Spine Deformity

www.spine-deformity.org

Spine Deformity 6 (2018) 545−551

Dual Sequential Short Anterior Correction in Double Major Adolescent Idiopathic Scoliosis

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Received 20 October 2017; revised 9 January 2018; accepted 14 January 2018

Abstract

Study Design: retrospective comparative study.

Introduction: The standard surgical technique for double major adolescent idiopathic scoliosis (AIS) has been the fusion of both thoracic and thoracolumbar/lumbar curves from the posterior approach. Although short anterior correction is established in AIS with single thoracic or thoracolumbar/lumbar curves, anterior correction in double major curves has not yet been described. The purpose of this study is to compare this novel technique with standard posterior pedicle screw instrumentation in double major AIS.

Methods: 19 consecutive patients with a double major AIS were treated surgically either with pedicle screw instrumentation and posterior fusion (n = 11) or dual anterior short instrumentation and fusion (n = 8) of both curves. The mean follow-up was 5.6 ± 3 years (2−10 years). Clinical and radiologic results, results of pulmonary function, and Scoliosis Research Society (SRS) questionnaire are analyzed and compared.

Results: The length of fusion was 7.6 ± 0.7 vertebrae with the anterior technique and 12 ± 1 vertebrae with the posterior technique ($p < .001$). Cobb angle correction was 78% and 53% in thoracic curves, and 80% and 59% in lumbar curves with posterior and anterior technique respectively ($p < .05$). The preoperative pulmonary function remained unchanged to the last follow-up in both groups. The scores of SRS-24 questionnaire were similar preoperatively and at the last follow-up in both groups.

Conclusion: This novel technique of dual sequential short anterior correction is an alternative to the standard posterior long fusions in the double major AIS. A significantly less amount of mobile segments needs to be fused leaving the thoracolumbar junction mobile and saving at least one lumbar mobile segment distally.

Level of Evidence: Level III.

Keywords: Adolescent idiopathic scoliosis; Double major; Anterior correction

Introduction

Anterior correction of single curves in adolescent idiopathic scoliosis (AIS) is an established alternative to posterior instrumentation and correction in single thoracic as well as in thoracolumbar/lumbar curves [1-12]. With the anterior technique, the length of fusion is much shorter than with the posterior method in single curves [1,8,11,13-15]. Although previous reports showed changes in pulmonary function after anterior instrumentation [16,17], more recent reports showed that the pulmonary function is not affected by the thoracotomy and anterior instrumentation [8,18]. For the double major AIS, the standard technique has been posterior instrumentation [19,20]. However, with the current techniques, long fusions with posterior instrumentation of the thoracic and lumbar curves are necessary. Those are associated with limitation of movement and predict adjacent segment degeneration [21]. Although combined anteroposterior surgical techniques have been described in the treatment of large double major curves [22,23], an all-anterior approach has never been reported to our knowledge. We have developed a surgical method, which combines the short anterior correction of thoracic curve and lumbar curve resulting in dual sequential correction of both curves in double major scoliosis aiming to reduce the length of fusion and keeping the spine as mobile as possible. The aim of this study was to analyze the results of

Author disclosures: KM (none), LJ (none), MF (none).

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https://doi.org/10.1016/j.jspd.2018.01.009

this novel surgical technique and to compare these results with those of posterior long fusions of the same surgeon in the same Institution.

Methods

The data of 19 consecutive patients with double major AIS who underwent surgical correction during February 1996 until July 2010 were collected prospectively and analyzed retrospectively. Fusion of both curves from posterior with pedicle screw alone instrumentation was done in 11 patients (posterior group, 2 male and 9 female), and sequential short anterior instrumentation of both curves was performed in 8 patients (anterior group, all female). All patients were followed at least 2 years clinically, radiographically, and with pulmonary function tests. The duration of follow-up was in mean 5.6 ± 3 years (2−10 years). Only 4 of the patients (3 posterior, 1 anterior) had a follow-up less than 5 years. Standard radiographs of the spine were done preoperatively, 6 weeks postoperatively, at 2 years, and at the last follow-up. Pulmonary function tests were done preoperatively, at 2 years, and at latest follow-up. Assessment of patient's satisfaction with the SRS-24 [24] questionnaire was done preoperatively, at 2 years and at the last follow-up.

The mean age (anterior 14.2 ± 1.7 years, posterior 15.2 ± 2.6. p = .355) and Risser stage (anterior: 1.9 ± 0.8, posterior: 2.2 ± 1.7, p = .605) were statistically similar. The thoracic curves were right-sided in all patients, with the apex at T7 (n = 4), T8 (n = 11), or T9 (n = 4). The thoracolumbar/lumbar curves were left sided, with the apex at L1 (n = 6), L2 (n = 12), or L3 (n = 1) with no differences between the groups. The patients and their families were thoroughly advised about both surgical techniques and the advantages and disadvantages of both techniques. Crucial in this series for the decision making was the preference of the patients and their families to choose independently between the two techniques. Those in the anterior group chose the technique because they wanted to avoid stiffness of the spine after long posterior fusion and the ones in the posterior group because they wanted to avoid two surgeries. The same surgeon (KM) performed all surgeries. Two independent readers analyzed the data; these readers were not involved in direct care of the patients.

Surgical techniques

Posterior surgery

Pedicle-screw-alone instrumentation of both curves was done in all patients. The implant density was 57% ± 8%. The upper end of the instrumentation was the upper end vertebra of the thoracic curve in all cases. The lower end of the instrumentation was the vertebra of the lumbar curve which, was touched by the midsacral line in the standing anteroposterior radiograph.

Anterior surgery

The choice of fusion levels and the operative technique was made according to previous reports for single-curve corrections. Corresponding to this, we used side-bending radiographs to evaluate the first caudal disc in the curve that is opening in the concavity. The last instrumented vertebra is then defined as the one directly proximal to this disc. The amount of vertebrae from the apex vertebra to the last instrumented vertebra is then counted and added in cranial direction starting from the apex vertebra to define the first or upper-end instrumented vertebra. After left-sided and, respectively, right-sided minithoracotomy, a 360° discectomy was conducted. Bicortical insertion of screws was then carried out about 10 mm in front of the spinal canal along the posterior cortices of the vertebral bodies under direct visualization [8,25]. The correction of the lower curve was carried out first because a single lung intubation was not necessary for the surgery of the lower curve, and in our opinion it is better to do the upper curve correction with a single lung intubation at the second stage. After the first surgery, standing radiographs of the whole spine were done routinely at the 5th postoperative day to assess the instrumented lower curve. The correction of thoracic curve was done one week later. Correction of both curves on the same day was not intended, as we wanted to limit the surgical strain on the patient by doing staged correction of the scoliosis. Ambulation of the patient began on the first day after each operation. Intraoperative neuromonitoring with SSEP and MEP was done routinely.

Statistical analyses

The statistical software PRISM (version 5 for Mac Os X, GraphPad) was used for statistical analyses. Descriptive statistics were used to report means and standard deviations (SD) of the patients' demographics, curves, amount of correction, and data of pulmonary function test as well as the SRS scores. Two-sided unpaired Student *t* test was employed for comparison between the groups and two-sided paired Student *t* test for intragroup time-dependent comparisons. A p value of $<.05$ was defined as statistically significant.

Results

Fusion levels

There was a significant difference with a mean of 7.6 ± 0.7 (range 7-9) fused vertebrae in the anterior versus 12 ± 1 (range 10-14) in the posterior group ($p < .001$). With the anterior technique, 4 or 5 vertebrae were instrumented for correction in the upper curve. Three vertebrae were instrumented in the lower curve in all but one patient. The uppermost instrumented vertebrae were T5 (n = 1), T6 (n = 4), and T7 (n = 3) in the anterior group and T4 (n = 4) and T5 (n = 7) in the posterior group. The lowest instrumented vertebra was either L2 (n = 4) or L3 (n = 4)

Table 1
Cobb angles of the upper and the lower curves of the all-anterior and all-posterior group preoperatively, postoperatively, after 2 years, and at final follow-up.

	Preoperative	Postoperative	2 years	At final FU	Final FU (years)
Upper curve					
Anterior					
Mean	54.63	25.88	26.50	28.38	4.55
SD	7.09	6.62	7.63	6.65	1.06
Posterior					
Mean	62.27	13.73	18.36	20.27	6.44
SD	14.97	9.01	9.43	10.73	3.72
p	.159	.004	.054	.059	.137
Lower curve					
Anterior					
Mean	58.63	23.88	23.38	21.75	4.55
SD	9.46	4.76	5.04	5.78	1.06
Posterior					
Mean	65.91	13.36	16.82	17.82	6.44
SD	13.80	8.02	8.91	9.52	3.72
p	.190	.002	.059	.280	.137

FU, follow-up; SD, standard deviation.

in the anterior and L2 (n = 1), L3 (n = 3), L4 (n = 6), or L5 (n = 1) in the posterior group.

Scoliosis correction (Cobb angle)

Thoracic curves

The Cobb angle of the thoracic curves were similar preoperatively with 54° ± 7° on standing and 34° ± 10° (39% correction) in supine bending in the anterior group, and 62° ± 15° on standing and 38° ± 11° (40% correction) in supine bending in the posterior group, with no statistical significance ($p = .159$, $p = .391$). The immediate postoperative correction was better in the posterior group (Table 1, Fig. 1). The thoracic curves were corrected to 14° ± 9° (78% correction) in the posterior group in contrast to 26° ± 7° (53 % correction) in the anterior group ($p = .004$).

Thoracolumbar/lumbar curves

The preoperative Cobb angles were also similar, with 59° ± 10° in the anterior group and 66° ± 14° in the posterior group. The curves in the anterior group were more flexible, with 25° ± 9° (61% correction) in bending in comparison to 34° ± 9° (48% correction) in the posterior group ($p = .034$). The curves were corrected to 13° ± 8° (80% correction) in the posterior group and to 24° ± 5° (59% correction) in the anterior group ($p = .038$).

Implant removal 1.7 years after the index operation was necessary in the posterior group in one patient because of late low-grade implant-associated infection. The upper curves of the posterior group without this patient behaved not differently than with inclusion of the patient; the initial correction was 78% from 62° ± 16° to 14° ± 10° and was partially lost to 19° ± 10° at 2 years and 20° ± 11° at final follow-up, which constituted a correction of 68% at last follow-up. The lower curve behaved similarly with an initial correction of 81% from 67° ± 14° to 13° ± 8°, with slight loss to 17° ± 9° at 2 years and 17° ± 10° at 10 years, with 74% correction at the last follow-up. Therefore, for further analysis, the data of the patient with implant removal was treated equally to the rest of the posterior group.

There was a loss of correction of thoracic curves of 5% in the anterior group and 10% in the posterior group during the follow-up period. Loss of correction of thoracolumbar/lumbar curves was 0% (no loss of correction) in the anterior group and 7% in the posterior group during the follow-up period.

Apical vertebral rotation (AVR) and apical vertebral translation (AVT)

The improvements of AVR and AVT of thoracic curves were 63% and 103% in the anterior group and 54% and 106% in the posterior group. The improvement of AVR and AVT of the thoracolumbar/lumbar curves were 41% and 44% in the anterior group and 47% and 44% in the

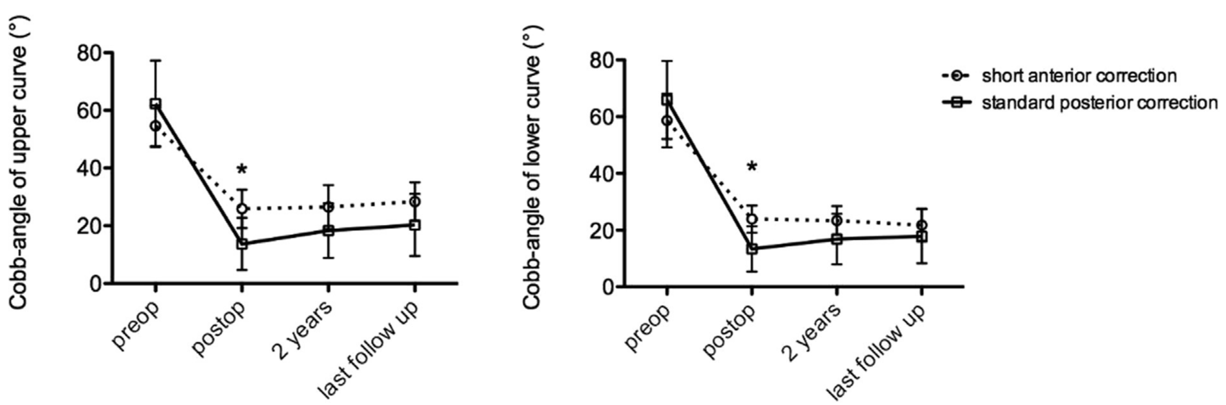

Fig. 1. A higher amount of initial correction is achieved with the posterior instrumentation technique in both the upper and lower curve (*$p < .05$). The correction of the upper curve lost slightly at last follow-up (4.6 ± 1 years in anterior and 6.4 ± 3.7 years in the posterior group). The correction of the lower curve lost slightly with the posterior technique and remained sustained with the anterior technique.

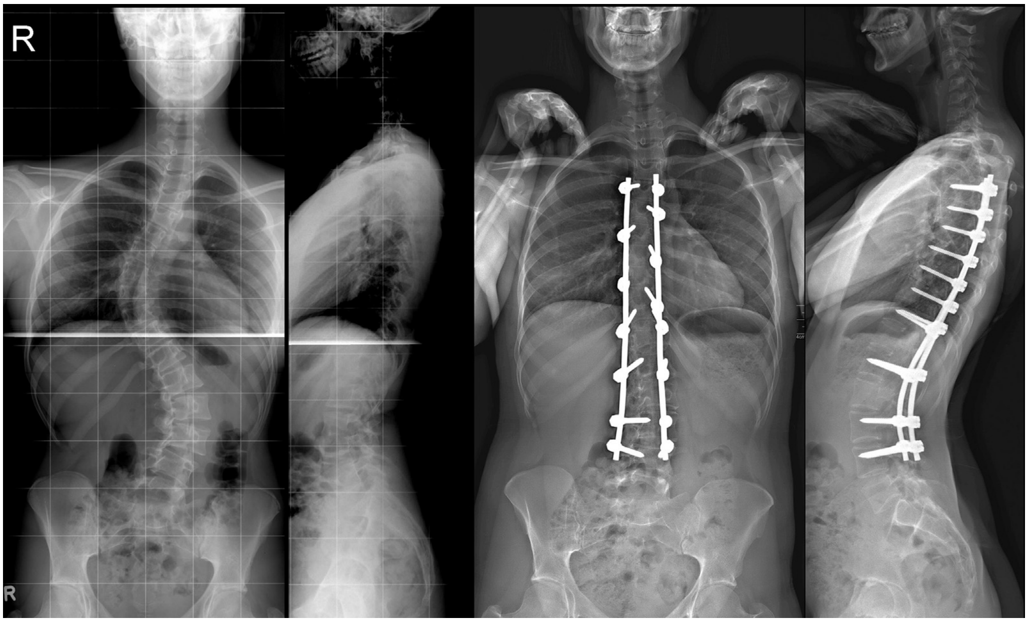

Fig. 2. Pre- and postoperative radiographs in posterior instrumentation with correction from 60° Cobb angle to 12° in lower curve and 60° to 10° in upper curve 5 years postoperative.

posterior group. The changes were comparable for both curves between the two groups (Tables 2 and 3).

Sagittal parameters

The distance of the C7 plumb line to the posterior edge of S1 was outside the ±40-mm range in five of eight patients in the anterior group and 6 of 11 in the posterior group preoperatively and in two patients of the anterior group and one of the posterior at final follow-up. There were no significant differences in lumbar lordosis or thoracic kyphosis between the groups or the time points (Table 4).

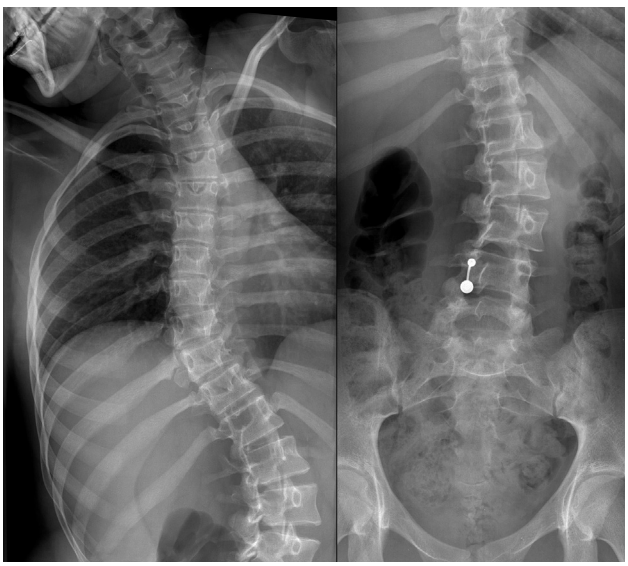

Fig. 3. Preoperative bending radiographs of the patient in Fig. 2.

Tilt of the last instrumented vertebra (LIVT)

LIVT is the angle of the last vertebra at the distal end of the instrumentation to the horizontal line. LIVT was 15° ± 6° preoperatively and 0° ± 6° at the last follow-up in the anterior group and 23° ± 6° preoperatively and 3° ± 5° at the last follow-up in the posterior group.

Pulmonary function

The preoperative percentage of expected forced vital capacity (%FVC) was 71% ± 8% in the anterior and

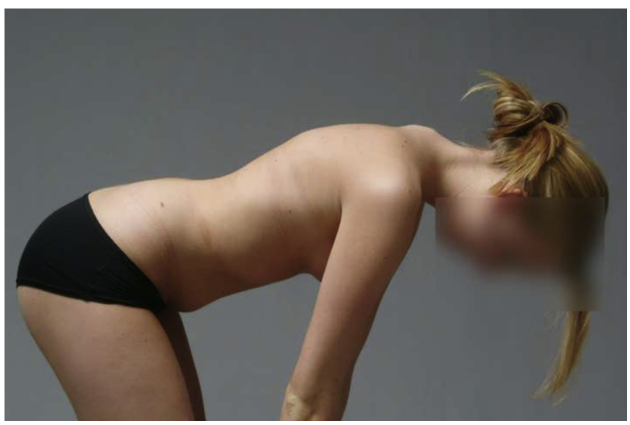

Fig. 4. Photograph 2 years after posterior instrumentation of the patient in Fig. 2.

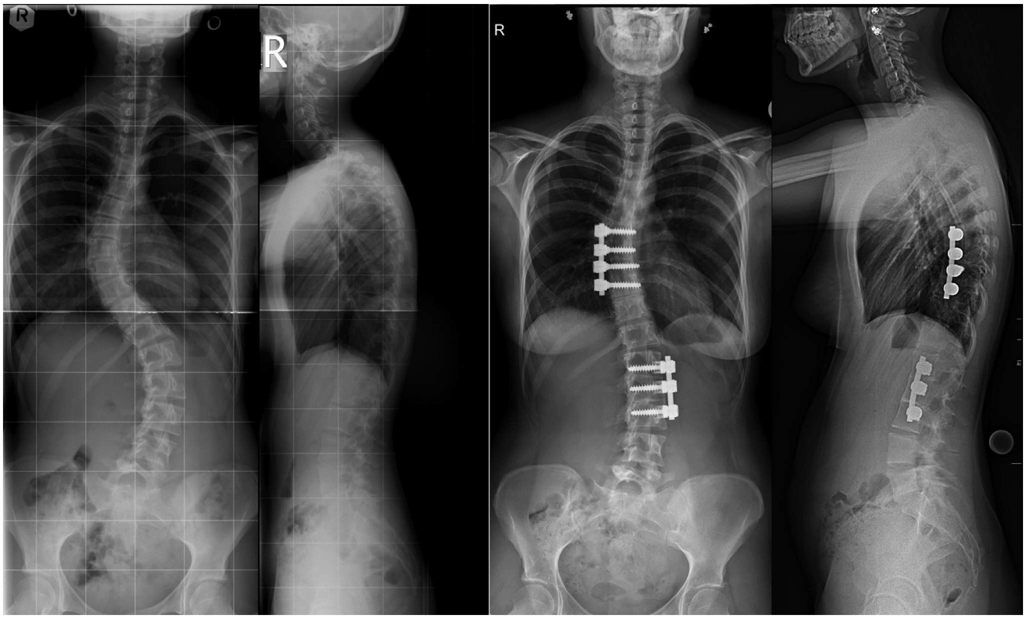

Fig. 5. Pre- and postoperative radiographs in anterior instrumentation with correction from 49° Cobb angle to 26° in lower curve and 50° to 20° in upper curve 5 years postoperative.

80% ± 16% in the posterior group (p = .142). At the 2-year follow-up, the %FVC remained unchanged, with 71% ± 8% in the anterior and 76% ± 19% in the posterior group. At the last follow-up, the %FVC was 72% ± 14% in the anterior and 71% ± 11% in the posterior group.

Patients' satisfaction

The scores of the SRS-24 questionnaire were not different in both groups. Preoperatively, the scores were 61 ± 11 and 57 ± 4 points in the anterior and posterior groups, respectively. At final follow-up, the scores were 101 ± 8 and 98 ± 12 points in the anterior and posterior groups, respectively.

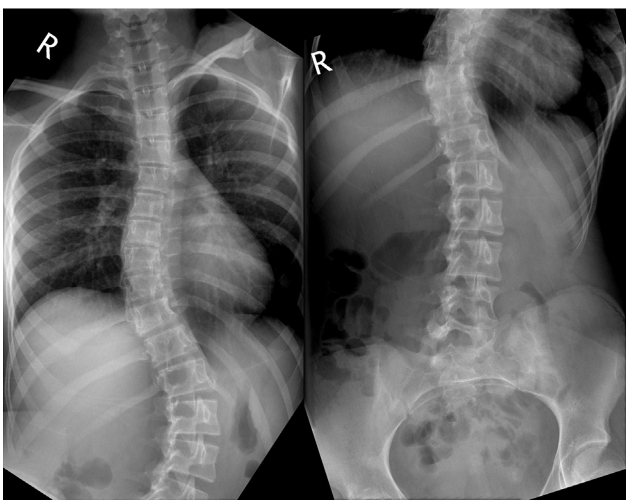

Fig. 6. Preoperative bending radiographs of the patient in Fig. 5.

Complications

One patient in the posterior group had a late low-grade implant-related infection with *Propionibacterium acnes*, which necessitated the removal of implant 1.7 years after the operation. The upper curve of this patient was initially corrected from 54° to 13° and the correction was partially lost to 17° at 2 years and 23° at the 10-year follow-up [26]. The lumbar curve was corrected from 63° to 19° and did not change during the 10 years. The patient's SRS-24 score at the 10-year follow-up was 97 points, which was comparable to others' in the group.

There were no other complications, no thoracotomy-associated complications like vessel or lung injuries, pneumothorax, or chylothorax in the anterior group and no

Fig. 7. Photograph 2 years after anterior instrumentation of the patient in Fig. 5.

Table 2
Apex vertebral rotation (AVR) of the upper and lower curve in the all-anterior versus all-posterior correction group.

	Preoperative	Postoperative	2 years	At final FU
AVR upper curve				
Anterior				
Mean	11.88	4.38	4.38	4.38
SD	6.51	3.20	3.20	3.20
Posterior				
Mean	15.91	7.27	5.91	6.82
SD	9.44	7.54	7.35	7.83
p	.286	.273	.547	.367
AVR lower curve				
Anterior				
Mean	26.25	15.63	16.88	16.25
SD	6.94	4.17	5.30	4.43
Posterior				
Mean	28.64	15.91	15.91	15.91
SD	9.77	13.19	13.19	12.41
p	.542	.948	.829	.934

FU, follow-up; SD, standard deviation.

Table 4
Thoracic kyphosis and lumbar lordosis preoperatively and at final follow-up in the all-anterior and all-posterior group, respectively.

	Preoperative	At final FU
Thoracic kyphosis		
Anterior		
Mean	34.38	33.88
SD	6.84	7.85
Posterior		
Mean	32.36	35.64
SD	9.95	15.33
p	.609	.750
Lumbar lordosis		
Anterior		
Mean	47.38	46.50
SD	8.73	8.73
Posterior		
Mean	55.82	54.00
SD	13.06	14.25
p	.110	.175

FU, follow-up; SD, standard deviation.

neurologic complications in both groups. Potential complications of single lung intubation (eg pneumomediastinum or pneumoperitoneum [27]) were not observed within the here reported cohort of patients.

Discussion

The currently most commonly used surgical technique for correction of double major scoliotic curves is posterior instrumentation. Here, an alternative all-anterior dual sequential correction technique is described and the long-term results are presented and compared with the standard posterior technique. This novel technique was introduced based on the established experiences with the anterior-only short correction technique for single AIS curves, that is known to result in a reduced fusion length [8,13,28]. With this study, we have shown that double major curves could be corrected with significantly less fused vertebrae, so that 3 segments could be spared in average. Initial correction of the curve is indeed higher in the posterior group; during the follow-up period, however, the loss of correction was in favor of the anterior group. We are not able to make conclusions on this difference. A study published in 2013 on 48 patients has shown that an implant density of 50% is sufficient to achieve a long term stable correction with a loss of 7% Cobb angle correction after minimal 10 years follow-up [29]. The data of our present series correspond to that study.

A methodological limitation of the study might be the relatively small sample size. However, the meticulous prospective collection of the data and no loss of follow-up allow sufficient comparison of the groups. Although clear differences, such as lesser fused vertebrae but also lesser curve correction with all anterior technique, could be documented even with small sample sizes, we found no significant differences in SRS score values or the pulmonary function of the patients and it could be documented that the spine is well balanced and the clinical results are similar in both groups. We believe that a larger sample size could produce statistical significance but not clinical significance in SRS score values or pulmonary function, but this remains a subject of larger series.

Another technical disadvantage might be the potential of complications associated with the anterior approach (vessel and lung injuries). We found no such complications in our series, and the lung function was comparable between the groups and it was unaffected by the anterior approach. Possible keys in our study to prevent reduction of the pulmonary function are the small incision during the minithoracotomy, the complete closure of the pleura, and use of low-profile single-screw, single-rod implants. Another main

Table 3
Apex vertebral translation (AVT) of the upper and lower curve in the all-anterior versus all-posterior correction group, respectively.

	Preoperative	Postoperative	2 years	At final FU
AVT upper curve				
Anterior				
Mean	17.00	−0.50	4.50	6.88
SD	8.21	11.61	3.59	4.45
Posterior				
Mean	21.36	−1.18	7.27	8.64
SD	15.31	14.37	7.72	10.16
p	.435	.910	.312	.617
AVT lower curve				
Anterior				
Mean	41.13	21.75	21.25	16.88
SD	8.29	7.61	4.50	4.45
Posterior				
Mean	46.55	26.00	17.36	15.45
SD	11.19	21.64	10.71	10.31
p	.242	.557	.298	.689

FU, follow-up; SD, standard deviation.

disadvantage that has to be considered is the need of two separate surgeries. Patients and their treating surgeons have to be aware that patients undergo perioperative risks twice.

Considering the mentioned limitations and technical aspects, we conclude that the here described novel technique of dual sequential short anterior correction is a valuable alternative to the standard posterior long fusions in the double major AIS to decrease the amount of mobile segments that need to be fused. It is our opinion that this possibility should be discussed with patients who have a double major AIS with a maximal curve magnitude of 70° Cobb and a flexibility of at least 50% as an alternative to posterior long spinal fusion.

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