2% in Group 2), and an absence of lateral recess stenosis ($p = 0.010$). Patients in Group 2 more frequently presented with lateral spondylolisthesis ($p = 0.011$), more severe endplate changes according to the TEPS classification (TEPS grades 4, 5, and 6: 77.3% in Group 2 vs. 50.1% in Group 1), and denser bone tissue in the adjacent vertebral bodies as measured in Hounsfield units – 165.0 [120.0; 217.5]; $p = 0.011$. The presence of anterolisthesis, the degree of spondyloarthrosis according to Grogan, changes according to Modic, the segmental angle of the spinal motion segment, the presence of retrolisthesis, spinal canal cross-sectional area, intervertebral foramen dimensions, paraspinal muscle fatty degeneration according to Goutallier, sagittal balance parameters, and implant width and height showed no significant differences (Table 2).

Using logistic regression models based on a multivariate model, it was found that the probability of effective indirect decompression increased with a lateral recess depth of less than 3.75 mm ($p = 0.001$), a BMI greater than 35.97 kg/m^2 ($p = 0.025$), and dynamic compression of neural structures ($p = 0.082$).

If the bone density in adjacent vertebral bodies is more than 157.5 HU ($p = 0.001$), the anterior intervertebral disc height is less than 3.75 mm ($p = 0.002$), the posterior height is less than 3.85 mm ($p = 0.004$), the middle height is less than 4.05 mm ($p = 0.002$), lateral spondylolisthesis is present ($p = 0.011$), the Pfirrmann disc degeneration grade is 4 or 5 ($p = 0.026$), and the TEPS grade is 4, 5, or 6 ($p = 0.033$), the likelihood of effective indirect decompression of the spinal roots within the spinal canal after XLIF also increases, as calculated using univariate logistic regression models (Table 3).

Using ROC analysis in a multivariate model, a decision threshold of 0.30 was established, which had the best sensitivity (77.3%) and specificity (93.1%) scores (Fig.), i.e., with a probability of 0.30 or higher in the multivariate model, a positive prediction of indirect decompression is made; otherwise, a negative prediction is made. Table 4 lists the predictive characteristics of the multivariate model for the obtained threshold. The achieved Hosmer–Lemeshow test significance value ($p = 0.812$) indicates that the multivariate model is compatible with the actual data, and the AUC metric = 92.4% confirms the good quality of the prediction.

Discussion

Our study included patients with single-level central degenerative spinal canal stenosis and instability of the spinal motion segment at the level of spinal canal stenosis who underwent isolated XLIF. Thus, a homogeneous group was selected, which is also confirmed by the comparison of the two groups by gender, age, side of surgical approach, spinal canal stenosis according to Schizas, level of degenerative stenosis, and the VAS score in the lower extremities before surgery, where these indicators did not differ significantly between the groups.

There are a number of studies focused on identifying predictors of effective indirect decompression of spinal nerve roots after XLIF. However, most of them do not specify the type of stenosis (intervertebral foramen, spinal canal, lateral recess) or assess the effectiveness of decompression of spinal nerve roots in intervertebral foramina in combination with or without stenosis in the spinal canal [12–16]. In a study to identify predictors of unsuccessful indirect decompression after ALIF and XLIF, Park et al. [31] examined the treatment outcomes of patients who underwent direct decompression as a second surgery several days after ALIF or XLIF and reported that some patients did not require the second stage since indirect decompression had already achieved a clinical effect. The results of this study are not fully applicable to predicting indirect decompression after XLIF because of the heterogeneity of the groups and the use of different surgical techniques. The principal difference between XLIF and ALIF in achieving indirect decompression is the ability to cross the longitudinal ligaments of the spine in ALIF and to place a higher cage than in XLIF. An increase in the height of the interbody space is one of the key techniques for achieving effective indirect decompression of the spinal roots.

There are a small number of articles about predictors of indirect decompression of spinal nerve roots specifically in the spinal canal in cases of central degenerative stenosis after XLIF. Thus, in a retrospective analysis of 73 patients with XLIF performed on 107 levels for spinal canal stenosis associated with spondylolisthesis, scoliosis, adjacent segment

Table 1

Main characteristics of patients in the study groups and their comparison

Parameter	Group 1 (n = 58)	Group 2 (n = 22)	p value
Males, n (%)	19 (32.8)	5 (22.7)	0.428
Females, n (%)	39 (67.2)	17 (77.3)	
Age, years	64.0 [58.2; 68.0] 63.50 ± 7.30 (41.0–84.0)	59.0 [54.8; 64.8] 59.20 ± 8.04 (42.0–74.0)	0.038*
Grades before surgery according to Schizas, n (%)			
B	6 (10.3)	1 (4.5)	Overall comparison: 0.481; category: p; p corrected B: 0.667; 0.667 C: 0.279; 0.667 D: 0.611; 0.667
C	14 (24.1)	8 (36.4)	
D	38 (65.6)	13 (59.1)	
Dynamic compression of spinal cord roots, n (%)			
Yes	12 (20.7)	11(50.0)	0.014*
No	46 (79.3)	11 (50.0)	
Obesity grade by BMI, n (%)			
Normal (BMI up to 25 kg/m^2)	5 (8.6)	2 (9.1)	Overall comparison: 0.081; category: p; p corrected [0; 25]: >0.999; >0.999 [25; 30]: 0.247; 0.412 [30; 35]: 0.183; 0.412 [35; 40]: 0.008*; 0.041* [40; 100]: >0.999; >0.999
Overweight (BMI 25–30 kg/m^2)	16 (27.6)	3 (13.6)	
Grade I (BMI 30–35 kg/m^2)	20 (34.5)	4 (18.2)	
Grade II (BMI 35–40 kg/m^2)	9 (15.5)	10 (45.5)	
Grade III (BMI more than 40 kg/m^2)	8 (13.8)	3 (13.6)	

* Significant differences; BMI — body mass index.

degeneration, or degenerative disc disease, Walker et al. [32] identified the following predictors of indirect decompression of spinal nerve roots: low BMI (contrary to our results), spondylolisthesis, and lower disc height.

We included only patients with monosegmental central degenerative spinal canal stenosis in our study; therefore, all patients underwent single-level surgery. Walker et al. [32] considered successful indirect decompression to be a reduction in lower extremity pain intensity to a score of three or less on the VAS. We considered indirect decompression to be successful if pain in the lower extremities decreased to 0–1 points on the VAS for more rigorous selection of patients for Group 2, and 1 point was allowed for patients who still had pain in the lower extremity on the approach side or as reflex pain syndrome in the early postoperative period after XLIF. In the study by Walker et al. [32], only 32 of 73 patients had single-level spinal canal stenosis, including six patients who underwent surgery for adjacent segment degeneration, six patients who suffered from intervertebral disc herniation and synovial intracanal cyst of the facet joint, and only 20 patients who had spondylolisthesis. Wang et al. [33] performed XLIF on 101 levels in 45 patients with spondylolisthesis as revision surgery because of degenerative segmental lesions, adjacent segment degeneration, instability of the spinal motion segment, traumatic spinal injury, spinal canal stenosis, and scoliosis of the lumbar spine. The heterogeneity of the selected patient groups in terms of nosology is a significant distinguishing feature compared to the patients in our study. The absence of the lateral recess stenosis was found to be the only predictor of effective indirect decompression, and we got a similar result. Nakashima et al. [34] report that XLIF can reduce pain intensity in the lower extremities by stabilizing the segment. We support this view, since there is no increase in the spinal canal cross-sectional area after XLIF in some cases, while radicular syndrome is relieved.

Shimizu et al. [35] found that Schizas grade D spinal canal stenosis is not a predictor of failure to achieve effective indirect decompression after XLIF. In our study, 13 (59.1%) of 22 patients with effective indirect decompression had Schizas grade D stenosis. Khalsa et al. [21] point out that if the intensity of pain in the lower extremities does not decrease when the patient is lying, direct decompression should be performed. We evaluated the significance of dynamic compression for predicting the effectiveness of indirect decompression after XLIF: this parameter is significant (p = 0.012) in a univariate model, while it is insignificant (p = 0.081) in a multivariate model. Therefore, in some patients, indirect decompression may be achieved even without dynamic compression of the spinal nerve roots. Li et al. [36] con-

Table 2

Radiological, MRI and MSCT characteristics of patients in the study groups and their comparison

Parameter	Group 1 ($n = 58$)	Group 2 ($n = 22$)	p value
Anterior disc height according to MSCT, mm	6.0 [4.2; 8.6] 6.40 ± 2.80 (0.3–14.0)	4.6 [3.0; 7.1] 4.80 ± 2.94 (1.0–10.0)	0.028*
Middle disc height according to MSCT, mm	6.4 [5.0; 9.1] 7.00 ± 3.00 (0.3–13.6)	4.7 [3.0; 8.9] 5.40 ± 3.22 (1.0–11.0)	0.046*
Posterior disc height according to MSCT, mm	4.3 [3.0; 5.9] 4.50 ± 2.10 (0.0–9.0)	3.0 [1.1; 4.2] 3.20 ± 2.08 (1.0–8.5)	0.013*
Intervertebral disc degeneration according to Pfirrmann, n (%)	1 – 0 (0) 2 – 1 (1.7) 3 – 34 (58.6) 4 – 12 (20.7) 5 – 11 (19.0)	1 – 0 (0) 2 – 0 (0.0) 3 – 7 (31.8) 4 – 11 (50.0) 5 – 4 (18.2)	Overall comparison: 0.053; category: p; p corrected 2: >0.999; >0.999 3: 0.045*; 0.090 4: 0.014*; 0.055 5: >0.999; >0.999
Lateral recess angle, degree	24.0 [20.0; 34.8] 27.30 ± 13.40 (0.0–70.0)	35.0 [26.0; 47.8] 36.60 ± 14.28 (15.0–70.0)	0.010*
Lateral recess depth, degree	2.9 [2.0; 4.0] 3.00 ± 1.50 (0.0–7.0)	4.8 [4.0; 5.8] 5.20 ± 2.35 (1.5–11.0)	<0.001*
Presence of lateral spondylolisthesis, n (%)	3 (5.2) [1.8; 14.1]	6 (27.3) [13.2; 48.2]	0.011*
Spinal canal cross-section area before surgery, mm^2	47.0 [37.2; 60.0] 56.60 ± 31.4 (28.0–174.0)	52.5 [47.0; 96.8] 76.00 ± 47.13 (28.0–219.0)	0.068
Thickness of the ligamentum flavum before surgery, mm	3.0 [2.4; 4.5] 3.40 ± 1.40 (1.0–6.7)	4.0 [2.1; 4.3] 3.60 ± 1.58 (1.3–7.0)	0.539
TEPS, n (%)	2 – 1 (1.7) 3 – 28 (48.3) 4 – 15 (25.9) 5 – 7 (12.1) 6 – 7 (12.1)	2 – 0 (0.0) 3 – 5 (22.7) 4 – 11 (50.0) 5 – 2 (9.1) 6 – 4 (18.2)	Overall comparison: 0.163 category: p; p corrected 2: >0.999; >0.999 3: 0.045*; 0.151 4: 0.060; 0.151 5: >0.999; >0.999 6: 0.483; 0.806
Bone density of the adjacent vertebral bodies, assessed according to Hounsfield, HU	127.5 [90.0; 150.0] 130.40 ± 69.60 (20.0–400.0)	165.0 [120.0; 217.5] 206.60 ± 177.28 (70.0–900.0)	0.011*

* Significant differences.

ducted a large study analyzing the treatment outcomes of 557 patients who underwent XLIF on 901 segments, followed by 7 days of follow-up. If indirect decompression was ineffective, a second-stage surgery was performed involving direct decompression. According to the results of the study, patients with Schizas grade C are considered to be better candidates to undergo successful indirect decompression with XLIF. However, the possibility of indirect decompression in patients with grade D is also considered possible, and lateral recess stenosis is defined as a moderate risk factor for unsuccessful indirect decompression. This study is the most extensive in terms of the patient number.

The aforementioned studies differ from our study mainly in the heterogeneity of the selected groups, which can significantly reduce the reliability of the findings (Table 5).

Table 3

Logistic regression models to identify predictors of indirect spinal root decompression in the spinal canal after XLIF

Parameter	Univariate model		Multivariate model	
	OR [95% CI]	*p*	OR [95% CI]	*p*
Lateral recess depth greater than 3.75 mm	11.81 [3.76; 45.93]	<0.001*	23.77 [4.43; 250.90]	0.001*
Body mass index over 35.97 kg/m^2	6.17 [2.16; 18.78]	0.001*	10.30 [1.61; 111.15]	0.025*
The presence of dynamic compression of the spinal cord roots	3.83 [1.35; 11.20]	0.012*	5.94 [0.85; 54.55]	0.082
Bone density of the adjacent vertebral bodies (Hounsfield scale) more than 157.5 HU	6.53 [2.22; 20.41]	0.001*	–	–
Anterior disc height according to MSCT less than 3.75 mm	7.34 [2.17; 27.58]	0.002*	–	–
Middle disc height according to MSCT less than 4.05 mm	6.07 [1.95; 20.09]	0.002*	–	–
Posterior disc height according to MSCT less than 3.85 mm	4.76 [1.71; 14.42]	0.004*	–	–
Presence of lateral spondylolisthesis	6.87 [1.63; 35.57]	0.011*	–	–
Intervertebral disc degeneration greater than 4 according to Pfirrmann	3.26 [1.19; 9.71]	0.026*	–	–
TEPS greater than 4	3.40 [1.17; 11.46]	0.033*	–	–

* Significant predictors.

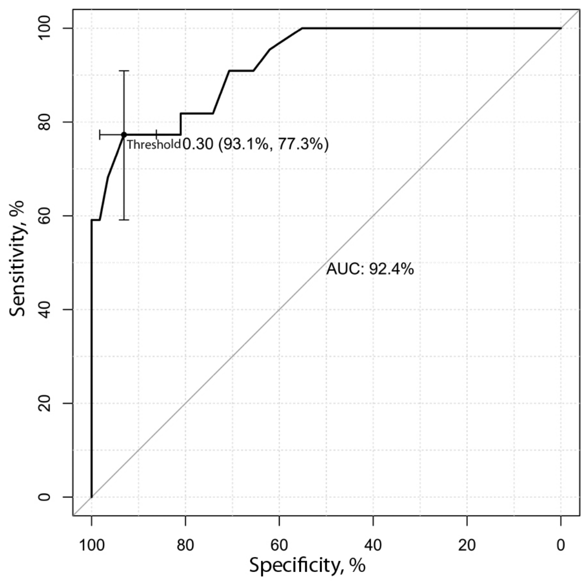

Fig.
ROC curve for a multivariate model of indirect decompression of spinal nerve roots in the spinal canal after XLIF

Our study is unique, as it formed a homogeneous group with a large number of patients (n = 80) compared to existing studies. We performed XLIF on our patients at only one level because of a monosegmental central degenerative spinal canal stenosis associated with segmental instability. XLIF was done without extra fixation or direct decompression of the spinal nerve roots, making it possible to fully evaluate XLIF as a decompression and stabilization procedure.

The results are relevant for patients with degenerative monosegmental central spinal canal stenosis associated with instability of the spinal motion segment at levels L2–L3, L3–L4, and less commonly L4–L5, because of the specific characteristics of the surgical approach to the spine using XLIF technology. The study does not include the most common patient models, namely those with degenerative stenosis of L4–L5, in whom microsurgical decompression is considered more appropriate because of the absence of instability of the spinal motion segment or multisegmental degenerative stenosis of the spinal canal. This limited our ability to enroll more patients. Only early postoperative outcomes were assessed.

Conclusion

Bone density in adjacent vertebral bodies (assessed in Hounsfield units), intervertebral disc height, the presence of lateral spondylolisthesis, the degree of disc degeneration according to the Pfirrmann classification, the condition of the endplates according to the Rajasekaran classification (TEPS), and the presence of dynamic compression of neural structures are significant parameters for predicting effective indirect decompression of spinal nerve roots in the spinal canal after XLIF. The predictors of indirect decompression have been identified: the depth of the lateral recess and BMI.

Table 4

Prognostic characteristics of a multivariate model of indirect decompression of spinal nerve roots in the spinal canal after XLIF

Characteristic	Value (95% CI)
Incidence rate of the technique	26.2 [17.0; 37.3]
Actual incidence rate	27.5 [18.1; 38.6]
Sensitivity	77.3 [54.6; 92.2]
Specificity	93.1 [83.3; 98.1]
Diagnostic accuracy	88.8 [79.7; 94.7]

Additional research is required to validate and test the identified prognostic criteria. It is important to evaluate the period of bone block formation in the surgical site, the frequency of implant subsidence and its clinical significance in the long term (12 and 24 months), the long-term effect of indirect decompression, and the results of the ODI and SF-12 scales in the long-term (12 and 24 months) postoperative period.

The study had no sponsors.
The authors declare that they have no conflict of interest.
The study was approved by the local ethics committee of the institution.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

Table 5

Similarities and differences in the analyzed thematic articles

Study	Year	Patients, *n*	Operated levels, *n*	Comments
Ozgur et al. [12]	2006	13	13	All patients with axial lumbar pain and without spinal stenosis
Wang et al. [14]	2014	21	23	The study included patients with adjacent segment disease, XLIF was performed without extension of transpedicular fixation of the spine, 4 of 21 patients underwent XLIF at two levels
Park et al. [31]	2020	86		The treatment outcomes of patients who underwent ALIF or LLIF were assessed
Walker et al. [32]	2021	73	107	73 patients were operated on at 107 levels, only 32 patients underwent single-level XLIF
Wang et al. [33]	2017	45	101	Only 37 of 45 patients had degenerative spinal stenosis. Lateral recess stenosis was found to be a predictor of failed indirect decompression
Nakashima et al. [34]	2019	102	136	74 patients underwent single-level XLIF; 22 patients underwent two-level XLIF; 6 patients underwent three-level XLIF; 27 patients underwent OLIF. No MSCT or MRI was performed in the early postoperative period
Shimizu et al. [35]	2020	42	45	It has been found that severe spinal stenosis is not a contraindication for XLIF aimed for achieving indirect decompression of spinal nerve roots
Li et al. [36]	2022	557	901	A lumbar spine MSCT scan was not assessed prior to surgery. Spinal canal stenosis of Schizas grade D is identified as a prognostic factor for failed indirect decompression

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Address correspondence to:
Isakov Ilya Dmitrievich
Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L.Tsivyan,
17 Frunze str., Novosibirsk, 630091, Russia,
doctorisakov@mail.ru

Received 04.06.2025
Review completed 18.09.2025
Passed for printing 07.11.2025

Ilya Dmitrievich Isakov, junior researcher, Research Department of Neurovertebrology, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 1255-9290, ORCID: 0000-0002-9228-3241, doctorisakov@mail.ru;
Abdugafur Jabborovich Sanginov, MD, PhD, researcher, Research Department of Neurovertebrology, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 3454-0039, ORCID: 0000-0002-4744-4077, Dr.sanginov@gmail.com;
Evgeny Andreyevich Mushkachev, junior researcher, Research Department of Neurovertebrology, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 4250-4886, ORCID: 0000-0003-0346-3898, mushkachevi@gmail.com;
Aleksey Vladimirovich Peleganchuk, MD, PhD, senior researcher, Research Department of Neurovertebrology, Head of the Department of Neurosurgery No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, 17 Frunze str., Novosibirsk, 630091, Russia, eLibrary SPIN: 2663-9450, ORCID: 0000-0002-4588-428X, apeleganchuk@mail.ru.