CERVICAL SPINE LORDOSIS AFTER SPINAL FUSION FOR ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objectives: To evaluate cervical lordotic angle (CLA) in patients with Adolescence Idiopathic scoliosis (AIS) following posterior spinal fusion (PSF) as well as radiological parameters such as coronal cobbs' angle, proximal and distal instrumented vertebrae.

Method: 38 patients with AIS treated with PSF surgery between 2016 and 2019 at King Hussien Medical Center were retrospectively reviewed. We measured CLA preoperatively, 6 months postoperatively and at 1 year follow up. Moreover, cobbs angle was measured preoperatively and postoperatively as well as proximal and distal instrumented vertebrae. Descriptive statistics were run using SPSS software for Windows version 22 and level of significance was set as $p < 0.05$. Paired sample t test and multiple linear regressions were applied.

Results: The mean correction rate of thoracic kyphosis (TK) was 69.5%. The mean of CLA preoperatively, at 6 month postoperatively and at 1 year postoperatively were 3.28° ± 5.05, 9.68° ± 6.05 and 15.55° ± 8.08 respectively increased significantly ($P < 0.001$). The mean preoperative Cobbs angle was 69.94° ± 14.56 and 21.36° ± 24.94 post-operatively. Mean difference between pre-operative and post-operative Cobbs angle was significant ($P<0.001$). A multiple linear regression model revealed that the CLA had a linear correlation ($R=.688$, adjusted $R2=.392$) with the preoperative CLA only.

Conclusion: We concluded that CLA increased significantly at the 1-year follow-up after posterior corrective fusion for AIS patients. Further evaluations of other sagittal parameters including the pelvic parameters are essential for analysis the sagittal outcome of AIS surgeries.

Keywords: Adolescence Idiopathic scoliosis, spinal fusion, thoracic kyphosis, cervical lordosis

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INTRODUCTION

Scoliosis is a deformity of a vertebral column that includes vertebral rotation, coronal curve and flattening of the sagittal profile (1). It's classified into structural and non-structural types (2). Structural type can also divide into idiopathic and non-idiopathic. Unfortunately, the majority of cases seen by spinal surgeons are idiopathic (2).

Adolescent idiopathic scoliosis (AIS) is a progressive deformity with an overall prevalence varying between 0.47% and 5.2% in recent literature due to the differences in methodology, age groups and sample size (3-5). AIS accounts for 80 to 85% of scoliosis cases (6). In literature, several treatment approaches have been used for the treatment

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sof AIS, including monitoring, exercise, use of braces and surgery (7-9). Meanwhile, the effectiveness of the previous mentioned approaches depends on patient's age, curve type and severity (9). Posterior spinal fusion (PSF) is the most widely used surgical approach to treat AIS (75%) followed by anterior (18%) and combined approach (7%), if conservative treatment failed (10). PSF aims to prevent curve progression and improve quality of life (6).

Various studies have been published about the effect of PSF on the correction of the coronal imbalance of the spine (11, 12) but, few were published on the effectiveness of this procedure on the sagittal balance of the cervical spine (13). Optimal sagittal balance is important to increase spinal biomechanical efficiency and decelerate adjacent segment deterioration (14). Recently, guidelines that govern surgical decision for treatment of thoracic and lumber deformity have focused on achieving sagittal spinal balance as determined by the sagittal vertical axis (SVA) and the relationship between lumbar lordosis (LL) and pelvic incidence (PI). Cervical spine alignment targets are less well recognized. This may due to variability of the normal cervical spine morphology (15). Moreover, large disparity in cervical spine alignment across normal adolescent has been reported (16).

Physiological cervical curvature is still controversial in many studies of both general population and scoliotic patients, this controversy is explained by lack of understanding of how regional, global and cervical alignments interact (15, 17). In recent studies of adult patients, it has been shown that sagittal alignment has a strong relation with health-related quality of life (18). Tang et al. have identified a similar result in AIS patients, who developed disabling neck pain due to the lack of normal lordosis of the cervical spine (19). Therefore, surgical planning for AIS has been focused on sagittal balance of the spine as an important parameter for success of the procedure. The relation between cervical lordosis (CL) and thoracic kyphosis (TK) was initially described by Hillebrand et al. (1995) who showed a significant correlation between lack of thoracic kyphosis and development of cervical kyphosis postoperatively in patients with AIS (20).

In the current study we evaluate the cervical lordotic angle in patients with AIS following PSF (preoperative and postoperative) as well as other radiological parameters such as coronal cobbs angle, proximal and distal instrumented vertebrae.

METHODS

disabling neck pain due to the lack of normal lordosis of the cervical spine (19). Therefore, surgical planning for AIS has been focused on sagittal balance of the spine as an important parameter for success of the procedure. The relation between cervical lordosis (CL) and thoracic kyphosis (TK) was initially described by Hillebrand et al. (1995) who showed a significant correlation between lack of thoracic kyphosis and development of cervical kyphosis postoperatively in patients with AIS (20). In the current study we evaluate the cervical lordotic angle in patients with AIS following PSF (preoperative and postoperative) as well as other radiological parameters such as coronal cobbs angle, proximal and distal instrumented vertebrae.

Patient population

This is a retrospective single-center study of 38 AIS patients who were surgically treated with posterior instrumentation and fusion between 2016 and 2019 at King Hussein Medical Center. Patients underwent whole spine X-Ray (anterior posterior and lateral views) preoperatively, six months and one year postoperatively. The radiographs were retrospectively analyzed with documentation of cobbs angle of the curves and cervical lordotic angle (CLA).

Patients less than 18 years, lenke type 1 to 6 AIS curve, with lumbar curve modifier A or B or C and having one year follow up after surgery with complete surgical radiograph (preoperative and postoperative) were included in the study. Whereas, patients who have congenital scoliosis or syndromic patients were excluded.

Ethical Cosiderations

Radiographs were analyzed anonymously by patient ID number. No contacts were made with patients. No additional radiographs were performed for the current study since radiographs were already performed as per protocol in our center. This study was approved by the Ethics Review Board at Royal Medical Services.

Radiological assessment:

Preoperative radiological evaluation is best assessed by new modality called EOS™ machine which is analyses the coronal, axial and sagittal parameters of the spine. EOS™ is an orthopedic medical imaging system that uses low-dose, weight-bearing x-ray technology and uses two-dimensional (2D) and three-dimensional (3D) orthopedic images. Since this modality is not available at our institute, we ordered it from private sector. Patients who were unable to do this study, Full-length standing anterior, posterior and lateral radiographs were obtained in a standardized upright position.

Lateral-view whole-spine radiographs were obtained with the patients in upright, relaxed, and "hands on clavicle" positions. The CLA (C2–7) was determined as the angle formed by the line along the posterior body of C-2 and the line along the posterior body of C-7. Thoracic kyphosis (TK; T5–12) was defined as the Cobb angle between the cranial endplate of T-5 and the caudal endplate of T-12. The CLA was measured immediately before urgery, 6 months after surgery, and 1 year after surgery whereas, TK was measured immediately before and after surgery.

Surgical Procedure

All patients underwent pedicle screws construct surgery by two senior spine surgeons using posterior approach. All the screws inserted with free hand technique with C Arm assistance, facetectomies of the fused levels, posterior release, pontes osteotomies in rigid cases and applying of bone graft after correction of the deformities. Freehand pedicle screw insertion technique is an accurate, reliable and safe technique used to avoid morbidity associated with radiation exposure, increased time expenditure, and possible workflow interruption (21, 22). **Figure 1**

Patiemts Classification

Patients were classified according to Lenke classification system for AIS (23). Lenke classification system has three components: "curve type (1 through 6), a lumbar spine modifier (A, B, or C), and a sagittal thoracic modifier (-, N, or +). The six curve types have specific characteristics, on coronal and sagittal radiographs, that differentiate structural and nonstructural curves in the proximal thoracic, main thoracic, and thoracolumbar/lumbar regions. The lumbar spine modifier is based on the relationship of the center sacral vertical line to the apex of the lumbar curve, and the sagittal thoracic modifier is based on the sagittal curve measurement from the fifth to the twelfth thoracic level. A minus sign represents a curve of less than +10 degrees, N represents a curve of 10 degrees to 40 degrees, and a plus sign represents a curve of more than +40 degrees".

Moreover, patients were classified according to spinal skeletal maturity based on Risser classification system. Risser system "divided the steps of ossification and fusion of the iliac apophysis into six stages (Risser Stages 0–5), with the higher numbers describing advancement toward skeletal maturity. Stage 0 describes an x-ray on which no ossification center is seen in the apophysis, whereas Stage 5 represents complete ossification and fusion of the iliac apophysis" (24).

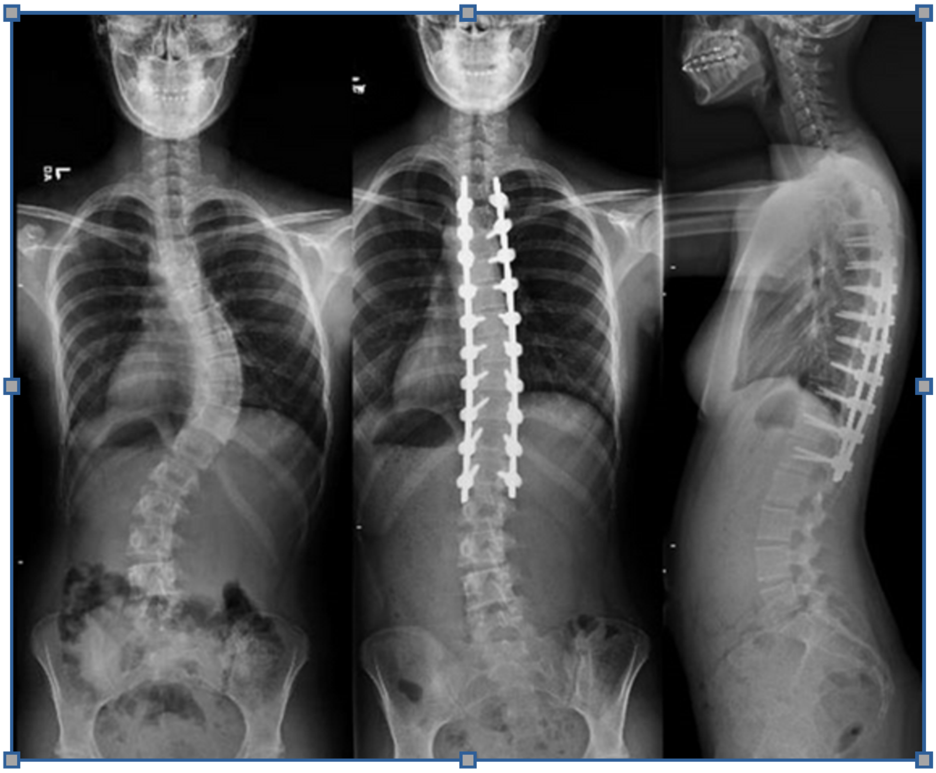

Figure (1): preoperative and postoperative (anterior posterior and lateral view) image for patient with AIS showing correction with posterior approach and pedicle screws construct

Statistical Analysis

Descriptive statistics were run using Statistical Package for the Social Sciences (SPSS) software for Windows version 22 and level of significance was set as $p < 0.05$. Normal distribution of variables was tested with Kolmogorov– Smirnov procedure. Mean (M), standard deviation (SD), and proportion were applied to summarize sample characteristics. Paired sample t test was run to compare between groups with regard to radiographic parameters (pre and postoperation).

Furthermore, multiple linear regression analysis (Enter method) was applied to define the relationship between the latest follow-up CLA and preoperative or immediate postoperative radiographic parameters.

RESULTS

A total of 38 AIS patients were included in the study. There were 36 (84.2%) females and 6 (15.8%) male patients. Mean age of patients at intervention time was 15.68 ± 1.29 years (range 13-18).

Regarding Lenke classification system, 15 patients were classified into Lenke type 1, 1 patient was type 2, 19 patients were type 3 and 1 patients was type 5 (figure 2). Also, 15 patients were classified into the Lenke sagittal modifier "-", 12 patients into "N", and 11 patients into "+" **(figure 3)**.

Spinal skeletal maturity of patients was classified according to Risser classification system as follows: 3 patients at stage 3 (7.9%), 22 patients at stage 4 (57.9%) and 13 patients at stage 5 (34.2%). Furthermore, mean of Risser stage was 4.26 ± .60 (range 3-5). The upper and lower instrumented vertebral distributions are presented in **Table 1**.

Patients' characteristics and radiographic parameters are presented in **Table 2**.

Radiographic Results

Cervical lordotic angle: the mean preoperative cervical lordotic angle was 3.28° ± 5.05 and 9.68° ± 6.05 postoperatively (after 6 months). Mean difference in cervical lordotic angle between pre operation and 6 month after operation was significant ($P<0.001$). Moreover, the mean post- operative cervical lordotic angle (after 12 month) was 15.55° ± 8.08. Mean difference in cervical lordotic angle between 6 month post operation and 12 month post operation was significant ($P<0.001$).

Cobbs angle: the mean preoperative Cobbs angle was 69.94° ± 14.56 and 21.36° ± 24.94 post-operatively. Mean difference in Cobbs angle between pre-operative and post-operative measurements was significant ($P<0.001$). The mean correction rate was 69.5%. **Table (3)**

Logistic Regression

Enter method of multiple linear regression analysis was adopted to explore predictors of post-operative CLA.

A multiple linear regression model revealed that the CLA had a linear correlation ($R=.688$, adjusted $R2=.392$) with the equation composed of preoperative CLA only (table 4). The equation was shown as follows: Post-operative CLA= 17.154 + 1.063 × pre-operative CLA

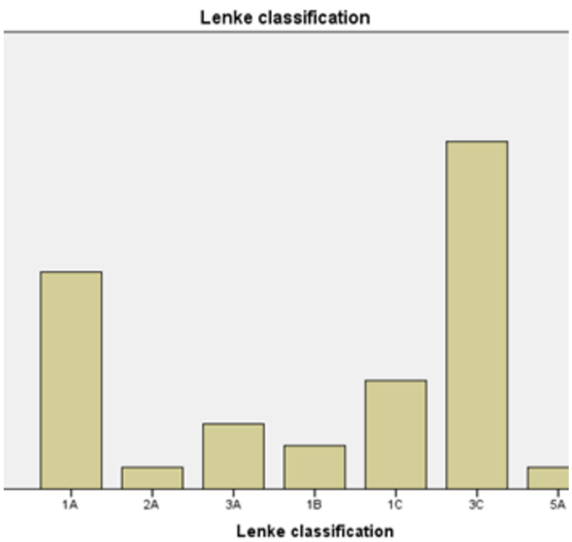

Figure (2): Lenke classification

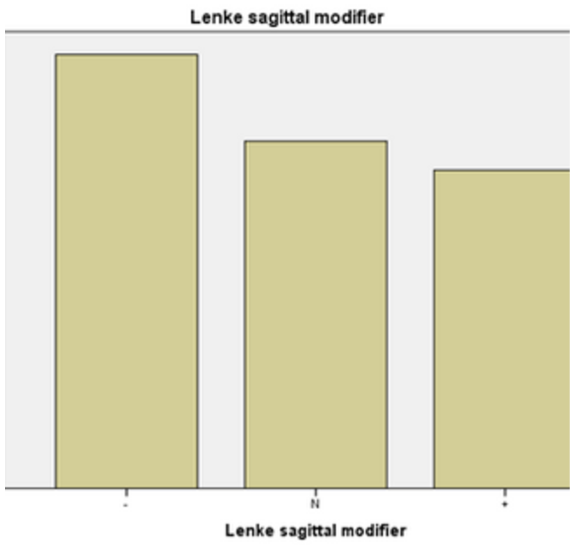

Figure (3): lenke Sagittal Modifier

Table 1 : Patient Characteristics

Patients NO	Age	Gender	Lenke type	Risser stage	CLA pre op	CLA post op (6 month)	CLA post op (12 month)	TK pre op	TK post op	LIL	UIL
1	17	M	1B	5	2	16	20	92	18	L3	T2
2	15	F	1A	4	4	11	16	62	12	L3	T2
3	16	F	1C	4	5	16	20	55	15	L3	T4
4	16	M	3C	4	7	14	22	110	45	L5	T3
5	16	F	1A	4	6	10	17	72	22	L3	T4
6	16	F	1A	5	12	18	22	65	18	L2	T4
7	14	F	1C	3	0	8	12	65	10	L4	T4
8	14	F	3C	3	-8	0	6	92	40	L4	T2
9	14	F	1B	4	2	2	8	65	18	L2	T3
10	16	F	1C	4	3	14	18	60	10	L4	T4
11	15	F	3C	4	11	18	24	65	25	L3	T2
12	15	F	3C	4	10	16	22	60	10	L4	T4
13	17	F	3C	5	8	13	20	55	15	L3	T2
14	16	F	3A	5	2	12	18	65	15	L3	T3
15	16	F	1C	4	-2	8	20	60	10	L4	T4
16	14	M	3C	4	-2	8	20	75	20	L4	T4
17	14	F	1C	4	-4	-4	8	65	20	L2	T2
18	13	F	3C	3	2	12	18	55	5	L4	T4
19	17	F	1A	5	2	2	4	50	5	L1	T3
20	16	F	3A	5	6	12	22	70	15	L3	T3
21	14	F	1A	4	-2	0	2	65	15	L4	T3
22	14	F	3C	4	6	10	12	85	20	L4	T4
23	15	M	3A	5	0	2	6	55	12	L4	T4
24	16	F	3C	4	10	22	30	65	10	L4	T3
25	17	F	3C	4	12	20	42	90	20	L3	T3
26	15	F	2A	4	2	4	4	60	5	L3	T2
27	14	M	5A	4	-5	8	12	75	25	L5	T10
28	17	F	1A	5	0	2	6	55	5	L2	T2
29	18	F	3C	5	2	10	16	50	0	L3	T2
30	17	F	3C	5	6	12	18	85	157	L4	T2
31	18	F	1A	5	6	10	18	70	15	L3	T2
32	18	F	3C	5	-8	0	2	65	20	L4	T3
33	16	F	3C	4	8	12	12	55	10	L3	T3
34	15	M	3C	4	6	12	18	88	45	L4	T3
35	16	F	1A	4	4	8	10	80	22	L3	T3
36	16	F	1A	4	8	10	12	95	40	L2	T2
37	16	F	1A	4	0	12	20	70	18	L2	T4
38	17	F	3C	5	4	8	14	92	25	L3	T3

Table 2: Patients' characteristics and radiographic parameters included in the study

Variables	M	SD	Min	Max
Age (yrs)	15.68	1.29	13.00	18.00
Riser grade	4.26	0.60	3.00	5.00
CLA				
Pre-operation	3.28	5.05	-8.00	12.00
Post operation (6 month)	9.68	6.05		
Post operation (12 month)	15.55	8.08	-4.00	22.00
			2.00	42.00
Cobbs angle				
Pre operation	69.94	14.56	50.00	110.0
Post operation	21.36	24.94	0.00	157.0
Variable	N	%		
Gender				
Male	6.00	15.8		
Female	32.00	84.2		

CLA: cervical lordotic angle, M: mean, SD: standard deviation, N: number, %: frequency, Min: minimum, Max: maximum

Table 3 : Comparison of Radiographic Parameters pre- and post-operation

	Preoperative		P value	Postoperative (6 months)		P value	Post-operative (12 months)	
	M	SD		M	SD		M	SD
CLA	3.28	5.05		9.68	6.05		15.55	8.08
			<0.001*			<0.001*		
	Preoperative		P value	Postoperative				
	M	SD		M	SD			
Cobbs angle	69.94	14.56		21.36	24.94			
			<0.001*					

CLA: cervical lordotic angle, M: mean, SD: standard deviation, * paired sample t test
Table (4): Multiple linear regression model shows correlations between the CLA and radiographic parameters (pre- and post-operative)

Table 4 : Correlation and Prediction Rates to the Multiple Linear Regression Model

R	R^2	Adjusted R^2	Std. error of the estimate
.688	.474	.392	6.309

B. Intercept and coefficients of the multiple linear regression

	Unstandardized coefficients		Standardized coefficients	t	Sig
Model	B	SE	B	B	SE
(Constant)	17.154	14.696		1.167	.252
CLA pre-op	1.063	.210	.665	5.068	.001
Cobbs angle pre-op	.025	.149	.045	.168	.867
Cobbs angle post-op	-.025	.049	-.077	-.503	.619
Riser stage	-1.446	1.835	-.107	-.788	.436
Lenke sagittal modifier	1.502	2.531	.154	.593	.557

CLA: cervical lordotic angle

DISCUSSION

At King Hussein Medical Center, our choice of surgical treatments for AIS is consistent with best practice recommendation of clinical trials studying surgical outcomes of AIS. Surgical decision depends on overall curve size and pattern, curve progression and skeletal maturity (9). Even though, those patients with skeletal immaturity, cobbs angle over 40° and/or curve progression showing continuous progression, surgical choice is considered (25). In the present study, mean riser grade was 4.26 and majority of patients (92.1%) had grade 4 and 5. Furthermore, prevention of curve progression, adequate coronal and sagittal realignment, and the preservation of as much motion as possible were reported as the main goal of surgery (25). In our study, 38 AIS patients were surgically treated with PSF approach. Literatures have shown advantages of PSF approach compared with anterior spinal fusion (ASF) and combined approach as it has the same correction rate as combined with other approaches and without negative impact on pulmonary function (26-29). Moreover, significant improvement in self-image and satisfaction were reported among AIS patients treated with PSF approach compared to non-operative treated AIS patients (30).

Although spinal fusion surgery is relatively safe but, complications were reported in 5% to 25% of cases (10). Therefore, surgeons should inform patients about the possibility of complications, such as dural tears, peripheral neuropathy, surgical-site infections, implant-related issues, thromboembolic events, visual loss, pseudarthrosis, crankshaft phenomenon, flatback phenomenon and proximal junctional kyphosis (10).

The current study aimed to quantify the changes in CLA in patients with AIS following PSF (pre-operation and post-operation) as well as other radiological parameters such as coronal cobbs angle, proximal and distal instrumented vertebrae. Cobbs angle significantly decreased from 69.94° preoperatively to 21.36° postoperatively, with correction rate around 70%. Whereas, the CLA was significantly increased from 3.28° preoperatively to 15.55° one year after posterior corrective surgery. Elnady et al. reported a similar improvement in thoracic kyphosis in a cohort of 50 patients with less severe deformities, as they found that average preoperative thoracic Cobb angle of 38.4° corrected to 30.36° (31). Another study including 51 AIS patients who underwent PSF reported an improvement in coronal thoracic curve with correction rate equal to 69.8% and significant increase of CLA after two years of surgery (32). The previous study also noted that patients with preoperative cervical kyphosis or small angles cervical lordosis had less improvement of cervical lordosis postoperatively. In contrast, Calado et al. study showed that patients who had greater value of CLA preoperatively developed a greater variation in postoperative period (33).

In literature, there are few reports about the effects of scoliosis surgery on cervical spine sagittal alignment. This issue is examined first by Hilibrand et al. (1995) who confirmed a positive correlation between preoperative CLA and TK. Moreover, those patients with preoperative hypo TK showed no progression of cervical kyphosis whereas, patients with normal TK showed significant increase in CLA at one year follow up (20).

Cervical kyphosis could be associated with cervical myelopathy or accompanying symptoms such as neck pain (34, 35).
This study showed that thoracic kyphosis can be improved with PSF surgery. However, there is no clear evidence of whether this treatment has a significant impact on the cervical spine or not. Multiple linear regressions showed a strong correlation between preoperative CLA and postoperative CLA and preoperative CLA was the only predictor for postoperative CLA. Hayashi K et al. study revealed that preoperative small CLA and small TK measurements were independent risk factors for postoperative cervical kyphosis (32). Recent study revealed that changes occurred in CLA after scoliosis surgery can occur in a linear correlation after sufficient restoration of thoracic kyphosis (36). Cho et al. study showed an improvement in cervical sagittal alignment after correction surgery (37). These conflicting statements have resulted from lack of consensus on what constitutes normal cervical spine alignment and how cervical alignment interacts with regional and global alignment.

To the best of our knowledge, the present study is the first conducted in Jordan that quantifying changes in CLA in patients with AIS following PSF surgery. However, the present study has some limitation, including retrospective design. The sample size was small and authors didn't observe the thoracic kyphosis in all patients, because most of them were referred from peripheral hospitals. Follow-up period was short therefore; authors can't explore future complications related to the cervical spine which include chronic neck pain and cervical myelopathies.

CONCLUSION

We demonstrated that CLA increased significantly at the 1-year follow-up after posterior corrective fusion for AIS patients. Further evaluations of other sagittal parameters, including the pelvic parameters are essential for analysis of the sagittal outcome of AIS surgeries. A longer follow up can further help to assess and confirm the results.

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