The Schwab-SRS Adult Spinal Deformity Classification: Assessment and Clinical Correlations Based On a Prospective Operative and Non-Operative Cohort

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The SRS-Schwab Adult Spinal Deformity Classification: Assessment and Clinical Correlations Based on a Prospective Operative and Nonoperative Cohort

BACKGROUND: The SRS-Schwab classification of adult spinal deformity (ASD) is a validated system that provides a common language for the complex pathology of ASD. Classification reliability has been reported; however, correlation with treatment has not been assessed.

OBJECTIVE: To assess the clinical relevance of the SRS-Schwab classification based on correlations with health-related quality of life (HRQOL) measures and the decision to pursue operative vs nonoperative treatment.

METHODS: Prospective analysis of consecutive ASD patients (18 years of age and older) collected through a multicenter group. The SRS-Schwab classification includes a curve type descriptor and 3 sagittal spinopelvic modifiers (sagittal vertical axis, pelvic tilt, pelvic incidence/lumbar lordosis mismatch). Differences in demographics, HRQOL (Oswestry Disability Index, SRS-22, Short Form-36), and classification between operative and nonoperative patients were evaluated.

RESULTS: A total of 527 patients (mean age, 52.9 years; range, 18.4-85.1 years) met inclusion criteria. Significant differences in HRQOL were identified based on SRS-Schwab curve type, with thoracolumbar and primary sagittal deformities associated with greater disability and poorer health status than thoracic or double curve deformities. Operative patients had significantly poorer grades for each of the sagittal spinopelvic modifiers, and progressively higher grades were associated with significantly poorer HRQOL ($P < .05$). Patients with worse sagittal spinopelvic modifier grades were significantly more likely to require major osteotomies, iliac fixation, and decompression ($P \leq .009$).

CONCLUSION: The SRS-Schwab classification provides a validated language to describe and categorize ASD. This study demonstrates that the SRS-Schwab classification reflects severity of disease state based on multiple measures of HRQOL and significantly correlates with the important decision of whether to pursue operative or nonoperative treatment.

KEY WORDS: Adult spinal deformity, Classification, Outcomes, Pelvis, Sagittal alignment, Surgery, Treatment

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Adult spinal deformity (ASD) is a complex clinical entity for the treating physician.[1-6] ASD has a broad range of clinical presentations; some patients experience severe disability, whereas others are asymptomatic. For the clinician, radiographic images are viewed in the context of disability and pain, which are commonly quantified through standard health-related quality of life (HRQOL) measures. The significant correlations between HRQOL scores and radiographic parameters, such as the sagittal vertical axis (SVA), pelvic tilt (PT), and mismatch between pelvic incidence and lumbar lordosis (PI-LL), have been previously reported in the literature.[7-9] Based on these parameters, the SRS-Schwab classification of ASD was recently developed to provide the clinician with a pragmatic approach to categorize radiographic elements of spinal deformity in the adult.[10]

ABBREVIATIONS: ASD, adult spinal deformity; **CCI,** Charlson Comorbidity Index; **HRQOL,** health-related quality of life; **ODI,** Oswestry Disability Index; **PI-LL,** pelvic incidence minus lumbar lordosis; **PT,** pelvic tilt; SVA, sagittal vertical axis

This new classification of ASD is a validated system that provides a detailed method of describing radiographic presentation. The SRS-Schwab classification (Figure 1) includes a curve type descriptor and 3 sagittal spinopelvic modifiers that reflect intrinsic components of the sagittal deformity, as well as compensatory mechanisms associated with the deformity. Classification reliability has been previously reported[10]; however, correlations with HRQOL disease state and treatment modality have not previously been assessed.

A reliable protocol for classification and treatment planning, and ultimately outcomes anticipation, is important for optimal treatment approaches to ASD. A classification system that does not offer a framework for clinical treatment provides only limited clinical value. The purpose of this study was therefore to assess the association between classification category and HRQOL and between classification category and treatment delivered (operative or nonoperative) in a prospectively acquired, multicenter cohort of ASD patients. Furthermore, this study sought to assess the relationship between curve type and classification modifier grades to surgical technique in the operative cohort. Our hypothesis was that the descriptive coronal curve type of the SRS-Schwab classification would not be correlated with treatment approach (operative vs nonoperative) but that patients with primary sagittal malalignment and poorer sagittal spinopelvic modifier grades would be more likely to receive operative treatment for their spinal deformity. Additionally, it was our hypothesis that surgical strategies would vary based on the severity of the modifier grade.

MATERIAL AND METHODS

Patient Population

This was a multicenter prospective study of consecutive adult patients with spinal deformity. Patients were drawn from the International Spine Study Group database, composed of 10 sites across the United States. Each enrolling site obtained institutional review board approval of a common protocol. Inclusion criteria for the database included adults (18 years of age and older) presenting with radiographic findings of spinal deformity, defined as a coronal Cobb angle = 20 degrees, SVA = 5 cm, PT = 25 degrees, and/or thoracic kyphosis = 60 degrees. In addition to database inclusion criteria, patients were included in this study only if they had baseline imaging sufficient to enable classification based on the SRS-Schwab system and had complete baseline HRQOL measures. Although the International Spine Study Group database captures patients with coronal Cobb angles as low as 20 degrees, for this study, patients having normal sagittal spinopelvic parameters (SVA, PT, and thoracic kyphosis) were required to have a minimum coronal Cobb angle of 30 degrees for inclusion.

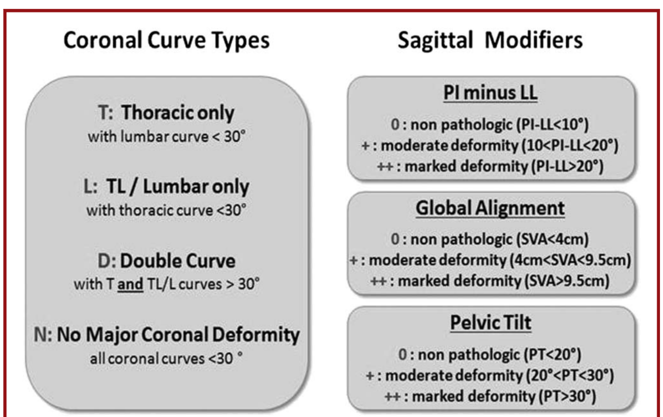

FIGURE 1. *SRS-Schwab classification of adult spinal deformity.*[10]

Data Collection

Data collection consisted of baseline HRQOL questionnaires (Oswestry Disability Index [ODI], SRS-22, and Short Form-36), clinical and demographic information, and surgical parameters. Comorbidities were quantified for each patient based on the Charlson Comorbidity Index (CCI).[11] All patients underwent full-length anteroposterior and lateral standing x-rays. Radiographic parameters were measured at a central location (NYU Hospital for Joint Diseases) using validated spine-specific software (SpineView, Laboratory of Biomechanics ENSAM ParisTech, Paris, France).[12,13] Radiographs were evaluated for Cobb angle, apex location, coronal alignment, and sagittal spinopelvic parameters, including SVA, PT, and PI-LL, as previously described.[14] These measures were used to classify each patient according to the SRS-Schwab classification (Figure 1).[10]

Statistical Analysis

After classifying patients based on the SRS-Schwab system, patients who underwent operative treatment were compared with patients who received nonoperative care to assess for potential differences in baseline demographics, clinical and radiographic measures, as well as HRQOL scores. An additional analysis was carried out for the operative group to compare surgical strategies (approach, instrumentation type, levels fused, osteotomies, interbody fusion and decompression) by classification. All statistical analyses (*t* test, χ^2, analysis of variance, Pearson's correlation) were completed using SPSS software (SPSS Corp., Chicago, Illinois) with a level of significance set at .05.

RESULTS

Patient Demographics and SRS-Schwab Classification

Between October 2008 and December 2011, 757 consecutive ASD patients were enrolled across participating sites. A total of 527 patients (70%) met inclusion criteria, with complete classification parameters and HRQOL scores, and comprise the study population. Two case examples are illustrated in Figures 2 and 3. The mean age of the study population was 52.9 years (SD = 16.2; range, 18.4-85.1 years), and 443 (84.1%) were women. Of the 527 patients, 308 (58.4%) underwent nonoperative treatment, and 219 (41.6%) underwent operative treatment. Operative patients were significantly older (55.8 years vs 50.2 years, $P < .001$), had a larger body mass index (27.7 vs 25.5, $P < .001$), had significantly greater comorbidities (mean CCI, 1.2 vs 0.8; $P < .001$), and were more likely to have a history of spinal surgery (43.5% vs 10.4%, $P = .001$), compared with nonoperative patients.

Patients were categorized according to the SRS-Schwab classification. Of the 572 patients, 31.3% had double curve type (D type), 14.3% had thoracic curve type (T type), 29.7% thoracolumbar or lumbar curve type (L type) deformities, and 16.8% had a pure sagittal deformity (ie, N type with at least 1 sagittal modifier

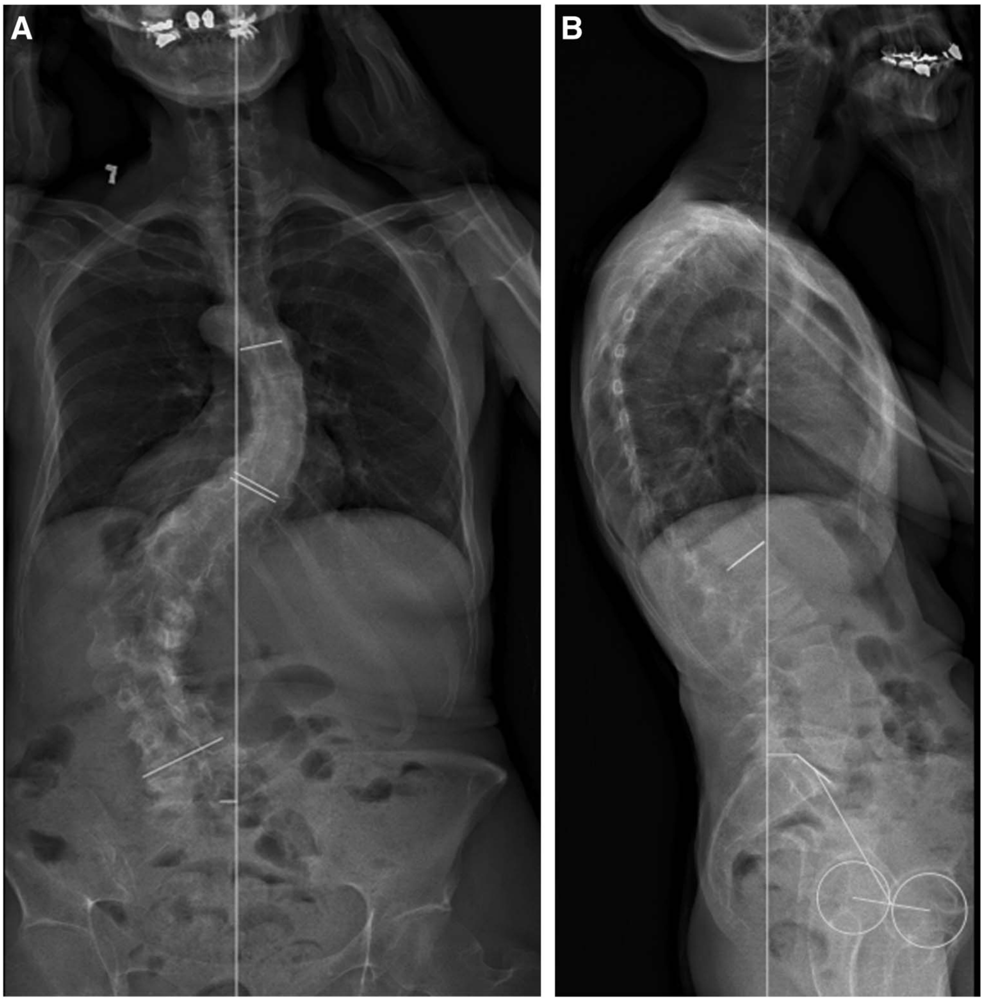

FIGURE 2. *Case example. A 51-year-old woman with a double major coronal curve (curve type D), global alignment modifier grade of 0, pelvic incidence-lumbar lordosis mismatch modifier grade of 0, and pelvic tilt modifier grade of +. Patient chose nonoperative management at enrollment. Shown are full-length anteroposterior (**A**) and lateral (**B**) standing x-rays.*

grade at + or ++) (Table 1). The overall distribution of operative vs nonoperative treatment approach did not differ significantly based on curve type (P = .196).

The distribution of sagittal plane modifier grades is summarized in Table 2 for the 527 patients who were classified based on the SRS-Schwab system. Patients with marked sagittal deformity (ie, patients with at least 1 sagittal spinopelvic modifier graded as ++) had significantly greater comorbidities based on the CCI (2.17 vs 1.21; $P < .001$) and were significantly older (62.6 vs 47.9 years; $P < .001$) compared with patients having normal sagittal modifier grades.

Comparisons of Operative and Nonoperative Patients Based on Classification

Patients with primary sagittal deformity (N type curve) were significantly more likely to present with history of spinal surgery (55.2% vs 19.0%, 18.3%, and 28.2% for the D, T, and L types, respectively; P = .0001). Among patients with a primary coronal deformity, the distribution of specific curve types (D, T, or L) did not differ significantly between the operative and nonoperative treatment groups (P = .356).

Operative patients had significantly poorer grades for each of the sagittal spinopelvic modifiers compared with nonoperative patients ($P < .001$) (Table 2, Figure 4). Nonoperative patients were less likely to have sagittal modifiers meeting deformity thresholds (grade + or ++) than operative patients.

Compared with nonoperative patients, at baseline, operative patients had significantly greater disability and poorer HRQOL based on all standardized HRQOL instruments and domains assessed (Table 3) ($P < .001$). Analysis by curve type demonstrated that patients with primary sagittal deformity (N type) had significantly

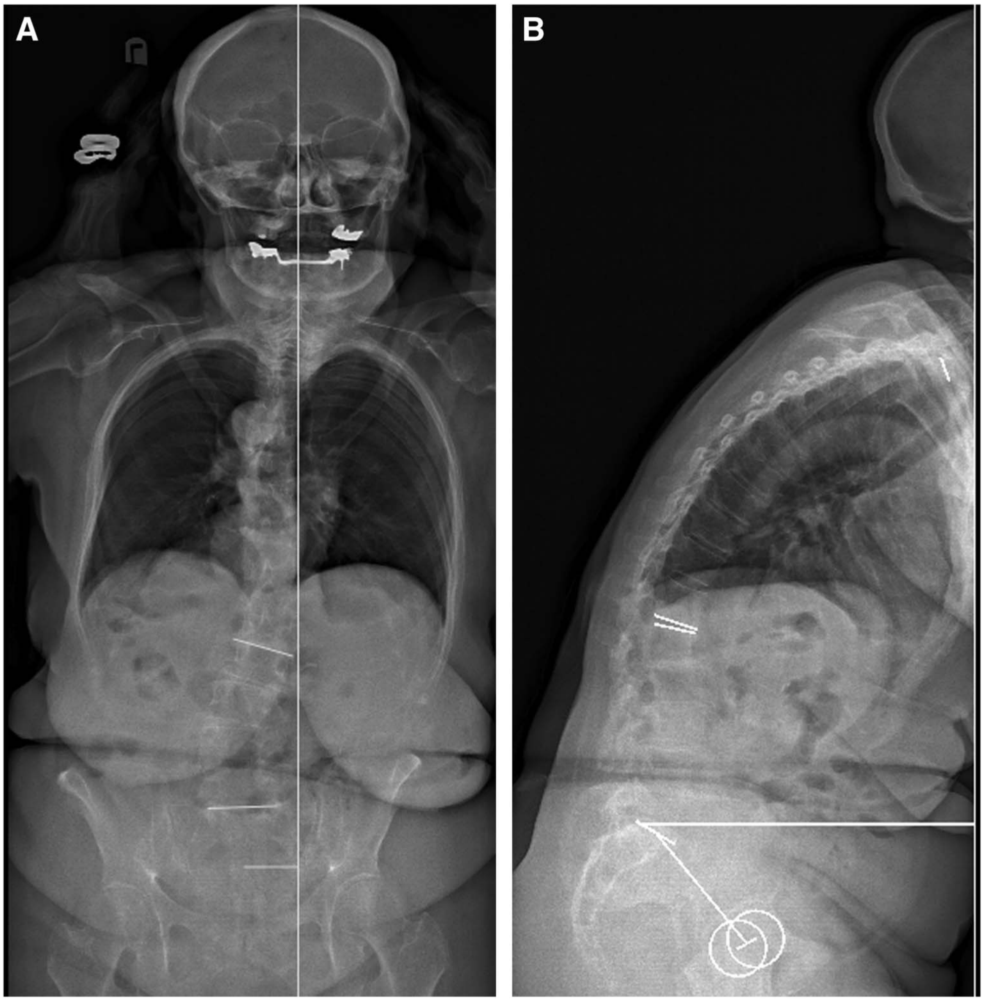

FIGURE 3. *Case example. An 80-year-old woman with no major coronal deformity (curve type N; ie, no coronal Cobb angle >30 degrees), global alignment modifier grade of ++, pelvic incidence-lumbar lordosis mismatch modifier grade of ++, and pelvic tilt modifier grade of ++. Patient chose operative management at enrollment. Shown are full-length anteroposterior (***A***) and lateral (***B***) standing x-rays.*

poorer HRQOL scores compared with those with primary coronal deformity or a combined deformity (Table 4). The SRS-Schwab sagittal spinopelvic modifier grades also demonstrated significant correlations with HRQOL measures (Table 5). Patients with a PT modifier grade of + or ++ had significantly worse HRQOL than did those with a normal PT modifier grade ($P < .001$). Patients with a PI-LL modifier grade of + had significantly worse HRQOL than those with a normal PI-LL modifier, and patients with a ++ PI-LL

TABLE 1. Curve Type Classification Based on the SRS-Schwab Classification for 527 Adults With Spinal Deformity[a]

Curve Type	All (N = 527)	Nonoperative Group (n = 308)	Operative Group (n = 219)
Double	179 (31.3%)	105 (58.7%)	74 (41.3%)
Thoracic	82 (14.3%)	55 (67.1%)	27 (32.9%)
Thoracolumbar/lumbar	170 (29.7%)	99 (58.2%)	71 (41.8%)
No major coronal deformity	96 (16.8%)	49 (51.0%)	47 (49.0%)

[a]Total number includes patients without major coronal deformity but with at least 1 abnormal sagittal spinopelvic modifier grade. The overall distribution of operative vs nonoperative treatment approach did not differ significantly based on curve type (χ^2, $P = .196$).

TABLE 2. Summary of SRS-Schwab Adult Spinal Deformity Classification Modifier Grades for 527 Patients, Stratified by Operative and Nonoperative Treatment Approaches[a]

	ALL (N = 527)	Nonoperative Group (n = 308)	Operative Group (n = 219)	*P* Value
PT, no. (%)				
0	251 (47.6%)	169 (67.3%)	82 (32.7%)	<.001
+	177 (33.6%)	95 (53.7%)	82 (46.3%)	
++	99 (18.8%)	44 (44.4%)	55 (55.6%)	
SVA				
0	310 (58.8%)	210 (67.7%)	100 (32.3%)	<.001
+	123 (23.3%)	68 (55.3%)	55 (44.7%)	
++	94 (17.8%)	30 (31.9%)	64 (68.1%)	
PI-LL				
0	287 (54.5%)	188 (65.5%)	99 (34.5%)	<.001
+	96 (18.2%)	56 (58.3%)	40 (41.7%)	
++	144 (27.3%)	64 (44.4%)	80 (55.6%)	

[a]PT, pelvic tilt; SVA, sagittal vertical axis; PI-LL, mismatch between pelvic incidence and lumbar lordosis.

modifier grade had significantly worse scores than those with + or normal modifier classification. Those with marked SVA offset (global sagittal alignment modifier) had significantly worse HRQOL measures than those with a moderate or normal global sagittal alignment modifier. Patients with a moderate global sagittal alignment modifier (+) also had significantly worse HRQOL scores than those with a normal modifier grade (Table 5).

Surgical Strategy by Classification

Descriptive Curve Type

Patients with D and L type deformities were significantly more likely to have circumferential procedures than patients with a T type deformity, whereas T type deformities were most likely to undergo posterior-only fusion (P = .003; Table 6). Patients with a primary sagittal deformity (N type) in this series were significantly more likely to be treated with a major osteotomy (grade III: pedicle subtraction and grade IV/V: subtotal or total vertebral body resection[15]) than those with coronal deformity with or without sagittal deformity ($P < .001$). Patients with T type deformities underwent fixation to the ilium more frequently than did those with T or D type deformities ($P < .001$), and use of interbody fusion was significantly more common among patients with either T or N type deformity compared with D or T type deformities ($P < .001$).

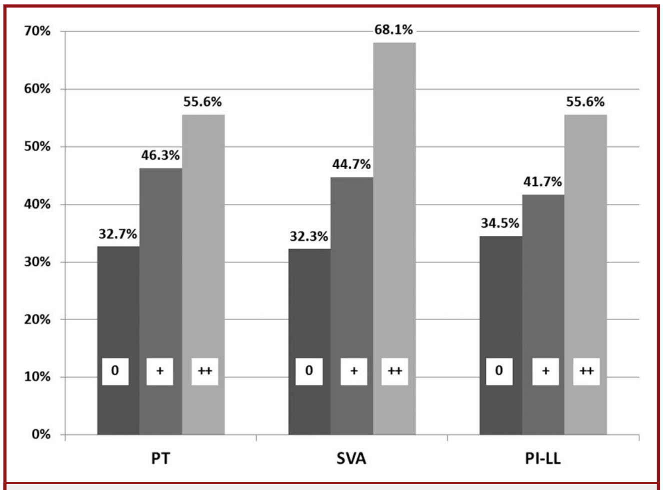

FIGURE 4. *Distribution of sagittal spinopelvic modifier grades based on the SRS-Schwab classification of adult spinal deformity among 219 surgically treated patients. PI-LL, pelvic incidence-lumbar lordosis; PT, pelvic tilt; SVA, sagittal vertical axis.*

Sagittal Spinopelvic Modifiers

There was a nonsignificant trend in favor of patients with an abnormal PT modifier grade undergoing circumferential surgical procedures compared with patients with a normal PT modifier (P = .082) (Table 7). Patients with an abnormal PT modifier grade were significantly more likely to undergo a major osteotomy ($P < .001$), have instrumentation extending to the ilium ($P < .001$), and undergo interbody fusion (P = .012).

Patients with a normal PI-LL modifier grade were significantly less likely to have instrumentation extending to the ilium (grade 0, 41.8%) compared with those having moderate (+, 74.4%) or marked (++, 85.7%) PI-LL modifier grades (P = .001) (Table 8). Patients with a marked (grade ++) PI-LL modifier were found to have significantly higher rates of major osteotomy (21.5%) than those with moderate (5.2%) or normal (4.1%) modifiers ($P < .001$). There were no significant differences in operative approach or the number of vertebral levels fused based on PI-LL modifier grade ($P > .05$).

Abnormal SVA modifier scores were associated with a higher rate of iliac fixation (grades +, 74.1% and ++, 82.3%) than for normal modifier scores (45.5%) ($P < .001$) (Table 9). Higher global alignment modifier was associated with a greater rate of major osteotomy (grade ++, 42.2%) than moderate (grade +, 14.5%) or normal global alignment (grade 0, 4.5%) ($P < .001$). Operative approach and number of levels fused were not found to differ significantly based on the global alignment modifier ($P > .05$).

TABLE 3. Baseline Health-Related Quality of Life Scores for 527 Adults With Spinal Deformity, Stratified by Operative and Nonoperative Treatment[a]

	All (N = 527)	Operative Group (n = 219)	Nonoperative Group (n = 308)	*P* Value
ODI	31.8	41.0	25.2	<.001
SF-36 PCS	38.1	33.0	41.8	<.001
SF-36 MCS	48.2	45.8	50.0	<.001
SRS score				
Activity	3.25	2.91	3.50	<.001
Pain	2.78	2.41	3.05	<.001
Appearance	3.12	2.69	3.42	<.001
Mental	3.73	3.47	3.92	<.001
Total	3.22	2.85	3.48	<.001

[a]ODI, Oswestry Disability Index; SF, Short Form; PCS, Physical Component score; MCS, Mental Component score; SRS, Scoliosis Research Society.

DISCUSSION

As changing demographics in the United States and other developed countries continue to swell the numbers of elderly individuals to unprecedented levels, the medical and surgical conditions that afflict these individuals will similarly expand. Spinal conditions are among the most common health problems that affect adults, and, although the precise prevalence of ASD is difficult to define, a recent study has suggested that as many as 60% of the elderly demonstrate some degree of ASD.[16] Fortunately, the majority of individuals will either be asymptomatic or have symptoms that are sufficiently addressed with nonoperative measures, but for others, the severity of pain and disability may warrant consideration of surgical treatment. Recent studies demonstrated significant potential for surgical treatment to improve pain and disability among adults with spinal deformity[3-6,17,18]; however, these procedures are not without significant risk of complications[6] and not all patients benefit equally.[19] Furthermore, despite the complexity of ASD, there remains remarkably minimal standardization to its classification and treatment approaches. The SRS-Schwab classification for ASD[10] was recently developed with the goals of providing a common language and creating an objective framework for a clinically meaningful classification that may ultimately prove useful for guiding treatment decisions, surgical planning, and counseling regarding outcome expectations. Although the validity of the SRS-Schwab classification with regard to inter- and intrarater reliability has been recently demonstrated,[10] its clinical relevance has not been previously reported. This study provides the basis for this clinical relevance by demonstrating that the parameters of the SRS-Schwab classification significantly correlate with standardized measures of HRQOL and with treatment approach in a prospectively collected, multicenter ASD population.

To be clinically relevant, a key aspect of any classification is ease of use; this classification was developed based on measurable radiographic parameters that are highly correlated with clinical outcomes. One aspect that is neglected by this methodology and is a limitation of this study is the lack of inclusion of the etiology of the deformity, despite its possible clinical relevance.[20] However, it should be recognized that in clinical practice, it is not uncommon for the etiology of an adult spinal deformity (eg, adult idiopathic scoliosis

TABLE 4. Baseline Health-Related Quality of Life Scores for 527 Adults With Spinal Deformity by Descriptive Curve Type According to the SRS-Schwab Classification[a]

	D	T	L	N	*P* Value[b]	Significance
ODI	27.6	21.8	34.5	43.2	<.001	D:L, D:N, T:L, T:N, L:N
SF-36 PCS	40.0	44.8	36.5	31.9	<.001	All
SF-36 MCS	49.7	48.3	47.4	47.2	.428	None
SRS activity	3.37	3.52	3.16	2.98	<.001	D:N, T:L, T:N
SRS pain	2.84	3.06	2.68	2.62	<.001	T:L, T:N
SRS appearance	3.15	3.44	3.02	2.94	<.001	T:L, T:N
SRS mental	3.85	3.82	3.66	3.57	.034	D:N
SRS total	3.33	3.47	1.13	2.96	<.001	D:L, T:L, T:N

[a]D, double curve; T, thoracic curve; L, thoracolumbar or lumbar curve; N, no major coronal deformity; ODI, Oswestry Disability Index; SF, short form; PCS, physical component score; MCS, mental component Score; SRS, = Scoliosis Research Society.
[b]*P* values reflect analysis of variance testing across all curve types for the corresponding health-related quality of life measure. Significant differences ($P < .05$) in outcome measures between specific curve type groups based on post hoc testing are listed in the column at the far right.

TABLE 5. Baseline Health-Related Quality of Life Scores for 527 Adults With Spinal Deformity by Sagittal Spinopelvic Modifier Grade According to the SRS-Schwab Classification[a]

	PT				SVA				PI-LL			
	0	+	++	Significance	0	+	++	Significance	0	+	++	Significance
ODI	24.8	36.2	41.7	0 vs +, 0 vs ++	25.6	35.1	47.8	All	24.5	34.9	44.2	All
SF-36 PCS	42.3	35.3	32.9	0 vs +, 0 vs ++	41.9	35.5	29.1	All	42.4	35.4	31.6	All
SF-36 MCS	49.4	47.8	46.1	None	49.7	47.5	44.4	0 vs ++	49.9	48.8	44.7	0 vs ++
SRS activity	3.4	3.1	3.0	0 vs +, 0 vs ++	3.4	3.1	2.8	All	3.5	3.2	2.1	All
SRS pain	2.9	2.7	2.5	0 vs +, 0 vs ++	2.9	2.7	2.3	All	3.0	2.8	2.4	All
SRS appearance	3.3	2.9	2.8	0 vs +, 0 vs ++	3.3	3.09	2.5	All	3.3	3.1	2.7	All
SRS mental	3.9	3.6	3.4	0 vs +, 0 vs ++	3.9	3.6	3.8	All	3.9	3.7	3.4	All
SRS total	3.4	3.1	2.9	0 vs +, 0 vs ++	3.4	3.09	2.7	All	3.4	3.2	2.8	All

[a]PT, pelvic tilt; SVA, sagittal vertical axis; PI-LL, mismatch between pelvic incidence and lumbar lordosis; ODI, Oswestry Disability Index; SF, short form; PCS, physical component score; MCS, mental component score; SRS, Scoliosis Research Society. The significance column indicates which comparisons among the 3 modifier graders were significant ($P < .05$).

vs de novo degenerative scoliosis) to be difficult to determine, especially for thoracolumbar and lumbar curves. The SRS-Schwab classification system also reviews coronal curve type and each sagittal modifier independently, ultimately combining each for a full clinical representation of the patient. However, to increase simplicity it does not, in its raw form, discriminate between patients solely with coronal deformity and patients who have multiplanar deformities. A patient with a L type deformity as well as marked PI-LL mismatch and a patient with just a L type deformity are both classified as L, with differing modifiers.

At baseline, patients choosing operative treatment in this study had significantly poorer scores on all standardized measures of HRQOL assessed, had more comorbidities, and had greater severity of deformity compared with the patients who pursued nonoperative care. These findings are consistent with those of previous studies. Based on a large, multicenter, prospectively collected cohort of operatively and nonoperatively treated adults with spinal deformity, Smith et al[4,5] demonstrated that patients pursuing operative treatment had significantly worse back and leg pain, greater disability based on the ODI, and greater severity of deformity compared with the patients pursuing nonoperative care. Similar results have also been reported based on another cohort of adults with spinal deformity.[3] In addition, Fu et al[21] reported that, compared with nonoperative patients, those treated surgically had poorer HRQOL (based on ODI, SRS-30, and SF-12) and also noted that the operative patients had a higher level of comorbidities based on the CCI.

A previously reported comparison of spinal deformity patients by Schwab et al[20,22] showed findings congruous with those of this study with regard to coronal and sagittal alignment parameters. Both studies show a high rate of osteotomies and iliac fixation in the surgical treatment of ASD patients. Regarding the global alignment parameter, both studies show a significantly higher osteotomy rate with increasing positive sagittal malalignment. Iliac fixation was more commonly used as global alignment became increasingly positive. Overall, there is an increase in complexity of surgical procedure based on increased severity of deformity parameters. The most explicit difference between these studies, however, is the expansion of the classification scheme used. The incorporation of the spinopelvic parameters has provided greater insight into the variability of impact of sagittal deformity in a given patient, with particular respect to the compensatory mechanism. A

TABLE 6. Surgical Strategies by Descriptive Curve Type Based on the SRS-Schwab Classification for Adult Spinal Deformity[a]

	D	T	L	N	*P* Value
Circumferential procedure, %	43.2	11.1	43.5	19.6	.003
Posterior-only fusion, %	55.4	88.9	56.5	76.1	
Anterior-only fusion, %	1.4	0	0	4.3	
Major osteotomy rate, %	13.5	7.4	12.7	40.4	<.001
Iliac fixation, %	59.5%	29.6%	77.9%	71.7%	<.001
Levels fused	12.4	11.6	10.4	8.9	<.001
Decompression Y/N, %	56.9	18.5	76.5	79.5	<.001
Osteotomy Y/N, %	72.2	37	79.1	75	.001
Interbody fusion Y/N, %	63	29.6	67.2	79.5	<.001

[a]D, double curve; T, thoracic curve; L, thoracolumbar or lumbar curve; N, no major coronal deformity.

TABLE 7. Surgical Strategies by Pelvic Tilt Modifier Grade According to the SRS-Schwab Classification for Adult Spinal Deformity

	0	+	++	*P* Value
Circumferential procedure, %	24.7	41.5	37.7	.082
Posterior-only fusion, %	72.8	57.3	62.3	
Anterior-only fusion, %	3.3	1.2	0	
Major osteotomy rate, %	2	7.3	22.2	<.001
Iliac fixation, %	42.7	74.1	20.8	<.001
Levels fused	10.9	11.2	10.0	.23
Decompression, %	45	73.4	75	<.001
Osteotomy, %	68.8	69.2	75	.71
Interbody fusion, %	51.3	73.4	67.3	.012

patient can mask a deformity using compensatory mechanisms; failing to appreciate this compensation can lead to undercorrection, poor surgical outcomes, and ultimately revision procedures, the prime example being a patient with high pelvic retroversion.

For this study, patients were drawn from multiple surgical practices from throughout the United States, including private and academic settings, as well as neurosurgical and orthopaedic specialties. The age range of the patients was wide (18-85 years), including patients from their late teens and 20s through elderly individuals in their 80s. In addition, and consistent with the spinal deformity focus of the participating centers, patients with a broad range of deformities were enrolled, including untreated adolescent idiopathic scoliosis, degenerative scoliosis, and primary sagittal malalignment. Despite the diversity of the studied patient cohort, all 527 patients in this study were classifiable based on the SRS-Schwab system, suggesting that this classification is sufficiently broad to enable classification of at least the vast majority of ASD patients meeting study inclusion/exclusion criteria.

Consistent with our initial hypotheses, the curve type descriptor (T, L, D, N types) was not significantly associated with treatment approach (operative vs nonoperative). However, significant differences in multiple HRQOL measures were identified among these curve types, with the L and N type deformities being associated with greater disability and poorer health status than the T or D type curve deformities. Sagittal alignment deformities in general have been reported to be key drivers of pain and disability,[7-9,23-28] which may account for poorer HRQOL in patients having N type curve classification. Degenerative curves, which typically afflict older patients[6] and are often associated with significant canal and foraminal stenosis,[29] are typically L type curves, which may at least partially account for the poorer HRQOL among patients with L type curves.

Compared with patients who chose nonoperative care, those pursuing operative intervention had significantly poorer grades for each of the SRS-Schwab sagittal spinopelvic modifiers (PT, SVA, and PI-LL). In addition, independent of treatment approach, patients with progressively higher modifier grades had significantly poorer HRQOL. Collectively, these findings demonstrate that the SRS-Schwab classification does reflect severity of disease state based on multiple measures of HRQOL and significantly correlates with the important decision of whether to pursue operative or nonoperative treatment.

Among the patients treated operatively, significant differences in operative approach and techniques were identified based on SRS-Schwab classification parameters. Patients with a T type curve and with an N type deformity were significantly more likely to be treated with an all-posterior approach, whereas patients with L or D curve types were almost equally likely to undergo an all-posterior approach vs a circumferential (combined anteroposterior) surgery. The observation that the majority of N type cases were performed

TABLE 8. Surgical Strategies by Pelvic Incidence/Lumbar Lordosis Mismatch Modifier Grade According to the SRS-Schwab Classification for Adult Spinal Deformity

	0	+	++	*P* Value
Circumferential procedure, %	30.9	35.9	35.9	.93
Posterior-only fusion, %	67.3	31.5	62.8	
Anterior-only fusion, %	1.8	2.6	1.3	
Major osteotomy rate, %	4.1	5.2	21.5	<.001
Iliac fixation, %	41.8	74.4	85.7	.001
Levels fused	10.8	11.5	10.4	.45
Decompression, %	47.5	86.5	72	<.001
Osteotomy, %	67.3	63.2	78.4	.16
Interbody fusion, %	52.5	68.8	75.7	.006

TABLE 9. Surgical Strategies by Global Sagittal Alignment Modifier Grade According to the SRS-Schwab Classification for Adult Spinal Deformity

	0	+	++	*P* Value
Circumferential procedure, %	36.4	35.2	27	.62
Posterior-only fusion, %	62.7	63	69.8	
Anterior-only fusion, %	0.9	1.9	3.2	
Major osteotomy rate, %	4.5	14.5	42.2	<.001
Iliac fixation, %	45.5	74.1	82.3	<.001
Levels fused	11.1	10.3	10.7	.46
Decompression, %	52	73.6	71.7	.009
Osteotomy, %	65.3	70.6	78.7	.20
Interbody fusion, %	54.1	74.1	69.5	.026

with an all-posterior approach may reflect substantial advances in posterior 3-column osteotomy techniques for sagittal realignment that mitigate the need for circumferential approaches for these cases. An all-posterior approach may be favored for T type curves due to the morbidity that may be associated with anterior thoracic approaches.[30] In addition, patients with worse grades for the sagittal spinopelvic modifiers were significantly more likely to require a major osteotomy, iliac fixation, and decompression. These findings demonstrate that surgical strategies vary based on the SRS-Schwab classification and provide an objective basis for further study of these associations.

Future analysis will examine the effectiveness of treatment approaches based on radiographic and clinical outcomes in relation to the classification. It is anticipated that other surgical modifiers or algorithm approaches may be added to the initial SRS-Schwab classification such that patient-specific guidelines can be established for the optimization of outcomes in the treatment of ASD. Future studies may include the etiology of the spinal deformity, as it has been suggested to have clinical relevance.[20] This study did not discriminate between idiopathic and de novo deformities; however, it is arguable that patients with de novo curvatures are more likely to be sagittally malaligned and to have worse modifiers than those with idiopathic deformities, which are typically mainly characterized by coronal deformity. This classification enables us to isolate the factors that contribute to variation in management based on deformity etiology. At this point, the classification does not provide guidelines in terms of levels of fusion. This is an important factor that future studies will aim to understand as we continue to demonstrate the clinical relevance of the classification.

Strengths of this study include the prospective design and inclusion of both operatively and nonoperatively treated patients. A single center (NYU Hospital for Joint Diseases) performed all radiographic measures using standardized image analysis software to minimize potential variability in technique. In addition, the multicenter design enhances the generalizability of the findings.

Limitations of this study include the lack of inclusion of the etiology of the deformity for this patient population. This study was limited by a lack of a standardized protocol to aid in the determination of operative vs nonoperative treatment approach; instead, these decisions were made based on the clinical judgment of each surgeon in conjunction with individual patient preferences. Furthermore, to be clinically relevant, 1 key aspect of any classification relates to its ease of use. In this context, the SRS-Schwab classification was developed based on the radiographic parameters that most highly correlated with patient reported outcomes. One drawback of this approach relates to the limited number of parameters that can be included in the classification without becoming prohibitively burdensome.

CONCLUSION

The SRS-Schwab classification provides a validated language to describe and categorize ASD. This study applies this classification to a large, prospectively collected, multicenter, diverse cohort of ASD patients. All patients meeting inclusion criteria could be classified. The curve type descriptor and the sagittal spinopelvic modifiers correlated significantly with multiple standardized measures of HRQOL. The classification modifiers also correlated with the decision to pursue operative or nonoperative treatment and were reflective of significant differences in surgical strategy, including the need for major osteotomies, pelvic fixation, and decompression. Collectively, these findings support the clinical relevance and validity of the SRS-Schwab classification.

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COMMENT

This is a very well done study. This subject is novel and relevant to clinical practice. The study is well designed and executed. The manuscript preparation is excellent. Another excellent study was conducted by Schwab et al.[1] This is a very similar study but did not include pelvic parameters in the classification. Going forward it will be of benefit to see what if any effects the addition of pelvic parameters had on the findings.

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