Spine Deformity
www.spine-deformity.org

Spine Deformity 7 (2019) 84−92

Surgery for the Adolescent Idiopathic Scoliosis Patients After Skeletal Maturity: Early Versus Late Surgery

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Received 30 January 2018; revised 18 May 2018; accepted 20 May 2018

Abstract

Introduction: Informed decision making for operative treatment of the skeletally mature adolescent idiopathic scoliosis (AIS) patient meeting surgical indications requires a discussion of differences in operative morbidity in adult scoliosis versus AIS. This study evaluated differences in operative data and outcomes between AIS and adult scoliosis patients based on an estimated natural history of curve progression.

Methods: Twenty-eight adult scoliosis patients (43.7 ± 15.8 years; 93% F) were 1:2 matched with 56 (Risser 4/5) AIS patients (15.7 ± 2.1 years) based on gender and curve type as vetted by 5 surgeons' consensus in committee. Curve progression of 0.3°/year for the first 10 years following skeletal maturity and a 0.5°/year thereafter was assumed to estimate curve progression from AIS to adulthood for the adult counterpart. Operative data, complications, and quality of life (Scoliosis Research Society [SRS-22r] questionnaire) measures were evaluated, with a minimum 2-year follow-up.

Results: Postoperative major Cobb and percentage correction were similar between adult versus AIS, whereas operative time, percentage estimated blood loss (EBL; % total blood volume), length of hospital stay (LOS), and total spine levels fused were greater for adult patients ($p < .05$). No difference was found in EBL, operative time, or LOS when normalized by levels fused. Ten (36%) adult scoliosis patients were fused to the pelvis compared with none in AIS ($p < .0001$). Major complication rate was higher for adult versus AIS (25% vs. 5.4%; $p < .05$). Preoperative SRS-22r scores were worse for adult patients; however, they demonstrated greater improvement in SRS-22r than the AIS cohort at final follow-up. A higher percentage of adult patients reached the MCID in self-image domain than the AIS patients (92.3% vs. 61.8%; $p = .0040$).

Conclusion: Treatment of the adult scoliosis patient who has undergone an estimated natural history of progression is characterized by greater levels fused, operative time, and higher complication rates than the AIS counterpart. Longer-term follow-up of AIS is needed to define the benefits of early intervention of relatively asymptomatic adolescent patients versus late treatment of symptomatic disease in the adult.

Keywords: Adolescent idiopathic scoliosis (AIS); Adult spinal deformity; Operative outcome; Natural history; Matched comparison

Author disclosures: BSL (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants from Setting Scoliosis Straight Foundation, personal fees from DePuy Synthes Spine, personal fees from K2M, Paradigm Spine, Spine Search, and Ethicon; nonfinancial support from *Spine Deformity Journal*; grants from AO Spine, John and Marcella Fox Fund Grant, and the Orthopaedic Research and Education Foundation [OREF], outside the submitted work), YR (grants from Setting Scoliosis Straight Foundation, during the conduct of the study), SB (grants from Setting Scoliosis Straight Foundation, grants from International Spine Study Group Foundation, during the conduct of the study; grants from DePuy Synthes spine, grants from k2 medical, grants from NuVasive, grants from Innovasis, grants from Stryker spine, grants from Medtronic, outside the submitted work; in addition, SB has a patent NuVasive pending, a patent Innovasis pending, and a patent k2 medical with royalties

https://doi.org/10.1016/j.jspd.2018.05.012

paid), MK (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants from Cervical Spine Research Society [CSRS], OREF, Cerapedics, AOSpine, Barnes Jewish Foundation, Fox Family Foundation, and Patient-Centered Outcomes Research Institute, outside the submitted work), HJK (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; personal fees from K2M, Zimmer-Biomet, grants from International Spine Study Group [ISSGF], grants and personal fees from AO Spine, outside the submitted work; in addition, HJK has a patent null pending), BY (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants and personal fees from K2M and DePuy Synthes Spine; personal fees from NuVasive, Medtronic, Orthopediatrics, Stryker, and Globus; grants from Setting Scoliosis Straight Foundation, outside the submitted work; in addition, BY has a patent with K2M with royalties paid), VL (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants from DePuy Spine, NuVasive, K2M, Stryker; personal fees from NuVasive, DePuy Spine, Medicrea, MSD, and K2M; other from Nemaris INC, outside the submitted work), MM (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; personal fees from Setting Scoliosis Straight, outside the submitted work), FM (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; other from DePuy Synthes Canada, outside the submitted work), CIS (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants from ISSG, personal fees from Medtronic, NuVasive, Zimmer-Biomet, K2M, and Stryker; grants from National Institutes of Health [NIH], AOSpine North America [AO], and Department of Defense, outside the submitted work; in addition, CIS has a patent Medtronic with royalties paid, a patent NuVasive with royalties paid, and a patent Zimmer-Biomet with royalties paid), PON (grants from Setting Scoliosis Straight Foundation, during the conduct of the study; grants and other from Setting Scoliosis Straight Foundation; other from Rady Children's Specialists; grants and personal fees from DePuy Synthes Spine; personal fees from Law firm of Carroll, Kelly, Trotter, Franzen & McKenna; personal fees from Law firm of Smith, Haughey, Rice & Roegge; grants from NIH and OREF; grants and other from Scoliosis Research Society [SRS]; grants from EOS Imaging; personal fees from Thieme Publishing; other from NuVasive; personal fees from Ethicon Endosurgery; other from Electrocore; personal fees from Cubist; other from International Orthopedic Think Tank and from Orthopediatrics Institutional Support; personal fees from K2M, outside the submitted work; in addition, PON has a patent "Anchoring Systems and Methods for Correcting Spinal Deformities" [8540754] with royalties paid to DePuy Synthes Spine; a patent "Low Profile Spinal Tethering Systems" [8123749] issued to DePuy Spine, Inc.; a patent "Screw Placement Guide" [7981117] issued to DePuy Spine, Inc.; and a patent "Compressor for Use in Minimally Invasive Surgery" [7189244] issued to DePuy Spine, Inc).

Funding: Research grant funding was received by Setting Scoliosis Straight Foundation to support Harms Study Group's research.

No Funding support was received for any aspect of the submitted work by the International Spine Study Group. Grants from DePuy were received by the International Spine Study Group for data collection.

IRB Approval: Institutional review board approval was obtained for this study from all participating sites.

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Introduction

Surgeons treating adolescent patients with idiopathic scoliosis commonly find themselves in the consultation room with the patient and their families facing the decision as to whether or not to proceed with surgical correction. This is particularly true for the patient who has reached skeletal maturity in whom curve progression in the near future is unlikely and in whom there are no major body image concerns, pain, or impact on activities which is often the case. Surgical and other treatment recommendations for adolescent idiopathic scoliosis (AIS) in the past half century have largely been guided by radiographic parameters, with relatively little attention given to patient and family priorities and values [1-3]. In the current era of health care, patient choice, and alternative treatment options, quality and safety are at the forefront of care decisions [4,5]. Decisions should be informed by as much data on the nature of those choices.

The decision for the family to proceed with surgery for the skeletally mature adolescent is impacted by the natural history of untreated disease; that is, curve progression, pain and disability, and pulmonary dysfunction in the adult [6-13]. Additionally, the nature of the surgical intervention in the adolescent patient in terms of surgical morbidity—levels fused, impact on function, and complication rates—as opposed to waiting to have an operative intervention when the patient potentially becomes symptomatic as an adult are important considerations for the family to take into account [14-16]. This last consideration is the basis for the current study. We investigated the extent of fusion, peri- and post-operative morbidity, and two-year quality of life (QOL) outcome differences between surgical intervention for the skeletally mature adolescent and the adult patient who was diagnosed with AIS and underwent the natural history associated with aging. We hypothesize that adult scoliosis patients will have longer fusions, greater operative times, estimated blood loss (EBL), and length of stay (LOS) than the surgically treated adolescent patient. In addition, adult scoliosis patients will have higher reoperation and complication rates within a two-year follow-up period than AIS patients.

Methods

This was a retrospective study in which consecutive patients were selected from two prospectively collected registries. One is a pediatric AIS registry, the other an adult spinal deformity operative registry. Institutional Review Board approval was obtained for this study from all participating sites. The pediatric AIS registry is the Setting Scoliosis Straight Foundation research database, established in 1995 and is the largest prospective AIS patient database in existence. There are 14 participating sites (12 in the United States and 2 in Canada) and more than 4,000 operative patients enrolled in the database. The adult spinal deformity operative registry, the International Spine Study Group database, established in 2008, consists of 11 sites and 15 physicians across the United States. Consecutive series of 737 patients with adult spinal deformity have been enrolled in this multicenter prospective database registry.

Six hundred sixty-one skeletally mature (Risser 4/5) surgical AIS patients with preoperative major curve ranging from 40° to 70° from the AIS registry and 55 adult patients with previously untreated AIS (adult scoliosis) from the adult registry with a minimum two-year follow-up and complete radiographic, surgical data, and QOL data in the form of the Scoliosis Research Society 22 (SRS-22r) questionnaire were included in the matching process. The matching process took into account the curve type and magnitude and the estimated natural history of progression in a skeletally mature AIS patient with similar curve type. This was done by taking an adult patient's record and back-calculating to its skeletally matured adolescent counterpart in the AIS registry because there were many more patients in the AIS registry to choose from, given its homogenous nature and longer time in existence. Based on the natural history data by Weinstein et al., a curve progression of 0.3° per year for the first 10 years after skeletal maturity, and 0.5° curve progression per year after the first 10 years was assumed for purposes of estimating the curve magnitude in untreated adult scoliosis counterpart. To facilitate this matching, a natural history of progression table was created based on a conservative use of the Weinstein et al. natural history data [7]. Table 1 shows an example of natural history of progression over 50 years for AIS with a 40° curvature at skeletal maturity. Idiopathic etiology in the adult cohort was determined by committee on several conference calls in which the adult cases were reviewed for radiographic parameters thought to be consistent with idiopathic scoliosis. These included significant apical rotation, typical curve patterns and apex location. Adult scoliosis with any sagittal plane deformities was excluded; however, increase of kyphosis over time was taken into consideration in the natural history assessment [17]. Matching was done in a 1:2 weighting adult-adolescent because of the larger number of accessible AIS cases.

Table 1
Estimation of curve progression after maturity in AIS with curve magnitude of 40° over 50 years.

AIS age (years) AIS curve = 40°	Adult age (years)/curve magnitude (°)				
10		30/48°	40/53°	50/58°	60/63°
11		31/48°	41/53°	51/58°	61/63°
12	22/43°	32/48°	42/53°	52/58°	62/63°
13	23/43°	33/48°	43/53°	53/58°	63/63°
14	24/43°	34/48°	44/53°	54/58°	64/63°
15	25/43°	35/48°	45/53°	55/58°	65/63°
16	26/43°	36/48°	46/53°	56/58°	66/63°
17	27/43°	37/48°	47/53°	57/58°	67/63°
18	28/43°	38/48°	48/53°	58/58°	68/63°
19	29/43°	39/48°	49/53°	59/58°	69/63°
20		40/48°	50/53°	60/58°	70/63°
21		41/48°	51/53°	61/58°	71/63°

AIS, adolescent idiopathic scoliosis.

Clinical and radiographic data collected included age at surgery, gender, height, weight, levels instrumented, anchor type, level of upper (UIV) and lower (LIV) instrumented vertebra, inclusion of the sacrum/pelvis, major Cobb angle, T5−T12 kyphosis, lumbar lordosis. Operative parameters such as total operative time, estimated blood loss (EBL), % EBL (percentage of blood volume lost), number of levels fused, LOS, major complications, as well as SRS-22r QOL outcome measures. A major complication (or serious adverse event) is formally defined as any untoward medical occurrence that 1) results in death, 2) is life-threatening, 3) requires inpatient hospitalization or prolongation of existing hospitalization, 4) results in persistent or significant disability/ incapacity, or 5) is a congenital anomaly/birth defect. Adult and pediatric minimal clinically important difference (MCID) in SRS-22r subdomains were based on the reported values by Crawford et al. [18] and Carreon et al. [19] for adult and pediatric patients, respectively. The MCID is 0.2 for pain, 0.08 for function, and 0.98 for self-image domains in AIS population. In adult spinal deformity patients, the MCID was set to be 0.19−1.23 for self-image, 0.23−0.6 for function, 0.24−0.57 for pain, and 0.17−0.71 for total domains. The operative data were further stratified and analyzed by Lenke curve types. Lenke 1 and 2 (primary thoracic curves); Lenke 3, 4, and 6 (double or triple major curves); and Lenke 5 (single curves) types were grouped based on the nature of the curvature to increase the sample size for statistical purposes.

Statistical analysis

Descriptive statistics was used to summarize the distributions of variables, which were given as means and standard deviations (±). Two-sided Student *t* test (for normally distributed data) and Mann-Whitney-Wilcoxon test (for nonparametric data) were used to determine the statistical differences in continuous data, whereas chi-square test was performed for categorical data analyses. There were <5% missing values in all radiographic, operative, and QOL outcome measurements. The missing data are likely due to measurement difficulties and are completely random. Only the available data were analyzed, and the missing data were ignored. Statistical Package for the Social Sciences (SPSS) version 19.0 (IBM, Armonk, NY) was used for statistical analysis. Probability value <.05 was considered significant.

Results

The final gender and curve matched cohorts consisted of 28 adult scoliosis cases (average age 43.7 years, range 23-70) and 56 AIS cases (average age 15.7 years, range 11-19), 93% were female patients. The AIS cohort had lower BMI than the adult cohort (21.8 vs. 26.0; p = .0018). Two-year postoperative major Cobb (21.8° ± 13.5° vs. 19.0° ± 5.9°; p = .1969) and percentage correction (61.7 ± 24.1 vs.

Table 2
Demographic and radiographic data of AIS and AS cohorts.

	AS (n = 28)	AIS (n = 56)	p value
Age, years	43.7 ± 15.8	15.7 ± 2.1	n/a
Female, n (%)	26 (93)	52 (93)	n/a
BMI	26.0 ± 5.4	21.8 ± 3.9	.0018
Pre-op Cobb	58.3° ± 12.1°	49.9° ± 8.0°	.0003
Post-op Cobb	21.8° ± 13.5°	19.0° ± 5.9°	.1969
% correction	61.7 ± 24.1	61.8 ± 11.2	.5274

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; BMI, body mass index; Pre-op, preoperation; Post-op, postoperation.

61.8 ± 11.2; p = .5274) were similar between adult versus adolescent idiopathic scoliosis (Table 2). However, operative time (414.3 ± 155.9 vs. 281.3 ± 130.4 min; p = .0001), EBL (1403.6 ± 1101.5 vs. 722.9 ± 470.1 mL; p = .0027), %EBL (35.1 ± 29.2 vs. 20.3 ± 13.8; p = .0027), LOS (6.3 ± 1.9 vs. 5.3 ± 1.2 days; p = .0043), and total spine levels fused (12.9 ± 2.9 vs. 9.4 ± 2.6 levels; p < .0001) were greater for adult cohort than those for AIS. The adult cohort received more anterior-posterior combined procedure (n = 8; 28.6%) than the AIS, all of which had posterior procedure only (p < .0001). Data on osteotomy utilization were not uniformly available. Differences in %EBL, total operative time and LOS between the two cohorts were abolished after they were normalized by number of levels fused (2.6 ± 1.7 vs. 2.1 ± 1.2; p = .1635). Ten (36%) adult scoliosis patients were fused to the pelvis compared with none in AIS (p < .0001) (Table 3).

In the analysis by Lenke curve type, we found the following: in Lenke 1 and 2, and Lenke 3, 4 and 6 groups, operative time and number of levels fused were significantly greater in the adult cohort (Tables 4 and 5), whereas EBL and %EBL were also higher in the adult cohort in Lenke 5 group (Table 6). The normalized %EBL and total operative time did not show significant differences between the 2 cohorts in any of the Lenke curve types. Longer normalized LOS was observed in the AIS cohort in the Lenke 5 group only (Tables 4–6). Several case examples are shown in Figure 1 A–C.

Rate of major complications was higher for adult versus AIS (25% vs. 5.4%, respectively; p = .0138). The adult

Table 3
Overall and Lenke curve type stratified comparisons of the operative data between AIS and AS cohorts: Overall data.

	AS (n = 28)	AIS (n = 56)	p value
% correction	61.7 ± 24.1	61.8 ± 11.2	.5274
Levels fused	12.9 ± 2.9	9.4 ± 2.6	<.0001
Fused to pelvis, n (%)	10 (35.7)	0	<.0001
Surgical approach, n (%)	PSF 20 (71.4) Combined 8 (28.6)	PSF 56 (100)	<.0001
Operative time, minutes	414.3 ± 155.9	281.3 ± 130.4	.0001
Operative time/level, minutes	31.9 ± 9.0	30.8 ± 19.6	.7794
EBL, mL	1,403.6 ± 1101.5	722.9 ± 470.1	.0027
%EBL	35.1 ± 29.2	20.3 ± 13.8	.0027
%EBL/level	2.6 ± 1.7	2.1 ± 1.2	.1635
Length of stay, days	6.3 ± 1.9	5.3 ± 1.2	.0043
Length of stay/level, days	0.51 ± 0.17	0.61 ± 0.28	.0755

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; EBL, estimated blood loss; %EBL, percentage of blood volume lost; PSF, posterior spinal fusion.

Table 4
Overall and Lenke curve type stratified comparisons of the operative data between AIS and AS cohorts: Lenke 1 and 2 curves.

	AS (n = 17)	AIS (n = 34)	p value
Age, years	38.5 ± 14.2	15.4 ± 2.2	n/a
% correction	64.9 ± 18.8	64.5 ± 11.1	.8012
Levels fused	11.8 ± 2.6	10.1 ± 1.6	.0375
Operative time, minutes	376.6 ± 156.7	279.0 ± 95.3	.0182
Operative time/level, minutes	31.9 ± 11.1	27.5 ± 8.9	.1700
EBL, mL	1,121 ± 778.2	746.9 ± 491.2	.0772
%EBL	26.4 ± 16.8	21.3 ± 13.3	.2064
%EBL/level	2.2 ± 1.4	2.1 ± 1.3	.7001
Length of stay, days	5.9 ± 1.6	5.2 ± 1.2	.2662
Length of stay/level, days	0.51 ± 0.15	0.52 ± 0.12	.6773

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; EBL, estimated blood loss; %EBL, percentage of blood volume lost.

Table 5
Overall and Lenke curve type stratified comparisons of the operative data between AIS and AS cohorts: Lenke 3, 4, and 6 curves.

	AS (n = 6)	AIS (n = 12)	p value
Age, years	55 ± 16.7	15.5 ± 1.9	n/a
% correction	53.8 ± 29.1	60.5 ± 8.1	.8201
Levels fused	14.3 ± 3.1	11.0 ± 2.4	.0521
Operative time, minutes	444.5 ± 151.1	291.7 ± 99.2	.0339
Operative time/level, minutes	30.5 ± 4.7	26.4 ± 6.3	.1797
EBL, mL	1,558 ± 1158	869.6 ± 492.3	.2052
%EBL	41.9 ± 37.3	26.0 ± 16.6	.6354
%EBL/level	2.6 ± 1.9	2.3 ± 1.4	.6354
Length of stay, days	7.5 ± 2.6	5.4 ± 1.1	.0588
Length of stay/level, days	0.56 ± 0.26	0.52 ± 0.18	.9419

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; EBL, estimated blood loss; %EBL, percentage of blood volume lost.

Table 6
Overall and Lenke curve type stratified comparisons of the operative data between AIS and AS cohorts: Lenke 5 curves.

	AS (n = 5)	AIS (n = 10)	p value
Age, years	39.8 ± 14.3	16.8 ± 1.9	n/a
% correction	60.4 ± 36.4	54.0 ± 11.4	.5738
Levels fused	14.8 ± 2.3	5.3 ± 0.9	.0003
Operative time, minutes	506.0 ± 138.9	276.7 ± 239.7	.0253
Operative time/level, minutes	33.7 ± 4.5	50.1 ± 37.8	.4938
EBL, mL	2,180 ± 1721	465.0 ± 255.0	.0047
%EBL	56.6 ± 44.0	10.1 ± 5.0	.0040
%EBL/level	3.6 ± 2.4	1.9 ± 0.9	.1898
Length of stay, days	6.4 ± 1.7	5.3 ± 1.6	.2860
Length of stay/level, days	0.43 ± 0.08	1.04 ± 0.38	.0020

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; EBL, estimated blood loss; %EBL, percentage of blood volume lost.

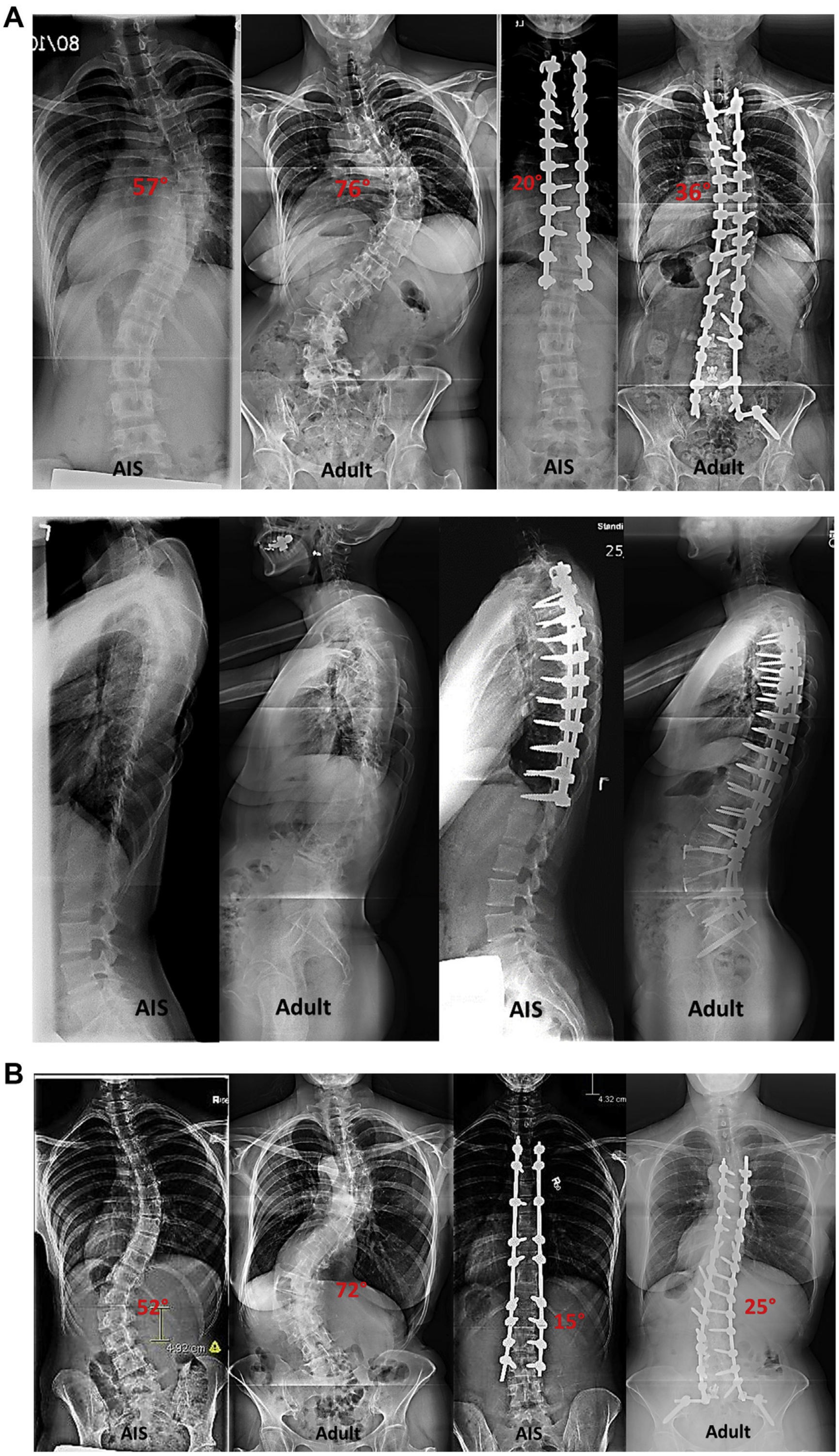

Fig. Radiographic and operative outcomes of the gender- and curve-matched AIS and AS case examples. (A) Primary thoracic curvatures (Lenke 1 AIS). AIS: age = 15 years; Δ = 65%; Levels fused = 10; Operative time = 335 minutes; EBL = 300 mL; LOS = 7; no major complications. AS: age = 55 years; Δ = 53%; Levels fused = 17; Operative time = 515 minutes; EBL = 1200 mL; LOS = 6; no major complications. (B) Double major curvatures (Lenke 6 AIS). AIS: age = 17 years; Δ = 71%; Levels fused = 11; Operative time = 300 minutes; EBL = 750 mL; LOS = 4; no major complications. AS: age = 54 years; Δ = 65%; Levels fused = 16; Operative time = 569 minutes; EBL = 1200 mL; LOS = 6; no major complications. (C) Single thoracolumbar major curvatures (Lenke 5 AIS). AIS: age = 14 years; Δ = 51%; Levels fused = 6; Operative time = 159 minutes; EBL = 350 mL; LOS = 4; no major complications. AS: age = 29 years; Δ = 76%; Levels fused = 12; Operative time = 369 minutes; EBL = 600 mL; LOS = 6; no major complications.

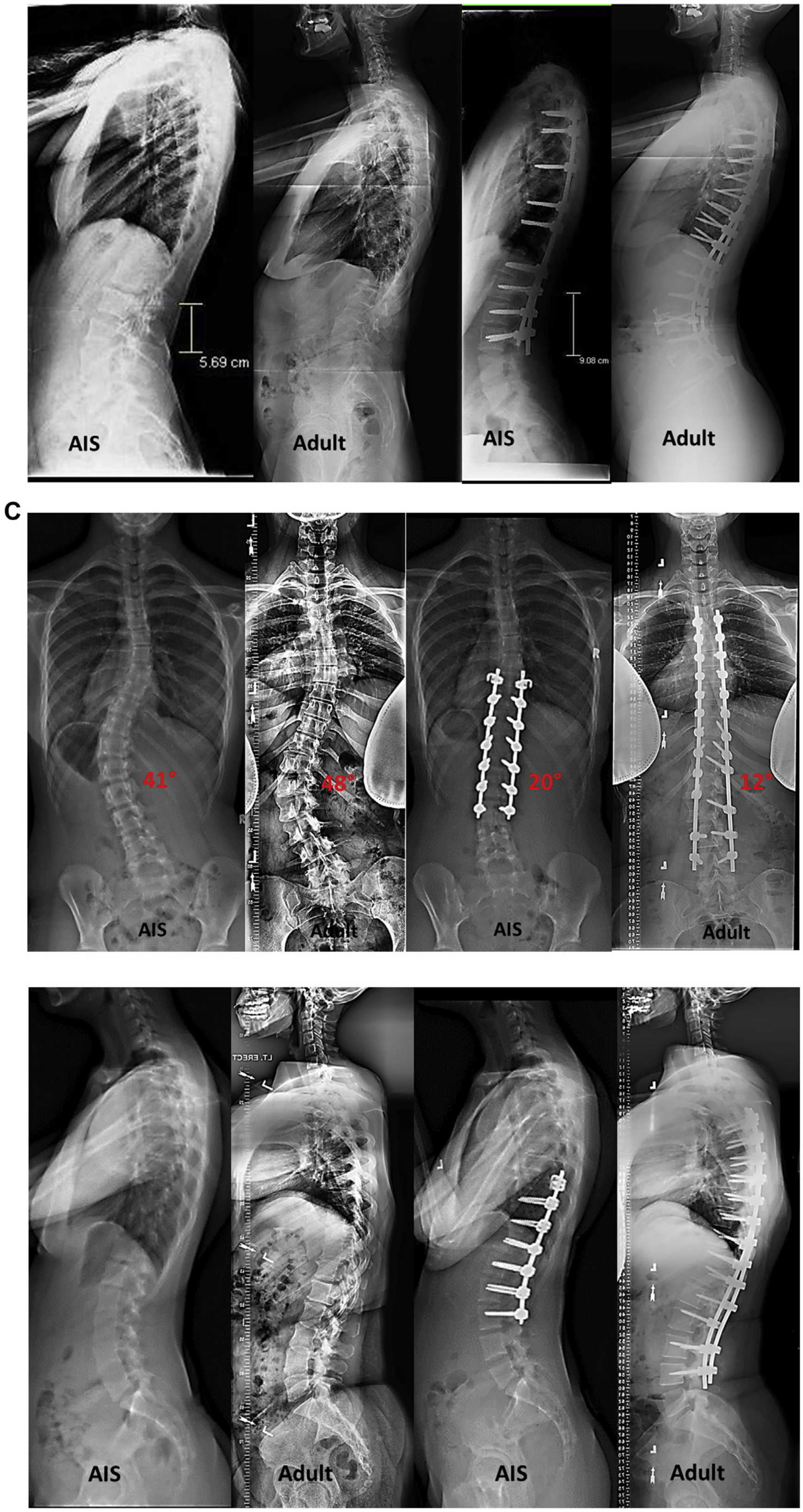

Fig. (*continued*).

Table 7
Comparisons of the complication data between AIS and AS cohorts.

	AS (n = 28)	AIS (n = 56)	p value
Major complications	7 (25%) 1 pleural effusion requiring chest tube 1 deep infection 1 instrumentation 4 neurologic	3 (5.4%) 1 pseudoarthrosis 1 instrumentation 1 neurologic	.0138
Reoperation	3 (10.7%)	2 (3.6%)	.3275

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis.

scoliosis cohort had three complications, which were one cardiopulmonary, one deep infection, and one instrumentation failure, resulting in reoperation (10.7%), whereas two complications (3.6%), one pseudoarthrosis and one instrumentation failure, in the AIS cohort required reoperation (p = .3275) (Table 7).

Preoperative and 2-year postoperative SRS-22r scores were worse in all domains in adult patients than their AIS counterpart; however, the adult cohort demonstrated greater improvement in SRS-22r than the AIS cohort at final follow-up in pain, function, and total domains. The MCID in the self-image domain was reached in 92.31% of the adult patients compared with 61.82% in the AIS group (p = .0040). The percentage of patients who reached the MCID in pain and function domains were not different between the 2 cohorts (for pain domain, 76.92% vs. 58.18%, p = .1375; for function domain, 61.54% vs. 45.45%, p = .2351) (Table 8).

Table 8
Comparisons of the QOL outcome (SRS-22r) data between AIS and AS cohorts.

	AS (n = 28)	AIS (n = 56)	p value
Pre-op Pain	2.9 ± 0.8	4.1 ± 0.7	<.0001
Pre-op Image	2.6 ± 0.8	3.3 ± 0.7	.0022
Pre-op Function	3.4 ± 0.8	4.5 ± 0.5	<.0001
Pre-op Mental	3.7 ± 0.8	4.0 ± 0.8	.2772
Pre-op total	3.1 ± 0.6	3.9 ± 0.5	<.0001
Post-op pain	3.7 ± 1.1	4.5 ± 0.5	.0003
Post-op Image	3.9 ± 0.8	4.5 ± 0.6	.0056
Post-op Function	3.9 ± 0.8	4.7 ± 0.5	.0003
Post-op Mental	4.0 ± 0.8	4.3 ± 0.7	.2684
Post-op Total	3.9 ± 0.7	4.5 ± 0.4	.0009
Δ pain	0.91 ± 1.07	0.42 ± 0.66	.0152
Δ Image	1.32 ± 1.16	1.13 ± 0.75	.3907
Δ Function	0.62 ± 0.72	0.10 ± 0.61	.0013
Δ Mental	0.36 ± 0.63	0.28 ± 0.77	.6526
Δ Total	0.87 ± 0.64	0.54 ± 0.47	.0108
Δ Pain reached MCID, %	76.92	58.18	.1375
Δ Image reached MCID, %	92.31	61.82	.0040
Δ Function reached MCID, %	61.54	45.45	.2351
Δ Mental reached MCID, %	n/a	n/a	n/a
Δ Total	88.46	n/a	n/a

AIS, adolescent idiopathic scoliosis; AS, adult scoliosis; MCID, minimal clinically important difference; QOL, quality of life; SRS-22r, Scoliosis Research Society 22 questionnaire.

Discussion

A common clinical scenario for the spine surgeon who treats AIS is the presentation of a skeletally mature patient with moderately severe curvature that meets radiographic criteria for surgical intervention but is asymptomatic [1-3]. Not uncommonly, in the current health care milieu in which the patient and family members are encouraged to question treatment alternatives and their rationale, discussions on the merits of intervention in the patient who has no pain, pulmonary dysfunction, or other disability, are undertaken. Surgical correction of the skeletally mature adolescent often evokes fear among family members as to the possibility of complications, especially paralysis [20]. The question that is frequently asked by parents: "should we send our daughter to you for surgery now, or should we consider waiting until symptoms develop or curve progression occurs." This is essentially a question of natural history of the disease and its subsequent treatment. We set out to provide data that can be used to counsel families and to inform surgical recommendations on the nature of the surgical intervention for the AIS patient versus the patient who has lived for a decade or more beyond adolescence and presents for surgery as an adult. We used two scoliosis prospective multicenter registries, one pediatric and one adult, to begin to answer this question.

Our data show that the average adult scoliosis patient in our study, nearly 30 years older than their 15-year-old AIS counterpart, has experienced a significantly greater impact on QOL compared with the adolescent by the time surgery is performed. Because of the deficit in quality of life, greater improvements in pain, function, and total score domains were found in the adult cohort. Despite this, two-year postoperative pain, image, function, and total domain scores were less for adult scoliosis than AIS patients. A higher percentage of patients in the adult cohort reached the MCID in self-image domain than that in the AIS cohort. What is unknown is the longevity of those outcomes beyond 2 years. Our data show that the adult scoliosis patient begins with worse QOL and improves to a greater extent in most domains than their adolescent counterpart but remain at a lower level in those same domains as preoperatively.

Consistent with our methodology, the adult scoliosis patients had larger curves at the time of surgery by just over 8° (58.3° vs. 49.9°). Despite this, percentage correction was similar for both groups (~62%) as were final curve magnitudes (21.8° vs. 19°). We did not expect to find this. However, larger cohorts are needed to age stratify and assess differences in radiographic corrections by age group. We chose a relatively conservative estimation of progression so as to not overstate the true observed natural history of progression. Weinstein et al., in their landmark natural history study, reported mean annual curve progression over a 40-year time span of 0.74° per year for thoracic curves, and 0.56° per year for thoracolumbar curves [7]. We used a factor 0.3° per year progression for the first 10 years, and 0.5° per year thereafter. We also took into account a gradual increase in kyphosis that takes place with aging as reported by Fon et al. [17]. We understand that this modeling is imperfect but it represents, we believe, a fair estimate of possible curve progression. Prospective, randomized studies are difficult to perform in this population as families seeking surgical intervention for the AIS patient would be asked to forego surgery in favor of allowing natural history to play out over decades, and others would be asked to consent to surgery even if this would not be desirable. In addition, prospective study would require decades to complete. This methodology allows for an estimation of the natural history and a first look at the question of differences in the QOL and surgical experience for the adult scoliosis versus AIS patient.

As we hypothesized, operative morbidity was significantly greater for the adult scoliosis patients than for AIS. Fusions were 3.5 levels longer in the adult scoliosis patients and fusion to the pelvis was required in 36% of them. In addition, nearly 30% of the adult scoliosis patients had combined anterior-posterior surgery. Operative time was longer (414 vs. 281 minutes; p = .0001), blood loss was nearly twice as much (~1400 vs. ~700 mL; p = .0027), and blood loss as a percentage of blood volume (35.1 vs. 20.3; p = .0027), and LOS (6.3 vs 5.3 days; p = .0043) were all greater for the adult scoliosis versus AIS cohorts. Although The differences in operative parameters became less evident between the two cohorts after stratifying by Lenke curve type because of the reduced sample size, and largely abolished with normalization by levels fused. Nevertheless, the trends are instructive and warrant further study with larger cohorts. We did not have data consistently available but it is also likely that blood transfusion requirements were greater for the adult study group given the higher EBL as a percentage of blood volume. Longer fusions in adults, when not extended to the sacrum, may also result in a self-fulfilling prophecy of distal segment disc degeneration potentially because of increased intradiscal pressures and fewer motion segments available to preserve motion [21-24]. Although we found increased numbers of fusion levels as well as fusion to the sacrum with pelvic fixation in the adults, we do not answer the question on the longevity of the fusion in the AIS patient; that is, will distal disc degeneration occur at some point, necessitating later extension of the fusion distally. Longer-term follow-up is required to begin to answer this question. Also, fusionless corrective surgery is beginning to find its way into the armamentarium of the pediatric scoliosis surgeon and may have a very profound impact on the fate of the nonoperated segments compared with fusion approaches [25,26].

Perhaps the most compelling information for families is the data on complications. We found major complication rates of 25% for the adult versus 5.4% for the AIS groups. There were 4/28 neurologic complications in the adult group and 1/56 in AIS, none of which required reoperation. Both groups had one case of implant loosening, there was one patient in the adult scoliosis group requiring a chest tube for pleural effusion and one deep wound infection and one pseudarthrosis in the AIS group, all of these complications requiring reoperation. Although reoperation rates were greater in the adult cohort (10.7% vs. 3.6%) this was not statistically significant likely because of the small sample size of this study.

We believe this study adds considerably to the information families and surgeons should consider in determining whether the timing for surgery for idiopathic scoliosis should be done in the adolescent or later in the symptomatic adult. The morbidity and quality of life in both groups has been outlined in this matched cohort from prospectively collected pediatric and adult spinal deformity registries. Nevertheless, we acknowledge some weaknesses of this investigation. Firstly, the numbers are relatively small. We had access to several hundred AIS patients who met the inclusion criteria for this study but far fewer adult scoliosis patients because of the methodology selected. We met by committee and excluded the vast majority of adult scoliosis cases from consideration if there was any question as to the etiology being idiopathic. We recognize that this expert consensus is not foolproof but it was the best we could do given the nature of the presentation of the adult patient and the lack of consistent data in the adult spinal deformity registry on whether or not diagnosis of the condition was made during the adolescent years. As a result of these small numbers, age stratification of the outcomes of interest could not be performed and are of interest for future study with larger cohorts. We would also like to further stratify by curve types to assess relative benefits of intervention early versus late by curve type. Although we made some attempt of that here, the numbers are too small to make definitive conclusions. We also cannot answer the question of the long-term impact of early fusion in AIS or whether or not fusionless strategies will change the equation. We have also not answered the question of the natural history of untreated AIS as a control group as it is recognized that there may be adolescents who may never require or go on to surgical intervention as an adult, nor have we answered the question of the potential need for late operation for distal disc degeneration, for example, in the previously operated adolescent. This point cannot be answered by our study and is an important consideration for the patient. Another component of analysis that would be beneficial from a societal perspective centers around determination of value, cost-benefit, of intervening early versus late and the associated costs, durability of outcomes, and overall resources required to treat each patient group as well as the impact on employment and role in society.

In conclusion, AIS patients have shorter fusions, less EBL, shorter operative time and LOS, and fewer major and minor complications than their adult counterparts who have undergone a natural history of curve progression and present for treatment later. Radiographic corrections are similar and QOL improvements are seen in both groups but to a greater extent in adults who start off with a greater impact of the disease on their QOL. Further study with larger cohorts is required.

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