Original Article

Cervical sagittal balance parameters after single-level anterior cervical discectomy and fusion: Correlations with clinical and functional outcomes

ABSTRACT

Background: Normal sagittal cervical alignment has been associated with improved outcome after anterior cervical discectomy and fusion (ACDF).

Objective: The aim of this study is to identify alterations of cervical sagittal balance parameters after single-level ACDF and assess correlations with postoperative functionality.

Methods: A retrospective chart review was performed between January 2010 and January 2014 to identify adult patients with no previous cervical spine surgery who underwent ACDF at any one level between C2 and C7 for the single-level degenerative disease. Tumor, infection, and trauma cases were excluded from the study. For the included cases, the following data were recorded preoperatively and 6 months–1 year after surgery: sagittal balance-marker measurements of the C1–C2 angle, C2–C7 angle, C7 slope, segmental angle at the operated level, and sagittal vertical axis (SVA) distance between C2 and C7, as well as the neck disability index and visual analog scale of pain.

Results: The present study included 47 patients (average age: 51.2 years; range: 28–86 years). A moderate negative correlation between a smaller C2–C7 angle and the presence of right arm pain before treatment was found ($P = 0.0281$). Postoperatively, functionality scores significantly improved in all patients. C1–C2 angle increased with statistical significance ($P = 0.0255$). C2–C7 angle, segmental angle, C7 slope, and SVA C2–C7 distance did not change with statistical significance after surgery. C7 slope significantly correlated with overall cervical sagittal balance ($P < 0.05$).

Conclusions: Single-level ACDF significantly increases upper cervical lordosis (C1–C2) without significantly changing lower cervical lordosis (C2–C7). The C7 slope is a significant marker of overall cervical sagittal alignment ($P < 0.05$).

Keywords: Anterior spine, cervical myelopathy, degenerative disease, radiculopathy, sagittal alignment, sagittal balance

INTRODUCTION

Degenerative cervical pathologies such as spondylosis and spondylolisthesis are caused mainly by disc degeneration, hypertrophic facet joints, and rotational forces in the cervical spine. Symptoms such as cervical pain, deteriorating function, and in severe cases of the degenerative disease, loss of forward gaze, are signs of significant changes in cervical lordosis.[1] Usually, these degenerative changes indicate the presence of cervical spondylotic myelopathy and cervical kyphosis.[2-6] Cervical spondylotic myelopathy has a strong correlation with cervical sagittal alignment as dynamic magnetic resonance imaging studies have proven.[7,8] In addition, cervical kyphosis may develop after multilevel laminectomies and in conjunction with diagnoses of infection, trauma, degenerative disorders, and tumors.[9] Other factors such as decreased bone density,

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disc pathologies, and thoracolumbar sagittal imbalance may be related to the appearance of cervical kyphotic changes.[10-17] The appearance of disorders in cervical alignment is an important element in recognizing defects in global spine imbalances.[13] Cervical imbalance causes morphological changes in the spinal cord that lead to microvasculopathy, neuronal degeneration, and impairment of function.[18]

Anterior cervical discectomy and fusion (ACDF) is a routinely performed surgical procedure for the treatment of benign structural anomalies of the cervical spine such as disk protrusions, cervical spondylosis, foraminal stenosis, and bony abnormalities. During the last decade, the study of cervical sagittal balance became highlighted as it links functionality and surgical outcome.[3,5,6,19-26] Cervical sagittal balance measurements include several radiological parameters; among these are C2–C7 lordosis, C1–C2 lordosis, sagittal vertical axis (SVA), segmental sagittal alignment at the operated level, and C7 and T1 slope.[5,10,11,14,20,24,25,27-37] The T1 slope is correlated with overall spine sagittal balance, including cervical spine balance.[27,29,38]

The aim of our retrospective study was to record the changes that single-level ACDF induces in the cervical sagittal alignment of patients with cervical radiculopathy or cervical myelopathy resulting from degenerative disc disease. In addition, we tried to relate these cervical sagittal alignment changes to patient-reported functional outcome scores, including the visual analog scale (VAS) and neck disability index (NDI). This comparison could provide valuable clinical information regarding the manifestations of cervical sagittal imbalance in patients treated for cervical myelopathy and/or radiculopathy with single-level ACDF.

METHODS

Population, setting

This retrospective chart review was conducted after obtaining the Institutional Review Board approval. The approval included a Health Insurance Portability and Accountability Act waiver of patient authorization owing to the retrospective nature of and use of de-identified data in this study. We included adult patients (>18-year-old) who underwent single-level ACDF for cervical radiculopathy and/or myelopathy for the first time between January 2010 and January 2014. All operations were right-sided Smith-Robinson approaches, performed at either of our two affiliated hospitals.

Surgeons used a polyetheretherketone (PEEK) anterior interbody cage with an allograft and an anterior plate in all procedures. VAS and NDI scores, as well as neutral standing cervical X-rays from before and at 6–12 months after surgery were available for these patients. Trauma, infection, and tumor cases were excluded from the study.

Data collection

Data collected included demographics and body mass index (BMI). In addition data collection included were preoperative and postoperative neurological examination findings and the Health-Related Quality of Life (HRQoL) scores for the VAS and NDI. Measurements were obtained of cervical sagittal alignment markers from each patient's pre-operative and post-operative standing cervical X-ray studies, including C7 slope, C1–C2 cervical lordosis (C1–C2 angle), C2–C7 cervical lordosis (C2–C7 angle), C2–C7 SVA (the horizontal distance between the plumb line of C2 and C7), and segmental angle (the angle between the inferior endplate of the upper vertebrae and the superior endplate of the next lower vertebrae, forming the disc space). Fusion status and surgical complications were also reviewed and recorded from medical records, X-rays performed during follow-up visits, and cervical spine CT scans obtained at 1 year after surgery.

Radiological measurements

All radiographic measurements were made using the picture archiving and communication system (Synapse, Fujifilm, Valhalla, New York). To ensure reproducibility and consistency of cervical sagittal alignment parameters, only standing neutral cervical X-rays were used before surgery and 6–12 months after surgery. Furthermore, by extending our measurements out for this length of time after surgery, we managed to achieve NDI and VAS scores that were not negatively affected by immediate postoperative pain.

We measured the lordosis between the C1 and C2 vertebrae, which reflects lordosis of the upper cervical spine, and between the C2 and C7 vertebrae, which reflects lower cervical lordosis. The C1–C2 lordosis measurement was performed by drawing the first-line parallel to the inferior endplate of C2 and the second line from the anterior tubercle of C1 to the posterior margin of the spinous process [Figure 1]. C2–C7 lordosis was measured by drawing a line parallel to the inferior endplate of C2 and a second-line parallel to the inferior endplate of C7. Perpendicular lines were then drawn at right angles to each of the previous two lines (Cobb technique).

The angle formed between the perpendicular lines represented the cervical lordosis angle of C2–C7 [Figure 1]. The functional segmental angle was measured by drawing lines from the superior and inferior vertebral body to the level where the fusion was performed [Figure 2]. The C7 slope was calculated by measuring the angle formed by the horizontal line to the C7 vertebra and the parallel line to the superior endplate of the C7 vertebra [Figure 3]. The cervical SVA was measured as the horizontal distance between the plumb line of the C2 and C7 vertebrae [Figure 4]. All measurements were performed by two of the coauthors.

Lordosis angles were thought to be negative and kyphosis angles were thought to be positive in all our performed measurements (C1–C2, C2–C7, and segmental angle). C2–C7 angles were classified as Lordotic angles: <-10, Neutral: -10-0, kyphotic >0 according to the value of C2–C7 sagittal cervical alignment. Segmental angle values were categorized into lordotic (segmental angle < 0), neutral (segmental angle = 0), and kyphotic (segmental angle > 0).

Statistical analysis

The SAS® statistical package (version 9.3; SAS Institute, Cary, North Carolina, USA) was used for the statistical analysis. Radiographic measures and normal distribution of HRQoL scores were determined using the Shapiro–Wilk test. The paired *t*-test (for normally distributed data) or the Wilcoxon signed-rank test (for abnormally distributed data) was used to compare the distributions of the variables before and after treatment. When the value of $P < 0.05$, the distribution of the variable was significantly different before and after treatment. Correlation between radiographic measures and HRQoL scores before and after treatment and changes before and after treatment was evaluated using Spearman correlation coefficient. When the $P < 0.05$, it was concluded that the correlation was statistically significant. Correlations and changes between angles before and after treatment were evaluated using Spearman correlation coefficient. When the $P < 0.05$, the correlation was considered statistically significant.

RESULTS

Descriptive data

A total of 47 patients were included in this study. The average age of these patients was 51.2 ± 14.9 years

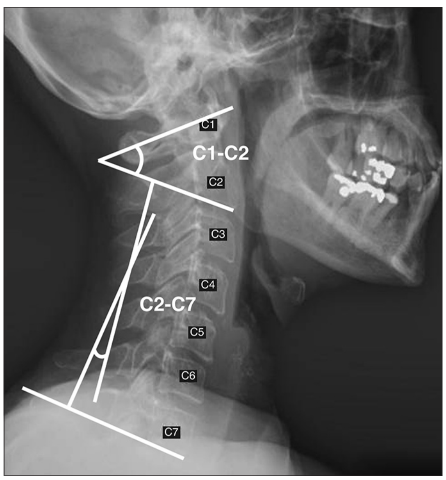

Figure 1: Lateral cervical spine X-ray. C1–C2 (upper cervical lordosis) and C2–C7 (lower cervical lordosis-by Cobb technique) angles are indicated

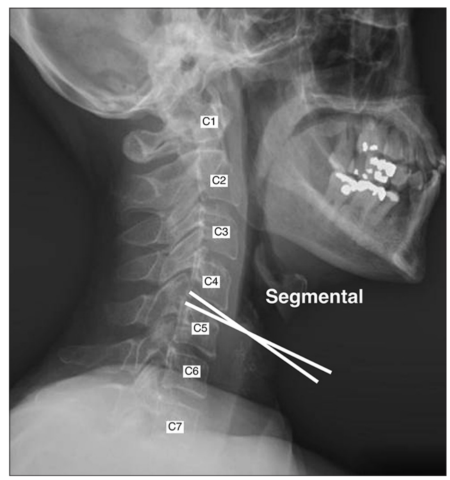

Figure 2: Lateral cervical spine X-ray. Formation of the segmental angle is indicated by parallel lines to the endplates of the involved vertebrae

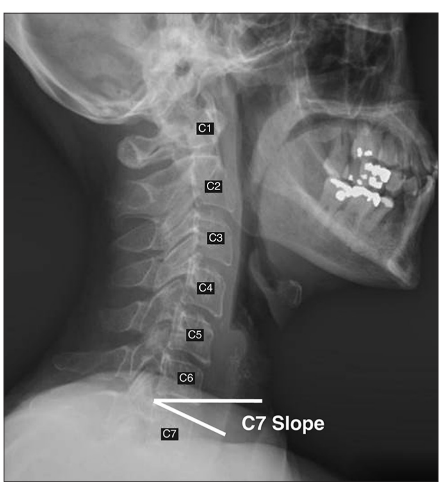

Figure 3: Lateral cervical spine X-ray. Formation of the C7 slope is indicated by the horizontal line at that level and the line that is parallel to the C7 superior endplate

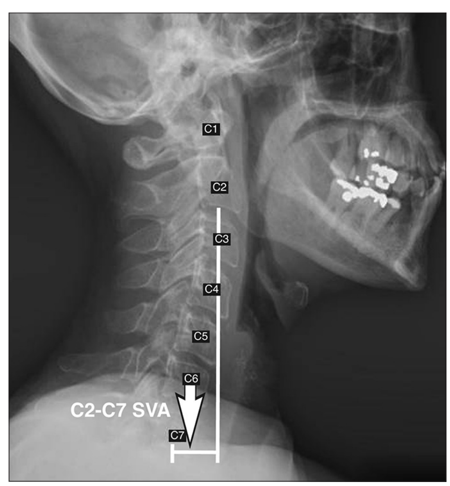

Figure 4: Lateral cervical spine X-ray. The sagittal vertical axis is calculated as the distance between the gravity centers of the C2 and C7 vertebrae

(standard deviation [SD]), (range: 28–86 years); 27 (57.5%) were women. The average BMI was 28.9 ± 5.5 (SD), ranging from 20.40 to 42.00 [Table 1]. Nineteen (40.4%) patients had cervical myelopathy, and 28 (59.6%) had cervical degenerative disc disease. Eleven patients (23.4%) were operated on at the C3–C4 level, five patients (10.6%) at the C4–C5 level, 21 patients (44.7%) at the C5–C6 level, and 10 patients (21.3%) at the C6–C7 level. According to our data, the average follow-up period was 212 ± 56 days.

The HRQoL scores, including VAS for neck and arm pain and NDI, significantly changed after treatment [Table 1]. The mean value for VAS neck pain was 6.2 preoperatively and decreased to 2.8 after surgery ($P < 0.0001$). The mean value for VAS right arm pain decreased from 3.9 to 1.5 and for left arm pain from 4.5 to 1.7 ($P < 0.001$). The preoperative mean value for NDI was 23.3 and was reduced postoperatively to 12.9 ($P < 0.0001$) showing improvement from moderate-to-mild disability. There was a moderate negative correlation (−0.32046) between the C2–C7 angle and the presence of VAS right arm pain ($P = 0.0281$) before treatment [Figure 5]. There was no statistical correlation between these variables after treatment.

Overall lordosis and sagittal balance changes

According to our data, the cervical spine was lordotic in 30 patients, neutral in 16, and kyphotic in 1 before surgery. Approximately 6 months to 1 year after the procedure, the cervical spine was lordotic in 25 patients, neutral in 19, and kyphotic in 3. Preoperatively, the segmental angle was lordotic in 41 patients, neutral in 2, and kyphotic in 4. After the ACDF procedure, there were 44 patients with a lordotic segmental angle, 1 with a neutral segmental angle, and 2 with a kyphotic segmental angle.

The C1–C2 angle was significantly changed 6 months to 1 year after the surgical procedure [Table 2]. The mean preoperative C1–C2 value was −34.6°; after surgery, the mean value was-36.3° ($P = 0.0255$). Pre- and post-operative mean values for the C2–C7 angle were −13.6 and −11.0, respectively, which translates to a minor reduction in lordosis. The mean value of the segmental angle was −2.8 before surgery and −4.8 after surgery. C7 slope also changed from a mean of −26.70 to −27.7; although, this change was insignificant ($P < 0.3143$). There was a minimal change in SVA mean values, from 2.90 preoperatively to 3.0 postoperatively.

Statistical analysis also revealed a moderate negative correlation between the C1 and C2 angle and the SVA ($r = 0.38332$) as well as a moderate negative correlation between the C1 and C2 angle and the segmental angle before surgery ($r = 0.39688$) [Table 3]. Furthermore,

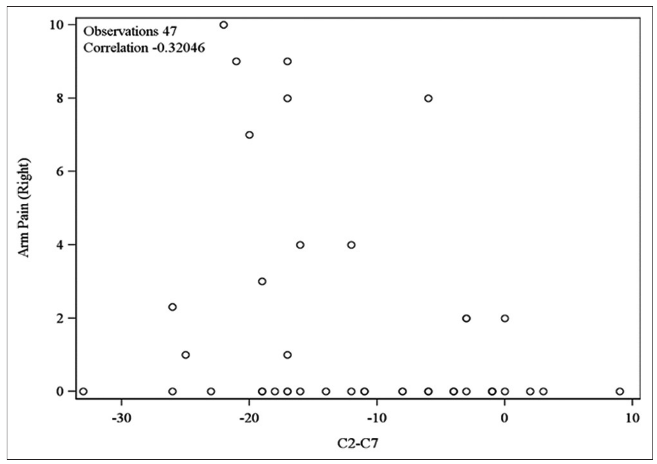

Figure 5: Scatter plot of the moderate negative correlation ($P = 0.0281$) between the presence of right arm pain and a smaller C2–C7 angle before treatment in 33 of 47 patients (14 patients did not have right arm pain, i.e., pain score of 0)

Table 1: Summary statistics of health-related quality of life scale scores

Treatment	Before and after treatment[a]					P^b
	n	Mean±SD	Median	Minimum	Maximum	
Neck pain[c]						
Before	47	6.2±2.9	7.00	0.00	10.00	<0.0001
After	47	2.8±3.1	2.00	0.00	10.00	
Arm pain (left)[c]						
Before	47	4.5±3.3	4.00	0.00	10.00	<0.0001
After	47	1.7±2.7	0.00	0.00	9.00	
Arm pain (right)[c]						
Before	47	3.9±3.3	4.00	0.00	10.00	<0.0001
After	47	1.5±2.9	0.00	0.00	10.00	
NDI (%)[d]						
Before	47	23.3±9.5	24.00	0.00	43.00	<0.0001
After	47	12.9±7.8	14.00	1.00	34.00	

[a]*n* - Number of patients; NDI - Neck disability index; SD - Standard deviation; [b]*P* values were derived from paired t test or Wilcoxon signed rank test. All *P* values in this table are statistically significant; [c]VAS: 0 - No pain; 10 - Worst pain; [d]NDI: 0-4 - No disability; 5-14 - Mild disability; 15-24 - Moderate disability; 25-34 - Severe disability; >35 - Complete disability. VAS: Visual analog scale

Table 2: Summary statistics of radiographic measures before and after treatment[a]

Variable	Treatment	*n*	Mean±SD	Median	Minimum	Maximum	*P*[b]
C1–C2 angle (°)	Before	47	−34.6±5.6	−35.00	−45.00	−24.00	0.0255[c]
	After	47	−36.3±5.4	−37.00	−51.00	−27.00	
C2–C7 angle (°)	Before	47	−13.6±8.8	−13.00	−42.00	5.00	0.1099
	After	47	−11.0±9.4	−11.00	−33.00	9.00	
SVA (mm)	Before	47	2.9±0.9	2.72	0.8	4.8	0.5563
	After	47	3.0±1.0	2.89	1.08	5.8	
Segmental angle at disk space (°)	Before	47	−2.8±4.3	−3.00	−15.00	13.00	0.2912
	After	47	−4.8±4.3	−3.00	−20.00	1.00	
C7 slope (°)	Before	47	−26.7±6.4	−26.00	−40.00	−14.00	0.3143
	After	47	−27.7±6.9	−26.00	−42.00	−14.00	

[a]*n* - Number of patients; SD - Standard deviation; SVA - Sagittal vertical axis; [b]*P* values were derived from paired *t*-test or Wilcoxon signed rank test; [c]Statistically significant

Table 3: Correlation coefficients and changes in angles before and after surgery

Angles	Before surgery			After surgery			Changes in the angles	
	SVA[(a)]	Segmental	C7 slope	SVA	Segmental	C7 slope	Segmental	C7 slope
C1–C2	−0.38332 (0.0078[b])	−0.39668 (0.0058[b])	0.01725 (0.9084)	−0.39110 (0.0066[b])	−0.08930 (0.5506)	0.29564 (0.0436)	−0.07526 (0.6151)	0.00706 (0.9625)
C2–C7	−0.15887 (0.2861)	−0.09878 (0.5089)	0.57130 (<0.0001[b])	−0.11144 (0.4558)	0.25909 (0.0787)	0.47229 (0.0008[b])	−0.13733 (0.3573)	0.52148 (0.0002[b])
SVA	1.0000	0.24687 (0.0943)	−0.21976 (0.1377)	1.0000	0.06846 (0.6475)	−0.49350 (0.0004[b])	0.25099 (0.0888)	−0.49519 (0.0004[b])

[a]SVA - Sagittal vertical axis; [b]Statistically significant relationship

the preoperative C2–C7 angle was associated with the preoperative C7 slope with a moderate positive correlation (r = 0.5713) [Table 3]. After surgery, C7 slope was associated with overall cervical lordosis (C1–C2 and C2–C7) with a moderate positive correlation ($r_{[C1-C2]}$ 0.29564, $r_{[C2-C7]}$ 0.47229) as well as with the SVA distance with a moderate negative correlation (r = 0.49350) [Table 3]. Regarding the existence of correlations between postoperative changes of the studied angles, statistical analysis showed a moderate negative correlation between C7 slope and SVA distance (r = 0.49519) and a moderate positive correlation between C7 slope and the C2–C7 angle (r = 0.52148) [Table 3].

DISCUSSION

Key results and interpretation

Cervical sagittal alignment has not been studied as extensively as alignment in conjunction with thoracolumbar deformities. There are several variations of normal cervical sagittal balance in the literature.[10] In general, the C1–C2 angle is the parameter that is most representative of cervical sagittal lordosis and is responsible for 75% of cervical sagittal balance overall.[10,29,39,40] In addition, the segmental angle has variations depending on the involved level, as Hardacker *et al*. noted in their study of asymptomatic adult volunteers.[39] Furthermore, cervical sagittal balance is influenced by age, according to the study of Gore *et al*. in asymptomatic men and women.[41]

In this study, C7 slope proved to be of great importance as a marker of cervical sagittal alignment as it was linked to C2–C7 angle measurements before and after treatment. The C7 slope was also significantly related to upper cervical lordosis (C1–C2 level) as well as the SVA after treatment. Moreover, changes in C7 slope were significantly associated with changes in both C2–C7 angle and SVA. This finding is also documented in other studies. According to Núñez-Pereira *et al*., C7 slope is a useful marker not only for occipitocervical alignment but also for overall sagittal alignment.[28]

Several studies have attempted to correlate functional outcome scores such as NDI, Short Form-36 physical component summary scores, and modified Japanese Orthopedic Association scores with postoperative cervical sagittal balance.[3,5,6,13,20-22,35,42-44] According to these studies, changes of cervical sagittal alignment subsequent to a cervical spine procedure may have a positive or a negative influence on functionality. We used the NDI and VAS pain scale for the clinical evaluation of our patients because this was a retrospective study and these were the forms that our patients routinely completed.

Investigators of recent studies of single-level ACDF did not find a significant relationship between functional outcome scores and segmental and/or cervical sagittal alignment expressed by the C2–C7 angle. Faldini *et al*. performed a prospective study regarding the efficacy of the PEEK anatomical cervical cage and allograft bone in single-level

ACDF.[45] They found that cervical lordosis increased 6 months after surgery from −15.8° to −20.9°; and at 1 year after surgery, it dropped to −18.5°. They did not find any correlation with functional outcome scores. In their comparison study regarding the effect of lordotic or parallel cage use after ACDF on functionality and cervical sagittal balance, Villavicencio *et al*. concluded that the maintenance or improvement of segmental lordosis may be linked to better functional outcome scores.[43] Another significant parameter of cervical sagittal balance is SVA, which has been associated with reduced functionality expressed by the NDI score when it exceeds 4 cm.[5]

In this study, the C1–C2 angle was significantly changed 6 months to 1 year after the surgical procedure. There was a reduction in C2–C7 lordosis 6 months to 1 year after surgery, although it was statistically insignificant. Moreover, SVA, C2–C7, and segmental angle were changed after surgery but not significantly. The increase in C1–C2 upper cervical lordosis could be explained by the existence of a negative correlation to C2–C7 lordosis, as documented in the literature.[28] Furthermore, Kim *et al*. concluded that ACDF can provoke changes in alignment of the operative level as well as indirect changes in the upper cervical sagittal alignment expressed by regional slope angles.[46] The C2–C7 cervical lordosis was reduced in our patients, although this change was not statistically significant. In addition, the segmental angle increased to more lordotic values resulting in better functional outcome scores.

With respect to functionality outcome scores in our patients, there was a correlation between the presence of right arm pain and C2–C7 lordosis before treatment. Patients with smaller overall C2–C7 lordosis had more pain in their right arm than the rest of the patients. This is an indication that restoration of overall lordosis should be one of the goals for spine surgeons to improve the functional outcome scores of their patients.

Limitations

The study has limitations. It has a retrospective design and a small number of patients.

CONCLUSIONS

In this study, we found that the ACDF procedure improved patient functionality significantly. Furthermore, upper cervical lordosis, represented by the C1–C2 angle, was affected significantly. On the contrary, lower cervical lordosis did not change significantly; although, it decreased. Furthermore, we found that C7 slope was a major marker of overall cervical alignment, as supported by other studies. Regarding functionality after the ACDF procedure, restoration of local and regional cervical lordosis has a significant impact on the neck and arm pain.

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Conflicts of interest

There are no conflicts of interest.

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