Posterior movement and enlargement of the spinal cord after cervical laminoplasty

Ikuo Aita, Koichiro Hayashi, Yasuyoshi Wadano, Takeshi Yabuki

From the University of Tsukuba, Ibaraki, Japan

We performed CT myelography in 38 patients with cervical myelopathy before and after laminoplasty to enlarge the canal. The sagittal and transverse diameters, the cross-sectional area, and the central point of the spinal cord were measured.

After cervical laminoplasty, the mean sagittal diameter of the spinal cord at C5 increased by 0.8 mm, but the mean transverse diameter decreased by 0.9 mm. The mean cross-sectional area of the cord increased by 7.4% and that of the dural sac and its contents by 33.8% at C5. The centre of the spinal cord moved a mean 2.8 mm posteriorly at this level.

Enlargement of the spinal canal is sufficient to decompress the spinal cord, but posterior movement may be the limiting factor in determining the decompressive effect of laminoplasty.

J Bone Joint Surg [Br] 1998;80-B:33-7.

Received 28 April 1997; Accepted after revision 8 July 1997

In patients with cervical myelopathy, anterior interbody fusion or laminoplasty is performed to expand the canal. In some cases, both anterior and posterior operations are done at the same time. We usually undertake laminoplasty for patients who have developmental spinal stenosis. There are many variations of the technique¹⁻⁷ and good clinical results have been reported for all of them. Our method is the 'open-door' type which uses the spinous processes as bone blocks, thereby requiring no additional theatre time for taking grafts from the iliac crest and avoiding the

complications of iliac-crest bone donor sites. Moreover, central laminar osteotomies to enlarge the spinal canal are very safe since the spinous processes have been previously resected.

After laminoplasty, the spinal cord is decompressed and also moves posteriorly (Fig. 1). Several studies have assessed the enlargement of the cord,⁸⁻¹³ but little is known about its posterior movement. The main factors affecting the clinical outcome after laminoplasty include the duration of symptoms,¹⁴⁻¹⁸ the degree of preoperative neurological impairment¹⁶ and age,¹⁴ but we did not consider the relationship between the changes in the spinal cord and the clinical result. Our aim was to investigate the enlargement and posterior displacement of the spinal cord.

Patients and Methods

We performed laminoplasty in 38 patients, 26 men and 12 women. Their mean age was 56 years (29 to 85) at the time of the operation. Nineteen patients had cervical myelopathy and 17 had ossification of the posterior longitudinal ligament. The remaining two had hypertrophy of the posterior longitudinal ligament and calcification of the ligamentum flavum.

The laminoplasty was performed from C3 to C7 in 36 patients, from C3 to T2 in one, and from C2 to T2 in one.

Operative technique (Fig. 2). The patient is placed prone and a straight midline skin incision is used. The paravertebral muscles are resected from the spinous processes and the posterior surfaces of the laminae are exposed. The insertion of the semispinalis muscle to C2 is preserved.

The spinous processes are resected so that their bases are longer than 5 mm, and their remnants are split with a high-speed drill. At the transitional portion of the laminae and facet joints, the laminae are thinned enough to allow them to be pushed laterally, the 'open-door' technique. The widths of the lateral gutters are determined by CT myelography (CTM) before the operation.

The laminae are opened and any adhesions to the dura mater are dissected off. Bone blocks approximately 10 to 15 mm long from the spinous processes are then inserted at the site of the laminoplasty to maintain the enlargement of the spinal canal.

After operation, patients are kept in bed for one week

I. Aita, MD, Orthopaedic Surgeon

K. Hayashi, MD, Professor

Department of Orthopaedic Surgery, Institute of Clinical Medicine, University of Tsukuba, Tennoudai 1-1-1, Tsukuba-shi, Ibaraki 305, Japan.

Y. Wadano, MD, Associate Professor

Department of Orthopaedics, Centre for Medical Science, Ibaraki Prefectural University of Health Science, 4669-2 Ami-Mati, Inashiki-Gun, Ibaraki 300-03, Japan.

T. Yabuki, MD, Orthopaedic Surgeon

Yabuki Orthopaedic Clinic, 2-12-18 Keyakidai, Moriya-Mati, Kitasouma-Gun, Ibaraki 302-01, Japan.

Correspondence should be sent to Dr I. Aita.

©1998 British Editorial Society of Bone and Joint Surgery
0301-620X/98/17919 \$2.00

Fig. 1a

Fig. 1b

CT myelography at C5 in a 45-year-old man before (a) and after (b) canal-expansive laminoplasty from C3 to C7. The dura mater has expanded and the spinal cord has moved posteriorly.

Fig. 2

Diagram showing canal-expansive laminoplasty. The spinous process is used as a bone block to maintain the opened laminae and is held between them by non-absorbable sutures.

Fig. 3

Diagram showing the measurements of the transverse diameter, sagittal diameter, and cross-sectional area of the spinal cord. The cross-sectional area of the dural sac is the area inside the dura mater.

and then allowed to walk using a Philadelphia collar.

CT myelography (CTM). We injected 10 ml of metrizamide (250 mgI/ml) or Isovist through a lumbar puncture and performed CTM after myelography in the supine position using General Electric CT/T 8800 or 9800 scanners (GE Medical Systems, Milwaukee, Wisconsin). The window level ranged from 500 to 2000 and window width from 100 to 250. The slice thickness was 5 mm. The slice level was at the middle of the vertebral body and intervertebral

disc from C1 to T1. The gantry level was kept as perpendicular as possible to the superior and inferior surfaces of the vertebral body. The second CTM was performed three weeks after the laminoplasty.

The sagittal and transverse diameters and the cross-sectional area of the spinal cord and the dural sac were also measured by CTM using a SPICCA-II Collor image processor (Nippon Avionics Co Ltd, Tokyo, Japan) (Fig. 3). We also measured the centre of the spinal cord, which was

Fig. 4

Diagram showing the measurement of the centre of the spinal cord which is determined by D1 and D2. D1 is the distance from the posterior surface of the vertebral body to the anterior surface of the spinal cord and D2 is the distance from the posterior surface of the vertebral body to the posterior surface of the spinal cord.

Table I. Mean ($\pm$ SD) sagittal diameter (mm) of the spinal cord before and after cervical laminoplasty

	Number	Preop		Postop		p value
		Mean	SD	Mean	SD	
C3	36	6.3	1.1	6.9	1.0	<0.0001
C3-C4	37	5.4	1.3	6.5	1.2	<0.0001
C4	37	5.6	1.4	6.4	1.4	<0.0001
C4-C5	38	4.8	1.4	6.1	1.5	<0.0001
C5	37	5.6	1.4	6.4	1.1	<0.0001
C5-C6	36	5.4	1.1	6.5	1.4	<0.0001
C6	35	6.1	1.0	6.8	1.0	<0.0001
C6-C7	33	6.0	1.1	6.8	0.8	<0.0001
C7	32	6.3	0.7	6.6	0.8	0.0002

Table II. Mean ($\pm$ SD) transverse diameter (mm) of the spinal cord before and after cervical laminoplasty

	Number	Preop		Postop		p value
		Mean	SD	Mean	SD	
C3	36	12.7	1.8	12.3	1.6	0.0083
C3-C4	37	13.3	1.9	12.6	1.6	<0.0001
C4	37	13.5	1.9	12.6	1.7	<0.0001
C4-C5	38	13.5	2.2	12.7	1.7	<0.0001
C5	37	13.3	2.0	12.4	1.6	<0.0001
C5-C6	35	13.2	1.9	12.2	1.6	<0.0001
C6	35	12.8	1.7	12.1	1.4	<0.0001
C6-C7	34	12.3	1.6	11.8	1.3	<0.0001
C7	32	11.5	1.3	11.2	1.1	0.0355

Table III. Mean ($\pm$ SD) cross-sectional area (mm^2) of the spinal cord before and after cervical laminoplasty

	Number	Preop		Postop		p value
		Mean	SD	Mean	SD	
C3	36	65.3	17.3	68.8	16.8	0.0083
C3-C4	37	59.1	18.6	65.9	18.5	<0.0001
C4	37	60.7	20.4	66.3	20.5	<0.0001
C4-C5	38	53.8	17.3	62.6	20.6	<0.0001
C5	37	60.6	19.8	64.9	18.9	<0.0001
C5-C6	35	55.6	14.9	60.8	16.7	<0.0001
C6	35	61.1	15.5	64.0	15.1	<0.0001
C6-C7	34	56.4	15.2	60.9	12.6	<0.0001
C7	33	55.3	11.5	57.1	13.0	0.0355

Table IV. Mean ($\pm$ SD) cross-sectional area (mm^2) of the dural sac before and after cervical laminoplasty

	Number	Preop		Postop		p value
		Mean	SD	Mean	SD	
C3	36	129.2	35.9	156.6	37.5	<0.0001
C3-C4	37	112.7	34.0	153.5	33.6	<0.0001
C4	37	115.6	38.4	166.5	40.6	<0.0001
C4-C5	38	101.8	35.2	161.2	40.0	<0.0001
C5	37	122.1	37.5	183.9	44.9	<0.0001
C5-C6	35	106.2	27.6	161.9	38.9	<0.0001
C6	35	130.1	33.8	180.2	39.9	<0.0001
C6-C7	34	126.4	38.5	159.9	35.9	<0.0001
C7	33	146.3	49.5	172.9	51.5	0.0014

expressed as $(D1+D2)/2$ where D1 is the distance from the posterior surface of the vertebral body to the anterior surface of the spinal cord and D2 is the distance to the posterior surface of the spinal cord (Fig. 4). Any change in this value after laminoplasty indicates movement of the cord.

We analysed the results using a paired *t*-test.

Results

Sagittal and transverse diameters of the spinal cord (Tables I and II). Before operation the mean sagittal diameter at C5 was 5.6 mm; after operation it was 6.4 mm. The increase in diameter was about 1 mm and was greatest at C4-C5.

The change in the transverse diameter of the spinal cord was opposite to that for the sagittal diameter. Before operation the transverse diameter at C5 was 13.3 mm; after operation it was 12.4 mm representing a decrease in diameter of about 1 mm, greatest at C5-C6.

Cross-sectional areas of the spinal cord and dural sac (Tables III and IV). The mean cross-sectional area of spinal cord was 53.8 mm^2 and was lowest at C4-C5 before the operation. After operation the largest increase (12%) was also at this level.

The mean preoperative cross-sectional area of the dural sac was 101.8 mm^2 and was also lowest at C4-C5 with a relative increase after operation of about 37.2%, three times as much as that of the spinal cord.

Table V. Mean ($\pm$ SD) distance (mm) from the posterior surface of the vertebral body to the centre of the spinal cord before and after cervical laminoplasty

	Number	Preop		Postop		Posterior movement		p value
		Mean	SD	Mean	SD	Mean	SD	
C3	36	5.8	1.4	7.0	1.4	1.2	0.8	<0.0001
C4	37	5.0	1.6	7.1	1.4	2.1	1.0	<0.0001
C5	37	5.2	1.6	8.1	1.8	2.8	0.9	<0.0001
C6	35	5.6	1.7	8.2	1.9	2.7	1.0	<0.0001
C7	32	6.5	1.4	8.2	1.5	1.7	1.0	<0.0001

Fig. 5

Diagram showing the posterior decompression, and that where the posterior movement of the spinal cord is maximal.

Posterior movement of the spinal cord (Table V). The mean posterior displacement of the spinal cord was 2.8 mm at C5. It was less at higher and lower levels.

Discussion

Anterior interbody fusion decompresses the anterior side of the spinal cord and is indicated for disc herniations, posterior spurs, and ossification of the posterior longitudinal ligament (OPLL). Laminoplasty enlarges the spinal canal and is best for developmental spinal stenosis.

Our study has demonstrated the morphological changes in the spinal cord. After laminoplasty, the sagittal diameter of the spinal cord increased and the transverse diameter decreased, causing the cord to change shape. In addition, it expanded, with an increase in the cross-sectional area of the cord by 12% at C4-C5 and of the dural sac by 37.2%, three times greater. This shows that the enlargement of the spinal canal by laminoplasty is more than enough to decompress the cord, which has sufficient subarachnoid space.

Our study also showed that the posterior movement of the spinal cord in the supine position was greater in the

middle of the cervical spine. We believe that this is due to the lordosis of the cervical spine. If the spinal cord tends to straighten, posterior movement will be greatest at the point of maximum concavity (Fig. 5).

Bone grafts placed at the site of the laminoplasty may limit the posterior movement of the spinal cord post-operatively, especially in patients with an increased cervical lordosis. In addition, the denticulate ligaments may tether the cord. We did not study these limitations of movement but think that the movement of the spinal cord is affected by the spinal curvature.

Clinically, both the enlargement and the posterior movement of the spinal cord are very important. If the spur or OPLL is very large, the cord cannot move posteriorly enough to be decompressed by the laminoplasty. Posterior movement and cord expansion therefore determine whether the laminoplasty can completely decompress the cord. If anterior cord compression is too extensive to be decompressed by laminoplasty, an anterior decompression is necessary.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Hase H, Watanabe T, Hirasawa Y, et al. Bilateral open laminoplasty using ceramic laminas for cervical myelopathy. *Spine* 1991;16:1269-76.
2. Hirabayashi K, Satomi K. Operative procedure and results of expansive open-door laminoplasty. *Spine* 1988;13:870-6.
3. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine* 1983;8:693-9.
4. Itoh T, Tsuji H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine* 1985;10:729-36.
5. Kawai S, Sunago K, Doi K, Saika M, Taguchi T. Cervical laminoplasty (Hattori's method): procedure and follow-up results. *Spine* 1988;13:1245-50.
6. Tsuji H. Laminoplasty for patients with compressive myelopathy due to so-called spinal canal stenosis in cervical and thoracic regions. *Spine* 1982;7:28-34.
7. Yoshida M, Otani K, Shibasaki K, Ueda S. Expansive laminoplasty with reattachment of spinous process and extensor musculature for cervical myelopathy. *Spine* 1992;17:491-7.
8. Fujiwara K, Yonenoba K, Ebara S, Yamashita K, Ono K. The prognosis of surgery for cervical compression myelopathy: an analysis of the factors involved. *J Bone Joint Surg [Br]* 1989;71-B:393-8.
9. Fukushima T, Ikata T, Taoka Y, Takata S. Magnetic resonance imaging study on spinal cord plasticity in patients with cervical compression myelopathy. *Spine* 1991;16:534-8.
10. Kawakami N. A clinical study on the morphological restoration of the spinal cord in cervical myelopathy by CT-myelography and ultrasonography. *Nippon Seikeigeka Gakkai Zasshi* 1988;62:951-64.
11. Kimura I, Oh-Hama M, Shingu H. Cervical myelopathy treated by canal-expansive laminoplasty. Computed tomographic and myelographic findings. *J Bone Joint Surg [Am]* 1984;66-A:914-20.
12. Matsuyama Y, Kawakami N, Mimatsu K. Spinal cord expansion after decompression in cervical myelopathy: investigation by computed tomography myelography and ultrasonography. *Spine* 1995;20:1657-63.
13. Yu YL, Stevens JM, Kendall B, du Boulay GH. Cord shape and measurements in cervical spondylotic myelopathy and radiculopathy. *AJNR-Am J Neuroradiol* 1983;4:839-42.
14. Bertalanffy H, Eggert HR. Clinical long-term results of anterior discectomy without fusion for treatment of cervical radiculopathy and myelopathy: a follow-up of 164 cases. *Acta Neurochir Wien* 1988;90:127-35.
15. Ebersold MJ, Pare MC, Quast LM. Surgical treatment for cervical spondylitic myelopathy. *J Neurosurg* 1995;82:745-51.
16. Fukui K, Kataoka O, Sho T, Sumi M. Pathomechanism, pathogenesis, and results of treatment in cervical spondylotic myelopathy caused by dynamic canal stenosis. *Spine* 1990;15:1148-52.
17. Koyanagi T, Hirabayashi K, Satomi K, Toyama Y, Fujimura Y. Predictability of operative results of cervical compression myelopathy based on preoperative computed tomographic myelography. *Spine* 1993;18:1958-63.
18. Yang KC, Lu XS, Cai QL, Ye LX, Lu WQ. Cervical spondylotic myelopathy treated by anterior multilevel decompression and fusion: follow-up report of 214 cases. *Clin Orthop* 1987;221:161-4.