Growing spine implants, is it time for Magic?

Joseph Perra
TCSC – Gillette Children’s
Magic – definition(s)

- the power of apparently influencing the course of events by using mysterious or supernatural forces
- the art of producing illusions as entertainment by the use of sleight of hand, deceptive devices
- a special exciting quality that makes something or someone different and better than others
Definition

- **Scoliosis**
  - Lateral deviation of spine
  - Curvature of the spine > 10° (Cobb Method)

- **Early Onset**
  - < 8 to 10 years of age

- **Etiology**
  - Numerous
  - EOS does not signify “type” of scoliosis
Why do we care?

- Severe cardiopulmonary problems can occur in untreated progressive cases
- James et al, 1959
  - Progressive early onset scoliosis “develops rapidly and relentlessly, causing the severest form of orthopaedic cripple with dreadful deformity, marked dwarfing and shortening of life”

James JI, Lloyd-Roberts GC, Pilcher MF. Infantile structural scoliosis. JBJS Br, 1959; 41: 719-735.
Types of Early Onset Scoliosis

- Idiopathic
  - Infantile – 0-3 years old
  - Juvenile – 3-10 years old

- Neuromuscular
  - Duchenne’s, SMA, CP, Myelodysplasia

- Syndromic
  - Neurofibromatosis, Glycogen Storage Diseases, Skeletal dysplasia, etc.

- Congenital
  - Failures of segmentation or formation, mixed

- Thoracogenic
  - Spondylocostal or spondylothoracic dysostosis

🌟 All can be associated with Thoracic Insufficiency Syndrome
Terminology

How is Thoracic Insufficiency Syndrome (TIS) defined?

- The inability of the thorax to support normal respiration or lung growth

Bob Campbell, MD (Spine Surgeon)
Goals of Management

- Minimize spinal deformity
- Maximize thoracic volume & function
- Minimize complications
- Include consideration of child development
- Consider Families’ ability to comply with treatment options
Case Examples

Infantile Idiopathic Scoliosis
(2 yrs + 6 mos)
Surgical Management of Patients with Early Onset Scoliosis
Surgical Management of EOS/TIS: Physiology

+ EOS can occur without TIS
+ TIS can occur without EOS
+ But the two are intimately linked in many circumstances
+ End Result
  + Inability to support normal respiration
    + Disrupts the diaphragmatic excursion/rib cage expansion mechanism of physiologic breathing
  + Inability to support normal lung growth
    + Diminished thorax or thoracic spine growth results in hypoplastic underlying lungs
Surgical Management of EOS/TIS: Physiology

+ Neonate to 3 yrs
  + Rapid somatic growth, increase in alveolar number and complexity, rapid spine growth
  + Greatest risk of death from pulmonary etiologies (1 mo to 1 yr)

+ Adolescent to Adult
  + Increase alveolar size, increase respiratory muscle strength, optimal lung mechanics

+ 8 yo
  + 50% volume of adult thoracic cage
  + Alveolar multiplication is complete
Surgical Management of EOS/TIS: Treatment Objectives

- Improving lung volume early should improve lung development more than late intervention.

- Preventing post-natal pulmonary hypoplasia is likely to improve lung function more than hoping for compensatory alveolar growth once it has developed.

- Ideal surgical treatment maximizes respiratory muscle function.
  - There is no procedure at this point that accomplishes all of these objectives.
Surgical Management of EOS/TIS: Surgical Planning

÷ Dimeglio & Bonnel, 1990
÷ Normal thoracic height by age
  ÷ Newborn 11 cm
  ÷ 5 yo 18 cm
  ÷ 10 yo 22 cm
  ÷ Adult Female 26.5 cm
  ÷ Adult Male 28 cm
**FIG. 9.** Thoracic spine. The figures are average values.
Thoracic Circumference

VOLUMETRIC GROWTH

New born  5 years  10 years  15 years

Management of EOS/TIS: Treatment Objectives

- In treating the curve
  - Improving lung volume early should improve lung development more than late intervention
  - Preventing post-natal pulmonary hypoplasia is likely to improve lung function more than hoping for compensatory alveolar growth once it has developed
  - Ideal surgical treatment maximizes respiratory muscle function
Treatment principles

+ Control curve
+ Allow spine / thoracic growth
+ Allow lung growth
Treatment choices

- Cast
- Brace
- Early fusion
- Instrumentation without fusion
Instrumentation without fusion

- First described by Harrington 1962
- Marchetti – end fusion-1971 (1977)
- Implants used
  - Large Harrington compression rod
  - Harrington rod
  - Moe rod
  - Luque rod
  - Growth rod
- Protected by Milwaukee Brace
Neurofibromatosis
Failure to control scoliosis, Fusion
age 10+6
I hook cut out, 2 rod breakages

Fused age 10 +2
Harrington instrumentation without fusion plus external orthotic support for the treatment of difficult curvature problems in young children.

- 20 cases –
  - 11 EOS, varied Diagnoses
  - 3/20 “not indicated” small growth gain
  - 9 definitive fusions
  - 10 pts, 22 complications
    - Rod breakage
    - Hook cut out

- Average length gain 2.8cm

Implant options

- Single rod
- Dual rod
- Rod type
  - Growth rod
  - Dual rods with connector
  - Rib based system (VEPTR)
  - Magnetic rod
- Insertion
  - Subcutaneous
  - Subfascial
- Fixation
  - Spine – Hooks, screws
  - Ribs
  - Ilium
Challenges

- Mixed diagnoses
- Mixed ages
- Variable amount of TIS
- Because of rarity of these cases
  - Series tend to be small
- Many series have short F/U
Why not do an early fusion

- Results in shortened thoracic spine & restrictive lung pathology
- FVC average 57.8% (pts < 9 yo at surg, avg age 3.3 yo)
- 8/12 pts with proximal fusion level of T1 or T2 had FVC < 50%
- 4/16 pts with proximal fusion level caudal to T2 had FVC < 50%
All pts with FVC < 50% had > 4 levels fused

16/28 pts thoracic height < 18 cm (5 yo)
  + Avg FVC 48.2%, 10/16 severe restrictive lung dz

8/28 pts thoracic height 18 cm – 22 cm
  + Avg FVC 63%, 2/8 severe restrictive lung dz

4/28 pts thoracic height > 22 cm (10 yo)
  + Avg FVC 85%, 0/4 severe restrictive lung disease
Surgical Management of EOS/TIS: Summary “Karol”

- Short & straight is not necessarily better than crooked & long

- Goals
  - If you must fuse early try to stay away from the apical spine (T1, T2)
  - If you fuse early try to fuse a very short segment
  - Goal thoracic height should be AT LEAST 18 cm with 22 cm preferable
Grow Preserving Treatments

- Control curve and allow for growth
- Internal bracing
- Distraction or growth “guidance”
Thompson GH et al. JPO: 27, 354, 2007
Complications of Growing-Rod Treatment for Early-Onset Scoliosis
Analysis of One Hundred and Forty Patients

By Shay Bess, MD, Behrooz A. Akbarnia, MD, George H. Thompson, MD, Paul D. Sponseller, MD, Suken A. Shah, MD, Hazem El Sebaie, FRCS, MD, Obeneba Boachie-Adjei, MD, Lawrence I. Karlin, MD, Sarah Canale, BS, Connie Poe-Kochert, RN, CNP, and David L. Skaggs, MD

Investigation performed at San Diego Center for Spinal Disorders, La Jolla, California

+ Growth Preserving Techniques/Growth Friendly Constructs
  + Two growth rods are better than one
    + 10% vs. 27% implant complications
  + Submuscular growth rods are associated with better outcomes
    + 10% vs. 26% wound complications
  + Risk of complications during treatment period decreases 13% for each year of increased pt age at initiation of treatment
Diminishing returns are noted with lengthening over time

- $T_1-S_1$ gain $1.76 \pm 0.71$ cm/yr
- BUT... 
- $T_1-S_1$ gain decreases significantly with repeated lengthenings
- $T_1-S_1$ gain decreases significantly over time
Proximal rib-based anchors are felt (by some) to be associated with less spontaneous ankylosis/fusion by avoiding spine exposure.

Hybrid constructs also may be associated with fewer complications.

Table 2. Complications in Growing Spine Surgery

<table>
<thead>
<tr>
<th>Major Complications</th>
<th>Ccx Rate</th>
<th>Ccx/cm Growth</th>
<th>Ccx/yr Treatment</th>
<th>Ccx/Planned Surgeries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual growing rods</td>
<td>2.30/patient</td>
<td>0.20/cm</td>
<td>0.52/yr</td>
<td>0.47/surgery</td>
</tr>
<tr>
<td>Hybrid</td>
<td>0.86/patient</td>
<td>0.19/cm</td>
<td>0.36/yr</td>
<td>0.29/surgery</td>
</tr>
<tr>
<td>VEPTR</td>
<td>2.37/patient</td>
<td>0.97/cm</td>
<td>0.52/yr</td>
<td>0.44/surgery</td>
</tr>
</tbody>
</table>

Ccx indicates complication; cmvisu, centimeter; yr, year.
Surgical Management of EOS/TIS: Surgical Planning Pearls

- Delay surgery as much as can safely
- When you operate
  - Dual rods
  - Submuscular rods
  - Consider hybrid constructs
  - Consider spine-to-rib (ambulatory) or pelvis-to-rib (non-ambulatory)
Surgical Management of EOS/TIS: “Other Treatments”

- Shilla
  - Apical fusion, spine grows cranial and caudal along rods

- Modified Luque Trolley (Ouellet)
  - Cranial & caudal instrumentation (2 level fusion), sublaminar wires with rods in intercalary segment, intercalary segment allowed to grow & rods travel along “trolley”

- “VEPTR” TBD later !!!
Surgical Management of EOS/TIS: Is it on time for some MAGIC??

- Magnetic Drive Growth Rods
- MAGEC, Phenix (in the ashes – can it rise?)
- Anterior Tethers?
- Growth Modulation options
Surgical Management of EOS/TIS: MAGEC/Phenix
Surgical Management of EOS/TIS: Anterior Tethers

Growth Modulation by Means of Anterior Tethering Resulting in Progressive Correction of Juvenile Idiopathic Scoliosis

A Case Report

By Charles H. Crawford III, MD, and Lawrence G. Lenke, MD

Investigation performed at the Department of Orthopaedic Surgery, Washington University School of Medicine, St. Louis, Missouri

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**TABLE II Measured Changes in Vertebral Height on Radiographs**

<table>
<thead>
<tr>
<th></th>
<th>Growth Between Upper End Plate of T6 and Lower End Plate of T12 (mm)</th>
<th>Growth Between T6 Screw and T12 Screw (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concave side growth</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>Central growth</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Convex side growth</td>
<td>16</td>
<td>0</td>
</tr>
</tbody>
</table>
Magnetic driven growth rods

- “MAGEC” trademark only one currently available
  - OUS for 7 years
  - In US since March 2014

- Telescoping rods driven by magnetic “motor”

- External electromagnetic rotor

- Internal earth magnet drive
MDGR

- Used similarly to prior growth rods
- Allows for lengthening at any schedule
- Outpatient and with perfect neuro monitor (awake patient)
- Programmed lengthening or until “clunking”
  - Limit of “power” to lengthen to magnetic attraction
Indications

- Similar to other growth rod options
- At risk for TIS
  - Curve failing other non-operative methods
  - Growth potential (significant)
    - Young age (≤10)
    - Bones with growth potential (not solid bar)
  - Bone quality/size to hold anchors
  - Long enough segment for straight portion of rod
    - 9 or 11.5 cm
Contra-Indications

- No substantial growth potential
  - Rigid or solid curve
  - Older age (biological –
    - Size too small
- Need for MRI (per company)
- Usuals,
  - Infection, medical
Difficulties --- Numerous

- Frequently multiple very challenging issues
- Comorbidities
- Poor bone quality – anchor issues
- Size – too small
- Unrealistic expectations
- Previous surgeries
Magic vs Not Magic ??
Magic !!!
Not without problems
Magic or not Magic? SMA
The future?? Need data – not run with fads.

- Not a one size fits all.
- Sometimes the fusion early is better than the complications of multiple operations
- Be guided by principles and track outcomes
- This is a difficult patient population, complications will be frequent and may be severe
- TEAM approach is needed.
Clinical Studies


Clinical Studies


- Improvement of Pulmonary Function in Children With Early Onset Scoliosis Using Magnetic Growth Rods. Yoon WW et al. Spine May 2014


- Direct costs associated with the management of progressive early onset scoliosis: estimations based on gold standard technique or with magnetically controlled growing rods. Charroin C et al. Orthop Traumatol Surg Res Sep 2014
