Predictors for Postoperative Loss of Lumbar Lordosis After Long Fusions Arthrodesis in Patients with Adult Scoliosis

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Statistical Analysis C
Data Interpretation D
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Background: Loss of lumbar lordosis (LL) is closely related to clinical symptoms and operative complications, however, few studies have identified its predictors. The purpose of our study was to identify the predictors for loss of LL in patients with adult scoliosis and provided evidence for surgical decision-making.

Material/Methods: There were 69 patients with adult scoliosis who underwent long fusions arthrodesis from January 2006 to March 2015 included in this retrospectively study. The patients were divided into two cohorts according the average loss of LL: cohort LL (loss of LL below the average) and cohort GL (loss of LL above the average). Multivariate logistic regression analysis and the receiver operating characteristic curve were used to identify the predictors.

Results: There were statistically significant differences between the two cohorts in preoperative LL (p=0.002), postoperative LL (p=0.036), last follow-up LL (p<0.001), postoperative loss LL (p<0.001), preoperative SVA (p=0.007), last follow-up SVA (p=0.018), and pelvic incidence (p=0.016). Preoperative LL <23.5 (OR=0.920, 95% CI=0.870–0.973, p=0.003) and preoperative sagittal vertical axis >4.28 (OR=1.199, 95% CI=1.007–1.429, p=0.041) had good accuracy to predict postoperative loss of LL.

Conclusions: Loss of LL commonly occurred after long fusions arthrodesis in patients with adult scoliosis. Postoperative deteriorated sagittal balance was more frequently than deteriorated coronal balance. Preoperative LL <23.5 and preoperative SVA >4.28 were the predictors for postoperative greater loss of LL in patients after long fusions arthrodesis. More attention should be paid to how to maintain the LL in patients with preoperative predictors, especially if both the identified predictors are present.

MeSH Keywords: Adult • Lordosis • Postoperative Period • Scoliosis • Spinal Fusion

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Background

Adult scoliosis, including idiopathic adolescent scoliosis in adult life and *de novo* scoliosis, is defined as a deformity with a Cobb angle of more than 10 degrees after skeletally mature [1]. As an important surgery strategy for adult scoliosis, long fusions arthrodesis procedures are able to correct deformity and complete decompression at the same time. Lumbar lordosis (LL) plays an important role in radiological evaluations not only preoperatively but also postoperatively in patients after long fusions arthrodesis [2–7]. Loss of LL has been shown to be closely related to clinical symptom and operative complications such as subsequent intervertebral disc degeneration and coronal and sagittal imbalance [2–4,6–9]. As for surgical design, appropriately, postoperative LL is one of the important standards that doctors use to predicted preoperative success [10–14]. There have been several studies that provide specialized discussion of the association between LL and other radiological parameters, or the risk factors for loss of LL in patients with adolescent idiopathic scoliosis [4,5]. However, few studied have identified the predictors for postoperative loss of LL in patients with adult scoliosis, and such predictors could influence surgical programs. The aim of this study was to identify predictors for loss of LL in patients with adult scoliosis and provide evidence for surgical decision-making.

Material and Methods

Patients

This study was approved by the Institutional Ethics Board of the Third Hospital of Hebei Medical University. Patient informed consent for measurement and evaluation of their data was approved by all participants. The methods were carried out in accordance with approved guidelines.

There were 69 patients with adult scoliosis who underwent long fusions arthrodesis at the Department of Spinal Surgery, the Third Hospital of Hebei Medical University in China from January 2006 to March 2015 who were included in this retrospectively study. The inclusion criteria included: 1) Cobb angle greater than 10 degrees; 2) posterior procedure with instrumentation only; 3) surgery segments with pedicle screw instrumentation equal or greater than four; and 4) minimum two-year follow-up. The exclusion criteria included: 1) spinal tumors or inflammation; 2) previous surgery involving spine; and 3) incomplete imaging data. The enrolled patients included 57 females and 12 males and the average age at surgery was 58.39±5.53 years. The patients were followed for an average of 3.21 years (range 2–8 years). Fifty-six patients (81.16%) had *de novo* scoliosis in adulthood, while 13 patients (18.84%) had a history of idiopathic adolescent scoliosis without treatment.

There were 52 patients (75.36%) who complained of radicular pain, 39 patients (40.63%) complained of claudication, and all of the patients complained of intractable low back pain. The duration of symptoms was 9.03±4.49 years, which was recorded from the onset of the intractable low back pain or neurological symptom to the time of surgery. The level of spinal stenosis or herniated disc that was responsible for the symptoms were performed decompression and interbody fusion with autogenous bone and PEEK cage. Patient age, gender, body mass index (BMI), preoperative LL, preoperative Cobb angle, preoperative coronal vertical axis (CVA), preoperative sagittal vertical axis (SVA), pelvic incidence (PI), number of instrumented vertebra, interbody fusion or not, smoking or not, and duration of symptoms were collected as potential predictors for postoperative loss of LL.

Radiological evaluation

Standing long posterior-anterior and lateral x-rays of the entire spine were taken preoperatively, postoperatively, and at last follow-up visit. Postoperative x-rays were taken at 7–10 days as appropriate after surgery, standing without brace. LL was defined as the angle between the upper end plate of L1 and the upper end plate of S1 (Figure 1). Cobb angle was measured between the upper and lower end-vertebras which were most inclination on standing long posterior-anterior x-ray (Figure 1). The horizontal distance from C7 plumb and posterosuperior corner of the sacrum was recorded as sagittal vertical axis, which if greater than 5 cm was regarded as sagittal imbalance [13,15] (Figure 1). The horizontal distance from C7 plumb and central sacral vertical line was recorded as coronal vertical axis, which if greater than 3 cm was regarded as coronal imbalance [13,15] (Figure 1). PI was defined as the angle between the perpendicular line from the cephalad endplate of S1 and a connecting line from the center of the femoral heads and the cephalad endplate of S1 in the preoperative lateral radiographs. If femoral heads was non-overlapping, the midpoint of the line connecting the respective center of the femoral head was regarded as center of the femoral heads (Figure 1). Each date was measured three times by the same author and the average was recorded for analysis.

Statistical analysis

SPSS program (version 22.0; SPSS Inc., Chicago, IL, USA) was used for the statistical evaluation. Quantitative date among the different groups was tested by Student's *t*-test or Mann-Whitney U-test, as appropriate. Qualitative data was tested by chi-square test. Multiple comparisons were performed if there was a statistically significant difference, whose significance level was corrected to 0.0167 according to Bonferroni correction to decrease type 1 error. Multivariate logistic regression analysis were applied for predictors for postoperative loss of
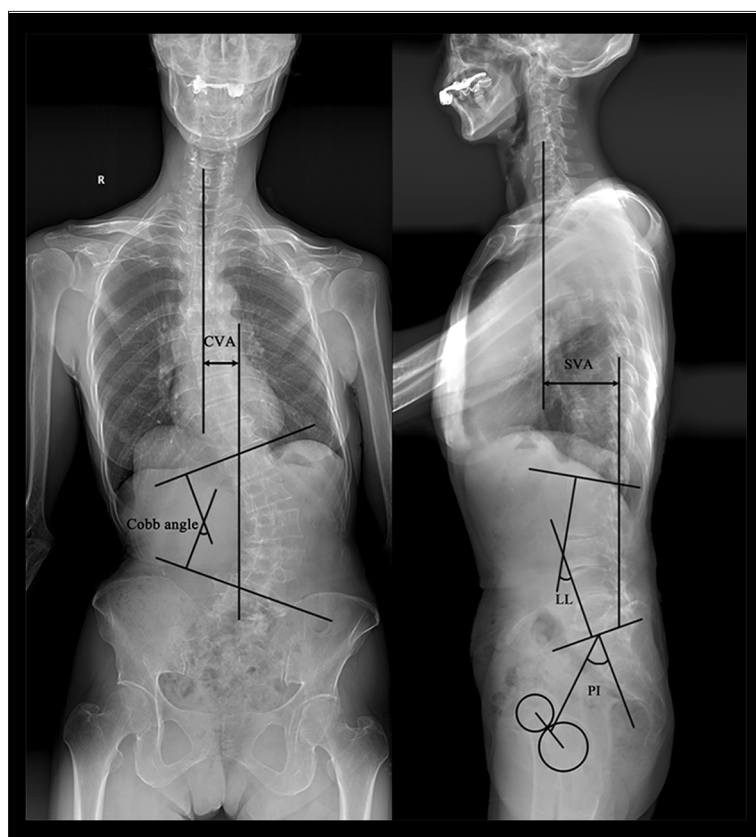
Figure 1. Measurement of Cobb angle, LL, PI, CVA and SVA.

LL. Adjusted odds ratios (ORs), 95% confidence intervals (CIs) and *p* values of respective predictors are provided. The factors in univariate analysis showing *p*<0.05 were selected into the multivariate logistic model. Finally, the logistic regression analysis was used again to identify the association between postoperative loss of LL and the predictors after adjusting for possible confounding factors. A *p* value <0.05 was considered statistically significant.

Results

Decompression and interbody fusion were performed in 54 patients (78.26%) and the average fused level number was 1.97±0.64. Instrumented vertebra numbers were four in two patients, five in 12 patients, six in seven patients, seven in eight patients, eight in 11 patients, nine in 10 patients, 10 in 12 patients, 11 in six patients, and 12 in one patient. The Cobb angle decreased to postoperative 9.43±4.97 from preoperative 36.57±9.43 (*p*<0.001) and the angle at last follow-up visit was 9.58±5.06 (compared with preoperative, *p* < 0.001, compared with last follow-up visit *p*=0.322). Preoperative CVA was 2.61±2.86 cm with 13 patients found with coronal imbalance. There were statistically significant differences between preoperative CVA and postoperative CVA (0.98±1.01 cm with coronal imbalance in one patients, *p*<0.001), and last follow-up

CVA (1.20±1.37 cm with coronal imbalance in three patients, *p*<0.001). Statistically significant difference could also be found between postoperative CVA and last follow-up CVA (*p*=0.010). SVA was corrected to postoperative 2.55±1.61 cm with sagittal imbalance in 18 patients from preoperative 4.79±4.38 cm with sagittal imbalance in three patients (*p*<0.001), and increased to last follow-up 3.24±2.21 cm with sagittal imbalance in nine patients (compared with preoperative or last follow-up visit, both *p*<0.001). Preoperative, postoperative, and last follow-up LL was 23.87±13.92, 31.33±11.19 and 25.62±12.62, respectively, and the average postoperative loss of LL was 5.71 ± 5.18. There were statistically significant differences between preoperative LL and postoperative LL (*p*<0.001), postoperative LL and last follow-up LL (*p*<0.001), while a statistically significant difference was not found between preoperative LL and last follow-up LL (*p*=0.022 >0.0167). The patients were divided into two cohorts according the average loss of LL: cohort less loss of LL (cohort LL) with a loss of LL below the average; cohort greater loss of LL (cohort GL) with a loss of LL above the average. In all, 32 patients were observed with a loss of LL greater than 5.71 and were included in the cohort GL, while the remaining 37 patients were included in the cohort LL. Comparison of patient characteristics between the two cohorts are shown in Table 1. Multiple comparisons of LL, Cobb angle, SVA, and CVA are shown in Table 2. There were statistically significant differences between the two cohorts

Table 1. Comparison of patient characteristics between Cohort LL and Cohort GL.

Variable	Cohort LL (n=37)	Cohort GL (n=32)	P-value
Age (years)	57.78±5.73	59.09±5.28	0.330[1]
Gender			0.361[2]
Male	5	7	
Female	32	25	
Body Mass Index	22.89±2.94	24.12±3.03	0.092[1]
Lumbar lordosis			
Preoperative	29.54±13.04	17.31±12.03	0.002[3]
Postoperative	33.95±11.27*	28.31±10.48*	0.036[1]
Last follow-up	32.19±10.94	18.03±9.97	<0.001[1]
Postoperative loss	1.76±1.88	10.28±3.82	<0.001[3]
Cobb angle			
Preoperative	37.03±9.56	36.03±9.41	0.638[3]
Postoperative	9.76±4.96*	9.06±5.02*	0.566[1]
Last follow-up	9.89±5.05*	9.22±5.12*	0.585[1]
Sagittal vertical axis			
Preoperative	3.43±2.54	6.36±5.46	0.007[3]
Postoperative	2.22±1.32*	2.94±1.83*	0.074[3]
Last follow-up	2.52±1.23*	4.07±2.74*	0.018[3]
Coronal vertical axis			
Preoperative	2.76±2.92	2.43±2.83	0.327[3]
Postoperative	0.87±0.85*	1.07±1.10*	0.504[3]
Last follow-up	1.13±1.07*	1.29±1.22*	0.643[3]
Pelvic incidence	58.38±9.13	53.16±8.25	0.016[1]
Instrumented vertebra number			0.355[2]
4–6	14	7	
7–9	14	15	
>9	9	10	
Interbody fusion			0.406[2]
Yes	30	24	
No	7	9	
Smoking			0.947[2]
No	31	27	
Yes	6	5	
Duration of symptoms (years)	8.86±4.38	9.22±4.67	0.628[3]

[1] Independent t-test; [2] Chi-square test; [3] Mann-Whitney U test; * Significantly different from preoperation (p<0.0167).

Table 2. Multiple comparison of lumbar lordosis, Cobb angle, SVA and CVA.

	Preoperative/postoperative	Preoperative/last follow up	Postoperative/last follow up
Lumbar lordosis			
Cohort LL	p=0.001	p=0.046	p<0.001
Cohort GL	p<0.001	p=0.058	p<0.001
Cobb angle			
Cohort LL	p<0.001	p<0.001	p=0.532
Cohort GL	p<0.001	p<0.001	p=0.501
Coronal vertical axis			
Cohort LL	p<0.001	p<0.001	p=0.105
Cohort GL	p<0.001	p<0.001	p=0.048
Sagittal vertical axis			
Cohort LL	p=0.001	p=0.015	p=0.029
Cohort GL	p<0.001	p=0.009	p=0.003

Table 3. Predictors for postoperative loss of lumbar lordosis: multiple logistic regression analysis.

Variable	Adjusted Odds Radio	95% Confidence Interval	P-value
Preoperative lumbar lordosis	0.920	0.870–0.973	0.003
Preoperative sagittal vertical axis	1.199	1.007–1.429	0.041
Pelvic incidence	0.941	0.876–1.009	0.089

in preoperative LL (p=0.002), postoperative LL (p=0.036), last follow-up LL (p<0.001), postoperative loss LL (p<0.001), preoperative SVA (p=0.007), last follow-up SVA (p=0.018), and PI (p=0.016). Univariate analysis showed statistically significant differences in preoperative LL (p=0.001), preoperative SVA (p=0.014), and PI (p=0.020). In multivariate logistic regression, preoperative LL (OR=0.920, 95% CI=0.870–0.973, p=0.003) and preoperative SVA (OR=1.199, 95% CI=1.007–1.429, p=0.041) were identify to be predictors for postoperative loss of LL, while PI (OR=0.941, 95% CI=0.876–1.009, p=0.089) failed to show significant difference (Table 3).

The receiver operating characteristic curve analysis (Figure 2) showed good accuracy for predicting loss of LL in preoperative LL (area under the curve: 0.800, p<0.001) and preoperative SVA (area under the curve: 0.689, p<0.001) (Table 4). The cutoff was defined as the value with maximum Youden index that represented the best compromise between sensitivity and specificity, which was 23.5 and 4.28 in preoperative LL and preoperative SVA, respectively (Table 4). The presence of two predictors (preoperative LL <23.5 and preoperative SVA >4.28) were significantly associated with postoperative loss of LL (p=0.001) (Table 5).

Discussion

LL is an important measurement to evaluate surgery whether preoperatively or postoperatively in patients with adult scoliosis. However, different standards of measuring LL have been used in different studies. Most studies adopted the same definition as our study: the angle between the upper end plate of L1 and the upper end plate of S1 [10,16–19]. Other measurement used in studies were the angle from the upper end plate of T12 and the upper end plate of S1 [4,5,7], and the angle from the lower end plate of T12 and the upper end plate of S1 [20]. The important thing in any study is to maintain the same method of measurement throughout the study. Loss of LL was commonly observed after long fusions arthrodesis. In the study of Lee et al. [7], the average loss of LL was 5.1±7.7 degrees from postoperative 49.9±17.0 to last follow-up 44.8±19.9 in 51 patients with mean follow-up period 69.1±31.3 months. They also observed that in the under-correction group (postoperative LL < ideal LL), the average loss of LL was to 7.2±9.4 degrees from postoperative 37.1±11.3 degrees to last follow-up 29.9±13.4 degrees. Cho et al. [6] observed 45 patients with degenerative lumbar scoliosis and found that the group L5 (caudal instrument extent to L5) lost LL at 6.6±11.4 degree and this number was significantly greater than the loss in the S1 group (caudal
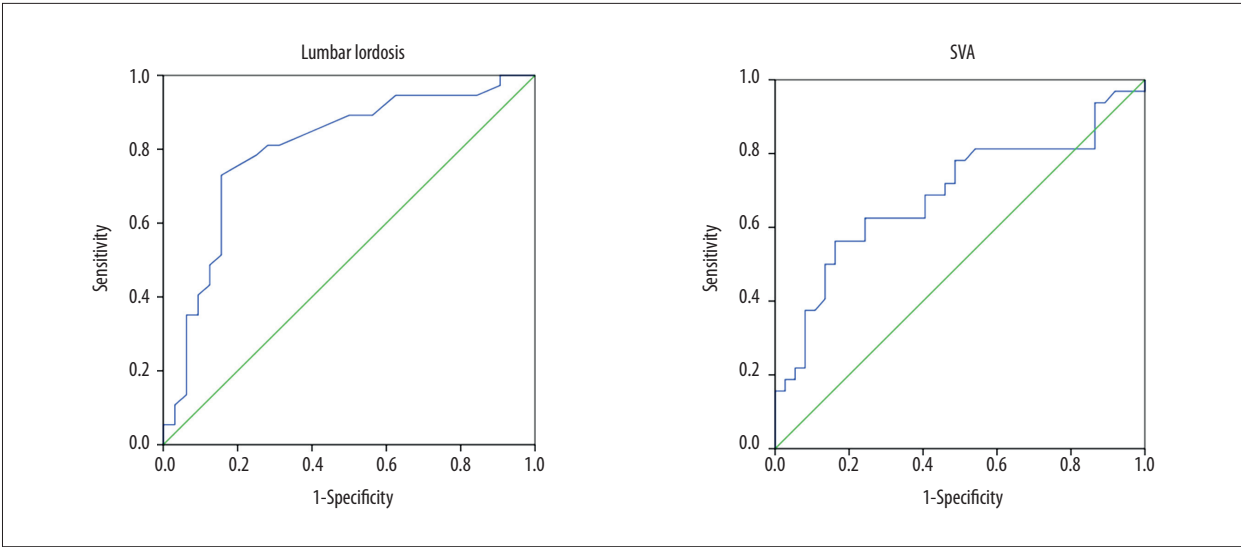
Figure 2. The receiver operating characteristic curve of LL and SVA.

Table 4. Sensitivity, specificity, AUC and cutoff of predictors.

Variable	Sensitivity	Specificity	AUC*	Cutoff	P-value
Preoperative lumbar lordosis	72.97%	84.38%	0.800	23.5	<0.001
Preoperative sagittal vertical axis	75.00%	68.89%	0.689	4.28	<0.001

* Area under the curve.

Table 5. Differences in the incidence of postoperative loss of lumbar lordosis in patients with 0, 1 or 2 predictors.

Predictor	Odds Radio	95% Confidence Interval	P-value
0 predictor	1		
1 predictor	1.450	0.554–3.790	0.449
2 predictors	6.224	2.081–18.614	0.001

instrument extent to S1) at −0.8±10.5 degrees (*p*=0.003). Our current study identified two predictors for postoperative loss of LL, which facilitated surgical decision-making in patients with adult scoliosis. Preoperative LL <23.5 and preoperative SVA >4.28 had good accuracy to predict postoperative loss of LL, especially when patients had both two predictors. Patient age, gender, BMI, Cobb angle, CVA, instrumented vertebra number, interbody fusion, smoking or not, duration of symptoms, and PI failed to be identified as predictors in this study.

Our study found that LL could be partially corrected by surgical procedure, while loss of the LL was observed in subsequent follow-up visits. Postoperative LL had a trend to revert to the original cohort. Patients with preoperative LL <23.5 suffered an average of 10.28 degree loss of LL in the last follow-up visit, while this number was only 1.76 degrees in patients with preoperative LL >23.5. High preoperative LL was identified as a risk factor for loss of LL from preoperative to

postoperative in several studies [5,21], while preoperative low LL was a risk factor for loss of LL from postoperative to last follow-up. Cobb angle was also partially corrected by surgical procedure; however, the correction was maintained in subsequent follow-up visits.

Preoperative SVA >4.28 was another predictor for loss of LL in this study. Cho et al. [6] found coronal balance maintained in good condition at follow-up period of 3.5±1.7 years, while sagittal imbalance was aggravated at the same time in patients with degenerative lumbar scoliosis; we found the same resulted in our current study. Sagittal balance was more likely to deteriorate over time after the surgery than coronal balance, especially in patients with preoperative sagittal imbalance. Preoperative high SVA has also been shown to be a risk factor of postoperative sagittal imbalance [13]. More attention about how to maintain the sagittal alignment is needed in patients with preoperative sagittal imbalance who are more likely

to suffered postoperative loss of LL and deteriorated sagittal balance. Lee et al. [7] found under-corrected LL was related to postoperative sagittal imbalance, and suggested one way to maintain sagittal alignment was by over-correction of LL. Another factor associated with deteriorated sagittal balance was subsequent disc degeneration, but the trigger remains unknown [6,22,23]. In our study, CVA was maintained in good postoperative condition, which indicated coronal balance was more stable after surgery than sagittal balance.

PI was a relatively fixed value in mature skeletons [24], so our study only measured the value on preoperative radiologic films. Trobisch et al. [5] analyzed the risk factors of loss of LL after surgery in patients with adolescent idiopathic scoliosis and found PI was not identified as a risk factor. In our study, PI was significantly greater in patients who lost more LL than who lost less LL. However, multivariate logistic regression failed to identified PI as one of the predictors for postoperative loss of LL. Interestingly, preoperative LL was one of the predictors while PI was not, even if a positive correlation was found between LL and PI in many studies [10,16,25,26]. This might be attributed to minor angle differences with statistical differences of PI in two cohorts.

This study had several limitations. First, this study was limited by its retrospective nature. Second, the study was a single-center study and there were only a limited number of patients with adult scoliosis after long fusions arthrodesis that were included. Third, the object of this study was purely radiographic measurement of data without analyzing the association with clinical outcomes. Therefore, these limitations suggest large-sample and multicenter studies would be needed to verify the results.

Conclusions

Loss of LL commonly occurred after long fusions arthrodesis in patients with adult scoliosis. Postoperative deteriorated sagittal balance was more frequent than deteriorated coronal balance. Preoperative LL <23.5 and preoperative SVA >4.28 were the predictors for postoperative greater loss of LL in patients after long fusions arthrodesis. More attention should be paid to how to maintain the LL in patients with preoperative predictors, especially if the patients have both of these identified predictors.

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