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The Spinopelvic Geometry in Different Lenke Curve Types of Adolescent Idiopathic Scoliosis

M. Farshad, MD, MPH, S. Catanzaro, S.L. Schmid, MD*

Department of Orthopaedics, Balgrist University Hospital, Forchstrasse 340, 8008 Zürich, Switzerland

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Abstract

Background: The Lenke classification is well established in differentiation of curve types in adolescent idiopathic scoliosis (AIS) and guides selection of fusion levels. However, to date, it has neglected the spinopelvic parameters that have been associated with compensatory mechanisms in balancing the human erect posture and adjacent segment problems after spinal fusion. The aim of this study was to investigate spinopelvic parameters in different types of AIS curves.

Material and Methods: Preoperative whole-spine radiographs from 100 patients with AIS were reviewed and the curves were classified according to Lenke. In addition, sagittal spinopelvic parameters (pelvic incidence, sacral slope, pelvic tilt) were measured and compared between different curve types and to normal population values.

Results: The spinopelvic balance was not statistically distinguishable in different Lenke curve types. Slight differences of the spinopelvic balance, compared with normal population values, were found in AIS Lenke Type 5 and 6 curves (major curve at the lumbar/thoracolumbar region) with a pelvic incidence of 44° ± 8° (norm 49°), sacral slope of 34° ± 7° (norm 41°), and pelvic tilt of 10° ± 7° (norm 8°).

Conclusion: Overall, the variances of spinopelvic parameters in different AIS curve types do not seem statistically large enough for a potential clinical relevance. However, the sacrum is more verticalized in AIS curves with major curves located in the lumbar/thoracolumbar region. It remains to be investigated whether such a verticalized sacrum might be a compensatory mechanism to keep the whole spine balanced and if it reverses with correction of the scoliosis.

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Keywords: Spinopelvic parameters; Lenke classification; Adolescent idiopathic scoliosis

Introduction

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional deformity of the spine with an incidence of 1%–3% and an etiology that is not well yet understood [1-5]. Treatment includes bracing in early stages and surgical correction in advanced stages [6,7]. Surgical techniques for correction of the AIS have evolved over the years, and several classifications have been proposed to better understand and capture different curve types in AIS. The selection of the fusion level has been a subject of controversy. Several techniques for selection of the fusion levels have been suggested, but the superiority of one or the other method has not been established [8-10]. In 1983 Howard King [11] presented a classification system for AIS; curves were divided into five types and guidelines and recommendations as to which levels should be instrumented were given. In 2001, Lawrence Lenke [12] introduced a new classification for AIS with the aim to account for all types of curves, even those not appreciated by the King classification. Meanwhile, the Lenke classification has become a well-established method to classify the different curve types in AIS and guides selection of fusion levels [13]. The Lenke classification accomplished valuable consideration of the coronal deformity as well as some sagittal aspects of scoliosis; however, to date, it has neglected the sagittal spinopelvic parameters. Whether these parameters differ between different curve types, and what their consequences would be in AIS, is not clear.

The concept of spinopelvic balance originated to understand the adoption of an upright position by humans

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*Corresponding author. Balgrist University Hospital, Forchstrasse 340, 8008 Zürich, Switzerland. Tel.: +41 44 386 1111; fax: +41 44 386 1109.

E-mail address: Samuel.Schmid@balgrist.ch (S.L. Schmid).

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that resulted in a broadening and verticalization of the sacrum. The importance of the more vertical position of the sacrum in the pelvis was found and described first as the "pelvisacral angle" by During in 1985 [14]. Some years later, Duval-Beaupère [15] coined the term *pelvic incidence* (PI), a parameter that is closely related to the lumbar lordosis in normal adults. Several other authors have since investigated the spinopelvic balance in normal children and adolescents during growth and the spinopelvic organization and adaptation in different pathologies [16-21]. The spinopelvic balance has further gained increasing attention in regard to adjacent segment pathologies after spinal fusions [22] and disc hydration after AIS surgery [23,24]. The objective of this study was therefore to investigate if different AIS types, as classified by Lenke et al. [12], differ in their sagittal spinopelvic parameters.

Materials and Methods

After ethics committee approval, 100 of 111 (90%) patients with AIS who underwent surgical correction in 2008–2013 at our institution and whose preoperative standing posteroanterior (PA) and lateral (LAT) spine radiographs (EOS Imaging, Paris, France; or Ysio, Siemens Healthcare, Erlangen, Germany [25-27]) and supine bending spine radiographs (3) were available, and both femoral heads on the LAT radiographs were visible, were included. Eleven (10%) patients were not included in the analyses because of the lack of one or more full-spine radiologic examinations. There were 82 female and 18 male patients, with a mean age of 16.4 ± 4.2 years.

Cobb angles and the C7 plumb line in the PA and LAT view as well as Cobb angles at the supine bending radiographs were measured by the same reader, and curves were classified according to Lenke curves Type 1 to 6 combined with lumbar spine modifier (A, B, C) and sagittal thoracic modifier (−, N, +). The measurements have been performed as described by Lenke [12]. A Type 1 curve is a main thoracic curve. Type 2 curves are double thoracic curves with a major main thoracic curve and a structural proximal thoracic curve. Type 3 curves are double major curves with a major main thoracic curve and a structural thoracolumbar or lumbar curve. Type 4 curves are triple major curves with proximal thoracic, main thoracic, and thoracolumbar or lumbar structural curves. Type 5 curves are thoracolumbar or lumbar major curves. Type 6 curves are major thoracolumbar or lumbar and structural main thoracic curves [12].

The sagittal spinopelvic geometry was quantified as described in previous studies [28] and included pelvic incidence (PI), which equals the sum of the sacral slope (SS) and the pelvic tilt (PT); thoracic kyphosis (TK) and lumbar lordosis (LL), which correspond to the angles contained by the arcs of circle used to model the thoracic and lumbar segments, respectively; and the thoracic tilt (TT) and the lumbar tilt (LT), which were defined as positive with respect to a vertical line when the segment is tilted forward and negative when tilted backward. The coronal plumb line was measured from the middle of C7 down to the sacrum, and the distance to the midline was measured. The sagittal plumb line was measured from C7 down to the sacrum, and the distance to the posterior edge of the sacrum was measured. Negative values were noted when the sagittal plumb line was behind the sacrum. Normal population values of sagittal spinopelvic parameters, derived from Mac-Thiong and colleagues' study of sagittal spinopelvic balance in normal children and adolescents [16], were used for comparison.

The six different Lenke curve types were compared regarding their corresponding spinopelvic geometry. Additionally, patients with a major lumbar curve (and the apex of the curve at L1/2 or below) were compared to patients with a major thoracic curve.

Statistical Analyses

Descriptive statistics were used to report mean, standard deviation (SD), and range of data, where adequate. A two-sided unpaired Student *t* test or Mann-Whitney test was used for intergroup comparison depending on expected distribution of the data. Correlation analysis was performed with Pearson correlation tests. A p value of $<.05$ was considered statistically significant.

Results

Lenke Type 1 curves were present in 38 cases (38%), Lenke Type 2 in 17 cases (17%), Lenke Type 3 in 5 cases (5%), a triple major curve (Lenke Type 4) in 4 cases (4%), Lenke Type 5 in 29 cases (29%), and finally, Lenke Type 6 were found in 7 cases (7%). The structural curvature had a right-sided apex in 68 of 100 cases (68%). The detailed results describing the coronal plan are listed in Table 1.

The measured parameters of the spinopelvic geometry parameters of all subjects were as follows: PI was 50° ± 12° (norm 49°), PT 12° ± 7° (norm 8°), and the SS 38° ± 10° (norm 41°). The TK measured 26° ± 13° and the LL 50° ± 12° (norm 48°). The TT was −5° ± 7° and the LT 1° ± 9° (Table 2). The coronal plumb line of all subjects was 18 ± 11 mm beside the midline. In right-sided main curves (n = 68), the plumb line was on the right side of the midline in 37 (54%) cases. Twenty-two (32%) showed a plumb line on the left side, and 7 (10%) were balanced. In left-sided main curves (n = 32), the plumb line was on the left side in 29 (91%) subjects. Two (6%) showed a plumb line on the right side, and one case (3%) was balanced. The lateral plumb line was overall 22 ± 16 mm around the posterior edge of the sacrum.

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