Characteristics of Cobb angle distribution in the main thoracolumbar/lumbar curve in adolescent idiopathic scoliosis

A retrospective controlled clinical study

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Abstract
A single-center retrospective analysis of 46 patients with Lenke 5 adolescent idiopathic scoliosis (AIS).

To compare Cobb angle distribution in different segments of the main thoracolumbar/lumbar curve in patients with Lenke 5 AIS, and differences in the lateral-bending flexibility, the correction rate, and correction index among these segments.

No studies have been reported the ratio of the different segments to the main thoracolumbar/lumbar curve in terms of curve angle distribution, lateral-bending flexibility differences between these segments, and the correction rate when surgical instrumentations are used to correct scoliosis.

Included in this study were 46 consecutive patients with Lenke 5 AIS. All of them received one-stage posterior correction and fusion with pedicle screw in the same center between January 2009 and January 2012. General data and radiological films before surgery, and at final follow-up were collected for further analysis. The wedging angles in the different discs were measured within main thoracolumbar/lumbar curve before and after surgery. This angle was also measured in the bending film. The preoperative flexibility, the correction rate, and the correction index of different disc segments were calculated.

There were 44 (95.65%) female and 2 (4.35%) male included in this study, with the average age of 15.26±2.19 years at the time of surgery. The mean Cobb angle was 45.09±9.40°. The average disc wedge angles in AV-2 (apex vertebral-2), AV-1, AV+1, and AV+2 segments were 5.59±2.28°, 10.46±3.41°, 9.85±2.43°, 5.68±2.80°, accounting for about 17.76%, 33.16%, 31.64%, and 17.44% of the Cobb angle in the main thoracolumbar/lumbar curve, respectively (P<.001). Flexibility of the supine lateral bending was 75.84%, 64.36%, 72.16% and 135.09% (P<.001), while the correction rates were 76.00%, 83.10%, 92.10%, and 109.65% (P<.001). The correction indexes were 1.16, 1.77, 2.02, and 1.11 for the disc of AV-2, AV-1, AV+1, and AV+2, respectively (P<.001).

The disc angles are symmetric distribution in the main thoracolumbar/lumbar curve, and the distal segment is more flexible than the proximal/apical segments. Furthermore, the correction index is the highest in the apical vertebral segment.

Abbreviation: AIS = adolescent idiopathic scoliosis.

Keywords: adolescent idiopathic scoliosis, correction rate, flexibility, wedge disc angle

1. Introduction
Adolescent idiopathic scoliosis (AIS) is a 3-dimensional deformity of spine, and the female are more susceptible to this disease.1 Several institutions had reported its prevalence ranged from 2% to 12% in adolescent population.1,2 However, the severe scoliosis patients merely accounted for 0.2% to 0.5%. For the severe scoliosis, correction surgery is essential to reconstruct the alignment.3 It is commonly accepted that Cobb angle is frequently used to quantify the severity of this deformity.4 In addition, the Cobb angle based on anteroposterior radiograph is the necessary prerequisite to plan the surgery, and correction surgery is always required when a Cobb angle >50°.5

On the other hand, assessing curve flexibility before surgery is also necessary to distinguish structural curves, which is significant to determine fusion segments. To quantitatively assess coronal flexibility, there were several methods such as supine side-bending radiograph,6 fulcrum-bending radiographic7 and push-traction film.8 Additionally, previous study had suggested that the remaining Cobb angle is a radiographic index to evaluate the surgical outcome. For instance, Aronsson et al9 proposed that surgical correction of vertebral axial rotation in
AIS could be predicted by side-bending radiographs. Furthermore, Cheung and Luk\cite{10} reported that fulcrum-bending films can be more accurate for predicting postoperative angles. Recently, Chen et al\cite{8} introduced the precisely controlled bidirectional correction forces to evaluate curve flexibility.

Although there are many studies focused on flexibility assessment of the scoliotic spine, and evaluation on correction rate of diverse instrumentations, there are few studies reporting the distribution characteristics of Cobb angle in the main curve. For instance, what is the proportion of the proximal, apical, and distal segments against the overall Cobb angle of the main curve? Is there any significant difference in flexibility and correction rate between different segments? The present study aimed to investigate the characteristics of Cobb angle distribution, differences in flexibility, and correction rate between these segments in the main thoracolumbar/lumbar curve in Lenke 5 AIS.

2. Methods

2.1. Patients populations

There were 46 consecutive patients enrolled in this study based on the following inclusion criteria: Lenke 5 type AIS patients with main thoracolumbar/lumbar Cobb angle involved in T11–L3 or T12–L4; treatment by one-stage posterior correction surgery with pedicle screw, without previous history of spinal surgery; no osteotomy was performed; the follow-up time >24 months. This study was approved by the Institutional Review Board of Chang Hai Hospital.

2.2. Radiographic assessment

All patients provided standing posterior–anterior, lateral, and supine lateral-bending X-ray films before surgery, and standing posterior–anterior and lateral X-ray radiography at follow-up. The disc wedge angle of the second disc above AV (apex vertebra – 2, AV – 2), the first disc above AV (AV – 1), the first disc under AV (AV +1) and the second disc under AV (AV +2) were measured on the lateral bending, and anterior–posterior films before and after surgery (Fig. 1). The disc wedge angle was the angle between lines along the inferior endplate of the upper and the superior endplate of the lower vertebra in a segment.\cite{11} Radiographic measurement was carried by 2 doctors, respectively, and the average value of each parameter was used for further analysis. The preoperative flexibility in different disc segments on the supine lateral-bending film, the postoperative correction rate, and the correction index (as described by Vora et al\cite{12}) were calculated as follows:

Preoperative flexibility(%) = (preoperative angle of each disc – residual disc angle on lateral bending)/ preoperative angle of each disc × 100%.

Postoperative correction rate = (preoperative angle of each disc – residual postoperative disc angle)/ preoperative angle of each disc × 100%.

Correction index = Correction rate of each disc/ preoperative flexibility of each disc.

2.3. Statistical analysis

Statistically analyses were performed by SPSS 17.0. Variance analysis of randomized block design was used to compare the differences in the distribution of the preoperative Cobb angle, supine lateral-bending flexibility, the postoperative correction rate, and correction index between different disc segments. That a 2-tailed P-value < .05 was statistically significant.

3. Results

There were 46 individuals included in this study including 44 (95.65%) female and 2 (4.35%) male. The mean age was 15.26 ± 2.19 years old at the time of surgery. The average Risser sign was 3.39 ± 1.39. The mean Cobb angle was 45.09 ± 9.40°. The mean follow-up time was 25.78 ± 3.76 months. Table 1 demonstrates the details on demographics.

This study detected significant difference in preoperative wedge angles between different main thoracolumbar/lumbar segments (P < .001). The wedge angles of AV – 2, AV – 1, AV + 1, and AV + 2 segment were 5.59 ± 2.28°, 10.46 ± 3.41°, 9.85 ± 2.43°, and 5.68 ± 2.80°, respectively (P < .001) (Fig. 2A). In addition, the disc segment of AV – 2, AV – 1, AV + 1, and AV + 2 accounted for 17.76%, 33.16%, 31.64%, and 17.44% of the main curve Cobb angle, respectively (P < .001) (Fig. 2B). Analysis between groups revealed significant difference in AV – 2 versus AV – 1 (P < .001), AV – 2 versus AV + 1 (P < .001), AV – 1 versus AV + 2 (P < .001), and AV + 1 versus AV + 2 (P < .001) (Fig. 2A).

When it referred to lateral-bending flexibility, the proportions of the disc of AV – 2, AV – 1, AV + 1, and AV + 2 segment were 75.84%, 64.36%, 72.16%, and 135.09%, respectively (P < .001). Furthermore, there was significant difference in AV –

### Table 1
Demographics and clinical characteristics.

| Variables                | Cases (n = 46) |
|--------------------------|---------------|
| Male                     | 2 (95.65%)    |
| Female                   | 44 (4.35%)    |
| Age, y                   | 15.26 ± 2.19  |
| Cobb, °                  | 45.09 ± 9.40  |
| Risser sign              | 3.39 ± 1.39   |
| Follow-up, mo            | 25.78 ± 3.76  |
2 versus AV − 1 (P < .001), AV − 2 versus AV + 1 (P = .014), AV − 2 versus AV + 2 (P = .002), AV − 1 versus AV + 2 (P < .001), and AV + 1 versus AV + 2 (P < .001) (Fig. 2C).

In terms of the postoperative correction rate, the proportions of AV − 2, AV − 1, AV + 1, and AV + 2 segment were 76.00%, 83.10%, 92.10%, and 109.65%, respectively (P < .05). Additionally, there was significant difference in AV − 2 versus AV + 1 (P = .017), AV − 2 versus AV + 2 (P < .001), AV − 1 versus AV + 1 (P = .019), AV − 1 versus AV + 2 (P < .001), and AV + 1 versus AV + 2 (P = .009) (Fig. 2D). The correction rate was significantly higher than the bending flexibility in apical segments (AV − 1, AV + 1), however, converse results was noted in the AV + 2 level. The correction index was 1.16, 1.77, 2.02, and 1.11 for the disc of AV − 2, AV − 1, AV + 1, and AV + 2, respectively. Furthermore,
there was significant difference in AV – 2 versus AV + 1 \((P=0.014)\), and AV + 1 versus AV + 2 \((P=0.010)\) (Fig. 2E).

4. Discussion

It was reported that the preoperative curve flexibility is closely correlated with correction rate,\(^{[13]}\) and there were various factors affecting the correlation.\(^{[14]}\) Although there are a lot of researches focused on the structural character and natural history of idiopathic scoliosis, it is lack of information about segmental characteristics in idiopathic scoliotic deformities. Initially, Hasler et al.\(^{[11]}\) investigated segmental disc angles in 76 preoperative thoracic AIS patients of standing and fulcrum-bending radiographs. However, thoracolumbar/lumbar curves were not enrolled in their study. The results of our study showed that the segmental distribution of disc angle in the main thoracolumbar/lumbar curve was in a symmetric state around the apex vertebra. Furthermore, the proportion of the proximal segment (AV – 2) was similar to the distal one (AV + 2), both of them accounted for about 1/3 of Cobb angle altogether. The apical segment (AV ± 1) demonstrated to be more rigid, and both of them accounted for about 2/3 of Cobb angle. Those findings also confirmed the relatively higher rigidity in the apex segments.\(^{[15]}\) However, it should be noticed that the vertebral wedge was not taken into account for that it was usually too small.

Flexibility distribution in the lateral-bending position revealed that the distal segments were more flexible than the proximal and apical segments. As the distal vertebral disks are usually larger than the proximal ones, the movability of the distal segment is better than the proximal one. Therefore, it was reasonable for that the range of movability related to those distal intervertebral disks contributed more to lateral-bending activity of the spine.

Overall, the distribution of the correction rate in different segments was almost consistent with the distribution of flexibility in this study, which revealed that the supine bending radiograph could predict the segmental postoperative correction effectively in thoracolumbar/lumbar curves. Vora et al.\(^{[12]}\) proposed to assess correction by a ratio (preoperative flexibility/postoperative correction). By this correction index, this surgeon can truly evaluate, and compare the corrective ability of different constructs. This study observed the correction index was the highest in the apical segment, which might result from local release, distraction and compression techniques to correct the apical segments. No significant difference was detected between AV ± 2 and AV – 1, which meant that this method to estimate flexibility might fail to reflect the strong correction strength of the modern instrumentation.\(^{[16]}\) On the other hand, the small size might fail to distinguish the difference.

Some recent studies have demonstrated that it is unnecessary to implant pedicle screws in every vertebral segment while using the posterior all pedicle screw correction technique for the treatment of AIS.\(^{[17]}\) The density of screw implantation could be reduced without affecting the correction outcome.\(^{[18,19]}\) However, there is no guideline for selecting the location of screw implantation. Our study may provide some information to reduce the use of pedicle screws. The apical vertebral segment contributes the most to the correction of the main curve. Theoretically, it would bear more stress, and the density of implanted screws should be higher. Conversely, the flexibility of distal segment is relatively good, and the density of implanted screws could be reduced. In addition, the same principle can also be employed to choose the segment for osteotomy.

Even through our study firstly reported the segmental characteristics in Lenke 5 AIS patients, several limitations should be taken into consideration. Firstly, the present study failed to perform analysis about the loss of correction during the 2-year follow-up period for that the loss of correction angle was small (3–5°) at the final follow-up. When divided into 4 parts, the loss of correction angle of each segment should be far smaller. Secondly, this is a single-center study, which might fail to reflect the distribution of the correction rate due to individuality of surgical techniques and different instruments.

5. Conclusion

The disc angles are symmetric distribution in the main thoracolumbar/lumbar curve, and the distal segment is more flexible than the proximal/apical segments. Furthermore, the correction index is the highest in the apical vertebral segment.

Author contributions

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