

Research Article

Proximal Segmental Kyphosis and Proximal Junctional Kyphosis after Growing Polysegmental Instrumentation in Early Onset Scoliosis Patients

Mezentsev Andriy, Petrenko Dmytro, Savenkov Volodymyr*

Department of Pediatric Orthopedic Surgery, Sytenko Institute of Spine and Joint Pathology National Academy of Medical Science of Ukraine, Kharkiv, Ukraine

***Corresponding author:** Savenkov Volodymyr, Department of Pediatric Orthopedic Surgery, Sytenko Institute of Spine and Joint Pathology National Academy of Medical Science of Ukraine, Kharkiv, Ukraine, Tel: +38(057)704-13-62; E-mail: redaczia_otp@mail.ru

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Abstract

Management of spinal deformity presented in growing children in the age of 5 years or less known as Early Onset Scoliosis (EOS) is a challenging problem in spinal surgery during many years. Due to the structural nature of the curvature such patients do not respond well to nonoperative methods and fusionless surgical interventions become a method of treatment choice [1]. Historically, growth-sparing procedures became reliable in 1962, when P. Harrington described concavity placed rod anchored to the spine with laminar hooks [2], but hook dislodgment and rod breakage obliged implant modification presented by Moe et al. [3]. They modified hardware configuration to reduce scar formation and allow sagittal contouring. Unfortunately, surgeons met the similar complications. Next generations of growth-friendly implants were aimed at improving spine fixation, deformity correction and spinal growth preservation. Despite advances in surgical techniques and instrumentation, modern era implants presented during the last decade have variable outcomes.

According to the growth sparing techniques classifications implants are divided into following groups: distraction instrumentation (growing rods, VEPTR etc.), growth guiding systems (Luque trolley-like, Shilla) and compression devices (staples, tethers) [4]. One of the most devastating complications of all fusionless surgical procedures, especially distraction-based, is the proximal junction kyphosis [5]. Contemporary scientific literature presents clinical studies describing this complication after dual-rod and VEPTR utilization in growing children [6]. Since 1999 we have been using growing polysegmental system allowing spinal deformity correction and growth preservation without revision surgeries and lengthenings [7]. The purpose of this study is to define if polysegmental growing instrumentation and derotation for the spinal correction result in proximal segmental kyphosis and proximal junctional kyphosis.

Keywords:

Early onset scoliosis; Proximal junctional failure; Growing instrumentation; Proximal junctional kyphosis; Osteosynthesis; Orthopedic physiatric; Regeneration

Methods

A comparative retrospective study in patients who had surgical correction of early onset scoliosis was performed in a single institution. The study was approved by Sytenko

Institute of Spine and Joint Pathology Review Board and by Ethical Committee. Twenty-six skeletal immature consecutive patients who underwent anterior convex growth arrest with posterior growing spinal instrumentation are included in this study. Inclusion criteria were: patients with early onset scoliosis, Risser 0, open triradiate cartilage. In all patients spinal derotation has been performed. The first group (13 pts) underwent hybrid instrumentation (thoracic spine hooks and lumbar spine screws) and the second group (13pts) treated with screws only.

All patients in groups had complete radiographic data, including preoperative standing anteroposterior, lateral and bending radiographs. All radiographs during follow-up were available. Preoperative, postoperative and follow-up films have been analyzed. Computer tomography scans were used for more precise measurements. Thoracic kyphosis (T5-T12 angle), postoperative proximal segmental kyphosis and proximal junctional kyphosis were studied preoperatively, postoperatively and after 4 years. Proximal junctional kyphosis has been defined as sagittal Cobb angle between the upper end instrumented vertebra and one vertebra cephalad measuring over 10° [8]. Proximal segmental kyphosis is defined between segment of the spine at the upper end of growing construct and spinal segment proximal to the construct [6]. Spinal growth was measured by length determination of the rod's upper segment after surgical treatment and during follow-up. The operative data that were assessed and compared for each group included number of the instrumented vertebrae and upper level of the spinal instrumentation. All assessed parameters in both groups were analyzed and compared to each other. Statistical comparison of data was performed using two means and standard deviations. Level of statistical significance was set at $p < 0.05$.

Indications for surgery

Surgery was recommended for the skeletal immature patients with progressive scoliosis with a Cobb angle over 40°, Risser 0 and open triradiate cartilage. In all patients anterior convex growth arrest and posterior growing spinal instrumentation were performed.

Selection of the fusion levels

Fusion levels were defined using anterior, lateral and supine bending films. In sagittal plane all pathologic curves were included into instrumentation zone. In the transverse plane, the upper instrumented vertebra was defined as a rotational neutral vertebra on standing anteroposterior film. Lower instrumented vertebra was defined using central sacral line on supine bending film.

Surgical technique

Anterior convex growth arrest was performed via open thoracotomy approach. Incision was made over the rib corresponding to the end vertebra of the curve. After

subperiosteal rib resection parietal pleura was incised and reflected of the spine one level above and below the involved area. Segmental vessels were ligated and divided. After apical disc identification partial discectomy and convex epiphyseodesis were performed. Intervertebral bone grafting with autorib pieces was performed. Chest tube was placed and thoracic cage was closed. Depending on patient's condition posterior spinal instrumentation was performed the same day or after 3-5 days breaks.

Posterior approach was performed through midline incision and main curve and secondary curves were subperiosteally exposed. Spinal anchoring was performed using conventional surgical technique. Pedicular hooks with additional internal screw for the secure fixation (1st group) or pedicular screws (2nd group) were put into the thoracic spine. Lumbar spine instrumented with pedicular screws. Rods were inserted into bone anchors and seated; deformity correction was performed by 90° concave rod derotation. Two medial screws and crosslinks were locked if predicted growth was more than 4 cm and other anchors were loose allowing the rods to slide during the patient's growth. Bottom screw tightening was used if anticipated growth was less than 4 cm. The brace was recommended full time after surgery and thereafter only when the patient was out of bed.

After growth end (closed triradiate cartilage, Risser 4, menarche) posterior spinal fusion was performed. The surgery included instrumented spine exploration, posterior fusion with autograft obtained from rib resected after convex thoracoplasty and construct transformation into rigid fixation by nut tightening.

Results

The first group (hybrid fixation) included thirteen patients with the mean age of 9,1 years at the moment of index surgery. Eleven (81%) patients had main thoracic, one had double curve (9,5%) and one had thoracolumbar deformity (9,5%). Results of radiographic measurements are shown in **Table 1**.

Preoperative mean thoracic kyphosis angle was $10.8^{\circ} \pm 5.33$. Mean number of the instrumented vertebrae in the first group was 12. In seven patients (53%) T4 was the upper instrumented vertebra, in four patients (30.7%) T5, T3 and T6 were the upper instrumented vertebrae in other two patients (29,3%). Mean growth of the instrumented spine during follow-up was 7.1 mm per year. Postoperative spinal kyphosis was $26.2^{\circ} \pm 10.83$ on the average, mean proximal segmental kyphosis was $8.9^{\circ} \pm 4.7$, proximal junctional kyphosis angle was $5.6^{\circ} \pm 3.32$.

After 4 years thoracic kyphosis was $29.8^{\circ} \pm 11.96$, mean proximal segmental kyphosis and proximal junctional kyphosis angles were $11.4^{\circ} \pm 8.9$ and $7.6^{\circ} \pm 3.01$. Two patients with upper hooks pull-out had cephalad instrumentation extension during final fusion (**Figure 1**) and in 4 patients hook displacement without loosening was observed (**Figure 2**). Final fusion was performed in all the patients out of this group.

	1 Group			2 Group		
	Preop	Postop	After 4 years	Preop	Postop	After 4 years
Thoracic Kyphosis	10.8°±5.33	26.2°±10.83	29.8°±11.96	40.6°±18.4	30.8°±6.9	37.7°±10.1
Proximal segmental kyphosis	-	8.9°±4.7	11.4°±8.9	-	12.8°±6.57	9.5°±5.32
Proximal junctional kyphosis	-	5.6°±3.32	7.6°±3.01	-	18.7°±4.1	10.7°±5.7

Table 1: Results of radiographic measurements data for the two groups.

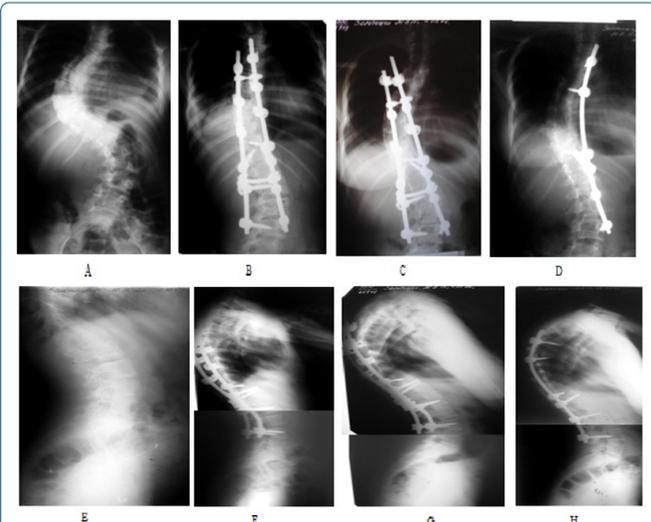


Figure 1: (A,E) A 9-year-old female with an 91° with juvenile idiopathic scoliosis and thoracic kyphosis 52°, Risser 1. (B, F) Patient underwent anterior convex growth arrest and posterior spinal instrumentation with growing hybrid system. Upper instrumented vertebra is T4. (C,G) After 4 years she had hook pull-out radiographs show hook pull-out, proximal segmental kyphosis was 27°, proximal junctional kyphosis was 18°. (D,H). Final fusion with instrumentation extension performed, concave rod was removed because of subcutaneous prominence.

The second group of patients (screw fixation) included thirteen female patients with the mean age of 8.2 years. Curve patterns distribution was the same as in the first group: eleven main thoracic, one double deformity and one thoracolumbar deformity. Before the index mean thoracic kyphosis was 40.6°±18.4 (**Figure 1**). Number of the levels fixed was 11.9. Six patients (46%) were instrumented with the upper instrumented vertebra T4, four patients (30%) had upper instrumentation level at T5. Upper instrumented levels at T2, T3 and T7 were instrumented in three more patients. Mean growth of the instrumented spine was 7.2 mm per year. Postoperative kyphosis in the second group was 30.8°±6.9 on the average. Proximal segmental kyphosis after the surgery was 12.8°±6.57 and proximal junctional kyphosis was 9.5°±5.32. Four years after deformity correction mean thoracic kyphosis was 37.7°±10.1, proximal segmental kyphosis was 18.7°±4.1 and proximal junctional kyphosis was 10.7°±5.7. In 4 patients out of the screw group proximal junctional kyphosis greater than 10° was observed. In one patient with thoracolumbar curve and proximal junctional kyphosis extended fusion two levels above were performed (**Figure 3**). In other three patients junctional hyperkyphosis didn't impact final outcome. Six patients of the 2nd group were finally fused.

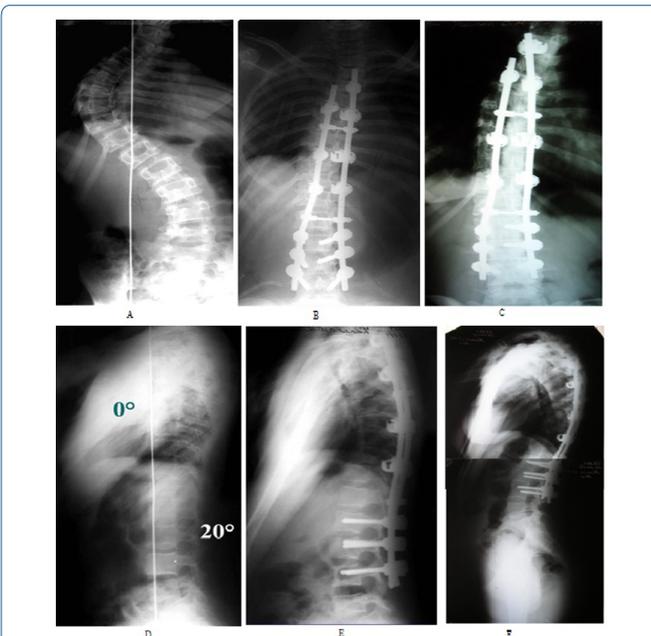


Figure 2: (A) Female patient with juvenile idiopathic scoliosis 90° diagnosed in the age of 4 years. (B) hybrid growing spinal instrumentation was performed, upper instrumented vertebra was T4. (D) spinal derogation increased thoracic kyphosis to 35° postoperatively. (E,F) 4 years post she complained of upper thoracic pain. On radiographs rotational hook displacement without loosening was diagnosed.

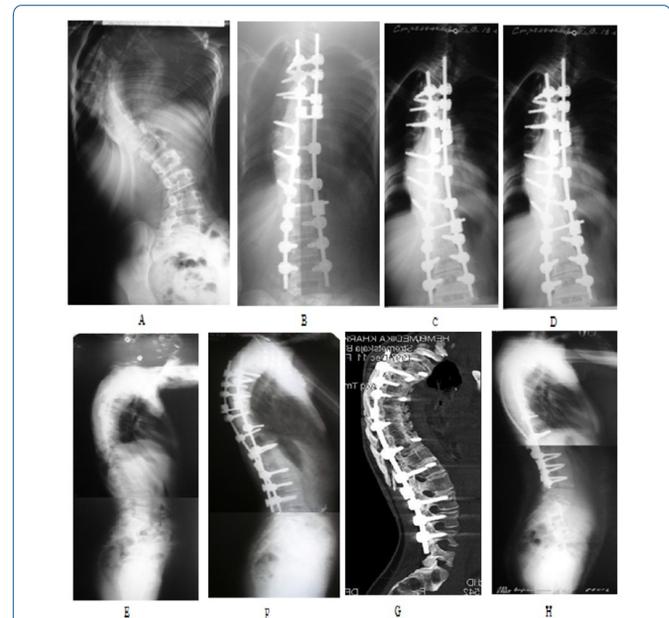


Figure 3: (A,E) Radiographs of the patient with thoracic juvenile idiopathic scoliosis 100 who underwent con-convex growth arrest and growing transpedicular instrumentation T4-L4 (B,F). (C,G) After 4 years proximal junctional kyphosis was 20.6°, proximal segmental kyphosis was 28°. Patient developed transitional kyphotic deformity and anchor subcutaneous prominence. (D,H) Prominent acres were removed, final fusion and instrumentation extension to T2 vertebra performed.

Discussion

Proximal junctional kyphosis is a recently recognized situation after posterior spinal instrumentation in idiopathic scoliosis. Kim Y.J. analyzed the long-term proximal junctional change in adolescent idiopathic scoliosis 5 years after surgery. The study included 193 consecutive adolescent idiopathic scoliosis patients after posterior instrumented fusion. The incidence of proximal junctional kyphosis was 26% (50 patients) after 7.3 years postoperatively. Thoracoplasty, hybrid instrumentation and a preoperative larger sagittal thoracic Cobb angle were found as the risk factors for developing of proximal junctional kyphosis [9].

In another study Wang J et al. found proximal junctional kyphosis in 35 out of 123 patients with an overall incidence of 28%. Authors of the paper concluded that inducing factors are: intraoperative decrease in thoracic kyphosis greater than 10°, thoracoplasty, the use of a pedicle screw at the top vertebra, autogenous bone graft and fusion below L2 [10].

Helgeson M.D. compared the incidence and risk factors for proximal junctional kyphosis in adolescent idiopathic scoliosis following posterior spinal fusion using different fixation strategies (hook, pedicle screw, or hybrid anchoring). Preoperative and postoperative radiographs of 283 patients were reviewed retrospectively. The incidence of proximal junctional kyphosis was 0% in hook group, 2.3% in hybrid group, 8.1% in screw group and 5.6% in screws with hooks only at the top level group. It was suggested that hook fixation at the upper-instrumented vertebrae could decrease the likelihood of junctional problems development [11].

Distraction methods such as Harrington instrumentation, dual growing rod technique [12] and VEPTR are recognized as the most effective procedures for the early onset spinal deformities [13]. Lengthening from 6 to 12 months promotes continued growth of the spine and delay of a formal spinal fusion closer to skeletal maturity. Restoration of the sagittal spinal balance is an important issue in young children who require growing instrumentation [14]. Proximal junctional kyphosis is the potential complication of these surgeries reported in the literature. Higher risks of proximal junctional kyphosis were found for older hyperkyphotic children and in patients with positive postoperative sagittal balance [15].

D. Skaggs presented a retrospective review of 32 cases with growing rods for early onset scoliosis. Average age at the initial surgery was 4 years and follow-up was 24-88 months. Eighteen patients (56%) out of this group had proximal junctional kyphosis and 8 patients out of them had upper anchor failure with required revision in 7 patients. Among 4 patients with proximal junctional kyphosis who underwent spinal fusion, 3 patients had fusion and instrumentation two levels cephalad to implant. Junctional kyphosis was more common in children with dual rods (62%) than with single rod

(38%) and in spine-to-spine constructs (59%) compared to upper hooks on ribs constructs [5].

Theoretically, utilization of VEPTR should minimize the risk of proximal junctional kyphosis since the upper anchor attached to the rib. Li Y. in his study assessed proximal spinal kyphosis in 68 patients who had VEPTR surgery. Five patients (7%) were found to have proximal segmental kyphosis. Before the intervention to progressive proximal segmental kyphosis average angle was 66°, mean increase in proximal segmental kyphosis was 25°. In all of the patients proximal segmental kyphosis developed within the first years after initial surgery. Authors concluded that risk factor for development of such complication in VEPTR patients is preexisting thoracic kyphosis, and the deformity can progress to severe and require revision surgery [6].

Reinker K. et al. retrospectively reviewed 14 patients who had VEPTR surgery of early-onset kyphoscoliosis. In spite of scoliotic deformity stabilization kyphosis increased by 22° at the last follow-up. Proximal cradle pull-out was periodically observed. Distal anchors placed too proximally had inadequate lever arms to control kyphosis. It was claimed in this study that attachment of the upper attachment point to the second rib bilaterally and distal extension of hybrid constructs to the pelvis would avoid kyphosis progression [16].

Polysegmental growing spinal instrumentation with apical attachment is another option for the early onset scoliosis treatment. Debnath U. and associates report long term results of growing Luque-trolley construct in growing children. The study cohort consisted of 37 patients: 7 patients had Luque-trolley instrumentation alone and 30 patients had convex fusion and posterior Luque-trolley instrumentation. Complications regarding development of junctional kyphosis were evaluated. Junctional kyphosis was observed in 8 cases: proximal-3 patients, distal-2 patients, apical-3 patients which was corrected at the time of definitive spinal fusion. Authors of this study concluded that patients with high concave rib-spinal angle and upper end vertebra tilt at initial presentation should be closely monitored for deterioration and junctional kyphosis. Spinal growth that exceeds the capacity of Luque-trolley to elongate leads to apical junctional kyphosis which needs regular surveillance [17].

In our study comparative analysis of hybrid versus screw growing polysegmental instrumentation was performed to evaluate the rate of proximal junctional kyphosis in skeletal immature children. There were similar curve etiology in both groups with a difference in the age of 9.1 years in the 1st group and 8,2 years in the 2nd group. We found an important difference in thoracic kyphosis parameters: 10.8° (1st group) versus 40.6° (2nd group). Polysegmental anchor placement and rod derotation maneuver result in normal sagittal contour restoration in all the patients, and postoperative values of thoracic kyphosis were normal. We observed increasing of thoracic kyphosis, proximal junctional kyphosis and

proximal segmental kyphosis in both groups, but in hybrid patients mean values of these parameters were less than in screw group. We found proximal junctional kyphosis over 10° only in 1 patient in the 1st group and in 4 patients in the 2nd group. Two patients with hook fixation at the thoracic spine had pull-out and 4 patients had hooks displacement after 4 years follow-up. Thereby thoracic hook fixation provides better control of the sagittal spinal shape as patient is growing but screw fixation avoids displacement of the anchor at the upper instrumented level. In our opinion, the best ways to avoid development of proximal junctional kyphosis in children after growing spinal instrumentation is utilization of screw fixation up to T2 and rod derotation for the deformity correction. As far as during spinal growth sagittal shape of the spine remains irreversible after the surgery, sagittal alignment should be restored according to the normative data for the adulthood (**Figure 4**).

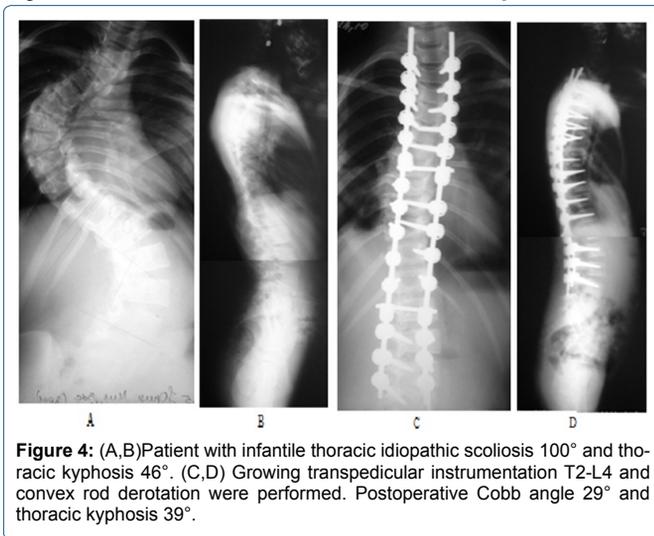


Figure 4: (A,B) Patient with infantile thoracic idiopathic scoliosis 100° and thoracic kyphosis 46°. (C,D) Growing transpedicular instrumentation T2-L4 and convex rod derotation were performed. Postoperative Cobb angle 29° and thoracic kyphosis 39°.

Conclusion

In spite of preexisting hypo- or hyperkyphosis, utilization of the growing polysegmental construct and performing spinal derotation restore normal sagittal profile in growing EOS patients.

Growth sparing surgery utilizing hook fixation in the thoracic spine decreases likelihood of proximal segmental kyphosis and proximal junctional kyphosis in skeletal immature EOS patients, but increases the rate of upper anchor displacement.

Summary

The purpose of this study is to define if polysegmental growing instrumentation and derotation for the spinal correction result in proximal segmental kyphosis and proximal junctional kyphosis. Twenty-six consecutive patients divided into two groups, who had undergone anterior convex growth arrest with posterior growing spinal instrumentation, are included in this study. We found proximal junctional kyphosis over 10° only in 1 patient in the 1st group and in 4 patients in the

2nd group. In spite of preexisting hypo- or hyperkyphosis, utilization of the growing polysegmental construct that we propose and performing spinal derotation restore normal sagittal profile in growing patients. Growth sparing surgery utilizing hook fixation of the thoracic spine decreases likelihood of proximal segmental kyphosis and proximal junctional kyphosis in skeletal immature EOS patients, but increases the rate of upper anchor displacement. Twenty-six consecutive patients who had undergone anterior convex growth arrest with posterior growing spinal instrumentation are included in this study. Growth sparing surgery utilizing hook fixation of the thoracic spine decreases likelihood of proximal segmental kyphosis and proximal junctional kyphosis in skeletal immature EOS patients, but increases the rate of upper anchor displacement.

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