CLINICAL ARTICLE

Anterior Selective Lumbar Fusion Saving More Distal Fusion Segments Compared with Posterior Approach in the Treatment of Adolescent Idiopathic Scoliosis with Lenke Type 5: A Cohort Study with More Than 8-Year Follow-up

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Objective: To investigate whether anterior selective fusion (ASF) could save more distal fusion segments compared with posterior approach in the treatment of Lenke type 5 adolescent idiopathic scoliosis with long term follow-up.

Methods: A retrospective cohort study. From 2008 to 2011, 22 AIS girls with Lenke type 5 who underwent ASF or posterior selective fusion (PSF) with more than 8-year follow-up, were extracted from the database. 13 girls in the ASF group had an average age of 14.3 ± 1.3 years and Risser sign of 3.3 ± 1.1; 9 PSF girls had an average age of 16.2 ± 3.6 years and Risser sign of 3.8 ± 1.5. The radiographic outcome was compared between groups preoperatively, 6-month postoperatively, 8-year postoperatively and at last follow-up (>8 years).

Results: The average follow-up duration was 8.7 ± 0.4 (ASF) and 8.8 ± 0.5 (PSF) years, respectively. There was no significant difference at baseline in age, Risser sign and preoperative curve pattern in the coronal and sagittal plane between the groups ($P > 0.05$). The ASF group had significantly shorter fusion segments (5.1 ± 0.6 vs. 7.0 ± 1.3) and decreased upper instrumented vertebra (UIV) ($T_{11} \pm 0.8$ vs. $T_{10} \pm 0.8$) than the PSF ($P < 0.05$); while no significant difference was found in the lower instrumented vertebra (LIV) and distal reserved segments ($P > 0.05$), which suggested that ASF could shorten the fusion segments by lowering UIV. The distal compensatory curve in the ASF group ($9.0° \pm 3.9°$) was significantly larger than in the PSF group ($3.3° \pm 2.4°$, $P = 0.003$), despite of no significant difference in the incidence of coronal imbalance ($P > 0.05$), indicating that both two approaches could obtain satisfactory correction in the coronal plane. In the sagittal plane, PSF patients had significantly larger lumbar lordosis (LL, $59.1° \pm 10.5°$), thoracic kyphosis (TK, $37.2° \pm 13.3°$) and proximal junctional angle (PJA, $13.3° \pm 6.1°$) at the last follow-up than the ASF (LL: $43.4° \pm 9.4°$; TK: $20.7° \pm 8.4°$; PJA: $4.7° \pm 3.4°$; $P < 0.05$), but without significant difference in proximal junctional kyphosis (PJK) and sagittal vertical axis (SVA) ($P > 0.05$). After controlling for age, Risser sign, and radiographic parameters related to the primary curve pattern, shorter fusion segments and more distal

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reserved segments still remained significant in the ASF group with greater Risser sign (*P* < 0.05). No major intra- or post-operative complications occurred.

Conclusions: Both ASF and PSF could obtain satisfactory coronal and sagittal correction for Lenke 5 AIS; compared with PSF, ASF could shorten the fusion segments by lowering UIV, and save more distal fusion segments only in patients with greater skeletal maturity.

Key words: Adolescent idiopathic scoliosis; Anterior; Approach; Posterior; Selective fusion

Introduction

Selective lumbar fusion was widely applied as the standard treatment for adolescent idiopathic scoliosis (AIS) with Lenke type 5, but the choice of surgical approach is still controversial[1]. Anterior selective fusion (ASF) has the advantages of better derotation and shorter fusion segments. After the selective correction and fusion for the primary thoracolumbar/lumbar (TL/L) curve, the thoracic curve would spontaneously be corrected[2,3]. Watkins *et al.*[4] reported that ASF with single rod instrumentation was able to maintain lumbar lordosis (LL) satisfactory alignment with 2-year follow-up. However, there was a risk of the occurrence of junctional kyphosis or pseudarthrosis[3]. With rapid development in recent years, the pedicle screw system was able to realign the scoliotic spine with powerful derotation and significantly reduce the occurrence of postoperative coronal decompensation[5,6]. However, longer fusion segments, paravertebral muscle injury, and so on, were the inevitable complications for the posterior selective fusion (PSF)[7].

Therefore, many studies have compared the clinical and radiographic outcomes between ASF and PSF in the treatment of Lenke 5 AIS[7–12]. In 2016, Luo *et al.*[9] conducted a meta-analysis on the outcomes of selective fusion with different approaches in Lenke 5 AIS. A total of seven case-control studies and 308 cases were included. It was shown that there was no significant difference between ASF and PSF patients in the curve magnitude and correction rate of the primary curve at the last follow-up in the coronal plane. PSF could obtain greater LL in the sagittal plane, whereas, ASF could save more than one segment than PSF. The results were consistent with that of another meta-analysis[12], which included 35 studies on the selective fusion for Lenke 5 AIS. It was reported that both ASF and PSF could obtain satisfactory correction, and there was no significant difference in the coronal correction between the two groups, but PSF showed better correction of thoracic kyphosis (TK) in the sagittal plane[12].

One of the goals of AIS surgical management was to save motion segments as many as possible[13]. However, whether the anterior approach could save the distal segments in Lenke 5 AIS is still controversial. Therefore, the purpose of the present study was to compare the correction outcome in Lenke 5 AIS between ASF and PSF groups, to explore whether ASF could save more distal fusion segments compared with PSF, and to investigate the intraoperative and postoperative complications with more than 8-year follow-up.

Methods and Materials

General Information

A retrospective cohort study, from January 2008 to December 2011, found 121 AIS patients with Lenke type 5 who had undergone selective lumbar fusion and were extracted from our database. Inclusion and exclusion criteria: (i) AIS girls with Lenke type 5; (ii) primary TL/L curve more than 40°; (iii) without pelvic deformity, previous spinal fracture, or other diseases which might affect the spinal balance; (iv) one-stage ASF surgery using a single rod with structural cages or PSF surgery with pedicle screw instrumentation; (v) minimum of 8 years of follow-up; and (vi) without incomplete radiographic data. According to the inclusion and exclusion criteria, 22 cases were extracted from our database. 13 girls in the ASF group had an average age of 14.3 ± 1.3 years and Risser sign of 3.3 ± 1.1, and the average TL/L curve magnitude was 42.5° ± 3.0°; and nine girls in the PSF group had an average age of 16.2 ± 3.6 years and Risser sign of 3.8 ± 1.5, and the average TL/L curve magnitude was 46.4° ± 7.8° (Table 1). The average follow-up duration was 8.7 ± 0.4 and 8.8 ± 0.5 years, respectively. All the informed consents were received from their parents. The present study was approved by the hospital ethics committee.

Surgical Methods

ASF

ASF was performed through an anterior thoracoabdominal approach in the right decubitus position under general anesthesia. The Hall fusion selection principle was applied for the selection of fusion levels[14]. After exposure of the vertebral region to be fused, thorough discectomies within this region would be performed. A titanium mesh cage (Medtronic, Sofamor, Danek) with bone graft was placed into every prepared intervertebral space. A pre-contoured rod was connected with screws placed in the instrumented region. A derotation maneuver and inter-segmental compression were then performed to achieve a normal TL/L alignment (Fig. 1).

PSF

PSF was performed in the prone position under general anesthesia. The fusion levels were chosen according to the Lenke criteria[15]. The surgical techniques involved pedicle screw instrumentation and Ponte osteotomy, rod manipulation, direct apex vertebra derotation technique, with local bone grafts from the spinous process and iliac bone. The

TABLE 1 Comparisons of the radiographic parameters related to the curve pattern and surgical fusion between the ASF and PSF group

Parameters	ASF group ($n = 13$)	PSF group ($n = 9$)	*P* value
UEV of thoracic curve [a]	5 ± 1.2 (T_5 ± 1.2)	5 ± 1.6 (T_5 ± 1.6)	0.431
UEV of TL/L curve [a]	11 ± 0.9 (T_{11} ± 0.9)	11 ± 0.4 (T_{11} ± 0.4)	0.324
LEV of TL/L curve [a]	15 ± 0.6 (L_3 ± 0.6)	15 ± 0.3 (L_3 ± 0.3)	0.845
Thoracic curve segments number [a]	6.2 ± 1.0	6.9 ± 1.5	0.262
TL/L curve segments number [a]	5.6 ± 0.7	5.3 ± 0.5	0.393
Apex rotation of thoracic curve [a]	1.0 ± 0.4	0.8 ± 0.4	0.211
Apex rotation of TL/L curve [a]	2.8 ± 0.4	3.1 ± 0.3	0.357
Thoracic curve flexibility *	0.605 ± 0.260	0.563 ± 0.312	0.492
TL/L curve flexibility *	0.600 ± 0.190	0.608 ± 0.188	0.926
UIV [a]	11 ± 0.8 (T_{11} ± 0.8)	10 ± 0.8 (T_{10} ± 0.8)	0.003
LIV [a]	15 ± 0.4 (L_3 ± 0.4)	16 ± 1.1 (L_4 ± 1.1)	0.209
Fusion segments number [a]	5.1 ± 0.6	7.0 ± 1.3	0.002
Distal reserved segments number [a]	2.9 ± 0.4	2.2 ± 1.1	0.209

ASF, anterior selective fusion; LEV, lower end vertebrae; LIV, lower instrumented vertebrae; PSF, posterior selective fusion; TL/L, thoracolumbar/lumbar; UEV, upper end vertebrae; UIV, upper instrumented vertebrae.; * means the comparisons between the two groups using independent *t* test; [a] means the comparisons between the two groups using Mann–Whitney *U* test.

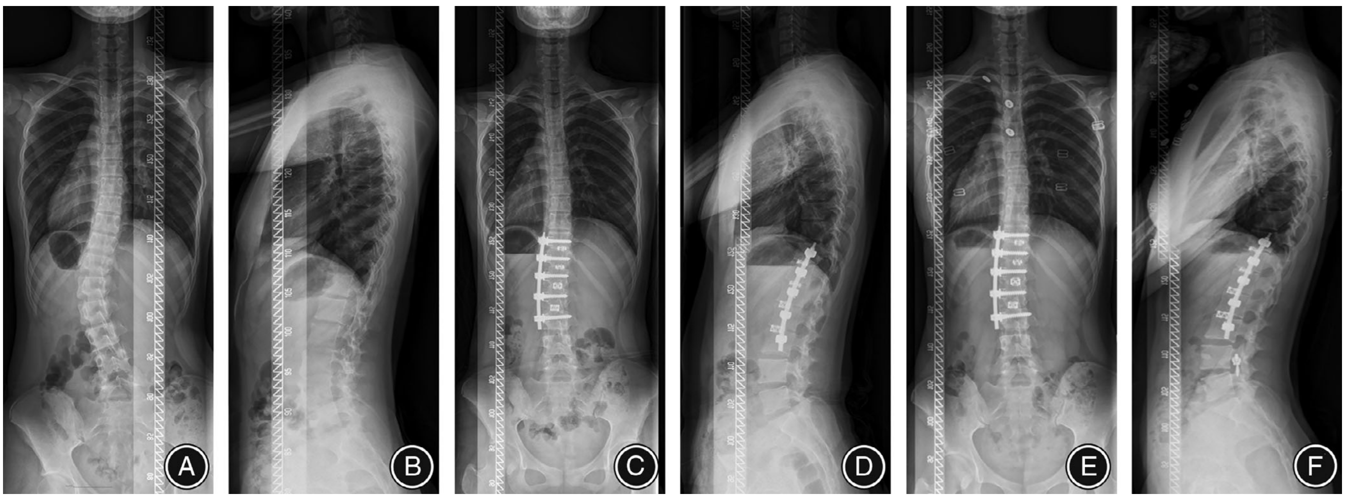

Fig. 1 A 14-year-old adolescent idiopathic scoliosis (AIS) girl, Lenke 5CN, anterior selective fusion. (A and B) Preoperative standing full-spine radiographs, TL/L curve magnitude of 40°, thoracic curve magnitude of 20° and sagittal vertical axis (SVA) of 1 mm. (C and D) 6-month postoperatively, TL/L curve magnitude of 2°, thoracic curve magnitude of 12° and SVA of 24 mm. (E and F) At the last follow-up, TLf/L curve magnitude 2°, thoracic curve magnitude of 5° and SVA of 24 mm, suggesting that no coronal and sagittal imbalance occurred.

specific screw-rod instrumentation systems used were the CDH Legacy system (Medtronic, Sofamor, Danek) (Fig. 2).

Radiographic Measurements

The comparisons of radiographic parameters were made between the groups preoperatively, 6-month postoperatively, 8-year postoperatively and at last follow-up (>8 years) with standing full-spine anteroposterior radiographs[16].

Coronal parameters: thoracic and TL/L curve magnitude, apex rotation (Nash-Moe method[17]), flexibility[10], fusion segments, upper instrumented vertebra (UIV), lower instrumented vertebra (LIV)[18], distal compensatory curve magnitude, trunk translation[19], LIV distal segments number, UIV disc angle (UIVDA), and LIV disc angle (LIVDA)[20] were included.

If the LIV distal compensatory curve was more than 5° and accompanied with UIVDA greater than 5° during the follow-up, it was regarded as an adding-on phenomenon[21,22] which was indicated the coronal imbalance.

Sagittal parameters: TK ($T_{4\text{-}12}$), LL (T_{12}-S_1), sacral slope (SS), sagittal vertical axis (SVA), thoracolumbar junction angle (TLJ) (T_{10}-L_2), and proximal junctional angle (PJA[23]) which was the angle between the lower endplate of UIV and the upper endplate of the second vertebral body above it.

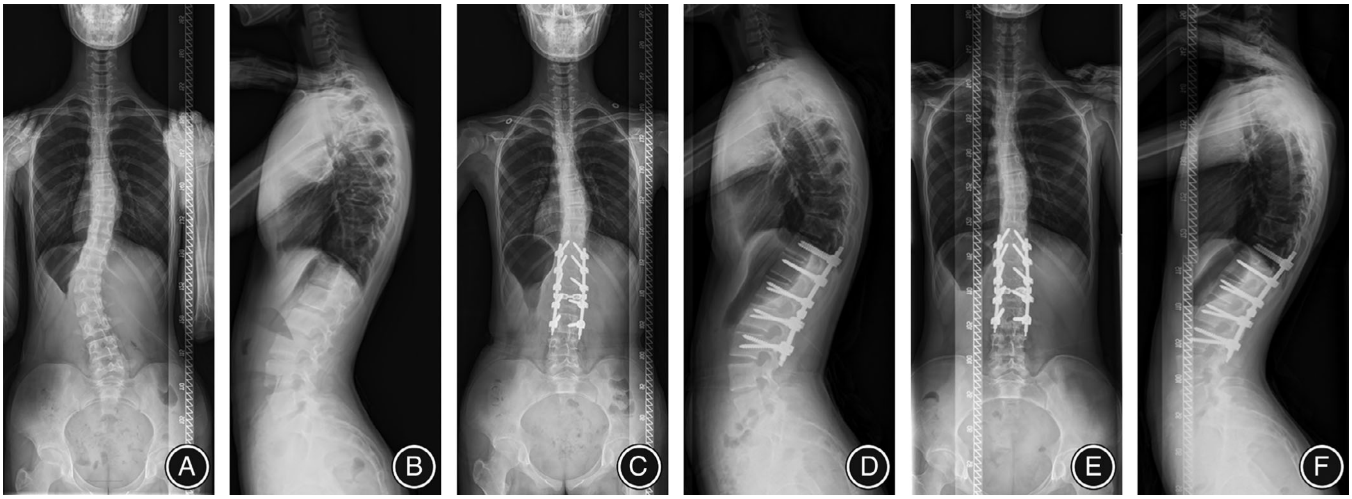

Fig. 2 A 18-year-old AIS girl, Lenke 5CN, posterior selective fusion. (A and B) Preoperative standing full-spine radiographs, TL/L curve magnitude of 40°, thoracic curve magnitude of 23° and SVA of 26 mm. (C and D) 6-month postoperatively, TL/L curve magnitude of 2°, thoracic curve magnitude of 16° and SVA of −16 mm. (E and F) At the last follow-up, TL/L curve magnitude 1°, thoracic curve magnitude of 14°, SVA of 3 mm, and proximal junctional angle (PJA) of 20°, suggesting that proximal junctional kyphosis (PJK) occurred in the sagittal plane.

If the postoperative PJA was greater than 10° and increased by more than 10° comparing with the preoperative PJA, it would be considered as proximal junctional kyphosis (PJK)[24,25] which was indicated in the sagittal imbalance. All imaging data were measured three times by the same surgeon with Surgimap 2.2.15 software (Nemaris, New York, NY, USA), and the average value of these three measurements was taken.

Statistical Analysis

The data were expressed as mean ± standard deviation (SD). For data that was normally or approximately normally distributed, a two-tailed student *t*-test was used to study the difference between groups. For skewed data or those with unconfirmed normality, the Mann–Whitney test was used for group comparison. Chi-square test (χ^2) was used to compare the incidence between the ASF and PSF groups. Multilinear regression analysis was used to compare the difference in the fusion segments and distal reserved segments (dependent variables) between ASF and PSF groups ($Group_{ASF/PSF}$, independent variable) with controlling age, Risser sign, and TL/L curve parameters (independent variable). In the regression model, the ASF group was assigned a value of "0" and the PSF group was "1." All the statistical analysis was performed with SPSS 17.0 software (SPSS, Chicago, IL, USA). In all tests, $P < 0.05$ was considered statistically significant.

Results

Comparisons at Baseline

There was no significant difference at baseline in age, Risser sign, and follow-up duration between the ASF and PSF groups ($P > 0.05$). The radiographic parameters related to the curve pattern had no significant difference in the curve magnitude, apex rotation, flexibility, upper end vertebra (UEV) and lower end vertebra (LEV) of the thoracic and TL/L curves between the two groups ($P > 0.05$, Tables 1 and 2). The ASF group showed significantly shorter fusion segments (5.1 ± 0.6) and decreased UIV (T11 ± 0.8) than the PSF (fusion segments: 7.0 ± 1.3; UIV: T10 ± 0.8; $P < 0.05$), but no significant difference was found in LIV and distal reserved segments number between groups ($P > 0.05$, Table 2), suggesting that the anterior approach was able to shorten the fusion segments by lowering UIV.

Comparisons of the Coronal and Sagittal Profile

The average correction rates of TL/L curve were 87.4% ± 10.1% and 85.6% ± 5.8% in the ASF and PSF groups, and the spontaneous correction rates of the thoracic curve were 54.4% ± 16.9% and 68.8% ± 24.0%, respectively; while, they had no significant difference between the two groups ($P > 0.05$). LIVDA (ASF: 6.1° ± 3.3° *vs* PSF: 2.5° ± 1.9°) and distal compensatory curve (ASF: 9.0° ± 3.9° *vs* PSF: 3.3° ± 2.4°) at the last follow-up in the ASF group were significantly greater than in the PSF group ($P < 0.05$), but the occurrence of adding-on phenomenon had no significant difference between the two groups ($P > 0.05$, Table 2). Meanwhile, UIVDA and trunk translation at the last follow-up had no significant difference between the two groups ($P > 0.05$).

In the sagittal plane, LL and TK in the ASF group had no significant difference from preoperatively to the last follow-up ($P > 0.05$); however, in the PSF group, both LL and TK became greater significantly from preoperatively (LL: 53.4° ± 13.5°; TK: 24.1° ± 12.1°) to the last follow-up (LL: 59.1° ± 10.5°; TK: 37.2° ± 13.3°; $P < 0.05$). The preoperative LL and TK had no significant difference between the

TABLE 2 Comparisons of the coronal and sagittal radiographic parameters between the two groups

Parameters	ASF group (n = 13)	PSF group (n = 9)	P value
TL/L curve magnitude (°)			
Preoperation *	42.5 ± 3.0	46.4 ± 7.8	0.182
6-month postoperation *	5.4 ± 4.4	6.8 ± 3.1	0.400
Correction rate *	0.874 ± 0.101	0.856 ± 0.058	0.623
Last follow-up *	7.1 ± 6.4	6.9 ± 5.2	0.966
Correction loss rate at the last follow-up *	0.057 ± 0.077	0.016 ± 0.035	0.156
Thoracic curve magnitude (°)			
Preoperation *	23.9 ± 5.5	23.8 ± 6.7	0.956
6-month postoperation *	11.2 ± 4.9	7.6 ± 6.3	0.152
Correction rate *	0.544 ± 0.169	0.688 ± 0.240	0.112
Last follow-up *	14.5 ± 8.0	9.1 ± 5.7	0.104
Correction loss rate at the last follow-up *	0.192 ± 0.302	0.164 ± 0.243	0.820
UIVDA (°)			
Preoperation *	1.6 ± 1.7	2.1 ± 2.0	0.606
6-month postoperation *	1.1 ± 1.0	2.6 ± 1.9	0.025
Last follow-up *	2.7 ± 2.0	2.2 ± 1.8	0.634
LIVDA (°)			
Preoperation *	2.9 ± 1.7	4.4 ± 3.3	0.134
6-month postoperation *	3.2 ± 2.0	2.4 ± 1.8	0.387
Last follow-up *	6.1 ± 3.3	2.5 ± 1.9	0.012
Distal compensatory curve (°)			
Preoperation *	4.2 ± 2.9	4.6 ± 3.9	0.565
6-month postoperation *	5.0 ± 2.5	3.0 ± 1.9	0.088
Last follow-up *	9.0 ± 3.9	3.3 ± 2.4	0.003
Adding-on (n, %) #	3/13, 23%	0/9, 0%	0.240
Trunk translation (mm)			
Preoperation *	18.2 ± 10.0	17.2 ± 9.7	0.830
6-month postoperation *	28.2 ± 21.4	22.2 ± 10.7	0.252
Last follow-up *	11.2 ± 10.0	12.4 ± 7.7	0.748
Coronal spinal imbalance (n, %)#	3/13, 23%	0/9, 0%	0.240
SS (°)			
Preoperation *	32.9 ± 10.0	37.6 ± 7.7	0.250
6-month postoperation *	28.9 ± 9.7	33.7 ± 7.4	0.229
Last follow-up *	30.4 ± 8.3	37.2 ± 7.7	0.070
LL (°)			
Preoperation *	44.8 ± 11.7	53.4 ± 13.5	0.125
6-month postoperation *	35.8 ± 9.8	53.2 ± 12.4	0.001
Last follow-up *	43.4 ± 9.4	59.1 ± 10.5	0.002
TK (°)			
Preoperation *	20.7 ± 10.5	24.1 ± 12.1	0.487
6-month postoperation *	18.2 ± 10.7	29.1 ± 10.7	0.029
Last follow-up *	20.7 ± 8.4	37.2 ± 13.3	0.002
TLJ (°)			
Preoperation *	10.1 ± 6.6	9.1 ± 7.2	0.739
6-month postoperation *	7.2 ± 4.4	6.2 ± 4.9	0.598
Last follow-up *	11.2 ± 7.8	9.5 ± 6.4	0.594
PJA (°)			
Preoperation *	4.1 ± 3.0	6.2 ± 5.0	0.128
6-month postoperation *	4.3 ± 3.0	8.3 ± 7.6	0.081
Last follow-up *	4.7 ± 3.4	13.3 ± 6.1	0.001
PJK (n, %)#	0/13, 0%	2/9, 22.2%	0.156
SVA (mm)			
Preoperation *	13.9 ± 13.6	24.6 ± 22.4	0.117
6-month postoperation *	22.4 ± 16.4	27.4 ± 15.9	0.481
Last follow-up *	19.2 ± 11.7	16.9 ± 16.1	0.697
Sagittal spinal imbalance (n, %)#	0/13, 0%	1/9, 11.1%	0.409

ASF, anterior selective fusion; LIVDA, lower instrumented vertebrae disc angle; LL, lumbar lordosis; PJA, proximal junctional angle; PJK, proximal junctional kyphosis; PSF, posterior selective fusion; SS, sacral slope; SVA, sagittal vertical axis; TK, thoracic kyphosis; TLJ, thoracolumbar junction kyphosis; TL/L, thoracolumbar/lumbar; UIVDA, upper instrumented vertebrae disc angle.; * means the comparisons between the two groups using independent t test; # means the comparisons between the two groups using *Chi-squared* test.

TABLE 3 Comparisons of the fusion segments and between the two groups in Lenke 5 AIS patients with multiple linear regressions

Parameters		Group (ASF/PSF)	Age	Risser sign	TL/L curve magnitude	TL/L curve apex rotation	TL/L curve flexibility	*P* value	Adjusted R^2
Fusion segments number	B	1.695	0.192	−0.317	0.074	−0.659	−0.933	0.001	0.655
	P	0.001	0.139	0.195	0.124	0.298	0.465		
Distal reserved segments number	B	−0.628	−0.109	0.383	−0.055	0.125	0.333	0.002	0.607
	P	0.034	0.175	0.020	0.076	0.748	0.674		

Enter method is one of the methods used in the multiple linear regression. With enter method, all independent variables are entered into the equation in one step, also called "forced entry". Besides ENTER, several other methods are available to build models, controlling how variables are included into a model. The main goal of this methods is to determine the best subset of variables explaining a dependent variable. In the regression model, fusion segments and distal reserved segments were taken as dependent factor, and group (ASF/PSF), age, Risser sign, TL/L curve magnitude, apex rotation and flexibility were taken as independent factors; in the group (ASF/PSF), ASF was regarded as 0, and PSF as 1. ASF, anterior selective fusion; PSF, posterior selective fusion; TL/L, thoracolumbar/lumbar.

ASF and PSF groups ($P > 0.05$), but they were both significantly greater at the last follow-up in the PSF group than in the ASF group ($P < 0.05$, Table 2), suggesting that PSF had better correction for the sagittal alignment compared with ASF. There was no significant difference between SS, TLJ, and SVA between the two groups ($P > 0.05$). In the PSF group, PJA was significantly increased from preoperatively (6.2° ± 5.0°) to the last follow-up (13.3° ± 6.1°, $P < 0.05$); while, in the ASF group, there was no significant difference. Additionally, the PSF group (13.3° ± 6.1°) had greater PJA at the last follow-up than the ASF (4.7° ± 3.4°, $P < 0.05$). However, the occurrence of PJK had no significant difference between the two groups (ASF: 0/13, *vs* PSF: 2/9, $P > 0.05$) (Table 2).

After controlling for age, Risser sign, TL/L curve magnitude, apex rotation and flexibility by multiple linear regression, shorter fusion segments number ($b = 1.79$, $P < 0.001$) and more distal reserved segments ($b = 0.802$, $P < 0.05$) still remained significant in the ASF group (Table 3).

Intra- and Postoperative Complications

There was no infection, vascular injury and nerve complications in both groups. In the ASF group, 3 cases occurred adding-on phenomenon and there was neither PJK nor other sagittal imbalance; meanwhile, in the PSF group, two cases of PJK and one case of sagittal imbalance occurred. No revision surgery occurred in both groups.

Discussion

Correction Outcome Between the ASF and PSF Groups

Several studies were investigated the correction outcome of different surgical approaches in Lenke 5 AIS[7–12,20,26,27]. It was widely accepted that both ASF and PSF could achieve satisfactory correction for TL/L and thoracic curves. Generally, the correction rate of TL/L curve was 54.4%–83.2%, and the spontaneous correction rate of the thoracic curve was 37%–48.5%[8–10,26,27]. In the present study, the correction rates of the TL/L curves were 87.4% ± 10.1% and 85.6% ± 5.8% in the ASF and PSF groups; and the spontaneous correction rates of the thoracic curves were 54.4% ± 16.9% and 68.8% ± 24.0%, respectively, which was in accordance with the previous studies[8–10,26,27]. Combined with no significant difference in trunk translation between the two groups, it was demonstrated that ASF and PSF had no significant difference in the correction for Lenke 5 AIS in the coronal plane.

ASF Saving More Distal Fusion Segments Than PSF

It was reported that the anterior approach could reduce fusion segments compared with the posterior. Luo *et al.*[9] conducted a meta-analysis on the clinical and radiographic outcome of different surgical approaches for the treatment of Lenke 5 AIS. A total of 308 cases were included. The results showed that ASF was able to have shorter fusion segments and save more than one segment compared with PSF. In another meta-analysis with 35 studies included[12], the outcome of the selective fusion for AIS with primary TL/L curve[12] was compared, showing that ASF had shorter fusion segments than PSF, consistent with the previous study[9]. Li *et al.*[10] also compared the radiographic outcome between 22 ASF and 24 PSF AIS patients with primary TL/L curve, finding no significant difference in the correction rate of the TL/L curve; nevertheless, ASF patients had significantly shorter fusion segments (5.09) than the PSF (6.13). In the present study, the ASF patients showed significantly shorter fusion segments (5.1 ± 0.6) than the PSF (7.0 ± 1.3), demonstrating that ASF could save one or two motion segments. Combined with the decreased UIV, it was concluded that the anterior approach could shorten the fusion segments by lowering UIV[8,9,12,20].

The surgical approach was an important factor of affecting the sagittal alignment for AIS[28]. In the meta-analysis conducted by Luo *et al.*[9], the effects of different surgical approaches on the treatment of Lenke 5 AIS were shown that PSF could obtain greater LL in the sagittal plane compared with ASF, but without no significant difference in TK. However, another meta-analysis[12] demonstrated that PSF had larger TK than ASF. In 2018, Li *et al.*[20] compared the radiographic outcome between 40 ASF and 37 PSF patients with Lenke 5 AIS with 5-year follow-up, showing that PSF patients could obtain greater TK and LL in the sagittal plane. In the present study, the PSF group showed significantly greater LL at the last follow-up than the ASF, suggesting that PSF obtained greater correction for the sagittal alignment in Lenke 5 AIS, consistent with previous literature[20]. Meanwhile, SVA was significantly improved in both groups from preoperative to postoperative, despite no significant difference at the last follow-up between the two groups[20], indicating that the surgical approaches made no significant difference in SVA.

Moreover, after controlling for age, Risser sign, and magnitude, rotation and flexibility of the TL/L curve, smaller fusion segments and more distal reserved segments still remained significant in the ASF group (Table 3), demonstrating that ASF could save more distal segments than PSF. However, limited by the less distal reserved segments (ASF: 2.9 ± 0.4 *vs* PSF: 2.2 ± 1.1), ASF could only save more distal fusion segments in patients with more skeletal maturity.

Complications

Furthermore, no complications such as screw and rod rupture, pseudarthrosis, or revision occurred in the present study. Li *et al.*[20] compared the effects of selective lumbar fusion between the anterior and posterior approach in Lenke 5 AIS, finding that the PSF patients had significantly higher incidence of PJK (5/37) than the ASF (1/40). In the present study, ASF patients showed greater distal compensatory curve than the PSF, but the incidence of the adding-on phenomenon or trunk imbalance had no significant difference between the two groups. In the sagittal plane, the PSF group had significantly larger PJA at the last follow-up than the ASF, but no significant difference was found in the incidence of PJK, which might be due to the limited sample size. It demonstrated that ASF had a relatively higher trunk imbalance in the coronal plane, whereas PSF showed a higher risk of PJA in the sagittal plane.

Limitations

The strength of the present study was the long-term follow-up, which allowed for the observation of the restoration of the coronal and sagittal balance after ASF and PSF. However, several influencing factors would affect the outcome of correction of spinal deformity, including surgical approach, fusion segments, intraoperative surgical manipulation, fusion methods[10], internal fixation systems[5,6], and so on. Therefore, the limited sample size in the present study might affect the outcome, and a further study with larger sample size would be needed in future. Moreover, the present study was limited by its retrospective nature and lacking SRS-22 outcomes, so the quality of life also needs to be further assessed.

To sum up, both ASF and PSF were effective and could obtain satisfactory coronal and sagittal correction for Lenke 5 AIS. Compared with PSF, ASF could shorten the fusion segments by lowering UIV, but only save distal fusion segments in patients with greater Risser sign due to the limited distal reserved segments. Moreover, ASF had a relatively higher risk of curve progression at the distal segments in the coronal plane, while PSF showed a better correction effect on the sagittal profile despite a higher risk of PJA progression.

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