3D and 4D Imaging of the Aortic Root

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Conflicts of Interest Disclosure

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Speaker's board: Bracco
Siemens

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Progressive root enlargement (Marfan's) with ECG gating

Jan '04

24 mm

45 mm

30 mm

Nov '04

28 mm

47 mm

32 mm

Sep '05

29 mm

49 mm

33 mm
3D and 4D Imaging of the Aortic Root

Learning Objectives / Outline

- Technique: 'gated chest' CT
- Surgical anatomy of thoracic aorta
- Clinical pre- and postop. imaging in
  - Marfan's disease
  - Bicuspid aortic valve disease / aneurysm
Aortic Root Aneurysms

Etiology and associated conditions

- genetic (congenital wall defect)
  - Marfan's
  - Bicuspid aortic valve
- atherosclerotic
- chronic dissection
- infectious ('mycotic', syphilis)
- vasculitis
- post-traumatic

very common

rare
## Aortic Root Aneurysms (TAA)

### Etiology and associated conditions

**congenital (intrinsic, defect of aortic wall):**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Gene/Protein</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.01-0.02 %)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicuspid AV</td>
<td>↓ fibrillin, ↑ MMP 2</td>
<td></td>
</tr>
<tr>
<td>(1-2 % prevalence)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ehlers-Danlos-IV</td>
<td><em>COL 3A1</em> gene (procollagen III)</td>
<td></td>
</tr>
<tr>
<td>Loeys-Dietz</td>
<td><em>TGFBR1</em> or <em>TGFBR2</em> gene</td>
<td></td>
</tr>
</tbody>
</table>

TGF: transforming growth factor, MMP: matrix metalloproteinase;
**BAV disease**
(bicuspid aortic valve disease)

**Prevalence** 1-2%

**Complications (>33%)**
- valve degeneration and stenosis
- endocarditis
- aortic root dilatation (50% of young pts.)

→ ao. root aneurysm
# Bicuspid aortic valve (BAV) Classification (Sievers)

A classification system for the bicuspid aortic valve from 304 surgical specimens

Hans-H. Sievers, MD, and Claudia Schmidtke, MD, MBA

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**main category:** number of raphes

<table>
<thead>
<tr>
<th>Type 0</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 raphe</td>
<td>1 raphe</td>
<td>2 raphes</td>
</tr>
<tr>
<td>21 (7)</td>
<td>269 (88)</td>
<td>14 (5)</td>
</tr>
</tbody>
</table>

**1. subcategory:** spatial position of cusps in Type 0 and raphes in Types 1 and 2

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-R</td>
<td>R-N</td>
<td>N-L</td>
<td>L-R/N-R-N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>216 (71)</td>
<td>45 (15)</td>
<td>8 (3)</td>
<td>14 (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**2. subcategory:** valvular function

<table>
<thead>
<tr>
<th>Type 0</th>
<th>Type 1</th>
<th>Type 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>s</td>
<td>b+s</td>
</tr>
<tr>
<td>6 (2)</td>
<td>1 (0.3)</td>
<td>79 (26)</td>
</tr>
<tr>
<td>7 (2)</td>
<td>5 (2)</td>
<td>119 (39)</td>
</tr>
<tr>
<td>1 (0.3)</td>
<td>15 (5)</td>
<td>7 (2)</td>
</tr>
<tr>
<td>3 (1)</td>
<td>1 (0.3)</td>
<td></td>
</tr>
</tbody>
</table>

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Sievers et al.; J Thorac Cardiovasc Surg 2007;133:1226-33
BAV disease
(bicuspid aortic valve disease)
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• Technique: 'gated chest' CT

• Surgical anatomy of thoracic aorta

• Clinical focus
  pre and postoperative imaging
  - Marfan's disease
  - Bicuspid aortic valve disease / aneurysm
**EKG gated CTA of the Thorax**
(16-channel MDCT)

*Gated Chest*

- entire thoracic aorta
- not thinnest collimation (1.25mm)
- no beta-blockers, no subling. nitro
- recon. 10 phases (0–90% of RR interval)
- no ECG-pulsing (constant mA)
**EKG gated CTA of the Thorax**
(16-channel MDCT)

<table>
<thead>
<tr>
<th>'Gated Chest'</th>
<th>Coronary CTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• entire thoracic aorta</td>
<td>• heart</td>
</tr>
<tr>
<td>• not thinnest collimation (1.25mm)</td>
<td>• thinnest collimation (0.75 mm)</td>
</tr>
<tr>
<td>• no beta-blockers, no subling. nitro</td>
<td>• beta-blockers, and subling. nitro</td>
</tr>
<tr>
<td>• recon. 10 phases (0–90% of RR interval)</td>
<td>• recon. 1 diastolic phase (65% of RR)</td>
</tr>
<tr>
<td>• no ECG-pulsing (constant mA)</td>
<td>• ECG pulsing on (dose reduction)</td>
</tr>
</tbody>
</table>
s/p  Ross procedure (pulmonary- to aorta autograft)
susp. leak/pseudoaneurysm

diastole  systole
“Gated Chest”
Dual-Source CT

Advantages:
- motion-'free' (3D) and dynamic (4D) visualization of thor. aorta + aortic root
- high 3D spatial resolution (0.5mm³)

Limitations:
- temporal resolution (~165ms) (~85ms)
- allows ECG-dose modulation
- radiation dose (25-50mSv*) (8-15mSv)

*(~3-6 times of std.chest CT)
58 yo woman

- abnormal valve (BAV?),
- aneurysmal aortic root
- LV dilatation, low-normal EF
- 53kg (117 lbs)
- 65 bpm heart rate

→ 100 kVp
→ ECG pulsing (30-70% of RR Interval)
Gated Chest, Dual-Source CT
27.01 mGy, (667mGy*cm), [~11mSv]

58 yo woman

→ 100 kVp
→ ECG pulsing (30-70% of RR Interval)
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**Thoracic Aorta Surgical Anatomy**

**Descending Aorta**

**Transverse Aorta**

**Ascending Aorta**

**Aortic Root**

- Sinotubular junction
- Sinuses of Valsalva
  - aortic valve
  - coronary ostia
- Aortic anulus

* Sino-tubular Junction
# Sinuses of Valsalva
## Normal diameter of thoracic aorta

<table>
<thead>
<tr>
<th>Anulus</th>
<th>Normal</th>
<th>23-27mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;27mm</td>
<td>Anuloaortic ectasia</td>
<td></td>
</tr>
</tbody>
</table>

### Thoracic aorta (incl. sinuses and STJ)

<table>
<thead>
<tr>
<th>Normal</th>
<th>Age-, sex-, body size dependent</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Ectatic'</td>
<td>Appears enlarged, but ≤4cm</td>
</tr>
<tr>
<td>&gt;4.0 cm</td>
<td>Aneurysm (root, asc., tra., desc.)</td>
</tr>
</tbody>
</table>

### Treatment indication (elective)

- >4.5-5.0cm (Syndromic patients)
- >6.0 +cm (Degenerative)
- Rapid diameter increase (>5mm/year)
- Ao. root Valve insufficiency
• 73 y/o retired RN
  ascending aortic aneurysm

MIP (thin-slab) centered at valve
Interactive Visualization – Interpretation

- **3D thoracic Aorta**
  - VR (candy-cane view)

- **Measurements**
  - MIP (5mm) ~ a-p
  - MIP (5mm) ~ lat.
  - (MPR orthogonal)

- **Coronary Anatomy**
  - VR

- **Sinuses + valve**
  - VR 'transparent'
  - MinIP (inverted)
  - 3 Chamber view
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Thoracic Aorta Surgical Options

Aortic Root

- **Anuloplasty**

- **Composite graft**
  - Contains valve
  - Coronary reimplantation

- **Valve Sparing Surgery**
  - Resect sinuses down to valve insertions
  - Preserve native valves
  - Coronary reimpl.
41 yo man
Marfan's

sinus of Vals.
anulus

sin.tub.-junct.
Valve Sparing Aortic Root Procedures
Tirone David - I "Reimplantation" Technique
27 y/o man, Marfan's
Surgical procedure

- coronary ostium
- valve leaflets
- coronary reimplanted
Bicuspid Aortic Valve

Raphe 'L+R' leaflet

Severe prolaps of R+L - leaflet
Bicuspid Aortic Valve

Severe prolapse of R/L-cusp due to rupture of commissural suspensory 'chord'

'L+R' sinus raphe/chord
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SUMMARY

- Technique: 'gated chest' CT
- Surgical anatomy of thoracic aorta
- Clinical focus
  - pre and postoperative imaging
  - Marfan's disease
  - Bicuspid aortic valve
Thank you..

DC Miller
RS Mitchell
M Fischbein