Spontaneous derotation of compensatory lumbar curve after thoracic fusion in adolescent idiopathic scoliosis

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Abstract:

Introduction: Currently, excellent three-dimensional correction can be achieved with use of segmental pedicle screw fixation in adolescent idiopathic scoliosis (AIS). In the majority of patients with major thoracic curves, selective thoracic fusion (STF) may be considered to maximize motion segment of the unfused lumbar spine. This study aimed to investigate the extent of spontaneous derotation of the lumbar curve following STF. Methods: AIS patients who underwent STF using posterior pedicle screw fixation were retrospectively reviewed. Angle of vertebral rotation was defined as the difference between the axial rotation angles of the apical vertebra and S1 vertebra on axial CT images. Radiographic measurements included major thoracic curve, thoracolumbar/lumbar curve (preoperative and postoperative), and side-bending curve. The relationships between the axial rotation of the lumbar spine and radiographic measurements were also analyzed. Results: Thirty patients (all females) were included. Preoperative thoracic Cobb measured 62.1±9°, which improved to 20.3±5° at 2 years postoperatively, resulting in 67% correction. Preoperative lumbar Cobb measured 38.0±9°, which spontaneously improved to 19.0±7°, indicating a 50% correction. Preoperatively, the axial rotation of apical lumbar vertebra was 10.2±5.5°, which changed to 7.0±4.8° (32% spontaneous correction). Comparing the correction between the axial rotation of the lumbar spine and other parameters, postoperative angle of axial rotation correlated well with preoperative (r=0.79) and postoperative (r=0.82) lumbar Cobb angle. Meanwhile, the improvement of axial rotation of the lumbar spine correlated with postoperative thoracic curve (r=−0.42), postoperative lumbar curve (r=−0.57), and thoracic apical translation change (r=0.43). Conclusions: In AIS patients with major thoracic curves, spontaneous axial derotation of the lumbar curves occurred with a mean correction rate of 32% after STF. A greater spontaneous derotation of the lumbar curve would be related to correction of the thoracic curve.

Keywords:

Adolescent idiopathic scoliosis, Spontaneous derotation of lumbar curve, Selective thoracic fusion, Computed tomography

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Introduction

One of the goals of surgical treatment of adolescent idiopathic scoliosis (AIS) is to achieve three-dimensional correction. Excellent coronal and axial corrections have been reported with increased use of posterior segmental pedicle screw fixation[1-6]. In most patients with major thoracic curves, selective thoracic fusion (STF) may be considered to maximize motion segment of the unfused lumbar spine. In particular, there still exists a controversy surrounding treatment of Lenke type C curves due to concerns about coronal decompensation after STF; nevertheless, a recent multicenter study showed that 75% of the patients with Lenke 1C curve underwent STF[7]. Many analyses have primarily focused on the balance, Cobb angle, and related factors in the coronal plane[8-11]. However, there have been few reports evaluating axial rotation of the unfused lumbar spine. This study aimed to investigate the extent of spontaneous derotation of the lumbar curve following STF.

Materials and methods

A retrospective review of a consecutive single center study of AIS patients was conducted. Patients with AIS,

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Lenke type 1 or 2 curves, who underwent posterior spinal fusion and instrumentation with lower instrumented vertebra (LIV) of T12 or L1 were included. Patients who underwent an anterior approach were excluded. In this series, two types of surgical procedures were included. In the early cases, posterior correction and fusion using segmental pedicle screws were performed. In the recent cases, a direct vertebral rotation (DVR) procedure with a manipulator was employed.

Radiographic evaluations were performed at preoperative, postoperative, and 2-year time periods. Preoperative coronal measurements included Cobb angle of the proximal thoracic, major thoracic, and thoracolumbar/lumbar curve and flexibility of the major thoracic and thoracolumbar/lumbar curve. Percent correction of the major thoracic curve and spontaneous correction of thoracolumbar/lumbar curve were measured postoperatively.

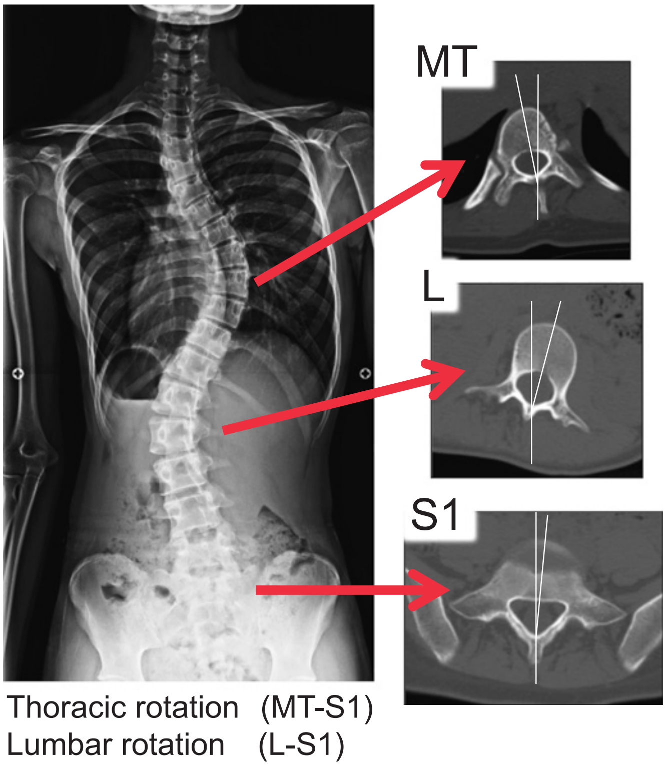

Figure 1. The angle of axial rotation of the apical vertebra in the thoracic and lumbar spine described by Aaro and Dahlborn. The difference between the axial rotation angles of the apical vertebra and S1 vertebra were evaluated to minimize measurement errors.

The degrees of axial rotation at the apical vertebra in the thoracic and lumbar spine were measured preoperatively and postoperatively on CT images 1 week postoperatively[12]. To minimize measurement error depending on the pelvic position, the difference between the axial rotation angles of the apical vertebra and S1 vertebra were evaluated (Figure 1). The relationships between the spontaneous axial derotation of the lumbar spine and the other radiographic parameters were analyzed. Statistical analyses were performed using SPSS and significance was set at $P<0.05$.

Results

Thirty female patients were included in the study, with the mean age at time of surgery of 16.3 ± 2.4 years (SD). There were 19 patients with Lenke type 1 curves and 11 with type 2 curves. The lumbar modifier was type A in 17 patients, type B in 7 patients, and type C in 6 patients.

The number of levels fused was 9.5 ± 1.1 vertebrae on average (range: 7-12). The upper instrumented vertebrae ranged from T2 to T5, and the level of lower instrumented vertebra (LIV) was T12 or L1. Regarding the relationship between LIV and end vertebra (EV)/stable vertebra (SV), the LIV distal to the EV was seen in 17 cases (EV=LIV: 13 cases, EV+1: 14 cases, EV+2: 3 cases). There were 18 cases who matched the levels of SV and LIV.

The coronal radiographic parameters and correction rates are described in Table 1. Preoperative thoracic Cobb measured 62.1 ± 9°, which improved to 20.3 ± 5° at 2 years postoperatively, resulting in a 67% correction. Preoperative lumbar Cobb measured 38.0° ± 9°, which spontaneously improved to 19.0 ± 7° (50% correction).

Preoperatively, the axial rotation of apical lumbar vertebra was 10.2 ± 5.5°, which changed to 7.0 ± 4.8° (32% spontaneous correction, $p<0.01$). Categorized by lumbar modifier, spontaneous lumbar curve correction (SLCC) rate was 53% in type A, 48% in type B, and 41% in type C. The spontaneous correction rate or axial rotation of the lumbar spine

Table 1. Coronal Radiographic Parameters.

	Pre-op.	Post-op.	2-year
Proximal thoracic curve	25.9±7.4	14.7±6.3	15.2±6.2
% flexibility	39.9±20.6		
% correction		44.3±15.7	42.0±14.4
Main thoracic curve	62.1±9.8	19.1±4.6	20.3±5.7
% flexibility	41.7±11.2		
% correction		69.0±5.9	67.2±7.4
Thoraco-lumbar curve	38.0±9.0	19.2±7.2	19.0±7.6
% flexibility	75.0±17.5		
% correction		49.7±12.6	50.6±13.7
Thoracic apical translation (mm)	52.4±16.5	5.1±11.6	8.5±9.7

Table 2. Spontaneous Lumbar Curve Correction according to Lumbar Modifier.

	Modifier A	Modifier B	Modifier C
Pre-op. lumbar Cobb angle	32.7±6°	44.2±8°	45.8±5°
Post-op. lumbar Cobb angle	15.3±4°	22.4±5°	26.6±8°
Coronal correction	53%	48%	41%
Pre-op. lumbar axial rotation	7.7±4°	13.2±5°	13.6±5°
Post-op. lumbar axial rotation	4.7±4°	9.5±4°	10.5±3°
Axial correction	54%	29%	21%

Table 3. Correlation between Postoperative Apical Lumbar Rotation and Other Parameters.

		r value	p value
Main thoracic curve	(preop.)	0.29	0.11
	(postop.)	0.42	<0.05
flexibility	(%)	0.25	0.18
Thoraco-lumbar curve	(preop.)	0.79	<0.05
	(postop.)	0.82	<0.05
flexibility	(%)	0.50	<0.05
Axial rotation - thoracic	(preop.)	0.28	0.12
- lumbar	(preop.)	0.90	<0.05

Table 4. Correlation between Improvement of Apical Lumbar Rotation and Other Parameters.

		r value	p value
Main thoracic curve	(preop.)	-0.33	0.07
	(postop.)	-0.42	<0.05
flexibility	(%)	0.02	0.88
Thoraco-lumbar curve	(preop.)	-0.67	<0.05
	(postop.)	-0.57	<0.05
flexibility	(%)	0.29	0.10
Axial rotation - thoracic	(preop.)	0.23	0.22
- lumbar	(preop.)	-0.64	<0.05
Thoracic apical translation change		0.43	<0.05

was 54% in type A, 29% in type B, and 21% in type C (Table 2). Comparing the correction between the axial rotation of the lumbar spine and other parameters, postoperative angle of axial rotation correlated well with preoperative ($r=0.79$, $p<0.05$) and postoperative ($r=0.82$, $p<0.05$) lumbar Cobb angle, lumbar curve flexibility ($r=0.50$, $p<0.05$), and preoperative axial lumbar rotation ($r=0.90$, $p<0.05$) (Table 3).

When comparing the improvement rate of apical lumbar rotation and other parameters, there was a correlation between improvement of apical lumbar rotation and postoperative thoracic curve ($r=-0.42$, $p<0.05$), postoperative lumbar curve ($r=-0.57$, $p<0.05$), and thoracic apical translation change ($r=0.43$, $p<0.05$) (Table 4). In 13 patients, DVR maneuver with a manipulator was employed. There were no significant differences regarding thoracic and lumbar curve magnitude pre- and postoperatively. The improvement of apical thoracic rotation of those who underwent DVR (30.4 ± 20%) was better than those who did not (11.4 ± 15%). Improvement of apical lumbar rotation was similar between the groups.

Discussion

Excellent coronal correction and vertebral derotation with the surgical treatment of AIS using segmental pedicle screw fixation has been reported previously [1, 4, 5]. Lee *et al*. compared major curve correction with the use of rod derotation group to a group that underwent the DVR procedure. They showed that the DVR group had better rotational and coronal correction[1]. Similarly, Dalal *et al*. evaluated axial rotation of instrumented apical vertebra and demonstrated the superiority of the DVR maneuver using uniplanar screws[4]. However, previous studies did not report on spontaneous derotation of unfused lumbar spine.

Since the first report by Moe[13], spontaneous correction of the lumbar curve after STF has been investigated. Lenke *et al*. compared spontaneous lumbar curve correction (SLCC) after selective anterior and posterior fusion. They demonstrated that the percentage of curve correction of the anterior (58%) group was greater than that of the posterior (38%) group and also showed that SLCC was superior for the anterior (56%) group versus the posterior (37%) group, indicating the extent of thoracic correction related to that of spontaneous correction[8]. Patel *et al*. evaluated related factors and surgical approach on SLCC after STF anteriorly or posteriorly[10]. They showed that the average SLCC in anterior approach (44%) was similar to that of the posterior approach (49%) when matched by lower instrumented vertebra. More recently, Liljenqvist *et al*. analyzed the SLCC focusing on Lenke type C curves after selective anterior fusion and reported that the rate of SLCC was 36%[11]. In the current study, the rate of SLCC was 50% with a curve flexibility of 74%, a correction rate comparable to other values reported in the literature.

There have been few reports to show the data regarding spontaneous derotation after STF. Schulte *et al*. evaluated vertebral derotation in secondary curves using scoliometer and rasterstereography after selective anterior fusion[14]. They reported that the mean derotation was 49% with rasterstereography and 70% with scoliometer measurement. Ritzman *et al*. compared derotation in unfused curves between STF and selective lumbar fusion. The spontaneous correction of 49% in lumbar spine was significantly greater than that of 26% in thoracic spine[15]. In this study, we evaluated vertebral rotation using CT images for a more direct measurement of the unfused curve. The average spontaneous derotation of apical lumbar vertebra was 32%. There was also a correlation between improvement of apical lumbar rotation and postoperative thoracic curve magnitude and thoracic apical translation change, indicating that a greater spontaneous derotation of the lumbar curve is related to correction of the thoracic curve. These results offer a better understanding to predict the spontaneous derotation of compensatory lumbar curve after STF and may influence the selection of fusion level depending on the lumbar modifier.

One limitation of this study is the small sample size and the retrospective nature of the study. A large-scale prospective multicenter study is recommended to demonstrate the related factors. However, the current study is the first investigation using CT images and is the first to evaluate using unified radiological protocol, which may provide information of the spontaneous vertebral derotation. Another limitation is that the current study was analyzed only using CT on supine position. For further evaluation on standing position, three-dimensional analysis using procedures such as a biplanar imaging system would be recommended. In conclusion, spontaneous axial derotation of the lumbar curves occurred with a mean correction rate of 32% after STF. A greater spontaneous derotation of the lumbar curve would be related to correction of the thoracic curve.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

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