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Sagittal Alignment After Surgical Treatment of Adolescent Idiopathic Scoliosis—Application of the Roussouly Classification

Søren Ohrt-Nissen, MD[a,*], Tanvir Bari, MD[a], Benny Dahl, MD, DMSc[b], Martin Gehrchen, MD, PhD[a]

[a]*Department of Orthopedic Surgery, Spine Unit, University Hospital of Copenhagen, Blegdamsvej 9, 2100 København, Denmark*
[b]*Department of Orthopedics and Scoliosis Surgery, Texas Children's Hospital, 6621 Fannin St, Houston, TX 77030, USA*

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Abstract

Study Design: Retrospective cohort study.
Objectives: To investigate spinopelvic alignment and spine shape in patients surgically treated for adolescent idiopathic scoliosis (AIS) and to assess the distribution and clinical applicability of the Roussouly classification.
Summary of Background Data: How spinopelvic alignment is affected in AIS patients is not well established. Roussouly et al. proposed a classification based on the sagittal spinal profile and spinopelvic alignment that may have clinical utility in these patients.
Methods: A consecutive cohort of 134 surgically treated AIS patients were included. Whole-spine standing lateral radiographs were analyzed preoperatively, one-week postoperatively and at two-year follow-up. Patients were categorized using the modified Roussouly classification and analyzed for sagittal alignment.
Results: Postoperatively, global thoracic kyphosis (TK) decreased by 2.6° and lumbar lordosis (LL) decreased by 6.2°($p \leqslant .012$) while Pelvic tilt (PT) increased 1.4° ($p = .024$). At two-year follow-up, TK and LL had returned to preoperative values ($p \geqslant .346$) while PT had decreased from preoperative 9.7 ± 7.6° to 7.0 ± 7.5° ($p > .001$). Proximal junctional angle increased from 8.4 ± 5.0° preoperatively to 12.8 ± 8.9 ($p < .001$). Preoperatively, Roussouly curve types were distributed equally apart from a lower rate of type 1 (12%). At final follow-up, 30% were categorised as type 3 with pelvic anteversion which is considerably higher than the normal adolescent population. Only three patients were type 1 at the final follow-up. Overall, we found a high rate of proximal junctional kyphosis (16%), PI-LL mismatch (60%) and pelvic anteversion (38%). In preoperative type 1 patients, the rate was 50%, 82% and 64%, respectively.
Conclusion: We found that immediate postoperative changes in lordosis and kyphosis were reversed at final follow-up and found evidence of proximal junctional kyphosation and pelvic anteversion as the main compensatory mechanisms. Poor sagittal alignment was frequent in type 1 curves, and surgical treatment may need to be individualized according to the sagittal profile.
Level of Evidence: III

Keywords: Roussouly; Classification; Adolescent idiopathic scoliosis; Posterior fusion; Sagittal alignment; Thoracic kyphosis

Introduction

The overall objective of corrective surgery for spinal deformity is to achieve a balanced spine requiring a minimal amount of energy expenditure [1]. Recent studies have suggested spinopelvic alignment to be a key factor in achieving optimal balance [2-5]. Spinopelvic alignment can be described as the interaction between the moving segments of the spine and the pelvis that modifies the body's center of gravity in relation to the hip joints. Sagittal sacropelvic alignment can be assessed by the pelvic tilt (PT) and the sacral slope (SS), which represent compensatory mechanisms of the pelvis in response to malalignment.

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*Corresponding author. Department of Orthopedic Surgery, Rigshospitalet, Blegdamsvej 9, 2100 Copenhagen East, Denmark. Tel.: +45 2991 5812; fax: +45 3545 2165.

E-mail address: ohrtnissen@gmail.com (S. Ohrt-Nissen).

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Pelvic incidence (PI) is a morphologic parameter, which is constant in the skeletally mature patient irrespective of positioning of the patient or surgical intervention. The three variables are interrelated by the formula PI = PT + SS [6].

The implications of spinopelvic alignment have been extensively studied in the adult population particularly in the setting of spondylolisthesis, degenerative back pain and deformity [6-9]. Although, less is known about the distribution of these parameters in adolescent idiopathic scoliosis (AIS). Skalli et al. [10] demonstrated in 30 patients that the pelvis plays a central role in compensation after surgery for AIS. However, patients were treated with a heterogeneous use of thoracoplasty and anterior releases limiting the external validity of their findings in patients undergoing only posterior fusion. Studies on adults has shown that sagittal malalignment typically presents as an exaggeration or deficiency of normal lordosis or kyphosis [11]. Compensatory mechanisms will attempt to maintain sagittal balance through the most energy-efficient way, and as such, a sagittal plane malalignment may be compensated by pelvic rotation or modulation of the sagittal profile of the spine [12]. Modern instrumentation strategy for AIS involves pedicle screw instrumentation, which is a powerful method of deformity correction. However, the high level of fixation between bone and construct will affect the alignment of the spine and potentially remove key compensatory mechanisms [13,14]. Furthermore, pedicle screw instrumentation has been consistently associated with a relative postoperative hypokyphosis [15,16] but the effects on spinopelvic alignment, however, is not yet clear. The spinopelvic compensatory mechanisms seen in AIS patients are poorly understood and may be key to understanding the long-term outcome in these patients. Roussouly et al. described a classification system based on the sagittal profile of the normal spine and the spinopelvic alignment [17,18]. This classification is well described in the healthy population but has not previously been described in a surgical cohort of AIS patients.

Objective

To investigate pre- and postoperative spinopelvic alignment in patients surgically treated for AIS. Furthermore, we aimed to assess the distribution of the Roussouly classification and determine whether certain curve types pose a higher risk of postoperative malalignment.

Materials and Methods

We performed a retrospective study on a consecutive single-center cohort of AIS patients surgically treated between May 2011 and May 2015. A subset of the population has previously been described [19]. The study was approved by the Danish Data Protection Agency and the Danish Patient Safety Authority. All patients were treated with one-stage posterior all-pedicle screw instrumentation without adjuvant anterior release. The surgical correction involved facetectomies on all fusion levels, and segmental uniplanar low-profile pedicle screws were used for fixation. Differential rod contouring with rod derotation was performed in a standardized fashion and direct vertebral rotation was applied when deemed necessary. Ponte osteotomies at the apex were not used routinely except in very stiff curves as verified intraoperatively.

Radiographic analysis

Whole-spine standing anteroposterior and lateral radiographs were analyzed with KEOPS analyzer (SMAIO) preoperatively, one-week postoperatively, and at two-year follow-up. On the anteroposterior radiograph, we measured the Cobb angle of the main curve and noted the Risser grade of the iliac crest. On the lateral x-rays, the following parameters were analyzed based on previous reports [6,11,17] (Fig. 1): fixed thoracic kyphosis (TK) (T5−T12), global TK, fixed lumbar lordosis (LL) (L1−S1), global LL, lumbar tilt, thoracic tilt, sagittal vertical axis (SVA), proximal thoracic alignment (T2−T5), proximal junctional (PJ) angle, PI, SS, PT, and spinosacral angle. Negative values of SVA, thoracic and lumbar tilt indicate a cranial posterior tilt. If the femoral heads were not adequately visualized on the lateral radiograph, we calculated the PT using the PI from a later radiograph using the formula PI = PT + SS. As PI remain constant in skeletally mature patients [20], we deemed this as a reasonable approach rather than excluding the patient and thereby lowering the statistical power of the study.

Patients were categorized using the recently published modified Roussouly classification [18], which is based on the SS, the number of vertebrae in the global LL, and the PI or PT as follows [17,18]:

Type 1: SS $\leqslant 35^\circ$ and less than four vertebrae included in the global LL

Type 2: SS $\leqslant 35^\circ$ and more than three vertebrae included in the global LL

Type 3: $35^\circ < SS < 45^\circ$

Type 3 anteverted (Type 3 AP): Type 3 with PI $<50^\circ$ or $PT < 5^\circ$

Type 4: SS $\geqslant 45^\circ$

To assess the clinical utility of this categorization, the groups were analyzed for indicators of poor postoperative sagittal alignment: Proximal junctional kyphosis (PJK) was defined as a PJ angle of more than 10° at final follow-up and 10° larger than the preoperative value [13,21]. PI-LL mismatch was defined as a difference between PI and fixed LL (PI-LL) of more than 10° [22,23]. Pelvic orientation was categorized based on the PT in relation to the PI as suggested by Mac-Thiong and Roussouly [5,24]: Pelvic anteversion was defined as PT $<20\%$ of PI/2 and retroversion was defined as PT $>80\%$ of PI/2.

Statistical analysis

All statistical analyses were performed using R version 3.4.0 (R Core Team). Data are reported as proportions (%),