Shinji Kimura
Fumio Gomibuchi
Haruka Shimoda
Yoshiyasu Ikezawa
Hiroyuki Segawa
Fujio Kaneko
Seiji Uchiyama
Takao Homma

Boomerang deformity of cervical spinal cord migrating between split laminae after laminoplasty

Received: 16 September 1999
Revised: 6 December 1999
Accepted: 16 December 1999

S. Kimura¹ (✉) · S. Uchiyama
T. Homma
Department of Orthopedic Surgery,
Niigata University School of Medicine,
1–757 Asahimachi-dori,
Niigata-shi, 951–8510 Japan
e-mail: kimuras@med.niigata-u.ac.jp,
Tel.: +81-25-2272272,
Fax: +81-25-2270782

F. Gomibuchi · H. Shimoda · Y. Ikezawa
H. Segawa · F. Kaneko
Department of Orthopedic Surgery,
Mito Saiseikai General Hospital,
Futabada, Mito-shi,
Ibaragi, 311–4198 Japan

Present address (till August 2001)
¹ Department of Orthopaedics,
University of California, San Diego,
350 Dickinson Street,
8894 San Diego, CA 92103, USA
e-mail: skimura@ucsd.edu,
Tel.: +1-619-5437441,
Fax: +1-619-5432540

Abstract Patients with cervical compression myelopathy were studied to elucidate the mechanism underlying boomerang deformity, which results from the migration of the cervical spinal cord between split laminae after laminoplasty with median splitting of the spinous processes (boomerang sign). Thirty-nine cases, comprising 25 patients with cervical spondylotic myelopathy, 8 patients with ossification of the posterior longitudinal ligament, and 6 patients with cervical disc herniation with developmental canal stenosis, were examined. The clinical and radiological findings were retrospectively compared between patients with (B group, 8 cases) and without (C group, 31 cases) boomerang sign. Moderate increase of the grade of this deformity resulted in no clinical recovery, although there was no difference in clinical recovery between

the two groups. Most boomerang signs developed at the C4/5 and/or C5/6 level, where maximal posterior movement of the spinal cord was achieved. Widths between lateral hinges and between split laminae in the B group were smaller than in the C group. Flatness of the spinal cord in the B group was more severe than in the C group. In conclusion, the boomerang sign was caused by posterior movement of the spinal cord, narrower enlargement of the spinal canal and flatness of the spinal cord.

Key words Cervical spine · Laminoplasty · Posterior cord migration · Surgical complication

Introduction

Cervical laminoplasty, for which there are three major methods – Z-shaped enlargement [4, 11], unilateral enlargement [2, 5, 8, 12, 20], and median enlargement [9, 15, 16] – is a useful method for surgical management of cervical myelopathy due to spinal canal stenosis [2]. Of these, Kurokawa's laminoplasty with median splitting of the spinous processes [15] has become the most widespread method in Japan, because it has certain advantages. The most critical advantage is the maintenance of physiological cervical lordosis through the preservation of the

posterior bony architecture. This procedure allows the cervical spinal cord to move posteriorly, and decompresses it by opening the laminae on both sides [15]. Some papers have reported satisfactory clinical outcome without serious operative complications using this procedure and its modification [17, 23].

However, we have already reported two cases of a curious complication after Kurokawa's laminoplasty [13]. We refer to this complication as a "boomerang sign", as it describes the boomerang shape of the cervical spinal cord caused by migration of the cord between the split laminae following Kurokawa's laminoplasty. The grade of the boomerang deformity progressed following surgery as

Table 1 Patient characteristics of boomerang group (*Dx.* diagnosis, *OPLL* ossification of the posterior longitudinal ligament, *CSM* cervical spondylotic myelopathy, *CDH* cervical disc herniation with developmental canal stenosis, *JOA* Japanese Orthopaedic Association score)

Case no.	Dx.	Age	Sex	Apex of lordosis	Most compressive level	Levels of boomerang sign	Grade of boomerang sign ^b (pre, post)	JOA pre	JOA post	Recovery rate
Case 1	OPLL	50	M	Straight ^a	C4/5	C4/5	3, 4	11	16	83
Case 2	CSM	67	F	C4/5	C4/5	C3/4-C5/6	2, 3	13	14	25
Case 3	CSM	59	M	C5/6	C4/5	C3/4-C5/6	3, 4	15	16	50
Case 4	CDH	40	M	C5/6	C5/6	C3/4-C5/6	2, 3	8	15	78
Case 5	OPLL	51	M	C3/4	C3/4	C3/4	3, 4	12	17	100
Case 6	CDH	59	M	C5/6	C4/5	C4/5, C5/6	3, 4	13	16	75
Case 7	CSM	62	M	C3/4	C5/6	C3/4, C4/5	2, 4	15	15	0
Case 8	OPLL	65	M	C5/6	C4/5	C4/5	3, 4	9	13	50

^aThe alignment of the cervical spine showed straight type

^bValue given is for the most compressive level among multiple levels of boomerang sign

compared to that observed preoperatively, regardless of changes in neurological symptoms. Subsequently, renewed neurological deficit developed postoperatively in the patients' upper extremities. In the previous report, we speculated that the boomerang sign resulted from posterior migration of the cervical spinal cord and from insufficient enlargement of the spinal canal at the apex of lordosis [13]. The purpose of this study was to clarify the mechanism underlying the boomerang sign and to further assess how to prevent it by comparing the cases demonstrating the boomerang sign with control cases, clinically as well as radiologically.

Fig. 1 Grading of boomerang sign using T1-weighted axial view of cervical spinal cord on magnetic resonance (MR) imaging (*T* transverse line connecting the bilateral margins of the cervical spinal cord, *S* sagittal line drawn through the center of the spinal cord, which was divided into four even parts)

Materials and methods

Patients

The study group was derived from 39 consecutive patients who had undergone Kurokawa's laminoplasty between 1991 and 1994.

Table 2 Criteria for evaluation of cervical myelopathy proposed by the Japanese Orthopaedic Association (JOA score) (*ADL* activities of daily living)

Upper limbs' ADL

- 0: Unable to feed oneself with either chopsticks or spoon
- 1: Able to feed oneself with a spoon but not chopsticks
- 2: Able to feed oneself with chopsticks, though awkwardly
- 3: Able to feed oneself regularly with chopsticks, but a bit awkwardly
- 4: Normal

Lower limbs' ADL

- 0: Unable to walk
- 1: In need of a cane or support even in walking on a level
- 2: In no need of a cane or support in walking on a level, but need one of them in climbing up stairs
- 3: In no need of a cane or support in either walking on a level or climbing up stairs, but awkward
- 4: Normal

Sensory disturbance of upper limbs

- 0: Definite sensory disturbance on physical examination
- 1: Slight sensory disturbance, or only numbness
- 2: None

Sensory disturbance of the lower limbs

- 0, 1 and 2 are the same as for the upper limbs

Sensory disturbance of trunk

- 0, 1 and 2 are the same as for the upper limbs

Urinary disturbance

- 0: Urinary incontinence
- 1: Severe dysuria or residual urine
- 2: Mild dysuria, i.e. pollakisuria or delayed start
- 3: Normal

These patients showed cervical compressive myelopathy, the diagnoses of which consisted of cervical spondylotic myelopathy (CSM, 25 cases), ossification of posterior longitudinal ligament (OPLL, 8 cases) and cervical disc herniation with developmental canal stenosis (CDH, 6 cases). The follow-up lasted an average of 27 months, ranging from 12 to 47 months. The series was composed of 34 men and 5 women. Their ages ranged from 28 to 72 years, with an average age of 58 years. The patients were retrospectively divided into two groups. The first was the boomerang group (B group, eight cases: CSM three cases; OPLL three cases; CDH two cases, Table 1), in which the cervical spinal cord had postoperatively migrated between the split laminae, demonstrating the boomerang deformity. The grade of this boomerang deformity progressed more significantly than the preoperative deformity. Grades were determined as follows (Fig. 1):

Grade 1: oval shape without anterior indentation of the spinal cord

Grade 2: mild boomerang shape with anterior indentation [transverse line (T), which connected to the bilateral margins of the cervical spinal cord, passed across the anterior second part in four divisions of the sagittal line (S), which was drawn through the center of the spinal cord]

Grade 3: moderate boomerang shape (T passed across the anterior first part in four divisions of S)

Grade 4: severe boomerang shape (T passed in front of S)

This grading was determined by two surgeons using the T1-weighted axial view on magnetic resonance (MR) images. The second group was the control group (C group, 31 cases: 22 CSM cases, 5 OPLL cases, and 4 CDH cases) and included boomerang

deformities of each grade. The grade of the deformity in this control group did not progress postoperatively as compared to the preoperative shape.

Surgical management and postoperative treatment

The original Kurokawa's procedure [15] was performed, except that we used variable-sized hydroxyapatite spacers (Bonecerum-P, Sumitomo, Japan), instead of autogenous bone, as spacers between the split laminae [16]. After surgery, the patients lay in bed for 10 days, then were allowed to ambulate with a cervical orthosis to immobilize the neck for 2 months.

Evaluation of clinical outcome

Clinical findings were evaluated according to the criteria for evaluation of treatment of cervical myelopathy of the Japanese Orthopaedic Association (JOA) [10] (Table 2). Recovery rate was calculated using the following formula according to Hirabayashi's method [6]: (Postoperative JOA–Preoperative JOA)/(17–Preoperative JOA) × 100% (Table 3).

Radiological evaluation of boomerang sign

To morphologically assess how this sign develops, radiological examinations were performed using pre- and postoperative plain radiographs, T1-weighted MR images (TE: 500, TR: 20, slice thick-

Table 3 Comparison between control (C) group and boomerang (B) group

$$\text{Recovery (Hirabayashi's method)} = \frac{\text{Postop score} - \text{Preop score}}{17 - \text{Preop score}} \times 100(\%)$$

	Unit	C group	B group	P-value
Clinical data				
Case no.		31	8	
Age		58 ± 12	57 ± 9	n.s.
Duration of symptom	Months	32 ± 43	20 ± 41	n.s.
Period of follow-up	Months	26 ± 10	29 ± 9	n.s.
Preop. JOA	Points	11 ± 2	12 ± 3	n.s.
Postop. JOA	Points	14 ± 2	15 ± 2	n.s.
Hirabayashi's recovery rate	%	59 ± 32	58 ± 33	n.s.
Radiological parameters				
Preop. angle of cervical lordosis (C2-C6)	Degree	17 ± 12	15 ± 4	n.s.
Postop. angle of cervical lordosis (C2-C6)	Degree	17 ± 10	13 ± 10	n.s.
Posterior movement of spinal cord				
C3/4	mm	2.6 ± 1.7	1.8 ± 1.8	n.s.
C4/5	mm	2.7 ± 2.2	1.0 ± 1.0	0.032
C5/6	mm	2.8 ± 2.2	1.6 ± 1.1	n.s.
C6/7	mm	2.7 ± 1.8	1.2 ± 1.6	n.s.
Width of spinal cord	mm	12.3 ± 2.2	12.0 ± 3.1	n.s.
Dural tube	mm	18.0 ± 2.0	17.9 ± 2.0	n.s.
Spinal canal	mm	22.8 ± 1.8	24.1 ± 1.6	n.s.
Flattening ratio ^a of spinal cord at most compressive level	%	29 ± 10	21 ± 9	0.027
Average flattening ratio of 3 consecutive levels ^b	%	35 ± 8	27 ± 6	0.015
Inner transverse diameter between lateral hinges	mm	21.3 ± 2.5	18.3 ± 1.9	0.003
Transverse diameter between split laminae	mm	13.0 ± 2.3	8.9 ± 1.5	0.0003

^aFlattening ratio: sagittal/transverse diameter

^bIncluding the cranial and caudal level adjacent to the most compressive level

Fig. 2 Radiological measurements using **A** preoperative computed tomographic myelogram, and **B** postoperative simple computed tomogram (ITDLH inner transverse diameter between lateral hinges, TDSL transverse diameter between split laminae)

ness: 6 mm, 0.5-T, SUPER, Toshiba, Japan), preoperative computed tomographic myelogram (CTM) and postoperative simple CT (window level: 150, window width: 1200, slice thickness: 5 mm, SPEED, Toshiba, Japan).

On the lateral view of cervical plain radiographs, the lordotic angle, which is a factor in obtaining posterior movement of the spinal cord after posterior decompression surgery [17], was measured between C2 and C6 in the pre- and postoperative states, as reported previously [21]. On MR images, the distance of the posterior movement of the spinal cord was determined by subtracting the preoperative distance between the anterior edge of spinal canal and the anterior margin of the spinal cord from the postoperative distance. Boomerang deformity of the cervical spinal cord was classified according to a four-grade scale in the pre- and postoperative states, as described above. The following parameters were measured on the preoperative CTM: width of the cervical spinal cord, dural tube and spinal canal; flattening ratio of the spinal cord (sagittal/transverse diameter $\times$ 100%) [21] at the most compressed level of the cervical spinal cord; and average flattening ratio of three consecutive levels, including the cranial and caudal level adjacent to the most compressed level (Fig. 2A). On postoperative simple CT images, furthermore, the inner transverse diameter between lateral hinges (ITDLH) and transverse diameter between split laminae (TDSL) were measured to evaluate the enlargement of the spinal canal (Fig. 2B). These measurements were all performed at intervertebral disc levels C3/4–C6/7.

All the measurements were carried out by one surgeon, except for grading of boomerang deformity, with a computed digitizer, and the results of three repeated measurements were averaged. Data were expressed as the mean $\pm$ SD, and the statistical differences were evaluated using the Mann-Whitney U test. A *P*-value of less than 0.05 was considered statistically significant.

Results

Cervical level causing boomerang sign

In three out of eight cases in the B group, the boomerang sign developed only at a single level (one at C3/4, two at C4/5). In the other five cases, it developed at multiple levels that varied from two to three levels. In total, the boomerang sign developed in an average of two levels in

the B group. Most boomerang signs developed at C4/5 and/or C5/6, which are apexes of cervical lordosis, the single exception being a case in which the boomerang sign developed at C3/4 (Table 1).

Comparison of clinical data and radiological parameters between the C group and the B group

There were no significant differences in the clinical data between the two groups in age, duration of symptoms from onset of illness, or period of follow-up. Interestingly, no significant differences were noted between the two groups with regard to pre- and postoperative JOA score or Hirabayashi's recovery rate [6]. However, one case (case 7 in Table 1), showing a two-grade increase of boomerang sign, resulted in no clinical recovery (Table 3).

As for radiological parameters, pre- and postoperative lordotic angles in the cervical spine in the B group were nearly equal to those in the C group on plain lateral radiographs. On MR images, the distance of the posterior movement of the spinal cord was at a maximum at C5/6 in the C group and at C3/4 in the B group. Moreover, that of the B group was approximately half that of the C group at all the cervical levels. In particular, the posterior movement at C4/5 in the B group was significantly less than that in the C group. Five out of eight patients in the B group exhibited increase of the boomerang deformity from grade 3 to 4. Of the remaining cases, two exhibited increase of the boomerang deformity from grade 2 to 3, and one showed increase from grade 2 to 4 (Table 1). There were also variable grades of the boomerang deformity in the C group (preoperative grade 1: 2 cases, grade 2: 9 cases, grade 3: 11 cases, grade 4: 9 cases). Eighteen out of the 31 cases in the C group showed no change in grade. Of the other 13 cases, 10 showed decrease of the boomerang deformity by one grade, and 3 decreased by two grades. On preoperative CTMs, there was no significant difference in width of the spinal cord, dural tube and spinal canal between the two groups. Furthermore, flatness of the spinal cord at the most compressive level as well as at the three consecutive levels including the cranial and caudal levels adjacent to the most compressive level in the B group was more severe than that in the C group. On postoperative simple CT images, the inner transverse diameter between lateral hinges (ITDLH) and transverse diameter between split laminae (TDSL) in the B group were significantly smaller than those in the C group (Table 3).

Case study (case 7 in Table 1)

A 62-year-old farmer was admitted to our hospital because his grip power had decreased and the clumsiness of his hands had worsened on both sides. He had first noticed numbness in his left hand 10 years previously, and further numbness in his right hand 7 years

Fig.3 T1-weighted MR image of Case study, **A** prior to operation, and **B** 2 years and 2 months after operation (*a* sagittal view of the cervical spine; *b*, *c*, *d* axial view at C3/4, C4/5, C5/6)

before admission. However, he was capable of walking without difficulty and had no abnormal sensation in his lower extremities. Neurologically, deep tendon reflexes in his left biceps and triceps and his bilateral patellar tendons were exaggerated. Sensations of light touch and pin prick were diminished in the bilateral C6 and C7 dermatomes, with motor weakness of grade “good” in the wrist extensors, extensor digitorum communis and finger flexors. In contrast, there was no motor weakness in the lower extremities, and the patient had neither sexual nor urinary disturbance. JOA score was 15 out of a possible 17 points. He was diagnosed as having central cord syndrome according to the Crandall classification [1].

A plain radiograph showed multiple osteoarthritic changes at C3/4, C4/5 and C5/6. The sagittal view of the cervical spine on MR imaging demonstrated moderate spinal cord compression at C5/6 due to bulging of the disc and ligamentum flavum (Fig. 3Aa). The axial view at C3/4, C4/5 and C5/6 displayed grades 2, 2 and 1 boomerang deformity, respectively (Fig. 3Ab–d). Conventional Kurokawa’s laminoplasty [15] was performed using hydroxyapatite spacers. During the operation, neither cord injury caused by the air drill tip [22] nor abnormal hypotension that can cause transient ischemic damage of the cord was present [7]. Two years and 2 months after the operation, JOA score was unfortunately unaltered, although clumsiness in the bilateral hands improved slightly. During follow-up, neurological findings had not deteriorated further. On postoperative CT images, ITDLH and TDSL were 19 mm and 9 mm, respectively. On the postoperative sagittal view of the cervical spine, the spinal cord was well decompressed, but touched the posterior split lamina at C3 (Fig. 3Ba). Axial views at C3/4, C4/5 and C5/6 showed boomerang deformity grades of 4, 3 and 1, respectively (Fig. 3Bb–d). This patient showed a typical boomerang sign.

Discussion

Clinical significance of the boomerang sign

In this study, there was no significant difference in recovery rate between the B group and the C group. Is the

boomerang sign, therefore, significant clinically? In the previous report [13], both patients who showed typical boomerang deformity experienced moderate neurological deterioration in their upper extremities after Kurokawa’s laminoplasty. In this series, however, most cases resulted in a satisfactory recovery, although boomerang deformity increased by one grade. However, the one case (case 7 in Table 1) that showed a two-grade increase in boomerang deformity also showed no clinical recovery. Therefore, increase of boomerang deformity by only one grade may not be clinically significant. These results may support the idea that the recovery rate is dependent on by how much the grade of the boomerang deformity increases when the boomerang sign develops.

In addition, the boomerang sign in the two reported cases occurred immediately after surgery, or when the upright position was allowed at the 7th postoperative day. This may suggest that the boomerang sign becomes symptomatic when posterior movement of the cervical spinal cord is achieved more quickly. These considerations help us note the presence of the boomerang sign after Kurokawa’s laminoplasty, which is important because this sign has the possibility of precipitating poor clinical recovery or other neurological deficits, as reported previously [13].

Factors associated with the boomerang sign

The boomerang sign is caused by three major factors:

1. Posterior movement of the cervical spinal cord at the apex of cervical lordosis after Kurokawa’s laminoplasty

2. Insufficient transverse diameter between lateral hinges and opening of split laminae
3. Possible involvement of flatness in the cervical spinal cord

Posterior movement of the cervical spinal cord at the apex of cervical lordosis after Kurokawa's laminoplasty

Posterior movement of the cervical spinal cord after this procedure is essential for decompression of the spinal cord in patients with compressive myelopathy [9]. Shibata et al. [17] reported that the posterior movement of the center of the spinal cord varied from 1.3 mm to 3.3 mm after Kurokawa's laminoplasty, and was maximal at C4–6, which corresponded to the apex of the cervical lordosis. Yonenobu et al. [22] also demonstrated a maximum shift of the spinal cord at C5, with an average of 2.3 mm, after the unilateral laminoplasty devised by Itoh et al. [8]. Consistent with these data, the posterior movement at C5/6 in the C group was 2.8 ± 2.2 mm, and was maximal at all cervical levels (Table 3). However, the posterior movement at all the cervical levels in the B group was approximately half that of the C group. In particular, the posterior movement at C4/5 in the B group was significantly less than that in the C group. These findings can probably be explained as follows. The posterior movement of the spinal cord in the B group was restricted by insufficient enlargement of the spinal canal, although that in the B group would be expected to be the same as in the C group. In conclusion, this strongly suggests that posterior movement of the spinal cord is a possible trigger for the boomerang sign.

Insufficient transverse diameter between lateral hinges and opening of split laminae

In this study, not only the ITDLH, but also the TDSL in the B group was significantly smaller than in the C group. These data suggest that narrower enlargement of the spinal canal causes the boomerang sign.

It is controversial where lateral hinges should be made in this procedure; in other words, whether they should be overlapped at the facet joint or not. Iwasaki et al. [9] emphasized that lateral hinges should be overlapped at the medial third of the facet joints, since the clinical results of this procedure were better than those of the procedure in which the lateral hinges were placed just at the medial site of the facet joints. However, Uematsu et al. [21] advocated that lateral hinges be positioned just at the medial border of the facet joints, but should not be overlapped at the medial site of the facet joint, in order to prevent post-operative radiculopathy after laminoplasty. In the current study, the recovery rate of the C group, in which the ITDLH was larger than that in the B group, was not differ-

ent from that of the B group. This discrepancy may be explained as follows: the lateral hinges in the C group were placed approximately at the lateral margin of the spinal canal, while those of the B group were placed at the lateral margin of the dural tube, so the lateral hinges did not overlap the facet joint in either group. From our results, therefore, we cannot conclude whether the lateral hinges should be overlapped at the facet joint or not.

An additional question is, to what degree should split laminae be opened? Hase et al. [3] have devised ceramic laminae with which Kirta's laminoplasty [14] was performed. The transverse diameter of lateral gutters in their ceramic laminae, which determined the TDSL, varied from 12 to 14 mm. Subsequently, a reasonable enlargement (55.4% at C5) of the anteroposterior diameter of the spinal canal was achieved. In this study, the TDSL in the C group was 13.0 ± 2.3 mm. In contrast, that in the B group was 8.9 ± 1.5 mm. Together with Hase's data [3], a TDSL of less than 10 mm may not be enough to decompress the spinal cord. Alternatively, coexistence of both small ITDLH and small TDSL might be a risk factor for the boomerang sign. Collectively, narrower width between lateral hinges and split laminae may not only cause insufficient decompression of the spinal cord, but may also result in the boomerang sign.

Possible involvement of flatness in the cervical spinal cord in boomerang sign

Animal experiments have demonstrated that multiple compressions of the spinal cord caused more severe deterioration functionally and electrophysiologically as well as histologically than a single compression [18]. Therefore, multiple compressive state of the spinal cord appears to have potent neural vulnerability. In a previous report, we discussed the possibility that flattened deformity of the spinal cord due to severe spinal canal stenosis, such as OPLL, may cause the boomerang sign. Indeed, the flattening ratio at the most compressive level, as well as the average flattening ratio of the three adjacent levels in the B group, was significantly lower than that in the C group. This result suggests that spinal cords with a flattened deformity may have a tendency to deform in the boomerang shape secondary to migration of the spinal cord between the split laminae, although it is unclear whether a multiple compression state of the spinal cord is necessary for eliciting the boomerang sign.

Prevention of boomerang sign

In order to prevent the boomerang sign, alternative surgical intervention such as laminectomy, perhaps with internal stabilization, may be considered in patients with cervical compression myelopathy. However, laminectomy

often results in malalignment of the cervical spine, such as kyphotic or swan-neck deformity [19], which may be more frequent than the boomerang sign. Further, if instruments are used to internally stabilize the cervical spine, renewed neurological deficit may develop due to technical complications related to instrumentation.

Posterior movement of the cervical spinal cord after laminoplasty and flatness of the spinal cord are common characteristics in patients with cervical compressive myelopathy. The position of the lateral hinges and opening of the split laminae are manually created by surgeons. Therefore, we must pay attention to this issue, since inadequate position of the lateral hinges or opening of split laminae may cause neurological deterioration, such as spinal cord lesion [13] or radiculopathy [21] after laminoplasty. Narrow width between lateral hinges appears to lead to the boomerang sign. Does this mean, however, that lateral hinges should be positioned more laterally? If these are positioned too laterally by overlapping the facet joints, direct neural damage of the nerve root or radiculopathy due to traction, tethering or kinking of the nerve root secondary to posterior shift of the spinal cord may develop [21]. Rough estimation of the position of the lateral hinges in the C group demonstrated only the lateral border of the spinal canal. This procedure showed no boomerang sign and satisfactory clinical outcome. Therefore, considering Uematsu's report demonstrating the prevention of

radiculopathy after laminoplasty [21], lateral hinges should be placed at the lateral margin of the spinal canal, in other words, just at the medial border of the facet joint. In addition, our data, together with Hase's data, suggest that a TDSL of less than 10 mm should be avoided, although too wide an opening of the split laminae should also be avoided to prevent radiculopathy after laminoplasty [21]. Finally, we would like to advocate that setting of lateral hinges and opening of the split laminae be planned precisely on the basis of preoperative CTM, because individual spinal canal size, anterior mass and subsequent deformities of spinal cord are variable.

Conclusions

In the current study, the boomerang sign was caused by the following three major factors: posterior movement of the spinal cord at the apex of the cervical lordosis; narrower width between lateral hinges and between split laminae; and flatness of the cervical spinal cord. To prevent this sign from occurring, the lateral hinges should be placed at the lateral margin of the spinal canal, and a TDSL of less than 10 mm should be avoided.

Acknowledgements We thank Gregory C. Steibach, Ph.D., for reading the manuscript.

References

1. Crandal PH, Batzdorf U (1966) Cervical spondylotic myelopathy. *J Neurosurg* 25:57-66
2. Ducker TB (1991) Cervical radiculopathies and myelopathies. In: John WF (ed) *The adult spine*. Raven, New York, pp 1187-1205
3. Hase H, Watanabe T, Hirasawa Y, Hashimoto H, Miyamoto T, Chatani K, Kageyama N, Mikami Y (1991) Bilateral open laminoplasty using ceramic laminas for cervical myelopathy. *Spine* 16:1269-1276
4. Hattori S (1978) Cervical myelopathy (in Japanese). *J Jpn Orthop Assoc* 52:581-593
5. Hirabayashi K, Watanabe K, Wakano K (1983) Expansive open-door laminoplasty for spinal stenotic myelopathy. *Spine* 8:693-699
6. Hirabayashi K, Satomi K, Sasaki T (1989) Ossification of the posterior longitudinal ligament in the cervical spine. In: Sherk HH (ed) *The cervical spine*, 2nd edn. JB Lippincott, Philadelphia, pp 678-691
7. Homma T, Uchiyama S, Yamazaki A, Katumi A, Okumura H (1993) Intra and post operative factors causing neurological deterioration in ossification of posterior longitudinal ligament of cervical spine (in Japanese). *Sekitsui Sekizui* 11:917-923
8. Itoh T, Tsuji H (1985) Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine* 10:729-736
9. Iwasaki Y, Ueta Y, Nishiyama S, Matuyama Y, Ishizaki Y, Masuhara K (1988) Extensive laminoplasty for OPLL of cervical spine (in Japanese). *Rinshou Seikeigeka* 23:517-522
10. Japanese Orthopaedic Association (1976) Criteria on the evaluation of the treatment of cervical myelopathy (in Japanese). *J Jpn Orthop Assoc* 50:Ad-denda 5
11. Kawai S, Sunaga K, Doi K, Saika M, Taguchi T (1988) Cervical laminoplasty (Hattori method): procedure and follow-up results. *Spine* 13:1245-1250
12. Kimura I, Oh-hama M, Shingu H (1984) Cervical myelopathy treated by canal-expansive laminoplasty. *J Bone Joint Surg Am* 66:914-920
13. Kimura S, Homma T, Uchiyama S, Yamazaki A, Imura K (1995) Posterior migration of cervical spinal cord between split laminae as a complication of laminoplasty. *Spine* 20:1284-1288
14. Kiritani Y, Miyazaki K, Lin T (1975) Posterior decompression in myelopathy due to ossification of the posterior longitudinal ligament (in Japanese). *Clin Orthop Surg* 10:1077-1085
15. Kurokawa T (1982) Enlargement of spinal canal with sagittal splitting of spinous process (in Japanese). *Bessatsu Seikeigeka* 2:234-240
16. Nakano K, Harata S, Suetsuna F, Araki T, Ito J (1992) Spinous process-splitting laminoplasty using hydroxyapatite spinous process spacer. *Spine* 17 [Suppl 3]:41-43
17. Shibata M, Sugiwaru O, Takemitsu Y, Harada Y, Netuta Y, Iwahara T (1988) Follow-up results and roentgenological studies of laminoplastic enlargement of the cervical canal by split spinous process method (in Japanese). *Rinshou Seikeigeka* 23:523-530

-
18. Shinomiya K, Mutoh N, Furuya K (1992) Study of experimental cervical spondylotic myelopathy. *Spine* 17: S 383–S 387
 19. Sim FH (1974) Swan-neck deformity following extensive cervical laminectomy. *J Bone Joint Surg Am* 56: 564–580
 20. Tsuji H (1982) Laminoplasty for patients with compressive myelopathy due to so-called spinal canal stenosis in cervical and thoracic regions. *Spine* 7: 28–34
 21. Uematsu Y, Tokuhashi Y, Matsuzaki H (1998) Radiculopathy after laminoplasty of the cervical spine. *Spine* 23: 2057–2062
 22. Yonenobu K, Hosono N, Iwasaki M, Asano M, Ono K (1991) Neurological complication of surgery for cervical compression myelopathy. *Spine* 16: 1277–1282
 23. Yoshida M, Otani K, Shibasaki K, Ueda S (1992) Expansive laminoplasty with reattachment of spinous process and extensor musculature for cervical myelopathy. *Spine* 17: 491–497