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Clinical Study

Surgical treatment for severe and rigid scoliosis: a case-matched study between idiopathic scoliosis and syringomyelia-associated scoliosis

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Abstract

BACKGROUND CONTEXT: Treatment guidelines for severe and rigid syringomyelia-associated scoliosis (SRSMS) are limited. Typically, surgeons apply practice guidelines for severe and rigid idiopathic scoliosis (SRIS) to treat SRSMS. No study has directly compared the results of surgical treatment between patients with SRSMS and those with SRIS.

PURPOSE: The present study was performed to compare the outcomes of surgical correction of SRSMS and SRIS from clinical and radiographic perspectives.

STUDY DESIGN: This is a retrospective, case-matched, single-center, institutional review board-approved study.

PATIENT SAMPLE: A total of 26 patients with SRSMS or SRIS treated by an anterior and posterior vertebral column resection approach or an internal distraction approach were enrolled.

OUTCOME MEASURES: The SRSMS and SRIS groups were compared on the following variables: fusion length, screw number, operation time, estimated blood loss, follow-up duration, different radiological parameters (including main thoracic curve, cranial compensatory curve, caudal compensatory curve, thoracic kyphosis, lumbar lordosis, thoracic apical vertebral translation, coronal balance, and sagittal vertical axis), Scoliosis Research Society (SRS)-22 scores, and complication rate.

METHODS: Thirteen patients with SRSMS were matched with patients with SRIS on curve magnitude, the flexibility of the main curve, surgical procedure, age, and gender. All patients had a minimum of 2 years of follow-up. The radiographic parameters and demographic data from patients were evaluated before surgery, immediately after surgery, and at the latest follow-up.

RESULTS: The case matches were relatively ideal except one pair with the main curve in the opposite direction. There was no significant difference in fusion length, screw number, operation time, estimated blood loss, or follow-up duration between the two groups. No significant differences were found between the two groups in the main curve or caudal compensatory curve before surgery, immediately after the operation, or at the final follow-up. The correction of thoracic apical vertebral translation in the SRIS group was better than that in the SRSMS group. The SRSMS group had a larger preoperative, postoperative, and final follow-up cranial compensatory curve and a lower correction rate than did the SRIS group. There was no significant difference in preoperative coronal balance between the two groups. After surgery, the coronal balance in the SRSMS and SRIS groups averaged 24.4±13.2 mm and 12.1±7.9 mm, respectively, which was significantly different (p=.04). At the most recent follow-up, the coronal balance in the SRSMS group improved to 14.8±12.6 mm, and it was 11.8±8.6 mm in the SRIS group. No significant difference was found between the two groups (p=.56). There was no significant difference in thoracic kyphosis, lumbar lordosis, or sagittal vertical axis before surgery, immediately after the operation, or at the final follow-up. Before surgery and at the final follow-up, the two groups had similar scores on function, pain, self-image, mental health, and satisfaction. There was no significant difference in complication rates between the two groups.

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CONCLUSIONS: Typically, surgical correction outcomes are similar in patients with SRSMS and SRIS. Patients with SRIS tended to have a smaller cranial compensatory curve and better correction of the cranial compensatory curve and thoracic apical vertebral translation. Patients with SRSMS tended to have a higher proportion and greater amount of postoperative coronal imbalance, which may be improved during follow-up.

Keywords: Anterior and posterior vertebral column resection; Chiari malformation; Coronal balance; Scoliosis; Severe and rigid curve; Syringomyelia

Introduction

Syringomyelia-associated scoliosis (SMS) is a common type of neuromuscular scoliosis. Surgical management for correction of adolescent idiopathic scoliosis (AIS) has been well-established [1], but the guidelines for SMS are obscure. Sha et al. compared the radiographic and clinical outcomes of posterior spinal fusion between patients with right thoracic SMS and those with right thoracic AIS. They concluded that despite the differences in preoperative status, adolescents with idiopathic right thoracic scoliosis and those with syringomyelia-associated right thoracic scoliosis had comparable clinical and radiographic outcomes from pedicle-screw-based posterior spinal fusion [2]. In their study, only patients with Cobb angles 50°–80° were included. In most of the literature, severe and rigid scoliosis is defined as coronal curves over 90° with flexibility of less than 30% [3–5]. Whether the conclusions of Sha et al.'s study can be applied to severe and rigid scoliosis is unknown.

To our knowledge, no study has compared outcomes from surgical correction of severe and rigid syringomyelia-associated scoliosis (SRSMS) and severe and rigid idiopathic scoliosis (SRIS). We performed a case-matched study between patients with SRIS and SRSMS with similar curve magnitude, main curve flexibility, age, gender, and surgical procedure to compare the outcomes of correction from clinical and radiographic perspectives.

Materials and methods

Patients

The present study was approved by the ethics board committee of our center. A retrospective review of all patients with SRSMS who received surgery in our center from January 2001 to June 2011 was performed. The inclusion criteria were (1) an over 90° main thoracic curve and flexibility less than 30% at presentation, (2) a minimum of 2 years of clinical and radiographic follow-up, and (3) no congenital spinal deformity or history of spine surgery. Thirteen patients (five male and eight female) were ultimately enrolled in the present study.

We also reviewed our database to identify patients with SRIS who had undergone spinal fusion for a thoracic curve during the same period and chose those who were the best matches to the patients with SRSMS with respect to curve magnitude (within 5°), the flexibility of the main curve, age, gender, and surgical procedure. If ideal matching was not available on all parameters, the preferred priority was (1) curve magnitude, (2) the flexibility of the main curve, (3) surgical procedure, (4) age, and (5) gender. Thirteen patients with SRIS (five male and eight female) served as the SRIS group.

Surgical procedures

Anterior and posterior vertebral column resection

Six pairs of patients received staged anterior and posterior vertebral column resection [6]. All surgeries were performed by two senior spine surgeons (LL and YS) with monitoring of somatosensory-evoked and motor-evoked potentials. The vertebral bodies of the apex were resected through a transthoracic approach in the first stage. In addition, intervertebral discs adjacent to the apex were excised back to the posterior longitudinal ligament to obtain adequate anterior release.

The posterior procedure was performed 1–2 weeks after the initial surgery. Pedicle screws were inserted and then the spinous process, lamina, facet joint, transverse process, and pedicle of the apical vertebrae were resected. Using persuasion and rod derotation, the deformity was corrected. A bone graft was placed along the spine for posterior fusion [7].

Internal distraction approach

Seven pairs of patients received the internal distraction approach. At the first stage of the surgery, four to five discs around the apex were excised through a transthoracic approach. Then, the patient was changed to a prone position to receive posterior internal distraction. Two small incisions were performed to expose the cranial and caudal vertebra that would be fixed. At least two points of fixation at the cranial end and two at the caudal end were used to achieve adequate fixation. One longer distraction rod connected to the cephalad fixation points was inserted subcutaneously, and another shorter distraction rod was connected to the caudal fixation points. Two rods were connected by a domino connector (Medtronic, Fort Worth, TX, USA). The pedicle screw caps were locked. After the screw caps on the medial side of the domino connector were locked, the distraction maneuver was performed between the distal pedicle screw and the domino connector. Then, the screw caps on the lateral side of the domino connector were locked, and the screw caps on the medial side of the domino connector were loosened. A similar distraction maneuver was performed between the domino connector and the rod holder. To take advantage of the viscoelastic nature of the spine and to maximize correction with minimal stress, we allowed a few minutes for stress relaxation between multiple episodes of distraction during each distraction procedure [8]. One to 4 weeks after the distraction, definitive posterior spinal fusion was performed.

Clinical and radiographic evaluation

The SRSMS and SRIS groups were compared on the following variables: fusion length, screw number, operation time, estimated blood loss, follow-up duration, different radiological parameters, and Scoliosis Research Society (SRS)-22 scores.

Radiological parameters included the main curve, cranial compensatory curve, caudal compensatory curve, thoracic kyphosis, lumbar lordosis, thoracic apical vertebral translation, coronal balance, and sagittal vertical axis [9]. Global coronal balance was determined by measuring the horizontal distance from the C7 plumb line relative to the center sacral vertical line, and a >20-mm shift of the C7 plumb line was considered to be coronal imbalance [10]. The sagittal vertical axis was determined by measuring the horizontal distance from the C7 plumb line relative to the posterior superior corner of the sacrum [11]. The SRS-22 scores [12] were used for outcome assessment. Scores ranged from 1 to 5 with 5 as the most favorable.

In patients with SRSMS, the size of the syrinx cavity, including its length and the maximal syrinx/cord ratio [13], was evaluated with preoperative magnetic resonance imaging. The maximal syrinx/cord ratio was calculated by dividing the maximal diameter of the syrinx by the diameter of the spinal cord at the same level, and the syrinx length was defined as the number of vertebral segments spanned by the syrinx [14].

Statistical analysis

All data were analyzed using the IBM SPSS Statistics for Windows version 22.0.0.1 (2013, IBM Corp., Armonk, NY, USA). The quantitative data were analyzed using paired *t* tests. Categorical data were analyzed using chi-square tests or Fisher exact tests. A p-value<.05 was considered significant.

Results

The patients in the two groups were case-matched for curve magnitude (within 5°), the flexibility of the main curve, surgical procedure, age, and gender. The case match was relatively ideal except one pair with the main curve in opposite directions. There were seven female and six male patients in both groups. Mean age at surgery in the SRSMS and SRIS groups was 15.4±2.3 years and 15.5±1.9 years, respectively. The characteristics of the main thoracic curve, including Cobb angle, flexibility, and apical vertebral translation, were similar (Table 1). There was no significant difference in fusion length, screw number, operation time, estimated blood loss, or follow-up duration between the two groups.

In the SRSMS group, the main curve was 95.5°±5.6° with flexibility of 16.9%±4.8% and was corrected to 32.9°±9.2° at immediate postoperative assessment, indicating a 65.6% scoliosis correction. At the most recent follow-up, the main curve was 34.7°±9.3°, with only a 1.8°±3.8° loss of correction compared with the immediate postoperative curve measurement (Fig. 1). In the SRIS group, the preoperative main curve was 96.6°±3.8° with flexibility of 17.6%±6.5% and was corrected to 30.9°±8.4°at immediate postoperative assessment, indicating a 68% scoliosis correction. At the most recent follow-up, the main curve was 32.4°±8.0°, with only a 1.5°±6.5° loss of correction compared with the immediate

Table 1
Comparison of patient characteristics and outcomes between two groups

	SRSMS	SRIS	p-Value*
No. of patient	13	13	
Age (y)	15.4 (11–18)	15.5 (11–18)	.67
Gender			
Male	6	6	
Female	7	7	
Risser grade	2.6 (0–4)	2.9 (0–4)	.56
Flexibility (%)			
Main curve	16.9 (4–23)	17.6 (10–30)	.72
Cranial compensatory curve	29.0 (17–60)	44.3 (20–65)	.04*
Caudal compensatory curve	48.3 (35–66)	52.3 (37–72)	.05
Syrinx/cord ratio	0.5 (0.2–0.8)		
Syrinx length (no. of vertebrae)	5.0 (2.5–8)		
Chiari-I malformation	6	0	
No. of screw	14.3 (12–16)	13.5 (12–16)	.23
No. of fused level	14.0 (13–15)	13.5 (12–15)	.25
Operation time (min)	481.5 (443–515)	477.8 (430–510)	.69
Estimated blood loss (mL)	1,174 (800–1650)	1,105 (800–1500)	.61
Follow-up (mo)	44.4 (27–84)	45.5 (24–80)	.89

SRSMS, severe and rigid syringomyelia-associated scoliosis; SRIS, severe and rigid idiopathic scoliosis.
* p<.05.

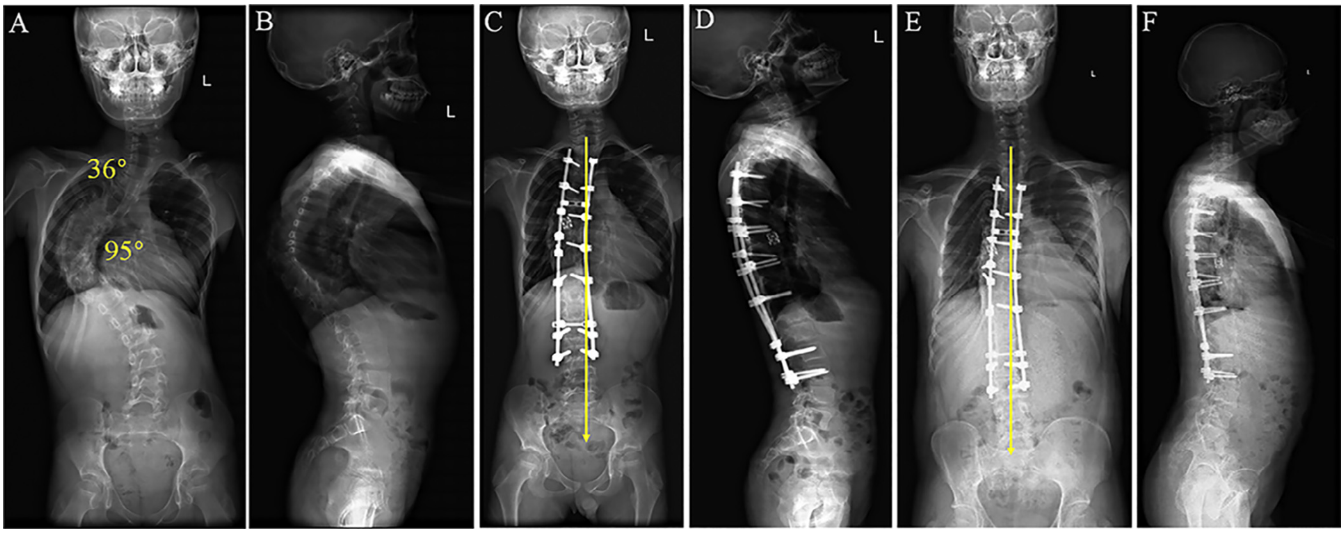

Fig. 1. A 15-year-old boy with a severe and rigid thoracic idiopathic curve (A, B). The radiographs demonstrate a thoracic curve of 95° and a cranial curve of 36°. Postoperative posteroanterior (C) and lateral (D) radiographs following posterior spinal fusion from T2 to L3 demonstrate excellent correction of the curves with postoperative values of 25°. Radiographs made 6 years after surgery (E, F) revealed well-maintained global coronal and sagittal balance.

postoperative curve measurement (Fig. 2). There was no significant difference in the preoperative, postoperative, or final follow-up main curves between the two groups (Table 2). No significant difference was found in the main curve correction rate immediately postoperatively or at the final follow-up between the two groups. There was no significant difference in loss of correction between the two groups (p=.82). Two patients in the SRSMS group (11° and 14°) and one patient in the SRIS group (12°) experienced loss of correction over 10°.

Before surgery, thoracic apical vertebral translation in the SRSMS and SRIS groups averaged 76.9±17.1 mm and 76.5±12.5 mm, respectively. There was no significant difference between the two groups. After surgery and at the most recent follow-up, thoracic apical vertebral translation in the SRSMS and SRIS groups averaged 29.1±8.6 mm and 30.1±9.3 mm, respectively, with the SRSMS measurement larger than the SRIS measurement.

In the SRSMS group, the preoperative Cobb angle of the cranial compensatory curve averaged 46.3°±11.5° with flexibility of 29.0%±14.8% that was corrected to 32.9°±13.1°, showing a 28.9% curve correction. At the most recent follow-up, the cranial compensatory curve was 29.8°±11.9°, and a decrease of 3.2°±4.3° was observed compared with the immediate postoperative curve measurement. In the SRIS group, the preoperative Cobb angle of the cranial compensatory curve averaged 38.3°±9.8° with flexibility of 44.3%±15.1% that was corrected to 20.8°±6.7°, showing a 45% curve correction. At the most recent follow-up, the cranial compensatory curve was 16.9°±7.0°, and a curve decrease of 4.2°±3.5° was observed compared with the immediate postoperative curve measurement. The preoperative, postoperative, and final follow-up cranial compensatory curves in the SRSMS group were larger than those in the SRIS group. The flexibility of the cranial compensatory curve in the SRSMS group was lower than that in the SRIS group. Immediately after the operation and at final follow-up, the correction rate of the cranial compensatory curve in the SRSMS group was lower than that in the SRIS group (Table 2). Before surgery, immediately postoperatively and at the final follow-up, there were no significant differences in the caudal compensatory curve between the two groups.

No significant difference was found in coronal balance between the two groups preoperatively. After surgery, six patients in the SRSMS group and two patients in the SRIS group had coronal imbalance (46.2% vs. 15.0%). The coronal balance in the SRSMS group and SRIS group averaged 24.4±13.2 mm and 12.1±7.9 mm, respectively, and a significant difference was found (p=.04). At the most recent follow-up, coronal imbalance remained in two patients in the SRSMS group and one patient in the SRIS group. The coronal balance in the SRSMS group improved to 14.8±12.6 mm, and it was 11.8±8.6 mm in the SRIS group. No significant difference was found between the two groups (p=.56). Before surgery, immediately postoperatively and at the final follow-up, no significant difference was found in thoracic kyphosis, lumbar lordosis, or the sagittal vertical axis between the two groups (Table 2).

On the initial clinical examinations, neurologic deficits were detected in 4 of 13 patients with SRSMS. Among these four patients, three patients had unilateral attenuated abdominal reflex with no evidence of other long tract signs, such as hypertonia, Babinski reflex, or clonus. One patient had 4/5 normal muscle strength and mild sensory disturbances with muscular atrophy on the right side of the limbs, and Hoffmann signs were found bilaterally. No neurologic deficits were detected in the other nine patients with SRSMS. At the last follow-up, all patients remained in the same neurologic status found

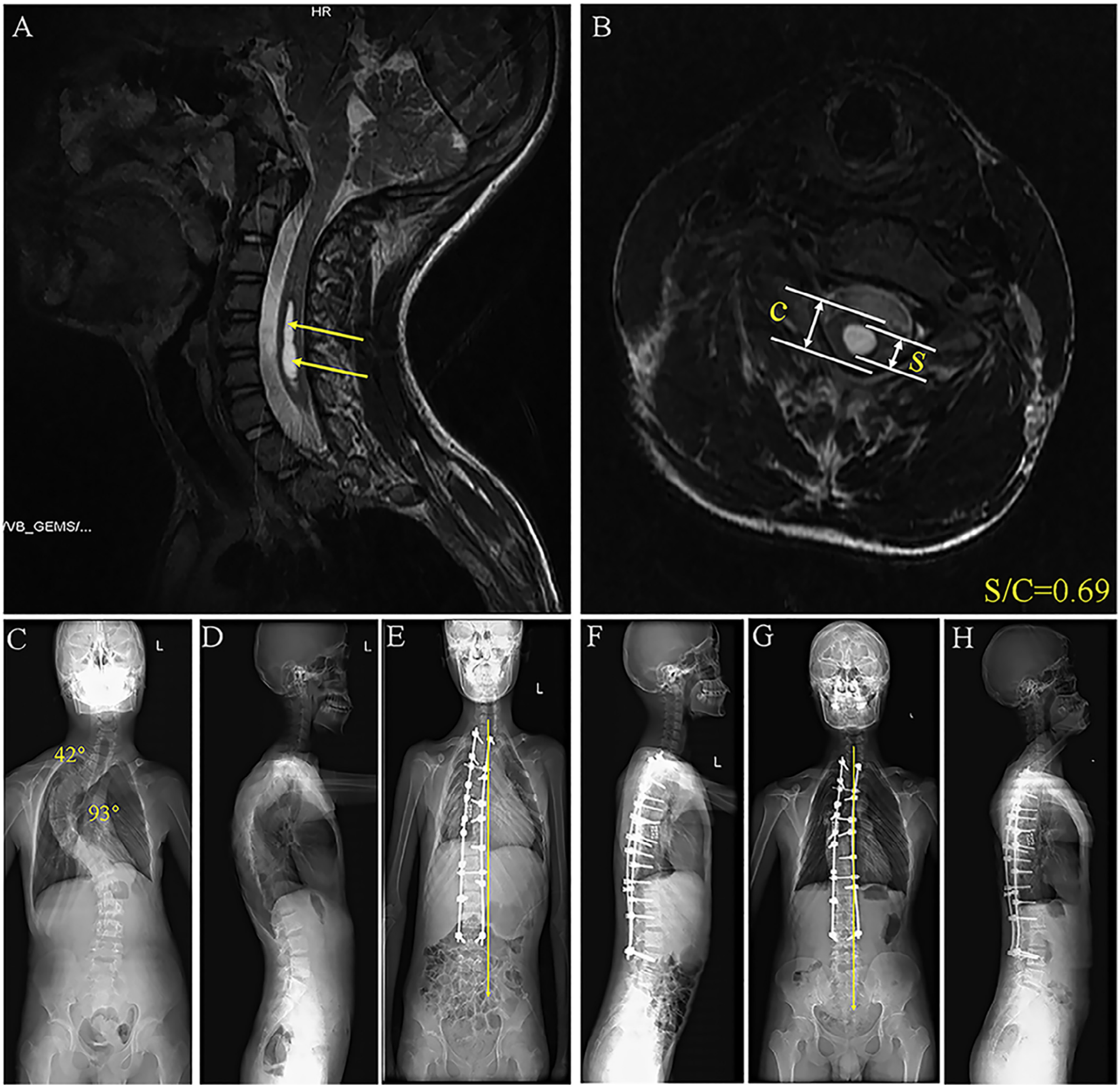

Fig. 2. A 15-year-old boy with a severe and rigid thoracic curve associated with syringomyelia (C, D). The radiographs demonstrate a thoracic curve of 93° and a cranial curve of 42°, the syrinx, with a syrinx/spinal cord (S/C) ratio of 0.6 and a length of 3.5 vertebrae (A, B), and postoperative posteroanterior (E) and lateral (F) radiographs following posterior spinal fusion from T2 to L4 demonstrate coronal imbalance of 30 mm. Radiographs made 6 years after surgery (G, H) reveal well-maintained global coronal and sagittal balance.

preoperatively. Six patients with SRSMS had Chiari I malformation, and posterior fossa decompression was performed in four patients before correction. A syrinx was found in the other seven patients during magnetic resonance imaging, but no Chiari malformation, tethered cord, or tumor was found. Because the syrinx in these seven patients was relatively small (average maximal syrinx/cord ratio was 0.3±0.1 preoperatively) and the patients had no neurologic symptoms, no intervention was given for the syrinx before scoliosis correction. The preoperative maximal syrinx/cord ratio and length of the syrinx averaged 0.5±2.5 and 5.0±1.8 vertebrae, respectively, in the SRSMS group (Table 1). The maximal syrinx/cord ratio of patients with Chiari I malformation decreased from 0.7±0.2 preoperatively to 0.3±0.1 at the last follow-up. The length of the syrinx decreased from 5.4±1.9 vertebrae preoperatively to 4.9±1.6 vertebrae at the last follow-up. The maximal syrinx/cord ratio of patients without Chiari I malformation was reduced from 0.3±0.1 preoperatively to

Table 2
Radiographic data for patients with SRSMS and SRIS

	SRSMS	SRIS	p-Value
Main curve (deg)			
Preoperative	95.5 (90–110)	96.6 (93–105)	.28
Immediate postop	32.9 (12–43)	30.9 (19–53)	.61
Latest follow-up	34.7 (15–46)	32.4 (23–55)	.48
Loss of correction	1.8 (−3 to 12)	1.5 (−10 to 14)	.88
Cranial compensatory curve (deg)			
Preoperative	46.3 (30–71)	38.3 (28–52)	.03*
Immediate postop	32.9 (10–52)	20.8 (10–35)	.02*
Latest follow-up	29.8 (8–49)	16.9 (6–29)	.02*
Decrease	3.2 (0–15)	4.2 (0–10)	.59
Caudal compensatory curve (deg)			
Preoperative	46.2 (34–72)	46.9 (33–63)	.88
Immediate postop	12.5 (5–32)	15.7 (6–28)	.39
Latest follow-up	11.1 (4–28)	14.0 (3–26)	.39
Decrease	1.4 (0–4)	1.7 (0–6)	.76
Thoracic apical vertebral translation (mm)			
Preoperative	76.9 (55–110)	76.5 (60–100)	.92
Immediate postop	29.1 (10–40)	21.9 (10–41)	.02*
Latest follow-up	30.1 (13–45)	22.5 (10–41)	.02*
Thoracic kyphosis (T5–T12) (deg)			
Preoperative	53.6 (28–70)	50.5 (40–79)	.39
Immediate postop	32.6 (12–43)	30.9 (19–53)	.45
Latest follow-up	34.7 (12–43)	31.7 (19–47)	.24
Lumbar lordosis (T12-S1) (deg)			
Preoperative	54.9 (40–73)	58.8 (40–87)	.37
Immediate postop	44.2 (33–67)	42.9 (22–60)	.79
Latest follow-up	40.7 (22–60)	41.9 (33–54)	.68
Coronal balance (mm)			
Preoperative	13.8 (10–41)	12.5 (0–38)	.74
Immediate postop	24.4 (0–38)	12.1 (0–22)	.04*
Latest follow-up	14.8 (0–38)	11.8 (0–25)	.56
Sagittal vertical axis (mm)			
Preoperative	7.6 (−30 to 40)	6.9 (−18 to 60)	.89
Immediate postop	13.0 (−10 to 75)	9.6 (−30 to 75)	.35
Latest follow-up	9.6 (−8 to 45)	7.8 (−10 to 45)	.64

SRSMS, severe and rigid syringomyelia-associated scoliosis; SRIS, severe and rigid idiopathic scoliosis.
* $p<.05$.

0.2±0.1 at the last follow-up. The length of the syrinx was reduced from 3.8±1.5 vertebrae preoperatively to 3.5±1.4 vertebrae at the last follow-up (Table 3).

Before surgery and at the final follow-up, all patients in both groups completed the SRS-22 questionnaire [12]. Analysis of the preoperative questionnaire values revealed no differences between the two groups. At the final follow-up, the two groups had similar scores for pain (4.3 vs. 4.2), self-image (4.0 vs. 4.6), function (4.3 vs. 4.6), and mental health (4.3 vs. 4.4).

Four complications were found in the SRSMS group. One patient required ventilator support for 12 hours after anterior surgery. Three screws in two patients were considered to have a medial breach between 2 and 4 mm. In the SRIS group, three patients had complications. One patient encountered mild dyspnea, which was resolved by greater oxygen inhalation. Malposition of one pedicle screw, which appeared as a cephalad breach into the intervertebral disc on the lateral radiograph, was found in one patient. One screw had a medial breach between 2 and 4 mm. No neurologic complications or any deep wound infections or complications of instrumentation were found in either group. Bone graft fusion was achieved in all patients in both groups, and there was no mechanical failure or non-union. No surgical revision was required in either group. There was no significant difference in the complication rate between the two groups.

Table 3
Syrinx features in patients with SRSMS

	Syrinx with Chiari-I	Syrinx without Chiari-I
No.	6	7
Preop		
Syrinx/cord ratio	0.7 (0.5–0.8)	0.3 (0.2–0.6)
Syrinx length (no. of vertebrae)	5.4 (3–8)	3.8 (2–6)
Last follow-up		
Syrinx/cord ratio	0.3 (0.2–0.6)	0.2 (0.1–0.4)
Syrinx length (no. of vertebrae)	4.9 (3–7)	3.5 (2–5)

SRSMS, severe and rigid syringomyelia-associated scoliosis.

Discussion

Lenke et al. [15] published a classification for AIS in 2001. A subsequent surgical guideline, which was presented in 2007, has been applied broadly [1]. However, there is no surgical guideline for SRSMS. Typically, the surgical treatment for a patient with SRSMS uses the treatment guidelines for SRIS, although there are some etiological and clinical differences [16]. Whether the surgical treatment for SRIS can be used in SRSMS effectively remains unknown. To our knowledge, the present study is the first that compared outcomes from surgical correction of SRSMS and SRIS. The results of the present study showed that the surgical correction outcomes were essentially similar in patients with SRSMS and SRIS. A higher proportion and greater amount of coronal imbalance were found in patients with SRSMS immediately postoperatively, whereas good coronal balance was achieved at the latest follow-up in both groups.

Immediately after the operation, a higher proportion and greater amount of coronal imbalance were found in the SRSMS group. This finding might be related to the cranial compensatory curve. No significant difference was found between the two groups in the main curve or caudal compensatory curve before surgery or immediately after surgery. However, the SRSMS group had larger preoperative and postoperative cranial compensatory curves and a lower correction rate than did the SRIS group. Therefore, coronal imbalance may be attributed to incomplete correction of the cranial compensatory curve. In addition, in some patients with SRSMS, the structural cranial compensatory curve extends to the cervical level with the apical vertebra located at a relatively higher level. However, for such patients, upper fixation of vertebra is usually chosen at T2, which does not extend to the upper end vertebra of the cranial compensatory curve and may cause postoperative coronal imbalance.

The present study showed that the incidence of immediate postoperative coronal imbalance in the SRSMS group was as high as 46.2%, whereas most patients in both groups achieved balance by the latest follow-up. Different theories have been proposed to explain coronal decompensation, but the mechanism remains unclear to date [17]. Yang et al. [18] retrospectively reviewed 80 patients with AIS (Lenke 5 or 6) and divided patients into coronal balance and immediate coronal imbalance. They believed that postoperative coronal imbalance could be compensated by distal disc wedging of the lowest instrumented vertebra. Sun et al. [19] believed that distal unfused segments play an important role in the reconstitution of coronal balance. In addition, many other factors might also exist for coronal balance reconstitution, such as reconstitution of muscle function, motor coordination of the trunk and compensation for the cranial and caudal curve. Therefore, it is not easy to identify any single factor responsible for the reconstitution of coronal balance by the latest follow-up in the present study.

With the wide use of pedicle screws, which provide three-column correction and fixation, the loss of correction reported in the literature is insignificant [20]. Wang et al. reported the surgical outcomes of 21 patients with syringomyelia-associated scoliosis treated by pedicle screws, and only a mean 3° loss of correction in the coronal plane was found. In our study, loss of correction averaged 1.8°±3.8°and 1.5°±6.5° in the SRSMS and SRIS groups, respectively, which was similar to the results in the literature. In Sha et al.'s study, eight patients with syringomyelia-associated scoliosis and five patients with AIS lost >10° of correction. In our study, two patients in the SRSMS group and one patient in the SRIS group experienced loss of correction over 10° after surgery. Although the mean major curve in our study was larger than that of Sha et al.'s study, the ratio of patients who lost >10° of correction was close.

Chiari I malformation is frequently associated with syringomyelia and scoliosis [21]. The surgical strategy for SRSMS with Chiari I malformation is controversial, especially with respect to surgical priority [22]. Whether it is advisable to perform a posterior fossa decompression before scoliosis correction remains a topic of debate among surgeons [23]. In our study, six patients with SRSMS had Chiari I malformation, and posterior fossa decompression was performed in four patients before correction without severe neurologic complications recorded in any patient. In a patient with a large syrinx or neurologic symptoms, we suggest performing posterior fossa decompression before scoliosis correction. In our study, the other seven patients with SRSMS only had scoliosis, and no Chiari malformation, tethered cord, or tumor was found. Because the syrinx of these seven patients was relatively small (average maximal syrinx/cord ratio was 0.3±0.1 preoperatively), and the patients had no neurologic symptoms, no intervention was given for the syrinx before scoliosis correction. Based on our study, no severe neurologic deficits were encountered in the SRSMS group even in the patient with a huge syrinx, which indicated that there was no direct correlation between the syrinx and neurologic function.

Although a direct comparison between SRSMS and SRIS at a single institution was performed, there were some limitations in our study. First, when matching the patients in the present study, we failed to match all criteria in each patient. If ideal matching was not available on all parameters, the preferred priority was as follows: (1) curve magnitude, (2) the flexibility of the main curve, (3) surgical procedure, (4) age, and (5) gender. Therefore, the case match was not ideal. Second, because the incidence of SRSMS is relatively low, the sample size was limited in the present study, which may affect the reliability of the results. Therefore, further research should improve on these shortcomings.

In conclusion, surgical correction outcomes are similar in patients with SRSMS and SRIS. Patients with SRIS tend to have smaller cranial compensatory curves and better correction of cranial compensatory curves and thoracic apical vertebral translation. Patients with SRSMS tend to have a higher proportion and greater amount of postoperative coronal imbalance, which may be improved during follow-up.

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