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Adolescent Idiopathic Scoliosis

A New Classification to Determine Extent of Spinal Arthrodesis

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Background: The lack of a reliable, universally acceptable system for classification of adolescent idiopathic scoliosis has made comparisons between various types of operative treatment an impossible task. Furthermore, long-term outcomes cannot be determined because of the great variations in the description of study groups.

Methods: We developed a new classification system with three components: curve type (1 through 6), a lumbar spine modifier (A, B, or C), and a sagittal thoracic modifier (–, N, or +). The six curve types have specific characteristics, on coronal and sagittal radiographs, that differentiate structural and nonstructural curves in the proximal thoracic, main thoracic, and thoracolumbar/lumbar regions. The lumbar spine modifier is based on the relationship of the center sacral vertical line to the apex of the lumbar curve, and the sagittal thoracic modifier is based on the sagittal curve measurement from the fifth to the twelfth thoracic level. A minus sign represents a curve of less than +10°, N represents a curve of 10° to 40°, and a plus sign represents a curve of more than +40°.

Five surgeons, members of the Scoliosis Research Society who had developed the new system and who had previously tested the reliability of the King classification on radiographs of twenty-seven patients, measured the same radiographs (standing coronal and lateral as well as supine side-bending views) to test the reliability of the new classification. A randomly chosen independent group of seven surgeons, also members of the Scoliosis Research Society, tested the reliability and validity of the classification as well.

Results: The interobserver and intraobserver kappa values for the curve type were, respectively, 0.92 and 0.83 for the five developers of the system and 0.740 and 0.893 for the independent group of seven scoliosis surgeons. In the independent group, the mean interobserver and intraobserver kappa values were 0.800 and 0.840 for the lumbar modifier and 0.938 and 0.970 for the sagittal thoracic modifier. These kappa values were all in the good-to-excellent range (>0.75), except for the interobserver reliability of the independent group for the curve type (kappa = 0.74), which fell just below this level.

Conclusions: This new two-dimensional classification of adolescent idiopathic scoliosis, as tested by two groups of surgeons, was shown to be much more reliable than the King system. Additional studies are necessary to determine the versatility, reliability, and accuracy of the classification for defining the vertebrae to be included in an arthrodesis.

Ideally, classification systems are used to assess a clinical entity, enable a surgeon to recommend specific treatment, and allow comparison of different treatment methods[1]. In 1983, King et al. measured scoliotic deformities on coronal radiographs, described five thoracic curve types, and recommended specific vertebral levels to be included in a spinal arthrodesis[2]. All of the patients in their study underwent a spinal arthrodesis with Harrington rod instrumentation to correct the coronal plane deformity. King et al. did not include thoracolumbar, lumbar, or double or triple major curves in their classification.

The King classification has continued to be utilized despite the increasing acceptance of the need to consider scoliosis as a three-dimensional deformity when considering operative intervention and the use of segmental spinal fixation[3-8]. Recently, the interobserver and intraobserver reliability of the King classification was found, by two groups of surgeons working independently, to have only poor-to-fair validity, reliability, and reproducibility[1,9]. The poor reliability of the King classification indicated the need for a new classification that would (1) be comprehensive and include all types of curves, (2) emphasize consideration of sagittal alignment, (3) help to define treatment that could be standardized, (4) be based on objective criteria for each curve type, (5) have good-to-excellent interobserver and intraobserver reliability, and (6) be easily understood and of practical value in the clinical setting.

We developed a new system for classification of adolescent idiopathic scoliosis, on the basis of radiographs made in the coronal and sagittal planes, that could be used to determine the appropriate vertebral levels to be included in an arthrodesis. Two groups of surgeons tested this new classification, and the results were used to calculate interobserver and intraobserver reliability.

Materials and Methods

Four radiographs of the spine (standing long-cassette coronal and lateral as well as right and left supine side-bending

TABLE I Description of Curve Types

		Characteristic Curve Patterns*			
Curve Type	Description	Proximal Thoracic	Main Thoracic	Thoracolumbar/ Lumbar	Structural Region of Each Curve Type
1	Main thoracic	Nonstructural	Structural (major)	Nonstructural	Main thoracic
2	Double thoracic	Structural	Structural (major)	Nonstructural	Proximal thoracic, main thoracic
3	Double major	Nonstructural	Structural (major)	Structural	Main thoracic, thoracolumbar/lumbar
4	Triple major	Structural	Structural (major†)	Structural (major†)	Proximal thoracic, main thoracic, thoraco-lumbar/lumbar
5	Thoracolumbar/ lumbar	Nonstructural	Nonstructural	Structural (major)	Thoracolumbar/lumbar
6	Thoracolumbar/ lumbar-main thoracic	Nonstructural	Structural	Structural (major)	Thoracolumbar/lumbar, main thoracic

*A structural proximal thoracic curve has a Cobb angle of ≥25° on side-bending radiographs and/or kyphosis between the second and the fifth thoracic level of at least +20°. A structural main thoracic curve has a Cobb angle of ≥25° on side-bending radiographs and/or kyphosis between the tenth thoracic and the second lumbar level of at least +20°. A structural thoracolumbar/lumbar curve has a Cobb angle of ≥25° on side-bending radiographs and/or kyphosis between the tenth thoracic and the second lumbar level of at least +20°. †Either the main thoracic or the thoracolumbar/lumbar curve can be the major curve.

views) for each of twenty-seven patients were reviewed by two groups of surgeons. One of the groups consisted of five surgeons, members of the Scoliosis Research Society, who had developed the new system and who had previously reviewed the same radiographs to test the reliability of the King classification[9]. The other group consisted of seven randomly selected members of the Scoliosis Research Society who had not been involved in the development of this new system. The scoliosis was classified according to curve type (1 through 6) combined with a lumbar spine modifier (A, B, or C) and a sagittal thoracic modifier (–, N, or +). The definitions established by the Scoliosis Research Society were used to determine the type of curve.

Thoracic curves, the apex of which is located between the second thoracic vertebral body and the eleventh and twelfth thoracic intervertebral disc, include proximal thoracic curves with the apex at the third, fourth, or fifth thoracic level and main thoracic curves with the apex between the sixth thoracic body and the eleventh and twelfth thoracic disc. The apex of thoracolumbar curves is located between the cephalad border of the twelfth thoracic vertebra and the caudad border of the first lumbar vertebra. The apex of lumbar curves is located

LUMBAR SPINE MODIFIER RULES
A, B, C

1. Examine upright coronal radiograph.
2. Accept pelvic obliquity <2cm. If >2cm, then must block out leg length inequality to level pelvis.
3. Draw CSVL = Center Sacral Vertical Line with a fine tip pencil/marker. Bisects proximal sacrum and drawn vertical to parallel lateral edge of radiograph.
4. Stable Vertebra – Most proximal lower thoracic or lumbar vertebra most closely bisected by CSVL. If a disc is most closely bisected, then choose next caudad vertebra as stable.
5. Apex of curve is the most horizontal and laterally placed vertebral body or disc.
6. SRS Definitions — Apex
   Thoracic Curves — T2-T11-12 disc
   Thoracolumbar Curves — T12-L1
   Lumbar Curves — L1-2 disc to L4

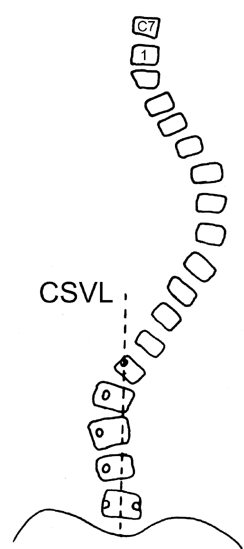


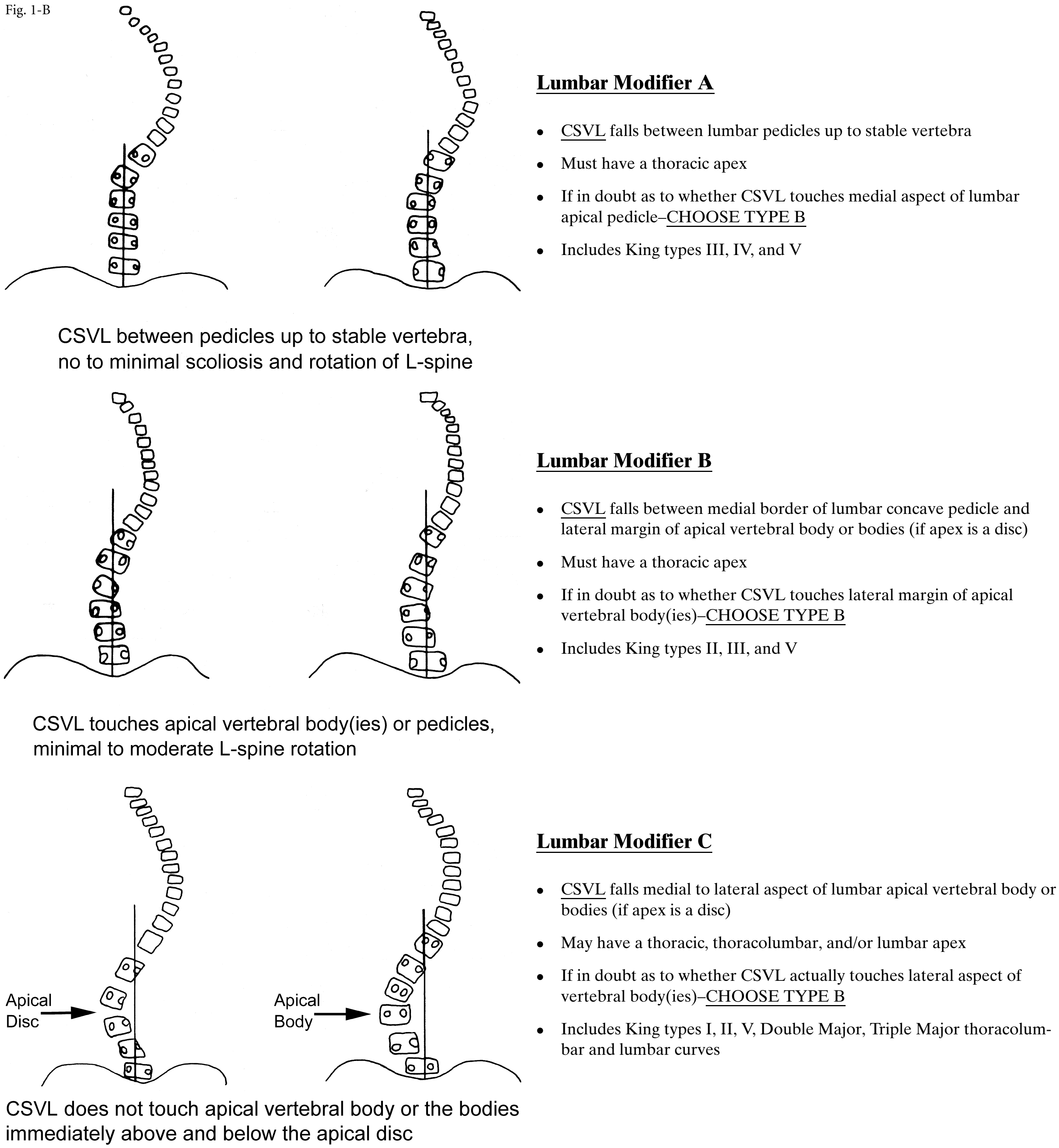
Fig. 1-A

Figs. 1-A and 1-B Rules and definitions for determining the lumbar spine modifiers A, B, and C. CSVL = center sacral vertical line, and SRS = Scoliosis Research Society.

between the first and second lumbar disc and the caudad border of the fourth lumbar vertebra. Structural curves, described by their location, lack normal flexibility and are termed as major (if they have the largest Cobb measurement) or minor. Minor curves can be structural or nonstructural.

In order to simplify the classification, there was some overlap between the structural characteristics of the minor curves. A structural proximal thoracic curve has a minimum residual coronal curve on side-bending radiographs of at least 25° (with or without a positive first thoracic tilt) and/or kyphosis (from the second to the fifth thoracic level) of at least +20°. A structural main thoracic curve has a minimum residual coronal curve of at least 25° and/or thoracolumbar kyphosis (from the tenth thoracic to the second lumbar level) of at

Fig. 1-B



Curve Type

Type	Proximal Thoracic	Main Thoracic	Thoracolumbar / Lumbar	Curve Type
1	Non-Structural	Structural (Major*)	Non-Structural	Main Thoracic (MT)
2	Structural	Structural (Major*)	Non-Structural	Double Thoracic (DT)
3	Non-Structural	Structural (Major*)	Structural	Double Major (DM)
4	Structural	Structural (Major*)	Structural	Triple Major (TM)
5	Non-Structural	Non-Structural	Structural (Major*)	Thoracolumbar / Lumbar (TL/L)
6	Non-Structural	Structural	Structural (Major*)	Thoracolumbar / Lumbar - Main Thoracic (TL/L - MT)

*Major = Largest Cobb Measurement, always structural
Minor = all other curves with structural criteria applied

STRUCTURAL CRITERIA
(Minor Curves)

Proximal Thoracic: - Side Bending Cobb ≥ 25°
- T2 - T5 Kyphosis ≥ +20°

Main Thoracic: - Side Bending Cobb ≥ 25°
- T10 - L2 Kyphosis ≥ +20°

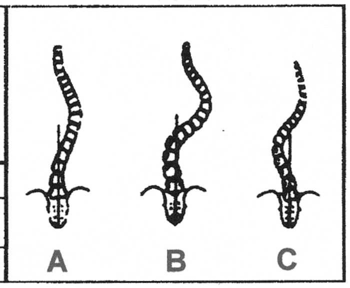
Thoracolumbar / Lumbar: - Side Bending Cobb ≥ 25°
- T10 - L2 Kyphosis ≥ +20°

LOCATION OF APEX
(SRS definition)

CURVE	APEX
THORACIC	T2 - T11-12 DISC
THORACOLUMBAR	T12 - L1
LUMBAR	L1-2 DISC - L4

Modifiers

Lumbar Spine Modifier	CSVL to Lumbar Apex
A	CSVL Between Pedicles
B	CSVL Touches Apical Body(ies)
C	CSVL Completely Medial



Thoracic Sagittal Profile T5 - T12	
- (Hypo)	< 10°
N (Normal)	10°- 40°
+ (Hyper)	> 40°

Curve Type (1-6) + Lumbar Spine Modifier (A, B, or C) + Thoracic Sagittal Modifier (-, N, or +)
Classification (e.g. 1B+):___________

Fig. 2

Synopsis of all necessary criteria for curve classification. SRS = Scoliosis Research Society, and CSVL = center sacral vertical line.

least +20°. A structural thoracolumbar/lumbar curve also has a minimum residual coronal curve of at least 25° and/or thoracolumbar kyphosis (from the tenth thoracic to the second lumbar level) of at least +20° even though sagittal malalignment may be due to a rotational deformity instead of a true kyphosis. A minor curve is structural if these criteria are present. On the basis of this classification, we propose that spinal arthrodesis include only the major curve and structural minor curves.

Curve Types (1 through 6)

Curve types (Table I) are based on the identification of the major curve and the structural characteristics of the minor curves.

Type 1—main thoracic: The main thoracic curve is the major curve, and the proximal thoracic and thoracolumbar/lumbar curves are minor nonstructural curves.

Type 2—double thoracic: The main thoracic curve is the major curve, while the proximal thoracic curve is minor and structural and the thoracolumbar/lumbar curve is minor and nonstructural.

Type 3—double major: The main thoracic and thoracolumbar/lumbar curves are structural, while the proximal thoracic curve is nonstructural. The main thoracic curve is the major curve and is greater than, equal to, or no more than 5° less than the Cobb measurement of the thoracolumbar/lumbar curve.

Type 4—triple major: The proximal thoracic, main thoracic, and thoracolumbar/lumbar curves are all structural; either of the two latter curves may be the major curve.

Type 5—thoracolumbar/lumbar: The thoracolumbar/lumbar curve is the major curve and is structural. The proximal thoracic and main thoracic curves are nonstructural.

Type 6—thoracolumbar/lumbar-main thoracic: The thoracolumbar/lumbar curve is the major curve and measures at least 5° more than the main thoracic curve, which is structural. The proximal thoracic curve is nonstructural.

If the difference between the lumbar and thoracic curves is <5°, the scoliosis can be categorized as type 3, 4, or 5 on the basis of the structural characteristics of the main thoracic and thoracolumbar/lumbar regions. For the sake of clarity, the

TABLE II Interobserver Reliability of Curve Classification by the Five Developers of the Classification System

Reviewers	No. of Curves Classified the Same	Percentage of Curves Classified the Same	Kappa Coefficient
1 and 2	27	100%	1.00
1 and 3	23	85%	0.83
1 and 4	26	96%	0.96
1 and 5	27	100%	1.00
2 and 3	23	85%	0.83
2 and 4	26	96%	0.96
2 and 5	27	100%	1.00
3 and 4	23	85%	0.83
3 and 5	23	85%	0.83
4 and 5	26	96%	0.96
Mean	25.1	93%	0.92

major curve (the curve with the largest Cobb measurement) always distinguishes between type 3 (main thoracic curve is major) and type 6 (thoracolumbar/lumbar curve is major). If the Cobb measurements of the main thoracic and thoracolumbar/lumbar curves are equal, then the thoracic curve is considered the major curve. Thus in Figures 4-A through 4-F, the curve classification is type 6.

Lumbar Spine Modifiers (A, B, or C)

When operative intervention is being considered, the degree of lumbar deformity must be assessed because it alters spinal balance and affects proximal curves. Three types of lumbar deformity were defined on the basis of the relationship of the center sacral vertical line to the lumbar curve as noted on the coronal radiograph (Figs. 1-A and 1-B). The center sacral vertical line should bisect the cephalad aspect of the sacrum and be perpendicular to the true horizontal. Pelvic obliquity secondary to limb-length inequality of <2 cm is ignored unless the surgeon believes that the pelvic obliquity increases the degree of spinal deformity. In those cases and when the discrepancy is >2 cm, the coronal radiograph is made with the appropriately sized lift under the short limb. The center sacral vertical line is extended in a cephalad direction, and the most cephalad lumbar or thoracic vertebra most closely bisected by the line is considered the stable vertebra. If a disc is most closely bisected by the center sacral vertical line, then the vertebra caudad to it is deemed to be the stable vertebra. The apex of a thoracolumbar or lumbar curve is the most horizontal and laterally placed vertebral body or intervertebral disc.

Modifier A: Modifier A is used when the center sacral vertical line runs between the lumbar pedicles to the level of the stable vertebra. The curve must have a thoracic apex at or cephalad to the eleventh and twelfth thoracic disc level. Therefore, modifier A can be used only for a main thoracic curve (types 1 through 4) and cannot be used to define thoracolumbar/lumbar curves (types 5 and 6). It also should not be used when the center sacral vertical line falls directly against the medial aspect of the lumbar apical pedicle.

Modifier B: Modifier B is used when, because of deviation of the lumbar spine from the midline, the center sacral vertical line touches the apex of the lumbar curve, between the medial border of the lumbar concave pedicle and the concave lateral margin of the apical vertebral body or bodies (if the apex is a disc). These curves all have an apex in the main tho-

TABLE III Interobserver Reliability of Curve Classification by the Seven Independent Reviewers

	Kappa Coefficient
Curve type	
1	0.816
2	0.773
3	0.683
4	0.384
5	1.000
6	0.407
Mean	0.740
Lumbar modifier	
A	0.763
B	0.738
C	0.880
Mean	0.800
Sagittal thoracic modifier	
+	0.901
–	1.000
N	0.930
Mean	0.938

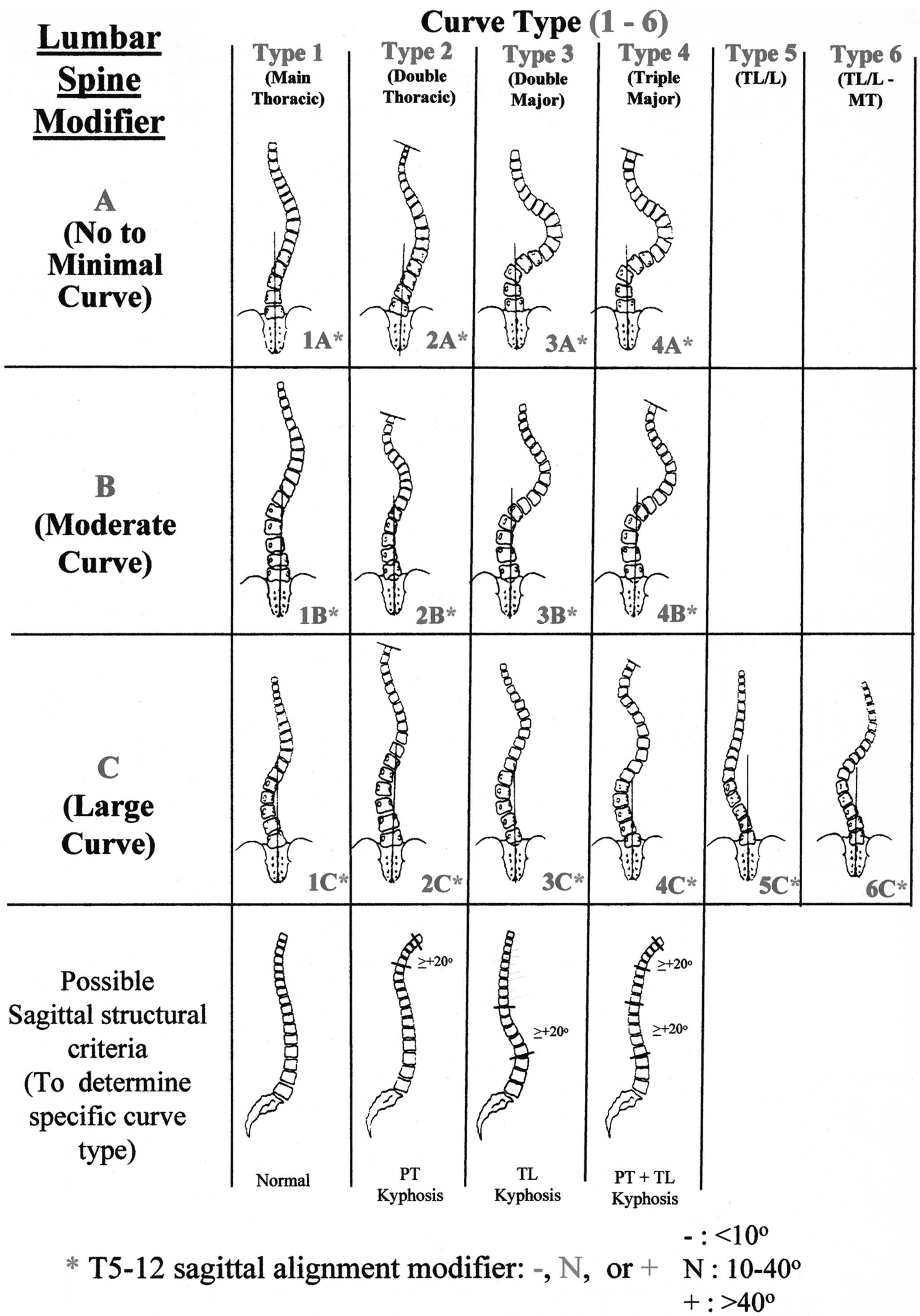


Fig. 3

Schematic drawings of the curve types and potential lumbar modifiers as well as possible sagittal structural criteria that determine specific curve types.

racic region, so thoracolumbar/lumbar curves are excluded. This modifier is also used when there is any doubt about whether the center sacral vertical line is, in fact, apposed to the lateral margin of the apical vertebral body or bodies.

Modifier C: Modifier C is used when the center sacral vertical line falls completely medial to the entire concave lateral aspect of the thoracolumbar or lumbar apical vertebral body or bodies (if the apex is a disc). These deformities of the

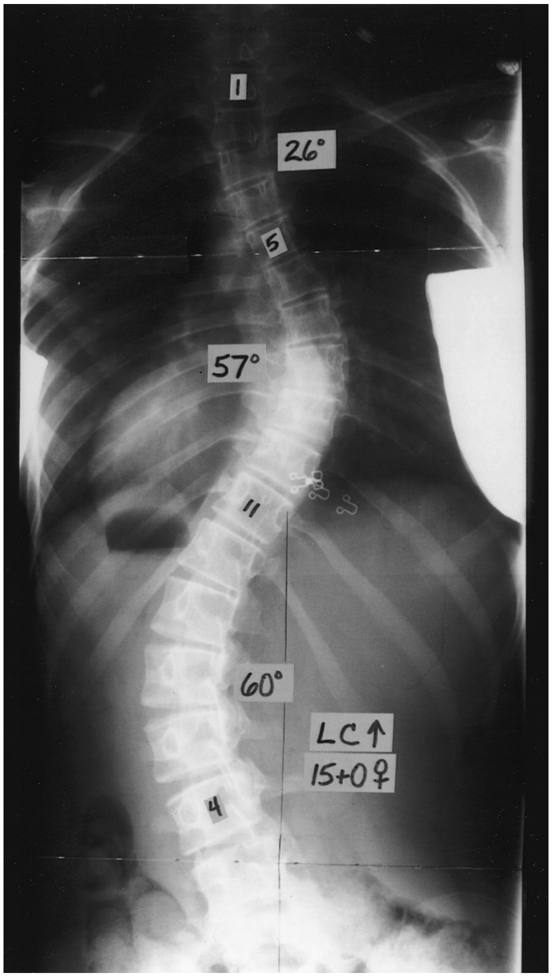


Fig. 4-A

Figs. 4-A through 4-F This series of radiographs shows a type-6CN curve in a fifteen-year-old girl who had adolescent idiopathic scoliosis. **Fig. 4-A** The anteroposterior radiograph shows a 26° proximal thoracic curve, a 57° main thoracic curve, and a 60° lumbar curve. The center sacral vertical line falls completely medial to the apex of the lumbar curve, which is equivalent to lumbar modifier C. The lumbar curve is the major curve.

lumbar spine may have a major curve with the apex at the thoracic, thoracolumbar, or lumbar level. When the center sacral vertical line does not fully lie off the lateral aspect of the apical thoracolumbar or lumbar vertebra or the apex is not clearly lateral to the center sacral vertical line, then modifier B should be used. Modifier C may include all major main thoracic curves (types 1 through 4) and must include all thoracolumbar/lumbar curves (types 5 and 6).

The three lumbar modifiers can be used to define the alignment of the lumbar spine in relation to the six curve types, and they can be used to assess the position of the lumbar spine after operative intervention[10].

Sagittal Thoracic Modifiers (–, N, or +)

The sagittal alignment of the thoracic spine is another critical factor when operative intervention is being considered for patients who have adolescent idiopathic scoliosis[4,11]. In an attempt to address this concern, we devised a sagittal thoracic modifier to further define the six curve types. The mean normal sagittal thoracic alignment from the fifth to the twelfth thoracic vertebra is +30° with a range of +10° to +40°[3]. Patients who have adolescent idiopathic scoliosis tend to have decreased thoracic kyphosis or even thoracic lordosis in comparison with normal controls[3,4]. The sagittal thoracic modifiers were determined by measurements from the superior end-plate of the fifth thoracic vertebra to the inferior end-plate of the twelfth thoracic vertebra on a standing lateral radiograph. A minus (–) sign (hypokyphosis) identified a curve of less than +10°, N (normal kyphosis) identified a curve of +10° to +40°, and a plus (+) sign (hyperkyphosis) identified a curve of more than +40°.

Classification of Curve Types

First the specific curve type (1 through 6) should be identified and then the lumbar spine modifier (A, B, or C) and sagittal

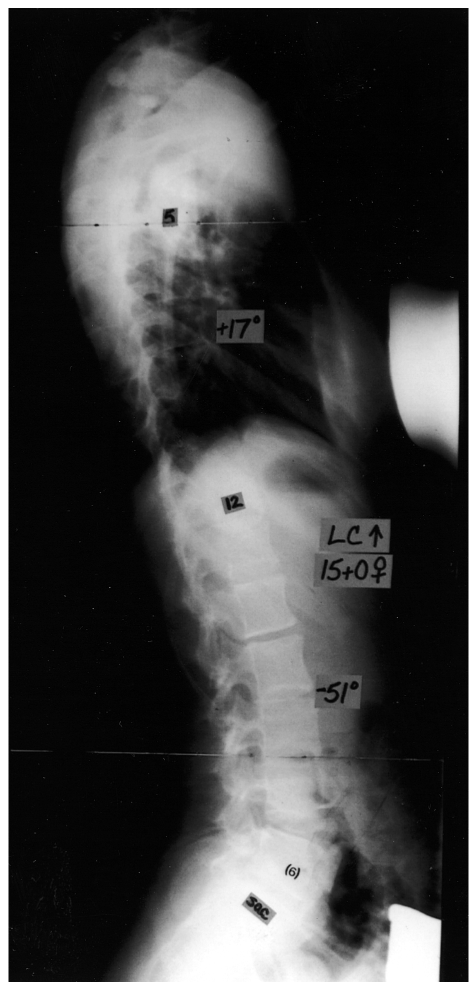


Fig. 4-B

The sagittal radiograph shows a curve of +17° from the fifth to the twelfth thoracic vertebra, which is equivalent to sagittal thoracic modifier N.

Fig. 4-C
The left side-bending radiograph shows the proximal thoracic curve to be nonstructural, with correction to 18°, and the thoracolumbar/lumbar major curve corrected to 25°.

thoracic modifier (–, N, or +) should be defined in order to determine the exact, complete classification of the curve (for example, 1A–, 1AN, 6CN, and so on) (Fig. 2).

Curve Reliability

Coronal and sagittal Cobb measurements and the center sacral vertical line were drawn on each radiograph. All of the radiographs were interpreted on one day and then reinterpreted a day later, in a different sequence. The two groups of reviewers were asked to choose the appropriate curve type (1 through 6), lumbar spine modifier (A, B, or C), and sagittal thoracic modifier (–, N, or +). Interobserver and intraobserver reliability were estimated by calculating the kappa coefficient values of simple and weighted components at 95% confidence intervals established with SAS software (SAS Institute, Cary, North Carolina). The kappa value was the balance of the part of agreement that would occur by random chance subtracted from the actual agreement. Thus, kappa coefficients ranged from +1 (perfect agreement), to 0 (chance agreement), to –1 (less agreement than expected by chance). Svanholm et al. suggested that kappa values of >0.75 represent good or excellent reliability; 0.5 to 0.75, fair reliability; and <0.5, poor reliability[12].

Finally, one of us (L.G.L.) retrospectively reviewed radiographs of 315 consecutive patients with operatively treated scoliosis to assess the prevalence of curve types in a typical surgical practice.

Results

Curve Classification

Among the five surgeons who had developed the new system, the mean interobserver reliability for determining the curve type was 93% (range, 85% to 100%), with a mean kappa value of 0.92 (range, 0.83 to 1.00), indicating good-to-excellent reliability (Table II). When the same five reviewers had applied the King classification, the mean interobserver reliability had been 64%, with a mean kappa value of 0.49, indicating poor reliability[9]. Using the new system, all five reviewers agreed about the curve type in twenty-two patients and four reviewers agreed about the curve type in the remaining five patients.

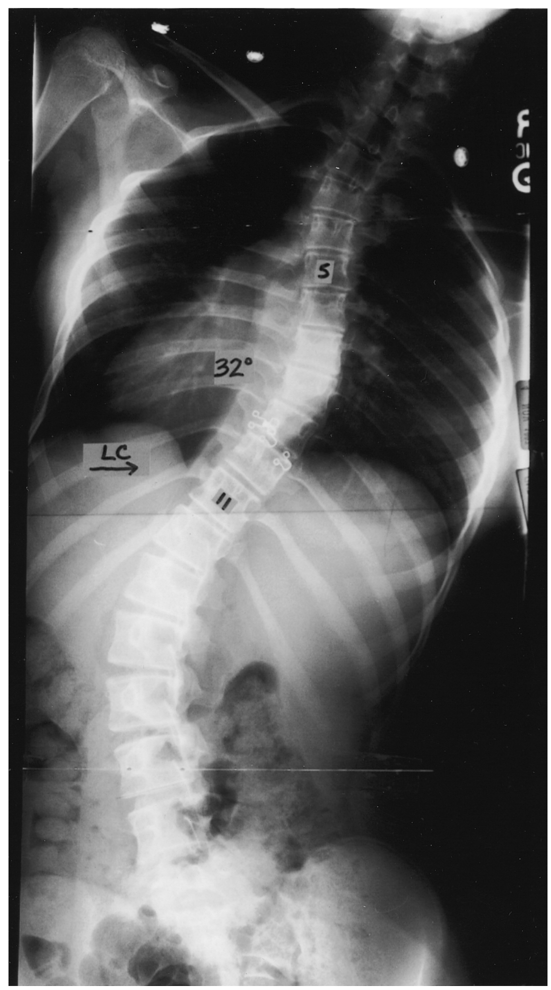


Fig. 4-D
The right side-bending radiograph shows correction of the main thoracic curve to 32°; thus, it is a structural minor curve.

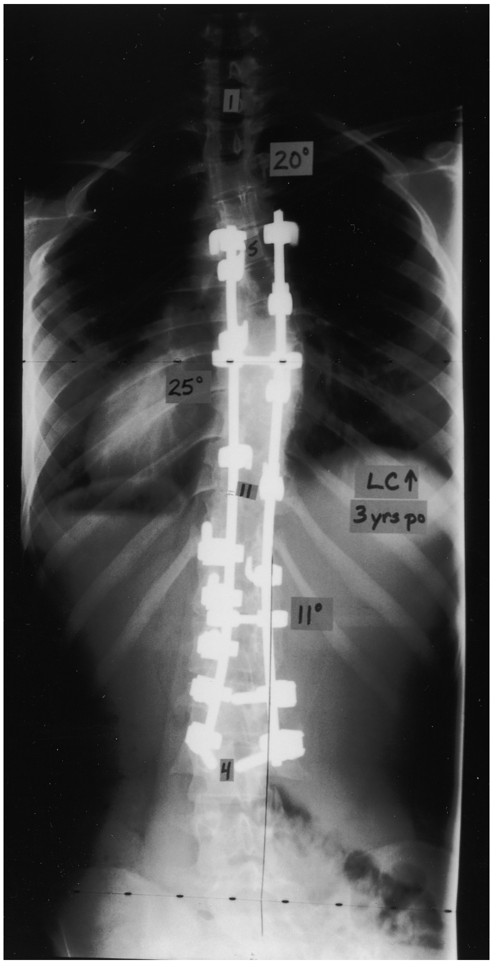


Fig. 4-E
This radiograph, made three years after a posterior spinal fusion from the fifth thoracic to the first lumbar level, shows the degree of coronal balance and correction obtained.

Using the King classification, all five had agreed about the curve type in only one of the twenty-seven patients. The intraobserver reliability of these surgeons with the new classification was 85% (range, 72% to 100%), with a mean kappa value of 0.83 (range, 0.79 to 1.0), indicating good-to-excellent reliability. The mean intraobserver reliability when these five surgeons had used the King classification had been 69%, with a mean kappa of 0.62, indicating fair reliability[9].

In the group of seven reviewers who had been randomly selected from the Scoliosis Research Society, the kappa values for interobserver reliability with the new classification were 0.740 (range, 0.384 to 1.000) for the curve type, 0.800 (0.738, 0.763, and 0.880) for the lumbar modifier, and 0.938 (0.901, 0.930, and 1.000) for the sagittal thoracic modifier (Table III). The respective values for intraobserver reliability were 0.893 (range, 0.75 to 1.00), 0.840 (range, 0.66 to 1.00), and 0.970 (range, 0.93 to 1.00) (Table IV). These values represent good-to-excellent reliability except for the interobserver reliability for curve type, which was 0.01 below the 0.75 level for good-to-excellent reliability.

Clinical Testing of the Classification System

In the consecutive series of 315 patients who had been treated operatively by one of us (L.G.L.), the structural regions were included in the arthrodesis, commensurate with the predictions derived from the classification system, in 284 patients (Table V). The main thoracic curve (type 1) was the most prevalent type of curve, being present in 126 (40%) of the 315 patients. The double thoracic curve (type 2) (fifty-six patients), the double major curve (type 3) (fifty-eight patients), and the thoracolumbar/lumbar curve (type 5) (fifty-six patients) were the next most common curves, with each being identified in 18% of the patients. The triple major curve (type 4) (eight patients) and the thoracolumbar/lumbar-main thoracic curve (type 6) (eleven patients) each had a prevalence of only 3%. The lumbar spine modifier A defined the curve in ninety-four (30%) of the patients; the modifier B, in sixty-seven (21%); and the modifier C, in 154 (49%). The sagittal thoracic modifier revealed hypokyphosis (−) in fifty-six (18%) of the patients, normal kyphosis (N) in 224 (71%), and hyperkyphosis (+) in thirty-five (11%).

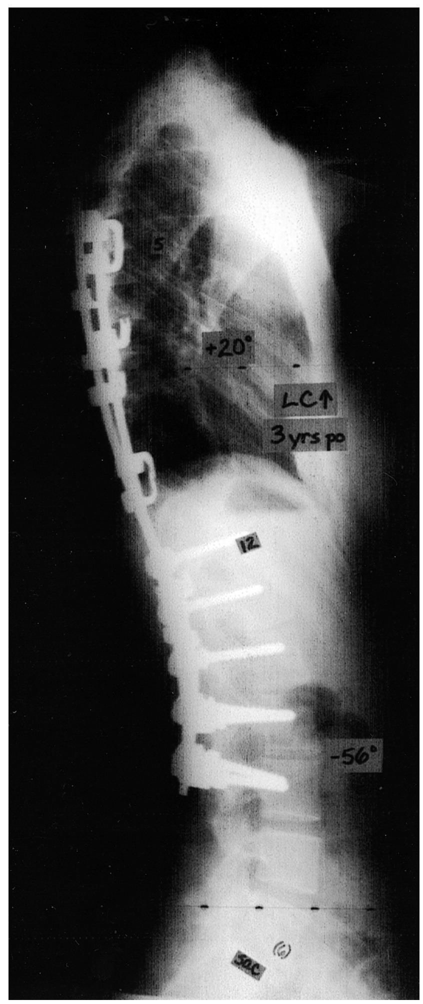


Fig. 4-F
This radiograph shows the postoperative sagittal alignment.

TABLE IV Intraobserver Reliability of Curve Classification by the Seven Independent Reviewers

	Kappa Coefficient		
Rater	Curve Type	Lumbar Modifier	Sagittal Thoracic Modifier
1	0.94	0.88	1.00
2	1.00	1.00	1.00
3	0.94	0.82	0.93
4	0.94	0.81	0.93
5	0.87	0.82	1.00
6	0.81	0.66	0.93
7	0.75	0.88	1.00
Mean	0.893	0.840	0.970

Discussion

The structural characteristics in the sagittal plane were critical factors in the development of this classification system, since sagittal alignment determines the regions of the spine to be included in an arthrodesis. Hyperkyphosis in the proximal thoracic and thoracolumbar/lumbar regions and lack of flexibility of the curve on side-bending are important components of the minor curves. The extent of arthrodesis and instrumentation of the main thoracic curve, the major curve in types 1 through 4, will be influenced by an increased kyphosis in the proximal thoracic and thoracolumbar/lumbar regions. In types 5 and 6, the thoracolumbar/lumbar curve is the major curve, and the main thoracic curve is nonstructural in type 5 and structural in type 6.

The center sacral vertical line, used to define the lumbar modifiers, does not account for any pelvic obliquity, unlike the center sacral line used in the King classification[2]. Lumbar modifier A indicates that there is minimal or no scoliosis, and modifier B indicates mild-to-moderate scoliosis. Curves assigned lumbar modifier B were difficult to classify with the King system; hence they were termed type II or III on the basis of the appearance of the lumbar curve on standing and side-bending radiographs[2,9]. We propose that, when curves are assigned lumbar modifier A or B, the lumbar spine should not be included in the arthrodesis unless there is a kyphosis of at least +20° in the thoracolumbar region. The curves that are assigned lumbar modifier C had been previously classified as King type I or II, or occasionally as type V, and also include all double major, triple major, and thoracolumbar and lumbar curves. In many cases, when a curve is assigned lumbar modifier C, the lumbar spine probably should be included in the arthrodesis. However, patients who have a 1C or 2C curve may have a selective thoracic arthrodesis as long as an acceptable balance of the lumbar curve is maintained[10].

The deviation of the lumbar curve from the center sacral vertical line increases from modifier A, to modifier B, to modifier C, with a corresponding increase in malalignment. The need for and method of correction of malalignment of the lumbar spine can be assessed more accurately with use of these lumbar spine modifers[10,13]. We believe that increased consistency in the assessment of various curve types will, in the future, permit comparative analysis of different treatments[9].

A sagittal thoracic modifier was developed because of the importance of assessing this area of the spine when determining the need for operative treatment[4,11], cosmesis, operative approach[6,14-16], type of instrumentation[5,8,17,18], and potential for decreased pulmonary function in patients who have loss of normal kyphosis or who have true thoracic lordosis[19]. Dickson suggested that lateral translation of the spine is preceded by apical thoracic lordosis[11]. A frequent criticism of the King classification is the lack of analysis of sagittal-plane alignment[9].

A selective thoracic arthrodesis of a type-1 curve with any lumbar modifier (A, B, or C), previously classified as King type II or III, has often led to coronal decompensation with segmental spinal instrumentation[6,15,18,20-22]. The thoracic and lumbar curves, considered to be false double major curves, both cross the midline; however, a selective thoracic arthrodesis with anterior or posterior instrumentation can often still be performed[10,14]. The lumbar curve should correct to <25° on side-bending, and thoracolumbar kyphosis should not be present[6,10,15,18,20-22]. In addition, the thoracic rotation should be more prominent than the lumbar rotation[23]. Of the 126 patients with a type-1 curve in our clinical series, 114 had only the main thoracic region included in the arthrodesis.

Type-2A curves (–, N, or +) include structural proximal thoracic and major main thoracic curves and a nonstructural thoracolumbar/lumbar curve[2,16,17]. Any structural thoracic or lumbar curve may also be associated with a structural proximal thoracic curve that has a residual curve of ≥25° on side-bending and/or increased kyphosis in the proximal thoracic region. The proximal structural curve in a type-2B thoracic curve has similar characteristics[9]. Unlike the King classification, the creation of a 2C group permits separation of the proximal thoracic and thoracolumbar/lumbar components. Of our fifty-six patients with a type-2 curve, fifty had both the proximal thoracic and the main thoracic components included in the arthrodesis.

Type-3A and 3B (–, N, or +) double major curves are rare and include structural main thoracic and thoracolumbar/lumbar curves. The residual lumbar component is of large magnitude and is structural in the coronal or sagittal plane even though the lumbar spine does not completely deviate from the midline. In a type-3C (–, N, or +) double major curve, the lumbar curve is structural and deviates completely from the midline. Thus, the main thoracic and thoracolumbar/lumbar components should be considered for the arthrodesis. In our clinical series, fifty-six of the fifty-eight patients with a type-3 curve had the main thoracic and thoracolumbar/lumbar components included in the arthrodesis.

All three regions (proximal thoracic, main thoracic, and thoracolumbar/lumbar) in type-4A and 4B (–, N, or +) triple major curves are structural, and the main thoracic or thoracolumbar/lumbar component is the major curve. The lumbar spine does not deviate completely from the midline, and when there is a large thoracic curve the residual lumbar component is sufficiently large to be inflexible on side-bending or to have a thoracolumbar kyphosis. The lumbar curve in type 4C deviates completely from the midline, as expected with a large structural thoracolumbar/lumbar curve. Of the eight patients with a type-4 curve, six had all three regions (proximal thoracic, main thoracic, and thoracolumbar/lumbar) included in the arthrodesis.

Thoracolumbar/lumbar major curves include type 5C, which has a nonstructural main thoracic component, and type 6C, which has a structural main thoracic component. When a patient has a type-5 curve, the arthrodesis should include only the thoracolumbar/lumbar region, whereas when a patient has a type-6 curve, the major thoracolumbar/lumbar and minor main thoracic structural curves both should be included in the arthrodesis (Figs. 4-A through 4-F). In our series, forty-nine of the fifty-six patients who had a type-5 curve had only the thoracolumbar/lumbar region included in the arthrodesis; nine of the eleven with a type-6 curve had the main thoracic and thoracolumbar/lumbar components included in the arthrodesis.

The interobserver reliability of the five reviewers who had designed the new system was 93% for the new system and 64% for the King classification; the intraobserver reliability was 85% for the new system and 69% for the King classification. These five reviewers found the new system to be more reliable than the King classification. The interobserver and intraobserver reliability of the new classification when used by the seven surgeons who had not been involved with its development was good-to-excellent[12] for all of the components except for interobserver reliability for curve type. Reports[1,9] have shown that the King classification is not reliable; therefore, because the criteria for each curve type are imprecise, the results of different treatment methods cannot be compared with use of that system.

Ideally, a classification system should reflect the current concept of a three-dimensional analysis of scoliotic deformities.

TABLE V Curve Classification in Retrospective Review of Three Hundred and Fifteen Surgically Treated Patients*

	Type 1 (Main Thoracic)	Type 2 (Double Thoracic)	Type 3 (Double Major)	Type 4 (Triple Major)	Type 5 (Thoracolumbar/Lumbar)	Type 6 (Thoracolumbar/Lumbar-Main Thoracic)
Modifiers						
A+	2	5	2	0	0	0
A–	14	7	0	0	0	0
AN	34	29	1	0	0	0
B+	4	3	2	1	0	0
B–	11	1	0	0	0	0
BN	35	8	2	0	0	0
C+	2	0	9	2	2	1
C–	4	2	4	2	8	3
CN	20	1	38	3	46	7
Total	126 (40%)	56 (18%)	58 (18%)	8 (3%)	56 (18%)	11 (3%)
Structural regions	Main thoracic	Proximal thoracic, main thoracic	Main thoracic, thoracolumbar/lumbar	Proximal thoracic, main thoracic, thoracolumbar/lumbar	Thoracolumbar/lumbar	Thoracolumbar/lumbar, main thoracic
Structural curves included in arthrodesis	114	50	56	6	49	9
Procedure	Posterior or anterior spinal arthrodesis	Posterior or anterior spinal arthrodesis	Posterior spinal arthrodesis	Posterior spinal arthrodesis	Anterior or posterior spinal arthrodesis	Posterior spinal arthrodesis

*The values indicate the number of patients.

An initial effort to include a grade for lumbar alignment in the axial plane as one of the structural criteria was found to be difficult to reproduce and thus was abandoned. This difficulty was related to problems with accurately assessing an axial plane deformity on biplanar radiographs. In the absence of a reliable, simple, and universally accepted method of three-dimensional modeling of scoliotic deformities, two-dimensional radiographs (coronal and sagittal) remain the standard. Though the new classification is based on two-dimensional radiographs, the inclusion of sagittal thoracic and coronal lumbar modifiers suggests that axial thoracic and lumbar modifiers can be included in the analysis when and if methods for three-dimensional analysis of scoliotic deformities become universally available.

One criticism of this classification concerns the definition of structural minor curves. There has been no universally accepted and reproducible definition of a structural minor curve. Previously published data, simplified to facilitate their use and to avoid variations, were employed to define the characteristics of structural minor curves[4,8,10,16,18]. The new classification permits minor modifications and inclusion of clinical findings to determine whether a curve is structural. Grading the curve as structural does not suggest that all structural minor curves, regardless of magnitude, are to be included in the arthrodesis. This is highlighted by the fact that, in the consecutive series of 315 operatively treated patients, thirty-one did not have structural regions included in the arthrodesis or had nonstructural regions included in the arthrodesis. Often the specific characteristics and ratios of structural curves, such as the degree of curvature, degree of apical vertebral translation and rotation, and degree of flexibility on side-bending, are more important than the absolute values. These criteria, assessed when an investigator is attempting to differentiate a true King type-II curve (new type 1C) from a double major curve (new type 3C)[15], need to be evaluated in relation to the new classification. The clinical examination of the patient is also a critical component in the surgical decision-making process and may override radiographic information for certain curve patterns[23].

A valid criticism of this classification is that forty-two different curve patterns can be derived. This complexity may deter the busy orthopaedic surgeon from using the classification in clinical practice. In defense of the new system, the six specific curve types should be well known to surgeons who treat scoliosis. The characteristics of the curve types should be clearly understood, and then the lumbar and sagittal thoracic modifiers can be added to the curve type, thereby providing additional information to assist in determining the appropriate treatment (Fig. 3).

At present, it is unknown whether this new classification is easy to use, universally acceptable, or useful in clinical practice. The classification will no doubt undergo changes as advances are made in imaging techniques. We hope that it will prove to be useful as a thorough two-dimensional radiographic evaluation predictive of spinal regions to be included in the arthrodesis and that it is a prelude to three-dimensional classification. ■

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