The Aorta - Where Do We Measure and What is Normal From Newborn to Older Children

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Disclosures

• No financial disclosures
• Off label use of gadolinium
Why do we measure?

• To know what is normal
• To follow imaging trends over time
• To guide us in clinical decision making

Intervention guidelines based on:
  – Too large
  – Too small
Where do we measure?

Annulus

Journal of Cardiovascular Magnetic Resonance 2008, 10:56
Why not just use echocardiography?

- Echocardiography of the aorta uses planar measurements not double-oblique measurements.
- Planar image is created along the aortic long axis.
- Only one diameter measured at a given level.
- Assumes that:
  1) The plane selected precisely bisects the aorta
  2) The aorta is perfectly round.
- Limitations: suboptimal acoustic windows
Aortic “annulus”: measuring the unicorn
What aortic annulus dimension should we use?

Annulus dimension:
- systole: 22.4 mm ± 2.1
- diastole: 22.2 mm ± 2.4

Annulus dimension:
- systole: 25.7 mm ± 2.1
- diastole: 26.2 mm ± 2.3

(Circ Cardiovasc Imaging. 2008;1:104-113.)
Measuring aortic SOV by MRI/CT vs echo

“echocardiographic parasternal long axis view ≈ MR/CT 3-chamber view”
What happens as the aorta dilates...elongates?
Measuring aorta by MRI/CT vs echo
MRI/CT: SOV double oblique measurements

Pediatr Cardiol. 2015 Jul 15.
Challenges:
What is the correct way to measure the SOV?

• Systole vs diastole?
• Cusp to commissure vs cusp to cusp?
• Inner edge to inner edge vs external diameter?
• Which MR technique?
Challenges:
Asymmetry of the aortic sinuses of Valsalva
• 11 of 15 patients (73%), largest aortic root diameter was not the diameter measured with echocardiography (RC cusp to NC cusp), 42 ± 7 mm
• RC cusp to LC cusp was largest (46 ± 7mm)
MRI/CT: SOV double oblique measurements
Bicuspid aortic valve

4.93 cm
4.23 cm
5.0 cm
4.39 cm
5.02 cm
4.29 cm
5.00 cm
Which CMR technique is best?
Asymmetry of the aortic root: STJ

- The non-coronary sinus is the tallest in height with the largest volume → NC > R > L
- Thus, the plane of the sinotubular junction does not lie parallel to a plane joining the bases of the sinuses but has a tilt of 11°


![Diagram showing measurements of different sinuses](image-url)
MRI/CT: AAo double oblique measurements

4.37 cm

4.37 cm
MRI/CT: TAO/DAO
double oblique measurements

Pediatr Cardiol. 2015 Jul 15.
What are the normal pediatric aortic dimensions?

- Limited normative data for the aorta using cross-sectional imaging with computed tomography (CT) and magnetic resonance (MR) imaging in children
- More difficult to know what is normal in children who change greatly in size over the course of childhood
- Difficult and/or unethical to recruit healthy children as volunteers for a CMR or CT studies
What is out there to guide us:
How to measure

• For CT or CMR aortic measurements:
  – “the external diameter should be measured perpendicular to the axis of blood flow.”
has led to nonuniformity in measurement techniques. Moreover, there is currently no standardized approach for reconciling aortic measurements across imaging modalities (echocardiography, CT, MRI, aortography) by trigger time (end-systole vs end-diastole) or by edge selection (leading edge, inner-inner, outer-outer). This writing committee had hoped to recommend a uniform and consistent measurement technique to minimize differences among these various imaging modalities. However, after much consideration, the group recommends that echocardiographic measurements continue to be made in the standard fashion from leading edge to leading edge, at end-diastole, and perpendicular to the long axis of the aorta. The advantages of end-diastolic measurements include greater reproducibility (because aortic pressure is most stable in late diastole) and the ease of identification of end-diastole by the onset of the QRS
What is out there to guide us?

CT

- CT scans on 137 patients
  - 88 chest
  - 110 abdomen/pelvis
- Patients were 0 to 20 years (mean, 9.9 years)
- BSA ranging from 0.19 to 2.52 m²
- Images reconstructed using axial 0.5mm collimation.
- Multiplanar reformations were double-oblique reconstructions obtained perpendicular to the aorta
- Data used to create z-scores
What is out there to guide us?

CT

Table 1

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>No. of Male Patients</th>
<th>No. of Female Patients</th>
<th>All (n)</th>
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<tbody>
<tr>
<td>0–2</td>
<td>11 (15)</td>
<td>9 (15)</td>
<td>20 (15)</td>
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<tr>
<td>3–5</td>
<td>12 (16)</td>
<td>12 (19)</td>
<td>24 (18)</td>
</tr>
<tr>
<td>6–11</td>
<td>14 (19)</td>
<td>12 (19)</td>
<td>26 (19)</td>
</tr>
<tr>
<td>12–16</td>
<td>20 (27)</td>
<td>22 (35)</td>
<td>42 (31)</td>
</tr>
<tr>
<td>17–20</td>
<td>18 (24)</td>
<td>7 (11)</td>
<td>25 (18)</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>62</td>
<td>137</td>
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</tbody>
</table>

Note.—Numbers in parentheses are percentages.
What is out there to guide us?

CT

- limitations of study:
  - ECG gating is not routinely performed for torso CT imaging.
  - Measurements are neither end-systolic nor end-diastolic
  - Measurements are not a true maximum or minimum aortic diameter.
- number of patients included in the study:
  - 88 thoracic studies
  - 110 abdominal studies
What is out there to guide us?

CT

• non-ECG gated CTA measurements are obtained at random phases during the cardiac cycle.

(J Vasc Surg 2014;59:74-9.)
What is out there to guide us?

CT

- ECG gated CTA measurements are different when taken in systole vs diastole.
Ascending Aortic and Main Pulmonary Artery Areas Derived From Cardiovascular Magnetic Resonance as Reference Values for Normal Subjects and Repaired Tetralogy of Fallot

Shelby Kutty, MD; Titus Kuehne, MD, PhD; Paul Gribben, BS; Eric Reed, MD; Ling Li, MD, PhD; David A. Danford, MD; Philipp B.J. Beerbaum, MD, PhD; Samir Sarikouch, MD, PhD

(Circ Cardiovasc Imaging 2012;5:644-651.)
Normal values of aortic dimensions, distensibility, and pulse wave velocity in children and young adults: a cross-sectional study

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age classes (years)</th>
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<tr>
<td></td>
<td>-5</td>
<td>5 - 10</td>
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<tr>
<td>male</td>
<td>n 2</td>
<td>10</td>
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<tr>
<td></td>
<td>% 6.7%</td>
<td>33.3%</td>
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<tr>
<td>female</td>
<td>n 2</td>
<td>7</td>
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<tr>
<td></td>
<td>% 4.9%</td>
<td>17.1%</td>
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<tr>
<td>Total study group</td>
<td>n 4</td>
<td>17</td>
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<tr>
<td></td>
<td>% 5.6%</td>
<td>23.9%</td>
</tr>
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</table>

Voges et al. Journal of Cardiovascular Magnetic Resonance 2012, 14:77
Normal values for aortic diameters in children and adolescents – assessment in vivo by contrast-enhanced CMR-angiography

Thomas Kaiser¹, Christian J Kellenberger², Manuela Albisetti³, Eva Bergsträsser⁴ and Emanuela R Valsangiacomo Buechel*¹
Conclusions

• In the absence of available standards/normative data and…

• Given the large number of possible image acquisition techniques and measurement techniques

• Goal at this time would be to avoid the introduction of variability in serial measurements reported by different observers.

• Variability can be minimized by carefully documenting in the report how images are obtained, how measurements were performed, and directly comparing with previous studies.

• Long-term goal would be to standardize measurement techniques and pool normative data