Observational Study

Medicine®

OPEN

Limited laminectomy and foraminal decompression combined with internal fixation for treating multi-segment cervical spondylotic myelopathy

Does it effectively improve neurological function and prevent C5 palsy?

Yue-jiang Zhao, MM*, Cai Cheng, MM, Han-wen Chen, MM, Min Li, MM, Lu Wang, MM, Zhi-yuan Guo, MM

Abstract

Laminectomy is an effective surgical treatment for multi-segment cervical spondylotic myelopathy (M-CSM) but usually results in C5 palsy. Some surgical techniques to restore the spinal sequence, increase the intervertebral foramen diameter, and limit the spinal cord drift distance have been proposed; however, it is unclear whether these procedures can avoid this complication.

To investigate the clinical efficacy of limited laminectomy and foraminal decompression with fixation (LLFDF) for improving neurological recovery and preventing C5 palsy.

A total of 71 patients with M-CSM were retrospectively analyzed. Thirty-nine of them were treated with LLFDF (group A) and 32 with normal laminectomy with fixation (NLF; group B) after 3 months of formal conservative treatment. Pre- and postoperative neurological function, spinal cord drift distance, cervical curvature index (CCI), and number of C5 palsy cases were recorded and analyzed.

There was no significant intergroup difference in the surgical time or intraoperative blood loss ($P > .05$). The laminectomy widths in groups A and B were 16.7 ± 2.6 mm and 21.8 ± 2.9 mm, respectively ($P < .01$), while the spinal cord drift distances were 2.3 ± 0.4 mm and 3.6 ± 0.7 mm, respectively ($P < .01$). The mean Japanese Orthopedic Association score of both groups increased significantly after surgery ($P < .01$), and no significant difference was noted at any observation time points ($P > .05$). Both groups demonstrated significant CCI improvements after surgery compared with those before surgery ($P < .01$). There were 2 cases of C5 palsy in group A (5.1%) and 8 cases in group B (25.0%), and the difference was significant ($P < .05$).

LLFDF can relieve spinal compression and considerably promote neurological recovery. Moreover, it restricts excessive spinal cord back drifting and decreases the incidence of C5 palsy.

Abbreviations: CCI = cervical curvature index, CT = computed tomography, JOA = Japanese Orthopedic Association, LLFDF = limited laminectomy and foraminal decompression with fixation, M-CSM = multi-segment cervical spondylotic myelopathy, NLF = normal laminectomy with fixation.

Keywords: C5 palsy, decompression, spine, spondylosis

1. Introduction

Multi-segment cervical spondylotic myelopathy (M-CSM), frequently observed in clinical practice, is usually treated with posterior decompression. Other common decompression methods include open-door laminoplasty,[1] laminectomy with pedicle screw fixation or lateral mass screw fixation,[2–4] and double-door expansive laminoplasty.[1,5] Embedding of various internal instruments via the cervical posterior approach markedly improves both initial stability and long-term stability of the cervical spine after laminectomy or laminoplasty.[6] Under the precondition that internal fixation provides insurance for cervical spinal stability, the intraoperative vertebral transverse incision could be enlarged properly to achieve adequate spinal cord decompression. However, the occurrence of postoperative C5 palsy has increased remarkably.[7,8] Furthermore, C5 palsy is associated with increased nerve root tension after excessive posterior drifting of the spinal cord.[7]

The scope to which the vertebral plate transverse incision width be controlled intraoperatively to decrease the occurrence of C5 palsy remains unclear. Studies reporting such data are lacking. The present study retrospectively analyzed the clinical data of 2 groups of patients with M-CSM who underwent limited laminectomy and foraminal decompression with fixation (LLFDF) and normal laminectomy with fixation (NLF) to identify differences in neurological recovery and occurrence of C5 palsy between them.

Editor: Xiaoxing Xiong.

The authors have no conflicts of interest to disclose.

Department of Orthopaedics, Cangzhou Central Hospital, Cangzhou, China.

* Correspondence: Yue-jiang Zhao, Department of Orthopaedics, Cangzhou Central Hospital, 16 Xinhua West Road, Cangzhou 061000, China (e-mail: doctors2015@163.com).

Medicine (2018) 97:47(e13327)

Received: 4 June 2018 / Accepted: 24 October 2018

http://dx.doi.org/10.1097/MD.0000000000013327

Table 1

Patients' baseline demographic data.

	Group A (n = 39)	Group B (n = 32)	t/X^2 value	*P* value
Sex				
Male	21	18	0.041	. 839
Female	18	14		
Mean age (years)	58.5 ± 15.8	59.8 ± 16.2	0.343	.733
Disease course (months)	18.4 ± 6.3	19.7 ± 7.1	0.264	.792
Diameter of the foramen at C4/5 (mm)	1.7 ± 0.5	1.8 ± 0.4	0.916	.363
Pathogenic factors				
Multi-segment disc herniation	22	18	0.019	.990
Ossification of the posterior longitudinal ligament ossification	8	6		
Ligamentum flavum hypertrophy with disc herniation	9	8		
Laminectomy range				
C3–7	28	21	0.503	.778
C3–6	7	6		
C4–7	4	5		

2. Materials and methods

2.1. Patients

This retrospective clinical study included 71 patients with M-CSM treated between May 2014 and October 2016. The patients were divided into 2 groups according to surgical method: 39 in group A (21 men and 18 women) treated with LLFDF and 32 in group B (18 men and 14 women) treated with NLF. Patient data, including age, sex ratio, disease course, laminectomy range, and pathogenic factors, are shown in Table 1. This study was approved by the Institutional Review Board of Cangzhou Central Hospital.

All patients had characteristic symptoms, such as upper-limb numbness, difficulty holding objects, diminished fine-motor skills of the affected fingers, diminished strength of the muscle controlled by the involved nerve, abnormal touch and pain sensations, unstable standing or walking ability of the lower limbs, tendon hyperreflexia, and positive Babinski sign.

Cervical spinal X-rays, computed tomography (CT) images, and magnetic resonance images were routinely collected and examined to observe the cervical curvature status and clarify whether a protruded intervertebral disc was calcified or identify the ossification type of the posterior longitudinal ligament (Fig. 2A-B). This information was used to determine the decompression scope and fixation segment.

2.2. Surgical method

All surgeries were performed by the same group of surgeons. After undergoing general anesthesia induction, the patients were placed in the prone position; their head was fixed on a Mayfield head frame, and their cervical spine was secured in a forward buckling status. A posterior median incision was created to expose the paraspinal muscles along the spinous process, followed by the lamina and cervical lateral mass. Internal fixation was performed in the diseased segment, and the lateral mass or pedicle screw (Medtronic Sofamor Danek, Memphis, TN) was embedded into the vertebral body according to the Magerl technique[9] and Abumi technique.[10] After the spinous process and ligament tissue were removed, separate slots were created along both sides 7 to 9 mm away from the external region of the midline (group A) and 2 mm away from the internal edge of the lateral mass (group B) using a high-speed drill. When the internal cortex of the vertebral plate was polished to paper thickness, the ligamentum flavum was severed at the head and tail ends; the epidural adhesion was separated, and the vertebral plate was lifted slowly using a towel clamp. Next, the posterior wall of the nerve root canal was decompressed at the C5 nerve root (Fig. 2C) to reduce the tension (group A).[2] Pre-bent titanium rods were placed in the u-shaped slot of the nail and locked to adjust the spinal curvature. The incision was sutured layer by layer after a drainage tube was placed internally.

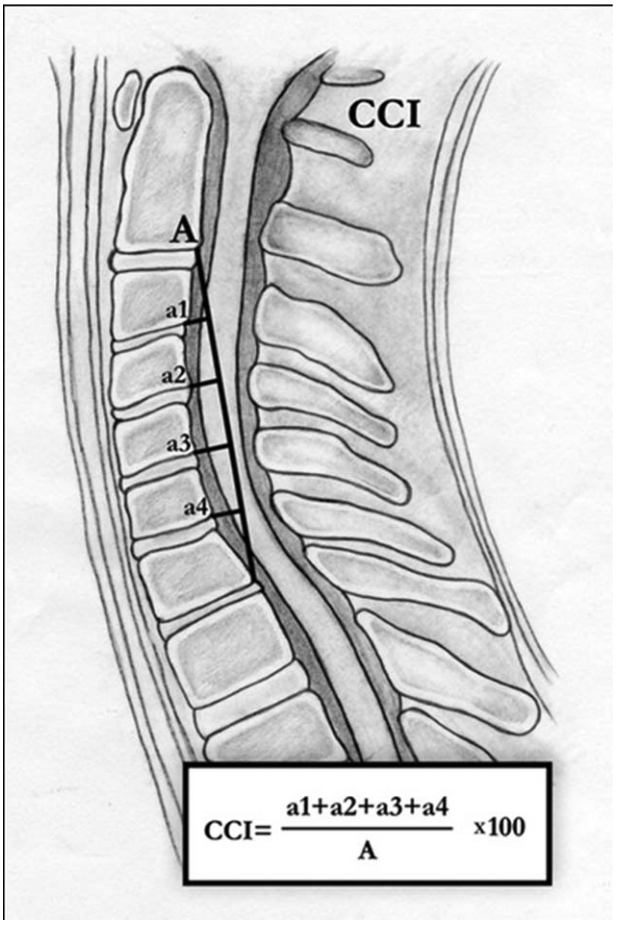

Figure 1. Calculation of the cervical curvature index.

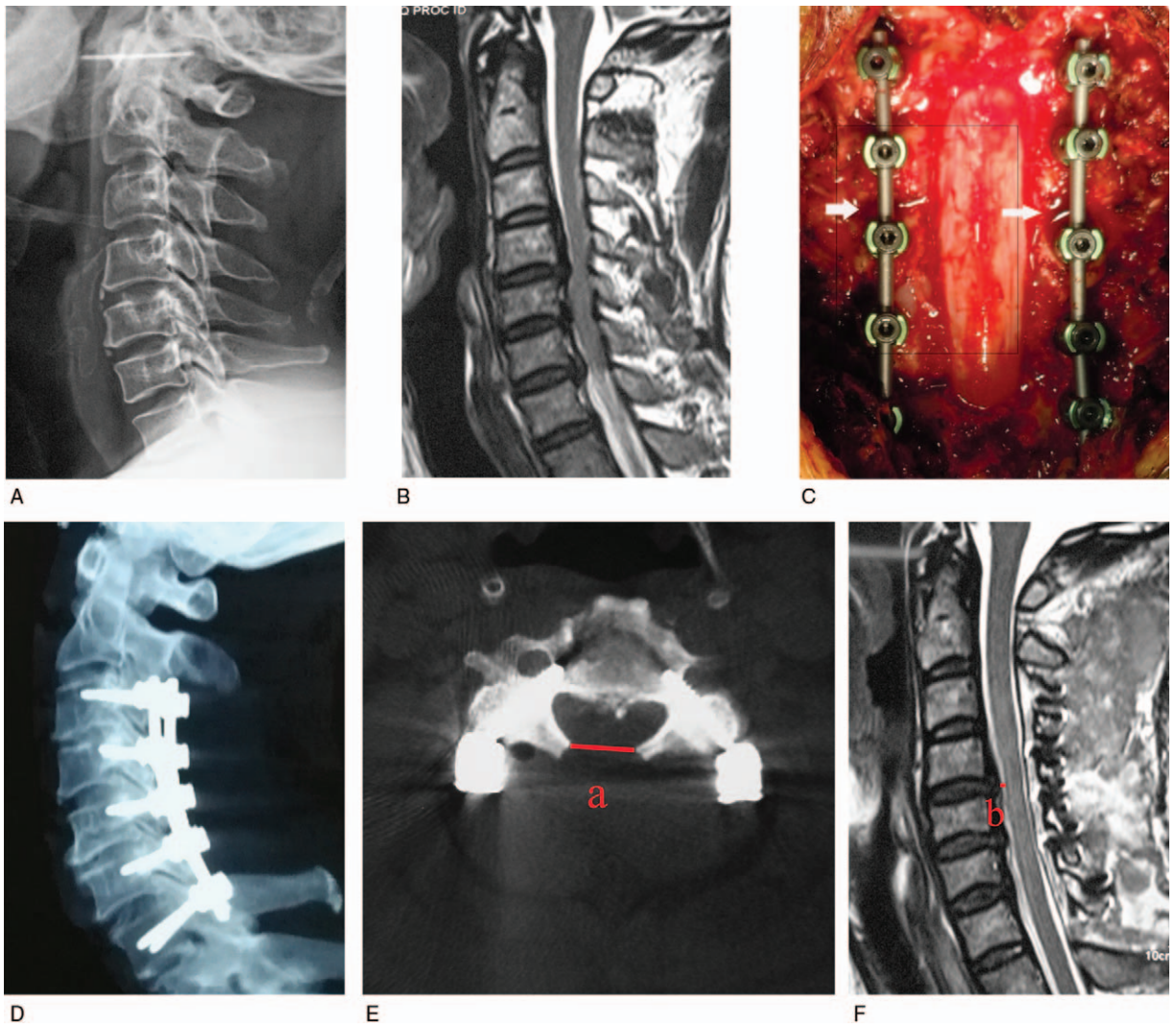

Figure 2. A 61-year-old woman with multi-segment cervical spondylotic myelopathy manifesting as a 21-month history of limb numbness and weakness. A: Preoperative X-ray showing cervical spine degeneration and the posterior longitudinal ligament ossification at the posterior vertebral edge. B: Spinal cord compression is evident in the C4–7 segments. C: The spinal cord was decompressed using limited laminectomy and foraminal decompression with fixation. D, E: Computed tomography scan confirming internal fixation position and a laminectomy width of 15.1 mm at C4 level. F: Magnetic resonance image taken 3 months postoperative showing adequate decompression of the spinal cord and a 2.1-mm drift distance at C5.

2.3. Follow-up and evaluation criteria

The Japanese Orthopedic Association (JOA) 17-point score system was used to evaluate pre- and postoperative neurological function[1] as follows: recovery rate = (postoperative score–preoperative score)/(17-preoperative score) × 100%. The C5 palsy diagnostic criteria were new postoperative occurrence of paralysis of the deltoid and/or biceps brachii, manifesting mostly as mild myasthenia, as patients can have comorbidities of C5 dermatome sensation disturbances and intractable pain.[11]

Photoshop CS5 software (Adobe Systems Inc., San Jose, California) was used to measure the laminectomy width on the CT transverse section, which was the average distance of the double edges in the C3–7 laminae (Fig. 2E and Fig. 3E). The C5-level spinal posterior drift distance was measured on mid-sagittal magnetic resonance images (Fig. 2F and Fig. 3F) as the distance between the C4/5 vertebral disc and the nearest point of the anterior margin of the spinal cord.[8] When ossification of the posterior longitudinal ligament was present at the C4/5 level, the distance between the posterior edge of ossification and the nearest point of the anterior margin was measured. The postoperative posterior spinal cord shift distance at the C4/5 level was obtained using the following formula: spinal cord shift distance = postoperative distance - preoperative distance.[8] The cervical curvature index (CCI) was used to evaluate the curvature change status of the cervical spine:[1] "a1" was defined as the distance from the posterior inferior edge of the C3 vertebral body to line "A" and "a2 (C4), a3 (C5), and a4 (C6)" using the same method. "A" was defined as the distance from the posterior-inferior edge of the C2 vertebral body to that of the C7 vertebral body (Fig. 1). To ensure measurement accuracy, 2 independent radiologists evaluated these images, and each was measured 3 times and averaged.

2.4. Statistical methods

SPSS (Version 17.0; IBM, Chicago, IL) was used to conduct the statistical analysis. Analysis of variance was used to compare the repeated measures at different time points. The 2 groups were

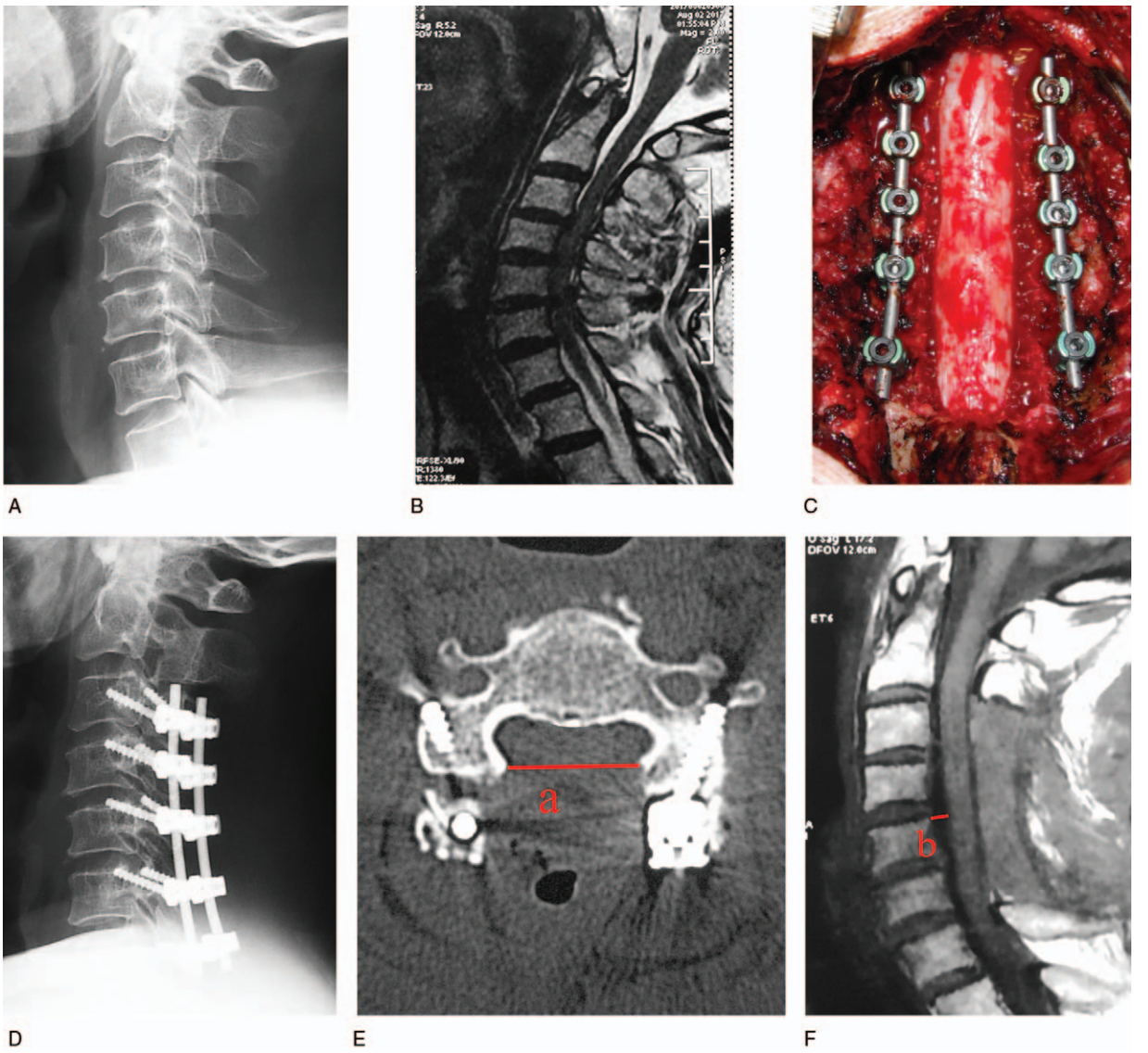

Figure 3. A 60-year-old man with multi-segment cervical spondylotic myelopathy manifesting as an 18-month history of bilateral lower-limb walking weakness. A: X-ray showing mild cervical spine degeneration. B: Overextension magnetic resonance image showing that the spinal cord was compressed anteriorly and posteriorly at C3–7. C: The spinal cord was decompressed using normal laminectomy with fixation. D, E: The cervical curvature index was well maintained during follow-up with a 22.3-mm laminectomy width at C5 level. F: Magnetic resonance image showing a 3.7-mm drift distance of the spinal cord at C5.

compared using an independent 2-sample *t* test or chi-square test. Two-sided *P* values of $<.05$ were considered statistically significant.

3. Results

All surgeries were completed successfully. There was no significant difference in the surgical time and intraoperative blood loss between the 2 groups ($P<.05$). The laminectomy width in group B was significantly greater than that of group A ($P<.05$). The spinal cord drift distance in group B was longer than that of group A ($P<.05$) (Table 2).

The postoperative JOA scores increased in both groups ($P<.01$), and no significant difference was noted at the different time points ($P>.05$). The mean recovery rate in group A was 64.2 ± 13.7%, while that in group B was 68.3 ± 15.1%; however, the difference was insignificant ($P>.05$). The mean postoperative CCI of the 2 groups significantly improved compared with their preoperative CCI and was maintained well until the final follow-up ($P<.01$). No significant difference was seen at any of the different observation time points ($P>.05$; Table 3).

There were 2 cases (2/39, 5.1%) of C5 palsy in group A and 8 cases (8/32, 25.0%) in group B, and their difference was significant ($X^2=4.211$, $P=.04$).

All patients were followed up for 22.5 ± 6.2 months (range, 16–47 months), during which time no cases of internal loosening, displacement, or fracture occurred.

4. Discussion

Cervical laminectomy is an indirect decompression technique. After the laminae are removed, the sagittal diameter of the spinal canal is increased, and the effective volume of the spinal canal is enlarged. Under the effect of the bowstring principle, the spinal

Table 2

Intraoperative conditions and radiological characteristics by group.

	n	Operative time (min)	Intraoperative blood loss (mL)	Laminectomy width (mm)	Spinal cord drift distance (mm)
Group A	39	151.2±27.3	312.9±55.4	16.7±2.6	2.3±0.4
Group B	32	147.6±26.5	298.3±57.1	21.8±2.9	3.6±0.7
t value	—	0.228	0.439	7.807	9.817
P value	—	.817	.671	<.001	<.001

Table 3

JOA score and CCI in group A and group B.

	JOA score					CCI (%)				
	Preop	3 months postop	Final follow-up	F value	*P* value	Preop	3 months postop	Final follow-up	F value	*P* value
Group A	7.8±2.2	13.1±3.5	13.7±3.6	41.051	<.001	12.6±2.7	16.4±3.5	15.7±3.1	16.416	<.001
Group B	7.6±2.0	13.7±3.4	14.0±3.9	40.694	<.001	12.3±2.4	16.9±3.7	15.3±2.9	18.791	<.001
t value	0.399	0.732	0.338	—	—	0.697	0.587	0.567	—	—
P value	.691	.467	.735	—	—	.487	.558	.572	—	—

CCI = cervical curvature index, JOA = Japanese Orthopaedic Association.

cord can "drift backward" to relieve spinal cord compression and promote neurological recovery.[2,7,8] Posterior decompression boasts the features of a low surgical risk, wide field of vision, and relatively simple surgery, and its use can provide multi-segmental compression of the spinal cord in a single procedure. However, the incidence of kyphosis deformity after laminectomy related to excessive incision of the stability-maintenance structure (i.e., spinous process, ligament tissue, and vertebral plate) is relatively high.[3] Therefore, it is especially important to maintain sagittal alignment and cervical curvature using internal fixation.

Du et al[2] used enlarged laminectomy and lateral mass screw fixation for multilevel cervical degenerative myelopathy associated with kyphosis and reported that the CCI had significantly increased from 8.4±2.5% preoperatively to 19.3±2.1% postoperatively. Among the many fixed apparatuses used in posterior cervical surgery, pedicle screw/lateral mass screw fixation is the most effective for the treatment of cervical spondylotic myelopathy with cervical instability and correction of deformity in the sagittal and coronal planes.[12,13] A previous clinical study has proven that the stability in laminectomy with fixation was superior to that in laminoplasty and laminectomy.[6] In the final follow-up, the CCI loss rate was 2.60% in the laminoplasty group, 3.20% in the laminectomy group, and 1.22% in the lateral mass screw fixation group. Further, CCI loss was considered to be correlated with poor neurological recovery and axial symptom severity.[3] To avoid postoperative kyphosis deformity in this study, all enrolled patients underwent pedicle screw or lateral screw fixation. Their postoperative CCIs improved significantly, and the cervical spinal curvature was well maintained during the follow-up period. There was no difference in the curvature change despite the differences in the laminectomy ranges.

Some experts and scholars found that once cervical kyphosis was corrected, the incidence of C5 palsy obviously increased.[14–16] Because the cervical sagittal sequence is restored to lordosis, the spinal cord is more likely to "drift backward" under the action of the bowstring principle, thereby significantly increasing nerve root tension. However, the backward shift distance of the spinal cord located atop the bowstring is at the maximum, which would over-retract the C5 nerve root, leading to the occurrence of the nerve root palsy phenomenon under the effect of ischemia and anoxia of the nerve root, segmental spinal cord obstacles, embolism, and reperfusion injury, among other factors.[7,8,17]

By measuring imaging data, Morishita et al[18] found that segmental nerve root palsy commonly occurs when the cervical cord drifts 4 to 5 mm backward at the C5 level. Posterior wall decompression at the C4/5 intervertebral foramen clearly decreased the occurrence of C5 palsy.[2,15] However, this technique did not improve neurological function. Nori et al[8] found that the diameter of the C4/5 nerve root canal of patients with C5 palsy was significantly smaller than that of healthy individuals. By performing preoperative dissection measurements, Lubelski et al[19] found that every 1-mm increase in the nerve canal root diameter would lead to a 98% decrease in the incidence of nerve palsy. Therefore, the alleviation of nerve root palsy could be realized by the limiting of the excessive backward shifting of the spinal cord and the expansion of the nerve root canal.

Many factors affect backward spinal cord drifting; among them, the cervical spinal curvature and laminectomy extent are the most closely related variables.[20,21] Once the rear pressure is relieved, the spinal cord will drift backward under the combined action of the "bow" formed by cervical lordosis and the longitudinal tension of the spinal cord; the drift distance is related to the resultant force.[22] In this study, the pre- and postoperative cervical curvatures of groups A and B were the same, which eliminates the potential effects that different curvatures will have on different spinal drift distances; the other key factor is the extent of laminectomy.

In this study, the patients in group A underwent LLFDF with a mean vertebral plate incision width of 16.7±2.6 mm, while those in group B underwent NLF with a mean incision width of 21.8±2.9 mm; the difference between them was significant ($P<.001$). The mean postoperative C5-level spinal cord drift distances were 2.3±0.4 mm in group A and 3.6±0.7 mm in group B, with a significant difference ($P<.001$). In addition to reducing the laminectomy width in group A, bilateral decompression of the C5 nerve root canal was targeted during surgery, which reduced the nerve root tension. During follow-up, there were 2 cases (5.1%) of C5 palsy in group A and 8 cases (25%) in group B; the difference between them was significant ($P=.04$). Therefore, LLFDF could effectively reduce the occurrence of C5 palsy. In

addition, the distance between the C4/5 vertebral disc and the nearest point of the anterior margin of the spinal cord was selected in this study, considering the vertex position of the C5 vertebrae, where the backward shift distance of the spinal cord peaked. From an anatomical point of view, the C5 nerve root was extended from the superior root canal of the C5 vertebral body, and the measurement of this site strengthens the conclusion.

Whether the laminectomy width affects the recovery of neurological function is controversial. In the study by Klement et al,[23] the mean C5 laminectomy width was 23.1 mm; however, Radcliff et al[7] reduced the mean laminectomy width to 19 mm. Some studies reported[24,25] that the mean transverse diameter of the spinal cord at C5 was only 13 mm. Therefore, the laminectomy width should at least exceed the transverse diameter of the spinal cord at the corresponding segment.[26,27] In this study, the mean incision width in group A (16.7 ± 2.6 mm) was significantly narrower than that in group B (21.8 ± 2.9 mm). However, the mean postoperative JOA scores of both groups significantly increased. Furthermore, the comparison of the different time points revealed no significant difference. The purpose of enlarging the vertebral plate excision was to mitigate compression on the interior portion of the pedicle root and bilateral "lateral recess" area of the cervical cord, as most of the degenerative lesions of the cervical vertebrae are located in the central canal and intervertebral foramen instead of the lateral recess. Thus, it will be worth investigating in future studies whether a more widespread vertebral plate incision is necessary during laminectomy.

5. Conclusions

Compared with NLF, LLFDF can relieve spinal cord compression using limited laminar resection and still yield satisfactory recovery of neurological function. Shortening the spinal cord retraction distance and decreasing the C5 nerve root tension via posterior wall nerve root canal decompression significantly decreased the incidence of C5 palsy.

Author contributions

Data curation: Lu Wang.
Formal analysis: Cai Cheng.
Project administration: Yue-jiang Zhao.
Software: Min Li.
Supervision: Zhi-yuan Guo.
Visualization: Lu Wang.
Writing – review & editing: Han-wen Chen.

References

[1] Nakashima H, Kato F, Yukawa Y, et al. Comparative effectiveness of open-door laminoplasty versus French-door laminoplasty in cervical compressive myelopathy. Spine 2014;39:642–7.
[2] Du W, Zhang P, Shen Y, et al. Enlarged laminectomy and lateral mass screw fixation for multilevel cervical degenerative myelopathy associated with kyphosis. Spine J 2014;14:57–64.
[3] Du W, Wang L, Shen Y, et al. Long-term impacts of different posterior operations on curvature, neurological recovery and axial symptoms for multilevel cervical degenerative myelopathy. Eur Spine J 2013;22:1594–602.
[4] Lee DH, Joo YS, Hwang CJ, et al. A novel technique to correct kyphosis in cervical myelopathy due to continuous-type ossification of the posterior longitudinal ligament. J Neurosurg Spine 2017;26:325–30.
[5] Harshavardhana NS, Dabke HV, Mehdian H. A new fixation technique for French-door cervical laminoplasty: surgical results with a minimum follow-up of 6 years. Clin Spine Surg 2017;30:E331–7.
[6] Miyamoto H, Maeno K, Uno K, et al. Outcomes of surgical intervention for cervical spondylotic myelopathy accompanying local kyphosis (comparison between laminoplasty alone and posterior reconstruction surgery using the screw-rod system). Eur Spine J 2014;23:341–6.
[7] Radcliff KE, Limthongkul W, Kepler CK, et al. Cervical laminectomy width and spinal cord drift are risk factors for postoperative C5 palsy. J Spinal Disord Tech 2014;27:86–92.
[8] Nori S, Aoyama R, Ninomiya K, et al. Cervical laminectomy of limited width prevents postoperative C5 palsy: a multivariate analysis of 263 muscle-preserving posterior decompression cases. Eur Spine J 2017;26:2393–403.
[9] Pal D, Bayley E, Magaji SA, et al. Freehand determination of the trajectory angle for cervical lateral mass screws: how accurate is it? Eur Spine J 2011;20:972–6.
[10] Abumi K, Itoh H, Taneichi H, et al. Transpedicular screw fixation for traumatic lesions of the middle and lower cervical spine: description of the techniques and preliminary report. J Spinal Disord 1994;7:19–28.
[11] Krätzig T, Mohme M, Mende KC, et al. Impact of the surgical strategy on the incidence of C5 nerve root palsy in decompressive cervical surgery. PLoS One 2017;12:e0188338doi: 10.1371/journal.pone.0188338. eCollection 2017.
[12] Abumi K. Cervical spondylotic myelopathy: posterior decompression and pedicle screw fixation. Eur Spine J 2015;24:186–96.
[13] Al Barbarawi MM, Allouh MZ. Cervical lateral mass screw-rod fixation: Surgical experience with 2500 consecutive screws, an analytical review, and long-term outcomes. Br J Neurosurg 2015;29:699–704.
[14] Cherian J, Mayer RR, Haroun KB, et al. Contribution of lordotic correction on C5 following cervical laminectomy and fusion. Neurosurgery 2016;79:816–22.
[15] Blizzard DJ, Gallizzi MA, Sheets C, et al. The role of iatrogenic foraminal stenosis from lordotic correction in the development of C5 palsy after posterior laminectomy and fusion. J Orthop Surg Res 2015;10:160doi: 10.1186/s13018-015-0297-2.
[16] Cherian J, Mayer RR, Haroun KB, et al. Contribution of lordotic correction on C5 palsy following cervical laminectomy and fusion. Neurosurgery 2016;79:816–22.
[17] Xia G, Tian R, Xu T, et al. Spinal posterior movement after posterior cervical decompression surgery: clinical findings and factors affecting postoperative functional recovery. Orthopedics 2011;34:e911–8.
[18] Morishita K, Kasai Y, Takegami K, et al. Disturbance of shoulder elevation after cervical laminoplasty (in Japanese). Jpn Spine Res Soc 2002;13:229–31.
[19] Lubelski D, Derakhshan A, Nowacki AS, et al. Predicting C5 palsy via the use of preoperative anatomic measurements. Spine J 2014;14:1895–901.
[20] Baba H, Uchida K, Maezawa Y, et al. Lordotic alignment and posterior migration of the spinal cord following en bloc open-door laminoplasty for cervical myelopathy: a magnetic resonance imaging study. J Neurol 1996;243:626–32.
[21] Suda K, Abumi K, Ito M, et al. Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy. Spine 2003;28:1258–62.
[22] Nori S, Shiraishi T, Aoyama R, et al. Posterior spinal cord shift does not affect surgical outcomes after muscle-preserving selective laminectomy. J Clin Neurosci 2018;50:226–31.
[23] Klement MR, Kleeman LT, Blizzard DJ, et al. C5 palsy after cervical laminectomy and fusion: does width of laminectomy matter. Spine J 2016;16:462–7.
[24] Ko HY, Park JH, Shin YB, et al. Gross quantitative measurements of spinal cord segments in human. Spinal Cord 2004;42:35–40.
[25] Sherman JL, Nassaux PY, Citrin CM. Measurements of the normal cervical spinal cord on MR imaging. Am J Neuroradiol 1990;11:369–72.
[26] Radcliff K. C5 palsy and cervical laminectomy width: what is the right answer. Spine J 2016;16:468–9.
[27] Bydon M, Macki M, Aygun N, et al. Development of postoperative C5 palsy is associated with wider posterior decompressions: an analysis of 41 patients. Spine J 2014;14:2861–7.