Preservation of Thoracic Kyphosis is Critical to Maintain Lumbar Lordosis in The Surgical Treatment of Adolescent Idiopathic Scoliosis

Mohammad Khakinahad[1], Ebrahim Ameri[2], Hassan Ghandhari[2], and Hossein Tari[2]

[1] *Department of Spine Surgery, Shafa Yahyaiian Hospital, Tehran University of Medical Sciences, Tehran, Iran*

[2] *Department of Orthopaedic Spine Surgery, Shafa Yahyaiian Hospital, Tehran University of Medical Sciences, Tehran, Iran*

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Abstract- Restoration of the sagittal alignment is one of the fundamental goals in scoliosis correction surgery. Having an increase in popularity of segmental spinal instrumentation, thoracic kyphosis (TK) is often sacrificed to achieve frontal and axial plane correction. Patients with a Lenke type 1 deformity underwent selective thoracic fusion (lowest instrumented vertebra of T12 or L1) using corrective segmental spinal instrumentation (Hook-Rod) and were followed up for 2 years. They were evaluated before and after operation for coronal and sagittal alignments using standing anteroposterior and lateral radiographs. There were 63 patients (21 male, 42 female) with a mean age of 15.8±2.1 years included to this study. TK reduction had significant correlation ($P \leq 0.001$) with lumbar lordosis (LL) decrease at preoperative (r=0.47), immediately postoperative (r=0.37) and at 2-year follow-up (r=0.5). The decrease in LL after 2-years was less than decrease in TK (4.5±8.5 *vs* 6±10, respectively).

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Introduction

The main goal of the the surgical treatment of Adolescent idiopathic Scoliosis (AIS) is to maximize deformity correction, achieve coronal and sagittal balance and retain spinal flexibility and the mobility of the lumbar spine (1,2). During the last years, Harrington instrumentation applied distraction and or compression forces for the correction and fixation of the curve, which resulted in the improvement of coronal deformity at the expense of the sagittal profile (3-5). Long term follow-up of these patients has then showed flat back syndrome including back pain and inability to stand erect (6).

Then with a goal of three-dimensional correction, several new instrumentation systems including segmental hook-rod system, segmental pedicle screw fixation and the derotation maneuver have been developed (7-10). Patients with a primary thoracic scoliosis are typically more hypokyphotic relative to non-scoliosis patients and Depending on instrumentation and correction techniques used, postoperative thoracic kyphosis (TK) has been shown to increase or decrease (11-15). Some studies have shown that procedures reducing TK also reduce LL (16-18). The purpose of this study was to evaluate the sagittal profile of surgically treated Lenke 1 patients and determine the variables that affect postoperative LL.

Materials and Methods

Clinical charts and radiographs of patients with AIS who were 11 to 19 years of age at the time of surgery and had Lenke type 1 deformity corrected by a selective thoracic fusion (lowest instrumented vertebra of T12 or L1) and had a minimum 2-year follow-up were retrospectively reviewed.Standing antero-posterior and lateral radiographs, (long-cassette; 36″) had to be available at Pre-operative, at discharge and 2-year later. All radiographs were evaluated manually by an independent observer not involved in the operative procedure. Thoracic and lumbar curves were measured using the Cobb methods, also TK and LL were measured on all radiographs .

All patients underwent posterior spinal fusion and instrumentation, using third generation (dual hook-rod systems) multi-hook constructs, performed by one senior orthopaedic spine surgeon. In addition to derotation with a precontoured rod, correction of the scoliotic deformity

Corresponding Author: Mohammad Khakinahad
Department of Spine Surgery, Shafa Yahyaiian Hospital, Tehran University of Medical Sciences, Tehran, Iran
Tel: +98 21 22007745, 912 3862631, Fax: +98 21 22007745, E-mail: khakinahad_m@yahoo.com

was achieved by a combination of distraction on the concave side and compression on the convex side. In situ bending or gradual translation maneuver was not used. If the preoperative reducibility on supine bending films was less than 50% or the curve was more than 70, anterior spinal release and fusion with morselized auto rib graft including the most rigid apical segments was performed.

In this study, TK was defined as the angle between superior endplate of T5 to the inferior endplate of T12, whereas LL was the angle between inferior endplate of T12 and the superior end plate of the S1.

Statistical analyses

Pearson correlation analyses were used to identify linear relations between the continuous variables (Pearson's r for normally distributed and Spearman´s r in skewed variables). The changes of spine angles analyzed by ANOVA and Cochran´s Q test used to analyze repeated assessment of qualitative data.P value less than 0.05 were considered statistically significant. The data were analyzed using SPSS software (V 17, Chicago, IL).

Results

A total of 63 patients registered in the AIS data base were evaluated. The mean age was 15.8±2.07 years. Anterior spinal release and fusion without instrumentation was performed in 32 (50.7%) patients. The proximal thoracic (PT) curve was corrected significantly (49% correction) from average of 20.8° (0-44°) before surgery to 10.9°(0-33°) at 2 years, the thoracolumbar/lumbar curve improved from 30.46° (0-58°) before surgery to 12.4° (0 to 40°,62.8% correction) after 2 years .The mean MT curve was 62.7° (40-100°) before surgery, 27.7° (10 to 62°, 55.8 % correction) immediately after surgery and 30.2° (0 to 67°, 51.8% correction) after 2 years of surgery (Table 1). Posterior surgery reduced TK 5.8°±10° immediately and 6°±10°after 2-years post-operation and LL decreased 3.9°±9° from pre-operation to early post-operative and 4.5°±8.5° after 2-years post-operation (Figure 1).

TK was less than 20° in 6 (9.5%) patients Pre-operatively, in 9 (14.3%) patients' immediately after operation and in 11 (17.5%) patients 2 years later. There was no patient with TK below 10° and LL below 30° preoperatively but LL was 28° in one case after surgery. Decrease in post-operative TK had significant correlation with LL reduction ($P \leq 0.001$) at pre-operative (r=0.47), immediately post-operative (r=0.37), and 2-year follow-up (r=0.5) (Figures 2-4). There was no differences in the sagittal alignment of patients when anterior spinal release was done prior to posterior spinal fusion and instrumentation. Lowest instrumented vertebra (LIV) was T12 in 4 and L1 in 59 patients and changes of TK and LL at post-operation was similar in both groups.

Table 1. Radiographic measurements (mean degrees, percent correction in parentheses**).**

Time Measurement	Preop	Early Postop	2-yr Postop
Main thoracic	62.7±17	27.7±15*(55.8)	30.2±15*(51.8)
Proximal thoracic	20.8±8	9.4±10*(54.8)	10.9±11*(47.5)
TL/lumbar cobb	30.4±12	11.3±11*(62)	12.4±11*(58.6)
Thoracic kyphosis	34.6±13	28.8±10*	28.6±10*
Lumbar lordosis	47.1±9	43.2±9*	42.6±8.5*

*P<0.001, TL (thoracolumbar)

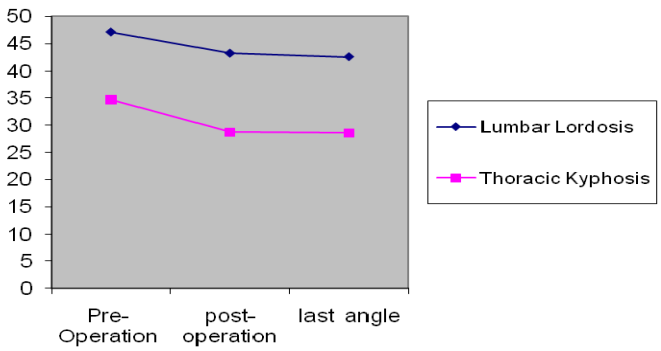

Figure 1. Changes in TK and LL at pre-operation, early post-operation and at 2-year (last angle).

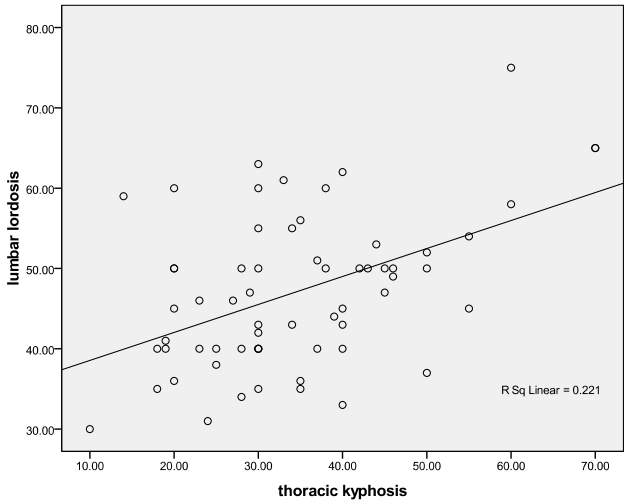

Figure 2. Correlation between the changes in TK and LL at pre-operation.

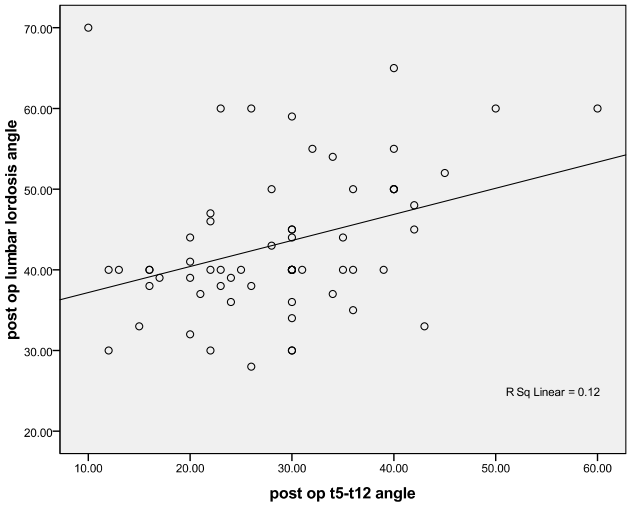

Figure 3. Correlation between the changes in TK and LL at post-operation.

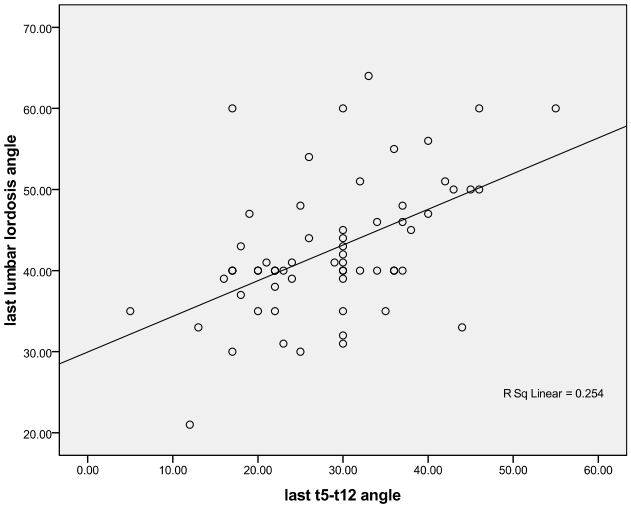

Figure 4. Correlation between the changes in TK and LL at 2 year post-operation.

Discussion

The treatment of AIS has been revolutionized after introducing the Harrington rod system. With third-generation implants, the concept of segmental fixation with multiple fixation points was introduced to better deal with the shortcomings of the Harrington rod systems, specifically suboptimal fixation, loss of correction, hook dislodgement and the induction of lumbar kyphosis increased (16-18). Segmental bone purchase on the posterior spinal elements and better three-dimensional control of the spine have improved coronal spinal correction from 18% into the range of 40% to 67% while preserving more normal sagittal alignment (16-21).

Symptoms associated with an iatrogenic loss of LL resulting in a positive sagittal balance include an inability to stand erect and disabling back pain. Recommendation to prevent an iatrogenic loss of LL include avoidance of distraction instrumentation in the lumbar spine , contouring the rod with LL , and intra-operative positioning that enhances physiologic lordosis (4,5). The previous studies reported that patients with a primary thoracic scoliosis are typically hypokyphotic than to nonscoliosis patients (6,16,18,22) but we found that in most of these patients TK was in the normal range with few were hypokyphotic (TK less than 20°) and only in one patient was 10°.

Newton PO et al, suggest that preservation of TK is critical in preventing iatrogenic loss of LL. They also found a correlation between the decrease in postoperative TK in Lenke type 1 curves with LL decrease, they demonstrated a 5.6° loss of LL associated with a 2° loss of TK in the posterior curves (16) but we detected 4.5°loss of LL associated with a 6° loss of TK after 2 years, so the LL reduction was less.

Keith DK *et al.* have reported that with the current spinal instrumentation systems, postoperative TK is mainly decided by rod precontouring and there was no difference in the sagittal plane deformity correction with the use of hook-rod or pedicle – screw rod constructs. They suggest that even if similar rod precontouring is performed, postoperative sagittal alignment in different curves is grossly affected by the inherent rigidity of the spine. They concluded that the tendency of coupled thoracic sagittal realignment on correction of frontal plane deformity is towards ″self-normalization″of kyphosis: a pre-operative hyperkyphosis tends to decrease, and a hypokyphosis tends to increase (18). Regarding normal range of all parameters of TK and LL and intra-observer variability, we concluded that after curves correction using all technical conditions, the final results are out of physician controls.

Pedicle screws have been suggested to provide better coronal and sagittal correction than hybrid or hook instruments but it cause more TK loss (12,13,15,22,23). In the present study hook-rod system was used and led in TK reduction.

In other studies there was a slight increase in TK and LL with time but we detected slight decrease in these measures after 2 years. Considering lordosis loss during aging it is acceptable to use techniques minimizing this reduction.It is unclear that this loss in LL after a decrease in TK will have an adverse effect in the patients long-term outcome. In conclusion, posterior selective thoracic fusion and instrumentation decreased thoracic kyphosis and also affects the sagittal alignment of the nonfused lumbar spine with the decrease in lumbar lordosis . more decrease in TK were immediately post-operation and then after changes were less.

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