ORIGINAL ARTICLE

Outcomes of surgical intervention for cervical spondylotic myelopathy accompanying local kyphosis (comparison between laminoplasty alone and posterior reconstruction surgery using the screw-rod system)

Hiroshi Miyamoto · Koichiro Maeno · Koki Uno · Kenichiro Kakutani · Kotaro Nishida · Masatoshi Sumi

Abstract

Purpose The surgical strategy for cervical spondylotic myelopathy (CSM) accompanying local kyphosis is controversial. The purpose of the present study was to compare and evaluate the outcomes of two types of surgery for CSM accompanying local kyphosis: (1) laminoplasty alone (LP) and (2) posterior reconstruction surgery (PR) in which we corrected the local kyphosis using a pedicle screw or lateral mass screw.

Methods Sixty patients who presented with local kyphosis exceeding 5° were enrolled. LP and PR were each performed on a group of 30 of these patients; 30 CSM patients without local kyphosis, who had undergone LP, were used as controls. The follow-up period was 2 years or longer. Preoperative local kyphosis angles in LP and PR were 8.3° ± 4.4° and 8.8° ± 5.7°, respectively. Preoperative C2–7 angles in LP, PR and controls were −1.7° ± 9.6°, −0.4° ± 7.2° and −12.0° ± 5.6°, respectively. The recovery rate of the JOA score, local kyphosis angle and C2–7 angle at post-op and follow-up were compared between the groups.

Results The recovery rate of the JOA score in the LP group (32.6 %) was significantly worse than that in the PR group (44.5 %) and that of controls (53.8 %). Local kyphosis angles in the PR and LP groups at follow-up were 4.0° ± 8.6° and 8.0° ± 6.0°, respectively. However, although the C2–7 angle at follow-up was improved to −11.1° ± 12.7° in PR, and maintained at −11.6° ± 6.2° in controls, it deteriorated to 0.5° ± 12.7° in LP.

Conclusions The present study is the first to compare the outcomes between LP alone and PR for CSM accompanying local kyphosis. It revealed that PR resulted in a better clinical outcome than did LP alone. This result may be due to reduction of local kyphosis, stabilization of the unstable segment, and/or the maintenance of C2–7 angle until follow-up in the PR group.

Keywords Cervical spondylotic myelopathy · Kyphosis · Laminoplasty · Posterior reconstruction · Outcome

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Introduction

The surgical strategy for cervical spondylotic myelopathy (CSM) accompanying local kyphosis remains controversial. Uchida et al. [1] reported that outcomes of anterior decompression/fusion for CSM with local kyphosis with an angle of 10° or more were equivalent to those of laminoplasty (LP) alone for the same pathology at follow-up in their series of 43 patients, and the recovery rates of the Japanese Orthopaedic Association (JOA) score were acceptable in both groups. In their series, the local kyphosis angle of the anterior decompression/fusion group at follow-up

was still a mean of 9.2°, so the correction of the local kyphosis would appear to be somewhat mild. Chiba et al. reported that several patients obtained an acceptable clinical outcome after LP alone, even in the context of cervical kyphosis, and they speculated that the slack of the spinal cord, especially in patients showing reduction of multilevel disc height, should allow acceptable recovery [2]. On the other hand, several authors have insisted that the outcome of LP alone for CSM with local kyphosis was not acceptable [3, 4]. Baba et al. [3] reported that patients with preoperative kyphosis (mean of 11.7°) showed significantly poorer neurological improvement. Suda et al. [4] also reported that outcomes of LP for CSM accompanying local kyphosis with an angle exceeding 13° (when coexisted with myelomalacia) and 5° (without myelomalacia) were poorer than those for CSM without local kyphosis in their multivariate logistic regression analysis.

The general principle of mechanisms underlying neurological recovery by means of LP is direct posterior decompression and indirect anterior decompression of the spinal cord by posterior shifting of the cord; therefore, maintaining lordosis of the cervical spine is a basic requirement for obtaining a good clinical outcome after LP [5]. Hence, a surgical strategy in which posterior reduction of local kyphosis using a posterior screw system [6–10] is performed in addition to LP should be considered, as it has been reported that posterior instrumentation such as lateral mass screw and pedicle screw assures stronger fixation compared to anterior plating in biomechanical tests [11, 12]. However, there is no comparative study of the outcome between LP alone and posterior reconstruction surgery using a screw-rod system (PR) for CSM patients with accompanying local kyphosis. The purpose of the present study, therefore, was to clarify the efficacy of PR by comparing the clinical and radiological outcomes of LP in this multicenter retrospective study. Another concern in terms of local kyphosis is that the presence of spinal cord atrophy, which can occur at the beak of kyphotic deformity, may cause a worse clinical outcome than that in CSM patients who do not have local kyphosis. Shimizu et al. [13] have reported that progressive kyphosis of the cervical spine resulted in demyelination of nerve fibers and a decrease in the vascular distribution of the spinal cord. Therefore, a second purpose of the present study was to compare the outcomes between patients with local kyphosis and those without it.

Clinical objective and methods

We reviewed medical records of 1,615 patients who underwent posterior decompression surgery from 1999 to 2009 at three spinal institutes in Kobe, Japan (National Hospital Organization Kobe Medical Center, Kobe Rosai Hospital and Kobe University Hospital) and identified 60 CSM patients accompanying local kyphosis whose angle in lateral neutral radiograph taken in the sitting position was 5° or more (5°–29°, mean of 8.6°). We defined local kyphosis as the extent to which the angle was kept positive between lines crossing the posterior margin of the proximal and distal end vertebrae (e.g., C3–6 in Fig. 1). Among these patients, 30 patients had undergone PR (mean age 68.0 years, 19 males and 11 females) and 30 patients laminoplasty alone

Fig. 1 C2–7 angle (*solid line*) and local kyphosis angle (*dotted line, left*). The area of the spinal cord in axial view of magnetic resonance image (*black part, Right*)
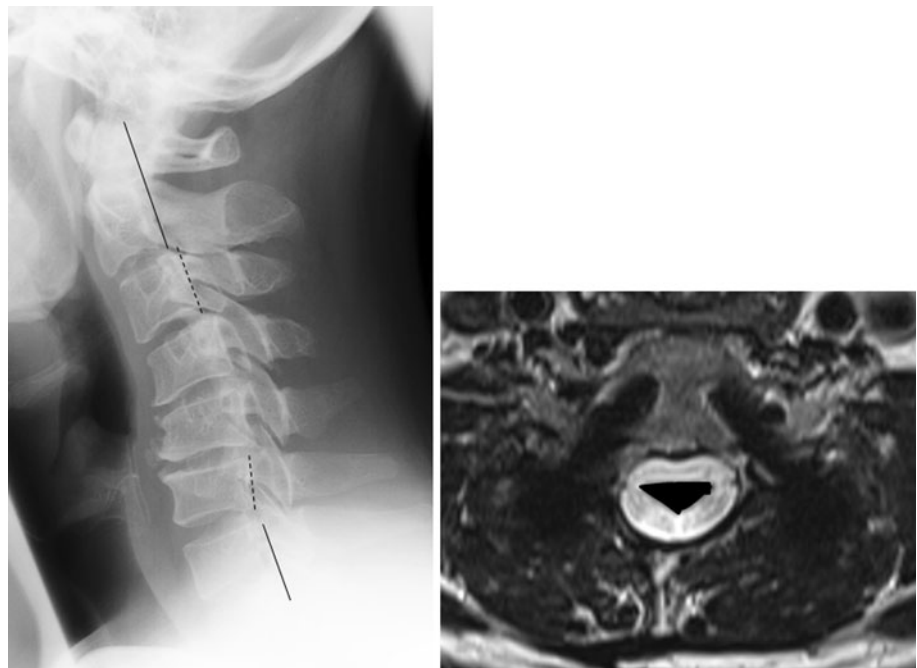
(mean age 69.2 years, 18 males and 12 females) (Table 1). Local kyphosis in the present study was taken to mean reducible kyphosis in which kyphosis could be reduced to zero or more degrees lordosis in lateral extension radiographs. Patients with irreducible kyphosis, local kyphosis exceeding 30°, cerebral palsy, ossification of posterior longitudinal ligament, rheumatoid arthritis, and those who had undergone a combination of anterior and posterior procedures were excluded from the study. Types of local kyphosis were divided into three groups: sigmoid, reverse sigmoid, and kyphosis [1] (Fig. 2). As controls, 30 CSM patients without local kyphosis who had undergone laminoplasty at the same period at the three institutes were randomly chosen by an independent clinical research coordinator (mean age 68.4 years, 17 males, 13 females) (Table 1).

In the PR group, 15 sigmoid, 9 reverse sigmoid, and 6 kyphosis were involved. We determined the extent of fusion as end-to-end of local kyphosis as follows: C2–C7:3, C3–7:1, C3–6:2, C3–5:7, C4–6:9, C4–5:5, C5–6:2, C7–T1:1. We tried to reduce the cervical alignment by adjusting a Mayfield skull holder immediately after general anesthesia using a lateral image intensifier, and when we got acceptable alignment, we performed in situ fusion. If we could not get acceptable alignment, we tried to correct the kyphosis using the Cantilever technique during surgery. Laminoplasty on suitable levels, normally from C3 to C6 or C7, was also carried out.

All laminoplasty procedures in this study were of the modified Kurokawa's method, in which mid-splitting of the spinous processes was performed using a T-saw [14, 15], separately at each local kyphosis level and the remaining part to minimize the possibility of harming the dura at the kyphotic beak. After spreading the split spinous processes, hydroxyapatite spacers were sutured as necessary between the opened spinous process at each level. The types of posterior fixation used in this study were PS for 12 patients and LMS for 18. The types of implant used were Olerud cervical system (Anatomica, Inc., Askim, Sweden) for 18 patients and Vertex MAX (Medtronic, Inc., Memphis, TN, USA) for 12 patients.

The same procedures were used in the LP group and in the controls; the splitting of all spinous processes which were to be decompressed using the T-saw were carried out simultaneously in controls. In LP group, types of local

Table 1 Clinical and radiological data of the patients from laminoplasty alone (LP), posterior reconstruction (PR), and controls at preoperation, postoperation, and final follow-up

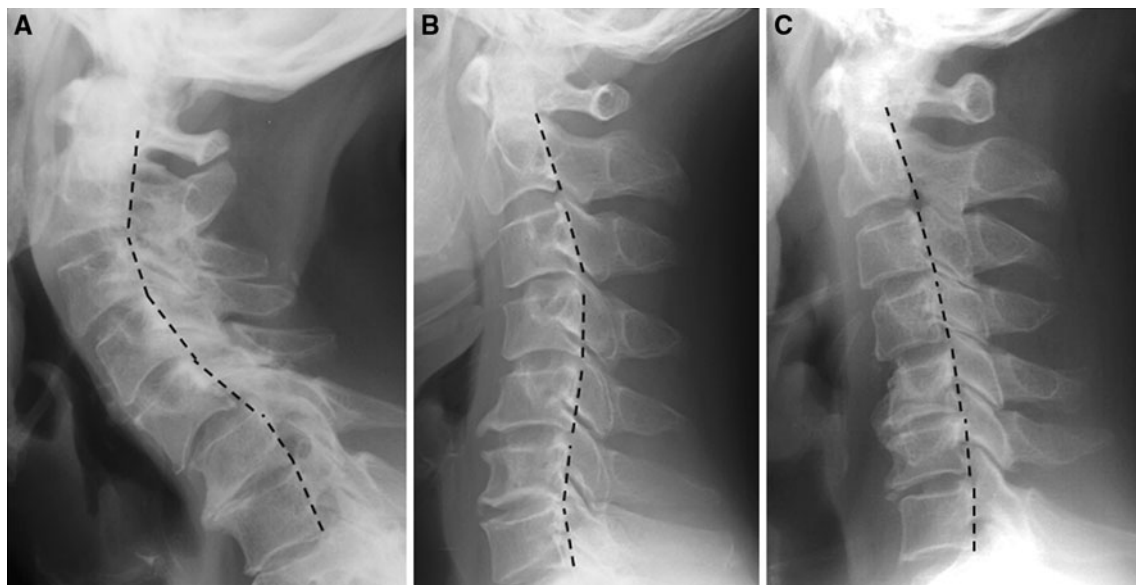|	Laminoplasty alone (LP)* (N = 30)	Posterior reconstruction (PR)¶ (N = 30)	Controls§ (N = 30)	P value
Age (years)	68.0	69.2	68.4	NS
Sex (M:F)	19:11	18:12	17:13	NS
Follow-up period (months)	37.9 ± 20.5	34.1 ± 17.3	34.3 ± 10.2	NS
Local kyphosis angle (°)				
Pre-op	8.3 ± 4.4	8.8 ± 5.7		NS
Post-op	8.2 ± 5.1	−2.3 ± 9.2		<0.05*,¶
Follow-up	8.0 ± 6.0	4.0 ± 8.6		<0.05*,¶
C2–7 angle (°)				
Pre-op	−1.7 ± 9.6	−0.4 ± 7.2	−12.0 ± 5.6	NS*,¶ <0.05*,§ <0.05¶,§
Post-op	−0.6 ± 8.7	−8.0 ± 11.1	−11.0 ± 4.8	<0.05*,¶ <0.05*,§ NS¶,§
Follow-up	0.5 ± 12.7	−11.1 ± 12.7	−11.6 ± 6.2	<0.05*,¶ <0.05*,§ NS¶,§
The JOA score (preop)	9.9 ± 2.6	9.2 ± 2.4	9.7 ± 2.5	<0.05¶,§
The JOA score (at follow-up)	12.3 ± 2.1	13.0 ± 2.0	13.8 ± 1.7	<0.05*,§
Recovery rate of the JOA score (%)	32.6	44.5	53.8	<0.05*,¶ <0.05*,§ NS¶,§
Area of the cord at follow-up (cm²)	0.56 ± 0.11	0.63 ± 0.16	0.63 ± 0.09	NS

Fig. 2 Classification of cervical local kyphosis: **a** sigmoid, **b** reverse sigmoid, and **c** kyphosis
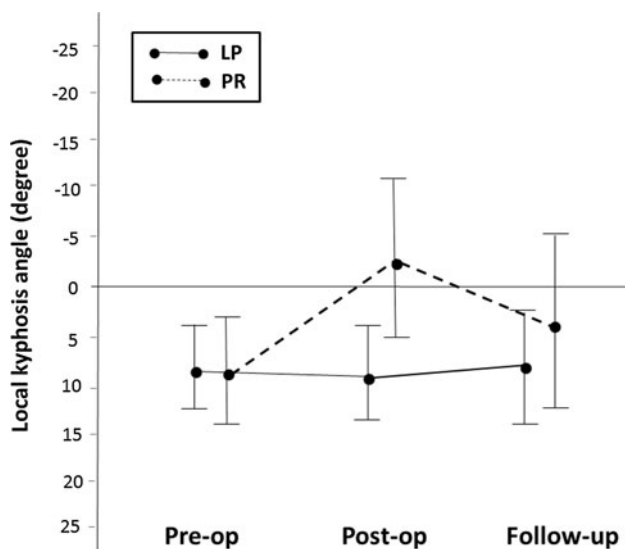

Fig. 3 Local kyphosis angle form laminoplasty alone (LP) and posterior reconstruction (PR) at preoperation, postoperation, and follow-up

kyphosis involved were: 18 sigmoid, 7 reverse sigmoid, and 5 kyphosis.

The follow-up period was 2 years or longer in each of the groups (34.1 ± 17.3 months in PR; 37.9 ± 20.5 in LP; 34.3 ± 10.2 in controls; Table 1).

Recovery rate of the JOA score at final follow-up, local kyphosis angle and the C2–7 angle preoperatively, post-operatively, and at final follow-up (from lateral radio-graphs) were compared between the groups. The area of the spinal cord at the beak of local kyphosis (from axial MRI) in LP and PR, and that at the causative level (the level of

myelomalacia if present, and if not, the narrowest level) in controls were also measured using ImageJ (version 1.44p, National Institute of Health, Washington DC, USA) at final follow-up (Fig. 1).

The Chi-square test was used for evaluation of gender difference between the groups. Student's t test was also used for evaluating age, local kyphosis angle, C2–7 angle, the JOA score, and the area of the spinal cord between the groups. In each statistical procedure, differences were considered significant at $p < 0.05$.

Results

The recovery rate of the JOA score for LP (32.6 %) was significantly worse than for PR (44.5 %) and for controls (53.8 %) with statistical significance. However, there was no significant difference in the recovery rate between PR and controls.

The local kyphosis angle in PR was reduced to −2.3° ± 9.2° postoperatively from 8.8° ± 5.7° preoperatively, with a mean correction angle of 11.1°. However, it decreased to 4.0° ± 8.6° at follow-up (Table 1; Fig. 3). In LP, the local kyphosis angle was maintained until follow-up (8.3° ± 4.4° preoperative, 8.2° ± 5.1° postoperative and 8.0° ± 6.0° at final follow-up; Table 1; Fig. 3). There was a statistically significant difference between LP and PR regarding local kyphosis angle at postoperation and at follow-up.

In terms of C2–7 angle, although the C2–7 angle at follow-up was improved from −0.4° ± 7.2° preoperatively to −11.1° ± 12.7° at follow-up in PR, and was maintained
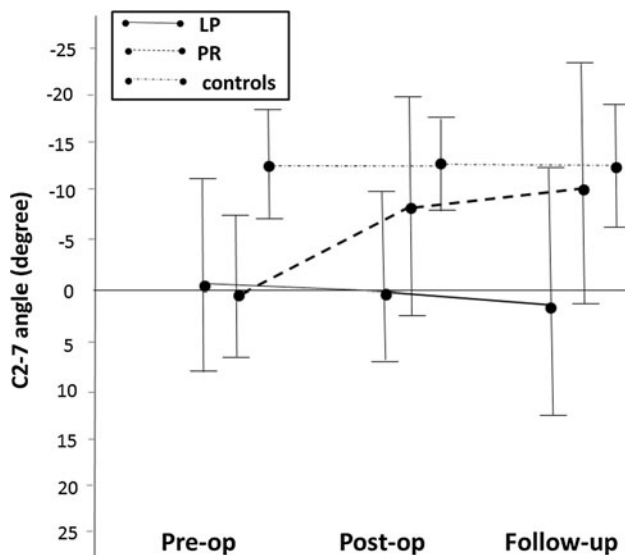
Fig. 4 C2–7 angle from LP, PR, and controls at preoperation, postoperation, and follow-up

as $-11.6° \pm 6.2°$ at follow-up in controls, it deteriorated from $-1.7° \pm 9.6°$ to $0.5° \pm 12.7°$ in LP (Table 1; Fig. 4). There was a statistically significant difference between LP and PR, and between LP and controls regarding C2–7 angle at follow-up (Fig. 4).

On the other hand, there was no significant difference regarding the area of the spinal cord at follow-up between the groups (0.56 ± 0.11 cm^2 in LP, 0.63 ± 0.16 cm^2 in PR, and 0.63 ± 0.09 cm^2 in controls; Table 1).

No additional surgery was needed in the present series due to complications.

Discussion

The present study is the first to compare outcomes between LP alone and PR using a screw-rod system for CSM accompanying local kyphosis. It has revealed that PR using a screw-rod system provided better clinical outcomes than LP alone for CSM with local kyphosis exceeding 5° (11.9 % better than LP alone in the JOA score with statistical significance). This result may be due to (1) reduction of local kyphosis and the subsequent maintenance of C2–7 angle until follow-up in the PR group and (2) fixing of unstable segment at the reducible local kyphosis.

Uchida and Kasai reported that the presence or absence of anterior or posterior subarachnoid space of the spinal cord in postoperative MR images was significantly correlated with the clinical outcome of LP [16]. Fujiyoshi et al. [17] also reported that when the K-line, which is the line between the mid-points of the spinal canal at C2 and C7 in lateral X-ray or MRI, touches the anterior compression such as OPLL (K-line (−) group), the surgical result was

significantly worse than for the K-line (+) group. Therefore, PR, in which realignment of local kyphosis using a posterior screw-rod system leads to maintenance of good whole cervical lordosis, is a logical procedure which can achieve not only posterior direct decompression but also anterior indirect decompression of the spinal cord by shifting it posteriorly. Despite several instances of loss of correction in the extent of local kyphosis, we obtained a good lordotic alignment of the whole cervical curvature at the follow-up, which was equivalent to that of the control group. We speculate that a mechanism for this may be as follows: (1) We tried to realign the end-to-end extent of the local kyphosis using posterior instrumentation, thereafter the whole cervical curvature theoretically gained lordosis immediately after surgery. Even though several instances of loss of correction occurred during the follow-up, it was better than nothing. (2) Some degree of realignment may accelerate recovery of the postural reflex to hold the neck erect. (3) Posterior decompression of thickened ligamentum flavum may play a precipitating role. These three processes may work synergistically in obtaining a good radiological outcome.

On the other hand, the fusing of the unstable segment of the reducible local kyphosis is another possible explanation of our results. Yagi et al. [18] reported that 16 of 71 compressive myelopathy patients who underwent conventional LP exhibited postoperative expansion of a high signal intensity area in T2-weighted MR images, and the clinical outcome was significantly worse in such patients. They reported that cervical instability was a risk factor for such expansion and suggested that surgical treatment should include a fusion procedure along with cervical LP [18]. In the present study, the local kyphosis was still reducible; therefore, fixing the unstable segment may have played a role in obtaining a better clinical outcome compared to LP alone.

The possibility of spinal cord atrophy due to local kyphosis was a concern. Morio et al. [19] observed a significant correlation between postoperative spinal cord atrophy and the final myelopathic symptoms in their series of conventional LP. In the present study, we did not find any significant difference in cord atrophy between those with and those without local kyphosis. That is, we can say that if we treat the CSM patients accompanying reducible local kyphosis whose angle was 5° or less with an adequate surgical procedure, we will be able to obtain an equivalent neurological recovery to that for conventional CSM patients.

The limitations of the present study should be noted. Sixty patients with local kyphosis exceeding 5° involved in the present series were all we experienced from 1999 to 2009. On the other hand, other 60 patients as controls were randomly picked up during the same period. This is a

retrospective comparative study; therefore, patients' selection could be a bias. Ideally, a prospective randomized control study will be needed in the future. However, the number of patients accompanying local kyphosis is small (3.7 % in this study); therefore, it would take very long time to acquire the data, so we believe this retrospective comparative study is worthy of being reported initially. Relatively small number of the patients and the selection of surgical procedures, which were dependent on the time of the surgery and the institute, are also the limitations.

In conclusion, it has been shown that PR provided better clinical outcome than LP alone for CSM accompanying local kyphosis.

Conflict of interest None of the authors has any potential conflict of interest.

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