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A Clinical Impact Classification of Scoliosis in the Adult

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Study Design. Multicenter, prospective, consecutive clinical series.

Objectives. To establish and validate classification of scoliosis in the adult.

Summary of Background Data. Studies of adult scoliosis reveal the impact of radiographic parameters on self-assessed function: lumbar lordosis and frontal plane obliquity of lumbar vertebrae, not Cobb angle, correlate with pain scores. Deformity apex and intervertebral subluxations correlate with disability.

Methods. A total of 947 adults with spinal deformity had radiographic analysis: frontal Cobb angle, deformity apex, lumbar lordosis, and intervertebral subluxation. Health assessment included Oswestry Disability Index and Scoliosis Research Society instrument. Deformity apex, lordosis (T12–S1), and intervertebral subluxation were used to classify patients. Outcomes measures and surgical rates were evaluated.

Results. Mean maximal coronal Cobb was 46° and lumbar lordosis 46°. Mean maximal intervertebral subluxation (frontal plane) was 4.2 mm (sagittal plane, 1.2 mm). In thoracolumbar/lumbar deformities, the loss of lordosis/higher subluxation was associated with lower Scoliosis Research Society pain/function and higher Oswestry Disability Index scores. Across the study group, lower apex combined with lower lordosis led to higher disability. Higher surgical rates with decreasing lumbar lordosis and higher intervertebral subluxation were detected.

Conclusions. A clinical impact classification has been established based on radiographic markers of disability. The classification has shown correlation with self-reported disability as well as rates of operative treatment.

Key words: scoliosis, adult, classification, clinical outcomes. **Spine 2006;31:2109–2114**

Classification systems play a crucial role in orthopedic surgery. Aside from providing a common language for purposes of communication, treatment approach and prognostic value can be guided by effective classification systems. In the arena of spinal deformity, the latter have held an important role in congenital, neuromuscular, and idiopathic scoliosis.[1,2] Surprisingly, for the adult scoliotic deformities, there are no accepted classification systems, and a transposition of pediatric/adolescent classification systems is not feasible. In adults, the clinical impact of the deformity and the treatment approaches are not related to skeletal age and rarely to projected progression, but rather to pain and disability. The lack of a classification in the adult deformity population has limited the study of prognostic markers and progress in establishing treatment algorithms.

Although the prevalence of scoliosis in the adult population has been reported as ranging from 2% to 32%, a recent study targeting elderly volunteers showed a prevalence of more than 60%.[3–8] With an increasingly aging population in the United States and increased attention to quality of life issues, adult scoliosis is becoming a considerable health care concern. Aside from the esthetic considerations of scoliosis in the adult, significant pain and disability can develop.[9]

A number of investigators have examined the impact of radiographic parameters on self-assessed function (outcomes instruments) in the setting of scoliosis in the adult.[10] In one recent study, the loss of lumbar lordosis and obliquity of lumbar vertebrae, but not Cobb angle, on a coronal radiograph were significantly correlated with pain scores. Other investigations have shown global imbalance, apical level of a scoliotic deformity, and intervertebral subluxation to be significantly related to outcomes scores.[10–12]

The purpose of this study was to create, and validate, a classification of scoliosis in the adult. The approach was based on a number of previously established clinically significant radiographic parameters. Although a wide range of radiographic parameters have been found to bear clinical impact, including global alignment, thoracolumbar sagittal alignment, endplate obliquities, intervertebral olisthesis, and lumbar lordosis, the current effort of classification (for matter of simplicity) was based on a limited set of high impact factors. It was hypothesized that a reliable (intraobserver and interobserver) radiographic classification could be established, with clinically distinct groups, based on health status measures and initial treatment approach (surgical *vs.* nonoperative).

Methods

This is a multicenter prospective study, including 947 adult patients (older than 18 years) with deformity of the spine. Subjects were drawn from the Spinal Deformity Study Group database. No distinction in terms of primary etiology of the spinal deformity was made. The database is composed of a multicenter effort involving 11 sites across the United States. Inclusion criteria included scoliosis more than 30° or other signifi-

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Table 1. Inclusion Criteria for Prospective Database

Patients must meet only 1 of the following conditions:
- ☐ Scoliotic curvature, idiopathic or degenerative, more than 30° (Cobb)
- ☐ Sagittal or coronal imbalance more than 5 cm
- ☐ Thoracic kyphosis more than 60° (T3 or T5–T12)
- ☐ Lumbar lordosis less than 30° and scoliosis ≥15°
- ☐ Thoracolumbar kyphosis (T12 or T10–L2) more than 20°
- ☐ Lumbar kyphosis (≥3 levels) more than 10°
- ☐ Documented progression (10° in coronal plane/10° in sagittal plane/ 3-mm listhesis)

cant spinal deformity, including primary deformity in the sagittal plane. The study also includes patients who have undergone previous surgical treatment of spinal deformity and who are more than 12 months from the time of their index procedure (Table 1).

All subjects were enrolled according to an institutional review board protocol approved at each study site. For all subjects, the radiographic analysis (from full-length standing films) included: frontal plane Cobb angle, apical level of the deformity, sagittal plane lumbar alignment (T12–S1), and intervertebral subluxation (frontal and sagittal plane).[13] Completed health assessment questionnaires were available for all subjects (*i.e.*, Oswestry Disability Index [ODI] and Scoliosis Research Society instrument [SRS-22], normalized to 100-point maximal score).[14,15] While higher scores on the ODI represent increasing disability, the inverse holds true for the SRS instrument, in which higher scores reflect less disability/pain than low scores.

The 947 patients in this study have the following demographics: 131 males and 814 females, with 2 undocumented; average age 48 years (standard deviation [SD] 18); and a mean maximal coronal Cobb angle of 46° (SD 19°). Distribution by apical level of the scoliosis was: 52 upper thoracic (T4–T7), 273 lower thoracic (T8–T10), 343 thoracolumbar (T11–L1), and 279 lumbar (L2–L4). Lumbar lordosis from T12 to S1 was measured for each subject. A subluxation modifier was established to assess maximal intervertebral subluxation in either frontal or sagittal planes.

The Classification. As described previously, 3 parameters were incorporated into the adult classification of scoliosis. The terminology used was as follows:

Apical Level. Patients were grouped by apical level and assigned a type: type I, thoracic-only scoliosis, with no thoracolumbar or lumbar component; type II, upper thoracic major curve, apex T4–T8, with a thoracolumbar or lumbar curve; type III, lower thoracic major curve, apex T9–T10, with thoracolumbar or lumbar curve; type IV, thoracolumbar major curve, apex T11–L1, with any other minor curve; and type V, lumbar major curve, apex L2–L4, with any other minor curve. Major curves were those with maximal frontal plane Cobb angle measured by standard technique. Minor curves were any additional curvatures less in magnitude than the major curve. If ≥2 curvatures had identical Cobb angle measurements, then the lower curve (by apex) was selected as the major curve for purposes of classification.

Lordosis Modifier. Lumbar lordosis was used as a method to define separate groups. Based on T12–S1 sagittal Cobb angle, 3 groups were established: no lordosis present (Cobb >0°), moderate lordosis (0°–40°), and marked lordosis (>40°). The lordosis modifier was applied as: A, marked lordosis (>40°); B, moderate lordosis (0°–40°); and C, no lordosis present (Cobb >0°).

Subluxation Modifier. Frontal and sagittal plane intervertebral subluxation was analyzed. In a pilot investigation, similar clinical impact for coronal or sagittal plane olisthesis was noted. Thus, for simplicity, the maximal intervertebral subluxation in coronal or sagittal plane was taken to represent the subluxation modifier score. The measurement technique for this has been reported in the *Spinal Deformity Study Group–Radiographic Measurement Manual*.[13] Based on maximal intervertebral subluxation noted at any level of the spine, 3 groups were established: no subluxation, moderate subluxation (1–6 mm), and marked subluxation (>7 mm). Thus, the subluxation modifier was defined as (Table 2): 0, no subluxation; +, subluxation 1–6 mm; and ++, subluxation >7 mm.

To assess the reliability of the classification, an interobserver and intraobserver analysis was pursued. The reliability analysis involved 8 surgeons who read a series of 20 adult scoliosis patient radiographs (full-length standing anteroposterior and lateral), with 4 surgeons performing a second classification of radiographs 2 weeks later. Excellent reliability was determined (k > 0.6 interobserver/0.8 intraobserver by type, k > 0.9/0.9 for lordosis and subluxation score).

Applying the classification of patients into groups as defined previously, comparisons were made among groups according to 1 or multiple parameters (apical level, lumbar lordosis, and intervertebral subluxation) (Figure 1). Statistical comparisons (*t* test) among these subgroups in terms of ODI and SRS function/pain scores were made. In addition to the comparisons of outcome scores among grouped patients, an analysis of treatment was pursued. The latter was based on the reported treatment by the surgeon as either surgical or nonsurgical. Applying the radiographic grouping approach (classification) as defined previously, comparisons were made among groups according to 1 or multiple parameters in terms of surgical rates (*t* test, $P <$ 0.05 was considered significant).

■ Results

The 947 patients included 814 females and 131 males (2 sexes not reported), with an average age of 48 years (SD 18). There were 17 type I curves, with single major thoracic only curves, and no thoracolumbar or lumbar component. In this group, average age was 39 years (SD 16),

Table 2. Outline: Classification of Scoliosis in the Adult

Classification	Radiographic Criteria
Type	
I	Thoracic-only curve (no other curves)
II	Upper thoracic major, apex T4–T8
III	Lower thoracic major, apex T9–T10
IV	Thoracolumbar major curve, apex T11–L1
V	Lumbar major curve, apex L2–L4
Lumbar lordosis modifier	
A	Marked lordosis (>40°)
B	Moderate lordosis (0°–40°)
C	No lordosis present (Cobb >0°)
Subluxation modifier	
0	No intervertebral subluxation any level
+	Maximal measured subluxation 1–6 mm
++	Maximal subluxation >7 mm

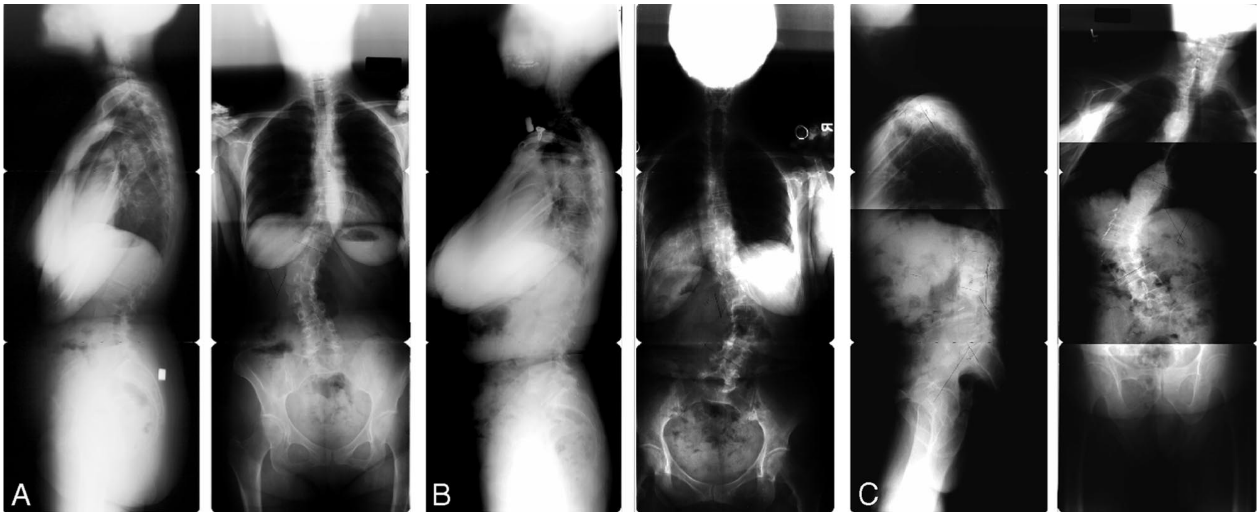

Figure 1. Example of classification for 3 patients with thoracolumbar/lumbar curves. (**A**) Patient A. The curve pattern is a type IV, with a marked lordosis (modifier A) and no subluxation (modifier 0). Health status measures reveal minimal disability (ODI 10 and SRS scores up to 88). (**B**) Patient B. The curve pattern is a type V, with a marked lordosis (modifier A) and moderate subluxation (modifier +). Health status measures reveal moderate disability (ODI 30 and SRS function 60). (**C**) Patient C. The curve pattern is a type IV, with a moderate lordosis (modifier B) and marked subluxation (modifier ++). Health status measures reveal pronounced disability (ODI 46 and SRS function 36).

and mean coronal Cobb was 43° (SD 17°). It is noteworthy that no significant correlation with coronal Cobb curve severity to any of the health measures was noted ($r < 0.06$). The study population included 48 type II curves, with upper thoracic major and apex T4–T7. In this group, average age was 40 years (SD 16), and mean coronal Cobb was 47° (SD 22°). The study population included 260 type III curves, with lower thoracic major curve and apex T8–T10. In this group, average age was 41 years (SD 15), and mean coronal Cobb was 50° (SD 20°). The study population included 343 type IV curves (thoracolumbar and apex T11–L1), with an average age of 50 years (SD 18). Mean coronal Cobb in this group was 47° (SD 19°). The overall study group included 279 type V curves, with lumbar major curves and apex L2–L4. Mean age in this group was 54 years (SD 17), and mean coronal Cobb was 42° (SD 19°) (Tables 3, 4).

Impact of Lordosis and Intervertebral Subluxation on Outcomes Measures

Mean lumbar lordosis (T12–S1) for the study population was 46° (SD 25°). A division into 3 groups (lordosis modifier A, B, and C) of decreasing lordosis revealed the following distribution: modifier A, marked lordosis/Cobb >40 (n = 557); modifier B, moderate lordosis/Cobb 0–40 (n = 261); and modifier C, no lordosis/Cobb >0 (n = 44). Lumbar lordosis measurement was not obtainable in 85 cases. For thoracic major curves (types I, II, and III), lumbar lordosis did not significantly impact self-assessed function. No significant difference in SRS-22 pain/function scores or the ODI scores was noted in this subgroup between patients with lordosis modifiers A *versus* C ($P > 0.05$). However, in the thoracolumbar and lumbar patient groups (types IV and V), lumbar lordosis significantly impacted outcomes scores. For the patients with types IV and V, loss of lordosis was associated with significantly lower SRS pain/function and higher ODI scores (lordosis modifier A *vs.* C, $P \leq 0.007$) (Table 5).

Table 3. Descriptive Data of the Study Population

Data	
Total study group (947)	
No. females	814
No. males	131
No. not applicable	2
Mean age (SD)	48 ys (18)
Mean coronal Cobb (SD)	46° (19°)
Mean lumbar lordosis (SD)	46° (25°)
Mean maximal subluxation frontal plane (SD)	4.2 mm (6.2)
Mean maximal subluxation sagittal plane (SD)	1.2 mm (3.1)
Mean SRS-22 pain score, ranging 0–100 (SD)	62 (19)
Mean SRS-22 function score, ranging 0–100 (SD)	67 (17)
Mean ODI score, ranging 0–100 (SD)	30 (20)

Intervertebral subluxation was measured from all radiographs. Maximal displacement was noted (frontal or sagittal plane), and a division into 3 categories (subluxation modifier 0, +, and ++) revealed: modifier 0, no subluxation (n = 526); modifier+, moderate subluxation/1–6 mm (n = 109), and modifier++, marked subluxation/>7 mm (n = 299). The intervertebral subluxation measurement was not obtainable in 13 subjects. Mean maximal measured intervertebral subluxation in the frontal plane (rotatory subluxation) was 4.2 mm (SD 6.2) and in the sagittal plane (spondylolisthesis or retrolisthesis) was 1.2 mm (SD 3.1). For thoracic curve patterns (types I, II, and III), increasing subluxation modifier score did not reveal increased disability by SRS function score or ODI. However, for thoracolumbar and lumbar curve patterns (types IV and V), a marked impact of subluxation modifier was noted. For subluxation modifier 0 *versus* ++, a marked increase in pain/disability was

Table 4. Patients Grouped by Classification

	No. Patients	Mean ODI	Mean SRS Pain*	Mean SRS Function*	Major Mean Coronal Cobb
Curve type					
I	17	27	67	66	43°
II	48	28	65	69	47°
III	260	24	65	72	50°
IV	343	31	60	65	47°
V	279	34	61	63	42°
Lordosis modifier					Mean lordosis 46° (SD 25°)
A	557	27	65	69	
B	261	36	57	62	
C	44	37	56	57	
Subluxation modifier					Mean frontal subluxation 4.2 mm
0	526	27	64	68	Mean sagittal subluxation 1.2 mm
+	109	30	62	66	
++	299	34	58	63	

*Reported mean scores normalized to a 100-point scale, with lower score representing higher disability/pain.

identified (SRS pain, SRS function, and ODI, all $P < 0.001$).

Combined Parameter Correlations

For thoracic curves (types I, II, and III), lower apical level combined with loss of lumbar lordosis (lordosis modifier A *vs.* C) led to significantly higher disability by SRS pain scores ($P = 0.02$). For thoracolumbar (type IV) and lumbar major (type V) curves, lower apex combined with loss of lordosis (lordosis modifier A *vs.* C) led to significantly higher disability by SRS function and ODI scores ($P < 0.005$), as well as SRS pain scores ($P < 0.05$).

Treatment Analysis

The type of treatment given to patients was divided into surgical or nonoperative. In terms of curve type, the percentage of surgical care was: type I, thoracic only, in 41%; type II, upper thoracic, in 35%; type III, lower thoracic, in 39%; type IV, thoracolumbar, in 48%; and type V, lumbar, in 37% of patients. Further analysis in terms of treatment for thoracic only curves (type I) was not performed because of the low patient number (n = 17). However, analysis of the other curve types (types II, III, IV, and V combined) revealed significant findings. A significant increase in reported surgical rate with increasing lordosis modifier was noted (A *vs.* C, 36% *vs.* 54%, respectively, $P < 0.04$). An increased surgical rate was also noted with higher intervertebral subluxation (modifier 0 *vs.* ++, 36% *vs.* 52%, respectively, $P < 0.001$) (Table 6).

Table 5. Summary of Significant Radiographic–Clinical Correlations*

Curve Type	Lordosis Modifier	Subluxation Modifier	*P*
I, II, and III	A, B, and C	—	Not significant
IV and V	A *versus* C	—	≤0.007†‡§
I, II, and III	—	0 *versus* ++	Not significant
IV and V	—	0 *versus* ++	<0.001†‡§

*Comparison of mean, †SRS pain, ‡SRS function, and §ODI scores (*t* test).

■ Discussion

This study is a unique multicenter analysis of scoliosis in adults. Previous studies have revealed risk factors for higher disability in adult scoliosis to include lower curve apex, loss of lumbar lordosis, frontal plane intervertebral subluxation, and sagittal plane intervertebral subluxation. Frontal plane Cobb angle in scoliosis of adult populations has not been found to bear significant correlation with self-assessed health.

Based on the work of previous studies and the updated findings of the Spinal Deformity Study Group adult deformity outcomes study, a classification of scoliosis in the adult was pursued. The method of creating groups in this population by radiographic parameters is not new. However, the significant number of patients and, thus, the statistical analysis permitted by larger sample sizes of subgroups give this work added weight. The population of this study included 947 patients.

To simplify a classification approach, the parameters of curve type (apex and major/minor patterns), lumbar lordosis, and maximal intervertebral subluxation were isolated. Apical level of the major curve was included in

Table 6. Summary: Treatment Analysis (surgical *vs.* nonoperative) of the Study Population

Patient Group	Surgical Care (%)	Significance in Comparisons
Curve type		Not significant
I	41	
II	35	
III	39	
IV	48	
V	37	
Lordosis modifier*		A *versus* C, $P < 0.04$
A	36	
B	51	
C	54	
Subluxation modifier*		0 *versus* ++, $P < 0.001$
0	36	
+	41	
++	52	

*Curve type I excluded from comparisons because of low patient numbers.

the classification, although, as an independent parameter, this did not have marked clinical significance. However, it was believed that the apex and identification of thoracic-only curves should be included, given its importance to offer visual description and clinical significance once surgical treatment is considered. Furthermore, with additional patients in an analysis, it cannot be excluded that the apex will play an important role on the clinical front. Lumbar lordosis had significant clinical impact in combination with curve apex for type IV and V patterns. The lack of significance in the analysis of type I, II, and III curves may relate to a preponderance of idiopathic curvatures in those groups (all with thoracic component, rare for de novo degenerative deformities). Possibly, the loss of lumbar lordosis impacts de novo degenerative thoracolumbar and lumbar patterns more significantly than major thoracic types, which are more troubled by parameters related to deformity in the thoracic spine.

However, it is noteworthy that further recruitment of patients into the Spinal Deformity Study Group database may still lead to significance of the lordosis modifier, even in the type I, II, and III curves. In terms of intervertebral subluxation, the maximal value was taken from either a frontal or sagittal image to create the subluxation modifier, given that earlier analysis revealed both to have similar clinical impact. As with the lordosis modifier, significant clinical impact was noted in combination with curve apex (*i.e.*, for type IV and V patterns only). It is possible that this correlation pertains to a preponderance of de novo degenerative curve types within the type IV and V patterns, while patients with thoracic deformity would seem most likely to have an idiopathic adolescent component. Again, it may be possible to explain the higher impact of subluxation in thoracolumbar and major lumbar curves, given that patients with thoracic scoliotic curvatures may be most troubled by parameters inherent in the apical of the deformity itself, perhaps as yet unstudied. Thus, the impact of lumbar lordosis and lumbar intervertebral subluxation may have less impact in the type I, II, and III deformities.

In addition to the analysis of the classification in terms of clinical impact by health-related quality of life measures (SRS and ODI instruments), an analysis of treatment program in the study population was pursued. The type of treatment given to patients was divided into surgical or nonoperative. Although the thoracolumbar apex group (type IV) had the highest surgical rate at 48% and the upper thoracic group (type II) the lowest at 35%, differences across curve type were not statistically significant. However, analysis of types II, III, IV, and V revealed a significant increase in reported surgical rate with increasing lordosis modifier (A *vs.* C, 36% *vs.* 54%, respectively, $P < 0.04$). An increased surgical rate was also noted with higher intervertebral subluxation (modifier 0 *vs.* ++, 36% *vs.* 52%, respectively, $P < 0.001$). These findings appear to mirror the increasing disability noted in the SRS and ODI instruments across the same groups (A *vs.* C and 0 *vs.* ++).

The findings in this study confirm that a radiographic and clinically relevant classification of scoliosis in the adult is feasible. With a simple system of graded clinical impact parameters (apex, lumbar lordosis, and intervertebral subluxation), a useful classification has been developed. The reliability of application has been confirmed through an intraobserver and interobserver analysis. It is noteworthy that the classification offers an assignment by apex/pattern, which has descriptive value and may have bearing on surgical strategy for operative patients. The lumbar lordosis and subluxation modifiers offer a stratification of patients into clinical groups. Higher grades (lordosis modifier A–C, subluxation modifier 0 to ++) are tied to increasing disability and pain by the outcomes tools used (*i.e.,* SRS-22 and ODI). Furthermore, the reported surgical rates were closely linked to the radiographic modifiers.

Limitations of this investigation are recognized. Although the number of subjects is substantially larger than most studies of this nature, some subcategories of curve description remain small (*e.g.,* thoracic-only curves, n = 17). It is also evident that the proposed classification is not fully descriptive but focuses on clinical impact parameters that are not the traditional radiographic markers used in adolescent scoliosis. For convenience and purposes of communication, it may still be helpful to add some descriptive parameters such as Cobb angle and end level, although these do not appear to reveal clinical importance by patient-reported outcomes measures.

It is noteworthy that the Spinal Deformity Study Group is prospectively obtaining measurements related to pelvic parameters, thoracolumbar sagittal alignment, and the lumbosacral junction. Future analyses will shed further light on the precise clinical impact of these parameters. Other clinical data (*e.g.,* comorbidities) and imaging methods (*e.g.,* magnetic resonance imaging, dynamic films, and computerized tomography) may also play an important part in further refinement of the proposed classification system, particularly with an effort to arrive at treatment algorithms and surgical planning for adults with spinal deformity.

Conclusions

A comprehensive clinical impact classification is offered based on analysis of a large adult scoliosis population. This classification permits a simple approach of radiographic analysis using established markers of disability by outcomes measurement instruments (SRS and ODI). A preliminary intraobserver and interobserver analysis reveals excellent reliability of the proposed classification. The proposed classification has shown correlation with self-reported disability as well as rates of operative treatment. Further work is important to refine further subcategories, perhaps add parameters from other imaging methods (*e.g.,* MRI), assess the impact of pelvic parameters, establish prognostic value, and tie the classification to a treatment algorithm and surgical strategies for patients who may benefit from operative intervention.

■ Key Points

- Radiographic parameters correlate with disability by outcomes measures in adult scoliosis.
- Classification by deformity apex, lumbar lordosis, and intervertebral subluxation was established.
- Reliability of the classification by intraobserver and interobserver analysis confirmed.
- In addition to self-assessed disability, surgical rates were linked to radiographic parameters.

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