Residual thoracolumbar/lumbar curve is related to self-image after posterior spinal fusion for Lenke 1 and 2 curves in adolescent idiopathic scoliosis patients

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OBJECTIVE Although it is well known that major curve severity in adolescent idiopathic scoliosis (AIS) is inversely related to self-image, surgeons often encounter patients who complain of low self-image with preoperatively mild curves or postoperatively well-corrected main curves, suggesting the presence of other factors. This study examined factors contributing to self-image in AIS.

METHODS A total of 86 consecutive patients who underwent posterior spinal fusion for AIS Lenke 1 or 2 curves and were followed for a minimum of 2 years were included in this study of patient self-image based on data that included scores reported on the Scoliosis Research Society survey (SRS-22r). The authors evaluated sex, BMI, Risser grade, age, angle of trunk rotation, Cobb angle of the main thoracic (MT) curve, Cobb angle of the thoracolumbar/lumbar (TL/L) curve, apical vertebral translation (AVT), T5–12 kyphotic angle, and clavicular angle. Univariate and multivariate general linear models were employed to identify preoperative and 2-year postoperative factors that impact self-image.

RESULTS Univariate analysis revealed no significant correlation between preoperative MT curve Cobb angle and SRS-22r self-image score ($p = 0.51$), although patients with a higher MT curve AVT had a significantly worse preoperative self-image ($p < 0.01$). Two years postoperatively, larger Cobb angle of the TL/L curve ($p = 0.01$) and higher Risser grade ($p = 0.03$) resulted in significantly lower self-image scores. In multivariate testing, preoperative MT curve AVT remained significantly related to diminished self-image ($p < 0.01$). Two years later, higher TL/L curve ($p < 0.01$), Risser grade ($p = 0.03$), and MT curve AVT ($p = 0.03$) had significant associations with lower self-image scores.

CONCLUSIONS Preoperative MT curve AVT appears more strongly related to self-image than does Cobb angle. Two years postoperatively, persistent TL/L region curvature and high Risser grade may also be associated with diminished patient self-image.

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KEYWORDS adolescent idiopathic scoliosis; Scoliosis Research Society-22r; self-image; posterior spinal fusion; cosmesis; Cobb angle; spine

ADOLESCENT idiopathic scoliosis (AIS) is a pathology that affects multiple domains of health-related quality of life (QOL).^{1,2} The Scoliosis Research Society survey (SRS-22r) is a commonly used patient-reported outcome tool to assess health-related QOL for scoliosis patients.³

Cosmesis is a critical factor for patients with AIS. Thus, an important surgical goal is the improvement of physical

appearance. Although it is well known that main curve severity in AIS is related to self-image,^{4–6} surgeons often encounter patients who complain of low self-image with preoperatively mild curves or postoperatively well-corrected main curves, suggesting the presence of additional factors that contribute to self-image. Other factors that influence cosmetic appearance and self-image in AIS include deformities such as a rib hump^{6,7} along with such patient char-

ABBREVIATIONS AIS = adolescent idiopathic scoliosis; ATR = angle of trunk rotation; AVT = apical vertebral translation; MT = main thoracic; SRS-22r = Scoliosis Research Society survey; TL/L = thoracolumbar/lumbar.

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acteristics as age and psychological factors.^{8–10} However, the relationship between curve severities other than that of the main thoracic (MT) curve, including thoracolumbar/lumbar (TL/L) curve severity, and self-image is unknown. We hypothesized that the MT curve severity as well as the TL/L curve severity and other patient features could influence the self-image of AIS patients with a Lenke type 1 or 2 curve.

In this study we analyzed perioperative factors contributing to diminished self-image in AIS, including several radiographic parameters and patient characteristics.

Methods

A total of 93 consecutive AIS patients underwent posterior spinal fusion for an AIS Lenke 1 or 2 curve at our hospital between October 2005 and April 2017. Among them, 86 patients (77 females and 9 males) who were followed for a minimum of 2 years and had completed SRS-22r outcome measurements preoperatively and at 2 years postoperatively were retrospectively enrolled. All patients were treated with an all-pedicle screw construct. Mean $\pm$ SD age was 15.1 ± 2.4 years (range 12–24 years). Informed consent was obtained from all patients and guardians. This study was approved by the institutional ethics review board (no. 4113).

We evaluated the parameters of age, Risser grade, BMI, findings from total spine anteroposterior and lateral standing radiographs, MT curve, angle of trunk rotation (ATR), and pre- and postoperative SRS-22r self-image scores. ATR was measured with a scoliometer. Radiographic parameters included MT and TL/L curve Cobb angle, MT curve apical vertebral translation (AVT), T5–12 kyphotic angle, and clavicular angle (absolute value). Lenke type was 1A in 38 patients, 1B in 12 patients, 1C in 19 patients, 2A in 13 patients, 2B in 3 patients, and 2C in 1 patient. All radiographic measurements were performed by a trained orthopedic surgeon who was uninvolved in the surgeries.

Univariate and multivariate general linear models were employed to identify factors associated with self-image at 2 years after surgery for AIS. The main outcome of interest was 2-year postoperative SRS-22r self-image score. Candidate variables for the multivariate general linear model were selected via a univariate general linear model using the selection criterion of $p < 0.2$. Comparisons of preoperative and 2-year postoperative SRS-22r scores were performed using paired t-tests.

Post hoc studies were carried out to test whether screw density or distal adding-on could have impacted postoperative self-image in association with residual TL/L curve. Distal adding-on was defined as 1) an increase in Cobb angle of $\geq 5^\circ$ and distalization of the end vertebra or 2) a change in disc angulation of $\geq 5^\circ$ below the lowest instrumented vertebra between the initial and 2-year follow-up radiographs.¹¹ Screw density was expressed as the number of screws per fusion segment. To reveal the relationship between distal adding-on and postoperative self-image, comparisons of 2-year postoperative SRS-22r self-image scores in groups either with or without distal adding-on were performed using Welch's t-test. To investigate the relationship between screw density and 2-year postoper-

ative SRS-22r self-image scores, univariate analysis was carried out using Pearson's correlation coefficient.

For all analyses, a p value of < 0.05 was considered statistically significant. Statistical analyses were carried out using the statistical package R, version 3.2.0 (available at <http://www.r-project.org>).

Results

No severe complications due to surgical invasion, such as neurological deficit, pulmonary complication, infection, or fatal blood loss, were observed. No revision surgery due to complications was performed in this series.

The mean $\pm$ SD SRS-22r self-image score was significantly improved at 2 years postoperatively (3.9 ± 0.7 vs preoperative 2.7 ± 0.5 , $p < 0.01$). Preoperative (Table 1) univariate analysis revealed no significant correlation between the preoperative MT curve Cobb angle and the preoperative SRS-22r self-image score ($p = 0.51$), although a higher AVT value of the MT curve was significantly associated with a lower preoperative self-image ($p < 0.01$). Higher MT curve AVT value ($p < 0.01$) remained significant after multivariate testing.

At 2 years after surgery (Table 2), higher values for the Cobb angle value of the TL/L curve and the Risser grade were associated with significantly worse SRS-22 self-image scores in univariate analysis ($p = 0.01$ and $p = 0.03$, respectively) and in multivariate analysis ($p < 0.01$ and $p = 0.03$, respectively,). A higher AVT value of the MT curve also had a significant impact on worse self-image in multivariate testing ($p = 0.03$). No remarkable relationships were observed for sex, BMI, age, MT curve ATR, T5–12 kyphotic angle, clavicular angle, or preoperative SRS-22r self-image score.

Three patients (3%) experienced distal adding-on. SRS-22r self-image scores did not differ significantly between patients with and without distal adding-on (4.6 ± 0.4 vs 3.9 ± 0.7 , $p = 0.07$). The mean $\pm$ SD screw density was 1.5 ± 0.2 . The correlation coefficient between screw density and 2-year postoperative SRS-22r self-image scores was low at -0.15 ($p = 0.17$).

Case Presentations

The following 2 representative cases illustrate the relationship between residual TL/L curve and SRS-22r self-image score.

Case 1

A 12-year-old girl presented with AIS (Fig. 1). Her MT curve from T6 to L1 was 59° and her curve pattern was Lenke type 1AN. The TL/L curve was 33° . The patient's preoperative SRS-22r self-image score was 1.8. She underwent posterior spinal fusion with skip pedicle screw fixation from T4 to L3. Postoperative radiographs obtained 2 years after surgery showed the MT and TL/L curves to be 14° and 4° , respectively. The patient's 2-year postoperative SRS-22r self-image score was good at 4.8.

Case 2

A 14-year-old girl presented with AIS (Fig. 2). Her MT

TABLE 1. Analysis results for the association of variables with the preoperative SRS-22r self-image score

Variable*	Crude		Adjusted	
	Value	p Value	Value	p Value
Sex (male)	0.11 ± 0.18	0.55		
BMI (+1 kg/m ²)	0.01 ± 0.03	0.66		
Risser grade (+1 grade)	-0.03 ± 0.04	0.49		
Age (+10 yrs)	-0.08 ± 0.23	0.73		
MT ATR (+10°)	-0.16 ± 0.12	0.19	0.10 ± 0.15	0.49
Radiographic parameters				
MT Cobb angle (+10°)	-0.05 ± 0.07	0.51		
TL/L Cobb angle (+10°)	0.01 ± 0.06	0.82		
MT AVT (+1 cm)	-0.09 ± 0.03	<0.01	-0.15 ± 0.04	<0.01
T5–12 kyphotic angle (+10°)	-0.06 ± 0.05	0.22		
Clavicular angle absolute value (+1°)	-0.04 ± 0.04	0.36		

Data are expressed as the value ± SE unless otherwise indicated. Boldface type indicates statistical significance at $p < 0.05$. Adjusted values were estimated using a multivariate general linear model. Candidate variables were selected via a univariate general linear model using the selection criterion of $p < 0.2$.

* Positive (+) values in parentheses indicate adjusted values estimated using a multivariate general linear model.

curve from T5 to T11 was 59° and her curve pattern was Lenke type 1C-. The TL/L curve was 42°. The patient's preoperative SRS-22r self-image score was 3.0. Posterior spinal fusion with skip pedicle screw fixation from T3 to T12 was performed. Postoperative radiographs 2 years postoperatively revealed MT and TL/L curves of 22° and 25°, respectively. The patient's 2-year postoperative SRS-22r self-image score was poor at 3.2.

Discussion

This study demonstrated that the mean SRS-22r self-

image score increased significantly from 2.7 to 3.9 in AIS patients who underwent posterior spinal fusion. This improvement was considered to have clinical importance based on Carreon et al.'s reported minimum clinically important difference for the self-image domain of 0.98.¹²

Adolescents with scoliosis are more likely to be dissatisfied with their appearance and to fear that their bodies are developing abnormally than are adolescents without scoliosis.¹³ One of the most obvious differences from a healthy person is a spinal deformity. Several reports have attempted to identify the correlations between deformity measures and self-image. Wang et al. found that self-

TABLE 2. Analysis results for the association of variables with the 2-year postoperative SRS-22r self-image score

Variable*	Crude		Adjusted	
	Value	p Value	Value	p Value
Sex (male)	-0.06 ± 0.25	0.80		
BMI (+1 kg/m ²)	-0.04 ± 0.04	0.34		
Risser grade (+1 grade)	-0.11 ± 0.05	0.03	-0.11 ± 0.05	0.03
Age (+10 years)	-0.09 ± 0.32	0.77		
MT ATR 2 years postop (+10°)	-0.24 ± 0.21	0.25		
Radiographic parameters 2 years postop				
MT Cobb angle (+10°)	-0.14 ± 0.10	0.19	-0.03 ± 0.13	0.82
TL/L Cobb angle (+10°)	-0.26 ± 0.10	0.01	-0.39 ± 0.14	<0.01
MT AVT (+1 cm)	-0.12 ± 0.09	0.17	-0.20 ± 0.09	0.03
T5–12 kyphotic angle (+10°)	-0.03 ± 0.09	0.74		
Clavicular angle absolute value (+1°)	-0.10 ± 0.06	0.09	-0.10 ± 0.05	0.05
Preoperative SRS-22r self-image score	0.11 ± 0.15	0.48		

Data are expressed as the value ± SE unless otherwise indicated. Boldface type indicates statistical significance at $p < 0.05$. Adjusted values were estimated using a multivariate general linear model. Candidate variables were selected via a univariate general linear model using the selection criterion of $p < 0.2$.

* Positive (+) values in parentheses indicate adjusted values estimated using a multivariate general linear model.

FIG. 1. Case 1. Preoperative (left) and 2-year postoperative (right) radiographs of Lenke type 1AN thoracic AIS. The TL/L curve was 4° postoperatively. The 2-year postoperative SRS-22r self-image score was good at 4.8.

image correlated negatively with MT curve Cobb angle and AVT in AIS patients who first visited an orthopedic center.⁶ Asher et al. investigated AIS patients who underwent surgery posteriorly and found that the Cobb angle of the MT curve was associated with the SRS-22 self-im-

age domain score, while trunk deformity magnitude was not.⁴ Theologis et al. reported that Cobb angle and lateral asymmetry measured on radiographs showed poor correlations with cosmetic spinal scores from ratings of clinical photographs by 10 nonmedical judges.⁷ Wilson et al. ana-

FIG. 2. Case 2. Preoperative (left) and 2-year postoperative (right) radiographs of Lenke type 1C- thoracic AIS. The TL/L curve was 25° postoperatively. The 2-year postoperative SRS-22r self-image score was poor at 3.2.

lyzed AIS patients with nonoperative, preoperative, and surgically treated curves to reveal that the Cobb angle of the major deformity had a negative association with self-image score.¹⁴ In our study, the MT curve Cobb angle did not correlate remarkably with self-image, whereas the MT curve AVT was significantly associated with self-image both before surgery and at 2 years afterwards. Based on these findings, surgical reduction of AVT may provide significant improvements in postoperative self-image score.

Previous studies have demonstrated that a rib protuberance also influences cosmetic appearance and self-image in AIS.^{6,7} However, MT curve ATR was not observed to significantly impact self-image in our cohort. Most analyses to date have evaluated the relationship between self-image and radiographic parameters of the major curve, with few focusing on residual lumbar curvature. Larson et al. reported that patients with long fusion lengths might be more pleased with the appearance of their back since a selective-fusion group had lower self-image scores than did a long-fusion group after surgery.¹⁵ The authors considered this result to be due to patient displeasure with residual lumbar curvature. In support of this finding, our study revealed the presence of a residual TL/L curve to be significantly related to self-image after surgery. Waistline perception may impact self-image, even if the main curve is well corrected by surgery. Accordingly, extending spinal fusion distally may be effective to reduce a residual lumbar curve, such as for spontaneous lumbar curve correction of a Lenke type 1 curve.¹⁶ However, because it is advisable to preserve as many caudal motion segments as possible to decrease the risk of disc degeneration¹⁷ and enable a return to athletic activity,^{18,19} distal fusion extension for better self-image is not a pragmatic option. Instead, patients should be informed of the possibility of lumbar curvature after surgery to help them accept any residual deformity.

Scoliosis is a deformity that appears in late childhood and adolescence. As Nathan argues, older scoliosis patients possess greater sensitivity to physical attractiveness and more acute awareness of their deformities, which may have psychological consequences.⁸ Other reported studies have also shown that psychological factors affect the self-image of adolescent scoliosis patients.^{9,10} In our study, a higher Risser grade was significantly related to worse self-image scores at 2 years after surgery in univariate and multivariate analyses. According to our univariate analysis, diminished flexibility may have influenced the residual lumbar curve, which is related to self-image. In multivariate analysis with adjustment for radiographic parameters, the significance of higher Risser grade likely reflected the psychological aspect of age in relation to self-image.

Study Limitations

This study had several limitations. First, it was performed in a patient group of limited size and had a retrospective design. Second, self-image in AIS was measured by SRS-22r self-image score alone, a method that might not have included all aspects of image assessment. For example, Bastrom et al. reported that the SRS-22 demonstrated an extensive ceiling effect at 2 years postoperatively and was psychometrically inferior in a postopera-

tive population.²⁰ The inclusion of other scales is therefore needed in future investigations. Third, since only patients who underwent posterior spinal fusion were included in this study, the effect of nonoperative mild deformity on self-image remains unknown. Fourth, as this series included Japanese patients only, there may have been factors impacting self-image that differed from those in other populations.

Conclusions

In summary, posterior spinal fusion for AIS significantly improved SRS-22r self-image scores. Perioperative AVT of the MT curve appears to be more strongly related to self-image than does Cobb angle. Two years after surgery, persistent curvature of the TL/L region and higher Risser grade may decrease gains in self-image. Informing patients preoperatively regarding the risk of residual lumbar curvature may help them to better accept possible postoperative deformity.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Takahashi, Mimura. Acquisition of data: Mimura. Analysis and interpretation of data: Mimura. Drafting the article: Mimura. Critically revising the article: Takahashi. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Takahashi. Statistical analysis: Mimura, Ikegami. Administrative/technical/material support: Kuraishi.

Supplemental Information

Previous Presentations

The abstract of this study was presented as an e-poster on July 17–20, 2019, at the 26th International Meeting on Advanced Spine Techniques, Amsterdam, the Netherlands.

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