Multimodality Imaging in Aortic Diseases:

Federico M Asch MD, FASE, FACC
Chair, ASE Guidelines and Standards Committee

MedStar Washington Hospital Center
MedStar Health Research Institute
Georgetown University
Washington, DC

January 2018

I have no financial disclosures related to this presentation
GUIDELINES AND STANDARDS

Multimodality Imaging of Diseases of the Thoracic Aorta in Adults: From the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Endorsed by the Society of Cardiovascular Computed Tomography and Society for Cardiovascular Magnetic Resonance

Steven A. Goldstein, MD, Co-Chair, Amaro Evangelista, MD, FESC, Co-Chair, Sahny Abbara, MD, Andrew Arul, MD, Federico M. Asch, MD, FASE, Lujo P. Badano, MD, PhD, FESC, Michael A. Bolen, MD, Heidi M. Connolly, MD, Hugo Cuellar-Calibria, MD, Martin Giering, MD, Richard B. Desvresses, MD, Raimund A. Erbel, MD, FASE, FESC, Rossella Fornari, MD, Eric M. Iselbacher, MD, Joseph M. Linshay, MD, Marti McCall, MBA, RDCT, FASE, Hector L. Michalena, MD, FASE, Christoph A. Nienaber, MD, FESC, Jie K. Obi, MD, FASE, Mauro Pepi, MD, FESC, Allen J. Taylor, MD, Jonathan W. Weissman, MD, Jose Luis Zamorano, MD, FESC, FASE, Contributing Editors: Harry Dietz, MD, Kim Eagle, MD, John Eikert, MD, Guillaume Jordeau, MD, PhD, FESC, Herve Rousseau, MD, PhD,


Survey for Imaging of the Aorta

Survey for Imaging of the Thoracic Aorta

Dear Imager,

A committee of international experts is working on a document titled “Multimodality Imaging of the Thoracic Aorta.” In an attempt to canvas the opinions and comments of a large number of both academic and clinical imagers, we would appreciate your input by responding to a very brief (only 10 questions) questionnaire on some select methodologic issues. Please reply to the following brief survey at your earliest convenience.

Thank you very much.
Survey for Imaging of the Aorta

1. Uniform protocol for measuring aorta

   - Inner-to-inner: 58%
   - Outer-to-outer: 42%

2. Which of the following is your recommended/preferred time to measure the aortic root?

   - End-systole: 44%
   - End-diastole: 56%
Survey for Imaging of the Aorta

3. Which of the following do you consider to be the reliable level of resolution of current imaging modalities?

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>41%</td>
</tr>
<tr>
<td>2 mm</td>
<td>47%</td>
</tr>
<tr>
<td>3 mm</td>
<td>6%</td>
</tr>
<tr>
<td>4 mm</td>
<td>6%</td>
</tr>
<tr>
<td>5 mm</td>
<td>0%</td>
</tr>
</tbody>
</table>

Survey for Imaging of the Aorta

4. Which of the following degrees of enlargement do you feel is significant during annual/serial follow-up of aortic size?

<table>
<thead>
<tr>
<th>Enlargement</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2 mm</td>
<td>18%</td>
</tr>
<tr>
<td>&gt;3 mm</td>
<td>23%</td>
</tr>
<tr>
<td>&gt;4 mm</td>
<td>24%</td>
</tr>
<tr>
<td>&gt;5 mm</td>
<td>35%</td>
</tr>
</tbody>
</table>
Imaging Techniques

- Chest X-ray
- Echo (TTE, TEE, 3D-echo, epiaortic)
- Intravascular echo (IVUS)
- Intracardiac echo (ICE)
- CT/MDCT
- Magnetic resonance imaging
- Aortography
Diseases of the Thoracic Aorta

• **Acute aortic syndromes**
  - Aortic dissection
  - Intramural hematoma
  - Penetrating aortic ulcer
  - Ruptured aortic aneurysm

• **Thoracic aortic aneurysms**
  - Bicuspid aortic valve-related aortopathy
  - Marfan syndrome
  - Other genetic diseases
    (Ehlers-Danlos; Loeys-Dietz, Turner syndrome, etc)

Diseases of the Thoracic Aorta

• **Traumatic injury of thoracic aorta**

• **Aortic coarctation**

• **Atherosclerosis**

• **Aortitis**
  - Noninfectious
  - Infectious
Measuring the Aorta

What to look for?

• Aortic Valve morphology
• Normal Aortic size in the adult:
  – Ao root < 40 mm
  – Ascending Ao < 37 mm
  – Descending Aorta < 28 mm
• These values are, however, very variable.
Aortic size to be adjusted by body size and age

< 20 yo  
20-40 yo  
> 40 yo

Roman M et al. Am J Cardiol 1989;64:507

Complications and Asc Ao size
Importance of accurate measurements

Elefteriades, JACC 2010;55:841
Complications and Asc Ao size
Importance of accurate measurements

Elefteriades, JACC 2010;55:841

Asc Aortic size at time of Type A Dissection

Pape et al for IRAD. Circulation 2007;116:1120
Aortic size predicts dissection even after prophylactic aortic graft surgery

- Reproducibility is similar in all modalities. A variation error in aortic measurements of $\pm 3$mm should be assumed.
- Consider:
  - 2D vs 3D methods
  - Gated imaging to select timing of the cardiac cycle
  - Blind spots / area of interest
  - Frequency of required follow-up
  - Additional benefit of each technique
  - Contraindications for each modality
  - Availability and expertise at each center

Which test to order?
TTE vs TEE vs CT vs MRI
Most importantly, measurements are very variable among different imaging modalities and even within each modality. For proper follow-up, it is critical to use the same modality and compare side to side images.

**MDCT**

**Strength:**
- 3D – Multiplanar
- Entire aorta and branches
- Landmarks/site

**Weaknesses:**
- Need for contrast
- Radiation
- Ao Root (non-gated)
- Cross-sections (axial CT)
TTE

Strengths:
- Aortic Root, AI
- Standardized measurements
- Availability
- Safety
- Great Screening tool for
  - Ascending aorta
  - Arch
  - Abdominal aorta

Weaknesses:
- All other segments

TEE

Strength:
- Accurate measurements
- Other cardiac structures

Weaknesses
- Blind spot: Arch and vessels
- No landmarks
- Tortuous Aorta
- Frequent follow-ups
- Semi-invasive
**MRI**

**Strength:**
- 3D – Multiplanar
- Entire aorta and branches
- Aortic walls
- Landmarks/site
- No contrast
- No Radiation

**Weaknesses:**
- Contrast (MRA)
- Ao Root (non-gated)

**Elongation and tortuosity can induce measurement errors**

Elefteriades, JACC 2010;55:841
Echo vs CT measurements- GenTAC

- 189 cases without grafts were identified with echo and CT performed within 30 days, and no events in-between.

- Inner edge to inner edge, systolic measurements.
Sinus of Valsalva = good correlation

N = 109  
ICC = 0.82

SinoTubular Junct = good correlation

N = 94  
ICC = 0.75
Asc Aorta = good correlation

N=87
ICC=0.77

AV Annulus – poor correlation

N=94
ICC=0.49

For cases with Gated CT:
N=23, ICC=0.74
Standardization of measurements is critical for reproducibility.

Variation between clinical centers and Core lab was lower for Echo than CT/MRI.

Measurement technique should be standardized for:
- All imaging modalities
- All Age groups
GUIDELINES AND STANDARDS

Multimodality Imaging of Diseases of the Thoracic Aorta in Adults: From the American Society of Echocardiography and the European Association of Cardiovascular Imaging
Endorsed by the Society of Cardiovascular Computed Tomography and Society for Cardiovascular Magnetic Resonance

Steven A. Goldstein, MD, Co-Chair; Amaro Evangelista, MD, FESC, Co-Chair; Sahar Abbada, MD; Andrew Arai, MD, Federico M. Asch, MD, FASE; Luigi P. Badano, MD, PhD, FESC; Michael A. Bolen, MD; Heidi M. Connolly, MD; Hug Cador-Caballa, MD; Martin Gervers, MD; Richard R. Desvignes, MD; Raimund A. Erbel, MD, FASE, FESC; Rossella Fantoni, MD; Eric M. Finkelstein, MD; Joseph M. Fijnheer, MD; Mari McCulloch, MBA, BDGS, FASE; Floret I. Michaux, MD, FASE; Christoph A. Nienaber, MD, FESC; Jae K. Oh, MD, FASE; Mauro Pepi, MD, FESC; Allen J. Taylor, MD; Jonathan W. Weissfarb, MD; Jose Luis Zamorano, MD, FESC, FASE; Contributing Editors: Harry Dietz, MD, Kim Eagle, MD; John Ekerdt, MD, Guillaume Jordeau, MD, PhD, FESC; Hervé Rousseau, MD, PhD;

Measure perpendicular to the long-axis of the aorta

Measurement Options

- Inner edge-inner edge
- Outer-outer
- Leading edge-leading edge
Recommended time to measure the aortic root

A. End-systole

B. End-diastole

- Greater reproducibility
  (Ao pressure more stable in late diastole)

- End-diastole easy to ID by QRS

Differences in Measurement timing and technique are small

Table 17: Recommendations for choice of imaging modality for TAA

<table>
<thead>
<tr>
<th>Modality</th>
<th>Recommendation</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>First-line</td>
<td>• First-line technique for staging, surveillance • Contrast enhanced CT and MRI very accurate for measuring size of all TAs (superior to echocardiography for distal ascending aorta, arch, and descending aorta) • All segments of aorta and aortic branches well visualized</td>
<td>• Use of ionizing radiation and IOM • Cardiac motion can cause imaging artifacts</td>
</tr>
<tr>
<td>MRI</td>
<td>Second-line</td>
<td>• Ideal technique for comparative follow-up studies • Excellent modality in stable patients • Preferred for follow-up for younger patients • Avoids ionizing radiation • Can image entire aorta</td>
<td>• Examination times longer than CT • Benefits from patient cooperation (breath hold) • Limited in emergency situations in unstable patients and patients with implantable metallic devices • Benefits from gadolinium</td>
</tr>
<tr>
<td>TTE</td>
<td>Second-line</td>
<td>• Usually diagnostic for aneurysms affecting aortic root • Useful for timely screening • Useful for following aortic root disease • Excellent reproducibility of measurements</td>
<td>• Distal ascending aorta, arch, and descending aorta not reliably imaged</td>
</tr>
<tr>
<td>TEE</td>
<td>Third-line</td>
<td>• Excellent for assessment of AR mechanisms • Excellent images of aortic root, ascending aorta, arch, and descending thoracic aorta</td>
<td>• Less valuable for routine screening or serial follow-up (semi-invasive) • Distal ascending aorta may be poorly imaged • Does not permit full visualization of arch vessels • Limited landmarks for serial examinations</td>
</tr>
<tr>
<td>Aortography</td>
<td>Third-line</td>
<td>• Reserved for therapeutic intervention • Useful to guide endovascular procedures</td>
<td>• Invasive; risk for contrast-induced nephropathy • Visualizes only aortic lumen • Does not permit accurate measurements</td>
</tr>
</tbody>
</table>

LV, L. ventricular.
Thoracic Aortic Aneurysms

Table 15  Etiologies of TAAs

1. Marfan syndrome
2. BAV-related aortopathy
3. Familial TAA syndrome
4. Ehlers-Danlos syndrome type IV (vascular type)
5. Loeys-Dietz syndrome
6. Turner syndrome
7. Shprintzen-Goldberg (marfanoid-craniosynostosis) syndrome
8. Noninfectious aortitis (e.g., GCA, TA, nonspecific arteritis)
9. Infectious aortitis (mycotic syndrome)
10. Syphilitic aortitis
11. Trauma
12. Idiopathic
You want to explore the ENTIRE Aorta, AT LEAST ONCE

Acute Aortic Syndromes
Dissection: Descending Thoracic Aorta

Mechanisms of Aortic Regurgitation
Intramural Hematoma

Ulcerated Aortic Plaque
Summary

Regardless of the Imaging Modality, methods should be unified

Leading edge,
End diastole

Table 5: Practical assessment of five imaging modalities in the evaluation of suspected AAS

<table>
<thead>
<tr>
<th>Advantages of modality</th>
<th>CTA</th>
<th>TTE</th>
<th>TEE</th>
<th>MRA</th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Readily available</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Quickly performed</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Performed at bedside</td>
<td>–</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Noninvasive</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>No iodinated contrast</td>
<td>–</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>No ionizing radiation</td>
<td>–</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>–</td>
</tr>
<tr>
<td>Cost</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>

CTA, Computed tomographic angiography; ++++, very positive; ++, positive; +, fair; −, no.
Adapted from Cigarroa et al.\textsuperscript{182} and Isselbacher.\textsuperscript{419}
Summary

• Indications for specific modality depends on:
  - Accuracy for specific diseases
  - Availability
  - Cost/benefit ratio

• TTE used most often for aortic root assessment

Summary

• CT-scan → high resolution of entire aorta including arch, mesenteric, and renal vessels

• MRI → greatest morphologic and dynamic information without radiation, but less widely available

• TEE → optimal procedure for guidance in OR safely performed in critically ill patients, even those on ventilators
Diseases of the Aorta

QUIZ

Which factor is most important to optimize Aortic diameter measurements reproducibility?

- A - Measure always in end diastole
- B - Use Leading edge to leading edge convention
- C - Use same imaging modality and methods with side by side comparison
- D - Only use CTA as it is more reliable and accurate
Which factor is most important to optimize Aortic diameter measurements reproducibility?

- A - Measure always in end diastole
- B - Use Leading edge to leading edge convention
- C - Use same imaging modality and methods with side by side comparison
- D - Only use CTA as it is more reliable and accurate

Thank you