Correlation Between Cervical Spine Sagittal Alignment and Clinical Outcome After Anterior Cervical Discectomy and Fusion

Jeffrey L. Gum, MD, Steven D. Glassman, MD, Lonnie R. Douglas, MD, and Leah Y. Carreon, MD, MSc

Abstract

Studies have shown that maintenance of lordosis improves outcomes after anterior cervical discectomy and fusion (ACDF). The relationship between maintenance or restoration of lordosis after ACDF and health-related quality of life (HRQOL) measures has not been evaluated.

Preoperative and 2-year postoperative cervical lordosis (C2-C7) and segmental lordosis were measured from upright lateral cervical spine radiographs in patients who had ACDF. Data on the Neck Disability Index (NDI), Short-Form-36 Physical Composite Summary Score, arm, and neck pain scores were also collected. Paired t-tests were used to compare preoperative and 2-year postoperative radiographic measures and HRQOL measures. Receiver operating characteristic curves were constructed to identify sagittal parameters that predict achievement of a Minimum Clinically Important Difference (MCID) in outcome measures.

One hundred one patients (75 female; mean age, 52 years) were included. There was improvement in all HRQOL measures from preoperative to 2 years postoperative. There was no significant difference in preoperative and 2-year postoperative sagittal alignment. Receiver operating characteristic curve analysis showed that a postoperative cervical lordosis of at least 6° predicted achievement of MCID for NDI (8 point change in NDI).

This suggests that maintenance or restoration of overall cervical lordosis is important in achieving a successful result after ACDF.

Recent literature has highlighted the critical role of regional and global sagittal alignment on health status and the importance of restoration or maintenance of alignment with surgical treatment.[1-5] While the primary focus has been on the lumbar and thoracolumbar spine, the cervical spine normally maintains a physiologic lordotic posture and loss of lordosis has been associated with clinical symptoms.[6,7] Correction of cervical kyphosis is a clearly identified concern in reconstructive procedures, but may be overlooked with commonly performed 1 and 2 level anterior cervical discectomy and fusion (ACDF) procedures.[8,9] An improved understanding of this dynamic is worthwhile, as cervical kyphosis or malalignment after ACDF has been associated with poor clinical outcomes.[10-12]

To our knowledge, the relationship between maintenance or restoration of cervical lordosis after ACDF and health-related quality of life (HRQOL) measures has not been evaluated. The objective of this study is to determine if any correlation exists between cervical sagittal alignment after ACDF and improvement in Neck Disability Index (NDI) scores.

Methods

This study was approved by the Institutional Review Board at the University of Louisville. We reviewed prospectively collected data from a series of adult patients who underwent single- or multi-level ACDF for the treatment of symptomatic cervical spondylosis or disc herniation, failing conservative treatment. All procedures were performed by a team of fellowship-trained spine and neurosurgeons at a single tertiary spine center, with all patients clinically and radiographically evaluated prior to surgery. The surgical technique has been described previously.[13] In short, the patient is positioned supine with the neck in slight extension. An anterolateral approach is taken, using the medial border of the sternocleidomastoid as a landmark. Dissection is carried out through the platysma, with the trachea and esophagus retracted medially and the neurovascular bundle with the sternocleidomastoid muscle laterally. After fluoroscopic confirmation of the affected level, a complete discectomy and decompression was performed with the help of a lamina spreader within the disc or screw post distractors in the cephalad and caudad vertebral bodies. An appropriate sized allograft is selected, trimmed, and tapped carefully into place. This is followed by the application of a plate to stabilize the construct.

Preoperative and 2-year postoperative neutral upright lateral cervical spine radiographs were measured by reviewers blinded to the patients' HRQOL measures. Overall cervical lordosis (C2-C7) and segmental cervical lordosis were digitally measured using the Cobb

Dr. Gum is Resident, Dr. Glassman is Professor, and Dr. Douglas is Resident, Department of Orthopaedic Surgery, University of Louisville School of Medicine, Louisville, Kentucky.
Dr. Carreon is Clinical Research Director, Norton Leatherman Spine Center, Louisville, Kentucky.

Address correspondence to: Leah Y. Carreon MD, MSc, Norton Leatherman Spine Center, 210 East Gray Street, Suite 900, Louisville, KY 40202 (tel, 502-584-7525; fax, 502-584-6851; e-mail, leah.carreon@nortonhealthcare.org).

Am J Orthop. 2012;41(6):E81-E84.

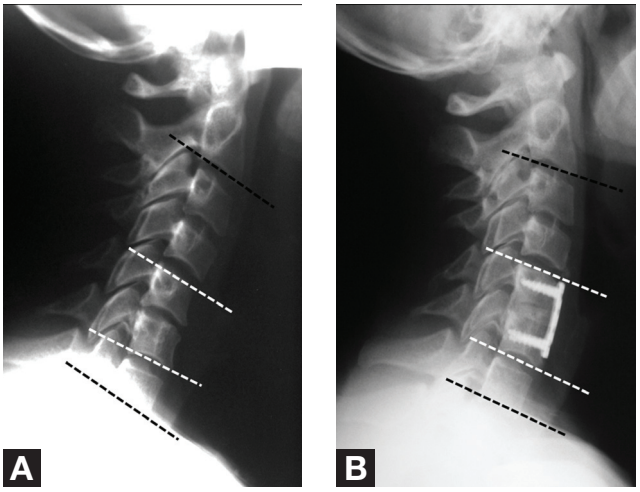

Figure. (A) Preoperative cervical lateral radiograph with C2-C7 measuring 2° of kyphosis (black line) and C5-C6 measuring 5° of kyphosis (white line). (B) Postoperative cervical lateral radiograph with C2-C7 measuring 6° of lordosis (black line) and C5-C6 measuring 3° of lordosis (white line). This translates to an 8° increase in total cervical lordosis and segmental lordosis.

method.[14] A line parallel to the inferior endplate of C2 and C7 were used for overall lordosis. Segmental lordosis was measured using a line parallel to the cranial and caudal endplates of the operative upper and lower vertebra, respectively (Figure). These values are considered positive in lordosis and negative in kyphosis.

Demographic data collected included age, gender, smoking history, medical comorbidities, and diagnosis. Surgical data included operative time, estimated blood loss, and fusion levels. Patient-reported HRQOL measures were from standardized questionnaires administered preoperatively and at 2-year follow up. Neck-specific disability, the primary outcome measure, was determined using the NDI.[15] Pain intensity for arm pain and neck pain were independently measured using a horizontal numeric rating scale ranging from 0 (no pain) to 10 (worst possible pain).[16,17] The questionnaires also included the Medical Outcomes Study Short Form-36 General Health Instrument (SF-36) as a measure of general-HRQOL.[18,19] Specifically, the Physical Composite Summary (PCS) score was used (SF-36 PCS). Improvement in outcomes was determined by the mean difference from preoperative to 2-year postoperative scores, as well as the percentage of patients reaching a Minimum Clinically Important Difference (MCID) in NDI. Previously published MCID threshold of 8.0 points for NDI was used.[20]

Statistical analyses were performed by Statistical Package for the Social Sciences (SPSS v17.0, SPSS Inc., Chicago, Illinois). Paired t-tests were used to compare preoperative and 2-year postoperative radiographic measures and HRQOL measures. Spearman correlations were calculated to determine associations between sagittal alignment and HRQOL measures. In order to control for confounding, a multivariate regression analysis was performed to determine factors predictive of 2-year postoperative NDI scores. Factors included in the regression analysis were age, preoperative NDI scores, preoperative SF-36 PCS and MCS scores, preoperative neck and arm pain scores, preoperative and change in overall cervical lordosis, and preoperative and change in segmental lordosis.

Receiver operating characteristic curves were constructed to identify sagittal parameters that could predict achievement of MCID in HRQOL measures. Receiver operating characteristic curves assesses each potential threshold value in order to optimize sensitivity and specificity in differentiating between cohorts. Sensitivity refers to the ability of the threshold value to correctly classify patients achieving the NDI MCID of 8 points of improvement. Specificity refers to the ability of the threshold to exclude those patients who did not achieve the NDI MCID. Receiver operating characteristic curve accuracy is measured by the calculated area under the curve (AUC). AUC between 0.90-1.00 is considered excellent, 0.80-0.90 good, 0.70-0.80 fair, 0.60-0.70 poor, and 0.50-0.60 failed.[21,22]

Table I. Operative Indication

Diagnosis	Frequency
Spondylosis	29
Herniated nucleus pulposus	21
Nonunion	20
Stenosis	12
Adjacent segment disease	7
Myelopathy	6
Instability	3
Radiculopathy	3

Table II. Operative Level(s)

Level	Single-level	Two-level	Three-level	Four-level
C2-C7	0	0	0	0
C3-C4	1	0	0	0
C3-C5	1	2	0	0
C3-C6	0	0	5	0
C3-C7	0	0	0	5
C4-C5	8	0	0	0
C4-C6	0	13	0	0
C4-C7	0	0	10	0
C5-C6	21	0	0	0
C5-C7	0	27	0	0
C5-T1	0	0	1	0
C6-C7	7	0	0	0
Total	**38**	**42**	**16**	**5**

Results

One hundred one patients, 26 male and 75 female, with an average age of 52±9.6 years were included in the study (average follow-up, 39.8±19.8 months). Among these patients, 24 were smokers. Operative indications included spondylosis (29), herniated nucleus pulposus (21), nonunion (20), stenosis (12), adjacent level degeneration

Table III. Outcome Data

Outcome measure	Preoperative	Postoperative	*P*-value
Neck Disability Index	27.5	21.7	<.001
SF-36 PCS	31.9	33.6	.06
Neck pain	7.4	5.1	<.001
Arm pain	6.2	4.1	<.001

Abbreviation: SF-36 PCS, Short Form 36 Physical Composite Summary Score.

(7), myelopathy (6), instability (3), and radiculopathy (3) (Table I). Operative levels, including single- (38) and multi-level (63) ACDF are detailed in Table II.

Statistically significant improvement was observed in all patient-reported HRQOL measures from preoperative to 2-years postoperative (Table III). Mean preoperative NDI score was 27.5, with a mean 2-year postoperative score of 21.7 (P<.001). Forty-five patients (44.6%) achieved an MCID in NDI. Mean SF-36 PCS scores improved from 31.9 to 33.6 (P = .06). Mean neck and arm pain scores improved from 7.4 and 6.2 to 5.1 (P<.001) and 4.1 (P<.001), respectively.

No statistically significant difference was observed between preoperative and 2-year postoperative radiographic measurements. Overall cervical lordosis (C2-C7) averaged 6.7° preoperatively and 7.7° postoperatively (P<.39), while segmental lordosis averaged 0.9° preoperatively and 2.2° postoperatively (P<.13).

No correlation between improvement in HRQOL scores and neutral upright cervical sagittal radiographic parameters was observed. Linear regression analysis identified only preoperative NDI score as predictive of 2-year postoperative NDI score. Receiver operating characteristic curves were analyzed using the sensitivity and specificity of the index procedure achieving MCID in NDI scores during the 2-year follow-up interval. A 2-year postoperative overall cervical lordosis of at least 6° predicted achievement of MCID in NDI with an AUC of 0.708.

Discussion

Proper global sagittal spinal alignment and balance is critical in maintaining an energy-efficient pain-free upright posture.[3] One of the principal goals of spinal reconstructive surgery is restoration or maintenance of the physiologic global sagittal spine profile.[9] Numerous reports have demonstrated improper sagittal alignment as a major source of pain, disability, and poor health status.[8,23-25] Although the focus has been on thoracolumbar and lumbar regional alignment, recent attention to sagittal cervical spine alignment has increased.[2,26,27]

Cervical kyphosis or malalignment after ACDF has been associated with construct failure, decreased fusion rate, development of adjacent segment disease, and poor clinical outcomes.[7,8,28-30] However, to our knowledge, there are no studies that have specifically examined the correlation between sagittal cervical spinal alignment and validated patient reported HRQOL measures. In an assessment of predictive factors for long-term outcome after ACDF, Peolsson and Poelsson[31] state that preoperative radiographic parameters, except for kyphosis, were insignificant as predictors of both short- and long-term outcomes (NDI and VAS) after ACDF. A prospective, randomized study with an average of 3-year follow-up comparing the use of lordotic or parallel allografts during ACDF found no difference in the 2 groups, but maintained or increased segmental cervical lordosis was related to improved clinical outcome.[32] To our knowledge, the current study is the first to investigate the correlation between neutral upright cervical sagittal alignment, overall and segmental, and HRQOL outcomes.

No significant difference between pre- and postoperative cervical lordosis was observed in the current study. The lack of significant change in cervical lordosis is consistent with a cohort of mostly 1- and 2-level ACDFs, where the inherent goal of the procedure is not necessarily sagittal correction. All HRQOL measures showed significant improvement from baseline to follow-up at 2 years, but Spearman correlation analysis revealed no significant correlation between improvement in patient-reported outcomes and cervical sagittal alignment. Preoperative NDI scores, as expected, were predictive of 2-year postoperative NDI scores. None of the radiographic parameters were found to be predictive of 2-year NDI scores. Although, biomechanically, it would presumably be ideal to mimic or achieve physiologic lordosis after cervical spinal reconstruction, as it appears small deviations are well tolerated, at least within our study parameters. Similarly, a multicenter, randomized controlled study investigating the use of dynamic versus rigid anterior cervical plates showed that a loss of up to 4.3° of segmental cervical lordosis had no correlation with NDI or VAS at 2-year follow-up.[33]

Sagittal balance is known to be the most critical sagittal parameter driving improvement in HRQOL measures.[3] Although all regional curves act together to optimize sagittal balance, the cervical spine has a smaller contribution compared to the lumbar spine or pelvis. This is observed in a recent report investigating the use of the T1 sagittal angle as an estimate for sagittal vertical axis.[34] The authors report that cervical alignment is not correlated with sagittal vertical axis, whereas pelvic incidence and lumbar lordosis are closely correlated. Also, Radcliff and colleagues[35] demonstrated that sagittal translational position of the cervical spine, as measured by the occipital condyle plumb line, correlated with patient-reported clinical outcomes after laminectomy and fusion, whereas angular alignment of the cervical spine did not.

Given the observation that small deviations from physiologic cervical spine sagittal alignment are well tolerated after ACDF, an important issue is whether there is a critical threshold predicting improvement in HRQOL outcomes. MCID, well described in the literature, represents "the smallest change that is important to the patient." At 2-year follow-up, 44.6% of our population achieved MCID. Receiver operating characteristic curve

analysis demonstrated that a cervical lordosis of at least 6° was fairly predictive of achieving of MCID for NDI.

Limitations of this study include its retrospective design. Ideally, evaluation of full-length spinal sagittal profile would be performed using standing 36-inch radiographs, although these studies are not routinely obtained as they offer inferior visualization of cervical graft incorporation. Another limitation is the relatively short-term follow-up. Small deviations in sagittal alignment that could lead to adjacent segment disease would likely be reflected in worse clinical outcomes at a longer follow-up interval.

To our knowledge, this is the first study to specifically investigate the correlation between cervical spine sagittal alignment and patient-reported HRQOL clinical outcome measures. It is known that maintenance or restoration of cervical sagittal profile is important after ACDF. It appears that small deviations at 2-year follow-up are tolerated and are not the driving factor for patient-perceived improvement. Although no statistical correlation in the improvement of patient-reported HRQOL outcomes and neutral upright cervical spinal alignment was observed, achievement of at least 6° of overall cervical lordosis (C2 to C7) appears to be important in obtaining a good clinical outcome after ACDF.

Authors' Disclosure Statement

Dr. Glassman would like to disclose that he is an employee of and receives research grant support from Norton Healthcare; receives consulting fees and royalties from Medtronic; receives support for trips and travel from OREF and is Vice President of the Scoliosis Research Society. Dr. Carreon wishes to disclose that she is an employee of and receives research grant support from Norton Healthcare and receives support for trips and travel from OREF, NIH, the University of Louisville and the Department of Defense. The rest of the authors report no actual or potential conflict of interest in relation to this article.

References

1. Ahn PG, Kim KN, Moon SW, Kim KS. Changes in cervical range of motion and sagittal alignment in early and late phases after total disc replacement: radiographic follow- up exceeding 2 years. *J Neurosurg Spine.* 2009;11(6):688-695.
2. Anakwenze OA, Auerbach JD, Milby AH, Lonner BS, Balderston RA. Sagittal cervical alignment after cervical disc arthroplasty and anterior cervical discectomy and fusion: results of a prospective, randomized, controlled trial. *Spine (Phila Pa 1976)*. 2009;34(19):2001-2007.
3. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. *Spine (Phila Pa 1976).* 2005;30(18):2024-2029.
4. Kumar MN, Baklanov A, Chopin D. Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. *Eur Spine J.* 2001;10(4):314-319.
5. Kuntz C IV, Levin LS, Ondra SL, Shaffrey CI, Morgan CJ. Neutral upright sagittal spinal alignment from the occiput to the pelvis in asymptomatic adults: a review and resynthesis of the literature. *J Neurosurg Spine.* 2007;6(2):104-112.
6. Jang JS, Lee SH, Min JH, Maeng DH. Influence of lumbar lordosis restoration on thoracic curve and sagittal position in lumbar degenerative kyphosis patients. *Spine (Phila Pa 1976)*. 2009;34(3):280-284.
7. Katsuura A, Hukuda S, Saruhashi Y, Mori K. Kyphotic malalignment after anterior cervical fusion is one of the factors promoting the degenerative process in adjacent intervertebral levels. *Eur Spine J.* 2001;10(4):320-324.
8. Ferch RD, Shad A, Cadoux-Hudson TA, Teddy PJ. Anterior correction of cervical kyphotic deformity: effects on myelopathy, neck pain, and sagittal alignment. *J Neurosurg.* 2004; 100 (1 Suppl Spine):13-19.
9. Jang JS, Lee SH, Min JH, Kim SK, Han KM, Maeng DH. Surgical treatment of failed back surgery syndrome due to sagittal imbalance. *Spine (Phila Pa 1976).* 2007;32(26):3081-3087.
10. Barsa P, Suchomel P. Factors affecting sagittal malalignment due to cage subsidence in standalone cage assisted anterior cervical fusion. *Eur Spine J.* 2007;16(9):1395-1400.
11. Faldini C, Pagkrati S, Leonetti D, Miscione MT, Giannini S. Sagittal segmental alignment as predictor of adjacent-level degeneration after a cloward procedure. *Clin Orthop Relat Res.* 2011;469(3):674-681
12. Steinmetz MP, Kager CD, Benzel EC. Ventral correction of postsurgical cervical kyphosis. *J Neurosurg*. 2003;98(1 Suppl):1-7.
13. Cloward RB. Lesions of the intervertebral disks and their treatment by interbody fusion methods The painful disk. *Clin Orthop Relat Res.* 1963;27:51-77.
14. Silber JS, Lipetz JS, Hayes VM, Lonner BS. Measurement variability in the assessment of sagittal alignment of the cervical spine: a comparison of the gore and cobb methods. *J Spinal Disord Tech.* 2004;17(4):301-305.
15. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther.* 1991;14(7):409-415.
16. Jensen MP, Chen C, Brugger AM. Postsurgical pain outcome assessment. *Pain.* 2002;99(1-2):101-109.
17. McCaffery M, Beebe A. Pain: *Clinical Manual for Nursing Practice.* Baltimore: V.V. Mosby Company; 1993.
18. Grevitt M, Khazim R, Webb J, Mulholland R, Shepperd J. The short form-36 health survey questionnaire in spine surgery. *J Bone Joint Surg Br.* 1997;79(1):48-52.
19. 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(6):473-483.
20. Carreon LY, Glassman SD, Campbell MJ, Anderson PA. Neck Disability Index, SF-36 PCS, and Pain Scales for Neck and Arm Pain: the Minimum Clinically Important Difference and Substantial Clinical Benefit after Cervical Spine Fusion. *Spine J.* 2010;10(6):469-474.
21. Hosmer DW, Lemeshow S. Applied logistic regression. New York: Wiley, Inc.;2000.
22. Tape TG. Interpreting diagnostic tests. http://gim.unmc.edu/dxtests/Default.htm. Accessed December 18, 2010.
23. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases A comparative study about 85 cases. *Eur Spine J*. 2007;16(9):1459-1467.
24. Hioki A, Miyamoto K, Kodama H, et al. Two- level posterior lumbar interbody fusion for degenerative disc disease: improved clinical outcome with restoration of lumbar lordosis. *Spine J.* 2005;5(6):600-607.
25. Kawakami M, Tamaki T, Yoshida M, Hayashi N, Ando M, Yamada H. Axial symptoms and cervical alignments after cervical anterior spinal fusion for patients with cervical myelopathy. *J Spinal Disord.* 1999;12(1):50-56.
26. Keorochana G, Taghavi CE, Lee KB, et al. Effect of sagittal alignment on kinematic changes and degree of disc degeneration in the lumbar spine: an analysis using positional MRI. *Spine (Phila Pa 1976).* 2011;36(11):893-898.
27. Yanbin Z, Yu S, Zhongqiang C, Zhongjun L. Sagittal alignment comparison of Bryan disc arthroplasty with ProDisc-C arthroplasty: a prospective, randomized controlled clinical trial. *J Spinal Disord Tech.* 2011;24(6):381-385.
28. Ozer E, Yücesoy K, Yurtsever C, Seçil M. Kyphosis one level above the cervical disc disease: is the kyphosis cause or effect? *J Spinal Disord Tech.* 2007;20(1):14-19.
29. Wang M, Gourab K, McGrady LM, Rao RD. Alteration of load sharing of anterior cervical implants with change in cervical sagittal alignment. *Med Eng Phys.* 2008;30(6):768-773.
30. Zdeblick TA, Bohlman HH. Cervical kyphosis and myelopathy Treatment by anterior corpectomy and strut-grafting. *J Bone Joint Surg Am.* 1989;71(2):170-182.
31. Peolsson A, Peolsson M. Predictive factors for long-term outcome of anterior cervical decompression and fusion: a multivariate data analysis. *Eur Spine J.* 2008;17(3):406-414.
32. Villavicencio AT, Babuska JM, Ashton A, et al. Prospective, randomized, double-blind clinical study evaluating the correlation of clinical outcomes and cervical sagittal alignment. *Neurosurgery.* 2011;68(5):1309-1316
33. Pitzen T. Loss of lordosis and loss of segmental height do not affect clinical results following ACDF: secondary endpoint results from a multicentric, randomized, controlled study. *Spine J.* 2010;10(9 suppl):33S.
34. Knott PT, Mardjetko SM, Techy F. The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. *Spine J.* 2010;10(11):994-998.
35. Radcliff KE, Dilorio T, Su B, et al. Occipital condyle plumb line predicts outcome of cervical laminectomy fusion. *Spine J.* 2010;10(9 suppl): 14S.