The impact of plating level on the postoperative loss of cervical lordosis in alternative skipped-level plating laminoplasty

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Abstract

Purpose: The aim of this study is to evaluate the impact of plating level on the loss of cervical lordosis (LCL) after laminoplasty with skipped-level plating. Methods: This retrospective study included patients who underwent alternative skipped-level plating laminoplasty from C3 to C6. Patients were divided into two groups according to the plating level. Group 1 had miniplate fixed at C3 and C5 (C3/C5 group), while patients in group 2 were fixed at C4 and C6 (C4/C6 group). The outcome of interest was the difference of LCL between the two groups; meanwhile, kyphosis development after laminoplasty was also compared. Results: A total of 70 patients were included in our study with a mean age of 60.44 ± 9.97 years. The median follow-up was 15 (12, 16) months. Median lordosis was 15.43° (9.35°, 22.23°) before surgery and 9.88° (4.15°, 18.94°) after, with a median LCL of 4.48° (0.66°, 8.11°). There were 17 patients in the C3/C5 group, whereas 53 patients in the C4/C6 group. While preoperative C2–C7 Cobb's angle was comparable between the two groups (15.32° (9.73°, 23.84°) vs. 15.51° (9.03°, 21.70°), p = 0.864), there were statistical differences regarding postoperative C2–C7 Cobb's angle (6.54° (2.49°, 16.42°) vs. 10.62° (5.89°, 18.85°), p = 0.006) and LCL (4.74° (4.17°, 12.03°) vs. 4.07° (1.89°, 6.69°), p = 0.034) between the C3/C5 group and the C4/C6 group. In all, 94.1% (16 of 17) of patients showed some degree of LCL after laminoplasty in the C3/C5 group, which was significantly higher when compared with 64.2% (34 of 52) of C4/C6 group (p = 0.038). Before surgery, there were no kyphosis patients in either the C3/C5 group or the C4/C6 group. Postoperatively, four patients (23.5%) developed kyphotic alignment in the C3/C5 group, but only one (1.9%) in the C4/C6 group (p = 0.013). Conclusions: Cervical alignment was compromised after laminoplasty. When alternative skipped-level plating is adopted in laminoplasty from C3 to C6, plating at C4/C6 may better preserve cervical lordosis than plating at C3/C5 after surgery.

Keywords

kyphosis, lordosis, loss of cervical lordosis, miniplates fixation, sagittal alignment, single-door expansive laminoplasty, skipped-level plating

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Introduction

Unilateral open-door laminoplasty, introduced by Hirabayashi et al.,¹ has been widely adopted by spinal surgeons and proved to be an effective surgical method for treating multilevel cervical degenerative disease.² In the original method described by Hirabayashi, hinge opening was maintained by stay sutures that anchored the spinous process to the capsule of facet joint.¹,² Although it
is simple and cost-effective, postoperative laminar reclosure has been reported to lead to renarrowing of the spinal canal and recurrence of symptoms. Since then, miniplates have been used as a more rigid fixation alternative to maintain laminae opening. Despite apparent clinical benefits, miniplates are costly, which can increase financial burden of patient’s family and society, especially in developing countries. To reduce medical expenses, skipped-level plating has been adopted in clinical practice. Recent studies showed that it is noninferior to all-level plating in terms of clinical and radiological outcomes for laminoplasty. Therefore, skipped-level plating has potential benefits in terms of saving costs as up to two plates per patient undergoing a standard C3–C6 laminoplasty may be omitted while still achieving similar clinical and radiological outcomes.

There are several morbidities following laminoplasty, one of which is postoperative loss of cervical lordosis (LCL). Postoperative development of sagittal malalignment after laminoplasty is associated with neurological dysfunction and neck pain. If the alignment changes after laminoplasty is associated with neurological dysfunction criteria were as follows: for laminoplasty from C3 to C6 were included. The inclusion criteria were as follows:

1. Diagnosis of cervical spondylotic myelopathy (CSM) or ossification posterior longitudinal ligament (OPLL).
2. No previous history of cervical spine surgery.
3. No structural spinal deformity.
4. The most cranial level of decompression was C3 and the most caudal level of decompression was C6.
5. Alternative skipped-level fixation of miniplates either at C3/C5 or at C4/C6.

Patients having other accompanied conditions such as trauma, tumor, and infection were excluded; meanwhile, laminoplasty anchored by full-level miniplate fixation or stay sutures was also excluded from this study. Finally, a total of 70 patients who fulfilled the study criteria were enrolled in the analysis.

Materials and methods

This study was a retrospective clinical study and was approved by the Nanfang Hospital, Southern Medical University Institutional Review Board. Consent to participate was obtained from the participants. The medical records and radiological imaging studies of patients who underwent single-door expansive laminoplasty between 2010 and 2016 in Nanfang Hospital Southern Medical University were retrospectively reviewed. To homogenize patient characteristics and standardize surgical procedure, only patients who underwent alternative skipped-level plating for laminoplasty from C3 to C6 were included. The inclusion criteria were as follows:

1. Diagnosis of cervical spondylotic myelopathy (CSM) or ossification posterior longitudinal ligament (OPLL).
2. No previous history of cervical spine surgery.
3. No structural spinal deformity.
4. The most cranial level of decompression was C3 and the most caudal level of decompression was C6.
5. Alternative skipped-level fixation of miniplates either at C3/C5 or at C4/C6.

Surgery procedures

Surgeries were performed using the same protocols that were first described by Hirabayashi et al. During surgery, the C2 and C7 paraspinal muscles were preserved as much as possible. The interspinous ligaments were also preserved during dissection. Interspinous ligament was cutoff in C2/3 and C6/7, while ligamentum flavum at these segments was cut only on the open side to the midline. The side with more symptoms was used as the opening side. A high-speed spherical burr or ultrasonic osteotome with a 2-mm blunt tip was used to open the lateral margin of the lamina on the open side; then, the dorsal cortex and cancellous bone on the other lateral margin of lamina were removed to make the gutters on the hinge side. After elevating the open side of the laminae, appropriate sized plates (CENTERPIECE Plate Fixation System, Medtronic Sofamor Danek, Inc., Memphis, TN, USA) were selected with two laminar and two lateral mass screws inserted per plate. All patients had two alternative levels plated, decision of whether to plate on C3/C5 or C4/C6 was based on the surgeons’ intraoperative assessment and preference. The nonplated segments were sutured to the adjacent plated laminae using nonabsorbable suture at the base of spinous processes to prevent lamina closure. The patient’s neck was immobilized externally using a collar for 3–4 weeks.

Radiological measurements

Enrolled patients were divided into two groups: those plated at C3/C5 and C4/C6. Cervical lateral radiographs were taken in the neutral standing position preoperatively and at 3 and 6 months postoperatively as well as at final follow-up. Cervical alignment was obtained by measuring C2–C7 Cobb’s angle in a picture archiving communication system. The C2–C7 Cobb’s angle is defined as the angle between two lines perpendicular to the lower endplates of C2 and C7, as shown in Figure 1. Kyphosis is defined as C2–C7 Cobb’s angle <0°; thus, the positive value of C2–C7 Cobb’s angle means lordosis and the negative value means kyphosis. Change of cervical alignment was calculated with the following formula: alignment
recorded and compared between the two groups. The incidence rates of patients who suffered LCL and the percentage of patients who developed postoperative kyphosis alignment were also developed postoperative kyphosis alignment were also developed postoperative kyphosis alignment were also developed postoperative kyphosis alignment were also.

The main interest of outcomes was the difference in LCL incidence rate of patients who suffered LCL and the percentage of patients who developed postoperative kyphosis alignment were also recorded and compared between the two groups.

**Statistical methods**

Data were imported into SPSS (version 22.0; SPSS Inc., Chicago, Illinois, USA) and tested for normality by using Shapiro–Wilk test. Normal distribution values such as patient age were presented as the mean \( \pm \) standard deviation and compared between the two groups using independent \( t \)-test, while non-normal data, including follow-up time, preoperative C2–C7 Cobb’s angle, and LCL, were presented as median and interquartile ranges. The preoperative C2–C7 Cobb’s angle and LCL were compared between the two groups using Mann–Whitney \( U \)-test. Linear mixed model was employed to compare postoperative C2–C7 Cobb’s angle between the two groups, where postoperative C2–C7 Cobb’s angle is taken as a dependent variable, time as a random variable, treatment as a fixed effect and preoperative angle as a covariate. The incidence rate of patients who suffered LCL and the percentage of patients who developed postoperative kyphosis alignment were also recorded and compared between the two groups by utilizing \( \chi^2 \) test. Statistical significance was set at \( p < 0.05 \).

**Results**

A total of 70 patients were included in the present study. Our study population consisted of 54 male patients and 16 females with ages ranging from 37 years to 78 years. The mean age was 60.44 \( \pm \) 9.97 years. Of those, 62 patients were diagnosed as CSM, while the other 8 as OPLL. The median follow-up time was 15 (12, 16) months (ranging from 6 months to 59 months). Before surgery, all patients had lordotic sagittal alignment. In the group as a whole, the median C2–C7 Cobb’s angle was 15.43° (9.35°, 22.23°) before surgery; however, after laminoplasty, the median C2–C7 Cobb’s angle reduced to 9.88° (4.15°, 18.94°), with the median LCL of 4.48° (–0.66°, 8.11°).

According to plating levels, patients were divided into two groups. Of those, 17 patients were plated at C3/C5 and the other 53 at C4/C6. No significant difference was noticed in terms of demography data, baseline radiological measurements and follow-up time between the two groups. Patient characteristics are summarized in Table 1.

Table 1. Comparisons of demographics and preoperative clinical and radiological data between the C3/C5 group and the C4/C6 group.

|                          | C3/C5 group | C4/C6 group | \( p \) Value |
|--------------------------|-------------|-------------|--------------|
| Number of patients       | 17          | 53          | n/a          |
| Age at surgery (years)*  | 60.65 ± 10.65 | 60.38 ± 9.84 | 0.923\textsuperscript{b} |
| Gender (male/ female)    | 13/4        | 41/12       | 0.940\textsuperscript{c} |
| Diagnosis (CSM/ OPLL)    | 15/2        | 47/6        | 0.960\textsuperscript{c} |
| Follow-up time (months)\textsuperscript{d} | 15 (10, 19) | 15 (12, 16) | 0.815\textsuperscript{a} |
| Preoperative C2–C7 Cobb’s angle (°)\textsuperscript{e} | 15.32 (9.73, 23.84) | 15.51 (9.03, 21.70) | 0.864\textsuperscript{a} |

CSM: cervical spondylotic myelopathy. OPLL: ossification posterior longitudinal ligament.

\*Data presented as mean \( \pm \) standard deviation.

\textsuperscript{a}Independent \( t \)-test.

\textsuperscript{b}\( \chi^2 \) test.

\textsuperscript{c}Data presented as median (interquartile ranges).

\textsuperscript{d}Mann–Whitney \( U \)-test.

In the C3/C5 group, the median C2–C7 Cobb’s angle after surgery is 15.32° (9.73°, 23.84°) and 6.54° (2.49°, 16.42°) after, with a median LCL of 4.74° (4.17°, 12.03°). In the C4/C6 group, the median C2–C7 Cobb’s angle before surgery is 15.51° (9.03°, 21.70°) and 10.62° (5.89°, 18.85°) after, with a median LCL of 4.07° (–1.89°, 6.69°). While the preoperative C2–C7 Cobb’s angle is comparable between the two groups (\( p = 0.864 \)), there are statistical differences regarding postoperative C2–C7 Cobb’s angle (\( p = 0.006 \)) and LCL (\( p = 0.034 \)). In all, 94.1% (16 of 17) of patients showed some degree of LCL after laminoplasty in the C3/C5 group, which is
Table 2. Comparisons of postoperative outcomes between the C3/C5 group and the C4/C6 group at the final follow-up.

|                               | C3/C5 group | C4/C6 group | p       | Value  |
|-------------------------------|-------------|-------------|---------|--------|
| Postoperative C2–C7 Cobb's angle (°) | 6.54 (2.49, 16.42) | 10.62 (5.89, 18.85) | 0.006b |
| Average LCL (°)               | 4.74 (4.17, 12.03) | 4.07 (–1.89, 6.69)  | 0.034c |
| Incidence rates of LCL (%)    | 94.1% (16/17)   | 64.2% (34/53)      | 0.038a |
| Postoperative kyphosis (%)    | 23.5% (4/17)    | 1.9% (1/53)        | 0.0139 |

LCL: loss of cervical lordosis.
^aData presented as median (interquartile ranges).
^bLinear mixed model.
^cMann–Whitney U-test;
^dχ2 test.

Significantly higher when compared with 64.2% (34 of 52) in the C4/C6 group (p = 0.038). Before surgery, there were no kyphosis patients in either C3/C5 or C4/C6 group, post-operatively, four patients (23.5%) developed kyphotic alignment in the C3/C5 group, but only one (1.9%) in the C4/C6 group (p = 0.013). The comparisons of postoperative outcomes between the C3/C5 group and the C4/C6 group are summarized in Figure 2 and Table 2. Images of representative patients from each group are shown in Figure 3.

Discussion

Laminoplasty is a successful surgical procedure in the management of the properly selected patient with cervical compressive myelopathy and provides good surgical outcome for long-term follow-up.21 It generates a direct posterior decompression effect and an indirect anterior decompression effect resulting from the posterior shift of the spinal cord from the anterior compressive lesions with motion preservation. Laminoplasty has been considered ideally suited for multilevel disease due to its extensible approach.23

The traditional method for keeping the lamina opening is by sutures, but there is a risk of laminar reclosure, where recurrence of symptoms may occur.4,5 Hence, recent trends have adopted more rigid devices like miniplates for fixation to help prevent complications, such as loss of fixation, hinge fracture, and laminar closure.22 While plates fixation provides more rigid support and prevents lamina reclosure, allowing early return to cervical exercise,23 it was also associated with expensive medical costs. The cost-effectiveness benefits of routinely using plates in laminoplasty are still debatable.3,24

Recently, skipped-level plating has been reported to be an effective cost-saving strategy for laminoplasty surgery.9–12 Cheung et al. reported a cohort study comparing the outcomes between skipped-level and full-level plating for laminoplasty with an average follow-up of 5 years, they found that skipped-level and all-level plating for open-door laminoplasty yielded similar clinical and radiological outcomes. The authors declared that, with no perceivable superiority with full-level plating, the implications of cost reduction with less plates used became more impactful and should be considered during management planning.9 Wang et al. reported a 40% cost saving when using alternative level plating instead of full-level plating in laminoplasty. They concluded that laminoplasty with alternative levels center-piece miniplate fixation was a safe, effective, and economical surgical method for cervical compressive myelopathy with 5-year follow-up.10 In our department, we routinely performed alternative skipped-level plating laminoplasty to save health care costs, especially for patients without full medical insurance coverage. During operation, the nonplated laminae were sutured to the adjacent plated laminae at the base of the spinous process to form a unit, so that the plated segments could provide adequate support to uphold the nonplated segments to avoid laminar closure.

Sagittal malalignment is one of the widely reported complications that may be associated with pain and unsatisfied neurological function recovery.14,15,25 LCL after laminoplasty contributes to kyphotic alignment change, which prevents indirect decompression via posterior cervical spinal cord shift and leads to postoperative residual anterior compression of cervical spinal cord. In the literature, the rate of kyphosis reported after laminoplasty ranged from 6% to 9%.21 Sakai et al. reviewed data from 66 patients, 28 of whom underwent anterior decompression with fusion (ACF) and the other 38 underwent laminoplasty. Their results found postoperative cervical sagittal alignment and balance were maintained after ACF but deteriorated following laminoplasty.26 In our study, we reported a median LCL of 4.48° (–0.66°, 8.11°) in all

Figure 2. Preoperative C2–C7 Cobb’s angle, postoperative C2–C7 Cobb’s angle, and loss of lordosis (LCL) after surgery, represented as box and whisker plots. The results show that while preoperative C2–C7 Cobb’s angles are comparable, there are significant differences regarding postoperative C2–C7 Cobb’s angle and LCL between the two groups.
patients enrolled, and 7.1% of patients (5 of 70) developed kyphosis postoperatively. Such results were consistent with previous reports.

Various factors are found to be associated with kyphotic change after laminoplasty. The lordotic curvature of the preoperative alignment has been shown to be closely associated with postoperative alignment, with Suk et al. reporting that a lordosis angle of <10° affected postoperative kyphosis, while Choi et al. found 8.5° to be the optimal cutoff value of preoperative lordosis for predicting the development of postoperative cervical kyphosis. Besides preoperative lordosis, loss of lordotic curvature is generally considered to be the result of posterior muscular–ligament complex disruption, especially the detachment of C2 extensor insertions during laminoplasty procedure.

In the present study, we found that plating at C3/C5 caused more LCL after laminoplasty when compared with those plated at C4/C6. Meanwhile, in the C3/C5 group, 94.1% of patients lost a certain degree of cervical lordosis and 23.5% of patients developed postoperative cervical kyphosis, both of which were significantly higher than the C4/C6 group. Such results indicated the selection of plating levels, especially the most cranial level of plating might impact on the disruption of posterior muscular–ligament complex.
complex. Anatomically, the distal portion of the C2 lamina is dorsal to, overlaps, and partially blocks the cephalad portion of the C3 lamina.28 When plating at C3, some extra exposure might be needed to properly install the instrumentation, both the miniplate and screws. Furthermore, the position of the plate was suggested to be adjusted toward the superior portion of the lateral mass to avoid penetration of the screws into the subjacent facet joint.12 Therefore, some degree of the muscle attaching to C2 might need to be sacrificed. In contrast, plating at C4 could be performed with less disturbing of the C2 extensor muscle insertions. Therefore, the C4/C6 group might preserve more muscle insertion at C2 than the C3/C5 group. Based on the similar potential mechanism, previous study suggested cephalad vertebral undergoing laminoplasty was associated with postoperative kyphosis.29 Michael et al. demonstrated that beginning laminoplasty at the C3 level, rather than C4 level, accelerated the LCL.28

Recently, the peculiarity of the C2/C3 level in laminoplasty has drawn the attention of spinal surgeons.30 Anatomically, the space between the spinous processes of C2 and C3 is relatively narrow compared to others due to anatomical peculiarity of C2 spinous process, which may lead to bony impingement between the spinous processes of C2 and C3 during motion of the neck, especially after C3 laminoplasty which caused posteriorly shifted arch of C3. Miniplate could provide rigid support, wider open angle, and larger anteroposterior diameter of the vertebral canal compared with suture suspension12,23; therefore, in the C3/C5 group, the plated C3 lamina could exacerbate the impingement that might result in limited motion and cervical malalignment.

Also as we previously mentioned, cervical extensor that attached caudally at C2 is critical in terms of maintaining cervical lordosis. The rigid fixed and dorsally shifted posterior arch of C3 as well as the instrumentation installed on C3 may come into contact with or irritate the posterior neck muscles attached at C2, especially during neck motion, disturbing muscle exercise, and resulting in postoperative malalignment and limited motion. To eliminate impingement between C3 arch and C2 spinous process as well as extensor muscle, Lee et al. suggested performing laminectomy instead of laminoplasty for the C3 segment in cases requiring multilevel laminoplasty surgery involving C3, which could produce greater postoperative outcomes in terms of postoperative neck pain and ROM based on their study.31

Our study has a number of limitations, including those associated with its retrospective design. First, we presented our results after a relatively short period of follow-up, with a minimal follow-up of 6 months. However, in a recent study by Choi et al., they found that LCL after laminoplasty peaked in the first month. Some of the lordotic angles were restored in the third and sixth months, before reaching a plateau after the sixth month.16 Therefore, our results might still be able to represent the long-term outcomes. Second, clinical outcomes such as neck pain and neurological recovery were not evaluated in this study. However, as previously noted, cervical kyphosis changes have long been shown to be closely associated with neck pain scores and neurological outcomes.14,26 And the retrospective investigation of clinical outcomes would have a risk of recalling bias. Therefore, a further prospective study would be preferable to address the impact of plating level on clinical outcomes.

Conclusions
In this study, when retrospectively analyzed, the cervical alignment changes in patients who underwent alternative skipped-level plating laminoplasty from C3 to C6, and we also found that patients who were plated at C3/C5, with C3 as the most cranial level of plating, demonstrated significantly more LCL after laminoplasty when compared with those plated at C4/C6. The incidence of postoperative cervical kyphosis was significantly higher in the C3/C5 group. Therefore, for C3–C6 skipped-level plating laminoplasty, plating at C4/C6 may better preserve lordosis after surgery than plating at C3/C5.

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