Factors influencing residual rib hump after posterior spinal fusion for adolescent idiopathic scoliosis with Lenke 1 and 2 curves

Abstract

Background: Despite remarkable improvement in Cobb angle after surgery for scoliosis, many patients have a residual rib hump. We studied the factors responsible for this hump and their influence on patient satisfaction.

Methods: We recruited 2 men and 38 women (mean age, 14.9 years) who underwent skip pedicle screw fixation combined with direct vertebral body derotation for adolescent idiopathic scoliosis with Lenke type 1 and 2 curves. Hump size was evaluated by measuring apical trunk rotation (ATR). Patients with postoperative ATR ≤ 10° were categorized as group A and those with postoperative ATR > 10° as group B. We analyzed postoperative self-image and satisfaction subscores of the SRS-22 questionnaire. We also compared the rate of postoperative improvement in ATR between patients who underwent additional Ponte osteotomy and those who did not.

Results: Preoperative ATR, preoperative apical translation, and preoperative and postoperative apical rotation significantly differed between groups A and B. In contrast, Cobb angles before and after surgery, Cobb angle correction rates, apical translation after correction, and postoperative self-image and satisfaction scores did not differ significantly between the groups. However, the rate of improvement in ATR showed a strong correlation with self-image (correlation coefficient, 0.64) and satisfaction (correlation coefficient, 0.52). This improvement rate did not differ significantly between subjects who underwent additional Ponte osteotomy and those who did not.

Conclusions: Preoperative apical rotation and ATR were clearly related to postoperative residual hump. For decreasing the postoperative rib hump, removal of the deformation by apical rotation was considered more important than correction of Cobb angle. Patient satisfaction and self-image scores were not significantly related to postoperative residual hump size, but they were influenced by improvement in ATR.

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity that accompanies apical rotation [1]. The most important issues in AIS surgery include cosmesis as well as respiratory dysfunction and back pain, which may occur during adulthood. The primary objectives of scoliosis surgery are to decrease the rib hump, which is considered a factor influencing postoperative patient satisfaction [2–5], and to improve trunk balance by adjusting pelvic symmetry, shoulder height, and sagittal alignment.

All-pedicle-screw construct is gaining popularity, with recent reports on the coronal correction rate, fixation strength, and minimal correction loss [6–13]. On the other hand, rotation in the thoracic spine, which is a major cause of rib hump, is difficult to correct by using conventional methods, and thus thoracoplasty has been used in combination with conventional methods to correct deformities in ribs [2, 14–16]. Since the publication of a report by Lee et al. [1] in 2004, devices that can directly correct the rotation of the vertebral body have been developed, and good correction of vertebral body rotation and rib humps has been reported [17, 18].

We studied preoperative factors that influence postoperative residual rib humps in patients who undergo skip pedicle screw fixation [19] combined with direct vertebral body derotation (DVBD) [1] without thoracoplasty. We also investigated the influence of rib hump correction on postoperative satisfaction of these patients.

Materials and Methods

This was retrospective diagnostic study. This study was approved by the Institutional Review Board of our hospital (Certified No. 2092). Forty subjects (2 men and 38 women; mean age, 14.9 ± 2.3 years) underwent skip pedicle screw fixation [19] combined with DVBD [1] without thoracoplasty for AIS with Lenke type 1 and 2 curves from August 2005 to March 2011. We investigated the following preoperative parameters: age; preoperative apical trunk rotation (ATR); Cobb angle of the main thoracic curve; flexibility measured by lateral-bending (calculated as [preoperative Cobb angle – Cobb angle in lateral-bending spine position]/preoperative Cobb angle); apical translation (AT; distance from center of apical vertebra to the central sacral vertical line [CSVL]); kyphotic angle of thoracic vertebra (T5–T12 kyphotic angle); and apical rotation (AR), measured by CT [20]. All surgeries were performed by the same surgeon. Patients predicted to have insufficient correction of Cobb angle underwent Ponte osteotomy [21]. The mean follow-up period was 21.2 months (range, 6–48 months). ATR measured using an inclinometer served as an indicator of rib hump (Figure 1).

Subjects were classified on the basis of postsurgical ATR into 2 groups: group A with a smaller residual rib hump (postoperative ATR ≤ 10°) and group B with a larger residual rib hump (postoperative ATR > 10°). Parameters related to the surgical procedure were presence/absence of Ponte osteotomy [21] and implant density [22], both of which were compared between groups A and B. Postoperative parameters were Cobb angle of main thoracic curve, AT, T5–T12 kyphotic angle, AR, and AR improvement rate. We also studied the correlation between the preoperative and residual ATR and the ATR improvement rate. All subjects completed the SRS-22 questionnaire, and we compared the subscores for self-image and satisfaction at final follow-up between groups A and B.

We used the statistical software JMP (SAS Institute; Cary, NC, USA). We calculated Pearson correlation coefficients and performed ANOVA and Student *t*-test; p values less than 0.05 were considered statistically significant.

Results

Preoperative parameters are summarized in Table 1. Group A included 28 subjects (mean age, 15.1 ± 2.4 years) and group B included 12 subjects (mean age, 14.4 ± 2.1 years); there was no significant difference in age between the groups. Preoperative ATR in groups A and B was 12.1° ± 1.1° and 18.3° ± 1.8°, respectively, with the values showing a significant difference ($p < 0.01$). Improvement rate of ATR in the 2 groups showed no significant difference. In groups A and B, preoperative AR by CT measurement was 13.9° ± 7.8° and 20.9° ± 6.8° ($p = 0.01$) and postoperative AR was 12.0° ± 1.5° and 17.2° ± 2.1° ($p = 0.05$), respectively, with both sets of values showing significant differences (Tables 1, 2). Preoperative AT was significantly different in groups A and B (31.1 ± 24.0 mm and 50.2 ± 19.6 mm, respectively). However, postoperative AT was not significantly different between groups A and B (4.0 ± 11.8 mm and 10.9 ± 29.0 mm, respectively) (Tables 1, 2). Preoperative AR and AT showed a significant positive correlation (correlation coefficient = 0.56, $p < 0.01$); however, postoperative AR and AT did not show a significant correlation ($p = 0.6$). Preoperative Cobb angle of main thoracic curve, flexibility measured by lateral-bending, and preoperative T5–T12 kyphotic angle showed no significant difference between groups A and B (Table 1).

Ponte osteotomy was performed in 2 subjects (7%) of group A and in 9 subjects (32%) of group B. Although a larger number of patients in group B underwent Ponte osteotomy, this was not a significant difference ($p = 0.3$), and implant density was not significantly different either ($p = 0.4$) (Table 2). ATR improvement rate in the subjects who underwent Ponte osteotomy was 34.6%±33.3, which was not significantly different from the rate in subjects who did not undergo Ponte osteotomy (35.1%±24.7) ($p = 0.97$).

Self-evaluation with SRS-22 showed no significant difference in preoperative and postoperative self-image and satisfaction scores between groups A and B (Table 3). Self-image and satisfaction scores did not show a significant correlation with postoperative ATR; however, they showed a significant and strong correlation with the ATR improvement rate (correlation coefficients: postoperative self-image, 0.64, $p < 0.01$; satisfaction, 0.52, $p < 0.05$) (Table 4).

In contrast, postoperative Cobb angle and Cobb angle improvement rate had significant influence on self-image, but their correlation with satisfaction was not significant (Table 4). Preoperative Cobb angle and Cobb angle improvement rate showed no significant correlation ($p = 0.1$), but postoperative Cobb angle and Cobb angle improvement rate showed a significant correlation (correlation coefficient, 0.79, $p < 0.01$). Preoperative ATR and ATR improvement rate had a significant correlation (correlation coefficient, 0.61, $p < 0.01$), however, there was no significant difference in ATR improvement rate between groups A and B (Table 2), and there was no significant correlation between postoperative ATR and ATR improvement rate (correlation coefficient = 0.24, $p = 0.3$). Pre- and postoperative AR did not have a significant influence on AR improvement rate ($p = 0.3$ and 0.1, respectively). AR improvement rate and ATR improvement rate also showed no significant correlation ($p = 0.4$).

Discussion

AIS has a considerable influence on appearance, and the extent of AIS is believed to have a significant mental influence on patients [2–5]. Deformities of the chest and ribs have been evaluated according to the size of the rib hump, and a surgical procedure has been developed to correct the deformity. The conventional surgical procedure involves spinal vertebral correction combined with additional thoracoplasty; reports indicate that this procedure has good outcomes [2, 14, 15, 23]. Improvement of the posterior device has enabled direct correction of vertebral rotation by using a pedicle screw, and good correction of vertebral body rotation has been reported [1, 17, 18]. However, there are no reports that clearly show the effectiveness of one procedure over the other. Samdani et al. [24] reported that, for a larger rib hump, ATR improvement was better in the procedure combining posterior correction with thoracoplasty; however, no difference was observed in postoperative evaluations of self-image.

We performed skip pedicle screw fixation [19] combined with DVBD [1, 25] without thoracoplasty;

after this procedure, some patients had a residual postoperative rib hump, although curve correction was good, it is not clear what parameters influence residual rib hump after DVBD; in this study, the 2 groups showed significant differences in preoperative ATR, AT, and AR. There was no difference in ATR improvement rate between groups, and preoperative ATR was directly related to the results. However, postoperative ATR and ATR improvement rate were not correlated.

A significant difference was observed in preoperative AT between the 2 groups, but the difference in postoperative AT was not significant. Preoperatively, AR and AT had a significant positive correlation, with a larger AT occurring more frequently with a larger AR. After correction, there was no longer a positive correlation between AR and AT nor did postoperative AT influence the hump. Good correction in the coronal plane is necessary; however, AR is a confounding factor for the presence of a hump. The influence of AT on the residual hump was negated by good correction in the coronal plane.

AR, the strongest influence on rib hump, was significantly large both before and after surgery in subjects with a large postoperative rib hump. No correlation existed between AR improvement rate and ATR improvement rate; thus, the AR improvement rate did not have a direct influence on the ATR improvement rate (mitigation of hump). Thus, a factor other than AR improvement must influence the mitigation of hump.

Hwang et al. [25] reported that, in patients who underwent correction by vertebral body rotation without thoracoplasty, improvement of the postoperative rib hump was not influenced by parameters such as preoperative size of the upper and main thoracic curve, flexibility, or T5–T12 kyphotic angle. Our study also showed that preoperative Cobb angle of main thoracic curve, flexibility, and T5-T12 kyphotic angle was not significantly different between subjects who had a postoperative residual ATR ≤ 10° and those with postoperative residual ATR > 10°.

There was no significant difference in satisfaction and self-image scores between subjects with or without a large postoperative residual rib hump. Moreover, there was no correlation between residual ATR and self-image or satisfaction score. However, the ATR improvement rate showed significant correlation with postoperative self-image and satisfaction scores.

In this study, larger preoperative ATR was related to higher ATR improvement rate; however, smaller postoperative ATR was not related to higher ATR improvement rate. These results showed that patients did not evaluate the surgical outcome according to the size of the residual rib hump, but according to the improvement in comparison with the preoperative condition. This result confirms that good correction of the hump is an important objective of the surgery for AIS. In contrast, both postoperative Cobb angle and Cobb angle improvement had a significant correlation with self-image score. This stronger correlation between Cobb angle and self-image score must be because of the more obvious effects of Cobb angle on appearance, including shoulder balance, which is influenced by coronal curve; asymmetry of waistline; and radiographic visual images. Postoperative satisfaction had no significant relationship with postoperative Cobb angle, although it had a significant correlation with ATR improvement rate. This is likely because postoperative satisfaction was dependent on more complex factors, including function or pain, than postoperative self-image, which was based on cosmesis. We performed skip pedicle screw fixation combined with DVBD. By using this method, coronal correction was good; however, sagittal kyphosis from T5 to T12 was still insufficient. We believe that improving the sagittal plane is very important for maintaining the long-term health of the spine.

In general, asymmetrical rib hump associated with a scoliotic curve is one of the problems that patients and their families notice most, and it has been correlated with patients' postoperative satisfaction with cosmetic outcome. In this study, patients completed the SRS-22 questionnaire. However, their families may have had concerns about the rib hump that the patients themselves were unaware of. Thus, it is likely that postoperative residual rib hump is very important, regardless of the results of this study. Improvement of the rib prominence is one of the primary goals of surgical treatment, and it has been correlated with severity of apical vertebral rotation. Better correction of rib hump is important in surgical patients.

Limitations

This study was limited by its retrospective design and small sample size. Additional significant differences may have been observed if the sample had been larger. Additionally, the rotation correction rate in early surgery was lower than that in other reports (42.5%) [1], even though the same surgeon performed all the procedures. Thus, improvement in the rotation correction rate might have affected the type of factors influencing residual rib hump.

Conclusion

Parameters that influenced postoperative rib hump in posterior spinal fusion were preoperative apical trunk rotation and preoperative and postoperative apical rotation, as measured by apical CT. Other parameters such as preoperative flexibility of main thoracic curve, thoracic kyphotic angle, and presence/absence of additional Ponte osteotomy did not influence postoperative residual rib hump. Patient satisfaction and self-image scores were not significantly related to postoperative hump size; however, they were influenced by improvement in ATR.

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Figure Caption

Figure 1. Apical trunk rotation was measured with an inclinometer to determine the extent of the hump.

Table 1. Comparison of preoperative parameters[a] between 2 groups classified by residual apical trunk rotation (ATR)

	Group A (postoperative ATR ≤ 10°)	Group B (postoperative ATR > 10°)	p
n	28	12	
Age (years)	15.1 ± 2.4	14.4 ± 2.1	0.33
Postoperative ATR (°)	7.4 ± 0.3	12.4 ± 0.5	<0.01
Preoperative ATR (°)	12.1 ± 1.1	18.3 ± 1.8	<0.01
Preoperative Cobb angle (main thoracic) (°)	52.4 ± 8.1	58.8 ± 17.3	0.11
Flexibility measured by lateral-bending (%)	33.3 ± 14.1	39.7 ± 14.1	0.19
Preoperative apical translation (mm)	31.1 ± 24.0	50.2 ± 19.6	0.02
Preoperative thoracic kyphotic angle (Th5-Th12) (°)	13.8 ± 9.3	12.7 ± 5.7	0.73
Preoperative AR (°)	13.9 ± 7.8	20.9±6.8	0.01

bbreviations: ATR, apical trunk rotation; AR, apical rotation

[a]Expressed as mean ± SD

Table 2. Comparison of postoperative parameters[a] between 2 groups classified by residual apical trunk rotation (ATR)

	Group A (postoperative ATR ≤ 10°)	Group B (postoperative ATR > 10°)	p
Postoperative Cobb angle (main thoracic) (°)	22.5 ± 7.9	25.9 ± 10.4	0.25
Postoperative apical translation (mm)	4.0 ± 11.8	10.9 ± 29.0	0.11
Postoperative thoracic kyphotic angle (Th5-Th12) (°)	20.0 ± 10.1	14.6 ± 9.3	0.11
Postoperative AR (°)	12.0 ± 1.5	17.2 ± 2.1	0.047
Improvement rate of AR (%)	9.2 ± 33.5	20.0 ± 22.6	0.3
Improvement rate of ATR (%)	35.6 ± 31.7	32.9 ± 20.5	0.84
Number of subjects who underwent Ponte osteotomy	2/12 (7%)	9/28 (32%)	0.3
Implant density	1.2 ± 0.3	1.2 ± 0.3	0.4

Abbreviations: ATR, apical trunk rotation; AR, apical rotation

[a]Expressed as mean±SD

Table 3. Comparison of self-image and satisfaction scores[a] between 2 groups classified by residual apical trunk rotation (ATR)

	Group A (postoperative ATR ≤ 10°)	Group B (postoperative ATR > 10°)	p
Preoperative self-image	2.8 ± 0.6	2.8 ± 0.6	0.8
Postoperative self-image	4.0 ± 0.7	3.8 ± 0.2	0.26
Satisfaction	4.1 ± 0.7	4.0 ± 0.8	0.5

Abbreviation: ATR, apical trunk rotation

[a]Expressed as mean ± SD

Table 4. Correlation between postoperative ATR, Cobb angle and self-image or satisfaction

	Coefficient of correlation	p value
Postoperative ATR and self image	-0.22	0.17
Postoperative ATR and satisfaction	0.0	1.0
ATR improvement rate and postoperative self image	0.64	<0.01
ATR improvement rate and satisfaction	0.52	0.01
Postoperative Cobb angle and postoperative self image	0.42	<0.01
Postoperative Cobb angle and satisfaction	-0.12	0.5
Cobb angle improvement rate and postoperative self image	0.40	0.01
Cobb angle improvement rate and satisfaction	0.22	0.2

Abbreviation: ATR, apical trunk rotation


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