Predictors of Curve Flexibility in Adolescent Idiopathic Scoliosis: a Retrospective Study of 100 Patients

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Abstract- Curve flexibility in adolescent idiopathic scoliosis (AIS) was one of the major concerns of spinal surgeons since the evolution of surgical correction techniques. In this respect, many tried to identify which criteria denote more rigid curve. In the present study, we aimed toward determining important factors influencing AIS curve flexibility on supine bending films. We assessed radiographs of 100 patients with AIS for direction of curves, number of involved vertebrae, apical vertebral translation and rotation, magnitude of main thoracic curve and T5-T12 kyphosis. Statistical analysis performed via stepwise linear regression model with these variables plus age and sex against flexibility index. According to regression analysis, there was a clear relationship between flexibility indexes (FI) and magnitude of main thoracic curve at all ($P<0.001$). When we consider flexible curves (FI>50%) against rigid curves, apical vertebral rotation was a major determinant of curve flexibility also ($P<0.001$). Adolescent idiopathic scoliosis curves with larger Cobb's angle and apical vertebral rotation show less flexibility on supine bending films.

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Introduction

Idiopathic scoliosis, a common entity has been the focus of attention since ancient times (1-2); there are many controversies to be elucidated. Since the past, one of major concerns for spine surgeons was determination of which curves could be considered flexible (3-9). These flexible curves have more opportunity to achieve full or near-full correction. But, with the advent of newer generations of spinal stabilization systems, this matter is of less importance but does not be pushed into a corner.

Radiographic analysis of scoliosis patients performs for multitude of reasons. Curve flexibility is one of the main determinants which surgeons take it into consideration for decision-making on which end-levels they could stop on (10,11).

Despite availability of many imaging modalities to reveal the extent of flexibility of curves, none of them is completely flawless (6-9). Due to these reasons, many spine surgeons believe that no imaging modality could predict how much correction will be achieved during surgery (12). It is clear that more rigid curves need more intensive operations and may need inter-operative skeletal traction to achieve maximal correction, but in the presence of newer instruments, this is a matter of debate (13). We conduct this study in a retrospective fashion to establish which radiographic parameter could reliably predict curve flexibility.

Materials and Methods

We reviewed preoperative and postoperative radiographs of 100 patients (27 male, 73 female) with adolescent idiopathic scoliosis treated surgically by senior spinal surgeon of this article. Routine preoperative radiographs were standing anteroposteriorly and lateral views as well as supine bending views. Postoperative views were obtained standing AP and lateral projections. All patients underwent posterior segmented instrumented fusion some with and some without anterior release and fusion. Mean age of patients was 15.8 ± 2.3 years (from 12 to 24). Evaluated radiologic parameters are listed on

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table1. Only single major curves included in this study. All parameters were analyzed by the same person. We assessed the magnitude of curves by Cobb's method. Apical vertebral translation (AVT) defined as the distance from the center of apical vertebral body to center-sacral line (CSL) and expressed in centimeters. Apical vertebral rotation (AVR) evaluated by Perdriolle technique. Curve location defined according to the position of their apical vertebrae. We defined flexibility as a flexibility index (FI) of more than 50%. FI calculated through following equation:

(Cobb angle-bending Cobb angle)/Cobb angle

Subsequently, relationship of each parameter was analyzed with curve flexibility using stepwise linear regression model. Statistical analysis performed by SPSS-12 software.

Table 1. Radiologic parameters

VARIABLE	MEAN	MAX	MIN	MODE	MEDIAN	SD
PT[1] curve	25.7	۵۳	۱۰	۳۰	۲۲	10.6
MT[2] curve	65.2	۱۳۲	۱۰	۵۰	۶۵	22.7
TL/L[3] curve	39.5	۸۰	۱۳	۳۰	۴۰	13.7
AVR[4]	30.1	۵۲	۱۵	۳۱	۲۹/۵	8.5
AVT[5]	7.5	۵۹	۲	۶	۶	5.8
Displacement from CSL[6]	1.9	۵/۵	۰	۲	۲	1.4
FI[7]	43.8	۱۰۰	۱۱	۲۵	۴۲/۵	17.6
Kyphosis T5-T12	35.5	۸۰	۰	۳۰	۳۰	19.5
Postoperative PT curve	10.0	۵۰	۰	۰	۷/۵	11.4
Postoperative MT curve	25.4	۹۰	۰	۰	۲۲	18.8
Postoperative TL/L curve	14.1	۵۰	۰	۰	۱۳	12.3
Postoperative kyphosis T5-T12	30.0	۶۵	۵	۳۰	۳۰	11.2

1. proximal thoracic 2. main thoracic 3. thoracolumbar/lumbar
4. apical vertebral rotation 5. apical vertebral translation 6. Center sacral line 7. flexibility index

Results

One hundred radiographs of adolescent idiopathic scoliosis patients were evaluated. Median age of patients at the time of surgery was 15.8 ± 2.3 (range: 12-24 years). Of these patients, 73 of them were female and remaining (27patients) were male. Ninety percent of curves (90 cases) faced toward right. With respect to radiologic parameters, the mean magnitude of main thoracic curves was 65.2 ± 22.7 degrees. Mean value for apical vertebral rotation (AVR) and apical vertebral translation (AVT) were 30.1 ± 8.5 and 7.5 ± 5.8 degrees, respectively. Coronal decompensation which defined as displacement from center-sacral line (CSL) was 1.9 cm on average (SD=1.4 cm). Average number of involved vertebrae was 7.9 ± 1.6 (ranged from 5 to 14). Mean flexibility index (FI) was 43.8% (SD=17.6). All patients underwent posterior instrumented spinal fusion using multi-segmented hook and rod systems.

We entered some variables including age, sex, direction of main thoracic curve, coronal decompensation, AVR, AVT, magnitude of main thoracic curve, number of involved vertebrae and preoperative T5-T12 kyphosis in stepwise generalized linear regression analysis. Of these variables, no significant correlation was found between flexibility index and these variables except magnitude of main thoracic curve and (P<0.001). These results are summarized in table 2.

Table 2. Significance of main thoracic curve in flexibility

	B	SE of B	Standardized β	t	*P*-value	95% CI for B
Main thoracic curve	-0.441	0.069	-0.556	-6.417	>0.001	(-0.578) - (-0.305)
Constant	72.123	4.743	--	15.205	>0.001	62.703 – 81.544

In the next step, we divide patients into two groups; patients with FI equal or more than 50% and patients with less than 50% flexibility and reassess above mentioned variables respect to this cut-off point and then compare these two groups. As shown on table 3, there is an inverse relationship between flexible curves (which is defined as FI more than 50%) and AVR (adjusted R2=0.201).

Also, in Pearson relation coefficient analysis, we found a strong linear relationship between magnitudes of preoperative proximal thoracic, main thoracic, thoracolumbar/lumbar curves and their postoperative values (P<0.001). These relationships are shown in the table 4.

Table 3. Relationship of AVR* with flexibility

	B	SE of B	Standardized β	t	*P*-value	95% CI for B
Apical vertebral rotation	0.025	0.005	0.458	4.935	>0.001	0.015-0.035
Constant	0.904	0.161	--	5.599	>0.001	0.583-1.224

*AVR: apical vertebral rotation

Table 4. Pearson relation coefficients for preoperative and postoperative values

	P-value	r
Proximal thoracic curve	<0.001	0.761
Main thoracic curve	<0.001	0.735
Thoracolumbar / lumbar curve	<0.001	0.596

Discussion

Since evolution of surgical techniques for correction of idiopathic scoliosis, flexibility of scoliotic curves was a major concern of spinal surgeons (3-9). Several studies were conducted to determine the threshold of structurality, determinants of curve flexibility, fusion levels and corrective strategy (3-19). Despite introduction of many ways to demonstrate maximal curve flexibility, supine bending radiographs are still the mainstay of preoperative planning (9,12,16,17). In this study, when considering all variables relative to flexibility index, we found a strong correlation between the magnitude of main thoracic curve and flexibility of them (adjusted R2=0.302, *P*<0.001). When we analyzed flexible curve against rigid ones with the same parameters, the most statistically significant factor was AVR (*P*<0.001). FI was inversely proportional to AVR (adjusted R2=0.201).

Age is a known factor affecting curve flexibility in a relatively linear fashion. In the present study, age did not achieve significance, although we should remember that ages of our patients, at their extremes, were just slightly more than one decade different. Thus jumping into conclusion for age influence according to these results may be unwise.

In the literature, gender is discussed under the topic of curve progression determinants and less as a factor influencing curve flexibility. In this analysis, gender did not meet statistical significance respect to FI.

Translatory shift of the entire spine is more dependent on the presence of curves at extremes of the spine (i.e. cervicothoracic and lumbosacral regions), where there is no room for compensation. Therefore, a large AVT may be representative of a large curve below MT curve. So, inclusion of this parameter may lead to bias in our opinion. Therefore, we consider AVT rather than the total coronal decompensation. Although in this respect, AVT did not achieve significance.

Adolescent idiopathic scoliotic curves are usually facing toward right. Leftward curves, especially if painful, raise the possibility of the presence of an intra-spinal pathology, but in our review, we did not encounter any evidence about relationship of direction and flexibility of curves. To disclose this relationship, we performed statistical analysis and did not find any correlation between the direction of MT curves and their flexibility.

Curves with larger Cobb's angle are expected to have more AVR and AVT. Despite gaining significance by MT curves, but AVR and AVT were not major determinants of FI in supine bending films.

In this study, there was no relationship between sagittal alignment (T5-T12 kyphosis) and FI. Analysis of the relationship between sagittal alignment and flexibility of scoliotic curves in the coronal plane is complicated. In lower Cobb angles, the difference between apparent sagittal alignments (as seen on routine lateral films) and true sagittal alignment (as seen on stagnant view) is negligible. But in larger ones, this difference gain significance. So, correlating such sagittal profile with flexibility in the coronal plane is somewhat difficult.

In summary, the major determinant of curve flexibility in adolescent idiopathic scoliosis is magnitude of main thoracic curve at all, but when comparing flexible curves versus rigid ones AVR becomes more impressive in an inverse fashion.

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