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ORIGINAL ARTICLE

Factors leading to postoperative pain in adolescent idiopathic scoliosis patients including sagittal alignment and lumbar disc degeneration

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Abstract

Purpose This study examined for factors contributing to postoperative pain in adolescent idiopathic scoliosis (AIS), including those of sagittal alignment and lumbar disc degeneration.

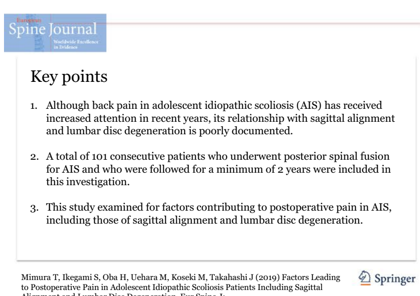
Methods A total of 101 consecutive patients who underwent posterior spinal fusion for AIS and who were followed for a minimum of 2 years were included in this investigation. We assessed Lenke curve type, age, Risser grade, body mass index (BMI), radiographic parameters, lumbar disc degeneration, correction rate, number of fused vertebrae, lowest instrumented vertebra, preoperative SRS-22r survey mental health score, and pre- and postoperative SRS-22r survey pain scores. Univariate and multivariate general linear models were employed to identify factors associated with pain 2 years after AIS surgery.

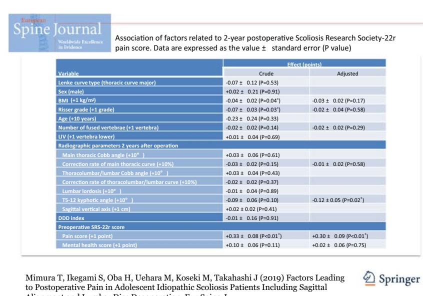
Results In multivariate analysis, patients with a lower preoperative pain score (i.e. higher pain) ($P < 0.01$) or higher postoperative T5-12 kyphotic angle ($P = 0.02$) had a worsened pain score 2 years after surgery. There were no remarkable differences for Lenke curve type, age, BMI, coronal radiographic parameters, lumbar disc degeneration, correction rate, number of fused vertebrae, or lowest instrumented vertebra. Higher preoperative Risser grade ($P = 0.01$) and lower preoperative SRS-22r mental health score ($P < 0.01$) were significantly related to a diminished preoperative SRS-22r pain score.

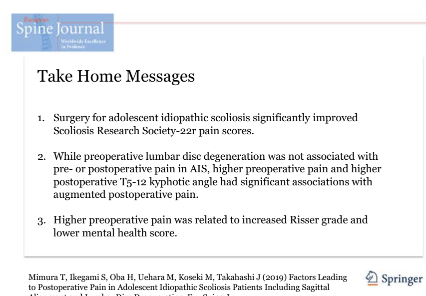
Conclusion While preoperative lumbar disc degeneration was not associated with pre- or postoperative pain in AIS, higher preoperative pain and higher postoperative T5-12 kyphotic angle had significant associations with augmented postoperative pain. Higher preoperative pain was related to increased Risser grade and lower mental health score.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







Keywords Adolescent idiopathic scoliosis · Scoliosis Research Society-22r · Pain · Posterior spinal fusion · Disc degeneration · Sagittal alignment

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Introduction

Surgeons tend to underestimate adolescent idiopathic scoliosis (AIS) as a cause of back pain because scoliosis in children is considered to be painless. However, a recent focus on back pain in AIS has shown that it is more prevalent than in healthy adolescents. Sato et al. reported that the lifetime prevalence of back pain was 32.9% in a non-scoliosis group and 58.8% in a scoliosis group [1]. Other studies showed back pain in 23–68% of patients with AIS [2, 3]. In many cases, pain after scoliotic curve correction is relatively transient and subsides with recovery from surgery [4]. In some patients, however, the pain can persist for months to years afterwards [5]. Chan et al. reported pain as the greatest preoperative concern of patients and parents before posterior spinal fusion (PSF) for AIS [6]. Accordingly, surgeons should know the precise factors associated with back pain after surgery.

Most analyses to date have focused on the relation between back pain and coronal parameters or patient demographic data. Indeed, it is well known that global sagittal parameters are able to predict clinical outcome in adult scoliosis [7, 8]. However, the link between back pain in AIS and sagittal alignment is poorly documented, and lumbar disc degeneration has also been implicated with back pain and sagittal alignment [9]. The aetiology of painful scoliosis is thought to include muscular pain due to eccentric loading on the apex of a curvature, intervertebral discs, facet joints, sacroiliac joint, or a combination of the above [10, 11]. In contrast, the progression from disc degeneration to discogenic pain is not fully understood, nor is the association of disc degeneration and pain. This study therefore examined for pre- and postoperative factors contributing to pain risk in AIS, including those of sagittal alignment and lumbar disc degeneration.

Materials and methods

Patients

A total of 123 consecutive AIS patients underwent PSF at our hospital for AIS between October 2005 and November 2015, among whom 109 were followed for a minimum of 2 years and had completed Scoliosis Research Society (SRS)-22r questionnaires preoperatively and at 2 years postoperatively. Ultimately, 101 patients (93 female and 8 male) who received preoperative lumbar magnetic resonance imaging (MRI) were retrospectively included in the present study. Mean ± standard deviation (SD) age was 14.8 ± 2.3 years (range 11–24 years). Mean ± SD body mass index (BMI) was 18.8 ± 2.3 (range 13.8–25.3). Forty-nine subjects had a Lenke 1 curve, 13 had a Lenke 2 curve, 1 had a Lenke 3 curve, 4 had a Lenke 4 curve, 24 had a Lenke 5 curve, and 10 had a Lenke 6 curve. Informed consent was obtained from all patients and guardians. This study was approved by the institutional ethics review board (No. 3801) of our hospital.

Reduction technique

For Lenke type 1 curves, a concave rod was over-bended, rotated dorsally, and set with pedicle screws. A convex rod was under-bended and set with pedicle screws to reduce hump. For Lenke type 2 curves, poly-axial screws were used on the convex side of the upper thoracic curve, upper instrumented vertebra (UIV), and lowest instrumented vertebra (LIV). A concave rod was over-bended, and the rotated dorsal side was set with pedicle screws. A convex rod was under-bended and set with pedicle screws to reduce hump. Lenke type 3 and 6 curves were treated similarly to Lenke type 1 curves. Lenke type 4 curves were corrected similarly to Lenke type 2 curves. For Lenke type 5 curves, a convex rod was over-bended and rotated ventrally. A concave rod was under-bended and set with pedicle screws.

Decision methods for UIV and LIV

We decided the UIV as T2 for Lenke 2 and Lenke 4 curves. The upper-end vertebra (EV) was chosen for Lenke type 1 AIS with right shoulder elevation. The upper EV + 1 was selected for Lenke type 1 AIS with horizontal shoulders, and the upper EV + 2 or T2 was used for Lenke type 1 AIS with left shoulder elevation. The LIV was the vertebra that last touched the central sacral vertical line when the lumbar modifier was Lenke 1A or 2A. For Lenke 1B, 1C, 2B, and 2C curves, we decided the LIV according to previous literature reported by Takahashi et al. [12]. For Lenke 3C, 4C, and 6C curves, the LIV was basically L3.

Measurements

We assessed Lenke curve type (Lenke type 1–4: thoracic curve major, Lenke type 5 or 6: thoracolumbar/lumbar curve major), sex, age, Risser grade, BMI, radiographic parameters (total spine, posterior–anterior, and lateral standing radiographs), correction rate calculated as: (Cobb angle of the main thoracic or thoracolumbar/lumbar curve before surgery − Cobb angle of the main thoracic or thoracolumbar/lumbar curve 2 years after surgery) × 100 /Cobb angle of the main thoracic or thoracolumbar/lumbar curve before surgery, number of fused vertebrae, LIV, pre- and postoperative SRS-22r mental health score, and pre- and postoperative SRS-22r pain scores.

Radiographic parameters included main thoracic and thoracolumbar/lumbar curve Cobb angle, lumbar lordosis (L1-S1), T5-12 kyphotic angle, and sagittal vertical axis (SVA). Lumbar disc degeneration was evaluated from sagittal plane T2-weighted preoperative MR images according to the Pfirrmann classification system [13]. Degenerative disc disease index (DDD index) scores were averaged for the 6 caudal-most mobile lumbar segments (ex., Th12-S1) [14]. All measurements were performed by a trained orthopaedic surgeon who was not involved in the surgeries.

Statistical analysis

Univariate and multivariate general linear models were employed to identify factors associated with pain at 2 years after surgery for AIS. The outcome of interest was 2-year postoperative SRS-22r pain score. Candidate variables for the multivariate general linear model were selected via the univariate general linear model using the selection criterion of $P<0.2$. Factors associated with pain before surgery were also identified using preoperative SRS-22r pain scores. DDD index comparisons between thoracic curve major and thoracolumbar/lumbar curve major types were conducted with Welch's *t* test. Comparisons of preoperative and 2-year postoperative SRS-22r scores were performed using paired *t* tests. To investigate the relationship between 2-year postoperative T5-12 kyphotic angle and 2-year postoperative lumbar lordosis or main thoracic Cobb angle, univariate analysis was employed 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 https://www.r-project.org).

Results

Compared with preoperative score, the mean ± SD SRS-22r pain score was significantly improved 2 years postoperatively (4.3 ± 0.6 to 4.5 ± 0.6, $P<0.01$). Mean ± SD lumbar lordosis (T12-S1) was 45.3° ± 10.8° (range 17°–69°) before surgery and 46.8° ± 12.6° (range 16°–77°) 2 years after. Mean ± SD T5-12 kyphotic angle was 16.3° ± 10.3° (range − 8° to 41°) prior to surgery and 22.1° ± 9.4° (range 1°–42°) 2 years after surgery. Mean ± SD SVA was − 0.7 ± 2.3 cm (range − 5.7 to 5.1 cm) prior to surgery and − 1.4 ± 2.5 cm (range − 8.4 to 3.1 cm) 2 years after surgery.

Median ± SD Pfirrmann classification was 2.5 ± 0.5 (range 2 to 4) at T12-L1, 2.6 ± 0.5 (range 2 to 4) at L1-2, 2.8 ± 0.5 (range 2 to 4) at L2-3, 2.7 ± 0.5 (range 2 to 4) at L3-4, 2.9 ± 0.4 (range 2 to 4) at L4-5, and 2.9 ± 0.5 (range 2 to 4) at L5-S1. The mean ± SD DDD index in all subjects was 2.7 ± 0.3 (range 2 to 3.8). Compared with thoracic curve major patients, thoracolumbar/lumbar curve major patients had a significantly higher incidence of disc degeneration (mean ± SD DDD index: 2.6 ± 0.3 for thoracic curve major vs. 2.8 ± 0.3 for thoracolumbar/lumbar curve major, $P<0.01$). The correlation coefficient of 2-year postoperative T5-12 kyphotic angle and 2-year postoperative lumbar lordosis was 0.54 ($P<0.01$), and that of 2-year postoperative T5-12 kyphotic angle and 2-year postoperative main thoracic Cobb angle was − 0.15 ($P=0.09$).

Association of factors related to 2-year postoperative SRS-22r pain score

In univariate analysis, lower preoperative SRS-22r pain score (i.e. higher pain) ($P<0.01$), higher Risser grade ($P=0.03$), and higher BMI ($P=0.04$) had a significantly worse pain score 2 years after surgery (Table 1). In multivariate analysis for relationships with postoperative pain, higher preoperative pain ($P<0.01$) and higher postoperative T5-12 kyphotic angle ($P=0.02$) had a significant impact on increased postoperative pain (adjusted $R^2=0.17$). There were no remarkable relationships observed for Lenke curve type, age, sex, coronal radiographic parameters, SVA, correction rate, number of fused vertebrae, LIV, or lumbar disc degeneration according to DDD index (Table 1).

Association of factors related to preoperative SRS-22r pain score

In univariate analysis, smaller lumbar lordosis ($P=0.02$), higher Risser grade ($P=0.01$), and lower SRS-22r mental health score ($P<0.01$) were significantly associated with lower preoperative SRS-22r pain score (i.e. higher pain) (Table 2). In multivariate analysis for relationships with preoperative pain, higher Risser grade ($P=0.01$) and lower SRS-22r mental health score ($P<0.01$) remained significant influences (adjusted $R^2=0.19$) (Table 2).

Discussion

The findings in this study showed that: (1) posterior spinal fusion for AIS significantly improved overall SRS-22r pain scores; (2) preoperative lumbar disc degeneration was not associated with pain in AIS; (3) higher preoperative pain and lower postoperative T5-12 kyphotic angle were significantly related to increased postoperative pain; and (4) higher preoperative Risser grade and lower preoperative SRS-22r mental health score were significantly associated with worsened preoperative pain.

Djurasovic et al. reported that AIS patients with significant preoperative pain experienced meaningful improvements after surgery [15]. Our study demonstrated the mean SRS-22r pain score was significantly improved from 4.3 to 4.5. This improvement was considered to have clinical importance because Carreon et al. reported the minimum clinically important difference for the pain domain was 0.20 [16]. Our study confirmed a significant amelioration

Table 1 Association of factors related to 2-year postoperative SRS-22r pain score

Variable	Effect (points)	
	Crude	Adjusted
Lenke curve type (thoracic curve major)	−0.07 ± 0.12 (P = 0.53)	
Sex (male)	+0.02 ± 0.21 (P = 0.91)	
BMI (+1 kg/m^2)	**−0.04 ± 0.02 (P = 0.04*)**	−0.03 ± 0.02 (P = 0.17)
Risser grade (+1 grade)	**−0.07 ± 0.03 (P = 0.03*)**	−0.02 ± 0.04 (P = 0.58)
Age (+10 years)	−0.23 ± 0.24 (P = 0.33)	
Number of fused vertebrae (+1 vertebra)	−0.02 ± 0.02 (P = 0.14)	−0.02 ± 0.02 (P = 0.29)
LIV (+1 vertebra lower)	+0.01 ± 0.04 (P = 0.69)	
Radiographic parameters 2 years after operation		
Main thoracic Cobb angle (+10°)	+0.03 ± 0.06 (P = 0.61)	
Correction rate of main thoracic curve (+10%)	−0.03 ± 0.02 (P = 0.15)	−0.01 ± 0.02 (P = 0.58)
Thoracolumbar/lumbar Cobb angle (+10°)	+0.03 ± 0.04 (P = 0.43)	
Correction rate of thoracolumbar/lumbar curve (+10%)	−0.02 ± 0.02 (P = 0.37)	
Lumbar lordosis (+10°)	−0.01 ± 0.04 (P = 0.89)	
T5-12 kyphotic angle (+10°)	−0.09 ± 0.06 (P = 0.10)	**−0.12 ± 0.05 (P = 0.02*)**
Sagittal vertical axis (+1 cm)	+0.02 ± 0.02 (P = 0.41)	
DDD index	−0.01 ± 0.16 (P = 0.91)	
Preoperative SRS-22r score		
Pain score (+1 point)	**+0.33 ± 0.08 (P < 0.01*)**	**+0.30 ± 0.09 (P < 0.01*)**
Mental health score (+1 point)	+0.10 ± 0.06 (P = 0.11)	+0.02 ± 0.06 (P = 0.75)

Data are expressed as the value ± standard error (P value)

BMI body mass index; *LIV* lowest instrumented vertebra; *DDD index* degenerative disc disease index; *SRS-22r* Scoliosis Research Society-22r

*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

Table 2 Association of factors related to preoperative SRS-22r pain score

Variable	Effect (points)	
	Crude	Adjusted
Lenke curve type (thoracic curve major)	−0.07 ± 0.13 (P = 0.56)	
Sex (male)	+0.02 ± 0.23 (P = 0.91)	
BMI (+1 kg/m^2)	−0.03 ± 0.02 (P = 0.26)	
Risser grade (+1 grade)	**−0.10 ± 0.04 (P = 0.01*)**	**−0.09 ± 0.03 (P = 0.01*)**
Age (+10 years)	−0.29 ± 0.27 (P = 0.28)	
Radiographic parameters		
Main thoracic Cobb angle (+10°)	−0.04 ± 0.04 (P = 0.22)	
Thoracolumbar/lumbar Cobb angle (+10°)	−0.03 ± 0.04 (P = 0.42)	
Lumbar lordosis (+10°)	**+0.13 ± 0.05 (P = 0.02*)**	+0.10 ± 0.05 (P = 0.05)
T5-12 kyphotic angle (+10°)	+0.07 ± 0.06 (P = 0.26)	
Sagittal vertical axis (+1 cm)	+0.02 ± 0.03 (P = 0.46)	
DDD index (+1 point)	−0.17 ± 0.18 (P = 0.36)	
Preoperative SRS-22r mental health score (+1 point)	**+0.28 ± 0.07 (P < 0.01*)**	**+0.26 ± 0.07 (P < 0.01*)**

Data are expressed as the value ± standard error (P value)

BMI body mass index; *DDD index* degenerative disc disease index; *SRS-22r* Scoliosis Research Society-22r

*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

in discomfort and identified several factors contributing to pre- and postoperative pain.

Relation to curvature size

Several articles have assessed for relationships between curvature angle of the spine before and after the surgical procedure and pain in AIS patients [11]. Watanabe et al. found that pain correlated with the magnitude of the correction angle as opposed to the preoperative curvature itself [17]. In our study, neither curvature angle nor correction rate of the coronal curve was associated with postoperative pain.

Relation to sagittal alignment

Segmental instrumentation for the surgical treatment of AIS was developed to provide a more stable construct over the previously used Harrington rod. Since segmental instrumentation has the ability for three-dimensional curve correction, its importance in AIS has been recognized to gain thoracic kyphosis and avoid thoracic flat back [18]. However, Mariconda et al. reported that AIS patients had comparable pain domain scores as controls after a minimum 20-year follow-up of Harrington rod fusion [19]. Thus, thoracic flat back may not affect back pain.

In our study, patients with a higher postoperative T5-12 kyphosis had significantly higher pain levels at 2 years after surgery. Several reasons for this finding are suspected. First, as shown in this study, higher postoperative thoracic kyphosis caused higher postoperative lumbar lordosis, which was comparable with previous reports [18], and might have affected back pain. Lumbar lordosis has been directly correlated to health-related quality of life [7, 20]. Patients with a significant loss of lordosis often require energy-consuming and subsequently painful compensatory mechanisms, such as pelvic retroversion, to restore gravity line [7]. In contrast, Makino et al. reported that higher lumbar lordosis was a risk factor for back pain after surgery in AIS patients [21]. Although the reason for this was unclear, another study indicated that lumbar lordosis was significantly larger in healthy people who experienced low back pain during 2 h of standing through high mechanical stress to the facet joints, disc annulus, or other spinal structures by the stimulation of nociceptors [22]. Second, patients who originally have higher thoracic kyphosis may have a different disease state. For example, Marfan syndrome has higher thoracic kyphosis of approximately 40° as compared to the dominance of hypokyphosis in AIS patients [23]. All patients were diagnosed as having AIS in our study; however, undetectable or unknown characteristics might have been confounding factors that affected postoperative pain by mechanical or psychological means separate from those in AIS.

Relation to disc degeneration

Although the influence of disc degeneration on back pain in adults has been debated [24], Butterman revealed disc degeneration and herniation to be unrelated to pain [25]. Bernstein et al. showed that thoracic hypokyphosis was significantly associated with lumbar disc degeneration in surgically treated patients with AIS, but no significant correlations between disc degeneration and pain were seen after an average follow-up of 7.5 years [14]. Preoperative lumbar disc degeneration was not remarkably associated with pain in our study, and so the contribution of postoperative lumbar disc degeneration to postoperative pain remains unclear. This was a limitation in that we could not evaluate disc degeneration after surgery due to incomplete postoperative MRI records.

Preoperative pain affects postoperative pain

One of the most significant predisposing factors to postoperative pain outcomes is preoperative pain severity [4, 26, 27], with no significant differences in comfort/pain scores according to age, Cobb angle, or curve location [28]. Yang et al. reported that preoperative opioid use was the strongest predictor of prolonged postoperative opioid use [29]. Persistent pain at baseline in AIS may reflect central neuronal plasticity and sensitization that, when coupled with surgical trauma, strengthens pain persistence beyond normal healing time. Thus, pre-emptive efforts at reducing pain prior to fusion surgery through medication [30] and coping techniques [31] may improve long-term outcomes. Our study agreed with earlier findings as preoperative pain was significantly associated with postoperative pain in the cohort.

Relation to mental health

The sensation of pain is a complex phenomenon that may be exacerbated by anxiety or depression. Multiple studies have demonstrated a link between depression and pain [32, 33], and Connelly et al. noted that baseline anxiety predicted a more prolonged pain course after surgery in AIS [4]. In our study, lower SRS-22r mental health scores were significantly associated with worsened SRS-22r pain scores prior to surgery, which was in line with other reports. However, since the SRS-22r questionnaire pain score section includes not only pain severity, but also the ability of social living and use of drugs, a natural correlation between SRS-22r pain and mental health scores can be logically presumed. Moreover, since prior pain might have worsened mental health in our cohort, the causal relationship between pain and mental health was unclear.

Relation to Risser grade

Jackson reported age as a risk factor for pain in AIS [11]. Similarly, Landman described that higher pain correlated with older age [5], and Ramirez found pain to be associated with age > 15 years or Risser grade ≥ 2 [2]. In our study, preoperative Risser grade, but not age, correlated significantly with preoperative pain. Thus, mechanical changes by maturation of the scoliotic curvature might be more strongly correlated with pain than are social or psychological development, i.e. AIS progression potentially worsens pain.

Limitations

The adjusted R^2 values obtained in this study were low (preoperative: 0.19 and 2 years after surgery: 0.17), which indicated that other variables not analysed in this series might have also affected scores, such as psychosocial factors not reflected in SRS-22r mental scores, coping ability to pain, and perioperative complications. Furthermore, since the femoral head was not included in most standing radiographs, no spinopelvic parameters were evaluated; the contribution of pelvic compensation to pain remains unclear.

Conclusion

The present study demonstrated that preoperative lumbar disc degeneration was apparently not associated with pain in AIS. In contrast, higher preoperative pain and higher postoperative T5-12 kyphotic angle were significantly related to higher postoperative pain, while higher preoperative pain was significantly associated with worsened Risser grade and preoperative lower mental health score.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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