

Junctional kyphosis after the treatment of adolescent idiopathic scoliosis

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Abstract

Introduction: In this retrospective study radiographic review was undertaken in patients treated for AIS (Adolescent Idiopathic Scoliosis), in order to determine the most important preoperative factors that are seen with postoperative junctional kyphosis.

Material &Methods: Sagittal spine profiles were measured on the standing radiographs before surgery, after surgery and in the last follow-up postoperative visit of the patients with AIS. The following parameters were measured on lateral views: lumbar lordosis, thoracic kyphosis, the sagittal offset distance of C7 to a vertical line from postero-superior edge of S1 (Sagittal Vertical Axis-SVA) and T9 sagittal offset angle.

Results: One hundred and twenty patients with a mean 42 months of follow-up (24-112 months) were included in the study. Mean values of the parameters before corrective surgery were: lumbar lordosis $45^{\circ} \pm 13.6^{\circ}$, thoracic kyphosis $28^{\circ} \pm 18.4^{\circ}$, SVA 35 ± 27.2 mm and T9 offset angle, $7.8^{\circ} \pm 5.1^{\circ}$. Mean values at last follow-up were: lumbar lordosis $49 \pm 9.8^{\circ}$, thoracic kyphosis $35 \pm 16.4^{\circ}$, SVA 39 ± 24 mm and T9 offset angle, $8.6^{\circ} \pm 5.8^{\circ}$. There were 10 upper junctional kyphosis (8.4%). T test statistics revealed significant correction of lumbar lordosis and thoracic kyphosis after fusion in all patients ($P < 0.001$, $P = 0.006$ respectively). Preoperative mean of T9 sagittal offset angle was higher in the patients with proximal junctional kyphosis ($P = 0.006$).

Conclusion: Normal sagittal balance of spine is essential for the optimum function of the intervertebral disks and preventing sagittal postoperative complication like proximal junctional kyphosis. More attention to preoperative sagittal parameters of the spine like T9 offset may be important to prevent such complications.

Keywords

- junctional kyphosis
- Adolescent idiopathic scoliosis
- fusion

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Introduction

A mal aligned spine after fusion may produce abnormal forces over mobile segments under or over the fusion area. Correct arrangement of the fused vertebrae is also very important to reduce muscle work during posture maintenance.

Although correction of the coronal plane used to be emphasized in the past, it is now known that the wellbeing of the spine is more related to the status of the sagittal plane. For example Lazennec et al¹ after radiological assessment of body posture before and after lumbosacral fusion, showed that a mal positioned spine and pelvis will be the predictor of the postoperative long-term post fusion pain.

A potential problem after spinal fusion is proximal or distal junctional kyphosis related to the preoperative factors like a larger sagittal thoracic Cobb's angle, associated thoracoplasty and hybrid instrumentation.

We analyzed the radiologic sagittal profile of our patient's scoliotic curve before and after fusion, to evaluate their longitudinal changes and to predict which patients were at risk for developing proximal junctional kyphosis.

Materials and methods

In this retrospective study patients with adolescent idiopathic scoliosis who had undergone posterior spinal fusion (PSF) at a single institution by one spine surgeon between 2005 and 2013 were reviewed. All patients had good-quality radiographs taken from the thoracic spine and were followed for at least 2-years. Data collection was carried out retrospectively by an independent spine neurosurgeon who was not involved in the surgery. Patients underwent PSF and anterior release was carried out by thoracoscopy or thoracoplasty. Hybrid instrumentation was used, which consisted of a proximal hook and distal pedicle screw or proximal Universal Clamp (ZIMMER SPINE) and distal pedicle screw, in all patients.

For all patients, complete radiographic follow-up consisting of: preoperative, one month postoperative, and the last follow-up postoperative visit, PA and lateral standing long-cassette radiographs were taken. The Spine View software (Surgiview, Paris, France) was used by a single observer to assess the sagittal alignment of the spine and pelvis. The software had already been evaluated in the previous studies^{2,3}.

All patients were classified according to the classification of AIS by the Lenke et al⁴ system. Radiographic computerized parameters, four spine sagittal parameters, were obtained:

1- Thoracic kyphosis (TK) is measured between point at the upper endplate of the T4 vertebra and the lower endplate of the T12 vertebra and assessed by the Cobb method.

2- Lumbar lordosis (LL) is measured between the upper endplate of L1 and the upper endplate of S1 and

assessed by the Cobb method.

3- Sagittal Offset angle of T9 (T9SA) is measured between a connecting line from the hip axis to the center of T9 and a vertical line from the hip axis.

4- Sagittal Offset of C7 or Sagittal Vertical Axis (SVA) is measured between the center of C7 and a vertical line from the postero-superior edge of S1.

Glattes et al⁵ defined the Proximal Junctional Angle (PJA) as the angle between the caudal endplate of the UIV to the cephalad endplate of two neighboring vertebrae which are superior to the UIV. Two disc spaces proximal to the UIV usually demonstrate the proximal junctional change. Abnormal Proximal Junctional Kyphosis (PJK) was defined by 2 criteria: (1) proximal junction sagittal Cobb angle more than 10° and (2) proximal junction sagittal Cobb angle as a minimum 10° more than the preoperative measurement. The presence of both criteria was necessary to be considered abnormal.

The data were analyzed using the SPSS (version 22, Chicago, IL). *P* values are based on the Student's *t* test for continuous variables. *P* values for categorical variables were generated using Chi-Square test. A *P* value of <0.05 was considered significant.

Results

This study included 120 consecutive AIS patients with a mean follow-up of 42 months (24-112 months). There were 86 (72%) female and 34 (28%) male patients. The average age at the time of surgery was 15.5 years (range: 11.2–23.4 years). The average number of fused vertebrae was 11.9 (range: 5–16). According to the classification of AIS by the Lenke et al⁴ system, the number of patients were: 54 for type 1 (main thoracic, 45%), 35 for type 2 (double thoracic, 29%), 11 for type 3 (double major, 9%), 4 for type 4 (triple major, 3.5%), 12 for type 5 (thoracolumbar/lumbar major, 10%), and 4 for type 6 (major thoracolumbar/lumbar and minor thoracic structural, 3.5%). Forty-eight patients had a lumbar A modifier, 30 had a lumbar B modifier, and 42 had a lumbar C modifier. A total of 80 patients had a normal thoracic kyphosis sagittal modifier, twelve patients had a thoracic hyperkyphosis sagittal modifier (T5–T12>40°). In twenty-eight patients had a thoracic hypokyphosis sagittal modifier was found (T5–T12 less than 10°). Hybrid instrumentation was used which consisted of proximal hook and distal pedicle screw in 74 and proximal Universal Clamp (ZIMMER SPINE) and distal pedicle screw in 46 patients. An anterior thoracoscopic release was performed in 36 patients and thoracoplasty was done in 62 patients.

The pre- and postoperative frontal and sagittal Cobb's angles, correction percentages and loss of correction values are given in Table 1. Our correction rate was 49.6%, and this was found to be statistically significant (*t* = 6.71, *P* value < 0.05). Before operation, for all patients, the TK was 28°±18.4°, the LL was 45°±13.6°, the T9SA was 7.8°±5.1° and the SVA was 35±27.2 mm. Mean values at last

T test statistics revealed significant correction of lumbar lordosis and thoracic kyphosis after fusion in all patients (P value<0.001 and P value=0.006 respectively).

as having abnormal proximal kyphosis above the instrumentation; among them there were 3 proximal dislodgment of fixation material (2 hook fixation and one Universal Clamp system fixation).

Table 1: Descriptive Statistics of pelvic parameters and sagittal spine profile before and after intervention, one normal series and comparison of preoperative and last follow-up mean values

	Preoperative Mean±(values)	Postoperative Mean±(Values)	Last visit Mean±(Values)	Normal values ^{1*}	P value **	P value ***
Thoracic Kyphosis	27.95(18.47)	28.00(11.52)	34.92(16.47)	41.3(9.2)	<0.001	0.102
Lumbar lordosis	45.12(13.64)	44.89(10.92)	48.90(9.83)	61(12.7)	<0.001	0.001
C7SO	35.61(27.11)	30.54(24.53)	39.05(24.22)			
T9SA	7.81(5.15)	5.31(3.44)	8.63(5.82)	10.3(3.1)	0.001	0.099

* In young adults, Student's t test from comparison of last visit mean values with preoperative mean value** and postoperative mean value***

1 Levassor N, Rillardon L, Deburge A, Guigui P. Pelvic and spinal parameters of sagittal spinal balance. JBJS 2005;87-B,Supp 2:95.

follow-up were: TK: $35^{\circ} \pm 16.4^{\circ}$, LL: $49^{\circ} \pm 9.8^{\circ}$, T9SA $8.6^{\circ} \pm 5.8^{\circ}$ and SVA 39 ± 24 mm(table 1).

There were no significant difference of PJK and dislodgement of fixation between various types

of fixation materials. In Group 1(normal proximal kyphosis), all but 48 spines, were fused to T4 or distally, but in Group 2 (abnormal proximal kyphosis), all spines were fused to T4 Table 2.

Table 2: Upper fixation levels in both groups

	Group 1 n(%)	Group2 n(%)
T1	8(7.5%)	0
T2	24(22.6%)	0
T3	16(15.1%)	0
T4 or lower	62(49.1%)	10(100%)

One hundred and ten patients (91.6%) had normal proximal kyphosis, whereas 10 (8.4%) were defined

The patient characteristics were analyzed for each group Table 3.

Table 3: Characterization of both groups

	Group1	Group2	
	Mean \pm (SD)	Mean \pm (SD)	P value*
Age	15.34(2.157)	11.80(0.44)	0.097
Cobb angle of main curve	56.13(20.10)	61.88(13.16)	0.541
Correction of main curve	60(17%)	51(7%)	0.046
Thoracic kyphosis	26.67(18.09)	41.20(19.04)	0.093
Lumbar lordosis	44.94(14.14)	47.00(7.21)	0.751
T9SA	7.47(5.28)	11.20(1.30)	0.001
C7SO	35.12(27.59)	32.60(24.30)	0.785
Fusion levels	11.92(2.08)	11.92(0.44)	0.895
Pain**	22.3(3.23)	23.4(2.43)	0.874
Activity level**	94.23(4.54)	93.45(5.34)	0.786

*Student's t test statistics, ** Last follow-up visit

Some patient variables such as the correction of the main curve (P value=0.046) and sagittal offset angle of T9 (P value=0.001) had significant correlation with an increased amount of the proximal junctional kyphosis. There was no significant correlation between the degree of the proximal thoracic curve in our patients preoperatively or their preexisting kyphosis at the proximal junction, type of the hybrid construct (proximal hooks or Universal Clamp), sagittal thoracic Cobb's angle or Lenke sagittal thoracic modifiers and thoracoplasty. Binary regression analysis showed that a higher T9SA could predict post-operative PJK (P value=0.043).

Discussion

An upright balanced posture of body is determined by spinal alignment and the pelvic state.⁶ The spine and pelvis interact with each other to minimize energy expenditure.⁷ Several studies with long-term follow-up have shown that the spine does not tolerate sagittal plane imbalance. For example, segmentally flat lumbar fusions and distraction forces affecting the lumbar spine may cause fixed sagittal imbalance syndromes.^{8,9} Also, ending a fusion just proximal to the apex of a kyphosis can lead to the development of junctional problems.

Mac-Thiong et al.² and Charlebois et al.¹⁰ explained that thoracic kyphosis depended mostly on the spinal deformity, whereas lumbar lordosis was associated with the pelvic anatomy, and the scoliotic curve type

was not associated with a specific pattern of sagittal pelvic morphology and balance.

The most important postoperative sagittal complication that had been noted in many studies is the proximal junctional kyphosis. This sagittal complication could be related to the preoperative sagittal spine profile or pelvis parameters.¹¹ Lee et al.¹² noted the proximal kyphosis in 46% of patients at 2-year follow-up after review of 69 patients treated with instrumented posterior spinal fusion. A preoperative kyphosis one level proximal to the proposed upper instrumented vertebra of greater than 5° was used to predict postoperative proximal kyphosis according to this study. This study demonstrated that the effect of PJK on clinical symptoms and patient outcomes was unknown. Rhee et al.¹³ demonstrated an increase in the proximal junctional measurement of 10° or more than 10° in 35% of patients treated with posterior instrumented fusion. This study demonstrated that PJK was more commonly associated with posterior instrumentation compared with anterior instrumentation. They stated that none of their patients needed revision at 2-year postoperation for PJK. In our study we found 10 patients (8.4%) with PJK which was defined as having more than 10° of kyphosis above the instrumentation level, among them, 3 had proximal dislodgment of fixation material.

More recently Kim et al.¹⁴ after 7.3 years follow-up of 193 patients, showed that the incidence of PJK was 26% (50 of 193 patients). They demonstrated that patients with preoperative thoracic hyperkyphosis

had a significantly higher incidence of PJK compared with normokyphotic and hypokyphotic patients. This result suggested that a substantial correction of the thoracic kyphosis may lead to a PJK. They found that thoracoplasty was associated with PJK. They did not explain the etiology of this association¹⁴. A significant correlation between the thoracoplasty and PJK was not found in the present study.

In conclusion, Normal sagittal balance of spine is

essential for the optimum function of the intervertebral disks and preventing sagittal postoperative complications such as proximal junctional kyphosis. More attention to preoperative sagittal parameters of the spine like T9 offset should be paid in order to prevent such complications. And the fusion level in PSF is the most important factor causing proximal junctional kyphosis.

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