Early Onset Scoliosis: Modern Treatment and Results

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Background: Early onset scoliosis (EOS) is a potentially fatal, challenging group of diseases the management of which has markedly changed in the last decade. The purpose of this review is to provide the reader with a brief description of each of these new therapeutic modalities, their indications for use, and early clinical results.

Methods: A systematic review of peer-reviewed publications and abstracts related to the treatment of EOS in the last decade was carried out and synthesized into a review of modern treatment methods.

Results: Recent advances in techniques and understanding of preserving the thoracic space have improved the morbidity and mortality of children with progressive EOS. Derotational casting may be used in younger patients with curves between 25 and 60 degrees. The vertical expandable prosthetic titanium rib is best suited for patients with thoracic insufficiency syndrome. Single or dual growing rods may be used alone or in combination with vertical expandable prosthetic titanium rib to treat patients with progressive EOS who are not candidates for casting. Shilla technique is an alternative to growing rods that avoids the morbidity of repeated lengthenings but is not as well proven as the techniques described above. Other methods such as automatic growing rods and growth modulation techniques are still investigational, and their role needs to be defined after further study.

Conclusions: Recent advances have improved the treatment of children with EOS. Treatment continues to be challenging with complication rates higher than treatment of idiopathic scoliosis.

Level of Evidence: Level V.

Key Words: early onset scoliosis, growing rods, VEPTR, hybrid growing rods, Shilla, vertebral stapling, derotation body cast


The management of severe, progressive early onset scoliosis (EOS) is challenging. The natural history can be severe deformity, restrictive pulmonary disease, cardiac disease, and early mortality.1-5 In the past, the standard of care for these children was early definitive anterior and posterior spinal fusion (PSF) and spinal instrumentation. The belief was that a short and straight spine was superior to a long and deformed spine despite the negative effects of a short trunk and disproportionate body habitus. The principles of EOS treatment have changed with the appreciation that early fusion of the thoracic spine limits the growth of the spine and lungs, and eventually leads to respiratory failure and increased mortality.3-6,7 The focus has shifted from the spine alone to the spine, chest wall, and lungs; and the goals of treatment to a well-aligned spine and a thoracic cavity sufficiently developed to support adequate pulmonary development and function. Recognizing the importance of pulmonary function, a few developmental principles should be understood. Bronchial tree and alveolar complement are maximally developed by 8 years of age, and the thoracic volume at 10 years of age is 50% of expected adult volume.8-12

The T1-S1 length increases most dramatically in the first 5 years of life (2.2 cm/y), is slower during the next 5 years (1 cm/y), and increases again at onset of puberty (1.8 cm/y).13,14 Achieving a T1-T12 length of at least 18 cm at maturity is associated with better pulmonary function.15

At present, a number of spinal and chest wall growth-sparing techniques have been developed and refined. Serial corrective cast treatment has resurfaced as an effective treatment, and recent studies document excellent results with derotational methods.16,17 The list of growth-sparing surgical techniques continues to increase, and these are being classified to facilitate treatment decisions.
(D.L. Skaggs, 2010, personal oral communication) (Table 1). The indications and effectiveness of each technique remain controversial. It is worthwhile to note that the instrumentation used in the following techniques is being used “off label” as defined by the Food and Drug Administration. The challenges associated with the use of these systems include obtaining and maintaining deformity correction, achieving adequate spinal growth, allowing adequate lung development, and decreasing the high incidence of complications. The purpose of this manuscript is to review the current options for growth-sparing treatment of EOS.

**DEROTATIONAL CASTING**

**Indications**

A patient with documented progression (progression of 10 to 20 degrees or progression past 25 degrees) but low magnitude (< 60 degrees) coronal deformity, or anticipated progression (rib-vertebral angle difference of > 20 degrees, rib phase 2) in whom no surgical methods have been attempted are common indications for serial casting technique.

**Concept**

Until recently, cast treatment, the standard of care for all scoliosis treatment before the advent of effective spinal instrumentation, was associated with many complications, including superior mesenteric artery syndrome, pressure sores, and rib or mandibular deformities. These problems have been addressed by the replacement of the Risser cast, which was based on a 3-point bending principle, with the derotational technique introduced in Europe in the 1960s and recently popularized by Mehta. The cast is applied to the intubated, anesthetized child using a specially designed table (Fig. 1) that permits the application of proximal and distal traction, supports the head, arms and legs, and exposes the trunk for the cast placement. The ribs are not pushed towards the spine, but are instead rotated using an anteriorly directed force on 1 side and posteriorly directed force on the other. Anterior and posterior windows are made. Casts are changed every 2 to 4 months and discontinued or replaced by orthotic treatment when the curve is < 10 to 20 degrees. Casts may not be tolerated in children with poor pulmonary function or children with sensory integration abnormalities that render them unable to tolerate cast immobilization.

**Clinical Results**

Several modern series have documented the positive results of derotational cast treatment. In Mehta’s series of 136 patients, results were related to age and curve severity at the time of the initiation of treatment. In children with a mean age of 1.6 years and a mean

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**TABLE 1.** Classification of Growth-sparing Surgical Techniques

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<thead>
<tr>
<th>Distraction Based</th>
<th>Guided Growth</th>
<th>Convex Compression Growth Inhibition</th>
<th>Other</th>
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<tr>
<td>Single rod</td>
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<td>Shape memory staples</td>
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<td>Dual rod</td>
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<td>VEPTR</td>
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<td>Hybrid growth rods</td>
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<td>Phenix/MAGEC</td>
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VEPTR indicates vertical expandable prosthetic titanium rib. Modified from Skaggs.18

**FIGURE 1.** Graphic (A) and photograph (B) depicting the position of the infant on the special casting table, the position of the surgeon’s hands as seen in the mirror, and the derotational forces applied to the chest wall (from Sanders et al.23).
(coronal) deformity of 32 degrees (group 1), the scoliosis resolved by 4 years of age. Further treatment was not needed. Children who were treated at a mean age of 2.5 years and a mean deformity of 52 degrees (group 2) had progression of their scoliosis and 15 of these children required definitive spinal fusion. In this and earlier studies, the prognosis was improved when the rib-vertebral angle difference was <20 degrees. The study also identified a phenotypic subtype of slender and ligamentously lax children in whom the deformity was rapidly progressive. Similar results were reported by Sanders et al. In 55 patients with documented or anticipated progression, treatment begun at a younger age, curve magnitude <60 degrees, and an idiopathic etiology were all seen to improve the prognosis. In a separate study comparing brace, cast, and vertical expandable prosthetic titanium rib (VEPTR) treatment, bracing was found to be ineffective, cast treatment effective for curvatures <52 degrees, and VEPTR best for larger curvatures.

DISTRACTION-BASED SURGICAL TECHNIQUES

Indications
These techniques are considered for progressive deformities when cast or brace treatment has failed or is contraindicated. In general, the rods are lengthened at 6-month intervals, making this modality problematic in children with high comorbidities that can complicate the numerous anesthetics, surgical procedures, and hospitalizations.

SINGLE GROWING RODS

Concept
The principle in distraction-based implants is to anchor instrumentation to the spine proximally and to the spine or pelvis distally and avoid exposure of the intervening spinal segment. Growth occurs through this central segment and the deformity is controlled by serial lengthening procedures that produce the spinal “growth.” There are a number of variations of this theme. The concept of a long subcutaneous rod spanning an unfused spine was first introduced in 1962 by Harrington, and later developed by other authors. The results were associated with a high complication rate including implant failure, loss of fixation at the anchor points, and spontaneous fusion of the spine resulting in limited spinal and thoracic growth. The results improved with the advent of more secure anchor points. Morin was the first to use segmental spinal instrumentation with a “claw” foundation consisting of a downgoing supra-laminar or transverse process hook and an upgoing sub-laminar hook placed 1 or 2 segments distal. A single growing rod employs either “claw” or pedicle screw foundations with a limited fusion performed about the foundation sites. A single pediatric (4.5 mm) or adult (6.2 mm) rod is left long (4 to 5 cm) above or below the proximal or distal foundation depending on the curve location, and is used for periodic lengthenings. Two rods overlapping in the middle and connected by side-by-side connectors may also be used. A thoracic-lumbar-spinal orthosis is sometimes used after surgery. Periodic lengthenings are performed. Once the child has reached sufficient age and size, a definitive PSF, or alternatively, an anterior spinal fusion and PSF with segmental spinal instrumentation, can be performed (Fig. 2).

Clinical Experience
Because single growing rods have the longest history, there are numerous series evaluating the results and complications associated with their use. One of the earliest large series was a group of 67 children with EOS.

**FIGURE 2.** A, Posteroanterior radiograph of a 3-year-old boy with idiopathic early onset scoliosis with a progressive curve measuring >50 degrees. B, Posteroanterior radiograph of the same patient 6 months later after the derotational cast has been applied. C, Frontal photograph of the same patient showing the cutouts and molding of the cast.
secondary to a variety of etiologies between 1973 and 1993. The deformity improved a mean of 20 degrees from 67 to 47 degrees at the time of definitive fusion. The rods were lengthened a mean of 31 mm over the mean treatment time of 3.1 years. The authors found the procedure to be safe; however, there was 1 death related to a rod exchange through a subfascial tunnel. There were numerous implant-related complications and more difficulty in lengthening the rod with each subsequent procedure. Other series have similar results with predominant infection and implant-related complication rates, of 24% to 59%.34,35

DUAL GROWING RODS

Concept
Dual growing rods, popularized by Akbarnia and colleagues, follow the same principle of single growing rods but provide improved stability and deformity correction. Each rod is composed of 2 sections that are connected by an end-to-end tandem connector through which the lengthenings are performed. The foundations are either pedicle screws or hook “claws” and these anchor points are fused.40 In neuromuscular patients the surgeon should consider pelvic fixation for the distal anchor. Sponseller et al41 demonstrated significantly better correction of pelvic obliquity and coronal deformity using dual rods and iliac screws compared with other types of pelvic fixation. The rods are lengthened every 6 months regardless of curve progression (Fig. 3).

Clinical Experience
The largest clinical series involving dual growing rods was published by Akbarnia et al in 2005. The mean curve magnitude improved from 82 degrees preoperatively to 38 degrees after the first surgery and 36 degrees at final follow-up. Patients were lengthened a mean of 6.6 times for a mean T1-S1 length increase of 1.2 cm/y and an increase in lung space ratio from 0.87 to 1. There were a total of 13 complications (56%) in 11 patients. Another, more recent, series showed a slightly better curve correction and more length gained when lengthenings were performed at intervals of ≤6 months.38 In a study comparing single rods, single rods with short apical fusion and dual rods, patients who underwent the short apical fusion had the poorest curve correction and length gained, whereas the dual rod group had the best initial correction, maintenance of correction, spinal growth per year, and the percentage of expected T1-S1 growth.33

Complications are frequent and related to the prolonged treatment required of distraction-based techniques. A comprehensive analysis of complications from single and dual rod constructs reports 58% of the 140 patients evaluated had at least 1 complication.42 The complication rate increased by 24% for each additional procedure performed, and complication rate decreased by 13% for each year of increased patient age at treatment initiation. There were less instrumentation complications in dual as opposed to single rods, and patients with subcutaneous rods had more wound complications, prominent implants, and unplanned procedures than those with submuscular rods (Table 2). Wound complications are more common when lengthenings are performed at more frequent intervals, whereas implant-related complications occur more often when lengthenings are performed at longer intervals.43 Regarding neurological safety, the insertion and lengthening of both single and dual

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<td>Wound complications</td>
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<td>Subcutaneous rod placement</td>
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<td>Submuscular rod placement</td>
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growing rods appears to be extremely safe with an overall incidence of neuromonitoring changes of 0.9%, and only 1 reported clinically detectable transient neurological deficit (0.1%)\textsuperscript{44} in a patient with a known intradural tumor. Finally, there appears to be a “Law of Diminishing Returns” for repeated lengthenings of growing rods. Sankar et al.\textsuperscript{45} reporting on 38 patients, noted the mean T1-S1 length gain from the first lengthening was 1.04 cm and progressively less with subsequent procedures.

**VEPTR**

**Concept**

The VEPTR (VEPTR-Synthes Spine, West Chester, PA) is a titanium alloy longitudinal rib distraction device. As with growth rods, repeated lengthenings are required. It was recently approved by the Food and Drug Administration under Humanitarian Device Exemption for treatment of skeletally immature patients with thoracic insufficiency syndrome (TIS).\textsuperscript{46-48} Approved anatomic diagnoses of TIS include flail chest syndrome, constrictive chest wall syndrome that includes rib fusion and scoliosis, hypoplastic thorax syndrome, which includes Jeunes syndrome, achondroplasia, Jarche-Levin syndrome, and Ellis van Creveld syndrome, and progressive scoliosis of congenital or neurogenic origin without rib anomaly.\textsuperscript{49} Infantile idiopathic or syndromic EOS are included in this group if a constrictive chest wall syndrome is present based on a windswept deformity of the thorax at the apex of the curve on computed tomography.\textsuperscript{30,51}

The operative strategy of VEPTR application varies by diagnosis. In type II volume depletion conditions (fused ribs and scoliosis), the goal is to maximize thoracic volume and symmetry of the deformed thorax by lengthening the constricted hemithorax through a transverse opening wedge thoracostomy of the concave side,\textsuperscript{47,46} either through osteotomy of fused ribs or intercostal muscle lysis. The scoliosis is corrected indirectly by the thoracostomy, and the thoracic reconstruction is stabilized by the addition of a rib to spine or rib to pelvis VEPTR construct, and another rib to rib VEPTR. No bracing is used postoperatively. The VEPTRs are lengthened on schedule every 4 to 6 months. As 50% of final thoracic volume depends on growth between age 10 and 15 years, final fusion is preferentially delayed until skeletal maturity (Fig. 4). Other conditions such as myelodysplasia, in which secondary TIS may develop, can be treated with VEPTR devices placed without expansion thoracoplasty.

**Clinical Experience**

Originally intended to treat children with TIS secondary to fused ribs and congenital scoliosis, the indications

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**FIGURE 4.** A, A 7-month-old child had a progressive scoliosis due to fused ribs and congenital spinal deformities. B–D, The initial rib resection and vertical expandable prosthetic titanium rib improved the chest size, but failed to halt the progressive deformity. E–G, Here the technique was adapted to the situation by adding an additional rib-to-spine rod to control the chest as well as the spine and an excellent result obtained (courtesy: John Emans, MD).
have expanded to include all etiologies of progressive EOS (congenital, neuromuscular, and syndromic with or without fused ribs) in which the surgeon wishes to avoid or minimize direct exposure of the spine. Campbell et al. studied 27 children with congenital scoliosis associated with fused ribs and found a mean correction of the scoliosis from 74 to 49 degrees, and thoracic spine height increased by a mean of 7.1 mm/y. There were 52 complications (193%) in 22 patients. The most common complication was “asymptomatic” proximal migration of the device through ribs in 7 patients. Hasler et al. studied 23 children with noncongenital EOS. Cobb correction was from 68 degrees preoperatively to 54 degrees at the final follow-up. Although space available for the lung (SAL) significantly increased, the percentage predicted pulmonary values were not reported. There were 23 complications (100%) of which 16 were wound complications and 7 implant-related complications. In children older than 10 years comparable correction and a lower complication rates have been documented. Use in “exotic scoliosis” has also been described. A recent study of the Chest Wall Disorders Study Group Database revealed that although there was a significant decrease in Cobb angle and increase in SAL, objective measures of pulmonary function did not seem to improve as expected. Computed tomographic examination has demonstrated no correction, but only stabilization of the transverse plane deformity seen in TIS. All authors caution the need for a multidisciplinary team approach when the VEPTR is used. With proper precautions its use appears to be relatively safe with low mortality even in the most severely affected patients who have a poor prognosis if no treatment is undertaken. Betz et al. studied 43 patients with either Jarcho-Levin or Jeune Syndrome, and found a total mortality rate of 9% of which all deaths occurred in patients with Jeune Syndrome from respiratory, liver, or renal failure. Another 9% had potentially life-threatening occurrences of which half were indirectly related to the surgery.

**HYBRID DISTRACTION-BASED GROWING RODS**

**Concept**

Fusion of the upper thorax, as is performed for the upper anchors of growing rods, has been shown to adversely affect pulmonary function. Hybrid systems utilizing standard hooks avoid this fusion by using ribs as the upper anchor. In addition, soft-tissue coverage of the hook on the rib position is usually better than when using spinal fixation (Fig. 5).

**Clinical Experience**

This is a recently described technique. A multicenter study has shown bilateral hybrid growing rods produce on average 1.2 cm/y of T1-S1 growth which is comparable with that found with dual growing rods and superior to that of VEPTR. In a comparison study in similar patient populations, the hybrid instrumentation had a complication rate of 0.86/patient, the dual growing rods 2.3/patient, and the VEPTR 2.37/patient.

![Figure 5](image-url) - A and B, The hybrid technique allows excellent spinal deformity correction while avoiding the morbidity of an upper thoracic fusion. Conventional instrumentation is used. Note the medial placement of the rib hooks (courtesy: David Skaggs, MD).
LESS CONVENTIONAL TECHNIQUES/
FUTURE DIRECTIONS REMOTE CONTROL:
PHENIX, MAGEC

Concept

Both the Phenix (France) and MAGEC [(Magnetic Expansion Control System) Ellipse Technologies, Inc., Irvine, CA] are distraction-based systems that can allow growth with remote control theoretically diminishing the complications of infection and lack of soft-tissue coverage. It may be especially helpful in children with comorbidities that make the repeated surgeries necessary with the usual distraction methods especially difficult.

Clinical Experience

The Phenix rod system, currently unavailable in the United States, was developed by Drs Lotfi Miladi Arnaud Soubiezan, and Jean Dubouset that uses magnets to produce gradual lengthening without repeated surgeries. Rib or spine fixation is possible. In a preliminary study, there was correction of the scoliosis from 63 to 33 degrees and a growth rate of 2 mm/mo. The MAGEC system is a similar magnetic device. An animal study has shown favorable results. Lengthenings can be performed in the office without anesthesia. Longer-term results of both systems will be needed to determine the efficacy and safety of this technology.

GROWTH INHIBITION: CONVEX COMPRESSION

Concept

These technologies, based on the Huester-Volkman Law, inhibit growth by compression of the convexity of the deformity. The idea is that the scoliosis will then correct through growth on the concavity. Historically, convex growth inhibition was performed through the technique of anterior and posterior hemiepiphyseodesis. Although this technique was primarily used for congenital scoliosis and was not found to be effective for other types of EOS. More recently, hemiepiphyseodesis has taken the form of shape memory alloy (SMA) staples, tethers, and transpedicular growth modulation of the neurocentral junction. Although most of these techniques are experimental there is a fair amount of clinical experience with SMA staple treatment in older children.

Anterior SMA Staples

Indications

Patients considered for this procedure should have at least 1 year of growth remaining and a deformity that could also be considered for bracing. According to Betz and colleagues, the thoracic and lumbar curves should be < 45 degrees with minimal rotation and flexible to < 20 degrees. The sagittal thoracic curve should be < 40 degrees.

Clinical Experience

Early spinal staples failed because of dislodgement. This problem now seems to be solved with a Nitinol (Nickle Titanium Naval Ordnance lab) staple. The prongs of the staple are straight when cooled but change to a “C” shape and stabilize within the bone when they heat up to body temperature. Using these staples, Betz et al followed 26 children with thoracic curves and 15 with lumbar curves who were a mean age of 9 when the staples were placed. In the thoracic curvatures, 78% either stabilized or improved when the curves were < 35 degrees at staple insertion. Larger curves demonstrated a 75% progression rate past 50 degrees. In patients less than age 10 with thoracic curves of all curve magnitudes, there was a 75% success rate. The stapling also appeared to have a positive effect on sagittal contour in patients with hypokyphosis. Lumbar curves demonstrated an 87% success rate overall and 100% success rate in patients under the age of 10. Complications included rupture of a previously unrecognized diaphragmatic hernia, overcorrection of 1 curve, atelectasis, and superior mesenteric artery syndrome. Similar results have been reported by others (Fig. 6).

Anterolateral Spinal Tethering

Concept

Tethers, like staples, produce correction by convex growth inhibition, but use flexible connections between the vertebral anchor points. Numerous animal models have demonstrated the ability of tethers to produce and correct scoliosis. Tethering is theoretically less likely to damage the intervertebral disks than rigid devices. Preservation of disks has been demonstrated in animal models, however, both tethers and staples do produce chemical, cellular, and vascular changes in the disk and endplate, although the significance of these changes is unknown.

Clinical Experience

Most of the experience is experimental. There is a case report of an 8-year-old boy treated with vertebral body screws connected by a polypropylene tether. The 40 degrees thoracic scoliosis was reduced to 25 degrees at the time of surgery and improved to 6 degrees at the 4-year evaluation.

Growth Guidance

Indications

This technique should be considered for progressive deformities when cast or brace treatment has failed or is contraindicated. As there is no need for repeated open distractions and associated anesthesia, the method seems better suited than distraction techniques in children with significant medical comorbidities.
FIGURE 6. A and B, A 11 year and 9 month old boy with early onset idiopathic scoliosis would not tolerate a brace. Convex staple hemiepiphyseodesis was chosen as treatment. C, The index procedure produced good correction of the coronal deformity. D, In the first year after surgery the deformity progressed. E, Follow-up radiograph demonstrates that with growth, the deformity improved. F and G, Lateral and posteroanterior radiographs 2 years after surgery demonstrate that the deformity continued to improve nicely with continued growth (courtesy: M. Timothy Hresko, MD).

**Shilla Procedure**

**Concept**

The precursor to the Shilla system (Medtronic Spine, Memphis, TN) was the Luque trolley system,\(^6\) which did not appear to provide reliable spinal growth or deformity correction.\(^6\) In the Shilla procedure, multiplanar correction is obtained by pedicle fixation at the apex of the deformity. This usually involves instrumentation and fusion of 3 to 4 segments. Four to 6 gliding pedicle screws (Shilla growing screws-Medtronic) are then placed at each end of the construct. These screws are placed without subperiosteal exposure to decrease the risk of inadvertent fusion of the proximal and distal segments. Good fluoroscopic technique and equipment are essential for placement of the proximal and distal anchor screws because the anatomic landmarks are not exposed. The rods are left long at the ends to allow the sliding screws to move along the rods with spinal growth. Normal sagittal contours are maintained and the anchor screws slide cranially and caudally on the dual rods as the patient grows. With correction and stabilization of the most deformed apical segment there is theoretically less stress on the end anchor points. The patients are placed in a thoracic-lumbar-spinal orthosis for 3 months after the surgery (Fig. 7).

**Clinical Experience**

Although the effectiveness of this concept has been proven in a caprine model,\(^9\) the Shilla technique has no
long-term follow-up series to date. Thus far, the results of 10 patients with > 2 year follow-up from a cohort of 36 patients have been reported.\(^{33}\) Curve magnitude went from a mean of 70.5 degrees preoperatively to 27 degrees postoperatively and 34 degrees at 2 years. Truncal height increased a mean of 12% and the SAL increased an average of 13%.

Other Treatments
A number of technologies that address possible etiologies of scoliosis to control scoliosis in a growth-sparing method are under investigation. Rib shortening and lengthening has been performed experimentally and clinically.\(^{94-96}\) Asymmetric epiphyseodesis of the neurocentral synchondrosis has shown some promise in experimental studies as well.\(^{78,97}\)

SUMMARY
Recent advances in operative and nonoperative techniques and understanding regarding the importance of preserving the thoracic space have improved the morbidity and mortality of children with progressive EOS. It is important to understand the concepts behind treatment of EOS and be aware of the range of treatments and their indications. Current treatment is evolving as existing techniques are refined and new methods evolve. Derotational body cast treatment should be considered in children with documented progression of a curve <60 degrees and no previous surgical treatment. In contrast, bracing does not appear to be effective in the management of EOS, and the role of bracing is limited to postcasting or postsurgical maintenance of correction. When the child has failed nonoperative treatment, there are a number of surgical options available to decrease progression, maintain SAL, and delay or eliminate a definitive fusion. Both single and dual growing rods are effective, but dual rods seem to have better initial correction, maintenance of correction, increased T1-S1 length gain, and decreased implant-related problems such as rod breakage and hook pullout. Children who cannot tolerate repeated lengthenings because of medical comorbidities should be considered for the Shilla technique. A hybrid system offers a promising distraction-based alternative and may be a better alternative in children who require a low-profile proximal anchor. VEPTM may be beneficial for those patients with congenital scoliosis and fused ribs and TIS, although improvement in pulmonary function with treatment is controversial.\(^{35}\) Growth modulation using SMA staples or other tethers show promise for milder curvatures, but further follow-up is needed to define their use.

Complication rates for all surgical techniques for treatment of EOS remain high because of the repetitive nature of the lengthening surgeries, the bulk of the instrumentation, and the stresses placed on instrumentation in a mobile spine.\(^{98}\) Younger children, neuromuscular and syndromic children, and higher curve magnitude appear to be associated with higher complication rates.

REFERENCES


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