

Clinical Article



The R-line: A New Imaging Index for Decision Making Regarding C2 Lamina Decompression in Cervical Ossification of the Posterior Longitudinal Ligament

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ABSTRACT

Objective: The optimal treatment modality for cervical ossification of the posterior longitudinal ligament (OPLL) including the C2 level remains controversial. Cervical laminoplasty is a widely accepted considering of advantages such as development of few postoperative complications, including kyphosis or neck pain. We encountered seven patients with postoperative disabilities resulting from incomplete decompression after undercutting of the C2 lamina. Based on this experience, we developed a new index to determine the degree of decompression in cervical OPLL—the rostral line (R-line).

Methods: Total of 79 consecutive patients who underwent posterior decompression of cervical OPLL were included in this study. Mean age at the time of operation, the C2-C7 cervical lordotic angle and OPLL thickness at the most stenotic level of the spinal canal, and preoperative/postoperative Japanese Orthopedic Association score was checked in these group. We compared the correspondence between the degree of C2 lamina decompression using the R-line and actual degree of decompression.

Results: In all patients, the R-line touched the upper half of the C2 lamina on preoperative magnetic resonance imaging (MRI). The C2-C3 local segment lordotic angle and maximal degree of spinal cord compression by OPLL were independently correlated to postoperative C2 cord shifting. This result indicates that the R-line is a valid indicator to determine the degree of C2 lamina decompression in OPLL extending to the C2 level.

Conclusion: The results showed that undercutting the C2 lamina can result in incomplete spinal cord decompression and poor clinical outcome if the R-line touches the upper half of the C2 lamina on preoperative MRI.

Keywords: Ossification of the posterior longitudinal ligament; Cervical spondylotic myelopathy; Laminoplasty

Conflict of Interest

The authors have no financial conflicts of interest.

INTRODUCTION

Ossification of the posterior longitudinal ligament (OPLL) can be defined as ectopic bone formation in the spinal ligament, resulting in spinal canal narrowing and consequent spinal cord compression.^{9,13)} OPLL mostly develops in the cervical spine but rarely extends to the C2 level.^{7,15)} The optimal treatment modality for cervical OPLL including the C2 level remains controversial.^{1,6,12,18)} Cervical laminoplasty is a widely accepted indirect decompressive surgery with advantages such as development of few postoperative complications, including postoperative kyphosis or neck pain.^{1,6,12)} Preservation of the cervical posterior extensor muscles is important to prevent neck pain and cervical lordosis loss following laminoplasty.^{16,17)} Therefore, posterior decompression of the C2 level is performed as undercutting of the C2 lamina to preserve the musculature attached to the C2 spinous process. We encountered seven patients with postoperative disabilities resulting from incomplete decompression after undercutting of the C2 lamina. Based on this experience, we developed a new index to determine the degree of decompression in cervical OPLL—the rostral line (R-line). In this study, we analyzed the association between preoperative radiographic factors and postoperative C2 cord shifting and evaluated usefulness of the R-line for determining the degree of C2 lamina decompression in OPLL extending to the C2 level.

MATERIALS AND METHODS**Patients and clinical assessment**

A total of 79 patients underwent posterior decompression of cervical OPLL between January 1999 and December 2017 in our institution. Of these, 7 patients (6 males and 1 female) who experienced postoperative neurologic deterioration due to incomplete C2 decompression were enrolled in this study. All patients were diagnosed with spinal cord compression of cervical OPLL extending to the C2 level, without spondylolisthesis or other instability. **TABLE 1** shows characteristics of the study patients. Mean age at the time of operation was 58.8 (51–73) years. Undercutting of the C2 lamina was performed in all patients at the first operation. Degree of spinal cord decompression was evaluated using postoperative magnetic resonance imaging (MRI). MRI revealed incomplete rostral decompression in all patients. Postoperative neurologic deterioration was checked by Japanese Orthopedic Association (JOA) score, mean value as 10.42 (10–11) preoperatively and 3 (2–4) postoperatively. In addition, the C2–C7 cervical lordotic angle and OPLL thickness at the most stenotic level of the spinal canal were measured on preoperative lateral plain radiographs and MRI, respectively (**FIGURE 1**).

Definition and evaluation of the R-line

We established the R-line on T2-weighted midsagittal MR images to determine the degree of rostral C2 lamina decompression in relation to the maximum degree of spinal cord

TABLE 1. Characteristics of the seven study patients

Characteristics	Mean (range)
Age at surgery (years)	58.71 (51.0–73.0)
Sex (male: female)	6:1
Preoperative JOA score	10.42 (10–11)
Postoperative JOA score	3 (2–4)
Preoperative C2–C7 lordotic angle (°)	15.28 (8–26)
Thickness of OPLL (mm)	5.75 (3.8–7.3)

OPLL: ossification of posterior longitudinal ligament, JOA: Japanese Orthopedic Association.

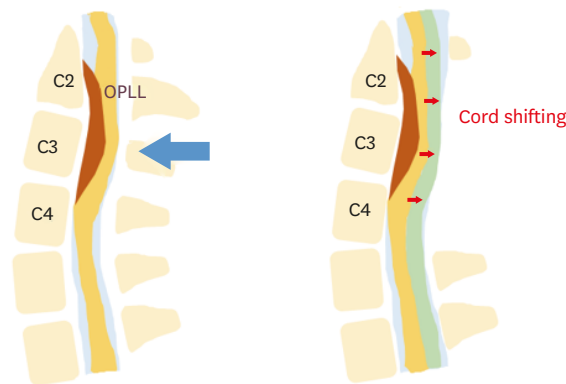


FIGURE 1. Schematic diagram of the postoperative state after total laminectomies of C2, C3, and C4 in cervical ossification of the posterior longitudinal ligament. After posterior decompression, the spinal cord shifts posteriorly similar to a bowstring.
OPLL: ossification of posterior longitudinal ligament.

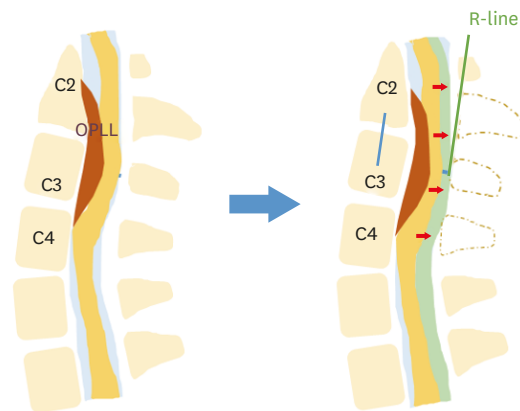


FIGURE 2. The R-line is defined as a line drawn through the posterior spinal canal parallel to the line connecting the center points of the C2 and C3 vertebral bodies at the level of maximum spinal cord compression.
OPLL: ossification of posterior longitudinal ligament, R-line: rostral line.

compression by OPLL and the local segment lordotic angle at C2-C3. The R-line was defined as a line drawn through the posterior spinal canal parallel to the line connecting the center points of the C2 and C3 vertebral bodies at the level of maximum spinal cord compression (**FIGURE 2**). We hypothesized that laminar bone and ligament touching the R-line should be removed and that total laminectomy at C2 is necessary if the R-line touches the upper half of the posterior C2 lamina (**FIGURE 3**).

Statistical analysis

Multiple linear regression analysis was performed to investigate the association between radiographic factors and postoperative C2 cord shifting. The value of $p < 0.05$ was considered statistically significant. All analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corporation, Armonk, NY, USA).

RESULTS

The R-line was retrospectively applied in seven patients with postoperative neurologic deterioration and incomplete posterior C2 cord decompression on postoperative MRI. In all

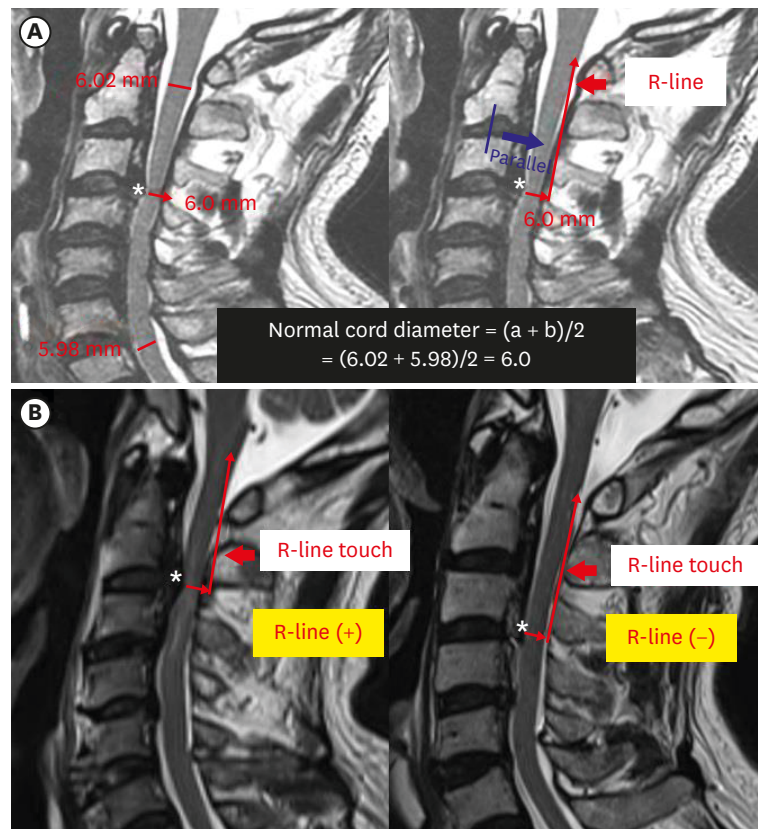


FIGURE 3. If the R-line touches the upper half of the posterior C2 lamina, total C2 laminectomy is necessary (R-line positive). In the R-line positive group, postoperative cord compression only through C2 undercutting results in neurologic deterioration due to incomplete decompression. R-line: rostral line.

patients, the R-line touched the upper half of the C2 lamina on preoperative MRI. **TABLE 2** shows the clinical and radiographic characteristics of the seven study patients. The C2-C3 local segment lordotic angle (unstandardized coefficient, 0.222; $p < 0.001$) and maximal degree of spinal cord compression by OPLL (unstandardized coefficient, 0.277; $p = 0.001$) were independently correlated to postoperative C2 cord shifting (**TABLE 2**). This result indicates that the R-line is a valid indicator of lamina bone and ligament that should be surgically removed.

TABLE 2. Clinical and radiologic characteristics of the seven study patients

Case	Sex	Age (years)	Diagnosis	Level	OPLL thickness at the most severe site (mm)	Operation modality	Preoperative JOA score	Postoperative JOA score	Preoperative C2-C7 lordotic angle
1	M	56	OPLL	C2-C4	3.8	Undercutting C2	10	3	3
2	M	64	OPLL	C2-C7	5.4	Undercutting C2	11	4	13
3	M	51	OPLL	C2-C6	6.2	Undercutting C2	10	3	14
4	M	51	OPLL	C2-C7	7.3	Undercutting C2	11	2	8
5	F	58	OPLL	C2-C4	5.6	Undercutting C2	11	3	18
6	M	58	OPLL	C2-C6	6.1	Undercutting C2	10	3	16
7	M	73	OPLL	C2-C5	5.9	Undercutting C2	10	3	12

OPLL: ossification of posterior longitudinal ligament, JOA: Japanese Orthopedic Association.

DISCUSSION

Cervical laminoplasty is widely performed in patients with cervical myelopathy with cervical stenosis of OPLL. Postoperative kyphosis can occur when the semispinalis muscles attached to the C2 spinous process are removed during surgery.^{16,20} Numerous studies have reported that preserving the posterior cervical muscles attached to the C2 spinous process reduces the risk of lordosis loss following laminoplasty.^{4,5,14,16,17,20} Based on this hypothesis, many surgeons undercut the C2 lamina to decompress the spinal cord and preserve the muscles.^{16,17} We used this strategy and experienced seven patients with cervical OPLL involving the C2 level who developed postoperative neurologic deterioration; all patients showed incomplete decompression on postoperative MRI. Therefore, we developed a new index, the R-line, to determine the degree of C2 laminar decompression by OPLL. The R-line is based on postoperative posterior spinal cord shifting after laminoplasty, which is related to improved clinical outcomes. In this study, we applied the R-line in all patients and showed that the R-line touched the upper half of the posterior C2 lamina in all cases.

After posterior decompression, such as laminoplasty, the spinal cord shifts posteriorly similar to a bowstring. Posterior spinal cord shifting distance after laminoplasty depends on several factors, including cervical sagittal alignment and space available for the spinal cord at the level of decompression.^{2,3,8,11,19} Cervical lordosis can affect posterior migration of the spinal cord.^{2,10,21,22} In this study, the C2-C3 local segment lordotic angle but not the C2-C7 lordotic angle was significantly correlated to postoperative spinal cord shifting at the C2 level. The C2-C3 local segment lordotic angle is thought to affect spinal cord shifting at the C2 level and is maintained after surgery. Our study showed that the maximal degree of spinal cord compression by OPLL and C2-C3 segmental lordosis angle were independently correlated to postoperative C2 cord shifting.

All patients who only underwent undercutting of the C2 lamina despite the R-line touching the upper half of the posterior C2 lamina showed an insufficient decompression on postoperative MRI and experienced poor clinical outcomes. This indicates that incomplete decompression with devastating neurologic deterioration will likely result if total laminectomy of C2 is not performed when the R-line touches the upper half of the posterior C2 lamina. In an attempt to preserve the muscles attached to the C2 spinous process, decompression of the C2 lamina should be considered carefully. Use of the R-line on preoperative MRI can guide decision making regarding undercutting the C2 lamina or performing total C2 laminectomy or muscle preserving laminotomy.

This study is a retrospective review with a relatively small sample size; further prospective studies in a larger cohort are warranted to validate the efficiency and accuracy of the R-line.

CONCLUSION

The results of the present study showed that undercutting the C2 lamina to preserve the semispinalis muscles can result in incomplete spinal cord decompression and poor clinical outcome if the R-line touches the upper half of the C2 lamina on preoperative MRI.

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