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The change of cervical sagittal alignment after surgery for adolescent idiopathic scoliosis

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ABSTRACT

Objective: The postoperative change in cervical sagittal alignment has an impact on health-related quality of life in adolescent idiopathic scoliosis (AIS) patients who have undergone deformity correction. However, the effect of deformity correction on sagittal cervical profile is still controversial in the literatures. The objective of this study was to investigate the postoperative change in the cervical sagittal alignment of patients with AIS.

Patients and methods: A total of 46 AIS patients treated by posterior instrumentation and fusion with pedicle screw constructs were included in the study. Radiographs were collected preoperatively, immediate postoperatively and at the final follow-up. The C2-C7 Cobb angle and C2-C7 sagittal vertical axis (cSVA) were used to assess the cervical sagittal alignment. Spinopelvic alignment parameters, such as thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), and sagittal vertical axis (SVA), were also measured. The correlations between the cervical sagittal parameters and spinopelvic parameters were analyzed.

Results: The incidence of cervical kyphosis was 67.4% preoperatively but increased to 87% postoperatively and 69.5% at the final follow-up. The C2-C7 Cobb angle significantly increased from pre-operation ($-1.5^\circ \pm 15^\circ$) to post-operation ($-5.4^\circ \pm 7.3^\circ$; $P < 0.05$) and spontaneously decreased to $-2.9^\circ \pm 10.5^\circ$ at the final follow up. The cSVA was 18.1 ± 13 mm preoperatively, 17 ± 12.3 mm after surgery and 18.5 ± 9.5 mm at the last follow-up, but the change was not statistically significant ($P > 0.05$). TK decreased significantly from pre-operation ($17.7^\circ \pm 14.4^\circ$) to post-operation ($14.2^\circ \pm 7.6^\circ$) and spontaneously improved to $16.9^\circ \pm 8.2^\circ$ at the final follow-up. TK showed a significant correlation with the C2-C7 Cobb angle, but not with cSVA, in the preoperative ($r = 0.709$, $P < 0.01$), postoperative ($r = 0.472$, $P < 0.01$), and last follow-up measurements ($r = 0.505$, $P < 0.01$). Compared with patients with preoperative thoracic hypokyphosis or hyperkyphosis, patients with a normal thoracic spine had more significant postoperative changes in the C2-C7 Cobb angle and TK.

Conclusions: Cervical sagittal alignment after deformity correction is altered in AIS patients. An increase in cervical kyphosis after surgery is correlated with a loss of thoracic kyphosis. The change in the cervical sagittal profile may be a compensatory mechanism in response to an abnormal thoracic sagittal profile.

1. Introduction

Scoliosis is a three-dimensional deformity of the spine that usually involves the coronal and sagittal planes [1]. Adolescent idiopathic scoliosis (AIS) is a common type of scoliosis, and the clinical symptoms of AIS are disfigurement of the torso with shoulder or waist asymmetry, trunk imbalance, or rib rotation [2]. The goals of surgical treatment for AIS are to correct the coronal deformity and restore the sagittal profile [2–4]. The use of pedicle screw constructs provides a satisfactory correction of spine deformity, especially in the coronal plane. However, the pedicle screw technique fails to restore the thoracic sagittal profile and creates a significant amount of thoracic hypokyphosis [5,6].

Flattening or kyphosis in the cervical region have been reported in AIS patients with thoracic hypokyphosis after surgery [5–7]. Postoperative changes in cervical sagittal alignment have an impact on the health-related quality of life in AIS patients who undergo deformity correction [8]. Kyphotic malalignment of the cervical spine has been associated with axial neck pain, degenerative changes in cervical disc and facet joint [9–11]. Although spinopelvic sagittal alignment has become an increasingly important consideration in AIS patients, the relevance of cervical sagittal balance is easily ignored [12–14]. In addition, the effect of deformity correction on sagittal cervical profile is still under debate in the literatures [3,6,15]. Thus, the purpose of the present study was to analyze the changes of the cervical sagittal

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Table 1
Details of preoperative, postoperative and final follow-up radiologic values.

	Pre-op	Post-op	Latest	*P* value*	*P* value†	*P* value‡
C2-C7 Cobb angle (°)	−1.5 ± 15.0	−5.4 ± 7.3	−2.9 ± 10.5	0.043	0.472	0.039
cSVA (mm)	18.1 ± 13.0	17.0 ± 12.3	18.5 ± 9.5	0.391	0.776	0.238
TK (°)	17.7 ± 14.4	14.2 ± 7.6	16.9 ± 8.2	0.026	0.635	< 0.001
LL (°)	−47.9 ± 11.3	−44.9 ± 11.0	−48.6 ± 8.6	0.070	0.682	0.005
PI (°)	43.8 ± 12.1	43.5 ± 10.7	46.3 ± 11.3	0.749	0.007	0.001
PT (°)	6.1 ± 8.1	6.0 ± 9.7	5.7 ± 8.4	0.957	0.770	0.743
SS (°)	38.5 ± 7.6	37.5 ± 7.4	40.5 ± 7.2	0.391	0.053	0.001
SVA (mm)	2.4 ± 30.2	−2.2 ± 33.1	5.7 ± 24.9	0.318	0.477	0.147

Note: *, Pre-op *vs.* Post-op; † Pre-op *vs.* Latest; ‡, Post-op *vs.* Latest; cSVA, C2-C7 sagittal vertical axis; TK, thoracic kyphosis; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis.

alignment of patients with AIS treated by posterior instrumentation and fusion with pedicle screw constructs.

2. Materials and methods

2.1. Patient population

We retrospectively analyzed the data of the AIS patients who underwent correction with posterior spinal fusion and instrumentation using pedicle screws between August 2009 and September 2015. Patients were included in the study if they met the following criteria: AIS treated with posterior spinal fusion and instrumentation, age at surgery between 10 and 20 years, and a minimum of 1 year of follow-up. We excluded patients with a diagnosis other than AIS, age over 20 years, prior spine surgery and unclear radiographs. This study was approved by the Southern Medical University Institutional Review Board.

2.2. Operative procedure

All the patients were treated by posterior instrumentation and fusion with all pedicle screw constructs. The pedicle screws were placed with the guidance of a C-arm X-ray machine (SIEMENS, Germany). A rod rotation maneuver was used for scoliosis correction in all the patients. Osteotomy procedures were performed to correct deformity in some patients with rigid scoliosis. Autogenous bone and allograft bone material were used for fusion in all cases. Neurophysiological monitoring was conducted throughout the operative procedure. All surgeries were performed by the same team.

2.3. Radiographic analysis

Radiographic measurements were taken of full-length standing anteroposterior and lateral radiographs of the spine taken before surgery, at the immediate postoperative period and at the last follow-up. The C2-C7 Cobb angle and C2-C7 sagittal vertical axis (cSVA) were considered the important parameters for evaluating cervical sagittal alignment [16]. The C2-C7 Cobb angle was defined as the angle between the lower endplate of C2 and the inferior endplate of C7. A positive value for the C2-C7 Cobb angle (≥ 0°) indicated cervical lordosis or straightness, whereas a negative value (< 0°) corresponded to cervical kyphosis [17]. cSVA was defined as the distance between the plumb line of the center of the C2 vertebrae and the posterior superior corner of the C7 vertebrae. In addition, we measured the spinopelvic alignment parameters, including thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT) and sagittal vertical axis (SVA). The definitions of these spinopelvic alignment parameters have been described in the literatures [12,15]. All radiographic measurements were independently performed by two authors, and the average of these measurements was used for analysis.

2.4. Statistical analysis

Statistical analyses were performed using SPSS for Windows, Version 22.0 (IBM Corp., Armonk, NY). The radiographic parameters from the preoperative, postoperative and the final follow-up were tested using paired t-tests. A correlational analysis was performed using Spearman's test. Binary logistic regression analysis was conducted to identify the independent risk factors for postoperative cervical kyphosis. *P* values < 0.05 were considered statistically significant.

3. Results

3.1. Demographic data and operative procedures

A total of 46 AIS patients were included in this study. There were 35 girls and 11 boys (average age 15 years, range 11–20 years). The average follow-up time was 34.5 months (range 12–72 months). According to the Lenke classification [18], 11 of the 46 patients had Lenke 1, 8 had Lenke 2, 8 had Lenke 3, 3 had Lenke 4, 11 had Lenke 5 and 5 had Lenke 6. Five of the 46 patients had undergone Ponte osteotomy, and 2 had undergone pedicle subtraction osteotomy. The mean main curve of the Cobb angle was 59.5° ± 14.7° preoperatively, 15.8° ± 8.9° immediately post-operation and 16.8° ± 9.7° at the last follow-up.

3.2. Change of cervical sagittal alignment

Cervical kyphosis was observed in 31 of the 46 (67.4%) patients before surgery, 40 patients (87%) postoperatively and 32 patients (69.5%) at the final follow up. The average preoperative C2-C7 Cobb angle of −1.5° increased to −5.4° postoperatively and −2.9° at the final follow up. The average cSVA was 18.1 mm before surgery, 17 mm post-operation and 18.5 mm at the final follow-up (Table 1).

3.3. Correlations between the cervical and spinopelvic sagittal alignment

TK was significantly decreased from pre-operation (17.7° ± 14.4°) to post-operation 14.2° ± 7.6°, and it spontaneously improved to 16.9° ± 8.2° at the latest follow up (Table 1). TK showed a significant correlation with the C2-C7 Cobb angle before surgery (r = 0.709, *P* < 0.01), immediately post-operation period (r = 0.472, *P* < 0.01) and at the latest follow up (r = 0.505, *P* < 0.01), but it was not significantly correlated with cSVA (Table 2). LL, PI and SS did not significantly change at the immediate postoperative period, but spontaneously increased at the latest follow up. PT and SVA were not significantly different after surgery (Table 1). C2-C7 Cobb angle was significant correlative with SVA at the latest follow up. cSVA showed a significant correlation with LL at the immediate postoperative period, and with SS at the latest follow up. However, PI and PT did not correlate with the C2-C7 Cobb angle or cSVA (Table 2 and Fig. 1).

Preoperatively, 30 of the 46 AIS patients had a hypokyphotic