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Vertebral Axial Asymmetry in Adolescent Idiopathic Scoliosis

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Abstract

Study Design: Retrospective study.
Objectives: To investigate parameters of axial vertebral deformation in patients with scoliosis compared to a control group, and to determine whether these parameters correlated with the severity of spine curvature, measured as the Cobb angle.
Summary of Background Data: Adolescent idiopathic scoliosis (AIS) is the most common type of spinal deformity. Many studies have investigated vertebral deformation, in terms of wedging and pedicle deformations, but few studies have investigated actual structural changes within vertebrae.
Methods: This study included 20 patients with AIS (Lenke 1−3, mean age: 15.6 years, range: 11−20). We compared preoperative low-dose computed tomography (CT) examinations of patients with AIS to those of a control group matched for age and sex. The control individuals had no spinal deformity, but they were admitted to the emergency department for trauma CTs. We measured the Cobb angles and the axial vertebral rotation (AVR), axial vertebral body asymmetry (AVBA), and frontal vertebral body rotation (FVBR) for the superior end, inferior end, and apical vertebrae, with in-house−developed software. Correlations between entities were investigated with the Pearson correlation test.
Results: The average Cobb angles were 49.3° and 1.3° for the scoliotic and control groups, respectively. The patient and control groups showed significant differences in the AVRs of all three vertebra levels ($p < .01$), the AVBAs of the superior end and apical vertebrae ($p < .008$), and the FVBR of the apical vertebra ($p = .011$). Correlations were only found between the AVBA and FVBR in the superior end vertebra ($r = 0.728$, $p < .001$) and in the apical vertebra ($r = 0.713$, $p < .001$).
Conclusions: Compared with controls, patients with scoliosis showed clear morphologic differences in the midaxial plane vertebrae. Differences in AVR, AVBA, and FVBR were most pronounced at the apical vertebra. The FVBR provided valuable additional information about the internal rotation and deformation of vertebrae.
Level of Evidence: Level III.

Keywords: Scoliosis; Morphology; Three-dimensional; Vertebral rotation; Low-dose CT

Introduction

Scoliosis is a three-dimensional (3D) structural deformity that affects the spine on both regional and local levels. The induced deformity is regional, in the sense that a group of vertebrae are affected, forming a scoliotic curvature. This deformity is typically described with a single measure, for example, the Cobb angle [1]. On the other hand, the deformation is local, because each vertebra is individually deformed; for example, sagittal or coronal wedging can occur in each vertebra.

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In idiopathic scoliosis, the most common form, great interest has focused on the development of models that better describe the relationship between regional spine deformations and more local deformations in each vertebra. One objective of this avenue of research is to gain a better understanding of the etiology and processes that contribute to the evolution of scoliotic deformities; this knowledge is currently lacking, to a large extent [2,3]. Another objective is to devise quantitative measures that can assess the degree of spinal deformity better than those currently available in clinical practice. It is well known that the most commonly used measure of scoliosis, the Cobb angle, has limited relevance for a full description of the degree of spinal deformity that occurs during scoliosis [4]. A third objective is to provide better guidance for surgeons in preoperative planning for patients with scoliosis that require corrective surgery.

In recent years, increasing interest has focused on a local measure, known as the axial vertebral rotation (AVR) [5-7]. Previously, the AVR was assessed with conventional 2D radiography [8,9]. However, results from those methods were of limited relevance, because of their inability to provide an accurate measure of the AVR. As a consequence, methods were developed to measure AVR based on 3D image data obtained from computed tomography (CT) [10] or magnetic resonance imaging (MRI) [11]. Interest in assessing the AVR has spurred the development of various computerized methods [12-15] to calculate the AVR, more or less automatically.

Another approach for assessing scoliotic curvature, which is not limited to the AVR measurement, is based on stereo-radiography and reconstruction techniques for 3D modeling of vertebrae. Brown et al. [16] introduced this approach, and recent work has been mostly related to the EOS system [17-20].

Most research has focused either on rotational parameters of the vertebral body as a whole (regardless of plane), or on deformities (asymmetries), described by wedging in the coronal and/or sagittal plane [21-25]. To our knowledge, no published study exists that attempts to describe and investigate the local deformation (asymmetry and rotation) of the vertebral body in the axial plane.

In the present study, we aimed to describe the deformation of the vertebral body in its local axial plane. Specifically, we attempted to quantify the asymmetry and determine whether the asymmetry forms an internal rotational pattern in this plane. Furthermore, we explored linear relationships between the parameters that describe vertebral body asymmetry and the magnitude of scoliotic curvature, given by the Cobb angle. Thus, the primary aim of this study was to investigate changes in morphologic parameters in scoliotic vertebrae compared to nonscoliotic vertebrae. The secondary aim was to investigate correlations between these parameters and the Cobb angle.

Materials and Methods

Included patients

This study had a retrospective design. Thus, included patients were not subject to any radiologic investigations, other than those routinely performed preoperatively in our department. The inclusion criteria were patients with late-onset idiopathic scoliosis, which were scheduled to receive corrective surgery. We included 20 patients with right thoracic curves. As part of the preoperative planning, all had undergone low-dose CT. Patients who had previously undergone spinal surgery were excluded. We included an age- and sex-matched control group of 20 patients with no known prior or obvious spine ailments. This group had undergone a trauma CT after admission to the emergency department. Baseline characteristics of the included patients and control subjects are shown in Table 1. This study was approved by the regional ethics committee in Linköping, Sweden (registration number 2012/366-31 and 2013/287-32).

CT equipment and protocol

Patients with scoliosis were examined with a 2×128-slice, dual-source, multidetector CT (MDCT) in one of two configurations: either the SOMATOM Definition Flash or the SOMATOM Definition Flash with Stellar detectors (Siemens Medical Solutions, Forchheim, Germany). Controls were examined with either a 16-slice MDCT (GE LightSpeed; GE Medical Systems, Milwaukee, WI) or a 128-slice MDCT (SOMATOM Definition Edge; Siemens Medical Solutions, Forchheim, Germany).

Measurements

The Cobb angle was measured in Sectra IDS 7 PACS 15.2 (Sectra AB, Linkoping, Sweden) with the coronal scout images (acquired in the supine position) from each examination. In the control group, the Cobb angle was measured at vertebral levels that corresponded to those used in the patients with scoliosis. The Cobb angle is usually measured between the endplates of the end vertebrae from standing examinations. However, because all other parameters were measured from the supine low-dose CT, we used this for measuring the Cobb angle as well, so the measurements would be comparable.

Local deformity measurements were performed with in-house-developed software, based on MeVisLab 2.5 (MeVis Medical Solutions, Bremen, Germany) and MATLAB R2013b (The Mathworks Inc., Natick, MA). With

Table 1
Baseline group characteristics and classifications according to Lenke.

Characteristic	Patients	Controls
Total number	20	20
Females	15 (75%)	15 (75%)
Males	5 (25%)	5 (25%)
Age, years	15.6 (11−20)	15.7 (11−21)
Lenke 1	10 (50%)	
Lenke 2	7 (35%)	
Lenke 3	3 (15%)	

Values represent the number of patients (%) or the mean (range).