Echo Board Review: Selected Topics

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Echo Board Review

- Chamber Dimensions, Systolic and Regional Function
- Aorta
- Diastology
- Valves
- Pericardium
- Congenital
- Miscellaneous/Potpourri
- Physics

Introduction

1. This is a review of subjects that are likely to be on the echo boards (after my review of Echo SAP) and assumes that you have experience in reading echoes:
   – Background with Doppler to assess hemodynamics
   – Familiarity with echo in diagnosis of common cardiac conditions
2. There are many slides detailing criteria for disease severity and focus will be directed at important cut-offs/thresholds
3. This is not intended to be a substitute for echo board exam preparation. The presentation is intended for use as a review just before taking the exam

Echo Board Review

- **Chamber Dimensions, Systolic and Regional Function**
- Aorta
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- Physics

	Male				Female			
	Normal Range	Mildly Abnormal	Moderately Abnormal	Severely Abnormal	Normal Range	Mildly Abnormal	Moderately Abnormal	Severely Abnormal
LV Dimension								
LV diastolic diameter (cm)	4.2 – 5.8	5.9 – 6.3	6.4 – 6.8	>6.8	3.8 – 5.2	5.3 – 5.6	5.7 – 6.1	>6.1
LV diastolic diameter/BSA (cm/m^2)	2.2 – 3.0	3.1 – 3.3	3.4 – 3.6	>3.6	2.3 – 3.1	3.2 – 3.4	3.5 – 3.7	>3.7
LV systolic diameter (cm)	2.5 – 4.0	4.1 – 4.3	4.4 – 4.5	>4.5	2.2 – 3.5	3.6 – 3.8	3.9 – 4.1	>4.1
LV systolic diameter/BSA (cm/m^2)	1.3 – 2.1	2.2 – 2.3	2.4 – 2.5	>2.5	1.3 – 2.1	2.2 – 2.3	2.4 – 2.6	>2.6
LV Volume								
LV diastolic volume (mL)	62 – 150	151 – 174	175 – 200	>200	46 – 106	107 – 120	121 – 130	>130
LV diastolic volume/BSA (mL/m^2)	34 – 74	75 – 89	90 – 100	>100	29 – 61	62 – 70	71 – 80	>80
LV systolic volume (mL)	21 – 61	62 – 73	74 – 85	>85	14 – 42	43 – 55	56 – 67	>67
LV systolic volume/BSA (mL/m^2)	11 – 31	32 – 38	39 – 45	>45	8 – 24	25 – 32	33 – 40	>40
LV function								
LV EF (%)	52 – 72	41 – 51	30 – 40	<30	54 – 74	41 – 53	30 – 40	<30
LV Mass by Linear Method								
Septal wall thickness (cm)	0.6 – 1.0	1.1 – 1.3	1.4 – 1.6	>1.6	0.6 – 0.9	1.0 – 1.2	1.3 – 1.5	>1.5
Posterior wall thickness (cm)	0.6 – 1.0	1.1 – 1.3	1.4 – 1.6	>1.6	0.6. – 0.9	1.0 – 1.2	1.3 – 1.5	>1.5
LV mass (g)	88 – 224	225 – 258	259 – 292	>292	67 – 162	163 – 186	187 – 210	>210
LV mass/BSA (g/m^2)	49 – 115	116 – 131	132 – 148	>148	43 – 95	96 – 108	109 – 121	>121
LV Mass by 2D Method								
LV mass (g)	96 – 200	201 – 227	228 – 254	>254	66 – 150	151 – 171	172 – 193	>193
LV mass/BSA (g/m^2)	50 – 102	103 – 116	117 – 130	>130	44 – 88	89 – 100	101 – 112	>112

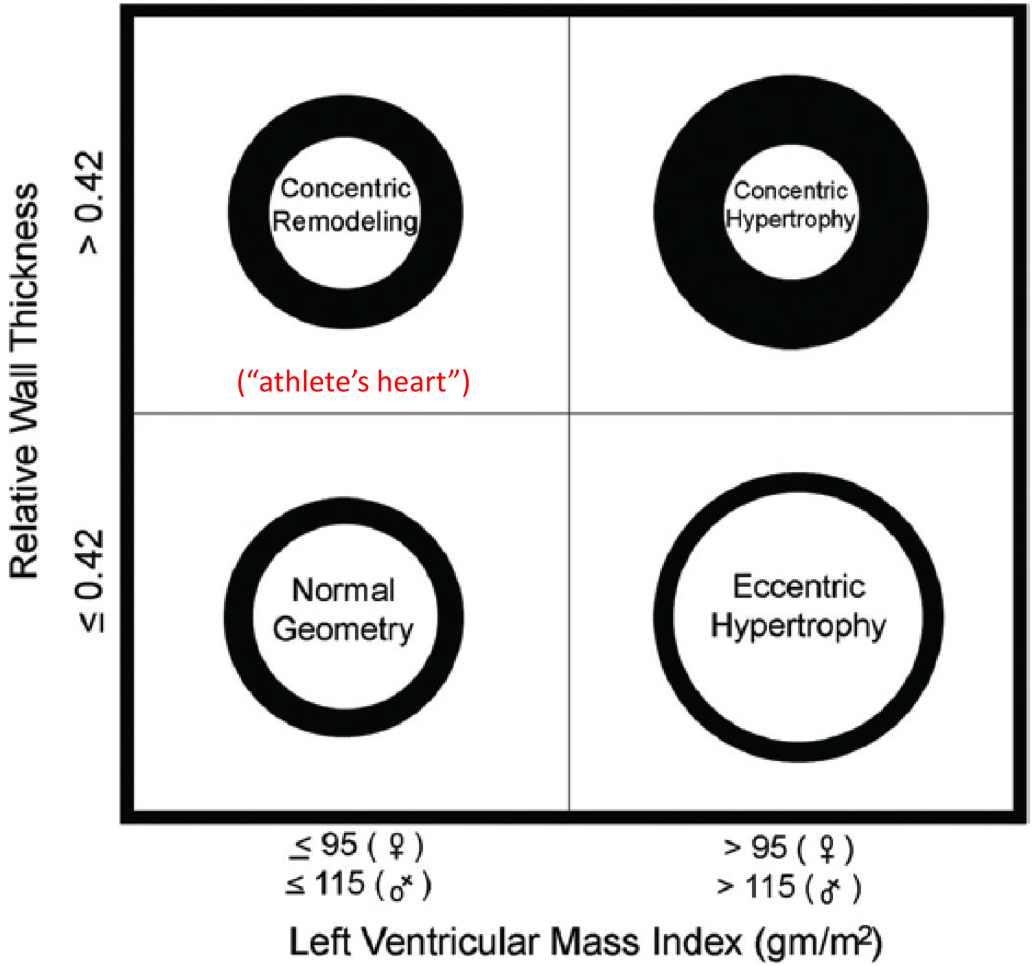
Sphericity Index (Length/Width) $\geq$ 1.5

LV Dimensions, Sphericity Index and LV Mass

- $LVID_d$ upper limit: 5.8 cm ♂ and 5.2 cm ♀
- LVEF upper limit: 52% ♂ and 54% ♀
- LV wall thickness: $\leq$ 1.0 cm ♂ and $\leq$ 0.9 cm ♀
- Sphericity Index (Length/width): SI < 1.5 is abnormal (reflects increase in width and LV dilation and remodeling)

LV Mass Index (> 115 gm/m² ♂ , > 95 gm/m² ♀)

Relative wall thickness = (2 x posterior wall thickness)/ LVIDd

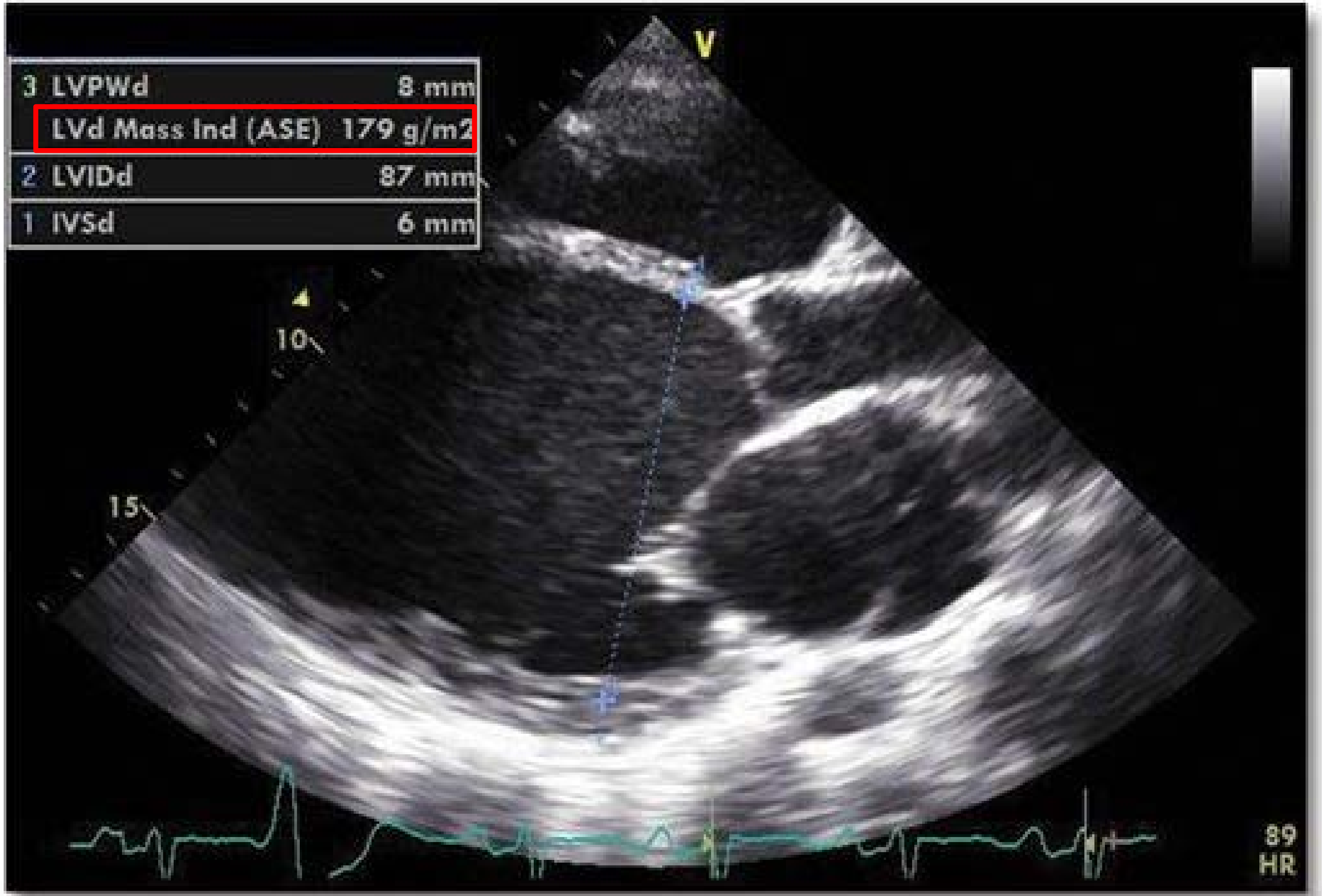


Feigenbaum's Echocardiography, 8th Ed

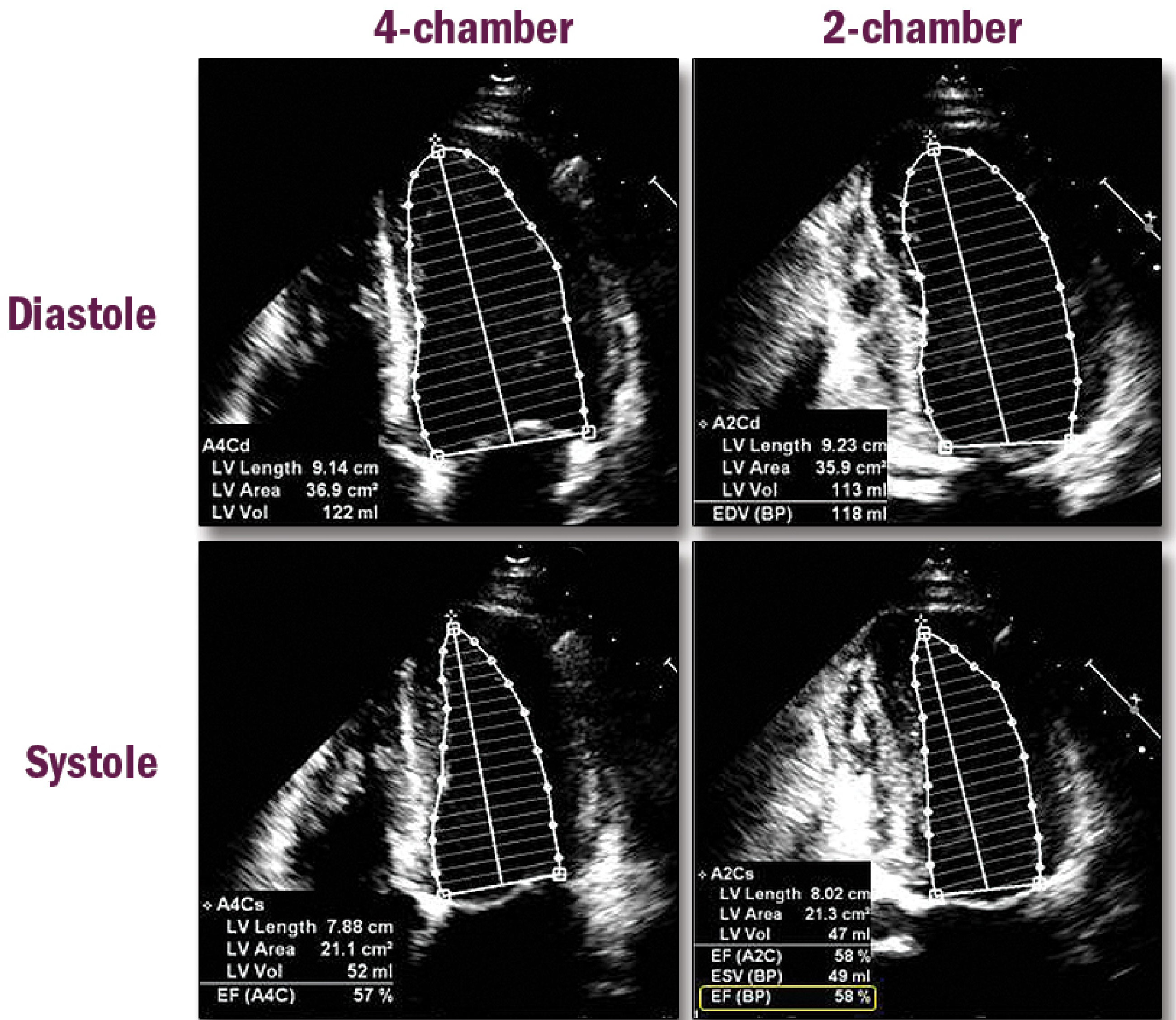
Eccentric Hypertrophy

Relative wall thickness: [2 x 8]/87 = 0.18 (< 0.42)

LV Mass Index 179 gm/m^2 (> 115 gm/m^2 ♂ , > 95 gm/m^2 ♀)



Left Ventricular Ejection Fraction Calculated From Biplane Simpson's Method



Wall Motion Scores

1 = Normal/Hyperkinetic

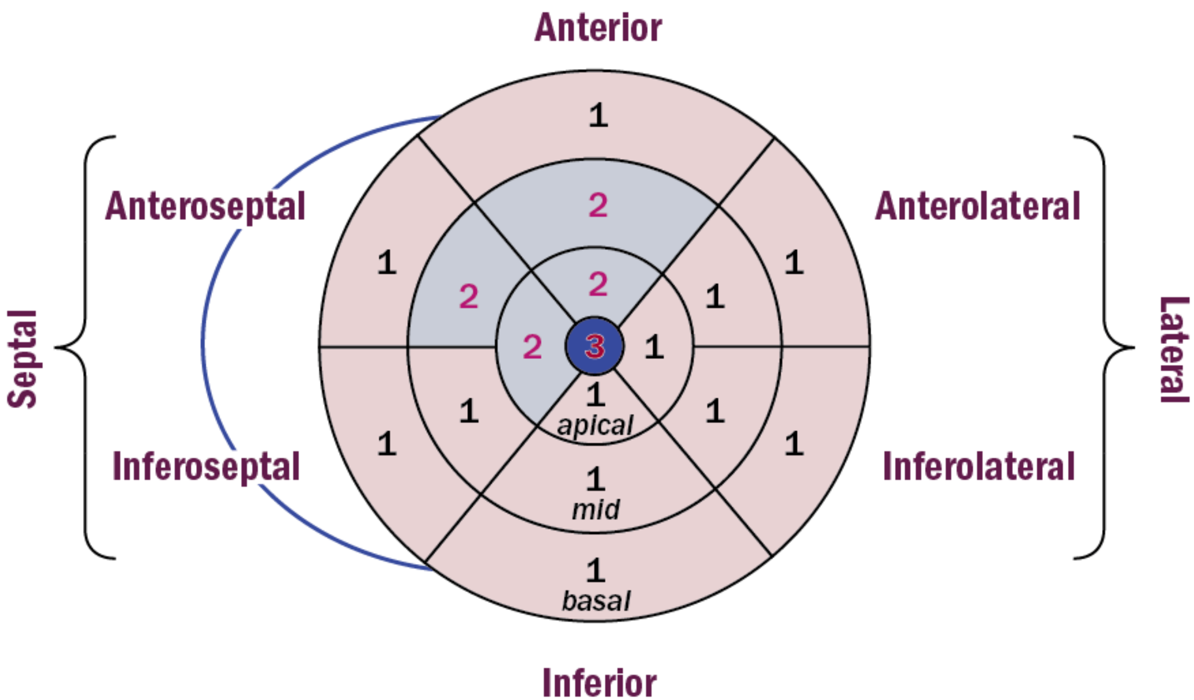
2 = Hypokinetic

3 = Akinetic

4 = Dyskinetic

Wall Motion Score Index

(used in interpretation of stress echo)

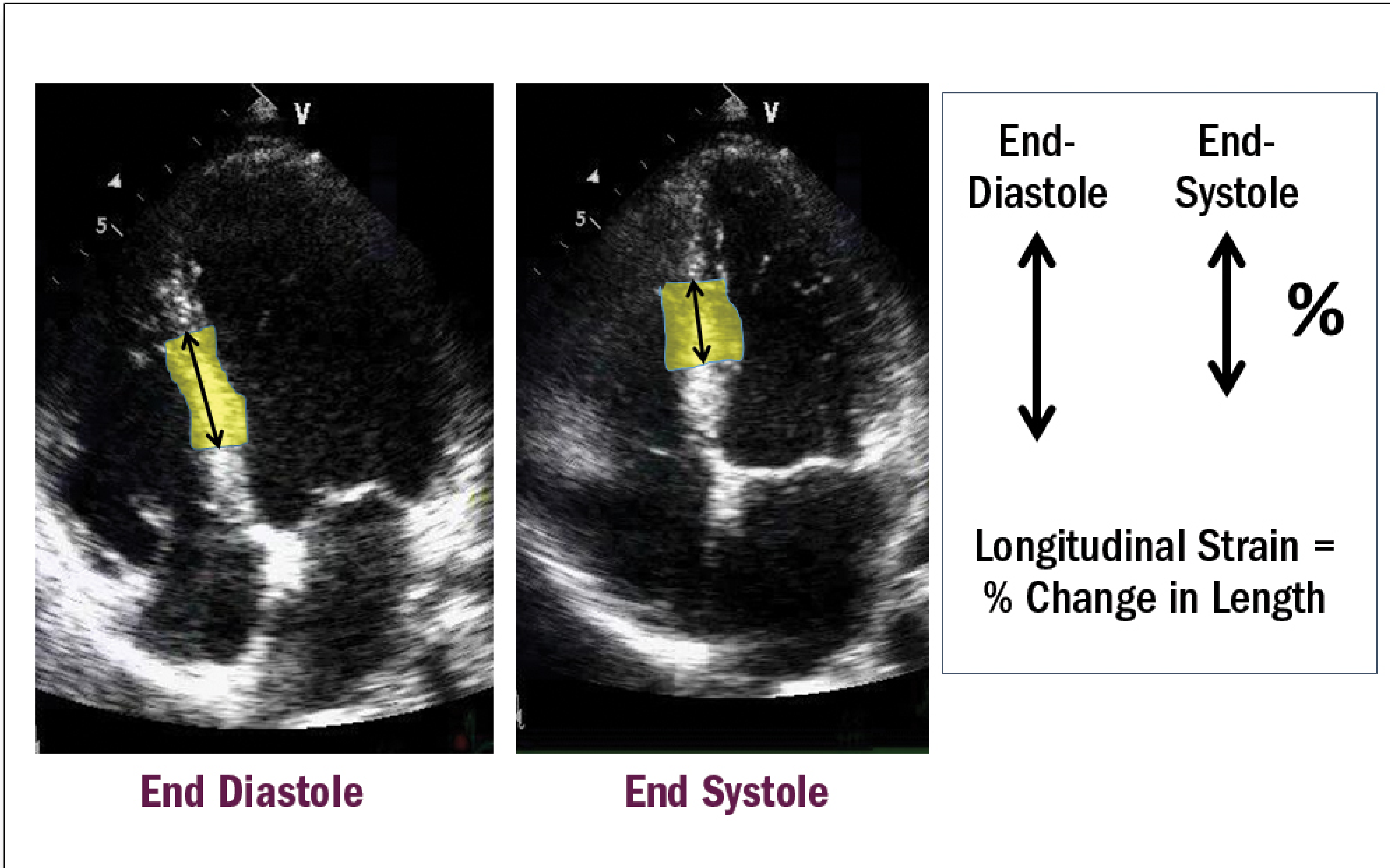


Wall Motion Score Index (WMSI) = $\sum$ 17 scores/17 segments

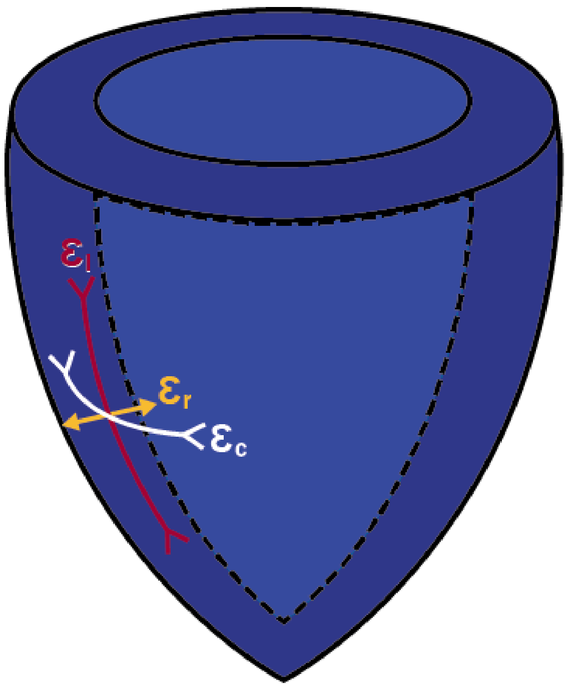
= 23/17 = 1.35

> 1 is Abnormal

An Illustration of Myocardial Shortening in the Apical Four Chamber View From End-Diastole to End-Systole Within a Region of Interest



Principal Components of Myocardial Strain



Longitudinal – ε_L

Myocardial shortening from base to apex

Negative

Circumferential – ε_c

Intramural myocardial shortening

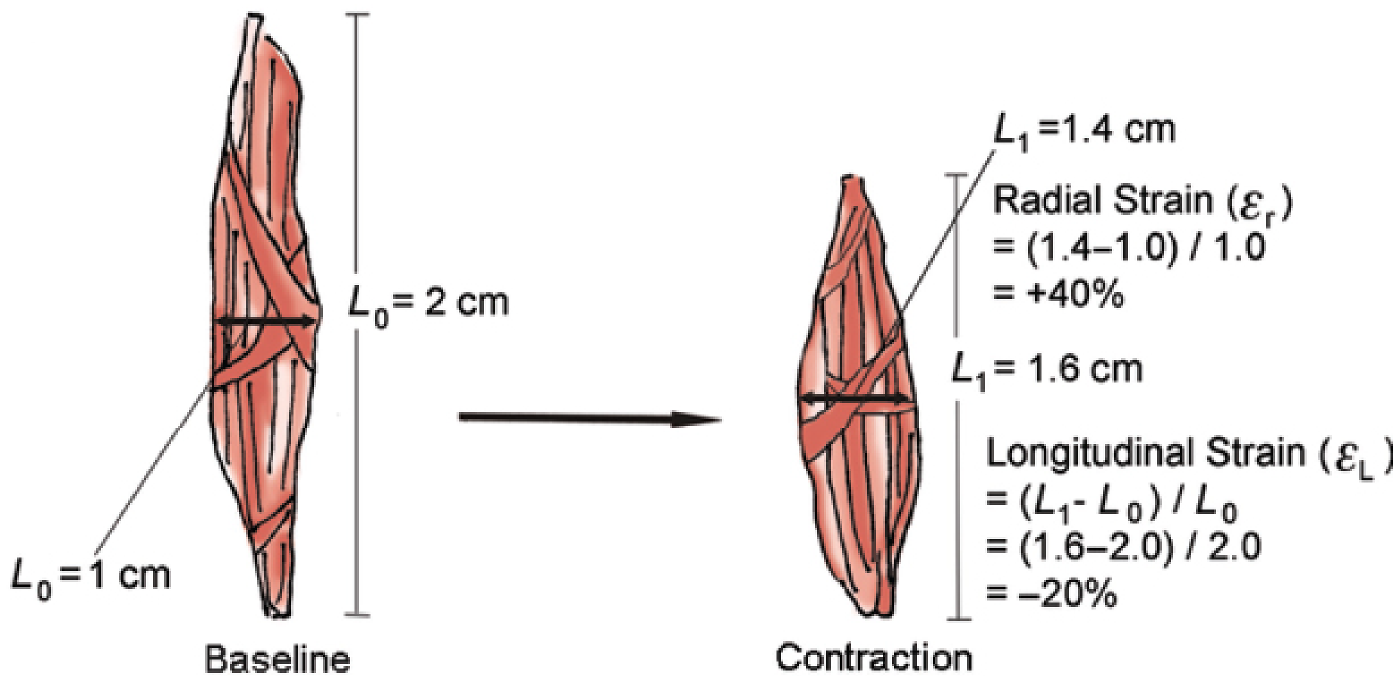
Negative

Radial – ε_r

Myocardial wall thickening

Positive

Demonstration of Strain (Longitudinal and Radial) Calculation in a Myocardial Segment



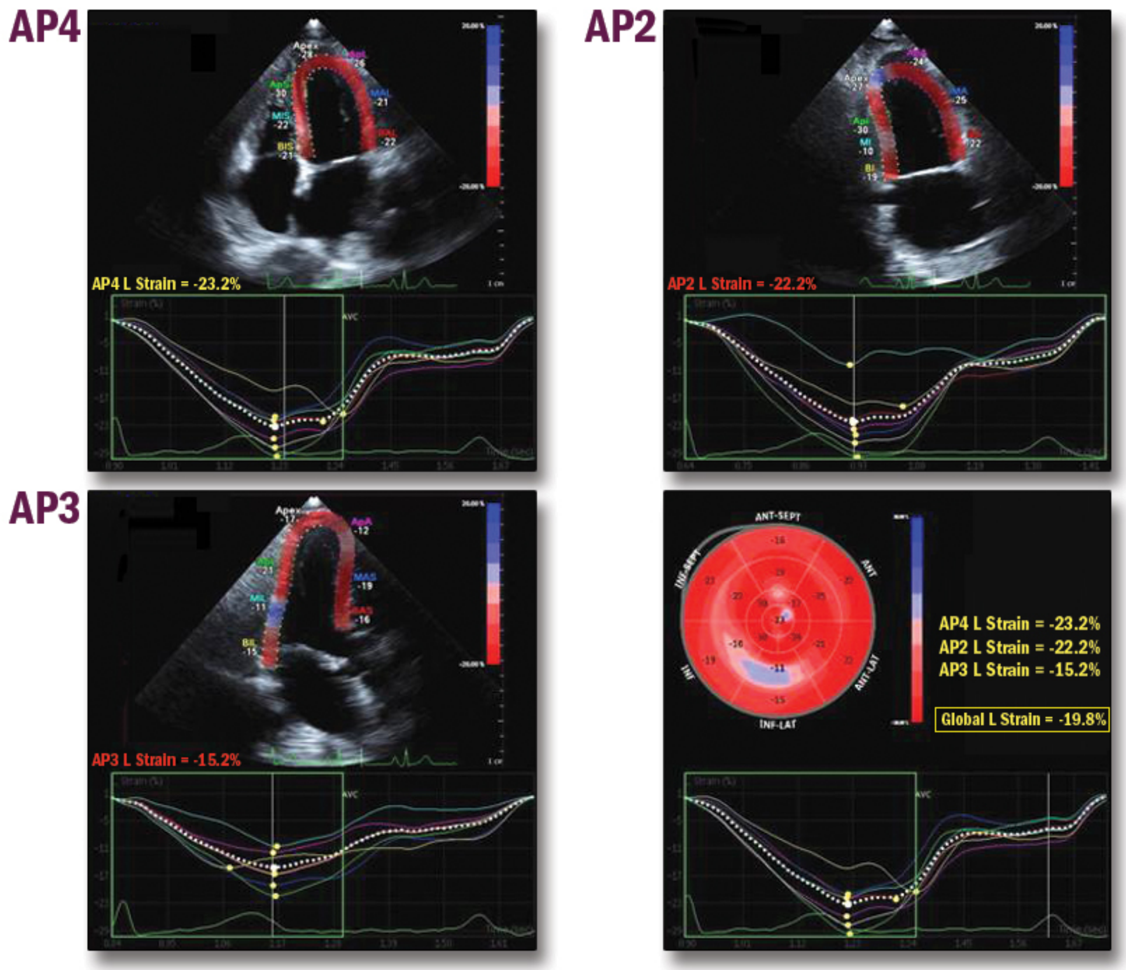
"Differences among vendors and software packages are still too large to recommend universal normal values and lower limits of normal. To provide some guidance, a peak GLS in the range of 20% can be expected in a healthy person" (2015 ASE Guidelines)

Feigenbaum's Echocardiography, 8th Ed

Strain

- “Speckle tracking technology” tracks myocardium
- High temporal resolution
- Angle independence
- GLS (longitudinal strain) is more sensitive to changes in LV systolic function than volumetric methods (eg, in oncology patients)

Global Longitudinal Strain

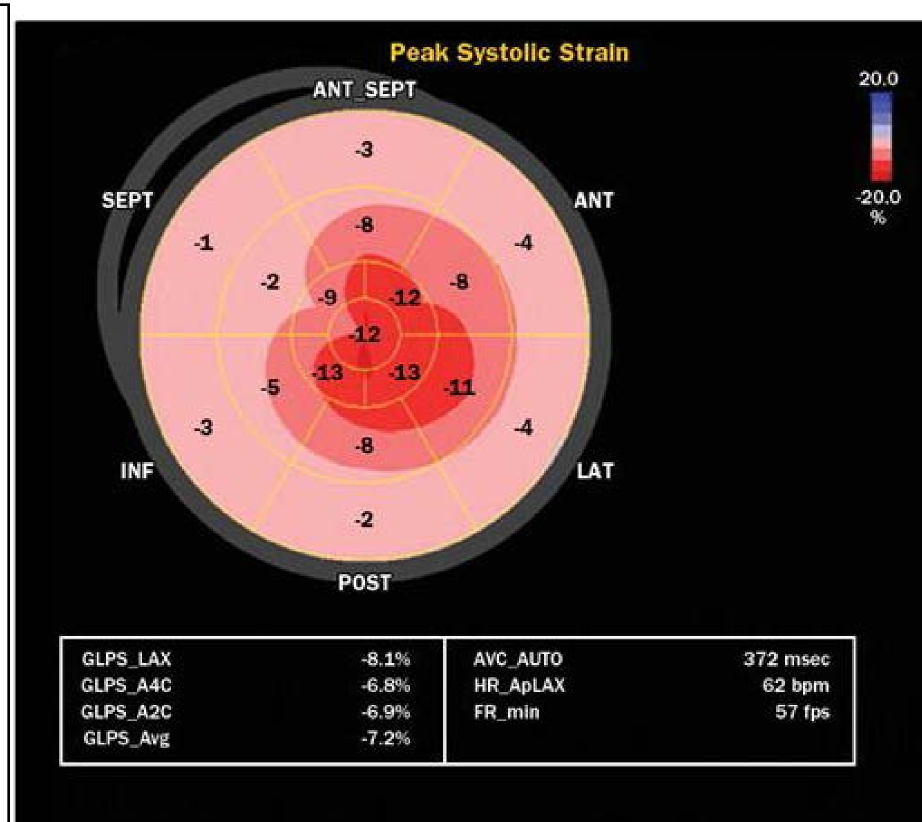


Diseases For Which Myocardial Strain Is Abnormal Prior To Detection of Traditional Findings

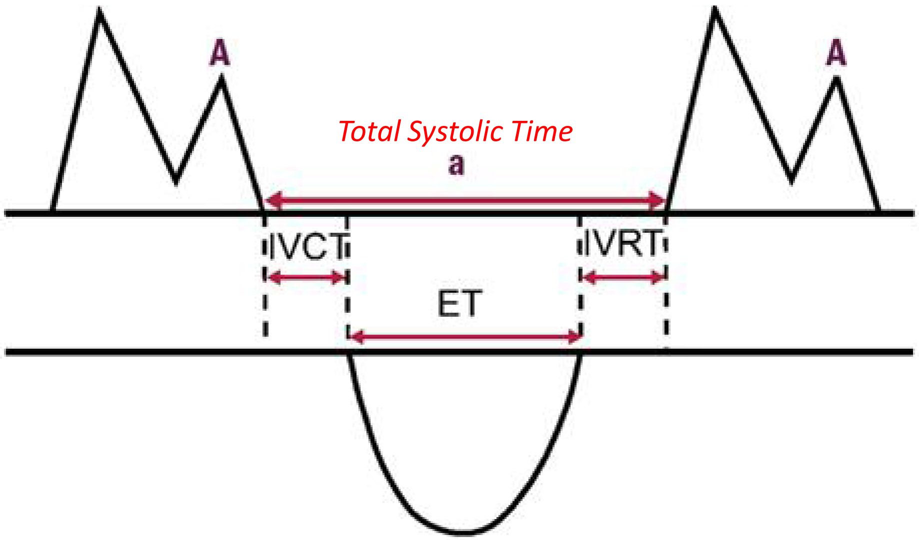
Systemic disease
Hypertension
Diabetes mellitus
Glycogen storage disease
Cardiac amyloid
Primary myocardial disease
Hypertrophic cardiomyopathy
Dilated cardiomyopathy
Adriamycin toxicity
Cardiac rejection posttransplant
Coronary artery disease
Low-grade ischemic
Hibernation/stunning
Stress-induced ischemia

Feigenbaum's Echocardiography, 8th Ed

Cardiac Amyloidosis



Myocardial Performance Index



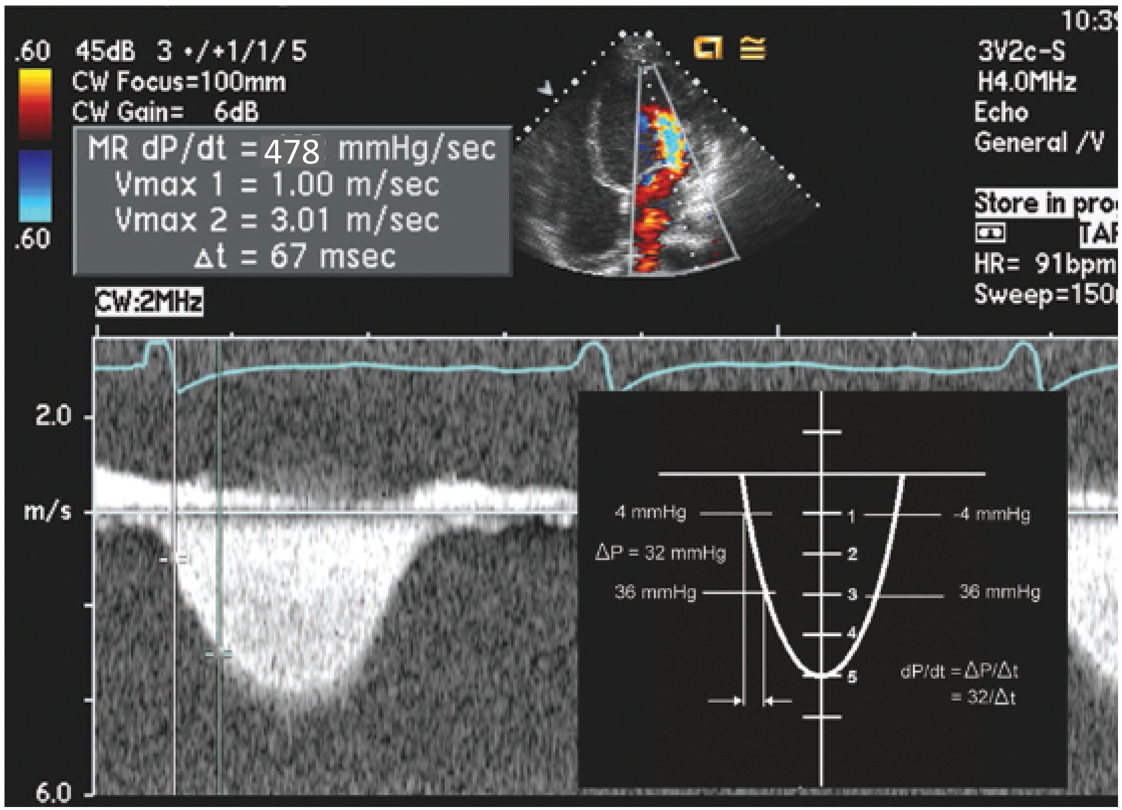
$$MPI = \frac{(IVCT + IVRT)}{ET} = \frac{(a - ET)}{ET}$$

Normal: < 0.40 for LV (< 0.43 for RV)

Is the LV systolic function normal?

dP/dt

- Slope of MR jet is change in pressure between LV and LA over time
- Measure time from 1 m/sec (4 mmHg) to 3 m/sec (36 mmHg)
- < 1000 mmHg/sec is abnormal (normal $\geq$ 1200)

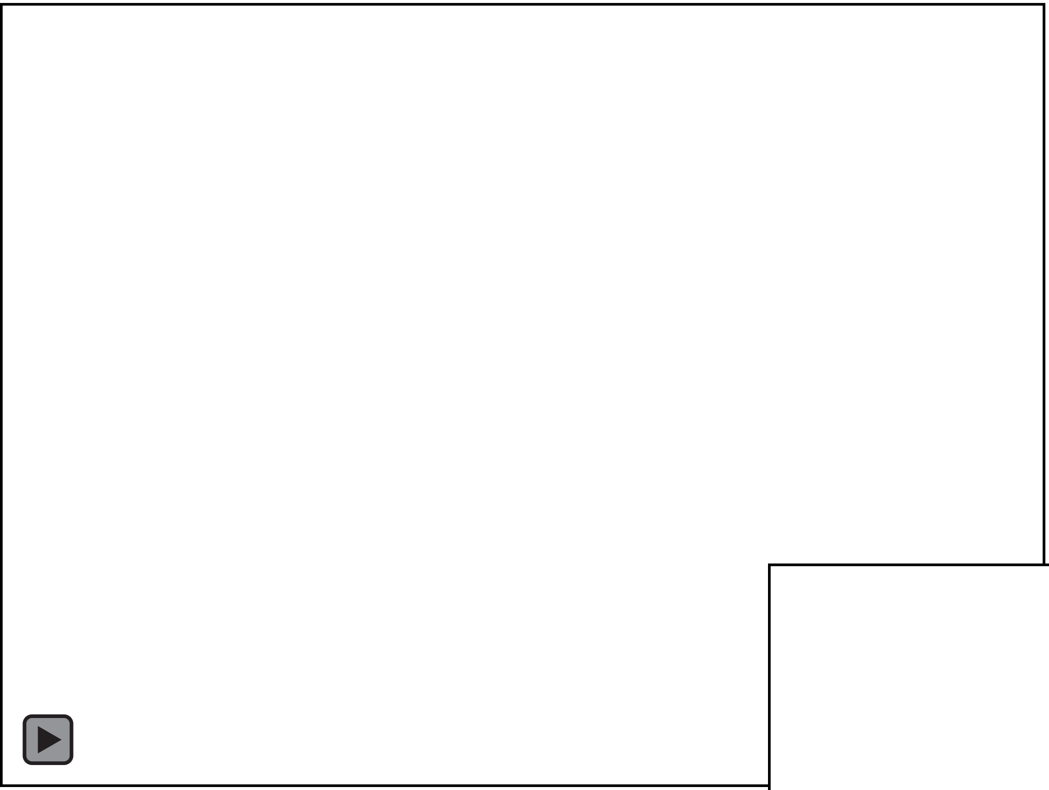


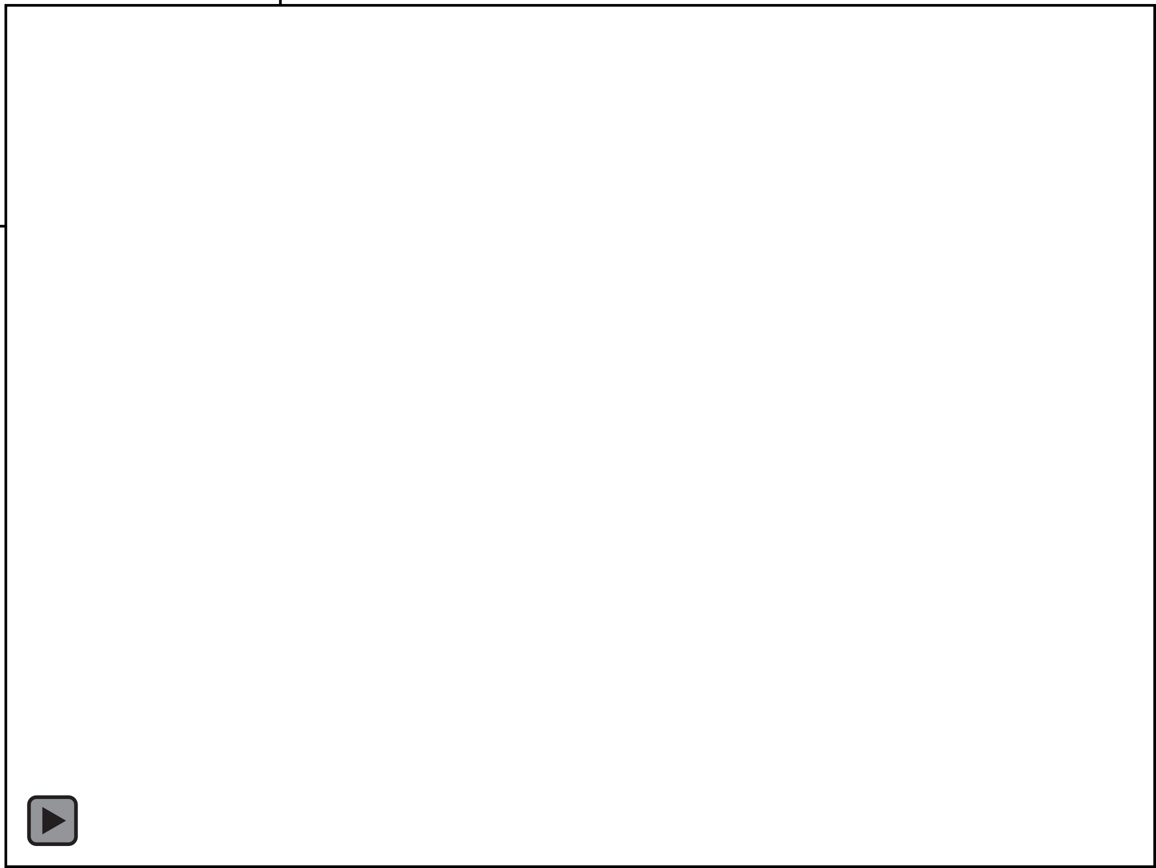
dP/dT = 32/.067
= 478

Feigenbaum's Echocardiography, 8th Ed

- A 78-year-old female with history of rheumatoid arthritis and hypertension presents with chest pain and shortness of breath x 1 week
- ECG: ST elevation

What is the likely culprit vessel?

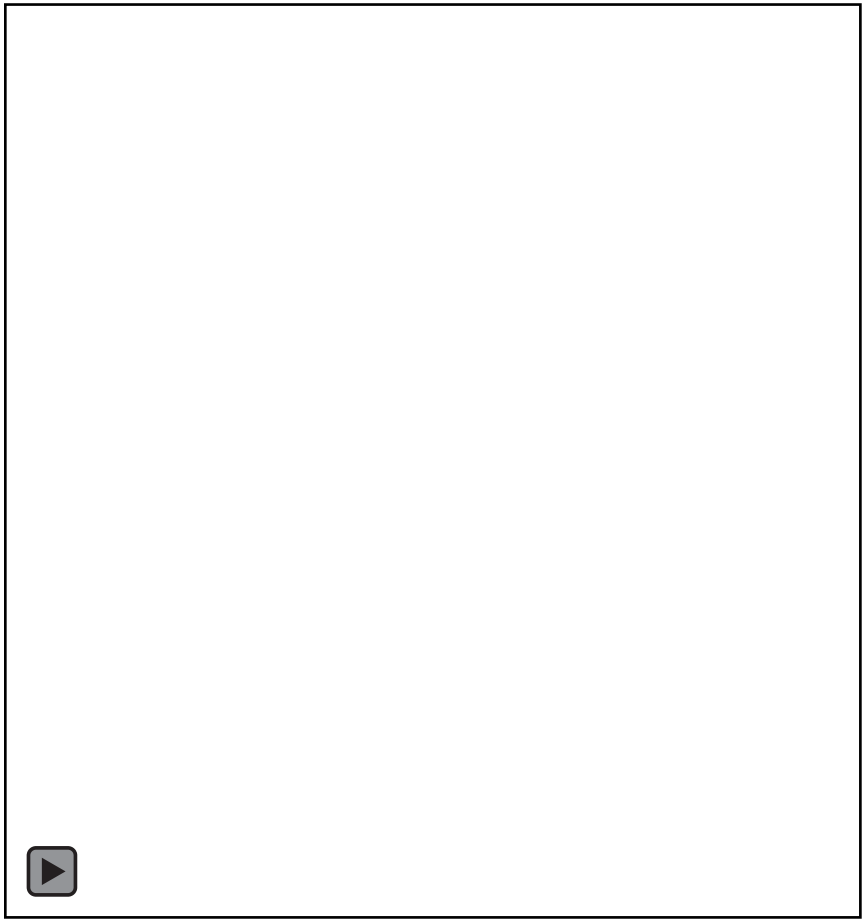


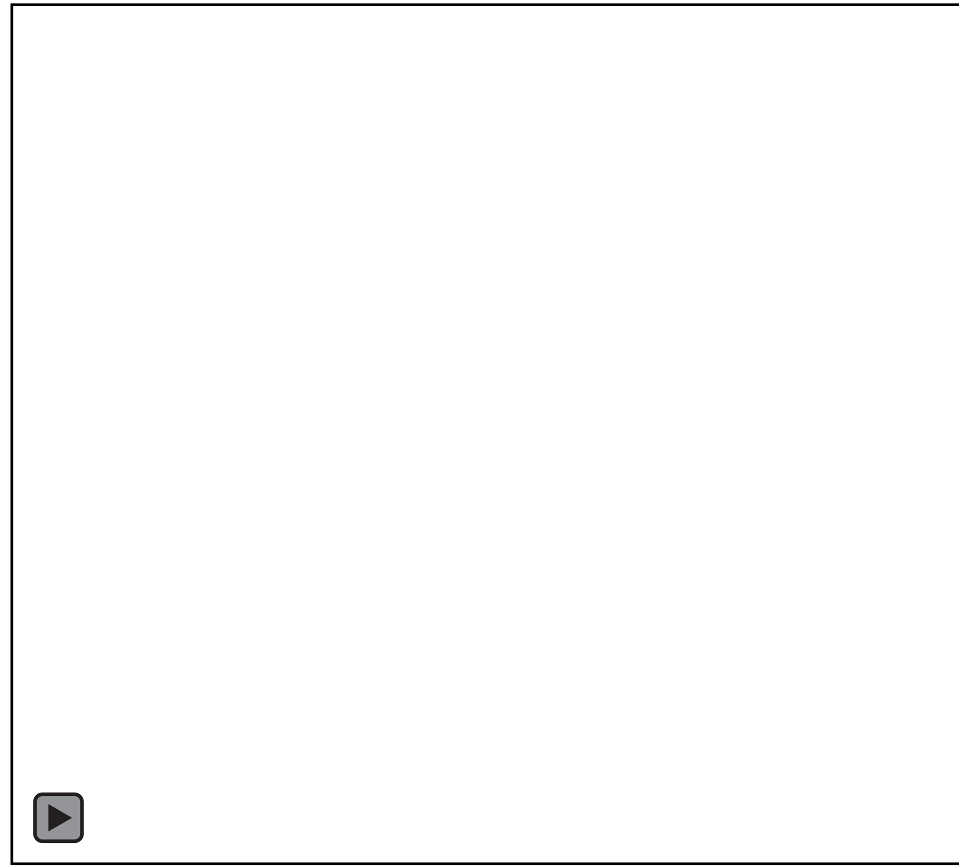


4/6 “harsh” systolic murmur left sternum

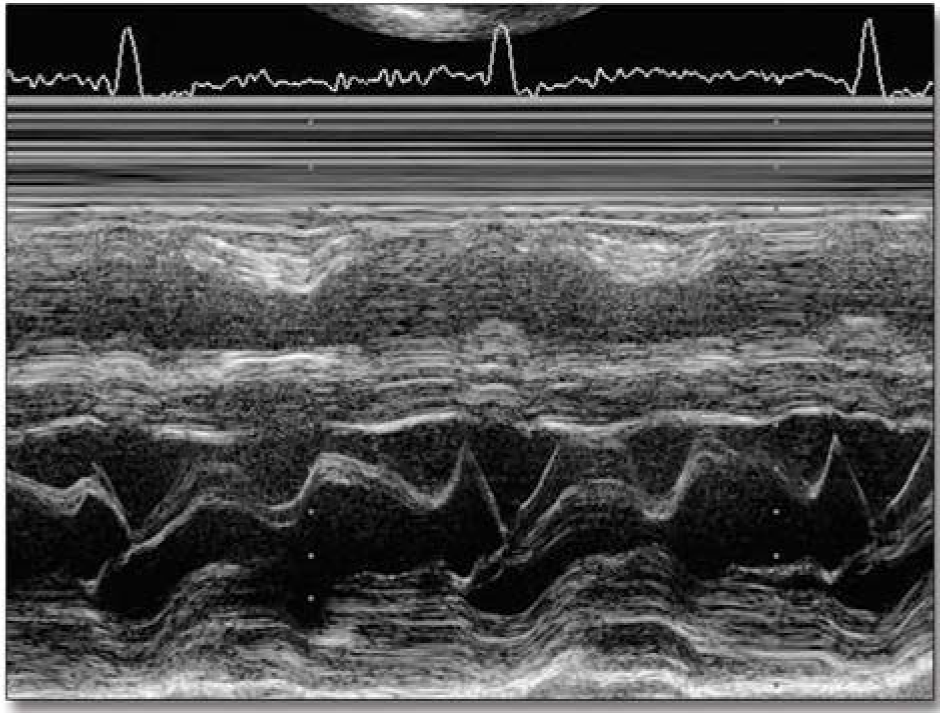
A 78-year-old male with history of tobacco use, hypertension, and chronic obstructive pulmonary disease presents with acute chest pain
ECG: ST elevation

What is likely culprit vessel?





Hypertrophic CMP



If exertional symptoms and resting peak gradient < 50 mmHg, obtain exercise Doppler

42 yr old male with one episode of syncope without warning. Electrocardiogram on presentation revealed T-wave inversions V1-V3.

Other Medical History: None

Family History: Father died suddenly at aged 45.

Physical Findings

Blood Pressure:	112/70 mm Hg
Pulse:	60 bpm
Chest and Lungs:	Clear
Cardiac Exam:	Normal S1 and S2. No extra heart sounds or murmurs audible.

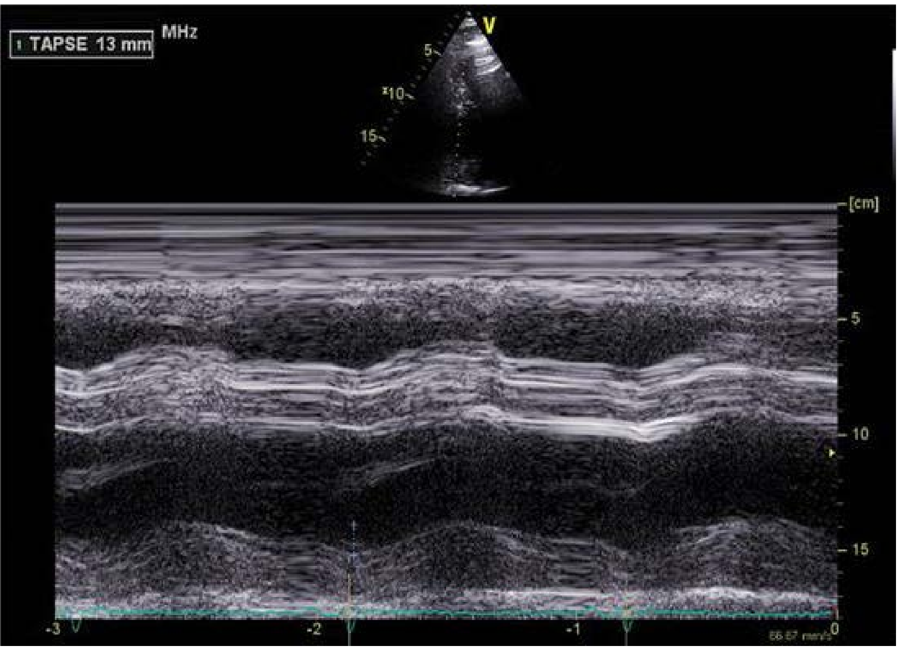
RV mid diameter 45 mm (normal $\leq$ 35 mm)

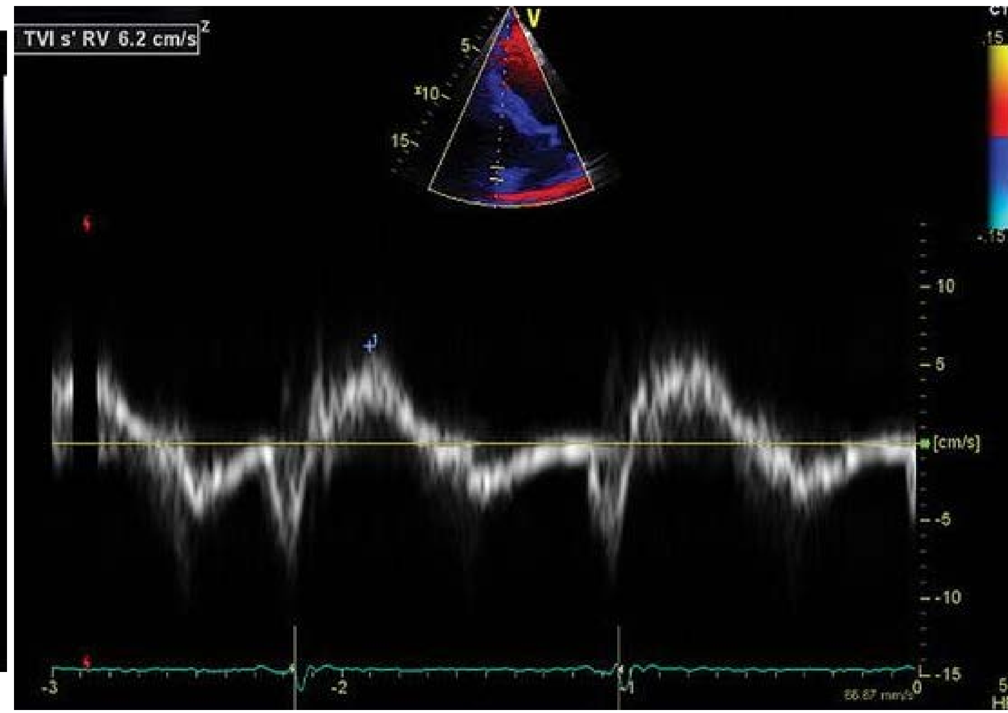
RV basal diameter 47 mm (normal $\leq$ 41 mm)

RV longitudinal diameter 60 mm (normal $\leq$ 83 mm)

FAC 20% (normal $\geq$ 35%)

Additional Parameters of RV Systolic Function





TAPSE 13 mm
Normal ≥ 17 mm

Tricuspid Annular Velocity 6.2 cm/sec
Normal ≥ 9.5 cm/sec

Normal Values for Parameters of RV Function

Parameter	Mean ± SD	Abnormality Threshold
TAPSE (mm)	24 ± 3.5	<17 *
Pulsed Doppler S wave (cm/sec)	14.1 ± 2.3	<9.5 *
Color Doppler S wave (cm/sec)	9.7 ± 1.85	<6.0
RV fractional area change (%)	49 ± 7	<35 *
RV free wall 2D strain* (%)	-29 ± 4.5	<-20 (<20 in magnitude with the negative sign)
RV 3D EF (%)	58 ± 6.5	<45
Pulsed Doppler MPI	0.26 ± 0.085	>0.43
Tissue Doppler MPI	0.38 ± 0.08	>0.54
E wave deceleration time (msec)	180 ± 31	<119 or >242
E/A	1.4 ± 0.3	<0.8 or >2.0
e'/a'	1.18 ± 0.33	<0.52
e'	14.0 ± 3.1	<7.8
E/e'	4.0 ± 1.0	>6.0

Normal Values for RV Chamber Size

Parameter	Mean ± SD	Normal Range
RV basal diameter (mm)	33 ± 4	25 – 41 *
RV mid diameter (mm)	27 ± 4	19 – 35 *
RV longitudinal diameter (mm)	71 ± 6	59 – 83 *
RVOT PLAX diameter (mm)	25 ± 2.5	20 – 30 *
RVOT proximal diameter (mm) PSAX	28 ± 3.5	21 – 35 *
RVOT distal diameter (mm)	22 ± 2.5	17 – 27
RV wall thickness (mm)	3 ± 1	1 – 5
RVOT EDA (cm^2)		
Men	17 ± 3.5	10 – 24
Women	14 ± 3	8 – 20
RV EDA indexed to BSA (cm^2/m^2)		
Men	8.8 ± 1.9	5 – 12.6
Women	8.0 ± 1.75	4.5 – 11.5
RV ESA (cm^2)		
Men	9 ± 3	3 – 15
Women	7 ± 2	3 – 11
RV ESA indexed to BSA (cm^2/m^2)		
Men	4.7 ± 1.35	2.0 – 7.4
Women	4.0 ± 1.2	1.6 – 6.4
RV EDV indexed to BSA (mL/m^2)		
Men	61 ± 13	35 – 87
Women	53 ± 10.5	32 – 74
RV ESV indexed to BSA (mL/m^2)		
Men	27 ± 8.5	10 – 44
Women	22 ± 7	8 – 36

PSAX RVOT 45 mm

(Normal ≤ 35 mm)

Diagnostic Terminology for ARVD 2010 Revised Criteria

- Global or regional dysfunction and structural alterations
- Tissue characterization of wall
- Repolarization abnormalities
- Depolarization/conduction abnormalities
- Arrhythmias
- Family history

I. **Definite** diagnosis: 2 Major, OR 1 Major and 2 Minor criteria, OR 4 Minor from different categories
II. **Borderline** diagnosis: 1 Major and 1 Minor, OR 3 Minor criteria from different categories
III. **Possible** diagnosis: 1 Major, OR 2 Minor criteria from different categories

Global or regional dysfunction and structural alterations: ARVD

(Note that 2D linear dimensions are at level of RVOT)

Major criteria by 2D echo:

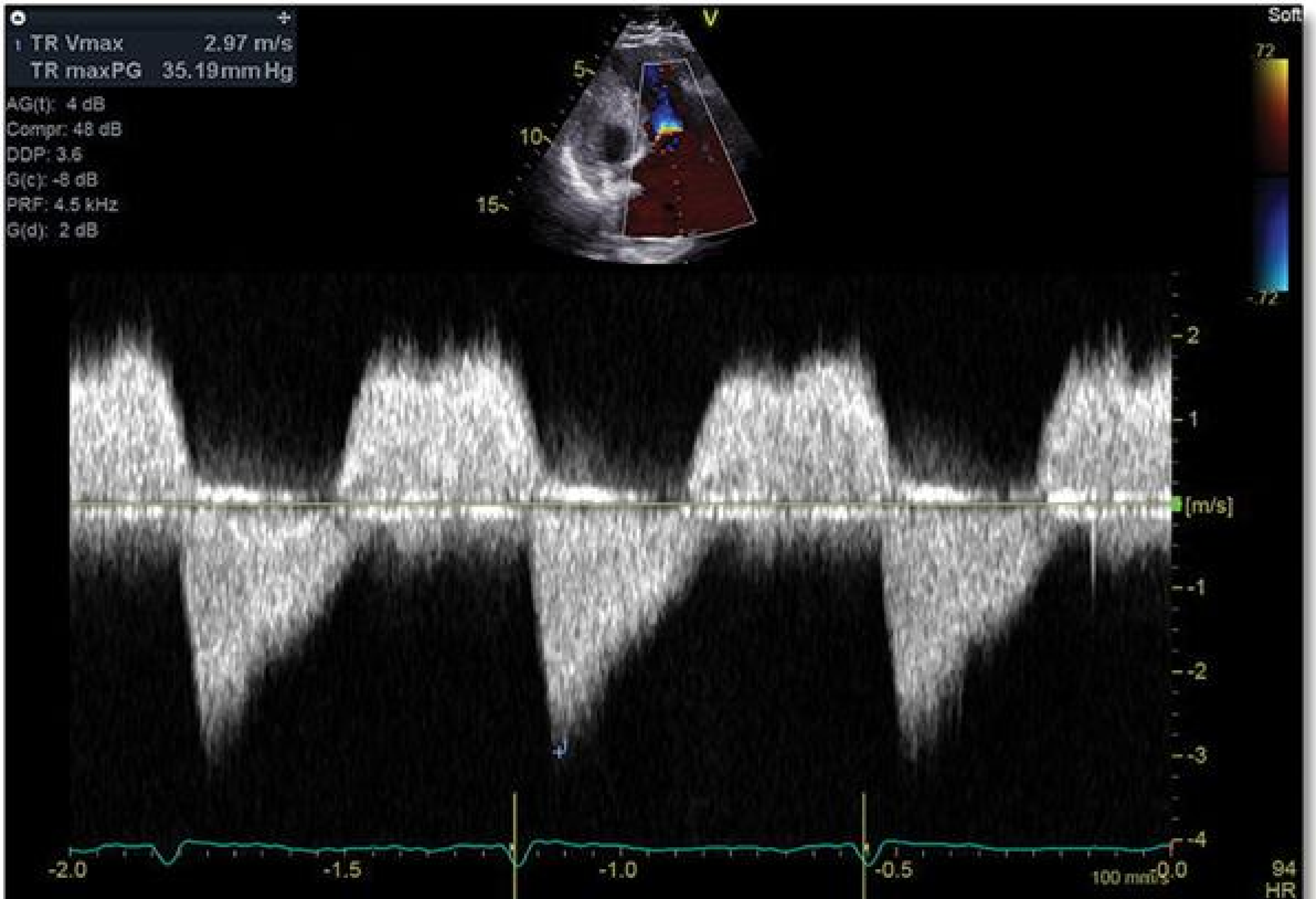
- Regional RV akinesia, dyskinesia, or aneurysm
- *and* 1 of the following (end diastole):
  - PLAX RVOT ≥32 mm (normal ≤ 30); (corrected for body size [PLAX/BSA] ≥19 mm/m^2)
  - PSAX RVOT ≥36 mm (normal ≤ 35); (corrected for body size [PSAX/BSA] ≥21 mm/m^2)
  - *or* fractional area change ≤33% (normal ≥ 35%)

Minor criteria by 2D echo:

- Regional RV akinesia or dyskinesia
- *and* 1 of the following (end diastole):
  - PLAX RVOT ≥29 to <32 mm (corrected for body size [PLAX/BSA] ≥16 to <19 mm/m^2)
  - PSAX RVOT ≥32 to <36 mm (corrected for body size [PSAX/BSA] ≥18 to <21 mm/m^2)
  - *or* fractional area change >33 percent to ≤40 percent

62 yr old woman with neuroendocrine tumor and worsening of her functional class over the last year. Now she gets short of breath after going up one flight of steps or walking one block on a flat surface.
She has also noticed paroxysmal nocturnal dyspnea and mild edema in the lower extremities.

Exam
Neck JVP is 10 cm with large V waves
3/6 holosystolic murmur at the base, unchanging with respiration



TR Vmax 2.97 m/s
TR maxPG 35.19 mm Hg
AG(t): 4 dB
Compr: 48 dB
DDP: 3.6
G(c): -6 dB
PRF: 4.5 kHz
G(d): 2 dB
V
5
10
15
Soft
72
-72
2
1
[m/s]
-1
-2
-3
-4
-2.0
-1.5
-1.0
-0.5
0.0
100 mm/s
94
HR

Carcinoid Heart Disease

- The 2D echocardiogram demonstrates severe tricuspid regurgitation as evidenced by thickened and fixed tricuspid leaflets with malcoaptation of the cusps.
- Continuous wave Doppler demonstrates triangular dense contour of the tricuspid regurgitant jet with short early peaking deceleration time consistent with early equilibration of right atrial, and right ventricular pressures are equivalent due to fixed open tricuspid valve.
- Significant tricuspid regurgitation is considered universal in patients with carcinoid heart disease, followed by tricuspid stenosis (38-44%), pulmonic valve regurgitation (31-38%), and pulmonic valve stenosis (25-31%). Left-side valve involvement is seen in around 30% of the patients with carcinoid disease, most commonly as result of right-to-left shunts, bronchial carcinoid, and in patients with very high levels of vasoactive substances.

Typical Findings of Carcinoid Heart Disease

- The right-sided chambers are markedly dilated
- Small, compressed, and hypercontractile left ventricle.
- Interventricular septal behavior with flattening in systole and diastole is consistent with right ventricular pressure and volume overload.
- The tricuspid valve leaflets are significantly thickened with restricted motion. The valve leaflets do not coapt due to annular dilatation and are fixed open throughout the cardiac cycle resulting in single-chamber physiology

Reminder:
When there is no coaptation of leaflets and severe TR, peak tricuspid regurgitation velocity can significantly underestimate the true PA systolic pressure.

- Rapid equalization of the pressures across the tricuspid valve and
- Lag in the time it takes to increase the pressure across the tricuspid valve due to the need to mobilize a large mass of blood

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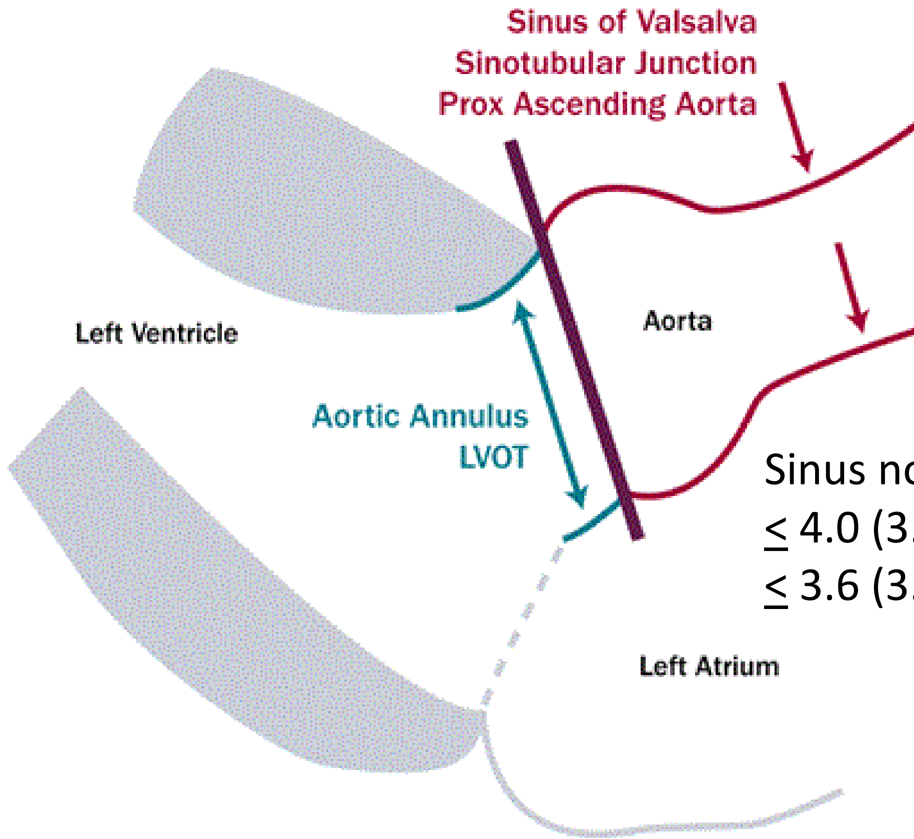
Aorta Measurements:
Annulus and LVOT are inner to inner edge
(annulus at mid-systole, not end-systole)



Asc Ao normal:
$\leq$ 3.8 (3.0 $\pm$ 0.4) cm ♂
$\leq$ 3.5 (2.7 $\pm$ 0.4) cm ♀

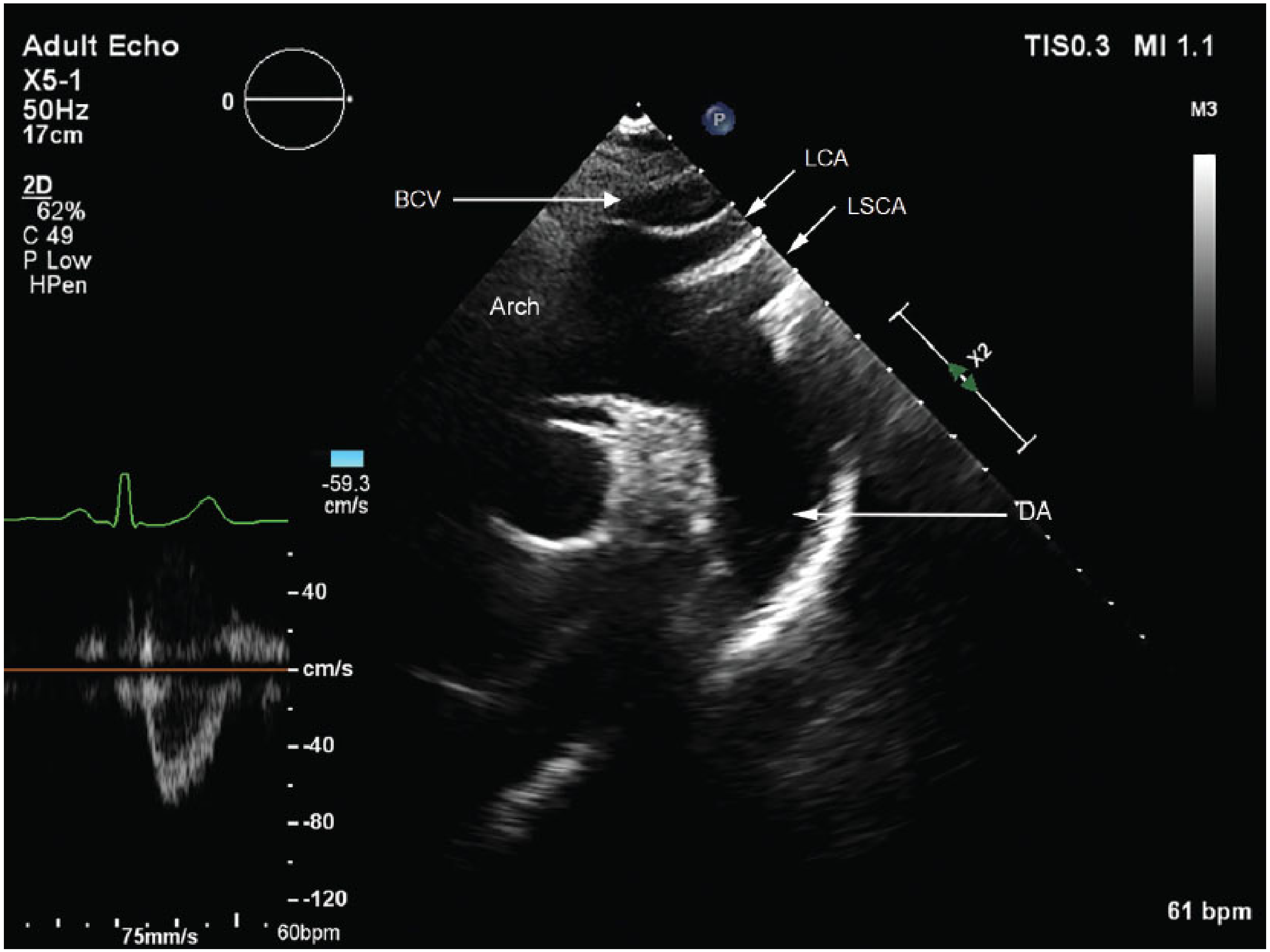
Sinus normal:
$\leq$ 4.0 (3.4 $\pm$ 0.3) cm ♂
$\leq$ 3.6 (3.0 $\pm$ 0.3) cm ♀

- After initial detection of dilated aorta, repeat echocardiography should be performed in 6 months to confirm stability.
- Small stable aneurysms (<4.5 cm in an adult) may be followed by annual imaging, whereas aneurysms ≥4.5 cm or those demonstrating growth should be followed every 6 months, or more frequently, depending on the particular circumstances.

When to Operate on Asymptomatic Thoracic Ascending Aorta Aneurysm (Class I Indications, 2010)

- **$\geq$ 5.5 cm in general**
- 4.0 to 5.0 cm ($\geq$ 4.5 cm per EchoSAP): Patients with Marfan syndrome or other genetically mediated disorders (vascular Ehlers-Danlos syndrome, Turner syndrome, bicuspid aortic valve, or familial thoracic aortic aneurysm and dissection)
- Patients with a <u>growth rate of more than 0.5 cm/y</u> in an aorta that is less than 5.5 cm in diameter
- Patients <u>undergoing aortic valve repair or replacement</u> and who have an ascending aorta or aortic root of <u>greater than 4.5 cm</u>

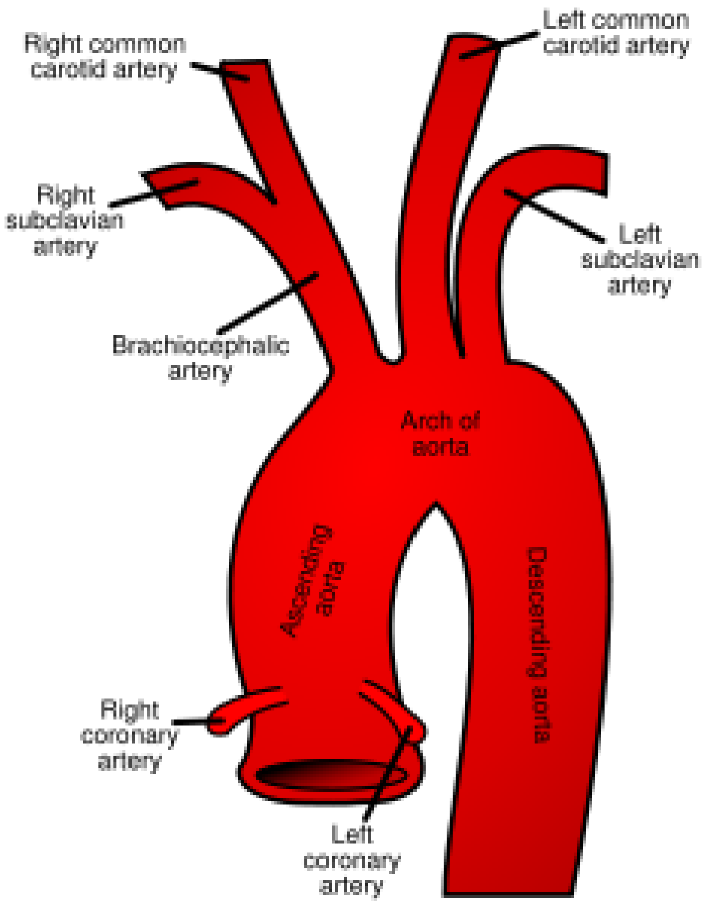
Suprasternal Notch

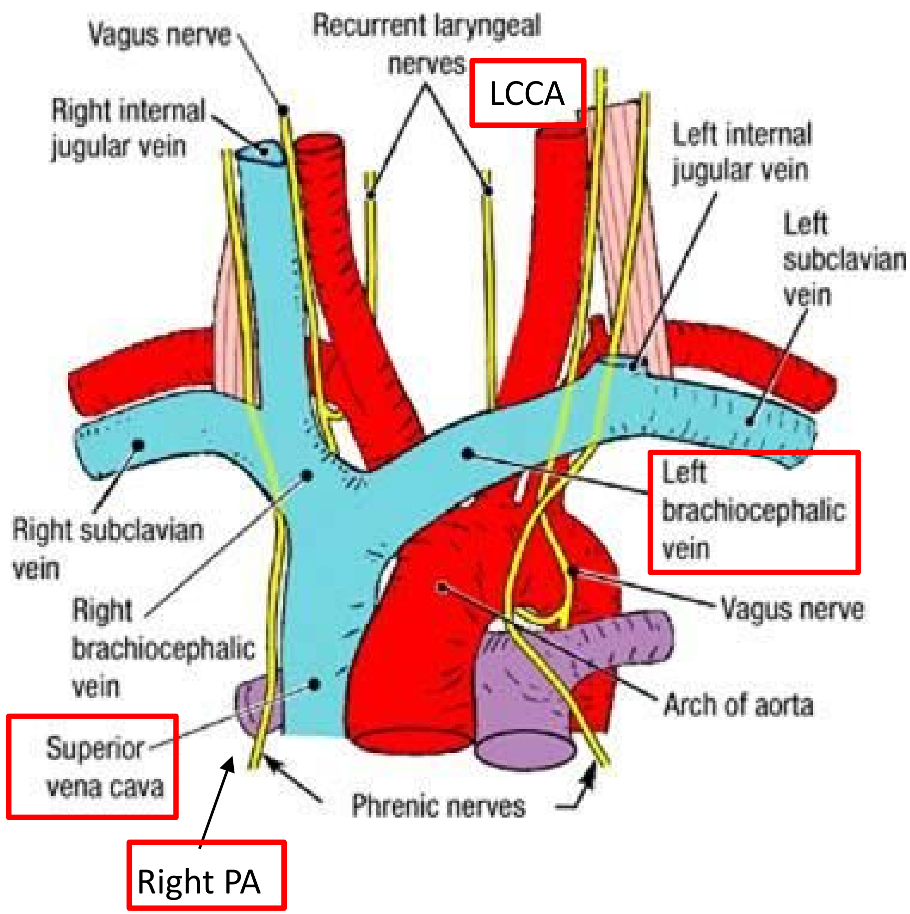


BCV:
Brachiocephalic vein

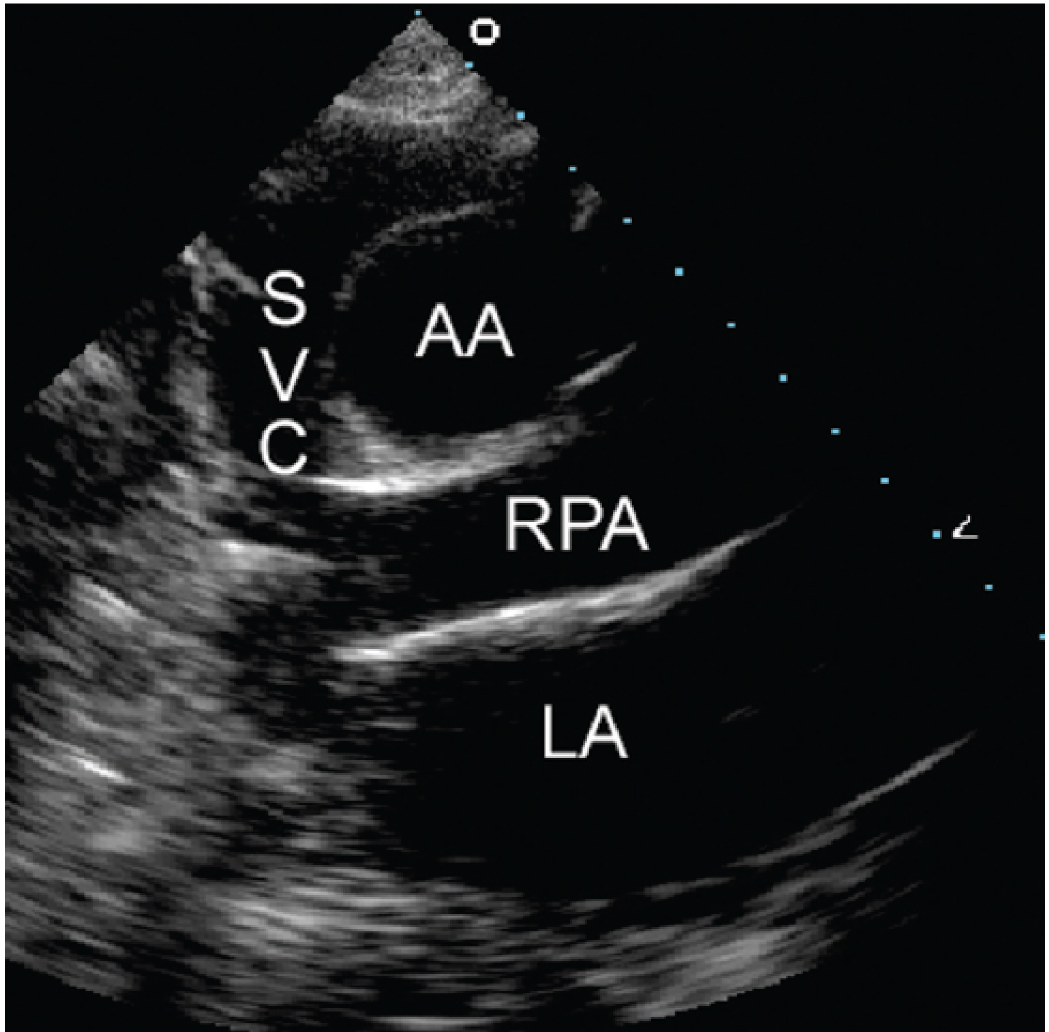
Feigenbaum's Echocardiography 2019

Great Vessels: Anatomy





Suprasternal Notch
SVC (to the right of the aortic arch)



Feigenbaum. 8th Ed, 2019

Do you see the abnormal finding on the next video?

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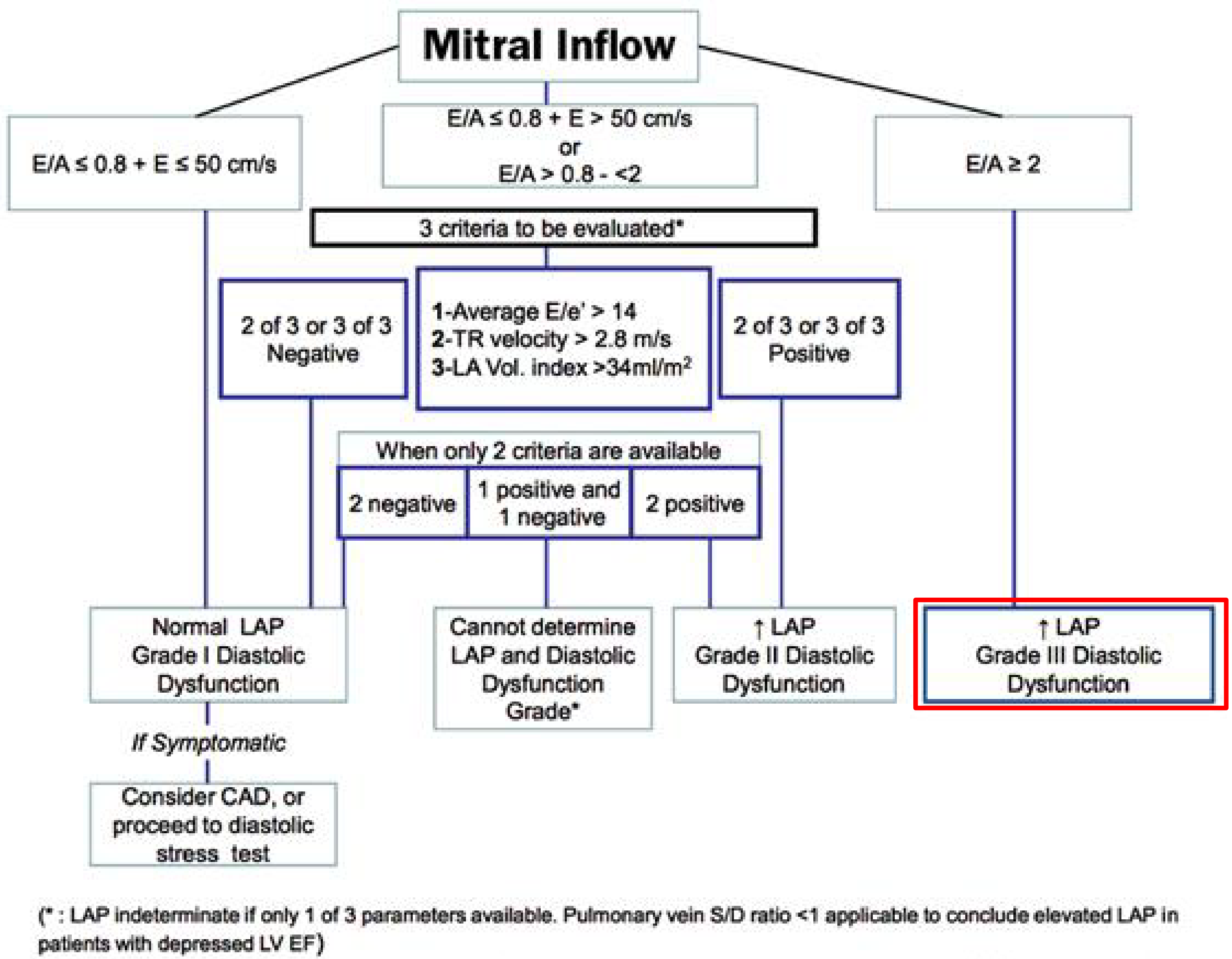
Diastology

- Abnormal cut-off values:
  - septal e’ < 7 cm/s
  - Lateral e’ < 10
  - Average E/e’ > 14
  - Other parameters: LA volume index > 34 ml/m^2 and TR velocity > 2.8 m/sec
- Doppler indicators associated with worse prognosis in HFrEf: e’ < 3, E/e’ > 15, DT < 140 ms

Algorithm for Diastolic Dysfunction Grades

For depressed LVEF or normal EF and myocardial disease



If atrial fib, suspect diastolic dysfunction if E/e’ > 11 and E > 1.9 m/sec

A 56-year-old male with known coronary artery disease is admitted to the hospital with what was thought to be pneumonia.

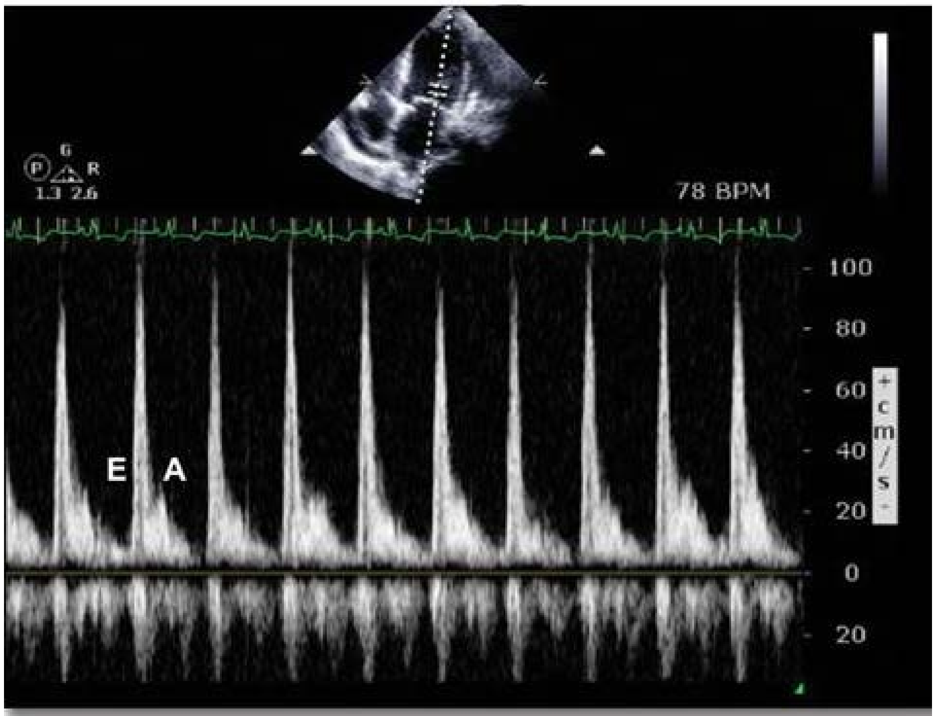
Onset: 3 days prior

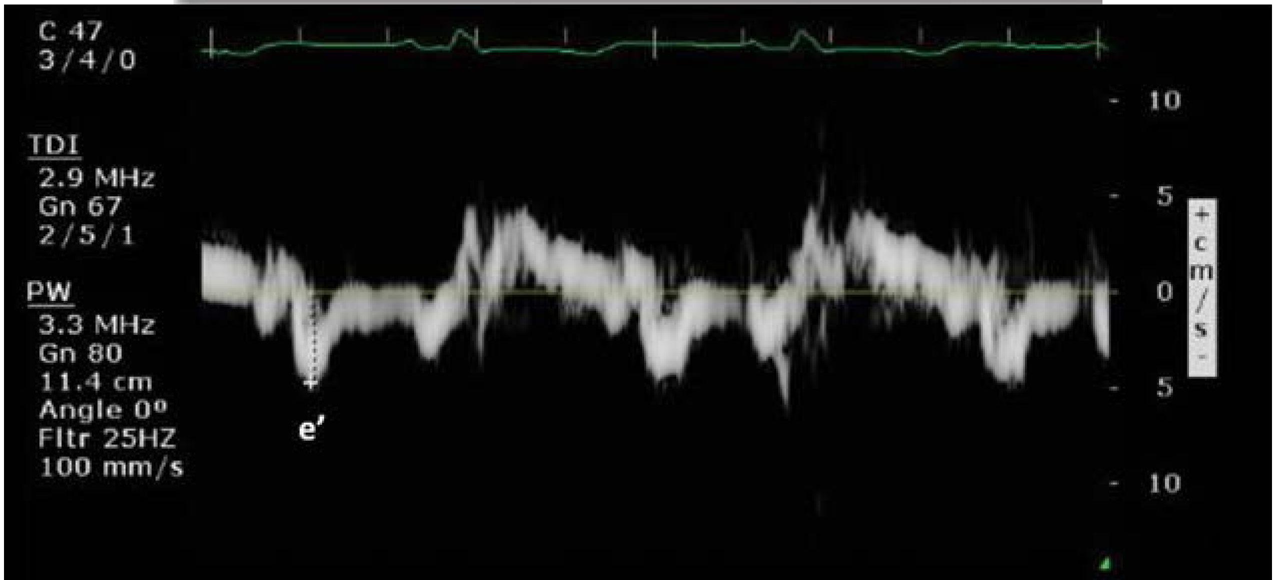
Duration: 3 days

Other Medical History: Prior myocardial infarction; hypertension

Echo: LVEF 25%

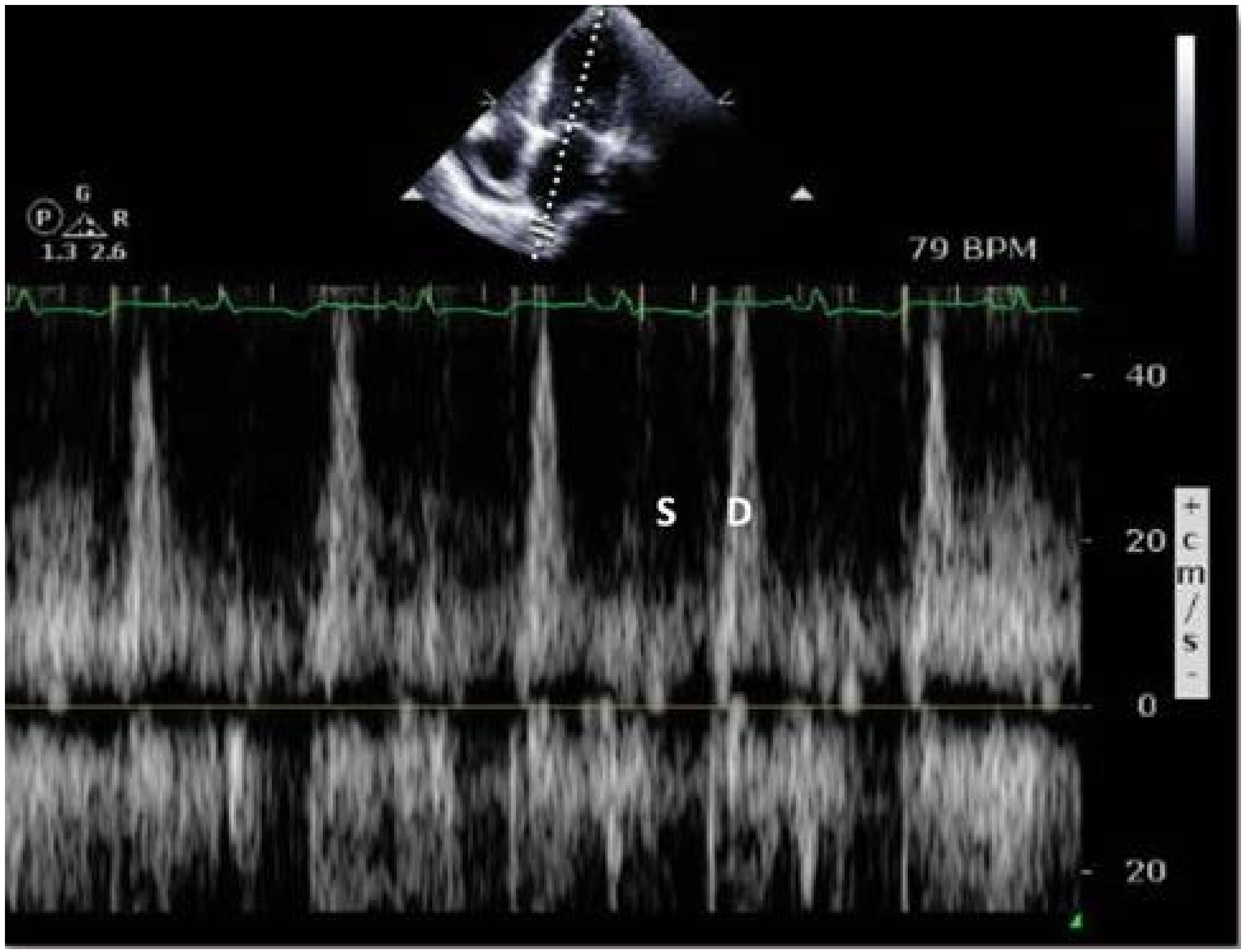
Grade 3 (severe) LV diastolic dysfunction





E = 100 cm/sec
A = 40 cm/sec
E/A = 2.5 (≥ 2 is Grade 3)
E' (septum) = 5 cm/sec
TR velocity: NA
LA vol: 40 ml/m2

Blunting of pulmonary vein systolic velocity: Elevated LA pressure vs MR



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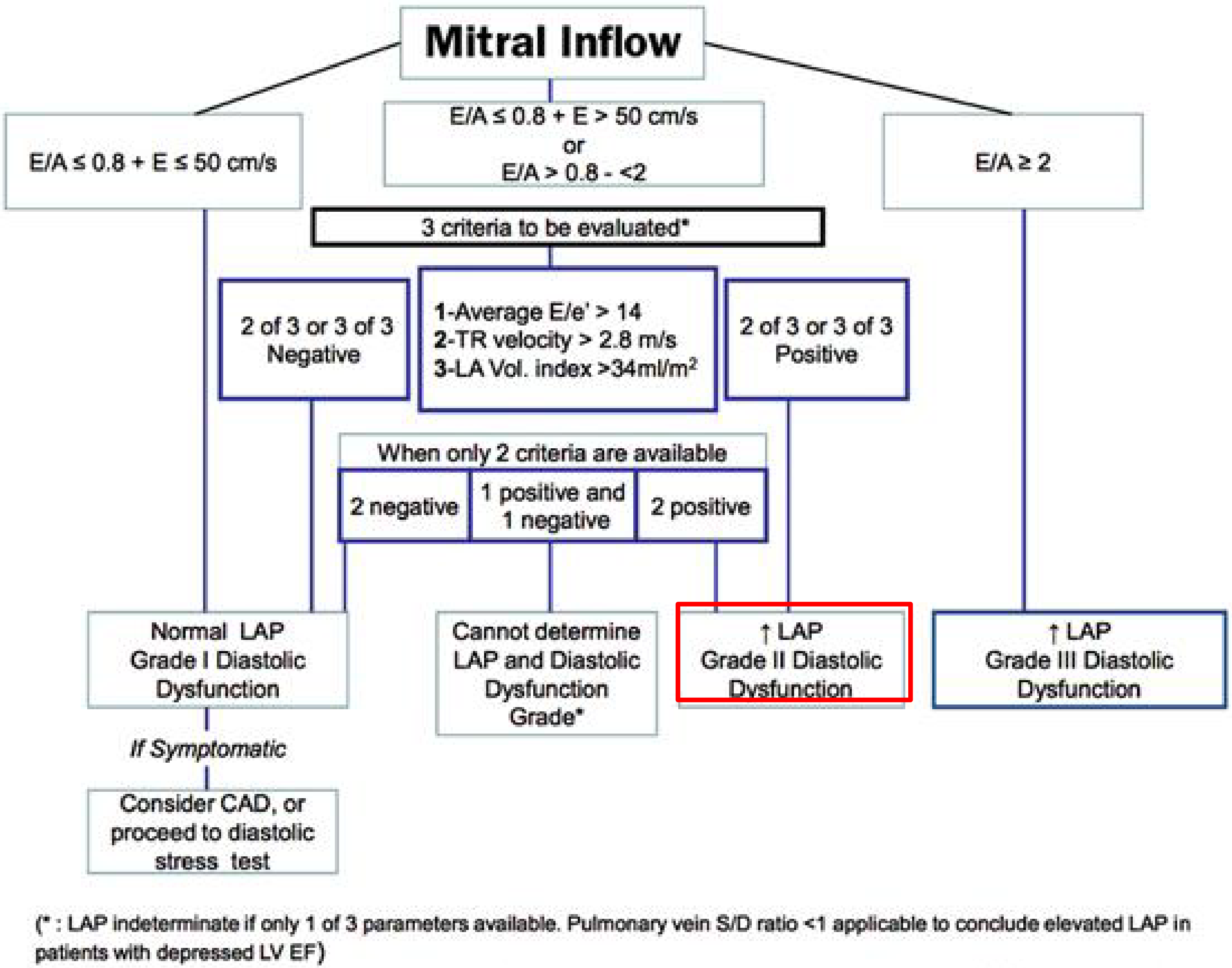


If atrial fib, suspect diastolic dysfunction if E/e' > 11 and E > 1.9 m/sec

A 72-year-old female complains of exertional dyspnea x 6 months. She feels fine at rest but has noted that routine activities such as housework make her feel “winded.” She has attributed this to weight gain and has managed to lose about 8 pounds through dieting with minimal improvement in symptoms.

Onset: 6 months

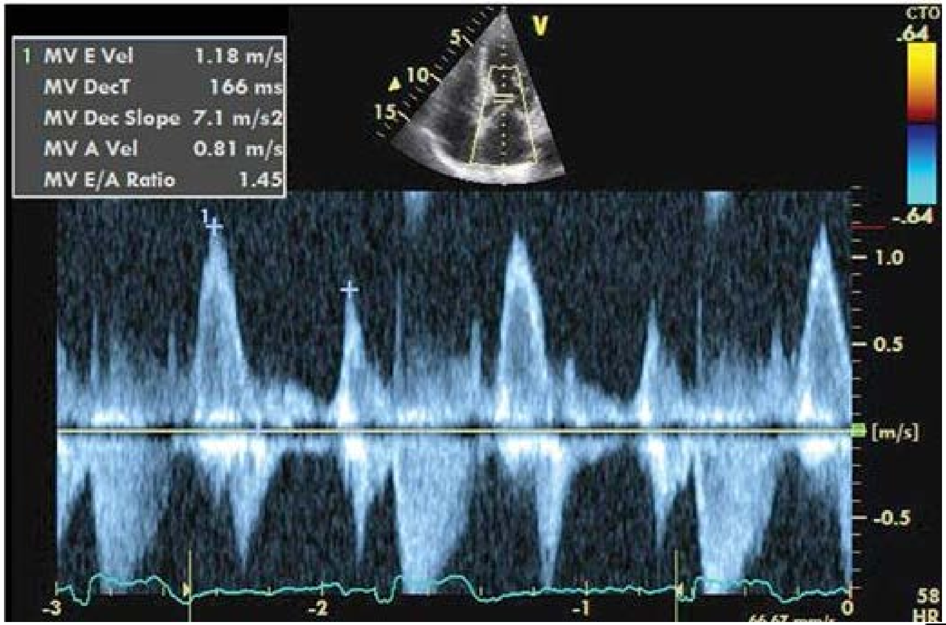
Duration: 6 months

Other Medical History: Hypertension

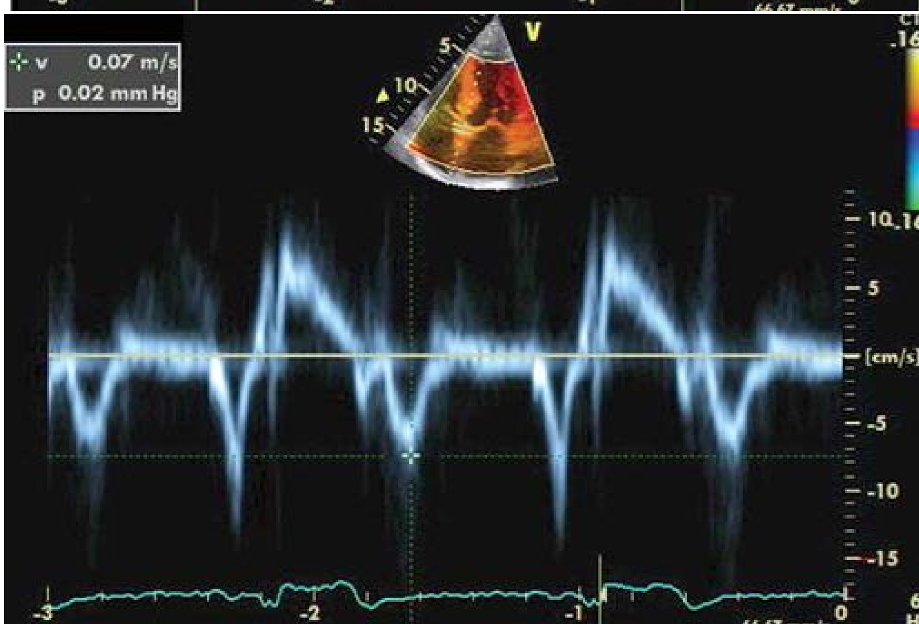
PE: unremarkable

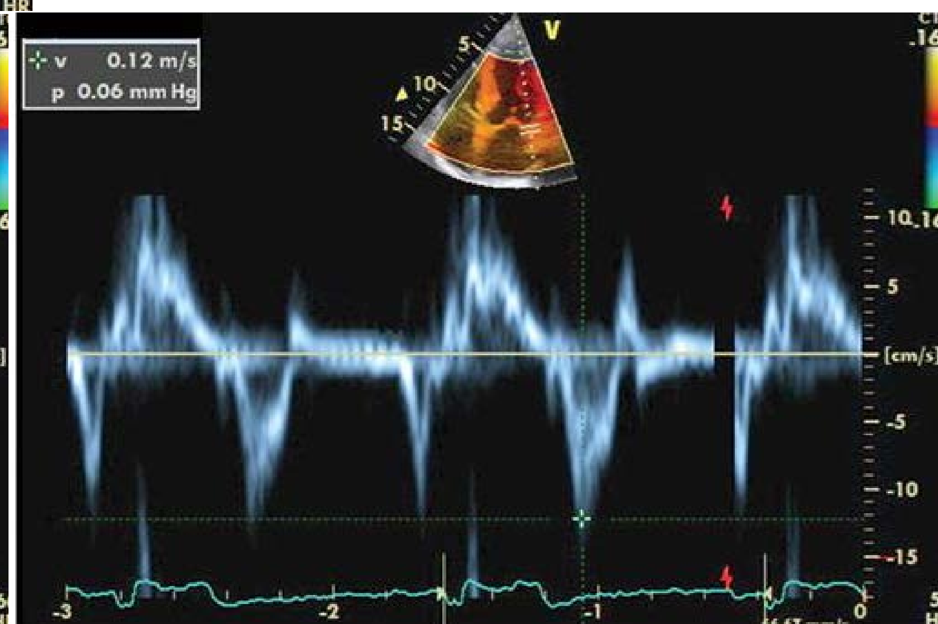
ECG: NSR, LVH

Grade 2 LV diastolic dysfunction

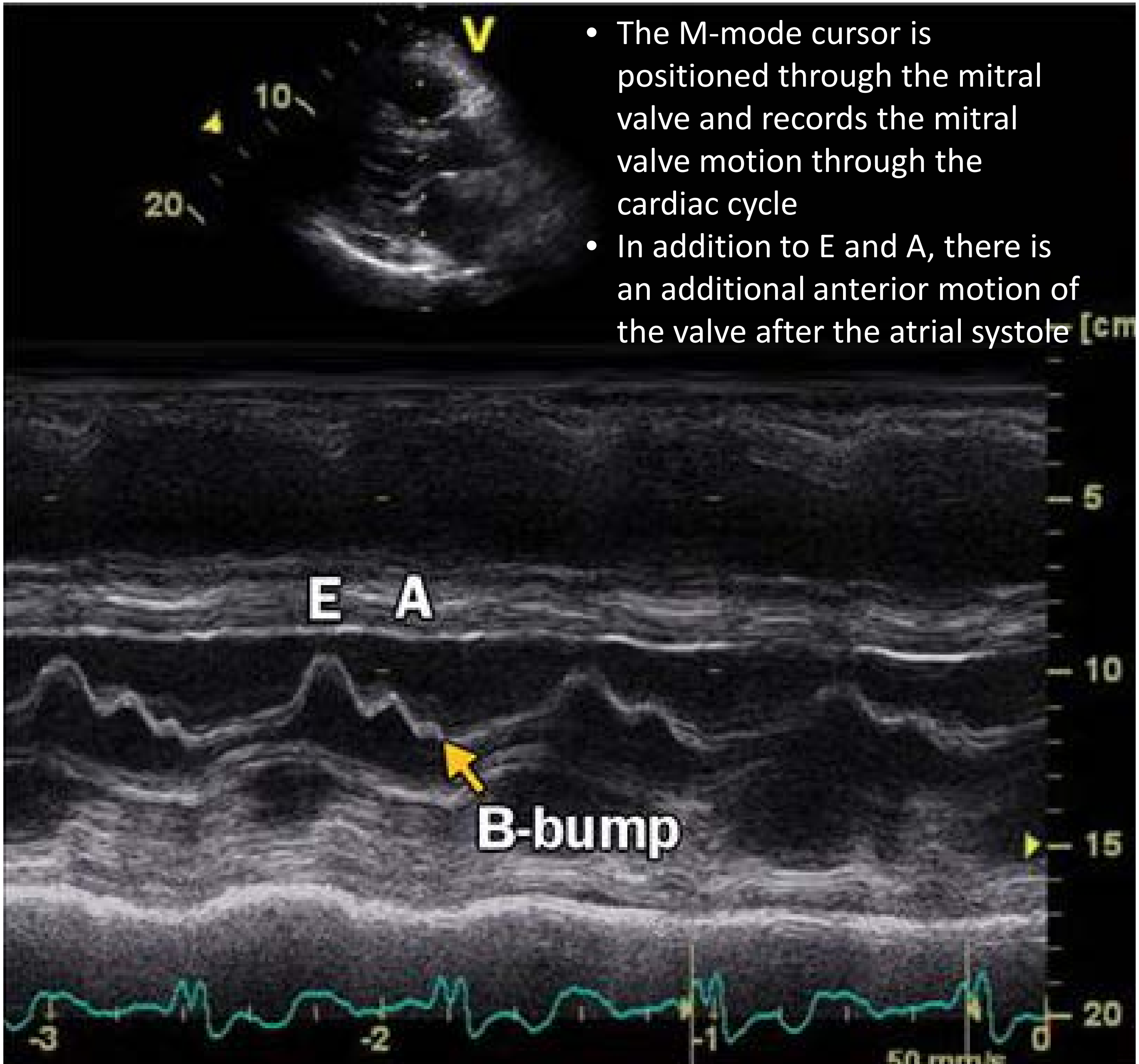


E = 118 cm/sec
A = 81 cm/sec
E/A = 1.45 (i.e., between 0.8 and 2.0)
e’ septal = 7 cm/sec
e’ lateral = 12 cm/sec
E/e’ average (118/9.5) = 12 negative
LA volume index = 45 ml/m2 positive
TR velocity = 3.5 m/sec positive



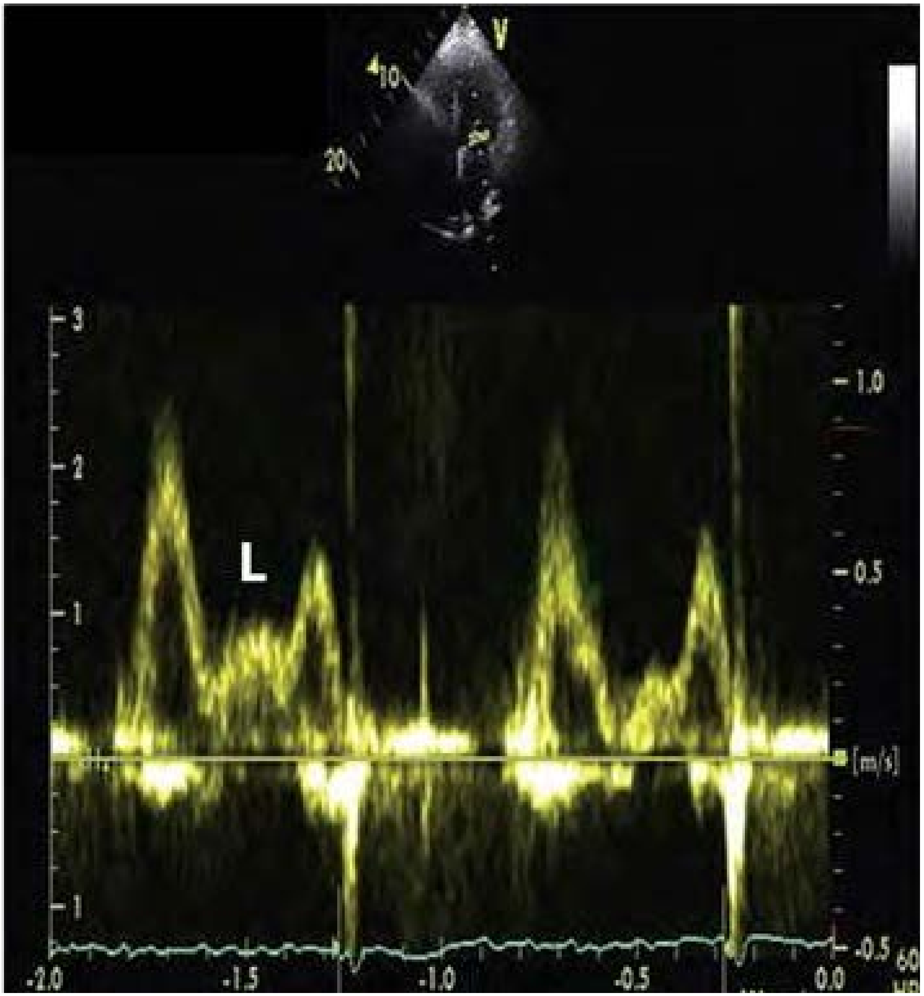


“B-bump”: a reliable indicator of elevated late diastolic pressure



- The M-mode cursor is positioned through the mitral valve and records the mitral valve motion through the cardiac cycle
- In addition to E and A, there is an additional anterior motion of the valve after the atrial systole

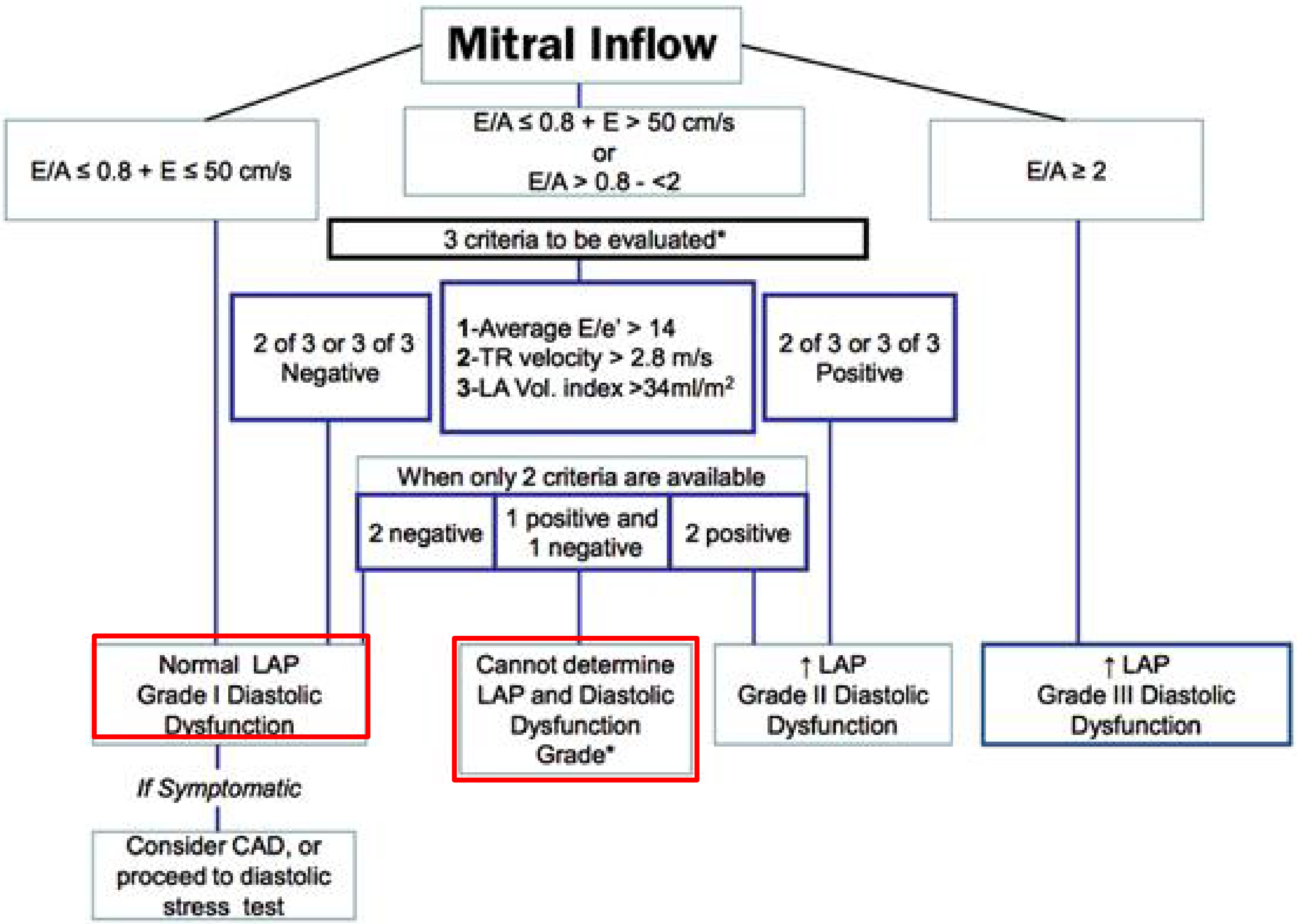
L wave and the "Batman" sign



- The L wave represents an advanced stage of diastolic dysfunction secondary to markedly delayed LV relaxation allowing for further LV filling during mid-diastole in the setting of elevated LV filling pressures.
- It is usually seen in the setting of people with known cardiac disease with relatively slow heart rates.
- The L wave is rarely seen in people with normal diastolic function.

Algorithm for Diastolic Dysfunction Grades

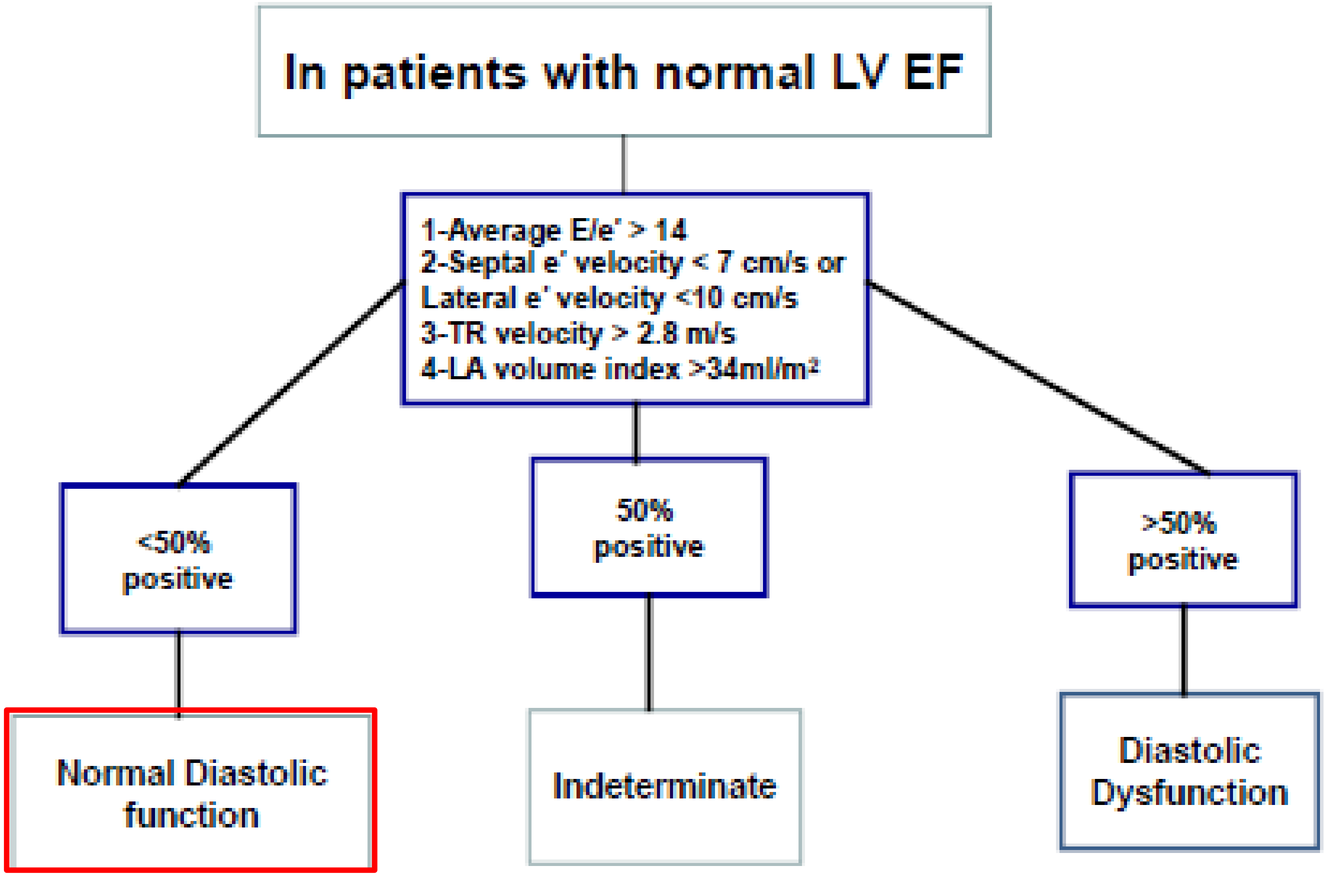
For depressed LVEF or normal EF and myocardial disease



(* : LAP indeterminate if only 1 of 3 parameters available. Pulmonary vein S/D ratio <1 applicable to conclude elevated LAP in patients with depressed LV EF)

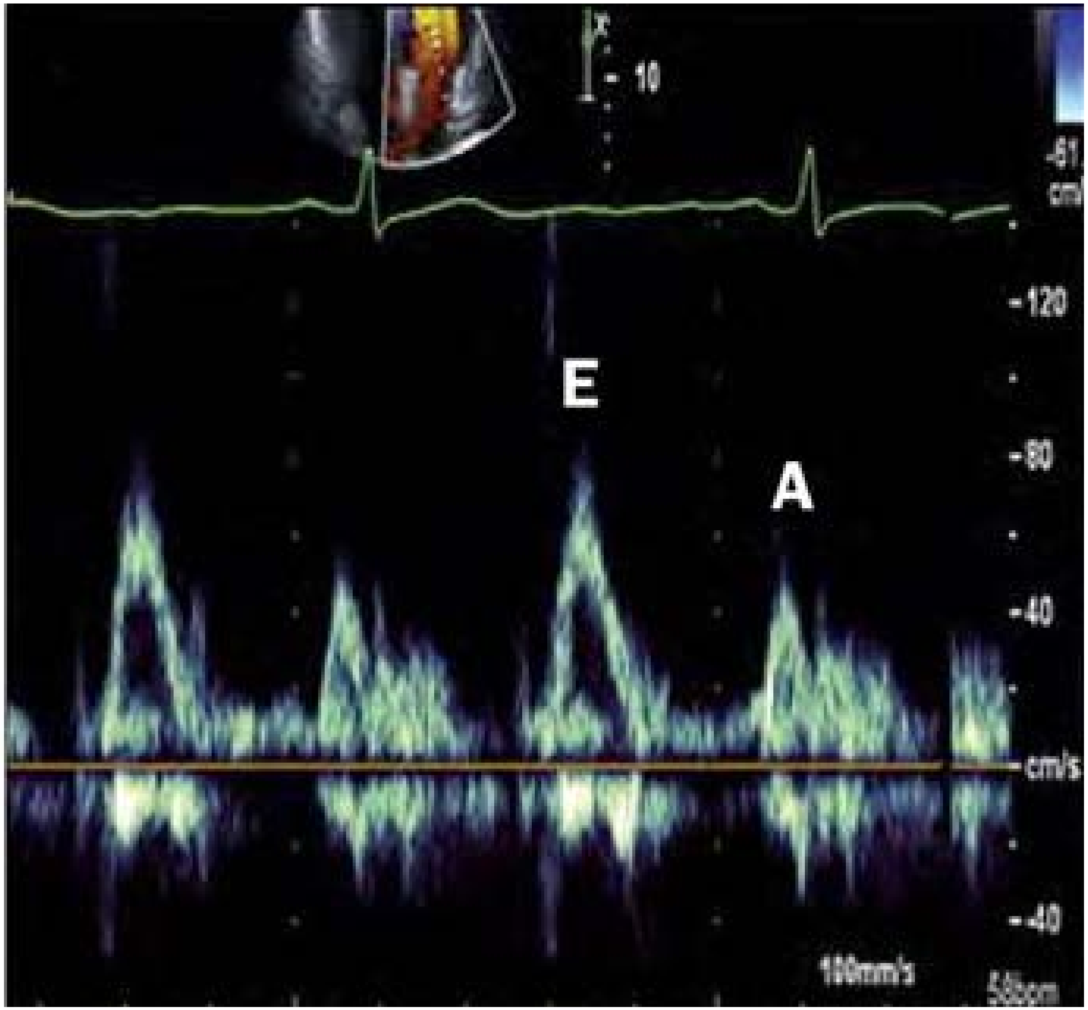
If atrial fib, suspect diastolic dysfunction if E/e' > 11 and E > 1.9 m/sec

Algorithm for Diastolic Dysfunction



21-year-old male with a past medical history of polysubstance including active tobacco use who presents for evaluation of symptomatic bradycardia. Per the patient, he has been noted to be bradycardic since birth and recently it has been associated with positional lightheadedness and episodes of presyncope, but he denies syncope.
ECG: Sinus brady
Echo: LVEF 60

Normal LV diastolic function and normal LV filling pressure

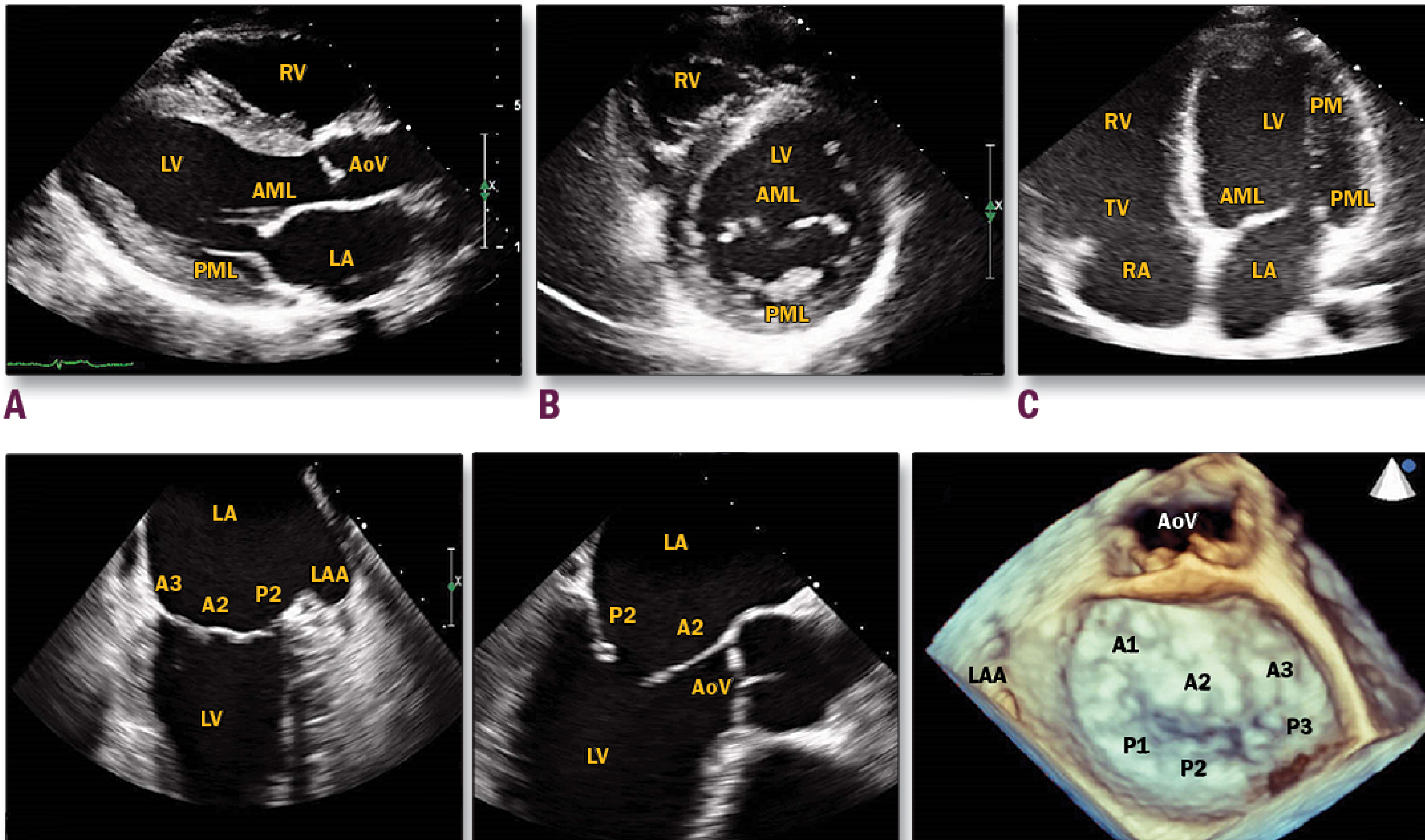


E = 80 cm/s
A = 50 cm/s
septal e’ velocity = 11 cm/s
lateral e’ velocity = 15 cm/s
Average E/e’ = 6
LA volume index = 28 mL/m2
Peak TR velocity is 1.0 m/s

Echo Board Review

- Chamber Dimensions, Systolic and Regional Function
- Aorta
- Diastology
- **Valves**
- Pericardium
- Congenital
- Miscellaneous/Potpourri
- Physics

Normal Transthoracic, Transesophageal, and 3D En-Face Views of the Mitral Valve



A B C D E F

medial

Both A + P middle scallops seen here

MR Stages

- At risk (Stage A): e.g., MVP with mild MR and normal LV
- Progressive (Stage B): severity < severe
- Asymptomatic severe (Stage C1): LVEF > 60% , LVESD < 4.0 cm
- Asymptomatic severe (Stage C2):LVEF $\leq$ 60% , LVESD $\geq$ 4.0 cm
- Symptomatic severe (Stage D)

Low velocity in acute MR (high LAP)

Asymptomatic Severe MR
Class I Indications for Surgery

- LVEF 30 – 60% or
- LVESD $\geq$ 4.0 cm
- Mitral repair is reasonable (Class IIa) for new a fib or PA systolic pressure > 50 mmHg

Quantitative Parameters for Grading Mitral Regurgitation Severity

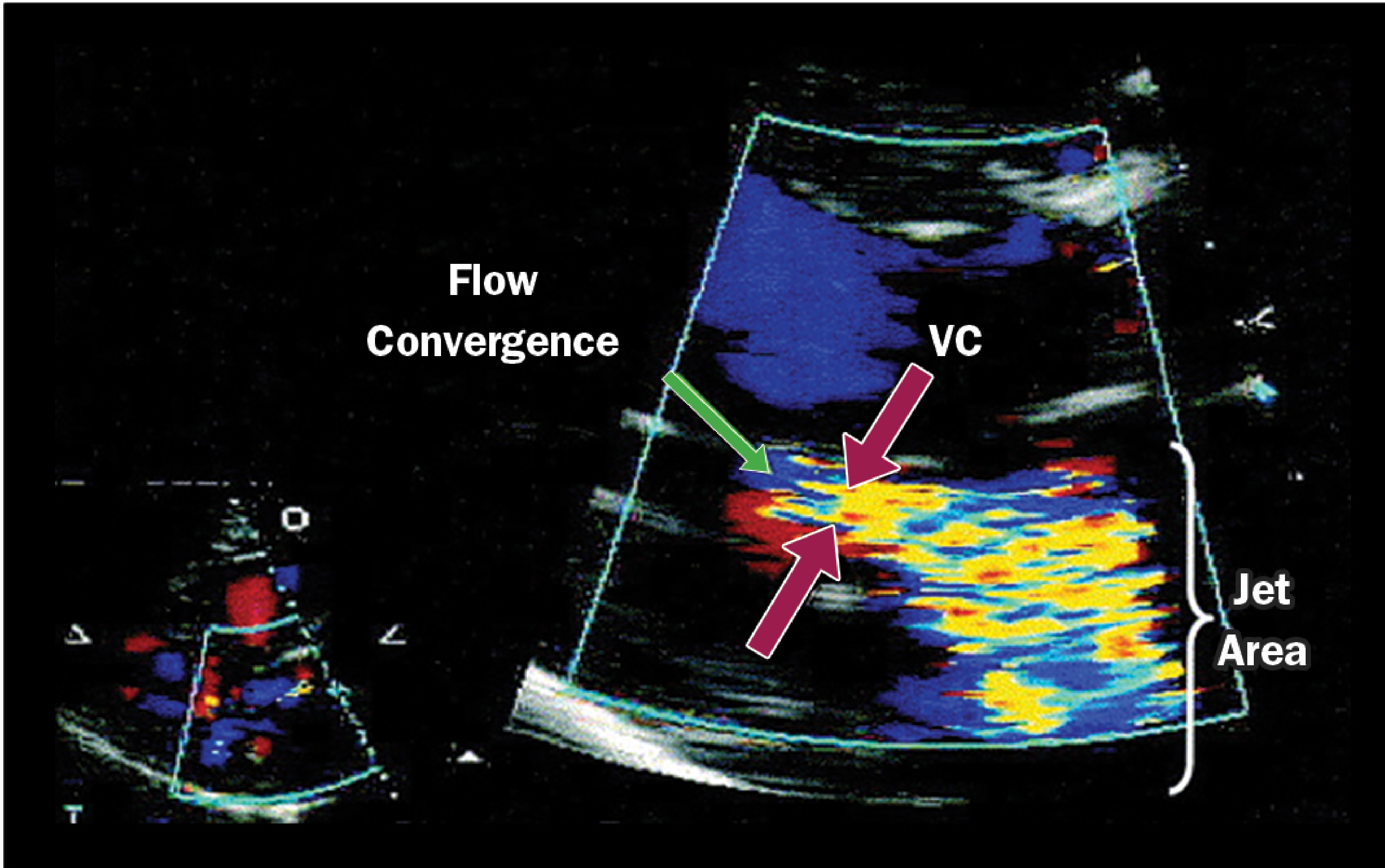
Note the Echo Criteria for Severe MR

Quantitative Parameter	Mild	Moderate		Severe
VC width (cm)	<0.3	0.3 – 7.0		≥0.8
Reg V (mL/beat)	<30	30 – 44	45 – 59	≥60
RF (%)	<30	30 – 39	40 – 49	≥50
EROA (cm^2)	<0.20	0.20 – 0.29	0.30 – 0.39	≥0.40

Jet Area *	< 4.0 cm^2	> 8.0 cm^2
Jet Area/LA area	< 20%	> 50%

* not accurate for < holosystolic MR (MVP)

Color Flow Recording of a Mitral Regurgitation Jet



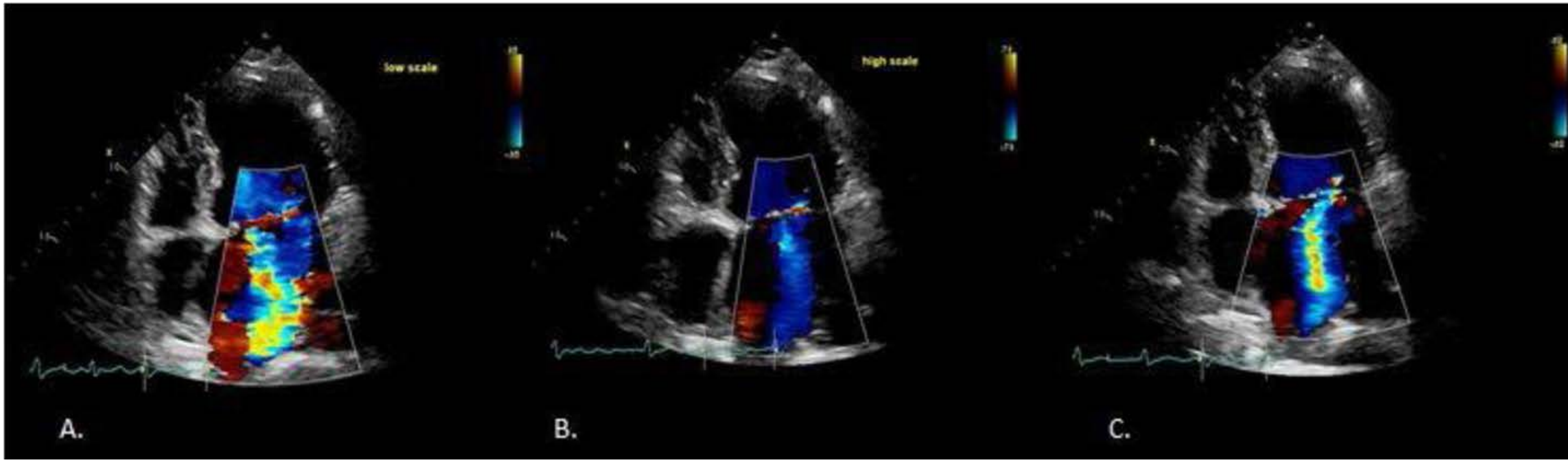
Color Doppler Jet Area:
Factors that reduce regurgitant jet area

- Wall impingement (Coanda effect)
- Lower driving pressure
- Low color gain setting
- Increased Nyquist limit

Nyquist limit effect on color jet area

same regurgitant volume appears considerably larger at a lower color scale compared with a higher scale

Low Scale | High Scale | Default



Lower velocities fall within a narrow band of ‘‘dark’’ low velocity near the baseline on the color scale

As a default, it is recommended that the color-flow scale (Nyquist limit) be set between 50 and 70 cm/sec in each direction for all routine color Doppler interrogation (but 30 cm/sec for low flow such as pulmonary vein)

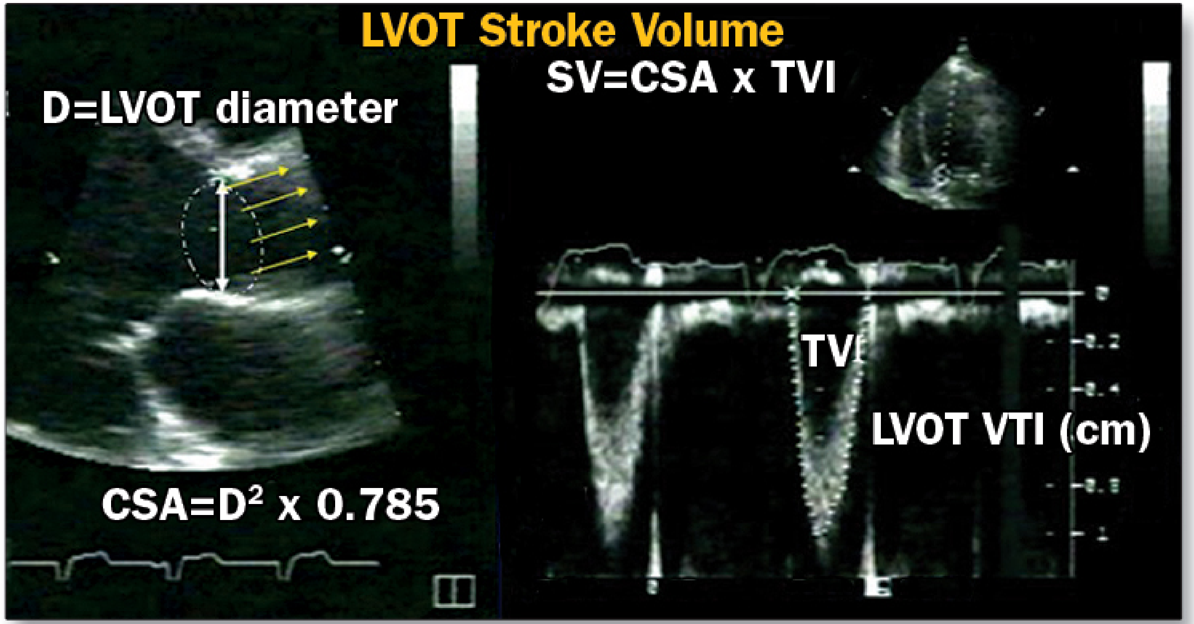
2019 JASE Guidelines and Standards

Calculating Regurgitant Volume and Fraction (Severe: RV $\geq$ 60 ml, RF $\geq$ 50%)

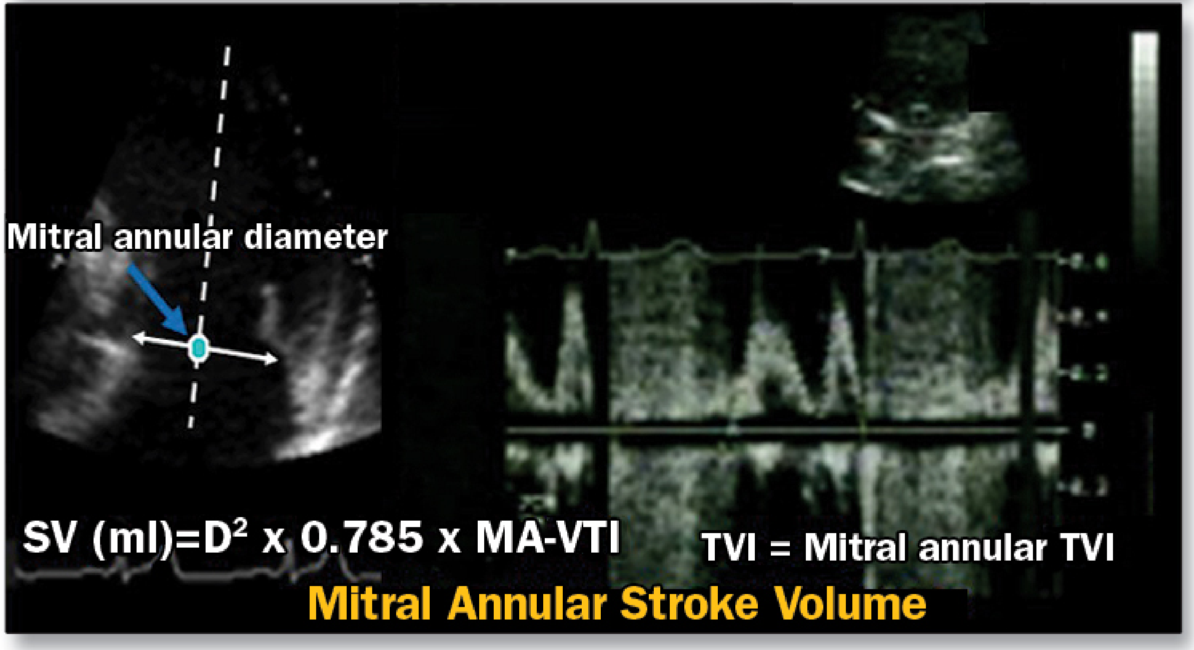
- Regurgitant Volume (method 1) = Total Stroke Volume (from 2D echo MOD trace LVEDV - LVESV) – Forward SV (LVOT area x LVOT VTI)
- Regurgitant Volume (method 2) = Total Stroke Volume (from Mitral annular area x Mitral VTI) – Forward Stroke Volume
- Regurgitant Fraction = Regurgitant Volume/Total Stroke Volume

Combined Doppler Method for Quantification of Flow Volumes

Calculating Forward Stroke Volume

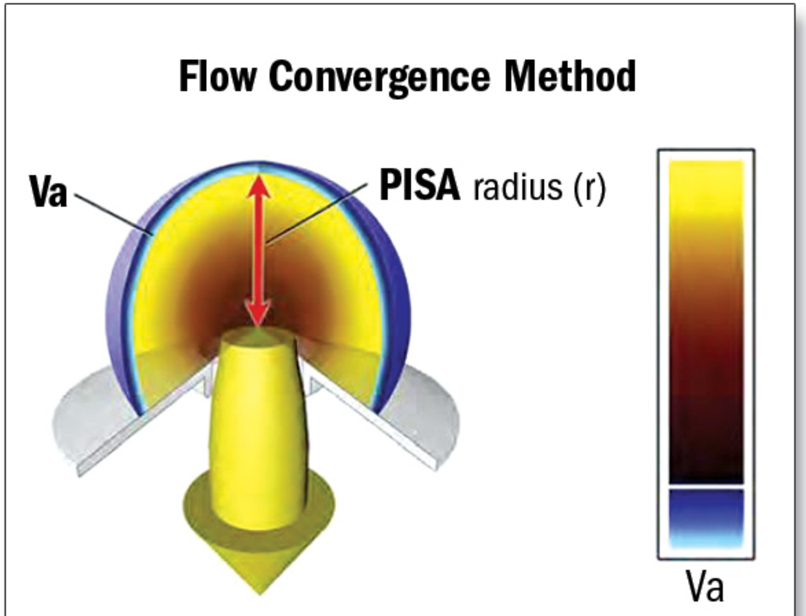


Calculating Total Stroke Volume (Method 2)

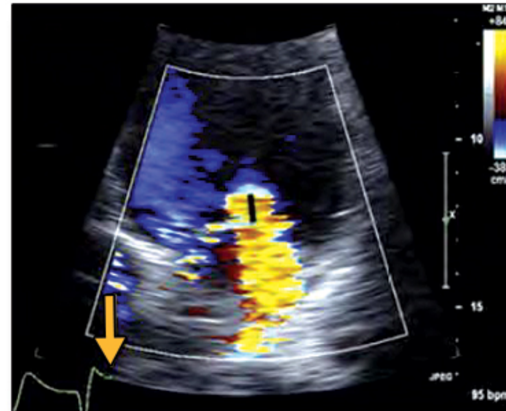


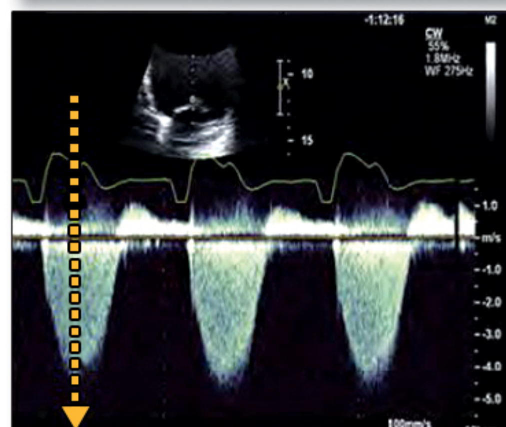
Schematic Representation of Proximal Isovelocity Surface Area (PISA) Method, or Flow Convergence Method

Severe MR: EROA ≥ 0.40 cm²



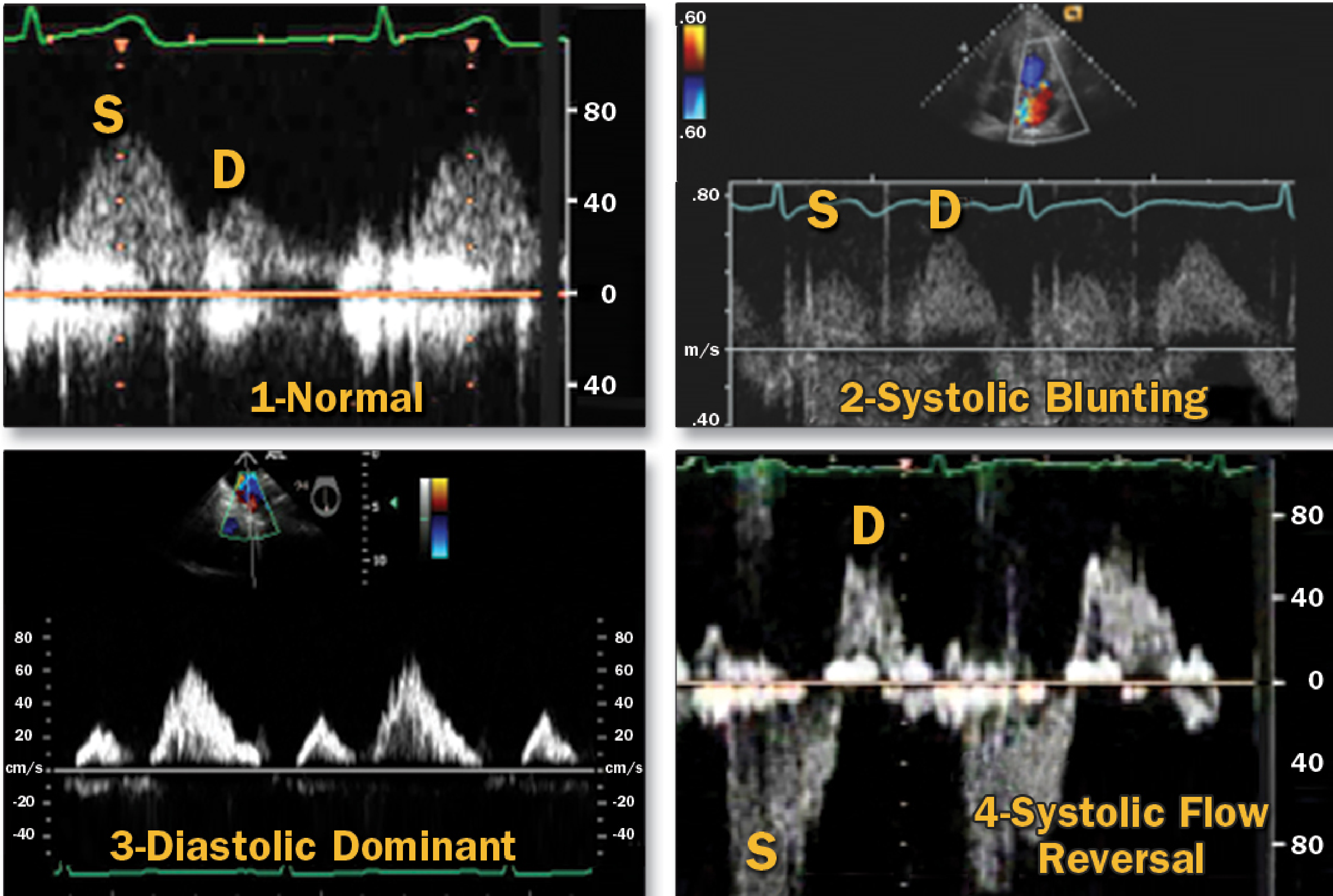
$$\text{Reg Flow} = 2\pi r^2 \times Va$$
$$\boxed{\text{EROA}} = \text{Reg Flow}/PKV_{Reg}$$
$$\text{R Vol} = \text{EROA} \times VTI_{Reg}$$



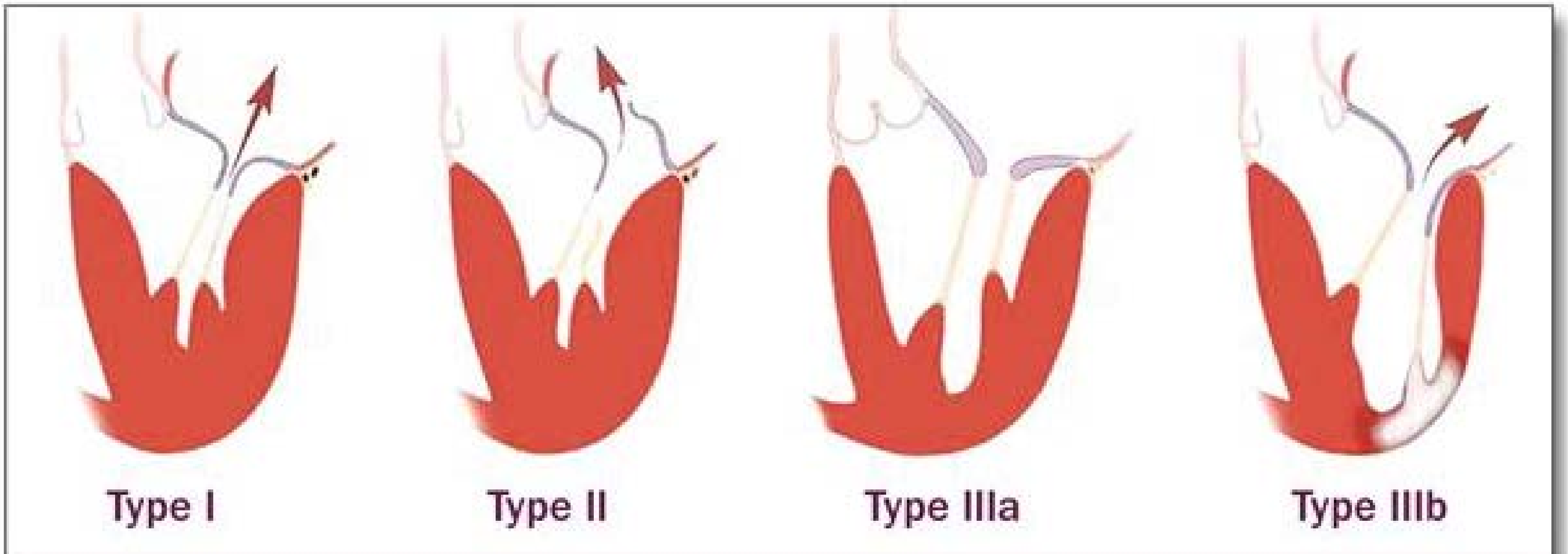


- Overestimates MR severity in MVP
- For multiple jets, sum the EROAs
- Angle correction of EROA: multiple by angle/180

Spectral Doppler Patterns Obtained on TTE (four-chamber view)



Carpentier Classification for MR (based on leaflet motion)



Type IV: SAM

Normal leaflet motion (e.g., leaflet perforation or dilated annulus *)

MVP *

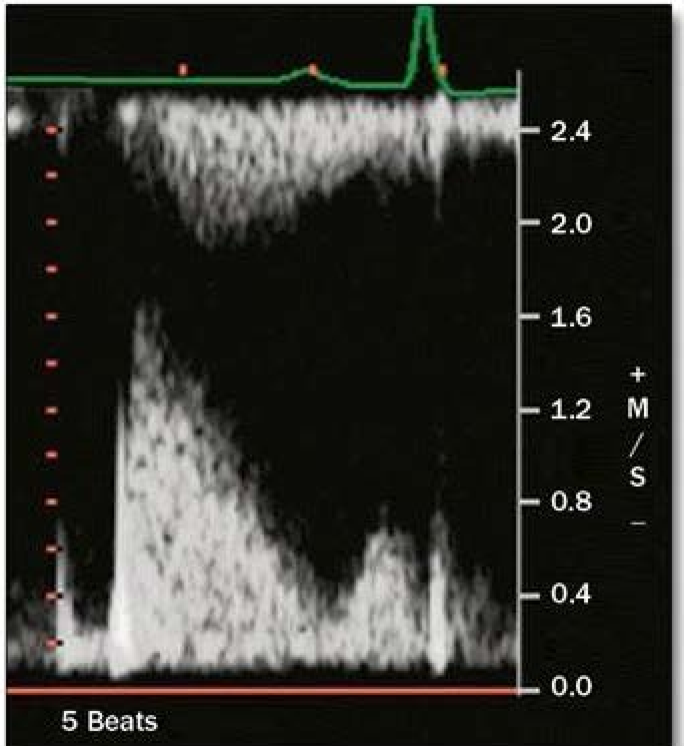
Rheumatic (Diastolic Restriction of Leaflets)

Ischemic (Systolic Restriction of Leaflets) *

* Suitable for annuloplasty

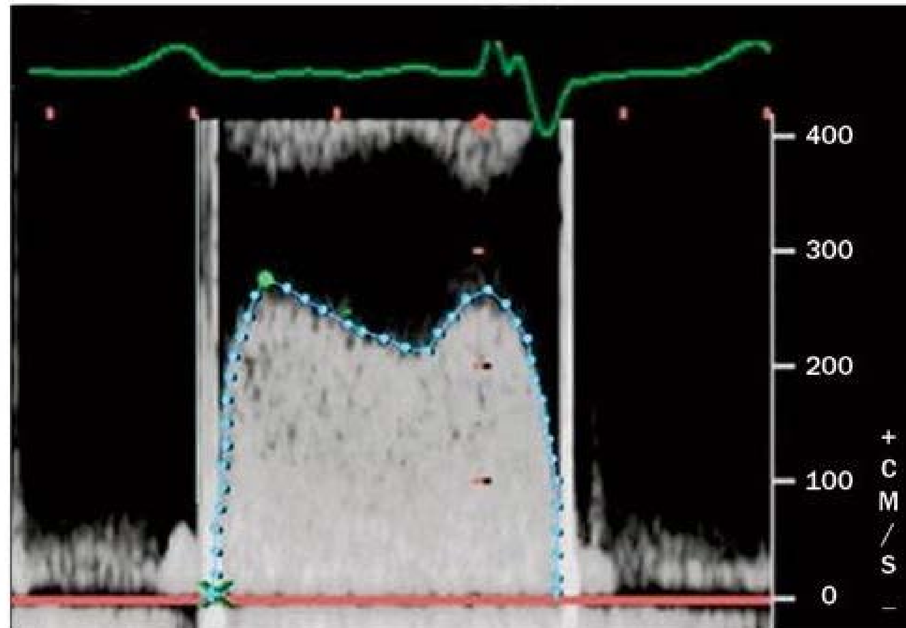
Normal and Obstructed MVR

Normal Prosthesis



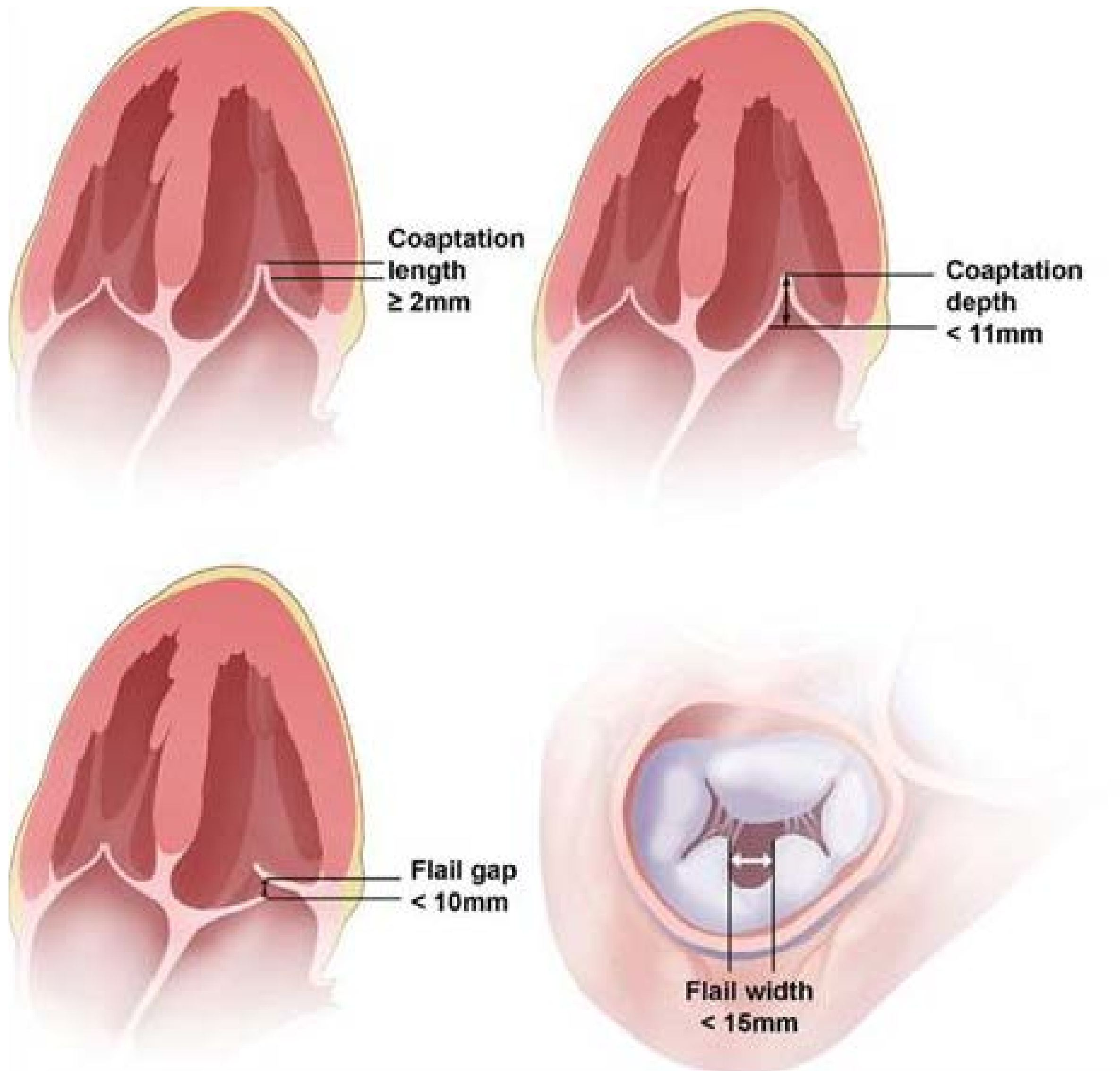
Peak E = 1.6 m/s
Mean Gradient = 4 mm Hg
PHT = 180 ms

Obstructed Prosthesis



Peak E = 8 m/s
Mean Gradient = 23 mm Hg
PHT = 390 ms

Mitral Clip Parameters for Candidacy
EVEREST trial

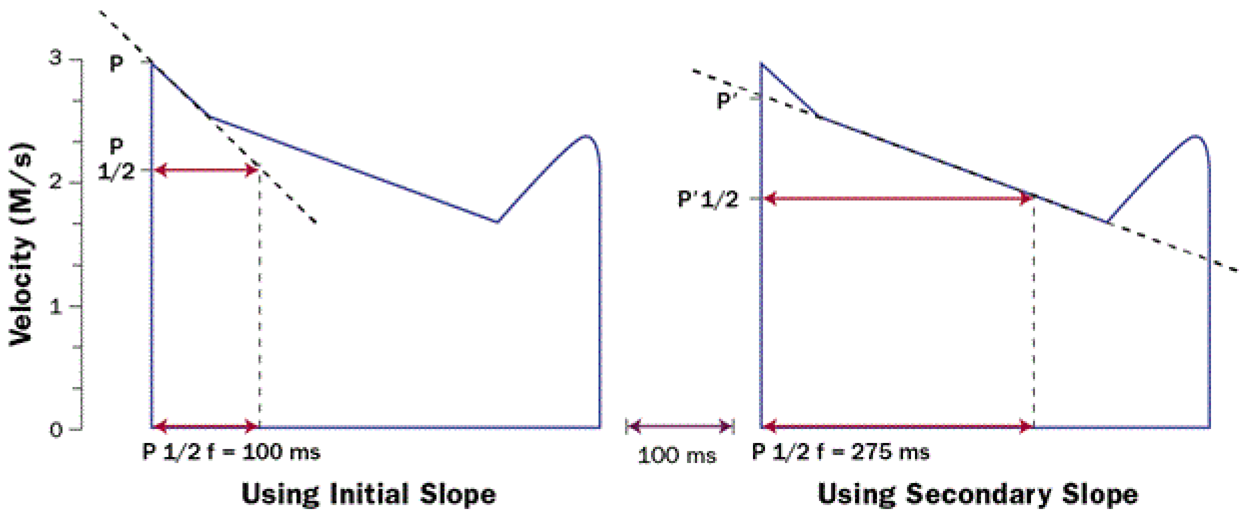


Mitral Stenosis

- MVA (cm^2) = 220/PHT (ms) for rheumatic not calcific
- Continuity equation: MVA = (LVOT area)(LVOT VTI)/MV VTI (but not if > mild AR or > mild MR)
- 3D echo planimetry is more accurate than PHT
- If gradient is borderline significant, obtain exercise Doppler. If mean gradient > 15 mmHg and PA systolic pressure > 60 mmHg, patient candidate for valve surgery. If PA systolic pressure increases but no increase in gradient, suspect pulmonary etiology of dyspnea

Severe Mitral Stenosis

- **Severe rheumatic**: area < 1.5 cm^2 and mean gradient 5 – 10 mmHg
- Very severe rheumatic: area < 1.0 cm^2 and mean gradient > 10 mmHg
- **Severe calcific** and non-rheumatic: area < 1.0 cm^2 and mean gradient > 10 mmHg



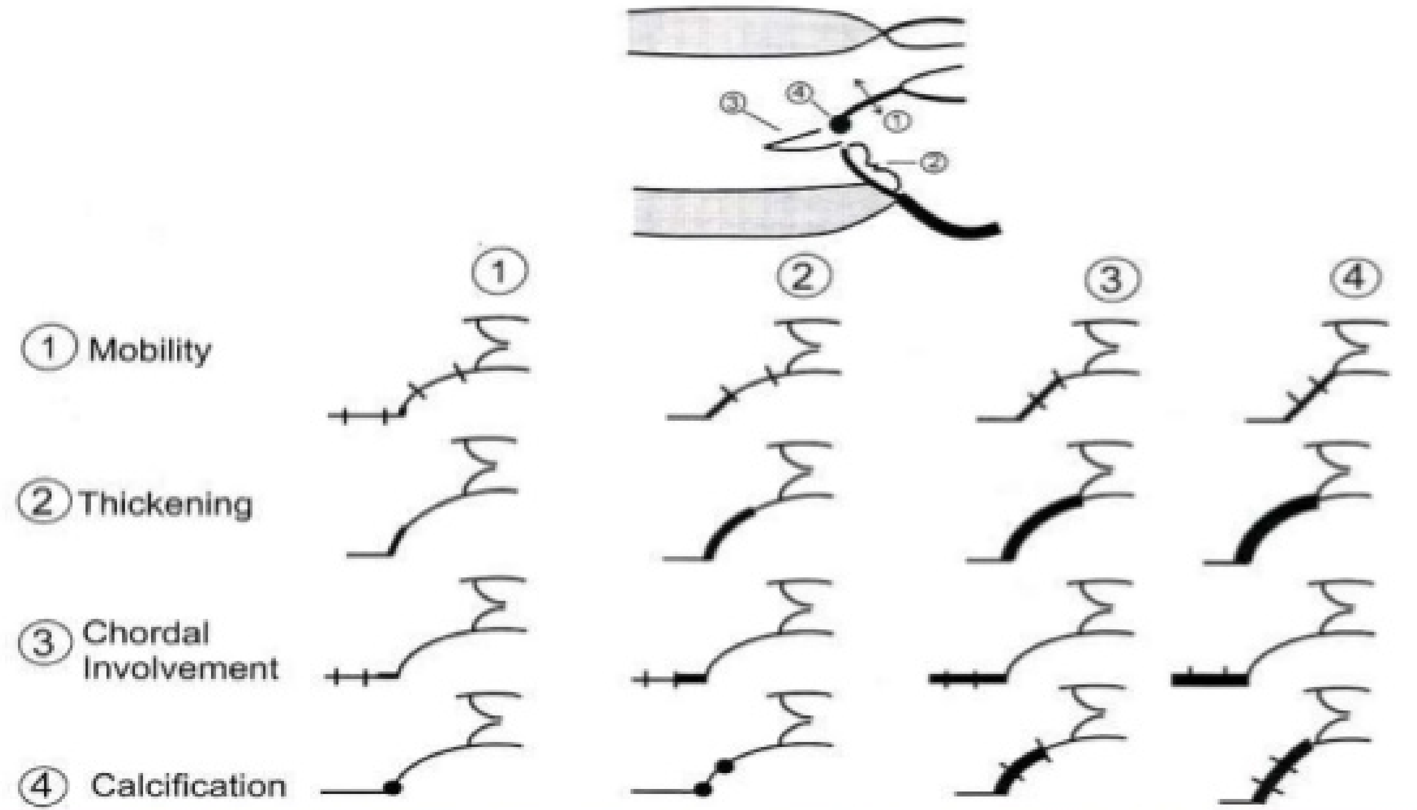
Velocity (M/s)
3
2
1
0
P
P
1/2
P 1/2 f = 100 ms
Using Initial Slope
100 ms
P'
P'1/2
P 1/2 f = 275 ms
Using Secondary Slope

*

Wilson Score: Candidate for PBMV if ≤ 8

Grade	Mobility	Subvalvular Thickening	Leaflet Thickening	Calcification
1	Highly mobile valve with only leaflet tips restricted	Minimal thickening just below the mitral leaflets	Leaflets near normal in thickness (4-5 mm)	A single area of increased echo brightness
2	Leaflet mid and base portions have normal mobility	Thickening of the chordal structures up to one third of the chordal length	Mid leaflets normal, considerable thickening of margins (5-8 mm)	Scattered areas of brightness confined to leaflet margins
3	Valve continues to move forward in diastole, mainly from the base	Thickening extending to the distal third of the chords	Thickening extending through the entire leaflet (5-8 mm)	Brightness extending into the mid-portion of the leaflets
4	No or minimal forward movement of the leaflets in diastole	Extensive thickening and shortening of all chordal structures extending down to the papillary muscles	Considerable thickening of all leaflet tissue (>8-10 mm)	Extensive brightness throughout much of the leaflet tissue

Immediately after PBMV, to assess status, use mean gradient not PHT



Schematic demonstration of the calculation of the mitral stenosis score.

work of Wilkins et al.

Criteria for Severity of Valvular Aortic Stenosis

	Max Aortic Valve Velocity (m/sec)	Mean Gradient (mm Hg)	AVA (cm^2)	AVAI (cm^2/M^2)	Dimensionless Index	Z_{va} (mm Hg mL^{-1} M^2)
Mild	2.0-2.9	<20	≥1.5	≥0.85	≥0.50	<3.5
Moderate	3.0-3.9	20-39	1.0-1.5	0.6-0.85	0.25-0.50	3.5-4.5
Severe	>4.0	≥40	≤1.0	≤0.6	<0.25	≥4.5

Echo may overestimate transaortic valve gradient relative to cardiac cath due to pressure recovery (cath measures downstream pressure more distal to valve)

AS Doppler Caveats

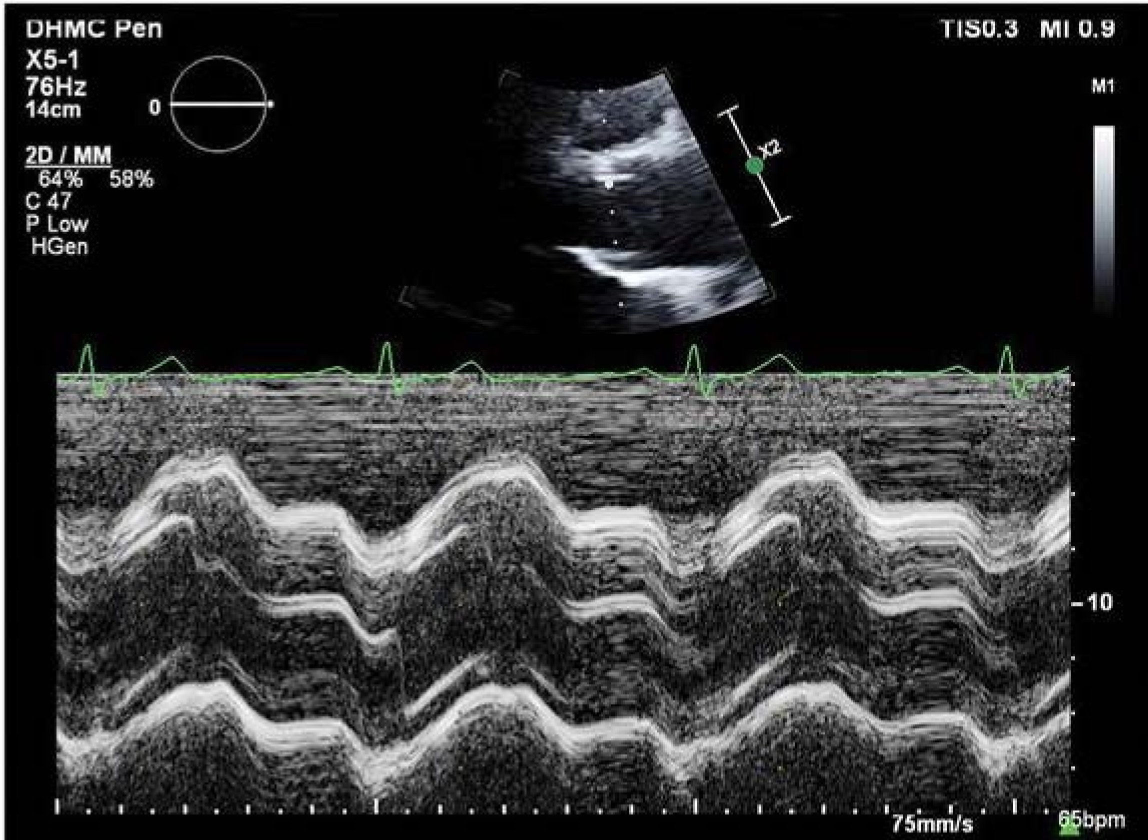
- If LVOT > 1.5 m/sec, $\Delta P = 4 (V2^2 - V1^2)$
- Mean gradient is about 70% of peak

AS: low flow

$$AVA = \frac{CO}{\sqrt{\text{P-P gradient}}}$$

- Low flow, low gradient:
  - Mean gradient < 40 mmHg, LVEF $\leq$ 40-50% and area $\leq$ 1.0 cm^2
  - Low dose DSE: In true AS, mean gradient > 40 vs in pseudo-AS, area > 1.0 cm^2
- Paradoxical low flow, low gradient: Normal LVEF but SV < 35 ml/m^2

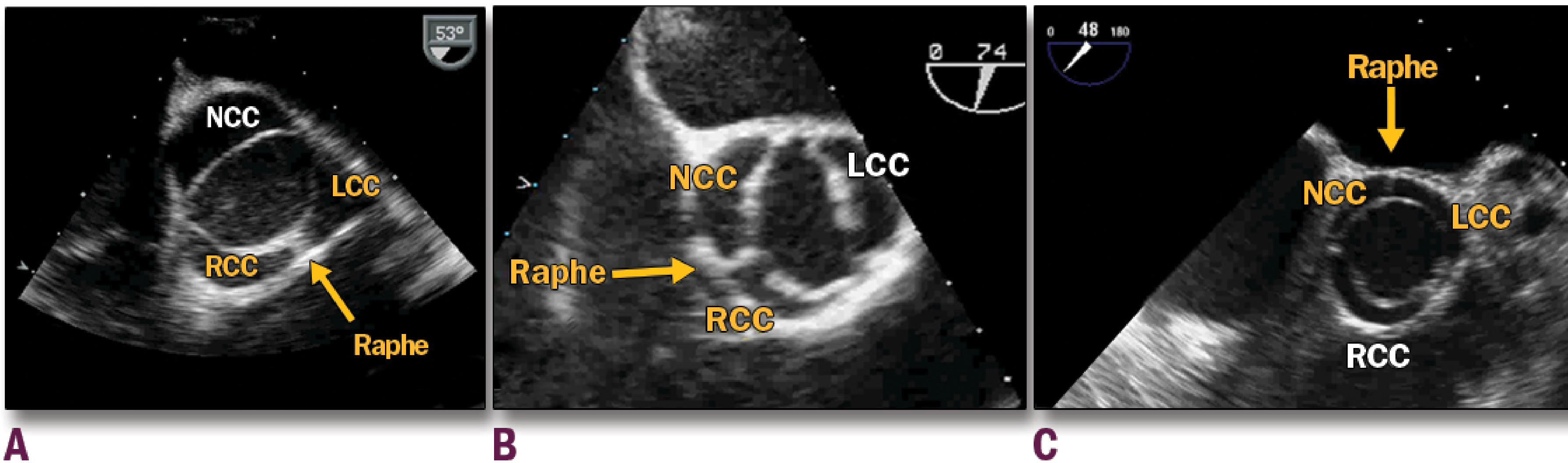
Bicuspid Aortic Valve
Eccentric Closure



- Associated with aortic root dilatation (and coarctation)
- Screen first degree relatives with echo

Bicuspid Aortic Valve

Variants



common

rare

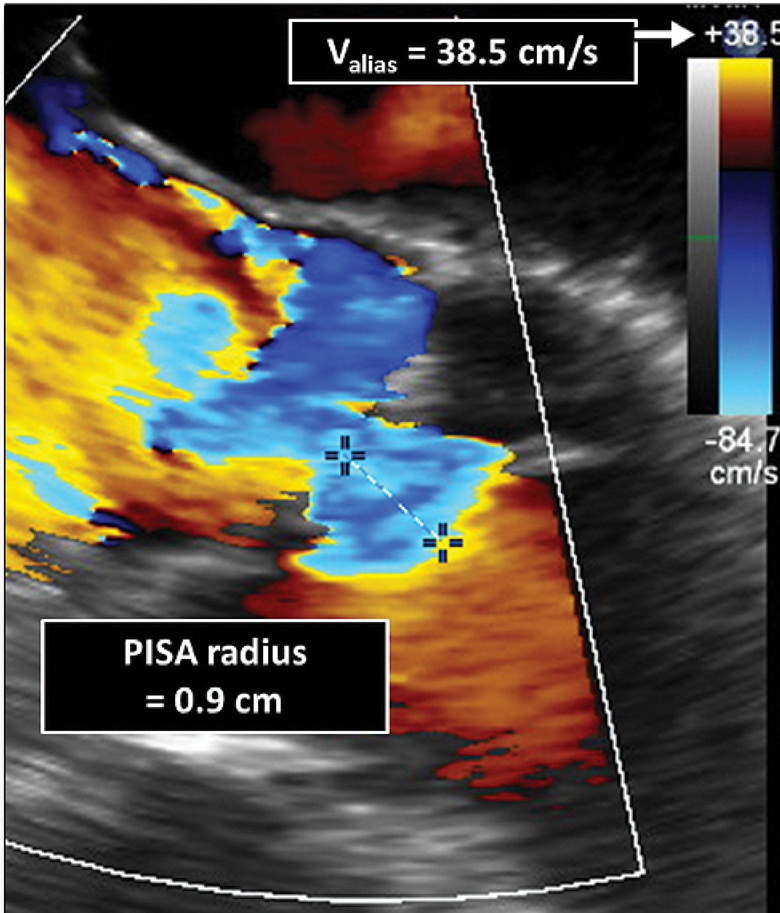
Non Valve Aortic Stenosis

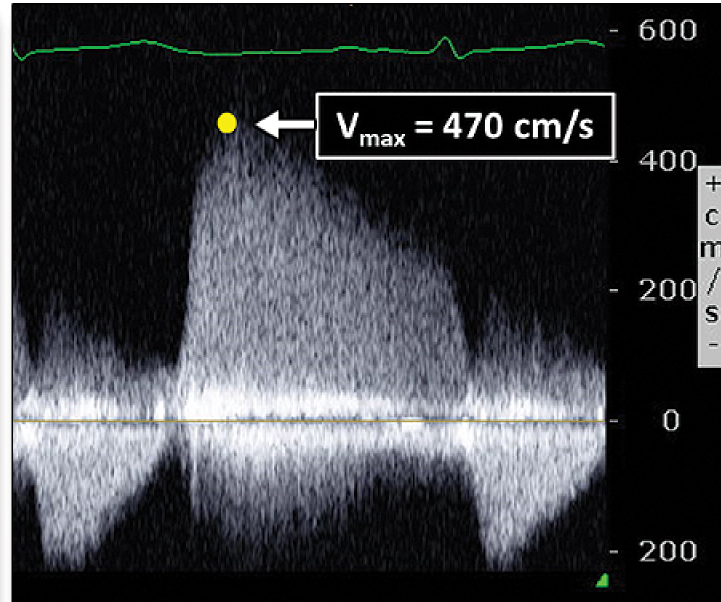
- Supravalvular
  - Obstruction at superior edge of sinuses
  - Associated with peripheral PS and aortopathy
  - **Williams syndrome**: elfin facies, intellectual disability, short stature, strabismus, hypercalcemia
  - Surgery if mean gradient > 50 or peak > 70
- Subaortic membrane
  - Valsalva decreases gradient (vs increases with HOCM SAM)
  - **Shone's complex**: some or all of the following: supravalvular MS, parachute MV, bicuspid AV, coarctation
  - Surgery if mean gradient > 30 or peak > 50

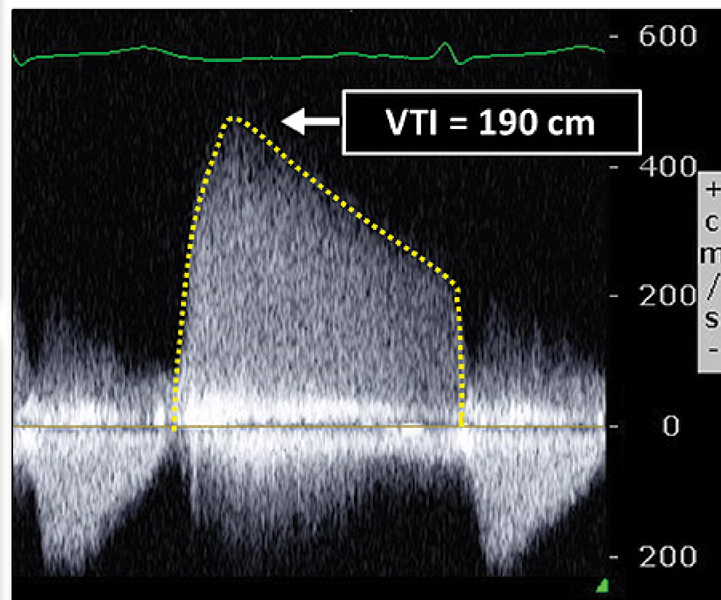
AR Severity Grades

	Mild	Moderate	Severe
Quantitative Parameters			
EROA (cm^2)	<0.10	0.10-0.29	≥0.30
Regurgitant Volume (mL)	<30	30-60	≥60
Regurgitant Fraction (%)	<30	30-50	≥50
Semiquantitative Parameters			
Vena Contracta (cm)	<0.3	0.3-0.6	>0.6
Jet Width Ratio (%)	<25	25-64	≥65
Jet Area/LVOT Area Ratio (%)	<5	5-59	≥60
Qualitative Parameters			
Pressure half-time (ms)	>500	500-200	<200
AR jet density	Faint	Dense	Dense
Visualization of PISA size	None or small	Intermediate	Large
Diastolic flow reversal	Brief early diastolic	Intermediate	Holodiastolic

PISA Method (for EROA and RV)







$EROA = 2\pi r^2 * V_{alias} / V_{max}$

$EROA = 2\ (3.14)\ (0.9)^2 * 38.5 / 470$

$EROA = 0.42\ cm^2$

RegVol = EROA * VTI = 0.42 * 190

RegVol = 79 mL

Stages of Chronic Aortic Regurgitation

Stage		AR Severity	Symptoms	LV Remodeling	LVEF
A		None or trivial	Asymptomatic	None	≥50%
B		Mild or moderate	Asymptomatic	None	≥50%
C	C1	Severe	Asymptomatic	• Mild to moderate LV dilatation (LVESD <50 mm)	≥50%
C	C2	Severe	Asymptomatic	• Severe LV dilatation - $\boxed{\text{LVESD >50 mm,}}$ or - Indexed LVESD >25 mm/m^2, or - LVEDD >65 mm	$\boxed{<50\%*}$
D		Severe	Symptomatic	Absent or Present	Any

Surgery for Asymptomatic, Severe AR

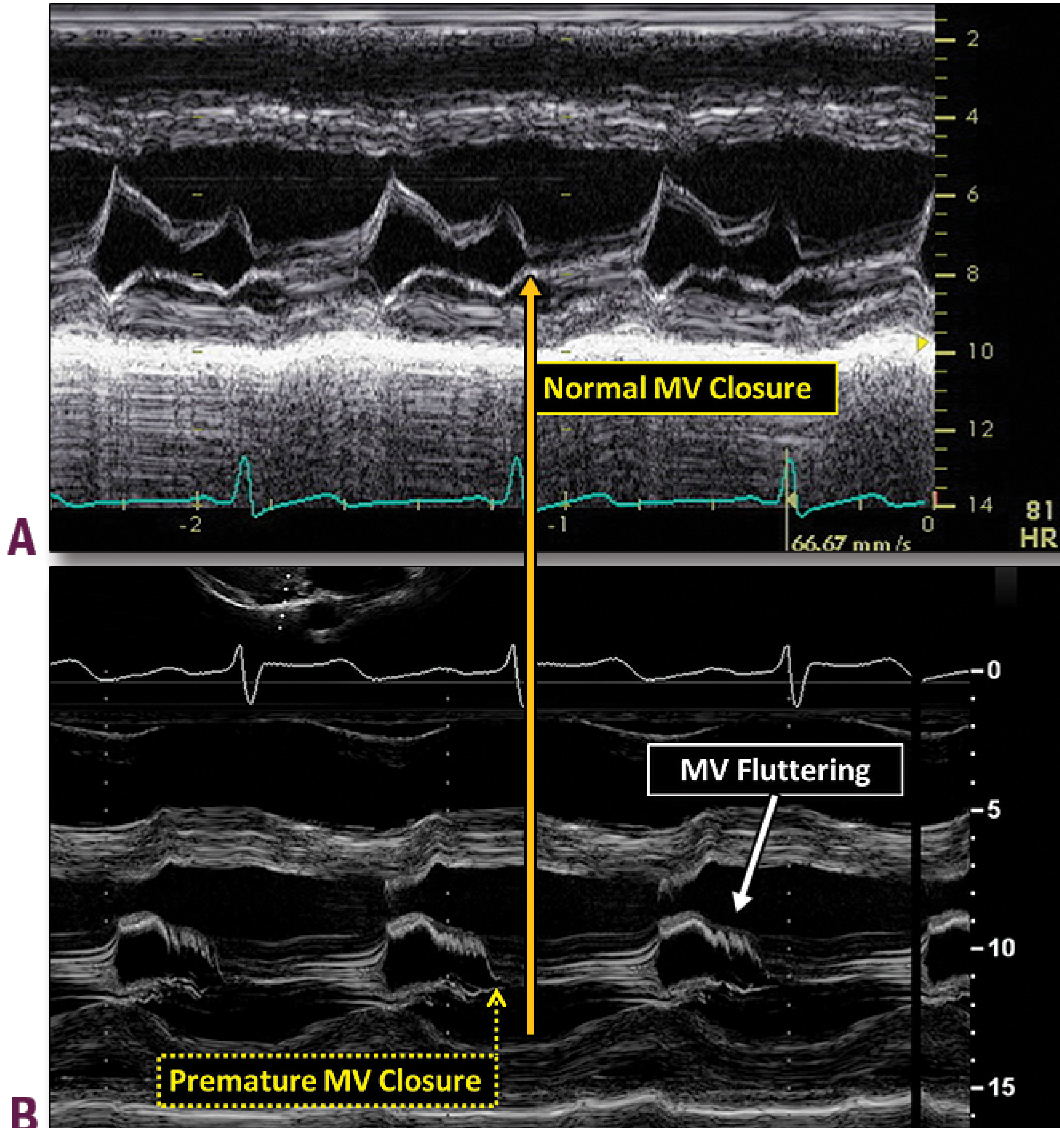
- LVEF < 50% - class I
- LVESD > 5.0 cm (with EF > 50%) – class I
- LVEDD > 6.5 cm (with EF > 50%) – class IIa

Surveillance Echo in AR

- Mild: every 3 – 5 years
- Moderate: every 1 -2 years
- Severe: every 6 – 12 months

Acute AR

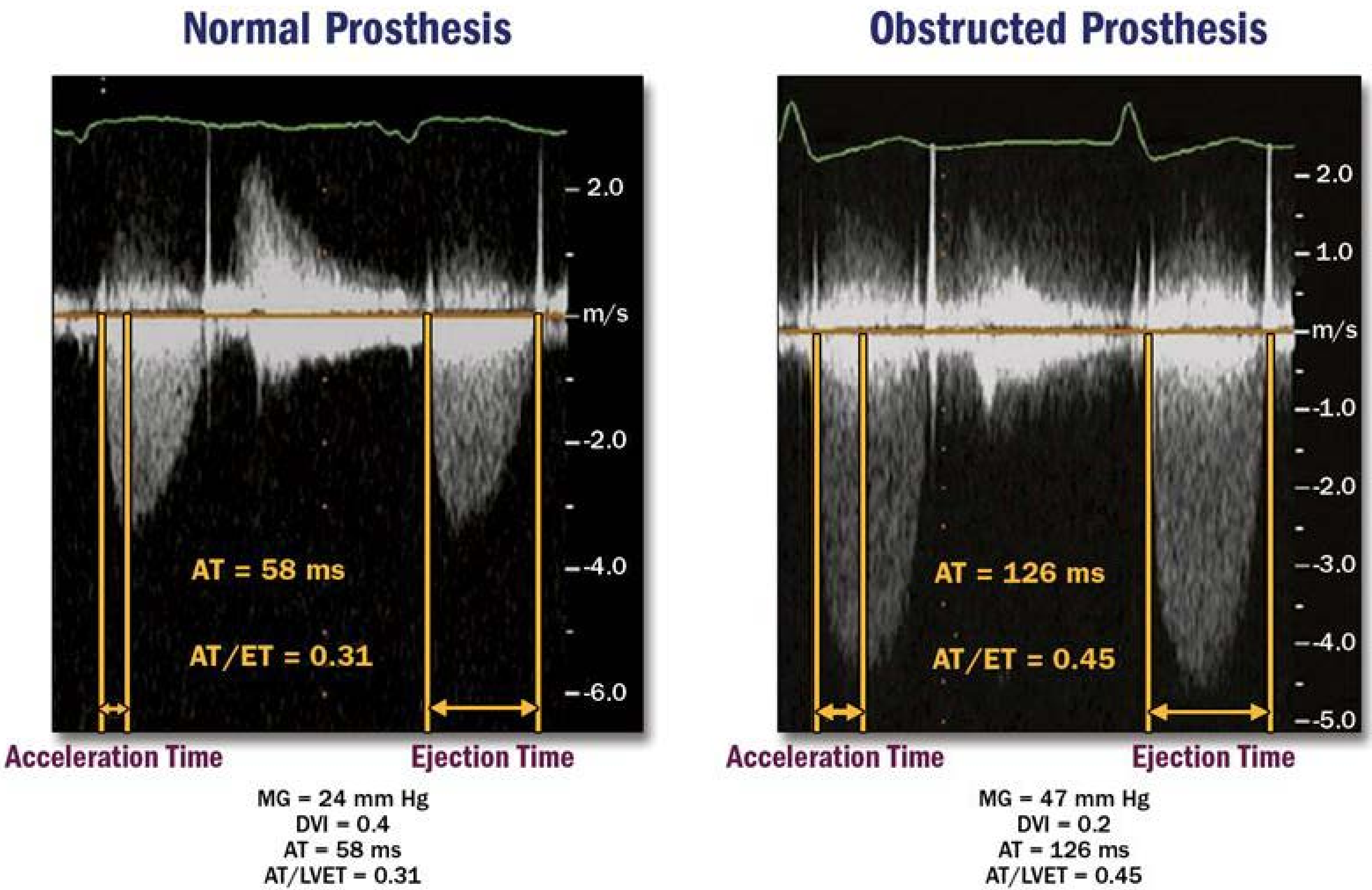
M-Mode – Early Mitral Valve Closure and Mitral Leaflet Fluttering



Acute vs. Chronic AR

	Acute AR	Chronic AR
Aortic Valve Complex Common Etiologies	Endocarditis Type A dissection	Degenerative AV disease Aortic aneurysm
Left Ventricle LV size Stroke volume	 Normal to slightly enlarged Normal to slightly increased	 Severely enlarged Greatly increased
Blood Pressure Systolic pressure Diastolic pressure Pulse pressure	 Normal or slightly decreased Normal or slightly decreased Normal or slightly increased	 Increased Decreased Increased

Normal and Obstructed AVR



Proposed Criteria for Grading Paravalvular Aortic Regurgitation (1 of 2)

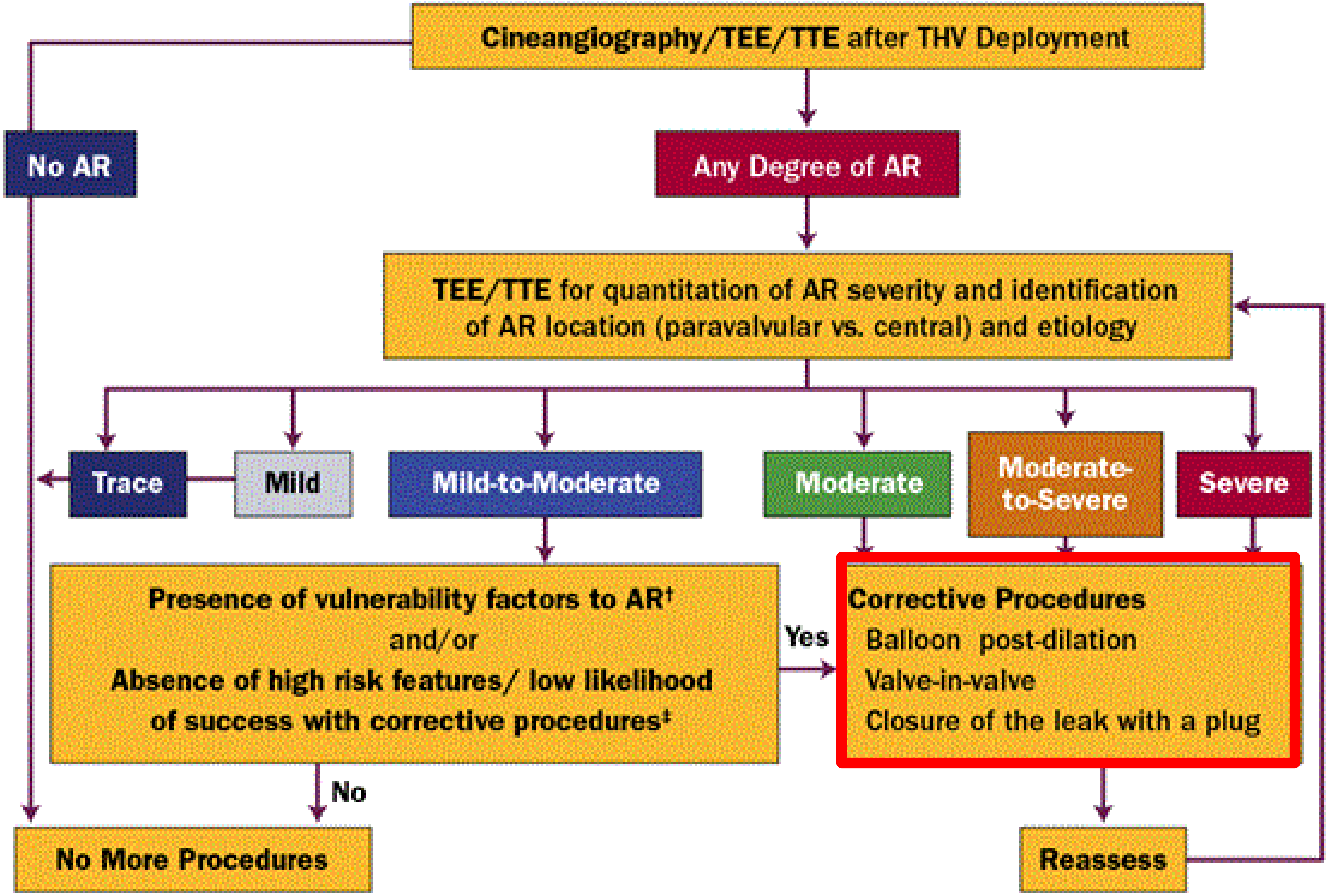
3-Class Grading Scheme	Trace	Mild	Mild	Moderate	Moderate	Severe
4-Class Grading Scheme	1	1	2	2	3	4
Unifying 5-Class Grading Scheme	Trace	Mild	Mild-to-Moderate	Moderate	Moderate-to-Severe	Severe
Cineangiography	Grade 1	Grade 1	Grade 1	Grade 2	Grade 3	Grade 4
Invasive hemodynamics						
Aortic regurgitation index*	>25	>25	>25	10–25	10–25	<10
Doppler echocardiography						
Structural parameters						
• Valve stent	Usually normal	Usually normal	Normal/abnormal†	Normal/abnormal†	Usually abnormal†	Usually abnormal†
◦ LV size‡	Normal	Normal	Normal	Normal/mildly dilated	Mildly/moderately dilated	Moderately/severely dilated
Doppler parameters (qualitative or semiquantitative)						
• Jet features§						
Extensive/wide jet origin	Absent	Absent	Absent	Present	Present	Present
Multiple jets	Possible	Possible	Often present	Often present	Usually present	Usually present
Jet path visible along the stent	Absent	Absent	Possible	Often present	Usually present	Present
Proximal flow convergence visible	Absent	Absent	Absent	Possible	Often present	Often present
◦ Vena contracta width (mm): color Doppler¶	<2	<2	2–4	4–5	5–6	>6
◦ Vena contracta area (mm2): 2D/3D color Doppler¶	<5	5–10	10–20	20–30	30–40	>40

Proposed Criteria for Grading Paravalvular Aortic Regurgitation (2 of 2)

3-Class Grading Scheme	Trace	Mild	Mild	Moderate	Moderate	Severe
4-Class Grading Scheme	1	1	2	2	3	4
Unifying 5-Class Grading Scheme	Trace	Mild	Mild-to-Moderate	Moderate	Moderate-to-Severe	Severe
* Jet width at its origin (% LVOT diameter): color Doppler‖	Narrow (<5)	Narrow (5–15)	Intermediate (15–30)	Intermediate (30–45)	Large (45–60)	Large (>60)
° Jet density: CW Doppler	Incomplete or faint	Incomplete or faint	Variable	Dense	Dense	Dense
° Jet deceleration rate (PHT, ms): CW Doppler*‡	Slow (>500)	Slow (>500)	Slow (>500)	Variable (200–500)	Variable (200–500)	Steep (<200)
° Diastolic flow reversal in the descending aorta: PW Doppler*‡	Absent	Absent or brief early diastolic	Intermediate	Intermediate	Holodiastolic (end-diast. vel. >20 cm/s)	Holodiastolic (end-diast. vel. >25 cm/s)
* Circumferential extent of PVR (%): color Doppler‖	<10	<10	10–20	20–30	>30	>30
Doppler parameters (quantitative)						
° Regurgitant volume (ml/beat)#	<15	<15	15–30	30–45	45–60	>60
° Regurgitant fraction (%)	<15	<15	15–30	30–40	40–50	>50
° Effective regurgitant orifice area (mm^2)**	<5	<5	5–10	10–20	20–30	>30
Cardiac magnetic resonance imaging						
Regurgitant fraction (%)††	<10 <15	<10 <15	10–20 15–25	20–30 15–25	20–30 25–50	>30 >50

Corrective Procedures for TAVR and AR

if more than mild AR

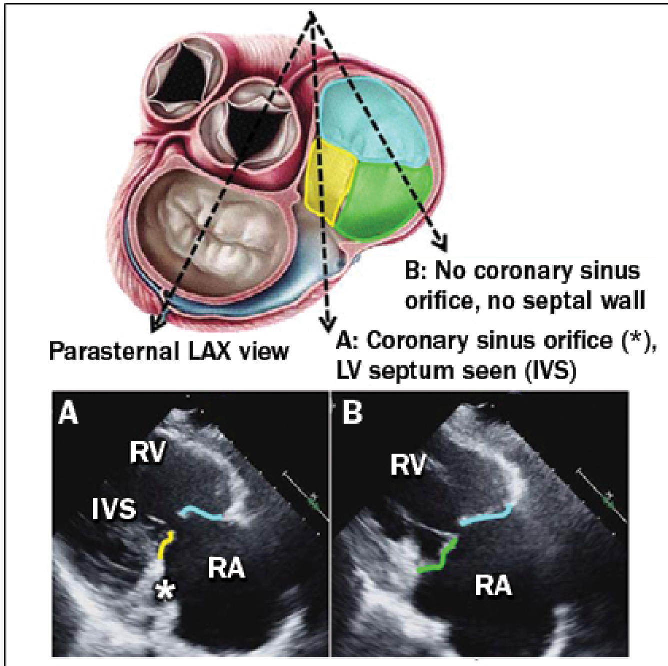


Parasternal Right Ventricle Inflow, Apical Four-Chamber, and Parasternal Short Axis Views (Tricuspid Valve)

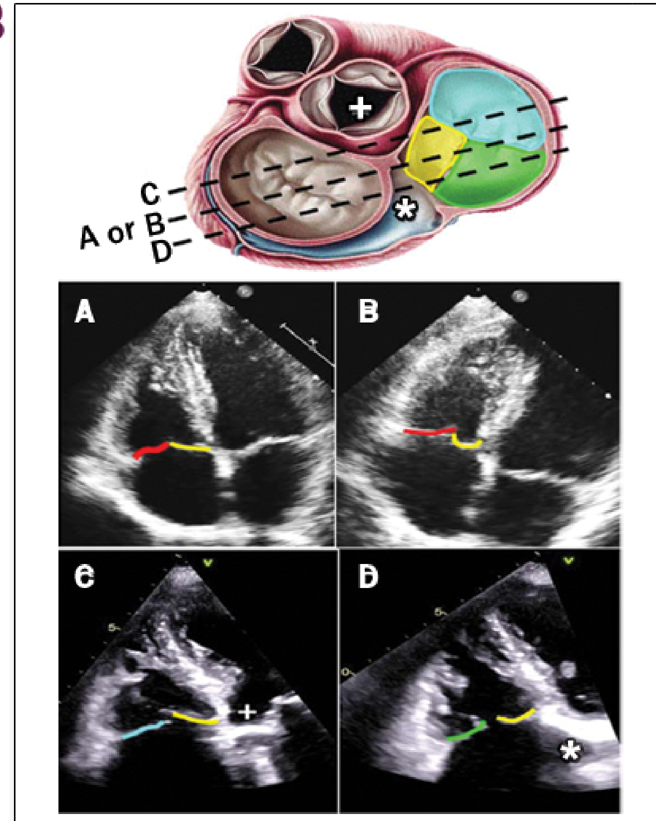
Anterior: blue (near field)
Septal: yellow
Posterior: green

Near field: Anterior
Far field: Septal or Posterior

A



B

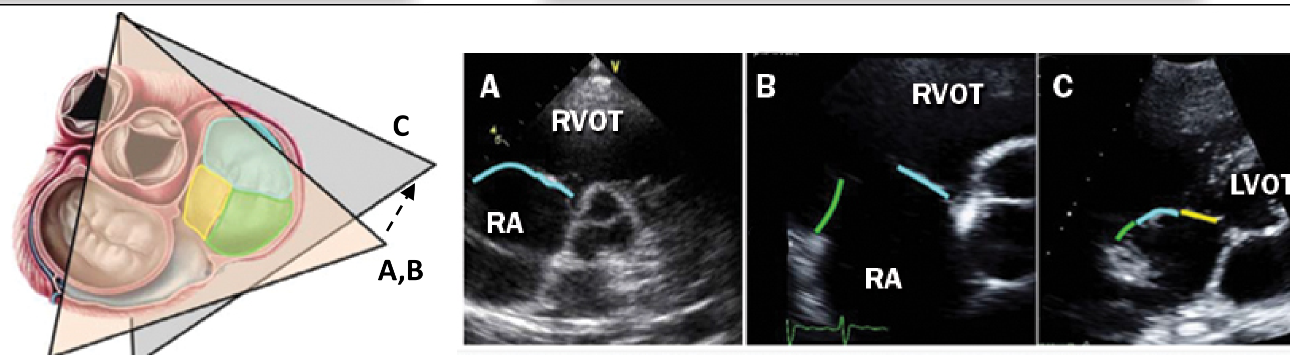


Red is anterior/ posterior overlap

C

A and B: SAX view at the level of AV will typically image just the anterior leaflet (A) however anterior and posterior leaflets may be seen (B)

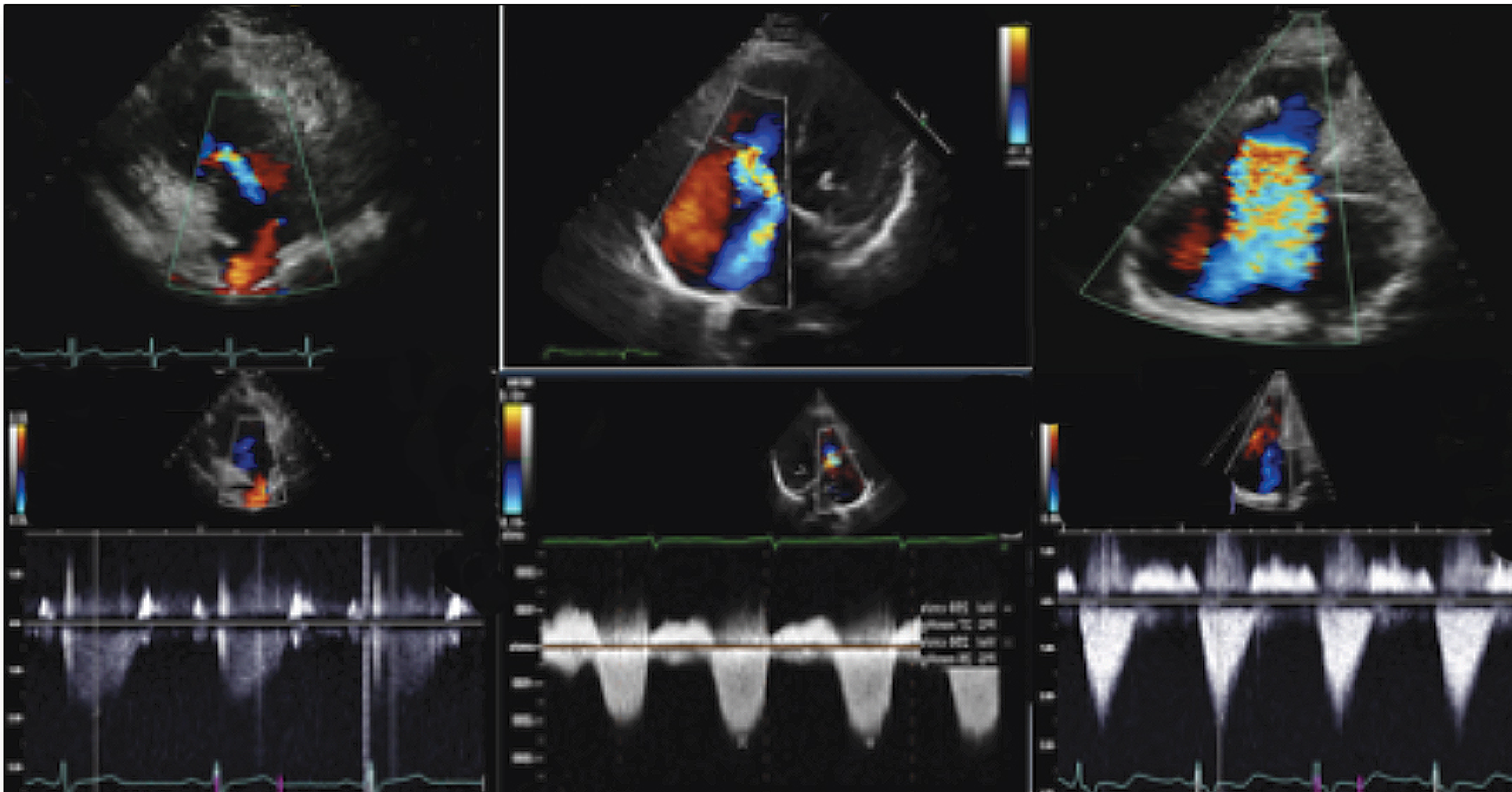
C: SAX at level of LV outflow tract (below AV) with imaging of the septal leaflet



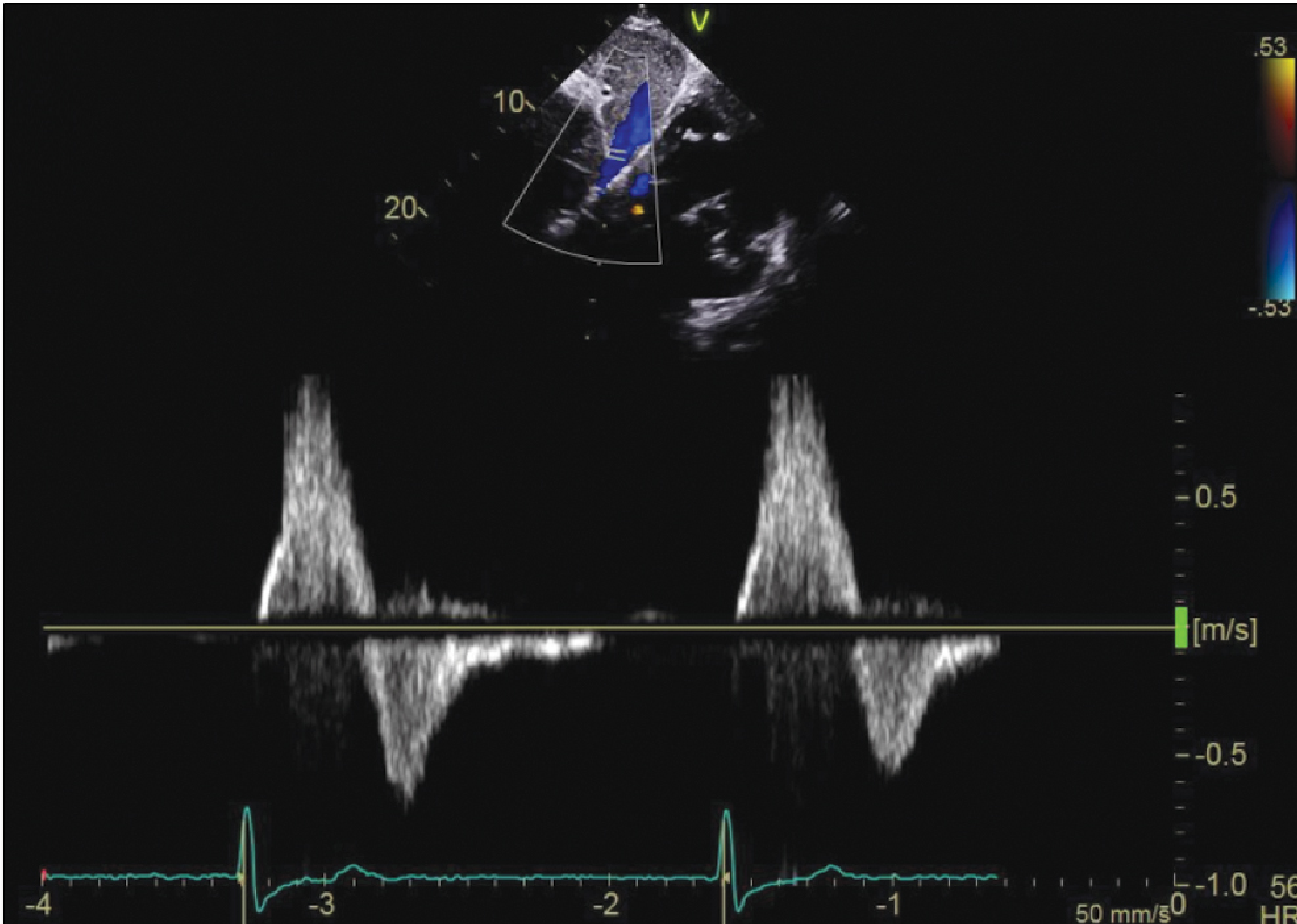
Tricuspid Stenosis/Regurgitation

- TS
  - 90% is rheumatic
  - Severe TS: Mean gradient $\geq$ 5 mmHg or area < 1.0 cm^2
- TR
  - 80% due to annular dilatation
  - Severe TR: jet area > 10 cm2or > 50% of RA; vena contracta 0.7 cm; hepatic vein systolic flow reversal

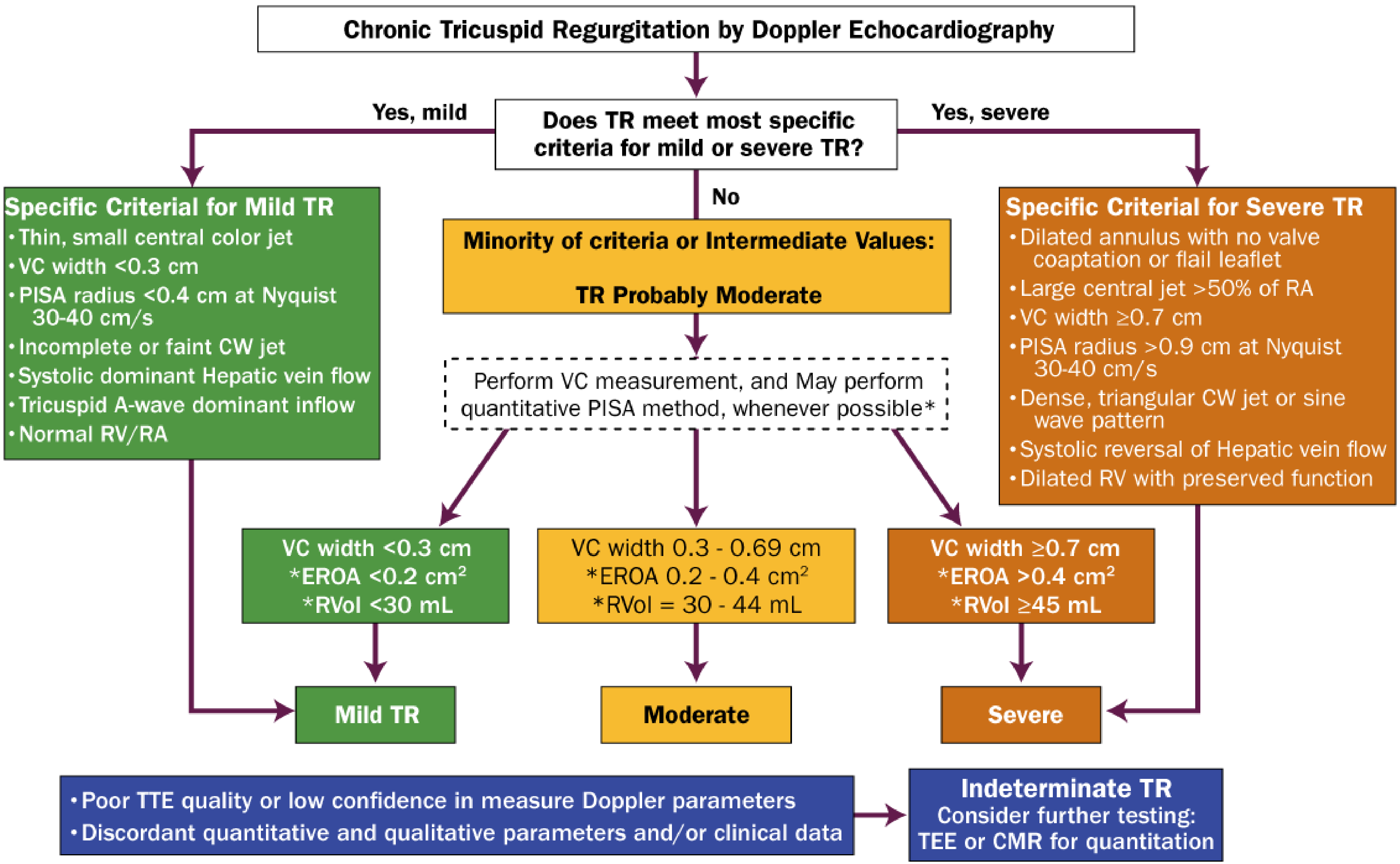
Mild, Severe Eccentric, and Severe Central Tricuspid Regurgitation



Pattern of Systolic Flow Reversal Seen on Pulsed Wave Doppler of the Hepatic Vein, Associated With Severe Tricuspid Regurgitation



Approach to Assessment of Tricuspid Regurgitation Severity by Echocardiography



*Clinical experience in quantitation or TR is much less than that with mitral and aortic regurgitation

Pulmonic Stenosis

	Mild	Moderate	Severe
Peak velocity (m/s)	<3	3-4	>4
Peak gradient (mm Hg)	<36	36-64	>64

Noonan Syndrome: PS due to dysplastic valve (doesn’t respond well to balloon valvuloplasty)

Surveillance Echo Doppler for PS and Indications for Balloon Valvuloplasty

- Peak < 30 mmHg: every 5 years
- Indications for balloon valvuloplasty (unless $\geq$ moderate PR)
  - Peak > 60 or mean > 40 and asymptomatic
  - Peak > 50 or mean > 30 and symptomatic

Echo Board Review

- Chamber Dimensions, Systolic and Regional Function
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- Congenital
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- Physics

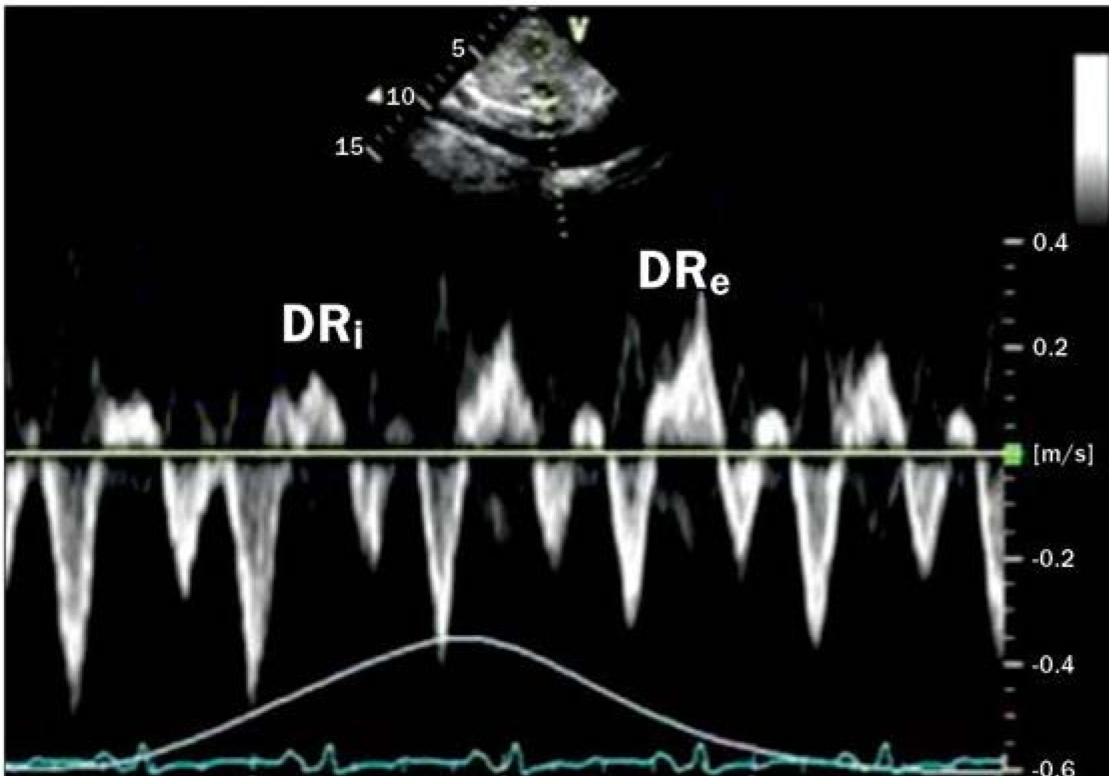
Tamponade

- RV diastolic collapse is specific for tamponade (90%) vs RA collapse (66% specific)
- Excessive respiratory variation (mitral > 30%, tricuspid > 60%)
- Hepatic vein Doppler in tamponade: flow occurs only in systole and may be observed only during inspiration.

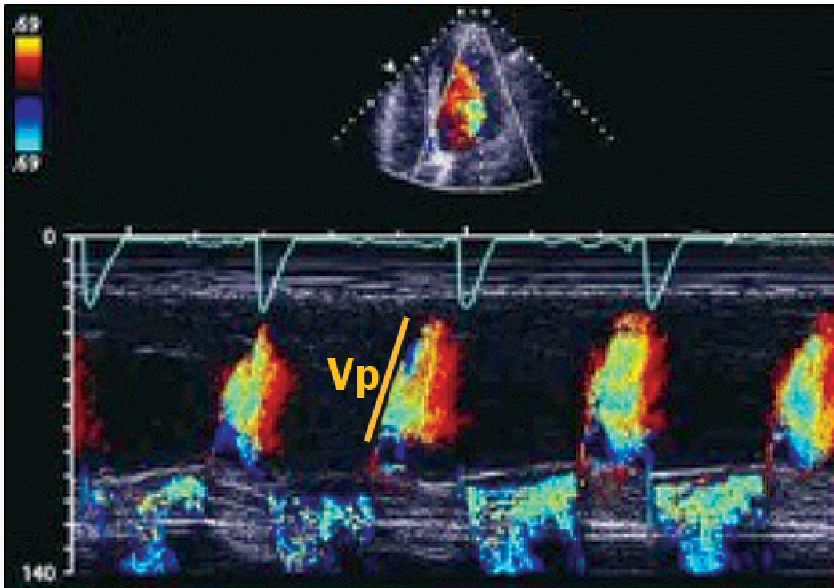
Constrictive Pericarditis

- Mitral E decel time < 150 msec
- Mitral respiratory variation > 25%
- Tricuspid respiratory variation > 40%
- IVC plethora
- Septal “bounce”
- Annulus reversus (mitral e’ > lateral e’ due to restraint)
- Annulus paradoxus (medial e’ increases and E/e’ decreases paradoxically)
- Hepatic vein Doppler: Diastolic flow reversal with expiration (with inspiration in restriction)
- Color m-mode velocity propagation > 100 cm/sec.

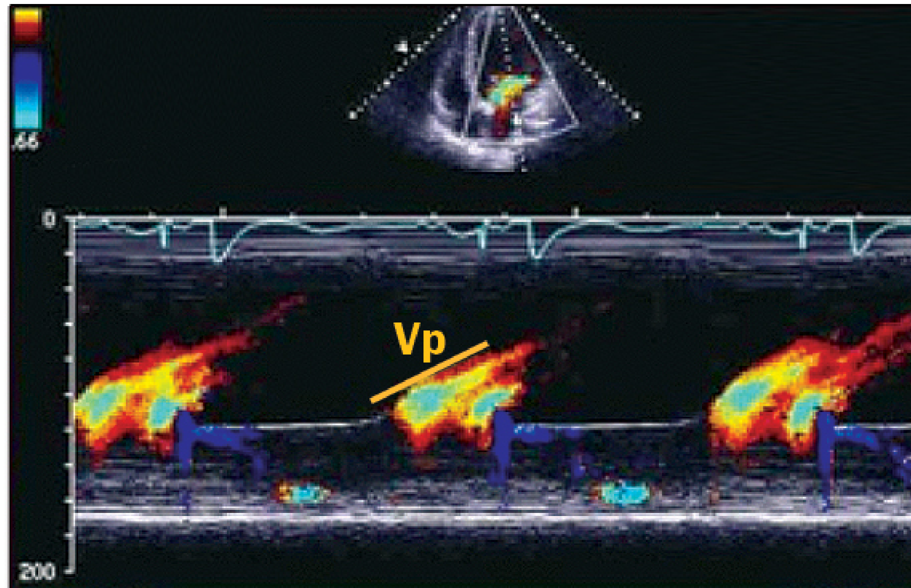
Hepatic vein Doppler:
Diastolic flow reversal with expiration in constriction



Color M-mode in the Assessment of Diastolic Function



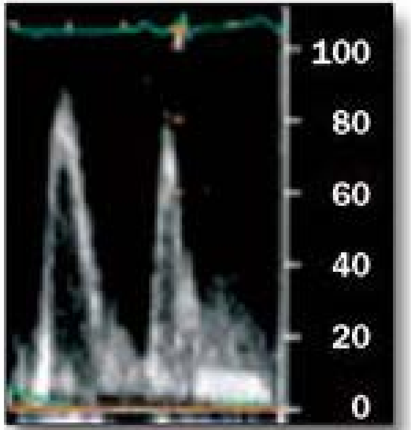
Normal ventricular diastolic function
with vertical (rapid) Vp slope

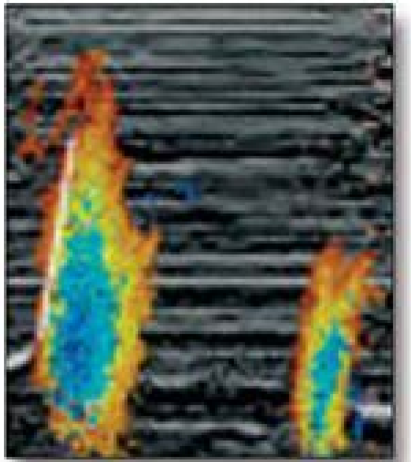


Severe diastolic dysfunction
with nearly flat (delayed) Vp slope

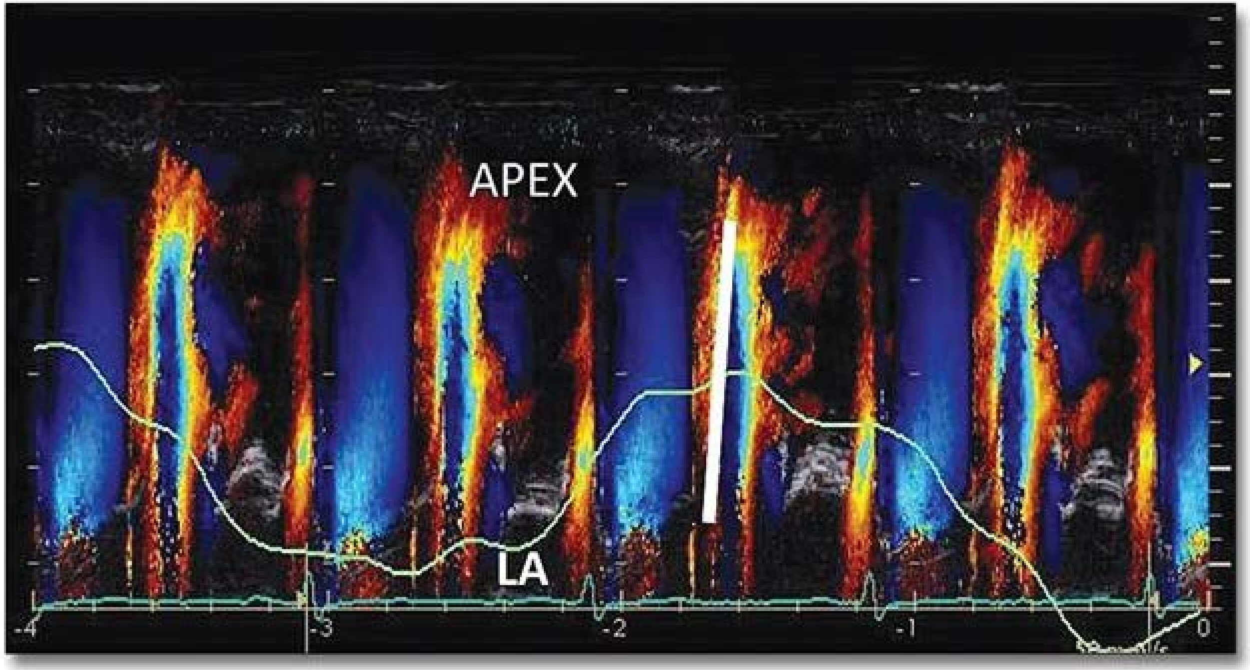
Constriction
Measure slope at aliasing velocity

Normal



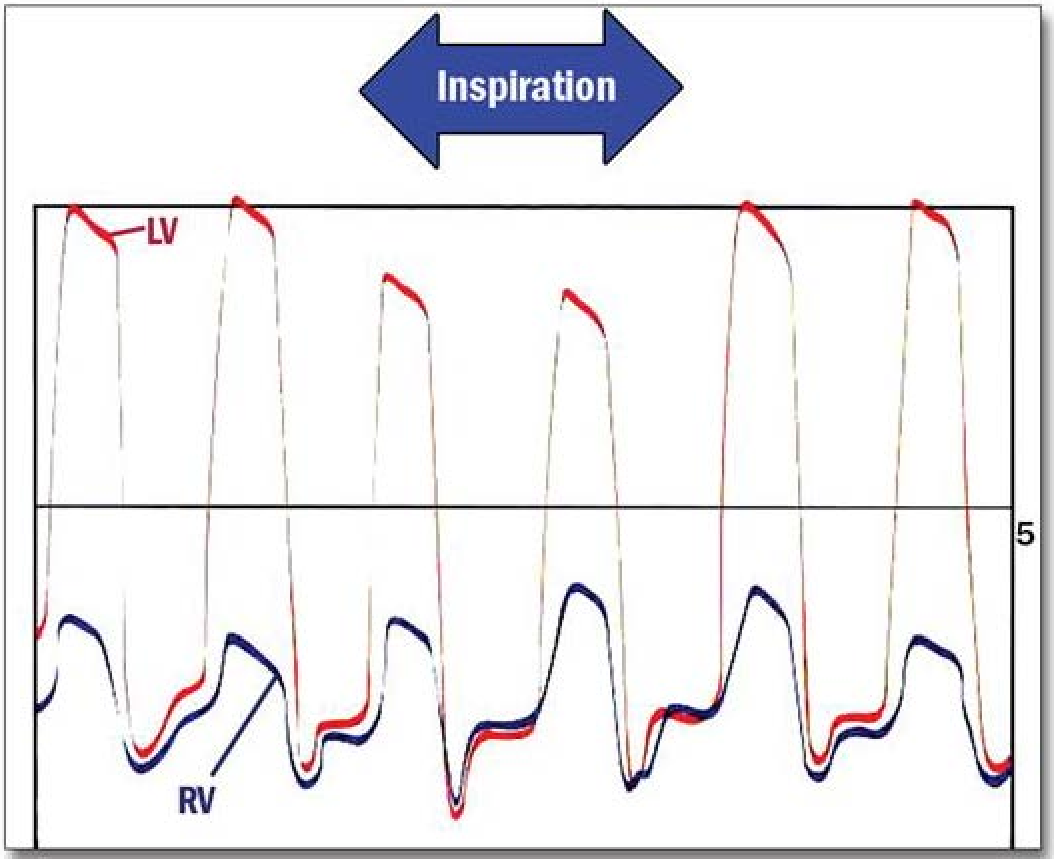


Constriction



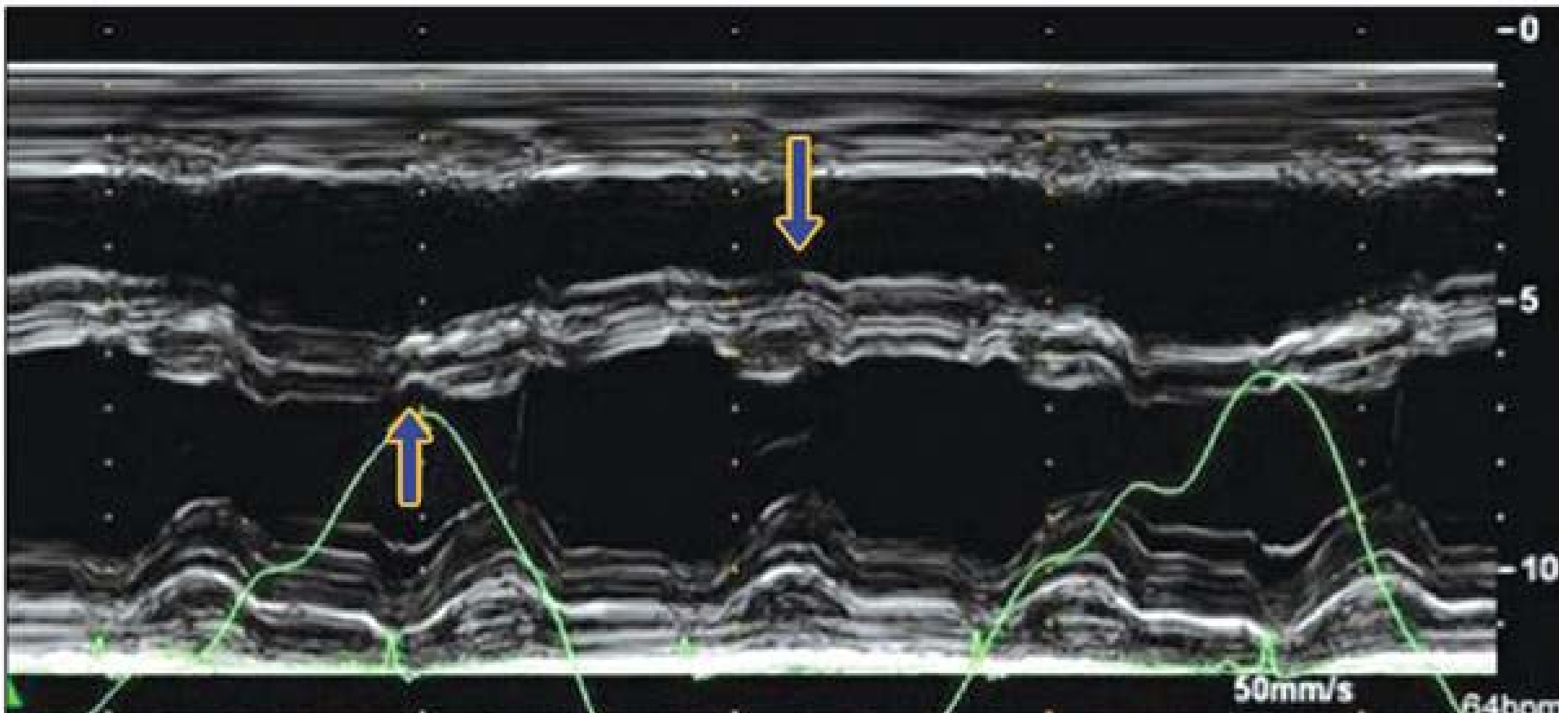
Color m-mode velocity propagation > 100 cm/sec

Effusive-Constrictive Pericarditis
LV and RV pressure after pericardiocentesis

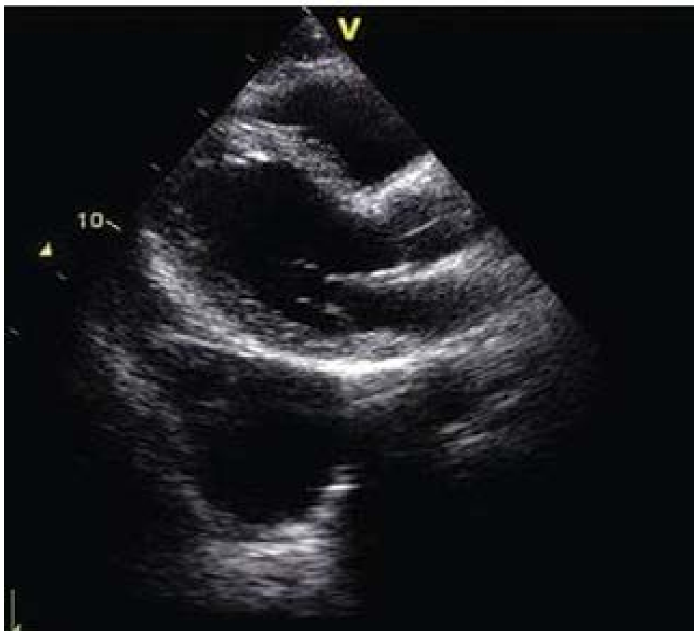


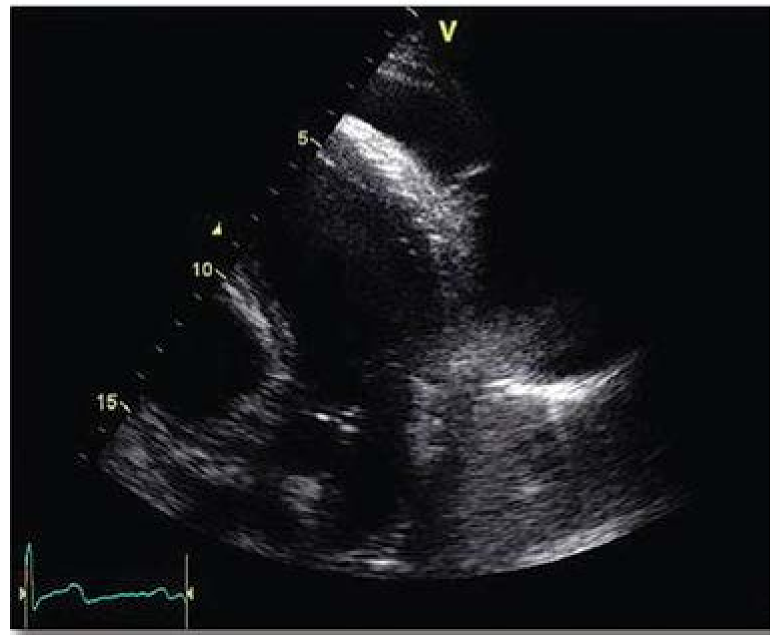
Square root sign: rapid ventricular filling due to high atrial pressure and sudden rise in diastolic pressure as LV is constrained by abnormal pericardium

Effusive-Constrictive
M-mode after Pericardiocentesis



Pericardial Cyst
(usually found incidentally)





Echo Board Review

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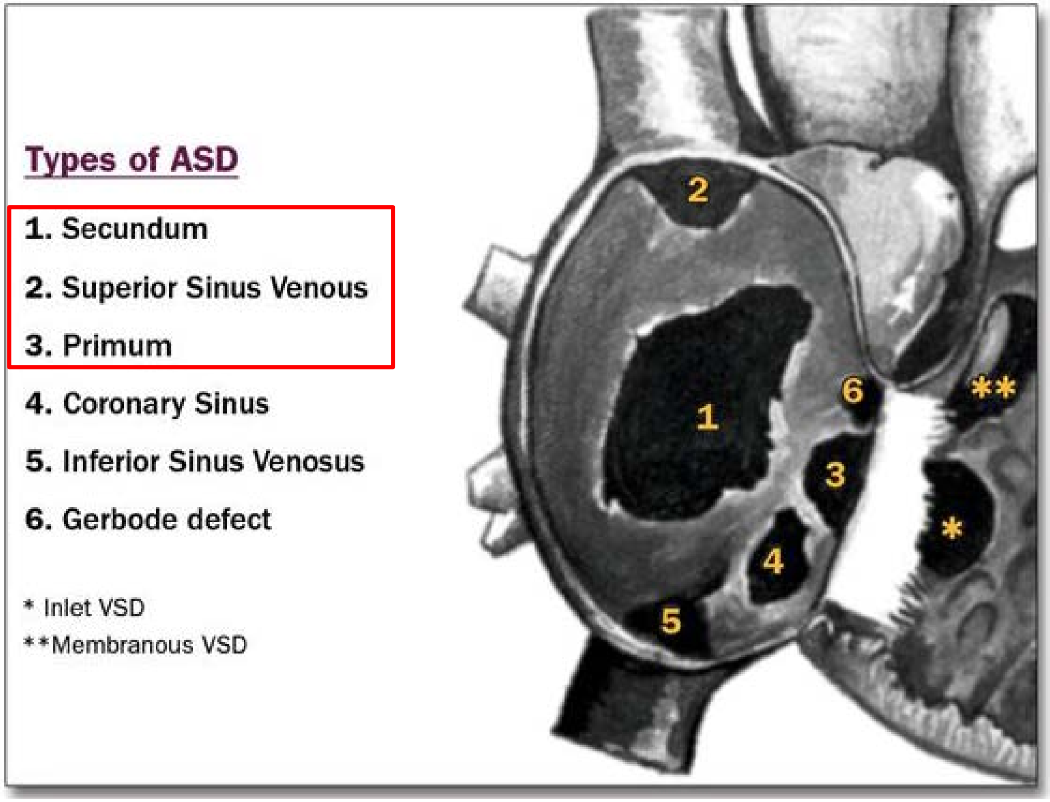
Coarctation of the Aorta

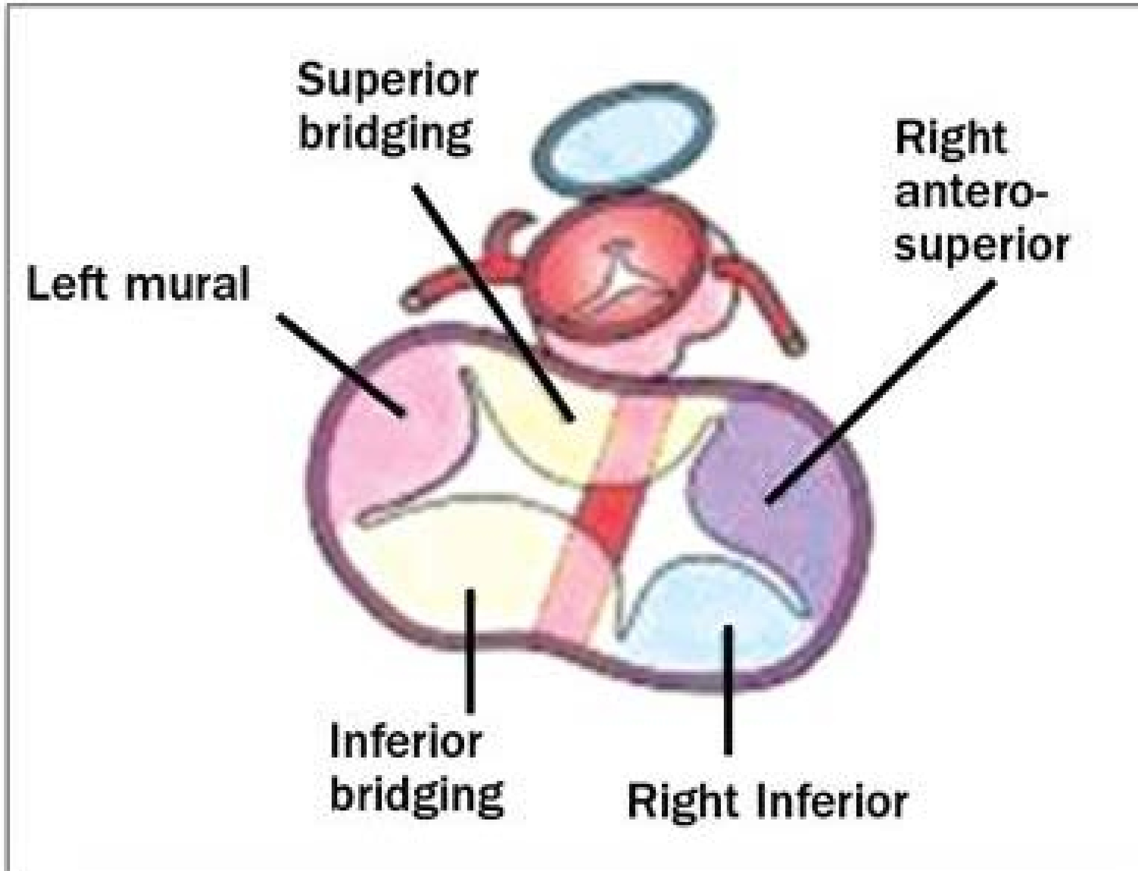
- Location: just distal to left subclavian artery
- Intervention if peak-peak gradient $\geq$ 20 mmHg

ASD



- Indication for closure: Qp/Qs $\geq$ 1.5 and signs of RV volume overload
- Sinus venosus ASD often involve partial anomalous venous return
- If symptoms persist after secundum ASD closure, check CT since 10-15% have partial anomalous venous return
- ASD > 38 mm should be treated surgically

Cleft Mitral Valve

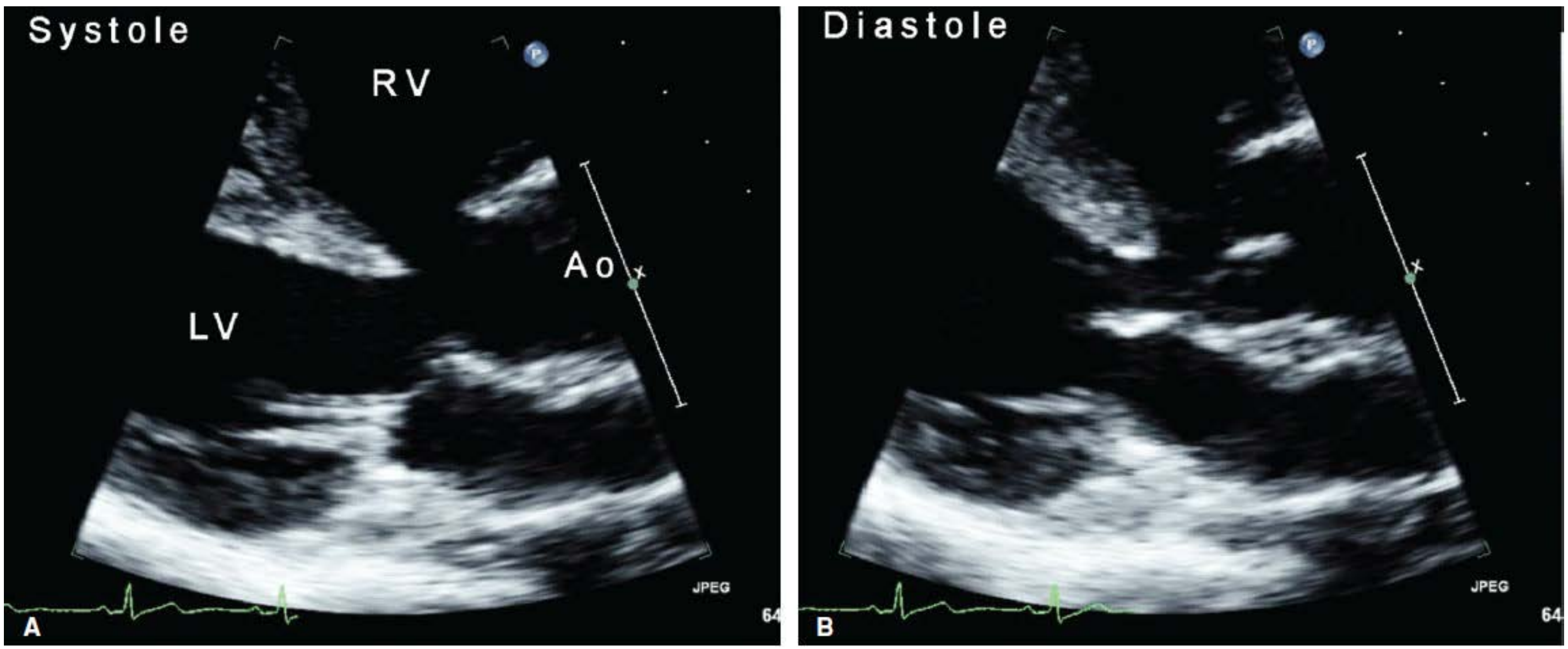


VSD

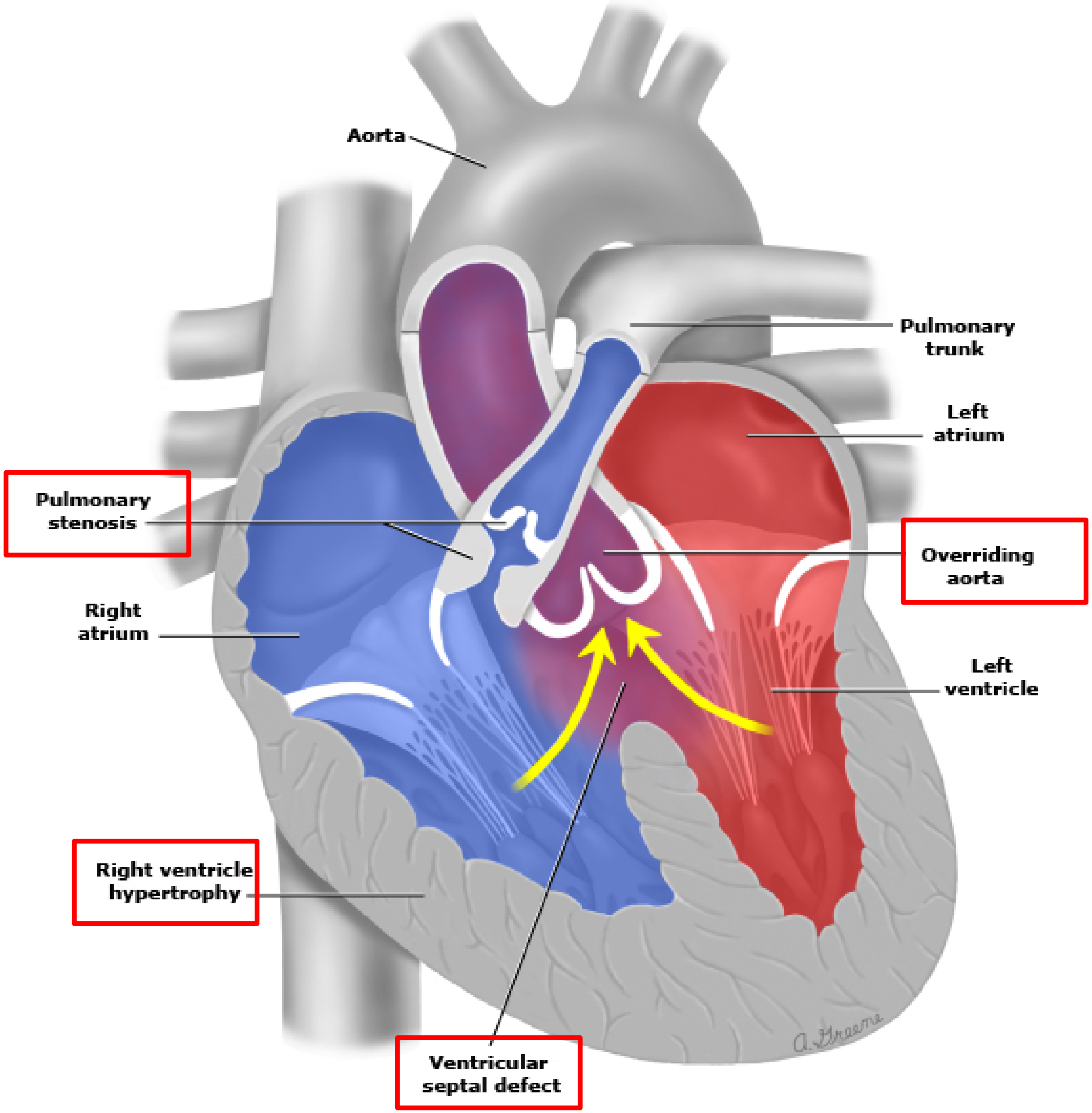
- Perimembranous: Parasternal SAX since Doppler can be parallel to flow
- Inferior muscular: subcostal
- Calculate RV/PA systolic pressure with restrictive VSD (smaller defects with high velocity flow). If no LVOT obstruction:

RVSP = Systemic BP - (LV-RV peak gradient)

Patient with murmur:
Velocity across pulmonic valve is 3 m/sec
What is diagnosis?



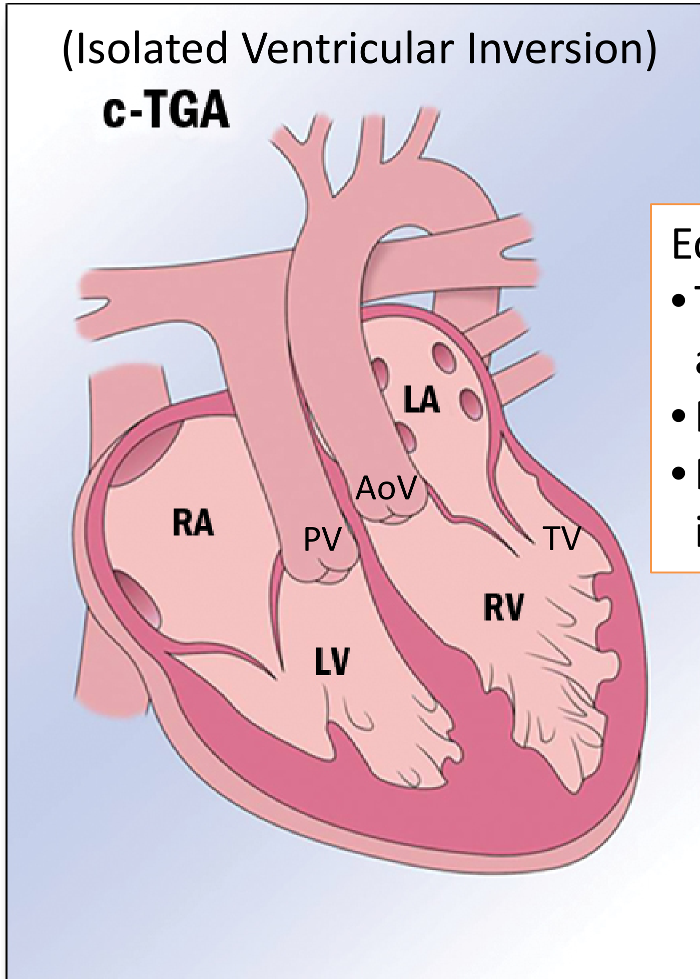
Tetralogy of Fallot



Patent Ductus Arteriosus
(Aorta to PA shunt)

- Creates volume load on LV
- LVE and LAE are class I indications to close PDA

Diagrammatic Representation of the Most Common Form of Physiologically Corrected Transposition of the Great Arteries (cTGA)

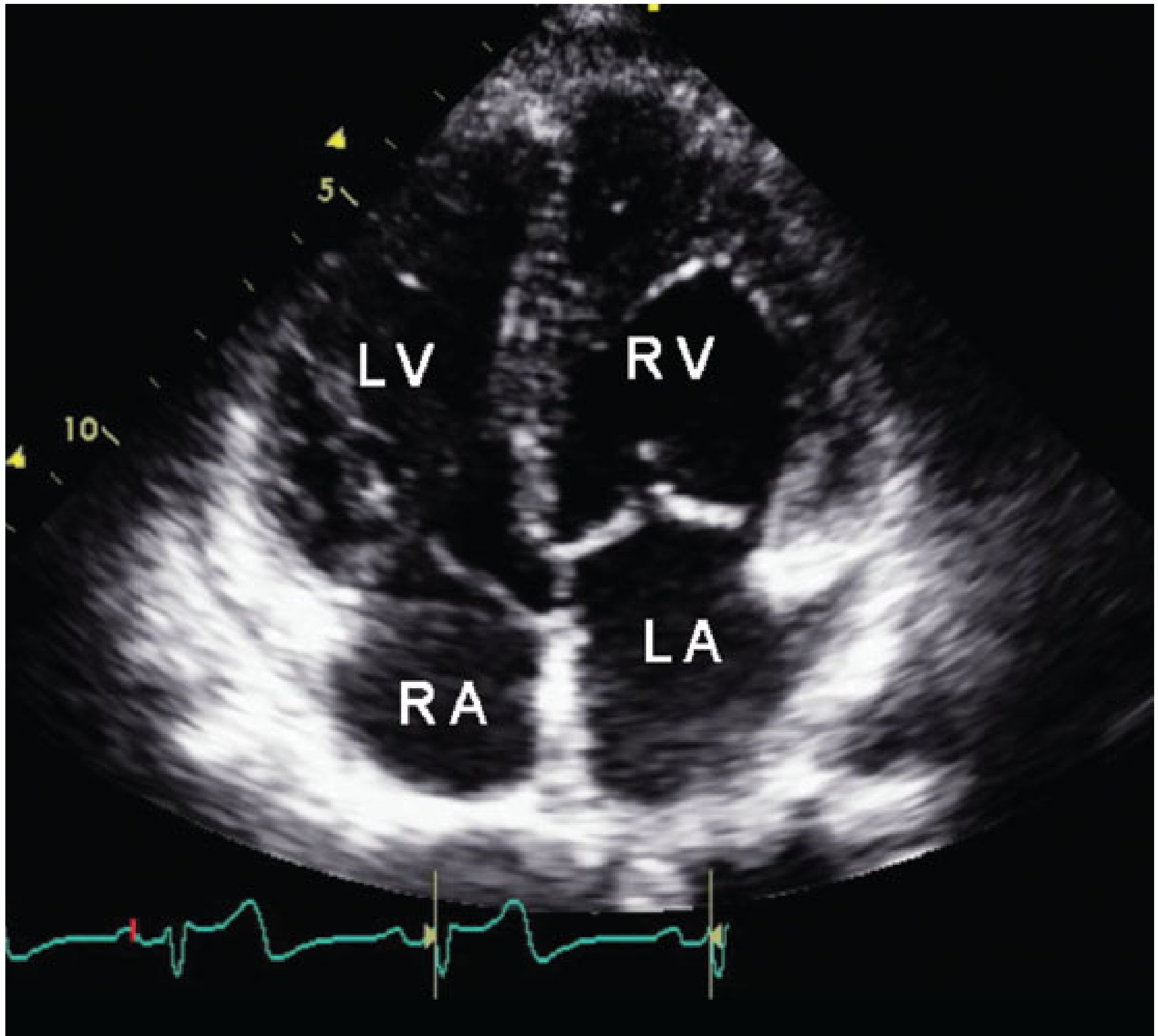


L-Transposition

Echo Diagnosis

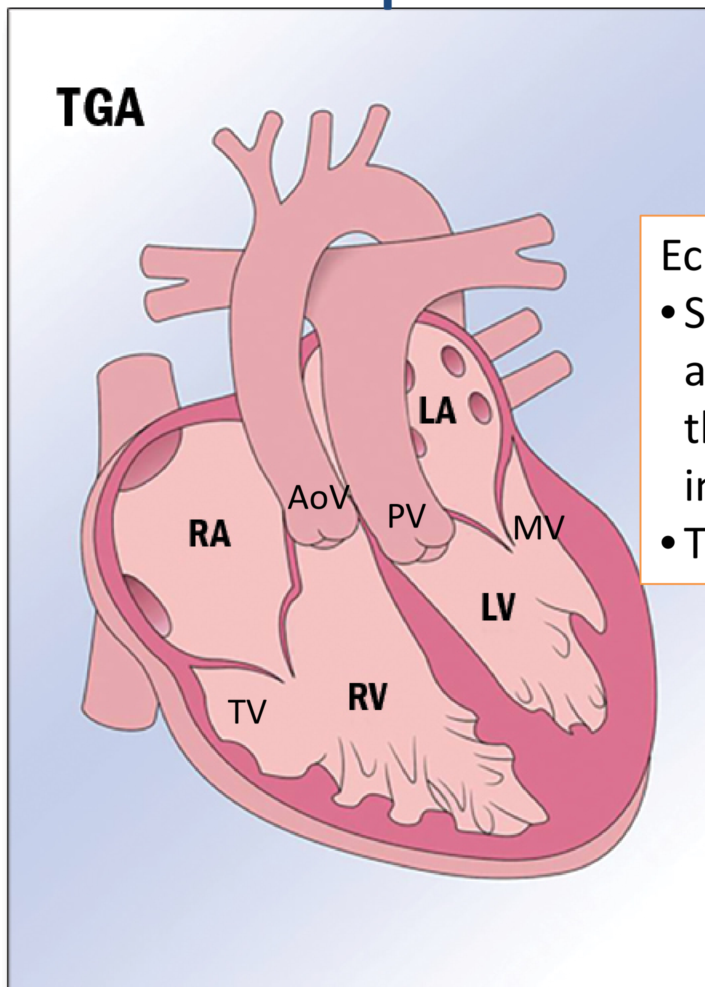
- Tricuspid valve (left sided) is apically displaced
- Note moderator band in RV
- No distinct papillary muscles in RV

L- (Corrected) Transposition



Diagrammatic Representation of the Complete Transposition of the Great Arteries

D- Transposition

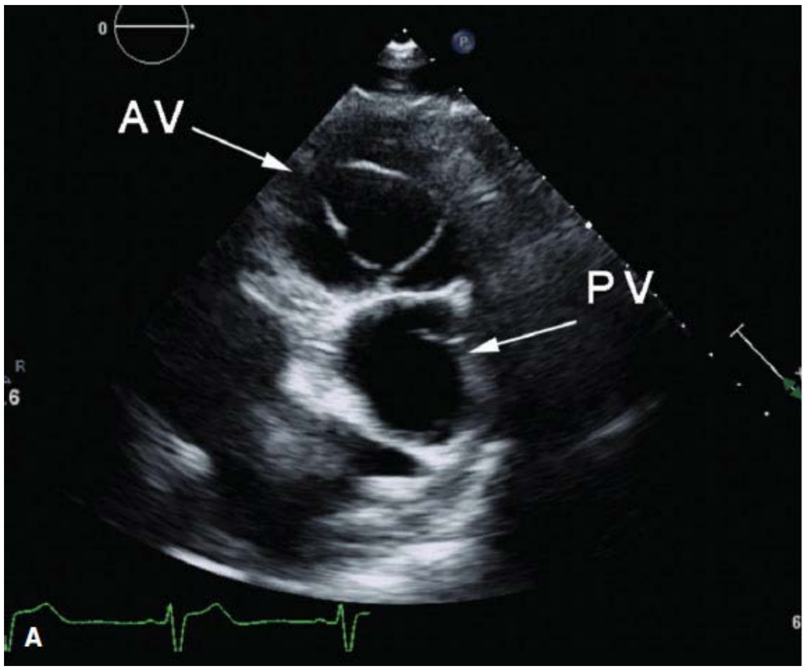


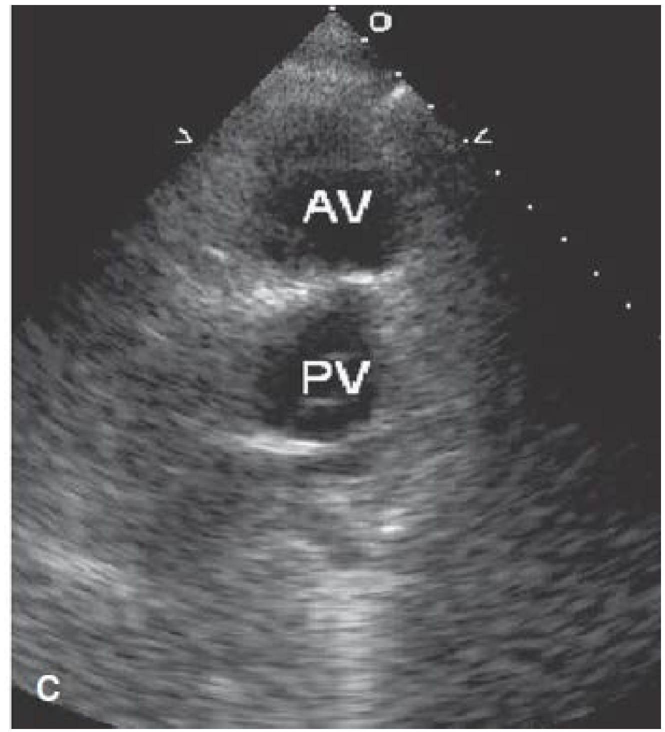
Echo Diagnosis

- SAX: Aortic valve is usually anterior and to the right of the PA (and valves are seen in same plane)
- The PA and aorta are parallel

Two parallel circuits is not compatible with life (ASD is usually present)

D- Transposition



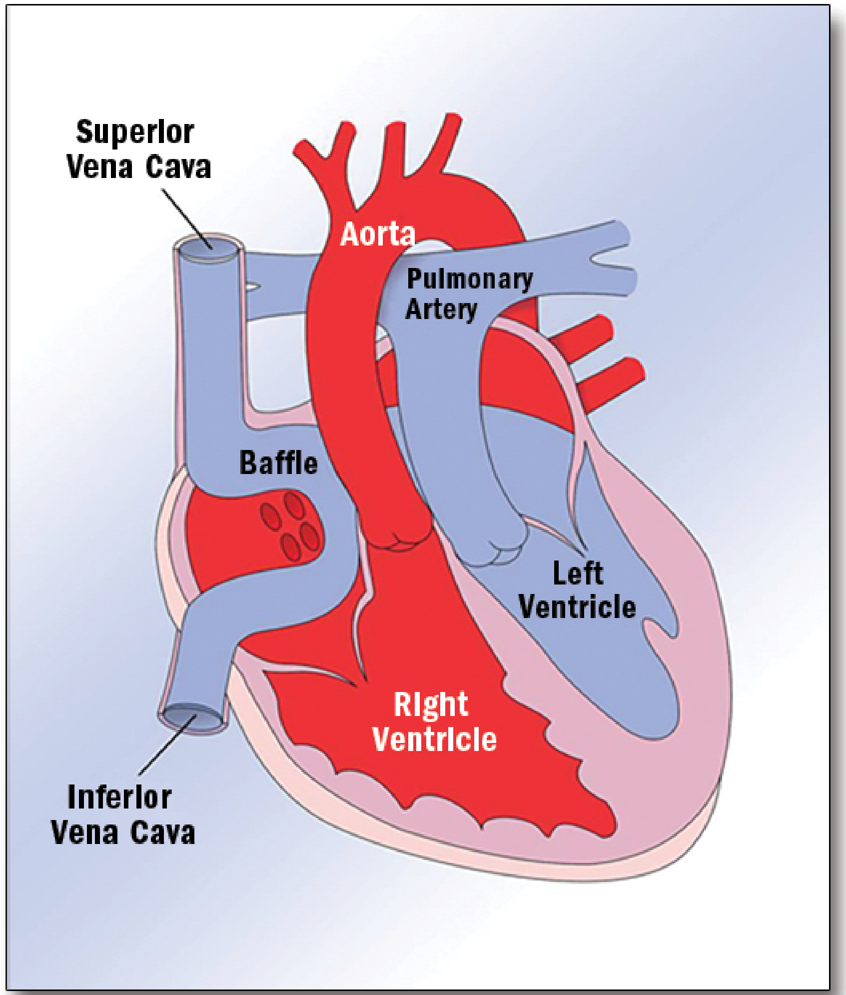


Atrial Switch Repair
(Senning or Mustard Procedure)

1957: Atrial flap   1963: Pericardium

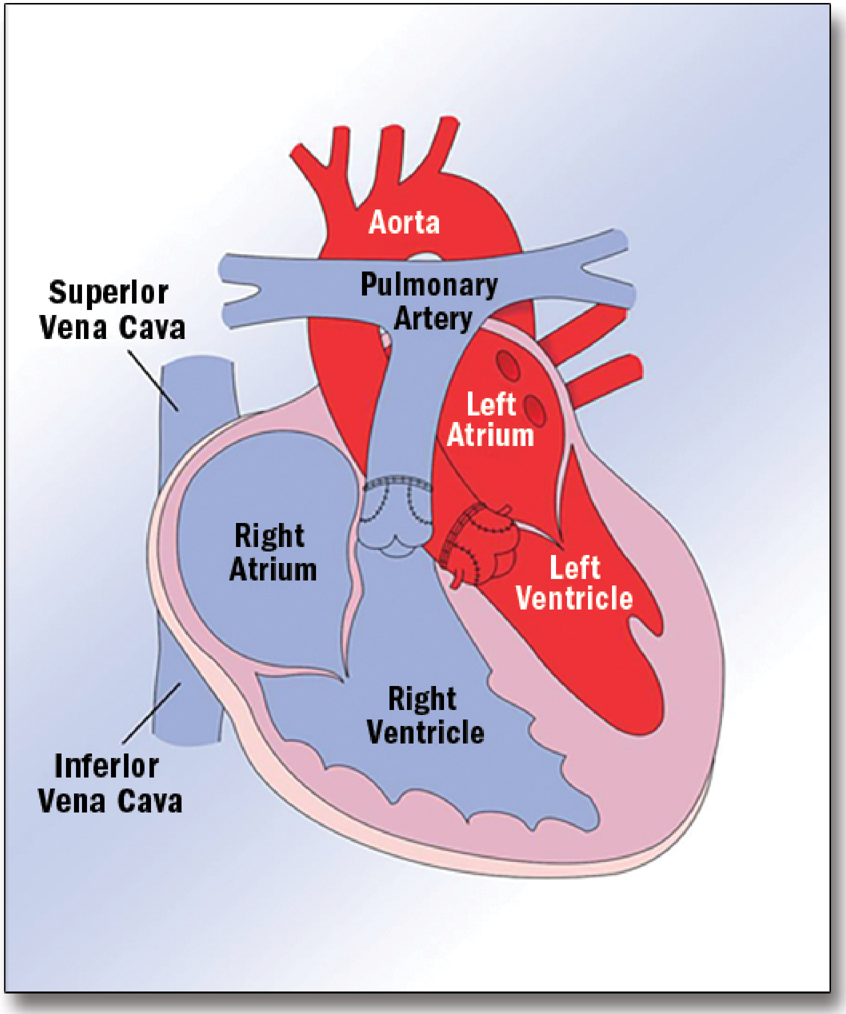
Baffle leak: unoxygenated enters systemic ventricle

Baffle obstruction: SVC syndrome



Arterial Switch Operation

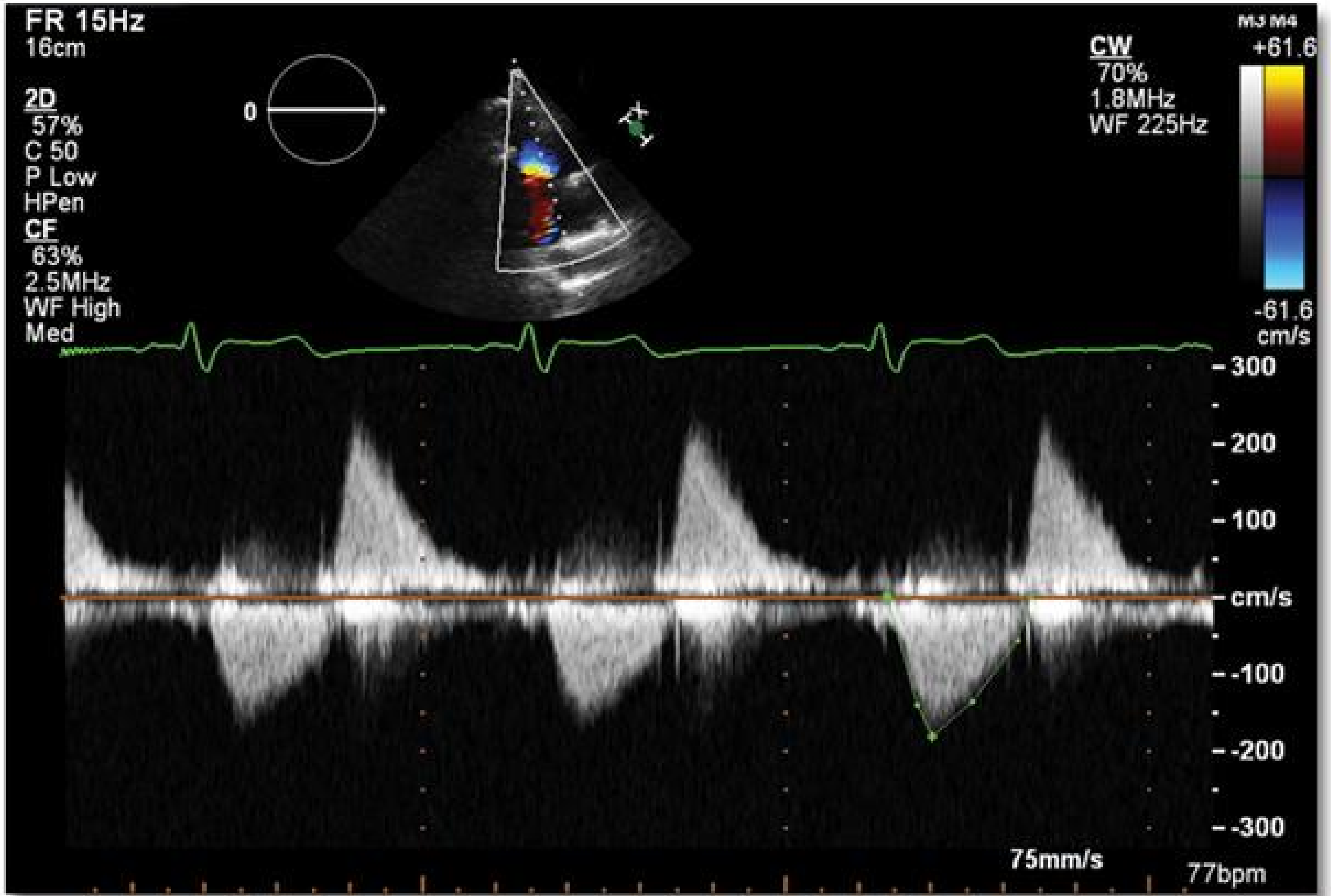
(1975: Jatene Procedure)



Echocardiographic and Doppler Parameters Useful in Grading PR Severity

Parameter	Mild	Moderate	Severe
Pulmonic valve	Normal	Normal or abnormal	Abnormal and may not be visible
RV size	Normal*	Normal or dilated	Dilated†
Jet size, color Doppler‡	Thin (usually <10 mm in length) with a narrow origin	Intermediate	Broad origin; variable depth of penetration
Ratio of PR jet width/ pulmonary annulus			>0.7§ *
Jet density and contour (CW)	Soft	Dense	Dense; early termination of diastolic flow *
Deceleration time of the PR spectral Doppler signal			Short, <260 msec *
Pressure half-time of PR jet			<100 msec‖ *
PR index¶		<0.77	<0.77
Diastolic flow reversal in the main or branch Pas (PW)			Prominent
Pulmonic systolic flow (VTI) compared to systemic flow (LVOT VTI) by PW#	Slightly increased	Intermediate	Greatly increased
RF**	<20%	20%-40%	>40%

Severe PI (CW Doppler)



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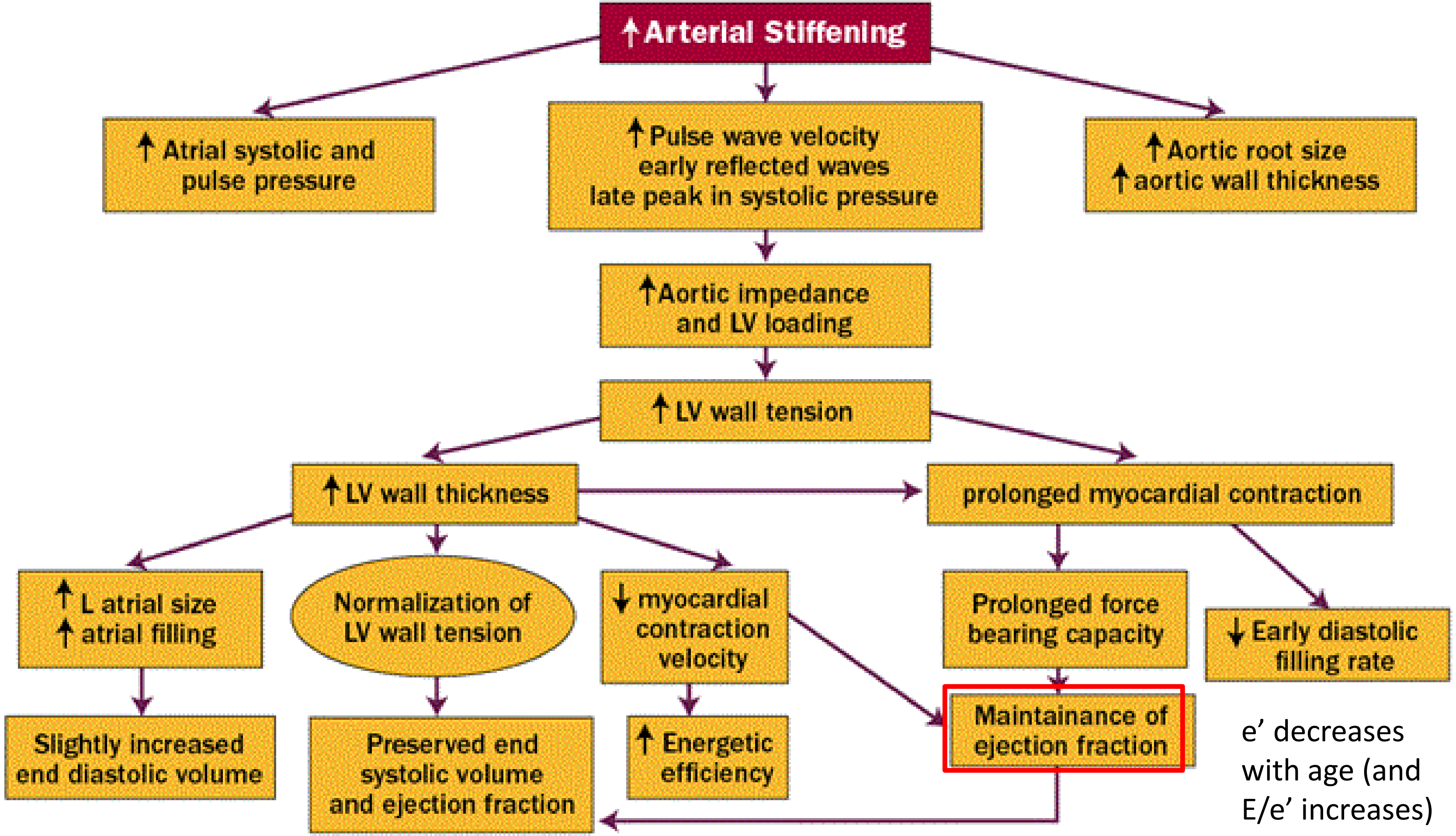
Aging and the Heart



e’ decreases with age (and E/e’ increases)

Noncompaction

- Jenn criteria: end-systolic ratio of non-compacted to compacted of $\geq$ 2.
- Color Doppler demonstrates flow in sinusoids

Contrast Echo

- To reduce swirl of echo contrast agent in apex
  - Lower mechanical index
  - Increase contrast infusion rate
  - Decrease frame rate
  - Move focus to near field
- Tumor vs Clot: perfusion will be seen if mass is vascular (ie, tumor)

Cardiac Tumors

- Primary tumors are rare (6%) of all tumors and most (94%) are benign.
  - Myxoma most common, next is papillary fibroelastoma
  - Angiosarcoma is most common sarcoma in adults
- Metastatic tumors are 40 x more common than primary tumors
- Tumor may perfuse with echo imaging agent

LVAD Surveillance Echo

- Assess septal motion and LVEDD
- Aortic valve opening
- Inflow and outflow cannula velocities

LVAD Surveillance Echo
Assess septal motion and LVEDD

- The degree of LV unloading can be inferred from LV chamber size and the position of the interventricular septum, which reflects the relative filling pressures in the LV and RV.
- Excessive LVAD speed, reduced LV preload (from dehydration, sepsis, bleeding, or tamponade), or RV failure would cause LV underfilling and a leftward shift of the septum
- Conversely, rightward septal shift indicates LV overfilling, whether due to inadequate LVAD speed, pump dysfunction (e.g., thrombosis), cannula obstruction, aortic regurgitation, or high LV afterload .
- Ideally, LV end-diastolic dimension (LVEDD) should reduce by 20-30% post-LVAD and the septum should be situated in a neutral or slightly rightward position.
- Measurement of LVEDD in the parasternal long-axis view at the mitral valve leaflet tips is the most reproducible method of assessing LV chamber size, which is crucial to maintaining consistency across serial echocardiograms.

LVAD Surveillance Echo
Aortic Valve Opening

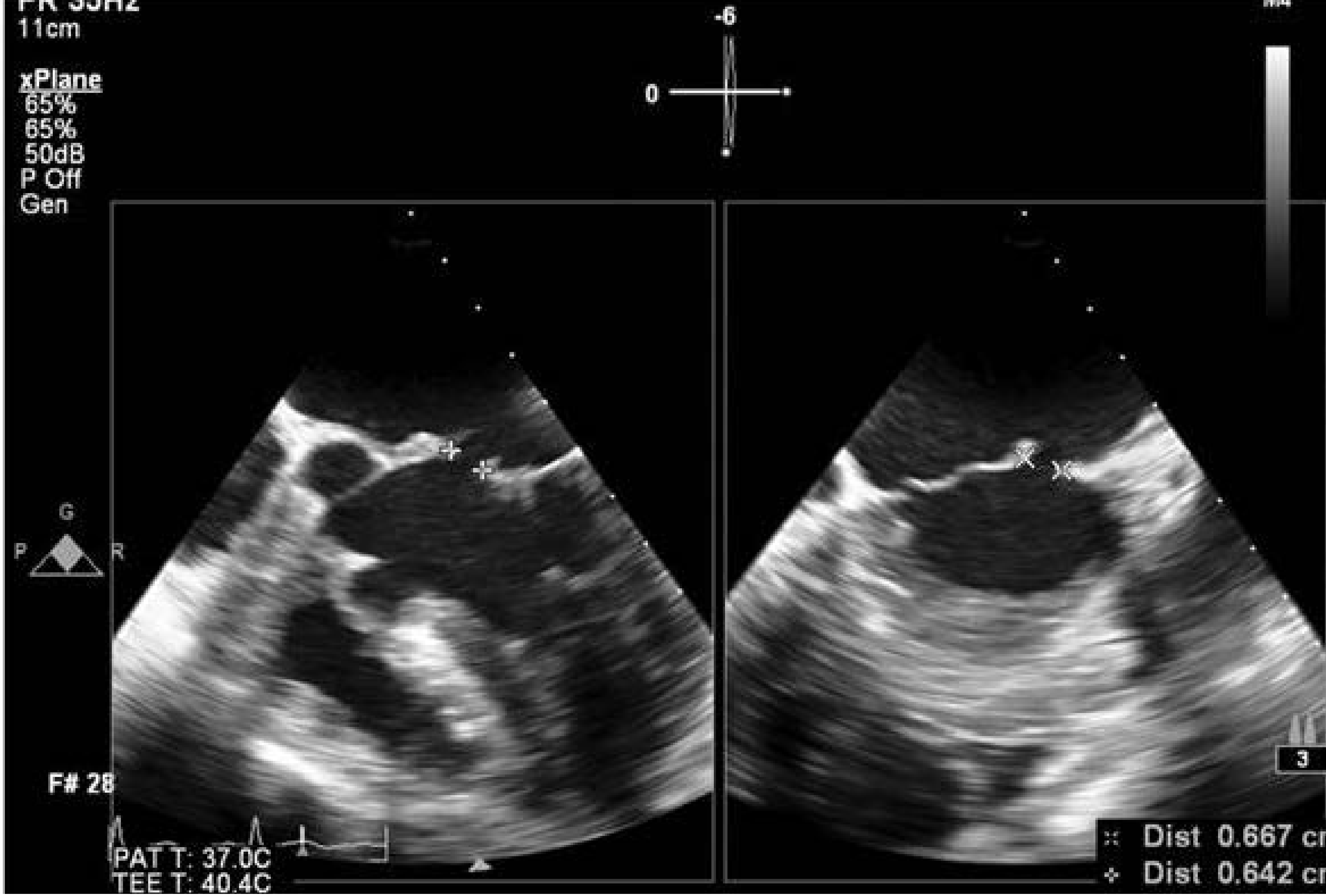
- Aortic valve (AV) opening is another indicator of the relative contribution of native LV contractility to the overall cardiac output.
- However, AV opening may also signify high LV pressure from LVAD dysfunction.
- Frequency, duration, and degree of AV opening can be evaluated with M-mode at low sweep speed (25-50 mm/s)
- LVAD speed should ideally be set to allow for intermittent AV opening since persistent AV closure (at higher LVAD speeds) increases the risk of aortic root thrombus and continuous AR.
- There are no well-defined guidelines on the grading of LVAD-associated AR. However, duration of AR, vena contracta width (≥0.3 cm), and jet width relative to the LV outflow tract dimension (≥46%) are recommended for identifying moderate-severe AR

LVAD Surveillance Echo
Inflow and Outflow Cannula Velocities

- The inflow cannula at the LV apex can usually be visualized from the parasternal or apical window and assessed for thrombus or vegetation formation.
- Spectral Doppler pattern should be laminar and low-velocity without evidence of turbulence or flow reversal .
- Some pulsatility in the flow pattern is usually present, due to intrinsic LV contractility, and results in a peak systolic velocity above a basal, or nadir, diastolic velocity.
  - High Doppler velocities (peak >1.5 m/s) in the inflow cannula suggest partial obstruction, whether due to thrombosis, kinking, or suction.
  - Low peak velocity with near-absent diastolic signal on spectral Doppler of the cannula indicates complete obstruction or pump thrombosis.
- The outflow graft is more difficult to visualize by transthoracic echocardiography and may be seen from the right-parasternal, high left-parasternal, right supraclavicular, or suprasternal views, depending on the anatomy.
- Due to the challenges in alignment with the angle of insonation, Doppler velocities in the outflow graft can be variable, though peak velocity >2 m/s is considered abnormal

A 21-year-old man with no significant past medical history presented with a stab wound on chest.

Blood Pressure:	90/60 mm Hg
Pulse:	112 bpm
Chest and Lungs:	Bibasilar rales
Cardiac Exam:	Regular rhythm. Systolic murmur in left parasternal border and apex


11cm
xPlane
65%
65%
50dB
P Off
Gen
-6
0
G
P
R
F# 28
PAT T: 37.0C
TEE T: 40.4C
3
Dist 0.667 cr
Dist 0.642 cr

A 51-year-old woman with substance abuse and uncontrolled hypertension presented with a stab wound on chest.
A chest tube was placed with 300 ml bloody drainage.
She was initially stable, but became hypotensive with increasing output from the chest tube.

Blood Pressure:	85/54 mm Hg
Pulse:	169 bpm
Cardiac Exam:	Tachycardia. Limited exam due to the chest wound

Hemopericardium

- Echocardiogram shows echogenic material within the pericardial cavity consistent with a large organized thrombus along the inferior and lateral aspect of the heart.
- The left ventricular (LV) cavity appears small and underfilled.
- Hemopericardium is commonly associated with cardiac rupture and a high mortality rate.
- Cardiac tamponade resulting from ventricular rupture is often fatal; however, bleeding from the lower-pressure atria may produce a slower accumulation of blood and a more gradual onset of cardiac tamponade.
- Besides cardiac chamber rupture, traumatic hemopericardium may also result from aortic root injury, myocardial contusion, and coronary artery laceration.

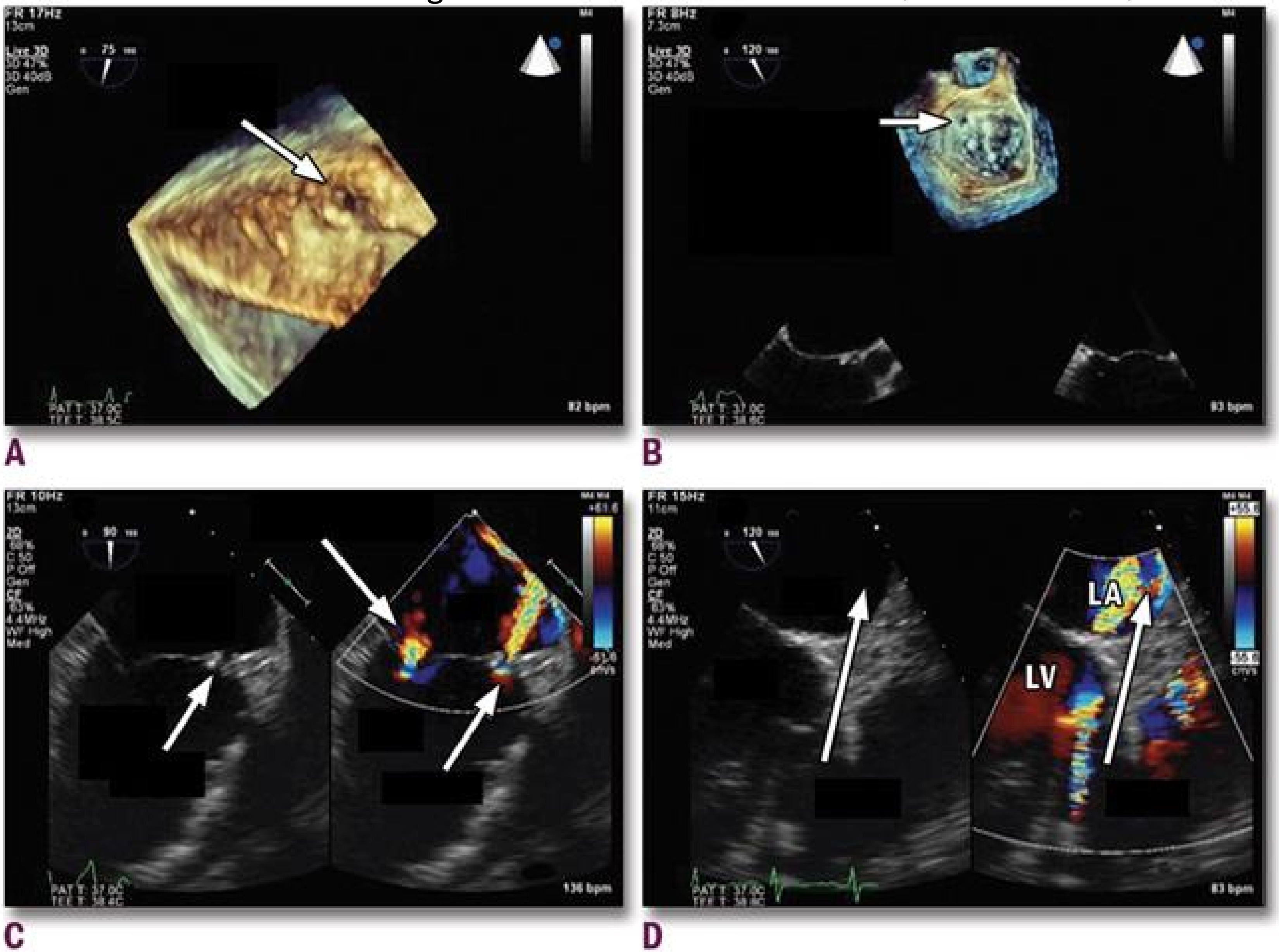
A 44-year-old man presented with signs and symptoms (chronic) of congestive heart failure

Twenty-five years before presentation, he had sustained a stab wound injury to the chest requiring emergent coronary artery bypass graft surgery and repair of the anterior right ventricular wall.

Blood Pressure:	100/65 mm Hg
Pulse:	93 bpm
General Appearance:	Alert, no apparent distress
Chest and Lungs:	Mild bibasilar rales
Cardiac Exam:	Regular rhythm. An apical grade IV holosystolic murmur

Muscular VSD communicating to RVOT

Paravalvular (mitral annulus) fistula



Paravalvular Fistula

- The mitral and aortic valves are at greater risk for injury than the tricuspid and pulmonic valves, as mural pressure is higher on the left side of the heart.
- In a large review of 711 cases of penetrating cardiothoracic trauma, mitral valve injury was detected in only two patients, suggesting that mitral valve injury is either incredibly rare or difficult to detect.
- This case illustrates the utility of real-time three-dimensional (3D) TEE in the characterization of cardiac injuries. In comparison with standard two-dimensional TEE imaging, 3D TEE renders images with a multiplanar probe and an all-at-once display, allowing for nontraditional views of a structure to be displayed.

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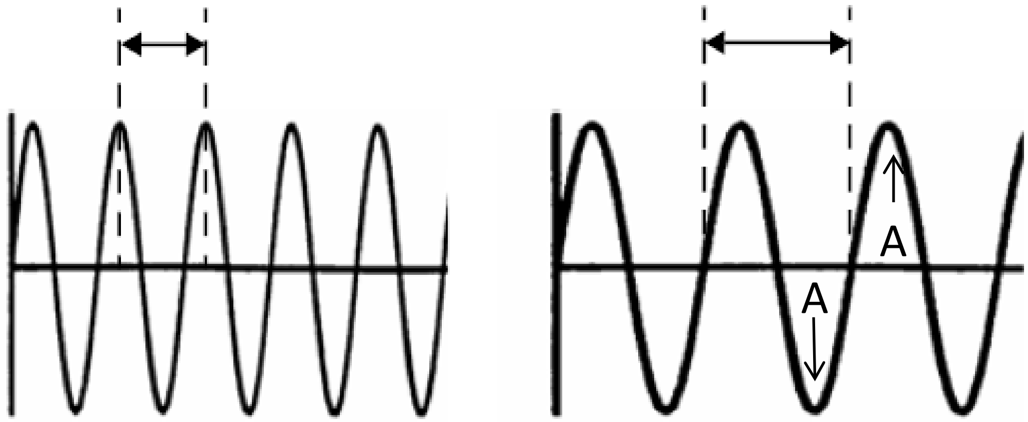
- **Physics**

- **Frequency**: number of cycles that occur one second
- **Wavelength**: length of one complete cycle ("cycle length")

Higher frequency also means shorter wavelength

Lower frequency also means longer wavelength.



Higher Frequency
Shorter Wavelength

Lower Frequency
Longer Wavelength

Improved near field spatial resolution
(resolution = 2 x wavelength)

Average speed of sound in biologic soft tissue is 1540 m/sec
1540 m/sec = frequency (cycle/sec) x wavelength (m/cycle)

- **Amplitude**: strength of the wave (difference between average and maximum [in dB])

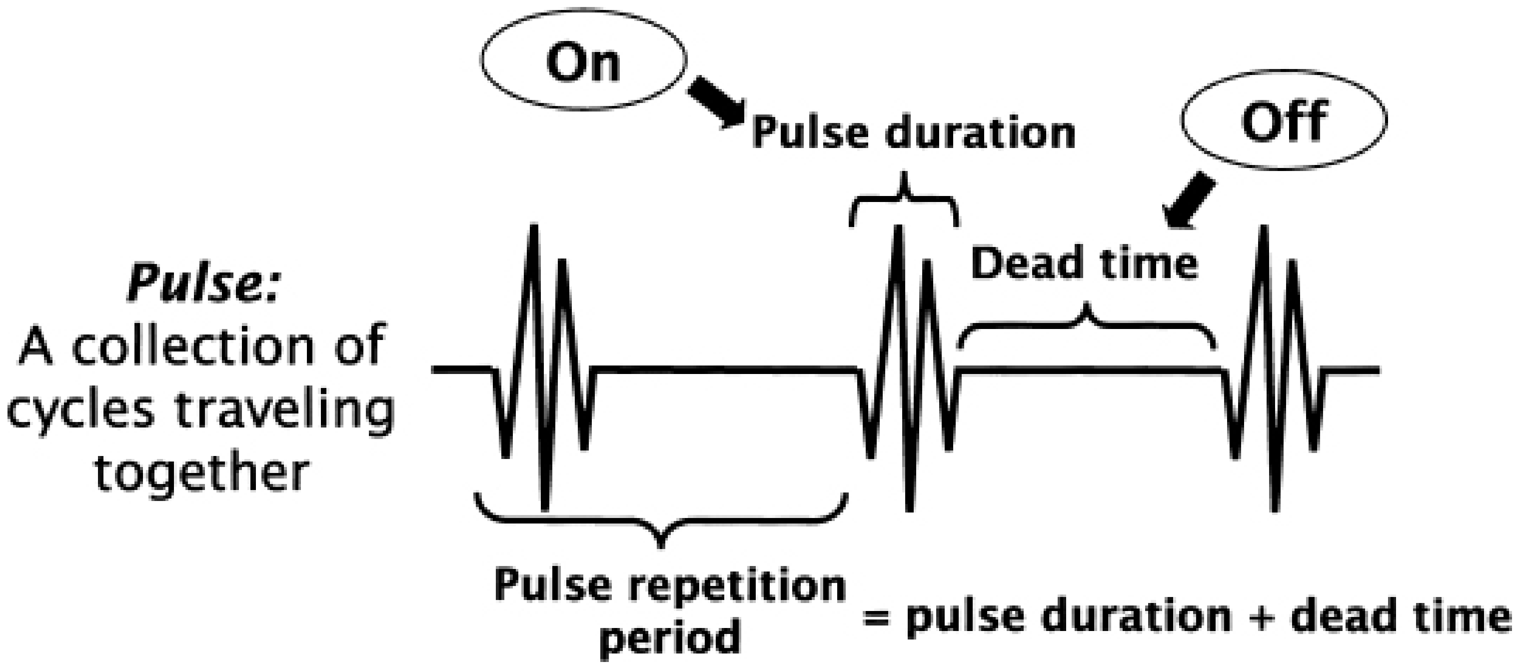
Attenuation: Loss of ultrasound as it propagates

3 Components

- Absorption
- Scattering
- Reflection

Duty Factor

- Ultrasound energy is usually emitted from the transducer in a series of pulses, each one representing a collection of cycles.
- Each pulse has a duration and is separated from the next pulse the the "dead" time.



Duty factor = pulse duration ÷ pulse repetition period

Dead time changes with depth of view

Feigenbaum. 8th Ed.

Doppler Equation

- $V = (f_d \times c)/(2 \times f_t \times \cos ø)$
  - V is velocity
  - f_d is Doppler shift
  - c is speed of sound in tissue (1540 m/sec)
  - f_t is transmitted frequency
  - ø is angle between ultrasound beam and RBCs
- Basic principles
  - Lower frequency transducer detects higher velocities (i.e., lower the transmitted frequency if aliasing occurs)
  - Ideal ø is 0
  - Change in speed through different medium affects velocity

Physics - Summary

- Resolution: 2 x wavelength
- Duty factor: fraction of time that ultrasound system transmits (increases with increasing depth)
- Aliasing: prevent by decreasing transducer frequency.
  - $V = (f_d \times c)/(2 \times f_t \times \cos ø\ )$

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