Pathophysiology in CHD: Normal Structure Measurements – Aorta and Valves

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Disclosure Information

I have no relevant financial relationships to disclose.
Learning Objectives

• Review the anatomy of the aorta

• Review techniques of aortic measurement and recognize the cardiovascular implications thereof.

• Review anatomy of cardiac valves
Background

• Methods for obtaining and reporting aortic measurements can vary significantly
• Age, sex and BSA correlate with the aortic size
• Surgical interventions are based on measurements in aortic aneurysms
• CT and CMR are ideally suited – 3D, high quality
Aorta: Histopathology
Comparison of Methods For Imaging Aorta

<table>
<thead>
<tr>
<th>Advantages/disadvantages</th>
<th>TTE</th>
<th>TOE</th>
<th>CT</th>
<th>MRI</th>
<th>Aortography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Diagnostic reliability</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
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<td>++</td>
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<tr>
<td>Bedside/interventional use</td>
<td>++</td>
<td>++</td>
<td>-</td>
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<td>++</td>
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<tr>
<td>Serial examinations</td>
<td>++</td>
<td>+</td>
<td>+++(+)</td>
<td>+++</td>
<td>-</td>
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<tr>
<td>Aortic wall visualization</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>-</td>
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<tr>
<td>Cost</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Radiation</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nephrotoxicity</td>
<td>0</td>
<td>0</td>
<td>-</td>
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</table>

+ means a positive remark and—means a negative remark

2014 ESC Guidelines on the diagnosis & treatment of aortic diseases
Techniques of Aortic Measurement: Echo

- Echocardiography is usually the first study
- Best suited to evaluate the aortic root and concomitant aortic valve function
- Normal range for aortic diameter at the SoV in age categories stratified by BSA are widely used
- Several blind spots and other patient specific limitations
95% confidence intervals for aortic root diameter at the SoV based BSA in: children & adolescents (A), adults 20-39 years (B) adults ≥ 40 years (C).

Roman MJ et al. Am J Cardiol 1989
Techniques of Aortic Measurement: CT and MR

- CT and CMR offer thorough evaluation
- Precise measurements using 3D datasets
- Best results with ECG gating
- Contrast and radiation exposure with CT
- 3D Balanced SSFP with prospective ECG triggering and respiratory navigation offer high SNR
3D vs. 2D Measurements of Aorta

5.6 cm maximal diameter

8.0 maximal diameter

Eric M. Isselbacher Circulation. 2005
MRA of Aorta

• Advantages of CMR in aortic imaging
  – Many choices of imaging planes
    • Sagittal, coronal, axial
  – Large area of aorta covered
  – Many imaging techniques
    • Anatomy, cine, angiography, flow
  – No ionizing radiation

• In acute setting consider alternative imaging - TEE (portable, fast) or CT (fast)
MRA of Aorta

Imaging planes used for reconstruction of cross sectional views
Segments of the ascending and descending aorta
Landmarks: Ascending Aorta
Normal Values of Aorta in Children and Adolescents: MRA

- z-value = \( \frac{\text{measured diameter} - \text{predicted diameter}}{\text{standard deviation of residuals}} \).

- Normative diameters
  - \((0.57 + 19.37 \times \text{BSA}^{0.5})\) mm for the aortic sinus
  - \((-3.52 + 18.66 \times \text{BSA}^{0.5})\) mm for the aortic arch
  - \((-3.37 + 16.52 \times \text{BSA}^{0.5})\) mm for the isthmic region
  - \((-1.27 + 9.89 \times \text{BSA}^{0.5})\) mm for the descending aorta at the level of the diaphragm.

Kaiser T, et al

*Journal of Cardiovascular Magnetic Resonance* 2008,
Range of Aortic Measurements in Children and Adolescents

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Median</th>
<th>(Range)</th>
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<tbody>
<tr>
<td>AS (mm)</td>
<td>20.7</td>
<td>(13.8 – 31.8)</td>
</tr>
<tr>
<td>STJ (mm)</td>
<td>17.5</td>
<td>(11.1 – 26.4)</td>
</tr>
<tr>
<td>AA (mm)</td>
<td>18.0</td>
<td>(12.0 – 26.7)</td>
</tr>
<tr>
<td>BCA (mm)</td>
<td>17.7</td>
<td>(11.4 – 26.0)</td>
</tr>
<tr>
<td>T1 (mm)</td>
<td>16.2</td>
<td>(9.6 – 25.1)</td>
</tr>
<tr>
<td>T2 (mm)</td>
<td>14.7</td>
<td>(9.4 – 22.9)</td>
</tr>
<tr>
<td>IR (mm)</td>
<td>14.0</td>
<td>(8.8 – 24.9)</td>
</tr>
<tr>
<td>DA (mm)</td>
<td>14.4</td>
<td>(9.1 – 22.6)</td>
</tr>
<tr>
<td>D (mm)</td>
<td>11.7</td>
<td>(7 – 17.3)</td>
</tr>
</tbody>
</table>
2014 ESC Guidelines on Aortic Diseases

Ascending aorta

Aortic arch
22–36 mm

Tubular ascending aorta
22–36 mm
(15 ± 2 mm/m²)

Sinotubular junction
22–36 mm
(15 ± 1 mm/m²)

Sinuses of Valsalva
29–45 mm
(19 ± 1 mm/m²)

Aortic annulus
20–31 mm
(13 ± 1 mm/m²)

Descending aorta
20–30 mm

Innominate artery

Left common carotid artery

Left subclavian artery

Ligamentum arteriosum

Diaphragm

PA
The most common aortic arch branching pattern found in humans has separate origins for the innominate, left common carotid, and left subclavian arteries.

The second most common pattern of human aortic arch branching has a common origin for the innominate and left common carotid arteries.

In this variant of aortic arch branching, the left common carotid artery originates separately from the innominate artery.

The aortic arch branching pattern found in cattle has a single brachiocephalic trunk originating from the aortic arch and eventually splits into the bilateral subclavian arteries and a bicarotid trunk.
Right Aortic Arch

- Low prevalence – 0.5%
- 25% of TOF patients
- Dysphagia and asthma symptoms
- Type I
  - Mirror image branching of great vessels
  - Compression by enlarged aorta or atretic ductus
- Type II
  - Aberrant L subclavian runs posterior to trachea (Kommerell diverticulum)
- Fragile and prone to aneurysm formation, AoD
Aortic Arch: R and L

I Left aortic arch
II Right aortic arch

A Right common carotid artery
B Left common carotid artery
C Right subclavian artery
D Left subclavian artery
Aortic Valve

- Right Ventricle
- Tricuspid Valve
- Right Atrium
- Posterior Cusp
- Right Cusp
- RVOT
- Comissure
- Left Cusp
- Aorta Descendens
Aortic Valve: Short Axis

Basal attachment of the leaflets do not transect the full diameter of the outflow tract but instead a tangent cut across the root.

Bicuspid Aortic Valve and Aortopathy

Bicuspid AV

Aortic medial changes
Normal Mitral Anatomy

Seguela et al.
Achieves of Cardiovascular Disease 2011
Tricuspid Valve

Right Leaflet

Tricuspid Valve Orifice

Posterior Leaflet

Mitral Valve

Left Leaflet
Normal Tricuspid Valve Anatomy

Badano et al. Eur Heart J 2009
Pulmonary Valve

- Ascending Aorta
- Right Atrium
- Left Atrium
- Pulmonary Valve
- Descending Aorta
Normal Pulmonary Valve Anatomy

Saremi et al. Radiographic 2014
Pulmonary Valve Stenosis

Saremi et al. Radiographic 2014
Key Elements

Assessment of stenotic and regurgitant valves

• What is the cause?
• How much is there?
• How does it affect the heart?
Summary

• Multimodality imaging maybe necessary for a comprehensive assessment of the aorta and valvular structures.

• CMR comes close to providing a one-stop shop approach in the evaluation aorta and valves.

• Accurate aortic measurements is critical since it affects medical and surgical management.