Modified open-door laminoplasty for treatment of neurological deficits in younger patients with congenital spinal stenosis: analysis of clinical and radiographic data

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Object. Multilevel anterior cervical decompressive surgery and fusion effectively treats cervical myeloradiculopathy that is caused by severe cervical spinal stenosis, but degenerative changes at adjacent vertebral levels frequently result in long-term morbidity.

The authors performed a modified open-door laminoplasty procedure in which allograft bone and titanium miniplates were used to treat cervical myeloradiculopathy in younger patients with congenital canal stenosis while maintaining functional cervical motion segments. Pre- and postoperative magnetic resonance imaging and/or computerized tomography myelography were performed to assess changes in cervical spinal canal dimensions. Pre- and postoperative flexion–extension radiographs were compared to determine the residual motion of the targeted operative segments.

Methods. Twenty younger patients (average age 37.7 years) underwent modified open-door laminoplasty for treatment of myelopathy or myeloradiculopathy related to significant cervical spinal stenosis with or without associated central or lateral disc herniation or foraminal stenosis. These surgeries were performed during a 2-year period and follow-up review remains ongoing (average follow-up period 21.6 months). Reconstructive procedures were performed on an average of 4.1 levels (range three–six). Operative time averaged 186 minutes (range 93–229 minutes). Average blood loss was 305 ml (range 100–650 ml). No cases were complicated by neurological deterioration, infection, wound breakdown, graft displacement, or hardware failure. The patients’ Nurick Scale grade improved from a preoperative average of 1.8 to a postoperative average of 0.5.

Pre- and postoperative sagittal spinal diameter averaged 11.2 mm (8–14 mm) and 16.6 mm (13–19 mm), respectively. The sagittal compression ratio (sagittal/lateral × 100%) increased from 48% pre- to 72% postoperatively. The spinal canal area increased an average of 55% (range 19–127%). In patients in whom pre- and postoperative flexion–extension radiographs were obtained, 72.7% residual neck motion was maintained. No patient developed increased neck or shoulder pain. Neurological symptoms improved in all patients, with total relief of myelopathy in 50% and partial improvement in 50%.

Conclusions. Modified open-door laminoplasty with allograft bone and titanium miniplates effectively treats neurological deficits in younger patients with congenital spinal stenosis. Although long-term results are unknown, short-term results are good and there is a low incidence of complications.

Key Words • cervical spine • laminoplasty • titanium miniplate • myeloradiculopathy

Cervical spondylotic myelopathy results from the degenerative process of vertebral columns and related soft-tissue structures. This results in stenosis and cervical cord compression with myeloradiculopathy. Non-surgical (conservative) treatment results in a 64% nonimprovement rate, with 26% of those patients displaying neurological deterioration. Anterior and posterior surgical approaches have been reported for treatment of cervical spondylotic myelopathy. With multisegment cervical disease, wide laminectomy has been a standard therapy. Complications associated with the use of multilevel cervical laminectomy include postoperative kyphosis, spinal instability, and postoperative laminectomy membrane. Anterior cervical decompression and spinal fusion (ACDF) is also a well-accepted method of treatment in patients with cervical spondylotic myeloradiculopathy; however, ACDF immobilizes segments of the cervical spine and results in high mechanical demands on the adjacent intervertebral segments. Over the patient’s lifetime, abnormal mechanical stresses can produce significant radiographic and clinical evidence of deterioration. Laminoplasty was developed as a method to avoid the complications associated with immobilizing the spine (the ACDF procedure) or destabilizing the spine (the laminectomy procedure). In a prospective study Herkowitz compared ACDF, laminoplasty, and laminectomy. The results demonstrated that ACDF and laminoplasty provided superior results, with no statistical difference between them.
Cervical laminoplasty was developed in Japan after significant complications were noted when performing multilevel laminectomy. Kiriya, et al. described an air-drill laminectomy technique that initiated the era of atraumatic spinal surgery. Oyama, et al. subsequently described the method that achieved comparable clinical outcomes with ACDF procedures while theoretically reducing the incidence of complications associated with ACDF and laminectomy.

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**Clinical Material and Methods**

**Patient Population**

This prospective study was conducted to evaluate the 2-year use of modified open-door cervical laminoplasty in a population of active-duty military personnel. Twenty younger patients (18 men and two women; average age at surgery 37.7 years [range 26–62 years]) with congenital spinal stenosis underwent a modified open-door laminoplasty in which allograft bone and titanium miniplates were used. All patients presented with signs and/or symptoms of cervical myelopathy. Ten of the patients experienced associated radicular symptoms. The preoperative diagnosis was cervical spinal stenosis with or without associated central or lateral disc herniation or foraminal stenosis. Some patients presented with minor trauma (for example, from hard landing during parachuting), but patients with significant cervical trauma and/or fractures were excluded from this study. Surgical indications included cervical canal stenosis, multilevel cervical spondylolisthesis, or posterior compression from ligamentous hypertrophy. Patients with focal anterior compression, isolated radiculopathy, cervical instability, or kyphosis were excluded from this study.

Patients underwent a comprehensive preoperative evaluation in which cervical spine flexion–extension radiographs, MR images, and/or CT myelographs were obtained. In four patients with significant myelopathy, preoperative flexion-extension radiographs were not obtained because of the risk of worsening deficit. In addition, in all patients without severe myelopathy a trial period of conservative therapy failed (nonsteroidal antiinflammatory medicine, cervical collar, and physiotherapy). Those patients with significant or progressive myelopathy were treated surgically shortly after evaluation.
The patient demographic and radiographic data are presented in Table 1. The follow-up period averaged 21.6 months (range 15.2–36.2 months). All patients underwent a modified canal expansive open-door laminoplasty procedure in which allograft bone fusion and titanium miniplates were placed. Four patients underwent a total of seven foraminotomies (average 1.7 per patient) on the open side of the laminoplasty. One patient also underwent a C4–5 disectomy during the same operation. In four patients previous cervical spine operations had been performed; these included one each of the following: a C3–5 ACDF with instrumentation; a C5–T1 partial hemilaminectomy and discectomy (PHLD); a C5–6 ACDF; or a C4–5 PHLD. In all patients cervical spine radiographs were obtained on the 1st postoperative day to evaluate hardware and graft placement. They were managed postoperatively in a rigid cervical collar for 6 weeks. At 6 weeks, the patients underwent clinical and radiographic evaluation, and the collar was removed. Ten weeks postoperatively, lateral cervical flexion-extension radiographs were obtained. An MR image or CT myelogram was obtained after the flexion-extension radiographs. (Radiographs are obtained every 6 months as part of our follow-up protocol to evaluate the status of the reconstruction, development of cervical kyphosis, or degenerative changes.) Each patient underwent pre- and postoperative myelopathy assessment based on the grading criteria in the Nurick scale (Table 2).

<table>
<thead>
<tr>
<th>Grade</th>
<th>Assessment</th>
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<tr>
<td>0</td>
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<td>1</td>
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<td>difficulty walking that prevents full-time employment or ability to do all housework, but that is not so severe as to require someone’s help to walk</td>
</tr>
<tr>
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<td>able to walk only w/ someone’s help or w/ the aid of a frame</td>
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Operative Technique

Preoperative radiographic studies were evaluated, and the areas of significant stenosis plus one level above and below were included in the laminoplasty and reconstructive procedure. In the operating room the patient’s head and neck were positioned after intubation, and the head was immobilized using three-point fixation. Patients received a dose of cefazolin (substituting vancomycin if the patient was allergic to penicillin) preoperatively and for 48 hours postoperatively. Utilizing a midline incision, the spino processes of C2–T1 were exposed for a typical C3–7 cervical laminoplasty. The muscles were mobilized bilaterally by performing a subperiosteal dissection while sparing the supraspinous ligaments, the interspinous ligaments, and taking care to preserve the facet capsules and soft-tissue attachments to the lateral masses. Foraminotomies, in some patients, were performed at levels at which clinical radiculopathy was observed when the presence of foraminal stenosis or a lateral disc herniation was noted. Care was taken to maintain a significant portion of the lateral mass to permit attachment of the titanium plate.

A high-speed burr drill was used to create a gutter at the junction of the lamina and medial aspect of the lateral mass through the outer cancellous bone (Fig. 1A). The cancellous bone on the "opening" side of the laminoplasty was removed and the inner cortex was thinned. Using a 1- or 2-mm Kerrison rongeur, transection of the lamina and ligamentum flavum was performed. On the "closing" side, the gutter was also formed at the junction of the lamina and the lateral mass. This gutter had to be sufficiently wide to permit a closing-wedge osteotomy with eventual approximation of the lamina against the lateral mass. In general, approximately 4 mm of bone was resected. The outer cortex and the majority of the cancellous bone were removed, but the inner cortex was left intact.

A “greenstick osteotomy” was performed by carefully displacing the spinous processes toward the closing osteotomy side while elevating the opening side of the lamina with a nerve hook (Fig. 1B). The lamina was opened en bloc on the side with the most radiographic evidence of compression or with the most prominent signs and symptoms of myeloradiculopathy. Fibular or iliac crest allograft was soaked in antibiotic solution and then cut into strips 1.1 to 1.5 cm in height by 0.5 to 0.7 cm in width and 0.5 to 0.7 cm in depth. Currently, allograft tricortical iliac crest is used to generate bicortical bone graft segments. A notch is burried into the superior and inferior aspects of the graft, which firmly lock it into place in the “open-door” portion of the laminoplasty between the opened lamina and lateral mass (Fig. 1C). Stabilization of each level was then performed by placing a 2-mm titanium miniplate. An appropriate segment (four or five holes) of straight plate was bent into an "open Z" shape (Fig. 1D). The plate was secured using a 2 × 6–mm screw at the superior aspect of the lamina and a 2 × 8–mm screw at the corresponding lateral mass (Fig. 2). One plate was used per level in all cases except in one patient who did not receive a plate at the C-4 level in a C4–7 laminoplasty. On completion of the procedure, an 18-in-round suction drain was placed, and the wound closed in the standard fashion with the canal diameter expanded. The preoperative MR images in Fig. 3

TABLE 2
Nurick scale for clinical assessment of myelopathy

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Cervical laminoplasty

Results

All 20 of the patients presented with myelopathy; 10 (50%) also presented with signs and symptoms of radiculopathy. Titanium miniplate and allograft cervical reconstructive procedures were performed in all patients on an average of 4.1 levels (range three–six levels). In four patients a total of seven (average 1.7 levels per patient) concurrent unilateral cervical foraminotomies were performed on the open side of the laminoplasty for the treatment of lateral disc herniation or focal severe foraminal stenosis. Operative time averaged 186 minutes (range 93–229 minutes). The average operative blood loss was 305 ml (range 100–650 ml). No case was complicated by neurological deterioration, infection, wound breakdown, graft displacement, cerebrospinal fluid leak, or hardware failure. All patients had improvement in their neurological symptoms. Myelopathy was completely resolved in 50% of patients and partially improved in 50% at last follow-up examination. The most common residual deficits included mild persistent lower-extremity hyperreflexia and failure of intrinsic hand muscle atrophy to resolve completely. Of the 10 patients with radiculopathy, six improved completely, two partially improved with mild intermittent symptoms, one experienced residual but improved radiculopathy, and one patient with persistent radiculopathy underwent ACDF without relief of radiculopathy. In no case did radiculopathy worsen. Although no patient had worsened neck or shoulder pain, two patients continued to experience neck and shoulder pain at their preoperative levels and required acetaminophen with codeine therapy periodically after the immediate postoperative period.

The preoperative sagittal canal diameter averaged 11.2 mm (range 8–14 mm), and the postoperative sagittal diameter averaged 16.6 mm (range 13–19 mm). The compression ratio preoperatively averaged 48% (range 35–55%) and postoperatively it was 72% (range 57–91%). The sagittal compression ratio increased from 47 to 72%.

Fig. 1. Drawings illustrating the operative technique for modified open-door laminoplasty. A: Bilateral gutters created using a high-speed burr drill. The lamina and ligamentum flavum are transected with a Kerrison rongeur. B: “Greenstick osteotomy.” C: Placement of bone graft with notching to lock it into place. D: Stabilization of spinal level with titantium miniplate. Drawings modified with permission from O’Brien, et al.

Fig. 2. Schematic drawing illustrating the orientation of the bone grafts and titanium miniplates for a C3–6 laminoplasty. Drawings modified with permission from O’Brien, et al.
postoperatively. The calculated canal area increased 55% (range 19–127%). The preoperative range of motion averaged 14.7˚ per level in the patients in whom preoperative flexion–extension radiographs were obtained. The postoperative motion per surgically treated motion segment averaged 11.1˚ (range 4.5–19˚). This represented a 72.7% residual motion in patients in whom both pre- and postoperative flexion–extension radiographs were obtained. The average Nurick scale grade improved from 1.8 to 0.5. No patient developed increased kyphosis or instability following the procedure.

Fig. 3. Preoperative T2-weighted sagittal (left) and axial (right) MR images obtained in a patient with persistent myelopathy.

Fig. 4. Imaging studies in a patient 12 weeks after C3–6 laminoplasty. Left: Lateral cervical spine radiograph demonstrating the maintenance of cervical lordosis. Right: Axial CT scans demonstrating the expanded canal.
Cervical laminoplasty

Discussion

Spondylotic cervical myelopathy has been successfully treated by several methods. Posterior decompressive surgery has been the treatment of choice in patients with multilevel cervical canal stenosis secondary to ossification of the posterior longitudinal ligament (OPLL) or spondylotic changes. The results of several studies suggest that there is no difference in postoperative decompression, instability, decompression, or neurological recovery between laminectomy and laminoplasty procedures. The results of other studies suggest that postoperative instability, especially kyphosis, is higher (up to 43%) after laminectomy. The results of yet other reports suggest that laminoplasty provides greater stability and range of motion compared with laminectomy, which may be protective against postoperative instability. The use of ACDF is effective treatment for cervical myelopathy, but the requirement of fusion of multiple levels can lead to significant radiographic and clinical evidence of deterioration at adjacent levels. Therefore, it appears that laminoplasty may be the superior treatment to simple multilevel laminectomy or multilevel ACDF in this patient population.

Several methods of cervical laminoplasty have been described and modified. In all the procedures there is an attempt to increase the spinal canal area, but they differ mainly in the location of canal entry and method of canal reconstruction. One problem in the laminoplasty procedure is the method of keeping the postoperative door “open” and maintaining the enlarged canal area. O’Brien, et al., have described a simple technique in which they use titanium miniplates for immediate stabilization while permanent stabilization relies on the small surface area of bone on the hinge side to form a permanent bony fusion.

In an attempt to form a better and more solid fusion, we augmented the titanium miniplate technique with allograft bone fusion between the free edge of the lamina and the corresponding lateral mass. This procedure provides some security in that the canal is entered laterally where the compression is least and the risk of neurological injury is reduced. The combination of titanium miniplates for immediate stabilization and allograft bone for long-term fusion led to no loss of canal decompression. We obtained good results treating 20 patients with cervical myeloradiculopathy: complete resolution of myelopathy in 50% and partial residual myelopathy in 50%. The Nurick scale measure of myelopathy decreased from a grade of 1.8 to 0.5.

The decompressive effects were measured in several fashions. In 1983 Kimura performed CT myelography and found that the average cervical sagittal diameter of the canal ranged from 12 mm at C-3 to 13 mm at C-7. In 1984 Tanaka obtained similar results in a postmortem study. The sagittal diameter in our patients increased from an average of 11.2 to 16.6 mm postoperatively. Similar results have been published by O’Brien, et al., (8.2–16.6 mm) and Satomi and colleagues (12–15.7 mm) after performing open-door laminoplasty. Our patient population was too small to allow us to determine if there was a correlation between extent of canal enlargement in the sagittal plane and symptomatic improvement. The average calculated area of the spinal canal over all surgically treated levels increased an average of 55%. O’Brien, et al., observed an average 78% increase in canal area at the most severely stenosed level after open-door laminoplasty. The canal area in our patients increased 88%, if only the most compressed level was used in the calculation. The authors of several studies identified that a decreasing sagittal compression ratio correlated with more severe neurological symptoms. The sagittal compression ratio, in our patients, increased from 48% preoperatively to 72% postoperatively. An increasing compression ratio corresponds to more area and less compression of the spinal cord. Lee and colleagues found a compression ratio increase to 63% from 37% in 25 patients who underwent open-door laminoplasty. Ogino and colleagues showed that the sagittal diameter was the most important component in the compression ratio and, therefore, the most important aspect in perpetuating mechanical cord trauma seen in patients with cervical myelopathy. It appears then that increasing the sagittal diameter and maintaining the sagittal decompression are the most important aspects in the surgical treatment of cervical myelopathy.

A consequence of ACDF in the treatment of cervical spondylotic myelopathy is immobilization of multiple motion segments. This has been shown to lead to long-term changes at adjacent-segment levels. In an attempt to maintain motion in the cervical spine we treated these patients with a modified open-door laminoplasty. It is known that open-door laminoplasty reduces cervical spinal motion ranging from 50% to 62%. We calculated the pre- and postoperative range of motion by using the sum of the Cobb angles. This angle was divided by the number of motion segments to obtain a range of motion per surgically treated segment. Other methods described involve measuring the motion at each segment, but we believed that the margin of error would be too high and elected to take the average over the total surgically treated levels. We observed 11.1° of range of motion per treated motion segment. In the literature postoperative range of motion after open-door laminoplasty has varied from 6.4° to 8.7° per level. Because our patients did not have OPLL, increased motion was present compared with most of the other series. By maintaining cervical motion, the complications at adjacent motion segments and the morbidity associated with loss of range of motion were avoided.

Our patients did not develop the significant morbidity that has been seen in other series. Of note, no patient developed C-5 radiculopathy or neck or shoulder pain, which has frequently been observed after laminoplasty. Hosono and colleagues retrospectively reviewed 72 patients who underwent laminoplasty and 26 who underwent ACDF with an average follow-up period of 52 months. They found that those patients in whom laminoplasty was performed (60%) had an increased incidence of axial symptoms (neck pain, shoulder pain, and shoulder muscle spasm) compared with those patients in whom ACDF was performed (19%). In examining patients’ pain, Hosono and colleagues noted that it usually developed on the “hinge” side of the laminoplasty, and they postulated that the pain could arise from the nonfused “hinge” side of the laminoplasty. Analysis of our data supports this hypothesis. Immediate fixation was attained with the titanium miniplates and long-term fusion with allograft bone in our patient population. No patient developed increased neck or shoulder pain. In fact, the preoperative neck and shoulder symptoms improved in many patients.
Conclusions

Although the follow-up period is short and the patient population is young, cervical laminoplasty in which titanium miniplates and allograft bone fusion are used was effective in reconstructing the spinal canal and improving or eliminating the symptoms of myeloradiculopathy in all patients. By using miniplates and allograft bone, the two greatest shortcomings of laminoplasty were overcome: there was no loss of correction and surgery was rapid. The “fiddle factor” was low, and immediate stable fixation of each surgically opened lamina was achieved. The incidence of complications was low, and early clinical results are comparable with those obtained in multilevel ACDF procedures. Greater than 70% of preoperative motion was maintained across the laminoplasty segments in the cervical spine. We have performed the described procedure in an additional 17 patients, not presented here due to short follow-up periods, without complication and with good relief of symptoms. Long-term follow-up review is required to assess whether spinal canal reconstruction performed using modified open-door laminoplasty in this young patient population will reduce the incidence of adjacent-segment degenerative changes frequently seen following extensive anterior procedures.

References

Cervical laminoplasty


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