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Int J Spine Surg 2018, 12 (1) 22-25

doi: <https://doi.org/10.14444/5004>

<https://www.ijssurgery.com/content/12/1/22>

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Prevalence and Factors Affecting Cervical Deformity in Adolescent Idiopathic Scoliosis Patients: A Single-Center Retrospective Radiological Study

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ABSTRACT

Background: It has been reported that adult spinal deformity patients have a high prevalence of cervical kyphosis (CK) and cervical positive sagittal malalignment (CPSM). However, the prevalence and possible factors affecting CK and CPSM in patients with adolescent idiopathic scoliosis (AIS) are less clear.

Methods: We retrospectively analyzed a consecutive series of AIS patients from a single center. Radiographic measurements included the Cobb angle, C2-C7 sagittal vertical axis (C2-C7SVA), and C2-C7 lordosis. Cervical deformity was defined as loss of lordotic or neutral cervical angle (CK) or C2-C7SVA more than 4 cm (CPSM). Patients were stratified by the degree of thoracic kyphosis and coronal thoracic curve.

Results: A total of 99 patients were included in this study. The patients' mean age was 14 years (range, 10-18 years). Mean cervical lordosis and C2-C7SVA were 1.5° and 30.4 mm, respectively. The CK and CPSM prevalence were 49% and 16%, respectively, and prevalence of CK and/or CPSM was 59%. CK was present in 32% of the patients who had >20° thoracic kyphosis, and it was present in 75% of the patients who had ≤20° thoracic kyphosis ($P = .003$). No association between CPSM and thoracic kyphosis was found. The patients who had >20° coronal thoracic curve had higher CK prevalence (64% versus 37%, $P = .05$), but no CPSM association was found.

Conclusions: Cervical deformity is highly prevalent in AIS patients. There is a significant correlation between the loss of thoracic kyphosis and the development of CK but not the development of CPSM. High coronal thoracic curve is associated with CK prevalence, but it is not associated with CPSM prevalence.

Other & Special Categories

Keywords: cervical deformity, adolescent idiopathic scoliosis, prevalence

INTRODUCTION

In humans, an optimal spinal balance helps to maintain the gravity line in an economic range that is also known as the cone of economy.¹ An adequate trunk balance in erect position also helps to align the head over the femoral heads and to sustain a horizontal visual gaze.² Adolescent idiopathic scoliosis (AIS) is recognized as a complex 3-dimensional deformation of the spine with lateral deviation in the coronal plane, alteration of the kyphosis/lordosis in the sagittal plane, and rotation of the vertebrae in the axial plane. It has been reported³ that there is a significant correlation between the loss of thoracic kyphosis and the development of cervical kyphosis (CK) in AIS patients. The development of cervical kyphosis in AIS patients may represent a compensatory measure from the thoracolumbar deformity.

The need to understand regional as well as global spinal alignment is increasingly recognized by spine

surgeons. In adult deformity patients, sagittal malalignment has been demonstrated as a significant source of pain and disability. Recently, Smith et al⁴ reported that cervical deformity (cervical kyphosis [CK] and cervical positive sagittal malalignment [CPSM]) are highly prevalent in adult patients with thoracolumbar deformity. However, the prevalence of CK and CPSM and possible factors affecting CK and CPSM in AIS patients are less clear. Our objective in this study is to assess the prevalence and possible factors affecting cervical deformity in a series of AIS patients.

MATERIALS AND METHODS

Patients

After institutional review board approval, a single center's database was retrospectively reviewed to identify all the AIS patients who were followed

Table 1. Demographics of the patients.

Patients, N	99
Mean age, y (range)	14 (10–18)
Gender, female:male	76:23
Cobb angle	
MT, mean ° (range)	36.3 (12–92)
TL/L, mean ° (range)	25.5 (6–71)

Abbreviations: MT, main thoracic; TL/L, thoracolumbar/lumbar.

between May 2010 and March 2014. Preoperative standing anterior-posterior and lateral radiographs and left and right side bending radiographs were reviewed. Coronal and sagittal curves were measured using the Cobb method. Flexibility of the thoracic and lumbar scoliotic curves was assessed from standing and bending radiographs.

Radiographic Measurements

Radiographic data collection consisted of full-length standing coronal and sagittal radiographs obtained in free-standing posture. All images were downloaded from picture archiving and communication systems (Digital Imaging and Communications in Medicine format) and analyzed using validated software (Surgimap, Nemaris, New York, New York). Measurements include coronal Cobb angle, C2-C7 sagittal vertical axis (C2-C7SVA), and C2-C7 sagittal Cobb angle (“–” values mean lordosis and “+” values mean kyphosis). Cervical deformity was defined as cervical lordosis more than 0° (CK) or C2-C7SVA equal to or more than 4 cm (CPSM). All measurements were performed by an independent researcher. Patients were stratified by the degree of thoracic kyphosis and coronal thoracic curve.

Statistical Analysis

Descriptive statistics, including means and standard deviations, were calculated for continuous variables. Nominal variables were analyzed using a χ^2 test. The Student *t* test was used for quantitative

Table 2. Prevalence of CK and CPSM.

SCA (sagittal cervical angle)	
Lordosis, n (%)	47 (47%)
Neutral, n (%)	3 (3%)
Kyphosis, n (%)	49 (49%)
C2-C7SVA	
Mean (range)	30.4 mm (4–55 mm)
<40 mm, n (%)	83 (84%)
≥40 mm, n (%)	16 (16%)

Abbreviations: CK, cervical kyphosis; CPSM, cervical positive sagittal malalignment.

Table 3. The relationship between cervical kyphosis (CK), cervical positive sagittal malalignment (CPSM), and thoracic kyphosis.

	Thoracic Kyphosis >20°	Thoracic Kyphosis ≤20°	P Value
CK	32%	75%	.003
CPSM	20%	14%	>.05

variables and the level of significance was set at $P \leq .05$.

RESULTS

A total of 99 patients were included in this study. The patients' mean age was 14 years (range, 10–18 years). There were 76 girls and 23 boys (Table 1). Forty-seven patients (47%) had cervical lordosis and their mean cervical lordosis angle was -10.1° (range, -1° to -30°). Three patients (3%) had a neutral cervical angle (0°). Forty-nine patients (49%) had cervical kyphosis and their mean cervical kyphosis angle was 12.8° (range, 1° to 50°). The patients' mean C2-C7SVA was 30.4 mm. Eighty-three patients (84%) had a C2-C7SVA less than 40 mm. Sixteen patients (16%) had a C2-C7SVA equal to or more than 40 mm (CPSM). The prevalence of CK and/or CPSM was 59% (Table 2).

CK was present in 32% of the patients who had $>20^\circ$ thoracic kyphosis; it was present in 75% of the patients who had $\leq 20^\circ$ thoracic kyphosis ($P = .003$). No association between CPSM and thoracic kyphosis was found (20% versus 14%, $P > .05$; Table 3).

CK was present in 64% of the patients who had $>20^\circ$ coronal thoracic curve, and it was present in 37% of the patients who had $<20^\circ$ or no coronal thoracic curve ($P = .05$). Meanwhile, no association between CPSM and coronal thoracic curve was found (19% versus 13%, $P > .05$; Table 4).

DISCUSSION

Normal cervical lordosis is reported to be between -6.6° and -22.2° in typically developed adults.⁵ The range of cervical lordosis in typically developing adolescents has not been reported, but it has been found that there is a trend of increasing cervical lordosis with age.⁶ In 1995, Hilibrand et al³

Table 4. The relationship between cervical kyphosis (CK), cervical positive sagittal malalignment (CPSM), and coronal thoracic curve.

	Coronal Thoracic Curve >20°	Coronal Thoracic Curve ≤20°	P Value
CK	64%	37%	.05
CPSM	19%	13%	>.05

studied the sagittal alignment of the cervical spine in 38 AIS patients and found that 89% of them had a straightened or kyphotic cervical spine alignment. They also noticed that there was a significant correlation between the loss of thoracic kyphosis and the development of cervical kyphosis for the entire group. Subsequently, Canavese et al.⁷ confirmed the high incidence of reduced cervical lordosis in AIS patients, with 34.4% of their patients having an average cervical kyphosis of 11°. In the current study we found that 49% of our patients had CK, which is consistent with these previous reports. We also found that the incidence of CK is significantly higher in those patients whose thoracic kyphosis curves are less than 20°. This is also consistent with the previous finding by Hilibrand et al.³

Other than the sagittal cervical angle, another cervical radiographic parameter that has been reported is C2-C7 sagittal vertical alignment (C2-C7SVA). Tang et al.⁸ found that in adults, there is a significant correlation between C2-C7SVA and neck disability index scores, with a threshold C2-C7SVA value of approximately 40 mm. Smith et al.⁴ studied the prevalence of cervical deformity in 470 adults with thoracolumbar deformity and found that CPSM was present in 29% of the patients. The threshold value for abnormal C2-C7SVA in adolescents has not been reported. Park et al.⁶ assessed the effect of age on cervical sagittal alignment in 100 asymptomatic participants and found that C2-C7SVA does not differ significantly on the basis of age. Thus, in this study we choose to define CPSM in these AIS patients as C2-C7SVA equal to or more than 4 cm. In this series, 16% of the patients were found to have CPSM. The lower prevalence of CPSM and higher prevalence of CK in young patients with such a deformity may be due to the fact that they have more flexible spines that are able to better compensate the thoracolumbar deformity.⁴ Meanwhile, we found that unlike CK, there is no association between CPSM and thoracic kyphosis. Together, our data may imply that the compensatory maneuver for loss of thoracic kyphosis is loss of cervical lordosis in an effort to maintain a neutral and balanced sagittal vertical axis.

We further studied the relationship between CK and/or CPSM prevalence and the patients' coronal thoracic curves. We found that the patients who had >20° coronal thoracic curve had higher CK

prevalence but no CPSM association was found. It has been reported⁴ that adult scoliosis patients, especially those who have thoracic scoliosis, have a high prevalence of CK. Although these cervical deformities are not necessarily symptomatic in AIS patients, our findings do suggest that a cervical deformity evaluation should be included in the assessment of thoracolumbar deformity. However, further studies will be needed to define the clinical significance of the high prevalence of cervical deformity in these young patients.

There are also limitations in our study. We did not collect the data regarding the patients' symptoms in this series, and it is not clear if there is a relationship between cervical deformity and the patients' clinical symptoms.

In conclusion, our study shows that cervical deformity is highly prevalent in AIS patients. There is a significant correlation between the loss of thoracic kyphosis and the development of CK but not the development of CPSM. A high coronal thoracic curve is associated with CK prevalence, but it is not associated with CPSM prevalence. Our finding suggests that adolescents have more ability to compensate and maintain a neutral sagittal vertical axis compared with adults. Further study is needed to define the potential clinical significance of cervical deformity in AIS patients.

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Disclosures and COI: The authors declare that there is no direct conflict of interest associated with this manuscript. No funds were received in support of this work.

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Published 30 March 2018

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