Recent Surgical Methods of Double-door Laminoplasty of the Cervical Spine (Kurokawa's Method)

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Abstract:

Introduction: Double-door laminoplasty (DDL) of the cervical spine (Kurokawa's method) was developed as one of posterior decompression surgical methods in the late 1970s and after then has been modified by adding various procedures such as the posterior muscle handling and the use of artificial spacers.

There are three principles of DDL: First, to decompress the cervical spinal cord by central splitting of the spinous processes and laminae, preserving those lengths as much as possible and widening the spinal canal space symmetrically. Second, to maintain the widened spinal canal space steadily by fixing spacers made of hydroxyapatite the contour is almost the same as the widened space. Third, to re-suture the semispinalis muscles to the C2 spinous process to restore the strength of the posterior cervical muscles.

Technical note: The important technical points in performing osteotomy are as follows: At each vertebra, osteotomy is performed from the caudal side and gradually proceeds to the cranial side because there is a space between the lamina and the dura mater at the caudal side and the osteotomy can be safely made. The surgeon must pay attention to the changes in color of the osteotomy site from red of cancellous bone, to white of the inner cortex, and finally to yellow of the yellow ligament and extradural fat tissue. Attention must be paid to the changes in sound and tactile sensation delivered from the air-drill when completing osteotomy of the inner cortex of lamina. By moving an air-drill slowly, tactile sensation can be more sensitive. During osteotomy, the process must be checked frequently by touching the inner cortex of the lamina with a probe.

Conclusion: At present, DDL is a useful surgical method for cervical myelopathy at multiple level lesions.

Keywords:
Cervical spine, Laminoplasty, Posterior decompression, Double-door type

Introduction

In 1973, the idea of cervical laminoplasty (CL) was first proposed by Oyama and co-workers[1] under the name of "Expansive lamina-Z-plasty." Thereafter, various methods of CL have been developed in Japan, and these have gradually become common around the world.

At present, the surgical methods of CL are divided into two types by the site of osteotomy: double-door type (DDL)[2] and open-door type (ODL)[3]. Various materials are used to maintain the enlarged spinal canal such as thread[3], autogeneous bone (spinous process[4,5], iliac bone[2,6]), hydroxyapatite spacer[7-17], and titanium plate and screw[18,19].

Double-door type was first developed by Kurokawa in the late 1970s and reported in 1982[2]. After then, it has been modified by adding various modifications such as the posterior muscle handling and the use of artificial spacers. In this paper, our recent surgical method[17] based on the original Kurokawa method[2,6] is presented focusing mainly on the method of osteotomy.

Technical Note

In most patients, this surgery is performed from the third cervical spine (C3) to C6 levels because the spinal cord is usually compressed at these levels except the patients in whom a long and large OPLL (ossification of the posterior longitudinal ligament) extends up to C1 and C2 level.
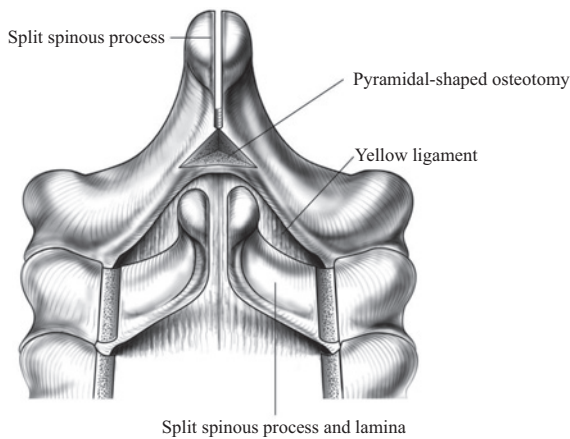
Figure 1. Pyramidal-shaped osteotomy at the cranial base of the spinous process and central splitting of the spinous process and lamina (transcription from reference 17, partially modified).

At first, a pyramidal-shaped osteotomy is made at the cranial base of the spinous process to obtain a good visual field. Next, the remaining part of the spinous process is split centrally from its surface and the split portion is connected to the pyramidal-shaped dome.

Figure 2. Formation of longitudinal groove (transcription from reference 17, partially modified).

A longitudinal groove of 3 mm in width is made bilaterally at the lamina-facet junction by resecting the outer cortex and a part of cancellous bone.

Under general anesthesia, Mayfield three point head fixator is fixed to the cranium of a patient and connected to the operation table with the cervical spine slightly flexed. Care must be taken not to hyperextend the cervical spine at the time of setting.

After identifying the level of C2 and C7 spinous processes by touching them over the surface of the skin, central longitudinal skin incision is made. The nuchal ligament is centrally incised not to damage the posterior branch of the posterior ramus of the cervical nerve, and the attachment of the nuchal ligament to C6 and/or C7 spinous processes is detached. By advancing deep into the row of the spinous processes exact centrally, the volume of bleeding can be minimized. After detaching the semispinalis muscles from C2 spinous process, these muscles are marked by non-absorbable threads. By detaching the paravertebral muscles from each spinous process, the laminae from the caudal side of C2 to the cranial side of C7 are exposed. The lateral side is exposed bilaterally to the mid-portion of each facet joint from C3 to C6 level.

After resecting the interspinalis muscles from C2 to C7, the caudal border of C2 lamina is resected in a dome shape using an air-drill exposing the yellow ligament at C2/C3 level. The spinous processes and laminae are split centrally from C3 to C6. At first, a triangle-shaped dome osteotomy is made at the cranial base of the C3 spinous process by using a 3 mm diamond burr to obtain a good visual field. Next, the remaining part of the spinous process is split centrally from its surface by using a 2 mm diamond burr, and the split is connected to the triangle-shaped dome (Fig. 1). These procedures enable to easily perform osteotomy of the inner cortex of the lamina that is otherwise hardly visual
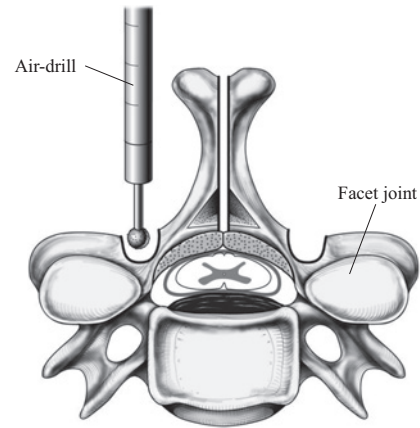
due to its depth.

To obtain bright surgical field at the deep inner cortex, lighting is set longitudinally from the cranial side. At each vertebra, osteotomy is performed at the caudal side and gradually proceeds to the cranial side because there is a space between the lamina and the dura mater at the caudal side and the osteotomy can be safely made. The surgeon must pay attention to the changes in color of the osteotomy site from red of cancellous bone, to white of the inner cortex, and finally to yellow of the yellow ligament and extradural fat tissue. Attention must be paid to the changes in sound and tactile sensation delivered from the air-drill when completing osteotomy of the inner cortex of lamina. By moving an air-drill slowly, tactile sensation can be felt more sensitively. During osteotomy, the process must be often checked by touching the inner cortex with a probe.

After completing the central splitting of C3, a longitudinal groove of 3 mm wide is made bilaterally at the lamina-facet junction by resecting the outer cortex and a part of cancellous bone (Fig. 2). Care must be taken not to resect the inner cortex to avoid breakage of the lamina which may cause radiculopathy. It is recommended that the surgeon stands at the cranial side of the patient to make the bilateral grooves symmetrically. After osteotomy of C3 is completed, a scissors is inserted between the split spinous process and lamina to widen the space (Fig. 3). During the time of widening, it is adequate to feel slightly stiff, because the stiffness of the split spinous process and lamina certainly decreases after resecting the hypertrophied yellow ligament. The same procedures are performed down to C6 level, and the cranial side of C7 lamina is resected in a dome shape.

After completing osteotomy, the constricting fibrous band above the dura mater and the hypertrophied yellow ligament are resected from C6 to C3 level. To equalize the stiffness
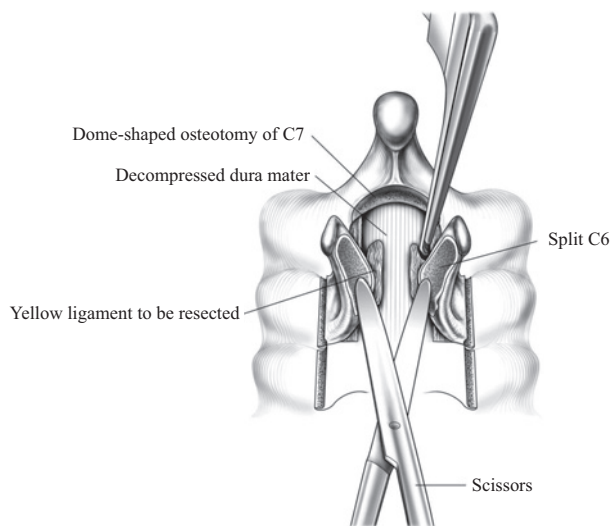
Figure 3. Widening the split spinous processes using a scissors (Maechenbaum) and decompression of the spinal cord using a rongeur (transcription from reference 17, partially modified).

A scissors is inserted between the split spinous process and lamina to widen the space. Decompression of the spinal cord is performed by resecting the constricting fibrous band above the dura mater and the hypertrophied yellow ligament using a rongeur.
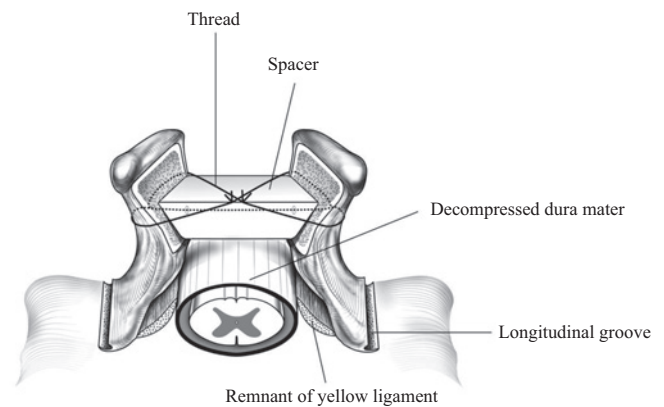

Figure 4. Fixation of a spacer seen from the cranial side (transcription from reference 17, partially modified).
Each spacer is fixed using one or two non-absorbable threads. It is noted that the cranial side is more widely opened than the caudal side at each level.

of bilateral split spinous process and lamina, the depth of a longitudinal groove is adjusted by adding resection of the inner cortex. At each level, the shape of the widened space is trapezoidal both on the axial and frontal sections; that is, the superficial side is more widely opened than the deep side and the cranial side is more widely opened than the caudal side. A trial spacer is placed into the widened space, and an appropriate size of real spacer is selected. A 2 mm hole to accommodate a thread for fixing the spacer is made at about 8 mm or more superficial from the inner plate of the lamina. The contour of the spacers is almost identical to the widened space, therefore, the spacers are firmly stabilized between the split spinous processes and laminae. During stabilization, the spacers slightly rotate into an appropriate position. Each spacer is fixed using one or two non-absorbable threads (Fig. 4).

During operation, the surgical field must be frequently irrigated by a large volume of physiological saline to avoid infection. Finally, the semispinalis muscles that are once resected from C2 spinous process are sutured to the ipsilateral inferior oblique occipital muscles. After one suction drainage tube is set, sutures are made in each layer.

Immediately after surgery, muscle exercises begin during bed rest. After a few days, the patient is ambulated using a walker or wheelchair with wearing a soft neck collar. At the end of 1 month postoperatively, the collar is removed.

Discussion

The principles of DDL are as follows: (1) decompress the cervical spinal cord by central splitting of the spinous processes and laminae, preserving their lengths as much as possible and widening the spinal canal space symmetrically[2,6,17,26]; (2) maintain the widened spinal canal space steadily by fixing spacers made of hydroxyapatite the contour is almost the same as the widened space [20-25]; (3) suture the semispinalis muscles that are once resected from the C2 spinous process before closing the incision to restore the strength of the posterior cervical muscles[6,17].

One of the reasons to preserve the length of the spinous processes as much as possible is to afford the adequate contact area for spacers to be stabilized between the split spinous processes and laminae. The degree of the widened space depends on both the transverse width of spacers and the depth of spacers placed between the split spinous processes and laminae[26]. The shorter the length of the spinous process is, the deeper a spacer must be placed and the narrower the contact area is. In this condition, a spacer tends to become unstable and may damage the dura mater and the spinal cord[27]. Although we usually fix the spacers at about 8 mm or more superficial from the inner plate of the lamina, the depth can be randomly changed if there remains an adequate length of the split spinous process.

The other reason to preserve the length of the spinous processes is to recover the tension of posterior cervical muscles by acting as an anterior support. This mechanism is thought to be the same as in *koto*. The tension of a *koto* string is maintained by the anterior support of a *kotoji*. The tips of the split spinous process, which are transferred bilaterally after fixing a spacer, can act as an anterior support to the semispinalis cervicis muscles that are originally located laterally. In posterior decompression surgery, how to avoid the development of postoperative kyphosis is one of the important challenges. The postoperative kyphosis does not relate directly to the deterioration of neurological findings in cervical spondylotic myelopathy but relate to the deterioration of neurological findings in some cases of OPLL[28,29].

One solution is to recover the tension of posterior cervical muscles by preserving the spinous process as long as possible as an anterior support like as a *kotoji* and re-suturing the semispinalis cervicis muscles that had earlier been detached from the C2 spinous process before wound closure[6]. In our series, 33 of 37 patients had lordotic alignment with an average of 14.0° preoperatively, which was reduced postoperatively by approximately 10° in 67% of patients. In three of four patients with preoperative kyphosis, kyphosis progressed by approximately 10°[17].

The position of the bilateral longitudinal groove influences the degree of the widening of the spinal canal, especially in the lateral side. The more lateral the groove is set, the wider the spinal canal becomes. We usually make the grooves at the lamina-facet junction that is at the inflection point. This is enough to obtain adequate decompression of the spinal cord and the spinal nerves without causing tethering effect due to excessive distraction force of the spinal nerves. However, care must be taken to equalize the stiffness of bilateral split spinous process and lamina to obtain symmetrical widening of the spinal canal by adjusting the depth of a longitudinal groove.

The most important technical point of CL is to decompress the spinal cord safely. The change in tactile sensation delivered from the air-drill at the time of complete osteotomy of the inner cortex of lamina is important. By moving an air-drill slowly, tactile sensation can be more sensitive. During osteotomy, the process must be checked frequently by touching the inner cortex of the lamina with a probe. The surgeons must perform decompression procedure of the inner cortex of the lamina from its dorsal surface. It is dangerous to perform decompression procedure from the inner side of the spinal canal by using T-saw because the dura mater and the spinal cord may be injured by friction within the narrowed spinal canal[27].

The indication of DDL are patients with spinal canal stenosis at multiple levels or anterior space occupying lesion at two or more levels, such as cervical spondylotic myelopathy, OPLL, cervical disc herniation, and destructive spondyloarthropathy due to renal disease. However, meticulous attention must be paid in patients with tiny spinous processes and/or the patients in whom the spinal cord is compressed between large OPLL and the inner surface of the lamina.

Conflicts of Interest: The author declares that there are no conflicts of interest.

References

1. Oyama M, Hattori S, Moriwaki N. Trial of one method of cervical laminectomy. Chubu-Seisaishi (Central Japanese Orthopaedic Surgery and Traumatology). 1973;16:792-4. Japanese.
2. Kurokawa T, Tsuyama N, Tanaka H, et al. Double-door laminoplasty by longitudinal splitting of spinous process. Bessatsu Seikeigeka (Suppl Orthop Surg). 1982;2:234-40. Japanese.
3. Hirabayashi K, Watanabe K, Wakano K, et al. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine. 1983;8:693-9.
4. Aida I, Hayashi K, Wadano Y, et al. Posterior movement and enlargement of the spinal cord after cervical laminoplasty. J Bone Joint Surg Br. 1998;80:33-7.
5. Ito T, Tsuji H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. Spine.1985;10: 729-36.
6. Kurokawa T, Tanaka H, Nakamura K, et al. Double-door laminoplasty by longitudinal splitting of spinous process-modified procedure and its surgical result. Bessatsu Seikeigeka (Suppl Orthop Surg.) 1986;9:30-32. Japanese.
7. Nakano K, Harata S, Suetsuna F, et al. Spinous process-splitting laminoplasty using hydroxyapatite spinous process spacer. Spine. 1992;17(3 Suppl): S41-3.
8. Tsuzuki N, Abe R, Saiki K, et al. Tension-band laminoplasty of the cervical spine. Int Orthop (SICOT). 1996;20:275-84.
9. Iwasaki M, Ebara S, Miyamoto S, et al. Expansive laminoplasty for cervical radiculomyelopathy due to soft disc herniation. A comparative study of laminoplasty and anterior arthrodesis. Spine. 1996;21:32-8.
10. Seich A, Takeshita K, Onishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. Spine. 2001; 26:479-87.
11. Shiraishi T. A new technique for exposure of the cervical spine laminae. Technical note. J Neurosurg. 2002;96:122-6.
12. Asano T, Hirabayashi S. Operative Neurosurgical Techniques Indications, Methods, and Results. 5th ed, Schmidek HH and Roberts DW ed., Saunders, USA; 2006. Chapter 133, Surgical management of ossification of the posterior longitudinal ligament; p.1879-95.
13. Kim P, Murata H, Kurokawa R, et al. Myoarchitectonic spinolaminoplasty: efficacy in reconstituting the cervical musculature and preserving biomechanical function. J Neurosurg Spine. 2007;7: 293-04.
14. Hirabayashi S, Yamada H, Motosuneya T, et al. Comparison of enlargement of the spinal canal after cervical laminoplasty--- open-door type and double-door type. Eur Spine J. 2010;19:1690-4.
15. Hirabayashi S, Matsushita T. Two types of laminoplasty for cervical spondylotic myelopathy at multiple levels. ISRN Orthop. 2011 Sep 7; 637185. doi:10.5402/2011/637185 eCollection
16. Shigematsu H, Kura T, Iwata E, et al. Increased segmental range of motion is correlated with spondylolisthesis in the cervical spine after laminoplasty. Spine. 2017;42(7):E385-91.
17. Hirabayashi S. Surgical technique and results of double-door laminoplasty at the cervical spine (Kurokawa's method) - focusing on the change of sagittal alignment. Int J Surg Surgical Porced. 2017;2:118. https://doi.org/10.15344/2456-4443/2017/118.
18. Tani S, Suetsuna F, Mizuno J, et al. New titanium spacer for cervical laminoplasty: initial clinical experience. Technical note. Neurol Med Chir. 2010;50:1132-6.
19. Tung KL, Cheung P, Kwork TK, et al. Single-door cervical laminoplasty using titanium miniplates alone. J Orthop Surg. 2015;23(2):174-9.
20. Hirabayashi S, Kumano K. Development of a new spacer well adapted to split spinous process in double-door laminoplasty. Seikeigeka (Orthop Surg). 1995;46:110-2. Japanese.
21. Hirabayashi S, Koshizuka Y. New method of measuring area of spinal canal after double-door laminoplasty. J Orthop Sci. 1999;4: 78-82.
22. Hirabayashi S, Kumano K. Contact of hydroxyapatite spacer with split spinous process in double-door laminoplasty for cervical myelopathy. J Orthop Sci. 1999;4:264-8.

23. Hirabayashi S, Kumano K. Finite element analysis of the space created by split spinous processes in double-door laminoplasty to optimize shape of an artificial spacer. J Muscloskeletal Res. 2000; 4:47-54.

24. Hirabayashi S, Saiki K, Sakai H. Occipitocervicothoracic fixation using a rod and hook system for patients with rheumatoid cervical spine. Mod Rheumatol. 2004;14:435-41.

25. Zhang J, Hirabayashi S, Saiki K, et al. Effectiveness of multiple-level decompression in laminoplasty and simultaneous C1 laminectomy for patients with cervical myelopathy. Eur Spine J. 2005;21:1-8.

26. Hirabayashi S, Murata K, Yamamoto I, et al: Significance of the maintenance of the spinous process and the stability of an artificial spacer in Double-door laminoplasty --- Figure analyses. J Spine Res. 2011;Vol.2:66-72. Japanese.

27. Kanemura A, Doita M, Iguchi T, et al. Delayed dural laceration by hydroxyapatite spacer causing tetraparesis following double-door laminoplasty. J Neurosurg Spine. 2008;8:121-8.

28. Chiba K, Ogawa Y, Ishii K, et al. Long-term results of expansive open-door laminoplasty for cervical myelopathy—average 14-year follow-up study. Spine. 2006;31(26):2998-3005.

29. Seichi A, Hoshino Y, Kimura A, et al. Neurological complications of cervical laminoplasty for patients with ossification of the posterior longitudinal ligament - a multi-institutional retrospective study. Spine. 2011;36(15):E998-1003.