Multimodality Imaging in Aortic Diseases:

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ASE American Society of Echocardiography

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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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J Am Soc Echocardiogr 2015;28:119-82

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 metholodogic 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%

Survey for Imaging of the Aorta

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?

1 mm	41%
2 mm	47%
3 mm	6%
4 mm	6%
5 mm	0

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 ?

>2 mm	18%
>3 mm	23%
>4 mm	24%
>5 mm	35%

Circulation

2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM
Diagnosis and Management of Patients With Thoracic Aortic Di
American College of Cardiology Foundation/American Heart As
Practice Guidelines, American Association for Thoracic Surgery
Radiology, American Stroke Association, Society of Cardiovasc
Society for Cardiovascular Angiography and Interventions, Soc
Radiology, Society of Thoracic Surgeons, and Society for V
WRITING GROUP MEMBERS, Loren F. Hiratzka, George L. Bak
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Williams

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European Journal of Echocardiography (2010) 11, 645–658
doi:10.1093/ejechocard/jeq056

RECOMMENDATIONS

Echocardiography in aortic diseases: EAE recommendations for clinical practice

Arturo Evangelista[1]*, Frank A. Flachskampf[2], Raimund Erbel[3], Francesco Antonini-Canterin[4], Charalambos Vlachopoulos[5], Guido Rocchi[6], Rosa Sicari[7], Petros Nihoyannopoulos[8], and Jose Zamorano[9] on behalf of the European Association of Echocardiography

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association.

2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines

Rick A. Nishimura, Catherine M. Otto, Robert O. Bonow, Blase A. Carabello, John P. Erwin III, Robert A. Guyton, Patrick T. O'Gara, Carlos E. Ruiz, Nikolaos J. Skubas, Paul Sorajja, Thoralf M. Sundt III and James D. Thomas

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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)

continued . . .

Diseases of the Thoracic Aorta

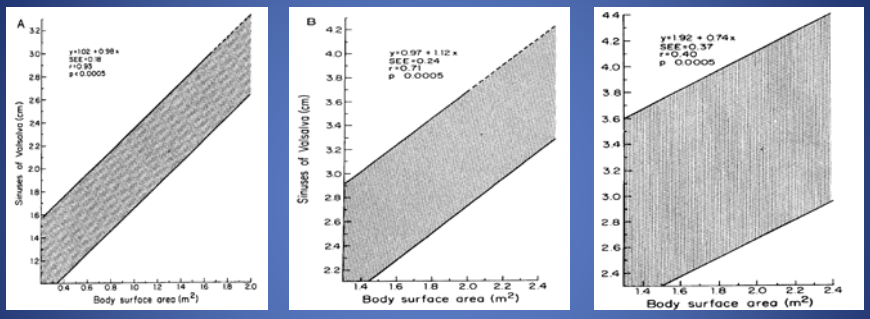
- **Traumatic injury of thoracic aorta**
- **Aortic coarctation**
- **Atherosclerosis**
- **Aortitis**
  - Noninfectious
  - Infectious

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

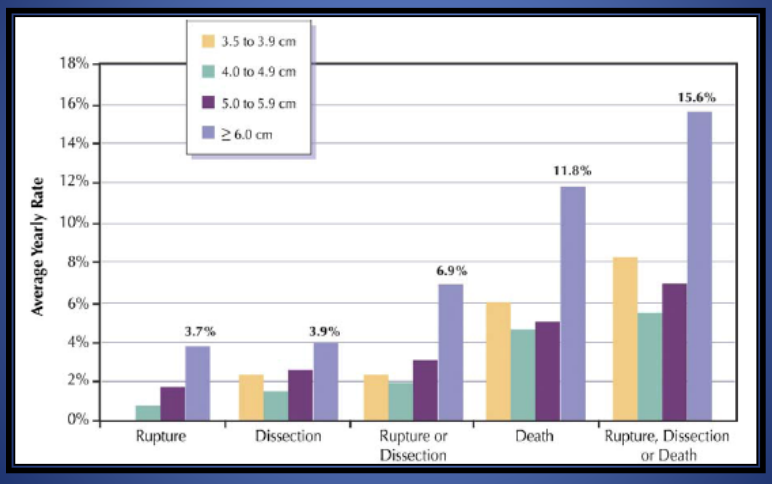


< 20 yo | 20-40 yo | >40 yo

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

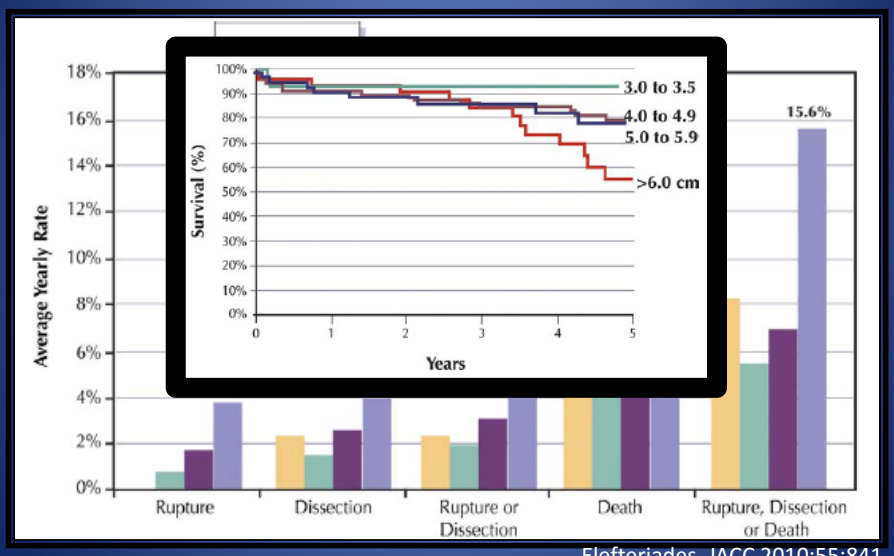
Complications and Asc Ao size

Importance of accurate measurements



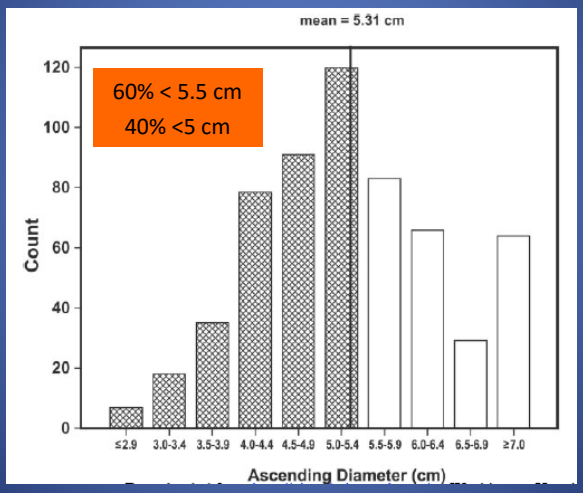
Elefteriades, JACC 2010;55:841

Complications and Asc Ao size
Importance of accurate measurements



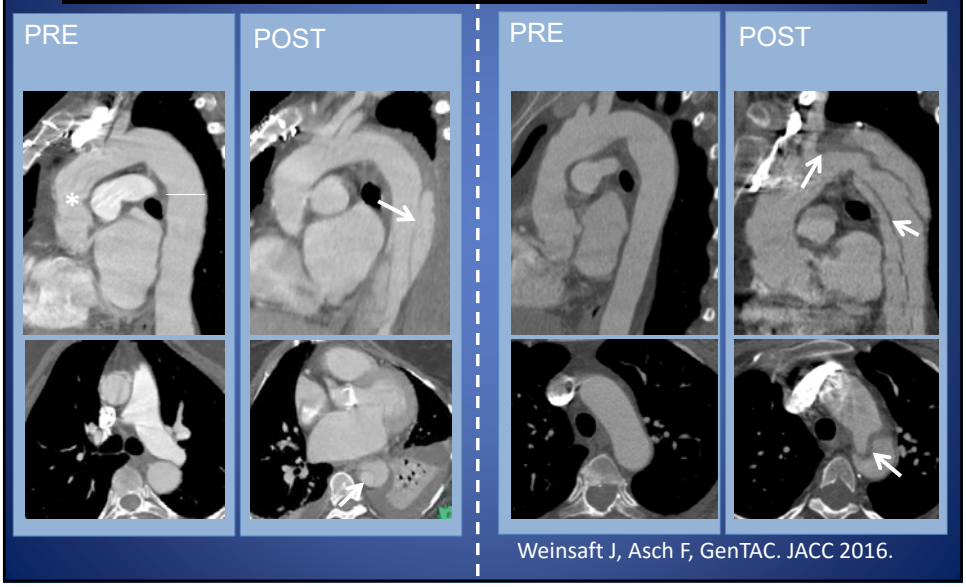
Elefteriades, JACC 2010;55:841

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



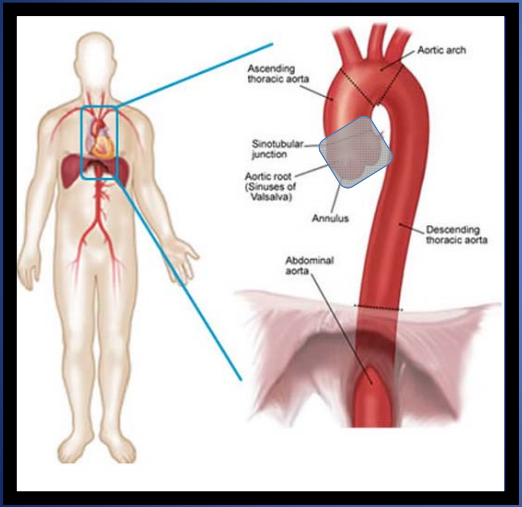
Weinsaft J, Asch F, GenTAC. JACC 2016.

Which test to order?
TTE vs TEE vs CT vs MRI

- Reproducibility is similar in all modalities. A variation error in aortic measurements of ≅ 3mm 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

- 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.

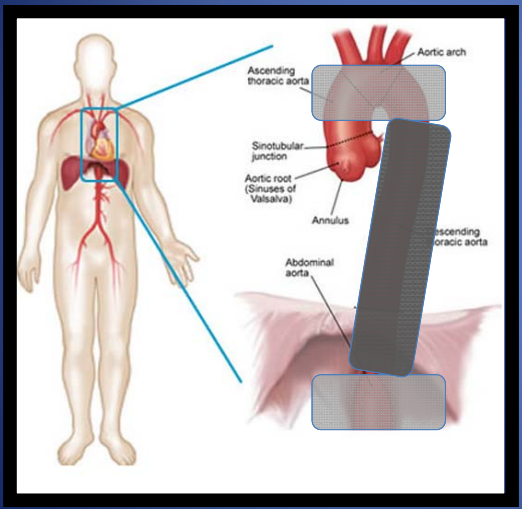
MDCT



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

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

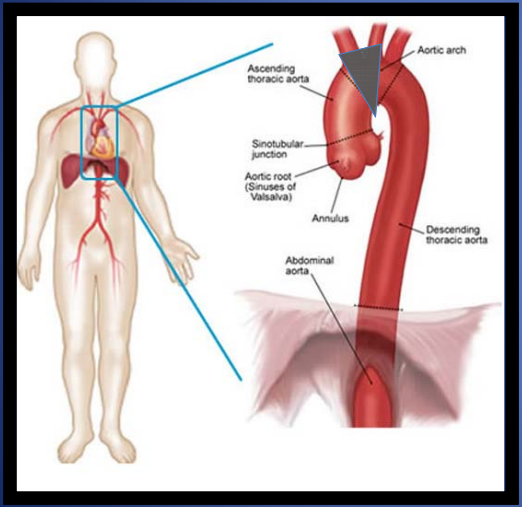
TTE



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

Weaknesses:
- All other segments

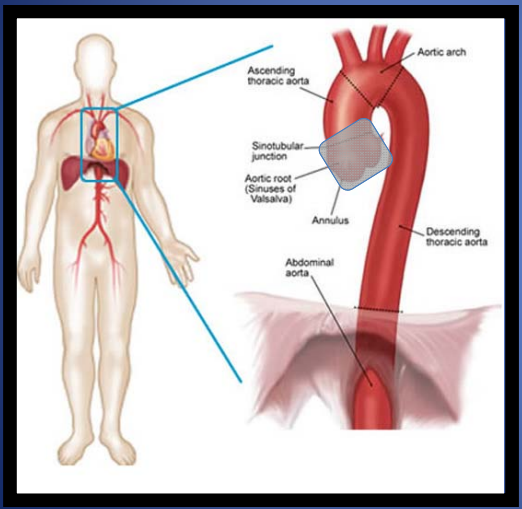
TEE



Strength:
- Accurate measurements
- Other cardiac structures

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

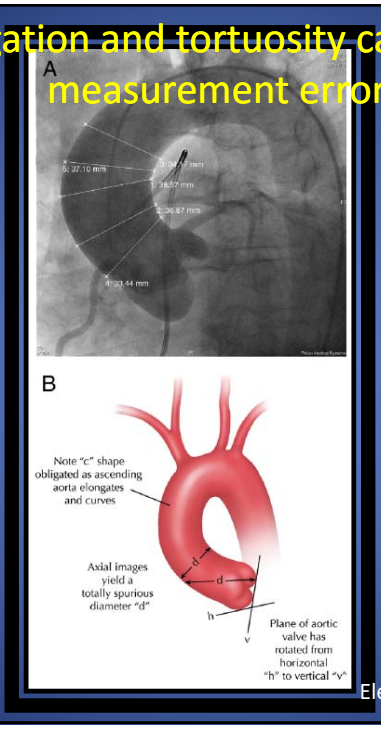
MRI



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

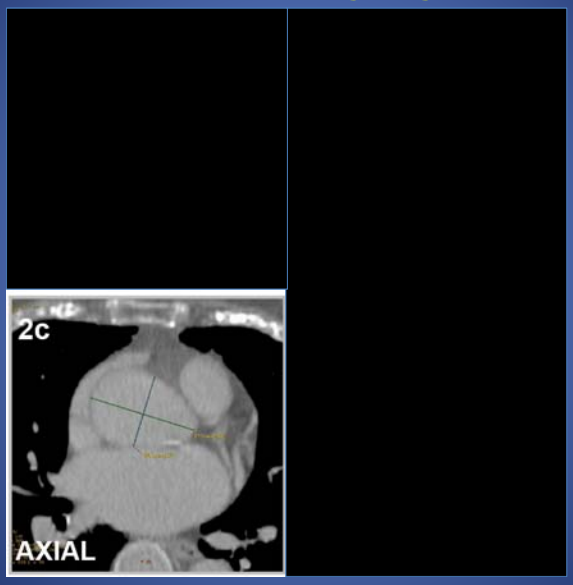
Weaknesses:
- Contrast (MRA)
-Ao Root (non-gated)

Elongation and tortuosity can induce measurement errors



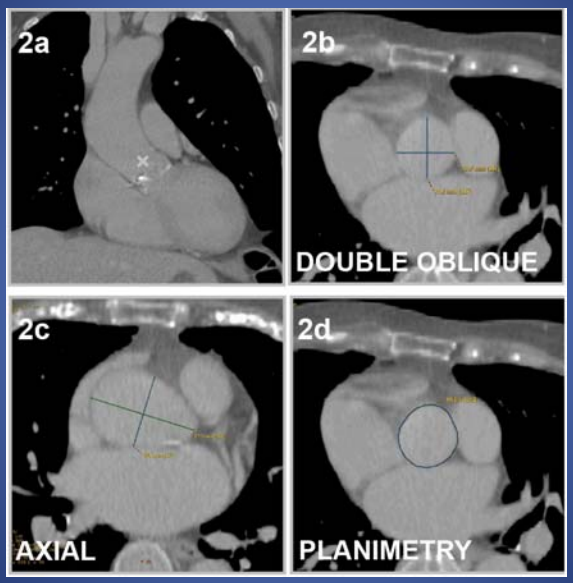
Elefteriades, JACC 2010;55:841

Importance of Imaging technique



Mendoza D, Weinsaft J et al. Ann Thorac Surg, 2011;92:904

Importance of Imaging technique



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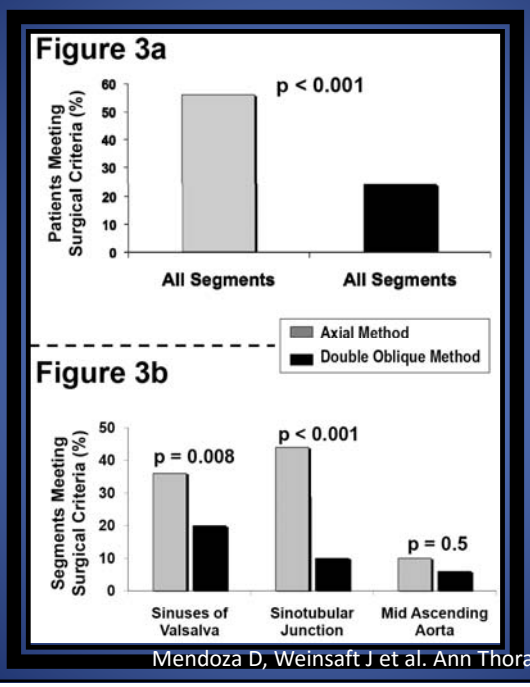
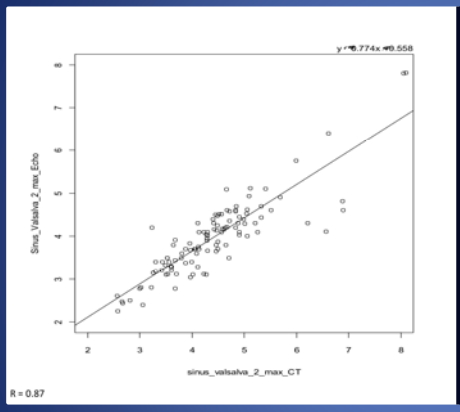


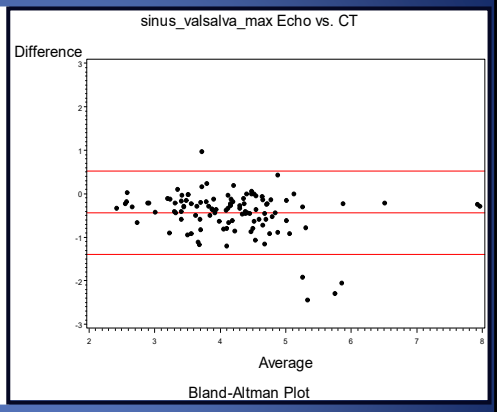
Mendoza D, Weinsaft J et al. Ann Thorac Surg, 2011;92:904

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

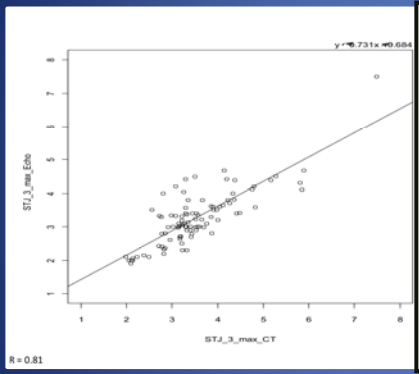
Sinus of Valsalva = good correlation

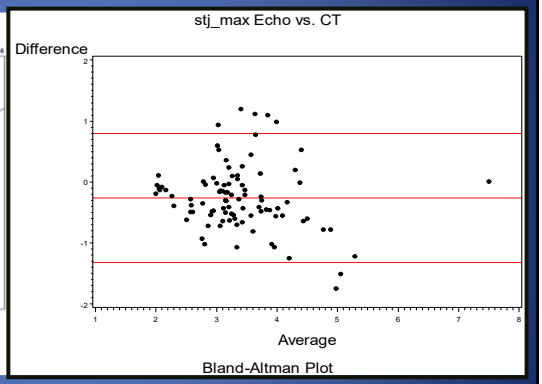




N= 109
ICC=0.82

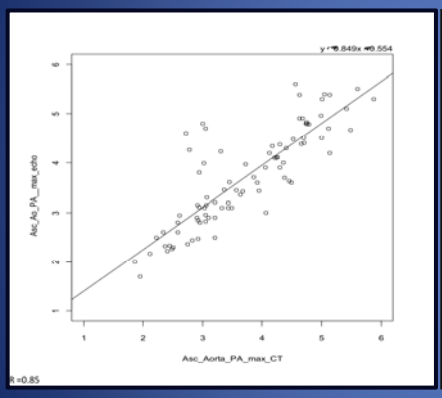
SinoTubular Junct = good correlation

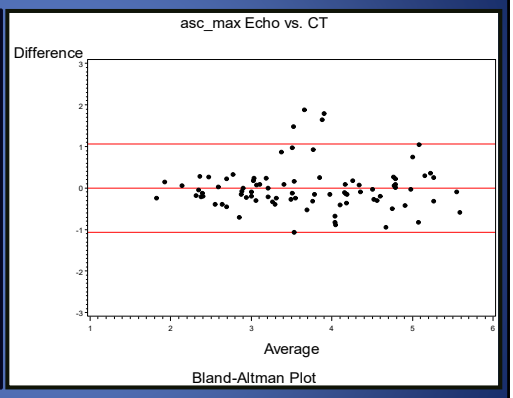




N= 94
ICC=0.75

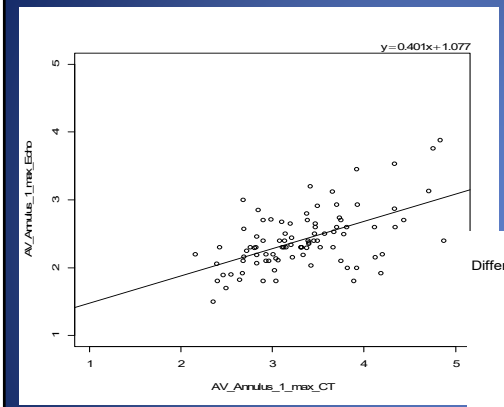
Asc Aorta = good correlation



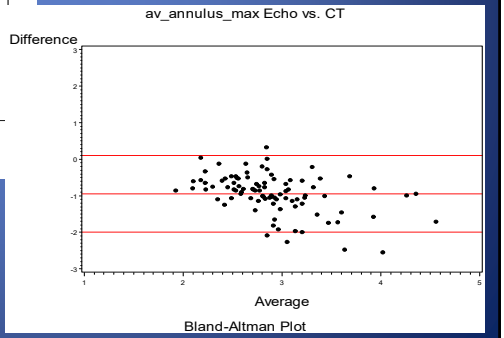


N=87
ICC=0.77

AV Annulus – poor correlation

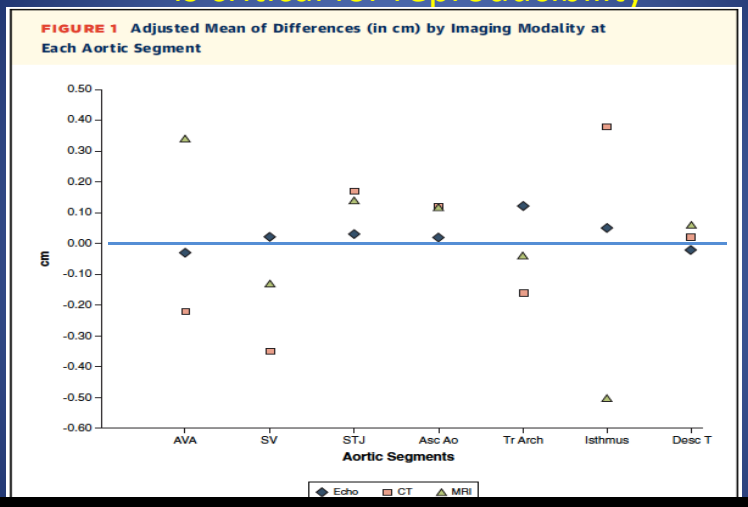


N=94
ICC=0.49



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

Asch FM, GenTAC invest. JACC img 2016;9:219-26

Measurement technique should be standardized for:

- All imaging modalities
- All Age groups

GUIDELINES AND STANDARDS

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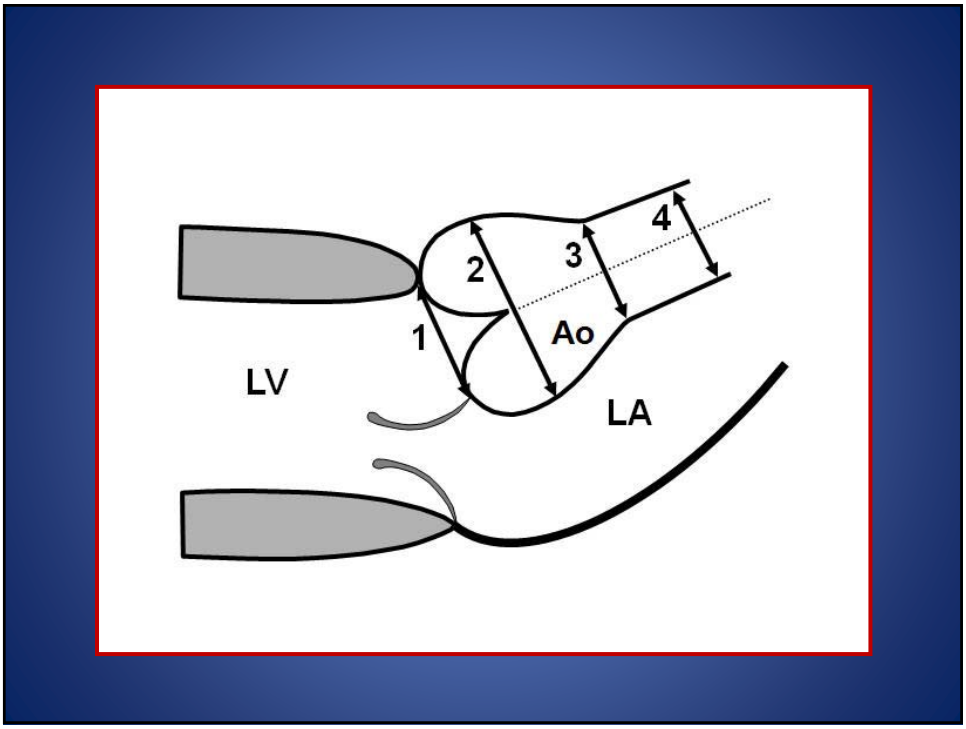
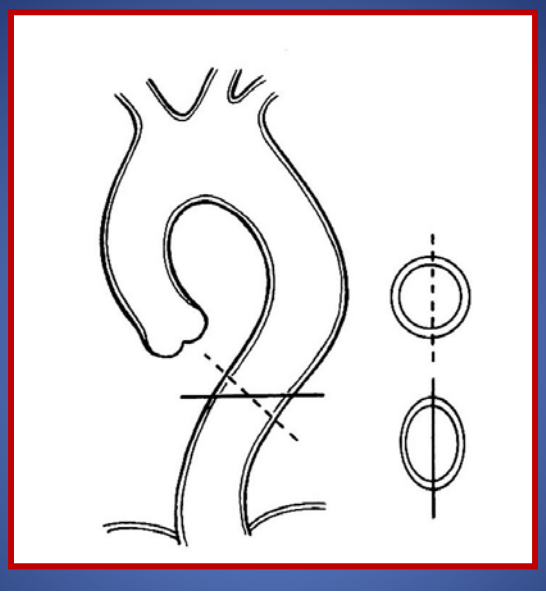
J Am Soc Echocardiogr 2015;28:119-82





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)

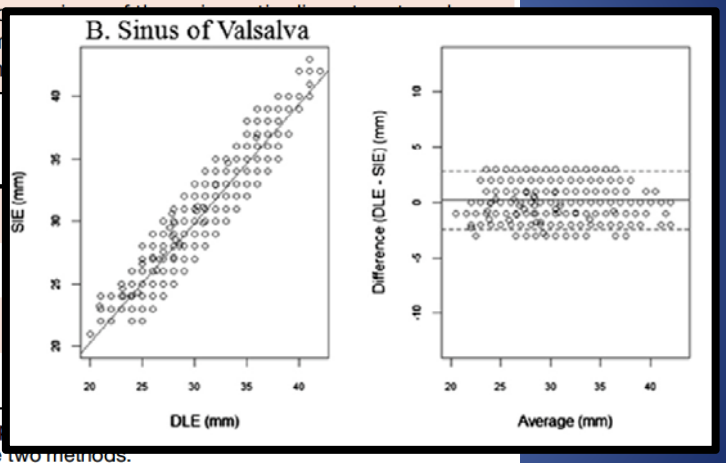
- End-diastole easy to ID by QRS

Differences in Measurement timing and technique are small

Table 2 Co
aortic segm
absolute m

Aortic segment
Aortic annulus
Sinuses of Valsalva
Sinotubular junction
Ascending aorta

Data are exp
between the two methods.

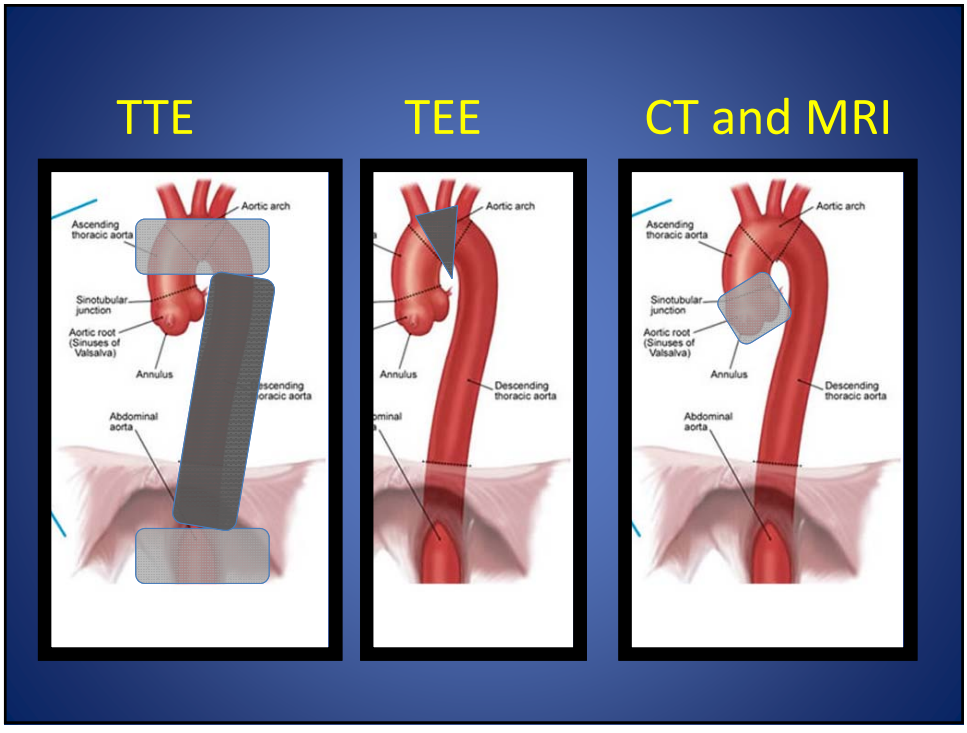


Bossone, Yuriditsky, Asch et al. J Am Soc Echocardiogr 2016;29:166-72

Table 17 Recommendations for choice of imaging modality for TAA

Modality	Recommendation	Advantages	Disadvantages
CT	First-line	• First-line technique for staging, surveillance • Contrast: enhanced CT and MRI very accurate for measuring size of all TAAs (superior to echocardiography for distal ascending aorta, arch, and descending aorta) • All segments of aorta and aortic branches well visualized	• Use of ionizing radiation and ICM • Cardiac motion can cause imaging artifacts
MRI	Second-line	• 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	• 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
TTE	Second-line	• Usually diagnostic for aneurysms effecting aortic root • Useful for family screening • Useful for following aortic root disease • Excellent reproducibility of measurements • Excellent for AR, LV function	• Distal ascending aorta, arch, and descending aorta not reliably imaged
TEE	Third-line	• Excellent for assessment of AR mechanisms • Excellent images of aortic root, ascending aorta, arch, and descending thoracic aorta	• 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
Aortography	Third-line	• Reserved for therapeutic intervention • Useful to guide endovascular procedures	• Invasive; risk for contrast-induced nephropathy • Visualizes only aortic lumen • Does not permit accurate measurements

LV, Left ventricular.



Thoracic Aortic Aneurysms

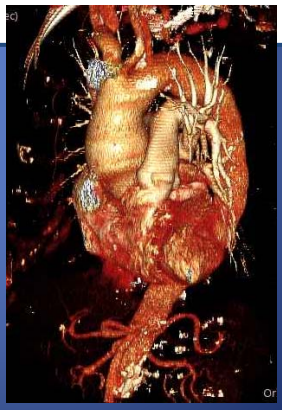
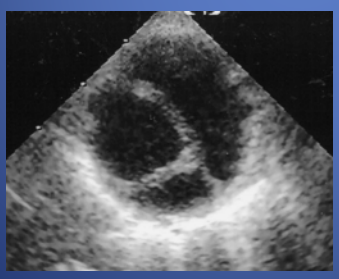


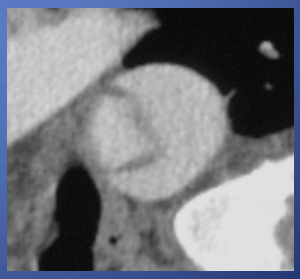
Table 15 Etiologies of TAAs

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

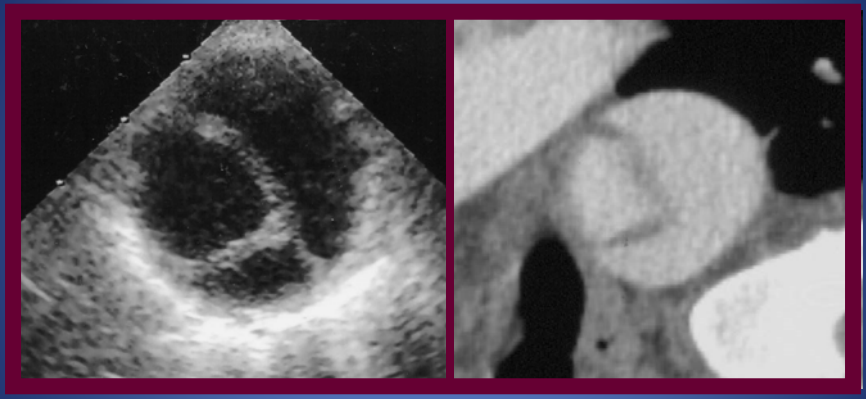
You want to explore the ENTIRE Aorta,
AT LEAST ONCE

Acute Aortic Syndromes



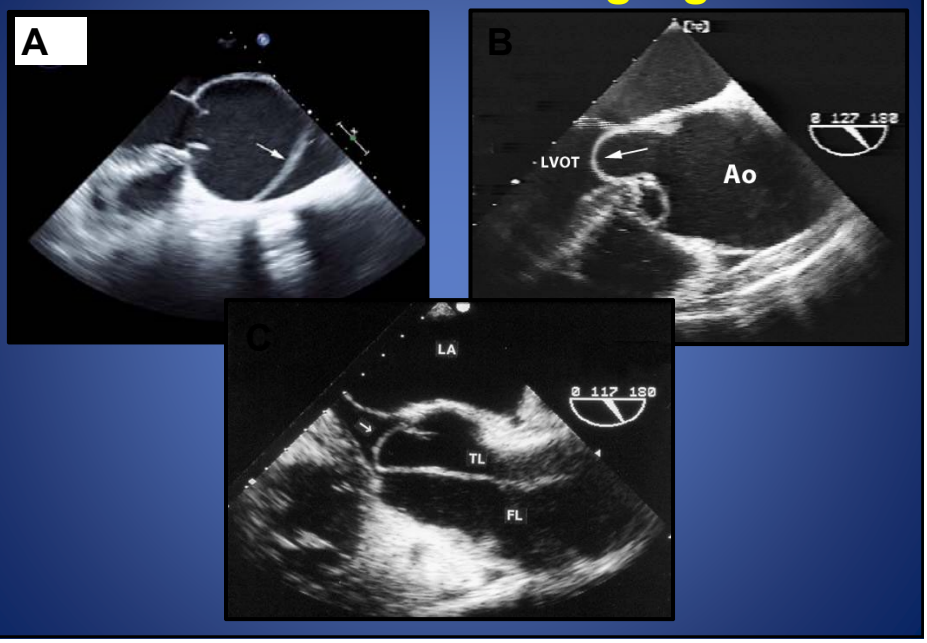


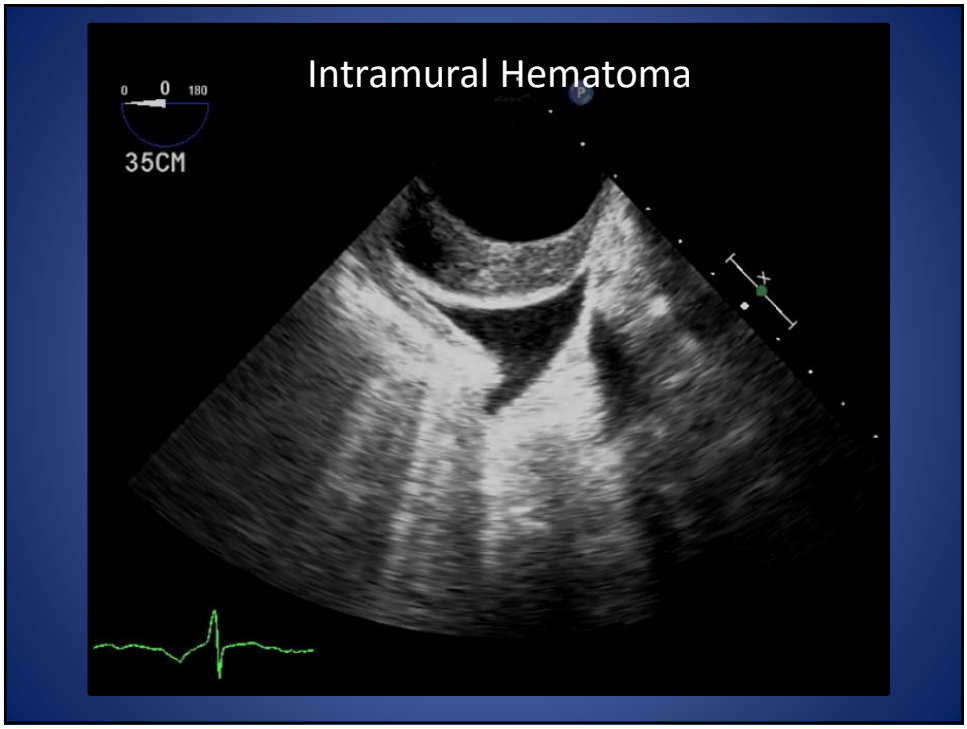
Dissection: Descending Thoracic Aorta



TEE CT-scan

Mechanisms of Aortic Regurgitation





Ulcerated Aortic Plaque

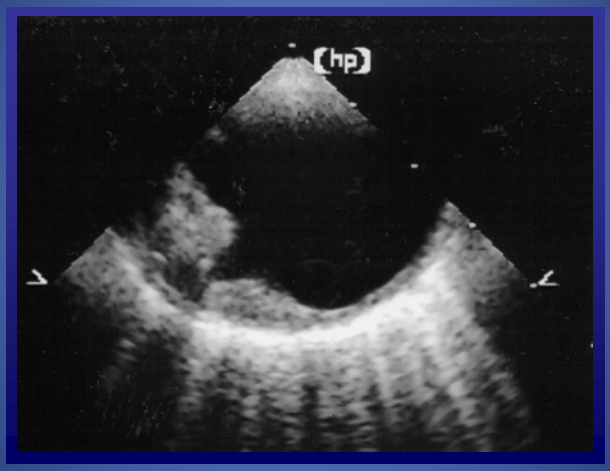


Table 5 Practical assessment of five imaging modalities in the evaluation of suspected AAS

Advantages of modality	CTA	TTE	TEE	MRA	Angiography
Readily available	+++	+++	++	+	+
Quickly performed	+++	+++	++	+	+
Performed at bedside	–	+++	+++	–	–
Noninvasive	+++	+++	+	+++	–
No iodinated contrast	–	+++	+++	+++	–
No ionizing radiation	–	+++	+++	+++	–
Cost	++	+	++	++	+++

CTA, Computed tomographic angiography; +++, very positive; ++, positive; +, fair; –, no.
Adapted from Cigarroa *et al*.[182] and Isselbacher.[419]

Summary

Regardless of the Imaging Modality, methods should be unified

Leading edge,
End diastole

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

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Thank you