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Research Article

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A Retrospective Cohort Study of a Modified Open-Door Laminoplasty With Reconstruction of The Cervical Posterior Ligamental Complex to Decrease Axial Pain in Cervical Spondylotic Myelopathy

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Abstract

Background: *Cervical spondylotic myelopathy patients with multiple segments are usually treated with surgery via the posterior approach, but expansive open laminoplasty (ELAP) often results in heavy, rigid, and acid bilge feelings in the neck, shoulder, and back, collectively known as axial symptoms. To evaluate the effect of modified posterior cervical ligament complex reconstruction and single-door laminoplasty with titanium plate fixation on postoperative axial symptoms in patients.*

Methods: *We conducted a retrospective study including 132 cases of cervical spondylotic myelopathy at our institute from June 2016 to March 2018. The patients who conformed to the inclusion criteria were randomly divided into two different surgical groups by by the surgeons. Gender, age, operation time, intraoperative blood loss, post-operative drainage volume, and follow-up time, Visual analogue scoring (VAS), cervical curvature index (CCI) and the cross-sectional area of the posterior cervical muscles of the two groups were recorded.*

Results: *There was statistical significance in the incidence of axial pain 3 months after surgery (P = 0.001), 6 months after surgery (P = 0.006), and 1 year after surgery (P = 0.015). Compared to group b, the VAS score in group A was decreased one month (P <0.0001), 3 months (P=0.0001), 6 months(P=0.0076), and 1 year(P=0.0085) after surgery. The CCI and the posterior cervical muscle area also differed significantly between the two groups (P < 0.0001).*

Conclusions: *Modified single open-door laminoplasty could relieve cervical axial pain in patients with cervical spondylotic myelopathy.*

Keywords: Cervical Spondylotic Myelopathy, Expansive Open-Door Laminoplasty, Axial Pain, Cervical Curvature Index, Posterior Cervical Muscle Atrophy

Abbreviations

CSM: Cervical Spondylotic Myelopathy
CSR: Cervical Spondylotic Radiculopathy
AVT: Arteria Vertebralis Type
SCS: Sympathetic Cervical Spondylosis
CT: Computed Tomography
MRI: Magnetic Resonance Image
MCSM: Multiple Cervical Spondylotic Myelopathy
AS: Axial Symptoms
CCI: Cervical Curvature Index
VAS: Visual Analogue Scale
ELAP: Expansive Open-Door Laminoplasty

1. Introduction

Cervical spondylosis is a syndrome characterized by a series of symptoms and signs due to various reasons, which stimulates or compresses the cervical nerve roots, spinal cord and blood vessels. Cervical spondylosis is currently divided into four types: cervical spondylotic myelopathy (CSM, it is a disease caused by the compression of the spinal cord or the blood vessels supplying the spinal cord by the degenerative structure of the cervical spine, it is the most serious type of cervical spondylosis), cer-

vical spondylotic radiculopathy (CSR), arteria vertebralis type (AVT), and sympathetic cervical spondylosis SCS) [1]. These types of cervical spondylosis could produce different symptoms spanning neck and back pain, limb weakness, finger numbness, abdominal band feeling, lower limbs cotton feeling, walking difficulties, dizziness, vomiting, blurred vision, tachycardia, swallowing difficulties, and other symptoms [2,3]. When conservative treatment (including drugs, traction, acupuncture, massage, etc.) fails, surgery is an essential and effective treatment [4,5]. For cervical spondylotic myelopathy with multiple segments (≥ 3 segments) (MCSM), posterior decompression surgery is often used [6-9].

Classic Hirabayashi open-door laminoplasty is a well-known procedure to treat cervical spondylotic myelopathy [10,11] and can help to achieve satisfactory recovery of spinal function. However, axial symptoms are the most frequent complications following this surgery [12-14] which rarely happens before surgery. Axial symptoms were firstly described by Kawaguchi in 1999 as chronic neck, shoulder and back pain after surgery [4, 13, 15-18]. Recent reports indicated that axial symptoms (neck and shoulder pain) are associated with damage to the cervical spinous process, posterior cervical ligaments, interspinous ligaments, and supraspinous ligaments [4,19-21]. To relieve axial symptoms, we modified single open-door laminoplasty with reconstruction of the posterior spinous ligamental complex which the functional structures of the posterior cervical spine, including the spinous process, ligamentum flava, supraspinous ligament, interspinous ligament, and posterior muscles, serve to counter posterior tensile stress. This study assessed whether this modified surgical method could effectively relieve axial symptoms and identified the factors that help to improve post-operative axial symptoms.

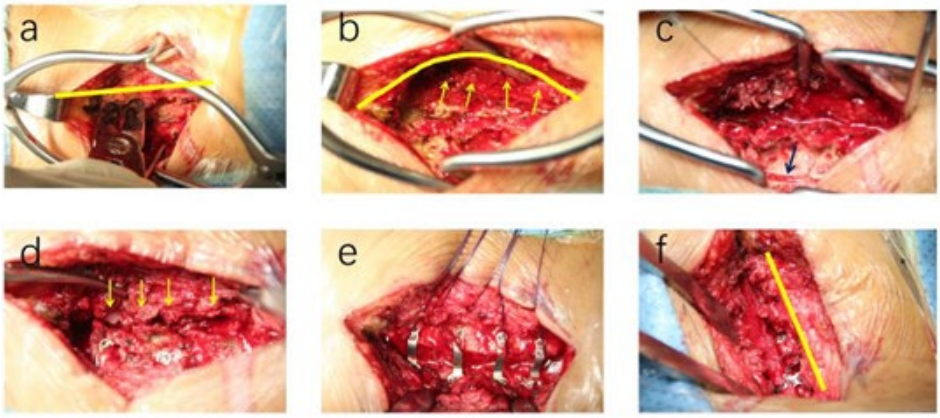
2. Materials and Methods

2.1 General Data

This is a retrospective single-center cohort study conducted in Qilu Hospital of Shandong University, Shandong province, China. A total of 132 patients with cervical spondylotic myelopathy admitted to the hospital from Jun 2016 to March 2018 were included. Inclusion criteria: The patient was diagnosed as cervical spondylotic myelopathy by imaging examination and pathological signs; the segments of cervical spondylotic myelopathy was C3 to C6, with obvious spinal stenosis; there was no cervical kyphosis and instability, exclusion criteria : Other types of cervical spondylosis; cervical kyphosis and instability; cervical spine with other lesions, such as infection, trauma, tumor, etc; patients with poor general condition who cannot tolerate surgery. The patients were divided into two groups. Group A included patients undergoing modified single open-door laminoplasty with titanium plate fixation and reconstruction of the cervical posterior ligamental complex, while patients in group B received the same open-door laminoplasty with fixation but without reconstruction of the cervical posterior ligamental complex. The patients were followed up for 1 year after operation, 3 patients' accidental death and the follow-up was terminated. The outcomes were assessed using the cervical curvature index, VAS score, and cross-sectional area (CSA) of the erector muscle on CT scanning.

2.2 Surgical Technique

Modified single open-door laminoplasty was designed to preserve the spinous process, supraspinal ligament, and unilateral paravertebral muscles. To perform the surgery, a midline skin incision was made from C3 to C6, while C2 and C7 were preserved because many posterior cervical muscles are attached to them. Part of the bottom of the C2 and C7 spinous process were removed by air drill to decompress a longer buffer for the backward movement of the spinal cord. The unilateral paravertebral muscles of the open side were dissected to expose the ipsilateral laminae. The spinous processes were cut at the base using bone shears. Subsequently, the contralateral paravertebral muscles and separated spinous processes were peeled off from the laminae to make a gutter on the hinge side. Finally, the lamina door was lifted, and a titanium micro-plate was placed to prevent its closure. The cut spinous processes, cervical posterior muscles, and ligaments were reset to the laminae and were firmly sutured (Supplementary Figure 1).



Supplementary Figure 1: Modified single open-door laminoplasty procedures disclosed. (a) Incise the skin and subcutaneous tissue to fully expose the spinous process (the yellow line), strip the paraspinal muscle along one side of the spinous process, completely expose the lamina, and cut the spinous process with bone biters at the root of the spinous process. (b) The severed spinous process and the attached muscle fascia tissue were lifted to the contralateral side (indicated by the arrows), dissection of the contralateral paravertebral muscles by the root of the spinous process and completely exposes the contralateral lamina. (c) The first side of the lamina was used as the opening groove (indicated by the arrows), and the second side of the lamina was used as the opening shaft. (d) A tiny titanium plate is implanted at the door opening to lift and fix the lamina for decompression. (e) The free spinous process and its muscle-ligament complex were tightly sutured with the lamina and implant. (f) After suturing, the spinous process muscle-ligament complex remained intact and was well reconstructed (The yellow line).

2.3. General Evaluation Index

Age, gender , operation time, intraoperative blood loss, postoperative drainage volume, and follow-up time of the patients in group A and B were recorded and compared.

2.4. Axial Symptoms (AS)

Visual analogue scoring (VAS)[18] was used to compare axial symptoms in the patients in group A and B 1, 3, 6 months, and 1 year after surgery. A score of 0 indicates no pain, 1-3 indicates mild pain (sleep is not affected), 4-6 indicates moderate pain (sleep is affected), and 7-10 indicates severe pain (sleep is severely affected). VAS score greater than 4 indicates severe axial pain [16]. The incidence of axial pain, severe axial pain, and VAS scores in the same time period were statistically compared between the two groups.

2.5. Cervical curvature index (CCI)

The CCI was measured using the ISHI-Hare method [22-24]. The C2 to C6 vertebral posterior margin on X-ray was connected to create the R line for all patients before and after surgery. The R line was perpendicular to the posterior edge of the C3, C4, and C5 vertebrae. Their distances were respectively expressed as r1, r2, r3, and CCI = Σri/R. The pre- and post-operative CCI values between the two groups were statistically compared.

2.6. Measurement of The Muscle Cross-Sectional Area (CSA) Of The Posterior Cervical Spine

The cross-sectional area of the posterior cervical muscles was measured using a method previously described by Fujimura [22]. The cross-sectional area of the posterior cervical muscles at the level of C3/4, C4/5, and C5/6 discs was measured by Photoshop on preoperative and post-operative CT films. The posterior cervical muscle area was obtained by the mean of three repeated measurements for each plane. Then, the sum of the posterior cervical muscle cross-sectional area at the level of the C3/4, C4/5, and C5/6 as the total cervical muscle area.

2.7. Statistical Method

The relevant data collected were analyzed by SPSS 24.0 statistical software. Pearson's correlation analysis was used for the correlation data. Continuous categorical variables were analyzed using the t test and chi-square test, respectively. $P < 0.05$ indicated statistically significant differences (* $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$).

3. Results

3.1. Baseline Characteristics of Patients in The Study.

All patients were completely followed up for this study. Two patients in group A died 50 and 60 days after surgery due to respiratory and digestive diseases. One patient in group B died 30 days after surgery due to digestive system disease. The follow-up was terminated one year after surgery, while patient's death the follow-up was terminated immediately. There was no statistically significant difference in age , gender , operation time , intraoperative and post-operative blood loss, follow-up time between group A and B (Table 1).

	A	B	P value
Age (years)	57.14± 9.48	59.22±11.91	0.0656
Gender (Male / Female)	54/20	41/17	0.8460
Surgery time (min)	144.6 ±5.2	156.3±6.6	0.1602
Intraoperative bleeding (mL)	237.8±13.3	253.1 ±9.8	0.3796
Postoperative bleeding (mL)	197.5±30.3	215.7±35.6	0.6963
Follow-up time (month)	11.7 ±0.2	11.8 ± 0.2	0.7281

Table 1: Baseline characteristics comparison between group A and group B

3.2. Preoperative and Post-Operative Imaging Data of Patients in Group A And B

The preoperative and post-operative imaging data of the patients in group A and B were compared (Figure 1). All of the patients in group A and B achieved bone healing (postoperative imaging showed no bone defect or edema around the internal implant, and the position of the internal fixation was satisfactory) in post-operative examinations. There was no loosening, slipping, or fractures of the internally fixed titanium plates and screws. None of the patients presented with increased neurological symptoms.

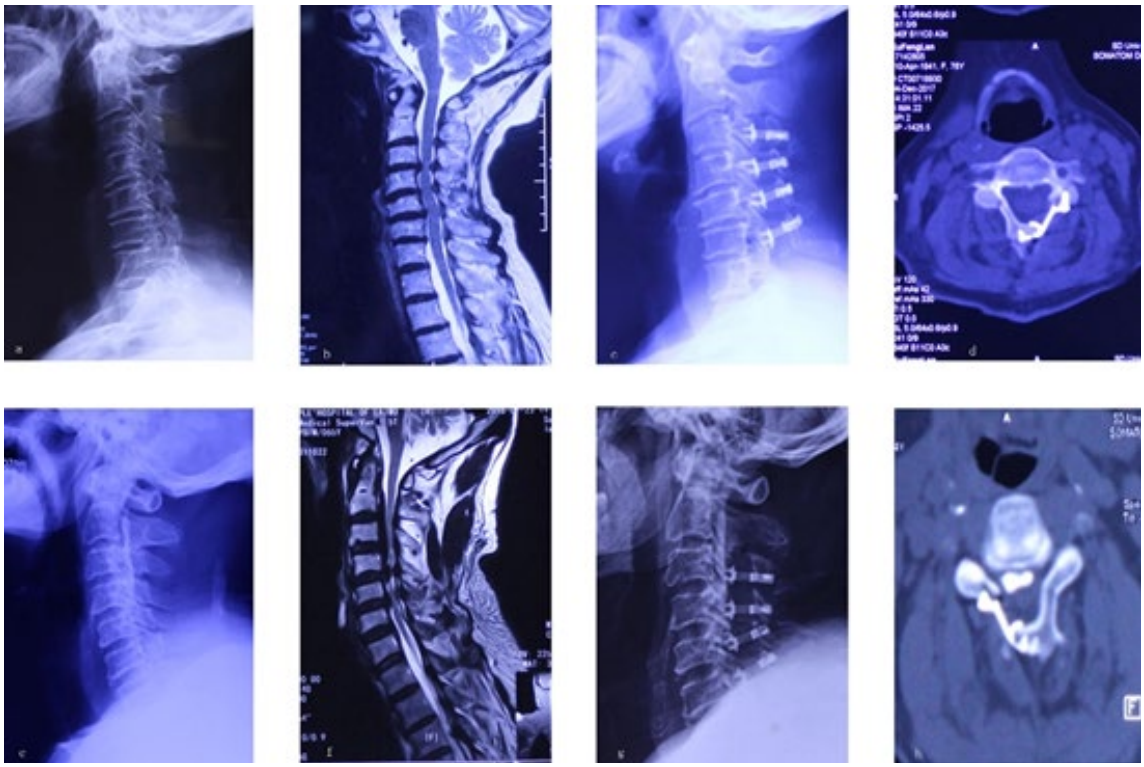


Figure 1: Comparison of preoperative and post-operative imaging data between group A (a-d) and B (e-f).

3.3. AS and postoperative outcomes between group A and B

The incidence of AS in group A and B was not statistically significant one month after surgery. However, group B had significantly higher incidence of AS 3 months, 6 months, and 1 year after surgery (figure 2a). Similar results were observed for severe AS in the two groups (figure 2b). At each time point after surgery, the VAS scores differ significantly between group A and B (figure 3). There was no difference in preoperative CCI values of patients in the two groups. However, patients in group A had lower CCI compared to those in group B. The preoperative and post-operative CCI values of patients in the group A were not different, while patients in group B had higher CCI post-operative CCI values compared to their preoperative value (figure 4a). Next, we compared the changes of preoperative and post-operative CCI value between group A and B, and patients in group A had less change in CCI value after surgery than group B (figure 4b). Finally, we also compared the preoperative and post-operative changes in the posterior cervical muscle area between group A and B. The results showed that patients in group A were associated with significantly smaller changes in the posterior cervical muscle area of the C3/4, C4/5, C5/6 levels, and the total posterior cervical muscle areas (figure 5).

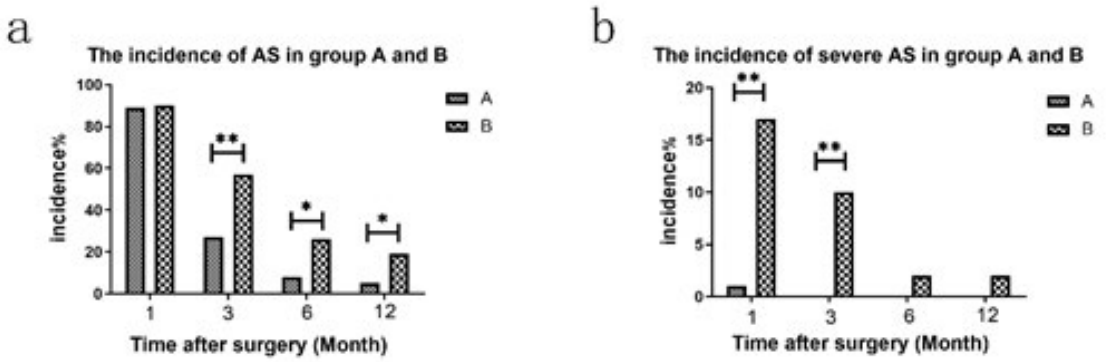


Figure 2: The incidence of AS (a) and severe AS (b) in group A and B. (*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$).

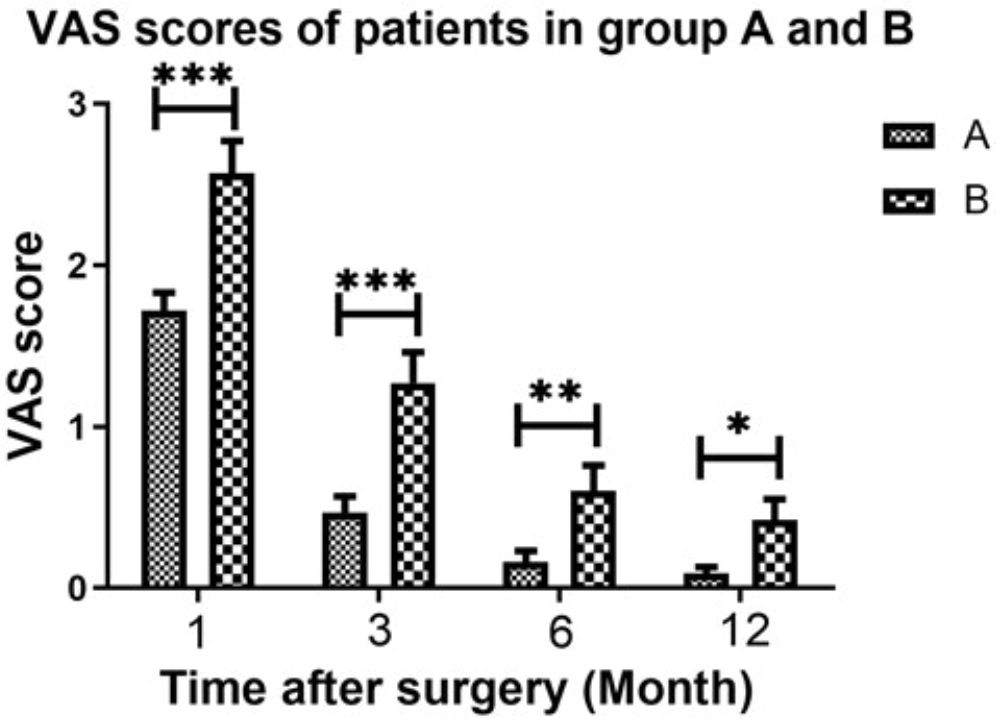


Figure 3: The VAS scores of the patients in group A and B were compared (*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$).

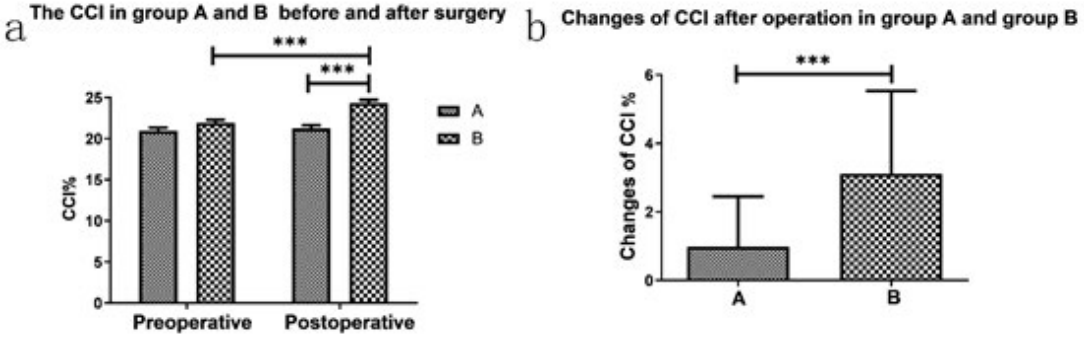


Figure 4: Preoperative and post-operative CCI values (a) and changes of the CCI values (b) of the patients in group A and B were compared (*P < 0.05, **P < 0.01, and ***P < 0.001). In group A, the preoperative, postoperative and changes of the CCI(%) values were respectively 20.95±0.37, 21.23□0.41, 0.98±0.17. In group B, the preoperative, postoperative and changes of the CCI(%) values were respectively 21.93±0.36, 24.34±0.37, 3.12±0.32.

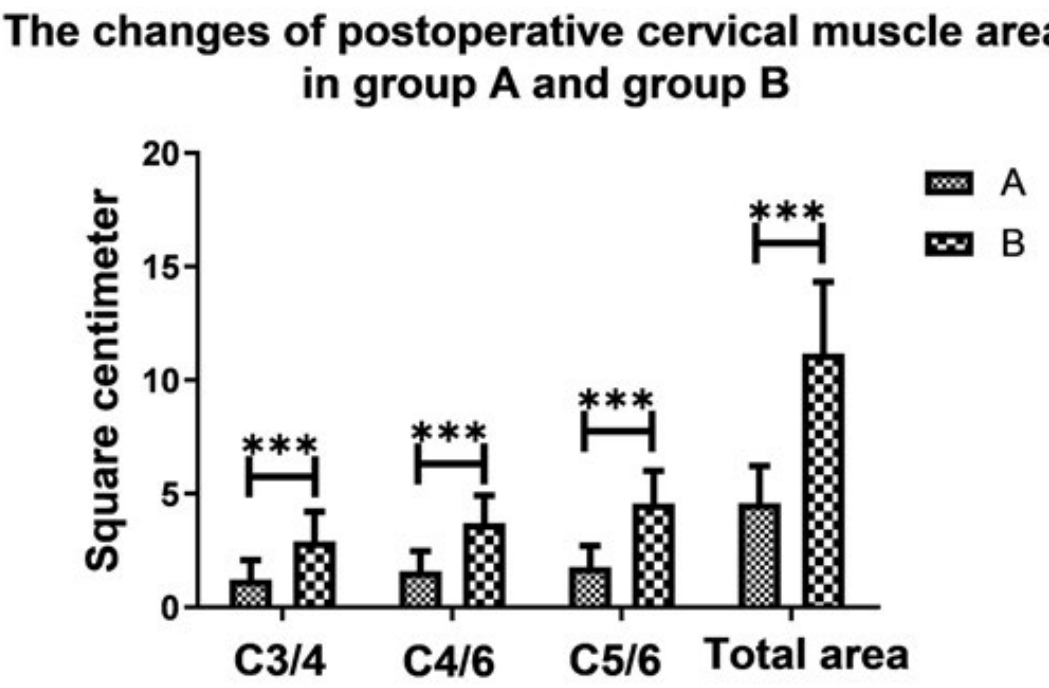


Figure 5: Preoperative and post-operative changes in the cervical posterior muscle area between group A and B (*$P < 0.05$, **$P < 0.01$, and ***$P < 0.001$).

4. Discussion

Cervical spondylosis is a degenerative disease. The main causes include chronic fatigue, cervical disc herniation, osteogenesis, arthritis, ligament thickening and ossification, and trauma. These disorders cause severe clinical symptoms due to compression to the spinal cord, nerve roots, vertebral arteries, and sympathetic nerves [25]. There are many types of cervical spondylosis, but they are mainly divided into the following four kinds: cervical spondylotic myelopathy, cervical spondylotic radiculopathy, arteria vertebralis, and sympathetic cervical spondylosis, among them, cervical spondylotic myelopathy is the most serious subtype, which often leads to severe sensory and motor impairment, and even paralysis [26]. For most patients, conservative symptomatic treatment with medications, acupunctures, tractions, and massages could relieve symptoms. However, for a few patients, con continuous servative treatment may not be effective, and the symptoms may be aggravated over time, cause serious complications. Posterior cervical surgery has been used as an alternative method since 1950 to treat cervical spondylosis. The advantage of posterior cervical spine surgery is that it avoids damage to the trachea, esophagus, important blood vessels, and nerves in front of the cervical spine, thus reducing the risk of surgery [27].

However, the posterior cervical spine also has its own defects, which can break down in the rear of the cervical muscle ligament complex, result in the destruction of the cervical vertebra rear anatomical structure and loss of stability, and cause post-operative stiffness, acid bilges, and pain in the neck, shoulder, and back, called axial symptoms (AS) [13,28,29]. Previous studies have shown that various factors may cause axial symptoms after surgery, including the choice of surgical method, the stability of posterior structures, the postoperative range of motion of the cervical spine, and the degree of soft tissue injury around the cervical spine. After decades of development, single open-door laminoplasty has become a major surgical method for the treatment of multilevel cervical spondylotic myelopathy, however, the incidence of postoperative axial symptoms is still high [1]. To alleviate axial symptoms after surgery, it is always the goal of surgeons to improve the posterior approach of cervical spine surgery, including posterior reconstruction, minor invasive surgery, and internal fixation [30-32]. In reconstructive surgery, expanded laminoplasty with preserved posterior spinous ligament complex proposed by Kawaguchi et al. could significantly alleviate axial symptoms in patients after surgery [33]. This modified surgical method restores the anatomical structure of the back of the cervical vertebra to the full extent, increasing the stability of the cervical vertebra after surgery, guaranteeing the physiological curvature and post-operative mobility of the cervical vertebra.

We conducted this retrospective study to further explore whether modified single open-door laminoplasty with reconstruction of the posterior spinous ligament complex (MLRP) has a significant effect on relieving axial symptoms after surgery and explore the possible factors leading to this result. Through analysis of the collected data, we found that the occurrence and severity of post-operative axial pain were not correlated with age, gender, operation time, intraoperative blood loss, and post-operative drainage volume of patients. In terms of the post-operative VAS scores, there was no statistical difference in the incidence of axial pain 1 month after surgery between groups A and B; However, the difference was significant 3 months, 6 months, and 1 year after surgery. The procedure did not reduce the incidence of post-operative axial pain in the first month post-surgery, but during the next follow-up from 3 months to 1 year, the incidence

of AS in group A was significantly lower than in group B. No patients in group A no longer suffered from severe axial pain 1 month after surgery, while the patients in group B still suffered from severe axial pain until 1 year after surgery. Generally speaking, compared with traditional single open-door laminoplasty, the modified surgical method with reconstruction of the posterior spinous ligament complex has obvious advantages in relieving patients' post-operative axial pain. The occurrence of post-operative axial pain in group A was significantly lower than in group B.

To study the reasons leading to this advantage, we measured the preoperative and post-operative X-rays of the patients in groups A and B, calculated the cervical curvature index (CCI) value of the patients, and conducted a statistical comparison. In group A, the comparison of the CCI values before and after surgery was not statistically changed, while in group B, the CCI values before and after surgery was statistically decreased. In addition, the changes between postoperative CCI and preoperative CCI in the two groups was also statistically significant. This proves that traditional single open-door laminoplasty significantly changes the curvature of patients' cervical vertebra because of instability and destroys the posterior cervical muscle-ligament complex and spinous processes. Posterior cervical spine instability after routine single-door laminoplasty is considered to be the main cause of postoperative axial symptoms, resulting in poor post-operative recovery and affecting the quality of life of patients.

However, MLRP may protect the muscles and ligaments that maintain the stability of the cervical spine. We analyzed the pre- and postoperative CT slices on the cervical back muscle cross-sectional areas. The results showed that the change in the value of the posterior cervical muscle cross-sectional area in group A was significantly lower than in group B, which may be because simple single open-door laminoplasty destroys the adhesion point of the muscle behind the spinous process, leading to significant post-operative muscle atrophy. This may be another important factor in the relief of post-operative axial pain in patients who undergo MLRP.

This retrospective study confirmed that MLRP could be of considerable significance in relieving patients' AS after surgery. Two relative factors are post-operative changes in the cervical curvature index and the cross-sectional area of the posterior cervical muscles. MLRP protects the posterior cervical muscles and prevents instability of the cervical spine via the reconstruction of the posterior cervical muscle-ligament complex and spinous processes. This study provides a novel alternative surgery to decrease axial pain in patients with cervical spondylotic myelopathy.

5. Conclusion

The incidence and severity of postoperative axial symptoms are significantly lower after modified single open-door laminoplasty with reconstruction of the posterior spinous ligament complex than the simple single open-door laminoplasty. This result could be related to changes in the cervical curvature index and the degree of atrophy of the posterior cervical muscles affected by the reconstruction of the posterior spinous process ligament complex of the cervical spine.

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References

1. Chiba, K., Ogawa, Y., Ishii, K., Takaishi, H., Nakamura, M., Maruiwa, H., ... & Toyama, Y. (2006). Long-term results of expansive open-door laminoplasty for cervical myelopathy− average 14-year follow-up study. Spine, 31(26), 2998-3005.
2. Feng, T., Zhao, P., & Liang, G. (2000). Clinical significance on protruded nucleus pulposus: a comparative study of 44 patients with lumbar intervertebral disc protrusion and 73 asymptomatic control in tridimentional computed tomography. Zhongguo Zhong xi yi jie he za zhi Zhongguo Zhongxiyi Jiehe Zazhi= Chinese Journal of Integrated Traditional and Western Medicine, 20(5), 347-349.
3. Yu, M., Zhao, W. K., Li, M., Wang, S. B., Sun, Y., Jiang, L., ... & Liu, Z. J. (2015). Analysis of cervical and global spine alignment under Roussouly sagittal classification in Chinese cervical spondylotic patients and asymptomatic subjects. European Spine Journal, 24, 1265-1273.
4. Hu, W., Shen, X., Sun, T., Zhang, X., Cui, Z., & Wan, J. (2014). Laminar reclosure after single open-door laminoplasty using titanium miniplates versus suture anchors. Orthopedics, 37(1), e71-e78.
5. Tan, H. L., Luo, C., Zhang, R., Wang, Z. Q., Ying, H., Jin, H. T., ... & Liu, J. M. (2017). Diagnosis and treatment of esophagustype cervical spondylosis. Zhongguo gu Shang= China Journal of Orthopaedics and Traumatology, 30(12), 1165-1170.
6. Li, N., Tian, W., Yuan, Q., & He, D. (2016). Cervical spondylotic myelopathy due to the ochronotic arthropathy of the cervical spine. Journal of Korean Neurosurgical Society, 59(1), 65-68.
7. Wang, S. J., Ma, B., Huang, Y. F., Pan, F. M., Zhao, W. D., & Wu, D. S. (2016). Four-level anterior cervical discectomy and fusion for cervical spondylotic myelopathy. Journal of Orthopaedic Surgery, 24(3), 338-343.
8. Michael, K. W., Neustein, T. M., & Rhee, J. M. (2016). Where should a laminoplasty start? The effect of the proximal level on post-laminoplasty loss of lordosis. The Spine Journal, 16(6), 737-741.
9. Yu, S., Li, F., Yan, N., Yuan, C., He, S., & Hou, T. (2014). Anterior fusion technique for multilevel cervical spondylot-

ic myelopathy: a retrospective analysis of surgical outcome of patients with different number of levels fused. PloS one, 9(3), e91329.
10. Garcia, R. M., Qureshi, S. A., Cassinelli, E. H., Biro, C. L., Furey, C. G., & Bohlman, H. H. (2010). Detection of postoperative neurologic deficits using somatosensory-evoked potentials alone during posterior cervical laminoplasty. The Spine Journal, 10(10), 890-895.
11. Hirano, Y., Ohara, Y., Mizuno, J., & Itoh, Y. (2018). History and evolution of laminoplasty. Neurosurgery Clinics, 29(1), 107-113.
12. Healy, A. T., Lubelski, D., West, J. L., Mageswaran, P., Colbrunn, R., & Mroz, T. E. (2016). Biomechanics of open-door laminoplasty with and without preservation of posterior structures. Journal of Neurosurgery: Spine, 24(5), 746-751.
13. Kawaguchi, Y., Matsui, H., Ishihara, H., Gejo, R., & Yoshino, O. (1999). Axial symptoms after en bloc cervical laminoplasty. Journal of spinal disorders, 12(5), 392-395.
14. Zhou, C., Liu, C., Panchal, R. R., Ma, X., & Chen, X. (2019). Modified expansive laminoplasty and fusion compared with anterior cervical surgeries in treating four-level cervical spondylotic myelopathy. Journal of International Medical Research, 47(6), 2413-2423.
15. Kato, M., Nakamura, H., Konishi, S., Dohzono, S., Toyoda, H., Fukushima, W., ... & Matsuda, H. (2008). Effect of preserving paraspinal muscles on postoperative axial pain in the selective cervical laminoplasty. Spine, 33(14), E455-E459.
16. Kimura, A., Shiraishi, Y., Inoue, H., Endo, T., & Takeshita, K. (2018). Predictors of persistent axial neck pain after cervical laminoplasty. Spine, 43(1), 10-15.
17. Li, F. H., Qiao, H. H., Yang, Y. C., Du, J. P., Jin, X. S., & Wang, B. (2019). Incidence and outcomes of C5 palsy and axial pain after open-door laminoplasty or laminectomy and fusion: a meta-analysis. World neurosurgery, 128, e1002-e1009.
18. Sakaura, H., Hosono, N., Mukai, Y., Oshima, K., Iwasaki, M., & Yoshikawa, H. (2008). Preservation of the nuchal ligament plays an important role in preventing unfavorable radiologic changes after laminoplasty. Clinical Spine Surgery, 21(5), 338-343.
19. Lawson, G. E., Nolet, P. S., Little, A. R., Bhattacharyya, A., Wang, V., Lawson, C. A., & Ko, G. D. (2020). Medial branch blocks for diagnosis of facet joint pain etiology and use in chronic pain litigation. International Journal of Environmental Research and Public Health, 17(21), 7932.
20. Tamai, K., Suzuki, A., Terai, H., Toyoda, H., Hoshino, M., & Nakamura, H. (2016). Laminar closure after expansive open-door laminoplasty: fixation methods and cervical alignments impact on the laminar closure and surgical outcomes. The Spine Journal, 16(9), 1062-1069.
21. Yoshida, M., Otani, K., Shibasaki, K., & Ueda, S. (1992). Expansive laminoplasty with reattachment of spinous process and extensor musculature for cervical myelopathy. Spine, 17(5), 491-497.
22. Ishihara, A. (1968). Roentgenographic studies on the mobility of the cervical column in the sagittal plane. Nihon Seikeigeka Gakkai Zasshi, 42(11), 1045-1056.
23. Chen, C., Li, J., Liao, Z., Gao, Y., Shao, Z., & Yang, C. (2020). C3 laminectomy combined with modified unilateral laminoplasty and in situ reconstruction of the midline structures maintained cervical sagittal balance: a retrospective matched-pair case-control study. The Spine Journal, 20(9), 1403-1412.
24. Zhang, K. R., Yang, Y., Liu, H., Wang, B. Y., Ding, C., Meng, Y., ... & Hong, Y. (2021). Multivariate analysis of factors associated with spinal cord area in single-door cervical laminoplasty with miniplate fixation. BMC Musculoskeletal Disorders, 22(1), 1-9.
25. Zheng, W., Chen, H., Wang, N., Liang, Y., Xiao, W., Xiong, W., ... & Wen, S. (2018). Application of diffusion tensor imaging cutoff value to evaluate the severity and postoperative neurologic recovery of cervical spondylotic myelopathy. World Neurosurgery, 118, e849-e855.
26. Luo, J., Cao, K., Huang, S., Li, L., Yu, T., Cao, C., ... & Zou, X. (2015). Comparison of anterior approach versus posterior approach for the treatment of multilevel cervical spondylotic myelopathy. European Spine Journal, 24, 1621-1630.
27. Fountas, K. N., Kapsalaki, E. Z., Nikolakakos, L. G., Smisson, H. F., Johnston, K. W., Grigorian, A. A., ... & Robinson Jr, J. S. (2007). Anterior cervical discectomy and fusion associated complications. Spine, 32(21), 2310-2317.
28. Liu, S., Yang, S. D., Fan, X. W., Yang, D. L., Ma, L., Sun, J. Y., & Ding, W. Y. (2019). Analyses of effect factors associated with the postoperative dissatisfaction of patients undergoing open-door laminoplasty for cervical OPLL: a retrospective cohort study. Journal of Orthopaedic Surgery and Research, 14(1), 1-8.
29. Yin, H., Han, G., Li, Q., He, X., & Wang, C. (2018). A clinical study on axial symptoms and imaging changes in paraspinal muscles after cervical posterior open-door laminoplasty. Zeitschrift für Orthopädie und Unfallchirurgie, 156(04), 399-406.
30. NOLAN Jr, J. P., & SHERK, H. H. (1988). Biomechanical evaluation of the extensor musculature of the cervical spine. Spine, 13(1), 9-11.
31. Wan, J., Xu, T. T., Shen, Q. F., Li, H. N., & Xia, Y. P. (2011). Influence of hinge position on the effectiveness of open-door expansive laminoplasty for cervical spondylotic myelopathy. Chinese Journal of Traumatology, 14(01), 36-41.
32. Wang, S. J., Jiang, S. D., Jiang, L. S., & Dai, L. Y. (2011). Axial pain after posterior cervical spine surgery: a systematic review. European Spine Journal, 20, 185-194.
33. Okada, M., Minamide, A., Endo, T., Yoshida, M., Kawakami, M., Ando, M., ... & Maio, K. (2009). A prospective randomized study of clinical outcomes in patients with cervical compressive myelopathy treated with open-door or French-door laminoplasty.