Laminoplasty versus multiple anterior cervical discectomy for cervical spondylotic myelopathy in patients with a lordotic cervical spine

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Received 1 January 2013
Accepted 15 March 2013

Egyptian Orthopedic Journal 2013, 48:369-375

Background
Using anterior or posterior surgery for multilevel cervical spondylotic myelopathy continues to be a subject of considerable debate. Studies comparing the two approaches are limited and few studies focus on anterior cervical discectomy and fusion (ACDF) as against open-door laminoplasty (ODL).

Study design
This investigation was designed as a prospective study.

Objective
The aim of the study was to compare the clinical outcomes, radiographic changes, and complications of patients with multilevel cervical spondylotic myelopathy who underwent ACDF and ODL in the lordotic cervical spine.

Patients and methods
We evaluated 40 patients (20 patients in the ACDF group and 20 patients in the ODL group) at our institution from September 2005 to December 2008. They were followed up for a minimum of 2 years. The clinical outcomes [Nurick grade and Japanese Orthopaedic Association (JOA) score], radiographic changes (radiograph and MRI), and complications were compared between the two groups.

Results
ODL showed significantly longer operative time (155 vs. 95 min) and more blood loss (438 vs. 215 ml) compared with ACDF. Both the ACDF and ODL groups showed significant improvement in Nurick grade from 3.5 and 3.4 preoperatively to 1.85 and 1.95, respectively, at last follow-up (P<0.05). Both groups showed significant improvement in the JOA score (P<0.05), and recovery rate was similar (63.2% in the ACDF group and 64.4% in the ODL group) (P>0.05). Cervical motion (on dynamic lateral radiograph) decreased significantly postoperatively in both groups (P<0.05) but was seen to have significantly improved in the ODL group at last follow-up. Minimal complications were reported in both groups.

Conclusion
Both ACDF and ODL are effective treatment modalities for multilevel cervical spondylotic myelopathy with no significant difference between the two groups in Nurick grade, JOA score, recovery rate, and MRI sagittal canal diameter widening. However, the ODL group showed significantly better cervical motion at last follow-up but, unfortunately, longer operative time and greater blood loss.

Keywords:
anterior discectomy, cervical, laminoplasty, radiculomyelopathy

Egypt Orthop J 48:369-375

1110-1148

Introduction

Cervical canal stenosis (CCS), whether primary or secondary to advancing degenerative changes, causes substantial neurologic dysfunction. Surgery is the predominant treatment for this disease, but controversy exists over which surgical approach is most appropriate.

Management of spinal stenosis is aimed toward symptomatic relief and prevention of neurologic sequelae. Conservative measures, such as pharmacologic therapy and physical therapy, may provide temporary relief. Surgery is indicated when the signs and symptoms correlate with the radiologic evidence of spinal stenosis. Generally, surgery is recommended when significant radiculopathy, myelopathy, or incapacitating pain is present. The choice of surgical procedure and the decision to fuse the spine should be individualized to optimize the outcome. Cervical stenosis progresses to myelopathy in as many as one-third of affected individuals.

Most surgeons use multiple anterior discectomy and/or corpectomy and fusion for treating patients with CCS with great success [1]. However, it has also been shown that the incidence of complications — namely, pseudarthrosis and adjacent segment degeneration — increases proportionately with the number of cervical discs excised or with the number of vertebral bodies removed [2].

Canal expansive laminoplasties were developed to diminish the undesirable effects of laminectomy, which include spinal instability, accelerated spondylotic changes, postoperative kyphotic changes, and constriction of the dura mater by extradural scar tissue formation [3,4]. Radiographic and biomechanical results in the goat model suggested that laminoplasty is superior to laminectomy in maintaining cervical alignment and preventing postoperative spinal deformities [5].

This study compares between open-door laminoplasty (ODL) and multiple-level anterior cervical discectomy and fusion (ACDF) for treating cervical spondylotic myelopathy (CSM) due to CCS as regards the clinical, radiological, and functional outcome as well as the incidence of complications.

Patients and methods

Between September 2005 and December 2008, 40 patients with CSM due to CCS were randomized into one of two surgical procedures and were prospectively evaluated both clinically and radiologically for a minimum of 2 years postoperatively. The first treatment group (ACDF group) was operated upon with multiple ACDF. The second group (the ODL group) was operated upon using the ODL technique. The demographic data of both groups are shown in Table 1. Statistical evaluation of all the demographic data of patients was performed and showed no statistical difference between the two groups. None of the patients included in this series had sustained a significant cervical trauma.

All patients of both groups underwent a detailed neurological examination and Nurick grading [6] preoperatively. The severity of myelopathy was also assessed using a modified Japanese Orthopaedic Association (JOA) scoring system, in which the ability to use chopsticks was replaced by testing the ability to unbutton a fixed shirt. This modification was validated several years ago [7]. All patients included in this series were suffering from myelopathy. Twenty-one patients also had radiculopathy. No patient included had radiculopathy only without myelopathy.

Table 1 Demographic data of the patients

	ACDF group	ODL group
Total number	20	20
Sex (male/female)	9/11	8/12
Age (range) (years)	60.3 (45–72)	53 (45–71)
Duration of symptoms (range) (months)	13.4 (3–38)	16.1 (1–38)
Symptoms and signs [*n* (%)]		
Myelopathy	20 (100)	20 (100)
Radiculopathy	12 (60)	9 (45)

ACDF, anterior cervical discectomy and fusion; ODL, open-door laminoplasty.

Radiological evaluation included plain cervical radiography and MRI. All patients included in this series had maintained cervical lordosis. Any patient with loss of cervical lordosis or with preoperative cervical kyphosis was excluded from this series. Dynamic cervical radiograph films obtained preoperatively showed no evidence of instability or hypermobility. Reduction of disc height, multiple osteophytic disc compression, and buckling of the ligamentum flavum contributing to CCS over three or more segments were present in all cases. All patients had areas of high-signal intensity in the spinal cord, which indicated edema or myelomalacia on T2-weighted MRI. The sagittal canal diameter was also measured by the MRI.

In the ACDF group, 13 patients had ACDF of three levels, six patients had ACDF of four levels, and one patient had ACDF of five levels. In the ODL group, the OLD technique used is that described by Hirabayashi *et al*. [8]. All patients had C3–C7 laminoplasty with undercutting of C2 and D1 laminae regardless of the levels of stenosis and cord compression. Care was taken to open the laminoplasty on the more symptomatic side and to keep the muscles attached to the C2 spinous process. All patients of both groups were treated with a cervical collar for 6 weeks and were engaged in an intensive physiotherapy program thereafter.

Immediately after surgery, routine anteroposterior and lateral plain radiographs and MRI scans were obtained to assess the extent of decompression. All patients in this series were followed up clinically and radiographically, undergoing plain and dynamic cervical spine radiography at 6, 12, and 24 weeks and every 6 months thereafter. The range of motion was measured as an angle between the lower border of C2 and C7 on lateral flexion and extension radiographs of the cervical spine.

For economic reasons, follow-up MRI could not be routinely performed. However, 23 patients (nine in group A and 14 in group B) included in this series underwent an MRI at 6 months postoperatively. The sagittal canal diameter was measured and compared with the preoperative and postoperative measurements.

All patients were asked about the presence or absence of axial symptoms (neck and/or shoulder pain). The surgical outcome was evaluated by the recovery rate (RR). A RR over 75% is described as excellent, that over 50% is good, that over 25% is fair, and less than 25% is unchanged:

$$RR = \frac{\text{Postoperative JOA score} - \text{Preoperative JOA score}}{17\ (\text{full score}) - \text{Preoperative JOA score}} \times 100.$$

Results

The minimum follow-up period of both groups was 2 years (mean 31.4 months, range 24–72 months). The mean operative time was 95 min (range 65–185 min) in the ACDF group and 155 min (range 130–200 min) in the ODL group ($P < 0.05$). The mean amount of blood loss was 215 ml (range 100–1000 ml) in the ACDF group and 438 ml (range 200–1850 ml) in the ODL group ($P < 0.05$) (Table 2).

Radiological results

Postoperative MRI confirmed significant enlargement of the cervical canal in all patients (Figs 1–4). The mean sagittal canal diameter increased from 12.5 mm (range 11–13.5 mm) preoperatively to 15.8 mm (range 14.5–17 mm) postoperatively in the ACDF group and from 12.9 mm (range 1113.5 mm) preoperatively to 16.3 mm (range 15–18 mm) postoperatively in the ODL group ($P < 0.05$), as evidenced by the restoration of the anterior CSF space. There was no significant difference between the two groups ($P > 0.05$) (Table 3).

Through the lateral dynamic (flexion and extension) radiographic views, motion of the cervical spine was seen to have decreased significantly postoperatively in both groups compared with the preoperative values ($P < 0.05$). In the ACDF group, the mean cervical range of motion decreased from 30.4° (range 28–33°) preoperatively to 16.9° (range 12–20°) postoperatively and to 20.6° (range 15–22°) at last follow-up. In the ODL group, it decreased from 32.8° (range 30–35°) preoperatively to 19.3° (range 16–22°) postoperatively but gradually increased to 29.1° (range 27–30°) at 2-year follow-up. There was significantly better range of motion in the ODL group than in the ACDF group at last follow-up ($P < 0.05$).

At the last follow-up, none of the patients in the ODL group were seen to have radiological evidence of instability or sagittal-plane malalignment. The follow-up MRI obtained at 6 months in 23 patients confirmed the maintenance of canal widening and cord decompression. All patients in the ACDF group achieved solid fusion.

Clinical results

All patients reported significant improvement in their neck and arm symptoms. Neurological improvement was also demonstrated at last follow-up in all patients. Progression of myelopathy was arrested in all patients. The mean Nurick score of the ACDF and ODL groups improved significantly from 3.5 (range 2–5) and 3.4 (range 2–5) preoperatively to 1.85 (range 0–3) and 1.95 (range 0–4) at last follow-up, respectively ($P < 0.05$). There was no

Table 2 Operative time and blood loss of both groups

	ACDF group	ODL group	*P* value
Operative time (range) (min)	95 (65–185)	155 (130–200)	0.035*
Blood loss (ml)	215 (100–1000)	438 (200–1850)	0.041*

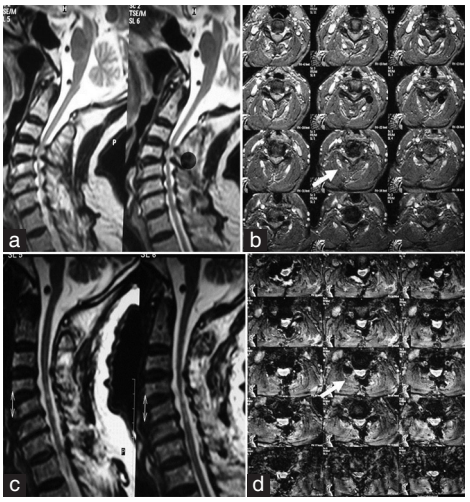
Mann–Whitney *U*-test; ACDF, anterior cervical discectomy and fusion; ODL, open-door laminoplasty; *Significant, $P < 0.05$.

Table 3 Radiological results of both groups

	ACDF group	ODL group	P_1 value
MRI sagittal diameter (range) (mm)			
Preoperative	12.5 (11–13.5)	12.9 (11–13.5)	0.674
Postoperative	15.8 (14.5–17)	16.3 (15–18)	0.508
P_2 value	0.012*	0.010*	
Lateral dynamic radiograph			
Preoperative	30.4° (28–33°)	32.8° (30–35°)	0.267
Postoperative	16.9° (12–20°)	19.3° (16–22°)	0.137
Last follow-up	20.6° (15–22°)	29.1° (27–30°)	0.000*
P_2 value (post)	0.000*	0.000*	
P_3 value (last)	0.005	0.000*	
Fusion	All patients (100%)	—	

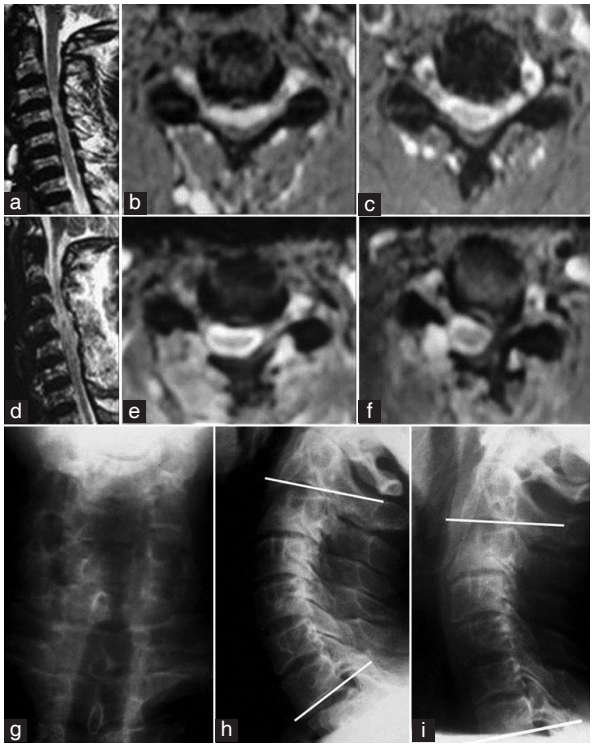
ACDF, anterior cervical discectomy and fusion; ODL, open-door laminoplasty; P_1 value, Mann–Whitney *U*-test; P_2 value, Wilcoxon signed-rank test; P_3 value, Wilcoxon signed-rank test; *Significant, $P < 0.05$.

Figure 1



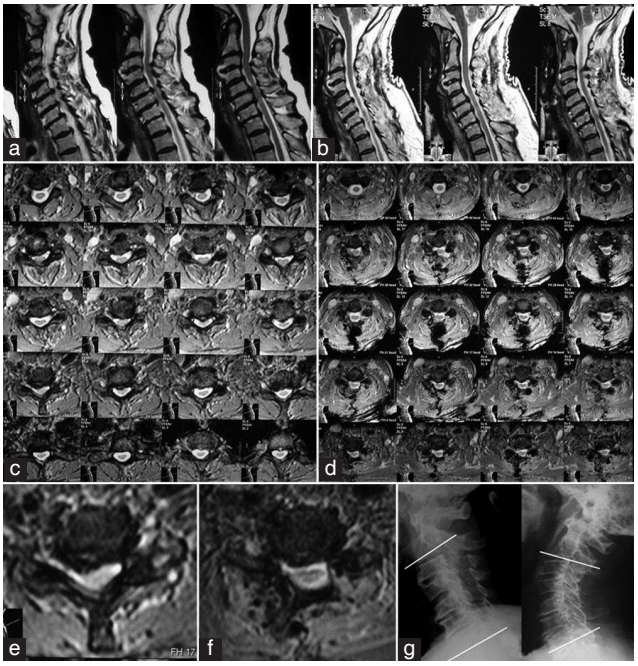
A 62-year-old male patient with cervical spondylotic myelopathy and maintained cervical lordosis. (a, b) Preoperative sagittal and axial T2-weighted MRI with marked degenerative canal stenosis opposite C3–C7 with obvious buckling of the ligamentum flavum. (c, d) Postoperative open-door laminoplasty sagittal and axial T2-weighted MRI confirms widening of the cervical canal and cord decompression as evidenced by the restoration of the CSF space both anterior and posterior to the cord. Note that the white arrow in figure (b) and (d) point to the same level.

Figure 2



A 61-year-old man with significant cervical canal stenosis. (a–c) Preoperative T2-weighted MRI showing canal stenosis. (d–f) Postoperative open-door laminoplasty T2-weighted MRI showing canal widening and cord decompression. (g–i) Two-year follow-up with no evidence of instability or sagittal malalignment.

Figure 3



A 57-year-old woman with cervical spondylotic myelopathy and right brachialgia. (a, b) Preoperative and postoperative sagittal MRI. (c, d) Preoperative and postoperative axial MRI. (e) Close-up view at C5–C6 disc level with large disc prolapse encroaching on the right nerve root. Anterior discectomy was planned as the second stage following laminoplasty. (f) Postlaminoplasty MRI at the same level with canal widening and cord and nerve root decompression. Brachialgia disappeared and no further surgery was necessary. (g) Dynamic views at 2-year follow-up with maintenance of cervical flexibility and stability.

significant difference between the two groups ($P > 0.05$) (Table 4).

All patients showed marked functional improvement, as reflected by the significant improvement in the JOA score. The preoperative JOA scores of the ACDF and ODL groups were 5.7 (range 3–11) and 5.95 (range 1–11), respectively. The follow-up JOA score improved significantly to 12.9 (range 10–15) and 13 (range 8–16), respectively ($P < 0.05$). The mean RR was 63.2% (range 30–92.3%) in the ACDF group and 64.4% (range 30.7–85.7%) in the ODL group ($P > 0.05$).

Complications

There were no intraoperative complications in either group. Neither dural laceration nor spinal cord or nerve root injuries were recorded. In the ACDF group, one (5%) patient developed superficial infection and three (15%) had persistent dysphagia for more than 10 days. In the ODL group, two (10%) patients demonstrated paresis of the unilateral upper extremity, which improved at 2 months' follow-up, and some epidural bleeding occurred in three (15%) patient, with each patient requiring 1 l of blood transfusion.

Discussion

CSM is the leading cause of spinal cord dysfunction in older patients. It is of utmost importance for the treating physician to recognize the early signs and symptoms of myelopathy, because the results of surgery in patients with prolonged and progressive myelopathy are compromised [9,10]. When medical and surgical treatments are compared, surgically treated patients appear to have better outcomes [10].

Hirabayashi [11] devised an ODL, which is a relatively easier and safer procedure than laminectomy. The decompression effect of the expansive laminoplasty is comparable to that of laminectomy and anterior decompression, followed by fusion, whereas the expansive laminoplasty has no adverse effect on adjacent disc levels that often are associated with anterior decompression followed by fusion [12–15].

At present, many authors consider all patients with CSM candidates for expansive laminoplasty, except for those having preoperative kyphosis and single-level lesion without canal stenosis [9,16]. Any patient with loss of cervical lordosis or with preoperative cervical kyphosis was excluded from this series.

Figure 4

A 63-year-old woman with cervical spondylotic myelopathy. (a, b) Preoperative and postoperative sagittal MRI. (c, d) Two-year follow-up plain radiographs after C3–C6 anterior cervical discectomy and fusion showing solid fusion.

Table 4 Clinical results of both groups

	ACDF group	ODL group	P_1 value
Nurick grade			
Preoperative	3.5 (2–5)	3.4 (2–5)	0.906
Last follow-up	1.85 (0–3)	1.95 (0–4)	0.852
P_2 value	0.000*	0.000*	
JOA			
Preoperative	5.7 (3–11)	5.95 (1–11)	0.652
Last follow-up	12.9 (10–15)	13 (8–16)	0.773
P_2 value	0.000*	0.000*	
RR (range) (%)	63.2 (30–92.3)	64.4 (30.7–85.7)	0.766
Outcomes [*n* (%)]			
Excellent	1 (5)	3 (15)	
Good	15 (75)	12 (60)	
Fair	4 (20)	5 (25)	

ACDF, anterior cervical discectomy and fusion; JOA, Japanese Orthopaedic Association; ODL, open-door laminoplasty; RR, recovery rate; P_1 value, Mann–Whitney test; P_2 value, Wilcoxon signed-rank test; *Significant, $P < 0.05$.

One theoretical technical problem related to the Hirabayashi technique of ODL is how to maintain the lamina open. Some authors tried to wedge a bone graft in the laminar opening, but this increased the operative time and the risk of graft dislodgement and neurological deterioration [17]. The use of titanium mini plates to stabilize the posterior elements after laminoplasty is suggested by other authors [18]. However, in addition to the increased operative time and costs, there is also increased risk of neural damage. In this study, the original technique of Hirabayashi was used, in which the spinous processes and ligaments were fixed by sutures to the capsular and parafacetal soft tissues. This, in our hands, proved to be a very simple, fast, and reliable technique, as supported by the good clinical and radiological outcomes achieved in patients of this series.

Compared with the ACDF group in this study, the ODL group experienced significantly longer operative time (155 vs. 95 min) and suffered more operative blood loss (438 vs. 215 ml) ($P < 0.05$). Similar results were reported in the series of Liu *et al.* [19] who reported longer operative time and more blood loss in the laminoplasty group.

In this study, there was significant improvement in the Nurick grading of both ACDF and ODL groups from an average 3.5 and 3.4 to 1.85 and 1.95 at last follow-up ($P < 0.05$). Also, the JOA score improved significantly from an average 5.7 and 5.95 preoperatively to 12.9 and 13, respectively, at last follow-up ($P < 0.05$). There was no significant difference between the two groups ($P > 0.05$). This was comparable to the results of Liu *et al.* [19].

The average RR of expansive laminoplasty for CSM has been reported to be ~60% and with long-term stability [5,8,12,13,15]. This is comparable to the results achieved in this study (64.4% in the ODL group and 63.2% in the ACDF group) with no significant difference between the two groups ($P > 0.05$).

Postoperative problems often seen after expansive laminoplasty of the cervical spine include persisting axial pain, restriction of neck motion, and loss of cervical lordosis [20]. In this study, motion of the cervical spine decreased significantly postoperatively in both groups compared with the preoperative values ($P < 0.05$), but ODL patients experienced restoration of much of their cervical range of motion when compared with the ACDF group of patients ($P < 0.05$) at last follow-up. This finding is of particular importance in today's world, where motion preservation techniques are gaining popularization and are being used increasingly more all over the world [21].

It is well recognized that the development of kyphosis and/or postoperative instability generally leads to a small degree of neurological recovery and to more residual neck pain. The axis plays a principal role in extending and stabilizing the head and neck. To serve this function, it has a large spinous process, which acts

as a lever arm to which there are more extensor muscles attached than to the other cervical vertebrae [22]. Several authors [23–26] have emphasized the importance of reattaching the removed muscles to the C2 spinous process as a means of preventing postoperative cervical malalignment. In all patients of the ODL group in this study, utmost care was taken to keep the muscles attached to the C2 spinous process. This might explain our low incidence of postoperative axial symptoms, the absence of any instability, and the maintenance of cervical lordosis.

We observed, as did other authors [8,12,13], some loss of cervical range of motion following the laminoplasty procedure. However, this compares favorably to techniques involving multilevel arthrodesis. A retrospective study comparing the long-term outcomes of subtotal corpectomy and laminoplasty for multilevel CSM concluded that both have an identical effect on the neurologic recoveries, which usually last for more than 10 years, and that in the subtotal corpectomy group the disadvantages were longer surgical time, more blood loss, and pseudarthrosis, whereas in the laminoplasty group axial pain occurred frequently [19,27].

Paresis of the upper extremities was demonstrated in two (10%) patients of the ODL group, which improved at 2 months' follow-up. Paresis of the upper extremities after posterior decompression of the cervical spine, usually in the C5 and C6 dominant muscles, has been known to occur independently of technical problems in 7–8% of cases [28–31]. This postlaminoplasty paresis has been thought to be radiculopathy because of the extradural tethering effect induced by posterior shift of the spinal cord after decompression. Weakness of shoulder girdle muscles, however, due to nerve root damage was not observed in any patient included in this study.

Many authors have tried to determine the predictive factors of good surgical outcome. The number of patients included in this study does not permit conclusive statistical analysis of the predictive factors of surgical outcome, but it seems that history of trauma, prolonged duration of symptoms, severity of neurological impairment, and preoperative loss of lordosis are associated with less probability of good surgical outcome. This concurs with the results obtained by many other authors [3,32].

Conclusion

Open-door expansive laminoplasty appears to be a safe and effective method for arresting the progression of myelopathy and for allowing marked functional improvement in patients with multilevel CSM. It compares favorably with multiple ACDF, especially as regards the neurological, functional, and radiological outcome. However, it preserves better cervical range of motion. Unfortunately, it takes longer operative time, causes more blood loss, does not remove the anterior compressive pathology, and is contraindicated in patients with loss of cervical lordosis.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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