In Patients with Early-Onset Scoliosis, Can Growing Rods Be Removed Without Further Instrumentation? An Evidenced-Based Review

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Abstract Early-onset scoliosis (EOS) is defined by the presence of spinal deformity in children 10 years of age or younger. Left untreated, patients with EOS are at high risk for thoracic insufficiency and early demise. This article provides a critical review of a recent prospective cohort study of children with EOS: “Graduation Protocol After Growing-Rod Treatment: Removal of Implants without New Instrumentation Is Not a Realistic Approach,” by Kocyigit and colleagues (*J Bone Joint Surg Am.* 2017;99(18):1554–1564). Treatment for EOS requires deformity correction while accommodating the growing spine. Dual growing rod implantation is a well-described technique that consists of the placement of two telescoping rods anchored to vertebrae proximal and distal to the apex of the curve. Multiple lengthening procedures are then performed as the child grows. Management of the endpoint of growing rod treatment remains controversial, with high complication rates associated with final fusion. As an alternative to final fusion or implant retention, Kocyigit and colleagues examined the removal of growing rods without spinal fusion and found that this procedure resulted in substantial worsening of the deformity in nine out of ten patients. This treatment group was terminated on ethical grounds. We believe this important result demonstrates that the removal of implants without fusion is an unacceptable treatment strategy that leads to poor outcomes.

Keywords growing rods · early-onset scoliosis · infantile idiopathic scoliosis · congenital scoliosis · juvenile idiopathic scoliosis

Introduction

Early-onset scoliosis (EOS) is a challenging condition in which spinal deformity appears in children prior to age 10 [18]. Without treatment, curve progression can lead to thoracic insufficiency, cardiopulmonary compromise, and early demise [9]. Alveolar growth occurs until age 8, after which time pulmonary function continues to increase as thoracic volume expands [7]. At ages 5 and 10, thoracic volume is approximately 30% and 50%, respectively, of the normal adult volume [10]. Thus, early spinal fusion prior to pulmonary maturity is associated with significant morbidity due to respiratory complications [13]. Today, multiple strategies are available to correct the deformity while accommodating the growing spine.

Non-operative treatment of EOS includes casting and bracing. Modern surgical techniques may be based on guided growth, vertebral compression, or distraction-based implants [3, 6, 19]. These techniques may be used alone or in combination. Casting has been successful in treating patients under age 2 and may result in cure for young, non-syndromic patients [15, 17]. The Shilla technique aims to guide the growth of the vertebrae along the implant without the need for multiple operations for lengthening [14]. Vertebral body tethering is a recent technique under investigation that restricts growth on the convexity of the curve and allows for growth at the concavity, similar in principle to a hemiepiphysiodesis [19]. Distraction-based implants include traditional growing rods, magnetic growing rods, and vertical expandable prosthetic titanium ribs (VEPTR). Of these surgical techniques, traditional growing rods are perhaps the best studied [1].

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Dual growing rod treatment typically consists of the placement of two telescoping rods that are anchored two vertebral levels proximal and distal to the curve. Thus, only the anchoring vertebrae are fused, allowing the in-between vertebrae to increase in height as the child grows. Interval lengthening during treatment may be required to exchange for longer rods and is typically performed at approximately 6–9-month intervals. Complications are common, with two studies reporting complication rates of 48% and 58% [2, 4]. Following growing rod treatment, final fusion is often performed at skeletal maturity. This final fusion is associated with a high complication rate for several reasons. Autofusion of segments spanned by the growing rod may occur in suboptimal position, necessitating corrective osteotomies during the final fusion. Multiple surgeries during growing rod treatment also lead to extensive scarring. Poe-Kochert et al. retrospectively analyzed reoperations for patients treated with growing rods with minimum 2-year follow-up after final fusion and found that 20 out of 100 patients had 30 complications and required 57 operations [16]. Retention of growing rods is another potential endpoint for growing rod treatment. Jain et al. compared retention of implants with final fusion and noted no significant difference in final curve magnitude between the two groups [11].

Given the numerous challenges of management at the conclusion of growing rod treatment, authors of a recent study examine the option of removing the growing rods without subsequent fusion.

The Article

Graduation Protocol After Growing-Rod Treatment: Removal of Implants Without New Instrumentation Is Not a Realistic Approach

Kocyigit IA, Olgun ZD, Demirkiran HG, Ayvaz M, Yazici M. *J Bone Joint Surg Am.* 2017;99(18):1554–1564.

This article describes a single-center prospective cohort study of 26 children who underwent growing rod treatment when they were 10 years old or younger [12]. The authors used an institutional database to identify 86 patients with traditional growing rods. Eligible patients were identified at age 14 and had complete medical records including radiographs, regular uncomplicated lengthening procedures, no complications (severity grade IIA, IIB, III, or IV), and minimum 2-year follow-up. Age 14 was selected because a majority of children at that age are mature enough for spinal fusion. Twenty-six patients met the inclusion criteria.

In group 1, skeletally mature patients with adequate correction and no interval changes requiring additional surgery underwent removal of their growing rods without instrumented fusion. In group 2, skeletally mature patients with inadequate correction or interval changes necessitating extension of fusion underwent removal of their growing rods and final spinal fusion. In group 3, skeletally immature patients continued growing rod treatment with regular lengthening procedures. Patients were followed every 6 months with standing radiographs. The authors defined

failure of treatment as greater curve progression of more than 10° (Table 1).

Of the ten patients in group 1, nine showed significant deformity progression after removal of growing rods; one remained stable. Of the nine patients with significant progression, the mean time to failure was 13.3 months (range, 6 to 16 months). The group 1 treatment pathway was discontinued on ethical grounds due to its high failure rate.

Commentary

The complication rate associated with treatment for EOS remains high, with Bess et al. reporting a 58% complication rate for patients followed over 18 years by the Growing Spine Study Group [4]. The treatment is multifaceted with many variables, such as the number and location of rods and age at the time of initial surgery. With regard to final instrumented fusion, Poe-Kochert et al. retrospectively reviewed a multicenter database of patients with EOS and found that 20% of patients undergoing final fusion had multiple complications requiring multiple reoperations [16]. Approximately half of these patients required reoperation due to infection. The remaining patients required reoperation due to instrumentation failure, symptomatic hardware, persistent coronal or sagittal plane deformity, or pseudoarthrosis. One patient required thoracoplasty for progressive crankshaft chest. These results highlight the importance of alternative endpoint strategies. In a study seeking to quantify the amount of correction attainable with final fusion, Cahill et al. reported an 89% autofusion rate in patients treated with growing rods, suggesting that final fusion may not be necessary in skeletally mature patients with good correction [5]. Jain et al. compared a cohort of 30 patients who underwent growing rod treatment but not final fusion with 137 who did undergo final fusion [11]. The investigators found no significant differences between these groups in terms of curve correction and curve magnitude. Of note, one patient with retained growing rods required removal due to infection.

In this context, Kocyigit et al. ask the important question of whether avoiding final fusion can be taken a step further with the removal of growing rods [12]. The authors hypothesize that autofusion results in enough stability to prevent further curve progression. Given the high rate of infection reported in the literature, removal of implants could potentially reduce the complication rate significantly. Unfortunately, the authors conclude convincingly that removal of growing rods in skeletally mature patients results in an

Table 1 Treatment methods in different groups

Group	Description
1	Removal of growing rods without instrumented fusion for skeletally mature subjects and stable radiographs
2	Removal of growing rods and instrumented fusion for skeletally mature patients without adequate correction
3	Continued growing rod treatment for skeletally immature patients

unacceptably high rate of deformity progression. This is likely due to the incomplete nature of autofusion. Flynn et al. commented on the spinal mobility of 58 patients undergoing final fusion, noting that 19% had a mobile spine and another 19% had decreased mobility only in areas of autofusion [8].

The primary strength of this study is the striking result that nine out of ten patients who underwent removal of growing rods without fusion experienced significant progression of their curve. Other strengths of this study are its prospective enrollment strategy and minimum 2-year follow-up for all patients included. Because patients were enrolled prospectively, the composition of each study group is less prone to selection bias compared with a retrospective design. This quality increases the validity of the negative result in group 1. Additionally, the authors excluded patients with any major complications during the lengthening treatment in order to attempt removal of growing rods without fusion in an “ideal” treatment group with the best potential to maintain alignment.

The weaknesses of this study include the arbitrary cutoff age of 14 years in the inclusion criteria and the presence of treatment selection bias. The authors support the age 14 cutoff, citing Flynn et al., in which only 7% of patients with growing rods did not undergo final treatment at age 14 [8]. Age was used as part of the inclusion criteria to facilitate enrollment of patients. However, of the 86 identified in their database, 30 patients were older than age 14. Perhaps using an alternative enrollment strategy or raising the cutoff age would allow for more patients to be included. The study design also inherently introduces response to treatment as a confounding variable. Patients in groups 1 and 2 differ in terms of the severity of their curve and treatment received. Thus, any comparison between the groups would be confounded by a difference in curve severity. Appropriately, the authors do not attempt to statistically compare results between study groups, nor do they draw conclusions based on comparisons between groups.

All studies examining the management at the endpoint of growing rod treatment will suffer from the statistical limitations of small sample sizes and difficulty with randomization. The importance of this article lies in its exploration of an undescribed strategy for treating a difficult problem for which all other strategies are associated with significant complications. We believe that this study’s results should strongly steer clinicians toward final fusion for the vast majority of patients treated with growing rods. For patients with good correction, retention of growing rods remains a reasonable option. While all patients in group 1 were skeletally mature radiographically, perhaps continued retention of growing rods would result in more complete autofusion, thus allowing for removal of implants when patients are older. Further studies would be needed to explore whether avoiding fusion can be considered for patients with evidence of stable autofusion trended over several years past skeletal maturity. However, until further studies re-explore the results of the removal of growing rods without fusion in different patient groups, final fusion should remain the standard of care.

In conclusion, the primary result of the study is the demonstration that in young patients being treated for EOS, the removal of growing rods without subsequent fusion is an unacceptable strategy. While the study design is limited by confounding variables between the study groups, this does not affect the validity of the high rate of curve progression seen in group 1. Further studies are needed to better describe the nature of autofusion with retained growing rods, as well as the long-term results of growing rod retention versus instrumented fusion. We also believe that the difficulties of growing rod treatment highlighted by this study point to the importance of alternative strategies such as the Shilla-guided growth, VEPTR, or vertebral body tethering.

Compliance with Ethical Standards

Conflict of Interest: Tony S. Shen, MD, William Schairer, MD, and Roger Widmann, MD, declare that they have no conflicts of interest.

Human/Animal Rights: N/A

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