Canal Expansive Laminoplasty in the Management of Cervical Spondylotic Myelopathy

Leon Kaplan MD[1], Yigal Bronstein MD[1], Yair Barzilay MD[1], Amir Hasharoni MD PhD[1] and Joel Finkelstein MD FRCS(C)[2]

[1]Spine Surgery Unit, Department of Orthopedic Surgery, Hadassah University Hospital and Hebrew University-Hadassah Medical School, Jerusalem, Israel
[2]Sunnybrook Spine Program, Sunnybrook and Women's College Health Sciences Center, University of Toronto, Toronto, Canada

Key words: cervical spondylotic myelopathy, laminoplasty, Nurick classification, Hirabayashi technique

Abstract

Background: Cervical spondylotic myelopathy is often progressive and leads to motor and sensory impairments in the arms and legs. Canal expansive laminoplasty was initially described in Japan as an alternative to the traditional laminectomy approach. The results of this approach have not previously been described in the Israeli population.

Objectives: To describe the technique of CEL and present our clinical results in the management of patients with CSM due to multilevel compressive disease.

Methods: All patients undergoing CEL during the period 1984–2000 were identified. Of these, 24 of 25 patients had complete clinical information. Mean follow-up was 18 months (range 4–48). Mean age was 60 years (range 45–72). One patient underwent CEL at three levels, 22 patients at four to five levels and 1 patient at six levels The primary outcome measure was improvement in spinal cord function (according to the Nurick classification).

Results: Twenty-three (96%) of the patients experienced relief of their symptoms. Of these, 11 patients showed improvement in their Nurick grade, 12 patients were unchanged and one had worsening. Intraoperative complications (epidural bleeding and dural tear) occurred in six patients. Two patients developed a late kyphosis.

Conclusions: Our treatment of choice for multilevel CSM is canal expansive laminoplasty as initially described by Hirabayashi. It provides the ability for posterior surgical decompression without compromising the mechanical stability of the spine. This approach has the benefit of not requiring internal fixation and fusion. Our clinical outcome and surgical complication rate are comparable to those in the literature.

IMAJ 2006;8:548–552

Cervical spondylotic myelopathy may arise from congenital (ossification of the posterior longitudinal ligament) or acquired conditions (degenerative spondylosis) [1,2]. Clinical symptoms of cervical spondylotic myelopathy or cervical myeloradiculopathies result in spinal cord and root dysfunction. CSM is the leading cause of spinal cord dysfunction in patients older than 55 years [3]. Treatment is directed at arresting further deterioration after the onset of clinical symptoms, and secondarily to improve neurologic dysfunction. Plain radiographs with dynamic films are critical to assess stability and sagittal alignment. Cross-sectional imaging with computerized tomography scan and magnetic resonance imaging is invaluable in determining the extent (number of levels) and location of compression (anterior or posterior) [2].

Anterior surgery is beneficial for anterior compression less than three levels. A kyphotic alignment of the spine is also best managed anteriorly (either alone or in conjunction with posterior decompression in the case of more than two-level disease) [4]. Anterior surgery has inherent risks related to the approach and dissection. These involve early and delayed complications, which include airway obstruction requiring prolonged postoperative intubation, injury to the recurrent laryngeal nerve, injury to the esophagus, dysphagia, spinal cord injury and hardware-related complications [4-7].

Posterior surgery is beneficial for extensive disease (more than three levels). The presence of a lordotic or neutral cervical spine will allow decompression by way of laminectomy without the need for fusion and instrumentation [8,9]. However, in the younger patient the loss of a normal sagittal alignment is a concern [10]. For this reason, canal expansive laminoplasty was developed to allow for canal expansion without compromising the mechanical stability of the spine and thereby reduce the risk of late kyphotic deformity [11].

CEL was initially described by the Japanese, and a number of procedures and vast clinical experience encorporating this concept have been described [11-13]. To our knowledge however, this has not been previously reported in any large series in the Israeli population. We describe our experience using canal expansive laminoplasty (the Hirabayashi technique) for cervical spondylitic myelopathy involving multiple levels of the cervical spine [11].

Patients and Methods

The study cohort consisted of all patients undergoing surgery for CSM with canal expansive laminoplasty (Hirabayashi technique). Patients were identified from the spine registry at Hadassah Hospital between the years 1984 and 2000. Myeloradiculopathy was present in all patients and imaging diagnosis was made using CT scan and myelography or MRI. (MRI was more prevalent as an imaging modality after 1998.) A retrospective chart and radiographic review was performed documenting patients' demographics, preoperative pain and neurologic function (as

CEL = canal expansive laminoplasty
CSM = cervical spondylotic myelopathy

Figure 1: Nurick Classification System for CSM

Grade 0:	Root involvement, no evidence of spinal cord disease
Grade 1:	Signs of spinal cord disease, no difficulty in walking
Grade 2:	Slight difficulty in walking, does not allow full-time employment
Grade 3:	Difficulty in walking, does not allow full-time employment, does not require help in walking
Grade 4:	Walks with help
Grade 5:	Chair-bound or bedridden

assessed by the Nurick criteria) [Figure 1] [14]. The primary outcome measure was a change in postoperative neurologic function as measured by the Nurick grading system. Peri-operative and postoperative complications were also recorded.

Surgical technique [11]

Awake fiber-optic intubation is performed. The Mayfield pin holder headrest is applied and the patient is turned prone on the operating table. The head and neck are maintained in neutral to slight flexion which opens the interspinous distances. Via a midline posterior approach a bilateral subperiosteal dissection of the posterior elements is performed according to the length or number of laminas that were planned preoperatively. Level identification is performed by palpation and visualization of the prominent and bifid C2 spinous process. Care is taken to preserve the attachments to C2 of the inferior oblique muscle and greater straight muscle of the head as this prevents local kyphotic deformity between C2 and C3. Holes are prepared in the bases of the spinous processes for each level to be included in the "open-door." The extent of the decompression is from the laminar level of one above to one below the stenotic site diagnosed by preoperative imaging.

Using a microdrill or high speed burr, a bony gutter with a thin bottom is drilled at the junction of the laminae and facet joints on the side that is most symptomatic. Care is taken to ensure that the cut is made perpendicular to the lamina without entering the facet. Resection of the remaining "eggshell" bone is performed with Kerison rongeurs. On the contralateral lamina, the outer cortex is cut using a microdrill or burr [Figure 2A]. It is important to maintain the integrity of the inner cortex as this acts as a hinge. The top and bottom lamina to be included in the "door" are separated from their adjacent levels with a Kerison rongeur by cutting the lamina and adherent ligamentum flavum. This creates three free sides for the "door" and one "hinge." Sutures are passed through the holes that were initially prepared at the bases of the spinous processes. The door is opened by rotating the "door" on the hinge, which effectively produces canal expansion [Figure 2B]. The laminae, via the sutures, are secured to the soft tissues including the fascia which maintains the "open door" [Figure 2C]. Oxicell™ or Gelfoam™ is placed over the dura, and the surgical wound is closed by layers. A postoperative collar is applied for pain relief.

Results [Table 1]

Twenty-five patients underwent CEL, of whom 24 were available for follow-up. The cohort of patients included 18 males and 6 females. Age ranged from 45 to 72 (mean 60 years). All patients presented with cervical myeloradiculopathy. Eight patients had cord atrophy, one had rheumatoid arthritis, and one had cerebral palsy. The mean preoperative Nurick grade was 3 (range 1–5). Patients presented with CSM of three to six levels (average four levels). One patient underwent CEL at three levels, 14 at four levels, 8 at five levels and 1 patient at six levels. Average follow-up was 18 months after surgery (range 4–48).

On clinical evaluation, 23 of the 24 patients (96%) experienced relief of their symptoms. According to the Nurick classification, 10 patients demonstrated improvement by one grade, one patient improved by two grades, 12 patients were unchanged and one had worsening of the Nurick grade. The two patients

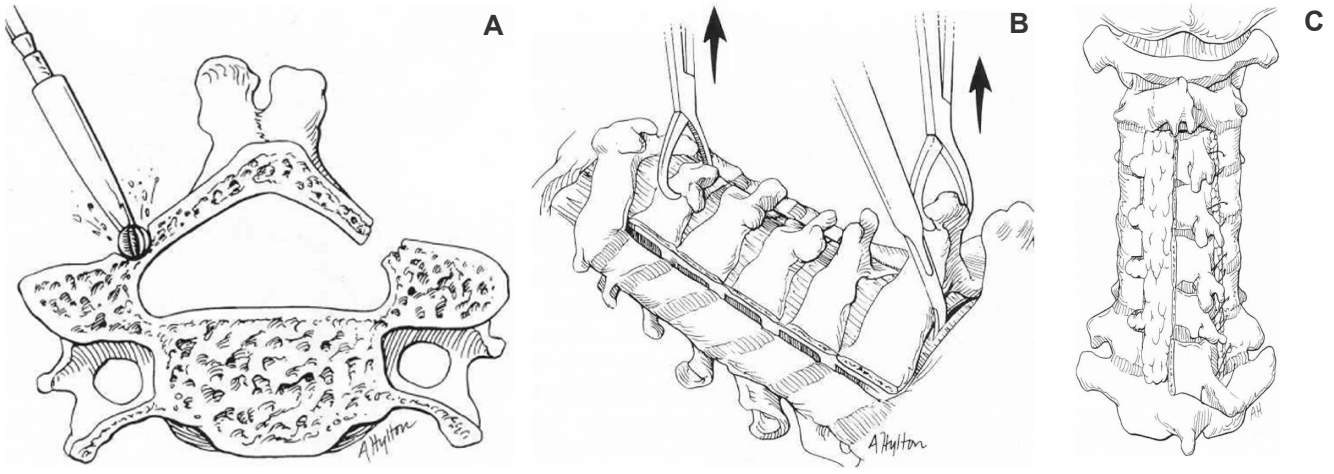

Figure 2. [A] Bilaminar trough is prepared on the more symptomatic side using a high speed burr. On the contralateral side, a trough with the inner cortex intact is created. This acts as a hinge. **[B]** A door with three free sides and a "hinge" is prepared which extends just beyond the most caudal and cranial levels of compression. Holes are prepared in the bases of the spinous processes for suture placement. **[C]** The "open-door" is rotated toward the hinge and secured to the soft tissue with sutures. Canal expansion is created. The exposed dura is covered with Oxycell or Gelfoam.

Table 1. Patient demographics and results

Patient no.	Age (yrs)	Gender	Cord atrophy	Nurick grade Pre-op	Level no.	Nurick grade Post-op	Complications	Follow-up (m0)
1	49	M	No	3	4	2		36
2	71	M	No	5	4	5	MI, died	6
3	58	F	No	3	4	2		4
4	72	M	No	2	5	2		16
5	46	M	No	2	5	1		12
6	55	M	Yes	3	4	3	Dural tear, C6 palsy	28
7	65	M	Yes	4	3	4		32
8	58	M	No	3	4	2	Epidural bleeding	40
9	68	M	No	2	4	2	Epidural bleeding	12
10	47	M	No	3	5	3	C5 palsy	24
11	45	M	Yes	3	6	4		24
12	71	M	No	5	5	4	Blindness	24
13	63	F	No	3	4	3		20
14*	59	F	Yes	5	5	5	Late kyphosis	24
15	66	F	No	1	5	1		16
16	49	F	Yes	2	4	2		16
17	69	M	Yes	2	4	2	Epidural bleeding, dural tear	12
18	60	M	Yes	3	5	2		48
19	61	M	No	3	4	3	Fracture lamina with dural compression, 2nd operation required	14
20	60	M	No	3	4	2		14
21	66	F	Yes	3	5	2	Epidural bleeding	6
22	65	M	No	3	4	2		48
23	69	M	No	4	4	2		7
24**	45	M	No	5	4	4	Late kyphosis	19

* Rheumatoid arthritis

** Cerebral palsy

with rheumatoid arthritis and cerebral palsy had initial Nurick grades of 5 (lowest functioning), and their postoperative scores were unchanged. The patient with cerebral palsy had lost the ability to ambulate and this was due to a combination of CSM, as documented on cervical CT scan, and spasticity due to the congenital disorder. Only one patient with a Nurick grade higher than 4 showed improvement postoperatively. Two patients had previously undergone anterior procedures to the CEL, neither of whom showed any change in their postoperative Nurick grades. Only two of the eight patients with preoperative cord atrophy improved in their Nurick grade. Eight of the 10 patients who improved a Nurick grade had no cord atrophy.

Surgical time ranged from 1 hour 40 minutes to 6 hours 30 minutes. The mean operative time was 2 hours 45 minutes. Where epidural bleeding occurred the times were prolonged. Surgical complications included a dural tear in two patients and epidural bleeding in four patients, requiring transfusion. C5 nerve root palsy developed in two patients with one resolving completely by 6 weeks and one with a permanent C5 partial deficit. A transient partial C6 palsy occurred in one patient with complete recovery by 6 weeks. One patient awoke with blindness in one eye and another patient had a fracture of the lamina noted peri-operatively, with dural compression requiring an urgent second operation.

Postoperative complications unrelated to the procedure were urinary tract infection in four patients and diabetes insipidus in one. One patient died of a myocardial infarction 6 months after surgery. In 2 of the 24 patients, loss of sagittal alignment occurred with development of a local kyphosis.

Discussion

Management of CSM is often controversial. The results of non-operative treatment in the case of progressive myelopathy are dismal. For this reason decompression of the canal is advocated and has been shown to be successful in improving spinal cord function [10]. Many approaches have been described, both anterior and posterior. Principles of management have been established to help guide treatment [10,15]. In general, maintenance or restoration of cervical lordosis is desired. In cases where cervical kyphosis is established, the inclusion of an anterior procedure is required [4]. For multilevel disease where cervical kyphosis is less than 13 degrees posterior, decompression is advocated [8,16]. The advantage of this is the lower incidence of complications that are inherent to the anterior approach. These include injury to the recurrent laryngeal nerve, the superior laryngeal nerve, esophagus and vertebral artery [2,3]. Other considerations include pain associated with the donor graft site and graft extrusion [17], and pseudoarthrosis [18]. Early and late postoperative complications are more significant following anterior surgery for multilevel disease [2-7]. Arguments against the posterior approach include the potential for destabilization and the development of kyphosis over time [19].

Laminoplasty over laminectomy is a technique whereby preserving the posterior elements maintains the tension band of the spine over the operative segment. This reduces (but does not eliminate) the potential for postoperative kyphosis. Neither laminectomy nor laminoplasty requires fusion in the lordotic spine; however, the loss of lordosis following laminectomy has been noted to lead to greater neck pain and poorer clinical outcome [20]. At our institution, laminoplasty is preferred for its capacity to preserve cervical lordosis. The CEL method of choice at our institution is the Hirabayashi technique [1]. We have been performing this procedure since 1984. Experience with CEL in a large series in the Israeli population has not been previously reported.

The clinical outcome in our cohort was comparable to other studies in the literature that report good to excellent results in

60% of the patients. In these studies, similarly to ours, factors that affect outcome are severity of neurologic deficit and presence of cord atrophy [20-22]. Regardless of the approach used for treatment, severity of the clinical picture and duration of the symptoms have been recognized as important factors that influence clinical outcome following surgery. Intervening in CSM at an earlier Nurick grade (1–2), as opposed to more advanced stages of CSM (grades 3–5) is desirable [21]. The presence of myelomalacia and cord atrophy is also a poor prognostic factor for recovery [22]. In our study, only 2 patients with cord atrophy showed improvement in their Nurick grade, while 8 of the 10 patients who improved a Nurick grade had no cord atrophy. Prevention of further deterioration in these patients is the primary goal of surgery.

In our cohort, two patients undergoing the Hirabayashi CEL developed late focal kyphosis. These patients had co-morbidities of rheumatoid arthritis and cerebral palsy. Both these patients had severe myelopathy (both with preoperative grade 5 Nurick score). Although development of late focal kyphosis has been recognized as a cause of poor outcome [20], in these patients with their severe premorbid conditions it is impossible to know how this affected their outcomes. Furthermore, in the patient with cerebral palsy, the neurologic picture is confounded.

Complications of surgery did occur in our patient population. One patient developed blindness due to positioning of the head on the headrest. This illustrates the importance of careful positioning such that no pressure is placed on the eyes for this or for any prone spinal procedure [23]. This complication occurred early in our series of patients and since then we have been using the Mayfield pins head-holder to stabilize the head throughout the procedure. Complications more commonly recognized include epidural bleeding requiring transfusion (n=4) and dural tears (n=2). These risks can be minimized by ensuring the trough is cut precisely perpendicular to the lamina without entrance to the facet joint. Deviating out towards the facet joint increases the risk of bleeding and nerve root injury.

Two of our patients had C5 nerve root palsies (one transient and one permanent). A transient partial C6 palsy occurred in one patient with complete recovery. The C5 nerve root is more commonly affected in posterior cervical procedures. The cause of this is multifactorial and may be due to the tethering effect of the C5 nerve root, marked anterior compression at the level of C3 and due to an increase in postoperative cervical lordosis [24]. In one patient a fracture of the "open door" lamina segment occurred, causing cord compression. This required an urgent secondary procedure. Fortunately, no permanent neurologic worsening resulted.

Reported disadvantages of laminoplasty are an increased incidence of axial neck/shoulder pain and a greater reduction in the range of motion compared to anterior approaches [18]. Since our study is not a direct comparison with anterior surgery, we cannot comment on differences in this regard; however, overall improvement in function was recorded in our patient population and seems to justify this potential drawback. Furthermore, it has been suggested that the resultant limitation in motion may help to prevent the progression of spondylosis and the development of deformity [2].

In summary, we report our experience using the Hirabayashi technique for canal expansive laminoplasty. This is the largest series of this approach to cervical spondylitic myelopathy in the Israeli population. In our opinion, this technique is a valuable treatment modality for multilevel disease. The outcome in our facility is comparable to other reported studies, and the complication rate can be minimized by adherence to principles of treatment. In this way the learning curve for this procedure can be shortened.

References

1. Hirabayashi K, Toyama Y, Chiba K. Expansive laminoplasty for myelopathy in ossification of the posterior longitudinal ligament. *Clin Orthop* 1999;359:35–48.
2. Law MD, Bernhardt M, White AA. Evaluation and management of cervical spondylotic myelopathy. J *Bone Joint Surg* (Am) 1994;76:1420–33.
3. Bernhardt M, Hynes RA, Blume HW, White AA. Cervical spondylotic myelopathy. J *Bone Joint Surg* (Am) 1993;75:119–28.
4. Zdeblick TA, Bohlman HH. Cervial kyphosis and myelopathy: treatment by anterior corpectomy and strut grafting. J *Bone Joint Surg* (Am) 1989;71:170–82.
5. Paramore CG, Dickman CA, Sonntag VK. Radiographic and clinical follow-up review of Caspar plates in 49 patients. J *Neurosurg* 1996;84(6):957–61.
6. Saunders RL, Bernini PM, Shirreffs TG, Reeves AG. Central corpectomy for cervical spondylotic myelopathy: a consecutive series with long-term follow-up evaluation. J *Neurosurg* 1991;74(2):163–70.
7. Vaccaro AR, Falatyn SP, Scuderi GJ, et al. Early failure of long segment anterior cervical plate fixation. J *Spinal Disord* 1998;11(5): 410–15.
8. Epstein JA. The surgical management of cervical spinal stenosis, spondylosis, and myeloradiculopathy by means of the posterior approach. *Spine* 1988;13:864–9.
9. Hukuda S, Ogata M, Mochizuki T, Shichikawa K. Laminectomy versus laminoplasty for cervical myelopathy; brief report. J *Bone Joint Surg* (Br) 1988;70:325–6.
10. Orr RD, Zdeblick TA. Cervical spondylotic myelopathy. Approaches to surgical treatment. *Clin Orthop* 1999;359:58–66.
11. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii T. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine* 1983;8:693–9.
12. Satomi K, Nishu Y, Kohno T, Hirabayashi K. Long term follow-up studies of open door expansive laminoplasty for cervical stenotic myelopathy. *Spine* 1994;19:507–10.
13. Itoh T, Tsuji H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine* 1985;10:729–36.
14. Nurick S. The natural history and the results of surgical treatment of the spinal cord disorder associated with cervical spondylosis. *Brain* 1972;95:101–8.
15. Grob D. Surgery in the degenerative cervical spine. *Spine* 1998;23: 2674–83.
16. Suda K, Abumi K, Ito M, Shono Y, Kaneda K, Fujiya M. Local kyphosis reduces surgical outcomes of expansive open door laminoplasty for cervical spondylotic myelopathy. *Spine* 2003;28:1258–62.
17. Fessler RG, Steck JC, Giovanini MA. Anterior cervical corpectomy for cervical spondylotic myelopathy. *Neurosurgery* 1998;43:257–65.
18. Wada E, Suzuki S, Kanazqwa A, Matsuoka T, Miyamoto S, Yonenobu K. Subtotal corpectomy versus laminoplasty for multi-

level cervical spondylotic myelopathy: a long-term follow-up study over 10 years. *Spine* 2001;26:1443–8.
19. Guigui P, Benoist M, Deburge A. Spinal deformity and instability after multilevel cervical laminectomy for spondylotic myelopathy. *Spine* 1998;23:440–7.
20. Kimura I, Shingu H, Nasu Y. Long-term follow-up of cervical spondylotic myelopathy treated by canal expansive laminoplasty. *J Bone Joint Surg* (Br) 1995;77:956–61.
21. Tanaka J, Seki N, Tokimura F, Doi K, Inoue S. Operative results of canal expansive laminoplasty for cervical spondylotic myelopathy in elderly patients. *Spine* 1999;24(22):2308–312.
22. Kohno K, Kumon Y, Oka Y, Matsui S, Ohue S, Sakaki S. Evaluation of prognostic factors following expansive laminoplasty for cervical spinal stenotic myelopathy. *Surg Neurol* 1997;48(3):237–45.
23. Hoski JJ, Eismont FJ, Green BA. Blindness as a complication of intraoperative positioning: a case report. *J Bone Joint Surg* (Am) 1993;75:1231–2.
24. Minoda Y, Nakamura H, Konishi S, et al. Palsy of the C5 nerve root after midsagittal splitting laminoplasty of the cervical spine. *Spine* 2003;28:1123–7.

Correspondence: Dr. J. Finkelstein, Dept. of Orthopedics, Hadassah University Hospital (Ein Kerem Campus), P.O. Box 12000, Jerusalem 91120, Israel.
Phone: (972-50) 894-6316
Fax: (972-2) 677-8052
email: joel.finkelstein@sunnybrook.ca