Observational Study

Medicine®

OPEN

Laminoplasty with lateral mass screw fixation for cervical spondylotic myelopathy in patients with athetoid cerebral palsy

A retrospective study

Hua Zhou, MD[a,b], Zhong-jun Liu, MD[a,b,*], Shao-bo Wang, MD[a,b], Sheng-fa Pan, MD[a,b], Ming Yan, MD[a,b], Feng-shan Zhang, MD[a,b], Yu Sun, MD[a,b,*]

Abstract

Although several studies report various treatment solutions for cervical spondylotic myelopathy in patients with athetoid cerebral palsy, long-term follow-up studies are very rare. None of the reported treatment solutions represent a gold standard for this disease owing to the small number of cases and lack of long-term follow-up. This study aimed to evaluate the outcomes of laminoplasty with lateral mass screw fixation to treat cervical spondylotic myelopathy in patients with athetoid cerebral palsy from a single center.

This retrospective study included 15 patients (9 male patients and 6 female patients) with athetoid cerebral palsy who underwent laminoplasty with lateral mass screw fixation for cervical spondylotic myelopathy at our hospital between March 2006 and June 2010. Demographic variables, radiographic parameters, and pre- and postoperative clinical outcomes determined by the modified Japanese Orthopedic Association (JOA), Neck Disability Index (NDI), and visual analog scale (VAS) scores were assessed.

The mean follow-up time was 80.5 months. Developmental cervical spinal canal stenosis ($P=0.02$) and cervical lordosis ($P=0.04$) were significantly correlated with lower preoperative modified JOA scores. The mean modified JOA scores increased from 7.97 preoperatively to 12.1 postoperatively ($P<0.01$). The mean VAS score decreased from 5.30 to 3.13 ($P<0.01$), and the mean NDI score decreased from 31.73 to 19.93 ($P<0.01$). There was a significant negative correlation between developmental cervical spinal canal stenosis and recovery rate of the modified JOA score ($P=0.01$).

Developmental cervical spinal canal stenosis is significantly related to neurological function in patients with athetoid cerebral palsy. Laminoplasty with lateral mass screw fixation is an effective treatment for cervical spondylotic myelopathy in patients with athetoid cerebral palsy and developmental cervical spinal canal stenosis.

Abbreviations: ACP = athetoid cerebral palsy, ADF = anterior cervical decompression and fusion, CSM = cervical spondylotic myelopathy, JOA = Japanese Orthopedic Association, MRI = magnetic resonance imaging, NDI = Neck Disability Index, VAS = visual analog scale.

Keywords: athetoid cerebral palsy, laminoplasty, myelopathy, spinal fusions, spinal stenosis

1. Introduction

Cerebral palsy (CP) describes a group of permanent disorders of movement and posture development that cause activity limitation. These disorders are attributed to nonprogressive disturbances that occur in the developing fetal or infant brain. Motor disorders in cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, epilepsy, and secondary musculoskeletal problems.[1] Cerebral palsy affects about 1 in 500 live born children,[2] and 1.8 to 6.0 per 1000 live births in China.[3] In cases of the less common athetoid CP (ACP), the disorder affects the basal ganglia, leading to disorganized movement patterns that, if severe, can be totally disabling. Speech production is often affected and some, but not all, individuals have preserved cognitive function.[4] An estimated 31% of patients with ACP develop cervical spondylotic myelopathy (CSM).[5] The associated degenerative changes in the cervical spine can be accelerated by involuntary movements of the head and neck, and neural elements can be stimulated or compressed by dynamic instability[6] and a herniated cervical disc,[7] particularly in the presence of developmental spinal canal stenosis.[8] Torg–Pavlov ratio[9] values of 0.80 or less have been shown to predict developmental spinal canal stenosis.[10] This ratio may be most helpful in identifying the likelihood of developing CSM.[10]

The most important surgical objectives for CSM in patients with ACP are adequate decompression of the compressed spinal cord and nerve roots, as well as stabilization of the cervical spine.[11] There are multiple methods used to try to attain these objectives. Harada and colleagues[12] reported good short-term

Editor: Bernhard Schaller.

The authors declare no conflicts of interest.

[a] Department of Orthopaedics, Peking University Third Hospital, [b] Beijing Key Laboratory of Spinal Diseases, Beijing, China.

[*] Correspondence: Yu Sun, Department of Orthopaedics, Peking University Third Hospital, No. 49 Huayuanbei Road, Haidian District, Beijing 100191, China (e-mail: sunyuor@vip.sina.com); Zhong-jun Liu, Department of Orthopaedics, Peking University Third Hospital, No. 49 Huayuanbei Road, Haidian District, Beijing 100191, China (e-mail: liuzj@medmail.com.cn).

Medicine (2016) 95:39(e5033)

Received: 20 March 2016 / Received in final form: 6 September 2016 / Accepted: 8 September 2016

http://dx.doi.org/10.1097/MD.0000000000005033

results with laminoplasty and posterior fusion. Haro et al[13] reported on 2 patients who underwent laminoplasty with posterior fusion supplemented with Luque segmental sublaminal instrumentation and had a favorable outcome. Jameson et al[14] reported satisfactory outcomes in 5 patients with ACP whose posterior fixations were achieved using a segmental device with articular screws from C3 to C6 and pedicular screws at C2 and C7. The limitation of these reports, however, is the small number of cases.[15]

In a biomechanical study, Schmeiser et al[16] compared the stabilization behavior of additional unilateral mass screw fixation with current standard procedures in patients with multilevel CSM. They demonstrated that laminoplasty with unilateral mass screw fixation exhibited sufficient stabilization of the cervical spine. Since this method can provide sufficient stabilization and is safer and easier than pedicle screw fixation, it may be a treatment option for CSM in patients with ACP. However, no long-term studies have been conducted on consecutive patients with ACP treated with laminoplasty and lateral mass screw fixation. The purpose of this study was to evaluate (for a minimum 5-year follow-up) the clinical outcomes of laminoplasty with lateral mass screw instrumentation and fusion for treating CSM in patients with ACP.

2. Materials and methods

2.1. Ethics statement

The Ethical Committee of Peking University Third Hospital approved this study (No. IRB00006761-2009015). All participants provided signed informed consent at admission before their data were stored in our hospital database and used for research purposes.

2.2. Patient population

We retrospectively reviewed the medical records of 22 adult patients with ACP and CSM who had surgery at Peking University Third Hospital between 2006 and 2010. Charts, medical documents, images, and interviews extracted data based on review of medical records. All adult patients with ACP were able to walk without any assistive devices and understand instructions without any problems. The major symptom at onset was limb muscle weakness and sensory disturbance. Fifteen consecutive patients were included in the present study. Inclusion was based on the following criteria: the patients with CP who were diagnosed by a pediatric neurologist during infancy; ACP patients with CSM who were diagnosed through clinical and radiographic methods; patients who had laminoplasty with a lateral screw; and a minimum follow-up period of 24 months. The exclusion criteria were as follows: spinal tumor, trauma, or infections; concomitant symptomatic disorders of the thoracic or lumbar spine; occipitocervical decompression and fusion for cervical myelopathy due to C1–C2 instability; and a history of cervical spine surgery.

2.3. Surgical management

The indication for surgical intervention was based on the evidence of cervical myelopathy noted during the neurological physical examination and the confirmation of spinal cord compression on magnetic resonance images. Laminoplasty with lateral mass screw fixation was performed in patients who had more than 3 herniated intervertebral discs or a developmental cervical spinal canal. Laminoplasty combined with anterior cervical decompression and fusion (ADF) was performed in patients if the anterior and posterior spinal cord compression was caused by developmental or degenerative cervical spinal canal stenosis with protrusion of an intervertebral disc, and an MRI showed an occupying ratio of more than 50% of normal intervertebral disc protrusion.[17]

All patients underwent Hirabayashi open-door laminoplasty.[18] The patients were administered general anesthesia and placed in prone position with their neck in slight flexion. A posterior midline incision was made, and the paraspinal muscles were dissected in order to expose the cervical spine from the inferior portion of the C2 lamina to the superior portion of the T1 lamina for a C3 to C7 laminoplasty. The spinous processes of the targeted laminae were cut short and pruned into strips for bone grafts. Gutters were then created on the bilateral lamina from C3 to C7. The gutters on one side were prepared for a hinge, while the laminae on the other side were completely cut for opening. Holes were drilled in the lateral masses using the Magerl technique,[19] and sutures were placed through the base of the spinous processes with a screw tail on the hinge side at each level. After the laminae were manually opened to maintain the expanded position and prevent closure of the laminar door, the sutures previously placed at the base of the spinous processes were securely tied. A fixation system of screws and rods was installed and the axis rods were bent to match the cervical curvature. Strip bone grafts were then placed under the sutures around the bone gutters of the hinged side. After the surgery, all patients were asked to wear a cervical collar for 8 to 12 weeks; no patients underwent a halo-vest treatment. The patients were followed up at 3, 6, 12, and 24 months after surgery and annually thereafter for life. Orthopedics residents obtained the modified Japanese Orthopedic Association (JOA), visual analog scale (VAS), and Neck Disability Index (NDI) scores postoperatively at the 6- and 24-month follow-up visits.

2.4. Radiological evaluation

The cervical lordosis angle of the posterior vertebral line from C2 to C7 on the lateral radiographs was measured. Cervical alignment was also classified into lordosis and straight or kyphosis, as reported by Demura et al.[20] Developmental cervical spinal canal stenosis was assessed by the Torg–Pavlov ratio.[9] Preoperative magnetic resonance images were obtained to examine the compressed spinal cord segments in all patients (Fig. 1). Postoperative magnetic resonance images were obtained to examine the decompression of the cervical cord at the 24-month follow-up visit (Fig. 2). Static and dynamic flexion-extension lateral radiographs obtained postoperatively at each follow-up visit were used to assess delayed fusion and instability.

2.5. Clinical evaluation

The clinical outcomes were evaluated using the JOA, VAS, and NDI scores before and after surgery. The JOA scoring system was used to evaluate neurological function. The recovery rate of neurological function evaluated by JOA scoring system was calculated using the following equation: (postoperative score − preoperative score)/(17 − preoperative score) × 100%.[21] The recovery rates were classified as excellent (>75% to ≤100%), good (>50% to ≤75%), fair (>25% to ≤50%), or unchanged or worse (≤25%).[11] The NDI was designed to measure activities of daily living in patients with neck pain. The VAS score was used to assess the preoperative and postoperative pain of the neck and extremities.

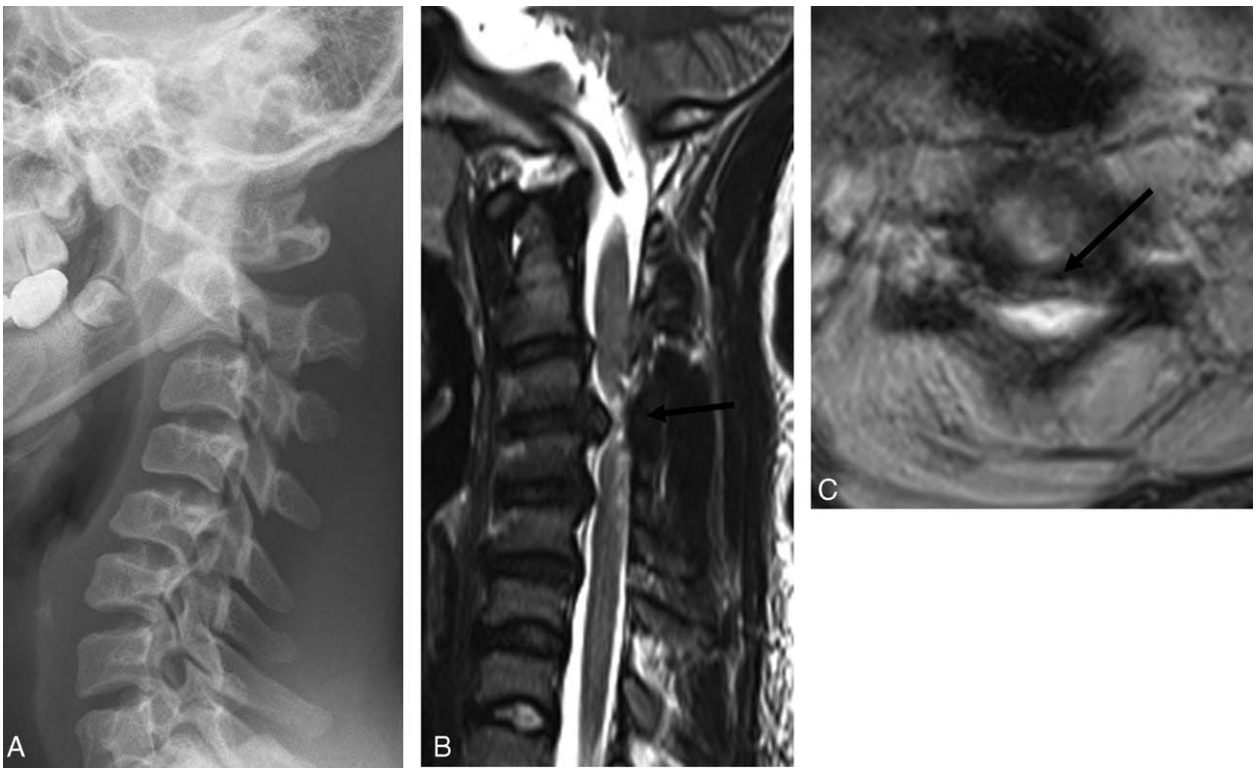

Figure 1. A 19-year-old female patient with athetoid cerebral palsy developed cervical spondylotic myelopathy. On the lateral radiograph, cervical kyphosis and cervical spinal canal stenosis are visible at C3/4 and C4/5 (A). On a sagittal magnetic resonance image (MRI), ventral and dorsal compression of the spinal cord is visible (B). On a horizontal MRI, compression of the C3/4 spinal cord is evident (C).

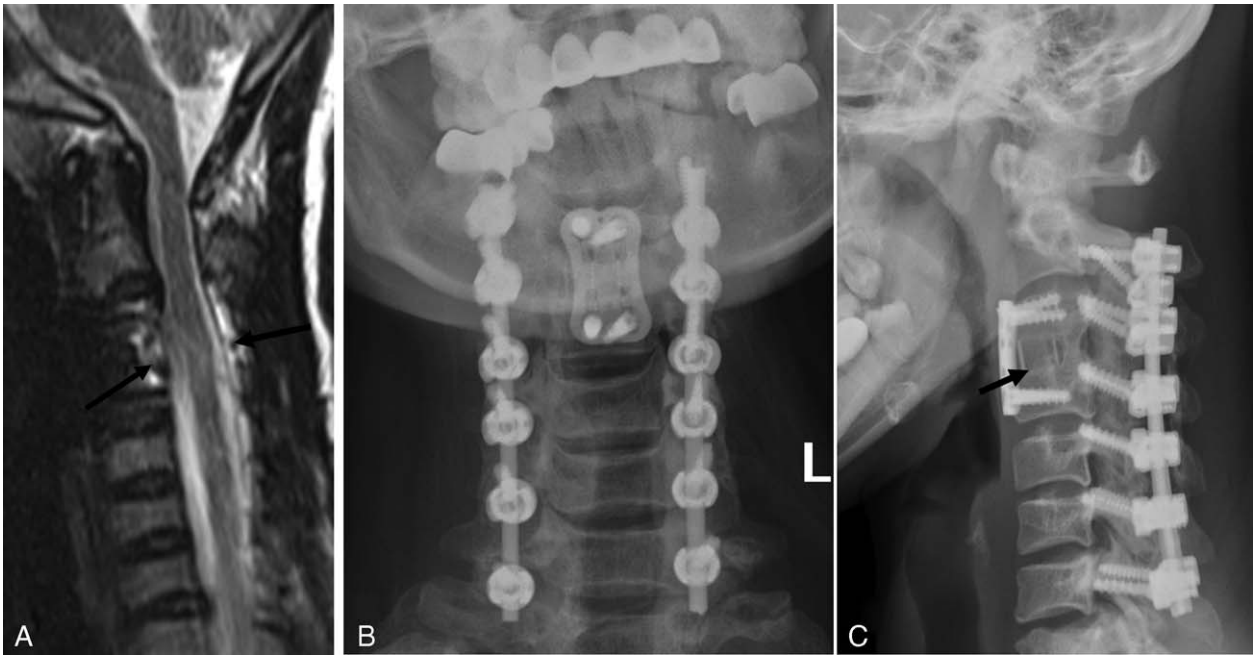

Figure 2. The patient underwent posterior combined and anterior decompression. The magnetic resonance image collected 2 years after the surgery shows no evidence of spinal cord compression (A). Laminoplasty with lateral mass screw fixation at C2–C7 and C3/4 anterior decompression and fusion with a plate and screw system was performed (B). The radiograph obtained 5 years after the operation shows the bone union at the C3/4 vertebrae (C).

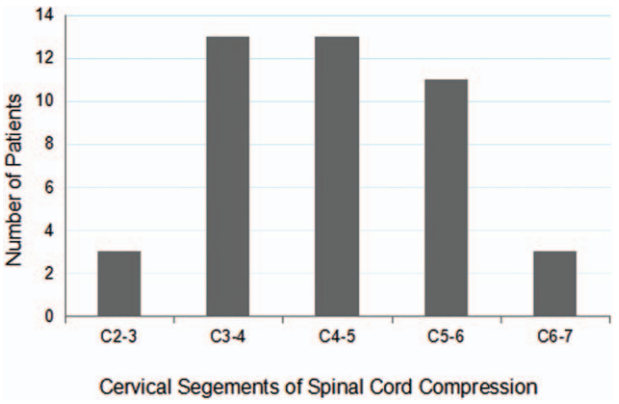

Figure 3. The levels of cervical spinal cord compressions. The most affected lesion sites were C3/4 and C4/5, followed by C5/6.

2.6. Statistical analysis

Continuous variables were presented as mean ± SD. The Shapiro–Wilk test was used to assess the normal distribution of the continuous variables (age, symptom duration, and compressed spinal cord segments). The Pearson correlation test was used to assess the association between age and disease severity. Spearman's rank correlation analysis was used to assess symptom duration, compressed spinal cord segments, developmental cervical spinal canal stenosis, cervical lordosis, and disease severity. We also used a repeated measures analysis of variance to examine the improvement of disease severity scores before versus after surgery. Unless stated otherwise, a 2-tailed $P < 0.05$ was considered statistically significant. Statistical analysis was performed using SPSS version 17.0 software (SPSS Inc., Chicago, IL).

3. Results

The study group consisted of 9 male and 6 female patients, with a mean age at the time of surgery of 37.7 years (range, 19–59 years old). The mean preoperative symptom duration was 16.2 months (range, 3–48 months). The mean number of compressed spinal cord segments was 2.9. Of the continuous variables, age was a normal distribution ($P = 0.14$), while symptom duration and compressed spinal cord segments were of non-normal distribution ($P < 0.05$). Laminoplasty with lateral mass screw fixation was performed in 15 patients, 3 of whom were also treated combined with ADF, as the transverse area of the spinal cord in MRI was reduced to less than 50% of the normal (Fig. 1). The mean follow-up time was 80.5 months (range, 60–101 months).

3.1. Radiography results

The levels of cervical compression are shown in Fig. 3. The most affected lesion sites were C3/4 and C4/5, followed by C5/6. Twelve patients had multiple levels (C3–C6 levels in 8 cases, C2–C5 levels in 2 cases, C4–C7 in 1 case, and C3–C7 in 1 case). Three patients had 2 levels involved (C2–C4, C3–C5, and C5–C7, respectively). Seven patients had developmental cervical spinal canal stenosis and 6 patients had cervical straight curve or kyphosis. Table 1 shows that developmental cervical spinal canal stenosis and cervical lordosis were significantly correlated with lower preoperative JOA scores ($P < 0.05$). However, age, symptom duration, and compressed spinal cord segments did not significantly affect the JOA, VAS, or NDI scores, nor did they affect the recovery rate measured by the JOA score. No complications of delayed fusion or adjacent segmental instability in lateral radiographs occurred at the final follow-up visit.

3.2. Clinical results

The preoperative and postoperative JOA, VAS, and NDI scores are shown in Table 2. The JOA, VAS, and NDI scores at 3 time points (preoperative, postoperative 6 months, and postoperative 2 years) had a significant difference ($P < 0.01$). The results of pairwise comparison for JOA, VAS, and NDI scores are shown in Table 2. The multiple comparisons of the mean JOA score at different time points (before surgery, 6 months after surgery, and the final assessment time point) revealed that the mean JOA score was 7.97 (range, 4–11) before surgery, 10.30 (range, 7–13.5) at 6 months after surgery, and 12.1 (range, 9–15) at 24 months ($P <$ 0.01). The mean VAS score decreased from 5.27 to 3.27 at 6

Table 1

Effects of preoperative variables on CSM severity.

	Preoperative JOA score		Preoperative VAS score		Preoperative NDI score		JOA recovery rate	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Age	0.25	0.36	−0.04	0.89	0.28	0.31	0.02	0.9
Symptom duration	−0.12	0.66	0.41	0.13	0.46	0.09	−0.04	0.5
Compressed segments	−0.10	0.73	0.27	0.34	0.18	0.53	0.1	0.49
Developmental canal stenosis	−0.61	0.02	−0.23	0.41	−0.33	0.23	−0.70	0.01
Cervical kyphosis	−0.54	0.04	−0.07	0.81	−0.27	0.33	−0.16	0.52

CSM = cervical spondylotic myelopathy; JOA = Japanese Orthopedic Association; NDI = Neck Disability Index; VAS = visual analog scale.

Table 2

JOA, VAS, and NDI scores before versus after surgery.

	Preoperative	Postoperative 6 months	Postoperative 24 months	F	*P*
JOA($\bar{x} \pm S$)	7.97 ± 2.42	10.30 ± 2.10*	12.1 ± 2.25*,†	52.1	<0.01
VAS($\bar{x} \pm S$)	5.27 ± 1.80	3.27 ± 1.33*	3.13 ± 1.25*	21.1	<0.01
NDI($\bar{x} \pm S$)	31.73 ± 8.91	20.93 ± 7.16*	19.93 ± 7.6*	46.7	<0.01

JOA = Japanese Orthopedic Association; NDI = Neck Disability Index; VAS = visual analog scale.
* Statistically significant ($P < 0.01$) change between pre- and postoperative scores.
† Statistically significant ($P < 0.01$) change between 6-month and 24-month postoperative scores.

months after surgery ($P < 0.01$) and to 3.13 at 24 months ($P < 0.01$). The mean NDI score decreased from 31.73 to 20.93 at 6 months after surgery ($P < 0.01$) and to 19.93 at 24 months ($P < 0.01$) (Table 2).

The recovery rate as measured by the JOA score after surgery was excellent in 1 patient (7%), good in 5 patients (33%), fair in 6 patients (40%), and unchanged or worse in 3 patients (20%). Developmental cervical spinal canal stenosis significantly affected the postoperative JOA recovery rate ($P < 0.05$) (Table 1).

There were no serious complications related to the surgical procedures. Transient C5 palsy was seen in 2 cases: 1 patient recovered one week post surgery with conservative treatment, while another patient recovered within 6 months post surgery with conservative treatment and rehabilitation therapy.

4. Discussion

In this series, the average age of patients with ACP who underwent surgical treatment for CSM was 37.7 years, and the majority of the patients with ACP had cervical spinal canal stenosis and intervertebral disc degeneration, particularly at C3/4 and C4/5 levels, followed by C5/6. Although patients with ACP tended to be younger because of their athetoid neck movements, these results are in accordance with those of other studies.[5,22] These changes are thought to lead to early-stage neurological deterioration and spinal deformity.[13,23,24]

The results of this series show that developmental cervical spinal canal stenosis and cervical lordosis are significantly correlated with poor preoperative neurological function of patients with ACP. There is a higher incidence of narrowing of the multilevel cervical canal in patients with ACP.[8] Laminoplasty is an option for decompressing multilevel cervical spinal canal stenosis.[16,25] Some reports have recommended laminoplasty without fusion as a better option in patients with multilevel spinal stenosis and/or cervical lordosis.[26–28] Even if the laminoplasty has a restrictive effect on intervertebral mobility regarding the decreased range of motion of the cervical spine,[29,30] the results of laminoplasty without spinal fusion for CSM in patients with ACP are unsatisfactory.[31] In a long-term follow-up, many patients with ACP who have undergone laminoplasty without fusion experience symptom recurrence and instability.[15,32]

Surgical intervention for CSM in patients with ACP is considered along with the neurological deficits and spinal cord decompression and stabilization to prevent future spine deformities. Laminoplasty relies on decompression by both direct removal of the offending posterior structures and indirect posterior translation of the spinal cord; thus, patients should undergo maintenance of lordosis or correctable kyphosis to enable adequate indirect decompression.[33] Furthermore, each patient's involuntary movements caused by ACP should be taken into account when selecting the surgical method, since they place constant excessive stress on the cervical spine. A biomechanical study found that laminoplasty with unilateral screw instrumentation exhibited almost the same degree of stabilization as laminectomy with bilateral instrumentation.[16] Haro et al[13] reported that patients with ACP underwent laminoplasty with lateral mass plating and posterior wiring treatment for CSM and maintained good outcomes and alignment for 3 years. In this series, developmental cervical spinal canal stenosis not only significantly affected preoperative JOA scores but also had a significant negative correlation with JOA recovery rate outcomes. Therefore, laminoplasty with lateral mass screw fixation is an effective treatment for CSM in ACP patients with cervical spinal canal stenosis.

In our series, 15 patients with ACP underwent laminoplasty with lateral mass screw fixation. Based on the JOA, VAS, and NDI scores in our series, the outcomes of patients with ACP were significantly improved and maintained for 5 years. Surgical intervention consisting of laminoplasty with lateral mass screw fixation appears to have successfully improved neurological function in the cases presented here. Thus, laminoplasty with lateral mass screw fixation may be an effective treatment option for ACP patients with CSM due to multilevel cervical spinal stenosis. If combined with preexisting kyphosis or single-segment huge disc herniation, the patient should undergo posterior decompression combined with ADF. Three patients in this series underwent laminoplasty with lateral mass screw fixation combined with ADF. Onari et al[7] found that posterior lateral mass plating and wiring with ADF is a favorable option for patients with cervical spinal canal stenosis and highly kyphotic deformity since it can preserve neurological status and cervical alignment postoperatively.

In this series, there were no neurovascular complications including injury to the vertebral artery and nerve root. Lateral mass screw fixation is safer and less complicated than pedicle screw fixation.[34] Some authors have reported that laminoplasty with pedicle screw fixation for cervical myelopathy in patients with ACP can improve neurological function and the ability to perform daily living activities.[20] In the cervical spine, pedicle screw fixation can provide better biomechanical strength than the lateral mass screw fixation.[35,36] Furthermore, postoperative rigid external fixation is not required, even in those with severe involuntary movements.[37]

Postoperative C5 palsy has been reported as a common significant complication of cervical laminoplasty. The incidence of postoperative C5 palsy is significantly higher after laminoplasty when it is combined with spinal fusion. In this series, 2 of the 15 (13.3%) patients developed postoperative C5 palsy. Yamanaka et al[38] reported that 6 of 24 patients who underwent laminoplasty with posterior lateral mass fixation developed C5 palsy compared with only 1 of 34 patients who underwent laminoplasty without fusion. Nakashima et al[39] suggested that patients with a posterior shift of the spinal cord and additional iatrogenic foraminal stenosis are more likely to develop postoperative C5 palsy after posterior instrumentation with fusion.

This study has several limitations. Firstly, it is a retrospective, single center study and lacked randomization, making biases and confounding difficult to control. Secondly, postoperative cervical kyphosis often occurs and develops up to 10 years postoperatively in patients with ACP.[15] Thirdly, the study group was small, presenting a limitation to our additional analyses. Therefore, the results should be interpreted with caution, and further studies with longer follow-up periods and a larger sample size are essential to evaluate the clinical outcomes of laminoplasty with lateral mass screw fixation for CSM in patients with ACP.

5. Conclusion

Cervical spinal canal stenosis is a major factor affecting recovery from CSM in patients with ACP. Laminoplasty with lateral mass screw fixation is an effective treatment for CSM in ACP patients with cervical spinal canal stenosis and features good postoperative outcomes after 5 years of follow-up.

Acknowledgments

The authors thank Dr. Liu Hua for English language editing.

References

[1] Haak P, Lenski M, Hidecker MJ, et al. Cerebral palsy and aging. Dev Med Child Neurol 2009;51(suppl 4):16–23.
[2] Graham HK, Rosenbaum P, Paneth N, et al. Cerebral palsy. Nat Rev Dis Primers 2016;2:15082.
[3] Tian CY, Leng LG, Tian ZM. How to deal with cerebral palsy in 21st century: a new epoch in clinic treatment. Zhongguo Ying Yong Sheng Li Xue Za Zhi 2014;30:511–5.
[4] Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy, April 2005. Dev Med Child Neurol 2005;47:571–6.
[5] Guettard E, Ricard D, Roze E, et al. Risk factors for spinal cord lesions in dystonic cerebral palsy and generalised dystonia. J Neurol Neurosurg Psychiatry 2012;83:159–63.
[6] Cho JH, Ha JK, Kim DG, et al. Does preoperative T1 slope affect radiological and functional outcomes after cervical laminoplasty? Spine (Phila Pa 1976) 2014;39:E1575–81.
[7] Onari K. Surgical treatment for cervical spondylotic myelopathy associated with athetoid cerebral palsy. J Orthop Sci 2000;5:439–48.
[8] Harada T, Ebara S, Anwar MM, et al. The cervical spine in athetoid cerebral palsy. A radiological study of 180 patients. J Bone Joint Surg Br 1996;78:613–9.
[9] Torg JS, Naranja RJ, Pavlov H, et al. The relationship of developmental narrowing of the cervical spinal canal to reversible and irreversible injury of the cervical spinal cord in football players. J Bone Joint Surg Am 1996;78:1308–14.
[10] Yue WM, Tan SB, Tan MH, et al. The Torg–Pavlov ratio in cervical spondylotic myelopathy: a comparative study between patients with cervical spondylotic myelopathy and a nonspondylotic, nonmyelopathic population. Spine (Phila Pa 1976) 2001;26:1760–4.
[11] Kim KN, Ahn PG, Ryu MJ, et al. Long-term surgical outcomes of cervical myelopathy with athetoid cerebral palsy. Eur Spine J 2014;23:1464–71.
[12] Harada T, Ebara S, Kajiura I, et al. Surgical treatment for cervical spondylotic radiculopathy and myelopathy in patients with athetoid cerebral palsy (in Japanese). Cent Jpn J Orthop Traumat 1994;37:555–6.
[13] Haro H, Komori H, Okawa A, et al. Surgical treatment of cervical spondylotic myelopathy associated with athetoid cerebral palsy. J Orthop Sci 2002;7:629–36.
[14] Jameson R, Rech C, Garreau DL. Cervical myelopathy in athetoid and dystonic cerebral palsy: retrospective study and literature review. Eur Spine J 2010;19:706–12.
[15] Azuma S, Seichi A, Ohnishi I, et al. Long-term results of operative treatment for cervical spondylotic myelopathy in patients with athetoid cerebral palsy: an over 10-year follow-up study. Spine (Phila Pa 1976) 2002;27:943–8.
[16] Schmeiser G, Schilling C, Grupp TM, et al. Unilateral laminoplasty with lateral mass screw fixation for less invasive decompression of the cervical spine: a biomechanical investigation. Eur Spine J 2015;24:2781–7.
[17] Sun Y, Pan S, Zhang F, et al. The surgical treatment of cervical spondylotic myelopathy with spinal stenosis and huge disc herniation or osteofyte (in Chinese). Chin J Spine Spinal Cord 2006;5:346–50.
[18] Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine (Phila Pa 1976) 1983;8:693–9.
[19] Jeanneret B, Magerl F, Ward EH, et al. Posterior stabilization of the cervical spine with hook plates. Spine (Phila Pa 1976) 1991;16(3 Suppl): S56–63.
[20] Demura S, Murakami H, Kawahara N, et al. Laminoplasty and pedicle screw fixation for cervical myelopathy associated with athetoid cerebral palsy: minimum 5-year follow-up. Spine (Phila Pa 1976) 2013;38: 1764–9.
[21] Fujimura Y, Nishi Y, Nakamura M, et al. Long-term follow-up study of anterior decompression and fusion for thoracic myelopathy resulting from ossification of the posterior longitudinal ligament. Spine (Phila Pa 1976) 1997;22:305–11.
[22] Durufle A, Petrilli S, Le Guiet JL, et al. Cervical spondylotic myelopathy in athetoid cerebral palsy patients: about five cases. Joint Bone Spine 2005;72:270–4.
[23] Sewell MD, Wallace C, Malagelada F, et al. Does spinal fusion and scoliosis correction improve activity and participation for children with GMFCS level 4 and 5 cerebral palsy? Medicine (Baltimore) 2015;94: e1907.
[24] Lee YJ, Chung DS, Kim JT, et al. Surgical treatments for cervical spondylotic myelopathy associated with athetoid cerebral palsy. J Korean Neurosurg Soc 2008;43:294–9.
[25] Lee CH, Lee J, Kang JD, et al. Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy: a meta-analysis of clinical and radiological outcomes. J Neurosurg Spine 2015;22:589–95.
[26] Minamide A, Yoshida M, Yamada H, et al. Efficacy of posterior segmental decompression surgery for pincer mechanism in cervical spondylotic myelopathy: a retrospective case-controlled study using propensity score matching. Spine (Phila Pa 1976) 2015;40:1807–15.
[27] Zhou H, Sun Y, Zhang F, et al. Clinical case report of expansive laminoplasty for cervical myelopathy due to both disc herniation and developmental cervical spinal canal stenosis in older adolescents. Medicine (Baltimore) 2016;95:e2879.
[28] Cheng Z, Chen W, Yan S, et al. Expansive open-door cervical laminoplasty: in situ reconstruction of extensor muscle insertion on the C2 spinous process combined with titanium miniplates internal fixation. Medicine (Baltimore) 2015;94:e1171.
[29] Nakashima H, Kato F, Yukawa Y, et al. Comparative effectiveness of open-door laminoplasty versus French-door laminoplasty in cervical compressive myelopathy. Spine (Phila Pa 1976) 2014;39:642–7.
[30] Chen H, Liu H, Deng Y, et al. Multivariate analysis of factors associated with axial symptoms in unilateral expansive open-door cervical laminoplasty with miniplate fixation. Medicine (Baltimore) 2016;95: e2292.
[31] Seichi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. Spine (Phila Pa 1976) 2001;26:479–87.
[32] Seichi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. Spine (Phila Pa 1976) 2001;26:479–87.
[33] Yeh KT, Yu TC, Chen IH, et al. Expansive open-door laminoplasty secured with titanium miniplates is a good surgical method for multiple-level cervical stenosis. J Orthop Surg Res 2014;9:49.
[34] Abumi K. Cervical spondylotic myelopathy: posterior decompression and pedicle screw fixation. Eur Spine J 2015;24(suppl 2):186–96.
[35] Kato S, Shoda N, Chikuda H, et al. Morphological characteristics of cervical spine in patients with athetoid cerebral palsy and the accuracy of pedicle screw placement. Spine (Phila Pa 1976) 2014;39: E508–13.
[36] Kothe R, Ruther W, Schneider E, et al. Biomechanical analysis of transpedicular screw fixation in the subaxial cervical spine. Spine (Phila Pa 1976) 2004;29:1869–75.
[37] Onari K, Kondo S, Mihara H, et al. Combined anterior-posterior fusion for cervical spondylotic myelopathy in patients with athetoid cerebral palsy. J Neurosurg 2002;97(1 suppl):13–9.
[38] Yamanaka K, Tachibana T, Moriyama T, et al. C-5 palsy after cervical laminoplasty with instrumented posterior fusion. J Neurosurg Spine 2014;20:1–4.
[39] Nakashima H, Imagama S, Yukawa Y, et al. Multivariate analysis of C-5 palsy incidence after cervical posterior fusion with instrumentation. J Neurosurg Spine 2012;17:103–10.