Original Article

Anterior versus posterior approach in Lenke type 1 adolescent idiopathic scoliosis: a comparison of long-term follow-up outcomes

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Background: After surgical treatment of adolescent idiopathic scoliosis (AIS), doctors should not only focus on the short-term surgical effect, but also pay special attention to whether the patients can live normally in the long-term. This work compared the long-term effects of thoracoscopy-assisted anterior spinal fusion (ASF) and posterior spinal fusion (PSF) in AIS.

Methods: Twenty-two patients underwent thoracoscopy-assisted ASF, and twenty-three patients underwent PSF from 2004 to 2009 were involved , including 14 males and 31 females with an average age of 14.8±2.6 years, and all patients suffered from only Lenke type 1 AIS. The mean follow-up time was 102 months, the radiographic parameters and operation time, hospitalization time, fusion segments and estimated blood loss were evaluated. Comparisons between groups were made such as Cobb's angle, thoracic kyphosis, the instrumented levels, curve correction, preoperative parameters, SF-36/SRS-22 questionnaire scores, and pulmonary function.

Results: There was no significant difference in age, gender, Risser sign and follow-up period between two groups. The instrumentation level had an average of 6 in the thoracoscopy-assisted ASF group and 9.7 in the PSF group (P<0.001). The average correction rate of the main curve was 67.4% in ASF group versus 79.2% in PSF group (P>0.05). The postoperative thoracic kyphosis was 16.2°±3.9° in ASF group and 25.6°±4.4° in PSF group (P=0.023). Patients had momentous advancement in self-image, vitality and mental health in the SRS-22 and SF-36 questionnaires. Compared to preoperatively, the pulmonary function of both groups was satisfactorily improved at the final follow-up.

Conclusions: Since there was no statistically significant difference in the general conditions of the two groups selected for this study, so we finally concluded that thoracoscopy-assisted ASF had a satisfactory correction rate, famous long-term radiography outcomes and desirable pulmonary function results. However, compared to PSF, it has a longer operation time, a more complicated surgical procedure and a weaker three-dimensional correction effect, and PSF has affirmative long-term outcomes, fewer complications, and satisfactory sagittal balance, all of which make PSF the standard operation to treat AIS.

Keywords: Adolescent idiopathic scoliosis (AIS); anterior spinal fusion (ASF); posterior spinal fusion (PSF); long-term follow-up; pulmonary function

Submitted Dec 30, 2021. Accepted for publication Mar 01, 2022.

doi: 10.21037/atm-22-573

View this article at: https://dx.doi.org/10.21037/atm-22-573

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Introduction

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional (3D) spinal deformity and is also the most common type of scoliosis. Approximately 1–3% of teenagers aged 10–16 years old are affected globally (1). In AIS, the vertebral bodies rotate and deflect toward the convex side of the curve, which can lead to spinal asymmetric deformity. This 3D deformity gradually increases along the curve and is maximal at the apex (2). The shape of the thoracic cavity is asymmetrical, and the volume of the concave side increases, while the volume of the other side decreases, resulting in protruding ribs on the convex side. Although AIS is generally not a threatening-life disease, it can affect children's development both physically and psychologically, and can result in back pain, poor personal appearance, and poor mental health. Although the absolute operation indication for adolescent idiopathic scoliosis has not been established, attention has always been paid to the continuous increase in deformity during growth and subsequent complications.

Since Harrington's report in the 1960s, posterior spinal fusion (PSF) has become the gold standard surgical treatment for AIS (3). The posterior approach provides easy access to the spine, which can also avoid direct invasion of the thoracic cavity and is relatively flexible in determining the fusion segments (4,5). Compared with anterior spinal fusion (ASF), posterior surgery reduces the risk of pulmonary complications, shortens the recovery time, and reduces the length of hospital stay (4-8). However, ASF was developed by Dwyer in 1974 in response to the disadvantages of the posterior approach, such as the "adding-on" effect, greater invasiveness of the rear area, and relatively long fusion segments (9-12). ASF benefits from a shorter fusion area, lack of paraspinal muscle dissection, and minor scarring, but often at the cost of pulmonary function (13-15). Thoracoscopy instrumentation and fusion, a less invasive anterior approach, has been used since the 1990s and 2000s. Endoscopic techniques have the advantages of being minimally invasive, resulting in less postoperative pain, and having no obvious effect on lung function. Unfortunately, long-term follow-up of radiographic parameters is rarely reported in the literature.

Both ASF and PSF are standard surgical methods for the treatment of Lenke type1 AIS, and both can achieve curative short-term effects. In response to the lack of long-term follow-up studies, we analyzed patients with thoracoscopy instrumentation-assisted ASF and patients under PSF over the past 10 years to compare and evaluate the long-term results of two surgical methods in the treatment of AIS. The main purport of this study is through a long-term follow-up comparison between two groups to develop a better understanding of the current status of thoracoscopy anterior instrumentation and fusion as a treatment for adolescent idiopathic scoliosis, make sure whether it can help patients achieve a good long-term life quality, and to discuss it in the context of the common techniques that are currently used globally. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-573/rc).

Methods

We retrospectively reviewed 24 patients undergoing ASF and 24 patients undergoing PSF operation by a single surgeon in Spine Surgery Ward of the Second Xiangya Hospital between 2002 and 2009. Only Lenke1-type adolescent idiopathic scoliosis was included. There were 22 patients with ASF and 23 patients with PSF included in the final follow-up assessment. Because of withdrawal, 3 patients were excluded from the final assessment. Then, a follow-up of at least 8 years (up to 14 years) was established. All patients underwent preoperative, postoperative, 6-month, and 2-year postoperative evaluations as well as a final follow-up evaluation. Although the sample size was small, but with the systematic long-term follow-up of both groups, the patient follow-up data was sufficient and reliable for representing all conditions that may occur during the whole follow-up process, so our group believed that this study has clinical significance.

Surgical technique

Anterior approach

All patients were under general anesthesia and in a side-lying position. Initially, a C-arm X-ray machine was used to determine the surface positions of the upper and lower vertebrae and the apical vertebrae of the scoliosis to establish the working tunnels on the head and caudal sides of scoliosis. The upper incision was located between the upper instrumented vertebral body and the lower vertebral body; the lower incision was located between the lower instrumented vertebral body and the upper vertebral body; the middle incision was located between the above two incisions, and then a channel was established in the 6th or 7th intercostal space of the midaxillary line (to prevent damage to the diaphragm) for the thoracoscopy lens. The

parietal pleura was carefully separated along the long axis of the spine, and the spine was exposed. Then, the loosened segments were determined, and Moss-Miami screws (7 mm diameter screws, length ranges 2.5–4.0 cm) were placed. All screws were placed under the monitoring of the C-arm X-ray machine. The discs of selected segments were then scraped afterwards to implant autogenous bone for intervertebral fusion. To fully release the scoliosis, multiple segments of the intervertebral disc tissue needed to be removed. Finally, the connecting rod was installed (5.5 mm connecting rod), the thoracic closed drainage tube was indwelled, and the wounds were sutured.

Posterior approach

All patients were under general anesthesia and were placed in the prone position. Initially, a C-arm X-ray machine was used to mark the upper and lower vertebrae and the apical vertebrae of the scoliosis to establish the appropriate incision. The paravertebral muscle was separated, and the spine was exposed. Then, Moss-Miami screws were implanted in the selected segments, one connecting rod was installed, and the scoliosis was rectified. Then, another connecting rod was installed, and the nuts were tightened. Finally, a drainage tube was placed, and the wound was sutured.

Clinical evaluation

The patients' general condition before surgery and their surgical data were recorded. In the final follow-up, the clinical evaluation included the patient's current status and complications. To assess patients' quality of life, the Scoliosis Research Society 22 questionnaire (SRS-22) and Medical Outcomes Study (MOS) item short from the health survey questionnaire (SF-36) were used in the last follow-up.

Radiographic analysis

To measure preoperative curvature, all patients received standing anteroposterior, lateral, and bending films, magnetic resonance imaging, and computed tomography before surgery. To measure postoperative curvature, once the patients were able to stand and walk independently (usually 1 week after surgery), anteroposterior and lateral films were taken. Further radiological evaluation was performed at 3 months, 2 years, and the final follow-up. The radiological follow-up evaluation included standard standing anteroposterior and lateral films. Coronal film was used to measure the Cobb's angle of the thoracic and thoracolumbar curves, and thoracic kyphosis was measured from T5 to T12 on the sagittal plane, we used Surgimap software (Nemaris, Inc., Mexico City, Mexico) to measure and analyze imaging findings. The global coronal balance was measured by the clavicle angle. At 3 months, 2 years, and the final follow-up, at which times we also measured pulmonary function.

The correction rate and correction loss rate were calculated by the following formulae:

$$\text{Correction rate} = \frac{(\text{Preoperative Cobb's angle} - \text{postoperative Cobb's angle})}{\text{Preoperative Cobb's angle}} * 100\% \quad [1]$$

$$\text{Correction loss rate} = \frac{(\text{Postoperative Cobb's angle} - \text{follow up Cobb's angle})}{(\text{Preoperative Cobb's angle} - \text{postoperative Cobb's angle})} * 100\% \quad [2]$$

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by The Second Xiangya Hospital Ethics Committee (No. 2021600), and individual consent for this retrospective analysis was waived.

Statistical analysis

The data analysis was performed using SPSS (v22.0, Inc., Chicago, Illinois). First, our group performed a significance test between the two groups using analysis of variance to determine whether the two groups were comparable. Afterwards a Wilcoxon rank sum test and a paired sample *t*-test with Bonferroni post-hoc analysis was used to determine the difference between test outcomes preoperatively, postoperatively, and at the final follow-up, and a significance level of 5% ($P \leq 0.05$) was set.

Results

A total of 48 Lenke1 AIS patients were recorded in this study; however, 3 of them were excluded because of withdrawal, and the remaining 45 patients with a mean follow-up period of 9 years were included. Twenty-two of the 45 patients underwent thoracoscopy-assisted ASF, and the others underwent PSF (*Table 1*).

The comparison of demographic and perioperative data of the two groups was made. The average operation time of the thoracoscopy assisted ASF group was 371±73 min,

Table 1 Summary of the demographic and perioperative data

Characteristics	Anterior surgery (n=22)	Posterior surgery (n=23)	P value
Age (years)	14.3±1.5	14.4±2.4	0.788
Sex (n)	7 (32%) male, 15 (68%) female	7 (30%) male, 16 (70%) female	0.946
Risser	3.8±0.8	3.7±0.7	0.245
BMI	20.1±2.2	21.1±1.7	0.687

BMI, body mass index.

Table 2 Summary of the surgical data

Characteristics	Anterior surgery (n=22)	Posterior surgery (n=23)	P value
Instrumental level	6.0±1.0	9.7±2.1	0.000
Anesthesia time (min)	371±73	314±36	0.000
Blood loss (mL)	700±340	820±280	0.000
Hospital stay (days)	11.4±4.9	13.5±3.8	0.203

which was significantly longer than the PSF group, which had an average of 314±36 min. Intraoperative bleeding of the thoracoscopy assisted ASF group was 350–1,100 mL, with an average of 700±340 mL, which was less than the PSF group, which had a mean of 820±380 mL. The average fusion length of the ASF group was 6.0±1.0 segments, which was far less than the PSF group, which had an average of 9.7±2.1 segments. The incision wound healed smoothly in both groups, and there was no incision or cavity infection. All patients in both groups passed the perioperative period safely (*Table 2*).

In the thoracoscopy-assisted ASF group, the average Cobb's angle of the thoracic main curve after the operation was 12.6°±5.3°, the average correction rate was 67.4%±11.7%, and the average Cobb's angle at the last follow-up was 16.6°±8.3°, with no significant correction loss during the whole follow-up. Compared with the thoracoscopy-assisted ASF group, the PSF group also achieved a satisfactory result; the average postoperative thoracic Cobb's angle was 6.7°±3.4° with a mean correction rate of 79.2%±10.5%, and the Cobb's angle at the last follow-up was 12.6°±5.1°, which also remained satisfactory. In the final follow-up, the clavicle angle of both groups showed a significant decrease, and there was no between-group variance (2.4±1.1 *vs.* 2.4±1.5; P=0.813). For the curvature of the sagittal plane, thoracic kyphosis remained at 16.2°±5.9° in the thoracoscopy-assisted ASF group. A more satisfactory result was achieved on thoracic kyphosis in the PSF group, with an average of 26.8°±6.9°. Nevertheless, the appearance was remarkably improved in both groups. Although both groups had similar preoperative apical vertebral column rotation angles, there was a significant difference between the two groups postoperatively (13.9°±5.4° in the ASF group *vs.* 9.8°±4.8° in the PSF group; P=0.001). The apical vertebral column rotation angle remained satisfactory throughout the whole duration of the follow-up in both groups. All patients underwent 96 to 144 months of follow-up, with an average of 102.1±22.5 months (*Table 3*; *Figures 1*,*2*).

In the thoracoscopy-assisted ASF group, the patients had a significant decrease in lung function 3 months postoperatively, while their lung function was restored 2 years postoperatively, and there was no significant difference compared with the preoperative outcomes. At the last follow-up, the patients' lung function had improved. For the PSF group, there was no significant damage to pulmonary function, and all the patients in this group had satisfactory pulmonary function test results. Additionally, at the final follow-up, the patients' lung function had greatly improved (*Table 4*).

In the thoracoscopy-assisted ASF group, 1 case exhibited an adding-on phenomenon. The patient reported experiencing back pain and unbalanced shoulders 6 months after the operation. We properly extended the fixed segment with posterior revision surgery, and the correction effect was satisfactory (*Figure 3*). Two other cases also exhibited the

Table 3 Comparison of radiographic parameters of the cases

Parameters	Preoperative	Postoperative (1 week)	Postoperative (3 months)	Postoperative (2 years)	Final follow-up
Thoracic Cobb's angle, °					
Anterior approach	44.9±10.6	12.6±5.3	15.4±6.4	15.1±7.5	16.6±8.3
Posterior approach	50.7±8.5	6.7±3.4	7.1±4.3	9.3±5.1	12.6±5.1
P value	0.371	0.042	0.037	0.099	0.155
Correction rate, %					
Anterior approach	–	67.4±11.7	–	–	–
Posterior approach	–	79.2±10.5	–	–	–
P value	–	0.032	–	–	–
Correction loss, %					
Anterior approach	–	–	14.5±10.3	14.3±9.6	15.7±7.9
Posterior approach	–	–	10.7±7.1	11.3±5.3	12.1±4.9
P value	–	–	0.335	0.186	0.737
Thoracic-Lumber Cobb's angle, °					
Anterior approach	16.6±3.7	6.6±4.5	7.7±3.2	9.3±5.1	10.4±5.1
Posterior approach	22.4±5.9	8.5±3.8	9.1±2.9	9.5±2.9	9.9±3.7
P value	0.318	0.192	0.106	0.805	0.906
Thoracic kyphosis, °					
Anterior approach	10.2±5.3	13.3±5.4	15.1±4.6	15.5±5.2	16.2±5.9
Posterior approach	9.7±4.8	24.3±8.9	25.6±8.4	25.7±8.9	26.8±9.9
P value	0.784	0.049	0.039	0.037	0.023
Clavicle angle, °					
Anterior approach	3.0±1.9	3.3±1.8	2.9±0.9	2.6±1.3	2.4±1.1
Posterior approach	3.1±1.7	2.8 ±1.5	2.3 ±1.7	2.3 ±1.9	1.9 ±1.5
P value	0.893	0.405	0.784	0.524	0.613
Apical vertebral column rotation angle, °					
Anterior approach	18.9±6.5	13.9±5.4	14.6±4.8	15.9±4.9	16.1±5.3
Posterior approach	19.4±7.1	9.8±4.8	10.3±5.1	11.2±4.7	12.4±5.9
P value	0.737	0.000	0.001	0.001	0.001

adding-on phenomenon; however, neither of them exhibited severe symptoms, and both underwent the regular follow-up.

The motor function of the remaining patients was preserved, they could live and work normally, and their appearance was significantly improved. During the follow-up, X-ray film showed that the texture of the lungs was clear and there was no loss of orthopedic degree. Re-examination of computed tomography (CT) showed that good bone fusion was achieved, and there was no obvious internal fixation loosening, fracture, or displacement. Both groups achieved similar results on the SRS-22 and SF-36 questionnaires (*Table 5*).

Discussion

The surgical treatment of AIS is aimed at correcting spinal

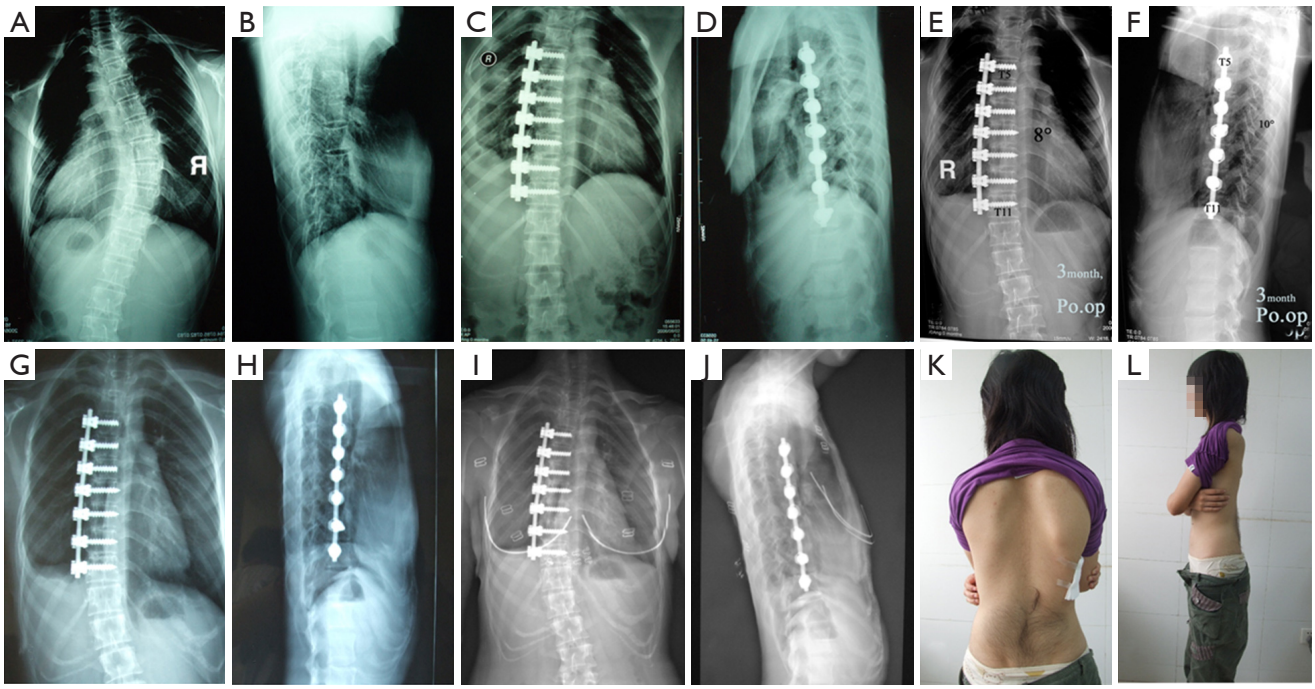

Figure 1 A 15-year-old girl diagnosed with adolescent idiopathic scoliosis (Lenke1 AN). (A,B) Preoperative spine X-ray showed the Cobb's angle of the main thoracic curve was 46°; the kyphosis angle of thoracic spine was 10°. (C,D) Spine X-ray 4 days after operation showed the Cobb's angle of the main thoracic curve was 9°, and the correction rate was 80.1%. (E-J) Spine X-ray 3–144 months after operation showed deformity correction was maintained. There were no signs of loosening of the internal fixation. In addition, there was an occurrence of a slight adding-on phenomenon, which did not affect the efficacy, so no further surgical intervention was taken. (K,L) Physical appearance of this patient 144 months after operation. Although a slight adding-on phenomenon occurred, self-image improved significantly. This image is published with the consent of the patient's guardians.

deformity, maintaining coronal and sagittal balance, and maintaining the flexibility of the spine as much as possible. Since the initial work of Dwyer and Zielke, ASF has made many technical improvements in the treatment of AIS (9,16). The improved fixation system is almost free from complications such as segmental kyphosis, implant failure, and pseudarthrosis, and it enables decent correction with preserved segmental fusion (15,17-19). Several studies described ASF as an ideal surgical option for AIS, and other techniques and equipment for AIS, such as double-rod fixation described by Turi *et al.* (20), also showed great improvement. With the passage of time, pedicle screw technology has become mature, and there have been many reports of AIS patients treated with posterior technology (21,22).

Our study analyzed data for 24 patients who underwent thoracoscopy-assisted ASF and 24 patients who underwent PSF to treat AIS by a single surgeon operation. A final follow-up of thoracoscopy-assisted ASF was performed on 22 patients, and the average value of the main curve correction rate was 67.4%, which was also similar to the value provided in the literature (23,24). In the PSF group, a final follow-up was performed on 23 patients, and the average main curve correction rate was 79.2%, both of which resembled the value presented in the literature (22,25). The comparison of the correction rate between the two groups concluded that using PSF had more satisfactory outcome in Lenke1 patients (79.2%±10.5% *vs.* 67.4%±11.7%; P=0.032). Long-term corrective loss is a major concern for AIS patients treated with either thoracoscopy-assisted ASF or PSF. During the entire follow-up time, the immediate postoperative imaging examinations of both groups improved significantly. In both groups throughout the entire follow-up process, the correction loss rate was within the acceptable range (15.7%±7.9% in the ASF group, 12.1%±4.9% in the PSF group), and there was no significant difference between the two groups. The coronal balance also appeared to be a satisfactory outcome.

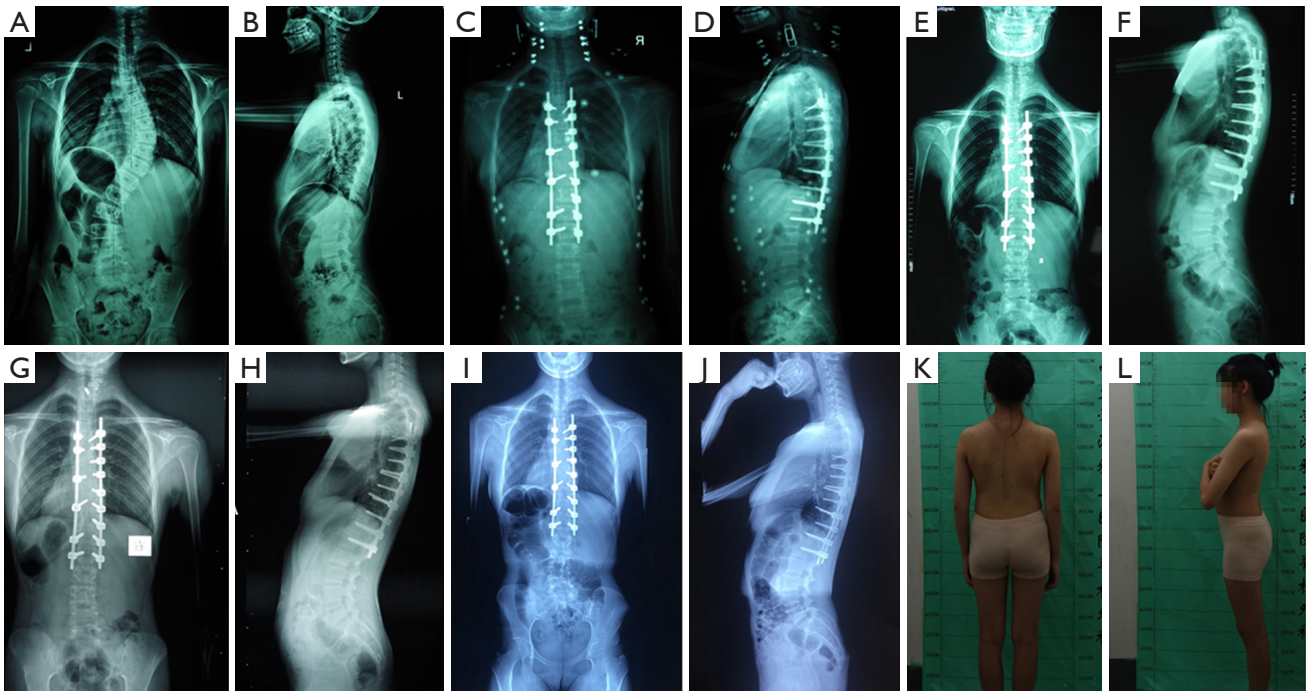

Figure 2 A 13-year-old girl diagnosed with adolescent idiopathic scoliosis (Lenke1 AN). (A,B) Preoperative full spinal X-ray showed the Cobb's angle of the main thoracic curve was 57°, and the kyphosis angle of thoracic spine was 22°. (C,D) Full spinal X-ray 4 days after operation showed the Cobb's angle of the main thoracic curve was 8°, and the correction rate was 86.1%. (E-J) Full spinal X-ray 3–96 months after operation showed that deformity correction was maintained. There were no signs of loosening of the internal fixation. (K,L) Physical appearance of this patient 96 months after operation. The patient's self-image had greatly improved. This image is published with the consent of the patient's guardians.

Table 4 Pulmonary function

Parameters	Preoperative	Postoperative (3 months)	Postoperative (2 years)	Final follow-up	P value1	P value2	P value3
Anterior spinal fusion group							
FVC	3.32±0.35	2.92±0.43	3.29±0.32	3.56±0.43	0.036	0.056	0.004
FEV1	2.93±0.31	2.41±0.25	2.89±0.32	3.14±0.41	0.027	0.327	0.000
TLC	4.38±0.54	4.08±0.47	4.35±0.38	4.53±0.47	0.019	0.651	0.006
Posterior spinal fusion group							
FVC	3.31±0.37	3.32±0.31	3.45±0.42	3.61±0.41	0.514	0.006	0.000
FEV1	2.92±0.28	2.98±0.35	3.07±0.38	3.24±0.37	0.427	0.017	0.000
TLC	4.43±0.61	4.40±0.42	4.54±0.41	4.58±0.52	0.432	0.009	0.000

P value1, P value of preoperative *vs.* postoperative (3 months). P value2, P value of preoperative *vs.* postoperative (2 years). P value3, P value of preoperative *vs.* final follow-up. FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; TLC, total lung capacity.

Although the clavicle angle of both groups had a transitory increase at the postoperative follow-up, it returned to the preoperative baseline 3-month postoperatively and had a prominent decrease at the last follow-up, and there was no difference between groups. Thoracic kyphosis in the final follow-up PSF group had a more famous consequence

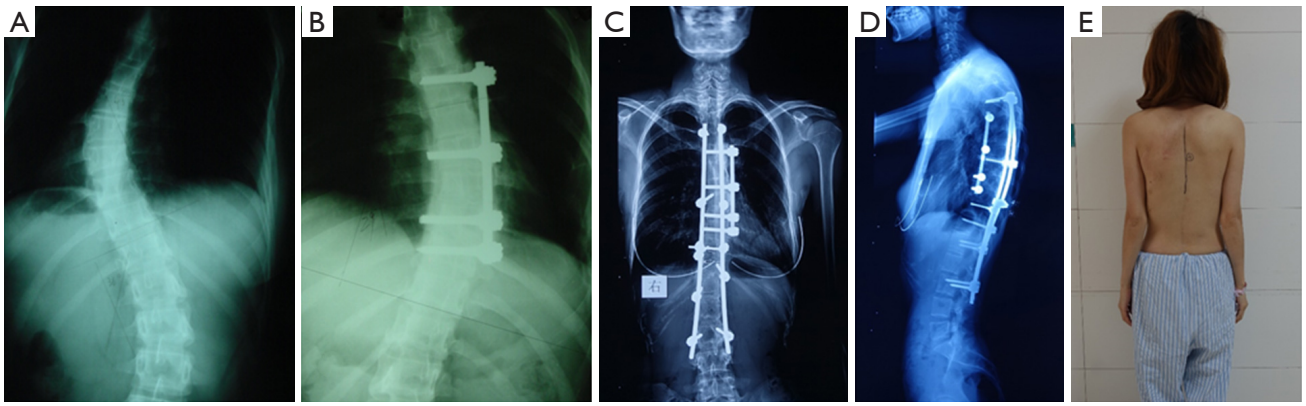

Figure 3 A fourteen-year-old girl diagnosed with adolescent idiopathic scoliosis (Lenke1 AN). The adding-on phenomenon occurred 27 months after the surgery and required reoperation. (A) Preoperative X-ray; (B) full spinal X-ray 24 months after operation showing that the adding-on phenomenon had appeared; (C,D) reoperation through the posterior approach to deal with the adding-on phenomenon (anteroposterior and lateral X-ray plain film); (E) physical appearance 120 months after operation, which had significantly improved. This image is published with the consent of the patient's guardians.

Table 5 Clinical assessment with the SRS-22 and the SF-36 questionnaires

Parameters	A, postoperative (1 week)	P, postoperative (1 week)	P value	A, postoperative (2 years)	P, postoperative (2 years)	P value
SRS-22						
Function/activity	3.9±0.5	3.4±0.6	0.065	3.7±1.1	3.7±0.3	0.961
Pain	4.6±0.4	4.0±0.8	0.143	3.5±1.2	3.7±0.7	0.751
Self-image	3.3±0.7	3.7±0.5	0.438	3.1±0.4	3.6±0.6	0.051
Mental health	3.9±0.4	4.2±0.5	0.129	4.3±0.9	3.6±0.5	0.313
Satisfaction	3.2±1.2	3.6±0.2	0.506	3.8±0.3	3.6±0.7	0.541
SF-36						
Physical functioning	27.6±2.5	28.6±1.1	0.231	24.2±1.1	23.8±1.5	0.543
Role-physical	7.6±0.9	7.2±1.5	0.374	7.2±1.1	5.0±0.7	0.071
Bodily pain	9.6±0.6	9.2±0.4	0.178	8.8±0.8	7.9±1.3	0.341
General health	21.2±4.2	21.8±1.8	0.810	19.4±3.3	18.6±3.9	0.735
Vitality	17.8±2.2	19.8±1.9	0.200	22.4±7.7	23.2±4.3	0.877
Social functioning	9.2±1.3	9.6±2.1	0.578	9.2±1.1	9.2±0.8	0.923
Role-emotional	5.2±1.1	5.6±1.1	0.568	4.8±1.6	4.7±1.1	0.893
Mental health	23.2±2.9	23.0±2.6	0.866	26.0±5.5	26.6±1.9	0.763

A, anterior approach; P, posterior approach; SRS-22, scoliosis research society 22 questionnaire; SF-36, short form-36.

(26.8°±9.9° *vs.* 16.2°±5.9°; P=0.023), and the PSF group also had a more obvious correction effect on the apical vertebral column rotation angle, both of which indicated that PSF can help patients achieve a more satisfactory sagittal balance because the posterior approach can achieve three-dimensional correction, which can better relieve vertebral rotation. Additionally, thoracic kyphosis can be determined by the curvature of rods, and longer rods can achieve a great

correction angle to restore sagittal balance.

Our operation duration and blood loss amount were similar to those described in the literature (6,8,26). Due to the anatomical pathway, the risk of neurological complications is lower with the anterior approach. In contrast, the risk of neurological complications caused by pedicle screw dislocation in the posterior approach can reach 1% (27). Compared with the posterior approach, the infection rate of anterior scoliosis surgery is lower (there were no postoperative infection cases in either group included in our data) (28). However, anterior spinal fusion also had complications such as vascular injury and feeble psoas major. The complications identified in our work are consistent with those represented in the literature, and 3 patients in the thoracoscopy-assisted ASF group experienced the "adding-on" phenomenon; 1 of them underwent reoperation, and the other 2 patients underwent the regular follow-up because the degree was not as severe (29). The greatest risk factor for the occurrence of the "adding-on" phenomenon is improper selection of the lowest instrumented vertebra (LIV); however, due to limitations of the surgical field and operating space compared with PSF, it seems more difficult for thoracoscopy-assisted ASF to achieve a satisfactorily long fusion area. Proximal junctional kyphosis (PJK) is also one of the complications that has received much attention in recent years, and its occurrence may be related to injury of the posterior soft tissue, the selection of upper instrumented vertebrae, and the state of sagittal plane balance. The appearance of distal junctional kyphosis (DJK) may have an important relationship with the choice of sagittal LIV. In our cases, we properly extended the instrumented segments to reconstruct the patient's normal spinal sequence, and none of the patients showed PJK or DJK.

Regarding pulmonary function, the patients in the thoracoscopy-assisted ASF group at the 3-month follow-up showed a significant decline compared with their preoperative values (FVC: P=0.036; FEV1: P=0.027; TCL: P=0.019). However, pulmonary function returned to the preoperative baseline at the 2-year follow-up (FVC: P=0.056; FEV1: P=0.327; TCL: P=0.651), which was similar to the results reported in the current literature (30). In the long-term follow-up pulmonary function results, as the patients grew up and the thoracic cavity became mature, pulmonary function was greatly improved compared with the preoperative baseline (FVC: P=0.014; FEV1: P=0.046; TCL: P=0.086).

In our study, the SRS-22 and SF-36 were used to evaluate patients' clinical efficacy, mental health, and social integration. After surgery, the scores of the psychological items were significantly, and the total score was also improved. Similar to the SF-36 evaluation scores of physical functioning, bodily pain and role-physical and social functioning did not improve greatly during the whole follow-up time. The vitality and mental health scores significantly improved. There was no significant difference between the ASF group and the PSF group (*Table 5*).

Finally, the advantages and potential disadvantages of thoracoscopy must be weighed. With the improvement of the posterior approach technique, as well as the improved correction instruments, an increasing number of surgeons are willing to consider the posterior approach operation as the first choice. Many surgeons also consider thoracoscopy techniques to be challenging. Therefore, only a few skillful spine surgeons can handle this technique proficiently. Unless the results of endoscopic anterior spinal fusion are clearly demonstrated to be superior to posterior spinal fusion, most spinal surgeons are unlikely to consider it the primary option. Most of the literature about anterior spinal fusion with thoracoscopy came from 2008 or even earlier, and the state of the art literature is mainly associated with the posterior approach. Moreover, many recent studies have highlighted the conclusion that the correction rate of the posterior approach is similar to that of the anterior approach and the complications associated with the anterior approach. Posterior spinal fusion has become the standard option for AIS because it can achieve satisfactory curve correction, achieve three-dimensional correction, relieve vertebral rotation, reduce blood loss and operation time, shorten hospitalization time, and reduce costs (31,32).

Our study has several limitations. First, this is a retrospective study. Second, there was no randomization between the two procedures. Third, we had a small sample size of patients, which was not representative. Although the systematic follow-up provides sufficient data support, it may still lead to false-negative results. The follow-up time varied from 8 to 14 years, so it was hard for us to standardize the result of the final follow-up. We did not collect patients' vertebral bone density, so we cannot systematically analyze the risk factors of mechanical complications of the internal fixation system postoperatively.

Conclusions

This study compared the long-term follow-up of thoracoscopy-assisted ASF and PSF as treatments for AIS. Thoracoscopy-assisted ASF group and PSF group have

similar corrective effects, long-term pulmonary function results, and patients of both groups could live a normal life. However, ASF has the longer operation time, has more complicated surgical procedure, and results in a lower long-term correction rate compared to PSF. ASF is rarely used to correct AIS at present. The limitations of the surgical view and operating space make it difficult for ASF to have full segment correction, which can cause recurrence of scoliosis in the adjacent segment and the "adding-on" phenomenon. Currently, with the continuous updating of posterior surgical instruments and technological innovation, compared with ASF, PSF has affirmative long-term outcomes, fewer complications, and satisfactory sagittal balance, and PSF has become the standard operation to address AIS.

Acknowledgments

Funding: This work was supported by the Scientific Research Project of Hunan Provincial Health Commission (No. 202204073640).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-573/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-573/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-573/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by The Second Xiangya Hospital Ethics Committee (No. 2021600), and individual consent for this retrospective analysis was waived.

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(English Language Editor: C. Mullens)

Cite this article as: Gu H, Li Y, Dai Y, Wang B. Anterior versus posterior approach in Lenke type 1 adolescent idiopathic scoliosis: a comparison of long-term follow-up outcomes. Ann Transl Med 2022;10(7):405. doi: 10.21037/atm-22-573