Posterior Revision Surgery for Cervical Open-Door Laminoplasty Because of Poor Expansion of the Spinal Canal

Wei Yuan and Yue Zhu

OBJECTIVE: **Few studies have addressed the causes of poor expansion of the spinal canal after open-door laminoplasty (ODL) that require revision surgery. The aim of this study is to identify the reasons of poor expansion of the spinal canal after ODL and to discuss the surgical methods and clinical outcomes of the posterior revision surgery.**

METHODS: **All patients who underwent posterior revision surgery because of poor expansion of the spinal canal after ODL were retrospectively reviewed at our spine center. Clinical data, radiologic findings, method of surgical revision, interval between surgeries, Japanese Orthopaedic Association (JOA) score, and complications were analyzed.**

RESULTS: **We identified 16 patients that underwent posterior revision surgery because of poor expansion of the spinal canal after ODL. The main causes of poor expansion of the spinal canal included inadequate expansion degree of the spinal canal (75%, 12/16) and improper expansion range of the spinal canal (25%, 4/16). Revision surgery was performed with posterior ODL, laminectomy and fusion (LCF), or laminectomy of responsible lamina. The interval between the initial procedure and revision surgery was 72.2 months (range, 0.5–168 months). The mean JOA score was restored from 10.6 (range, 8–13) to 14.3 (range, 13–17) after the revision surgery.**

CONCLUSIONS: **The main causes of poor expansion of the spinal canal after ODL were inadequate expansion degree of the spinal canal and improper expanded range of the spinal canal. Posterior revision surgeries, such as ODL, LCF, and laminectomy of responsible lamina, could guarantee fine clinical results.**

INTRODUCTION

Decompression surgery could well improve the neurologic function in patients with moderate to severe or progressive compressive cervical myelopathy (CCM). Anterior decompression and fusion was first introduced to treat CCM in the 1950s, and it can yield satisfactory clinical outcomes for CCM that involves 1 or 2 levels with a low incidence of complications.[1] However, when >3 levels are involved (multilevel compressive cervical myelopathy [MCCM]), an anterior surgical approach could yield an increased complication rate, and cases of fusion failure, adjacent level degeneration, instrumentation failure, and dysphagia have been reported.[2] On the other hand, the posterior surgical approach has shown a lower complication and reoperation rate than the anterior approach according to a recent meta-analysis study.[3]

Open-door laminoplasty (ODL) was first reported in the 1970s,[4] and this technique has been widely used in patients with MCCM caused by cervical spondylosis, ossification of the posterior longitudinal ligament (OPLL), congenital spinal stenosis, or a combination of these. ODL can decompress the spinal cord by expanding the spinal canal and preserving the dorsal elements, and therefore can successfully relieve symptoms.[5-7] However, various postoperative complications were still observed, including axial neck pain, neck stiffness, nerve root palsy, loss of lordosis, and closure of the open lamina,[8,9] which could ultimately affect neurologic

Key words
- Cervical spine
- Laminoplasty
- Myelopathy
- Posterior approach
- Revision surgery

Abbreviations and Acronyms
ADS: Anterior decompressive surgery
CCM: Compressive cervical myelopathy
CT: Computed tomography
JOA: Japanese Orthopaedic Association
LCF: Laminectomy and fusion
MCCM: Multilevel compressive cervical myelopathy
ODL: Open-door laminoplasty
OPLL: Ossification of the posterior longitudinal ligament

Department of Orthopedics, First Hospital of China Medical University, Shenyang, China

To whom correspondence should be addressed: Yue Zhu, M.D., Ph.D. [E-mail: zhuyuedr@163.com]

Citation: World Neurosurg. (2019) 130:e90-e97.
https://doi.org/10.1016/j.wneu.2019.05.240

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

functions. These complications have been extensively studied, but few studies have focused on the revision surgery after ODL.[10-14]

The aim of this study was to review our patients who underwent posterior revision surgery after ODL because of poor expansion of the spinal canal, to evaluate the reasons for poor expansion of the spinal canal and the clinical outcomes of the posterior revision surgery.

MATERIALS AND METHODS

Patients

We retrospectively reviewed all patients who underwent ODL in our department from January 2012 to December 2018. Patients who underwent posterior revision surgery after ODL were included. Exclusion criteria included a history of cervical spine surgery before ODL, revision because of cervical spine fracture or dislocation after the initial surgery, and lost follow-up. Approval was obtained from the institutional review board of our hospital.

Clinical data were collected from the medical records and radiographs at the time of the initial surgery, revision surgery, and follow-up. Clinical data included age, duration of symptoms, neurologic status, interval between surgeries, reasons for revision surgery, revision surgical technique, and complications. Radiographic data including radiograph, computed tomography (CT) scan, and magnetic resonance imaging were recorded for analyzing the reasons for revision surgery. Neurologic status was assessed using the Japanese Orthopaedic Association (JOA) score.[15] The JOA score recovery rate was used to evaluate the recovery of normal function, and the calculation method of the recovery rate is as follows: ([postoperative JOA score − preoperative JOA score])/[17 − preoperative JOA score]) × 100%.[16]

Surgical Intervention

All surgeries were performed by the same surgical team. The ODL procedure was performed at the C3-6/C3-7 levels in our department.[17] After exposing the spinous processes and laminae of C3-6/C3-7, a trough was drilled at the junction of the lateral mass and the lamina on the less symptomatic side with a high-speed drill. The contralateral lamina-facet junction was drilled from C3 to C7 down to the ligamentum flavum. The left lamina was conventionally opened and fixed to the contralateral articular capsule with a tread. A posterior approach was applied in all the revision procedures, including ODL, single-segment laminectomy, and laminectomy and fusion (LCF). LCF started with a similar procedure to the ODL, except that drilling at the gutters was performed bilaterally and the bone was removed completely. Lateral mass screws were placed bilaterally to C3, C5, and C7 and were fixed with rods. The autograft was placed posterolaterally.

Statistical Analysis

SPSS 18.0 software (SPSS Inc., Chicago, Illinois, USA) was applied for statistical analysis. Paired t test was used to compare JOA score before and after surgery. $P < 0.05$ was considered statistically significant.

RESULTS

A total of 241 patients who underwent ODL in our department from January 2012 to December 2018 were retrospectively reviewed, and we identified 13 patients (5.39%) who underwent revision surgery with a posterior approach. In addition, there were 3 patients who underwent ODL in other hospitals and were transferred to our department for posterior revision surgery. A total of 16 patients were included in this study, including 9 men and 7 women, with a mean age of 55.8 years (range, 39–72 years) at the initial ODL surgery. There were 9 cases of OPLL, 4 cases of MCCM, and 3 cases of cervical spinal canal stenosis. The mean interval between the initial procedure and revision surgery was 72.2 months (range, 0.5–168 months). The mean JOA score of the revision cases before and after the initial ODL was 9.6 (range, 5–13) and 12.6 (range, 8–16), respectively. The mean JOA recovery rate for the revision cases was 46.7% and that for the population without revision surgery was 58.1%. The mean JOA score before and after the revision surgery was 10.6 (range, 8–13) and 14.3 (range, 13–17), respectively. The mean JOA recovery rate was 54.1%. The mean follow-up duration after the revision surgery was 18.8 months (range, 12–24 months). There were 2 cases with C5 palsy and 3 cases with axial symptoms after the initial procedure, and the cases with C5 palsy and 2 cases with axial symptoms recovered fully before the revision surgery. There were 1 patient with dural tear, 1 patient with wound infection, 1 case with C5 palsy, and 2 cases with axial symptoms at the revision surgery. The clinical data are shown in **Table 1**.

For the causes of revision surgery, in terms of clinical symptoms, the patients required revision surgery because of inadequate symptomatic relief (31.3%, 5/16) and recurrent or new-onset myelopathic symptoms (68.8%, 11/16). In terms of radiographic findings, the patients required revision surgery because of poor expansion of the spinal canal after ODL, which included inadequate expansion degree of the spinal canal (75%, 12/16) and improper expansion range of the spinal canal (25%, 4/16). Inadequate expansion of the spinal canal mainly involved a lack of open angle of the laminae (37.5%, 6/16) or laminae closure (18.8%, 3/16), which was treated with ODL revision surgery, and the progression of primary compression (18.8%, 3/16), which was treated with LCF. Improper expansion of the spinal canal mainly involved the expansion of wrong segments (12.5%, 2/16) or the adjacent segment compression (12.5%, 2/16), which was treated with laminectomy of the responsible lamina. The revision reasons are shown in **Table 2**. The cases are shown in **Figures 1–4**.

DISCUSSION

ODL has been reported as a safe and effective treatment option for MCCM for decades,[17] but a few studies have reported revision surgery after ODL. The current study focused on revision surgery after ODL for MCCM, and we reviewed 16 patients who underwent posterior revision surgery after ODL over a period of 7 years.

Revision Surgery Rate

Reoperation rate is a crucial indicator of the efficacy of a surgical approach,[18] and it shall never be overlooked in evaluating the efficacy of ODL. Until now, only a few studies have reported the revision surgery after ODL, and the reoperation rate of ODL ranged from 0% to 13.3%.[5-7,10-14,19,20] In the Liu et al. study,[10] 12 of 130 patients (9.2%) who underwent laminoplasty required revision surgery. Regarding long-term follow-up after ODL, a retrospective case series

Table 1. Clinical Data

Case Number	Age at the Initial ODL (years)	Sex	Initial Diagnosis	Duration from Initial to Revision (months)	Reason for Reoperation	Type of Reoperation	mJOA before Initial ODL	mJOA after Initial ODL	mJOA before Revision	mJOA after Revision	Complications of Revision Surgery
1	45	M	MCSM	8	Lamina closure	ODL	13	15	12	17	
2	65	M	OPLL	0.5	Expansion of wrong segments	SSL	9	9	9	13	Wound infection
3	67	F	CS	4	Lamina closure	ODL	9	12	10	13	
4	64	F	OPLL	15	Progress of primary compression	LCF	10	16	12	15	C5 palsy
5	44	M	OPLL	168	Adjacent segment compression	SSL	ND	ND	10	13	Dural tear
6	53	F	OPLL	72	Progress of primary compression	LCF	10	13	10	13	
7	47	M	OPLL	120	Progress of primary compression	LCF	8	13	11	13	
8	55	M	CS	3	Lack of open angle of the laminae	SSL	ND	ND	10	16	
9	49	F	OPLL	6	Lamina closure	ODL	13	15	12	16	Axial symptoms
10	72	F	MCSM	5	Lamina closure	ODL	11	15	11	15	
11	52	M	OPLL	4	Lamina closure	ODL	13	15	13	13	
12	53	M	MCSM	2	Lack of open angle of the laminae	ODL	ND	ND	9	17	
13	61	M	OPLL	1	Expansion of wrong segments	SSL	6	7	8	13	
14	48	F	CS	2	Lack of open angle of the laminae	ODL	ND	ND	13	15	Axial symptoms
15	59	M	MCSM	4	Lamina closure	ODL	8	12	9	13	
16	66	F	OPLL	62	Adjacent segment compression	SSL	5	13	10	13	

CS, congenital stenosis; F, female; LCF, laminectomy and fusion; M, male; mJOA, modified Japanese Orthopaedic Association score; MCSM, multilevel cervical spondylosis myelopathy; ND, no data; OPLL, ossification of the posterior longitudinal ligament; ODL, open-door laminoplasty; SSL, single-segment laminectomy.

of 237 patients with an average of a 15-year follow-up period showed that only 5 patients (2.1%) required revision laminoplasty.[11] A study based on a national database found that the reoperation rate after ODL surgery for degenerative cervical disease from 2009 to 2014 was 7.93% (31/391).[20] In the current study, the reoperation rate was 5.39% (13/241), and there were 3 patients who underwent initial ODL in other hospitals and were transferred to our department for the revision surgery. The low revision surgery rate could be because the patients received the revision surgery at different hospitals, and hence the follow-up at the initial hospital was lost. In addition, the patients who experienced poor outcomes from their first operation might not be willing to receive the revision surgery.[13] To decrease the reoperation risk of ODL, early ODL was suggested before the deterioration of cervical myelopathy symptoms.[21]

Reasons for Revision Surgery

Patients would receive revision surgery after ODL mainly because of aggravating neurologic symptoms[10,11] and postoperative complications such as wound infection and seroma.[19,20,22] Liu et al.[10] classified the reasons into 3 categories, including technical

Table 2. Causes of Poor Expansion of the Spinal Canal

Etiologies	Symptoms	Number of Patients (%)
Inadequate expansion degree of the spinal canal		
Lamina closure	recurrent myelopathic symptoms	6 (37.5)
Lack of open angle of the laminae	Inadequate symptomatic relief	3 (18.8)
Progression of primary compression	Recurrent or new-onset myelopathic symptoms	3 (18.8)
Improper expansion range of the spinal canal		
Expansion of wrong segments	Inadequate symptomatic relief	2 (12.5)
Adjacent segment compression	New-onset myelopathic symptoms	2 (12.5)

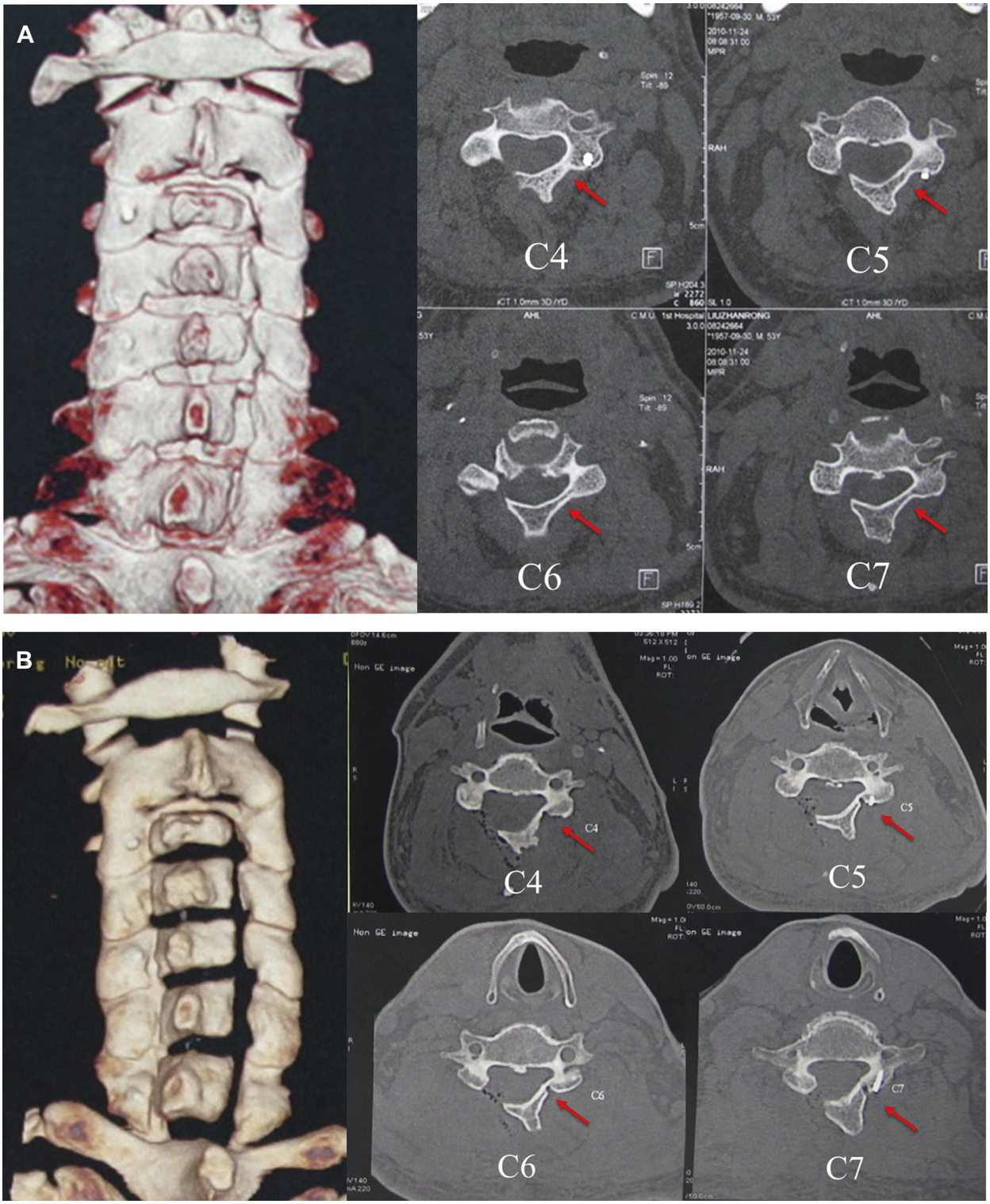

Figure 1. A 53-year-old man that underwent initial open-door laminoplasty (ODL) in another hospital admitted to our department 2 months later for revision surgery. (**A**) Three-dimensional (3D) computed tomography (CT) scan after the initial ODL showed the open angle of the laminae was not inadequate, and the *red arrows* show there was no trough in the hinge side. (**B**) 3D CT scan after the revision ODL showed the laminae opened well, and the *red arrows* show the trough in the hinge side.

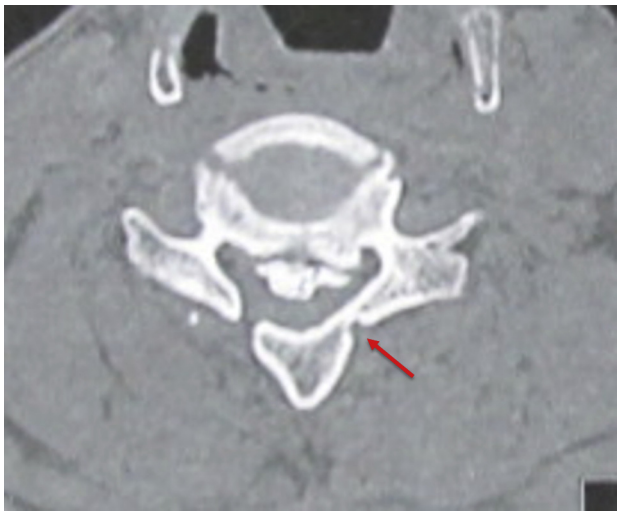

Figure 2. A 49-year-old woman with laminae closure that happened 6 months after the initial open-door laminoplasty. The *red arrow* shows the trough in the hinge side lamina.

problems (early new-onset postoperative symptoms), inadequate treatment (residual preoperative symptoms), and disease progression (late new-onset postoperative symptoms). Shigematsu et al.[11] reported 5 cases of revision surgery because of recurrent myelopathy or new-onset radiculopathy, and their findings on the causes of laminoplasty failure were similar to these of Liu et al.[10] In our study, the patients who underwent revision surgery were all because of their neurologic symptoms caused by poor expansion of the spinal canal, including inadequate expansion of the spinal canal and improper expansion of the spinal canal. Lamina closure, lack of open angle of the laminae, and progression of primary compression could lead to anteroposterior stenosis of the spinal canal; expansion of wrong segments and adjacent segment compression could cause improper expansion range of the spinal canal.

Lamina closure of the spinal cord after ODL could lead to restenosis of the spinal canal. Although numerous studies have reported the complications of lamina closure after laminoplasty, the degree of closure and the relationship between lamina closure and neurologic deterioration have not been elucidated.[5,6,9,23] Lamina closure was the most common reason for revision surgery in our study, but the lamina closure rate could be calculated because CT scan was not routine during the follow-up after ODL. In a study by Wang et al.,[9] they defined lamina closure as a 4-mm decrease in the anteroposterior spinal canal, and the lamina closure rate was 10% (3/30) among their patients in the 6 months after surgery. The postoperative neurologic deficit was associated with lamina closure.[9] In contrast, in the Matsumoto et al. study,[23] they retrospectively assessed 86 patients who underwent ODL and found that lamina closure occurred with a rate of 34%, and the

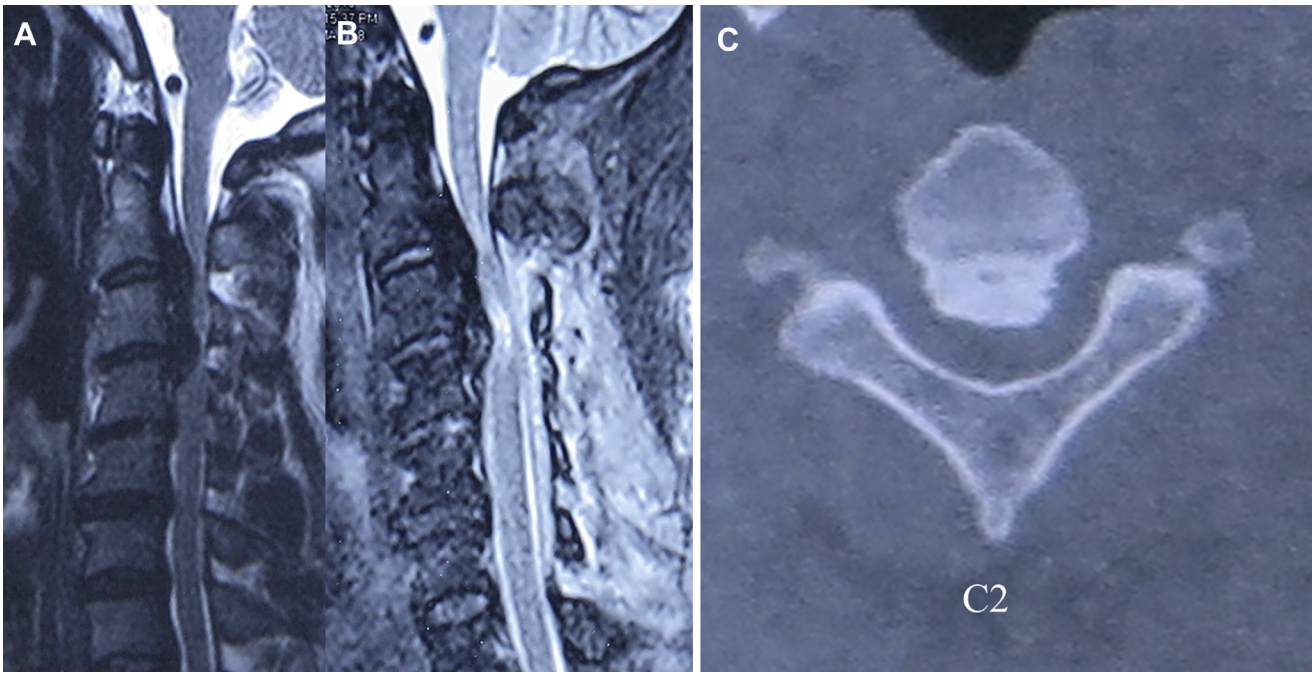

Figure 3. A 65-year-old man that underwent C3-6 initial open-door laminoplasty (ODL) received revision surgery of laminectomy of C2 2 weeks later because of expansion of the wrong segments: (**A**) magnetic resonance imaging (MRI) before the initial ODL, (**B**) MRI after the initial ODL, and (**C**) ossification of the posterior longitudinal ligament at C2.

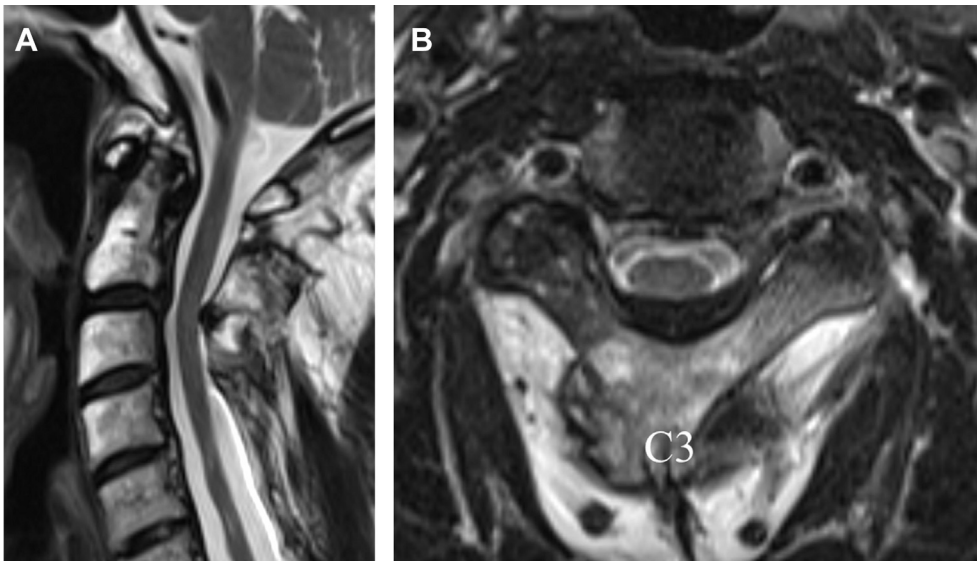

Figure 4. A 44-year-old man underwent revision surgery of laminectomy of C3 148 months after the initial open-door laminoplasty (ODL) because of adjacent segment compression: (**A**) magnetic resonance imaging after the initial ODL at 148 months and (**B**) hypertrophy of the ligamentum flavum at C3.

patients with lamina closure obtained equivalent recovery from myelopathy compared with those who did not have closure. To reduce the incidence of lamina closure, several modifications to Hirabayashi's original method have been reported, including the use of anchor screws, bone grafts, spacers, and titanium plates.[11,24] Further research is needed to clarify the revision surgery rate after lamina closure.

The opening angle of the lamina affects the effective volume of the spinal canal and the degree of spinal cord compression, which is closely related to postoperative outcomes. All patients that needed revision surgery because of a lack of the opening angle in our study received the initial ODL in other hospitals. Inadequate knowledge of the ODL technique might cause inadequate opening angle of the laminae. Another revision cause because of surgeons in our study is the expansion of wrong segments. Two cases underwent C3-6 ODL, and the C2 segment compression was not considered. In the Zhang et al. study,[25] they thought that the open-door angle should be maintained between 15° and 30°, which can improve neurologic function and reduce the incidence of C5 palsy and axial symptoms. Itoh and Tsuji[26] thought that the optimal distance between the laminae and dural sac was 4 mm. Our experience is that raising the lamina parallel to the posterior edge of the vertebral body could yield a satisfactory open-door angle, which is also easy to operate by surgeons.

Three patients in our study required revision surgery because of the progression of primary compression. Two patients required revision surgery because of adjacent segment compression, and they underwent revision surgery 5–14 years after the initial surgery. In a recent review of 11 studies involving 429 patients that underwent laminoplasty, the prevalence of radiologic OPLL progression was 62.5% after laminoplasty in the long-term follow-up, but it did not present significant clinical deterioration.[27] Only a few studies have described adjacent canal stenosis after laminoplasty, and the authors considered that the adjacent canal stenosis was caused by biomechanical changes attributable to elevation of the lamina[11,28,29] and the decreased cervical range of motion over time after ODL.[30]

Procedure of Revision Surgery

Surgical strategies for the revision procedure after a laminoplasty procedure include the anterior approach and posterior approach. However, because of the low incidence of reoperation, it is difficult to compare the efficacy of the 2 procedures. Komura et al.[13] thought that it was essential to obtain direct anterior decompression and to restore the stability of the cervical spine. They chose anterior cervical discectomy and fusion as the revision procedure for all 6 patients, and the results showed anterior cervical discectomy and fusion was effective for failed laminoplasty.[13] The 11 patients in the Kawaguchi et al. study[12] underwent anterior decompressive surgery (ADS) as revision for cervical OPLL after laminoplasty; the results showed that the JOA score improved in all patients after ADS. The authors thought that a second surgery of ADS could be considered as a salvage procedure after ODL.[12] Shigematsu et al.[11] conducted the revision surgery by a posterior approach in 6 patients and reported satisfactory outcomes. In our department, the patients underwent the initial ODL with the indication of MCCM caused by OPLL, disk herniation, or spinal stenosis. Considering the nature of poor expansion of the spinal canal, we chose the posterior approach for revision because the anterior approach has shown higher complication risks and certain difficulty. ODL was applied for cases with a lack of open angle of the

laminae and lamina closure. LCF was applied for cases with progression of primary compression, and laminectomy of the responsible lamina was applied for cases with expansion of wrong segments and the adjacent segment compression. The patients showed certain recovery of neurologic function as assessed by the JOA. In addition, we suggest that for OPLL occupying >50% of the spinal canal in the cross section or patients with a long course of disease, LCF is preferred for revision surgery.

Limitations

First, this is a retrospective study. The follow-up of some patients with deteriorating symptoms who need revision surgery may be lost; hence, the rate of revision surgery may not be precise. Second, the rate of lamina closure and that of OPLL progression could not be defined because CT scan was not routine during the follow-up after ODL. In addition, it is necessary to compare the efficacy of the posterior approach with ADS or other treatment modalities as revision procedures.

In conclusion, in this study, the patients who underwent revision surgery were all because of the poor expansion of the spinal canal. The causes of the poor expansion included inadequate expansion degree of the spinal canal (lamina closure, lack of open angle of the laminae, and progress of primary compression) and wrong expansion range of the spinal canal (expansion of wrong segments and adjacent segment compression). Posterior revision approaches such as ODL, LCF, and laminectomy of responsible lamina could guarantee fine clinical results.

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Conflict of interest statement: This study was supported by the National Key Research and Development Program of China (2017YFC1104903).

Received 25 April 2019; accepted 28 May 2019

Citation: World Neurosurg. (2019) 130:e90-e97.
https://doi.org/10.1016/j.wneu.2019.05.240

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

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1878-8750/$ - see front matter