Artificial lamina-assisted laminoplasty performed in seven cases

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Object. The authors attempted to simplify the operative approach to severe multilevel cervical spondylotic myelopathy. Seven patients with progressive and severe myelopathy underwent modified double-door laminoplasty during a 5-month period.

Methods. The double-door laminoplasty procedure was modified by using two artificial titanium laminae obtained by simple surgical 0.5-mm Ti-mesh (rather than by bone graft or ceramic spacers).

Preoperatively, gait disturbance was present in all patients with long-tract signs on neurological examination. In all cases the sagittal diameter of the cervical spinal canal was somewhat reduced (<10 mm) by congenital stenosis, and further severe compression of the spinal cord resulted from osteophytic bars and calcified ligamenta flava at different levels. No abnormal alignment, pathological movements, or instability was present. Computerized tomography (CT) studies demonstrated severe multilevel cervical compression, and T2-weighted magnetic resonance (MR) imaging demonstrated pathological areas of hyperintensity within the spinal cord in all cases.

In the initial follow-up study (range 8–12 months), the patients who underwent this procedure experienced marked improvement of gait disturbance without any significant incidence of morbidity or complications. Postoperative CT and MR imaging studies demonstrated complete spinal cord decompression and restoration of the patency of the subarachnoid spaces.

Conclusions. The proposed procedure has the advantage of achieving both an immediate stabilization of the open laminae by means of a bridgelike mechanism and protection from the possible compression of the dural sac by paravertebral muscles.

KEY WORDS • cervical spondylosis • ossification of the posterior longitudinal ligament • laminoplasty

MULTILEVEL cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal liga-

ment or a combination of these diseases is fairly common, and their recognition has become markedly in-

creased, probably because of the enlarged elderly population and improved diagnostic procedures.3,20,24,26,29,33,34

The natural history of the disease seems quite unpredictable, but in the case of rapidly progressing motor deficit, surgical decompressive surgery in which stabilization is performed should be recommended.3,33

The most relevant surgical options are anterior procedures such as multilevel discectomy and spondylotic bar removal or multilevel corpectomy in which subsequent stabilization and fusion are performed with or without instru-

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or–approach options include procedures such as laminectomy with or without posterior fac-

et fusion and laminoplasty.2,4,7,10,14,23

Surgery via the anterior approach (and mostly anterior multilevel corpectomy) can be extremely effective in achieving adequate spinal cord decompression. Nevertheless, these procedures remain hazardous because of the need for sub-

sequent stabilization and fusion. Sometimes the patient must be placed in an external halo vest for 3 months or long-

er in cases in which multilevel corpectomy has been performed.9,19,31 Posterior laminoplasty (such as open-door, tension-band laminoplasty, suspension laminotomy, or dou-

ble-door laminoplasty) has received increasing attention in recent years, and the reported clinical results appear ex-
tremely favorable; however, practice of this procedure has not been widely adopted because of complications in achieving a proper and stable bone construct.11–13,15,18,25,27,30

We present a new modified double-door laminoplasty procedure in which artificial titanium laminae (ATLs) are used; this appears to be an extremely simple and effective procedure based on our experience in treating seven cases.

Clinical Material and Methods

Seven patients with CSM underwent laminoplasty in which ATLs were used at the Neurological Institute of Milan during a recent 5-month period. There were five men and two women. Two patients were in the fifth and five in the seventh decades of life.

The indication for surgery in all cases was progressive and severe myelopathy. In three patients, the clinical history was shorter than 6 months, and in four cases it was longer, although never lasting more than 18 months.

The main clinical complaint in all cases was difficulty in walking: four patients were classified as Nurick Grade 3 and three as Nurick Grade 4.24 More or less pronounced upper-extremity deficits (from clumsy hand only to severe motor dysfunction) were also observed in all cases but one. The x-ray films demonstrated that the curvature of the cervical spine was either lordotic or neutral, with a flexion–extension arc of less than 40°. Gross spinal instability was absent in all the cases.

The severity and extent of spinal cord compression was documented by both magnetic resonance (MR) imaging and computerized tomography (CT) studies. In all cases CT and MR investigations documented a severe reduction of the sagittal diameter (< 10 mm) of the entire cervical spinal canal below C-2 due to developmental stenosis. Furthermore, the spinal cord appeared symmetrically compressed by ventral osteophytic bars and by dorsal hypertrophic infolded ligamenta flava with superimposed congenital stenosis of the cervical canal. As a result, in all cases extreme spinal stenosis (sagittal diameter < 5 mm) was present at a minimum of two vertebral levels. In all cases, T₂-weighted MR imaging demonstrated focal areas of signal hyperintensity within the compressed spinal cord (Fig. 1). The most pronounced abnormalities were at the C4–5 and C5–6 levels in our seven patients.

The patients were discharged from the hospital by the 5th postoperative day. We recommended that they wear a soft collar for approximately 4 weeks postoperatively. At that time CT scans or MR images were obtained before the removal of the collar. All patients received a minimum of 8 months of follow-up care (range 8–12 months).

The clinical status and the Nurick functional grade were compared with those of the preoperative neurological examination. The spinal canal sagittal diameter, as well as the shape of the subarachnoid spaces and the spinal cord at every operated level were evaluated by postoperative CT and MR imaging to ascertain whether surgery had attained the goal of complete dural and spinal cord decompression.

Operative Technique

Patients are placed prone; the head and neck are placed in slight flexion and maintained in position by a three-point head holder.

A standard double-door laminoplasty is then performed. Through a midline incision, the spinous processes and the posterior aspect of the laminae of the cervical spine are exposed from C-2 to T-1. The main phases of the laminoplasty are illustrated in Fig. 2.

After the paravertebral muscles are detached and retracted bilaterally, the facet joints are exposed and clearly outlined bilaterally. The interspinous ligaments are removed at the C2–3 and C6–7 levels, and the spinous processes of C3–6 are cautiously resected just at the junction with the laminae. A partial resection of the C-2 spinous process and of the upper portion of the lamina of C-7 are performed. The ligamentum flavum is then removed using a small Kerrison punch with a 0.5- to 1-mm-wide blade both at the C2–3 and C6–7 interlaminar spaces.

Extension of the C-7 laminectomy should be planned and performed according to the clinical and neuroradiological evidence of spinal cord compression at the C6–7 level.

A standard electric drill with Lindemann tip is used to drill three parallel vertical gutters. Two are symmetrical (one on each side) with a slight converging inclination at the medial margin of the facets, drilled through the cancellous bone with sparing of the inner cortex; the third
Artificial lamina-assisted laminoplasty

Fig. 2. Artist drawings illustrating the main phases of the ATL-assisted laminoplasty operation. A: The spinous processes have been removed from C-3 to C-6. The spinous process of C-2 has been also partially reduced. The ligamentum flavum has been removed both at the C2–3 and C6–7 levels. In the case of C6–7 spinal cord compression, the erosion of the lamina of C-7 can be widened to an enlarged laminectomy. Three symmetrical gutters are made using an electrical drill with a Lindemann tip. B: Because of its conical shape and its milling capacity, the Lindemann tip makes it easier to create a V-shaped gutter on each side in the proximity of the articular processes and to spare the inner laminar cortex. The midline gutter is completely opened using micro-rongeurs and curettes. C: The four laminae (C3–6) are then fractured and opened laterally on each side (double door), and a hole is made in each. The four opened laminae are still connected by the residual ligamentum flavum. D: The two ATLs (approximately 5 cm long, 0.5 mm thick, 1 cm high) are then positioned (one for every two laminae) and secured to the laminae with sutures so that the laminae will remain wide open. E: The final construct as it usually appears at the end of the operative field. The ATLs should be molded in a way so that their extremities will lie securely against the articular facets. Applying mild finger pressure against the ATLs will confirm the stability of the system. An epidural drainage system is usually left in place for approximately 2 days. Posterolateral fusion (with bone beneath the lateral edges of the ATLs) and association with lateral mass fixation systems are also possible.

Gutter (approximately 1-mm wide) is made in the midline and is extended to the inner cortex, which is gradually opened using a small Kerrison rongeur.

Using a large curette, the laminae are opened on both sides. If resistance is felt, the groove in the hinges is widened in a “V” shape and deepened by the drill. The complete opening of the two doors is achieved by delicate and progressive lifting, and it is immediately followed by marked dilation of the dural sac.

A small hole is drilled through every open lamina (C3–6) on both sides. Silk or reabsorbable sutures are passed through these holes.

At this time, two ATLs are placed behind the four opened laminae, and the laminae are suspended from the ATLs with the aid of the sutures.

The ATLs are obtained by making a midline cut in a standard surgical (0.5-mm-thick × 1-cm-high × 10-cm-long) piece of Ti-Mesh which is then curved in such a way that it can be used like a bridge system. The curvature and the length of the ATL can be easily modified so that its extremities will lie against the facet joints. The laminae are then lifted and fixed to the ATLs by the sutures; when the knots are tied, the four laminae are firmly suspended; at the same time, the ATLs are kept in place against the facet joints. Two laminae are connected to each ATL, and therefore, a four-level (C3–6) standard laminoplasty will require the use of two ATLs.

The distance that remains within the two ATLs is considered important for preserving the extension movement of the cervical spine (Fig. 3). Arthrodesis can be accomplished with posterolateral autogenous spinous processes bone grafting or even by autogenous iliac crest.

When the retractors are released, the paravertebral muscles will return to their place and further contribute to ATL stabilization. A drain is left in the epidural space, and the wound is closed in layers in the usual fashion.

Results

Within 1 week of surgery patients experienced severe neck and shoulder pain, which subsided in few days after initiating analgesic and steroid therapy.

Neck pain was not reported as a major discomfort by the patients at follow-up study. The clinical status was markedly improved in all seven patients in the immediate postoperative period (30–45 days). Three patients experienced a dramatic improvement of spasticity, with return to a fairly normal gait within 6 weeks. At late follow-up review (8–12 months), four patients were classified as Nurick Grade 2 and three patients as Nurick Grade 3. No surgery-related morbidity or complications were observed in the seven cases in the series (nor in eight additional patients in whom surgery was subsequently performed).

Preoperatively, the spinal cord appeared symmetrically compressed by ventral osteophytic bars and by dorsal hypertrophic infolded ligamenta flava (Figs. 1 and 4 upper). In all the cases, MR imaging studies demonstrated focal areas of hyperintense signal on T2-weighted images within the compressed spinal cord (Fig. 1).

Postoperative CT scans were obtained in seven cases and MR images in five. These neuroradiological evaluations led to the conclusion that a complete spinal cord decompression had been achieved in all the cases (Fig. 4 center), on the basis that the sagittal spinal canal diameter exceeded 15 mm along the entire longitudinal extension of the operative site. At 2 months, follow-up CT scans revealed that the dead space between ATLs, vertebral laminae, and the dural sac had been filled with epidural scar formation, which was unchanged on 12-month CT studies.
Nevertheless, there was no epidural constriction, and the dural sac was shown to have the same dilation and sagittal diameter as in the early postoperative CT study (Fig. 4 lower).

The most relevant features were the visualization of a normal outline of the spinal cord and the restoration of the patency of the subarachnoid space. The pathological high-intensity signal in the spinal cord on the T2-weighted images (consistent with some spinal cord myelomalacic changes), which was present preoperatively in all the cases (Figs. 1 and 5 left), appeared relatively unchanged on postoperative MR imaging studies (Fig. 5 right).

Surprisingly, the gross anterior abnormalities impinging on the spinal cord (protruded, degenerated discs and osteophytic bars) appeared quite “reduced” after surgery. This fact was obviously a consequence of the marked enlargement of the spinal canal, the dural sac, and the subarachnoid space (Figs. 3, 4 center, and 5 right).

On postoperative dynamic radiographic follow-up study (8–12 months) no significant abnormality in spinal alignment or curvature was demonstrated and the cervical range of motion was relatively unchanged.

**Discussion**

Cervical spondylosis is the most common cause of myelopathy in the elderly population, and in many cases patients can experience stabilization or regression of their myelopathy.3,20,29,33

Calcification of the posterior longitudinal ligament will cause a similar clinical syndrome, with insidious onset and unpredictable clinical course. Both of these pathological conditions, however, can lead to severe paraparesis or tetraparesis, sometimes with acute aggravation.24,26

Both of these groups of patients need to undergo extensive decompressive treatment of the cervical spinal canal. The different indications for anterior and posterior surgery have been extensively analyzed and discussed during the recent years since anterior surgery has become widely adopted.8,23,29,35,36

Some authors have proposed very clear algorithms that should help the clinician in making the difficult choice between surgery or conservative treatment and between the anterior or posterior surgical approach.14,33 However, thus far, there has not been any clear statistical demonstration of the superiority of the clinical results achieved by any single approach.8,29,35,36

The prognostic importance of the preoperative duration and severity of the clinical symptoms as well as the presence of focal high-intensity signal areas in the spinal cord on T2-weighted MR images is still unclear, and therefore, the clinical outcome seems quite unpredictable in single cases regardless of which procedure is performed.1,17,22,28

There is general agreement concerning some main points. 1) Spinal cord decompressive surgery should be as complete as possible. 2) Anterior surgery is a longer and more complicated procedure with a higher incidence of complications and morbidity. 3) Simple laminectomy is associated with late clinical deterioration in approximately 20 to 30% of cases, and recurrent myelopathy is probably caused by postlaminectomy scar formation. 4) Laminoplasty is a complicated procedure and difficult to accomplish properly. 5) Anterior and posterior procedures can achieve immediate good results in approximately 50 to 80% of cases, and these good results are maintained during the long-term follow-up period, but approximately 20 to 30% of these cases can show late deterioration in recovery grade. 6) Prospective random-
ized studies in which the natural history of the different diseases are compared with the long-term results of the anterior and posterior approaches are still needed.

In view of these considerations, we think that in patients with multilevel CSM or opacification of the longitudinal ligament and without spinal instability, the placement of ATLs should be considered a valuable surgical technique.

This procedure appears extremely simple and less invasive and risky than extensive anterior multilevel corpectomy and stabilization. Laminoplasty, in which two ATLs extend from C-4 to C-6, is a suitable treatment for cervical spinal stenosis that extends from C-2 to C-7 by simple association with more or less extended laminectomy of C2–7 laminae. It appears to be a safe procedure and can provide an immediate stabilization of the laminar “doors” anteriorly as well as valuable protection posteriorly from paravertebral muscle compression against the spinal cord when the cervical spine is in the extended position. The ATLs can be secured to the laminae by different means (silk sutures, reabsorbable sutures, or metal wires). Hardware displacement is unlikely, and it did not occur in the seven patients in this series or in eight additional patients in whom this procedure has been performed since the time of this preliminary clinical review. The bone healing of the fractured laminae and the soft-tissue scar are the most relevant factors concerning the strengthening of this construct.

A possible criticism of laminoplasty in which ATLs are used is related to the excessive enlargement of the spinal canal. This condition could create a dead space (underneath the excessively open and suspended laminae and the ATLs) with possible subsequent reconstriction of the dural sac by progressive epidural scar formation. This complication has been reported, but it has not yet been demonstrated in the early clinical and neuroradiological follow-up review in this series. It is, in our opinion, unlikely (Fig. 4 lower).

In fact, it has been demonstrated by dynamic MR imaging studies that postlaminectomy delayed recurrent cervical myelopathy could be related to spinal cord compression that occurs when paravertebral muscles are pushed anteriorly while the patient’s neck is in the extended position and not by scar reconstriction. However, this possible disadvantage of the technique could be easily overcome simply by positioning an autogenous fat tissue graft beneath the ATL.

We think that the use of one ATL for every two laminae maintains a sufficient distance between the ATLs to allow a fairly unchanged flexion–extension movement of the neck. We did not observe any significant reduction in cervical mobility in these seven patients, but longer dynamic follow-up studies are still needed. For ATL-assisted laminoplasty we selected only patients with relatively normal cervical lordosis and without abnormal cervical movements or instability in whom the use of ATLs could be extended. In fact, ATLs can be easily associated with posterior facet fusion and lateral mass plates for a posterior treatment of minor cervical instability.

A major implication, which could be inferred from the analysis of pre- and postoperative MR and CT studies and three-dimensional surface viewing of CT studies, was that the relevance of anterior spinal abnormalities (such as osteophytic bars and disc protrusion) had been overrated.

![Fig. 4. Computerized tomography studies.](image_url)
Larger series and longer follow-up studies are needed to accumulate significant data to support the use of this new operative technique. In our hands it appeared to be a very effective tool for treating multilevel cervical myelopathy, mostly when managing the older patient population. The absence of any significant complications in these initial seven patients, and in eight additional patients, should not be underestimated.

References


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