Multimodality Imaging of the Thoracic Aorta

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DISCLOSURE

I have **NO** relevant financial relationships
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
Imaging Modalities
Imaging Techniques

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

- Chest X-ray
- **Echo** (TTE, TEE, 3D-echo, epiaortie)
- Intravascular echo (IVUS)
- Intracardiac echo (ICE)
- **CT/MDCT**
- Magnetic resonance imaging
- Aortography
Acute Aortic Syndromes
Acute aortic syndrome

Although the chest pain of acute aortic dissection is widely recognised, less consideration has been given to pain associated with other aortic pathologies. In light of contemporary concepts in aortic pathology we would like to present the pathology of a new cardiovascular syndrome—acute aortic syndrome (AAS).¹

Isidre Vilacosta and José Alberto San Roman
Acute Aortic Syndromes

- Heterogeneous group of conditions
- Disruption of the aortic wall
- Similar clinical picture
  - Chest and/or back pain (“aortic pain”)
  - Usually underlying hypertension
- Need for prompt diagnosis → urgent care
Acute Aortic Syndromes

- Classic aortic dissection
- Intramural hematoma (variant of AD)
- Penetrating atherosclerotic aortic ulcer
- Ruptured/leaking aortic aneurysm

Aortic trauma usually considered separately
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
Acute Aortic Syndromes

Imaging Modalities

Rapid, accurate diagnosis essential

- CT-scan
- Echocardiography (TTE; TEE)
- Magnetic resonance imaging

Preferred in acute setting
Aortic Dissection
Aortic Dissection

Tear

Adventitia
Media
Intima

Tear

False Lumen

Blood

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

<sup>*</sup>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>
</tr>
<tr>
<td>Hashimoto</td>
<td>1989</td>
<td>22</td>
<td>22</td>
<td>100%</td>
<td>N/A</td>
</tr>
<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 or unstable clinical situations
• Caution with use of gadolinium in renal failure
Diagnosis of Aortic Dissection
Comparative Study of Spiral CT, MRI, TEE

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

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

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
Cases
Case 1
Case 2

RM - 46 year old man
Known bicuspid aortic valve
S/P coarct repair (remote)
Sudden onset of severe chest pain
Syncope
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 10  Prevalence of IMH (as percentage of aortic dissection or nontraumatic AAS)

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>%</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohr-Kahaly</td>
<td>1994</td>
<td>27/114</td>
<td>23%</td>
<td>420</td>
</tr>
<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 3
Case 4
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>
<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.\textsuperscript{182} and Isselbacher.\textsuperscript{419}
The End