OPERATIVE TECHNIQUES

Expansion of Spinal Canal with Lift-Open Laminoplasty: A New Method for Compression Cervical Myelopathy

Huan Wang, PhD  Lei Zhang, PhD
Spinal Surgery Unit, Shengjing Hospital of China Medical University, Shenyang, China

Objective: This study is to introduce lift-open laminoplasty and verify the increase of the spinal canal area following this surgical technique according to the preoperative anatomical measurement.

Methods: There are 82 patients (43 male and 39 female) analyzed in our study from January 2019 to December 2020. The average age was 63.2 ± 3.21 years (from 41 to 84 years). All of them were treated with open-door laminoplasty, with a decompression segment range from C3 to C6. The increase of the spinal canal area after open-door laminoplasty was measured on postoperative CT images of the patients, and the distances between both lamina-facet junctions and lamina length was measured on preoperative CT images. Using the Pythagorean theorem for the equation of calculation area after the expansile open-door laminoplasty. Based on previous measurement parameters, spinous process length, lateral mass width, distance between osteotomy line and lamina-facet junctions line were additionally measured on preoperative CT images. Pythagorean theorem was used for calculating the area after the expansile lift-open laminoplasty. The results were recorded and a statistical analysis was undertaken. Then, there were six patients (five male and one female) treated with lift-open laminoplasty on C6, open-door on C3–C5, who suffer from cervical spondylotic myelopathy from December 2020 to January 2021. The average age was 60.3 ± 1.7 years (from 56 to 71 years). Operation time, blood loss, and Japanese Orthopaedic Association (JOA) score recovery rate were recorded. Intraoperative and postoperative complications were observed.

Results: The increase of the spinal canal area after open-door laminoplasty measured on postoperative CT images was 123.01 ± 17.06 mm² and the calculation of the increase of the spinal canal area using the Pythagorean theorem after open-door laminoplasty was 122.86 ± 15.86 mm². A comparison of the actual value with calculative value showed no significant difference (T value = 0.057, P value = 0.955). The calculation of the increase of the spinal canal area after lift-open laminoplasty was 183.57 ± 62.99 mm², which was larger than that after open-door laminoplasty (T value = 8.462, P value < 0.001). Mean operation time was 153.3 min and operative blood loss was 600 mL of the six patients treated with lift-open laminoplasty. At 1 month follow-up, all patients had recovered well. JOA score recovery rate was 37.6% and no intraoperative and postoperative complications occurred.

Conclusion: Lift-open laminoplasty could preserve nearly 100% of extensor muscle, avoid damaging C7 paraspinal muscles and C6-7 posterior muscle-ligament complex, reconstruct the spinous process firmly in the midline, and expand adequate spinal canal area after operation. These advantages could reduce the incidence rate of complications and bring better clinical results than traditional laminoplasty.

Key words: Axial symptoms; Extensor muscles; Lift-open laminoplasty; Open-door laminoplasty; Spinal canal area

Address for correspondence Lei Zhang, PhD, Spinal Surgery Unit, Shengjing Hospital of China Medical University, No. 36, Sanhao Street, Heping District, Shenyang, Liaoning Province, China 110004 Tel: +86-18940257395; E-mail: cmu_zl@163.com
Received 28 February 2021; accepted 1 April 2021

Orthopaedic Surgery 2021;9999:n/a  DOI: 10.1111/os.13026
This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.
Introduction

Open-door laminoplasty (LP), made popular by Hirabayashi et al., is an effective posterior cervical decompression method for treating multisegmental cervical myelopathy (CSM), ossification of the posterior longitudinal ligament (OPLL) or multilevel cervical disk herniation associated with developmental spinal canal stenosis. Clinical follow-up results indicated that LP has gratifying feedback from patients and the long-term neurological recovery rate was between 50% and 70%. The deep extensor muscles, such as the semispinalis cervicis and multifidus muscles attached to the lamina and spinous processes, act as dynamic stabilizers of the cervical spine. In conventional LP, it is often necessary for bilateral paravertebral muscles to cut off from the lamina and spinous process, which will lead to the structural damage of the posterior cervical tension band and weaken the power source from the posterior paravertebral muscles, resulting in irreversible muscle atrophy and cervical sagittal imbalance. Consequently, postoperative complications, such as axial symptoms (AS), restriction of neck motion, loss of lordotic curvature, and so on, would occur. According to previous documents, 34% of patients developed secondary cervical spinal stenosis, 0% to 30% of patients developed C5 nerve root palsy, almost 100% of patients developed reduction of cervical range of motion, 5% to 86% of patients developed axial symptoms, and 16% of patients developed hinge fusion failure or fracture.

Axial symptoms after operation, including neck pain and stiffness, can have a significant negative impact on clinical outcomes and quality of life. Although the exact cause of axial neck pain has not been detected, disturbing the attachments of the deep extensor muscles to the laminae and spinous processes can be one of the main causes of postoperative AS. In recent decades, several types of improved laminoplasty have been described to reduce the incidence of axial symptoms after operation. A lower incidence of AS correlated with better deep extensor muscle preservation and better postoperative biomechanical stability. Therefore, improved surgical techniques can be divided into two categories: one focuses on protection of soft tissue, including preserving the muscular attachments to the spinous processes and minimally invasive surgical approach; the other one focuses on stability enhancement post-operation, including soft tissue reconstruction and rigid internal fixation.

Lin et al. found that LP with preservation of unilateral paravertebral muscles had the advantage of less soft tissue detachment and provided greater stability, as well as better muscular alignment and reduced postoperative AS. Liu et al. indicated that preserving bilateral paravertebral muscles is an encouraging method to maintain or restore the physiological curve and prevent kyphosis during LP, which could reduce incidence rate of postoperative AS. Shiraishi et al. had performed a modified double-door laminoplasty in which the deep extensor muscles were detached unilaterally and then re-approximated to the spinous processes after expanding the cervical canal. This is a new exposure technique for the cervical spine laminae, which has enabled the spinal canal to be expanded with semispinalis cervicis and multifidus attachments left undisturbed. Therefore, muscular strength necessary for extending and stabilizing the neck is not appreciably weakened. Shiraishi et al. have introduced skip laminectomy to expand the spinal canal while preserving the semispinalis cervicis and multifidus muscles. The spinous processes and laminae are split at the midline, and the muscles are left attached. By limiting excision of the posterior anatomic structures, skip laminectomy successfully prevented postoperative complications. Kim et al. introduced a method named myoarchitectonic spinolaminoplasty, in which semispinalis and splenius capitis muscles are divided from the spinous process and are subsequently reattached to the reconstructed HA artificial spinous process. There was nearly 100% extensor muscle preservation, and postoperative neck pain and shoulder strain were effectively suppressed. The results at 1-year follow-up showed that the incidence of axial neck pain was 22.2%. Furthermore, other researchers suggested that reducing the invasion of the cervical extensor and retaining muscles attached to the spinous process significantly lowered the incidence of AS and decreased the loss of sagittal cervical lordosis after surgery.

Until now, the lowest incidence of AS reported was about 20%, there are still not effective surgical techniques to reduce postoperative axial symptoms. Thus, we designed a new laminoplasty method, named lift-open laminoplasty, in which deep extensor muscles are preserved better and stay in place. Various potential prognostic factors may affect the clinical outcome of cervical laminoplasty. The increase of the spinal canal area (SCA) is one of the important factors affecting the clinical efficacy of cervical laminoplasty. The possibility of recovery of spinal cord function was positively correlated with the degree of spinal cord decompression. If the sagittal canal diameter or SCA is not increased sufficiently, the spinal cord compression will not be relieved, resulting in unsatisfactory results after cervical laminectomy. Therefore, it is important to clarify the increase of SCA following lift-open laminoplasty for further clinical application.

The purpose of this study was: (i) to introduce the surgical technique of lift-open laminoplasty; (ii) to verify the increase of the spinal canal area following lift-open laminoplasty according to the preoperative anatomical measurement; (iii) to observe the short-term complications after operation.

Materials and Methods

Patient Data

Eighty-two patients treated with open-door laminoplasty from January 2019 to December 2020 in our department...
were randomly chosen for this study (43 males and 39 females, mean age was 63.2 years). The decompression segment range of all the patients was C3–C6. And all patients underwent preoperative and postoperative cervical three-dimensional computed tomography (3D-CT) at our hospital. The inclusion criteria were: (i) cervical pathologies with multilevel cord compression and corresponding myelopathic symptoms requiring posterior decompression surgery; (ii) age >18 years. Patients who met any of the following criteria were excluded: (i) suffered from fractures, tumors, infections, rheumatoid diseases, and malformations that affected bone morphology; (ii) a history of anterior decompressive and fusion surgery or posterior fusion surgery.

**CT Procedure**

Aquilion Multi 64 helical CT (Toshiba Tungaloy Co. Ltd., Nirasaki, Japan) was used to perform CT examinations and measurements on patients. Scanning parameters: thickness 1 mm, pitch 0.938, distance 0.5 mm, tube tension 120 kV, electric current 250 mA, window width 1000, and window level 300. CT scanning operated at 120 kV, 54 mA, 10 × 10 cm field of view, 512 × 512 matrix, and a table speed of 1 mm/0.5 s.

**CT Images**

The distances between both lamina-facet junctions and lamina length were measured on preoperative CT images (Fig. 1). And the increase of the SCA after open-door laminoplasty were measured on postoperative CT images. The laminoplasty opening size was defined as the distance between the split points at the opened lamina. In our study, line D is the laminoplasty opening size, this value was defined as 12 mm, because most of the titanium miniplates used in C6 were 12 mm (Fig. 2). Based on previous measurement parameters, spinous process length, lateral mass width, distance between osteotomy line and lamina-facet junctions line were additionally measured on postoperative CT images (Fig. 3). The images were measured using the Picture Archiving Communication System (Agfa Corporation, Ridgefield, NJ) and the measurement accuracy was 0.01 mm and 0.01 mm². Two clinicians independently evaluated all the images twice.

**Calculation of the Increase of the SCA after Open-Door Laminoplasty**

We used the Pythagorean theorem for the equation of calculated area after the expansile open-door laminoplasty.

The calculation of increase of the SCA after open-door laminoplasty is as follows:

$$\text{Area}_{\text{postoperative}} = \text{Area}_{\text{preoperative}} + \frac{1}{2} \times \text{D} \times (X + \text{Y})$$

**Fig 1** X: the distances between both lamina-facet junctions; Y: lamina length; red zone: the calculation of SCA preoperative.

**Fig 2** X: the distances between both lamina-facet junctions; D: the laminoplasty opening size; red zone: the calculation of SCA preoperative; yellow zone: the calculation of increase of the SCA after open-door laminoplasty.

**Fig 3** L: spinous process length; H1: lateral mass width (right); H2: lateral mass width (left); W: width of osteotomy line; d: distance between osteotomy line and lamina-facet junctions line; X: the distances between both lamina-facet junctions; red zone: the calculation of SCA preoperative.
Calculation of the Increase of the SCA after Lift-Open Laminoplasty
We also used the Pythagorean theorem for the equation of calculated area after lift-open laminoplasty.

The calculation of SCA after lift-open laminoplasty is as follows:

$$\frac{1}{2} \times d \times (X + W) + \frac{1}{2} \times H \times \sqrt{L^2 - \left(\frac{H}{2}\right)^2}$$

$$- \frac{1}{2} \times X \times \sqrt{Y^2 - \left(\frac{X}{2}\right)^2}$$

$L$: spineous process length; $W$: width of osteotomy line; $d$: distance between osteotomy line and lamina-facet junctions line; $X$: the distances between both lamina-facet junctions; $H$: average width of bilateral lateral mass; $Y$: lamina length)

Statistical Analysis
SPSS 22.0 software (IBM Corp. Armonk, NY, USA) was used for statistical analysis. A variance component analysis was also performed for the study. Measurement data were presented as mean ± standard deviation. Enumeration data were expressed as a percentage. The differences between clinical data and prediction results were evaluated with a paired t-test. $P < 0.05$ indicated a significant difference.

Surgical Technique and Postoperative Protocol
After successful general anesthesia, patients were placed prone with the cervical spine in mild flexion, and the head was supported by a Mayfield headstock. A midline skin incision was made from the C2 spinous process to the C6 spinous process. The nuchal ligament was incised in the midline. Then, the incision was continued between the bilateral splenius capitis and semispinalis capitis down to the spinous processes from C3 to C6.

Split the C6 spinous process longitudinally from cranial to caudal direction with an ultrasonic bone scalpel. Lift a little soft tissue on dorsal side of lamina to expose the bone and cut off the bilateral laminae of C6 at the outer margin of the epidural from cranial to caudal. The inclination angle of lamina osteotomy is 15° (Fig. 5). Lift the C6 split spinous process and laminae dorsally, open the two parts from inside to outside and place the lateral edge of the lamina on the center of the lateral mass (Fig. 6). Fix the ends of laminae on the lateral masses with screws and suture the split spinous process (Fig. 7). The inner edge of the spinous process was partially scraped to avoid compressing the dura. C3–C5 was formed by traditional open-door laminoplasty.

Patients were allowed to sit up and walk on the first day postoperative, meanwhile isometric cervical muscle exercises were started. Patients were instructed to wear a Philadelphia cervical collar for 2 weeks.

Evaluation Method and Observation Index
Operation time and blood loss were recorded. Spinal dura mater tear, spinal cord injury, root nerve injury, and abnormal bleeding were monitored during the surgery. Cerebrospinal fluid leakage, poor wound healing, wound infection, and axial symptoms were monitored after surgery. The JOA...
Fig 5  Split the C6 spinous process longitudinally from cranial to caudal direction with an ultrasonic bone scalpel. Lift a little soft tissue on dorsal side of lamina to expose the bone and cut off the bilateral laminae of C6 at the outer margin of the epidural from cranial to caudal. The inclination angle of lamina osteotomy is $15^\circ$.

Fig 6  Lift the C6 split spinous process and laminae dorsally, open two parts from inside to outside, and place the lateral edge of the lamina on the center of the lateral mass.

Fig 7  Fix the ends of laminae on the lateral masses with screws and suture the split spinous process.

scores were recorded before surgery and at final follow-up. And the JOA score recovery rate was calculated according to the recorded data.

Fig 8  The increase of the SCA after open-door laminoplasty measured on postoperative CT images was $123.01 \pm 17.06 \text{ mm}^2$ and the calculation of the increase of the SCA after open-door laminoplasty was $122.86 \pm 15.86 \text{ mm}^2$. A comparison of the actual value with calculative value showed no significant difference.

Fig 9  The calculation of increase of the SCA after lift-open laminoplasty was $183.57 \pm 62.99 \text{ mm}^2$ and the calculation of the increase of the SCA after open-door laminoplasty was $122.86 \pm 15.86 \text{ mm}^2$. There was a significant statistical difference between two methods.

Fig 10  The increased percentage of SCA after lift-open laminoplasty was $73.83\%$ and the increased percentage of SCA after open-door laminoplasty was $49.41\%$. There was a significant statistical difference between the two methods.
3D-CT images of the cervical spine were obtained at postoperative day 3 and 1 month after operation.

**Results**

**Calculation Method Validation**
The constructed calculation value was verified using clinical data. The increase of the SCA after open-door laminoplasty measured on postoperative CT images was $123.01 \pm 17.06$ mm$^2$ and the calculation of the increase of the SCA after open-door laminoplasty was $122.86 \pm 15.86$ mm$^2$. A comparison of the actual value with calculative value showed no significant difference (T value = 0.057, $P$ value = 0.955) (Fig. 8). This finding supports the validity of the calculative method. Therefore, the accuracy of the calculative method can be considered adequate for the current study.

**Calculation of the Increase of the SCA after Lift-Open Laminoplasty**
The calculation of increase of the SCA after lift-open laminoplasty was $183.57 \pm 62.99$ mm$^2$. A comparison increased in the SCA between open-door and lift-open laminoplasty showed significant difference (T value = 8.462, $P$ value < 0.001) (Fig. 9). The increased percentage of SCA

![Images of CT scans showing cervical spine](image-url)
after different laminoplasties also showed significant difference (T value = −4.6489, P value < 0.001) (Fig. 10). These finding indicated that lift-open laminoplasty is better than open-door laminoplasty on increasing the SCA.

General Characteristics and Complications
There were six patients (five male and one female) treated with lift-open laminoplasty on C6, open-door on C3–C5, who suffer from cervical multisegmental cervical myelopathy from December 2020 to January 2021. Mean age was 60.3 ± 1.7 years (from 56 to 71 years). Mean operation time was 153.3 min, and operative blood loss was 600ml. No intraoperative and postoperative complications occurred. At an average 1-month follow-up, all patients had recovered well. JOA score recovery rate was 37.6%. 3D-CT was conducted at 1 month after operation. Image examination showed that the lamina was in a good position and there was no incidence of screw loosening (Fig. 11).

Discussion
Cervical laminoplasty has been an established and standard surgical method for multiple compressive myelopathy caused by CSM or OPLL, and satisfactory results have been reported with it, even over long-term observation. Various laminoplasty techniques have been developed. However, postoperative problems such as persistent axial pain, restriction of neck motion, and loss of lordotic curvature remain unsolved. Many studies have suggested that preserving the muscle during laminoplasty can reduce cervical ROM restriction and axial neck pain. Especially, detachments of the muscles attached to the spinous process of C2 or C7 were associated with postoperative axial neck pain and kyphosis.

Preserving the Deep Extensor Muscles
Lift-open laminoplasty preserved deep extensor muscles absolutely and allowed them to stay in place, as the spinous processes are split at the midline without damaging the posterior extensor muscles. The method of splitting was from cranial to caudal longitudinally. The advantage of this method is C7 paraspinal muscles and C6–C7 posterior muscle-ligamentous structure were not damaged at all. This became possible to reduce the incidence of axial neck pain. In our patients, no axial symptoms occurred.

Another advantage of this surgery was that the spinous process was reconstructed firmly in the midline with four lateral mass screws and enhanced through suturing the apex of spinous process with nonabsorbable suture. This method will improve the fusion rate and biomechanical stability, meanwhile keeping the extensor muscles attached and the apex of spinous process in original place, which was beneficial for early postoperative exercises and improving cervical-spine activity. This may decrease the loss of cervical ROM and the incidence of axial neck pain.

The Increase of the SCA after Lift-Open Laminoplasty
A variety of potential prognostic factors may affect clinical outcomes after cervical laminoplasty. Increased SCA after cervical laminoplasty is one of the critical factors to affect clinical results. It is positively correlated with the recovery rate of spinal cord function. If the sagittal canal diameter or SCA is not increased sufficiently, the spinal cord compression will not be relieved, resulting in unsatisfactory results after cervical laminoplasty. With regard of the increase of SCA, one study indicated that increasing the area by 95 mm² will achieve good functional recovery rate, while another study indicated that patients with an SCA of ≥160 mm² postoperative achieved better clinical outcomes.

Many researchers have studied canal expansion after open-door laminoplasty and the results indicate it is effective at increasing of the SCA. Similar results were obtained in our study, the calculation of the increase of the SCA was 122.86 ± 15.86 mm² and the increased percentage of SCA was 49.41% after open-door laminoplasty, which are close to previous studies. The calculation of the increase of the SCA after lift-open laminoplasty was 183.57 ± 62.99 mm², which much larger than 95 mm². And the increased percentage of SCA was 73.83% after lift-open laminoplasty. These results showed that patients treated with lift-open laminoplasty could achieve good clinical outcomes.

Avoid Hinge Fractures and Hinge Fusion Failure
Some recent studies have indicated that hinge fractures can cause axial pain or palsy that may be chronic. Satomi et al. reviewed postoperative CT scans of patients with weakness on the hinge side, which implicated the lamina dropping into the spinal canal as the cause of weakness in four patients among 16. It is suggested that the nerve root may be injured by the lamina moving downward to the spinal canal. Hosono et al. suggested that the hinge side of the gutter can cause shoulder pain until the bony healing of this area is completed. Tsuji reported that the hinge gutter showed radiographic healing within 1 year, and the postoperative shoulder pain also subsided during this period. Park et al. also reported that multiple fractures of laminae can aggravate postoperative VAS and NDI.

There are many factors that can lead to hinge fracture, such as the location of the hinge, bone mass and its strength, the width of the hinge, the methods used to elevate the lamina, and so on. All the reasons above are related to the laminoplasty method of open-door. The laminoplasty method of lift-open is totally different from previously reported methods. We lift up and open the spinous process and lamina split by ultrasonic bone scalpel from inside to outside, then fix the laminae on the bilateral lateral masses with two lateral mass screws, respectively. There is almost no possibility of hinge fracture after lift-open laminoplasty.
Limitation
There are some limitations. First, the number of cases treated with lift-open laminoplasty was few and the follow-up time was rather short; more cases treated with lift-open laminoplasty and long-term effects and complications need further investigation. Second, in this study, patients treated with lift-open laminoplasty and the calculation of increase in the SCA after operation was only on C6. Further research is needed to determine whether C3–C5 could be treated with this method.

Conclusion
Lift-open laminoplasty could preserve nearly 100% of extensor muscle, avoid damaging C7 paraspinal muscles and C6–C7 posterior muscle-ligament complex, reconstruct the spinal process firmly in the midline, and expand adequate SCA after operation. These advantages could reduce the incidence rate of complications and bring better clinical results than traditional laminoplasty. However, more patients and longer follow-up time are necessary to provide more evidence for further clinical application.

References
1. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine, 1983; 8: 693–696.
2. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. Spine, 1981; 6: 354–364.
3. Rok T, TsujI H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. Spine, 1985; 10: 723–736.
4. Seiichi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. Spine, 2001; 26: 479–487.
5. Hyun SJ, Riew KD, Rhim SC. Range of motion loss after cervical laminoplasty: a prospective study with minimum 5-year follow-up data. Spine J, 2013; 13: 384–390.
6. Ogawa Y, Chiba K, Matsumoto M, et al. Long-term results after expansive open-door laminoplasty for the segmental-type of ossification of the posterior longitudinal ligament of the cervical spine: a comparison with non-segmental-type lesions. J Neurosurg Spine, 2005; 3: 198–204.
7. Jiang YQ, Li XL, Zhou XG, et al. A prospective randomized trial comparing anterior cervical discectomy and fusion versus plate-only open-door laminoplasty for the treatment of spinal stenosis in degenerative diseases. Eur Spine J, 2017; 26: 1162–1172.
8. Matsumoto M, Watanabe K, Hosogane N, et al. Impact of lamina closure on long-term outcomes of open-door laminoplasty in patients with cervical myelopathy; minimum 5-year follow-up study. Spine, 2012; 37: 1288–1291.
9. Satomi K, Ogawa J, Ishii Y, Hirabayashi K. Short-term complications and long-term results of expansive open-door laminoplasty for cervical stenotic myelopathy. Spine J, 2001; 1: 26–30.
10. Matsumoto M, Watanabe K, TsujI T, et al. Risk factors for closure of lamina after open-door laminoplasty. J Neurosurg Spine, 2008; 9: 530–537.
11. Sakaura H, Hosono N, Mukai Y, Ishii T, Yoshikawa H. C5 palsy after decompression surgery for cervical myelopathy: review of the literature. Spine, 2003; 28: 2447–2451.
12. Kimura A, Endo T, Inoue H, Seiichi A, Takeshita K. Impact of axial neck pain on quality of life after Laminoplasty. Spine, 2015; 40: E1292–E1298.
13. Lee S, Chung CK, Kim CH. Risk factor analysis of hinge fusion failure after plate-only open-door laminoplasty. Global Spine J, 2015; 5: 9–16.
14. Yoon ST, Raich A, Hashimoto RE, et al. Predictive factors affecting outcome after cervical laminoplasty. Spine, 2013; 38: S232–S252.
15. Rutliff JK, Cooper PR. Cervical laminoplasty: a critical review. J Neurosurg, 2003; 98: 230–238.
16. Duetzmann S, Cole T, Rutliff JK. Cervical laminoplasty developments and trends, 2003-2013: a systematic review. J Neurosurg Spine, 2015; 23: 24–34.
17. Lin S, Zhou F, Sun Y, Chen Z, Zhang F, Pan S. The seventy of operative invasion to the posterior muscular-ligament complex influences cervical sagittal balance after open-door laminoplasty. Eur Spine J, 2015; 24: 127–135.
18. Liu J, Ebrehim NA, Sanford CG Jr, et al. Preservation of the spinous process-ligament-muscle complex to prevent kyphotic deformity following laminoplasty. Spine J, 2007; 7: 159–164.
19. Kotani Y, Abumi K, Ito M, et al. Impact of deep extensor muscle-preserving approach on clinical outcome of laminoplasty for cervical spondylotic myelopathy: comparative cohort study. Eur Spine J, 2012; 21: 1536–1544.
20. Shiraiishi T, Yato Y, Yoshida H, Abe T, Ikegami T. New double-door laminoplasty procedure to preserve the muscular attachments to the spinous processes including the axis. Eur J Orthop Surg Traumatol, 2002; 12: 175–180.
21. Shiraiishi T. A new technique for exposure of the cervical spine laminae. J Neurosurg, 2002; 96: 122–126.
22. Shiraiishi T, Fuji OK, Yato Y, Nakamura M, Ikegami T. Results of skip laminectomy-minimum 2-year follow-up study compared with open-door laminoplasty. Spine, 2003; 28: 2667–2672.
23. Shiraiishi T, Kato M, Yato Y, et al. New techniques for exposure of posterior cervical spine through intermuscular planes and their surgical application. Spine, 2012, 37: E286–E296.
**NEW METHOD FOR COMPRESSION CERVICAL MYELOPATHY**

| lamina angle: a simulation study. J Korean Neurosurg Soc, 2021, 64: 229–237. |
|---|
| 44. Park JH, Roh SW, Rhim SC, Jeon SR. Long-term outcomes of 2 cervical laminoplasty methods: midline splitting versus unilateral single door. J Spinal Disord Tech, 2012, 25: E224–E229. |
| 45. Nakashima H, Kato F, Yukawa Y, et al. Comparative effectiveness of open-door laminoplasty versus French-door laminoplasty in cervical compressive myelopathy. Spine, 2014, 39: 642–647. |
| 46. Hosono N, Yonenobu K, Ono K. Neck and shoulder pain after laminoplasty. A noticeable complication. Spine, 1996, 21: 1969–1973. |
| 47. Tsuji H. Laminoplasty for patients with compressive myelopathy due to so-called spinal canal stenosis in cervical and thoracic regions. Spine, 1982, 7: 28–34. |
| 48. Park YK, Lee DY, Hur JW, Moon HJ. Delayed hinge fracture after plate-augmented, cervical open-door laminoplasty and its clinical significance. Spine J, 2014, 14: 1205–1213. |