The Impact of Standing Regional Cervical Sagittal Alignment on Outcomes in Posterior Cervical Fusion Surgery

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BACKGROUND: Positive spinal regional and global sagittal malalignment has been repeatedly shown to correlate with pain and disability in thoracolumbar fusion.

OBJECTIVE: To evaluate the relationship between regional cervical sagittal alignment and postoperative outcomes for patients receiving multilevel cervical posterior fusion.

METHODS: From 2006 to 2010, 113 patients received multilevel posterior cervical fusion for cervical stenosis, myelopathy, and kyphosis. Radiographic measurements made at intermediate follow-up included the following: (1) C1-C2 lordosis, (2) C2-C7 lordosis, (3) C2-C7 sagittal vertical axis (C2-C7 SVA; distance between C2 plumb line and C7), (4) center of gravity of head SVA (CGH-C7 SVA), and (5) C1-C7 SVA. Health-related quality-of-life measures included neck disability index (NDI), visual analog pain scale, and SF-36 physical component scores. Pearson product-moment correlation coefficients were calculated between pairs of radiographic measures and health-related quality-of-life scores.

RESULTS: Both C2-C7 SVA and CGH-C7 SVA negatively correlated with SF-36 physical component scores ($r = -0.43$, $P < .001$ and $r = -0.36$, $P = .005$, respectively). C2-C7 SVA positively correlated with NDI scores ($r = 0.20$, $P = .036$). C2-C7 SVA positively correlated with C1-C2 lordosis ($r = 0.33$, $P = .001$). For significant correlations between C2-C7 SVA and NDI scores, regression models predicted a threshold C2-C7 SVA value of approximately 40 mm, beyond which correlations were most significant.

CONCLUSION: Our findings demonstrate that, similar to the thoracolumbar spine, the severity of disability increases with positive sagittal malalignment following surgical reconstruction.

KEY WORDS: Cervical fusion, Cervical spine, HRQOL, Radiographic parameters, Sagittal alignment, Spinal deformity

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Sagittal malalignment of the spine has been linked to disability and unfavorable health-related quality-of-life (HRQOL) scores in previous studies.[1-3] Patients with poor sagittal alignment have increased energy expenditure during activities and at rest, and they often develop painful compensatory alignment changes to maintain upright posture including knee flexion, pelvic retroversion, thoracic hypokyphosis, and cervical hyperlordosis.[4-7]

ABBREVIATIONS: CGH, center of gravity of head; **HRQOL,** health-related quality-of-life; **NDI,** neck disability index; **PCS,** physical composite score; **SVA,** sagittal vertical axis; **VAS,** visual analog scale

Common parameters used to define sagittal alignment include the sagittal vertical axis (SVA), regional Cobb angles (cervical lordosis, thoracic kyphosis, and lumbar lordosis), pelvic tilt, sacral slope, pelvic incidence, and the pelvic incidence–lumbosacral lordosis mismatch.[1,8-17] Furthermore, the use of the gravity line has been recently proposed as another tool to assess global sagittal alignment in addition to the standard C2 and C7 plumb lines.[12,14,18-24] Multiple studies have examined the relationship between radiographic parameters and HRQOL scores, both in asymptomatic and spinal deformity patients, and correlations between the 2 measures have been well established.[1-3,12,25-27] Glassman et al[1] found that sagittal alignment in spinal deformity by use of the C7 plumb line is the most reliable predictor of HRQOL scores, whereas coronal deformities have less impact. The same group also found that the severity of symptoms in adult patients with spinal deformity increases with progressive sagittal malalignment.[2] However, these studies have largely focused on the thoracolumbar or spinopelvic regions. Villanvicencio et al[28] recently reported a higher degree of improvement in clinical outcomes associated with improved or maintained cervical alignment but did not look specifically at cervical SVA.

Normative data have been reported for regional and global alignment of the cervical spine.[9,29,30] For example, cervical SVA by using the deviation of the C2 plumb line from C7 has been used to characterize sagittal plane alignment.[9] Hardacker et al[9] found that cervical sagittal alignment measured by C2 plumb to C7 vertebral body (cervical SVA) fell in a very narrow range in asymptomatic volunteers (16.8 ± 11.2 mm). Angular measurements of cervical lordosis are also recognized as appropriate means to assess sagittal alignment; however, the normal range published in these studies varies[9,29-31] and Kuntz et al[32] even suggest that the spinal curvature between C2 and C7 has the widest range of "normal" compared with other regions of the spine.

To date, no study has evaluated the relationship between standing cervical sagittal alignment and postoperative HRQOL scores for patients receiving multilevel cervical fusion. The goals of this study were to (1) evaluate the relationship between sagittal alignment of the cervical spine and patient-reported HRQOL scores following multilevel posterior cervical fusion and (2) identify the radiographic parameters in the cervical spine most predictive of postoperative disability.

PATIENTS AND METHODS

After obtaining institutional review board approval, a retrospective analysis of clinical and radiographic outcomes was performed for patients that received single-stage, long-segment posterior cervical fusion (≥3 segments) from 2006 to 2010. Patients presenting with trauma or infection of the spine were excluded. Because this was a retrospective study, and only a small subset of patients had standing preoperative radiographs, only standing postoperative radiographs were analyzed. Postoperative lateral standing radiographic measurements were obtained by using standard lateral cervical x-ray series protocol with the patients standing in a neutral position and instructed to look straight ahead with knees locked.[1,2,9,12,14,29-31,33] The following spinal parameters were assessed: (1) C1-C2 lordosis angle, (2) C2-C7 lordosis angle, (3) C1-C7 SVA (distance between the C1 plumb line and C7), (4) C2-C7 SVA (distance between the C2 plumb line and C7), and (5) center of gravity of head (CGH)-C7 SVA (distance between a plumb line from the CGH and C7). The CGH was approximated at the anterior margin of the external auditory canal.[34] Because the patients were imaged standing, global spinal alignment, while not directly measured, would be reflected in the final cervical alignment.

Three self-assessment HRQOL measures were obtained from each patient: neck disability index (NDI), visual analog pain scale (VAS), and the SF-36 Physical Composite Score (PCS). HRQOL values were collected at the most recent time point between 3 months and 1 year postoperatively. This intermediate follow-up time frame (goal 6 months) was selected to facilitate evaluation of patients that had recovered from surgery but before they became at risk for symptomatic pseudoarthrosis. This is the standard time frame used to assess the direct effect of postoperative sagittal balance on outcomes.

C1-C2 and C2-C7 lordosis were measured using sagittal Cobb angles.[1,2,8,10,35] The measurement of C1-C2 lordosis was calculated between a line connecting the anterior tubercle to the posterior margin of the C1 spinous process and the inferior end plate of C2 (Figure 1, left).

C1-C7 SVA was measured as the deviation of the C1 plumb line (extending from the anterior margin of C1) from the posterior superior end plate of C7. The C2-C7 SVA was defined as the deviation of the C2 plumb line (extending from the centroid of the C2 vertebra) from the posterior superior end plate of C7, with positive sagittal alignment defined as an anterior deviation. CGH-C7 SVA was measured as the deviation of the CGH plumb line (extending from the anterior margin of the external auditory canal[34]) from the posterior superior endplate of C7 (Figure 1, right).

Statistical analyses were performed using commercially available software (JMP v5.0, SAS Institute, Inc., Cary, North Carolina) to determine correlations between HRQOL and radiographic measurements. After determining that the data followed a parametric distribution using the Shapiro-Wilk normality test (P = .15 where $P > .05$ suggests that the data are from normal distribution), Pearson product-moment correlation coefficients were calculated for all combinations of radiographic measures and HRQOL scores. The level of significance was set at $P < .05$. For significant correlations observed between radiographic parameters and HRQOL scores, further analyses using both a linear regression and a logistic regression model with binary variables were performed to determine a possible threshold of radiographic measures for which the correlation with HRQOL scores was most significant. Specifically, the logistic regression model assigned values of C2-C7 SVA as binary variables greater or less than a predicted threshold value, and a Pearson test was conducted to determine the strength of correlation. Predicted threshold values were made at every 1-mm increment of C2-C7 SVA value and a Pearson test was subsequently performed to assess correlation. The approximate value of C2-C7 SVA for which correlations with NDI scores demonstrated an inflection point indicating the most significance (lowest P value) was determined to be a rough threshold value for the logistic regression. For the linear regression, correlations were evaluated to determine a threshold of disability based on a raw NDI score of 25.

An analysis of potentially confounding variables that may affect correlations observed between radiographic parameters and HRQOL scores, including age and history of prior surgery, was conducted. A subgroup of patients presenting with either myelopathy or stenosis as a surgical indication was separately analyzed to assess whether any correlations demonstrating improvement in HRQOL scores may be attributable to spinal cord or nerve root decompression.[36]

NDI and PCS at intermediate follow-up were further compared with preoperative scores for only 71 and 42 patients, respectively, because preoperative scores were not recorded for the rest. Improvement in NDI scores following surgery was evaluated by categorizing scores into the following standard intervals: no disability (0-4) and mild (5-14), moderate (15-24), severe (25-34), and complete disability (greater than 34). The percentage of change of PCS following surgery was also calculated.

RESULTS

A total of 113 patients (M = 61, F = 52) were evaluated, and the mean age was 59 ± 12 years (range, 24-87 years). The most

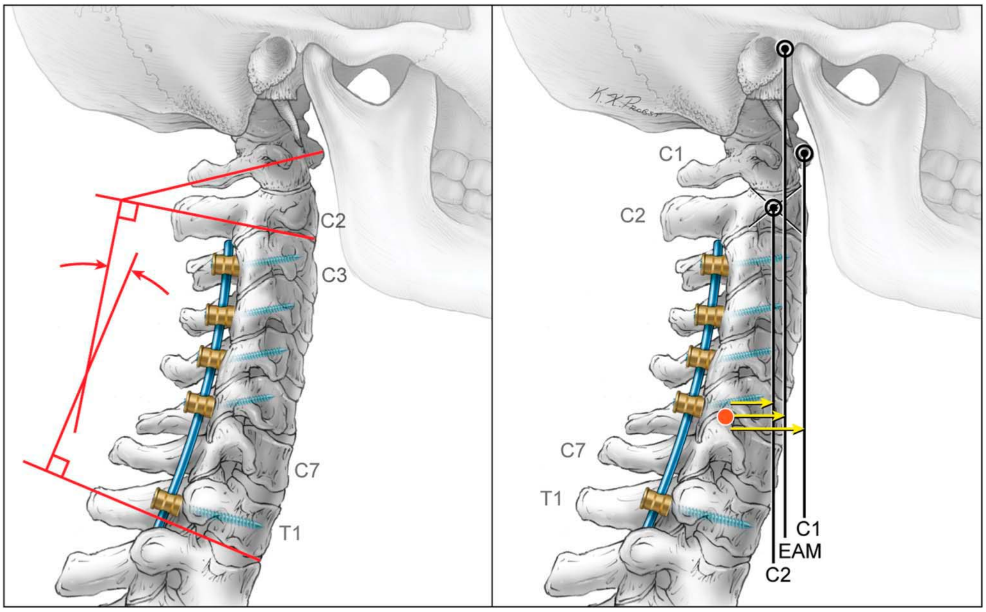

FIGURE 1. *Visual representation of the technique used to measure (**left**) cervical lordosis and (**right**) cervical SVA. C1-C2 lordosis was measured as the angle of intersection between a line connecting the anterior tubercle to the posterior margin of the C1 spinous process and a line parallel to the inferior end plate of C2. C2-C7 lordosis was measured as the angle of intersection between lines parallel to the inferior end plates of C2 and C7. The arrows represent the distance between the posterior superior corner of C7 and a plumb line dropped from C2 (C2-C7 SVA), the external auditory meatus (EAM; CGH-C7 SVA), and C1 (C1-C7 SVA). SVA, sagittal vertical axis; CGH, center of gravity of head.*

common indications for long-segment cervical fusion included cervical stenosis (n = 65), myelopathy (n = 38), deformity (n = 14), and degenerative disc (n = 13) with several patients presenting with a combination of indications. The number of levels fused ranged from 3 to 11 with a mean of 5.6 ± 1.9 levels. The average follow-up time for which radiographic measurements and HRQOL scores were obtained postoperatively was 187 ± 108 days.

C1-C2 lordosis angles ranged from 8 to 55 degrees with a mean of 35.4 ± 8.2 degrees. C2-C7 lordosis angles ranged from 0 to 54 degrees with a mean of 12.6 ± 10.4 degrees. C1-C2 lordosis constituted 76.0% ± 15.8% of total cervical lordosis (measured as the sum of C1-C2 lordosis and C2-C7 lordosis). C1-C7 SVA ranged from 0 to 123.4 mm with a mean of 50.9 ± 20.2 mm. C2-C7 SVA ranged from -5.5 to 95 mm with a mean of 36.2 ± 15.9 mm. CGH-C7 SVA ranged from −17.9 to 127.1 mm with a mean of 43.6 ± 23.7 mm. Table 1 summarizes the mean values of cervical lordosis and SVA in comparison with normative data from asymptomatic patients.[9]

Raw NDI scores ranged from 1 to 46 with a mean of 20.9 ± 11.0. VAS scores ranged from 0 to 10 with a mean of 4.32 ± 2.9. The SF-36 PCS ranged from 20.2 to 58.7 with a mean of 35.8 ± 10.1.

Comparisons between radiographic parameters and HRQOL scores demonstrated significant correlations, particularly between cervical SVA measurements and PCS and NDI scores (Table 2). C2-C7 SVA exhibited a significant positive correlation with NDI scores (r = 0.20, P = .04, Figure 2). Both C2-C7 SVA and CGH-C7 SVA exhibited a significant negative correlation with PCS ($r = -0.43$, $P < .001$, Figure 3, and $r = -0.36$, $P = .005$, respectively). For the subgroup of patients presenting with cervical myelopathy or stenosis, significant positive correlations also existed between C2-C7 SVA and NDI scores (r = 0.23, P = .04), between C2-C7 SVA and PCS ($r = -0.52$, P = .001), and between CGH-C7 SVA and PCS ($r = -0.44$, P =.002). Stronger correlations were observed between C2-C7 SVA and PCS than between C2-C7 SVA and NDI scores. To assess whether these differences in correlations could reflect differences in the patient populations that completed these outcomes

TABLE 1. Comparison of Cervical Measurements to Normative Data[a,b]

Measurement	Asymptomatic	Our Study
C1-C2 lordosis	31.9 ± 7.0 deg	35.4 ± 8.2 deg
Mean cervical lordosis	40.9 ± 9.7 deg	48.0 ± 12.12 deg
C2-C7 SVA	16.8 ± 11.2 mm	36.2 ± 15.9 mm

[a]SVA, sagittal vertical axis.
[b]Mean values of cervical lordosis and SVA compared with normative data from asymptomatic patients.[9]

TABLE 2. Correlations Between Radiographic Measures and HRQOL Score[a,b]

Radiographic Measure	HRQOL Score	Sample Size	Correlation (Pearson *r*)	*P*
C1-C7 SVA	NDI	108	0.1863	.054
C1-C7 SVA	PCS	58	−0.4097	.001[c]
C2-C7 SVA	NDI	108	0.2015	.037[c]
C2-C7 SVA	PCS	58	−0.4262	.001[c]
C2-C7 SVA	NDI	58	0.2957	.024[c]
CGH-C7 SVA	NDI	108	0.1873	.052
CGH-C7 SVA	PCS	58	−0.3613	.005[c]

[a]HRQOL, health-related quality of life; SVA, sagittal vertical axis; NDI, neck disability index; PCS, physical component score; CGH, center of gravity of head.
[b]Significant correlations found between pairs of radiographic parameters and HRQOL scores using Pearson product-moment analysis.
[c]Denotes significance between correlations.

measures (all 108 patients completed the NDI, but only 58 of the patients completed the PCS), separate correlation analysis was performed between C2-C7 SVA and NDI scores only including the 58 patients for whom PCS data were available. This analysis demonstrated preservation of a positive correlation of C2-C7 SVA and NDI scores for these 58 patients (r = 0.30, P = .024).

C1-C7 SVA and CGH-C7 SVA showed positive correlations with NDI scores; however, for both correlations, the P values were slightly greater than the set threshold values for significance (r = 0.19, P = .053 and r = 0.19, P = .052, respectively). C1-C7 SVA correlated negatively with PCS (r = −0.41, P = .001).

Evaluation for correlations among the cervical radiographic parameters was performed and demonstrated significant correlations between each of the cervical SVA measurements and between each cervical SVA measurement and C1-C2 lordosis (Table 3). Specifically, significant correlations were found between C1-C7 SVA and C2-C7 SVA (r = 0.96, $P < .001$), between C1-C7 SVA and CGH-C7 SVA (r = 0.90, $P < .001$), and between C2-C7 SVA and CGH-C7 SVA (r = 0.88, $P < .001$). In addition, significant correlations were found between C1-C7 SVA and C1-C2 lordosis (r = 0.28, P = .002), between C2-C7 SVA and C1-C2 lordosis angles (r = 0.33, P = .001), and between CGH-C7 SVA and C1-C2 lordosis angles (r = 0.22, P = .02). No other significant correlations were identified among the radiographic parameters. Significant correlations were not identified between radiographic parameters and VAS scores.

Because of lower sample size for patients that reported PCS (n = 58), significant correlations were further analyzed only between C2-C7 SVA and NDI scores (n = 108). Both logistic and linear regressions were used to determine a possible C2-C7 SVA threshold at which onset of disability can be defined by NDI scores. The logistic regression model predicted a value of 41 mm for C2-C7 SVA (χ^2 = 6.60, P = .011) at which the P value for the correlation tests was lowest. The linear regression predicted a threshold C2-C7 SVA value of 37 mm for a raw NDI score of 25 (r^2 = 0.04, P = .037). Adjusting for potentially confounding variables revealed that neither history of prior surgery nor patient age significantly correlated with either NDI scores or PCS ($P > .05$).

Overall, at the intermediate follow-up, 80% of patients experienced an improvement of NDI scores or remained the same compared with preoperative conditions. Twenty percent of patients experienced a deterioration of NDI scores. PCS improved an average of 22.0% ± 37.5% following surgery.

DISCUSSION

Global positive sagittal malalignment, traditionally defined as a C7 plumb line greater than 50 mm anterior to the posterior

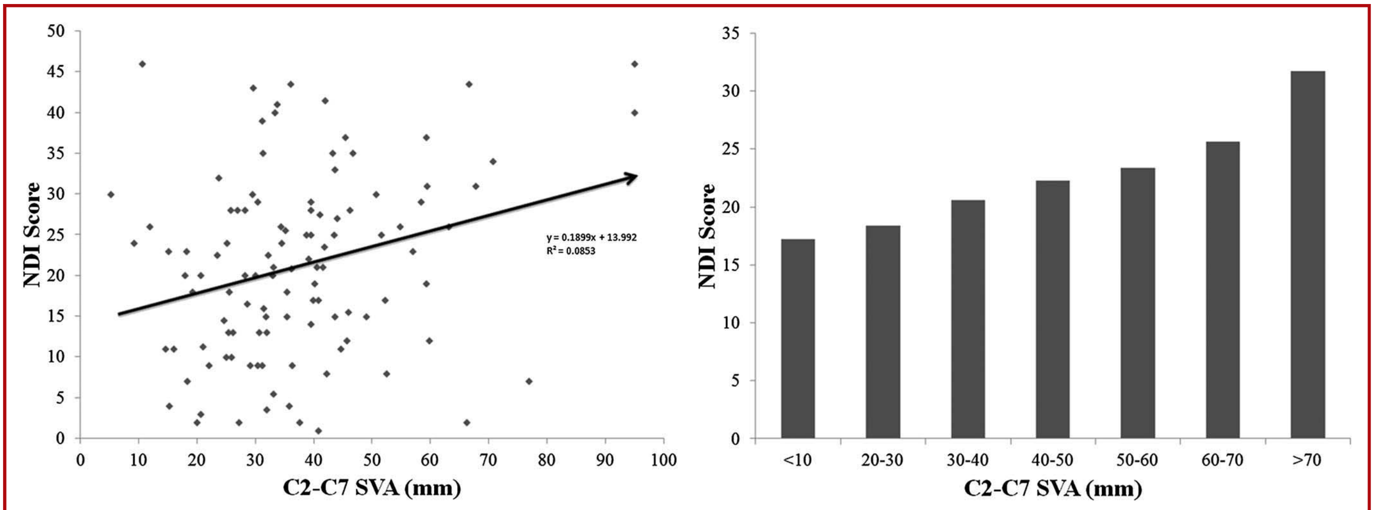

FIGURE 2. *Positive correlation observed between C2-C7 SVA and NDI scores.* **Left**, *regression results superimposed on raw data.* **Right**, *bar graph of mean data. SVA, sagittal vertical axis; NDI, neck disability index.*

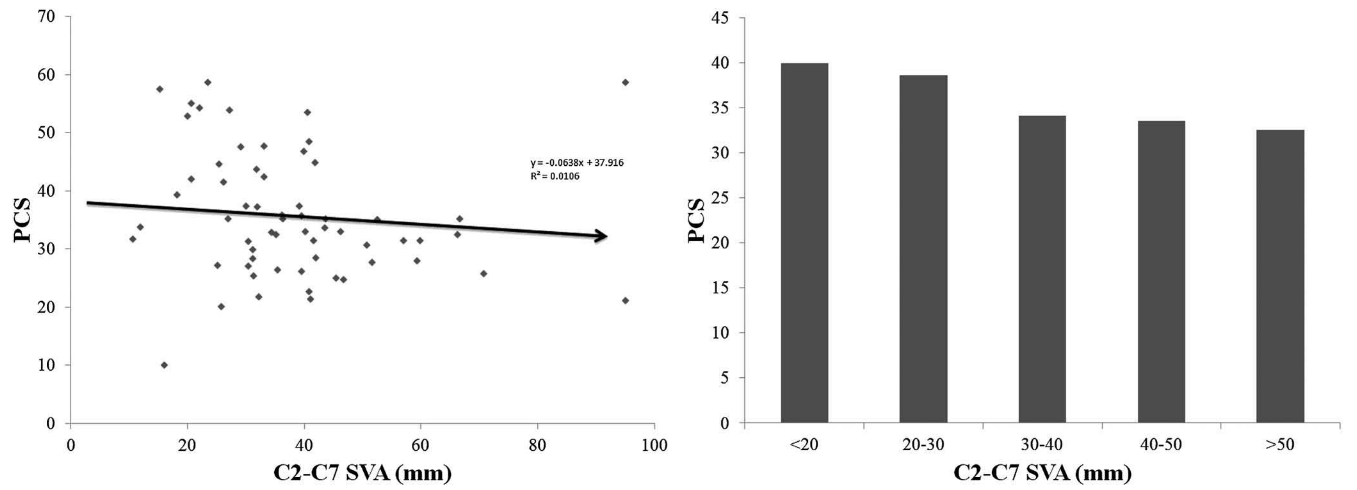

FIGURE 3. *Negative correlation observed between C2-C7 SVA and PCS scores.* **Left**, *regression results superimposed on raw data.* **Right**, *bar graph of mean data. SVA, sagittal vertical axis; PCS, physical component score.*

superior sacral margin, has been repeatedly shown to correlate with pain and disability in thoracolumbar fusion.[1,2] Multilevel cervical fusion is commonly performed, yet the impact of cervical sagittal alignment on outcomes has not been reported. There currently exists no commonly acknowledged standard of how to measure cervical sagittal balance. In fact, practice patterns vary, and not all centers perform cervical radiographs in the standing position. Unless these radiographs are performed standing, the true cervical alignment cannot be assessed, because the cervical sagittal alignment will be affected by global alignment variables.

This is the first study to examine the impact that standing regional SVA in the cervical spine has upon HRQOL following multilevel cervical fusion. Our findings demonstrate that, similar to the thoracolumbar spine, the severity of disability increases with positive sagittal malalignment following surgical reconstruction.

Positive cervical sagittal malalignment, measured by C2-C7 SVA, negatively affects HRQOL scores following multilevel posterior cervical fusion at intermediate follow-up (Figure 4). Further analysis for significant correlations between C2-C7 SVA and NDI indicates possible threshold values of C2-C7 SVA for which trends are most noteworthy. Although sagittal malalignment has previously been defined as a C7 plumb line of greater than 50 mm from the posterior superior corner of the sacrum, this study proposes a similar conclusion in the cervical spine where a C2 plumb line greater than approximately 40 mm from the posterior superior aspect of C7 (in the standing position) suggests a clinical concern of cervical sagittal malalignment that may negatively impact HRQOL. It is interesting to note that 40 mm falls outside the upper normal range as reported by Hardacker et al[9] in asymptomatic patients of 16.8 ± 11.2 mm.

Correlations between measures of cervical SVA and C1-C2 lordosis suggest that these parameters are linked as patients attempt to optimize craniocervical alignment. C1-C2 alignment may be the terminal link between the cranium and the cervical spine to regulate the angle of gaze. This relationship is analogous to the manner by which the pelvis changes alignment to maintain upright posture.

The concepts behind these findings may be explained by Dubousset's "Conus of Economy" theory,[37] which states that the body adapts to changes in balance in order to regulate the center of gravity over as narrow a perimeter as possible. This notion applied to the cervical spine suggests that in the presence of positive cervical sagittal alignment, the cervical spine will adopt more drastic changes in curvature, namely hyperlordosis of C1-C2, as a compensatory mechanism to preserve the CGH within a fine range. Beier et al[34] noted that the CGH sits almost directly above the centers of the C1 and C2 vertebral bodies, which may provide further reasons behind the high percentage of cervical standing lordosis localized to C1-C2. Indeed, this study confirms the predominance of lordosis localized to terminal

TABLE 3. Correlations Between Pairs of Radiographic Measures[a,b]

Radiographic Measure	Radiographic Measure	Sample Size	Correlation (Pearson's r)	P
C1-C7 SVA	C2-C7 SVA	113	0.9639	<.001[c]
C1-C7 SVA	CGH-C7 SVA	113	0.8950	<.001[c]
C2-C7 SVA	CGH-C7 SVA	113	0.8769	<.001[c]
C1-C7 SVA	C1-C2 lordosis	113	0.2824	.002[c]
C2-C7 SVA	C1-C2 lordosis	113	0.3305	.001[c]
CGH-C7 SVA	C1-C2 lordosis	113	0.2225	.018[c]

[a]SVA, sagittal vertical axis; CGH, center of gravity of head.
[b]Significant correlations found between pairs of radiographic parameters using Pearson's product-moment analysis.
[c]Denotes significance between correlations.

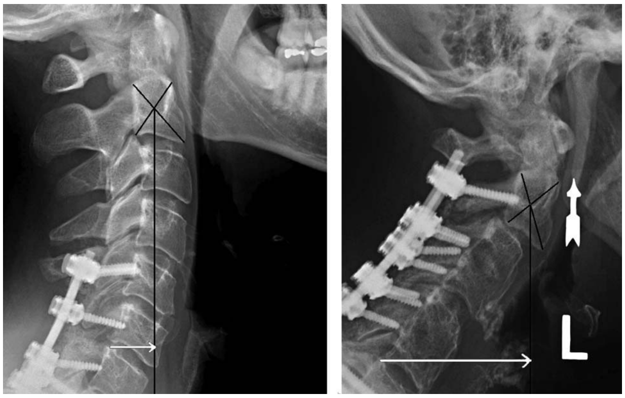

FIGURE 4. *Comparison of effects of positive sagittal alignment on NDI and PCS scores.* **Left**, *patient with C2-C7 SVA of 20.9 mm exhibiting PCS score of 55.1 and NDI score of 3 (no disability).* **Right**, *patient with C2-C7 SVA of 59.2 mm exhibiting PCS score of 28 and NDI score of 37 (severe disability). SVA, sagittal vertical axis; NDI, neck disability index; PCS, physical component score.*

segments, where C1-C2 lordosis constitutes almost 80% of total cervical lordosis.[9,11] Given all these adaptive changes that require greater energy expenditure to maintain upright posture, the correlation between positive cervical sagittal alignment with adverse HRQOL scores is not unexpected.

CGH-C7 SVA may potentially be an important measure, because the overall center of gravity of the body, a term identified as the "gravity line," is becoming a particularly useful tool in assessing sagittal alignment. In fact, previous studies[12,14] have determined this gravity line as an individual-specific parameter by using a force plate and have found correlations between the location of this gravity line and HRQOL scores. In asymptomatic adults, the gravity line of the entire body crosses the femoral heads in the sagittal plane,[14] and T9 has been demonstrated to be relatively at the same level as the center of mass of the upper body.[38] In patients with deformities, however, anterior malalignment can be visualized as rotation of the trunk around T9. This study applied a similar concept to characterize the CGH and is the first to define a new SVA parameter determined radiographically by quantifying the distance between a plumb line from the head's center of gravity to the posterior superior aspect of C7. The high correlation seen between this and the more widely used C2-C7 SVA suggests a possible additional method to define cervical SVA.

The lack of correlations observed between radiographic parameters and VAS scores may reinforce the subjective nature of pain. Because the tolerance for pain varies considerably among individuals, VAS scores may not be as reliable a tool from which to draw correlations based on radiographic parameters for this particular study. Sagittal balance studies previously published, which established the critical role of sagittal alignment in thoracolumbar surgery, also reported general health and disease-specific measures but not VAS.[1,2,28]

Limitations of the study include the lack of preoperative standing radiographs to assess preoperative cervical and global spinal alignment in this population. Many patients in this study only had preoperative supine MRI scans or seated cervical radiographs, which cannot be used to assess standing sagittal alignment. Therefore, only the postoperative alignment was able to be accurately quantified. Based in part on the results of this study, we now obtain standing preoperative and postoperative cervical radiographs and 3-foot standing films on all patients undergoing cervical fusion. Because standing regional cervical alignment has a direct effect on outcomes and global alignment parameters have a direct effect on the regional cervical alignment, 3-foot standing films should be obtained to better plan ideal postoperative cervical alignment; the specific analysis of the magnitude of the effect of lumbar/pelvic and thoracic alignment on cervical fusion outcomes is the subject of future study. In addition, it is likely that the amount of required lordosis for acceptable cervical alignment is set to some extent by the T1 slope.[39] This allows calculation of the preoperative alignment and analysis of factors such as upper thoracic kyphosis or flat back, which may have a direct impact on cervical alignment.

The lack of preoperative scores for some patients is another limitation, because, without these data, no adjustments can be performed for baseline disability in analyzing the relationship between cervical alignment and outcome measures. We also now routinely obtain preoperative HRQOL scores due in part to this study.

Because preoperative myelopathy and myelopathy improvement were not separately assessed with a myelopathy scale, it cannot be determined whether patients with better sagittal alignment also experienced greater improvement in myelopathy and to what extent myelopathy improvement correlates to NDI scores or PCS. Given the impact of myelopathy on patient function and HRQOL, this subject warrants further investigation.

To create a more homogeneous population, only patients who underwent single-stage posterior cervical fusion were included. Anterior procedures and the resultant swallowing morbidity could create issues with respect to HRQOL, and we believed that the posterior-only population would allow the most accurate preliminary analysis of a correlation between alignment issues and HRQOL.

Ultimately, there is a need for a prospective study with a homogeneous population to control more tightly for possible confounding factors and allow for a more meaningful interpretation of the true effect of cervical sagittal alignment on HRQOL measures. It is also worth noting, however, that such seminal studies as Glassman et al[2] also involved a heterogeneous population.

Sagittal alignment, while often correlated to regional kyphosis and lordosis, is a different measurement and depends also on the alignment of subjacent segments such as the pelvis and lumbar spine. Sagittal alignment has important implications for muscular energy expenditure in maintenance of posture.

CONCLUSION

Although the reality remains that there are inherently large variations in radiographic parameters even in asymptomatic patients,[11,40] this study elucidates a similar relationship that was previously observed only in the thoracolumbar spine, in which disability of the neck increases with progressive cervical standing sagittal malalignment. Many factors play into the HRQOL each patient experiences, and this study highlights the pivotal relationship of sagittal radiographic parameters to the HRQOL status of patients with posterior cervical fusion.

Disclosures

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COMMENTS

The authors present an important well-performed and well-written study on the relationship between cervical sagittal alignment and clinical outcomes. They use established radiographic parameters such as C1-C7 (distance between the C1 plumb line and C7); C2-C7 (distance between the C2 plumb line and C7); and CHG-C7 SVA (distance between a plumb line from the center of gravity of the head and C7) to measure and illustrate the degree of lordosis or kyphosis of the cervical spine. In brief, the study shows that the amount of postoperative positive sagittal balance (kyphosis) of the cervical spine directly correlates with the severity of disability as measured by validated functional outcome measures, such as neck disability index and SF-36. Their conclusion falls in line with the generally accepted principle that the physiologic sagittal balance is important for normal function of the spine.

However, even after reviewing this excellent study, one continues to wonder whether maintenance and improvement of cervical lordosis have an effect on postoperative functional outcomes. The spinal curvature between C2 and C7 has the widest range of "normal" compared with any other region of the spine.[1] Moreover, most of the published studies examined sagittal alignment as a postoperative result without analyzing its relationship to the preoperative status,[2] a weakness of the present study.

In addition, it is not clear if improvement in functional outcome after surgery is a result of correction of the kyphotic cervical deformity, or if such improvement is attributable to the spinal cord or nerve root decompression itself[3]; it is unclear in the present study how many of the 113 patients had concurrent decompression of neural elements.

Finally, as stated above, it is widely thought that global spinal balance following reconstructive spine surgery releases stress on the surrounding bony ligamentous and muscle soft tissue structures. The authors attempt to validate this assumption through study of regional plain radiographs localized to the cervical spine. However, it may be that with study of full-length spine radiographs, the overall global sagittal balance may be even more important than regional cervical sagittal alignment and may be more predictive of significantly improved functional outcomes.

Compared with thoracic and lumbar sagittal alignment, cervical sagittal alignment has received far less attention in the literature. The authors are to be congratulated in this effort to add to our understanding of alterations of cervical sagittal alignment and how it affects patient outcomes.

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1. Kuntz CT, Levin LS, Ondra SL, Shaffrey CI, Morgan CJ. Neutral upright sagittal spinal alignment from the occipute to the pelvis in asymptomatic adults: a review and resynthesis of the literature. *J Neurosurg Spine*. 2007;6:104-112.
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Although there is significant literature to support the impact of global sagittal balance on disability, the impact of cervical sagittal alignment has not been as well evaluated. This study analyzed the relationship between multiple parameters of cervical sagittal alignment and patient-reported health-related quality-of-life (HRQOL) scores. A significant positive correlation between the C2-C7 sagittal vertical axis (SVA) and the neck disability index (NDI) was found. A significant negative correlation between the C2-C7 SVA and center of gravity of the head (CGH)-C7 SVA with the physical composite score (PCS) of the SF-36 was also observed. These results suggest that increasingly positive cervical sagittal alignment as measured by these radiographic parameters leads to increasing disability. Interestingly, no correlation was noted with pain as measured by the VAS. Although noteworthy and analogous to the impact of global sagittal balance, the findings of this study should be interpreted cautiously. The study is retrospective, and, as a consequence, many variables were not available to be analyzed such as preoperative cervical radiographs, scoliosis radiographs, and a large number of preoperative HRQOL scores. The study population was also heterogenous. In addition, the C2-C7 SVA relationship to the NDI, while significant, was only a weak correlation (r = 0.20, P = .04). Although the correlation was modestly stronger with the PCS score, there was a large selection because as only 58 of 113 patients were analyzed. Even with these limitations, the study serves to highlight the potential significance of cervical sagittal alignment on disability.

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The literature has a large number of studies examining the relationship between postoperative thoracolumbar sagittal alignment and outcomes. Less literature examining the same questions in the cervical spine exists. The authors present a well-conceived and executed study of this. This study serves 2 important purposes. First, it is an excellent reference for the various measurements used to describe sagittal alignment in the cervical spine. Second, it shows that postoperative sagittal misalignment in the cervical spine correlates with higher disability scores. The authors used standard measurement scales to assess outcomes (NDI, VAS, PCS of the SF-36). The study is retrospective. So, it does not directly support the assumption that correction of sagittal misalignment leads to better outcomes. It simply shows that, patients with poor sagittal alignment, do worse than patients with more anatomic alignment. By its design, the study does not allow us to conclude that surgical correction of sagittal alignment issues led to better outcomes. That would require a prospective study.

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