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Cervical Spine Compensation in Adolescent Idiopathic Scoliosis

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Abstract

Study Design/Setting: Cross-sectional.
Objectives: To determine associations between cervical spine alignment and Lenke type for adolescent idiopathic scoliosis (AIS).
Summary of Background Data: Although the lumbosacral spine and pelvis are standard considerations for evaluation of AIS, few studies have examined cervical spine alignment. These studies did not consider Lenke types upon which treatment decisions are based.
Methods: Stratified random sampling from 3,654 full-length preoperative lateral films of patients in a multicenter database of surgically treated AIS was done to obtain a representative sample from all Lenke types and thoracic curve modifiers. The C2–C7 sagittal Cobb and C2–C7 sagittal vertical axis (SVA) distances were measured by reviewers unaware of the patient's Lenke classification. C2–C7 sagittal Cobb and C2-C7 SVA among curve types and thoracic modifiers was compared using analysis of variance.
Results: There were 387 females and 84 males among patients in 471 randomly selected films; mean age at surgery was 14.8 ± 2.0 years. Significantly less cervical kyphosis was seen in Lenke 3 or 4 curves and greater cervical kyphosis in Lenke 1, 2, 5, and 6 curves. No significant differences in C2–C7 SVA were seen.
Conclusions: Patients with AIS appear to compensate for abnormal thoracic sagittal alignment with changes in cervical sagittal alignment. This seems intuitive for Lenke 1 and 2 curves in which surgical restoration of thoracic kyphosis is a recognized goal and has been shown to improve cervical alignment. Cervical kyphosis was also noted in Lenke 5 and 6 curves, which suggests a need to consider compensatory thoracic and cervical sagittal alignment during surgical planning. Patients with Lenke 3 and 4 curves had more normal cervical alignment, which suggests that with the major portion of the curve located in the middle of the spine, there is more ability above and below to maintain a more normal sagittal alignment.
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Keywords: Adolescent idiopathic scoliosis; sagittal measures; Lenke type; radiograph

Introduction

Scoliosis is a 3-dimensional deformity [1-3] in which there appears to be correlation between the regional segments in the coronal and sagittal planes. For this reason, sagittal alignment of the lumbosacral spine and pelvis is a standard consideration for evaluation and surgical planning in patients with adolescent idiopathic scoliosis (AIS) [1,4-10]. Restoration of thoracic kyphosis after surgical intervention and its association with lumbar lordosis have been well-studied [11-14]. In contrast, only recently have studies examined the patterns of cervical spine alignment at baseline or in response to treatment [15-20]. Studies that have examined the cervical spine in AIS have not differentiated findings between individual Lenke curve types [21] upon which treatment decisions and reported outcomes are currently based.

Cervical kyphosis has been reported in patients who have thoracic hypokyphosis at baseline [15-18,20]. Loss of normal cervical lordosis is correlated with neck pain in degenerative and posttraumatic conditions [22-24]. Neck pain appears to be a major symptom at long-term follow-up

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after scoliosis fusion [25,26]. In addition, several studies have explored the impact surgical treatment has had on the cervical sagittal alignment [6,15-18,20]. However, no study to the authors' knowledge has explored how variations in Lenke curve type affect cervical spine alignment at baseline.

The purpose of this study was to determine the association, if any, between radiographic measures of cervical spine sagittal alignment and Lenke curve type for AIS. A better understanding of cervical spine alignment may influence selection of fusion levels, correction strategies, and counseling with regard to long-term outcome.

Methods

Patient selection

The Prospective Pediatric Scoliosis Study database (PPSS), which is maintained by the Spinal Deformity Study Group, is a multicenter database of AIS treated surgically. The PPSS has been enrolling consecutive surgical patients with AIS since March 2003 and continues to enroll new subjects and longitudinally follow-up currently enrolled subjects. Inclusion criteria are thoracic, thoracolumbar, and/or lumbar idiopathic scoliosis in patients aged 8 to 18 years at diagnosis and under age 21 years at surgery. Subjects were enrolled in the database from March 2003 to December 2009. A total of 12% of patients who met eligibility criteria were not enrolled owing to language constraints, patient refusal, or inability to follow-up. There were 18 sites with 27 surgeons participating.

The authors obtained institutional review board approval from their local institution's committee to perform a cross-sectional study of patients within the PPSS database. Patients with a high thoracic or cervicothoracic scoliosis were excluded. To obtain a representative sample from all Lenke types (1−6), subtypes (A, B, and C) and thoracic curve modifiers (1 = less than 10° kyphosis; 2 = 10° to 40° kyphosis; 3 = more than 40° kyphosis), stratified random sampling was done from 3,654 available 36-inch preoperative lateral films of patients enrolled in the database. Random numbers were assigned to each subject and the first 10 subjects from each of the 42 Lenke curve subtypes were selected and their 36-inch lateral films evaluated. This was done through 3 iterations. Because there is an unequal distribution of cases among the 42 Lenke subtypes, in some iterations no more type 4, 5, or 6 subjects were left to randomize. Thus, only 1,101 cases were randomized.

Per PSSS protocol, preoperative radiographic measures including Lenke curve type and T5−T12 kyphosis were determined by trained reviewers from digital radiographic images with specifically designed software. Radiographic measurements of the cervical spine were not collected as part of the PPSS database. Thus, the authors specifically measured the C2−C7 sagittal Cobb and C2−C7 sagittal vertical axis (SVA) distance from the randomly selected films. The C2−C7 sagittal Cobb angle was defined as the angle formed between the inferior end plates of C2 and C7. A positive value for C2−C7 Cobb corresponded to a kyphotic curve whereas a negative value corresponded to a lordotic curve. The C2−C7 SVA distance was measured as the distance between a plumbline dropped from the center of C2 and the posterior superior aspect of C7.

All films were independently reviewed by 2 authors who were unaware of the Lenke classification of the patient. Differences in C2−C7 sagittal Cobb and C2−C7 SVA among the different Lenke curve types and based on thoracic modifier were determined using analysis of variance. All analysis was performed using IBM SPSS Statistics for Windows (Version 21.0, IBM Corp., Armonk, NY). Threshold p value was set at $p < .01$ owing to multiple concurrent analyses.

Results

Of the 1,011 randomly selected patients, 471 had preoperative 36-inch lateral radiographs from which the cervical spine measures could be determined. There were 387 females and 84 males; mean age at surgery was 14.8 ± 2.0 years. Based on Lenke classification [21], there were 159 Lenke type 1, 117 Lenke type 2, 63 Lenke type 3, 40 Lenke type 4, 49 Lenke type 5, and 43 Lenke type 6 curves. For the entire cohort mean proximal thoracic Cobb angle was 23.9° ± 12.7°, mean main thoracic Cobb angle was 55.6° ± 16.3°, and mean thoracolumbar Cobb angle was 41.7° ± 13.7°.

Table 1 lists mean cervical kyphosis among the different thoracic kyphosis modifiers. Difference in cervical kyphosis was statistically significant among the 3 thoracic modifier groups, with decreasing cervical kyphosis with increasing thoracic kyphosis ($p = .000$).

Cervical kyphosis (average, +9.0°) for the entire study cohort was higher relative to normal subjects (average, −9.5°) [27] (Table 2). In addition, there was a statistically significant difference in C2−C7 sagittal Cobb and thoracic modifier (T5−12) among the different Lenke types ($p = .001$). More thoracic kyphosis and less cervical kyphosis were seen in patients with double major (Lenke 3) and triple major (Lenke 4) curves ($p = .001$). More thoracic hypokyphosis and greater cervical kyphosis were seen in patients with main thoracic, double thoracic, thoracolumbar/lumbar, and thoracolumbar/lumbar−main thoracic (Lenke 1, 2, 5, and 6). No statistically significant difference in C2−C7 SVA

Table 1
Mean C2−C7 Cobb stratified by thoracic kyphosis.

T5−T12 (degrees)	N	C2-C7 Cobb (degrees)
<10	138	14.2
10-40	215	10.3
>40	118	0.7
Total	471	9.0
p value		.000

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