Acute Aortic Conditions

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NO FINANCIAL DISCLOSURES
Educational Objectives

♦ Review aortic anatomy / vocabulary
♦ Augment CT knowledge of acute aortic conditions
♦ Strengthen understanding of continuum of disease
♦ Avoid pitfalls of aorta CT interpretation
Innominate origin

Lig. arteriosum

Aortic valve

Aortic hiatus
PRACTICE GUIDELINE: EXECUTIVE SUMMARY

2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM Guidelines for the Diagnosis and Management of Patients With Thoracic Aortic Disease: Executive Summary


Endorsed by the North American Society for Cardiovascular Imaging

Normal Adult Thoracic Aortic Diameters

<table>
<thead>
<tr>
<th>Thoracic Aorta</th>
<th>Range of Reported Mean (cm)</th>
<th>Reported SD (cm)</th>
<th>Assessment Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root (F)</td>
<td>3.50 to 3.72</td>
<td>0.38</td>
<td>CT</td>
</tr>
<tr>
<td>Root (M)</td>
<td>3.63 to 3.91</td>
<td>0.38</td>
<td>CT</td>
</tr>
<tr>
<td>Ascending (F,M)</td>
<td>2.86</td>
<td>NA</td>
<td>CXR</td>
</tr>
<tr>
<td>Mid-descending (F)</td>
<td>2.45 to 2.64</td>
<td>0.31</td>
<td>CT</td>
</tr>
<tr>
<td>Mid-descending (M)</td>
<td>2.39 to 2.98</td>
<td>0.31</td>
<td>CT</td>
</tr>
<tr>
<td>Diaphragmatic (F)</td>
<td>2.40 to 2.44</td>
<td>0.32</td>
<td>CT</td>
</tr>
<tr>
<td>Diaphragmatic (M)</td>
<td>2.43 to 2.69</td>
<td>0.27 to 0.40</td>
<td>CT, arterio</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAA</th>
<th>Max</th>
<th>Normal</th>
<th>2.9 cm*</th>
<th>2.6 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 cm</td>
<td>4 cm</td>
<td>3.6 cm</td>
<td>2.5 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.4 cm</td>
<td>4 cm</td>
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</tbody>
</table>


AAA

<table>
<thead>
<tr>
<th>TAA</th>
<th>Max</th>
<th>Normal</th>
<th>1.6 cm</th>
<th>2 cm</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5 cm</td>
<td>3 cm</td>
</tr>
</tbody>
</table>

ASER 2010 sledbetter@partners.org
Thoracic Aortic Aneurysm (TAA)

- Atherosclerosis (overall most common cause)
- Cystic median necrosis (most common for ascending)
  - Marfan syndrome
  - Homocystinuria
  - Ehlers-Danlos syndrome
  - Osteogenesis imperfecta
  - Idiopathic (up to 1/3rd of cases)
- Trauma
- Aortitis
  - Infectious (e.g., syphilis, mycotic)
  - Noninfectious (e.g., inflammatory disease)
- Aortic Dissection

Thoracic Aortic Aneurysm (TAA)

- Association with HTN, age and smoking
- Incidence - overall 450 per 100K
- 3:1 M:F → 75% occur in men
- 75% occur in the descending aorta
- 1/3rd TAA associated with AAA
Abdominal Aortic Aneurysm (AAA)

♦ Vast majority are caused by atherosclerosis
♦ Rare before 50 yo
♦ 4% of population >50 yo
♦ 90% are infrarenal
Aortic Aneurysm (AA)

♦ Most discovered in asymptomatic pts.
♦ 75% result from atherosclerotic disease
♦ 75% are fusiform
♦ Symptoms
  – Usually late and indicate an active process
    • Expansion (chest and/or back pain)
    • Mass effect (stridor, cough, hoarseness, dysphagia)
    • Rupture (hypotension, shock, “impending doom”)
The Non-Traumatic Aortic Emergencies

- Aortic Rupture
- Aortic Dissection
- Intramural Hematoma
- Penetrating Atherosclerotic Ulcer
Figure 1. Types of aortic aneurysms.
Otherwise healthy 42 year old male presents with subjective fever, abdominal and back pain.
15 days later –
saccular aneurysm
involving origin of right
renal artery
Aortic Aneurysm Assessment

- Maximal aortic diameter
- Shape and extent
- Branch vessel involvement
- Presence of mural thrombus
- Relationship to / effect on other structures
- Presence / risk of rupture
Abdominal Aortic Aneurysm

- Findings of aneurysm rupture
  - Retroperitoneal hematoma, most common

- Findings of impending rupture
  - Size of aneurysm >7cm – Laplace law $T = PR$ ($T =$ circum. wall tension, $P$ is trans-mural pressure, and $R$ is the vessel radius)
  - Interval increase in size (10mm within 1 year)
  - Low or diminishing thrombus to lumen ratio
  - Interval interruption in wall calcification
  - Draping aorta sign
  - Hyperattenuating crescent sign

Spectrum of CT findings in rupture and impending rupture of abdominal aortic aneurysms.
Rakita D, Newatia A, Hines JJ, Siegel DN, Friedman B.
Figure 6b. Draped aorta sign in a 55-year-old man with a known abdominal aortic aneurysm and recent vague back pain.

Rakita D et al. Radiographics 2007;27:497-507


Draped aorta: CT sign of contained leak of aortic aneurysms. Halliday KE, al-Kutoubi A.
Figure 10b. Impending aneurysm rupture in a 57-year-old man with a known abdominal aortic aneurysm and increasing abdominal pain.

Rakita D et al. Radiographics 2007;27:497-507

High-attenuating crescent in abdominal aortic aneurysm wall at CT: a sign of acute or impending rupture.

Mehard WB, Heiken JP, Sicard GA.
Rupture

- Intimal, medial and adventitial breached
- Blood leaks into adjacent tissues / spaces
- Absent trauma, invariably coexists with other aortic pathology
Continuum of Aortic Conditions

PAU

IMH

AD

AA

Rupture
Diseases Associated With Thoracic Aortic Aneurysm and Dissection

- **Genetic syndromes**
  - Marfan, Loeys-Dietz, Ehlers-Danlos, Turner

- **Inflammatory**
  - Takayasu arteritis, Giant cell arteritis, Behcet disease, ankylosing spondylitis

- **Gene defects with familial component**
  - TGFBR2, MYH11, ACTA2 mutations
Ritter Rules

Ritter Rules are life-saving reminders to recognize, treat and prevent thoracic aortic dissection, a deadly tear in the large artery that carries blood away from the heart. Named for actor John Ritter, who died of a thoracic aortic dissection, Ritter Rules combine knowledge with action. Know the urgency, symptoms, who is most at risk and which imaging tests are required to diagnose this medical emergency.

URGENCY: Thoracic aortic dissection is a medical emergency. The death rate increases 1% every hour the diagnosis and surgical repair are delayed.
Acute Aortic Conditions

- Aortic Rupture
- Aortic Dissection
- Intramural Hematoma
- Penetrating Atherosclerotic Ulcer
Aortic Dissection

- Intimal breach
- Blood accesses / propagates in media, lifting intima
- Creates true / false lumen
- Stop in media, break back through intima, break out through adventitia
- May thrombose
Clinical presentation

♦ Severe chest pain in >90% with acute dissection
  – May describe as “tearing,” “ripping,” “shearing,” etc.
  – Onset usually “sudden,” “abrupt,” etc.
  – Often substernal (type A) or intrascapular (type B)
  – May radiate to back, neck or even abdomen
  – Migration may signal progressive dissection
  – Maximum pain intensity usually at onset (vs. MI)
  – May completely or near-completely resolve
Risk Factors and Demographics

♦ Most common acute aortic condition, highest mortality
♦ Prevalence: 0.2-0.8% in large series of autopsies*
♦ 3:1/M:F; Most patients 50-70 years old
♦ Hypertension is the strongest risk factor (~75% in PMH)
♦ Trauma
  – Blunt / Catheterization / Aortic surgery
♦ Vascular inflammatory conditions
  – Giant cell / Takayasu’s / Behcet’s

*Hagan et al., International Registry of Acute Aortic Dissection, JAMA 2000
Risk Factors in Young Patients

- **Abrupt ↑ BP**
  - Weightlifting / Cocaine
- **Pregnancy**
  - 3rd trimester / post-partum
- **Congenital anomalies**
  - Bicuspid valve / Coarctation
- **Connective tissue disease**
  - Marfan / Ehlers-Danlos
- **Genetic disorders**
  - Turners – 5% coarctation

28 y.o. male with chest pain
Marfans patient with aortic dissection
23 y.o. pregnant female (38 wks) with back and pelvic pain
→ → → LE paralysis & no fetal heart
Chest pain & the CXR

- Is not sufficiently sensitive or specific for:
  - AD / PE / ACS
  - 1 in 5 AD have an essentially normal CXR

- Evaluate for more common causes of CP
  - PTX / pneumonia

- Evaluate for secondary signs of CV issues
  - pulmonary edema / cardiac silhouette

- Cross-sectional imaging required for AD
Cross-sectional Imaging Methods

♦ MDCT ★★★★
  – Widely available / easily performed
  – Very accurate / fast results
  – High NPV / frequent alternate diagnosis

♦ ECHO (TEE)
  – Unstable patients / low GFR / cardiac function

♦ MRI
  – Severe contrast allergy / gado (+) MRA
  – Low GFR → NSF / gado (-) MRA*

Aortic Dissection – CT Findings

Unenhanced

♦ Intramural hematoma
♦ Displaced intimal calcification
Aortic Dissection – CT Findings

Enhanced

♦ Intimal flap within the aorta
♦ Compression of the true lumen by the false lumen
Aortic Dissection - Classification

♦ Stanford-Daily
  – Type A  Involves the ascending aorta +/- arch/D
  – Type B  Post-SCA, not involving ascending

♦ DeBakey (superseded by S-D classification)
  – Type I  Originates ascending, but extends beyond
  – Type II Originates and confined to ascending
  – Type III Originates in descending
Stanford-Daily Type A Dissection
Stanford-Daily Type B Dissection
Innominate origin

Type A
~60%

Aortic valve

Lig. arteriosum

Type B
~40%

Aortic hiatus
Acute vs. Chronic

- Arbitrarily defined as: acute < 14D < chronic
- Time Zero defined by symptom onset
- Symptoms can completely resolve
- Untreated mortality rate
  - 1-2%/hour (first 24h)
  - 80% within 2 weeks
  - <30% overall in-hospital
Things to Report on Imaging

- Type A or B, entry site / extent of dissection
- What is perfused by true / false lumen
- Aortic caliber (outer wall to outer wall)
- Complications
  - Hemopericardium / tamponade
  - Branch vessel involvement / ischemia
  - Thrombus / occlusion
  - Aneurysm / rupture / impending rupture
HEMOPERICARDIUM
BRANCH VESSEL INVOLVEMENT
ORGAN OR BOWEL ISCHEMIA
ACUTE AORTIC OCCLUSION, RUPTURE
ANEURYSMAL DILATATION
# Type A vs. Type B Aortic Dissection

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Stanford Type A</th>
<th>Stanford Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Mortality rate when surgically managed</td>
<td>★★★★ ★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Mortality rate when medically managed</td>
<td>58%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Hagan et al., JAMA 2000
Type B Aortic Dissection

- 20% have complications requiring intervention
  - Aortic aneurysm expansion / impending rupture
  - Organ or limb ischemia
  - Uncontrolled HTN
  - Intractable pain

- Endovascular treatment preferred over surgery
  - Stent grafting
  - Fenestration

**True vs. False Lumen**

- Can be difficult: intimal displacement / folding / spiraling
- Connection with uninvolved true lumen – most reliable
- Intimomedial disruption – ~ 8%, but highly reliable
- **False lumen**
  - Frequently larger, make contain clot / “cobwebs”
  - “Beak” sign, flap convexity toward, slower / more turbulent flow
  - Usually R anterolateral ascending, L posterolateral descending
Pitfalls in AD Imaging

- Over-reliance on CXR → 20% normal
- Failure to consider CTA → consult with EM
- Artifacts simulating AD
- Normal structures simulating AD
- Pathology simulating AD
- Thrombosed AD without conspicuous intimal flap
- Alternate diagnoses / complications at CTA
Pitfalls in AD Imaging

- Over-reliance on CXR → 20% have normal CXR
Pitfalls in AD Imaging

♦ Over-reliance on CXR → 20% normal
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Pitfalls in AD Imaging

♦ Over-reliance on CXR → 20% normal
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PULSATION ARTIFACT
BEAM HARDENING ARTIFACT
Pitfalls in AD Imaging

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RIGHT ATRIAL APPENDAGE
SUPERIOR PERICARDIAL RECESS
SUPERIOR INTERCOSTAL VEIN
LEFT INFERIOR PULMONARY VEIN
Pitfalls in AD Imaging

- Over-reliance on CXR $\Rightarrow$ 20% normal
- Failure to consider CTA $\Rightarrow$ consult with EM
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- Normal structures simulating AD
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- Alternate diagnoses / complications at CTA
LEFT LOWER LOBE ATELECTASIS
MURAL THROMBUS VS. INTRAMURAL HEMATOMA
PENETRATING ULCER VS. INTIMAL FLAP
Pitfalls in AD Imaging

- Over-reliance on CXR → 20% normal
- Failure to consider CTA → consult with EM
- Artifacts simulating AD
- Normal structures simulating AD
- Pathology simulating AD
- Thrombosed AD without intimal flap
- Alternate diagnoses / complications at CTA
Intramural hematoma (IMH)
Completely thrombosed false lumen
Pitfalls in AD Imaging

♦ Over-reliance on CXR ➔ 20% normal
♦ Failure to consider CTA ➔ consult with EM
♦ Artifacts simulating AD
♦ Normal structures simulating AD
♦ Pathology simulating AD
♦ Thrombosed AD without intimal flap
♦ Alternate diagnoses / complications at CTA
Acute Aortic Conditions

♦ Aortic Rupture
♦ Aortic Dissection
♦ Intramural Hematoma
♦ Penetrating Atherosclerotic Ulcer
Intramural Hematoma (IMH)

♦ Clotted blood in the medial layer, no blood / contrast flow
♦ Intima may or may not be intact
♦ If intact → “spontaneous”
♦ If not intact → associated with other condition (AD, PAU)
Spontaneous / Isolated IMH

- Bleeding from vasa vasorum into media w/ intact intima
- Pathologically distinguishes this from other conditions
- Differentiation at imaging may be difficult
- Co-exists with other acute aortic conditions
- Chest or back pain is the most common chief complaint
- Older HTN patients
- ~8% of patients thought to have AD have isolated IMH
- 10-20% of acute aortic syndromes
IMH – CT Findings

- Acute stage – hyperdense and smooth, crescentic or concentric layer within the aortic wall (I- CT)
- Does not enhance following IVCM
- Aortic lumen rarely narrowed
- Classified as type A/B (just like aortic dissection)
- No intimal flap / breach
Intramural hematoma (IMH)
Type A or Type B ??
IMH – Treatment and Outcome

♦ May be complicated by AD, ulcer, aneurysm or rupture

♦ Type A IMH
  – 50% complication rate w/in 30 days if untreated
  – Emergent surgical management generally undertaken

♦ Type B IMH
  – Good short-term outcome with management of HTN
  – Progression more likely if aneurysm, ulcer, dissection, impending rupture or wall thickness >10mm
  – Follow-up imaging for all within 30 days
  – If progressed, consider surgical/endovascular Rx
Acute Aortic Conditions

- Aortic Rupture
- Aortic Dissection
- Intramural Hematoma
- Penetrating Atherosclerotic Ulcer
Penetrating Ulcer (PAU)

- Intimal breach, usually from ulcerative plaque disruption
- Blood accesses, but rarely propagates in subintimal layer
- Localized IMH
PAU – Clinical Presentation

♦ Elderly, HTN patients
♦ Commonly in 8th decade
♦ Chest or back pain most common chief complaint
♦ Clinically indistinguishable from other acute aortic conditions
PAU – CT Findings

♦ Unenhanced CT
  – Usually localized IMH
  – Displaced intimal calcification

♦ Enhanced CT - Presence of an ulcer
  – Overhanging edges can mimic “dissection flap”
  – 90% occur in the mid to distal descending aorta
  – Shallow/deep, single/multiple, extend mm/cm
PAU – Treatment and Outcome

- Medical management – control of HTN
- May be complicated by AD, aneurysm or rupture
- Follow-up imaging for all within 30 days
- If progressed, consider surgical/endovascular Rx
- Progression reported in up to 40% of patients
Essential Elements of Aortic Imaging Reports

♦ 1. The location at which the aorta is abnormal.
♦ 2. The maximum diameter of any dilatation, measured from the external wall of the aorta, perpendicular to the axis of flow, and the length of the aorta that is abnormal.
♦ 3. For patients with presumed or documented genetic syndromes at risk for aortic root disease measurements of aortic valve, sinuses of Valsalva, sinotubular junction, and ascending aorta.
♦ 4. The presence of internal filling defects consistent with thrombus or atheroma.
♦ 5. The presence of IMH, PAU, and calcification.
♦ 6. Extension of aortic abnormality into branch vessels, including dissection and aneurysm, and secondary evidence of end-organ injury (e.g., renal or bowel hypoperfusion).
♦ 7. Evidence of aortic rupture, including periaortic and mediastinal hematoma, pericardial and pleural fluid, and contrast extravasation from the aortic lumen.
♦ 8. When a prior examination is available, direct image to image comparison to determine if there has been any increase in diameter.

Normal anatomy of the thoracoabdominal aorta with standard anatomic landmarks for reporting aortic diameter

1. Aortic sinuses of Valsalva
2. Sinotubular junction
3. Mid ascending aorta (midpoint b/t 2 and 4)
4. Proximal aortic arch (at origin of innominate)
5. Mid aortic arch (b/t LCC and LSCA)
6. Proximal descending thoracic (begins at isthmus)
7. Mid descending aorta (midpoint b/t 6 and 8)
8. Aorta at diaphragm (2 cm above celiac axis)
9. Abdominal aorta at the celiac axis origin

American College of Cardiology Foundation, et al.
J Am Coll Cardiol 2010;55:1509-1544
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Thank You for your attention