SPINAL CANAL STENOSIS: COMPARATIVE ANALYSIS OF MINIMALLY INVASIVE BILATERAL DECOMPRESSION THROUGH A UNILATERAL APPROACH AND LAMINECTOMY

A.G. Aganesov, M.M. Aleksanyan, E.G. Gemdzhian
Petrovsky National Research Centre of Surgery, Moscow, Russia

Objective. To analyze and compare the results of treatment of lumbar spinal stenosis using minimally invasive unilateral decompression and classical laminectomy.

Material and Methods. The retrospective comparative monocentric study included 68 patients (2 groups of 34 patients each) operated on in 2018—2021 for spinal stenosis in the lumbar spine who met certain eligibility criteria. Patients of one group were operated on using minimally invasive bilateral decompression through a unilateral approach, while patients in the other group were operated on using classical laminectomy. The results of surgical treatment were compared during 24 months by assessing pre- and postoperative indicators of the intensity of pain in the back and lower extremities using a 10-point VAS, and the patient's functional activity — using the Oswestry index.

Results. A statistically significant clinical effect of surgical treatment was noticed in both groups. At the end of the follow-up period, the results of back pain relief in the minimally invasive surgery group were significantly better (0.3 vs 0.9, respectively), and the improvement in functional activity was comparable to the laminectomy group (8.8 vs 9.8, respectively). A clinical effect of pain relief in the lower extremities was obtained in both groups (up to 1.2 and 1.4, respectively). The length of hospital stay, time to activation, and volume of blood loss were significantly lower in minimally invasive decompression group.

Conclusion. Minimally invasive unilateral decompression of the spinal canal for lumbar spinal stenosis demonstrates a better effect in relieving back pain than classical laminectomy, with no significant difference in relieving pain in the lower extremities. The minimally invasive technique allows patients to rehabilitate as quickly as possible and return to everyday life and work. It has socio-economic advantages compared to classical laminectomy — a shorter period of activation and hospital treatment, and less blood loss.

Key Words: spinal stenosis, laminectomy, minimally invasive treatment, spinal decompression.

Please cite this paper as: *Aganesov AG, Aleksanyan MM, Gemdzhian EG. Spinal canal stenosis: comparative analysis of minimally invasive bilateral decompression through a unilateral approach and laminectomy. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2024;21(1):35—43. In Russian. DOI: http://dx.doi.org/10.14531/ss2024.1.35-43.*

Degenerative lumbar stenosis is the most common indication for surgical treatment in elderly and senile patients (over 60 years of age), who are often comorbid [1, 2]. Degenerative changes include herniation of spinal discs, hypertrophy or ossification of yellow ligaments, often in combination with hypertrophy of facet joints. These changes result in compression of nerve roots in the spinal canal, lateral canals and intervertebral foramen, causing pain and neurological disorders that significantly reduce the quality of life [2, 3]. In the absence of therapeutic effect, surgery is the only option, but the optimal surgical approach, especially in comorbid elderly patients, remains a matter of debate among spine surgeons today [4–6]. Classical procedures include laminectomy, resection of the medial facet joints, and foraminotomy. These procedures require an extensive surgical approach that can lead to injury to paravertebral muscles and a highly radical resection of posterior supporting complex of the spine [7, 8]. Massively resecting bone tissue or injuring muscle tissue can cause instability, muscle dysfunction, atrophy, or failed back surgery syndrome [6, 9]. If stenosis and instability are combined in a spinal motion segment, decompression alone is not enough to produce a clinical outcome, and surgery should be supplemented with stabilization, usually using a transpedicular system [10, 11]. If lumbar spine deformities are detected, decompressions can be performed if there are no risk factors for instability development [12]. It is important to consider the area of decompression. It is recommended to perform the procedure on the convexital side of the deformity for ease of approach and maximum preservation of the stability of the spinal motion segment [13, 14].

Given the fact that central stenosis mainly develops in the interlaminar space, surgical techniques slowly shift towards minimally invasive procedures [15]. Previously used in microdiscectomies, microendoscopic tubular retractors began to be used to treat stenosis, making this technique a viable alternative to classical laminectomies (Fig. 1). Minimally invasive decompression aims to maximally reduce the amount of bone resection and intraoperative injury to paravertebral tissue, as well as the risk of postoperative instability [8]. With minimally invasive approaches, paravertebral muscles are bluntly separated while maintaining the integrity of median structures of muscle fixation point and the ligamentous apparatus, reducing intraoperative blood loss and postoperative pain syndrome [16]. A technique similar to the described one is minimally invasive bilateral decompression through a unilateral approach. This technique can also be applied to multisegmental lesions. [17–19].

Unfortunately, the world literature still contains very few studies clearly describing the advantages of this minimally invasive technique compared to classical laminectomy [20–24].

The objective is to analyse and compare the results of treatment of lumbar spinal canal stenosis using minimally invasive unilateral decompression and classical laminectomy.

The level of evidence is 3b.

Material and Methods

A total of 637 patients with degenerative and dystrophic conditions of the lumbar spine underwent surgery at the Spine Surgery Unit of the B.V. Petrovsky National Research Centre of Surgery (Moscow) in 218–2021.

All surgeries were performed by one surgical team in the same operating room. All patients gave voluntary consent to surgery. The study was approved by the local ethics committee of the hospital.

Inclusion criteria:

1) symptomatic lumbar spinal stenosis causing radiculopathy (pain syndrome, weakness and numbness in the lower extremities), neurogenic claudication or pelvic organ dysfunction;

2) visually confirmed (MRI or CT) combined lumbar stenosis associated with hypertrophy of facet joints, hypertrophy/ossification of the yellow ligament and broad-based disc protrusion [25];

3) spinal canal stenosis at no more than two levels;

4) lack of a therapeutic effect for more than 3 months;

5) follow-up period of 24 months;

Exclusion criteria:

1) spinal motion segment instability, lumbar spine deformity, confirmed by standard and functional radiological imaging;

2) surgical procedures on the lumbar spine in the case history;

3) anterior compression of neural structures (herniated disc);

4) severe pathology of other organs and systems (according to the examinations of subject matter experts and anaesthesiologists);

5) focuses of purulent inflammation.

Sixty eight (11 %) patients met the specified criteria and were divided into two groups of 34 patients, depending on the surgery performed. The severity of spinal stenosis was evaluated according to the Lee classification [26] that distinguishes 3 grades: mild (Grade 1), moderate (Grade 2) and severe (Grade 3).

The main demographic, clinical, physical, radiological and functional features of patients are shown in Table 1.

The surgical outcomes were evaluated by comparing pre- and postoperative parameters, including functional activity (intensity of pain in the back and lower extremities using the 10-point VAS, level of functional activity using the Oswestry Disability Index). Patients were surveyed before surgery, 5 days after surgery, 6 weeks, 12 months and 24 months later. The follow-up periods in both groups were the same; 61 patients attended follow-up appointments, and 7 completed online surveys. In addition, the length of hospital stay, time to patient activation after surgery and surgical blood loss were analysed.

In both groups, surgeries were performed under general anaesthesia on an operating table with a Wilson frame, with the patient in the knee-elbow position to straighten the lumbar lordosis. Before suturing the wound, ropivacaine was injected into the paravertebral muscles to reduce postoperative pain.

Standard Laminectomy Technique. An incision of the skin was made in the projection of the central line, followed by dissection of the thoracodorsal fascia and subperiosteal separation of the paravertebral muscles from the spinous processes and vertebral arches. After that, retractors were placed on both sides. Decompression was performed by removal of the spinous process, vertebral arches, yellow ligament, medial resection of the facet joints, superior articular process to the inner wall of the pedicle of the caudal vertebral arch to visualise the lateral canal, and was completed with radiculolysis. Haemostasis was achieved using bipolar coagulation and, if necessary, haemostatic materials (Surgicel).

The technique of minimally invasive bilateral decompression through a unilateral approach. The incision of the skin up to 3 cm was performed 1.5 cm laterally from the median line, after intraoperative marking of the required level using a radiological image intensifier. Next, the thoracodorsal fascia was dissected sequentially in an arc wise manner, and a minimally invasive tubular wound retractor was placed to expose the interspinous space, vertebral arch and yellow ligament. Muscles and soft tissues in the approach area were subperiosteally skeletonized. Decompression was performed with a high-speed microsurgical spine drill using a surgical microscope. To facilitate visualisation of the contralateral side, the base of the spinous process, the medial section of the hypertrophic facet joint (its medial third) and the inferior edge of the superjacent vertebral arch were removed. At this point, the deep layer of the yellow ligament remained intact, acting as an excellent barrier to protect the dura mater. Next, the anterior part of the contralateral arches and the hypertrophied joints were resected. After visualising the lateral canal on the opposite side, the yellow ligaments were elevated from the cranial side using a hooked probe or a curved curette, and then resected to perform central decompression. Lateral canals and intervertebral foramina were visualised on both sides, providing an option for full-fledged root revision to verify the relevance of the decompression (Fig. 2). Haemostasis was achieved through bipolar coagulation and, if necessary, haemostatic materials (Surgicel).

During statistical analysis, a parametric method (two-tailed unpaired Student's t-test) was used to assess the difference in measurement results since the normality assumption of the compared distributions was not rejected by verification (the Shapiro – Wilk test). Pain intensity (according to the VAS) and functional activity (according to the Oswestry Disability Index) are presented as mean values (in points). The calculations were performed using Statistica 10.

Results

There was no significant difference in the indicators of pain intensity according to the VAS and functional activity according to the Oswestry Disability Index in the compared groups before treatment (Table 1). As a result of surgery, a significant clinical and statistical ($p = 0.01$) reduce (relief) of the pain syndrome and an improvement in functional activity were observed in both groups (Figs. 3, 4).

In the early postoperative phase (the fifth day after surgery), the mean intensity of back pain in patients following minimally invasive surgery was lower than in patients after laminectomy (2.0 vs 2.7). This difference remained in the long-term postoperative period: 1.1 vs 1.6 after 12 months and 0.3 vs 0.9 at the end of follow-up (Fig. 3). Thus, the effectiveness of reducing back pain after minimally invasive surgery was consistently better than after laminectomy. Radicular pain in the lower limbs was stopped in all patients, and there was no significant difference in the effectiveness of pain relief between minimally invasive surgery and laminectomy (Tables 2, 3).

In the postoperative period, the mean value of the Oswestry Disability Index in patients after minimally invasive surgery was higher than in patients after laminectomy: 11.7 vs 12.5 after 12 months and 8.8 vs 9.8 after 24 months (Fig. 4). This suggests that functional activity improvement with minimally invasive techniques is not worse than with laminectomy.

In one of the patients, a hematoma developed after extensive decompression and required ultrasonography-guided puncture. There were 3 cases of injury to the dura mater with the development of intraoperative cerebrospinal fluid leakage (2 of them in the group of minimally invasive surgery). In two cases, primary suture of the dura was performed; in the third one, cerebrospinal fluid was stopped during surgery, suturing the wound was not necessary. There was suture line disruption after laminectomy in one case, requiring surgical debridement. No lethal outcomes occurred in both groups. A lower back pain syndrome returned in one patient following minimally invasive decompression after 8 months, and was stopped by radiofrequency denervation of facet joints. No revision surgeries were needed at that time of follow-up.

Statistical analysis indicates that minimally invasive surgery has several advantages, and corresponding parameters differ significantly or approach statistical significance.

Discussion

With a stable spinal motion segment, classical laminectomy results in good and excellent treatment outcomes for spinal stenosis in 64–82 % of cases. Nevertheless, massive intraoperative injury to soft tissues and a large amount of bone resection can result in the formation of instability and cicatricial changes in the paravertebral muscles [9, 27]. According to the literature [28], the mean incidence of instability after spinal decompression surgery is 5.0–6.0 %, with 13.0 % after laminectomy and 3.2 % after minimally invasive surgery. The frequency of revision

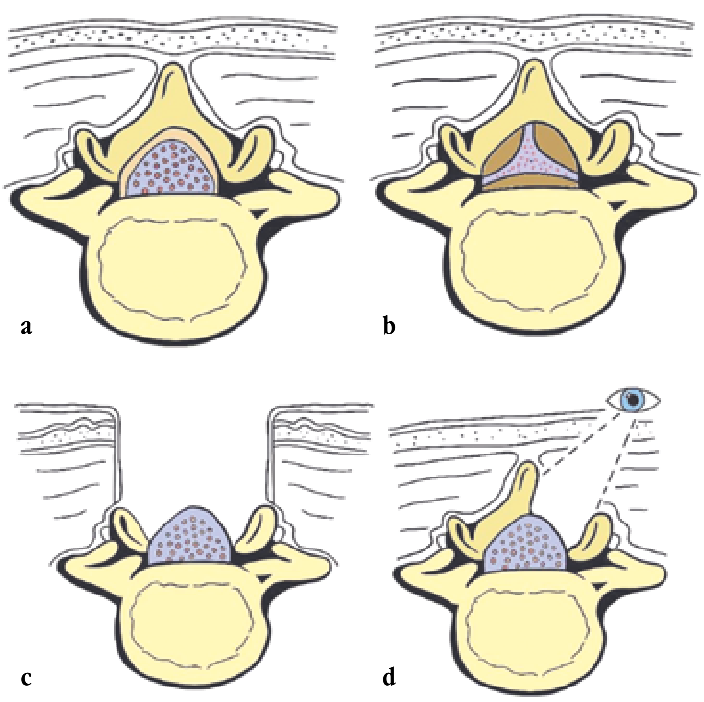

Fig. 1
Schematic illustration of a normal spinal canal **(a)**, spinal canal stenosis **(b)**, classical laminectomy **(c)** and minimally invasive unilateral decompression **(d)**: minimal damage to soft tissues and minimal amount of bone resection can be noted, but at the same time there is excellent visualisation and possibility for decompression (drawing by O.A. Spirin)

Table 1

Features of patients in the study groups

Parameter	Minimally invasive unilateral decompression (n= 34)	Classical laminectomy (n = 34)
Age median, years	69	66
Gender, n (%)		
Male	18 (52.9)	20 (58.8)
Female	16 (47.1)	14 (41.2)
Follow-up median, months	12	12
Stenosis severity according to Lee classification, n (%)		
Grade 1	4 (11.8)	5 (14.7)
Grade 2	15 (44.1)	16 (47.0)
Grade 3	15 (44.1)	13 (38.3)
Initial symptoms, n (%)		
Back pain	20 (57.7)	23 (68.3)
Radiculopathy	22 (65.7)	25 (74.8)
Neurogenic claudication	23 (67.1)	20 (58.4)
Pelvic organ dysfunction	2 (4.2)	3 (10.3)
Concomitant factors and comorbidity, n (%)		
Smoking	7 (20.5)	6 (18.6)
Obesity	10 (29.6)	9 (25.4)
Hypertension	19 (56.7)	20 (58.1)
Cardiovascular diseases	10 (29.1)	11 (31.7)
Respiratory diseases	6 (18.5)	8 (23.3)
Diabetes mellitus type 2	2 (4.5)	4 (11.3)
Pain syndrome and functional activity before surgery		
VAS (back), points	7.4	7.1
VAS (extremities), points	6.5	5.4
Oswestry Disability Index	39.8	42.2
Operated segments, n (%)		
L2–L3	4 (11.8)	2 (5.9)
L3–L4	8 (23.5)	6 (17.6)
L4–L5	22 (64.7)	24 (70.6)
L5–S1	5 (14.7)	3 (8.8)

Checking with Fisher's exact test showed that the compared groups did not differ statistically significantly in terms of the given features ($p > 0.05$).

surgeries also varies: 11.0 % after open surgery, 0.7 % after minimally invasive surgery, and the presence of spondylolisthesis before surgery increases the risk of instability by 4–10 times. The extensive blind spaces that form as an outcome of surgery are an environment for the development of bacteria and the formation of scar tissue. Such complications result in the development of chronic pain syndrome and failed back surgery syndrome.

The newly developed minimally invasive techniques allow for the limitation of amount of bone resection and relevant decompression of neural structures [4, 21, 22, 29]. Tubular or endoscopic decompression of the spinal canal are used in practice, with the amount and efficiency of decompression not statistically differing. However, blood loss is lower and rehabilitation is earlier with the endoscopic technique [30]. Preservation of the contralateral facet joint and preserving resection of the ipsilateral joint are crucial in maintaining the stability of the spinal motion segment [9, 31]. Minimally invasive decompression is a safe and efficient technique for treating spinal stenosis that minimizes intraoperative soft tissue injury, blood loss, and reduces the length of hospital stay [32, 33]. According to the literature [22, 23, 34–36], unilateral decompression falls within the reasonable timelines, results in small blood loss and a lower intake of analgesics compared to the classical laminectomy technique. Minimally invasive surgical techniques result in a reduction in the incidence of intraoperative complications [37]. All these advantages make it possible to perform such surgeries under local anaesthesia in comorbid patients with contraindications for general anaesthesia [38].

Meanwhile, the researchers found no difference in efficacy between minimally invasive decompression and traditional laminectomy, when comparing these two techniques. However, the second approach has a greater number of complications and repeat procedures (although patients differed due to the presence of obesity) [39]. During a comparison of standard open bilateral decompression with bilateral unilateral decompression after 3 years, no difference was found. In this respect, the complexity of minimally invasive treatment is not justified [40].

There is ongoing debate in the world literature about the influence of a patient's age on the outcome of surgery [1]. Elder age implies worse outcomes due to changes in bone and soft tissue structures: smoothing of the lumbar lordosis, fatty degeneration of the paravertebral muscles and weakness of the extensor muscles of the back.

Some advantages of minimally invasive techniques were observed during the postoperative period. Since most patients with degenerative disc disease belong to the elderly and senile age groups (over 60 years old), reducing back pain, the time to activation, length of inpatient treatment, and recovery are of particular importance [31, 42].

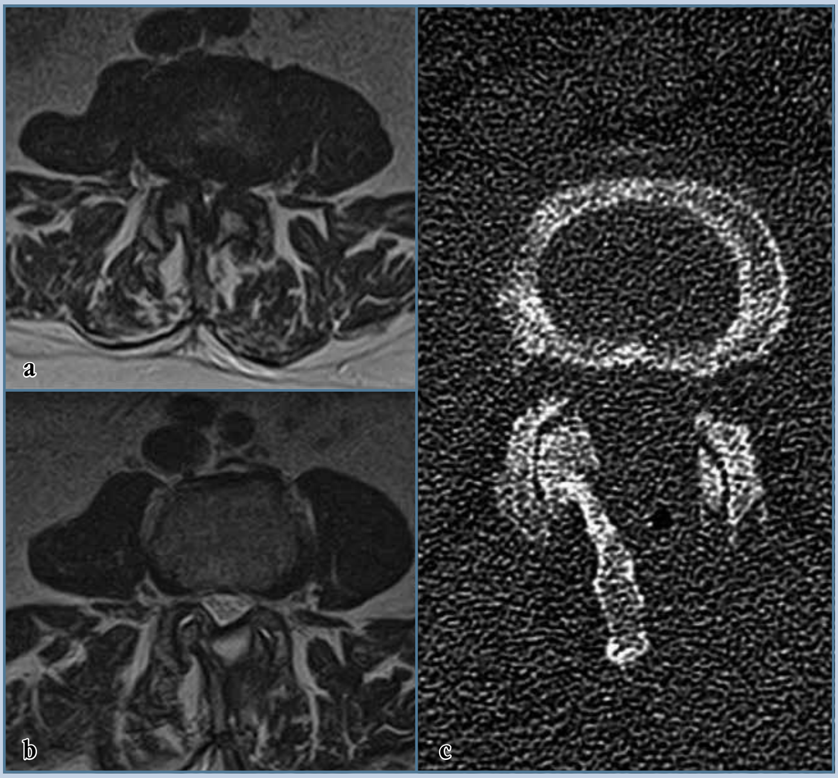

Fig. 2
Preoperative MRI **(a)**: L3–L4 spinal canal stenosis associated with hypertrophied facet joints, yellow ligaments and intervertebral disc protrusion (Grade 3 according to Lee); MRI 6 weeks after surgery **(b)**: relevant decompression of neural structures with minimal injury to soft tissues (moderate edema); postoperative CT scan **(c)** shows preserving resection of bone tissue – medial resection of the facet joint on the left, marginal resection of the base of the spinous process, lower arcotomy

The only disadvantage of minimally invasive surgical treatment for stenosis is the long learning curve for surgeons [44], during which the complication rate is higher (especially injury to the dura mater and cerebrospinal fluid leakage), as well as the need for repeated surgeries due to recurrence. Therefore, it is recommended that the first 30 procedures be performed under the supervision of experienced doctors [32, 45]. All procedures in our research were performed by a qualified surgeon with experience in both open and minimally invasive spine surgery techniques.

Conclusion

An analysis of the treatment outcomes based on the VAS and Oswestry Disability Index data revealed a statistically significant clinical benefit of surgical treatment for spinal canal stenosis using minimally invasive bilateral decompression through a unilateral approach compared to classical laminectomy. This benefit persisted for 24 months after surgery. Using minimally invasive surgery, the results in relieving back pain, especially in the early postoperative period, were found to be better than those achieved with laminectomy. The results of improving functional activity in the groups are comparable; the clinical effect on relieving radicular pain syndrome in the lower extremities with minimally invasive decompression and laminectomy was almost the same.

In the group of patients who underwent minimally invasive bilateral decompression through a unilateral approach, the time to activation, the length of inpatient stay, and the amount of blood loss were all significantly lower compared to those who had undergone laminectomy.

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.

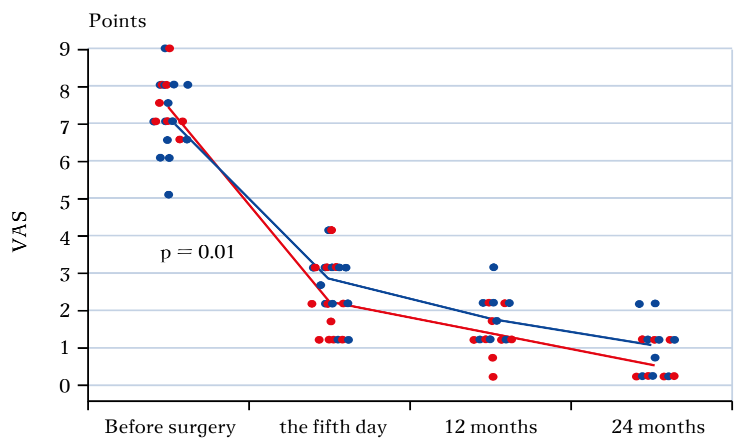

Fig. 3
Changes of pain intensity according to the VAS in the back in patients with minimally invasive unilateral laminotomy (red line) and classic laminectomy (blue line)

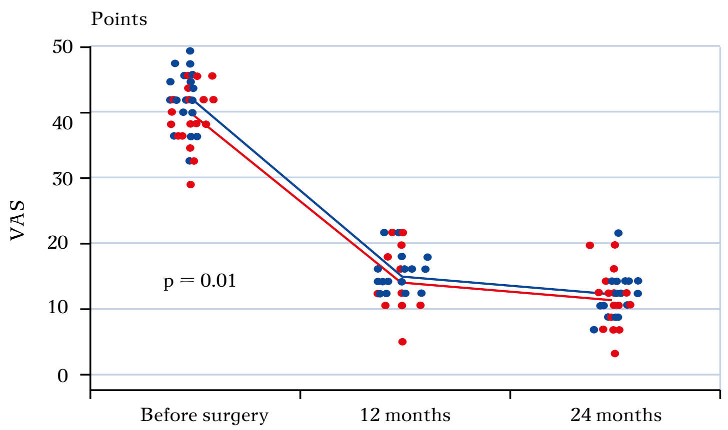

Fig. 4
Changes of the Oswestry Disability Index in patients with minimally invasive unilateral decompression (red line) and classic laminectomy (blue line), indicating a positive result

Table 2

Changes of the pain intensity reduction in the lower extremities of patients in the study groups after surgical treatment

Period	Pain intensity according to the VAS, points	
	Laminotomy*	Laminectomy*
Before surgery	6.5 (1.7)**	5.4 (2.0)
The fifth day	1.4 (1.6)	1.6 (1.8)
12 months after	1.6 (0.8)	1.5 (0.6)
24 months after	1.2 (0.8)	1. 4 (0.8)

* Values are not statistically significantly different;
** mean (standard deviation).

Table 3

Blood loss and treatment duration in patients of the study groups

Parameter	Minimally invasive unilateral decompression	Classical laminectomy
Mean blood loss, ml	200*	800*
Time to activation, hours	15**	26**
Length of hospital stay, days	4	6

* p = 0.05;
** p = 0.01.

References

1. **Papavero L, Thiel M, Fritzsche E, Kunze C, Westphal M, Kothe R.** Lumbar spinal stenosis: prognostic factors for bilateral microsurgical decompression using a unilateral approach. Neurosurgery. 2009;65(6 Suppl):182–187. DOI: 10.1227/01.NEU.0000341906.65696.08.
2. **Rosen DS, O'Toole JE, Eichholz KM, Hrubes M, Huo D, Sandhu FA, Fessler RG.** Minimally invasive lumbar spinal decompression in the elderly: outcomes of 50 patients aged 75 years and older. Neurosurgery. 2007;60:503–509. DOI: 10.1227/01.NEU.0000255332.87909.58.
3. **Costa F, Sassi M, Cardia A, Ortolina A, De Santis A, Luccarell G, Fornari M.** Degenerative lumbar spinal stenosis: analysis of results in a series of 374 patients treated with unilateral laminotomy for bilateral microdecompression. J Neurosurg Spine. 2007;7:579–586. DOI: 10.3171/SPI-07/12/579.
4. **Pao JL, Chen WC, Chen PQ.** Clinical outcomes of microendoscopic decompressive laminotomy for degenerative lumbar spinal stenosis. Eur Spine J. 2009;18:672–678. DOI: 10.1007/s00586-009-0903-2.
5. **Alexanyan MM, Kheilo AL, Mikaelian KP, Gemdzian EG, Aganesov AG.** Microsurgical discectomy in the lumbar spine: efficiency, pain syndrome and obesity. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2018;15(1):42–48. DOI: 10.14531/ss2018.1.42-48.
6. **Yang F, Chen R, Gu D, Ye Q, Liu W, Qi J, Xu K, Fan X.** Clinical comparison of full-endoscopic and microscopic unilateral laminotomy for bilateral decompression in the treatment of elderly lumbar spinal stenosis: a retrospective study with 12-month follow-up. J Pain Res. 2020;13:1377–1384. DOI: 10.2147/JPR.S254275.
7. **Yamashita K, Ohzono K, Hiroshima K.** Five-year outcomes of surgical treatment for degenerative lumbar spinal stenosis: a prospective observational study of symptom severity at standard intervals after surgery. Spine. 2006;31:1484–1490. DOI: 10.1097/01.brs.0000219940.26390.26.
8. **Oppenheimer JH, DeCastro I, McDonnell DE.** Minimally invasive spine technology and minimally invasive spine surgery: a historical review. Neurosurg Focus. 2009;27:E9. DOI: 10.3171/2009.7.FOCUS09121.
9. **Chen KT, Choi KC, Shim HK, Lee DC, Kim JS.** Full-endoscopic versus microscopic unilateral laminotomy for bilateral decompression of lumbar spinal stenosis at L4–L5: comparative study. Int Orthop. 2022;46:2887–2895. DOI: 10.1007/s00264-022-05549-0.
10. **Heider FC, Mayer HM.** [Unilateral approach for over the top bilateral lumbar decompression]. Oper Orthop Traumatol. 2019;31:513–535. DOI: 10.1007/s00064-019-00632-z.
11. **Gizatullin ShKh, Kristosturov AS, Davydov DV, Stanishevsky AV, Povetkin AA.** Comparison of endoscopic and open methods of surgical treatment for lumbosacral spinal canal stenosis: a systematic literature review. Russian Journal of Spine Surgery (Khirurgiya Pozvonochnika). 2022;19(1):46–55. DOI: 10.14531/ss2022.1.46-55.
12. **Nikitin AS, Grin AA.** Combination of degenerative lumbar spinal stenosis and spinal deformity. Literature review. Russian journal of neurosurgery. 2018;20(3):91–103. DOI: 10.17650/1683-3295-2018-20-3-91-103.

13. **Mayer HM, Heider F.** "Slalom": microsurgical cross-over decompression for multilevel degenerative lumbar stenosis. Biomed Res Int. 2016;2016:9074257. DOI: 10.1155/2016/9074257.
14. **Kim JS, Park CW, Yeung YK, Suen TK, Jun SG, Park JH.** Unilateral bi-portal endoscopic decompression via the contralateral approach in asymmetric spinal stenosis: a technical note. Asian Spine J. 2021;15:688–700. DOI: 10.31616/asj.2020.0119.
15. **Castro-Menendez M, Bravo-Ricoy JA, Casal-Moro R, Hernandez-Blanco M, Jorge-Barreiro FJ.** Midterm outcome after microendoscopic decompressive laminotomy for lumbar spinal stenosis: 4-year prospective study. Neurosurgery. 2009;65:100–110. DOI: 10.1227/01.NEU.0000347007.95725.6F.
16. **Ikuta K, Arima J, Tanaka T, Oga M, Nakano S, Sasaki K, Goshi K, Yo M, Fukagawa S.** Short-term results of microendoscopic posterior decompression for lumbar spinal stenosis. Technical note. J Neurosurg Spine. 2005;2:624–633. DOI: 10.3171/spi.2005.2.5.0624.
17. **Oertel MF, Ryang YM, Korinth MC, Gilsbach JM, Rohde V.** Long-term results of microsurgical treatment of lumbar spinal stenosis by unilateral laminotomy for bilateral decompression. Neurosurgery. 2006;59:1264–1269. DOI: 10.1227/01.NEU.0000245616.32226.58.
18. **Spetzger U, Bertalanffy H, Naujokat C, von Keyserlingk DG, Gilsbach JM.** Unilateral laminotomy for bilateral decompression of lumbar spinal stenosis. Part I: Anatomical and surgical considerations. Acta Neurochir (Wien). 1997;139:392–396. DOI: 10.1007/BF01808872.
19. **Wipplinger C, Kim E, Lener S, Navarro-Ramirez R, Kirnaz S, Hernandez RN, Melcher C, Paolicelli M, Maryam F, Schmidt FA, Hartl R.** Tandem microscopic slalom technique: the use of 2 microscopes simultaneously performing unilateral laminotomy for bilateral decompression in multilevel lumbar spinal stenosis. Global Spine J. 2020;10(2 Suppl.):88S–93S. DOI: 10.1177/2192568219871918.
20. **Armin SS, Holly LT, Khoo LT.** Minimally invasive decompression for lumbar stenosis and disc herniation. Neurosurg Focus. 2008;25:E11. DOI: 10.3171/FOC/2008/25/8/E11.
21. **Cavusoglu H, Kaya RA, Turkmenoglu ON, Tuncer C, Colak I, Aydin Y.** Midterm outcome after unilateral approach for bilateral decompression of lumbar spinal stenosis: 5-year prospective study. Eur Spine J. 2007;16:2133–2142. DOI: 10.1007/s00586-007-0471-2.
22. **Pao JL, Lin SM, Chen WC, Chang CH.** Unilateral biportal endoscopic decompression for degenerative lumbar canal stenosis. J Spine Surg. 2020;6:438–446. DOI: 10.21037/jss.2020.03.08.
23. **Palmer S, Turner R, Palmer R.** Bilateral decompressive surgery in lumbar spinal stenosis associated with spondylolisthesis: unilateral approach and use of a microscope and tubular retractor system. Neurosurg Focus. 2002;13:213–217. DOI: 10.3171/foc.2002.13.1.5.
24. **Cavusoglu H, Turkmenoglu O, Kaya RA, Tuncer C, Colak I, Sahin Y, Aydin Y.** Efficacy of unilateral laminectomy for bilateral decompression in lumbar spinal stenosis. Turk Neurosurg. 2007;17:100–108.
25. **Andreisek G, Deyo RA, Jarvik JG, Porchet F, Winklhofer SFX, Steurer J.** Consensus conference on core radiological parameters to describe lumbar stenosis – an initiative for structured reporting. Eur Radiol. 2014;24:3224–3232. DOI: 10.1007/s00330-014-3346-z.
26. **Ko YJ, Lee E, Lee JW, Park CY, Cho J, Kang Y, Ahn JM.** Clinical validity of two different grading systems for lumbar central canal stenosis: Schizas and Lee classification systems. PLoS One. 2020;15:e0233633. DOI: 10.1371/journal.pone.0233633.
27. **Jayarao M, Chin LS.** Results after lumbar decompression with and without discectomy: comparison of the transspinous and conventional approaches. Neurosurgery. 2010;66(3 Suppl Operative):152–160. DOI: 10.1227/01.NEU.0000365826.15986.40.
28. **Guha D, Heary RF, Shamji MF.** Iatrogenic spondylolisthesis following laminectomy for degenerative lumbar stenosis: systematic review and current concepts. Neurosurg Focus. 2015;39:E9. DOI: 10.3171/2015.7.FOCUS15259.
29. **Zhang J, Liang D, Xu M, Yan K, Zhang D, Qian W.** Comparison of the short-term effects of lumbar endoscopic and microscopic tubular unilateral laminotomy with bilateral decompression in the treatment of elderly patients with lumbar spinal stenosis. Eur J Med Res. 2022;27:222. DOI: 10.1186/s40001-022-00847-0.
30. **Carrascosa-Granada A, Velazquez W, Wagner R, Mazzei AS, Vargas-Jimenez A, Jorquera M, Albacar JAB, Sallabanda K.** Comparative study between uniportal full-endoscopic interlaminar and tubular approach in the treatment of lumbar spinal stenosis: a pilot study. Global Spine J. 2020;10(2_suppl.):70S–78S. DOI: 10.1177/2192568219878419.
31. **Min WK, Kim JE, Choi DJ, Park EJ, Heo J.** Clinical and radiological outcomes between biportal endoscopic decompression and microscopic decompression in lumbar spinal stenosis. J Orthop Sci. 2020;25:371–378. DOI: 10.1016/j.jos.2019.05.022.
32. **Lee CW, Yoon KJ, Jun JH.** Percutaneous endoscopic laminotomy with flavectomy by uniportal, unilateral approach for the lumbar canal or lateral recess stenosis. World Neurosurg. 2018;113:e129–e137. DOI: 10.1016/j.wneu.2018.01.195.
33. **Zhang B, Kong Q, Yan Y, Feng P.** Degenerative central lumbar spinal stenosis: is endoscopic decompression through bilateral transforaminal approach sufficient? BMC Musculoskelet Disord. 2020;21:714. DOI: 10.1186/s12891-020-03722-3.
34. **Palmer S.** Use of a tubular retractor system in microscopic lumbar discectomy: 1 year prospective results in 135 patients. Neurosurg Focus. 2002;13:E5. DOI: 10.3171/foc.2002.13.2.6.
35. **Overdevest GM, Peul WC, Brand R, Koes BW, Bartels RH, Tan WF, Arts MP.** Tubular discectomy versus conventional microdiscectomy for the treatment of lumbar disc herniation: long-term results of a randomised controlled trial. J Neurol Neurosurg Psychiatry. 2017;88:1008–1016. DOI: 10.1136/jnnp-2016-315306.
36. **Pich J.** Effectiveness of posterior decompression techniques compared with conventional laminectomy for lumbar stenosis. Orthop Nurs. 2018;37:318–319. DOI: 10.1097/NOR.0000000000000482.
37. **Lin GX, Yao ZK, Xin C, Kim JS, Chen CM, Hu BS.** A meta-analysis of clinical effects of microscopic unilateral laminectomy bilateral decompression (ULBD) versus biportal endoscopic ULBD for lumbar canal stenosis. Front Surg. 2022;9:1002100. DOI: 10.3389/fsurg.2022.1002100.
38. **Pan W, Ruan B.** Surgical decompression via the unilateral intervertebral foraminal approach with local anesthesia for treating elderly patients with lumbar central canal stenosis. Neurosurg Focus. 2021;51:E5. DOI: 10.3171/2021.9.FOCUS21420.
39. **Ang CL, Tow BPB, Fook S, Guo CM, Chen JLT, Yue WM, Tan SB.** Minimally invasive compared with open lumbar laminotomy: no functional benefits at 6 or 24 months after surgery. Spine J. 2015;15:1705–1712. DOI: 10.1016/j.spinee.2013.07.461.
40. **Ulrich NH, Burgstaller JM, Gravestock I, Pichierri G, Wertli MM, Steurer J, Farshad M, Porchet F.** Outcome of unilateral versus standard open midline approach for bilateral decompression in lumbar spinal stenosis: is "over the top" really better? A Swiss prospective multicenter cohort study. J Neurosurg Spine. 2019;31:236–245. DOI: 10.3171/2019.2.SPINE181309.
41. **Huang Y, Chen J, Gao P, Gu C, Fan J, Hu Z, Cao X, Yin G, Zhou W.** A comparison of the bilateral decompression via unilateral approach versus conventional approach transforaminal lumbar interbody fusion for the treatment of lumbar degenerative disc disease in the elderly. BMC Musculoskelet Disord. 2021;22:156. DOI: 10.1186/s12891-021-04026-w.
42. **Bouras T, Stranjalis G, Loufardaki M, Sourtzis I, Stavrinou LC, Sakas DE.** Predictors of long-term outcome in an elderly group after laminectomy for lumbar stenosis. J Neurosurg Spine. 2010;13:329–334. DOI: 10.3171/2010.3.SPINE09487.
43. **Cho DY, Lin HL, Lee WY, Lee HC.** Split-spinous process laminotomy and discectomy for degenerative lumbar spinal stenosis: a preliminary report. J Neurosurg Spine. 2007;6:229–239. DOI: 10.3171/spi.2007.6.3.229.

44. **Parikh K, Tomasino A, Knopman J, Boockvar J, Hartl R.** Operative results and learning curve: Microscope-assisted tubular microsurgery for 1- and 2-level discectomies and laminectomies. Neurosurg Focus. 2008;25:E14. DOI: 10.3171/FOC/2008/25/8/E14.
45. **Park J, Park HJ, Park SM, Choi JY, Kim HJ, Yeom JS.** Learning curve for microscopic unilateral laminectomy for bilateral decompression surgery using the cumulative summation test for learning curve. Medicine (Baltimore). 2022;101:E31069. DOI: 10.1097/MD.0000000000031069.

Address correspondence to:
Aleksanyan Mark Mikaelovich
Petrovsky National Research Centre of Surgery,
2 Abrikosovskiy pereulok, Moscow, 119991, Russia,
Alexanyanmm@gmail.com

Received 07.07.2022
Review completed 29.01.2024
Passed for printing 18.02.2024

Alexandr Georgyevich Aganesov, DMSc, Prof., Chief of Spine Surgery Department, Petrovsky National Research Centre of Surgery, 2 Abrikosovskiy pereulok, Moscow, 119991, Russia, ORCID: 0000-0001-8823-5004, aaganesov@gmail.com;
Mark Mikaelovich Aleksanyan, MD, PhD, senior researcher, Spine Surgery Department, Petrovsky National Research Centre of Surgery, 2 Abrikosovskiy pereulok, Moscow, 119991, Russia, ORCID: 0000-0003-1321-086X, Alexanyanmm@gmail.com;
Eduard Georgyevich Gemdzhian, biostatistician, Petrovsky National Research Centre of Surgery, 2 Abrikosovskiy pereulok, Moscow, 119991, Russia, ORCID: 0000-0002-8357-977X, edstat@mail.com.