Health-related quality of life outcomes in complex adult spinal deformity surgery

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OBJECTIVE Significant health-related quality of life (HRQOL) benefits have been observed for patients undergoing primary and revision adult spinal deformity (ASD) surgery. The purpose of this study was to report changes in HRQOL measures in a consecutive series of patients undergoing complex spinal reconstructive surgery, using Scolio-RISK-1 (SR-1) inclusion criteria.

METHODS This was a single-center, retrospective cohort study. The SR-1 inclusion criteria were used to define patients with complex ASD treated between June 1, 2009, and June 1, 2011. Standard preoperative and perioperative data were collected, including the Scoliosis Research Society (SRS)–22r instrument. The HRQOL changes were evaluated at a minimum 2-year follow-up. Standardized forms were used to collect surgery-related complications data for all patients. Complications were defined as minor, transient major, or permanent major. Patients who achieved a minimum 2-year follow-up were included in the analysis.

RESULTS Eighty-four patients meeting SR-1 criteria were identified. Baseline demographic and surgical data were available for 74/84 (88%) patients. Forty-seven of 74 (64%) patients met the additional HRQOL criteria with a minimum 2-year follow-up (mean follow-up 3.4 years, range 2–6.5 years). Twenty-one percent of patients underwent posterior fusion only, 40% of patients had a posterior column osteotomy, and 38% had a 3-column osteotomy. Seventy-five percent of patients underwent a revision procedure. Significant improvements were observed in all SRS-22r domains: Pain: +0.8 ($p < 0.001$); Self-Image: +1.4 ($p < 0.001$); Function: +0.46 ($p < 0.001$); Satisfaction: +1.6 ($p < 0.001$); and Mental Health: +0.28 ($p = 0.04$). With the exception of Mental Health, more than 50% of patients achieved a minimum clinically important difference (MCID) in SRS-22r domain scores (Mental Health: 20/47, 42.6%). A total of 65 complications occurred in 31 patients. This includes 29.8% (14/47) of patients who suffered a major complication and 17% (8/47) who suffered a postoperative neurological deficit, most commonly at the root level (10.6%, 5/47). Of the 8 patients who suffered a neurological deficit, 1 (13%) was able to achieve MCID in the SRS Function domain.

CONCLUSIONS The majority of patients experienced clinically relevant improvement in SRS-22r HRQOL scores after complex ASD surgery. The greatest improvements were seen in the SRS Pain and SRS Self-Image domains. Although 30% of patients suffered a major or permanent complication, benefits from surgery were still attained. Patients sustaining a neurological deficit or major complication were unlikely to achieve HRQOL improvements meeting or exceeding MCID for the SRS Function domain.

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KEY WORDS adult spinal deformity; scoliosis; osteotomy; subtraction; outcomes; complex; Scolio-RISK-1

ADULT spinal deformity (ASD) surgeries are associated with high complication rates, including new neurological deficits.^{7–9,11,12,16} Complication rates exceeding 70% have recently been reported.²⁷ In addition to medical complications, the most complex deformities are associated with high neurological risks. Recent prospective studies of complex ASD surgeries have reported

new neurological deficit rates of approximately 20%.^{23,26} Despite these risks, the number of spinal deformity surgeries performed yearly is increasing.^{13,15} Given the inherent risk associated with these complex procedures, a benefit from surgery must be achieved. In a value-driven health care economy, the benefits of complex ASD surgeries will need to be defined.

ABBREVIATIONS ASD = adult spinal deformity; HRQOL = health-related quality of life; IOM = intraoperative neurophysiological monitoring; MCID = minimum clinically important difference; SR-1 = Scolio-RISK-1; SRS = Scoliosis Research Society; 3-CO = 3-column osteotomy.

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There is a paucity of health-related quality of life (HRQOL) data related to complex ASD surgery. Several large, prospective, multicenter database studies have reported outcomes of ASD, with coronal and sagittal plane deformities defining ASD.^{1,4,6,18,20,22,23,25,27–29} Embedded within these cohorts are patients undergoing the highest-risk surgeries, with 3-column osteotomies (3-COs) and preexisting spinal cord deficits such as myelopathy. In general, HRQOL improvements are attained after these surgeries. However, complications are known to negatively affect HRQOL scores, particularly if the complication results in a permanent condition.¹⁹ Complex ASD surgeries are associated with the highest risk for these types of complications.

The purpose of this study was to examine the effect of surgery for complex ASD on HRQOL scores from a single center at a minimum 2-year follow-up. We hypothesized that surgery would offer benefits to the majority of patients, in the setting of high complication rates. Furthermore, we expected that “recoverable” complications would not have a negative effect, whereas permanent conditions would negatively affect HRQOL.

Methods

Patient Selection

After institutional review board approval, patients treated for ASD between June 1, 2009, and June 1, 2011, were identified in the surgical registry of a single center. Patient consent was not required. The inclusion criteria were adopted from the Scolio-RISK-1 (SR-1) study, defining complex ASD (Table 1). Only patients with completed preoperative Scoliosis Research Society (SRS)–22r questionnaires and minimum 2-year follow-up with completed SRS–22r questionnaires were included in the analysis. Patients were excluded if they had a history of recent substance dependency, psychosocial disturbance (e.g., schizophrenia), active malignancy, active bacterial infection (systemic or local), recent trauma (within 3 months), prior paraplegia, or were pregnant or nursing.

Surgeries were performed by 1 of 3 fellowship-trained spine surgeons. The procedures were tailored to the needs of the patient and at the discretion of the attending surgeon. Antifibrinolytic therapy was used during surgery, except when contraindicated by a prior venothromboembolic event, impaired renal function, or a history of color blindness. In all cases, intraoperative neurophysiological monitoring (IOM) with somatosensory evoked potentials, descending neurogenic evoked potentials, and electromyography was used. In the absence of reliable IOM, intraoperative Stagnara tests were performed. All patients underwent a neurological examination prior to extubation.

Data Collection

Standardized data collection sheets were used to collect demographic, radiographic, and perioperative data. Demographic data collected included age, sex, race, body mass index, primary diagnosis, and any prior history of spine surgery. Standard radiographic variables were measured preoperatively and at a minimum 2-year follow-up. Coronal measurements included maximum coronal Cobb

TABLE 1. Scolio-RISK-1 inclusion criteria

Age 18–80 yrs
Primary scoliosis, kyphosis, or kyphoscoliosis, w/ major Cobb angle $\geq 80^\circ$
Congenital spinal deformity undergoing reconstruction w/ any osteotomy
Revision spinal deformity undergoing reconstruction w/ any osteotomy
Any patient undergoing a 3-CO
Any patient w/ myelopathy due to the spinal deformity
Any patient w/ ossification of the ligamentum flavum or posterior longitudinal ligament, & undergoing a reconstruction w/ decompression

angle and C-7 alignment (magnitude and direction). Sagittal measurements included major sagittal Cobb angle, thoracic kyphosis Cobb angle (T5–12), lumbar lordosis Cobb angle (T12–S1), pelvic incidence, sacral slope, and C-7 sagittal vertical axis. Perioperative data collected included whether the surgery was a revision, the type of osteotomy performed, intraoperative neurological deficit, operating time, estimated blood loss, and any postoperative complications. Complications were classified as minor and major, according to the system proposed by Glassman et al.¹⁹

The primary outcome for this study was the HRQOL score collected via the SRS–22r questionnaire.^{2,5} The mean differences in preoperative and minimum 2-year follow-up SRS scores were calculated for each domain. Individual patients' improvement in each SRS domain was calculated and compared with a minimum clinically important difference (MCID) reference value. The MCID values were defined as SRS Pain (0.4), SRS Self-Image (0.8), SRS Function (0.4), SRS Mental Health (0.4), and SRS Subscore (0.4).¹⁰

Statistical Analysis

Frequency distributions and summary statistics were calculated for all variables. Paired samples t-tests were used to compare pre- and postoperative radiographic parameters. Wilcoxon signed-rank tests were used to compare paired pre- and postoperative HRQOL, and the Wilcoxon rank-sum test was used to compare groups according to complication occurrence. The independent samples t-test was used to compare continuous data between included groups and those lost to follow-up. The chi-square test was used to compare demographic and perioperative rates between included groups and those lost to follow-up. The HRQOL difference scores for each patient were compared with the MCID to determine if a clinically significant difference had been achieved. The HRQOL changes were analyzed by complication type (none/minor/major/permanent) and by neurological deficit (no deficit/root/spinal cord). Statistical significance was defined as $p < 0.05$; SPSS version 24 software (IBM, Inc.) was used for all analyses.

Results

Descriptive Data

Using the SR-1 criteria, 84 patients were identified as

TABLE 2. Preoperative demographic data in 74 patients with complex ASD surgery

Variable	Included, n = 47	Lost to FU, n = 27	p Value
Age in yrs	50.7 ± 16	47.4 ± 18	0.42
Female sex	33 (70.2)	20 (74.1)	0.72
BMI	30 ± 6.3	27 ± 8	0.08
Nicotine use	2 (4.3)	8 (29.6)	0.002
No preop neuro deficit	41 (87.2)	19 (70.4)	0.08
Revision procedure	35 (74.5)	18 (66.7)	0.47
ASA score			0.19
1	0 (0)	1 (3.7)	
2	34 (75.6)	16 (59.3)	
3	11 (24.4)	9 (33.3)	
4	0 (0)	0 (0)	
Missing	2 (4.3)	1 (3.7)	

ASA = American Society of Anesthesiologists; BMI = body mass index; FU = follow-up; neuro = neurological.

Values expressed as no. of patients (%) or mean ± SD.

having undergone complex ASD surgery between 2009 and 2011. Demographic and surgical data were available for 74 (88%) of these patients. Baseline and minimum 2-year follow-up radiographic and HRQOL data were available for 47/74 (64%) patients. Of these, 33 (70.2%) were female and 14 (29.8%) were male. The majority of patients underwent an osteotomy (37/47, 79%). The average follow-up was 3.4 years (range 2–6.5 years). Baseline demographic data for all patients are summarized in Table 2, including those lost to follow-up.

Table 3 summarizes the perioperative data collected for all patients. The majority of patients (40/47, 85%) underwent a single-stage procedure. A total of 65 perioperative complications occurred in 31 patients. Excessive bleeding was the most common complication overall (18/65, 27.7%). A majority of patients had at least 1 medical complication postoperatively (68.1%), and 17% experienced postoperative neurological deficits. Of those lost to follow-up, 7.4% (2/27) experienced postoperative neurological deficits. The majority of deficits were at the root level (spinal cord: 3/47, 6.4%; root: 5/47, 10.6%; cauda equina: 0/47, 0%). Three patients sustained permanent, major complications: 2 with neurological deficits at the spinal cord level, and 1 with deep wound infection.

Outcome Data

There was a significant improvement in both coronal and sagittal major Cobb angles, sagittal alignment, and lumbar lordosis at 2-year follow-up (Table 4). There was no significant change in coronal alignment or thoracic kyphosis (T5–12). The HRQOL outcome measures are presented in Table 5. The SRS-22r scores across all domains showed significant increases. The HRQOL increases were stable at the 1-year and latest follow-up time points. The greatest improvements were seen in the SRS Self-Image (+1.4, $p < 0.001$) and SRS Satisfaction (+1.6, $p < 0.001$) domains. The majority of patients experienced clinically significant improvements in all domains, with the excep-

TABLE 3. Perioperative data in 74 patients with complex ASD surgery

Variable	Included, n = 47	Lost to FU, n = 27	p Value
Osteotomy type			0.65
None	10 (21.3)	5 (18.5)	
PCO	19 (40.4)	8 (29.6)	
PSO	12 (25.5)	8 (29.6)	
VCR	6 (12.8)	6 (22.2)	
Staged procedure			0.34
Yes	7 (14.9)	2 (7.4)	
Stage 1			
No.	46 (97.9)	27 (100)	
Op time, min	469.2 ± 99.4	469.7 ± 111.5	0.98
Mean EBL ± SE, ml	1974.5 ± 208.2	1857.6 ± 234.3	0.72
Stage 2			
No.	3 (6.4)	2 (7.4)	
Op time, min	309.3 ± 71.7	273.5 ± 85.6	0.64
Mean EBL ± SE, ml	1166.7 ± 768.8	1250 ± 250	0.94
Stage 3			
No.	1 (2.1)	0 (0)	
Op time, min	245	0	
Mean EBL, ml	500	0	
Fusion levels	12.5 ± 3.7	13.6 ± 3.9	0.23
Any medical complication			0.81
Yes	32 (68.1)	17 (63.0)	
Postop neuro deficit			0.55
Root level	5 (10.6)	1 (4)	
Cauda equina syndrome	0 (0)	0 (0)	
Spinal cord level	3 (6.4)	1 (4)	
Mean follow-up in yrs	3.4 ± 1.3	NA	

EBL = estimated blood loss; NA = not available; PCO = posterior column osteotomy; PSO = pedicle subtraction osteotomy; VCR = vertebral column resection.

Unless otherwise specified, the values are expressed as no. of patients (%) or mean ± SD.

tion of SRS Mental Health (SRS Pain: 32/47, 68.1%; SRS Self-Image: 37/47, 78.7%; SRS Function: 27/47, 57.4%; SRS Mental Health: 20/47, 42.6%). Of the 27 patients lost to follow-up, 23 (85.2%) had baseline HRQOL data, and 8 (29.6%) had available 1-year HRQOL data. No statistically significant HRQOL differences were observed at the baseline or 1-year time points between the included group and those lost to follow-up.

Tables 6 and 7 describe changes in HRQOL values by complication type and neurological deficit. Patients who suffered any temporary major complication experienced less improvement in SRS Pain than patients with no complications (+0.12, $p = 0.03$). Patients with postoperative root-level deficits had less improvement in SRS Function than patients who suffered no neurological deficit (−0.11, $p = 0.03$). Two patients sustained permanent neurological deficits at the spinal cord level; both deficits were classified as ASIA (American Spinal Injury Association)

TABLE 4. Preoperative and postoperative radiographic data in patients with complex ASD surgery

Variable	Mean $\pm$ SD	p Value
Major coronal Cobb angle		
Baseline	49.5° $\pm$ 29.2°	
Postop	26.7° $\pm$ 20°	<0.001
Coronal balance, mm		
Baseline	29.1 $\pm$ 24.6	
Postop	21.2 $\pm$ 17.4	0.09
Major sagittal Cobb angle		
Baseline	50.5° $\pm$ 37.8°	
Postop	33.1° $\pm$ 28.2°	<0.001
Thoracic kyphosis (T5–12)		
Baseline	38° $\pm$ 24.4°	
Postop	35° $\pm$ 16.6°	0.28
Lumbar lordosis (T12–S1)		
Baseline	38.3° $\pm$ 22.6°	
Postop	44.9° $\pm$ 14.7°	0.001
Pelvic incidence		
Baseline	52.6° $\pm$ 17.1°	
Postop	52.9° $\pm$ 13.6°	0.95
Sacral slope		
Baseline	27.8° $\pm$ 13.9°	
Postop	31.1° $\pm$ 9.9°	0.01
Sagittal alignment (C-7 SVA), mm		
Baseline	96.4 $\pm$ 75.2	
Postop	44.2 $\pm$ 34.9	<0.001

SVA = sagittal vertical axis.

Grade D. Both patients experienced improvements in SRS Pain (+0.8 in one, +1.4 in the other) and SRS Self-Image (+0.9 in one, +2.9 in the other). One patient had a globally weak (4/5 strength) right lower extremity with a worse SRS Function score (−0.6). One patient had bilateral foot drops (3/5 bilateral tibialis anterior) without worsening of function (+0.6). One patient with a transient right-sided root-level deficit had worse pain scores at last follow-up (−1.6). Patients sustaining a neurological deficit or major complication were unlikely to achieve HRQOL improvements of, or exceeding, the MCID for SRS Function (none: 67%; major complication: 36%; neurological deficit: 13%).

Despite major complications and neurological deficits, improvements in SRS Pain (none: 80%; major complication: 57%; neurological deficit: 75%) and SRS Self-Image (none: 67%; major complication: 93%; neurological deficit: 100%) reaching the MCID level were common.

No significant differences in HRQOL improvement were observed between patients who underwent 3-COs (n = 18) and those who did not (n = 29). For each group, patients achieved significant improvement in all domains except SRS Mental Health (no 3-CO: +0.27 [p = 0.16]; 3-CO: +0.28 [p = 0.11]). Patients not undergoing a 3-CO suffered a total of 34 complications, compared with 31 complications in the 3-CO group. We did not observe a significant difference between groups with respect to any complication rate (no 3-CO: 62.1%; 3-CO: 77.8% [p = 0.27]), major complication rate (no 3-CO: 31%; 3-CO: 27.8% [p = 0.98]), or postoperative neurological deficit rate (no 3-CO: 17.2%; 3-CO: 16.7% [p = 0.96]).

Discussion

As the population ages, the rate of surgeries performed for ASD will increase.^{13,15} Advances in technique, instrumentation, and perioperative care have allowed these surgeries to become increasingly complex. These complex procedures are associated with a concomitantly increased risk of complication.¹⁴ Numerous studies have indicated improvement in pain, function, and HRQOL measures after ASD surgery.^{1,4,6,18,20,22,25,27–29} No study has reported HRQOL outcomes after complex spinal deformity surgery according to the SR-1 definition for complex surgery.²³ The purpose of this study was to analyze changes in HRQOL patient outcome measures for a consecutive series of patients treated for complex spinal deformity and to evaluate the effect of complications on outcomes at a minimum 2-year follow-up.

We identified 47 patients with complex deformities and a minimum 2-year follow-up. Significant corrections of major coronal and sagittal Cobb angles, and of sagittal alignment were obtained. Improvements across all HRQOL domains (SRS Pain, SRS Self-Image, SRS Function, SRS Satisfaction, and SRS Mental Health) and SRS Subscore were found at an average of 3.4 years' follow-up. The greatest improvements were seen in the SRS Self-Image (+1.4, p < 0.001) and SRS Satisfaction (+1.6, p < 0.001) domains. The least improvement was seen in the SRS Mental Health domain (+0.28, p = 0.04). No significant differences in HRQOL improvement were observed

TABLE 5. Comparison of baseline and minimum 2-year follow-up HRQOL parameters in 47 patients with complex ASD surgery

Variable	Pain	Self-Image	Function	Satisfaction	Mental Health	Subscore
Baseline	2.8 $\pm$ 0.9	2.3 $\pm$ 0.7	2.9 $\pm$ 0.9	2.8 $\pm$ 1.2	3.6 $\pm$ 0.8	2.9 $\pm$ 0.7
1-yr FU	3.5 $\pm$ 0.9	3.8 $\pm$ 0.7	3.2 $\pm$ 0.9	4.2 $\pm$ 0.9	3.9 $\pm$ 0.7	3.6 $\pm$ 0.7
Latest FU	3.6 $\pm$ 0.9	3.7 $\pm$ 0.8	3.3 $\pm$ 0.9	4.4 $\pm$ 0.8	3.8 $\pm$ 0.8	3.6 $\pm$ 0.7
Mean improvement	+0.8 $\pm$ 1.1	+1.4 $\pm$ 0.8	+0.46 $\pm$ 0.8	+1.6 $\pm$ 1.5	+0.28 $\pm$ 0.8	+0.74 $\pm$ 0.7
% above MCID (no.)	68.1% (32)	78.7% (37)	57.4% (27)	NA	42.6% (20)	74.5% (35)

Unless otherwise specified, the values are expressed as the mean $\pm$ SD. The p values for mean improvement were as follows: p < 0.001 for Pain, Self-Image, Function, Satisfaction, and Subscore; p = 0.04 for Mental Health.

TABLE 6. The HRQOL changes by complication type in patients with complex ASD surgery

HRQOL Domain	Complications & Changes in SRS-22r Score (mean $\pm$ SD)			
	None, n = 15	Any Minor, n = 17	Any Major, n = 11	Permanent, n = 3
Pain	1.2 $\pm$ 1.1*	0.83 $\pm$ 1.1*	0.12 $\pm$ 1.2†	1.0 $\pm$ 0.35
Self-Image	1.4 $\pm$ 1.0*	1.3 $\pm$ 0.74*	1.5 $\pm$ 0.72*	1.6 $\pm$ 1.1
Function	0.67 $\pm$ 0.7*	0.65 $\pm$ 0.87*	0.07 $\pm$ 0.8	0.0 $\pm$ 0.6
Satisfaction	1.5 $\pm$ 1.4*	1.7 $\pm$ 1.4*	1.9 $\pm$ 1.5*	0.5 $\pm$ 2.6
Mental Health	0.31 $\pm$ 0.93	0.44 $\pm$ 0.84	0.02 $\pm$ 0.76	0.07 $\pm$ 1.0
Subscore	0.87 $\pm$ 0.77*	0.84 $\pm$ 0.71*	0.45 $\pm$ 0.69	0.70 $\pm$ 0.7

* Wilcoxon signed-rank test $p < 0.05$ comparing pre- and postoperative means according to complication group.

† Wilcoxon rank-sum test $p < 0.05$ comparing "None" as reference group.

between patients who underwent 3-CO procedures and those who did not. More than 50% of patients achieved the MCID or greater for all domains except SRS Mental Health (20/47, 42.6%). The greatest MCID achievement rates were seen in the SRS Self-Image (37/47, 78.7%) and SRS Pain (32/47, 68.1%) domains.

Bridwell et al. reported results of a prospective cohort study of patients with de novo adult symptomatic lumbar scoliosis.⁶ Surgery was associated with significant increases in the SRS Subscore, although no analysis of the individual domain scores was offered. Smith et al. presented results from a prospective cohort study of patients with a wide range of ASD pathologies.²⁷ Patients who were treated experienced significant improvement across all 5 SRS domains. Improvements in HRQOL scores associated with surgery are a common finding, although there are no studies in which the present a priori definition of complex spinal deformity has been used to assess the success of surgery in the setting of greater risk.

Complex spinal deformity surgeries are not uncommonly associated with major complications, including new neurological deficits. The SR-1 cohort reported a new neurological deficit rate of 22%.²³ At 6-month follow-up, half of these new neurological deficits had improved. These findings might suggest that with adequate recovery and follow-up, HRQOL outcomes may not be negatively affected by new neurological deficits. This theory is sup-

ported by Auerbach et al., who found that so-called recoverable major complications were not associated with poor results at 2-year follow-up.³ These findings are distinctly different from those of Glassman et al., who found that major complications did negatively affect HRQOL.¹⁹ We observed that patients with major complications had worse SRS Pain scores at 2-year follow-up than patients with no complications. Similarly, patients with root-level deficits reported less improvement in SRS Function scores than those without a new neurological deficit. This is probably due to residual lower-extremity weakness affecting walking or more vigorous physical activity. Temporary and permanent major complications were rare, and comparisons with other groups were not powered to detect differences. Our results, combined with those of Auerbach et al., reinforce the need for longer-term follow-up of patients with ASD who sustain complications. With adequate follow-up and more patients, definitive conclusions regarding the effect of recoverable complications are possible.

A large percentage of patients (74.5%) included in the study were undergoing revision spine surgery. Kelly et al. reviewed a series of 94 patients with ASD undergoing repeat revision surgery, mainly to correct pseudarthroses or to treat a deep wound infection.²² They reported significant increases in HRQOL measures across all 5 domains, with the greatest improvement seen in SRS Satisfaction, SRS Pain, and SRS Self-Image. These findings suggest that patients with ASD who undergo multiple revisions benefit from surgery, despite the inherent risk of such procedures. The fact that patients with both primary and revision deformities were able to recover from these surgeries and the related complications is due, in part, to the high-volume nature of the hospital. The entire care team is experienced with the care of patients with complex ASD, with dedicated operating teams. Thus, early identification of complications was possible. This is true of IOM as well, where the surgeon, nursing staff, monitoring staff, and anesthesia team are prepared for alerts with loss of data. It is mandatory to have an experienced team to take care of these complicated cases, so that all personnel along the care pathway can identify complications and respond appropriately and quickly.

In this series, significant improvements in patient-reported HRQOL measures were observed across all SRS domains. Using the values of MCID derived by Crawford

TABLE 7. The HRQOL changes by neurological deficit in patients with complex ASD surgery

HRQOL Domain	Deficits & Changes in SRS-22r Score (mean $\pm$ SD)		
	No Deficit, n = 39	Root Level, n = 5	Spinal Cord, n = 3
Pain	0.85 $\pm$ 1.2*	0.55 $\pm$ 1.3	0.67 $\pm$ 0.81
Self-Image	1.4 $\pm$ 0.87*	1.5 $\pm$ 0.37*	1.6 $\pm$ 1.1
Function	0.59 $\pm$ 0.81*	-0.11 $\pm$ 0.30†	-0.20 $\pm$ 0.69
Satisfaction	1.6 $\pm$ 1.4*	2.6 $\pm$ 1.6*	0.33 $\pm$ 2.5
Mental Health	0.29 $\pm$ 0.86*	0.29 $\pm$ 0.79	0.0 $\pm$ 1.0
Subscore	0.78 $\pm$ 0.73*	0.62 $\pm$ 0.55	0.50 $\pm$ 0.79

* Wilcoxon signed-rank test $p < 0.05$ comparing pre- and postoperative means according to complication group.

† Wilcoxon rank-sum test $p < 0.05$ comparing "No Deficit" as reference group.

et al., individual improvement for the SRS Pain, SRS Self-Image, and SRS Function domains exceeded the MCID threshold, with more than 50% of patients achieving MCID.¹⁰ The achievement of “clinically” important improvement for most patients suggests a benefit for complex ASD surgery. However, one should note that the definition of MCID is that of HRQOL improvement deemed beneficial in the absence of extra cost or risk associated with the intervention.²¹ Complex ASD surgeries are among the costliest and riskiest procedures performed. Therefore, a goal of exceeding, rather than meeting, MCID may be warranted. Further research defining the substantial clinical benefit for these patients is required.

This study is limited by the retrospective, single-center design and the lack of a nonoperative comparison cohort. Because this was a single-center study, these results may not be generalizable to other centers. Additionally, these results probably apply to complex ASD only; we did not examine common diseases, such as de novo adult lumbar scoliosis. Furthermore, we are probably underpowered to detect differences in HRQOL scores across complication groups, including neurological deficits. It is inappropriate to claim that new neurological deficits are not associated with worse outcomes based on our results. A larger cohort is required to describe the effect of new neurological deficits on HRQOL in patients with ASD.

Retrospective studies are subject to recall bias, although HRQOL data were collected at pre- and postoperative visits. In addition, retrospective cohort studies are limited by the information that is available in the chart upon review, which may underestimate complications such as new neurological deficits.²⁴ This study is compromised by a 36% rate of loss to follow-up. Such a high rate might skew the patient-reported outcomes to overestimate or underestimate the true HRQOL improvement. However, we did not observe a significant HRQOL difference between included and excluded groups at the baseline or 1-year time points. We have shown that those patients lost to follow-up are not substantially different from those who remained compliant with follow-up with respect to baseline data, with the exception of smoking. Whether their outcomes are similar is unknown. Nicotine-use histories may predispose patients to more complications, including nonunion and worse HRQOL.^{17,30} Thus, we may overestimate the benefit of surgery and underestimate complication rates and the detrimental effect of complications. Finally, we have a minimum 2-year follow-up with a mean of 3.4 years, which is inadequate to assess the results and durability of ASD surgery. Complications related to proximal junctional kyphosis and pseudarthrosis occur at 5 years postoperatively and beyond, necessitating longer follow-up in these complex cases.²²

Conclusions

Our results suggest that a majority of patients attain clinically relevant improvement in HRQOL after surgery. More than 50% of patients experienced domain score improvements exceeding the MCID for SRS Pain, SRS Self-Image, and SRS Function. Patients suffering major complications and new neurological deficits were less likely to

achieve MCID for SRS Function, whereas MCID thresholds were often met for SRS Pain and SRS Self-Image. As the name suggests, the MCID represents a threshold for minimum improvement. Due to the risk and cost associated with these complex procedures, the threshold for clinically significant improvement may be greater. Ongoing research regarding substantial clinical benefit thresholds may provide a more useful measure for evaluating clinical outcomes after complex ASD surgery. The data presented here will provide valuable information for the shared decision-making process in these complex surgeries.

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