



# The safety and efficacy of one-stage posterior surgery in the treatment of presumed adolescent idiopathic scoliosis associated with intraspinal abnormalities a minimum 3-year follow-up comparative study

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## Abstract

**Purpose** Adolescent idiopathic scoliosis (AIS) is a common type of idiopathic scoliosis. Previous studies reported that the incidence of intraspinal abnormalities among the presumed idiopathic scoliosis was 13–43%. Intraspinal abnormalities were also considered increasing the risks of progressing of scoliosis and neurological complications following scoliosis corrective surgery. The surgical strategy of presumed adolescent idiopathic scoliosis (PAIS) associated with intraspinal abnormalities remains controversial. The purpose of this study was to investigate whether one-stage posterior surgery safe and effective for the PAIS patients associated with intraspinal abnormalities.

**Materials and methods** One hundred and thirteen consecutive patients who underwent one-stage posterior correction surgery were included. Thirty PAIS patients with intraspinal abnormalities without preoperative neurological symptoms were matched with eighty-three AIS patients for sex, age, blood loss, operating time, number of levels and location of instrumentation and curve magnitude. Radiographic and clinical parameters of the patients were evaluated before surgery, within 1 week after surgery, and more than 3 years at the last follow-up for complications and changes in main curve correction, global coronal balance, thoracic kyphosis, sagittal vertical axis, and ODI scores.

**Results** On average, the duration of follow-up was 51.5 months in the PAIS group compared to 52.5 months in the AIS group. The preoperative mean major coronal curve was 79.6° (ranged 56.2°–106.7°) and improved to 22.4° (ranged 6.4°–58.1°) at the last follow-up for a 71.9% of correction in the AIS group. The preoperative mean major coronal curve was 80.4° (ranged 63.4°–108.1°) and improved to 23.2° (ranged 4.8°–66.2°) at the last follow-up for a 71.1% of correction in PAIS group. The preoperative ODI score was 32.4 (10–42) in the PAIS group and improved to 11.4 (4–22) at last follow-up, 33.4 (12–42) in the AIS group and improved to 11.5 (5–22) at last follow-up. The global coronal balance, TK and SVA were all significantly improved after surgery and maintained to the last follow-up in the two groups. The neurological complications were observed in 3.3% of PAIS patients and 3.6% of AIS patients. No statistical difference in the parameters between the two groups was observed at the last follow-up.

**Conclusion** One-stage posterior corrective surgery is safe and effective in PAIS patients associated with intraspinal abnormalities without preoperative neurological symptoms. Surgical guidelines of AIS are appropriate for the treatment of PAIS patients associated with intraspinal abnormalities.

**Keywords** Intraspinal abnormalities · Presumed adolescent idiopathic scoliosis · Surgery

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## Introduction

Scoliosis is a common three-dimensional spinal deformity that has been classified as congenital, idiopathic, neuromuscular, and syndromic. Adolescent idiopathic scoliosis (AIS) is a common type of idiopathic scoliosis from 10 years to maturity. The treatment guidelines of AIS have been well

established [1, 2]. With the development of magnetic resonance imaging (MRI), intraspinal abnormalities such as syringomyelia, Chiari malformations, tethered cord, split cord malformation, and intrinsic spinal cord tumor have been found increasingly in patients with presumed adolescent idiopathic scoliosis (PAIS). Previous studies reported that the incidence of intraspinal abnormalities among the presumed idiopathic scoliosis was 13–43% [3–9]. Intraspinal abnormalities were also considered increasing the risks of progressing of scoliosis and neurological complications following scoliosis corrective surgery. The surgical strategy of PAIS patients associated with intraspinal abnormalities remains controversial. Some spine surgeons considered that the intraspinal malformations should be proceeded before the correction of scoliosis because of its increase in the risk of neurological deterioration. But some studies suggested that proceeded neurosurgery may not need for asymptomatic patients [10–18, 28–30]. There has been no study investigated whether surgical guidelines of AIS appropriate for the PAIS patients associated with intraspinal abnormalities. In this study, we retrospectively analyzed 113 consecutive patients (30 PAIS patients associated with intraspinal abnormalities compared to 83 AIS patients) who underwent one-stage posterior correction surgery. The purpose of this study was to investigate whether one-stage posterior surgery safe and effective for the PAIS patients associated with intraspinal abnormalities.

## Materials and methods

### Patients

We performed a retrospective review of all patients with scoliosis who underwent posterior spinal fusion at our hospital from January 2012 to December 2015. The inclusion criteria were (1) presumed AIS in the anterior–posterior (AP) and lateral whole spine X-ray (2) preoperative MRI was acquired (3) a minimum of 3 years follow-up (4) no neurologic symptoms before surgery (5) no congenital spinal deformity and history of spine surgery (6) no neurological intervention (7) All right thoracic curves. Solo chiari malformation patients were excluded. One hundred and thirteen consecutive patients who underwent one-stage posterior correction surgery were included. 83 AIS patients (59 female and 24 male) and 30 PAIS patients associated with intraspinal abnormalities (22 female and 8 male) were included in this study. Syringomyelia was found in 15 patients, Syringomyelia with Chiari deformity was found in 7 patients (All grade I Chiari deformity), syringomyelia with a tethered cord was found in four patients, Splitcord was found in three patients, myelocyst

was found in one patient. The characteristics of patients with intraspinal abnormalities were summarized in Table 1.

### Surgical procedures

All the patients received Occipital-jaw belt traction for 2 weeks starting with 1/6 bodyweight and finally reached 1/3 bodyweight. Posterior spinal correction and fusion with pedicle screw (titanium; Wego) instrumentation was performed by the same senior surgeon (Y.H.) for all patients. Somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) and the wake-up test was applied for all patients during surgery.

### Data collection

Radiographic parameters including major coronal curve, global coronal balance (C7PL-CSVL), thoracic kyphosis (TK, Cobb angle from T5-T12) and the sagittal vertical axis (SVA) were measured preoperatively, early postoperatively (within 1 week), and at a minimum of 3 years postoperatively. The global coronal balance was the horizontal distance from a vertical line extended from the center of the C7 vertebrae to the CSVL. SVA was defined as the distance between the C7 plumb line and the posterior superior corner of S1, it was considered positive when the vertical plumb line lies anterior to the posterior superior corner of S1. Oswestry Disability Index (ODI) were also compared between the PAIS and AIS groups.

### Statistical analysis

SPSS version 19.0 (IBM) was used. The data were compared between the groups using Fisher's exact or Student's *t* test according to the data type. *P*-value < 0.05 was considered to be significant.

**Table 1** Description of intraspinal abnormalities detected on preoperative MRI

Types of intraspinal abnormalities	No.
Syringomyelia	15
Syringomyelia with Chiari malformation	7
Syringomyelia with tethered cord	4
Splitcord	3
Myelocyst	1
Total	30

## Results

### Preoperative characteristics

The baseline data of patients in the two groups were similar and summarized in Table 2. On the initial physical examinations, no neurological deficits or just mild low back pain were found in all the patients.

Preoperative radiographic and clinical data of the two groups are summarized in Table 3. For patients in the AIS group, the mean major coronal curve was 79.6°, the mean global coronal balance was 19.8 mm, the mean TK was 53.7° and the mean SVA was -18.8 mm, the mean ODI score was 34.1. For patients in the PAIS group associated with intraspinal abnormalities, the mean major coronal curve was 80.4°, the mean global coronal balance was 21.3 mm, the mean TK was 54.6° and the mean SVA was -21.2 mm, the mean ODI score was 33.4. All the preoperative parameters were comparable without statistical difference between the two groups (Table 2).

### Postoperative characteristics

On average, the duration of follow-up was 51.5 months in the PAIS group compared to 52.5 months in the AIS group. Radiographic measurement was made by the same independent blinded reviewer (Fig. 1). The results of the postoperative radiographic data of the two groups are summarized in Table 4. The preoperative mean major coronal curve was 79.6° (ranged 56.2°–106.7°) and improved to 22.4° (ranged 6.4°–58.1°) at the last follow-up for a 71.9% of correction in the AIS group. The preoperative mean major coronal curve was 80.4° (ranged 63.4°–108.1°) and improved to 23.2° (ranged 4.8°–66.2°) at the last follow-up for a 71.1% of correction in PAIS group. The global coronal balance, TK and SVA were all significantly improved after surgery and maintained to the last follow-up in the two groups. No statistical difference in the parameters between the two groups was observed at the last follow-up. Furthermore, the preoperative ODI score was 33.4 (12–42) in the PAIS group and improved to 11.7 (5–22) at last follow-up, 34.1 (12–43) in the AIS group and improved to 11.1 (4–21) at last follow-up. It was also comparable without statistical difference between the two groups (Table 4).

**Table 2** Baseline data comparison of adolescent idiopathic scoliosis (AIS) patients and presumed adolescent idiopathic scoliosis (PAIS) patients associated with intraspinal abnormalities

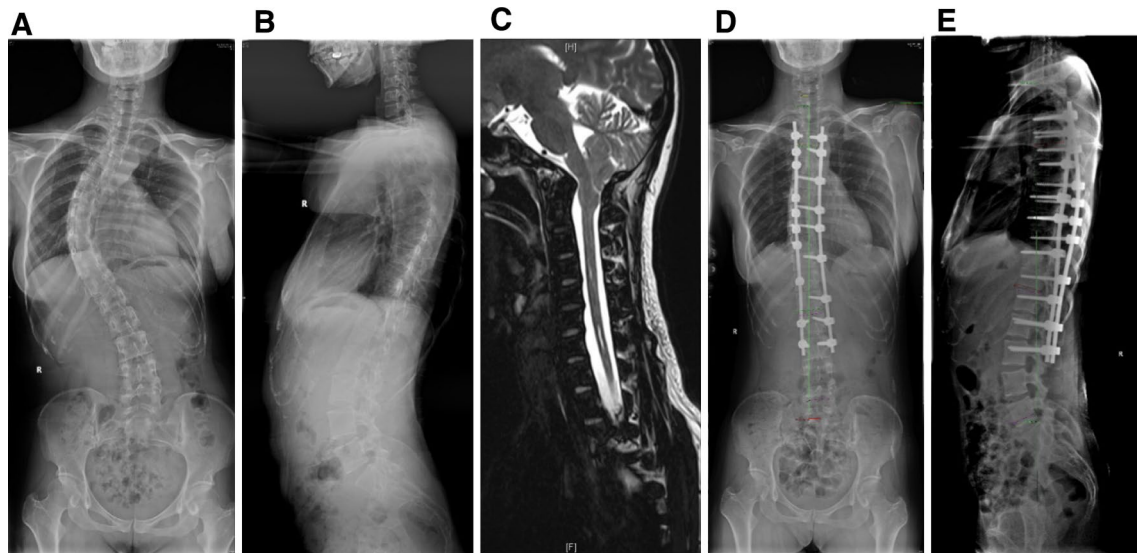
	PAIS	AIS	P value
Age (year)	18.7 (12–24)	17.7 (11–23)	0.27
Sex (% male)	30.0	30.1	0.72
Risser grade	2.6 (0–5)	2.6 (0–5)	0.81
Blood loss (mL)	811.9 (580–1320)	771.3 (520–1280)	0.42
Operating time (min)	259.1 (180–395)	248.6 (175–372)	0.63
Levels of instrumentation	12.3 (9–14)	13.1 (9–15)	0.41
Numbers of screws	24.3 (17–28)	26.6 (17–30)	0.35
Duration of follow-up (months)	51.9 (44–58)	52.5 (42–66)	0.67
Location of anomalies			
Above the correction	17	–	–
Within the correction	6	–	–
Below the correction	7	–	–

All the values are given as the mean with the range in the parentheses except sex

**Table 3** Preoperative characteristics for patients with adolescent idiopathic scoliosis (AIS) and presumed adolescent idiopathic scoliosis (PAIS) associated with intraspinal abnormalities

	PAIS	AIS	P value
No.	30	83	
Major coronal curve (°)	80.4 (63.4–108.1)	79.6 (56.2–106.7)	0.65
Global coronal balance (mm)	21.3 (4.2–45.1)	19.8 (6.4–45.6)	0.46
Thoracic kyphosis (°)	54.6 (8.3–71.2)	53.7 (10.1–68.7)	0.59
Sagittal vertical axis (mm)	-21.2 (-124.4–95.7)	-18.8 (-117.6–78.9)	0.07
ODI	33.4 (12–42)	34.1 (12–43)	0.57

All the values are given as the mean with the range in the parentheses



**Fig. 1** Preoperative anteroposterior (a) and lateral (b) radiographs obtained in a 16-year old female scoliosis patient associated with Syringomyelia and Chiari deformity (c). Last, follow-up anteroposterior (d) and lateral (e) radiographs showing good correction

**Table 4** Comparison of postoperative characteristics between the adolescent idiopathic scoliosis (AIS) group and presumed adolescent idiopathic scoliosis (PAIS) group

	PAIS	AIS	P value
Major coronal curve (°)			
Immediate postop.			
Magnitude (°)	20.4 (3.5–62.3)	19.4 (6.3–56.6)	0.04*
% Correction	74.6 (36.3–94.8)	75.6 (44.1–96.2)	0.13
Last follow-up			
Magnitude (°)	23.2 (4.8–66.2)	22.4 (6.4–58.1)	0.03*
% Correction	71.1 (33.5–95.8)	71.9 (40.1–94.2)	0.44
Correction loss (°)	2.9 (–7.3–12.6)	3.0 (–10.1–14.4)	0.25
Global coronal balance (mm)			
Immediate postop.	10.7 (0.6–38.2)	11.4 (0.3–40.1)	0.19
Last follow-up	9.9 (1.2–41.1)	11.1 (2.1–38.6)	0.23
Thoracic kyphosis (°)			
Immediate postop.	43.3 (10.1–62.5)	40.5 (8.3–58.2)	0.05*
Last follow-up	42.8 (8.7–56.2)	40.1 (10.6–58.8)	0.35
Sagittal vertical axis (mm)			
Immediate postop.	–5.32 (–106.2–92.4)	–6.2 (–98.1–78.9)	0.27
Last follow-up	–15.4 (–94.2–77.7)	–13.9 (–93.2–74.1)	0.22
ODI			
Immediate postop	15.3 (7–21)	15.4 (4–24)	0.57
Last follow-up	11.7 (5–22)	11.1 (4–21)	0.64

All the values are given as the mean with the range in the parentheses

\*Statistically significant

**Complications**

One patient got mild lower limb sensory dysfunction in the PAIS group postoperatively. Two patients had mild neurologic complications in the AIS group postoperatively, one of them got mild lower limb motor dysfunction, one of them

got mild lower limb sensory dysfunction. All of them were detected changes of MEP or SSEP during surgery after which we performed milder correction and used 500 mg methylprednisolone for them. They all recovered after conservative treatment in 3 months. Besides, one patient had a superficial infection in the AIS group after surgery. No

neurologic deteriorations in two groups were observed at the last follow-up.

## Discussion

Scoliosis associated with intraspinal abnormalities has been reported increasingly in patients with PAIS with the common use of MRI. The incidence of intraspinal abnormalities among the presumed idiopathic scoliosis was 13–43% in the published literature. And most of them were unidentified by preoperative physical examinations. Routine MRI was suggested for the presumed idiopathic scoliosis patients [3–9]. The scoliosis patients received routine Pre-Op MRI in our hospital due to the high incidence of intraspinal abnormalities.

Previous studies have shown that scoliosis correction was associated with a higher risk of postoperative progression and neurological complications in PAIS patients associated with intraspinal abnormalities compared to AIS patients [19–23]. Bradley et al. [21] reported four syringomyelia-associated scoliosis (SMS) patients of progression in eleven surgically treated series. Charry et al. [13] also reported one case of SMS patient who developed motor dysfunction of lower extremities at 5 years follow-up. Increased traction on the abnormal spinal tissue and changes of cerebrospinal fluid pressure may be responsible for the increased risks of progression and neurological complications. Tomlinson et al. [24] and Qin et al. [25] investigated syringomyelia-associated scoliosis patients who underwent correction surgeries and indicated that scoliosis patients with intraspinal deformities were supposed to receive neurological intervention before spinal corrective surgery. The scoliosis correction in the PAIS group in this study was reported higher than the previous studies of syringomyelia cases [22, 23]. It could be that the previous studies have included more patients with syringomyelia within the instrumented field of surgery whereas in this study more patients had the abnormality above or below the correction. And the patients in this study had relatively soft and mild curves.

In contrast to previous studies, our patients' series were all received single-stage corrective surgery. Over an average of 52 months follow-up, the radiographic and clinical outcomes are comparable between the PAIS group and the AIS group. The progression of over 10 degrees was found in 6% of intraspinal abnormalities patients and 7% of AIS patients. The neurological complications were observed in 3.3% of PAIS patients and 3.6% of AIS patients. Most of the patients got mild complications and all recovered within 6 months. We did not have postop MRI for these patients, because they have only mild symptoms. We chose conservative treatment for these patients after which they all recovered and had non-neurologic deteriorations at the last follow-up. The correction

rate, ODI scores in the PAIS group was comparable to the AIS group. The complications were also comparable and mild. Single-stage corrective surgery is safe and effective in PAIS patients associated with intraspinal abnormalities without preoperative neurological symptoms. Our study has similar results in some well-designed studies. Sha et al. [11] compared the radiographic and clinical outcomes of single-stage posterior spinal fusion between patients with right thoracic AIS and SMS and found no significant difference. Zhang et al. [10] also evaluated one-stage posterior scoliosis correction surgery in patients with syringomyelia with no or mild neurological symptom. They suggested that neurologic intervention was not necessary for intraspinal abnormalities in patients without preoperative neurological symptoms.

Moreover, the patients in our study all received Occipital-jaw belt traction for 2 weeks. Preoperative traction is a safe and effective way to maximize correction and help to estimate the adaptation of the spinal tissue after corrective surgery. When doing the traction, physical examination was required every day, because complications were reported related to traction. Ginsburg et al. [26] reported a case of hypoglossal nerve injury with 40% of the patient's body weight when doing traction.

Monitoring of SSEP and MEP and the wake-up test was conducted in all patients in this study during surgery. Previously published studies also indicated that spinal cord monitoring of SSEP and MEP and the wake-up test was necessary when doing spinal corrective procedure [10, 27].

Although the study was well-designed, we do have some limitations. We only investigated PAIS patients, and there are still some other patients who had either similar intraspinal anomalies with non-AIS like curves or with similar-looking curves who had staged procedures. The treatment for them also remained controversial and we will investigate these patients in our next study.

## Conclusions

One-stage posterior corrective surgery is safe and effective in PAIS patients associated with intraspinal abnormalities without preoperative neurological symptoms. Surgical guidelines of AIS is appropriate for the treatment of PAIS patients associated with intraspinal abnormalities.

**Authors' contributions** All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Jingwei Liu, Shuo Zhang, Yong Hai, Nan Kang and Yiqi Zhang. The first draft of the manuscript was written by Jingwei Liu and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**Availability of data and material** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Code availability** We have permissions for the use of software, questionnaires/(web) surveys and scales in their studies.

## Compliance with ethical standards

**Conflicts of interest/Competing interests** We do not have a financial or personal relationship with a third party. We have full control of all primary data and we agree to allow the journal to review their data if requested. On behalf of all authors, the corresponding author declares that there is no conflict of interest.

**Ethics approval** The study was approved by the Department of Ethics, Beijing Chaoyang Hospital, Capital Medical University.

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