Biomechanical and Clinical Evaluation of Rib Anchors

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Current thoughts on management of kyphosis

*Papers roughly fall into 1 of 3 categories*

• “We got this”

• “We got this…..I’m not so sure”

• “We got this ....I don’t think so”
Papers in your outline

• Positive papers generally deal with kyphosis in or near normal range
• “I’m not so sure “ papers focused on Growing Rods, increased kyphosis associated with worse results
• “I don’t think so” papers more associated with VEPTR
“Normal” thoracic kyphosis in children

• 20-50 degrees, Boseker, Moe et al, 2000
• Average 39.9 degrees in children 8-19, Ghandhari et al, 2013
Evaluating the Extent of Clinical Uncertainty Among Treatment Options for Patients with Early-Onset Scoliosis

Jacqueline Corona, MD, Daniel J. Miller, MD, Jenny Downs, PhD, MSc, Behrooz A. Akbarnia, MD, Randal R. Betz, MD, Laurel C. Blakemore, MD, Robert M. Campbell Jr., MD, John M. Flynn, MD, Charles E. Johnston, MD, Richard E. McCarthy, MD, David P. Royle Jr., MD, David L. Skaggs, MD, John T. Smith, MD, Brian D. Snyder, MD, PhD, Paul D. Sponseller, MD, MBA, Peter F. Sturm, MD, George H. Thompson, MD, Muharrem Yazici, MD, and Michael G. Vitale, MD, MPH

Investigation performed at Columbia University Medical Center, New York, NY

Results: Collective equipoise was identified in numerous scenarios in the survey spanning a range of ages and magnitudes of scoliosis, and additional questions were identified during the nominal group technique. Areas that had the greatest clinical uncertainty included the management of patients who have finished treatment with a growing rod, timing of rod-lengthening intervals, and indications for spine-based and rib-based proximal instrumentation anchors. The use of rib anchors compared with spine-based anchors was ranked highly for consideration in future clinical trials.
The Rib Construct (RC) - How it started

5 year old boy with VATER syndrome
Initial management single growing rod
Age 12, bone age delayed 2 years
Rapid development lumbar curve, kyphosis
Rods extended to pelvis – good correction but a problem – he cried for 3 months until they were removed
Risser casts, brace unsuccessful now 6 months after instrumentation removed

Note strenum compressing stomach
I thought his radiographs looked pretty suggestive for osteoporosis.
Osteoporosis – an overlooked variable?

- Search for osteoporosis and growing rods, and osteoporosis and VEPTR, zero results
- “BMD has close relationship with the stability of pedicle screws in vivo” Okuyama, et al
**Development and Initial Validation of the Classification of Early-Onset Scoliosis (C-EOS)**

Brendan A. Williams, MD, Hiroko Matsumoto, MA, Daren J. McCalla, BS, Behrooz A. Akbarnia, MD, Laurel C. Blakemore, MD, Randal R. Betz, MD, John M. Flynn, MD, Charles E. Johnston, MD, Richard E. McCarthy, MD, David P. Roye Jr., MD, David L. Skaggs, MD, John T. Smith, MD, Brian D. Snyder, MD, PhD, Paul D. Sponseller, MD, MBA, Peter F. Sturm, MD, George H. Thompson, MD, Muhtarrem Yazici, MD, and Michael G. Vitale, MD, MPH

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### BLE II Variable Content Validity Rankings*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Not Useful</th>
<th>Useful</th>
<th>Essential</th>
<th>CVR</th>
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<tbody>
<tr>
<td>Major curve angle</td>
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<td>1</td>
<td>13</td>
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<td>Etiology</td>
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<td>Kyphosis</td>
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<td>Age</td>
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<td>0</td>
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<td>0.29</td>
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<tr>
<td>Progression</td>
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<td>5</td>
<td>6</td>
<td>-0.14</td>
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<tr>
<td>Curve flexibility</td>
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<td>Chest wall abnormalities</td>
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<td>8</td>
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<td>Other comorbidities</td>
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<td>Pulmonary function</td>
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<td>Nutritional status</td>
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<td>7</td>
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<td>Ability to walk</td>
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<td>Mental function</td>
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<td>Bone quality</td>
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Fourteen surgeons participated in the primary survey of classification content. The participants rated the thirteen proposed variables included on the primary survey with a 3-point Likert scale used to assess the content validity ratio (CVR) as proposed by Lawshe.

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If everyone is thinking alike, then somebody isn't thinking.

(George S. Patton)
Role of BMD in pedicle screw purchase

• “Understanding the effects of pedicle morphology, **BMD**, pedicle screw design, insertion technique, and screw tapping is paramount to effectively correct spinal deformity”  *Lehman et al, 2012*

• “For the same thread design and size, insertional torque is directly related to BMD, which, in turn, is directly related to pullout strength” *Cho et al, J Bone Joint Surg(Br), 2010;92-B: 1061-5*
So, now what to do?

- I did not get very much help
The rib construct
Condensing his course, Rib construct effective, 4 additional procedures over 7 years

“S” rods consistently migrated into sacrum in patients with osteoporosis
Current status
7 years postop initial procedure

Note sternal pressure on stomach relieved - still has G tube

More on him a little later
Clinical results – Thoracic Kyphosis

- 14 patients (7 syndromic, 4 neuromuscular, 3 congenital), age 4-21
- Treated in Charleston, SC or Nablus, Palestine
- Preop kyphosis average 107.8 degrees (71-145)
- Followup average 44.4 months (29-84)
- Postop average kyphosis 69.5 degrees (32-113)
- 4 Charleston patients had BMD studies, T scores ranged from -2.7 to -6.9, average -4.2
Diastematomyelia - 140 degrees preop kyphosis, 85 degrees postop

Neurofibromatosis – 134 degrees preop, 55 postop after conversion to 5.5 rods
Complications

• 2 patients died of unrelated causes
• 5 proximal loss of fixation, salvaged
• 2 proximal fixation failures, both osteoporosis, and early in series
• 2 delayed wound infections, 1 reinstrumented one year later with salvaged result
Biomechanics of proximal kyphosis
(Yongren Wu, PhD, Clemson)
Ventilator dependent child. Kyphosis 145 degrees, multiple failed procedures.

Rib construct inserted. Kyphosis 113 degrees despite displacement of 2 superior hooks. Died 6 months after this radiograph.
Deforming forces - which can be visualized as a force vector - were neutralized.

Total Bending moment: 1109.4 N.cm.
Gravity center: \( y = 18.6 \) cm

Total Bending moment: 374.3 N.cm.
Gravity center: \( y = 6.3 \) cm
Resistance of pedicle screws and rib construct to kyphotic pullout forces

• 2011 SRS new investigator grant
  ▪ Original submission designed to test rib construct, pedicle screws (growth rods), and VEPTR
    ▪ Synthes spine refused to make VEPTRs available for study – could not even purchase
Work done by......

Hai Yao, PhD

Greg Wright, PhD Candidate
Pedicle screws

As kyphotic deflection and force increased, there was a partial failure (arrow), then complete failure in all specimens.
Pedicle screws – all failed at remarkably consistent deflection angle

Figure 1. The pedicle screw group with failure.
No failure in any of the 6 constructs tested
Rib Construct – no failures

Figure 2. The rib construct group without failure.

- No implant failure
- Maximum angle: 50.3 ± 9.1 (degree)
- Maximum force: 119.7 ± 13.9 (N) (mean±sd)
Practical applications
Congenital Dislocation of Spine
11 months old
Resection of hemivertebra age 18 months

Initially after surgery

5 months later, pullout of superior screws
Instrumentation removed

19 months

24 months
First RC age 28 months

preop

Deforming force reduced

Subluxation above screw - not controlled
Screws replaced 1 level superiorly
Now 41 months postop initial procedure – with 2 revisions

More anterior remodeling needed
Original and current
Alternative to VCR
age 9+5
Mini-thoracotomy, anterior release, RC, 2 revisions, now skeletally mature

Instrumentation did not bother her, Left in place
The first case
What I did
“Scapulopexy”
Preop and postop
Effect of shoulder protraction on kyphosis

Hai Yao

\[
\frac{W_s}{W_s} \quad \text{weight of shoulder}
\]

\[
L_1 \quad \text{moment arm (pre-operation)}
\]

\[
L_2 \quad \text{moment arm (post-operation)}
\]

\[
M_1 \quad \text{kyphotic moment induced by shoulder (pre-operation)}
\]

\[
M_2 \quad \text{kyphotic moment induced by shoulder (post-operation)}
\]

Kyphotic moment induced by shoulder weight:

\[
M = W_s \cdot L
\]

\[
\therefore L_2 < L_1
\]

\[
\therefore M_2 < M_1
\]
Preop motion
Postop motion
Alaa’s technique for kyphosis associated with spina bifida
postop
Conclusion

The rib construct is versatile and reliable
Thank you