

Anterior Versus Posterior Surgical Approaches to Treat Cervical Spondylotic Myelopathy

Outcomes of the Prospective Multicenter AOSpine North America CSM Study in 264 Patients

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Study Design. A prospective observational multicenter study.

Objective. To help solve the debate regarding whether the anterior or posterior surgical approach is optimal for patients with cervical spondylotic myelopathy (CSM).

Summary of Background Data. The optimal surgical approach to treat CSM remains debated with varying opinions favoring anterior versus posterior surgical approaches. We present an analysis of a prospective observational multicenter study examining outcomes of surgical treatment for CSM.

Methods. A total of 278 subjects from 12 sites in North America received anterior/posterior or combined surgery at the discretion of the surgeon. This study focused on subjects who had either anterior or posterior surgery (n = 264, follow-up rate, 87%). Outcome measures included the modified Japanese Orthopedic Assessment scale, the Nurick scale, the Neck Disability Index, and the Short-Form 36 (SF-36) Health Survey version 2 Physical and Mental Component Scores.

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Results. One hundred and sixty-nine patients were treated anteriorly and 95 underwent posterior surgery. Anterior surgical cases were younger and had less severe myelopathy as assessed by mJOA and Nurick scores. There were no baseline differences in Neck Disability Index or SF-36 between the anterior and posterior cases. Improvement in the mJOA was significantly lower in the anterior group than posterior group (2.47 vs. 3.62, respectively, $P < 0.01$), although the groups started at different levels of baseline impairment. The extent of improvement in the Nurick Scale, Neck Disability Index, SF-36 version 2 Physical Component Score, and SF-36 version 2 Mental Component Score did not differ between the groups.

Conclusion. Patients with CSM show significant improvements in several health-related outcome measures with either anterior or posterior surgery. Importantly, patients treated with anterior techniques were younger, with less severe impairment and more focal pathology. We demonstrate for the first time that, when patient and disease factors are controlled for, anterior and posterior surgical techniques have equivalent efficacy in the treatment of CSM.

Key words: surgery, cervical spondylotic myelopathy, CSM, multicenter trial, surgical outcomes.

Level of Evidence: 3

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Cervical spondylotic myelopathy (CSM) is a progressive, degenerative disease that results in compression of the cervical spinal cord, leading to neurological dysfunction.^{1,2} CSM is the commonest cause of spinal cord impairment in elderly patients worldwide,^{1,2} and yet many controversies exist regarding the optimal management and the outcomes of surgical treatment. Although a number of studies have shown improved neurological outcomes in patients with severe neurological deficits who receive surgical treatment,³⁻⁶ the effects of surgery on the full spectrum of CSM cases, ranging from mild to severe, remains in question. Moreover, the relative efficacy of anterior versus posterior approaches to treat CSM remains hotly debated. Several studies have addressed the uncertainty of anterior versus posterior surgical decompression in CSM

with the balance of this literature yielding variable yet similar functional outcomes in both cohorts.^{6,7,8} These studies have their key limitations including inadequate follow-up,⁶ unvalidated outcome measures,⁷ or retrospective analysis.⁸ As such, there remains a lack of high-quality evidence guiding surgical management of cervical degenerative myelopathy. This is due to the absence of large, prospective studies using consistent and validated outcome measures supporting any single surgical technique's superiority over another.

In this prospective, controlled multicenter study of patients with mild, moderate, and severe CSM we critically examine the overall efficacy of surgical treatment and particularly focus on the results of anterior and posterior surgical techniques. We present novel data that show for the first time the dramatic efficacy of surgery for patients with the full spectrum of CSM. Moreover, we demonstrate that, when patient and disease factors are controlled for, anterior and posterior surgical techniques have equivalent efficacy in the treatment of CSM.

MATERIALS AND METHODS

Subjects

Two hundred and seventy-eight symptomatic patients with clinically and radiographically confirmed CSM were enrolled in a multicenter prospective study at 12 sites in North America between December 2005 and September 2007. The study was ethically approved by institutional review boards at all sites and was registered at clinicaltrials.gov (NCT00285337). Subjects were 18 years or older, had symptomatic CSM confirmed by MRI imaging, had no prior cervical spine surgery, and did not have symptomatic lumbar stenosis. Subjects were treated by either an anterior or posterior decompressive/reconstructive approach at the discretion of the operative teams. In this article, we report on 264 subjects who have received either anterior or posterior surgery in isolation. Fourteen subjects who received circumferential anterior-posterior surgery were excluded.

Outcome Assessments

Outcome evaluations included the modified Japanese Orthopaedic Association score (mJOA),⁶ the Nurick score,⁹ the Neck Disability Index (NDI),¹⁰ the Short Form-36 (SF-36) version 2,¹¹ and an assessment of treatment complications. Subjects were classified as having mild (mJOA > 15), moderate (mJOA, 12–14) or severe CSM (mJOA < 12) based on the mJOA scores at baseline. However, in this article, patients with the full spectrum of myelopathic impairment were grouped to simplify the data presentation. The SF-36 version 2 Physical Component Score (PCS) and the Mental Component Score (MCS) were calculated using established norms and orthogonal transformations. Adverse events were prospectively tracked using independent assessors with third-party data monitoring.

Statistical Analysis

The study endpoints were the absolute changes between the preoperative and 12-month postoperative scores in the various

outcome measures described in the earlier text. Missing data were imputed using the multiple imputation method.^{12,13} Of note, this is the method suggested by the Food and Drug Administration for handling missing data in therapeutic trials.¹⁴ Using the imputed datasets, a *t* test–like approach was used to compare patient outcomes at 1 year postoperatively with patient status preoperatively. An analysis of differences between the groups was performed using a *t* test–like approach on multiple imputed samples. This was followed by adjusted multivariate analyses to account for key differences in baseline predictive variables (determined by multiple linear regression techniques). All statistical analyses were performed using SAS version 9.2 (SAS Institute Inc, Cary, NC).

RESULTS

Of the 264 subjects, 169 patients were treated using anterior techniques (discectomy/corpectomy with instrumented fusion) and 95 underwent posterior surgery (either laminectomy and fusion: 86% or laminoplasty: 14%). One subject died at 12 months after surgery of unrelated causes. Eighteen subjects withdrew from the study prior to the 12-month follow-up. Twelve-month follow-up was obtained in 214 (87.0%) out of 246 eligible subjects. Fourteen patients underwent combined anterior and posterior approaches, generally for fixed kyphotic deformity or complex pathology, and were excluded from analysis. An additional 22 patients did not meet the inclusion criteria of a preoperative mJOA score within the range of 7 to 16.

The key demographic, clinical, and outcome baseline parameters in the study group are summarized in Table 1 and subdivided by the route of surgical approach. Of note, it is clear that clinicians selected different groups of patients for anterior and posterior surgery. Subjects in the anterior group were younger and had more focal cervical pathology, less neurological impairment (with better baseline mJOA and Nurick scores), and better SF-36 version 2 MCS scores.

Table 2 summarizes the unadjusted analysis of changes in the outcomes parameters between baseline and 12-month follow-up for the anterior and posterior groups. The 95% confidence intervals around the mean change scores show that all outcome variables improved significantly from their baseline values in patients treated by either anterior or posterior methods. The extent of improvement in the mJOA was significantly lower in the anterior group than that in patients undergoing posterior surgery (2.47 vs. 3.62, respectively, $P < 0.01$), although as indicated in Table 1, the groups started at different levels of baseline impairment. The extent of improvement in the Nurick score, NDI, SF-36 version 2 PCS score, and SF-36 version 2 MCS score did not differ between the anterior and the posterior groups.

Table 3 summarizes the analysis of the changes (between baseline and 12-month follow-up) in the outcomes parameters between the anterior and posterior groups with adjustment for baseline confounders. In the adjusted analysis, all outcomes assessments continued to be significantly improved in both the anterior and posterior groups (as reflected by the change scores and 95% confidence intervals). Of note, and in

TABLE 1. Baseline Characteristics of Subjects Classified by Surgical Approach (N = 264)

	Anterior (N = 169)	Posterior (N = 95)	P
Age (yr)	52.53 (10.63)	62.83 (10.68)	<0.0001
Female sex	42.60%	37.89%	0.4551
Current smoker	27.37%	25.44%	0.7327
Symptom duration (mo)	26.06 (48.52)	26.95 (42.82)	0.8817
mJOA	13.47 (2.46)	11.84 (2.86)	<0.0001
Nurick score	3.96 (.95)	4.40 (.97)	<0.0001
Neck Disability Index	40.98 (21.86)	43.11 (19.34)	0.4461
SF-36 version 2 PCS	36.64 (9.75)	35.68 (9.59)	0.4603
SF-36 version 2 MCS	40.23 (11.03)	39.86 (10.75)	<0.0001
No. levels operated*	3.13 (.88)	5.12 (0.78)	<0.0001

*Defined by number of vertebrae (e.g., C5–C6 = 2 vertebral levels).
 PCS indicates Physical Component Score; MCS, Mental Component Score; mJOA, modified Japanese Orthopedic Assessment; SF-36, Short-Form 36.

contrast to the unadjusted analysis presented in Table 2, with adjustment for baseline confounders, there were no significant differences in outcomes between patients treated with the anterior and posterior surgical approaches.

The anterior- and posterior-only groups did not differ significantly with regard to the overall complication rates. Twenty patients (11.8%) in the anterior and 17 patients (17.9%) in the posterior group had treatment-related complication ($P = 0.197$). Seven subjects (4.1%) in the anterior and 3 (3.2%) in the posterior group experienced a new neurological deficit ($P = 1.00$). There were 5 transient postoperative C5 palsies, which occurred in association with both posterior- and anterior-only procedures, and there was no significant difference in the rates based on surgical approach. Three other transient nerve root deficits occurred, as well as 2 cases of deterioration in spinal cord function (0.8%). Of the 2 cases of spinal cord deterioration, 1 occurred in the anterior group and 1 in the posterior group.

There were 5 superficial infections in total: 1 in the anterior group and 4 in the posterior group ($P = 0.058$). The remaining complications ($n = 22$) comprised a heterogeneous

group of adverse events including cardiopulmonary complications such as myocardial infarction and pulmonary embolus, instrumentation malposition/migration, durotomy, epidural hematoma, renal complications, altered mental status, worsened axial neck pain, dysphonia, wound dehiscence, symptomatic adjacent segment disease, and symptomatic pseudoarthrosis. All occurred sporadically and with no significant difference between the 2 groups.

DISCUSSION

This prospective observational multicenter study of 264 patients demonstrates novel data that when patient and disease factors are controlled for, anterior and posterior surgical approaches have equivalent efficacy in the treatment of CSM. Despite being the most common cause of acquired neurological disability in those older than 50² years, there remains a lack of high-quality evidence guiding surgical management of cervical degenerative myelopathy. This is due to the absence of large, prospective studies using consistent and validated outcome measures to support any single surgical approach compared with another. The lack of high-level evidence is

TABLE 2. Improvement in the Outcome Variables at 12 Months

	Anterior (N = 160)	Posterior (N = 86)	P
mJOA	2.47 (2.01–2.94)	3.62 (2.95–4.29)	0.0061
Nurick score	1.61 (1.38–1.84)	1.62 (1.28–1.96)	0.9530
NDI	12.77 (9.74–15.80)	10.87 (6.25–15.49)	0.5126
SF-36 version 2 PCS	6.73 (5.14–8.33)	4.14 (1.79–6.50)	0.0869
SF-36 version 2 MCS	5.90 (4.29–7.51)	5.16 (2.49–7.83)	0.6547

Numbers in parentheses are 95% confidence intervals.
 PCS indicates Physical Component Score; MCS, Mental Component Score; mJOA, modified Japanese Orthopedic Assessment; NDI, Neck Disability Index; SF-36, Short-Form 36.

TABLE 3. Improvement in the Outcome Variables at 12 Months Adjusted for the Baseline Characteristics

	Anterior (N = 160)	Posterior (N = 86)	P
mJOA	2.85 (2.46–3.24)	2.93 (2.35–3.50)	0.8291
Nurick score	1.68 (1.47–1.90)	1.49 (1.15–1.83)	0.3643
NDI	11.77 (8.46–15.08)	12.74 (7.05–18.43)	0.8039
SF-36 version 2 PCS	5.16 (3.37–6.95)	7.06 (3.87–10.25)	0.3890
SF-36 version 2 MCS	5.79 (4.35–7.23)	5.37 (2.82–7.91)	0.7908

Numbers in parentheses are 95% confidence intervals.

PCS indicates Physical Component Score; MCS, Mental Component Score; mJOA, modified Japanese Orthopedic Assessment; NDI, Neck Disability Index; SF-36, Short-Form 36.

compounded by the diversity of both the patient population and the surgical modalities with which they are treated. This methodological heterogeneity also makes interstudy evaluation of the literature difficult to interpret. Expert opinion and general consensus support the notion that any modality that effectively decompresses the affected segments of spinal cord and nerve roots are equally efficacious in the short term. Options include posterior approaches in the form of laminectomy, laminectomy plus instrumented arthrodesis, or laminoplasty (Figure 1A, B). Anterior approaches include anterior cervical discectomy or corpectomy and fusion (Figure 2A, B). A third category encompasses circumferential decompression with both anterior and posterior reconstructive techniques using combinations of the above-mentioned approaches.

The surgical strategy elected is dependent upon multiple factors, most importantly the cause of compression, the primary site of compression, the number of levels involved and the sagittal alignment of the spine. Patient age, general medical status, and comorbidities are also important considerations.

Last but not the least, the surgeon's familiarity and comfort level with each technique must be considered. Although there are no absolute indications for any given approach, some guiding principles are generally followed. These include approaching the cervical spine anteriorly when the primary site of compression is ventral, and *vice versa*. Anterior approaches are usually reserved for compression at 3 levels or less; however, this is not always the case (Figure 3). Anterior approaches are generally preferred when restoration of cervical lordosis is a primary surgical goal. Taking these factors into account, a single optimal surgical approach can usually be chosen. Whether or not the specific approach is taken, be it anterior or posterior, results in disparate outcomes are addressed in this study.

After surgical decompression, symptoms of patients with CSM, including those of patients with the full spectrum of impairment ranging from mild to severe neurological dysfunction, improved significantly in all evaluated endpoints, including neurological (mJOA and Nurick scores), functional (NDI), and generic (SF-36 version 2) health outcome

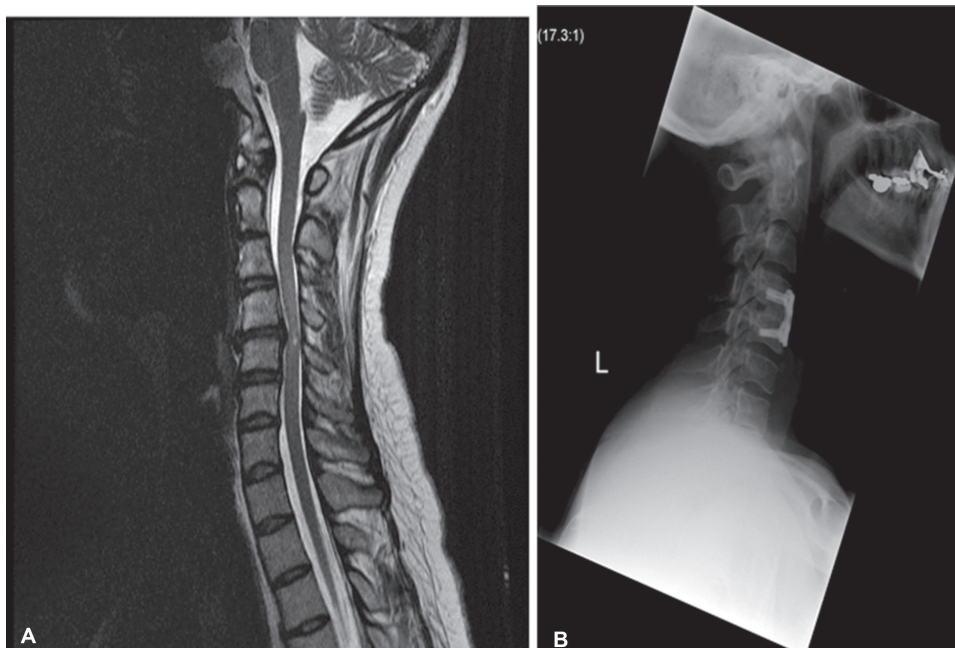


Figure 1. A, B, Example of a typical posterior case.

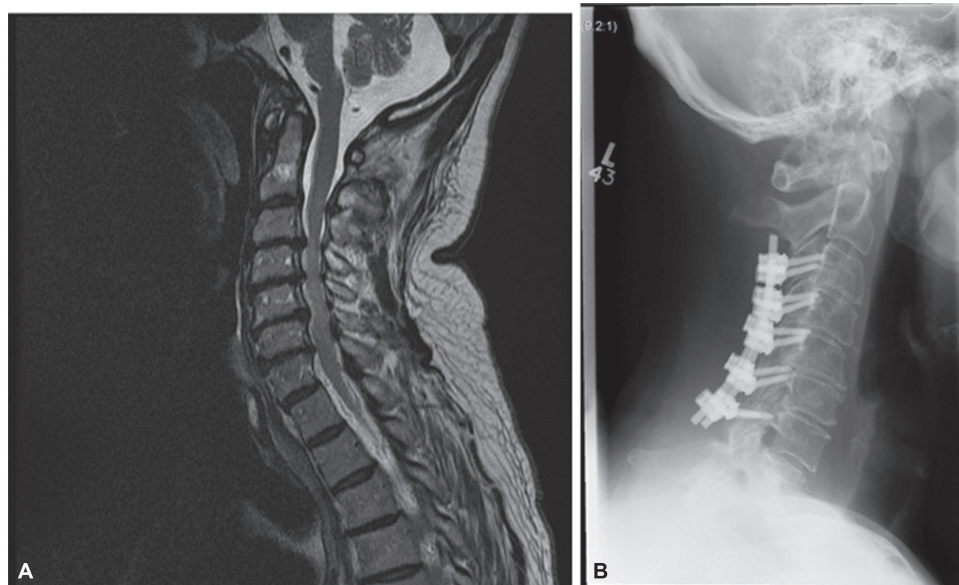


Figure 2. A, B, Example of a typical anterior case.

measures. This is in contrast to the only prospective randomized trial to date in CSM, which failed to detect a beneficial effect of surgery, but was limited by a single-center design, small enrollment and the use of nonvalidated outcomes.¹⁵

Importantly, the baseline differences between the anterior and posterior groups were significant and impacted on the outcomes. In particular, surgeons chose anterior techniques to treat patients who were younger and who presented with less impairment and more focal cervical pathology. On the unadjusted analyses, patients treated with posterior surgical methods had higher apparent improvement in mJOA scores and those treated with anterior techniques had superior outcomes

based on SF-36 PCS scores. However, with adjustment for key baseline covariates, there were no differences in the outcomes between the groups treated with anterior or posterior surgical techniques. Moreover, major complications were similar in the 2 groups, although there was a trend for a higher infection rate with posterior surgical techniques.

The key limitation of our study design is the lack of randomization. However, the investigators in SpineNet (AOSpine Clinical Research Network) thought that randomization to nonoperative *versus* operative management or that based on the choice of surgical technique would be ethically and logistically very challenging. In most cases, surgeons do not

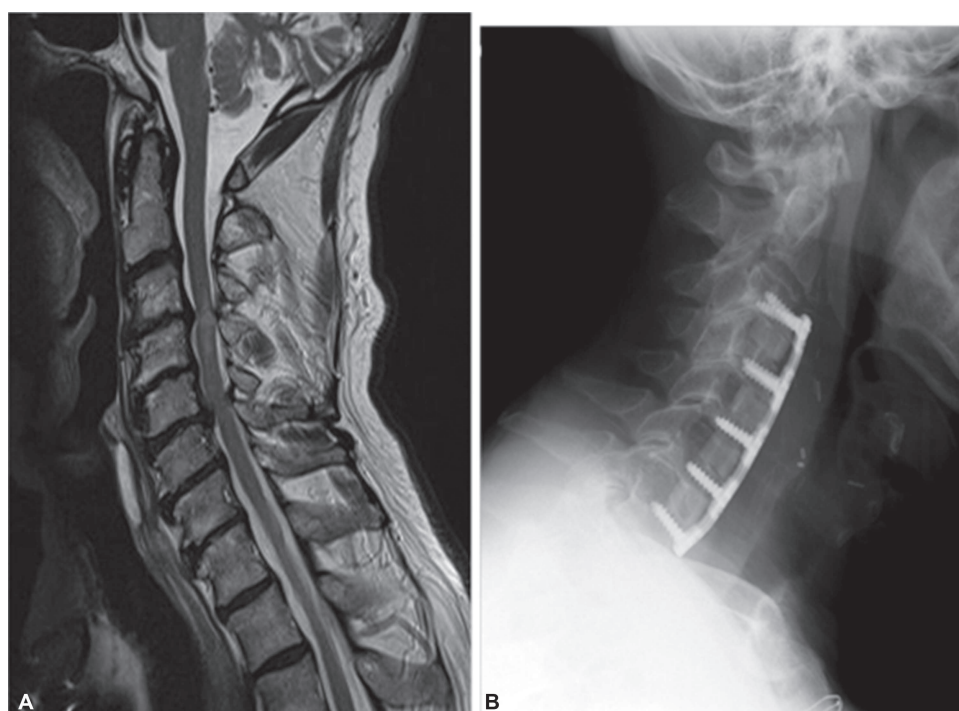


Figure 3. A, B, Example of a case in which there may be equipoise between anterior and posterior surgery. **A**, T2 sagittal MRI. Multilevel spondylosis with compression both ventrally and dorsally. Myelomalacia within the spinal cord can be appreciated. **B**, Lateral radiograph of a patient who was treated with a 4-level ACDF. ACDF indicates anterior cervical discectomy fusion.

perceive equipoise between anterior and posterior techniques, although admittedly some cases can be treated by either methodology. It was very apparent that patient variables and the nature of the pathology were prime drivers in surgical decision making. Patients with more focal pathology underwent anterior surgery and conversely, those with multilevel cervical involvement usually were treated by posterior techniques. Indeed, the literature supports the selective application of anterior and posterior techniques based on these considerations.³⁻⁶

In our view, the design of our study, despite the limitations imposed by the lack of randomization was successful in addressing the key questions that were posed on the basis of the high level of prospective enrollment of consecutive cases, the use of multiple outcome measures and the excellent follow-up (87% at 1 yr). Of note, the only randomized trial to date, which failed to show a beneficial effect of surgery for CSM, had several serious flaws including limitation of the assessments to only 1 nonvalidated outcome measure and low enrollment at a single center.¹⁵

This study may be viewed by some as largely a demonstration of surgeon's trends and preferences regarding the management of cervical degenerative myelopathy. Despite the lack of randomization, it is the authors opinion that this limitation can be looked upon favorably as it represents as close to a "real-world" consecutive series of patients as possible. In reality, only a small subset of patients would truly be eligible for randomization. These would include patients with a straight or lordotic spine who had compressive pathology at 3 levels or less.

We applied advanced multivariate techniques to adjust for potential confounders between the anterior and the posterior group. Moreover, rather than excluding subjects who were lost to follow-up, we used multiple imputation statistical techniques to re-create the complete sample.¹⁶ However, we acknowledge that there may still be a window to consider a randomized prospective trial of anterior *versus* posterior surgery for selected patients with CSM where there is true equipoise between surgical strategies.

CONCLUSION

The results from this large, prospective multicenter study validate the relative equivalence between anterior and posterior treatment for CSM that many spine surgeons think exists. This study demonstrates for the first time that anterior and posterior surgery, when the treatment choice is left to surgeon, experience significant, and similar improvements with regard to neurological, functional, and quality-of-life outcomes with comparable and very low rates of neurological complication.

➤ Key Points

- ❑ CSM is the commonest cause of spinal cord impairment in elderly patients worldwide, yet the relative efficacy of anterior *versus* posterior

approaches to treat CSM remains a matter of debate.

- ❑ The results from this large, prospective multicenter study support the idea of relative equivalence between anterior and posterior surgery for CSM that many spine surgeons think exists.
- ❑ Patients treated with anterior techniques (n = 169) were younger, had less severe neurological impairment, and more focal pathology than those treated with posterior approaches (n = 95).
- ❑ This study demonstrates for the first time that anterior and posterior surgery, when the treatment choice is left to surgeon, have equivalent efficacy in the treatment of CSM.

References

1. Young WF. Cervical spondylotic myelopathy: a common cause of spinal cord dysfunction in older persons. *Am Fam Physician* 2000;62:1064-70, 73.
2. Nurick S. The pathogenesis of the spinal cord disorder associated with cervical spondylosis. *Brain* 1972;95:87-100.
3. Moore AP, Blumhardt LD. A prospective survey of the causes of non-traumatic spastic paraparesis and tetraparesis in 585 patients. *Spinal Cord* 1997;35:361-7.
4. Kalsi-Ryan S, Karadimas SK, Fehlings MG. Cervical spondylotic myelopathy: the clinical phenomenon and the current pathobiology of an increasingly prevalent and devastating disorder. [published online ahead of print November 30, 2012] *Neuroscientist* 2013;16:406-21.
5. Komotar RJ, Mocco J, Kaiser MG. Surgical management of cervical myelopathy: indications and techniques for laminectomy and fusion. *Spine J* 2006;6:252S-67S.
6. Kaminsky SB, Clark CR, Traynelis VC. Operative treatment of cervical spondylotic myelopathy and radiculopathy. A comparison of laminectomy and laminoplasty at five year average follow-up. *Iowa Orthop J* 2004;24:95-105.
7. Benzel EC, Lancon J, Kesterson L, et al. Cervical laminectomy and dentate ligament section for cervical spondylotic myelopathy. *J Spinal Disord* 1991;4:286-95.
8. Carol MP, Ducker TB. Cervical spondylitic myelopathies: surgical treatment. *J Spinal Disord* 1988;1:59-65.
9. Medow JE, Trost G, Sandin J. Surgical management of cervical myelopathy: indications and techniques for surgical corpectomy. *Spine J* 2006;6:233S-41S.
10. Ebersold MJ, Pare MC, Quast LM. Surgical treatment for cervical spondylitic myelopathy. *J Neurosurg* 1995;82:745-51.
11. 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.
12. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity [erratum in: *J Manipulative Physiol Ther* 1992;15:followi]. *J Manipulative Physiol Ther* 1991;14:409-15.
13. Ware JE, Jr, Sherbourne CD. The MOS 36-item Short-Form Health Survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992;30:473-83.
14. Shafer J. *Analysis of Incomplete Multivariate Data*. ed. London: Chapman & Hall; 1997.
15. Rubin D. *Multiple Imputation for Nonresponse in Surveys*. ed. New York: John Wiley and Sons; 1987.
16. Rubin D. *Expert Report on Multiple Imputation*. ed. Silver Spring, MA: Food and Drug Administration; 2006.