Thoracic Volume Modeling in Early Onset Scoliosis

David Matson, MS2; Charles Ledonio, MD2; David Polly Jr., MD2; Kristin England, MD2; Jeff Pawelek, BS4; and Behrooz Akbarnia, MD3,4

1University of Minnesota Medical School; Minneapolis, MN. 2Department of Orthopaedic Surgery, University of Minnesota Medical School; Minneapolis, MN. 3Department of Orthopaedic Surgery, University of California, San Diego; San Diego, CA. 4San Diego Center for Spinal Disorders; La Jolla, CA.
Disclosures

• David Matson: no disclosures
• Charles Ledonio, MD:
  – Grants/Research: Medtronic, DoD, OREF
• David Polly, Jr, MD:
  – Grants/Research: DoD, OREF
• Kristin England, MD: no disclosures
• Jeffery Pawelek: no disclosures
• Behrooz Akbarnia, MD:
  – Grants/Research: DePuy Spine
  – Consulting: Ellipse, Kspine, K2M
  – Ownership/Shareholder: Nuvasive, Ellipse, Kspine
  – Royalty/Patent: DePuy Spine, K2M
Background

• Virtual thoracic volume modeling from plain radiographs has been used in the adolescent idiopathic scoliosis (AIS) and early onset scoliosis (EOS) populations. Thoracic volume from modeling correlates within 3-4% of thoracic volume from CT scans.

• Early onset scoliosis (EOS) → ↓ thoracic volume and lung volume

• For AIS patients with poor pulmonary function, the modeled 2 year post-op thoracic volume change is strongly correlated with the two year post-op pulmonary function test.
Virtual modeling of scoliotic deformity

- As coronal deformity (Cobb Angle) increases, thoracic volume decreases.
- Cobb Angle >70°, sagittal deformity does not appear to impact thoracic volume (England).
Purpose

• Objective: to assess thoracic volume change with growing rod interventions in patients with early onset scoliosis.
Methods

- Retrospective case study of children 10 years of age and younger with diagnosis of EOS
- Convenience sample of 6 patients with EOS from Growing Spine Study Group
- Coronal and sagittal radiographs used to model thoracic volume
Methods

- Patients all underwent growing rod surgery with varying number of lengthening procedures for treatment of diagnosed early onset scoliosis
- Blender software (2.71, open access) to create 3D model from coronal and sagittal radiographs
  - ‘computationally deformed’ to match chest X-rays
- 3D models created with pre- and post-operative radiographs
  - Post-op taken from midpoint of treatment and final lengthening
  - Up to 3 models per patient
- Thoracic volume determined from models in Blender
Results

- Pre-op thoracic volume = 1384-2943 cc
- Thoracic volume increased 19-62% over the course of treatment
- Pre-op major curve (Cobb angle) = 42-87°
- Cobb angle corrected 13-71% over the course of treatment
Percent change in thoracic volume with growing rod treatment in EOS

Baseline Thoracic Volume
Case 1: 1384 cc
Case 2: 1510 cc
Case 3: 1699 cc
Case 4: 2079 cc
Case 5: 2182 cc
Case 6: 2943 cc

<table>
<thead>
<tr>
<th>Case</th>
<th>Baseline Thoracic Volume</th>
<th>Percent Change</th>
<th>Post Index</th>
<th>Post L1</th>
<th>Post L2</th>
<th>Post L3</th>
<th>Post L4</th>
<th>Post L5</th>
<th>Post L6</th>
<th>Post L7</th>
<th>Post L8</th>
<th>Post L9</th>
<th>Post L10</th>
<th>Post Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1384 cc</td>
<td>61%</td>
<td>3357 cc</td>
<td>22°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td>1510 cc</td>
<td>36%</td>
<td>1886 cc</td>
<td>38°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 3</td>
<td>1699 cc</td>
<td>33%</td>
<td>2001 cc</td>
<td>76°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 4</td>
<td>2079 cc</td>
<td>27%</td>
<td>2766 cc</td>
<td>68°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 5</td>
<td>2182 cc</td>
<td>19%</td>
<td>2023 cc</td>
<td>47°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 6</td>
<td>2943 cc</td>
<td>2%</td>
<td>1729 cc</td>
<td>47°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Correlational Findings: Thoracic Volume

- Strong correlation with T1-T12 thoracic height ($r = 0.85$, 95% CI: 0.94, 0.62)
- Moderate inverse correlation with Cobb angle ($r = -0.59$, 95% CI: -0.84, -0.16)
- Moderate inverse correlation with kyphosis ($r = -0.53$, 95% CI: -0.81, -0.07)
- All correlations statistically significant (p<0.05)
Correlational Findings

Coronal T1-T12 vs Thoracic Volume

- Coronal T1-T12: Red circles
- Cobb Angle: Blue diamonds
- Kyphosis: Black squares

Correlations:
- Coronal T1-T12 vs Thoracic Volume: $r = 0.85$
- Cobb Angle vs Thoracic Volume: $r = -0.59$
- Kyphosis vs Thoracic Volume: $r = -0.53$

University of Minnesota
Driven to Discover
Conclusion

• Growing rod technique effectively increases thoracic volume with subsequent lengthenings
• Increased thoracic space for lung expansion during child growth
• Changes in thoracic volume correlate significantly with other markers such as thoracic height, Cobb angle, and kyphosis
Discussion

- Alternative assessment of spinal deformity and thoracic volume to CT scan, reducing radiation exposure to pediatric patients
- Quantitative analysis and comparison of techniques used to treat EOS and other chest wall and spinal deformities
- May prompt earlier intervention in pediatric patients with severely compromised volume when used as an alternative assessment to pulmonary function testing
- Surgical intervention simulations with patient-specific models may improve pre-op planning and inform treatment decisions
Thank You!