Genij Ortopedii. 2023;29(3):285-292.

Original article

https://doi.org/10.18019/1028-4427-2023-29-3-285-292

Long-term treatment results of multilevel cervical spine stenosis with the method of bilateral osteoplasticic decompression laminoplasty and simultaneous foraminotomy

A.A. Sufianov[1,2,3], A.V. Burtsev[4], D.N. Nabiev[2]✉, A.Sh. Magomedova[1,2], R.A. Sufianov[1], M.T. Karsanova[1,2], V.A. Piterov[1,2]

[1] Sechenov First Moscow State Medical University, Moscow, Russian Federation
[2] Federal Centre of Neurosurgery, Tyumen, Russian Federation
[3] Peoples' Friendship University of Russia, Moscow, Russian Federation
[4] Ilizarov National Medical Research Centre for Traumatology and Orthopedics, Kurgan, Russian Federation

Corresponding author: David N. Nabiev, davidnabiev82@gmail.com

Abstract

Introduction Stenosis of the cervical spine can lead to serious complications resulting from spinal cord dysfunction. There are different methods of posterior decompression of the spinal canal. The method of choice for surgical treatment of cervical stenosis is laminoplasty. **Purpose** Analysis of long-term (from 2 to 5 years) results of clinical outcomes after bilateral decompression laminoplasty and simultaneous foraminotomy **Materials and methods** Study design: case series (27 patients); a single center retro/prospective study. Patients who were treated at the Federal Center for Neurosurgery in Tyumen were examined. In the pre- and postoperative periods, the clinical condition of patients was assessed using questionnaires and scales JOA, VAS, Nurick. The stenosis severity was objectively assessed using a standard closed polygon measuring instrument. The cross-sectional area of the dural sac and the average linear dimensions were measured according to neuroimaging data. **Results** In the late postoperative period, patients had positive dynamics in pain relief, improvement in motor functions, and partial recovery of sensory disorders. There was a slight increase in the average cross-sectional area of the dural sac measured at the follow-up. Discussion The method of bilateral osteoplastic laminoplasty is one of the surgical treatment options and allows full visualizing of the neurovascular structures, as well as safe performance of hemostasis and foraminotomy at the levels of interest. **Conclusion** Thus, the effectiveness of this technique was shown by this study.

Keywords: cervical stenosis, myeloradiculopathy, laminoplasty

For citation: Sufianov A.A., Burtsev A.V., Nabiev D.N., Magomedova A.Sh., Sufianov R.A., Karsanova M.T., Piterov V.A. Long-term treatment results of multilevel cervical spine stenosis with the method of bilateral osteoplasticic decompression laminoplasty and simultaneous foraminotomy. *Genij Ortopedii*. 2023;29(3):285-292. doi: 10.18019/1028-4427-2023-29-3-285-292

INTRODUCTION

Multilevel stenosis of the cervical spine associated with myelopathy is the cause of neurological signs and is accompanied by a decrease in the quality of life of patients and possible disability [1]. Patients with cervical spinal stenosis have a mixed clinical picture of myeloradiculopathy. The choice of the correct treatment strategy for cervical stenosis has been still discussed in the literature [1-10]. Timely surgical treatment plays a key role in preventing irreversible changes in the spinal cord and regression of neurological symptoms [10, 11]. One of the surgical methods of choice for extended stenosis is laminoplasty. Cervical laminoplasty was first described by Oyama M in 1973 [4]. Since then, a whole palette of laminoplasty modifications has been presented in the history of neurosurgery, but the Hirabayashi (open door) and Kurokawa (French door) techniques deserve the most attention [12]. The advantage of laminoplasty as an alternative option for posterior decompression of the spinal cord is the absence of postoperative kyphosis, preservation of the range of motion in the cervical spine with a minimal risk of developing instability of the spinal motion segments [13]. At the Federal Center for Neurosurgery (Tyumen), bilateral laminoplasty with simultaneous foraminotomy has been applied. The technique used by us for the treatment of multilevel stenosis in the cervical spine was an incentive to study long-term treatment results in the patients with the follow-ups from 2 to 5 years.

Purpose To assess long-term results and clinical outcomes after bilateral decompression laminoplasty with simultaneous foraminotomy in the follow-up from 2 to 5 years.

MATERIALS AND METHODS

We retrospectively analyzed the results of surgical treatment of 27 patients, 22 men and 5 women in the age from 46 to 80 years old (mean age, 61.7 years), treated at the Federal Center for Neurosurgery in the period 2017-2022. The criteria for selecting patients for laminoplasty were: extended multilevel stenosis (3 levels and more), clinical signs of myeloradiculopathy, presence of an ossified posterior longitudinal ligament,

impossible anterior decompression, preserved lordosis or its slight straightening. All patients were operated on by the same neurosurgical team. After receiving a written voluntary informed consent to carry out the necessary diagnostic measures, the patients were examined in a hospital setting. Evaluation of long-term results was carried out according to subjective, objective and instrumental data. A complete clinical examination included the collection of complaints, catamnesis, an independent clinical and neurological examination by related specialists (neurosurgeon/neurologist), as well as filling in the questionnaires: VAS to determine the severity of pain in the upper limbs, the Japanese Association of Orthopedists (JOA) and Nurick grading to assess the functional condition of patients and dynamic control of symptoms of myeloradiculopathy. All patients underwent neuroimaging studies: MRI of the cervical spine on MRI Discovery MR750w 1.5 T, CT of the cervical spine on Aguilion Prime SP TSX-303B. Using the standard measuring tools of the RadiAnt DICOM Viewer software, an objective assessment of the severity of stenosis was performed. The average linear dimensions and cross-sectional area of the dural sac were measured on transverse MRI slices. The anteroposterior section of the spinal canal was calculated as a linear characteristics of the severity of stenosis in the preoperative, early, and late postoperative periods. The nonparametric Wilcoxon T-test and Mann-Whitney U-test were used to assess the statistical significance of the results. Differences were considered significant at $p < 0.05$. The results are presented as $M \pm m$, where M is the arithmetic mean and m is the standard error of the mean.

Surgical technique

The position of the patient was lying on his stomach with arms fixed along the body. The body was fixed with a belt (Fig. 1). Before complete fixation of the patient, electrodes for neuromonitoring were placed. The spinous processes served as an anatomical landmark for performing a median skin incision. The subcutaneous tissue and muscles were dissected along the midline (avascular region). Skeletonization of the spinous processes and arches, and partially of the facet joints of the vertebrae was performed. The next step was sawing through the arches at the place of their transition into the facet joints using a Misonix bone scalpel on both sides (Fig. 2). Carefully dissecting the yellow ligament, a temporary extraction of the bone flap was performed. Using a high-speed drill and Kerrison-type nippers, foraminotomy was performed at the levels of interest (Fig. 3). The next step was the modeling of mini-plates with their subsequent fixation to the flap using 6-mm screws (Fig. 4, 5). The finished complex was placed in its original position and fixed to the joints so that there was some gap between the joints and arches to increase the space (Fig. 5). The flap was fixed to the facet joints with 8-mm screws (Fig. 5, Fig. 6 a). An osteoinductive material was placed along the mini-plates at the cut site (Fig. 6 b). Layer-by-layer suturing of the woundfollowed, neck muscles were sutured in three layers.

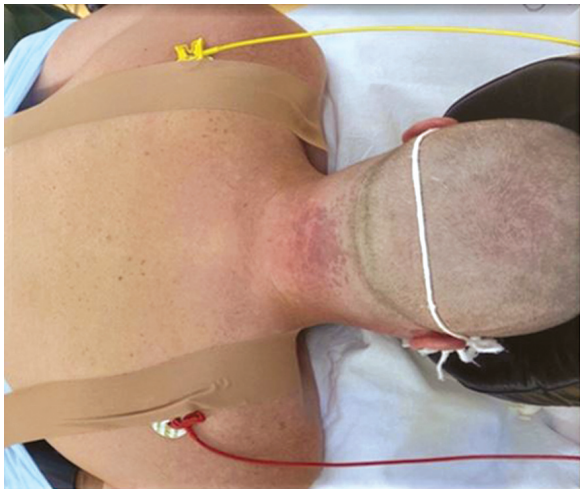

Fig. 1 Positioning of the patient on the operation table

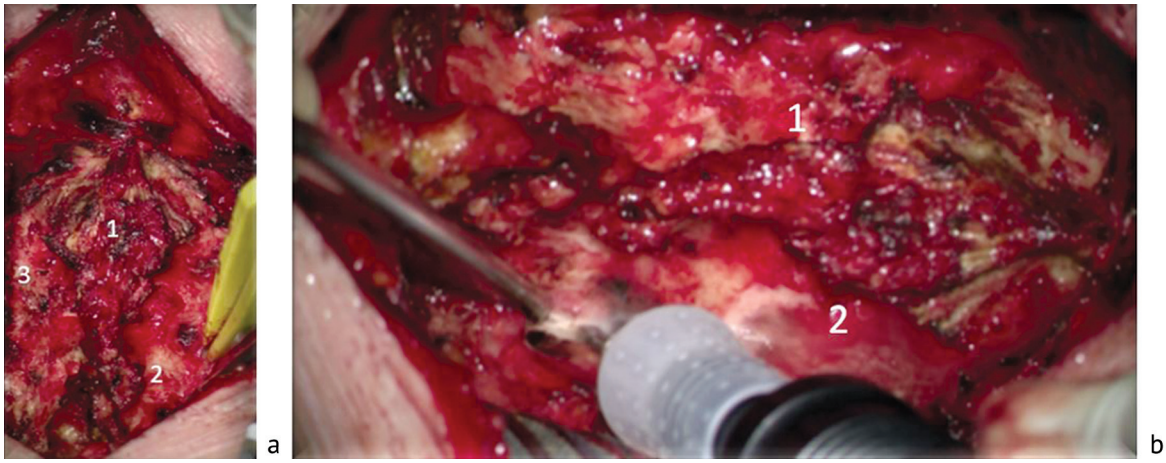

Fig. 2 Exposure of spinous processes (a) and sawing through the arches using an ultrasonic bone scalpel Misonix (b): 1 – spinous processes; 2 – arch of the vertebra; 3 – joint

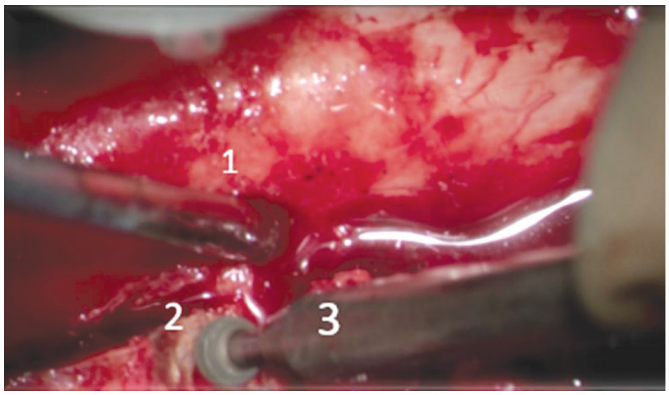

Fig. 3 Temporary removal of the bone flap with simultaneous foraminotomy: 1 – dural sac; 2 – area of root formation; 3 – Stryker drill

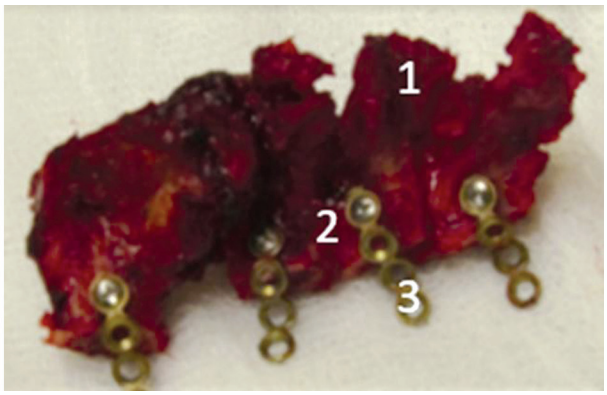

Fig. 4 Bone flap with attached mini-plates, ready for installation: 1 – spinous process; 2 – arch of the vertebra; 3 – titanium mini-plate

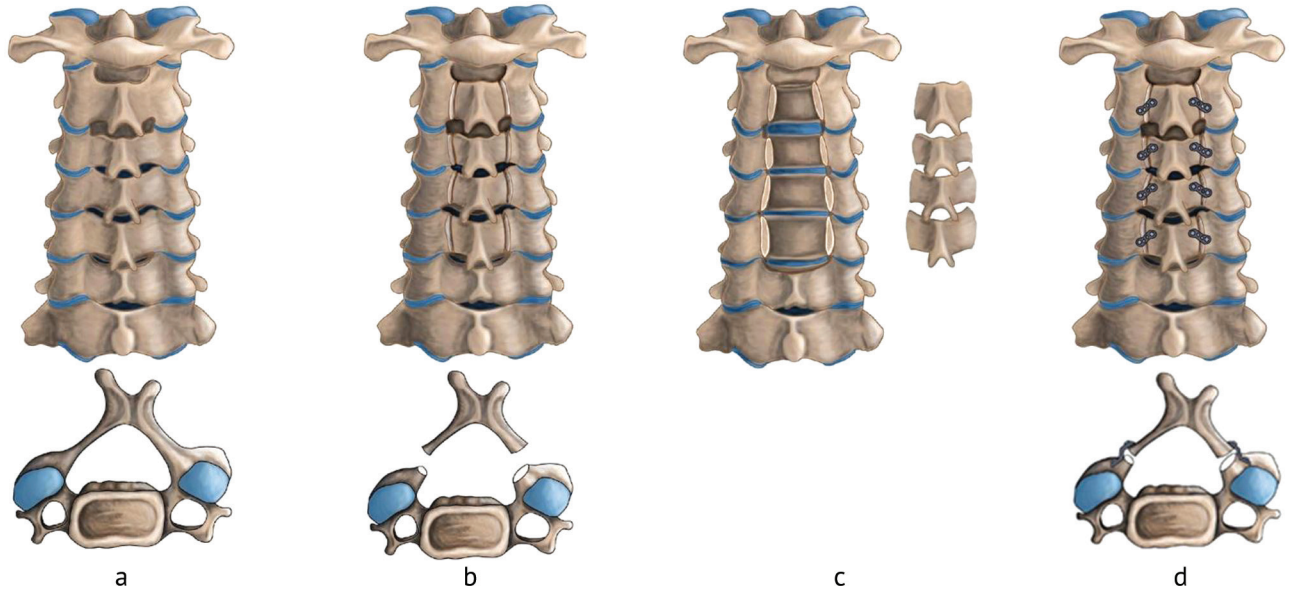

Fig. 5 Diagrams of bilateral osteoplastic laminoplasty in frontal and axial projections: a – cervical spine before surgery; b – cervical spine after sawing through the arches on both sides; c – temporary removal of the bone flap; d – reinstalled bone flap, fixed with mini-plates

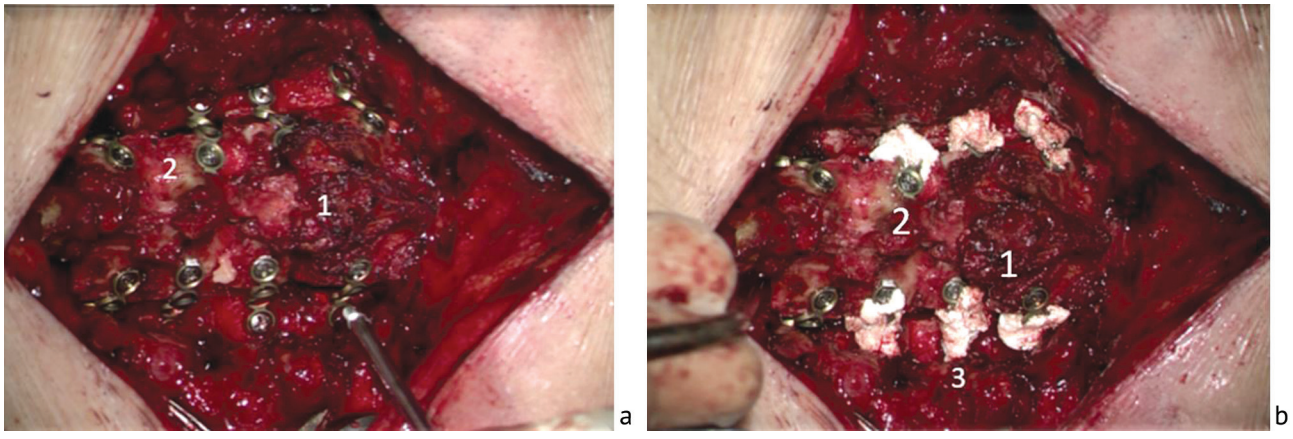

Fig. 6 Fixation of the bone flap to the facet joints (a), application of osteoinductive material on mini-plates (b): 1 – spinous process; 2 – facet joint; 3 – osteoinductive material

RESULTS

At admission in the preoperative period, all patients showed characteristic clinical symptoms of neurological deficit, manifested by myeloradiculopathy. They determined the solution to perform the combination of laminoplasty and foraminotomy. The severity of neurological manifestations correlated with the magnitude of the narrowing of the average area of the spinal canal and the extent of multilevel stenosis. According to neuroimaging MRI of the cervical spine, seventeen patients out of 27 had a four-level stenosis of the CS, four had a three-level stenosis, and five patients had a two-level stenosis. The average number of stenotic levels was 3.4. The patients reported positive dynamics: regression of radicular pain, improvement of motor functions, and partial recovery of sensory disorders. The average radicular pain in the upper extremities in the preoperative period compared with the early and late postoperative period according to the VAS scale was 6 ± 2.3, $p < 0.05$; according to the Nurick motor impairment scale 2 ± 1.3, $p < 0.05$; according to the JOA scale – 11.6 ± 2.8, $p < 0.05$. The mean value of pain on the VAS scale in the early postoperative period compared with the preoperative period was 3.9 ± 1.8, $p < 0.05$; on the Nurick scale 1.8 ± 1.1, $p < 0.05$; according to the JOA scale, 12.6 ± 2.0, $p < 0.05$ (Fig. 7). Two out of 27 patients had complications. In one case, there was an increase in pain along the affected dermatome, weakness in the right upper limb, and gait disturbance in the early postoperative period. In the second case, an epidural hematoma developed in the early postoperative period. After revision surgery, removal of the hematoma contributed to a favorable outcome. In the long-term postoperative period (from two to five years), compared with the preoperative period, the mean value of pain radicular syndrome on the VAS scale was 2.9 ± 1.97, $p < 0.01$, the functional state on the Nurick myelopathy scale averaged 1.1 ± 0.97 points, $p < 0.05$. Using the modified JOA scale, the mean score was 13.7 ± 1.9, $p < 0.05$.

Important criteria for a comparative analysis of long-term results are the data of instrumental studies. In particular, we measured the average cross-sectional area of the spinal canal using the above-mentioned RadiAnt DICOM Viewer software. According to neuroimaging data in the early postoperative period, all patients showed a significant increase in the average area of the transverse size of the spinal canal from 0.79 ± 0.20 cm^2 to 1.74 ± 0.43 cm^2 at $p < 0.01$ (Fig. 8). In the late postoperative period, a slight increase in the average cross-sectional area was observed, equal to 1.9 ± 0.44 cm^2, $p < 0.05$.

Case report 1 Patient F., 57 years old, was admitted with complaints of pain in the cervical spine radiating to the right upper limb, weakness in the lower limbs, numbness in the body below the level of the chest line and in both hands, dysfunction of the pelvic organs. The neurological status was dominated by symptoms of radiculopathy in the C5 dermatome on the right, conductive type of sensory disturbance from the T5 segment, spastic tetraparesis: mild in the upper limbs, moderate in the lower ones. On examination, the following data were obtained on the scales: VAS – 7 points, JOA – 13 points, Nurick – 1 point. Neuroimaging: MRI picture of spinal stenosis at the level of C4-C7 vertebrae with myelopathy, paramedian herniated disc at the level of C4-C5 vertebrae. The measured average cross-sectional area of the dural sac with the Radiant Dicom Viewer software was 0.8182 cm^2 (Fig. 9).

The patient underwent surgery: osteoplastic bilateral decompression laminoplasty at the level of C3-C7 with simultaneous foraminotomy of C4-C5 on the right and left under neurophysiological control; removal of the herniated disc at the level of C4-C5 on the right; fixation with laminoplasty plates.

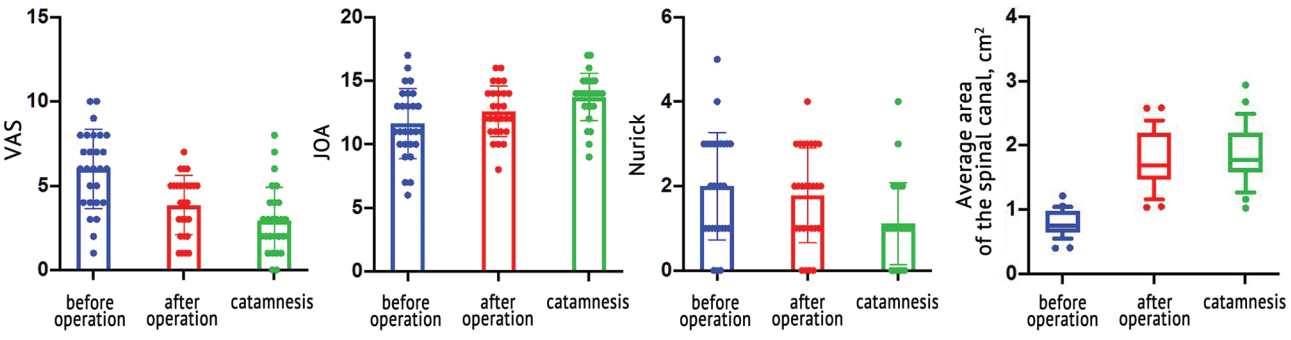

Fig. 7 Evaluation of the severity of pain and the results of dynamic control of symptoms of radiculopathy and myelopathy according to VAS, the Japanese Association of Orthopedists (JOA) and Nurick in the preoperative, early and late postoperative periods

Fig. 8 Assessment of the average area of the spinal canal in the preoperative, early and late postoperative periods

On the first day after surgery, the patient showed positive dynamics: regression of pain in the right upper limb according to VAS to 4 points. In the late post-surgical period (2 years after surgery) it was 2 points.

The functional state according to the Nurick myelopathy scale did not change compared to the preoperative period, a constant value of 1.

According to the MRI study, using standard computational tools, it was found that the average cross-sectional area of the dural sac increased to 1.741 cm^2 in the early postoperative period (Fig. 10).

In the postoperative period, the patient was recommended to fix the cervical spine with a Shants collar for 3-4 weeks. On day 2 the patient was activated, the sutures were removed on the 14th day.

Case report 2 Patient K., 47 years old, was admitted with complaints of pain in the cervical spine, radiating to the left upper limb, numbness in both upper and lower limbs, as well as in the chest and abdomen, in the back, gradually increasing weakness, fine motor impairment. In the preoperative period, the symptoms of radiculopathy in the C7 dermatome on the left, the conductive type of sensory disturbance from the C5 segment prevailed. On examination, the following data were obtained on the scales: VAS – 6 points, JOA – 12 points, Nurick – 1 point. MRI before surgery showed MRI picture of spinal canal stenosis at the level of C3-C7 and myelopathy at the level of C4-C6 vertebrae. The average cross-sectional area of the dural sac measured 1.355 cm2.

The patient underwent decompression laminoplasty at the C3-C6 level with simultaneous foraminotomy at the C4-C5 level on the right and left under neurophysiological control; fixation with laminoplasty plates. Pain syndrome regressed in the left upper limb according to VAS down to 3 points and in the late period to 2 points.

The functional state according to the Nurick myelopathy scale did not change compared to the preoperative period, a constant value of 1.

The average cross-sectional area of the dural sac in the late postoperative period increased to 3.319 cm^2 (Fig. 12).

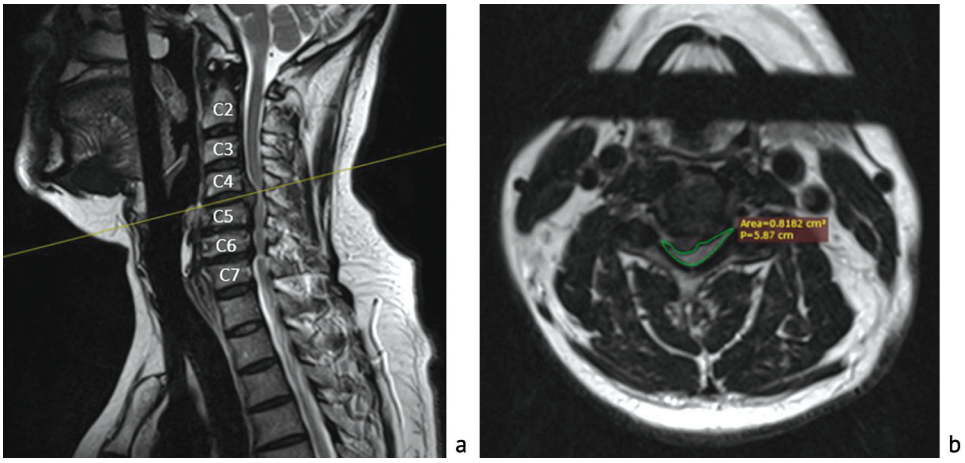

Fig. 9 MRI of the cervical spine before surgery: a sagittal view; b axial view. Measurement of the cross-sectional area of the spinal canal with Radiant Dicom Viewer

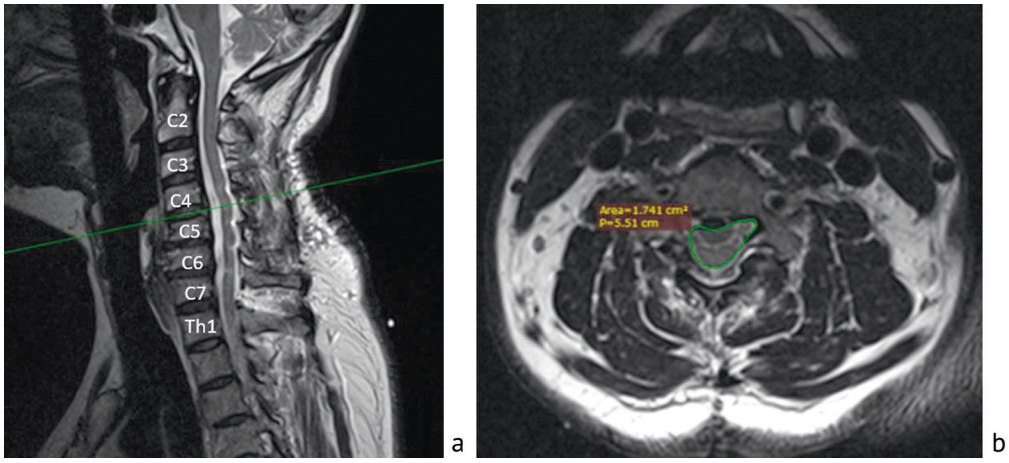

Fig. 10 MRI of the patient's cervical spine; condition after laminoplasty at the level of C4-C7; without signs of central stenosis: a sagittal view; b axial view

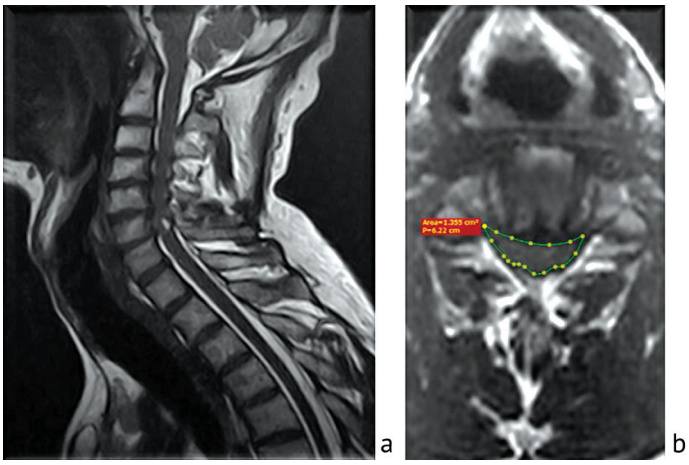

Fig. 11 MRI of the patient's cervical spine before surgery: a sagittal view; b axial view

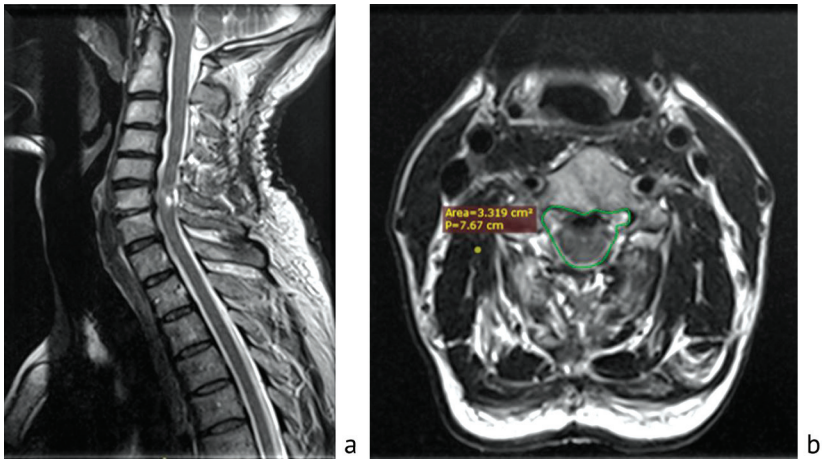

Fig. 12 MRI of the patient's cervical spine after surgery at the level of C3-C6 vertebrae: a sagittal view; b axial view

DISCUSSION

There is still no consensus in the literature about the optimal tactics of surgical treatment of multilevel stenosis. It is known that most stabilizing operations from both the anterior and posterior approaches are quite traumatic [14-16]. The main objective of surgical treatment for stenosis of the cervical spine is the decompression of the spinal canal and roots with the maximum preservation and restoration of the support ability of the spine. Laminectomy was used previously. This method of treatment allows excellent visualization of neurovascular structures, safe hemostasis and foraminotomy. However, it has a number of shortcomings, first of all, the development of post-laminectomy syndrome, which includes segmental instability and postoperative kyphosis [17].

Therefore, laminoplasty is one of the methods of choice for the surgical treatment of extended stenoses. Currently, there are several modifications of laminoplasty. The most widely used are Hirabayashi's "open door" and Kurokawa's "French door" methods [12]. Single-door laminoplasty, described by Hirabayashi in 1976, consists in expanding the spinal canal by fixing the posterior arch on one side at the junction of the plate and the facet joint and performing a complete osteotomy on the contralateral side. These techniques provide the possibility of complete displacement of the plate without removing the posterior part of the vertebral arch. This technique, due to its easiness of implementation and long-term results, has become widely used in practice, has been modified and supplemented many times, which allowed Kurokawa to propose an alternative method of double-door laminoplasty in 1982, in which the spinous processes are dissected along the midline, cuts are formed with both sides at the junction of the plate of the arch with the intervertebral joints. Although surgeons have improved the way laminoplasty is performed over time, the general principles of this technique still include preservation of the dorsal elements, preservation of segmental motion, and expansion of the spinal canal. After laminoplasty, according to Tomita, out of 25 patients followed up for 2.9 years, 72 % had positive results in the late postoperative period [18]. Edwards et al described the clinical picture in 18 patients followed up for 2 years who underwent the Kurokawa laminoplasty; 67 % of them showed an increase in strength in the upper limbs, 83 % had regression of pain syndrome, 67 % gait

improvement [19]. Russian authors assessed the results in the late postoperative period using the VAS, Nurick, JOA scales. Patients reported positive dynamics [17, 20]. However, according to the literature, among the frequently described complications are restenosis, migration of a broken arch and of allografts [17, 21].

The technique of bilateral osteoplastic laminoplasty is one of the options for surgical treatment. This method of surgical treatment, as in the case of laminectomy, allows to fully visualize the neurovascular structures, as well as safely perform hemostasis and foraminotomy at the levels of interest. All patients underwent foraminotomy at the level of C4-C5 segments of the cervical spine. Thus, according to the literature and clinical observations, the incidence of paresis of the muscles innervated by the C5 root at the level of C4-C5 reaches 8 % [22].

According to the authors, this method of laminoplasty is an effective way to treat extended stenoses in the cervical spine [17, 20, 23].

In our clinical work, we analyzed the long-term results after bilateral osteoplastic laminoplasty with simultaneous foraminotomy. Evaluating the results in the long-term period from 2 to 5 years, we found that this surgical technique significantly relieves the radicular pain syndrome, the signs of myelopathy decrease, and the increased volume of the spinal canal remains preserved (Fig. 7, 8).

Thus, pain according to the VAS scale in the early postoperative period decreased by an average of 35 %; myelopathy symptoms on the Nurick scale by 10 % and on JOA scale by 7.2 %. The effectiveness of the performed laminoplasty is also evidenced by an increase in the cross-sectional area of the spinal canal [15, 16]. In the early postoperative period, according to standard measuring instruments, the cross-sectional area increased by 50 %.

The analysis of the results of neuroimaging studies showed that in the late postoperative period, all patients showed an insignificant increase in linear characteristics compared to the early period. It is known that decompression of the spinal cord and stabilization of the cervical spine in all cases results in the development of spinal cord edema [24]. This probably explains the slight increase in the cross-sectional area of the spinal canal in the follow-up compared with the early period, according to neuroimaging data. Therefore, the average cross-sectional area of the spinal canal increased in the late postoperative period by 15.8 %.

The severity of pain syndrome according to the VAS scale in the late postoperative period decreased by an average of 25.7 %; the functional state of patients improved according to the Nurick scale by 38.9 %; according to the scale of the Japanese Association of Orthopedists (JOA) by 8.8 %. In the late postoperative period from 2 to 5 years, according to our data, in comparison with the early period, patients had a positive dynamics; there was a slight increase in the cross-sectional area of the spinal canal according to neuroimaging data. Thus, the clinical evaluation scales and neuroimaging revealed a significant effectiveness of the treatment.

CONCLUSION

The results of the study convincingly testify to the effectiveness of this technique. The described technique, contributing to favorable long-term results, can be recommended for patients with multilevel stenosis, clinically manifested by myeloradiculopathy.

Conflict of interest *The authors declare no conflict of interest.*

Financing. *The study was not sponsored.*

REFERENCES

1. Motosuneya T, Maruyama T, Yamada H, Tsuzuki N, Sakai H. Long-term results of tension-band laminoplasty for cervical stenotic myelopathy: a ten-year follow-up. *J Bone Joint Surg Br*. 2011;93-B(1):68-72. doi: 10.1302/0301-620X.93B1.24532
2. Truumees E, Herkowitz HN. Cervical spondylotic myelopathy and radiculopathy. *Instr Course Lect*. 2000;49:339-60.
3. Ma L, Liu FY, Huo LS, Zhao ZQ, Sun XZ, Li F, Ding WY. Comparison of laminoplasty versus laminectomy and fusion in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: A systematic review and meta-analysis. *Medicine* (Baltimore). 2018;97(29):e11542. doi: 10.1097/MD.0000000000011542
4. Lin X, Cai J, Qin C, Yang Q, Xiao Z. Comparison of clinical outcomes and safety between laminectomy with instrumented fusion versus laminoplasty for the treatment of multilevel cervical spondylotic myelopathy. *Medicine* (Baltimore). 2019;98(8):e14651. doi: 10.1097/MD.0000000000014651
5. Gibson J, Nouri A, Krueger B, Lakomkin N, Nasser R, Gimbel D, Cheng J. Degenerative Cervical Myelopathy: A Clinical Review. *Yale J Biol Med*. 2018;91(1):43-48.
6. Fehlings MG, Wilson JR, Kopjar B, Yoon ST, Arnold PM, Massicotte EM, и др. Efficacy and Safety of Surgical Decompression in Patients with Cervical Spondylotic Myelopathy: Results of the AOSpine North America Prospective Multi-Center Study. *J Bone Joint Surg Am*. 2013;95(18):1651-1658. doi: 10.2106/JBJS.L.00589
7. Sherman BP, Lindley EM, Turner AS, Seim HB 3rd, Benedict J, Burger EL, Patel VV. Evaluation of ABM/P-15 versus autogenous bone in an ovine lumbar interbody fusion model. *Eur Spine J*. 2010;19(12):2156-2163. doi: 10.1007/s00586-010-1546-z
8. Blizzard DJ, Caputo AM, Sheets CZ, Klement MR, Michael KW, Isaacs RE, Brown CR. Laminoplasty versus laminectomy with fusion for the treatment of spondylotic cervical myelopathy: short-term follow-up. *Eur Spine J*. 2017;26(1):85-93. doi: 10.1007/s00586-016-4746-3
9. Boogaarts HD, Bartels RHMA. Prevalence of cervical spondylotic myelopathy. *Eur Spine J*. 2015;24(S2):139-141. doi: 10.1007/s00586-013-2781-x
10. Lauweryns P, Raskin Y. Prospective Analysis of a New Bone Graft in Lumbar Interbody Fusion: Results of a 2- Year Prospective Clinical and Radiological Study. *Int J Spine Surg*. 2015;9:2. doi: 10.14444/2002

11. Boogaarts HD, Bartels RHMA. Prevalence of cervical spondylotic myelopathy. *Eur Spine J*. 2015;24(Suppl 2):139-141. doi: 10.1007/s00586-013-2781-x
12. Nasto LA, Muquit S, Perez-Romera AB, Mehdian H. Clinical outcome and safety study of a newly developed instrumented French-door cervical laminoplasty technique. *J Orthop Traumatol*. 2017;18(2):135-143. doi: 10.1007/s10195-016-0440-9
13. Roselli R, Pompucci A, Formica F, Restuccia D, Di Lazzaro V, Valeriani M, Scerrati M. Open-door laminoplasty for cervical stenotic myelopathy: surgical technique and neurophysiological monitoring. *J Neurosurg*. 2000;92(1 Suppl):38-43. doi: 10.3171/spi.2000.92.1.0038
14. Yoon ST, Hashimoto RE, Raich A, Shaffrey CI, Rhee JM, Riew KD. Outcomes After Laminoplasty Compared With Laminectomy and Fusion in Patients With Cervical Myelopathy: A Systematic Review. *Spine* (Phila Pa 1976). 2013;38:(22 Suppl 1):S183-S194. doi: 10.1097/BRS.0b013e3182a7eb7c
15. Lau D, Winkler EA, Than KD, Chou D, Mummaneni PV. Laminoplasty versus laminectomy with posterior spinal fusion for multilevel cervical spondylotic myelopathy: influence of cervical alignment on outcomes. *J Neurosurg Spine*. 2017;27(5):508-517. doi: 10.3171/2017.4.SPINE16831
16. Hitchon PW, Woodroffe RW, Noeller JA, Helland L, Hramakova N, Nourski KV. Anterior and Posterior Approaches for Cervical Myelopathy: Clinical and Radiographic Outcomes. *Spine* (Phila Pa 1976). 2019;44(9):615-623. doi: 10.1097/BRS.0000000000002912
17. Dreval' M.D., Gushcha A.O., Arestov S.O., Korepina O.S. Surgical treatment of severe spondylogenic cervical myelopathy by laminoplasty. *Zh Vopr Neirokhir im N N Burdenko*. 2015;79(6):77-84. doi: 10.17116/neiro201579677-84
18. Kimura I, Shingu H, Nasu Y. Long-term follow-up of cervical spondylotic myelopathy treated by canal-expansive laminoplasty. *J Bone Joint Surg Br*. 1995;77-B(6):956-61.
19. Edwards CC, Heller JG, Hal Silcox D. T-Saw Laminoplasty for the Management of Cervical Spondylotic Myelopathy: Clinical and Radiographic Outcome. *Spine* (Phila Pa 1976). 2000;25(14):1788-1794. doi: 10.1097/00007632-200007150-00009
20. Krutko A.V., Simonovich A.E., Zaidman A.M., Gladkov A.V. Decompressive laminoplasty using porous titanium nickelide for degenerative spinal canal stenoses: an experimental clinical study. *Spine Surgery*. 2004;(4):47-56 (in Russ)
21. Kurokawa R, Kim P. Cervical Laminoplasty: The History and the Future. *Neurol Med Chir* (Tokyo). 2015;55(7):529-539. doi: 10.2176/nmc.ra.2014-0387
22. Ratliff JK, Cooper PR. Cervical laminoplasty: a critical review. *J Neurosurg*. 2003;98(3 Suppl):230-238. doi: 10.3171/spi.2003.98.3.0230
23. Sufianov A.A., Nabiev D.N., Kalinin I.V., Sufianov R.A., Shapkin A.G., Zaytsev M.K., Cherkasov A.V., Sagdiev R.H. Bilateral osteoplastic decompression laminoplasty with simultaneous foraminotomy to treat multilevel cervical stenosis. *Spine Surgery*. 2021;18(2):54-63. doi: 10.14531/ss2021.2.54-63
24. Hellenbrand DJ, Quinn CM, Piper ZJ, Morehouse CN, Fixel JA, Hanna AS. Inflammation after spinal cord injury: a review of the critical timeline of signaling cues and cellular infiltration. *J Neuroinflammation*. 2021;18(1):284. doi: 10.1186/s12974-021-02337-2

The article was submitted 16.01.2023; approved after reviewing 28.02.2023; accepted for publication 20.04.2023.

Information about the authors:

1. Albert A. Sufianov – Doctor of Medical Sciences, Professor, Head of the Department, Sufianov@gmail.com, https://orcid.org/0000-0001-7580-0385;
2. Aleksandr V. Burtsev – Doctor of Medical Sciences, Director, bav31rus@mail.ru, https://orcid.org/0000-0001-8968-6528;
3. David N. Nabiev – neurosurgeon, Head of Neurosurgical Department, davidnabiev82@gmail.com, https://orcid.org/0000-0002-5380-8367;
4. Asiyat Sh. Magomedova – resident physician, neurosurgeon, asya_mag_95@mail.ru, https://orcid.org/0000-0001-8197-930X;
5. Rinat A. Sufianov – assistant, neurosurgeon, Rinat.sufianov@gmail.com, https://orcid.org/0000-0003-4031-0540;
6. Maria T. Karsanova – neurosurgeon, asya_mag_95@mail.ru, https://orcid.org/0000-0002-8919-1012;
7. Vladislav V. Piterov – neurosurgeon, Piterovva@mail.ru, https://orcid.org/0000-0001-7024-0016.