

Echocardiography: Diseases of the Aorta

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2010

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

J. Am. Coll. Cardiol. 2010;55:e27-e129

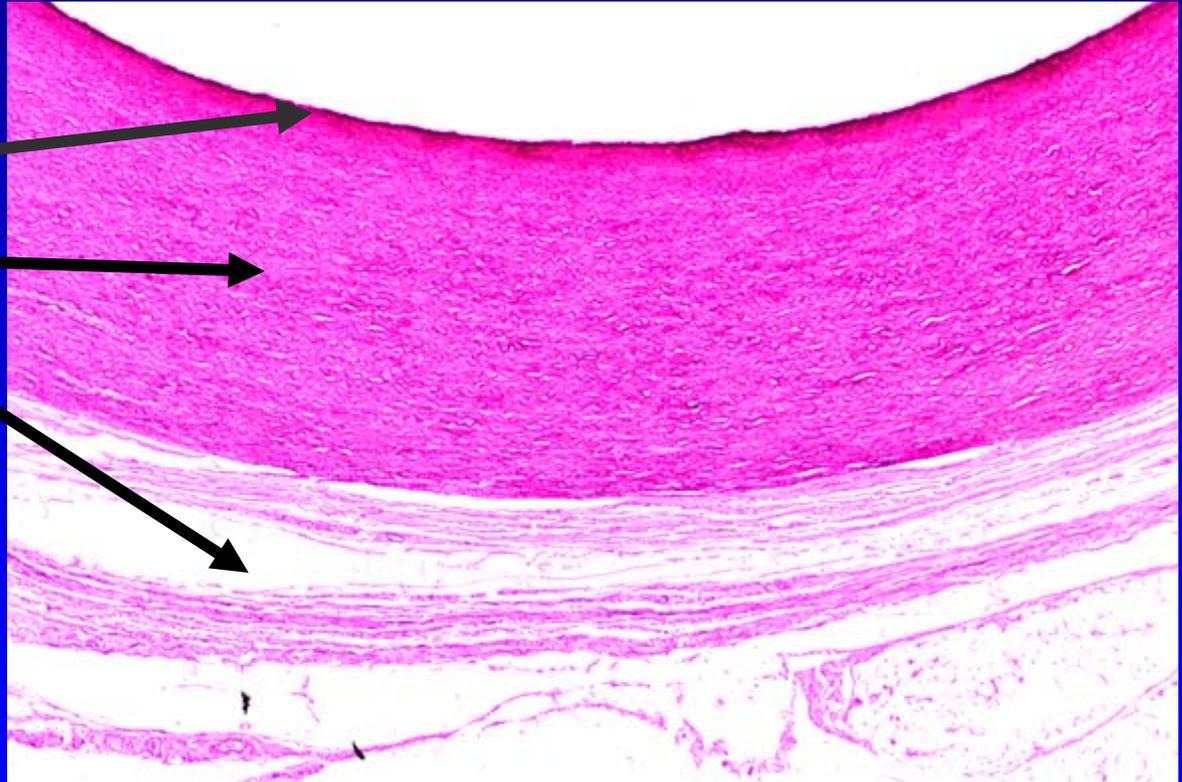
2015

**Multimodality Imaging of Diseases of
The Thoracic Aorta in Adults**

J. Am. Soc. Echocardiogr 28:119-82

The Aorta

- Comprised of 3 layers:
 - Intima
 - Media
 - Adventitia



<http://erl.pathology.iupui.edu/HI/STO/GENER29.HTM>

4 Discrete Segments of Aorta

1. Aortic Root

- Aortic valve annulus
- AV cusps
- Sinus of Valsalva

2. Ascending tubular aorta

- From sinotubular junction to brachiocephalic origin

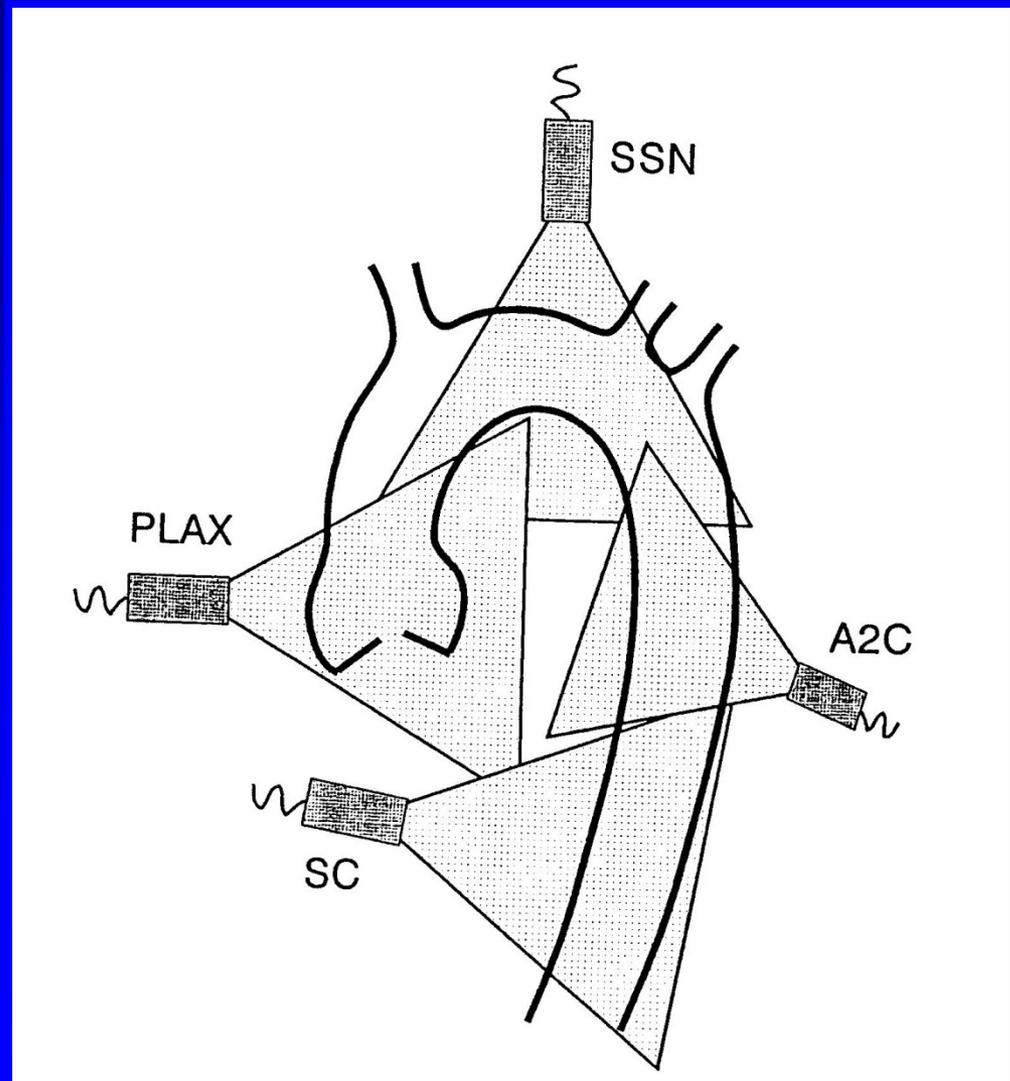
3. Aortic arch

- From brachiocephalic to left subclavian origin

4. Descending thoracic aorta

- Distal to left subclavian origin

Transthoracic Imaging



Textbook of Clinical
Echocardiography
Otto, 2nd ed

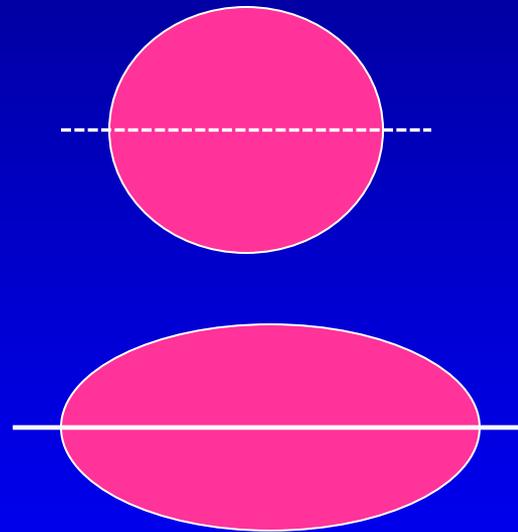
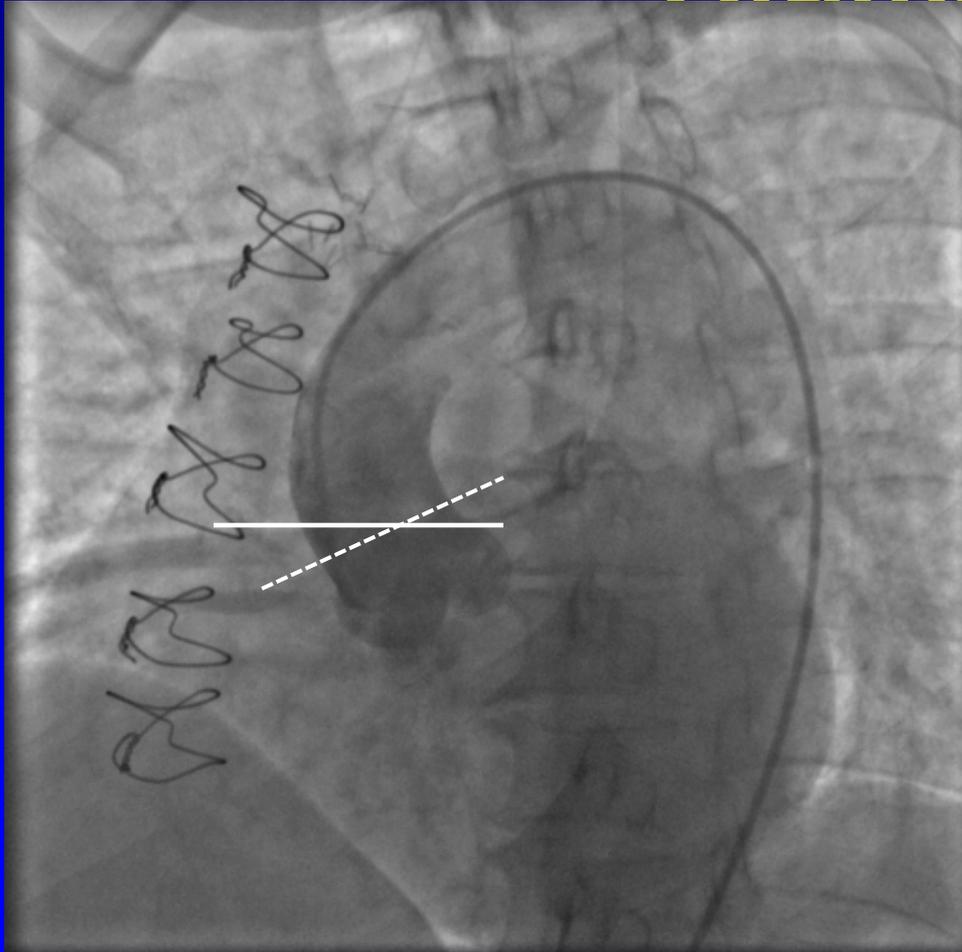
Transesophageal (TEE) Imaging of Aorta

- **Ascending aorta**
 - Midesophageal @ 100-140°: long axis
 - Midesophageal @ 45-60°: short axis
- **Descending thoracic aorta**
 - 0° and 90°: short and long axis
- **Blind spot:** upper ascending aorta and proximal arch

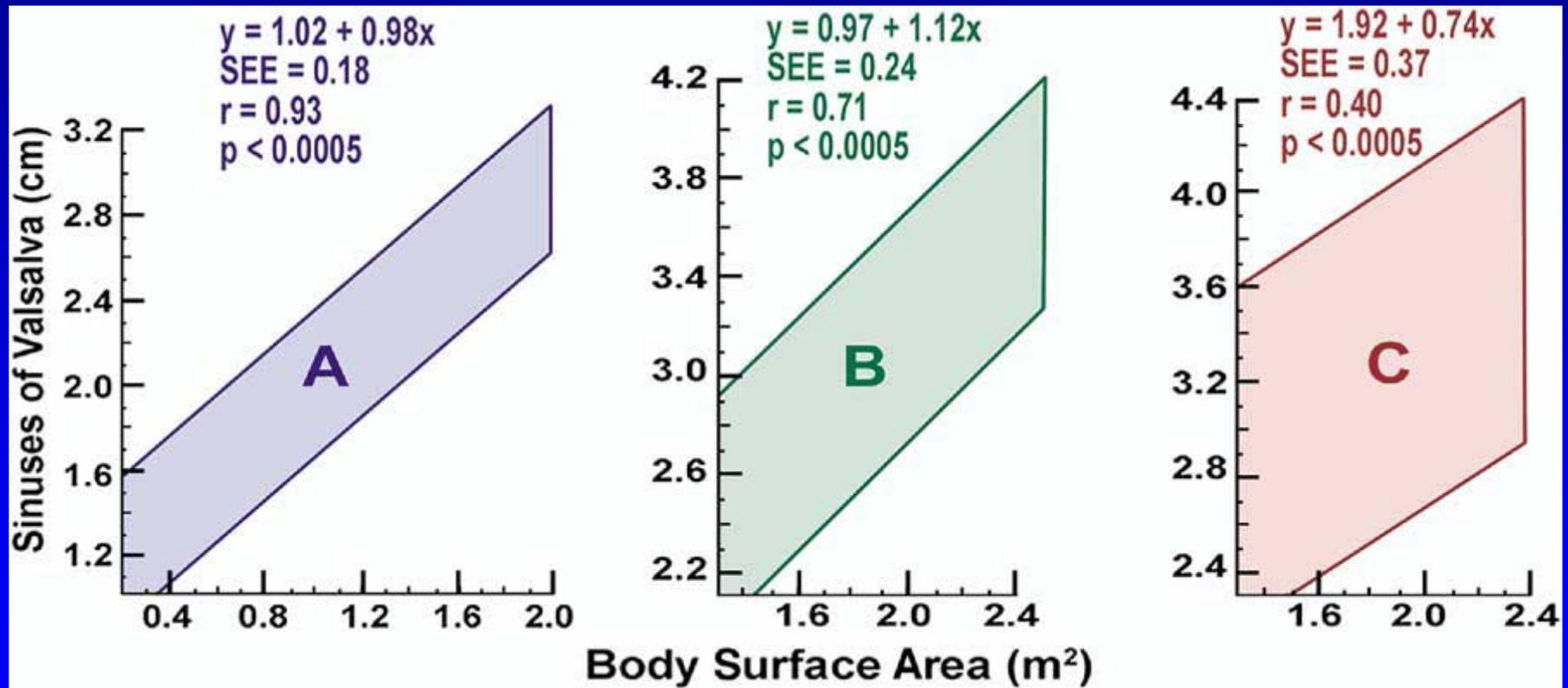
Measuring the Aortic Diameter

- Obtain a non-oblique image
- Measure the maximal diameter perpendicular to the long axis of the vessel
- Leading edge to leading edge technique at end-diastole

Measuring the Aortic Diameter



Aortic Root Diameters by Body Surface Area

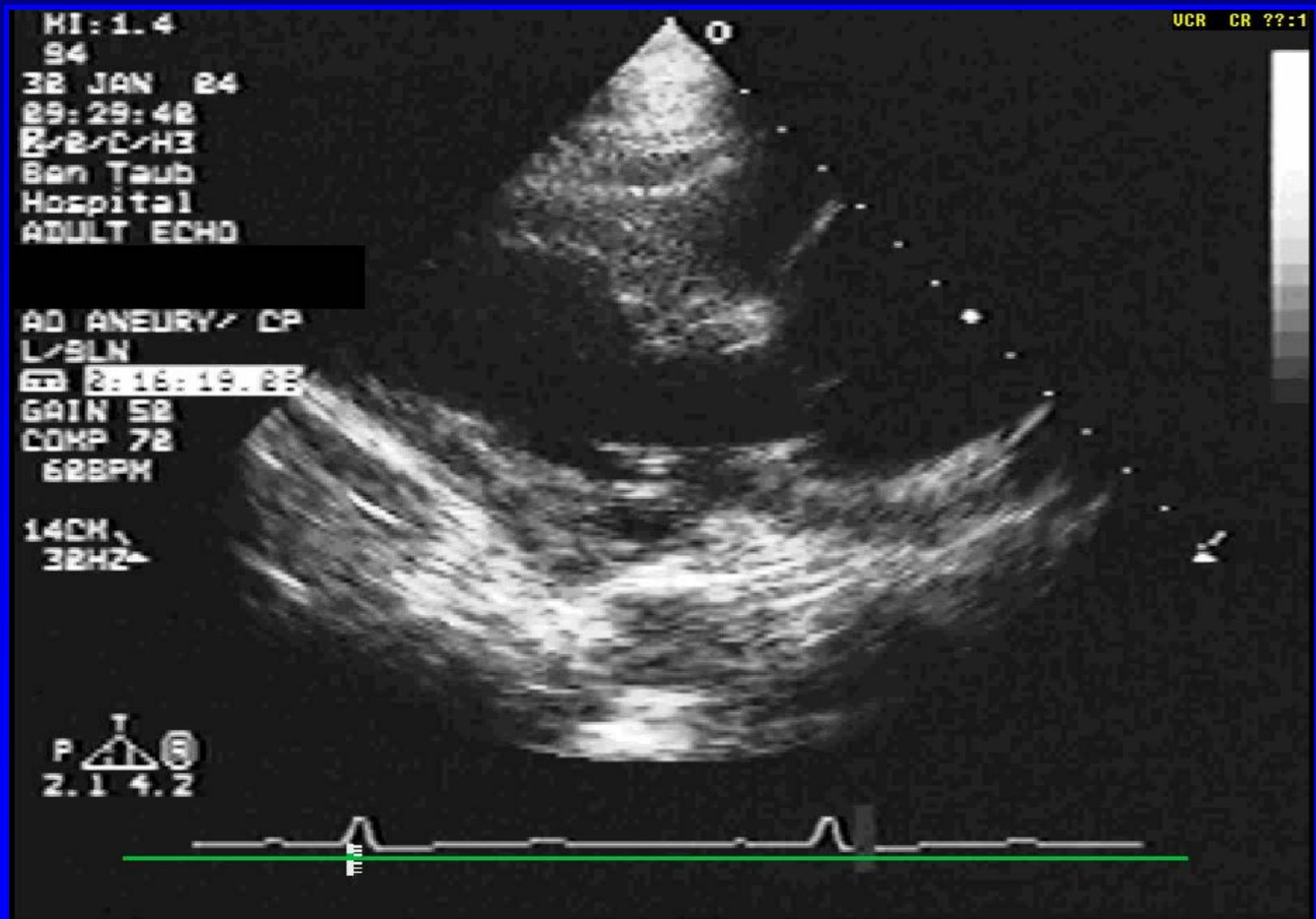


How big is the aorta?

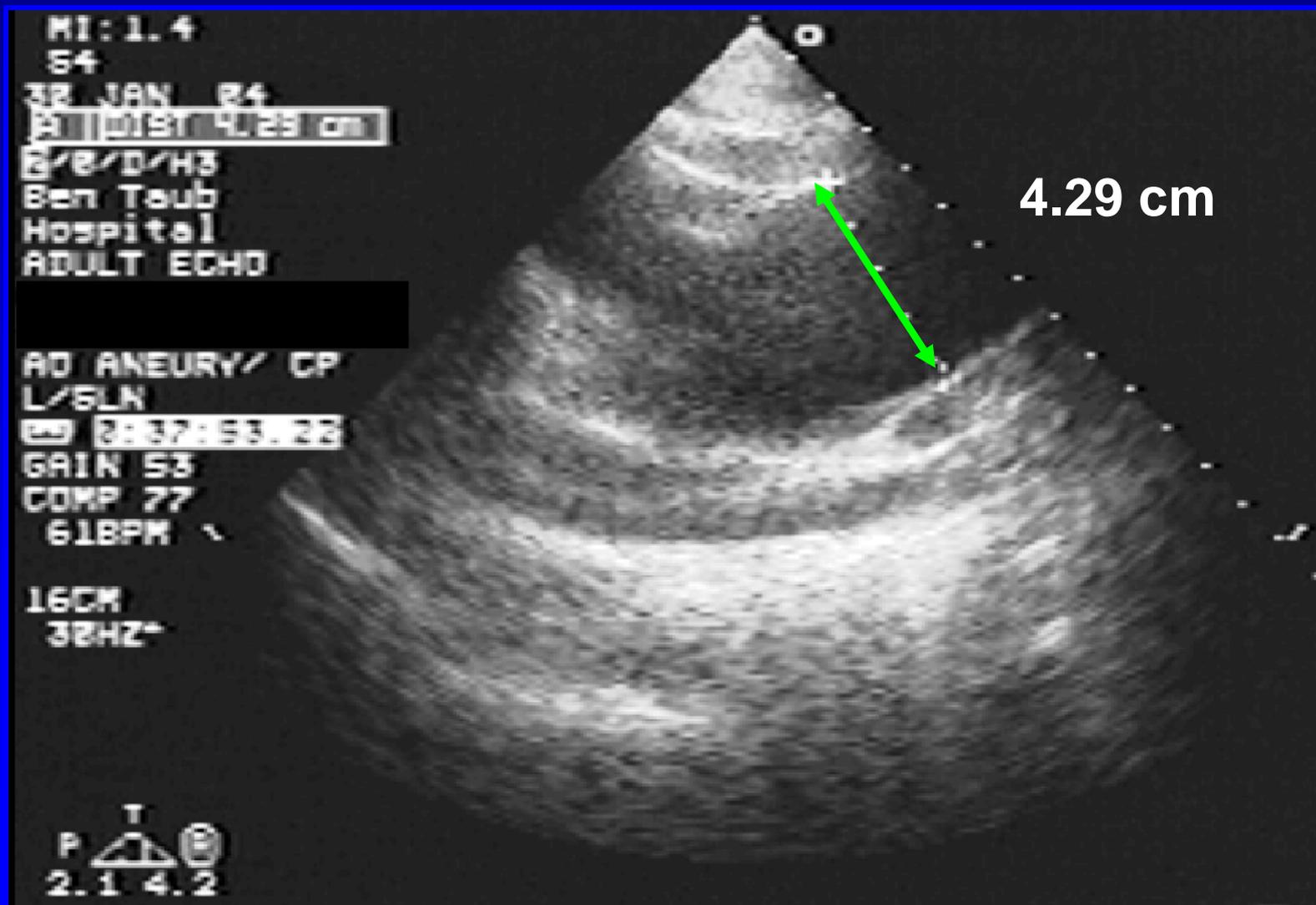
- Not an easy answer
- Unlikely to reliably measure a change $< 3-4$ mm on any imaging modality due to resolution issues
- Must ensure that serial measurements are performed at same level
 - As the aorta dilates, it elongates as well

Modality	Pros	Cons
CT	<ul style="list-style-type: none">•Availability•Images entire aorta & branch vessels•Fast•Detect other disease processes that may mimic aortic dz•Preferred post-procedurally	<ul style="list-style-type: none">•Radiation•Contrast
MRI	<ul style="list-style-type: none">•Images entire aorta & branch vessels	<ul style="list-style-type: none">•Prolonged imaging time
TEE	<ul style="list-style-type: none">•Portable•Assess secondary sequelae of dissection	<ul style="list-style-type: none">•Blind spot / artifacts•Unable to image abd aorta•Sedation

Transthoracic Echocardiogram



Further Transthoracic Aortic Evaluation



Suprasternal Window



Subcostal Window

MI: 1.4
S4
07 DEC 04
11: 11: 46
2/0/B/H3
Ben Taub
Hospital
1

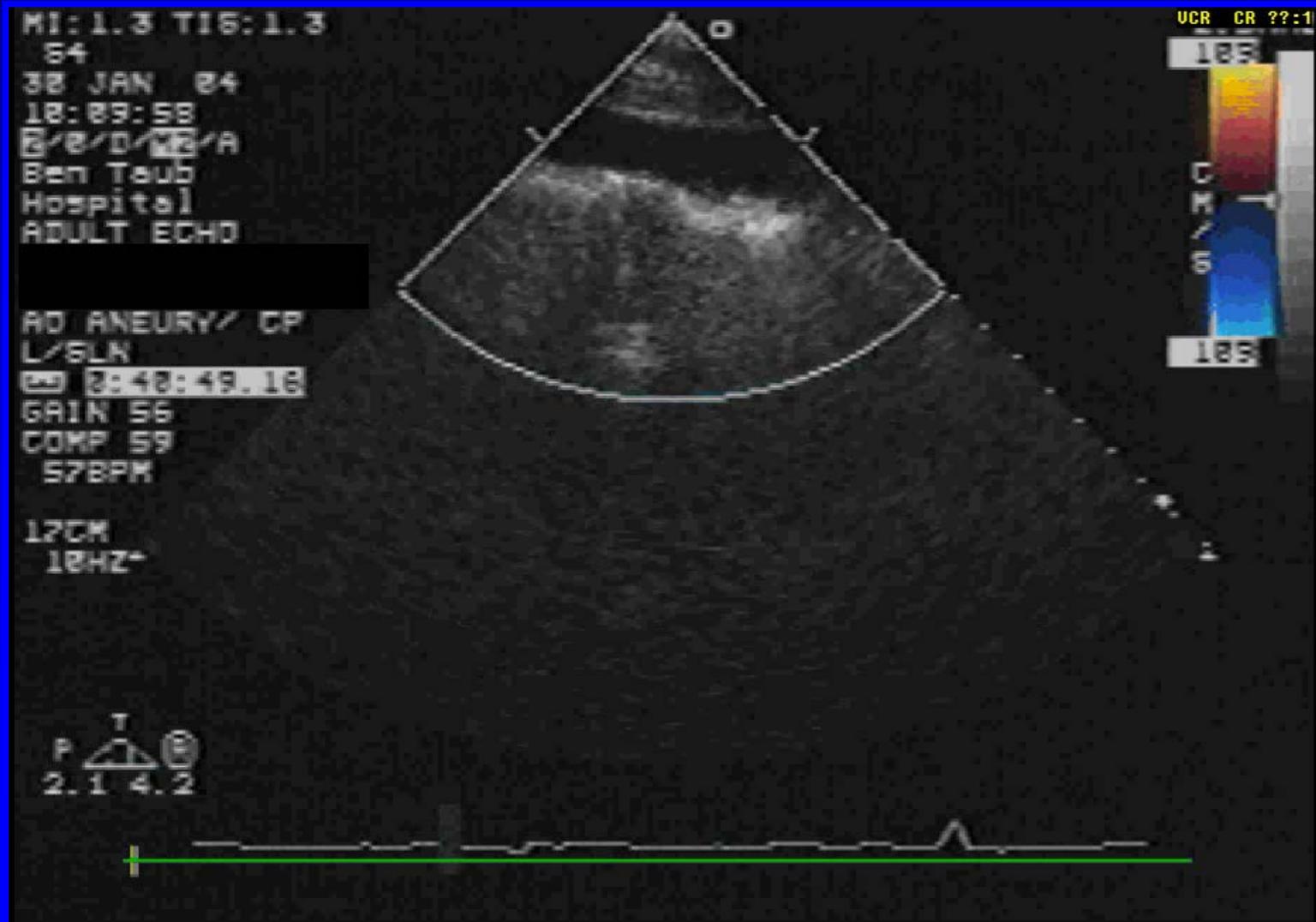
GAIN 91
COMP 70
57BPM

23CM
30HZ

T
P 
2.1 4.2



Abdominal Aorta



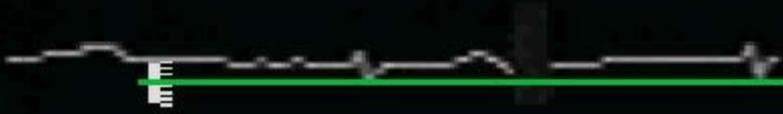
TEE Evaluation



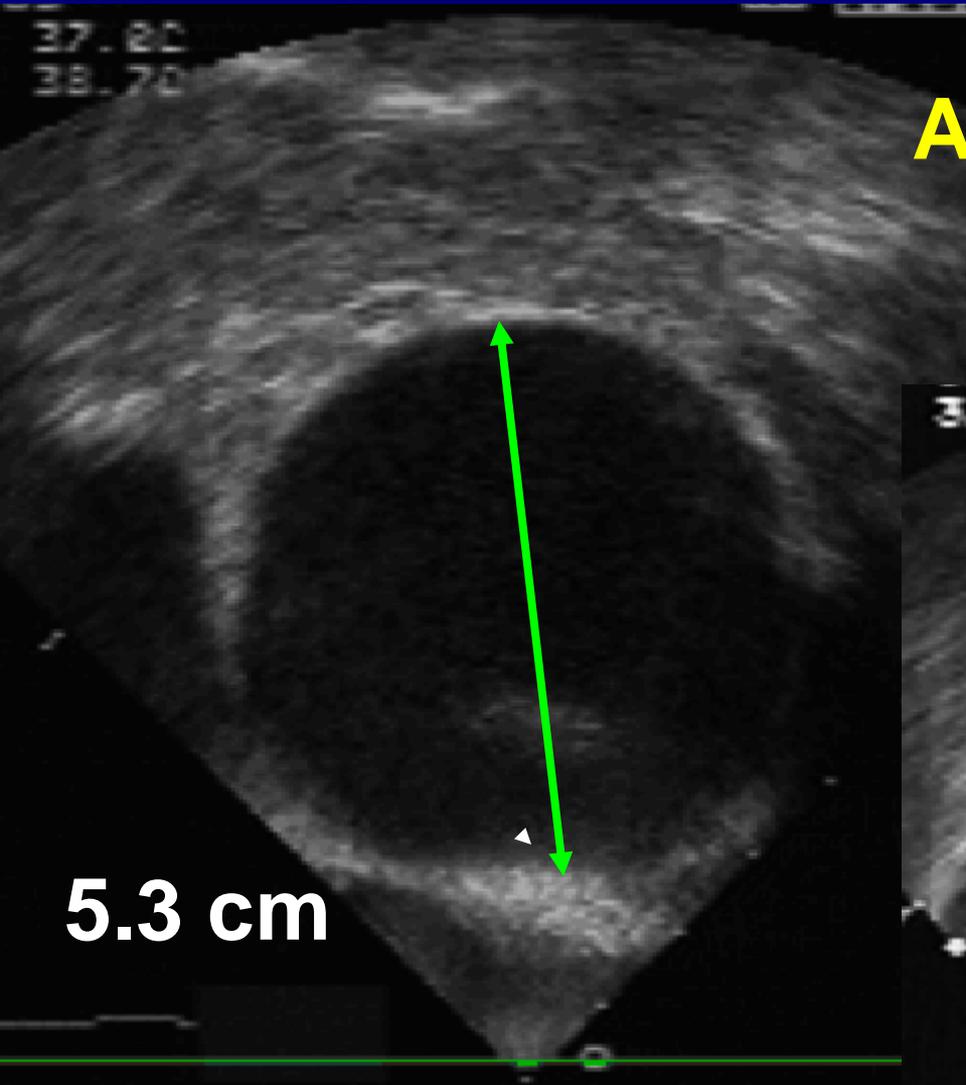
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30 JAN 84 13:39:10
E/E/F3 12CM
GAIN 50 COMP 65 40HZ
588BPM PAT T: 37.0C
TEE T <37.0C

Ben Taub
Hospital
TEE
18:05:52.25

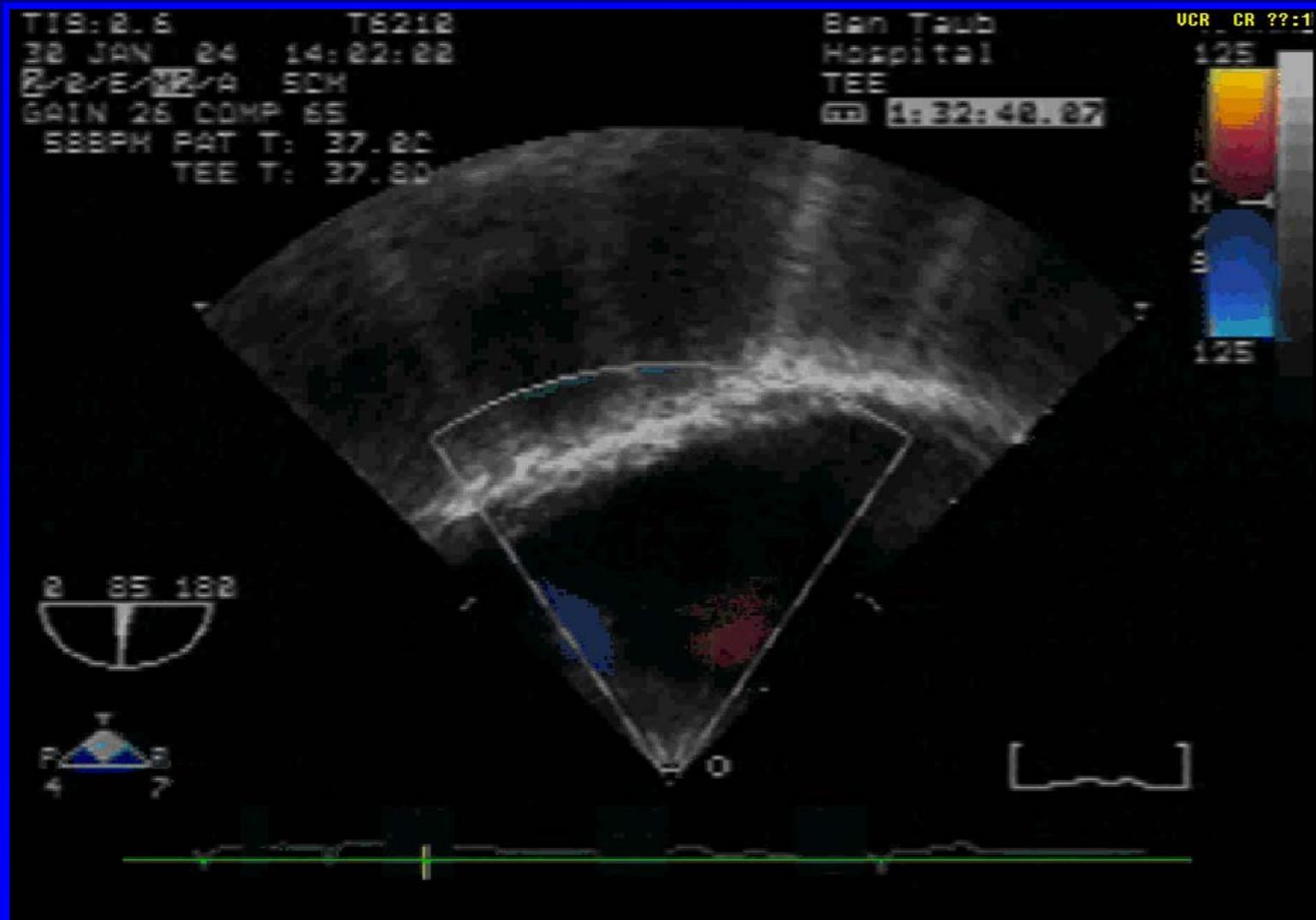
UCR CR ??:1



Ascending Aorta by TEE



Descending Aorta with Color Flow



Class I Indications

Echocardiography of the Aorta

- Aortic dissection (diagnosis and follow-up)
- Aortic aneurysm
- Aortic intramural hematoma
- Aortic rupture
- Aortic root dilatation in Marfan's Syndrome or other connective tissue disease
 - Screening of first degree relatives
- Degenerative / traumatic aortic disease with clinical atheroembolism

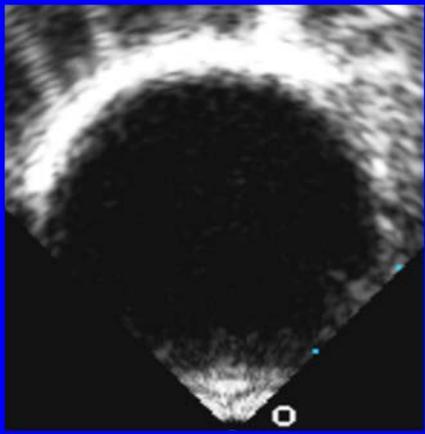
Pathology of the Aorta

- Atherosclerosis
- Aortic Aneurysm
- Aortic Dissection
- Aortic Trauma
- Intramural Hematoma
- Pseudoaneurysm
- Sinus of Valsalva Aneurysm
- Coarctation

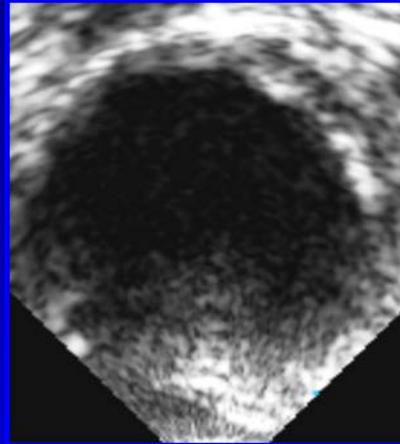
Grading System for Aortic Atherosclerosis

Grade	Severity	Description
1	Normal	Intimal thickness <2 mm
2	Mild	Mild intimal thickening of 2-3 mm
3	Moderate	>3-5 mm (no mobile or ulcerated components)
4	Severe	>5 mm (no mobile or ulcerated components)
5	Complex	Grades 2,3, or 4 + mobile or ulcerated components

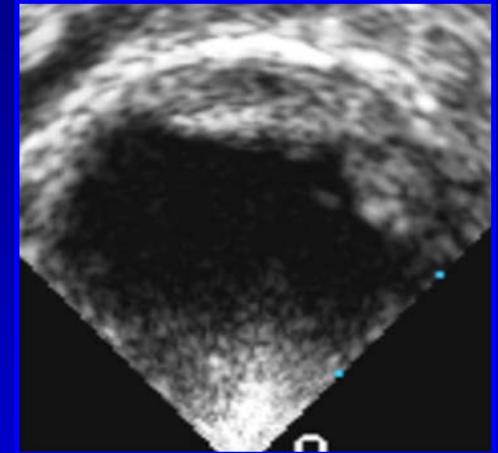
Aortic Atherosclerosis



Grade 1



Grade 2



Grade 4

↑ **Risk of Neurologic Injury**

- Thickness > 3 mm
- Presence of mobile components
- Ascending aortic location

Aortic Aneurysms

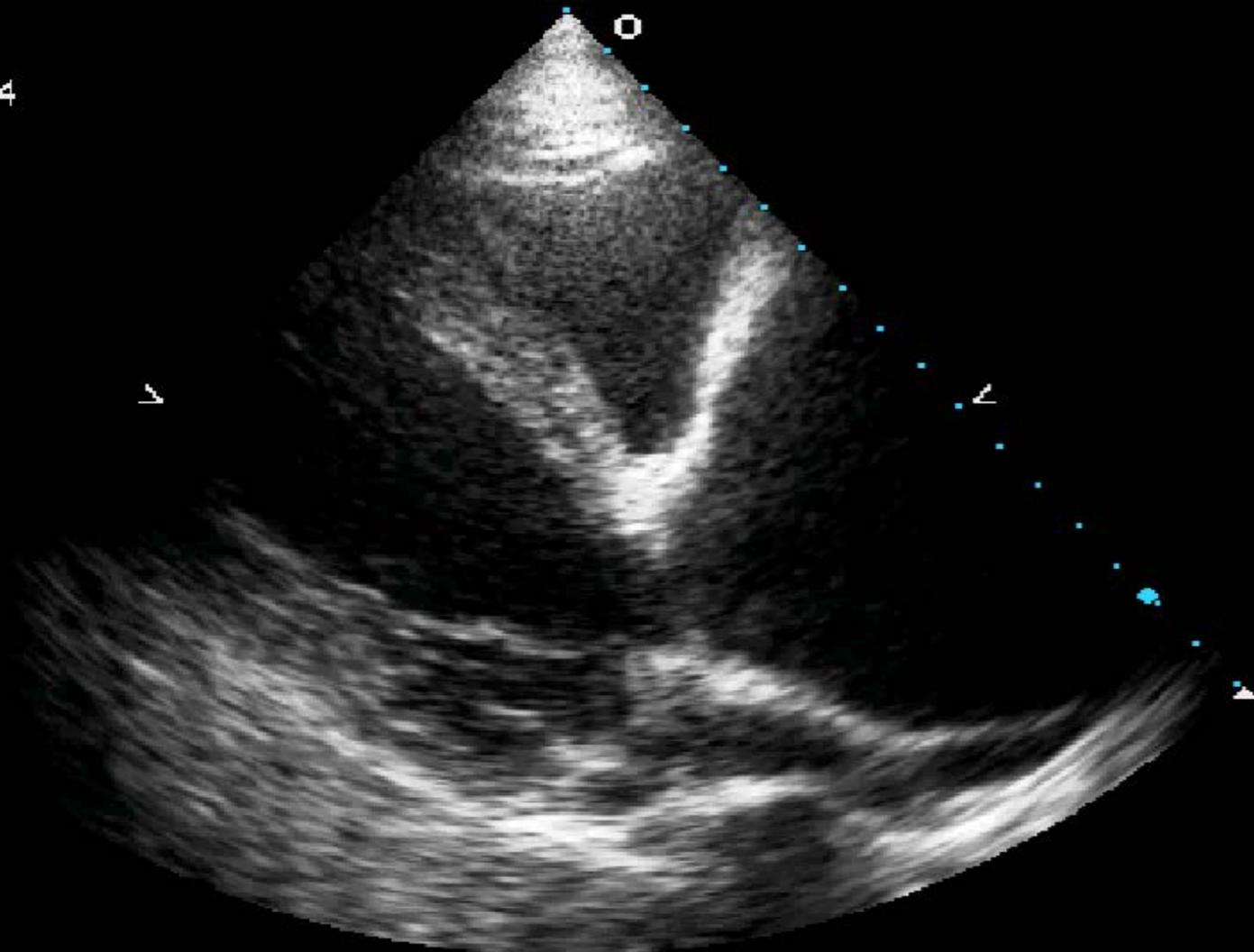
Aortic aneurysms

- **True Aneurysm:** localized dilatation of artery
- **Pseudoaneurysm:** Occurs when a full-thickness defect in the aortic wall allows blood to circulate outside of the confines of the artery and is contained by periarterial connective tissue

MI: 1.6
S4
07 DEC 04
11:01:15
2/0/B/H2
Ben Taub
Hospital
1

GAIN 81
COMP 70
59BPM

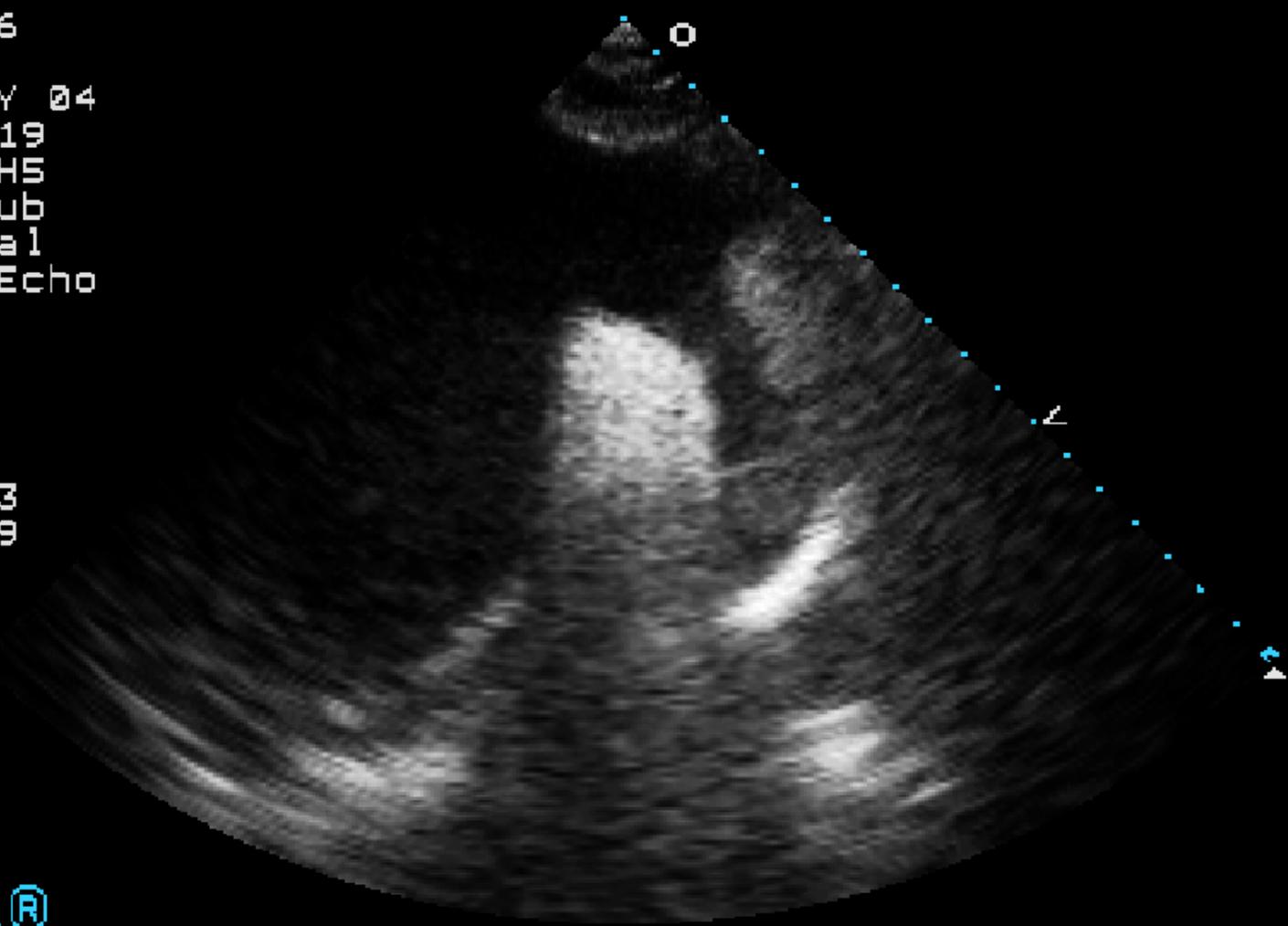
17CM
30HZ



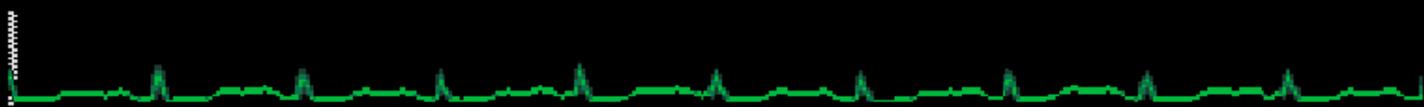
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14:05:19
2/0/D/H5
Ben Taub
Hospital
Adult Echo

GAIN 53
COMP 59
77BPM

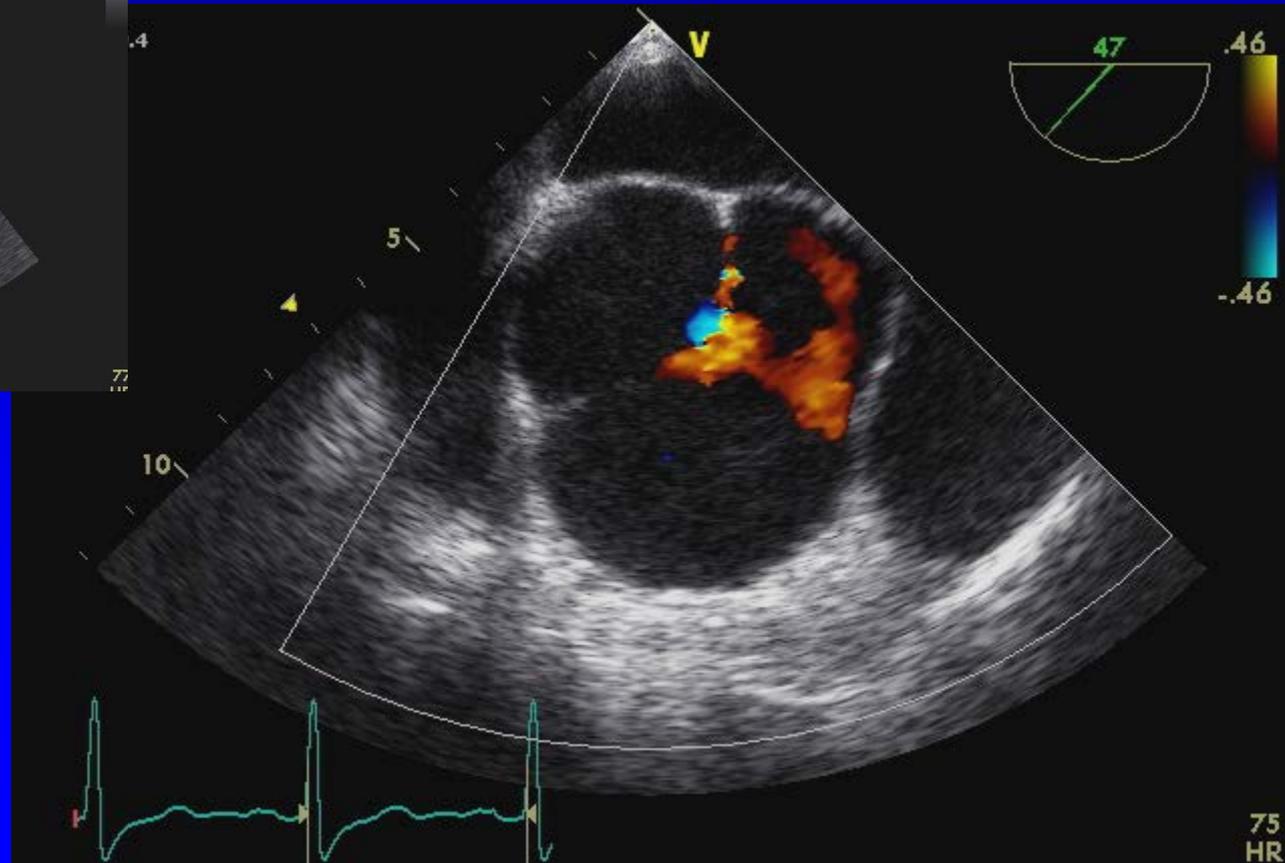
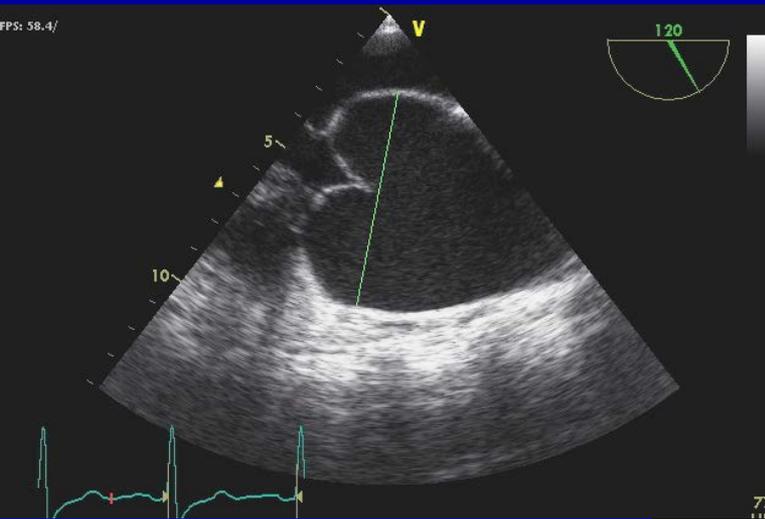
19CM
45HZ



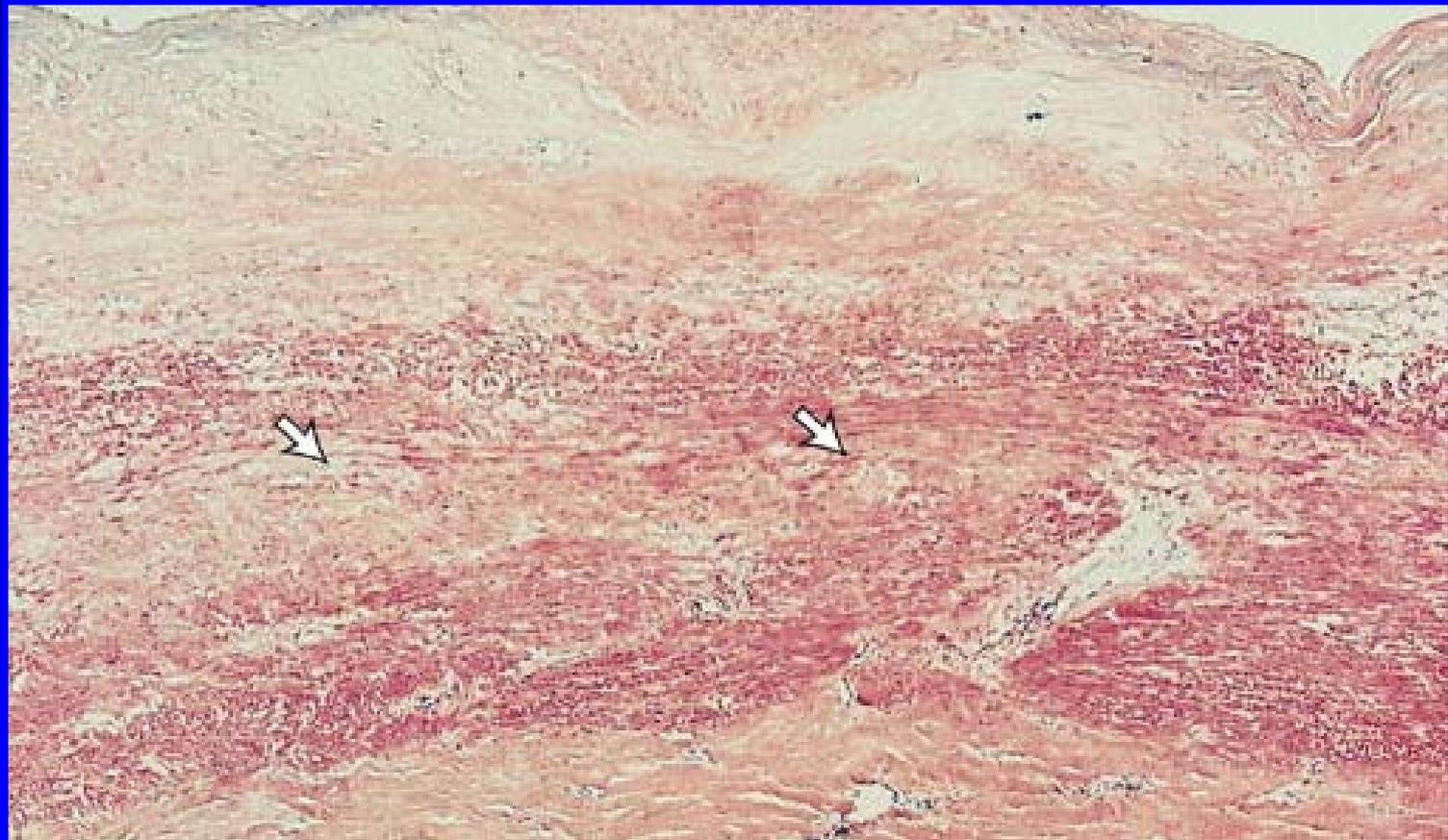
T
P 1.6 3.2 R



Ascending Aortic Aneurysm by TEE



Cystic Medial Necrosis



Isselbacher E. [Atlas of Heart Diseases: Vascular Disease](#).
Edited by Eugene Braunwald (series editor), Mark A. Creager.

Circumferential Stress

- Stress = Force / Area
- $\delta = Pr/h$
 - δ = stress
 - P = radial pressure
 - r = radius
 - h = wall thickness



Genetics of Aortic Aneurysms

- In Yale database, 21% of probands have a family member with known arterial aneurysm
- Class I: Aortic imaging is recommended for first-degree relatives of patients with thoracic aortic aneurysm and/or dissection to identify those with asymptomatic disease



JACC 55(9): 841-57, 2010

Genetic Syndrome	Clinical Features	Genetic Defect	Aortic Disease
Marfan	Aortic root dilatation MVP Arachnodactyly Pectus excavatum Ectopia lentis	FBN1 mutations	Surgical repair when: aortic root \geq 5.0 cm, rapidly expanding, <5.0 cm with family hx of AoD, significant AR
Loeys-Dietz	Bifid uvula, cleft palate Arterial tortuosity Hypertelorism Skeletal features of MFS	TGFBR1 or TGFBR2 mutations	Surgical repair \geq 4.2 cm by TEE or 4.4-4.6 cm by CT
Ehlers-Danlos	Easy bruising Arterial , GI, uterine rupture	COL3A1 (type III collagen) mutations	Surgical repair complicated by friable tissue
Turner	Short stature Bicuspid aortic valve Aortic coarctation Webbed neck	45 X karyotype	\uparrow risk with bicuspid AV, coarctation, HTN, pregnancy

Risk of Aortic Rupture / Dissection

- SIZE is the most important determinant of the risk of rupture / dissection
- Mortality:
 - Acute dissection 22-25%
 - Elective ascending aorta surgical repair 1.5-2.5%
- Surgical referral recommended:
 - Aneurysm size ≥ 5.5 cm
 - 4.5-5 cm in Marfan's, bicuspid AV, familial patients
- Symptomatic aneurysms should be resected regardless of size

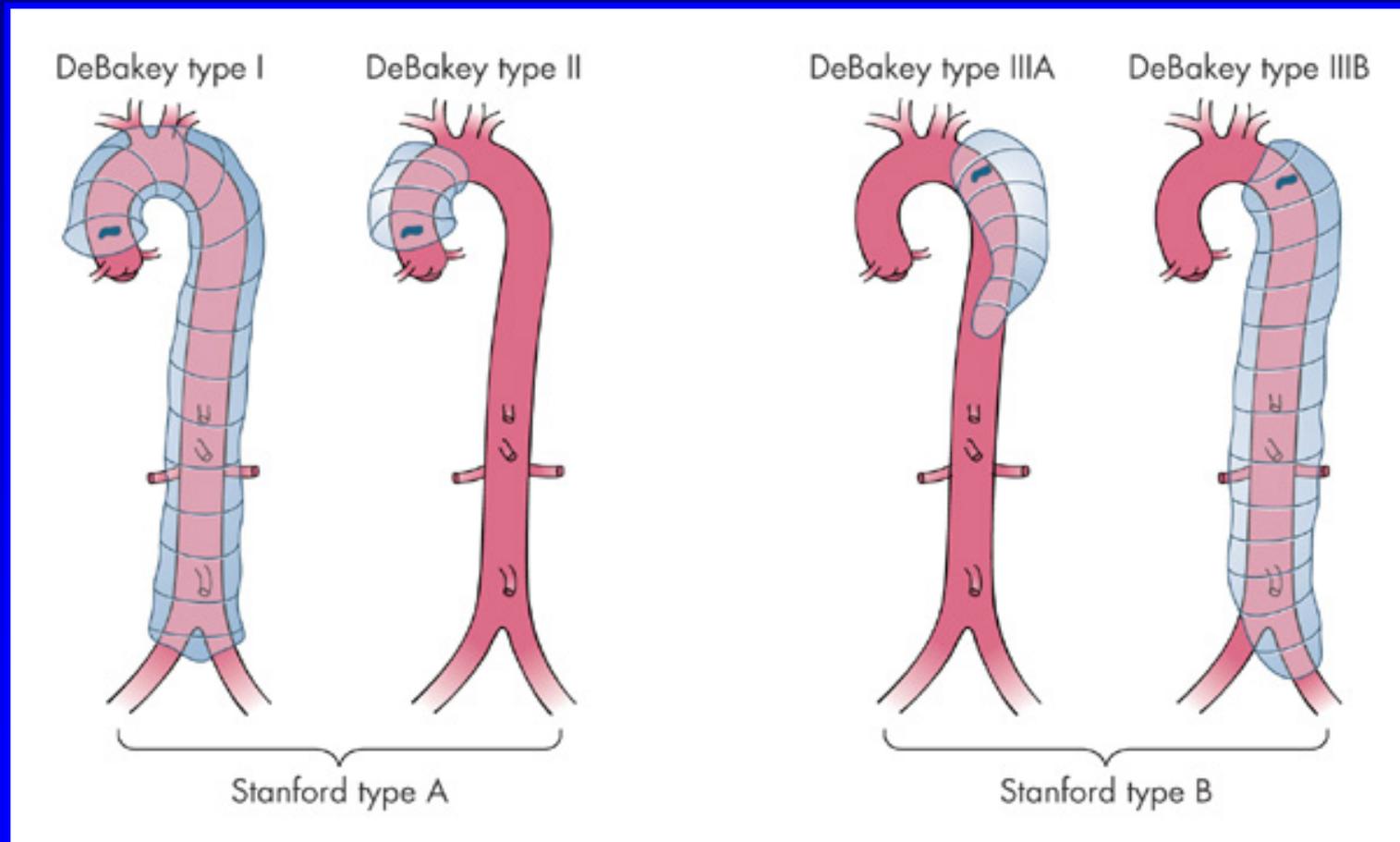
Ann Thorac Surg 74(5):S1877-80, 2002

NEJM 340:1307-13, 1999

Ann Thorac Surg 83:S846-50, 2007

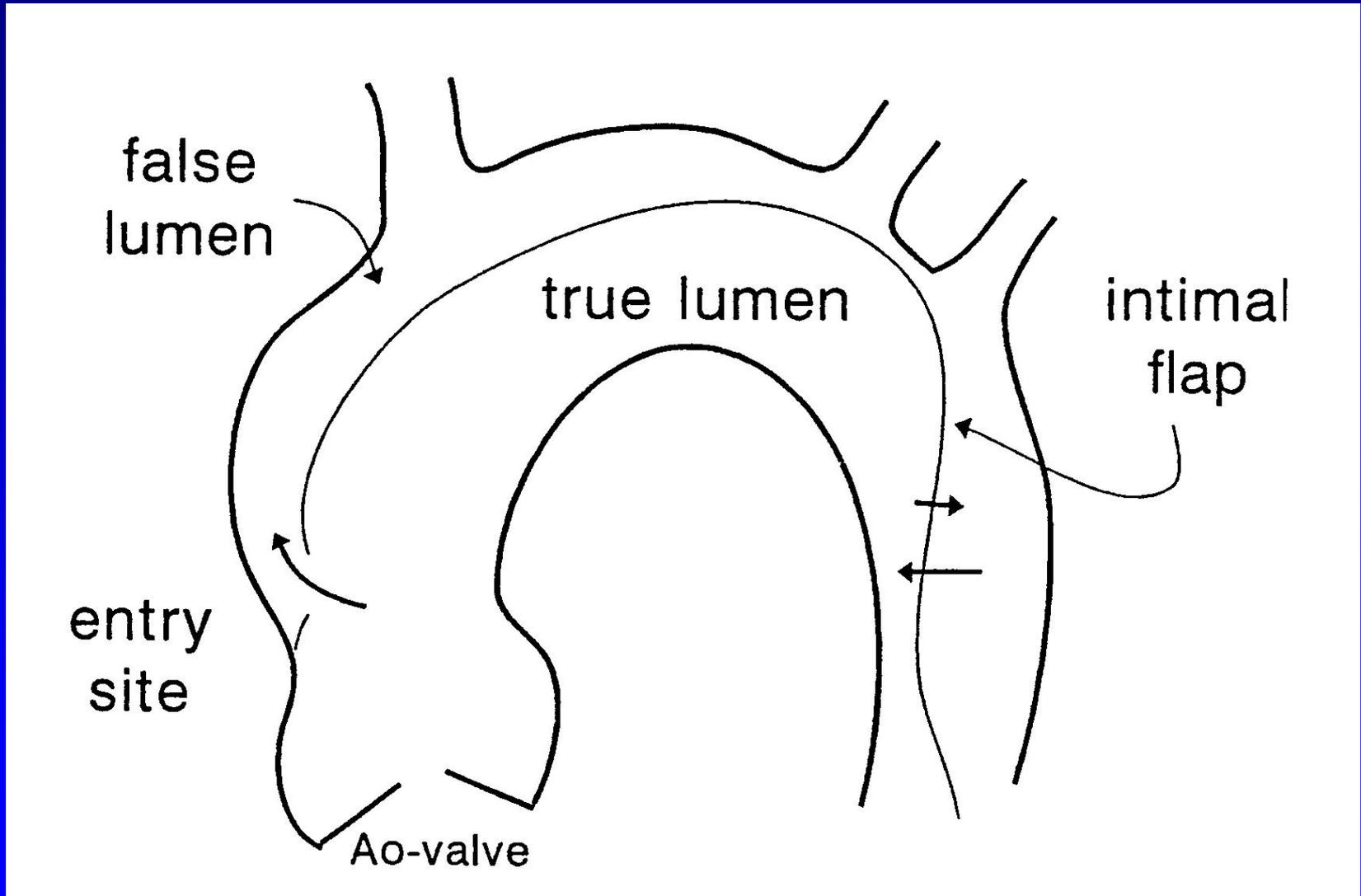
Aortic Dissection

Types of Aortic Dissection



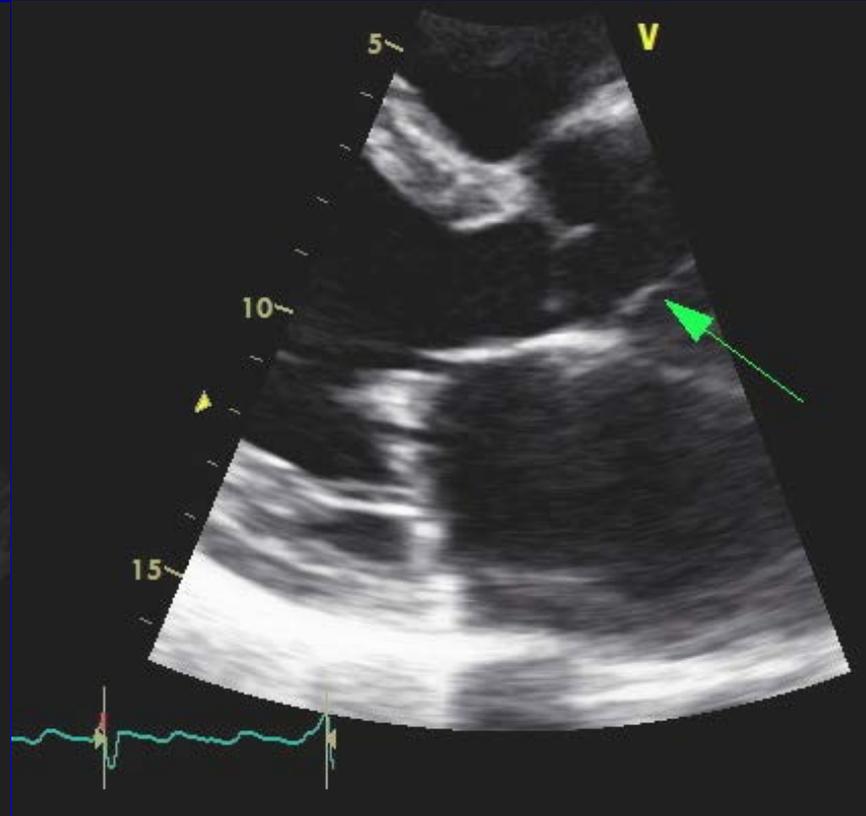
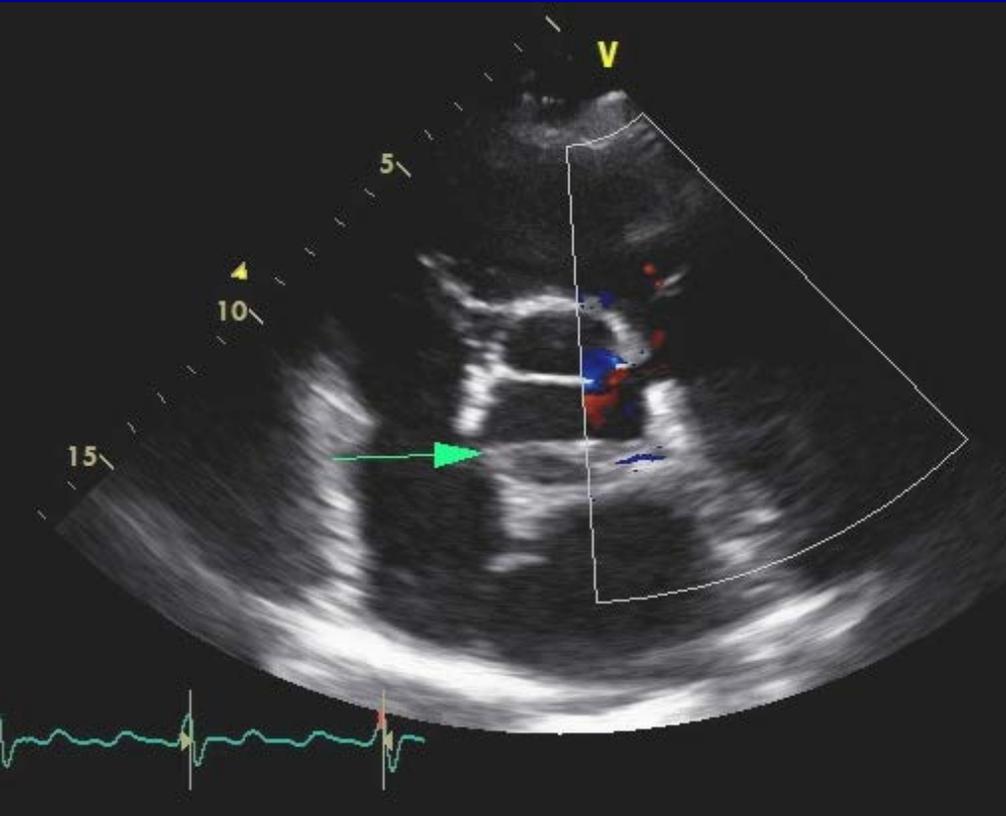
Smith M, Grichnik K. [Atlas of Anesthesia: Cardiothoracic Anesthesia](#). Edited by Ronald Miller (series editor), J.G. Reves. 1999

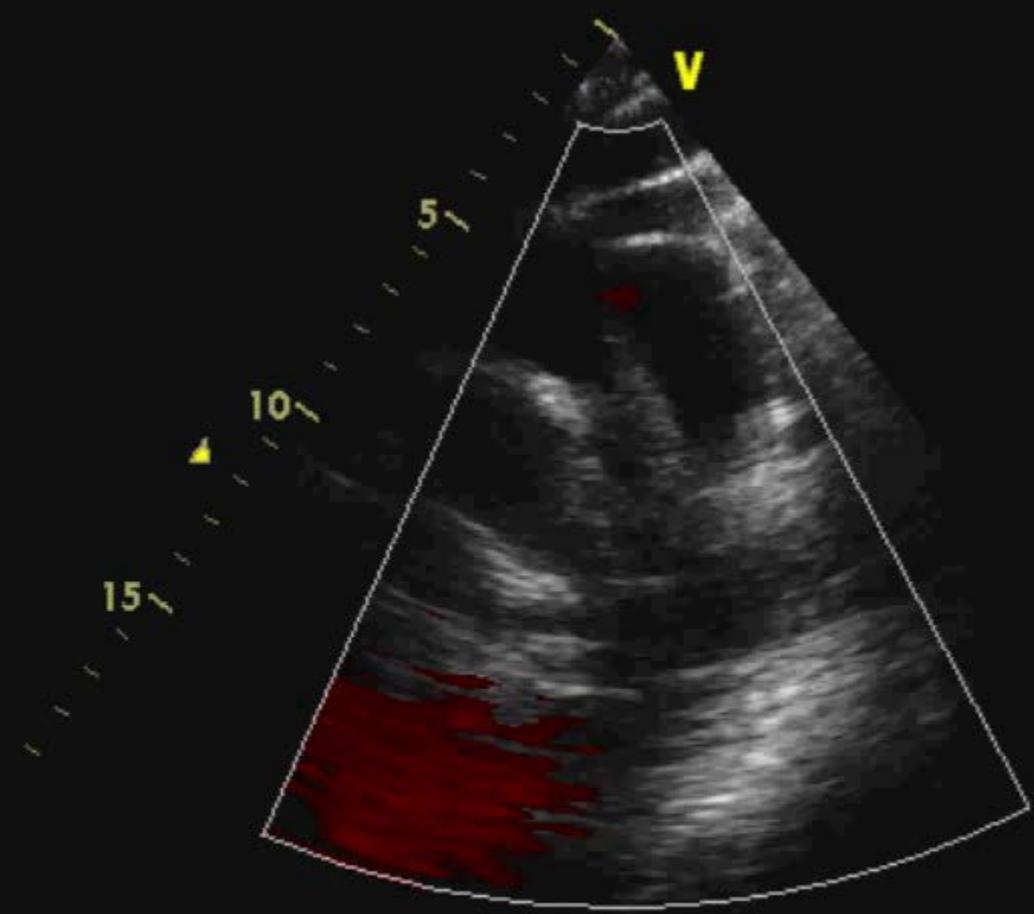
Aortic Dissection



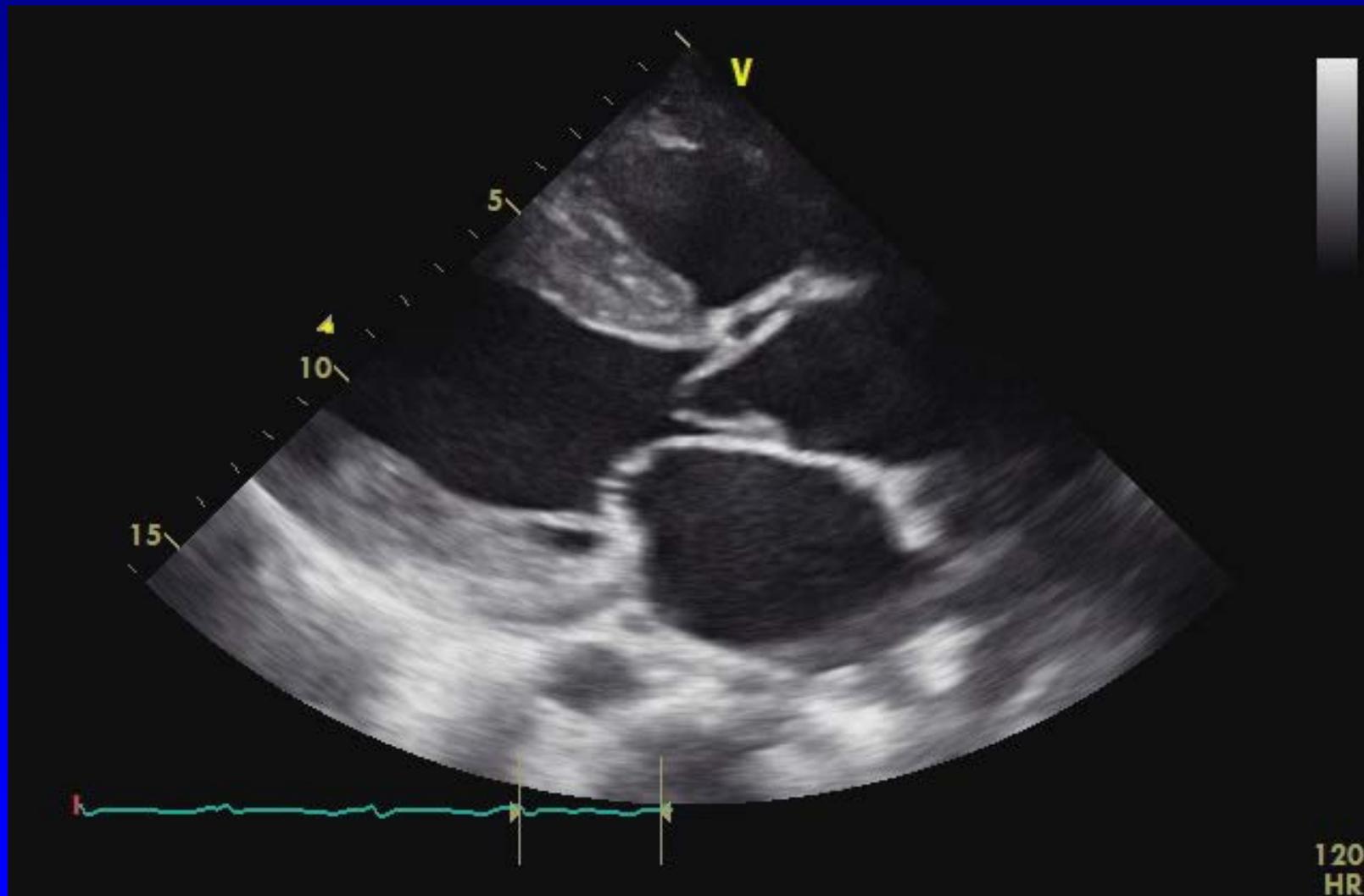
Aortic Dissection

by Transthoracic echocardiography

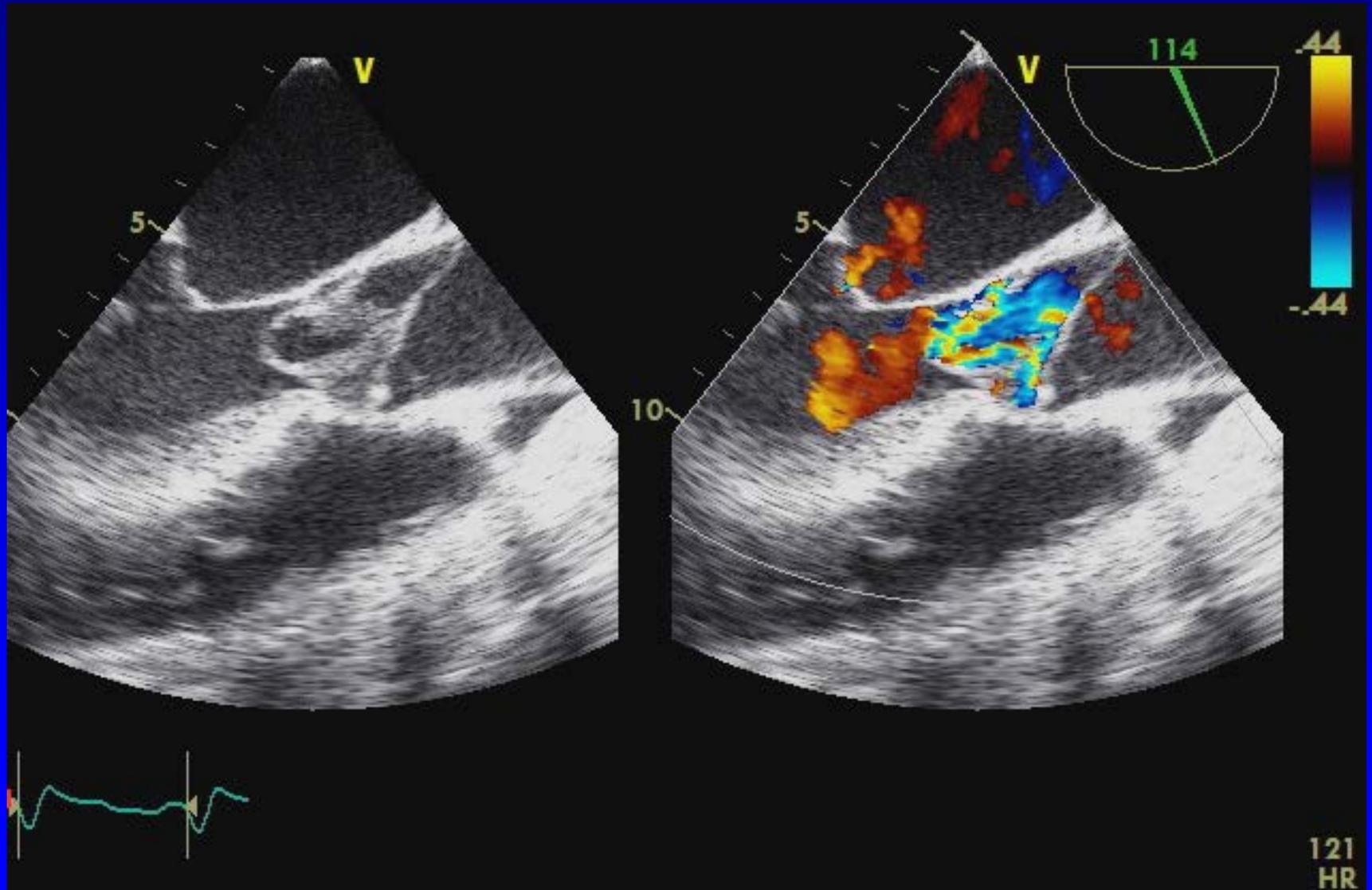




Aortic Dissection by TTE

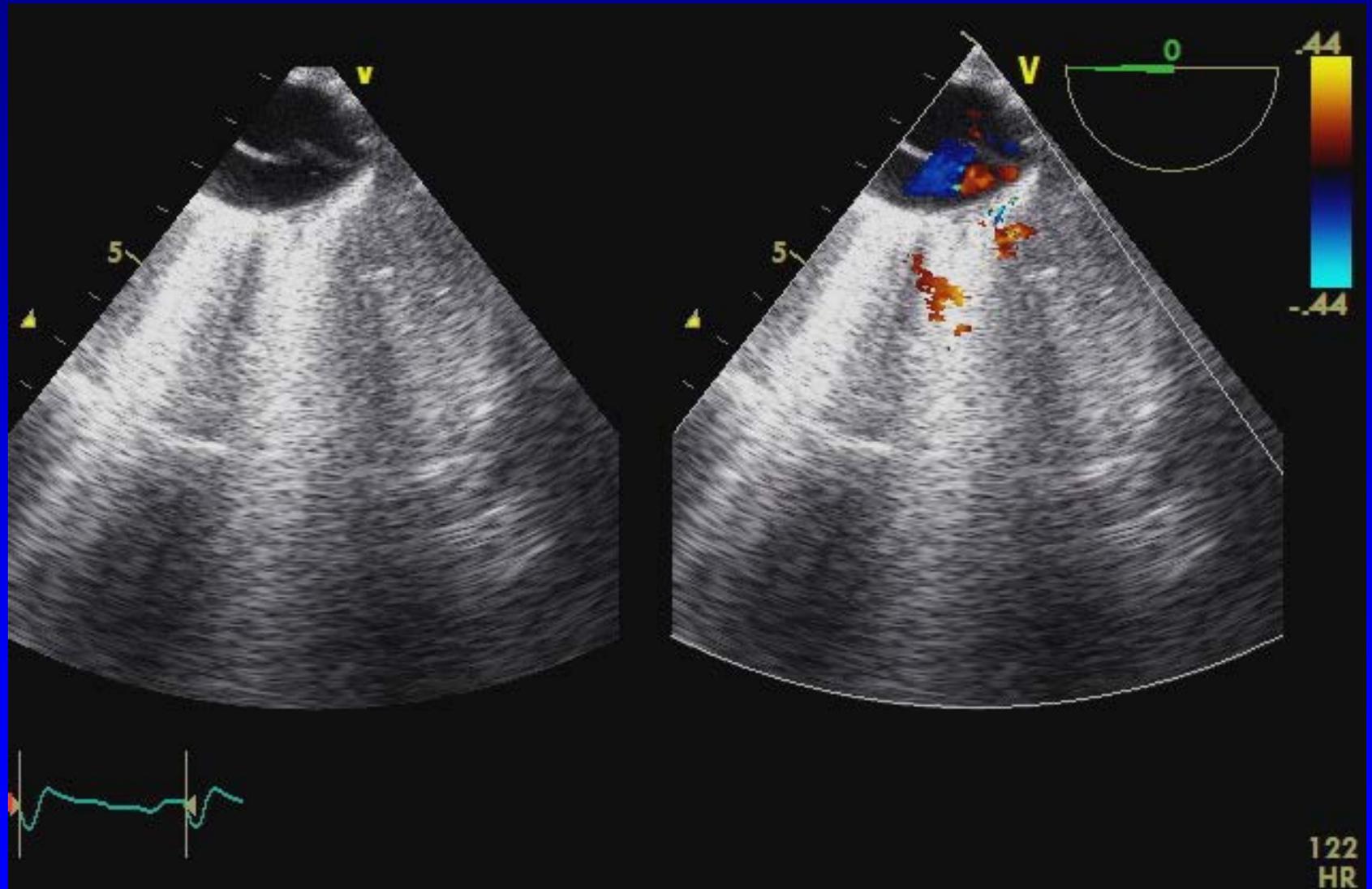


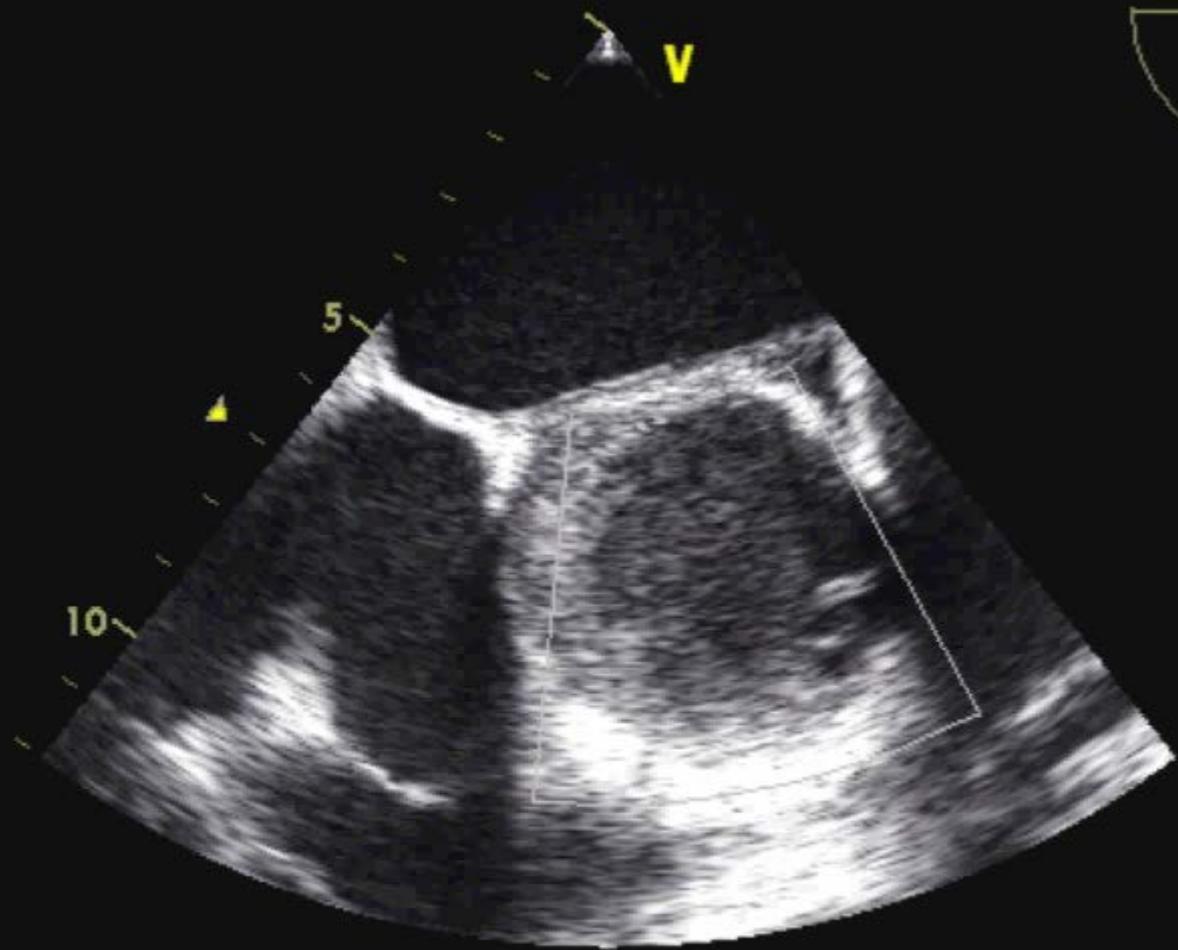
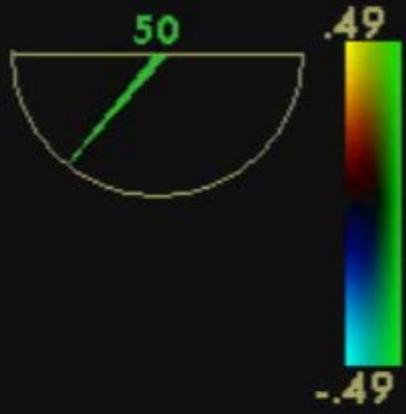
Aortic Dissection by TEE

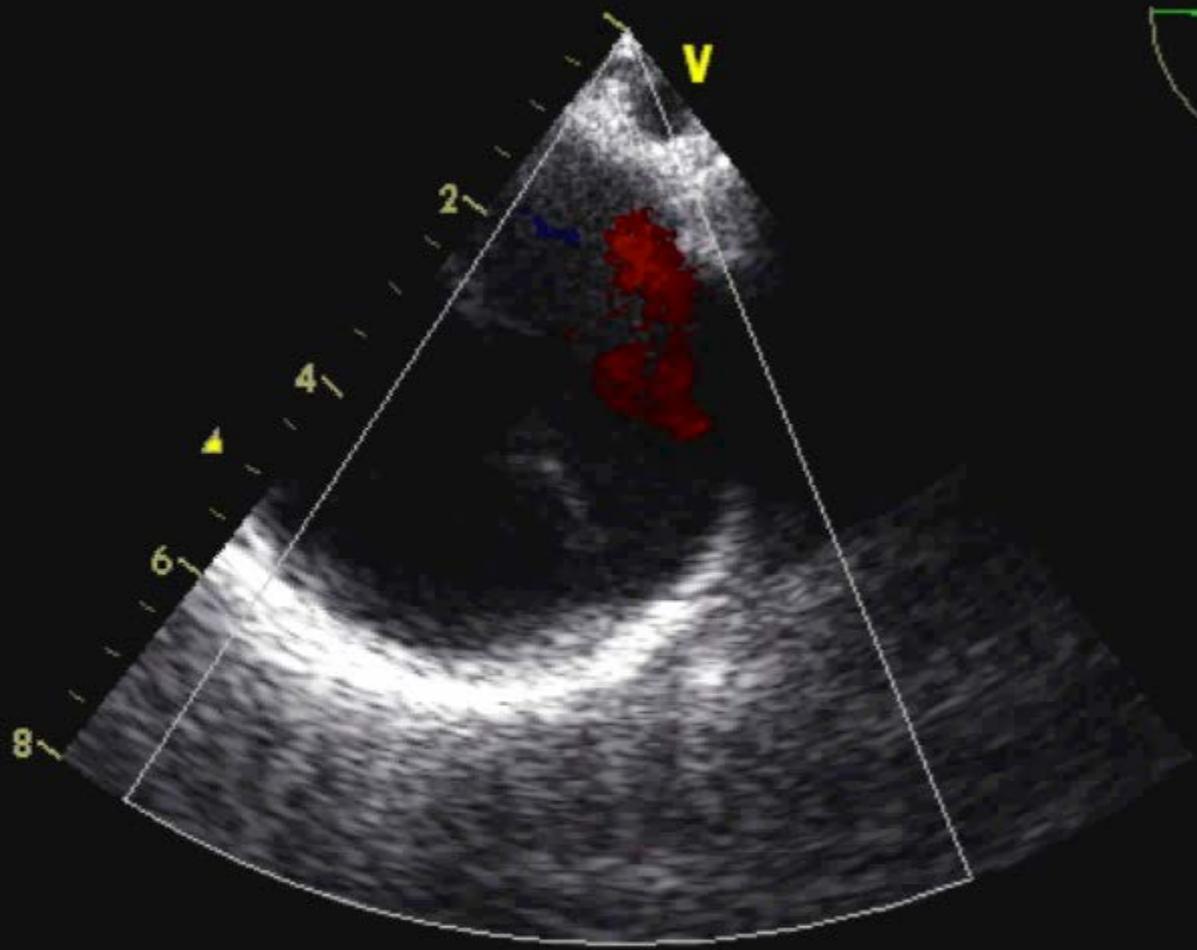


Aortic Dissection

Descending thoracic aorta







Conditions Associated with Aortic Dissection

- **↑ Aortic Wall Stress**
 - HTN
 - Pheochromocytoma
 - Cocaine / Stimulants
 - Weight Lifting / Valsalva
 - Trauma
 - Deceleration / Torsion
 - Coarctation
- **Inflammatory**
 - Takayasu, Giant Cell
 - Behcet
- **Genetic**
 - Marfan
 - Ehlers-Danlos
 - Bicuspid aortic valve
 - Turner
 - Loeys-Dietz
 - Familial
- **Other**
 - Pregnancy
 - PKD
 - Infections
 - Iatrogenic

Echocardiographic Features

Aortic Dissection

- An intimal flap is typically seen as a linear mobile density in a dilated aortic lumen
- Other entities mistaken for “dissection flap”
 - Beam width / reverberation artifact / Brachiocephalic vein
 - Artifacts may be vague, cross anatomic barriers, not independently mobile or assoc with differential blood flow
- Identifying the true lumen
 - Expands during systole
 - More circular in shape
 - May be the smaller of 2 lumens

Caveats for Imaging Aortic Dissection

- Must evaluate in multiple planes
- Use of color flow Doppler
 - Assess for differential blood flow
 - Identify communication points between true and false lumens
- Blind spot: distal ascending aorta – superior transverse arch

Advantages of TEE in Imaging Aortic Dissection

- Readily Available
- Perform at Bedside
- No need for contrast or radiation
- Detects secondary complications

Complications of Aortic Dissection

- Aortic Regurgitation
 - Dilatation of aortic root
 - Disruption of annular support
 - Pressure from dissecting hematoma
 - Prolapse of intimal flap through AV
 - Pre-existing AV disease (ie. Bicuspid AV)
- LV function and coronary involvement
 - RCA is most commonly affected
- pericardial effusion \pm tamponade

Sensitivity of Imaging Modalities

Aortic Dissection

Type of Dissection	TTE	TEE	CT	MRI
Type A	78%	96%	83%	100%
Type B	10%	100%	96%	97%

NEJM 328:1-9, 1993, Arch Int Med 166:1350-6, 2006

Pros and Cons

Modalities for Imaging Aortic Dissection

- **CT:**

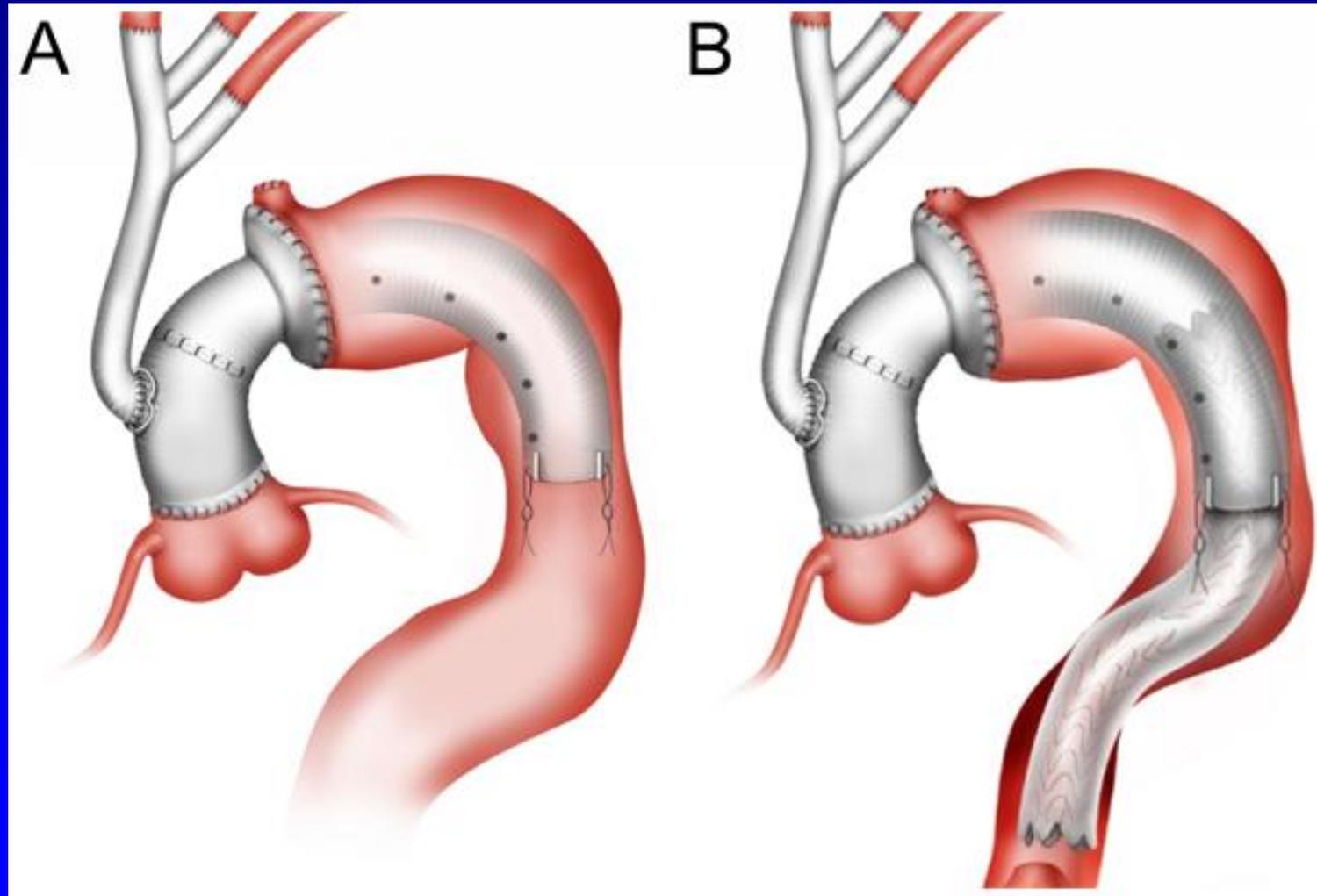
- Widely available
- Better at assessing branch vessel involvement
- Requires contrast and radiation
- Unable to evaluate aortic regurgitation

- **MRI:**

- Does not require radiation or iodinated contrast
- Incompatible with implanted metal devices
- Not amenable to hemodynamically unstable patients

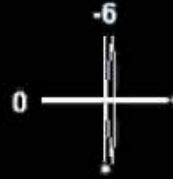
Surgical Repair of Aortic Dissection

The Elephant Trunk Procedure

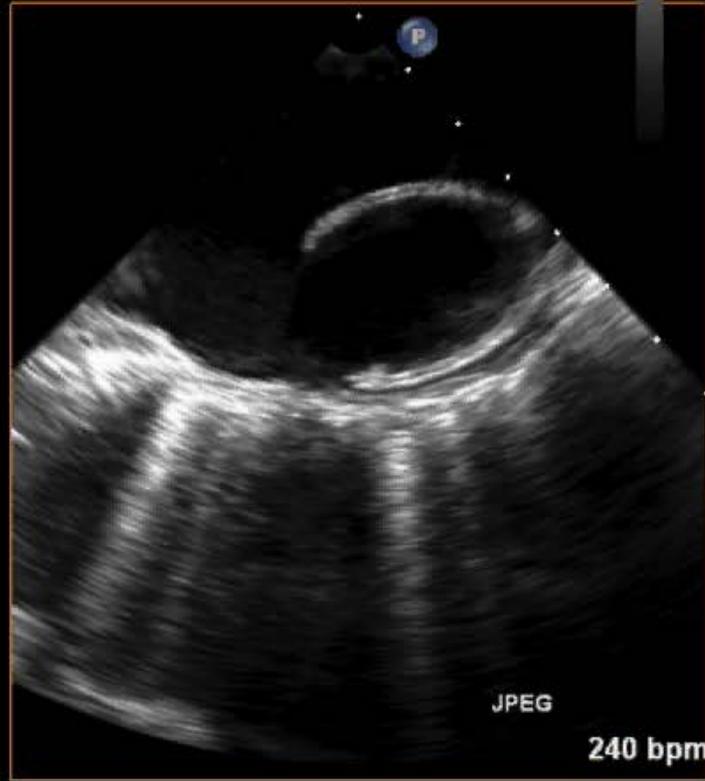
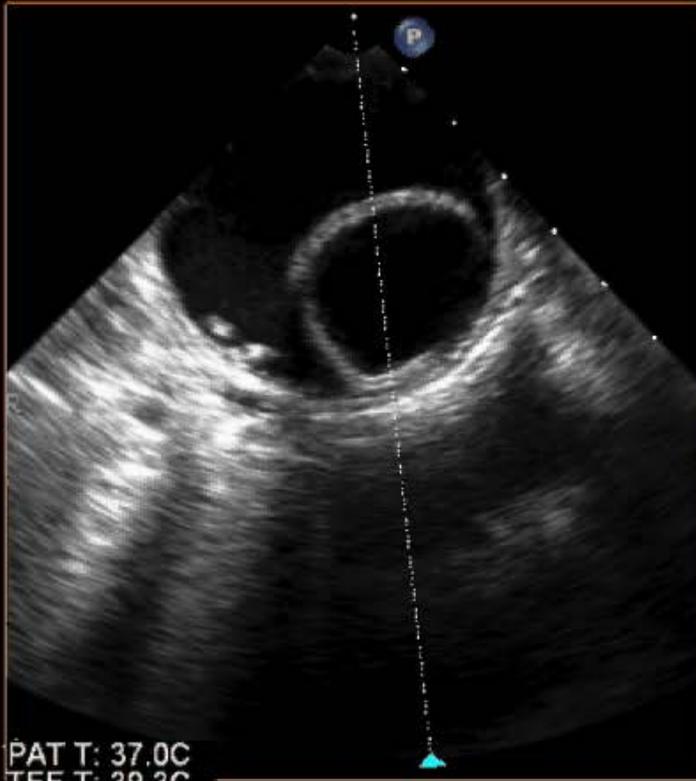


FR 29Hz
10cm

xPlane
61%
61%
50dB
P Low
Gen



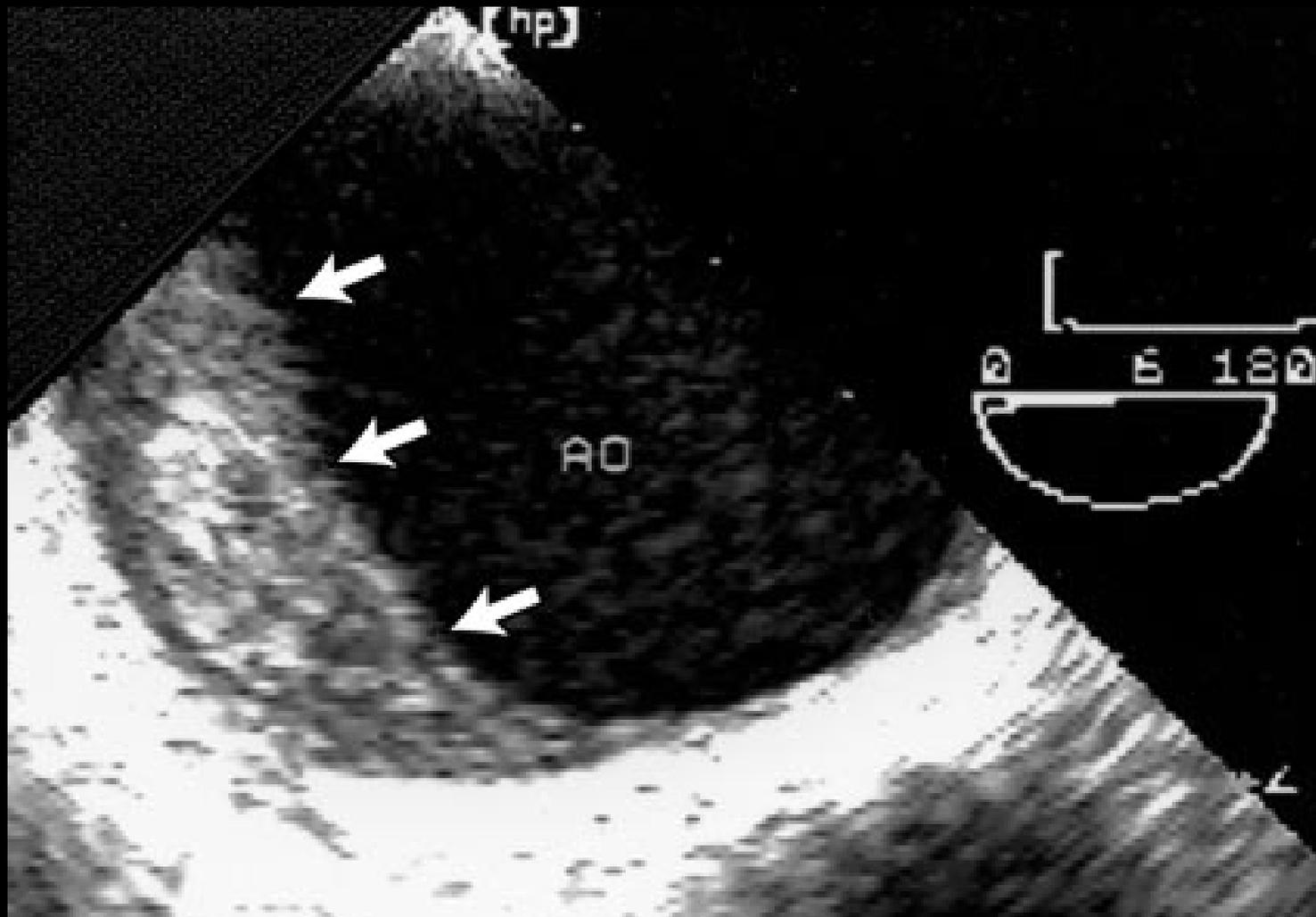
M4



PAT T: 37.0C
TEE T: 39.3C

IMH – Intramural Hematoma

- Intramural thickening or pocket of non-communicating blood in the aortic wall
- Hemorrhage into the media
- Appears as smooth thickening of the aortic wall in a crescentic-shaped or concentric pattern
- Absence of dissection flap or false lumen



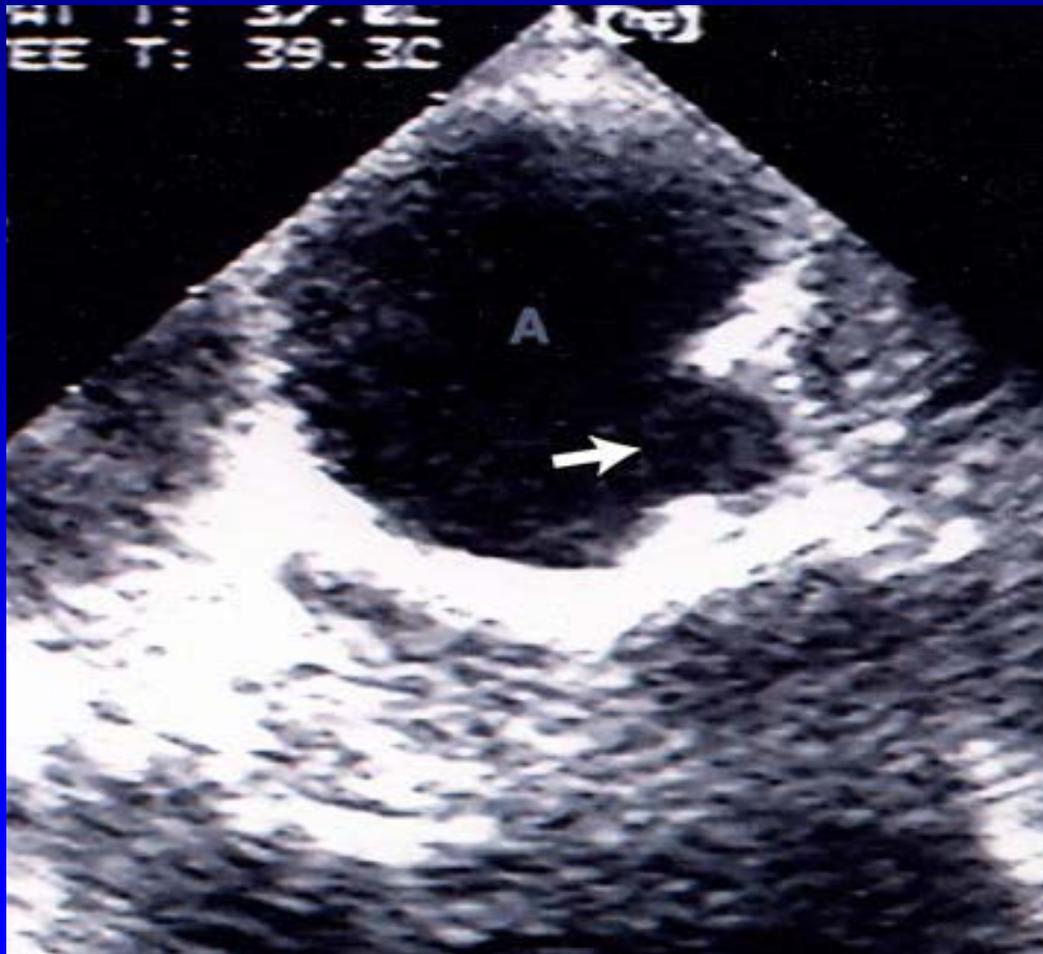
Current Treatment Options in Cardiovascular Medicine 2004, 6:99-104

Follow-Up of IMH

- Potential for rupture / dissection:
 - Proximal 73%
 - Distal 44%
- 30 day mortality rate of 20%
- Variable natural history:
 - 12-30% progress to dissection
 - 34% regress
 - 30% become aneurysmal
 - 24% develop pseudoaneurysms
- **SERIAL IMAGING IS REQUIRED!!**

Heart 2004, 90:372-374, Circ 2003, 108:583-589

Penetrating Aortic Ulcer



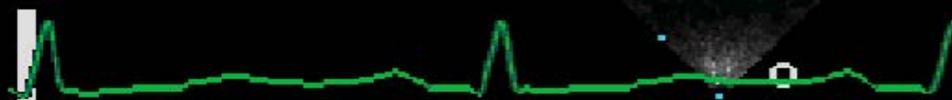
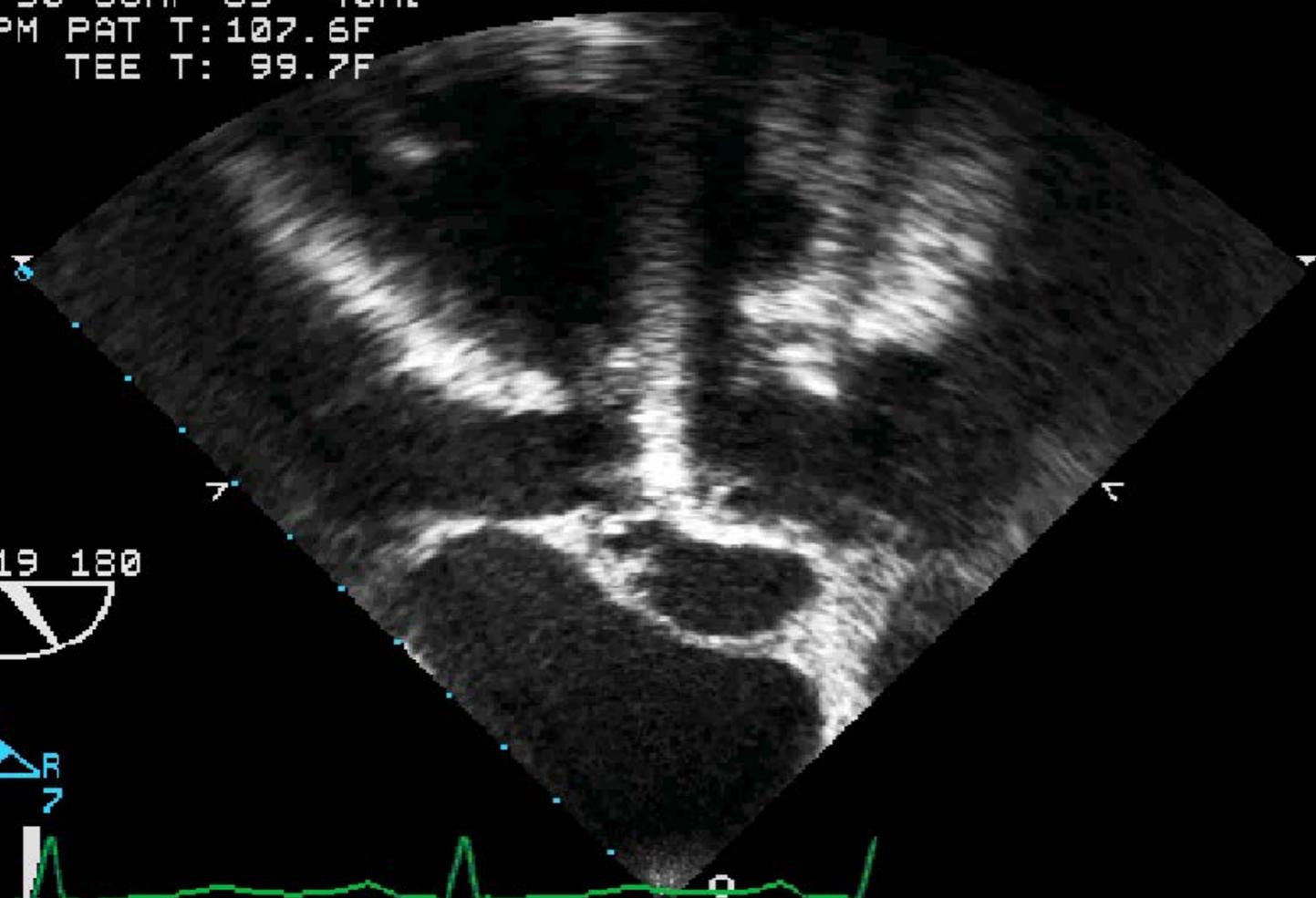
- Atherosclerotic ulceration that penetrates the internal elastic lamina and allows hematoma formation
- Most common in mid-distal descend aorta
- Debate as to surgical vs. medical management

Ann Thorac Surg 83:S835, 2007

Aortic Pseudoaneurysm

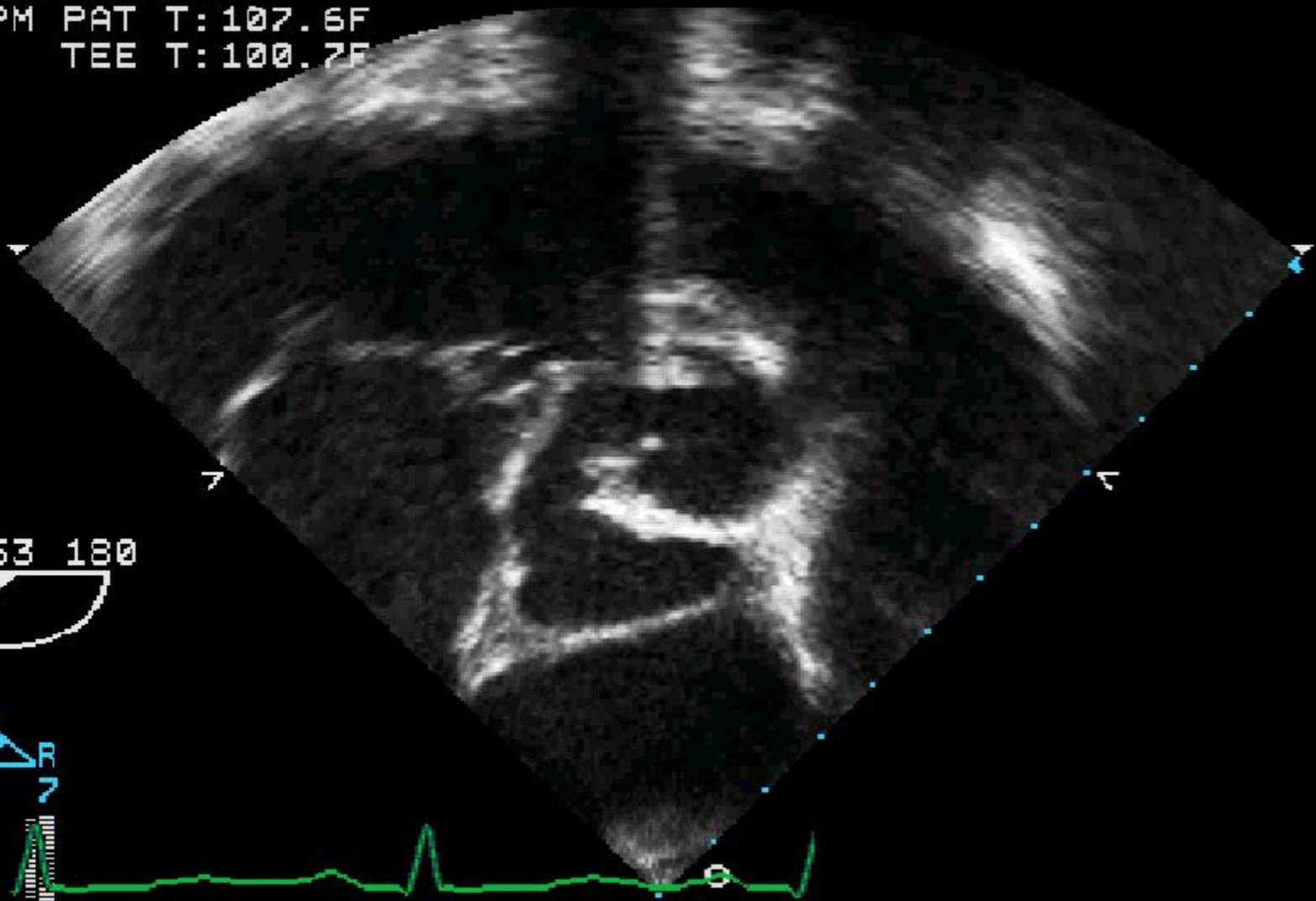
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GAIN 50 COMP 65 40HZ
93BPM PAT T: 107.6F
TEE T: 99.7F

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TEE



MI: 0.5
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2/0/E/F3 12CM
GAIN 50 COMP 6E
98BPM PAT T: 107.6F
TEE T: 100.2F

Ben Taub
Hospital
TEE

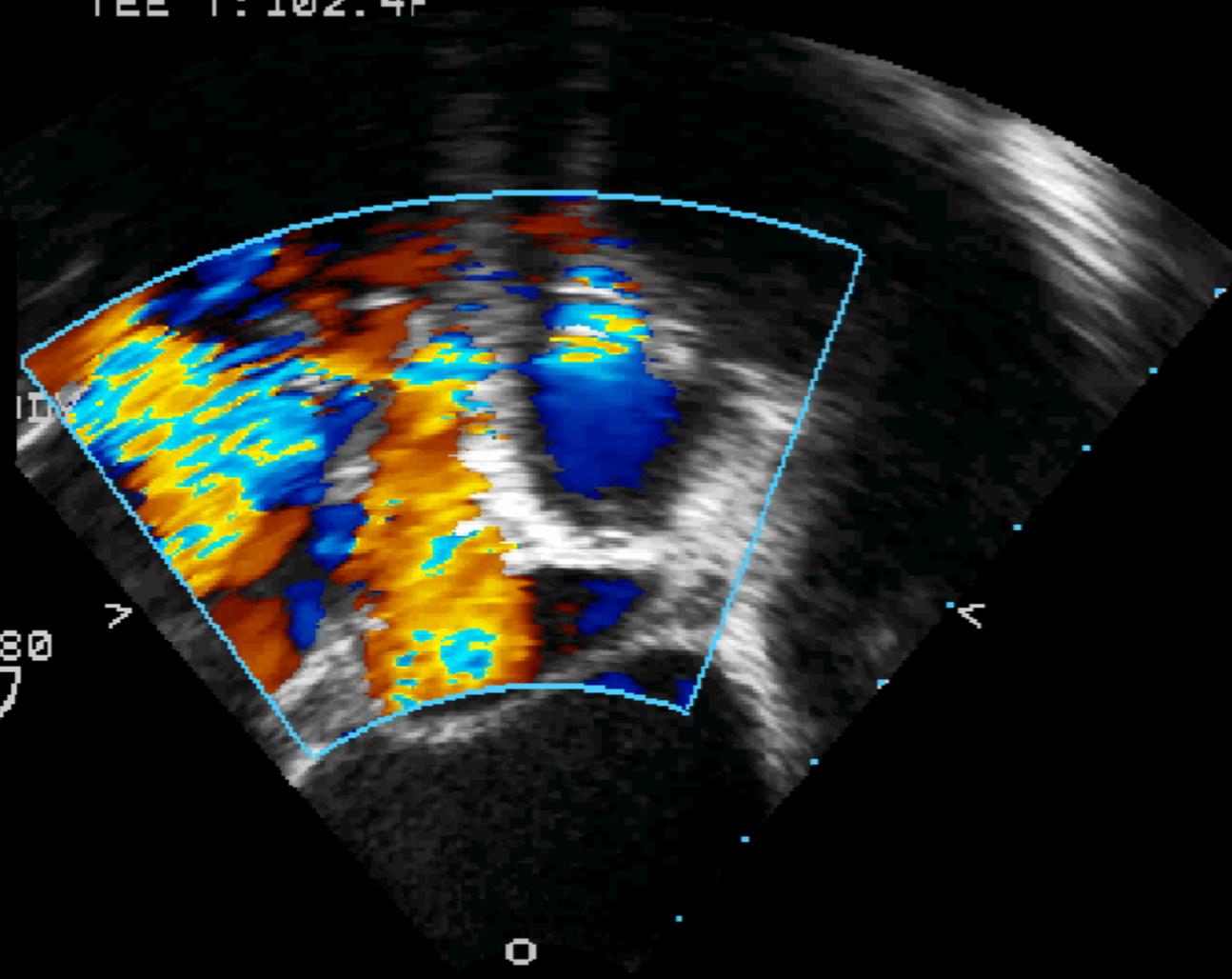


TIS: 0.8
T6210
13 AUG 04
10:32:00
2/0/E/M2/A
Ben Taub
Hospital

PAT T: 107.6F
TEE T: 102.4F



GAIN 50
COMP 65
97BPM



Echo Features of Pseudoaneurysm

- Presence of echo free space between graft and aortic wall.
- Color flow Doppler to assess for flow into this echo free space.
- If suspicious, perform TEE

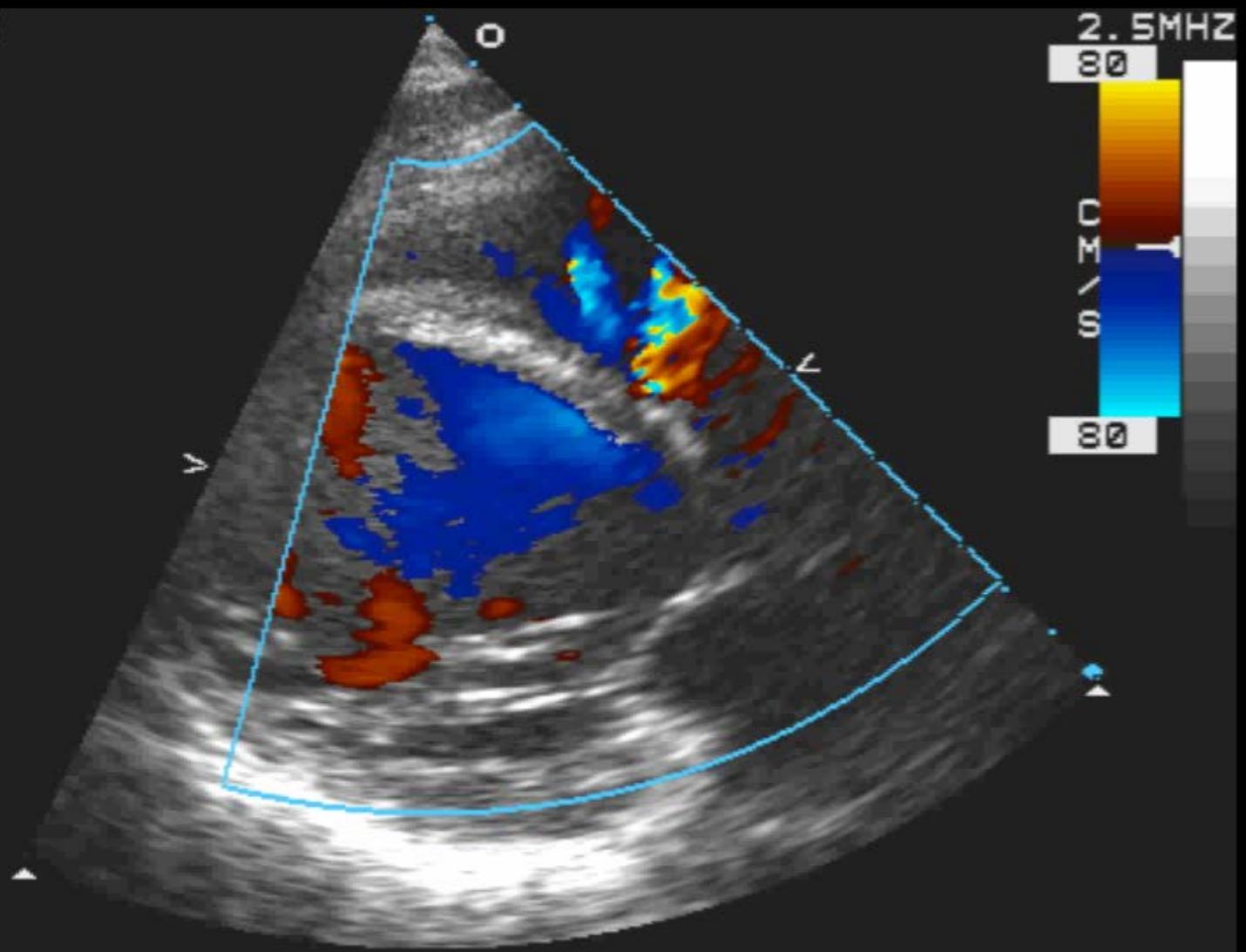
Ruptured Sinus of Valsalva Aneurysm

MI: 1.1 TIS: 1.3

S4
27 NOV 06
08:55:01
2/0/D/M2/A
Ben Taub
Hospital



WJ
GAIN 65
COMP 63
76BPM
15CM



P T R
2.1 4.2



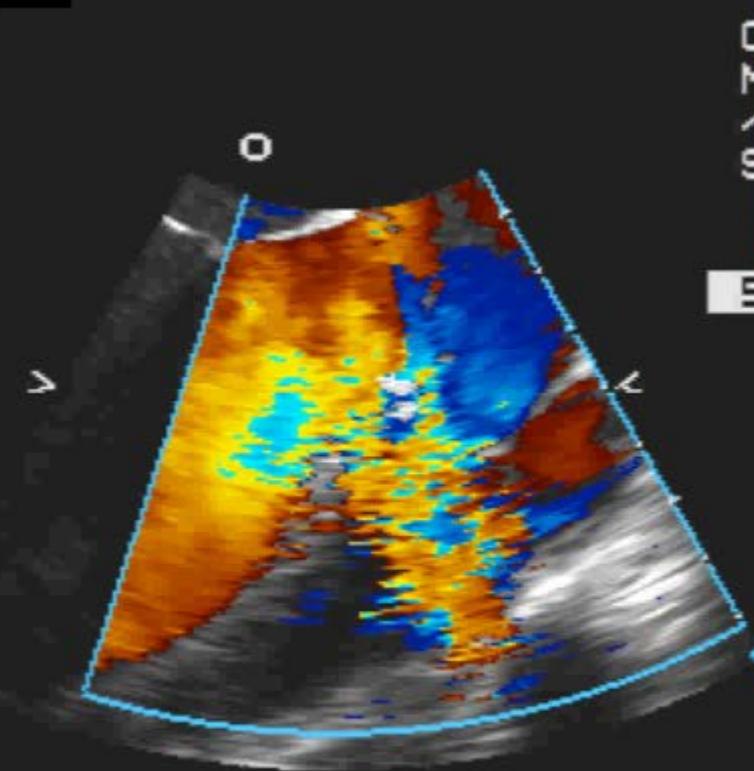
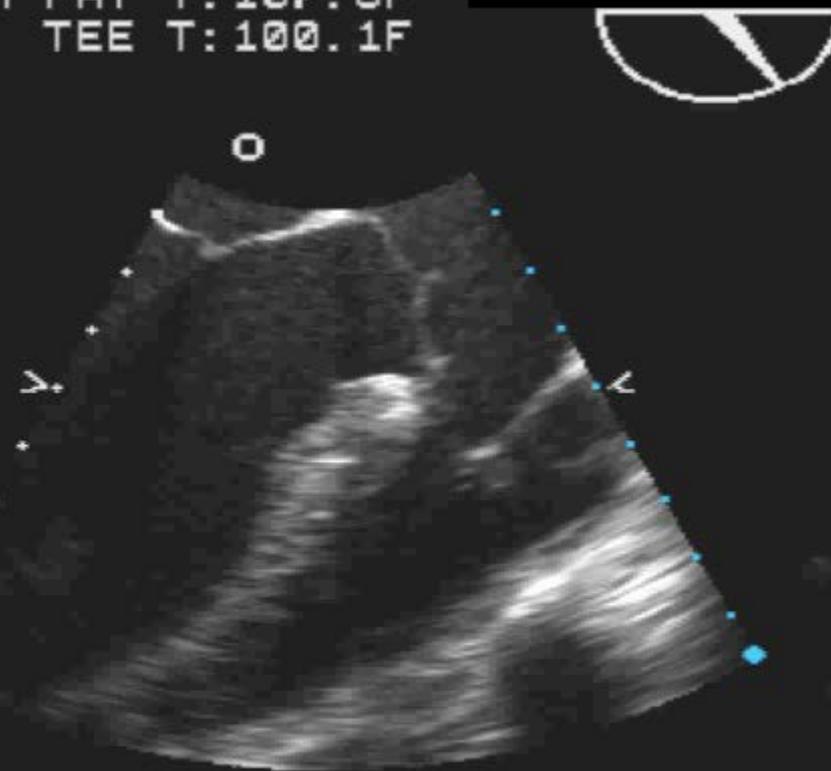
5/29/2004 06:05 PM T6210
29 MAY 04 18:23:58
2/0/E/12/A 15CM
GAIN 57 COMP 65 15HZ
77BPM PAT T:107.6F
TEE T:100.1F

Philips Medical 4.4MHZ
Systems
TEE 1

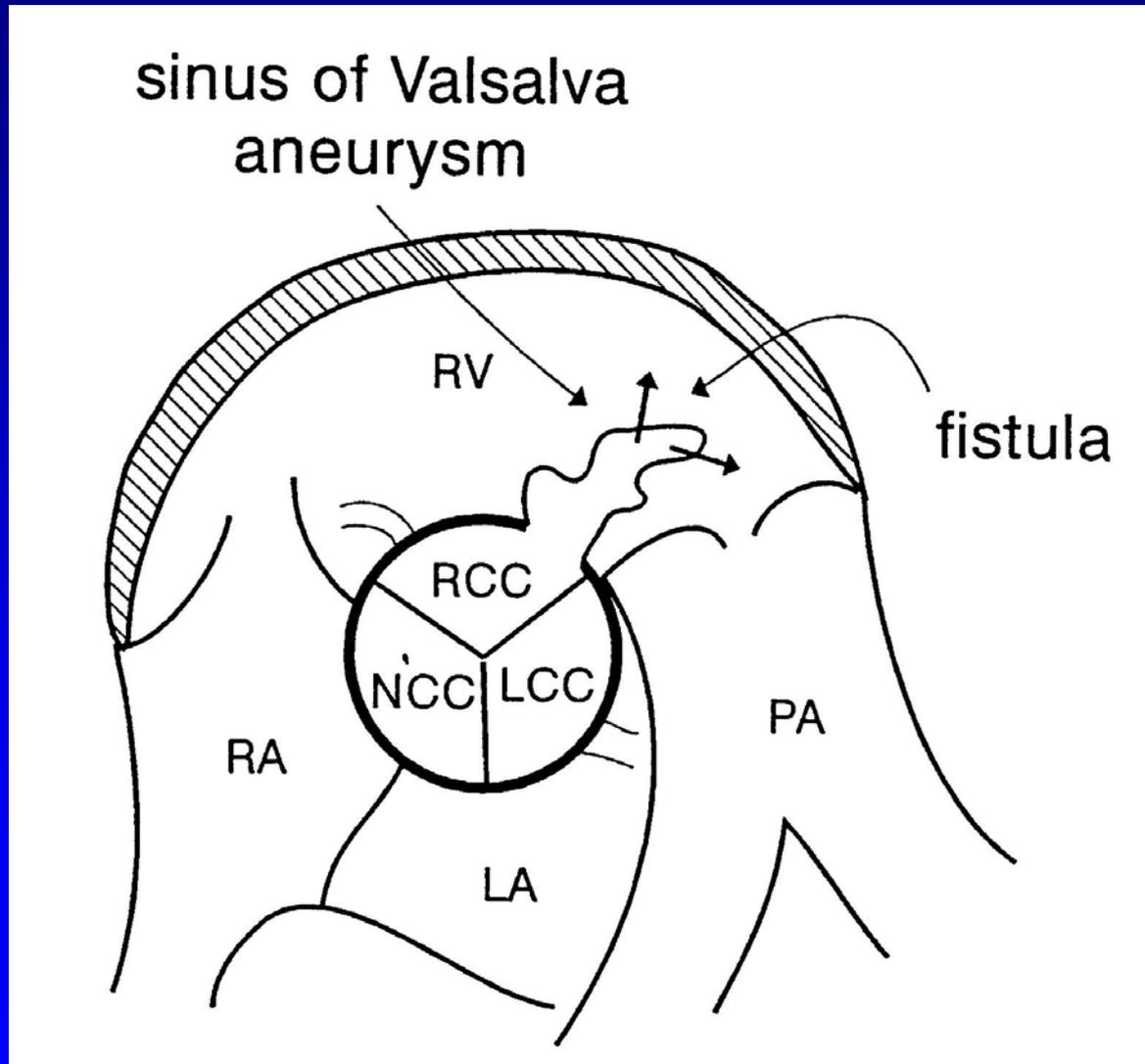
S1

C
M
/
S

S1



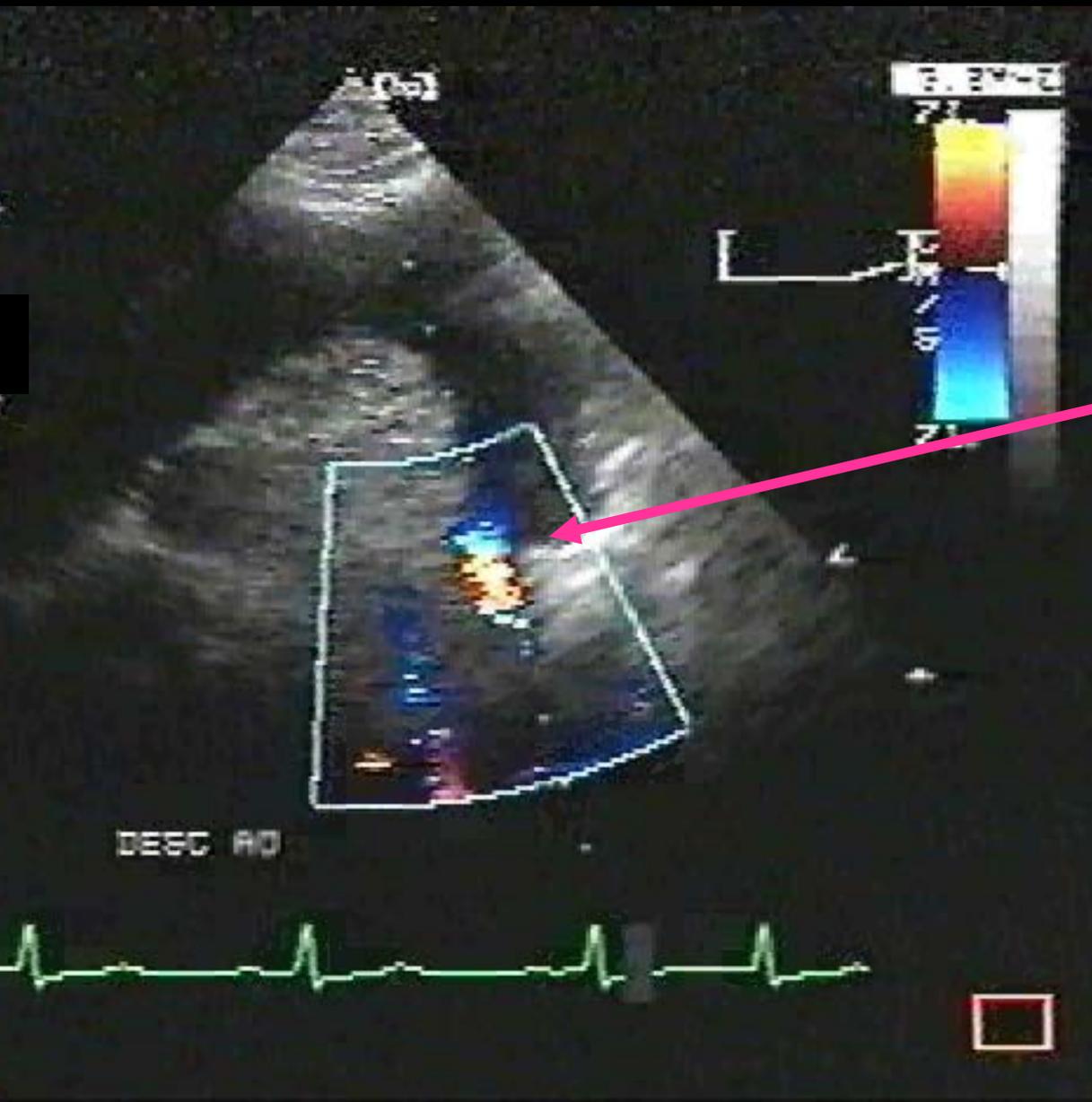
Sinus of Valsalva Aneurysm



Sinus of Valsalva Aneurysm

- Of 274 patients,
 - 75% had R coronary sinus involvement
 - 21% non-coronary sinus
 - 4% L coronary sinus
- Symptoms:
 - R-sided: RV failure, Pulmonic outflow murmur, complete heart block
 - L-sided: Unstable angina or MI, dysphagia

Aortic Coarctation



Typically a discrete narrowing distal to L subclavian artery

CW Doppler of Descending Aorta



Gradient \approx 64 mmHg

Expanded Bernoulli Equation

- $4 (V_2^2 - V_1^2)$
- V_2 = maximum coarctation velocity
- V_1 = velocity in the transverse arch proximal to obstruction
- Be cautious with gradient interpretation as collaterals may reduce gradient
- Must define anatomy of coarctation. MRI may be helpful

Coarctation of the Aorta

- Males > Females
- Associated with:
 - a bicuspid aortic valve
 - ~50% of pts with coarctation have BAV
 - <10% of pts with BAV have coarctation
 - VSD
 - Turner's Syndrome
 - PDA
 - cerebral aneurysms in Circle of Willis

Summary

- Measure the maximal diameter perpendicular to the long axis of the vessel
- TEE Blind spot: upper ascending aorta and proximal arch
- Class I indications: root dilatation / aneurysm, dissection, atherosclerosis, hematoma / rupture

References and Further Detail

2010

**ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/S
VM Guidelines for the Diagnosis and
Management of Patients With Thoracic Aortic
Disease**

J. Am. Coll. Cardiol. 2010;55:e27-e129

2015

**Multimodality Imaging of Diseases of
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J. Am. Soc. Echocardiogr 28:119-82

Aortic Trauma

- Deceleration injury causes shearing forces that are maximal at the aortic isthmus (site of ligamentum arteriosum)

Aortic Rupture vs. Aortic Dissection by TEE

- **RUPTURE**
 - Thick, highly mobile medial flap
 - No entry / reentry tear
 - Absence of thrombus
 - Similar blood flow velocities on both sides of flap
 - Limited to aortic isthmus
- **DISSECTION**
 - Thin intimal flap
 - Presence of entry/reentry
 - Thrombus in false lumen
 - Different blood flow velocities in true / false lumens
 - More extensive depending on type

Circulation 92(10): 2959, 1995

Fibrosing Mediastinitis

- Proliferation of fibrous tissue within the mediastinum
- Causes obstruction of mediastinal structures
 - Central veins, pulm arteries, airways, esophagus
- Etiologies:
 - Histoplasma, TB, other fungal, autoimmune, radiation therapy, methysergide

JACC 60(25): 2693, 2012; RadioGraphics 221:737-757, 2001

Fibrosing Mediastinitis



BEN TAUB GENERAL HOSP

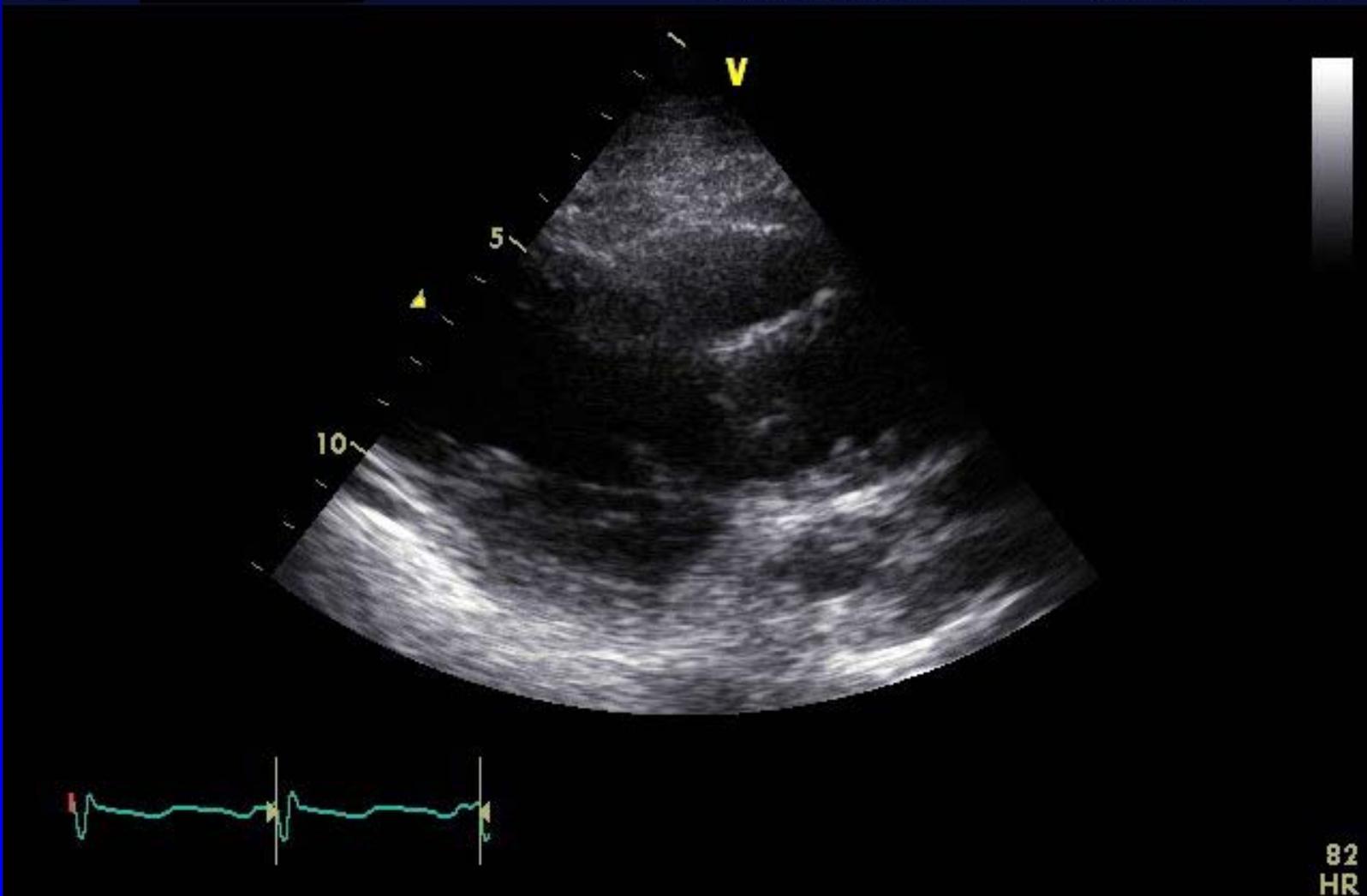
3S RS

MI 1.1

02/14/2013 10:58:28 A TEC

Cardiac

TIS:0.8



82
HR



BEN TAUB GENERAL HOSP

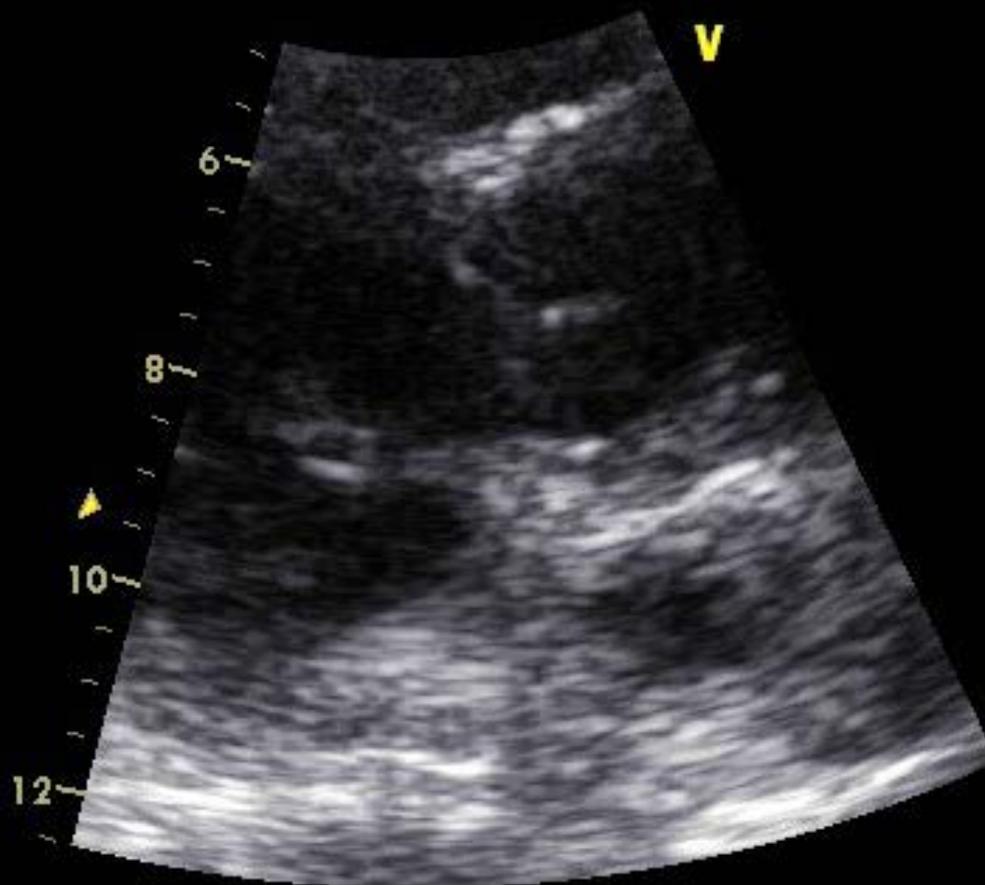
3S RS

MI 0.9

02/14/2013 10:58:57 A TEC

Cardiac

TIS:0.8



83
HR

CT Chest

