Multimodality Imaging of Diseases of Thoracic Aorta

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DISCLOSURE

I have NO relevant financial relationships
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

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www.asecho.org → Guidelines
Multimodality Imaging of the Aorta

Special Features ("unique")

1. Uniform protocol for measuring aorta
   - Leading edge to leading edge
   - Inner-to-inner
   - Outer-to-outer

2. Variability of measurements (what represents real change: 2, 3, 4, 5 mm?)

3. Firstline, secondary tests for each entity

continued . . .
Measuring The Aorta
Measure perpendicular to the long-axis of the aorta
Imaging Modalities
Imaging Techniques

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

continued . . .
Diseases of the Thoracic Aorta

- Traumatic injury of thoracic aorta
- Aortic coarctation
- Atherosclerosis
- Aortitis
  - Noninfectious
  - Infectious
Acute Aortic Syndromes
Acute Aortic Syndromes

- Aortic dissection
- Intramural hematoma
- Penetrating aortic ulcer
- Ruptured aortic aneurysm
Acute Aortic Syndromes

- Delay in recognition and treatment is associated with unacceptable increase in mortality
- Signs and symptoms may be subtle/atypical
- Diagnosis requires high index of suspicion
Aortic Dissection
Aortic Dissection - Imaging

Primary Objectives

- Identify entry site
- Determine type A vs B
- Involvement of coronary arteries?
- Identify complications:
  - Presence, severity, mechanism of AR
  - Pericardial or pleural effusion
  - Rupture?
  - Branch ischemia
<table>
<thead>
<tr>
<th>Modality</th>
<th>Recommendation</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| **CT**   | First-line     | - Initial test in >70% of patients*  
- Widely available, quickest diagnostic times  
- Very high diagnostic accuracy  
- Relatively operator independent  
- Allows evaluation of entire aorta, including arch vessels, mesenteric vessels and renal arteries  | - Ionizing radiation exposure  
- Requires iodinated contrast material  
- Pulsation artifact in ascending aorta (can be improved with ECG gating)  |  |
| **TEE**  | First- and second-line | - Very high diagnostic accuracy in thoracic aorta  
- Widely available, portable, convenient, fast  
- Excellent for pericardial effusion, and presence, degree and mechanism(s) of AR and LV function  
- Can detect involvement of coronary arteries  
- Safely performed on critically ill patients, even those on ventilators  
- Optimal procedure for guidance in OR  | - Operator dependent (depends on skill of operator)  
- “Blind spot” upper ascending aorta, proximal arch  
- Not reliable for cerebral vessels, celiac trunk, SMA, etc.  
- Reverberation artifacts can potentially mimic dissection flap (can be differentiated from flaps in vast majority)  
- Semi-invasive  |  |
| **TTE**  | Second-line    | - Often initial imaging modality in ER  
- Provides assessment of LV contractility, pericardial effusion, RV size and function, PA pressure  
- Presence and severity of AR  | - Sensitivity not sufficient distal to aortic root  
- Descending thoracic aorta imaged less easily and accurately  
- Misses IMH and PAU  |  |
| **MRI**  | Third-line     | - 3D multiplanar, and high resolution  
- Very high diagnostic accuracy  
- Does not require ionizing radiation or iodinated contrast  
- Appropriate for serial imaging over many years  | - Less widely available  
- Difficult monitoring critically ill patients  
- Not feasible in emergent or unstable clinical situations  
- Longer examination time  
- Caution with use of gadolinium in renal failure  |  |
| **Angiography** | Fourth-line  | - Rarely necessary  | - Often misses IMH (up to 10%–20% of ADs)  
- Long diagnostic time  
- Requires ICM  
- Morbidity  
- Less sensitivity than CT, TEE, and MRI  |  |

*AD, Aortic dissection; ECG, electrocardiographic; ER, emergency room; ICM, iodinated contrast media; IMH, intramural hematoma; LV, left ventricular; OR, operating room; PA, pulmonary artery; PAU, penetrating atherosclerotic ulcer; RV, right ventricular; SMA, superior mesenteric artery. *In IRAD.
Imaging Modalities for Aortic Dissection

CT-Scan

- Initial test in >70% of patients (IRAD)
- Widely available, quickest diagnostic times
- Very high diagnostic accuracy
- Relatively operator independent
- Allows evaluation of entire aorta (including arch vessels, mesenteric vessels, and renal arteries)
CT-Scan for Aortic Dissection

Disadvantages

- Ionizing radiation exposure
- Requires iodinated contrast material
- Pulsation artifact in ascending aorta
  (can be improved with ECG gating)
Imaging Modalities for Aortic Dissection

**TEE**

- Very high diagnostic accuracy
- Widely available, portable, convenient, fast
- Excellent for:  
  - Pericardial effusion
  - Presence, degree, mechanism of AR
  - LV function
- Can detect involvement of coronary arteries
- Safely performed on critically ill patients
- Optimal procedure for guidance in OR
### Detection of Aortic Dissection

#### Accuracy of TEE

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>With Diss'n</th>
<th>Sens</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erbel</td>
<td>1989</td>
<td>164</td>
<td>82</td>
<td>99%</td>
<td>98%</td>
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<tr>
<td>Hashimoto</td>
<td>1989</td>
<td>22</td>
<td>22</td>
<td>100%</td>
<td>N/A</td>
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<tr>
<td>Adachi</td>
<td>1991</td>
<td>45</td>
<td>45</td>
<td>98%</td>
<td>N/A</td>
</tr>
<tr>
<td>Ballal</td>
<td>1992</td>
<td>61</td>
<td>34</td>
<td>97%</td>
<td>100%</td>
</tr>
<tr>
<td>Simon</td>
<td>1992</td>
<td>32</td>
<td>28</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Nienaber</td>
<td>1993</td>
<td>110</td>
<td>44</td>
<td>98%</td>
<td>77%</td>
</tr>
<tr>
<td>Kang</td>
<td>1998</td>
<td>200</td>
<td>100</td>
<td>100%</td>
<td>91%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td>655</td>
<td>376</td>
<td><strong>99%</strong></td>
<td><strong>94%</strong></td>
</tr>
</tbody>
</table>
TEE for Aortic Dissection

Disadvantages

- Depends on skill of operator
- “Blind spot” upper ascending aorta
- Not reliable for cerebral vessels, mesenteric vessels, renal arteries
- Semi-invasive
- Reverberation artifacts (rarely a problem)
Imaging Modalities for Aortic Dissection

MRI

- Very high diagnostic accuracy
- 3D multiplanar and high resolution
- Does not require ionizing radiation or iodinated contrast material
- Appropriate for serial imaging over many years
MRI for Aortic Dissection

Disadvantages

• Less widely available
• Difficult monitoring critically ill patients
• Longer examination time
• Not feasible in emergent of unstable clinical situations
• Caution with use of gadolinium in renal failure
## Diagnosis of Aortic Dissection

Comparative Study of Spiral CT, MRI, TEE

<table>
<thead>
<tr>
<th>Method</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral CT</td>
<td>100%</td>
<td>100%</td>
<td>28 min</td>
</tr>
<tr>
<td>MRI</td>
<td>100%</td>
<td>94%</td>
<td>27 min</td>
</tr>
<tr>
<td>TEE</td>
<td>100%</td>
<td>94%</td>
<td>45 min</td>
</tr>
</tbody>
</table>

49 suspected aortic dissection
25 had dissection (18 type A; 7 type B)

Aortic Dissection
2D-Echo Findings

- **Hallmark**: dissection flap
- Double-channel aorta (TL and FL)
- Dilated aorta (usual)
- Re-entry sites (ostia of intercostals)
- “Cobwebs” (false lumen)
- Aortic insufficiency
- Pericardial and/or pleural effusion
Descending Thoracic Aorta

TEE

CT-scan
Aortic Arch

CT-scan

TEE
Aortic Regurgitation

Mechanisms of Aortic Regurgitation

- Dilatation of aortic root leading to incomplete aortic leaflet copatation
- Cusp prolapse
- Disruption of aortic annular support resulting in flail leaflet
- Invagination of dissection flap through the aortic valve in diastole
- Pre-existing aortic valve disease (eg, Bic AoV)
Mechanisms of Aortic Regurgitation

A

B

C

LVOT

Ao

LA

TL

FL
Cases
Case 1
Case 2
Intramural Hematoma
"Atypical" Aortic Dissection (Intramural Hematoma)

Typical = Dissection flap and false lumen

"Atypical" = No dissection flap; Medial hematoma
"Atypical" Aortic Dissection (Intramural Hematoma)

- Prevalence 10-20% in CT/MRI/TEE studies
- Type III more common
- Normal size lumen
- False negative aortograms
<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>%</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>Mohr-Kahaly</td>
<td>1994</td>
<td>27/114</td>
<td>23%</td>
<td>420</td>
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<tr>
<td>Nienaber</td>
<td>1995</td>
<td>25/195</td>
<td>12.8%</td>
<td>421</td>
</tr>
<tr>
<td>Keren</td>
<td>1996</td>
<td>10/49</td>
<td>20%</td>
<td>422</td>
</tr>
<tr>
<td>Harris</td>
<td>1997</td>
<td>19/84</td>
<td>23%</td>
<td>423</td>
</tr>
<tr>
<td>Vilacosta</td>
<td>1997</td>
<td>15/88</td>
<td>17%</td>
<td>229</td>
</tr>
<tr>
<td>Nishigami</td>
<td>2000</td>
<td>59/130</td>
<td>45%</td>
<td>424</td>
</tr>
<tr>
<td>Ganaha</td>
<td>2002</td>
<td>66/725</td>
<td>9%</td>
<td>425</td>
</tr>
<tr>
<td>Evangelista</td>
<td>2003</td>
<td>68/302</td>
<td>22%</td>
<td>154</td>
</tr>
<tr>
<td>Attia (meta-analysis)</td>
<td>2009</td>
<td>—</td>
<td>17%</td>
<td>426</td>
</tr>
</tbody>
</table>

**Totals** 289/1,687 17%
Intramural Hematoma
Imaging Features

- Focal aortic wall thickening
- Preserved luminal shape with a smooth luminal border
- Absence of dissection flap and false lumen
- Echolucent regions may be present in the aortic wall

Note: Often missed by aortogram which is a luminogram
Intramural Hematoma
Intramural Hematoma
CT-scan
Intramural Hematoma

MRI
Case 4

RM - 46 year old man
Known bicuspid aortic valve
S/P coarct repair (remote)
Sudden onset of severe chest pain
Syncope
Summary

• Advances in imaging techniques have greatly increased our understanding of thoracic aortic diseases

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

• TTE used most often for aortic root assessment

continued . . .
Summary

- CT-scan $\rightarrow$ high resolution of entire aorta including arch, mesenteric, and renal vessels

- MRI $\rightarrow$ greatest morphologic and dynamic information without radiation, but less widely available

- TEE $\rightarrow$ optimal procedure for guidance in OR safely performed on critically ill patients, even those on ventilators
Table 4: Comparison of five imaging modalities for diagnostic features of AAS

<table>
<thead>
<tr>
<th>Diagnostic performance</th>
<th>CTA</th>
<th>TTE</th>
<th>TEE</th>
<th>MRA</th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Specificity</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Ability to detect IMH</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Site of intimal tear</td>
<td>+++</td>
<td>-</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Presence of AR</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Coronary artery involvement</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Presence of pericardial effusion</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Branch vessel involvement</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{243}
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. \(^{182}\) and Isselbacher. \(^{419}\)
The End