RESEARCH ARTICLE

# Assessment of Coronal Radiographic Parameters of the Spine in the Treatment of Adolescent Idiopathic Scoliosis

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## Abstract

**Background:** To determine the most important preoperative factors that affect postoperative coronal parameters of scoliotic curves.

**Methods:** All Adolescent Idiopathic Scoliosis (AIS) patients included in the study were classified according to Lenke and King Classification. The fusion levels were selected according to the rigidity of the existing curves (correction less than 50%), tilt of T1 and shoulders, sagittal angle of the curves and with considering stable and neutral end vertebra. The radiographic coronal parameters: shoulders tilt angle, iliolumbar angle and coronal balance were measured in all patients before, after, and in the last follow- up visit.

**Results:** One hundred twenty patients after mean of 25 months follow-up (18-40 months) were included in the study. Before operation, abnormal coronal balance (more than 2 cm shift) was noticed in 46 patents (38%) and in the last visit, was noted in 22 patients (18%). Multivariate regression analysis revealed a significant predictive value of the preoperative coronal balance on the last visit coronal balance (P value=0.01).

**Conclusion:** Preoperative coronal balance is very important to make a balanced spine after surgery. Other parameters like Lenke classification or main thoracic overcorrection did not affect postoperative coronal decompensation.

**Keywords:** Adolescent idiopathic scoliosis, Deformity, Spine, Trunk balance

## Introduction

Postoperative standing posteroanterior spine radiographs in some patients demonstrate C7 or T1 lateral deviation from the vertical line bisecting the sacrum (central sacral line [CSL]). Decompensation or spinal imbalance is a possible complication in the management of idiopathic scoliosis when selective fusion of the thoracic or thoracolumbar/lumbar curve is performed or it may be related to other preoperative or operative factors if nonselective fusion is performed (1, 2).

The Scoliosis Research Society (SRS) defines "compensation" as the vertical alignment of the midpoint of C7 with the midpoint of the sacrum in the coronal plane (coronal balance [CB]) (3). This definition aptly describes the head position over the pelvis. For the SRS, decompensation occurs when this alignment strays away from the midline higher than an investigator's specified threshold value, usually reported as more than 2 centimeters. In addition to CB, other aesthetic coronal parameters like shoulders and pelvic obliquity should be considered in the definition, because aesthetically, for example the shoulders tilt is as important as CB (3).

This study was undertaken to evaluate other factors rather than Lenke or King classification on producing postoperative truncal imbalance.

## Materials and Methods

One hundred-twenty consecutive patients with adolescent idiopathic scoliosis who had indication for posterior spinal instrumented fusion (PSIF) were operated in Robert Debre Hospital, Paris, France and Taleghani Hospital, Tehran, Iran between 2010 and 2015. Indications for surgery included thoracic curve of 45° or more, lumbar or thoracolumbar curve of 40° or more in an immature patient, highly progressive curves, and failure of bracing treatment program.

For selecting upper and lowest instrumented vertebrae (UIV and LIV), Lenke or King classifications were taken.

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All coronal curves were measured. Usually three coronal curves could be found. The most severe curves were considered as the main curves. Then UIV and LIV were determined as follow:

1. Use of the side-bending radiographs to differentiate structural from compensatory curves, as the compensatory curves are more flexible.
2. Lower fusion level at a level that was centered over the sacrum, to create a stable base as described by Harrington (4).
3. Upper fusion level at T2, when T1 was tilted into the upper curve and the shoulder was elevated on the convex side of the upper curve.

Complete radiographic follow-up for all patients consisted of preoperative, one month postoperative, and the last visit follow-up, were taken. SpineView V1.0.0.1 software (Surgiview, Paris, France) was used by a single observer to assess the coronal parameters of the spine.

The following radiographic computerized parameters were obtained pre and postoperatively:

1. Cobb coronal angles of all coronal curves.
2. Coronal balance (CB).
3. Shoulders and pelvic coronal tilt angle.
4. Iliolumbar angle (IL), measured between the upper endplate of the L4 and a horizontal reference line.
5. T1 tilt angle measured between the upper endplate of the T1 and a horizontal reference line.

The data were analyzed using the SPSS (version 23.0, Chicago, IL). P values were based on the student t test and ANOVA for continuous and non-continuous variables. P values for categorical variables were generated using Fisher exact test. A *P* value of <0.05 was considered as significant.

## Results

There were 86 (72%) female and 34 (28%) male patients. The average age at the time of surgery was 15.5 years (range: 11.2–23.4 years). The average number of fused vertebrae was 11.9 (range: 5–16). The mean follow-up period was 28 months (24-40months) According to the AIS classification by the Lenke et al the number of patients were: 54 for Type 1 (main thoracic (MT), 45%), 35 for Type 2 (double thoracic, 29%), 11 for Type 3 (double major, 9%), 4 for Type 4 (triple major, 3.5%), 12 for Type 5 (thoracolumbar/lumbar (TL/L) major, 10%), and 4 for Type 6 (major thoracolumbar/lumbar and minor thoracic structural, 3.5%) (5). Forty-eight patients had a lumbar modifier A, 30 had a lumbar modifier B, and 42 had a lumbar modifier C. A total of 80 patients had a normal thoracic kyphosis sagittal modifier, twelve patients had a thoracic hyperkyphosis sagittal modifier (T5–T12>40°), twenty-eight patients had a thoracic hypokyphosis sagittal modifier (T5–T12 <10°). According to the AIS classification by King et al the number of patients were: 4 for Type 1 (3.4%), 46 for Type 2 (38.6%), 22 for Type 3 (18%), 22 for Type 4 (18%), 14 for Type 5 (12%), and 12(10%) were unclassified according to King classification (lumbar or thoracolumbar curves) (6). Hybrid instrumentation was used which consisted of proximal hooks, distal pedicle screws in 74 and proximal Universal Clamps and distal pedicle screws in 46 patients.

The pre- and postoperative and the last visit frontal Cobb's angles, T1, shoulders and pelvic horizontal tilt angle as well as the iliolumbar angle are given in Table 1.

The mean value of CB was increased after operation; however, the value was diminished significantly in the last follow-up examination [Table 1]. PA spine radiography was performed after PF and instrumentation and before decortication, and a correcting maneuver with distraction or compression between screws at the lower instrumented curve was performed to balance the vertebral column in case of any coronal imbalance. A Thoracic-Lumbo-Sacral Orthosis (TLSO) was prescribed for 3 months if postoperative abnormal coronal balance was noticed. The mean pre and postoperative CB were 19.38 mm and 30.91 mm, respectively, while the final follow-up CB value was 15.08 mm [Figure 1]. Abnormal coronal balance (more than 2 cm shift) before operation and thereafter at the last visit were noticed in 46 (38%) and 22 patients (18%), respectively. Multivariate regression analysis revealed a significant predictive value of the preoperative coronal balance on the last visit coronal balance (*P*=0.01). More correction of the thoracic structural curve to lumbar structural or compensatory curve could normalize the last visit coronal balance (r =-0.35, *P* = 0.03).

The ANOVA test did not show any significant difference between the CB correction at the last visit and various type of scoliosis (Lenke or King classification or various

**Table 1. pre , post and last visit values of the coronal parameters(with Student t test values)**

| | Preoperative values | Postoperative values | Last visit values | Comparison between pre-OP & post-OP | Comparison between pre-OP & last visit | Comparison between Post-OP & last visit |
|---|---|---|---|---|---|---|
| Proximal curve | 27.18±12.94 | 19.91±9.98 | 21.12±11.42 | 12.82 ** | 2.46* | -10.9** |
| Middle curve | 56.62±19.58 | 22.57±10.84 | 28.85±12.49 | 19.18** | 10.96** | -7.2** |
| Distal curve | 39.45±13.46 | 11.02±6.52 | 14.18±8.43 | 17.65** | 12.6** | -3.34* |
| Iliolumbar angle | 12.05±3.31 | 4.28±4.3 | 4.88±4.09 | 7.88** | 4.8** | -2.9** |
| T1 tilt angle | 5.88±6.73 | 6.28±4.89 | 4.97±3.93 | -.342 | -.06 | .92 |
| Coronal Balance | 19.38±14.18 | 30.91±21.44 | 15.08±12.04 | -4.13** | 1.18 | 4.90** |
| Pelvic tilt | 3.79±5.23 | 2.46±1.68 | 2.60±1.69 | 1.82 | 1.61 | -.82 |
| Shoulders tilt | 3.18±2.49 | 3.76±2.98 | 3.08±2.26 | -.97 | -.09 | .81 |

* *P* value≤.05, ** *P* value≤.001

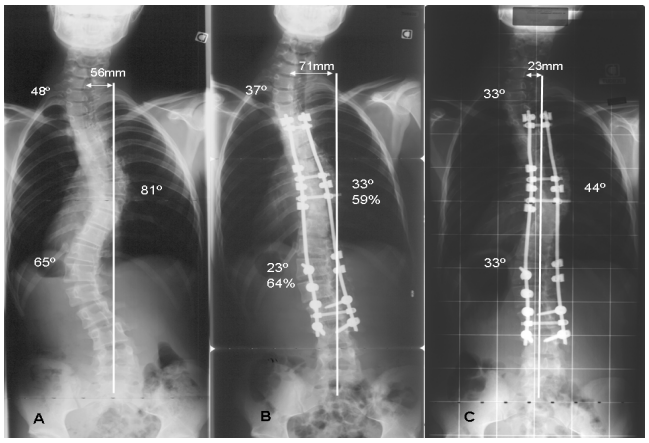


**Figure 1**. Nonselective fusion with a greater correction of the thoracolumbar curve was performed for a Lenke 3CN (A), but interestingly, his coronal balance was deteriorated(B). After 26 months(C) , the main thoracic curve had some loss of correction and the coronal balance was improved.

Lenke lumbar modifiers) (*P*=0.2).

The shoulders tilt angle was the other important coronal parameter. No significant decrease was seen in the shoulders tilt angle before the operation (3.18º (0-11º)) and in the last follow-up visit (3.08º (0-8º)) [Table 1] (*P*=0.3).

The T1 tilt angle was nonsignificantly reduced in the last visit from 5.88º to 4.97º (*P*=0.3). Although the T1 tilt angle was increased postoperatively, however, it decreased to lower than preoperative value but in the last visit.

The Iliolumbar angle (IL) was significantly reduced after operation and at the last visit (t=4.8, *P*<0.001) [Table 1]. There was a weak but significant correlation between the CB and the IL angle and shoulders tilt angle preoperatively (r=0.4, *P*=0.008 and r=0.39, *P*= 0.003 respectively), but they had no predictive effects on postoperative CB. Pelvic horizontal tilt angle was also reduced nonsignificantly from 3.79º to 2.60º (*P*=0.1).

## Discussion

The authors have defined coronal decompensation as 20mm lateral deviationof C7 from the CSL in the frontal plane. The SRS defines “compensation” as the vertical alignment of the midpoint of C7 within 15 mm of the sacral midpoint at the coronal plane. Due to the close relationship between CB, the lateral trunk shift, and thoracic apical vertebral translation, the authors have only used CB in this study (7). Although several studies have used this definition to analyze coronal decompensation, there are some other reports stressing the importance of factors such as shoulder symmetry, lateral trunk shift and plumb line from the center of T1 and its relationship with the CSL.

The sagittal and coronal balances were regarded as the first and second goals of surgical correction and the most important parameters when 50 spine surgeons were asked to rank 20 parameters of scoliosis correction and to provide weights for correction in the coronal, sagittal, and transverse planes and for mobility (8). In this study, coronal parameters were evaluated to elucidate their important role in the subjective and objective scoliosis corrections.

The mean CB value was increased after operation from 19.4 mm to 30.9 mm but at the last visit, the value was diminished significantly to 15 mm, within acceptable limit which was determined by SRS. This progressive improvement in the trunk shift to within 2 cm of the central sacral line along with progressive leveling and stabilization of the shoulder and pelvic horizontal tilt had also been noted by Frez et al (2). The capacity for correction and compensation increased with time, suggesting that the coordination of the corrective forces may also be enhanced overtime.

Coronal imbalance was noticed in 46 patents (38%) before operation and in 22 patients (18%) at the last visit. A former study has reported 30% decompensation of more than 2 cm after over 2-years follow-up of 67 patients with King type 2 scoliosis, indicating that coronal decompensation still exists with a lower frequency even when newer generations of spinal instrumentations are used (9).

Multivariate regression analysis revealed a significant predictive value of the preoperative coronal balance on the last visit coronal balance (*P*=0.01). Patients with Lenke 1C have been reported to have a preoperative tendency for left decompensation. Majority of preoperative decompensation in patients who underwent a selective thoracic fusion was reported to remain greater than 2 cm to the left at 2-year follow-up. It was emphasized that surgeons should be prepared for modest coronal decompensation in 40% of patients with Lenke 1C treated with selective thoracic curve fusion alone (10).

Our results showed that this complication may happen after all type of AIS. Therefore, special attention must be paid to selection of the fusion parameters in the presence of preoperative coronal imbalance. The authors suggest intra-operative radiographs and manipulation of the lower instrumented curve by distraction or compression of the rod at LIV for a more horizontal adjustment.

Overcorrection of the primary thoracic or TL/L curve has been considered a primary determinant of coronal decompensation. Decompensation is believed to be worse when the thoracic or TL/L curve undergoes significant correction during surgery but the compensatory curve is not spontaneously corrected well enough and is larger than the primary curve after selected thoracic or lumbar fusion. When analyzing relative thoracic curves to proximal or distal curves correction, the results revealed that more correction of the thoracic structural curve to TL/L structural or compensatory curve, could normalize the last visit coronal balance (r =-0.35, *P*= 0.03). It has been reported that overcorrection of either the primary or the composite curve (sum of the measurable curves) relative to the preoperative bending films was not related to postoperative worsening of spinal balance (11). Skeletal immaturity, male gender, and less correction of the major curve have been reported to be related with higher rates of coronal decompensation (12). Maximal selective thoracic correction by cantilever bending technique for Lenke type 1C and 2C has been shown to enhance the capacity for spontaneous correction and compensation of the lumbar spine (13).

However, the decompensation phenomenon is not completely understood, and other causative factors have been implicated. For example, inappropriate selection of

fusion levels (King type 2 and 5 or Lenke 1C or 2) or hook patterns and the derotation maneuver are considered by some as possible reasons for decompensation after Cotrel-Dubousset (CD) instrumentation for idiopathic scoliosis (13, 14). UIV translation, and LIV tilt are among other reported factors. The possible effect of these two parameters on coronal decompensation was reported by Liu et al in Lenke 5C patients (15). Gomez et al also reported 6.4% (57/890) coronal decompensation two years after PSIF in patients with AIS. They did not demonstrate a significant association between coronal decompensation and a change in coronal position of the lowest instrumented vertebra (LIV) and change in LIV tilt angle (12). In our opinion, post-operative changes in UIV and LIV position or angle are secondary variables related to coronal shift and are not causative risk factors for coronal decompensation; hence these parameters are not useful preoperative predictors for determination of postoperative coronal decompensation.

Spontaneous correction of TL/L curve has been shown to occur consistently by correcting the main thoracic curve and making the LIV more horizontal after posterior thoracic fusion (16). It has been revealed that more distal fixation in order to achieve a stable vertebra resulted in more postoperative shifting of coronal balance to the left.

Although other possible coronal factors like iliolumbar angle or T1 tilt may be important to cause postoperative coronal decompensation of scoliotic curves, however, no significant correlation was found in our study.

In this study Lenke or King classifications rules were not taken to select upper and lower fusion level, therefore the selected thoracic fusion in King type 2 or 5 might not have been performed. A Lenke and King-based classification was performed after operation. There was no significant postoperative difference between the coronal decompensation and the shoulder tilt angle among various types of King or Lenke classifications or Lenke lumbar modifiers. Ward et al showed that perhaps neither of these classification systems is as valuable as commonly assumed for providing distal fusion guidelines to prevent decompensation (17).

In conclusion, in spite of selecting the fusion level without considering Lenke or King classification, there was 18% postoperative coronal decompensation which was mainly within 30mm. Coronal decompensation is possible after all types of scoliosis so precise attention to the preoperative coronal balance is very important in the prevention of postoperative decompensation through LIV leveling at the end of the operation.

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