www.jkns.or.kr

Clinical Article

Young-Sung Kim, M.D.
Seung-Hwan Yoon, M.D.
Hyung-Chun Park, M.D.
Chong-Oon Park, M.D.
Hyeon-Seon Park, M.D.
Dong-Keun Hyun, M.D.

Department of Neurosurgery Inha University College of Medicine, Incheon, Korea

J Korean Neurosurg Soc 42 : 168-172, 2007

Technical Modification and Comparison of Results with Hirabayashi's Open-door Laminoplasty

Objective : Hirabayashi's open-door laminoplasty is a good procedure to use to treat patients with myelopathy of the cervical spine; however, the authors have experienced problems in maintaining an open-window in cervical spines after the surgery. The authors developed a modified method of the expanded open-door laminoplasty and compared the radiological and clinical results with those of the classical method.

Methods : In the modified method, wiring fixation with lateral mass screws on the contra lateral-side instead of fixing the paraspinal muscle or facet joint, as in the classical methods, was used in the open window of the cervical spine. Fifteen patients with cervical myelopathy were treated using the classical method and 12 patients were treated using the modified method. Preoperative and postoperative clinical conditions were assessed according to the Japanese Orthopedic Association (JOA) score. The radiological results were compared with the preoperative and postoperative computed tomography (CT) findings.

Results : In both methods, the clinical results revealed a significant improvement in neurological function ($p<0.001$). Image analysis revealed that the cervical canals were continuously expanded in patients treated using the modified methods. However, authors have observed restenosis during the follow-up periods in 4 patients treated using the original method. Progression to deformity and spinal instability were not observed in any of the patients in the radiological results.

Conclusion : Although analysis with a larger population and a longer follow-up period needs to be undertaken, our modified open-door laminoplasty has shown an advantage in better maintaining an open window in comparison with the Hirabayashi's open-door laminoplasty.

KEY WORDS : Laminoplasty · Myelopathy · Ossification of the posterior longitudinal ligament · spondylosis.

INTRODUCTION

Open-door laminoplasty in cervical multilevel ossification of the posterior longitudinal ligament (OPLL) or spondylotic myelopathy was first described by Hirabayashi et al. and established as the management modality of multilevel cervical stenosis[6-8]. In Hirabayashi's classic method, maintaining the laminae in an opened state was secured by suturing to adjacent muscles. The method has proved to be effective in expanding spinal canal dimensions with good clinical efficacy[6].

Prevention of restenosis has been an important issue for maintaining initial clinical improvement. For the purpose of securing the laminae in their open position, some surgeons have reported the use of variable implants or spacers using the allo bone or hydroxyapatite[12,13,16,17].

The authors designed a new method using a wiring and anchoring system between the spinous process and lateral mass screw in the gutter segment of the laminae. This system maintains the laminae in their open position. We named this procedure the modified Hirabayashi laminoplasty. Preoperative and postoperative diameters of spinal canal were measured to assess the effectiveness of this technique and to find the advantages of our method in comparison with those of Hirabayashi's method.

MATERIALS AND METHODS

Between January 2002 and December 2004 at Inha University Hospital, 27 patients with cervical stenotic myelopathy were treated using Hirabayashi's open-door laminoplasty as well as a modified method of Hirabayashi's open-door laminoplasty. Of the patients

• Received : February 23, 2007
• Accepted : August 10, 2007
• Address for reprints :
Seung-Hwan Yoon, M.D.
Department of Neurosurgery
Inha University College of Medicine
7-206 Sinheung-dong 3-ga
Jung-gu, Incheon 400-711, Korea
Tel : +82-32-890-2370
Fax : +82-32-890-2947
E-mail : nsysh@inha.ac.kr

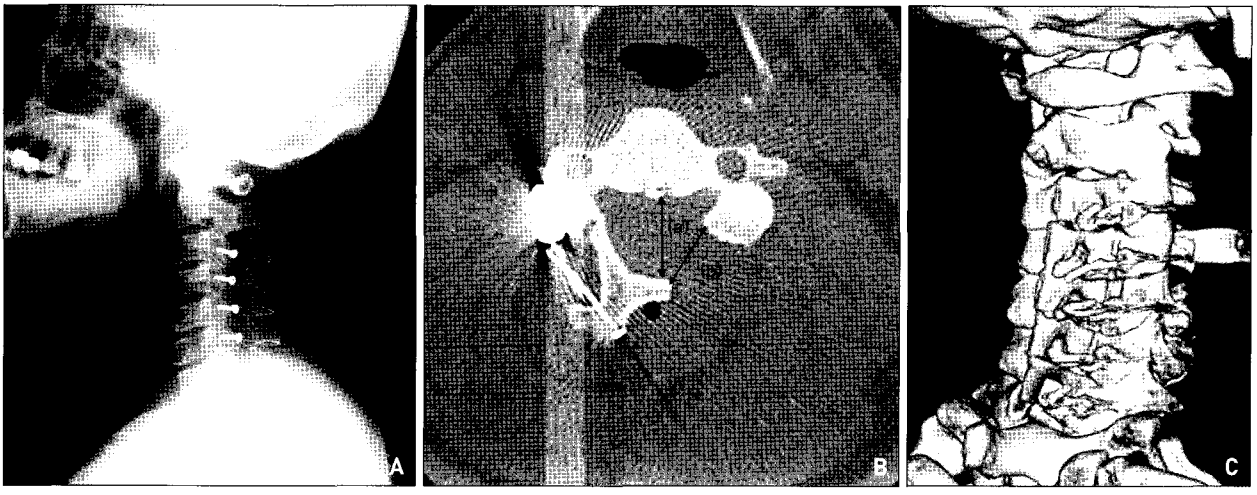

Fig. 1. Postoperative image of modified hirabayashi open-door laminoplasty. The wiring and anchoring between the spinous process and lateral mass screw are shown. A : Lateral view of the modified method. B : Computed tomography (CT) axial view of the modified method. a) The anterior-posterior diameter of the cervical canal. b) The gap length of the resected segment. (It is obtained by measuring the shortest distance between the most medial points of the resected laminae to the lateral mass of the open side.) C : Three-dimensional CT scan of the modified method from the final examination.

treated, 3 were women and 24 were men, ranging in age from 30 to 86 (mean : 55±12 years). These patients had OPLL, spondylosis, or canal stenosis with degenerative changes. All patients in this study were followed up for at least 15 months. All patients were divided into two groups according to the type of surgical procedure. Patients in Group I were treated using Hirabayashi's method and patients in Group II were treated using a modified procedure of Hirabayashi's methods. Fifteen patients (Group I) were treated using Hirabayashi's method, and 12 patients (Group II) were treated using a modified method of Hirabayashi's laminoplasty. Patients were randomly assigned irrespective of the patients' preoperative conditioning. The selection criteria for both groups were identical and were as follows : first, the patient's clinical symptoms or signs in relation to myelopathy showed are refractory to conservative management; second, the neurological deficit should be in continuous progression; third, cervical lordotic alignment should be relatively maintained, as observed on a neutral cervical spine lateral x-ray. However, the patients with injured cervical lordotic curves who complained of neck pain only without myelopathy were excluded from this study. The preoperative clinical neurological finding was evaluated using the Japanese Orthopedic Association (JOA) score. Preoperative cervical alignment and instability were examined with the cervical spine anterior-posterior (AP), lateral, and dynamic lateral views. Preoperative magnetic resonance imaging (MRI) on the cervical spine was studied to evaluate cervical canal narrowing and cord signal change. Preoperative and postoperative axial CT scans were performed to evaluate the increase in the cervical canal diameter and to confirm correct instrumentation. Postoperative CT axial scans were examined immediate postoperative period and at the end of the follow-up period to observe canal maintenance.

Surgical procedure

After the patients are anesthetized, a Mayfield three-pin head holder is applied on the head in the prone position and the Mayfield device is secured into position to stabilize the head and neck. The reverse Trendelenburg position is always used to help alleviate epidural vein compression in the patient. The incision proceeds along the median raphe down to the tips of the spinous processes from C2 to T1. Subperiosteal dissection is carried out on the lateral portion of the lateral masses. Laminoplasty is usually performed from C3 to C7. The authors usually choose the right side as the open side on the lamina and left side as the gutter. If supplementary foraminotomy is planned to relieve the patient's radiculopathy, then the portion would become converse to the patient's anatomical structure. To open the laminae, the authors sequentially use a 3- to 4- mm cutting burr and 1.0-mm burr until the laminae are completely open. Hemostasis can be achieved with the use of thin bone wax and bipolar forceps. After the bone separation is completed, the ligamentum flavum is resected with a 1-mm Kerrison punch. After the gutter on the contralateral side is made with the cutting burr and diamond burr, the laminae are then sequentially opened from one end to the other. Before the laminae are completely opened, a 3.5-mm diameter and 12-mm-long screw are inserted into the lateral mass of the gutter position, then each level of the spinous processes is pierced by a wire. This wire is used to anchor the screw head while the open segment was widened. To widen the spinal canal sufficiently to view cord pulsation, final fixation between the wire and

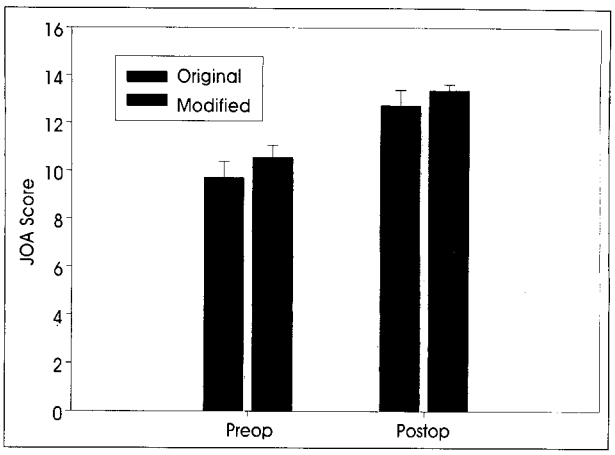

Fig. 2. Preoperative and postoperative Japanese Orthopedic Association (JOA) scores. There are significant improvements in the postoperative JOA scores for both groups ($p<0.001$). A difference in clinical results between the groups is not observed.

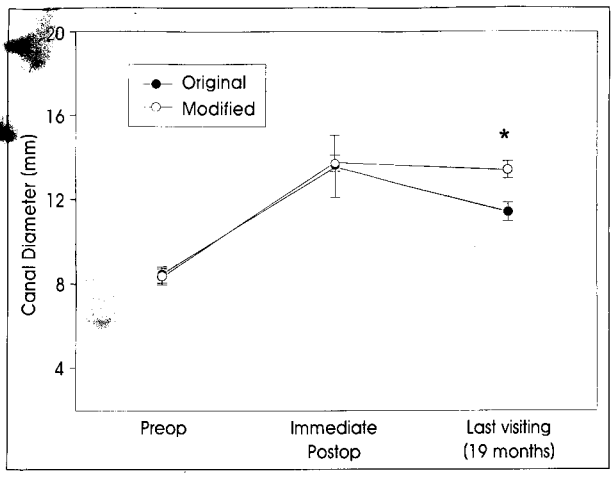

Fig. 3. Changes in canal diameter in both groups. There are improvements in the canal diameter during the immediate postoperative period for both groups. ($p<0.001$) However, we observed the difference in the canal diameter during the last examination and there was a decrease in the canal diameter for the patients who were treated using the Hirabayashi's classical open-door laminoplasty. * The modified method is more effective for the prevention of restenosis (p=0.021).

screw head is completed. Postoperative radiographic images are shown in Fig. 1.

Assessment

The patient's neurological status was evaluated according to the JOA score just before surgery and at the last examination of the follow-up period. The mean postoperative follow-up period was 19 months (range, 15-23 months). The AP diameter of the cervical canal was measured with axial CT scans. The AP diameter of the spinal canal was obtained by measuring the shortest distance between the middle point of the posterior margin of the cervical spinal body and the vertebral laminae. Changes in the AP diameter of the cervical canal and the JOA scores before and after surgery were compared for the two groups.

Statistical Analysis

To evaluate the consistency of the clinical and demographic data of both groups and to test differences in clinical outcomes and postoperative results, statistical methods using the paired t-test were applied. Statistical significance was considered if the p-value was less than 0.05.

RESULTS

All demographic data are shown in Table 1. There were no statistical differences between two groups regarding the demographic characteristics. Also, there was no significant difference on amount of blood loss in two groups; however, patients in Group II required longer time in surgery due to the fixation procedure.

The preoperative JOA score for Group I was 9.7±2.6, and the postoperative JOA score improved to 12.8±2.4.

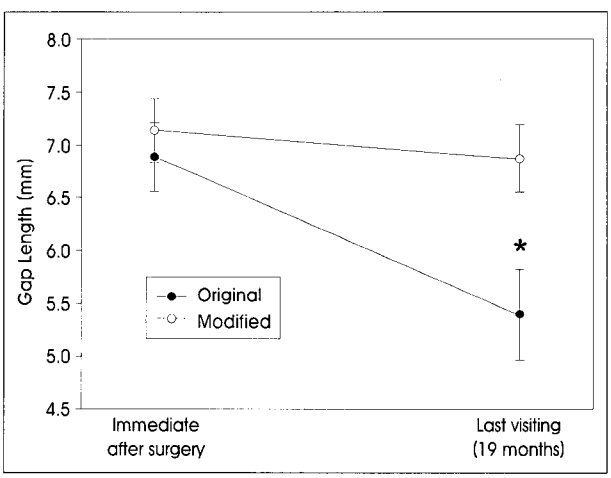

Fig. 4. Changes in the gap length of the resected segment for both groups. The decrease in the gap length of the resected segment means that restenosis has been generated. Compared to Hirabayashi's classical open-door laminoplasty, restenosis is less fregnent for the modified method. * The modified method is more effective for the prevention of restenosis (p=0.005).

The postoperative JOA score for Group II improved to 13.0±1.9 from the initial score of 10.5±1.7 (Fig. 2). The CT findings regarding the canal diameter and maintenance of canal detachment were significant. The postoperative canal diameters seen on the axial image of the CT scan were wider than the preoperative measurements for both groups (Fig. 3). The mean diameters of the patients preoperative anterior-posterior cervical canals at the most compressed level were 8.4±1.4 mm (Group I) and 8.3±1.3 (Group II). Postoperative measurements at the same level were 13.5±1.7 mm (Group I) and 13.7±1.7 mm (Group II). These mean changes represent 61% and 65% increases in the

Table 1. Clinical and demographic data of patients undergoing laminoplasty

	Sex	Age	Preoperative diagnosis	Surgical level	Preoperative JOA score
Group I (n=15)	M : F=14 : 1 93.3% : 6.7%	53.8±11	OPLL; 8 (53.3%) Spondylosis; 4 (26.7%) HCD; 2 (13.3%) Cord contusion; 1 (6.7%)	3 level : 7 (46.7%) 4 level : 7 (46.7%) 5 level : 1 (6.7%)	9.7±2.6
Group II (n=12)	M : F=10 : 2 83.3% : 16.7%	55.7±14.6	OPLL; 6 (50.0%) Spondylosis; 3 (25%) HCD; 1 (8.3%) Cord contusion; 2 (16.7%)	3 level : 6 (50.0%) 4 level : 4 (33.3%) 5 level : 2 (16.7%)	10.5±1.7

Table 2. The radiographic data of cases with restenosis

Case	1	2	3	4
Preoperative canal *diameter	8.5	6.5	7.4	8
Postoperative canal diameter	12.3	13	12	14
Canal diameter on last visiting	8.6	8.5	8.5	8.4
Postoperative resected *length	6.5	6.9	6.9	8.1
Resected length on last visiting	3.1	3	3	2.9

*The unit of measurement is millimeter (mm).

sagittal diameter for Group I and II, respectively. The gap length of the resected segments of both groups were recorded as 6.9 and 7.1 mm. Although the results of the groups were similar ($p<0.001$), the axial images seen on the CT scans at the final examination differed significantly. The mean AP diameter and gap length of the resected segments of the patients of Group I were not maintained. The canal widening seen in the patients of Group II was shown to be effectively maintained (Fig. 3, 4).

Postoperative clinical results on both groups indicated improvement. But, 4 new cases of radiculopathy developed in Group I, which were related to canal restenosis. The patients' axial images in CT scans showed evidence of restenosis. Their radiographic findings are summarized in Table 2. The decrease observed in the mean AP diameter was about 30 % of the immediate postoperative value. Also, the change observed in the gap length of the resected segment was more than 50%. There were complications associated with the procedure, such as postoperative neck pain (10 cases in Group I and 8 cases in Group II) and fractures of the widening segment (3 cases in Group I and 2 cases in GroupII). There were no statistically significant differences in the complication rate between the two groups.

DISCUSSION

Spondylosis of the cervical spine and OPLL are the most common causes of myelopathy in patients older than 50 years of age. Operative management may be considered in patients who have progressive neurologic deficit and have failed conservative management[4]. The decision to select either an anterior or posterior approach depends on the number of affected segments, alignment of the spine, and familiarity of the surgeon with various surgical techniques. Chiles[2] reported that anterior cervical decompression and fusion have shown good results with a greater than 90% improvement rate and a minimal complication rate; however, cervical stenosis involving three or more levels is associated with a less predictable outcome and a higher frequency of complications.

Historically, posterior approaches, including laminectomy with or without fusion and laminoplasty, have been regarded as the standard treatment for the multilevel cervical stenosis with well-preserved cervical lordotic curvature. However, laminectomy has been a less popular method because of disadvantages, including segmental instability, kyphosis, and perineural adhesion[1,3,14]. These disadvantages of the laminectomy procedure prompted the development of laminoplasty. Although the clinical improvements seen in patients who undergo laminoplasty are similar to those seen in patients who undergo laminectomy, fewer complications are observed after laminoplasty[4].

Although the Hirabayashi's laminoplasty is a good method for widening narrowing segments with the least destruction of the anatomical structure, disadvantages are not avoidable. The most common disadvantage is restenosis due to hinge closure in a portion of the anchoring segment. To avoid this complication, several researchers have developed a number of suturing techniques to secure the elevated laminae to overlying muscle or fascia[7,15]. Hirabayashi et al.[8] reported that the hinge side must be supported by three or four sutures through the muscle sheaths to prevent restenosis. Even with quite number of careful sutures being performed, the Hirabayashi open-door laminoplasty has a risk of restenosis due to the friability of muscle.

Plate fixation or bone graft on widening segments are elegant methods to prevent the restenosis[10,11,17]. Itoh and Tsuji[10] used a bone block held by wire to maintain the open position, and O'Brien et al.[17] used titanium plates to preserve the open position. Although theses techniques showed good results, they also have some disadvantages. They are technically difficult, and they require implants with the danger of injury when they were introduced[10,12,13,17]. Furthermore, the tailed trapezoid iliac grafts are not always in satisfactory shape as the good spacer used in the Kurokawa technique. The bone-ceramic piece is expensive and not affordable for all patients. The Itoh technique requires multilevel grafts with multiple

silk wiring, and it is not easy to make a hole in the facet to anchor the silk wiring.

We attempted to stabilize the elevated laminae using screw and wiring methods, and they were effective in preserving the open position of the laminae. Also, the operative technique is quick, relatively easy to apply, and safe. The method of a screw on the lateral mass and wiring fixation offers stability in the spinous process in addition to the preservation of the motion segment of the cervical spine. During long-term follow-up, widening of the narrow segment was maintained, and was observed in serial CT scan data. The mean AP diameter observed during the final examination was not significantly different. The mean AP diameter during the immediate postoperative periods and the last follow-up period was recorded as 13.7±1.2 mm and 13.4±1.3 mm. Dynamic x-rays of the segment that was operated on were obtained for all patients. There were no wiring breaks or loosening. Therefore, our anchoring method remained effective.

The improvements in the JOA scores were definitely related to the maintenance of canal widening long-term after surgery. Preserving canal widening on narrowing segments was the most important factor for maintaining clinical improvement. The amount of canal widening has been an issue of debate according to previous authors. Hirabayashi et al.[8] showed that widening of the sagittal diameter by approximately 4 or 5 mm is sufficient to obtain a good result. Herkowitz[5] reported no correlation between excellent or good results and the size of expansion of the canal obtained. Also, Hukuda et al.[9] reported that excessive opening of the canal probably does not improve the outcome. This is more likely dictated by the ability of the cord to rebound to its more normal size and shape. Excessive opening should be avoided because this necessitates detachment of the posterior ligamentous structures at the transition from intact to open laminae and to prevent the hinge from breaking. Our results were in agreement with such data. The mean diameter of canal widening in Group II was recorded as 13.7±1.2 mm, and we achieved enlargement of the spinal canal of a mean of 5.4 mm in canal diameter and a mean expansion ratio of 65%. Although it was relatively smaller than any other data, the mean improvement in the postoperative JOA scores was 2.5 for our patients and there was no recurrence of symptoms. We believe that the prevention of restenosis is an important factor in open-door laminoplasty and that our method has shown good clinical results without restenosis.

CONCLUSION

Although analysis with a larger population and a longer follow-up period need to be undertaken, our modified open-door laminoplasty is technically simpler than other methods and has an advantage in maintaining an open-window in comparison with the Hirabayashi's classical open-door laminoplasty. We believe that our modified Hirabayashi method is an ideal surgical option for cervical laminoplasty.

References

1. Butler JC, Whitecloud TS 3rd : Postlaminectomy kyphosis : Causes and surgical management. **Orthop Clin North Am 23** : 505-511, 1992
2. Chiles BW 3rd, Leonard MA, Choundhri HF, Cooper PR : Cervical spondylotic myelopathy : patterns of neurological deficit and recovery after anterior cervical decompression. **Neurosurgery 44** : 762-769, 1999
3. Guigui P, Lefevre C, Lassale B, Deburge A : Static, dynamic changes of the cervical spine after laminectomy for cervical spondylotic myelopathy. **Rev Chir Orthop Reparatrice Appar Mot 84** : 17-25, 1998
4. Heller JG, Edwards CC 2nd, Murakami H, Rodts GE : Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy. **Spine 26** : 1330-1336, 2001
5. Herkowitz HN : Surgical management of cervical disc disease : 'open-door' laminoplasty. **Seminar in Spine Surgery 1** : 245-253, 1989
6. Hirabayashi K : Expansive open-door laminoplasty for cervical spondylotic myelopathy. **Jpn J Surg 32** : 1159-1163, 1978
7. Hirabayashi K, Toyama Y, Chiba K : Expansive laminoplasty for myelopathy in ossification of the longitudinal ligament. **Clin Orthop 359** : 35-48, 1999
8. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y : Expansive opendoor laminoplasty for cervical spine stenotic myelopathy. **Spine 8** : 693-699, 1983
9. Hukuda S, Ogata M, Mochizuki T, Shichikawa K : Laminectomy versus laminoplasty for cervical myelopathy : Brief report. **J Bone Joint Surg Br 70** : 325-326, 1988
10. Itoh T, Tsuji H : Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. **Spine 10** : 729-736, 1985
11. Jeon SC, Chough CK, Park HK, Lee KJ, Rha HK, Kim MC : Surgical technique and long-term follow-up of cervical laminoplasty using titanium miniplates. **J Korean Neurosurg Soc 36** : 369-374, 2004
12. Kamo Y, Takemitsu Y, Hamada O : Cervical laminoplasty by splitting the spinous process using AW glass-ceramic lamina spacer. **Rinsho Seikeigeka 10** : 1115-1122, 1992
13. Koyama T, Handa J : Cervical laminoplasty using apatite beads as implants : experiences in 31 patients with compressive myelopathy due to developmental canal stenosis. **Surg Neurol 24** : 663-667, 1985
14. Lonstein JE : Post-laminectomy kyphosis. **Clin Orthop 128** : 93-100, 1977
15. Mochida J, Nomura T, Chiba M, Nishimura K, Toh E : Modified expansive open-door laminoplasty in cervical myelopathy. **J Spinal Disord 12** : 386-391, 1999
16. Nakano K, Harata S, Suetsuna F, Araki T, Itoh J : Spinous process-splitting laminoplasty using hydroxyapatite spinous process spacer. **Spine 17** : 41-43, 1992
17. O'Brien MF, Peterson D, Casey AT, Crockard HA : A novel technique for laminoplasty augmentation of spinal canal area using titanium miniplate stabilization : a computerized morphometric analysis. **Spine 21** : 474-484, 1996