Risk Factors for Lateral Translation in Residual Adolescent Idiopathic Scoliosis with a Thoracolumbar/Lumbar Curve

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Abstract:

Introduction: Although lateral vertebral translation is associated with inducing curve progression and pain, no study has analyzed risk factors for lateral slip in patients with residual adolescent idiopathic scoliosis (AIS). This study aimed to investigate risk factors for lateral slip in patients with residual AIS.

Methods: We included 42 preoperative patients with residual AIS with a thoracolumbar/lumbar (TL/L) curve (3 male, 39 female; age 41.9±18.2 years, TL/L Cobb angle 55.5±10.0°). All patients were >20 years and had been diagnosed with AIS during their adolescence. Lateral slip was defined as more than a 6-mm slip on coronal CT images.

Results: Patients were divided into slip (n=22) and nonslip (n=20) groups. Significant differences were observed in age, TL/L Cobb angle, TL/L curve flexibility, lumbar lordosis, thoracolumbar kyphosis, apical vertebral rotation, apical vertebral translation, and L3 and L4 tilt between the groups. Multivariate analyses and receiver operating characteristic curves found that only older age was a significant risk factor for lateral slip (odds ratio: 1.214; 95% confidence interval: 1.047-1.407; *P*= 0.010), with a cutoff value of 37 years old.

Conclusions: Older age, especially >37 years, is a risk factor for lateral slip in patients with residual AIS. These findings suggest that surgery for residual AIS should be considered before patients are in their mid-30s to avoid lateral translation.

Keywords:

adolescent idiopathic scoliosis, surgery, lateral translation

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Introduction

Lateral translation in the thoracolumbar/lumbar (TL/L) region on X-ray images is often seen in patients with residual adolescent idiopathic scoliosis (AIS) after they reach middle age. By contrast, lateral translation is rarely present in adolescent patients with idiopathic scoliosis, even if the scoliosis curve is large[1)] (Fig. 1).

Previous studies have identified lateral translation as a risk factor for the progression of scoliosis[2-4)]. In addition, lateral translation has been found associated with greater back and leg pain[5-8)]. Therefore, understanding the factors that are associated with lateral translation may help identify patients who are at higher risk for progressive scoliosis and pain.

Although lateral translation has these adverse effects, no study has analyzed risk factors for lateral translation in patients with residual AIS. Because lateral translation occurs at some point between adolescence and middle age, performing surgery before slippage occurs seems ideal. To date, there is a lack of literature regarding the age-related characteristics of residual AIS[9)].

The present study aimed to investigate risk factors for lateral translation in patients with residual AIS. We were especially interested in what age the lateral slip occurs. We hy-

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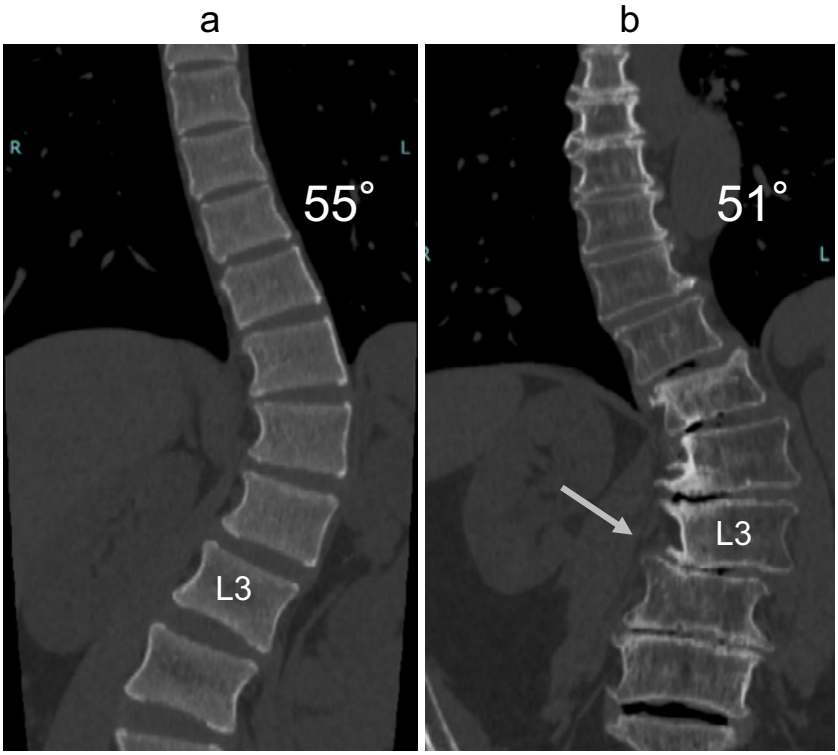

Figure 1. Examples of cases of residual AIS in a 20-year-old woman (a) and a 79-year-old woman (b).
Coronal CT imaging showing lateral slip between L3 and L4 in the 79-year-old woman (indicated by arrows), although both patients had similar degrees of thoracolumbar curvature.

pothesized that menopause and greater TL/L curvature were the risk factors for developing a lateral translation.

Materials and Methods

This retrospective study of patients from a single center with residual AIS with a TL/L curve was approved by our institutional review board. We included consecutive preoperative patients who had been diagnosed with AIS during their adolescence, age >20 at the time of surgery, TL/L Cobb angle more than 40°, and with complete radiographic and clinical data. All the patients were treated with correction surgery in our institute between May 2011 and December 2019. Patients with de novo degenerative scoliosis[3,10], scoliosis other than AIS, and those with previous spine surgery were excluded. Patients with scoliosis undiagnosed in adolescence were strictly excluded because they may have de novo, rather than residual, AIS. Ultimately, we included 42 patients (3 male, 39 female; age 41.9±18.2 years, TL/L Cobb angle 55.5°±10.0°).

All patients had standing anteroposterior and standing lateral radiographs of the whole spine and lumbar spine computed tomography (CT) preoperatively. All radiographic measurements were conducted by the same experienced spine surgeon. Coronal Cobb angle of the thoracic and TL/L curve, lumbar lordosis (LL) (L1-S1), thoracolumbar kyphosis (TLK) (T10-L2), and coronal C7 plumb line offset (C7 translation) were recorded. TL/L curve flexibility in side bending films was defined as TL/L curve flexibility (%)= [(Cobb angle-bending Cobb angle)/Cobb angle]×100%. For the TL/L curve, the absolute value of apical vertebral translation (AVT) from the central sacral vertical line and apical vertebral rotation (AVR, evaluated using Nash-Moe grade) were recorded. The absolute value of the superior endplate tilting from the horizontal line (L1, L2, L3, L4 tilt) and lateral translation between L1-L2, L2-L3, L3-L4, and L4-L5 (L1, L2, L3, L4 shift) were recorded.

Spinal CT was performed in the axial plane with 1.25-mm slice thickness and two-dimensional reconstruction using software (Synapse Vincent, Fujifilm Medical, Tokyo, Japan). Intersegmental measurements at each lumbar level from L1-L2 to L4-L5 involved lateral translation in the CT coronal plane (Fig. 1). Patients with at least one intervertebral space with a slip of 6 mm or more[11] on CT images were classified as being in the slip group and the remainder as in the nonslip group. Back pain and leg pain were quantified using visual analog scale (VAS) collected from the patients before surgery.

All statistical analyses were performed using SPSS Statistics (version 25, IBM Corp, Armonk, NY, USA). We used *t* tests to compare the averages of continuous variables (such as age) and χ^2 tests to compare the proportions of categorical variables (such as sex) between the slip and nonslip groups. Next, multivariate logistic regression analysis was

Table 1. Characteristic of Patients with Slip and Nonslip.

	Slip group (n=22)	Nonslip group (n=20)	P
Age (years)	55.2±13.1	27.0±8.4	<0.001*
Sex (male/female)	2:20	1:19	0.537
Coronal Cobb angle			
Thoracic curve (°)	43.3±14.8	40.9±21.2	0.662
TL/L curve (°)	60.4±8.5	50.4±8.6	<0.001*
TL/L curve flexibility (%)	38.2±11.0	60.6±19.5	<0.001*
Sagittal parameters			
LL (L1-S1) (°)	27.7±21.0	50.2±12.5	<0.001*
TLK (T10-L2) (°)	25.4±17.3	8.5±13.2	<0.001*
|C7 translation| (cm)	2.0±1.7	1.2±0.9	0.039*
|AVT| (cm)	5.1±1.4	4.2±1.1	0.027*
AVR (Nash and Moe Grade 1 vs 2 vs 3)	0:7:15	1:16:3	0.002*
|L1 tilt| (°)	15.7±8.3	12.6±7.5	0.209
|L2 tilt| (°)	9.0±5.6	7.6±4.5	0.394
|L3 tilt| (°)	19.4±7.5	14.8±6.1	0.038*
|L4 tilt| (°)	23.6±6.6	15.0±4.2	<0.001*
L1 shift (mm)	2.7±3.5	0.1±0.6	0.002*
L2 shift (mm)	2.6±2.8	0.2±0.9	0.001*
L3 shift (mm)	7.6±3.7	0.5±1.1	<0.001*
L4 shift (mm)	4.4±3.9	0.3±1.0	<0.001*
Number of slipped vertebrae	1.5±0.7	0.0±0.0	<0.001*

Data are expressed as means±standard deviation.

TL/L, thoracolumbar/lumbar; LL, lumbar lordosis; TLK, thoracolumbar kyphosis; AVT, apical vertebral translation; AVR, apical vertebral rotation

* Statistically significant at $P<0.05$

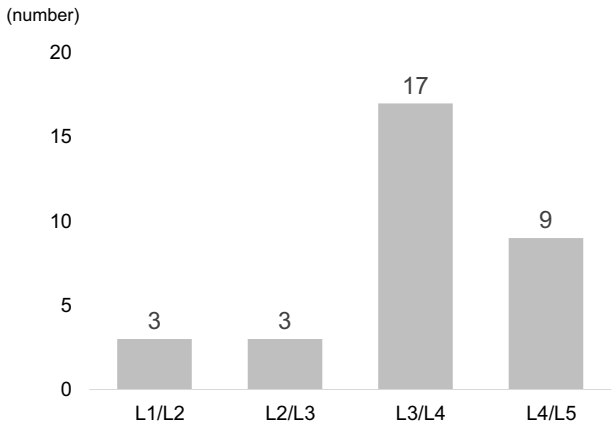

Figure 2. Distribution of lateral slip by level.
Lateral translation was most frequent in L3–L4, followed by L4–L5.

performed to obtain risk factors for the slip group as the dependent variable. The factors included in the multivariate model were age, TL/L curve, LL, TLK, |AVT|, |L3 tilt|, and |L4 tilt|, because they had $P<0.25$ in the univariate analyses and were variables we consider clinically important. A receiver operating characteristic (ROC) analysis was used to calculate the cutoff value for age based on whether patients were in the slip group or nonslip group. The point at which the distance from the upper left corner of the ROC curve was minimized was considered the cutoff point. The threshold for significance was set at $P<0.05$.

Results

Table 1 summarizes the characteristics of the patients. Patients were categorized into slip (n=22) and nonslip (n=20) groups. No significant differences were observed in the sex ratio or the Cobb angle of the thoracic curve between the slip and nonslip groups. Significant differences were observed in age, TL/L Cobb angle, TL/L curve flexibility, LL, TLK, absolute value of AVT, AVR, and L3 and L4 tilt, and L1, L2, L3, or L4 shift between the groups. In the slip group, a lateral slip of 6 mm or more was found at 1.5 levels on average. Lateral translation was most frequent in L3-L4, followed by L4-L5 (Fig. 2). In assessing the pain, the VASs for back pain and leg pain in slip group were significantly higher than those in nonslip group.

Multivariate logistic regression analyses (Table 2) and ROC curves (Fig. 3) found that only older age was a significant risk factor for lateral translation (odds ratio: 1.214; 95% confidence interval: 1.047-1.407; $P=0.010$), with a cutoff value of 37 years old (area under the curve [AUC]: 0.953; sensitivity=90.9%, specificity=90.0%). Fig. 1 shows an example.

Table 2. Multivariate Logistic Regression Analysis of Factors for Lateral Translation.

	P	Odds ratio	95% confidence interval
Age	0.010*	1.214	1.047–1.407
TL/L curve	0.208	-	-
LL	0.415	-	-
TLK	0.292	-	-
|AVT|	0.967	-	-
|L3 tilt|	0.633	-	-
|L4 tilt|	0.078	-	-

TL/L, thoracolumbar/lumbar; LL, lumbar lordosis; TLK, thoracolumbar kyphosis; AVT, apical vertebral translation
* Statistically significant

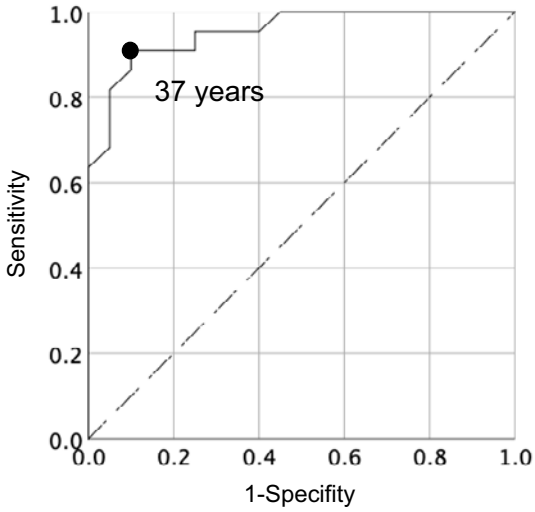

Figure 3. Receiver operating characteristic curve indicating the cutoff value for age-associated lateral translation in patients with residual AIS.
The cutoff value was 37 years old.

Discussion

Here, we analyzed risk factors for lateral translation in patients with preoperative residual AIS. We found that older age was a significant risk factor for lateral translation with a cutoff value of 37 years old. Contrary to our expectations, a large TL/L curve was not a significant risk factor for lateral translation. Lateral translation was most common at L3-L4, which is consistent with reports of degenerative scoliosis[11,12].

Previous investigators have reported comparisons of surgical outcomes for patients with AIS in different age groups. Young adult patients with AIS ≥19 years had a greater number of levels fused, higher blood loss, and lower major Cobb correction than patients with AIS aged from 10 to 18 years[13,14]. Patients with scoliosis in midlife, i.e., those aged over 50 years, tended to have less satisfactory radiographic results than their younger counterparts[9]. These studies show that surgery at an earlier age is preferable in patients with residual scoliosis. However, they do not tell us specifically by what age it is preferable to have the surgery.

Age and the absence of hormone replacement therapy in postmenopausal patients with degenerative scoliosis have been reported as the main factors associated with lateral spondylolisthesis. In the absence of hormone replacement therapy, a significantly higher risk was observed above the age of 66 years[15]. Although there is a difference between the degenerative scoliosis studied and residual AIS in the present study, we expected that slippage in patients with residual AIS would occur during menopause due to the impact of estrogen on the tissues responsible for spinal alignment[15].

However, our study showed that lateral translation occurs before patients are aged 40 years, earlier than menopause, and the size of the TL/L curve was not associated with the onset of lateral translation. The mechanism by which the lateral translation occurs near age 40 years is unclear because there have been no studies analyzing the mechanism of lateral slip in residual idiopathic scoliosis. We speculate that lateral translation occurs before patients are 40 years old, when the anatomical structures of the spine, such as the discs, ligaments, and muscles, which are affected by aging[16], are unable to resist the lateral loading caused by scoliosis, which has continued since their adolescence.

Preventing the occurrence of lateral translation may be valuable not only in preventing further progression of scoliosis but also in avoiding pain and low quality of life[8,15]. Previous investigators observed that patients with lateral vertebral translation (LVT) ≥6 mm had a higher rate of curve progression than those with LVT <6 mm[3,17-19]. Moderate to severe lateral translation ≥6 mm is associated with clinical symptoms including greater bodily pain than that associated with milder lateral slip[8]. The present study also showed that back pain and leg pain were more severe in the slip group than in the nonslip group. Based on these studies, we believe that surgery is preferable in patients with residual AIS before the lateral slip reaches 6 mm.

Although there is a certain consensus among spine surgeons about the indications for surgery in patients with residual AIS[13,14], the decision to undergo surgery is still difficult from the perspective of the patient and their family. Some patients with residual AIS and their families have chosen to delay surgery to avoid social conflicts[14]. The late 30s is a difficult time to decide on surgery, especially for women, because it coincides with childbirth and child-rearing. However, this study shows that after the late 30s, the risk of lateral translation, causing pain and further progression, increases. We believe that for patients with residual AIS, surgery should be recommended by the mid-30s, considering the risk of lateral translation. Our present findings provide useful information for patients with residual AIS and spine surgeons who are considering the appropriate timing of surgery.

Several limitations should be acknowledged in the present study. First, it is a cross-sectional study and not longitudinal. Second, the study included data from a relatively small sample size. Third, clinical symptoms after surgery were not ob-

tained. Fourth, degeneration of the intervertebral discs was not evaluated. Nevertheless, this study identifies risk factors for lateral translation in patients with residual AIS. Another strength of our study is that we excluded de novo scoliosis and focused only on those with residual AIS. We believe that these results will be beneficial in planning surgical strategies for patients with residual AIS.

In conclusion, older age is a significant risk factor for lateral translation with a cutoff value of 37 years old. To avoid lateral translation, surgery for residual AIS should be considered before the patient is in their mid-30s.

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

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Informed Consent: Informed consent was obtained from all participants in this study.

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