Use of 3D Technology in Assessment and Treatment of EOS

René M. Castelein, MD PhD
Professor and Chair, Department of Orthopaedic Surgery
University Medical Center Utrecht, Utrecht, The Netherlands
r.m.castelein@umcutrecht.nl
Disclosures

- K2M Research Grant
- AO Research Grant
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- Fondation Yves Cotrel Grant 2006 and 2017
Outline:

- Example
- 3D in detail
- How to acquire 3D
Let’s start with a cool example of 3D
Let's start with a cool example of 3D
After 2\textsuperscript{nd} operation: December 9\textsuperscript{th} 2016
February 1\textsuperscript{st} 2017: Lack of anterior support
3D printing
Postoperative June 2017
Postoperative June 2017
How new is 3D?
How new is 3D?

Die Mechanik der Skoliose.
Ein Beitrag zur Lehre von den Missgestaltungen des Knochengerüstes.
Von Prof. G. Hermann Meyer in Zürich.

THE BASIC ANATOMY OF SCOLIOSIS

ROBERT ROAF, LIVERPOOL, ENGLAND
Now: What about this Relative Anterior Overgrowth (RASO)?
2000 Porter: **Idiopathic Scoliosis**

**The Relation Between the Vertebral Canal and the Vertebral Bodies**

Richard W. Porter, FRCS

- The results of this study are consistent with a conceivable hypothesis that in some patients with idiopathic scoliosis, there may be impaired growth in the length of the spinal cord.

<table>
<thead>
<tr>
<th>Lateral view</th>
<th>Antero-posterior view</th>
<th>Antero-posterior view</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Reduction of thoracic kyphosis</td>
<td>B. Lateral deviation</td>
<td>C. Rotation of the apical vertebral body</td>
</tr>
</tbody>
</table>

2001 Porter: **The pathogenesis of idiopathic scoliosis: uncoupled neuro-osseous growth?**

Richard W. Porter

These observations do not establish that a short spinal cord will result in scoliosis, but the results are compatible with this hypothesis, and that impairment of spinal cord growth factors may sometimes be responsible for scoliosis.
+7.1%

1.0 ± 2.7%

+11.2%
Thoracic lordosis
### Disc versus vertebra: ‘Anterior-overgrowth’

#### Main thoracic curve

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebrae</td>
<td>+2.6%</td>
</tr>
<tr>
<td>Discs</td>
<td>+9.8%</td>
</tr>
</tbody>
</table>

+3.9% anterior overgrowth

**P** < .001

#### (Thoraco)lumbar curve

<table>
<thead>
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<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebrae</td>
<td>+3.1%</td>
</tr>
<tr>
<td>Discs</td>
<td>+35%</td>
</tr>
</tbody>
</table>

+9.4%

**P** < .001

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*Anterior-posterior length difference* 
(ΔA-P)
3-D deformity is most in the disc in all regions of the spine!

**Anterior-posterior length difference (ΔA-P)**

- Vertebral bodies
- Intervertebral discs

**Mechanical torsion**

- Vertebral bodies
- Intervertebral discs

Spinal region:
Anterior “overgrowth” specific for idiopathic scoliosis, or secondary to the scoliotic deformity?

CT scans of:
- 30 NM patients
- 30 AIS patients
- 30 Non-scoliotic controls

10-18 years of age

AIS

56° ±13°

NM

52° ±21°
Thoracic lordosis in idiopathic and neuromuscular scoliosis

<table>
<thead>
<tr>
<th></th>
<th>Controls (n=30)</th>
<th>Idiopathic (n=30)</th>
<th>Neuromuscular (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>-3.0%</td>
<td>+1.2%</td>
<td>+0.9%</td>
</tr>
<tr>
<td><strong>Vertebra</strong></td>
<td>-3.4%</td>
<td>-2.5%</td>
<td>-3.5%</td>
</tr>
<tr>
<td><strong>Disc</strong></td>
<td>-1.5%</td>
<td>+17.5%</td>
<td>+19.1%</td>
</tr>
</tbody>
</table>
Congenital scoliosis?
Thoracic lordosis in idiopathic, neuromuscular and congenital scoliosis

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>AIS</th>
<th>NM</th>
<th>Congenital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
<td>-3.0%</td>
<td>+1.2%</td>
<td>+0.9%</td>
<td>+1.1%</td>
</tr>
</tbody>
</table>
Relative anterior lengthening or relative posterior shortening?
3D semi-automatic measurements (CT scans)

Absolute heights (mm): AIS (n=80) vs matched controls (n=30)

* = significant difference between AIS and controls.
So:

- No discussion if RASO exists, all scoliosis are *lordotic* (not hypo-kyphotic)

- RASO is not a generalized phenomenon, it is restricted to the apex of the curve

- It is not active growth, it is passive expansion of the disc and compression of the interspinous space

- It is part of any scoliotic mechanism, idiopathic, neuromuscular, compensatory congenital

- It is not the *cause* of scoliosis, it is its *consequence*!
How to acquire 3D

• CT (gold standard)
• EOS
• Ultrasound
Application of Low-dose Stereoradiography in In Vivo Vertebral Morphologic Measurements: Comparison With Computed Tomography

Saba Pasha, PhD,* Tom Schlösser, MD, PhD,† Xiaowei Zhu, PhD,‡ Xochitl Mellor, BS,* René Castelein, MD, PhD,† and John Flynn, MD*

J Pediatr Orthop • Volume 00, Number 00, □□ 2017
Upright, prone, and supine spinal morphology and alignment in adolescent idiopathic scoliosis

Rob C. Brink¹, Dino Colo¹, Tom P. C. Schlösser¹, Koen L. Vincken², Marijn van Stralen³, Steve C. N. Hui⁴, Lin Shi⁵, Winnie C. W. Chu⁴, Jack C. Y. Cheng⁶ and René M. Castelein¹
Several valid and reliable ultrasound angles

Reliability and accuracy of ultrasound measurements with and without the aid of previous radiographs in adolescent idiopathic scoliosis (AIS)
Michelle Young · Douglas L. Hill · Rui Zheng · Edmond Lou

A reliability and validity study for Scolioscan: a radiation-free scoliosis assessment system using 3D ultrasound imaging
Zheng et al. Scoliosis and Spinal Disorders (2016)

the lifetime solid cancer incidence increases at a rate of 1.4% and 2.4% for men and women, respectively.
Scolioscan
Telefield Medical Imaging Ltd, Hong Kong

2000 transverse images
Scan speed: 1 cm/sec
Methods – X-ray vs. Ultrasound

Cobb X-ray

Manual TP angle

Manual SP angle

Automatic SP angle
Results

Cobb X-ray

Manual TP angle
Manual SP angle
Automatic SP angle

Thoracic
29 ± 11°
21 ± 9°
22 ± 10°
24 ± 9°

Lumbar
38 ± 20°
24 ± 14°
26 ± 13°
30 ± 14°
Excellent linear correlations (validity)

\[ y = 1.55x \]
\[ R^2 = 0.99 \]

\[ y = 1.34x \]
\[ R^2 = 0.98 \]

\[ y = 1.45x \]
\[ R^2 = 0.99 \]

\[ y = 1.26x \]
\[ R^2 = 0.97 \]

\[ y = 1.30x \]
\[ R^2 = 0.99 \]

\[ y = 1.16x \]
\[ R^2 = 0.99 \]
Good to excellent reliability

Patient

Scan 1
- Angles
  - Intra ICC ≥ 0.96

Scan 2
- Angles
  - Inter ICC ≥ 0.93

Scan 1
- Angles
  - Intra ICC ≥ 0.94
  - Inter ICC ≥ 0.84

ICC = interclass correlation coefficient

= observer 1
= observer 2
Conclusions

- Excellent correlations between ultrasound and X-ray
- High reliability
- No differences in reliability and validity between different ultrasound measurements

Scoliosis progression can be assessed without ionizing radiation