Available online at www.sciencedirect.com
SCIENCE DIRECT
Journal of Clinical Neuroscience 13 (2006) 23–30
Journal of Clinical Neuroscience
www.elsevier.com/locate/jocn

Clinical study

Posterior cervical decompression and fusion for circumferential spondylotic cervical stenosis: Review of 50 consecutive cases

Lali H.S. Sekhon *

SpineNevada 75 Pringle Way, Suite #605 Reno, NV 89502, USA

Received 6 December 2004; accepted 28 February 2005

Abstract

Purpose of Study: This study presents a clinical and radiological evaluation of 50 consecutive patients with symptomatic spondylotic cervical myelopathy and circumferential spinal cord compression who were managed with a single stage wide posterior laminectomy and lateral mass instrumented fusion. *Methods Used:* 50 consecutive patients (33 male, 17 female) over a 4 year period presenting with symptomatic cervical myelopathy due to circumferential cervical spondylotic spinal stenosis were evaluated and operated upon by a single surgeon and followed in a prospective fashion. All patients underwent pre- and postoperative clinical, radiological and MRI evaluation. *Summary of Findings:* No deaths occurred and no instrumentation-related neural or vascular injuries were noted. No patient required reoperation for ventral compression and in all cases CSF was visible anterior to the cord on postoperative MRI scanning, with relief of the circumferential compression. Most patients improved by at least 1 Nurick grade. Three patients (6%) had single level screw pullouts which did not affect clinical outcome, and required no intervention. Slight worsening of kyphosis occurred in 4% of cases but as group there was no measured difference in sagittal balance ($P = 0.10$). Oswestry Neck Disability Scores improved from 25.7 ± 3.6 to 16.6 ± 7.1 ($P < 0.05$). One patient required a foraminotomy/posterior discectomy 12 months postoperatively at an adjacent level. *Conclusions:* This study demonstrates that multisegmental spondylotic circumferential cervical stenosis causing symptomatic myelopathy can be managed by single stage decompression and fusion via a posterior approach with very low morbidity and excellent clinical and radiological outcome. The incidence of adjacent segment disease is lower than for anterior interbody fusions with a 1%/year incidence at follow up to date.

Keywords: Cervical; Fusion; Lateral mass; Myelopathy; Stenosis

1. Introduction

Cervical myelopathy and cord compression due to spondylotic disease (CSM) or acute disc herniation is a common spinal disorder with controversy over the role and timing of surgical intervention as well as the optimal treatment.[1–8] Over the past 50 years, various combinations of anterior and posterior instrumented surgeries have been devised and refined and continue to be utilized. In the absence of arthrodesis, kyphotic deformity is always a feared complication.[9,10] The shortcomings associated with interbody or posterior cervical fusion are that typically a reduction in effective motion occurs and there are significant morbidities associated with bone graft harvest.[11] If autograft is not used, allograft usage may be associated with higher risks of disease transmission. Coupled with this, the incidence of symptomatic adjacent segment deterioration, requiring reoperation, has been quoted as being as high as 3% per year cumulatively.[12] Consequently, there has been a more recent emphasis on surgical techniques such as cervical laminoplasty or cervical disc arthroplasty to maintain motion, avoid deformity, reduce adjacent segment stresses and allow for an adequate decompression without having to use bone graft.

* Tel.: +1 775 348 8800; fax: +1 775 348 8818.
E-mail address: sekhon@spinenevada.com.

0967-5868/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jocn.2005.02.006

For circumferential spondylotic disease, anterior decompression and fusion can be followed by interval posterior laminectomy, if required, or alternatively, via multilevel posterior cervical laminectomy as a standalone procedure. Multilevel anterior decompression and fusion is not a low morbidity procedure.[13–16] With recent improvements in posterior instrumentation,[17,18] a resurgence of interest in posterior instrumentation and decompression has occurred.

This study presents a clinical and radiological prospective evaluation of 50 patients with symptomatic spondylotic cervical myelopathy who were managed with a wide posterior decompression and lateral mass instrumented fusion. In all cases, an attempt was made to address circumferential pathology via a single posterior approach.

2. Patients and methods

Fifty consecutive patients (33 male, 17 female) over a 4 year period presenting with symptomatic cervical myelopathy due to circumferential cervical spondylotic spinal stenosis were evaluated and operated upon by a single surgeon and followed in a prospective fashion. Patients with severe kyphotic deformity or no dorsal compression were excluded. No patients were lost to follow up and no patients were excluded from the study. All patients underwent preoperative clinical, radiological and MRI evaluation. Clinical assessment consisted of a detailed history and neurological assessment, Nurick grading[19] and patient surveys consisting of Oswestry Neck Disability Index[20] (ONDI) scoring. MRI evaluation was performed by an independent observer. The MRI scans were graded in a yes/no fashion for residural stenosis and the presence of cerebrospinal fluid (CSF) on T2-weighted sagittal imaging anterior to the spinal cord at all levels in the cervical spine. All patients had preoperative MR imaging that documented both ventral and dorsal cervical cord compression. A typical case is shown in Fig. 1A and B. Postoperative fusion and stability was assessed with plain radiography which included dynamic films 6 weeks after initial surgery. The patient demographics are summarized in Table 1. Comparison of ONDI scores and Nurick grades was perfomed using paired t-tests. A P value <0.05 was regarded as significant. All data is presented as mean $\pm$ standard deviation.

Surgical intervention was offered for those patients with symptomatic myelopathy, T2-weighted MRI signal change in the spinal cord at the site of compression or severe cord deformation or compression. The surgery was performed in a consistent fashion by a single surgeon. Intubation was performed for cases with severe stenosis in an awake fiberoptic fashion. The patient was positioned prone using 3 pin skull fixation on a radiolucent spinal operating table. All cases were performed with fluoroscopic guidance. Via a midline cervical incision a bilateral subperiosteal exposure was effected to the lateral margins of the facet joints. The motion segments to be fused had their facet joints decorticated. Great care was taken to protect the facet joints above and below the instrumented levels. The lateral masses were cannulated and tapped prior to the decompression. Placement of instrumentation was performed after the decompression. A modified trajectory was taken for screw placement from standard trajectories. The entry point was 1 mm medial to the midpoint of the facet joint. The screws were angulated 20–25° laterally and superiorly to try and attain the best purchase of the lateral mass with minimal risk of neural or vascular injury (Fig. 2A, B), which is basically a modification of the Anderson technique.[21] Morcellized posterior elements were placed over the decorticated lateral masses and into the appropriate facet joints prior to screw placement (Fig. 3). Fusion was performed in situ with no attempt made to alter preoperative alignment. Typical operating time was 2–3 hours. The patients were monitored overnight and typically discharged from hospital 5–10 days postoperatively in an Aspen® collar (Aspen Medical Products. Long Beach, CA). A thin-slice reconstructed CT scan was performed on day 1 postop to confirm adequate screw placement.

Postoperatively, patients were evaluated clinically and radiologically at 6 weeks, 3 months, 6 months, 12 months and yearly thereafter. No patients were lost to follow up. The most recent ONDI and clinical assessment was used for this evaluation. MRI scanning was performed 3 months postoperatively and reviewed in a blinded fashion for the adequacy of decompression and the presence of residual compression. Fig. 4 illustrates postoperative imaging from a typical case.

Sagittal balance and worsening of kyphosis was calculated using preoperative neutral lateral c-spine xrays and comparing these to neutral postoperative lateral c-spine xrays, with the latest visit used as the postoperative study of choice. The method of calculation is shown in Fig. 5. A line was drawn parallel to the vertical posterior border of C2. This was repeated at C7. The acute angle between these two lines was calculated (C2/C7 angle) and comparison was made using a two-sample t-test assuming equal variances. A P value less than .05 was regarded as significant.

3. Results

Seven patients had diabetes and six patients smoked cigarettes preoperatively. Preoperative Nurick Grade was 1.93 ± 2.5. All 50 patients underwent a posterior cervical laminectomy and lateral mass fusion with local autograft. The results are summarized in Table 2. The typical width of the decompression is shown in Fig. 2. Between 1 and 4 levels were instrumented (mean $= 2.88 \pm 1.00$). In 22 patients the Axis® plate/screw system (Medtronic Sofamor-Danek, Memphis, TN) was used and in the last 28 patients a polyaxial screw/rod system was used, either Vertex® (Medtronic-Sofamor Danek, Memphis, TN), Summit® (DepuySpine, Raynham, MA) systems or Oasys®. (Stryker Spine, Cestas, France).

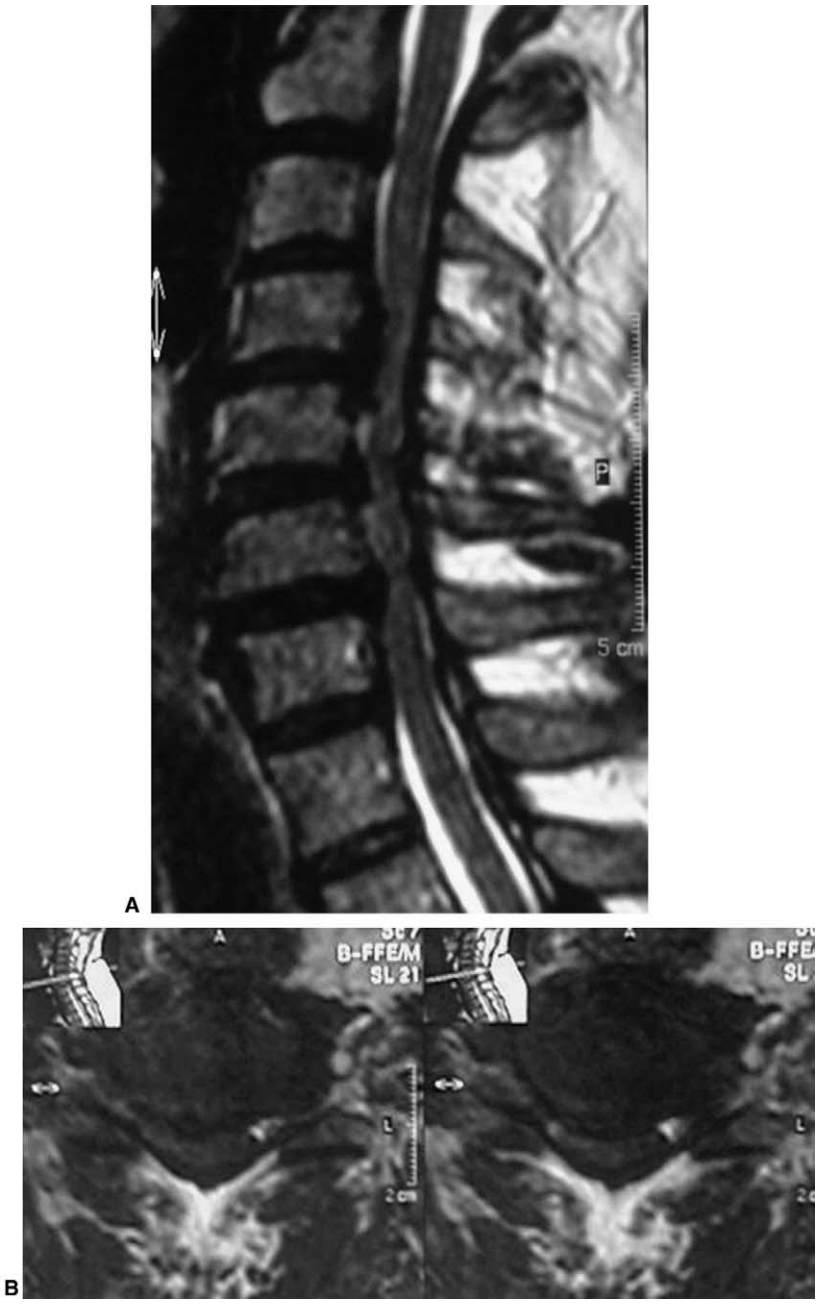

Fig. 1. T2-weighted sagittal (A) and axial (B) MRI scans of the cervical spine of a typical patient presenting with myelopathy and circumferential spinal cord compression due to spondylotic disease. At several levels, cerebrospinal fluid is not visualized anterior to the spinal cord.

Table 1
Patient demographics $n = 50$, (mean $\pm$ s.d.)

Male	33
Female	17
Average age (years)	63 ± 12.4
Diabetes	12%
Smoker	14%
Clinical myelopathy	95%
Cord signal change on sagittal T2W MRI scan	75%
Preoperative Nurick grade	1.93 ± 2.5
Preoperative Oswestry Neck Disability Score	25.7 ± 3.6
Preoperative circumferential cord compression	100%
Preoperative C2/C7 angle	$13.4° \pm 14.3°$

No deaths occurred and no instrumentation-related neural or vascular injuries were noted. No myelopathic deterioration was noted postoperatively, although one patient suffered a C5 root lesion which had not recovered 12 months after the initial surgery. Three patients had greater than 500 ml blood loss during the procedure but only one patient was transfused. There were three dural tears repaired intraoperatively, and one superficial infection treated with antibiotics. Postoperative neck pain typically resolved within 3–4 weeks in all patients.

Mean followup was 30.1 ± 9.03 months. Three patients (6%) had single level screw pullouts at follow up which did

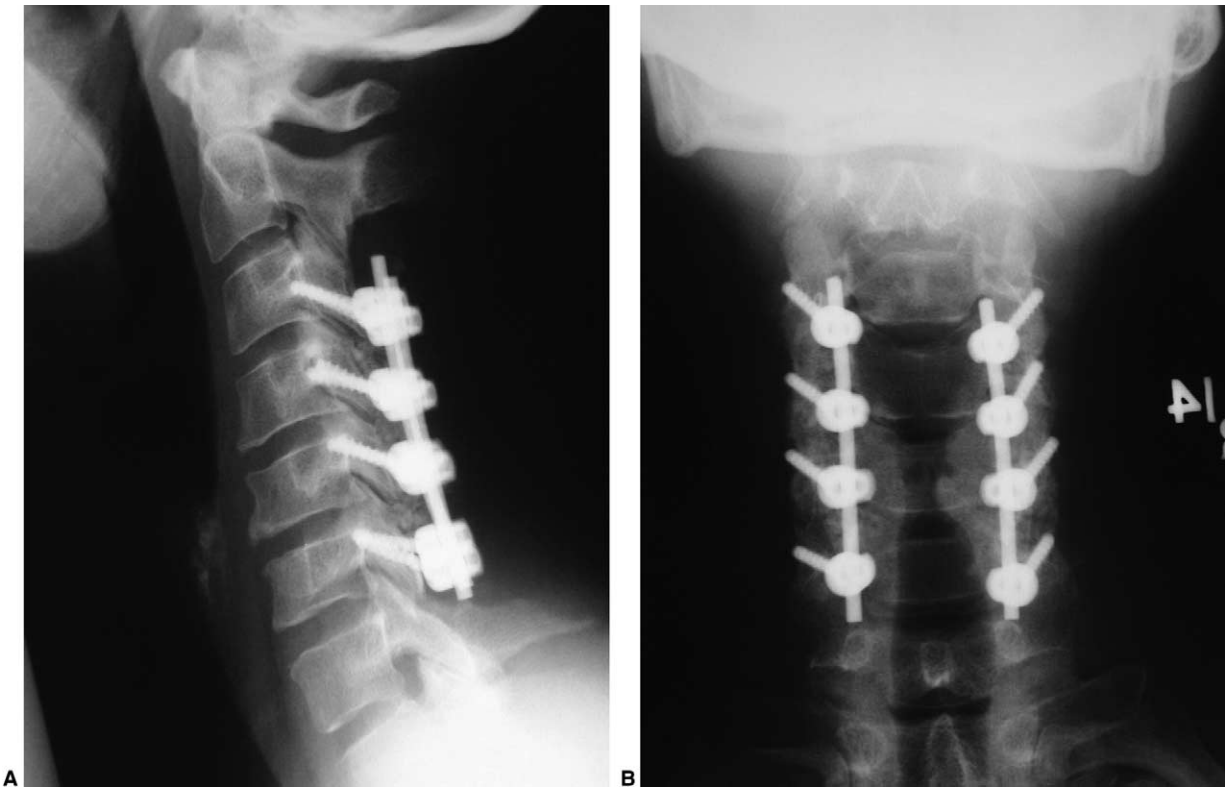

Fig. 2. Postoperative lateral (A) and anterior-posterior (B) X-rays of the cervical spine of the patient from Fig. 1 showing typical placement of the lateral mass screws with a solid fusion posteriorly.

not affect clinical outcome, and required no intervention. Two of these (4%) developed a slight worsening of kyphosis. One patient required extension of the laminectomy by one level 6 months after initial surgery because of posterior migration of the spinal cord and impingement on a more caudal posterior element. No patient required reoperation for ventral compression after the initial procedure. One patient had a C6/7 posterolateral disc protusion 12 months after initial surgery which required a posterior laminoforaminotomy and disc fragmentectomy.

Postoperative MRI scanning at 3 months showed an absence of persisting compression at the operated levels in 100% of cases. In all cases CSF was visible anterior to the cord on postoperative MRI, with relief of the circumferential stenosis. In some patients large anterior osteophyte/disc complexes appeared to have regressed or appeared less pronounced on the postoperative study (see Fig. 4). Most patients improved by approximately one Nurick grade (see Table 1) ($P < 0.05$). A good range of movement was present in all patients, with no subjective limitations, except for the extremes of extension in some cases with four level arthrodeses. All patients reported adequate neck mobility for daily living. No patient had subjective complaints of a loss of motion that interfered with their life. ONDI improved from 25.7 ± 3.6 to 16.6 ± 7.1 ($P < 0.05$). There was no difference between the results in patients who were instrumented with a screw/plate construct as opposed to a screw/rod construct. Assessment of fusion was difficult despite the use of reconstructed CT scanning. When looking specifically at widening of the interspinous spaces on dynamic imaging at follow-up, no patients had symptomatic or radiological pseudoarthroses. Finally, when looking at the C2/C7 sagittal balance angle as illustrated in Fig. 5, preoperatively this angle was a mean of $13.4° \pm 14.3°$ whereas postoperatively this angle was $6.3° \pm 13.3°$. Statistical analysis showed no sginificant difference between the preoperative and postoperative measures ($P = 0.10$).

4. Discussion

Lateral mass spinal fixation is a safe and effective stabilization technique. An improvement in myelopathy with low morbidity can be achieved. Acceptable outcomes in terms of neck pain and mobility can be achieved and prevent of postoperative defomity is better than that with laminectomy alone.

Laminectomy was first described in 1901 in the management of cervical trauma.[22] Simple posterior decompression has been utilized for over 40 years in the management of spondylotic disease. Poorer outcomes in comparison to anterior approaches and postoperative kyphotic deformity have always been the downfalls of this technique.[23,24] Kaptain et al.[25] reported that up to 30% of patients with straight cervical spines develop kyphosis after simple laminectomy. The outcomes reported here, however, are better

Fig. 3. Intraoperative view of the width of the decompression with local autografting of the posterior elements into the facet joints and over the decorticated surfaces of the posterior and lateral surface of the lateral masses.

Fig. 4. Postoperative T2-weighted sagittal MR scan on the patient shown in Fig. 1 showing the degree of decompression attained from a posterior approach. Of interest is the amount of spinal fluid now visible anteriorly and posteriorly to the spinal cord, the presence of myelomalacia that is often not clearly seen preoperatively because of the tight stenosis and the apparent regression of osteophytic material anteriorly.

than those reported in earlier simple laminectomy series.[26,27] Only 4% of this group worsened their preoperative deformity. As stated by Houten and Cooper[28], it may be that maintenance of cervical alignment and avoidance of kyphosis may improve overall outcome.

Laminoplasty was developed in order to maintain motion and prevent kyphosis and numerous series have described good results with this technique.[29–32] This technique preserves motion but has been reported to have a higher incidence of root injury[33] and axial neck pain.[34,35] Coupled with this, the technique is preferably performed in patients with lordotic spinal alignment, with neutral or kyphotic patients potentially worsening their deformity after surgery. When looking at this surgical series, all patients had improvements in the ONDI and reported neck movements that did not interfere with activities of daily living. Of the group, 96% maintained their preoperative alignment with no statistical difference in the C2/C7 sagittal balance measure. Longer fusion over three levels did however report difficulties in head turning associated with parallel car parking. One potential advantage of this technique over laminoplasty, aside from the more forgiving technical skill required and lower incidence of postoperative kyphotic deformity is that, in theory, by fusing diseased segments, regression of spondylotic disease may be achieved, a scenario that may not occur after laminoplasty.

Adjacent segment disease has been an area of focussed research over the past 10 years with the precise incidence still unclear. Hilibrand reported that up to 30% of patients undergoing anterior interbody fusions developed symptomatic adjacent segment disease at 10 years with one half to two thirds of these eventually undergoing surgery.[12] In the posterior arthrodesis group, the incidence of symptomatic adjacent segment disease, with a mean followup of 25.6 months, was 2%. The followup is still relatively short but it may be that posterior arthrodesis will have a lower incidence of developing adjacent segment disease than similar anterior procedures. The reasons for this may be several.

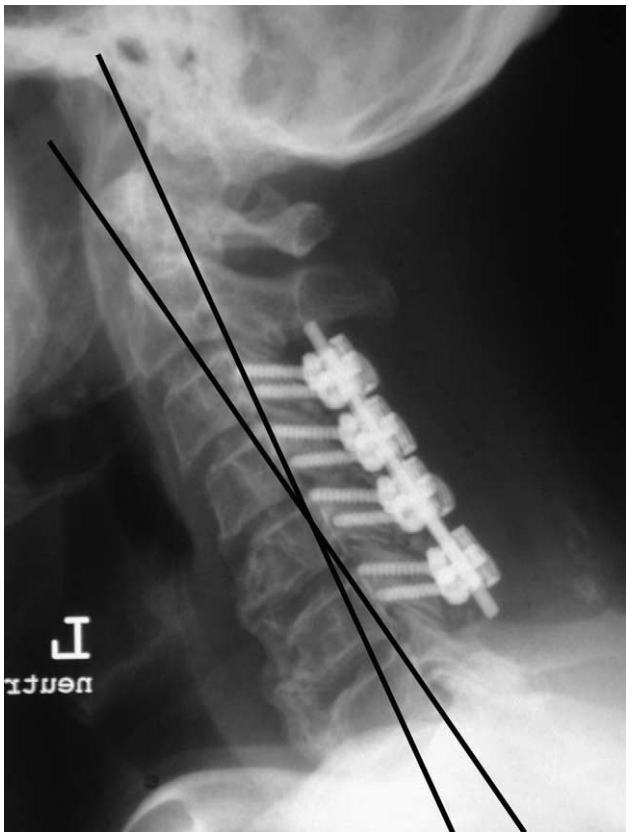

Fig. 5. Typical postoperative neutral lateral c-spine X-ray showing how the C2/C7 sagittal balance angle was measured. Two lines parallel to the posterior vertebral body borders of C2 and C7 were made and their angle at intersection were calculated. If there was kyphosis, the angles were negative with lordosis giving positive angles.

Table 2
Results summary (mean ± s.d.)

Total levels instrumented	138
Average levels instrumented	2.88 ± 1.00
Total number of screws placed	376
Postoperative Nurick grade	1.21 ± 1.2
Postoperative circumferential cord compression	0%
Postoperative Oswestry Neck Disability Score	16.6 ± 7.1
Worsening of preoperative deformity with screw pullout	4%
Reoperation?	2%
Adjacent segments requiring surgery	2%
Range of follow-up (months)	12–50
Average follow-up (months)	30.1 ± 9.03
Postoperative C2/C7 angle	13.4° ± 14.3°

Firstly, the follow-up may be too short to clearly define the true natural history of posterior segmental fixation. Some of the patients in this group will undoubtedly undergo further surgery over the next 7–8 years, possibly as a result of the progression of disc degeneration that would have occurred even if surgery had not been done. Of interest, however, is that although lateral mass fixation is a relatively new technique, posterior wire fixation has been performed by surgeons for over 30 years and yet the reported incidence of reoperation at adjacent levels in those patients is low. If this trend is real, the mechanisms presumably relate to the relatively less rigid fixation achieved with these constructs. The phenomenon that provides this protection can be analogized to the movement seen on a diving board. In that scenario, one end is firmly fixed to the ground and does not move, yet the other end allows excursions upward and downward of a significant distance. In these cases, posterior tension banding may still allow micromotion anterior at the disc space in a fashion akin to a diving board. Consequently, this spring board motion may provide a shielding for the intervertebral discs by allowing micromotion. Such a scenario would not occur with anterior interbody fixation where the fusion surface area is relatively large and the potential for segmental motion low.

Lateral mass posterior fixation for myelopathy has been described by several groups in the literature. Recently, Huang et al. reported on 32 patients who underwent similar surgery in the treatment of myelopathy.[36] They demonstrated excellent outcomes with low morbidity. Their recruitment ws focussed on myelopathic patients without specifically looking at those patients with circumferential disease but nevertheless they showed improvements in Nurick grade, low surgical complications and felt that the procedure was ideal for the management of cervical myelopathy. Houten and Cooper similarly reported on 38 patients undergoing lateral mass fixation for spondylotic disease.[37] They suggested that Nurick assessment was a poor assessment of functional outcome in myelopathy as it only focussed on lower limb function. They did however, report low morbidity and results at least equivalent to mutlilevel anterior techniques.[38] Their patient selection again did not focus on patients with circumferential compression alone, but they did comment that postoperative MRI suggested complete decompression. Heller et al. reported a higher complication are with this technique in comparison to laminoplasty.[39] Their results are at odds with the above authors and the results reported in this series.

When contrasting this procedure with decompression, two potential negatives relate to prosthetic costs and artifact on MRI scanning. Looking firstly, at cost, the placement of 10–12 poylaxial screws is expensive when compared to 1–2 level instrumented lumbar fusions. The non-constrained plate/screw systems (Axis® plates), however, are approximately 20% of the cost of the polyaxial screw/rod constructs (Vertex®, Summit® and Oasys® systems). Realising the limitations of these constructs (screw pullouts in this series only occurred in patients with non-constrained plate/screw constructs) they nevertheless provide a cheap yet satisfactory option for subaxial disease, perhaps with polyaxial screw constructs reserved for junctional pathologies. With respect to imaging, blooming artifact did occur around the screw heads, however, midline and paramedian sagittal MR images had minimal artifact and the CSF spaces around the spinal cord, as well as spinal cord parenchyma, could be adequately visualised

(see Fig. 4). In most cases the foramina were also adequately visualised.

The complications most feared from lateral mass fixation relate to vertebral artery injury or nerve root injury. Of the 376 screws placed in this series, no clinical or radiological vertebral artery injuries occurred and the only root injury was as a result of over aggressive foraminal decompression of the C4/5 foramen. The use of local bone deserves comment. Hillibrand et al.[40] reported a high rate of patient dissatisfaction and clinician-reported complications from anterior iliac crest harvesting. A similar complication rate probably occurs for posterior iliac crest harvesting. This technique had a greater than 90% fusion rate with 6% of patients having two screws pulling out at follow up. With this technique, local bone harvest avoids the complications of iliac crest harvesting, the potential risks of disease transmission associated with allograft usage and yet still achieves an acceptable fusion rate.

The mechanism of providing a circumferential decompression illustrates the shortcoming of the anterior approach. Because there is no limitation in terms of the proximity of the vertebral arteries, decompression posteriorly was in most cases wider than that achievable from an anterior approach and significantly was wider by several millimeters than the equatorial lateral diameter of the thecal sac (see Fig. 3). This effectively allowed the entire dural tube and cord to drift off any ventral compression in a posterior direction without removal of anterior osteophytic disease. This would be analogous to a boat, beached on a sandbank being lifted off by the rising tide. The sandbank would be undisturbed but water would now flow freely under the hull of the boat. Of interest is that the postoperative MRI scan, performed 3 months after surgery, often showed apparent regression in the size of the anterior osteophytic disease (compare Fig. 1A and 5 where the osteophytic disease at C4/5 and C5/6 appears to reduce in size ventrally postoperatively). Most likely this phenomenon is an exaggeration of preoperative appearances by the MRI scanning that for reasons unknown is not seen in the postoperative imaging, and may be artifactual, but nevertheless appears to a reproducible phenomenon and may in fact reflect some reduction of disc bulging that may actually occur with posterior stablization.

5. Conclusions

This study demonstrates that multisegmental circumferential spondylotic cervical stenosis causing symptomatic myelopathy can be managed by single stage decompression and fusion via a posterior approach with very low morbidity and excellent clinical and radiological outcome.

Investment/Financial disclosure

The author is a consultant for Stryker Spine and Medtronic Sofamor-Danek.

References

1. Kumar VG, Rea GL, Mervis LJ, McGregor JM. Cervical spondylotic myelopathy: functional and radiographic long-term outcome after laminectomy and posterior fusion. *Neurosurgery* 1999;**44**:771–7.
2. Adams CB, Logue V. Studies in cervical spondylotic myelopathy. I. Movement of the cervical roots, dura and cord, and their relation to the course of the extrathecal roots. *Brain* 1971;**94**:557–68.
3. Adams CB, Logue V. Studies in cervical spondylotic myelopathy. II. The movement and contour of the spine in relation to the neural complications of cervical spondylosis. *Brain* 1971;**94**:568–86.
4. Adams CB, Logue V. Studies in cervical spondylotic myelopathy. III. Some functional effects of operations for cervical spondylotic myelopathy. *Brain* 1971;**94**:587–94.
5. Carol MP, Ducker TB. Cervical spondylitic myelopathies: surgical treatment. *J Spinal Disord* 1988;**1**:59–65.
6. Ebersold MJ, Pare MC, Quast LM. Surgical treatment for cervical spondylitic myelopathy. *J Neurosurg* 1995;**82**:745–51.
7. Saunders RL, Bernini PM, Shirreffs Jr TG, Reeves AG. Central corpectomy for cervical spondylotic myelopathy: a consecutive series with long-term follow-up evaluation. *J Neurosurg* 1991;**74**:163–70.
8. 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.
9. Butler JC, Whitecloud III TS. Postlaminectomy kyphosis. Causes and surgical management. *Orthop Clin North Am* 1992;**23**:505–11.
10. Orr RD, Zdeblick TA. Cervical spondylotic myelopathy. Approaches to surgical treatment. *Clin Orthop Relat Res* 1999;**359**:58–66.
11. Malloy KM, Hilibrand AS. Autograft versus allograft in degenerative cervical disease. *Clin Orthop Relat Res* 2002;**394**:27–38.
12. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlman HH. Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. *J Bone Joint Surg Am* 1999;**81**:519–28.
13. Yang KC, Lu XS, Cai QL, Ye LX, Lu WQ. Cervical spondylotic myelopathy treated by anterior multilevel decompression and fusion. Follow-up report of 214 cases. *Clin Orthop Relat Res* 1981;**221**:161–4.
14. Shinomiya K, Okamoto A, Kamikozuru M, Furuya K, Yamaura I. An analysis of failures in primary cervical anterior spinal cord decompression and fusion. *J Spinal Disord* 1993;**6**:277–88.
15. Sonntag VK, Klara P. Controversy in spine care. Is fusion necessary after anterior cervical discectomy?. *Spine* 1996;**21**:1111–3.
16. Fielding JW. Complications of anterior cervical disk removal and fusion. *Clin Orthop Relat Res* 1992;**284**:10–3.
17. Muffoletto AJ, Hadjipavlou AG, Jensen RE, Nauta HJ, Necessary JT, Norcross-Nechay K. Techniques and pitfalls of cervical lateral mass plate fixation. *Am J Orthop* 2000;**29**:897–903.
18. Graham AW, Swank ML, Kinard RE, Lowery GL, Dials BE. Posterior cervical arthrodesis and stabilization with a lateral mass plate. Clinical and computed tomographic evaluation of lateral mass screw placement and associated complications. *Spine* 1996;**21**:323–8.
19. 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.
20. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther* 1991;**14**:409–15.
21. Anderson PA, Henley MB, Grady MS, Montesano PX, Winn HR. Posterior cervical arthrodesis with AO reconstruction plates and bone graft. *Spine* 1991;**16**:S72–9.
22. Edwards CC, Riew KD, Anderson PA, Hilibrand AS, Vacarro AF. Cervical myelopathy: current diagnostic and treatment strategies. *Spine J* 2003;**3**:68–81.
23. Albert TJ, Vacarro A. Postlaminectomy kyphosis. *Spine* 1998;**23**:2738–45.
24. Zdeblick TA, Abitbol JJ, Kuntz DN, McCabe RP, Garfin S. Cervical stability after sequential capsule resection. *Spine* 1993;**18**:2005–8.

25. Kaptain GJ, Simmons NE, Replogle RE, Pobereskin L. Incidence and outcome of kyphotic deformity following laminectomy for cervical spondylotic myelopathy. *J Neurosurg* 2000;**93**:199–204.
26. Jenkins DH. Extensive cervical laminectomy: long-term results. *Br J Surg* 1973;**60**:852–4.
27. Snow RB, Weiner H. Cervical laminectomy and foraminotomy as surgical treatment of cervical spondylosis: a follow-up study with analysis of failures. *J Spinal Disord* 1993;**6**:245–50.
28. Houten JK, Cooper PR. Laminectomy and posterior cervical plating for multilevel cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament: effects on cervical alignment, spinal cord compression, and neurological outcome. *Neurosurgery* 2003;**52**:1081–7.
29. Chiba K, Toyama Y. Development of new surgical treatments in spinal surgery: expansive open-door laminoplasty and percutaneous nucleotomy. *Keio J Med* 2001;**50**:142–51.
30. Hirabayashi K, Watanabe K, Wakano K, Suzuki N, Satomi K, Ishii Y. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. *Spine* 1983;**8**:693–9.
31. Herkowitz HN. A comparison of anterior cervical fusion, cervical laminectomy, and cervical laminoplasty for the surgical management of multiple level spondylotic radiculopathy. *Spine* 1988;**13**: 774–80.
32. Tsuji H. Laminoplasty for patients with compressive myelopathy due to so- called spinal canal stenosis in cervical and thoracic regions. *Spine* 1982;**7**:28–34.
33. Uematsu Y, Tokuhashi Y, Matsuzaki H. Radiculopathy after laminoplasty of the cervical spine. *Spine* 1998;**23**:2057–62.
34. Hosono N, Yonenobu K, Ono K. Neck and shoulder pain after laminoplasty. A noticeable complication. *Spine* 1996;**21**:1969–73.
35. Kawaguchi Y, Matsui H, Ishihara H, Gejo R, Yoshino O. Axial symptoms after en bloc cervical laminoplasty. *J Spinal Disord* 1999;**12**:392–5.
36. Huang RC, Girardi FP, Poynton AR, Cammisa Jr FP. Treatment of mutlilevel cervical spondylotic myeloradiculopathy with posterior decompression and fusion with lateral mass fixation and local bone graft. *J Spinal Disord* 2003;**16**(2):123–9.
37. Houten JK, Cooper PR. Laminectomy and posterior cervical plating for multilevel cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament: effects on cervical alignment, spinal cord compression, and neurological outcome. *Neurosurgery* 2003;**52**:1081–7.
38. Macdonald RL, Fehlings MG, Tator CH, Lozano A, Fleming JR, Gentili F, et al. Multilevel anterior cervical corpectomy and fibular allograft fusion for cervical myelopathy. *J Neurosurg* 1997;**86**:990–7.
39. Heller JG, Edwards CC, Murakami H, Rodts GE. Laminoplasty versus laminectomy and fusion for multilevel cervical myelopathy: an independent matched cohort analysis. *Spine* 2001;**26**:1330–6.
40. Silbert JS, Anderson G, Daffner SD, Brislin BT, Martin Leland J, Hilibrand A, et al. Donor site morbidity after anterior iliac crest bone harvest for single-level anterior cervical discectomy and fusion. *Spine* 2003;**28**:134–9.