Aortic Regurgitation: Etiology and Echo Quantification

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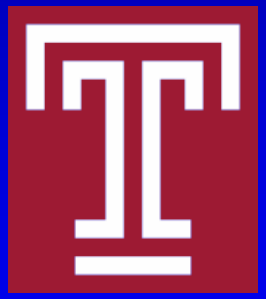
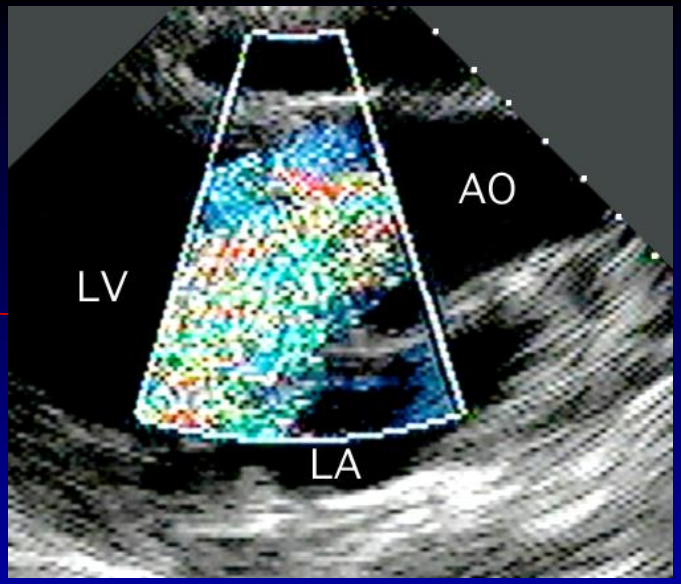


Review Question #1



- Possible reasons that this color Doppler evaluation may overestimate AR include:

A. Low color Doppler gain setting

B. Use of too small a color Doppler sector

C. Low Nyquist velocity setting

D. High pulse repetition frequency (PRF)

Review Question #2

- Which condition may lead to over-estimation of AR severity by deceleration slope (or P1/2) of diastolic Continuous Wave (CW) Doppler:

A. Advanced restrictive myocardial disease

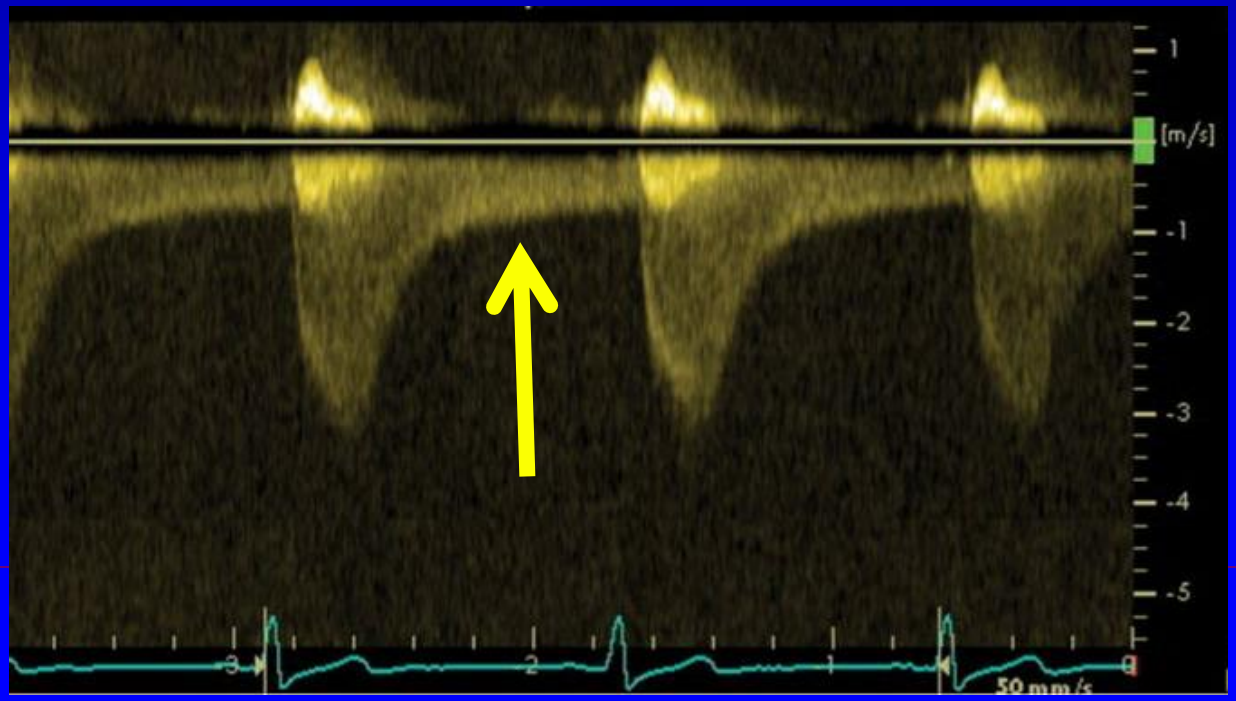
B. Severe mitral valve stenosis

C. Severe aortic valve stenosis

D. Low Nyquist limit setting

Review Question #3

- A continuous wave Doppler cursor is placed at the junction of the aortic arch and proximal descending aorta, just beyond the left subclavian artery. The following is obtained:



Review Question #3

- The etiology of the diastolic Doppler flow indicated by the arrow is:

A. Stenosis of the left subclavian artery

B. Severe aortic regurgitation

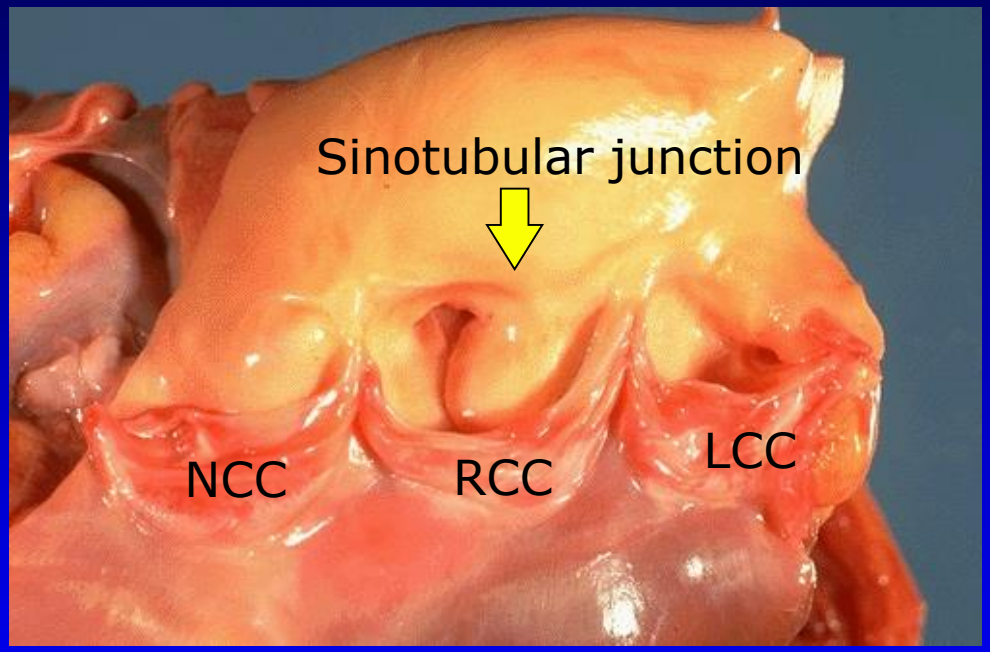
C. Moderate aortic regurgitation

D. Severe coarctation of the aorta

Aortic Regurgitation: Etiology

- **Valve**
  - Congenital (Bicuspid AV, Subaortic Stenosis)
  - Endocarditis
  - Degenerative
  - Traumatic
  - Rheumatic
- **Aortic Root**
  - Dilated aortic root
    - Marfan, Loeys-Dietz, Ehlers Danlos
    - Hypertension
    - Vasculitis
  - Aortic Dissection

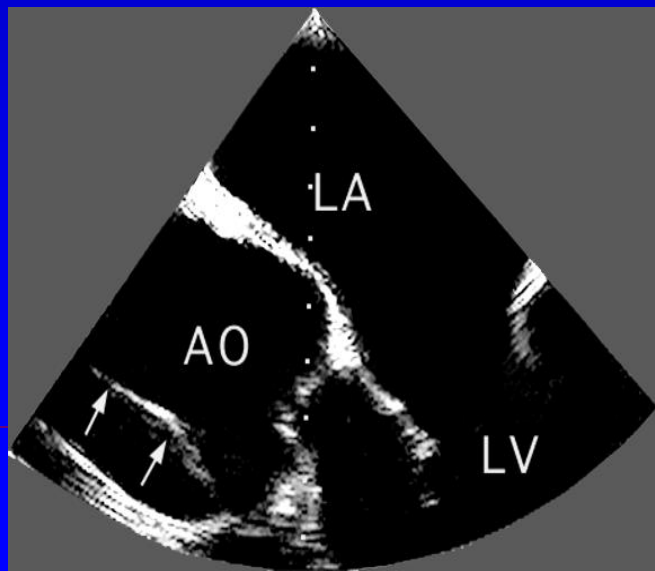
"The Aortic valve is the Root"



- Cusps attached to root in "coronet"
- Sinuses and motion of root important for valve opening and competence

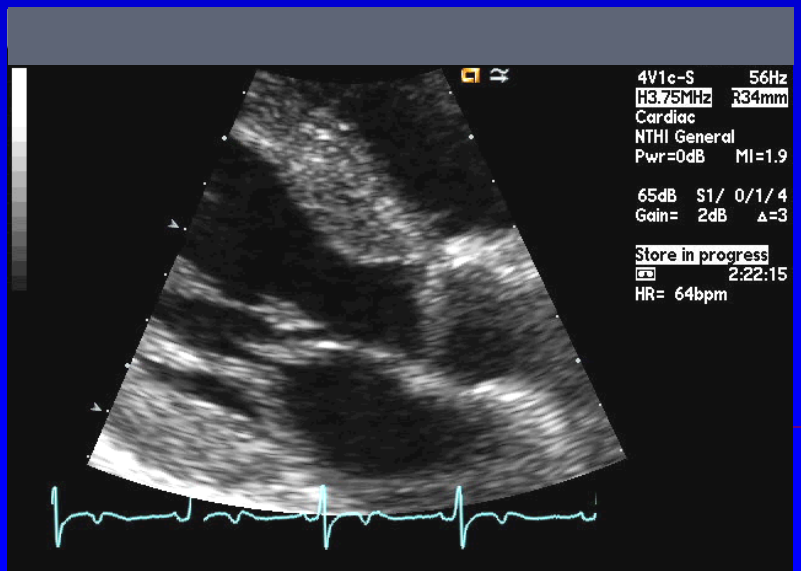
Anatomy of Regurgitation: *Leaflet Malcoaptation*

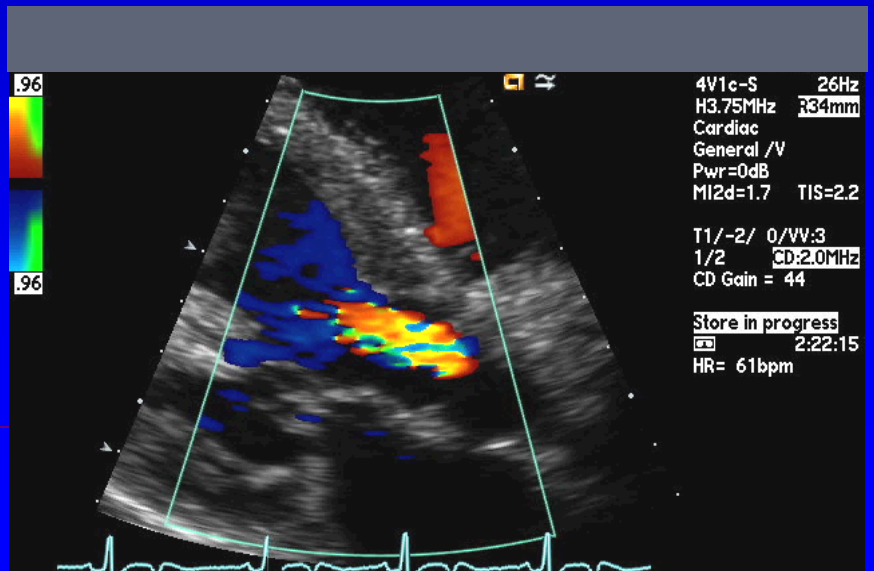
- **Proximal aortic dilatation**
  - Central Regurgitation
- **Leaflet thickening/retraction**
  - Rheumatic, degenerative
- **Leaflet destruction**
  - Endocarditis, Trauma
- **Leaflet prolapse**
  - Aortic dilatation / dissection



Etiology of Regurgitation: *Bicuspid Aortic Valve*

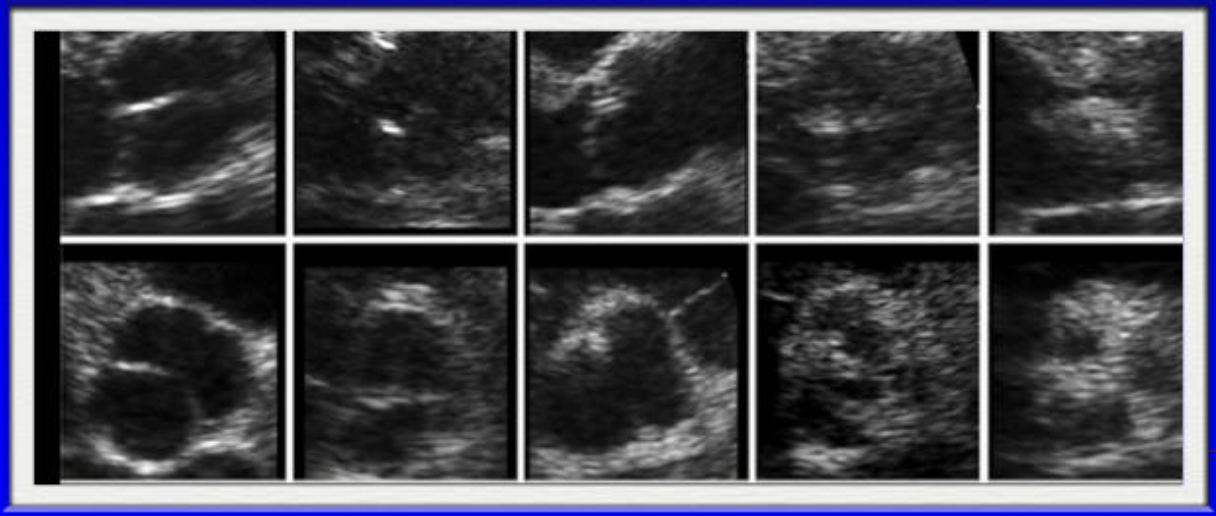
- Most common "congenital" AV abnormality
- Significant premature valve disease
  - Aortic Regurgitation in 40%
  - Aortic Stenosis in 30%





Etiology of Regurgitation: *Degenerative / Rheumatic*

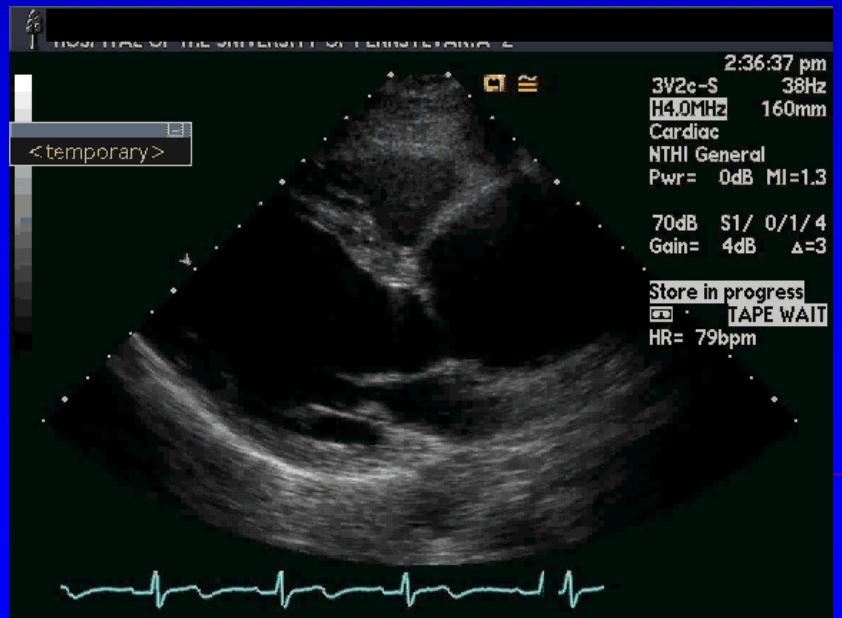
- Degenerative Malcoaptation
  - Calcific deformities of cusps and commissures
- Rheumatic Malcoaptation
  - Thickening/retraction of cuspal edges and commissures

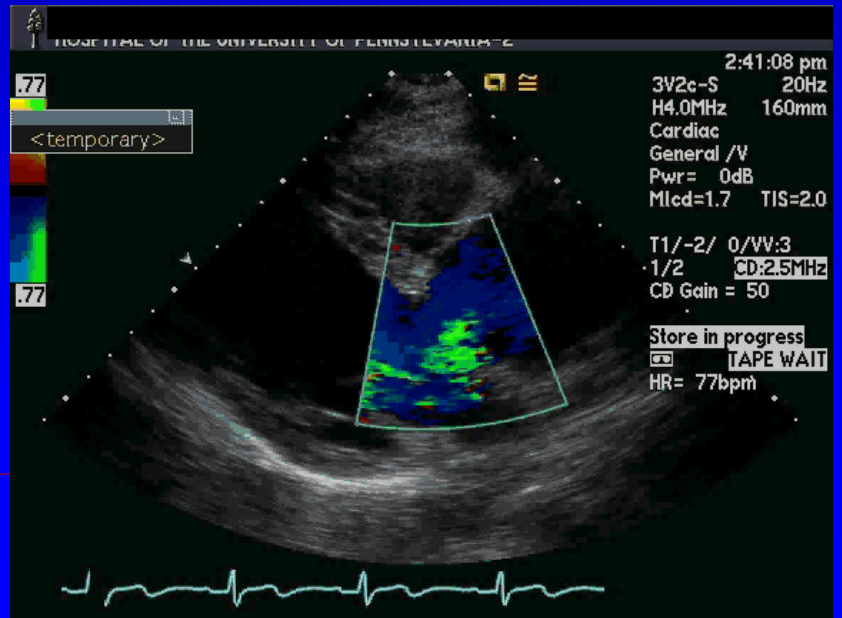


Schaefer BM. Heart (2008) 94:1634-38; Rosenhek R. NEJM (2000) 343:611–7.

Etiology of Regurgitation: *Proximal Aortic Dilatation*

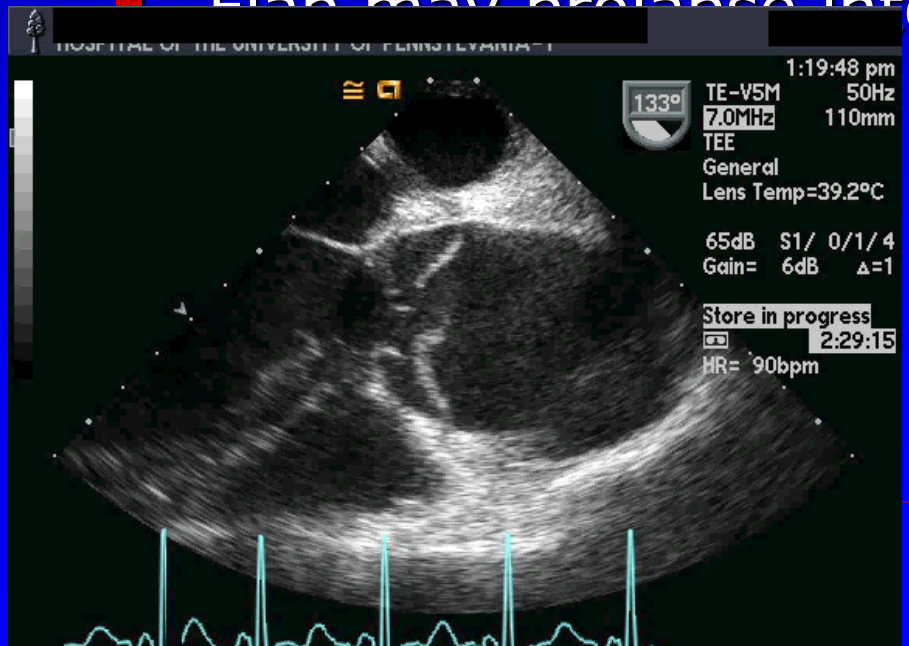
- Marfan, Loeys-Dietz, Ehlers-Danlos
- Non-syndromic aneurysms
- Chronic Hypertension





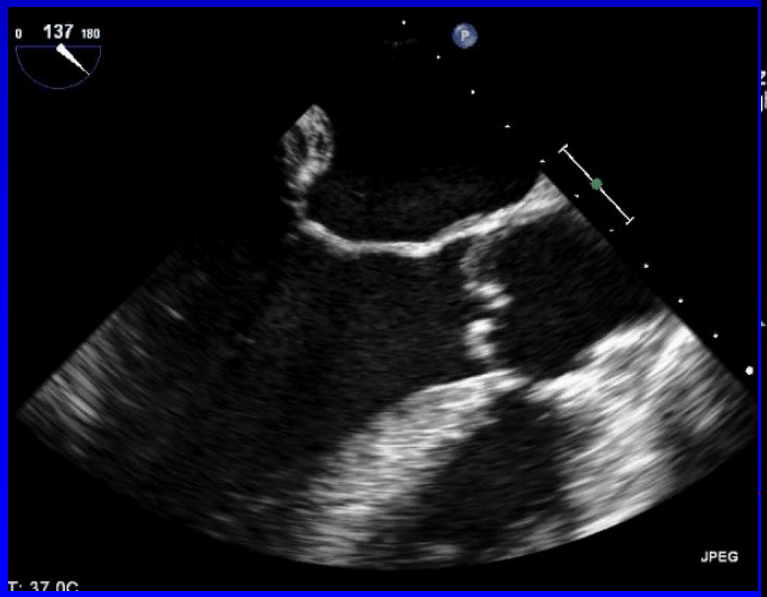
Etiology of Regurgitation: *Aortic Dissection*

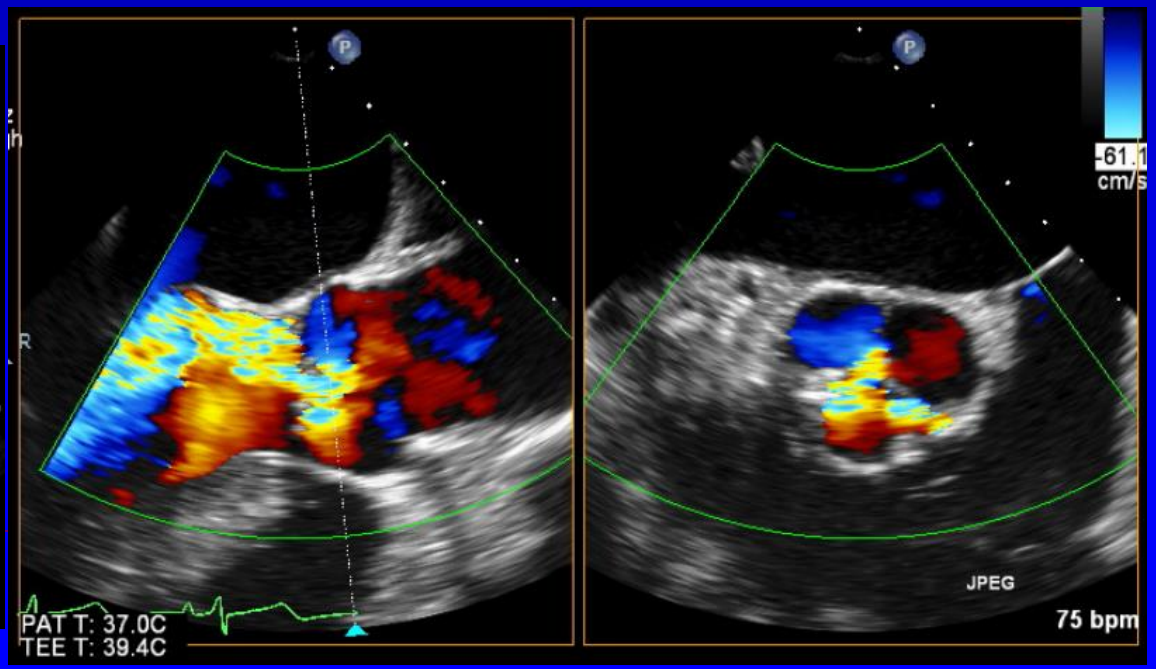
- Retrograde extension past (proximal) ST junction
- Frequently associated with
  - Rupture into pericardial space, coronary dissection
- Flap may prolapse into/through aortic valve



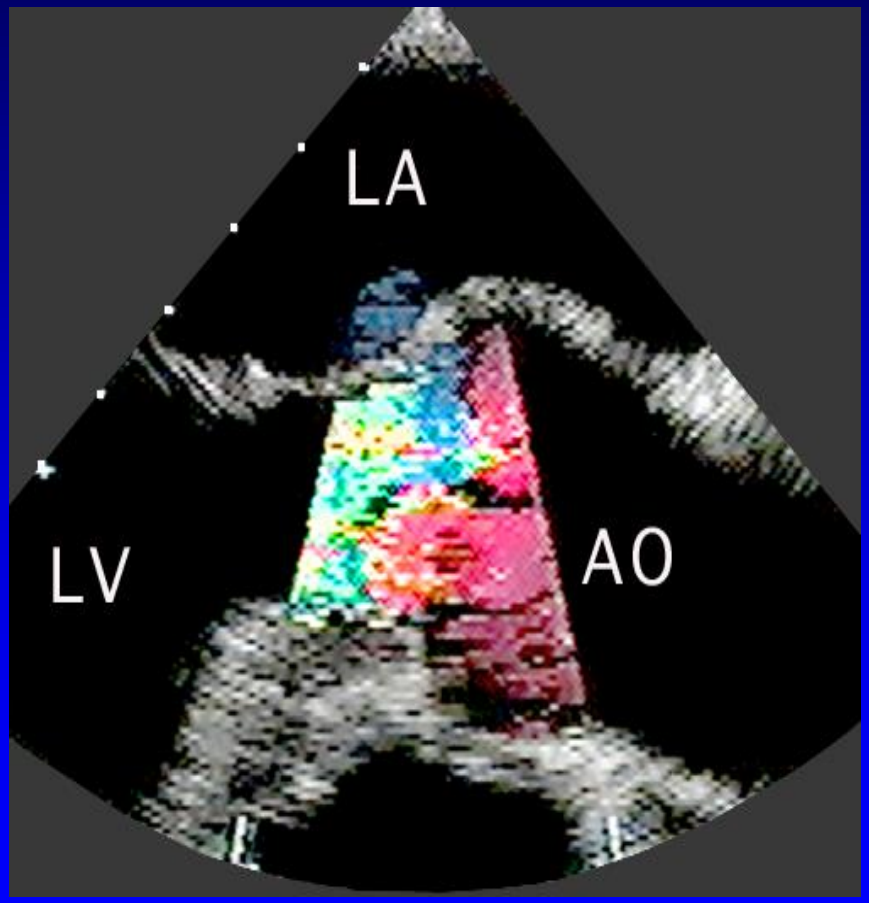
Etiology of Regurgitation: *Leaflet Prolapse*

- Myxomatous / Congenital Abnormality
- Loss of commissural support
- Partial tear of cusp (trauma)
- **Best seen on PLAX or on TEE 120°**





Etiology of Regurgitation: *Leaflet Destruction by Endocarditis*



Pathophysiology: *Acute Aortic Regurgitation*

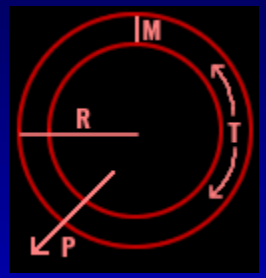
- Sudden, large regurgitant volume
  - ↑ LVEDV ⟶ Marked ↑↑ LVEDP
  - Pulmonary Edema
- Decrease forward stroke volume
  - Cardiogenic shock
- Urgent intervention required
  - Nitroprusside/Inotropic agents
  - Surgical Repair

Pathophysiology: *Chronic Aortic Regurgitation*

- Primary Volume Overload
  - Increased Preload (… & Afterload!)

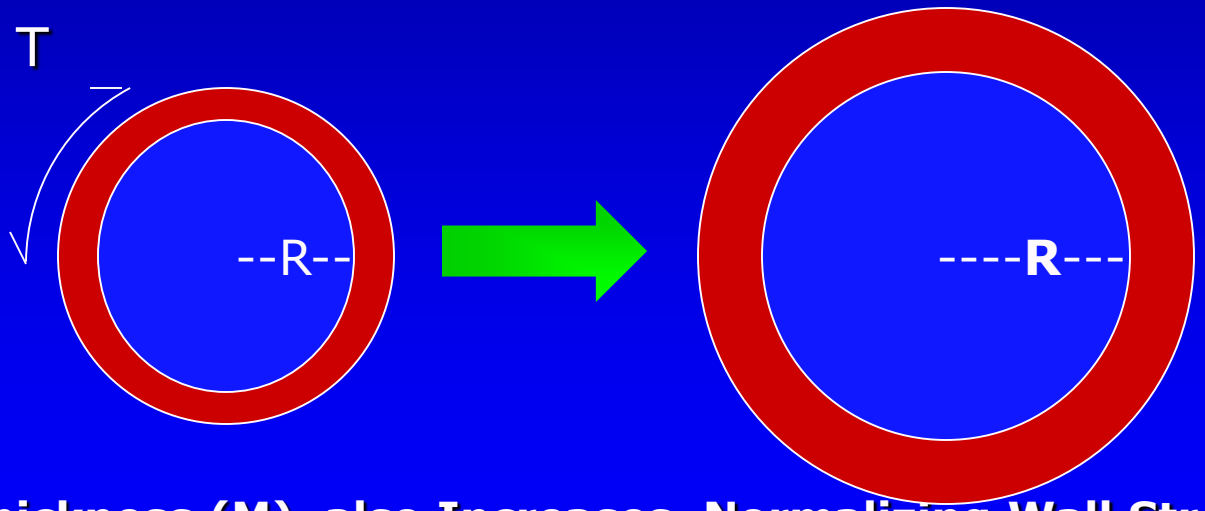
- ***Progressive ventricular dilation***
  - Chamber compliance increases
    - Mild intracavitary pressure increase
- ***Myocardial hypertrophy***
  - Compensation for increased wall stress
    - Maintains functionality of the ventricle

Chronic Aortic Regurgitation: Hypertrophy Process



La Place's Law: T = (P*R)/M

Increase in Radius (R) Compensates for Volume Overload



Wall Thickness (M) also Increases, Normalizing Wall Stress (T)

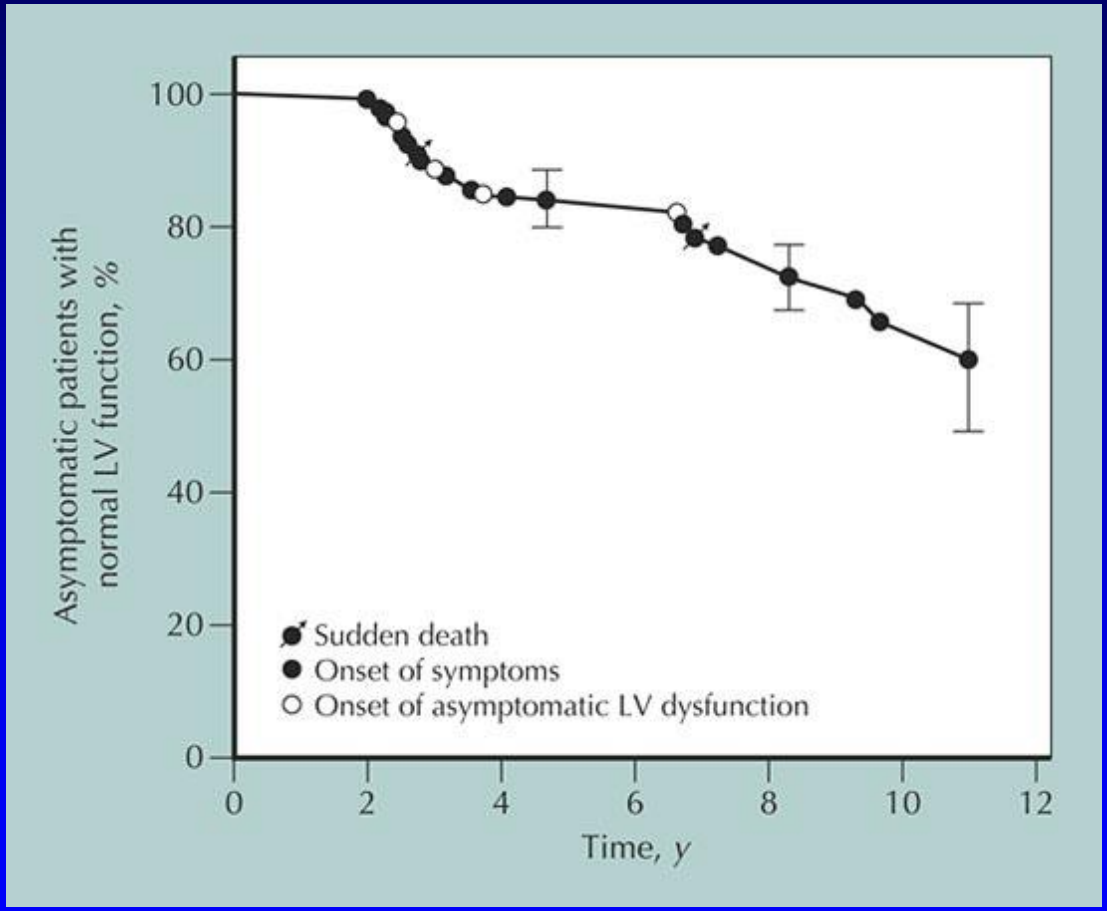
Grossman W, et al. *J Clin Invest* (1975) 56:56-64

Chronic Aortic Regurgitation:

PROGRESSIVE MYOCARDIAL DYSFUNCTION

- Impaired myocardial function
  - Slow increase in functionally abnormal myocytes
- Decreased coronary flow reserve
  - Secondary to hypertrophy
- **Patients become symptomatic at different levels of LV dysfunction**

Chronic Aortic Regurgitation: *Natural History*



Bonow RO, Lakatos E, Maron BJ, Epstein S. *Circulation* 1991, 84: 1625–1635

Chronic Aortic Regurgitation
Indications for Surgery

- **S y m p t o m s**

- End-systolic LV dimension >5.0 cm
- Ejection fraction <50%
- Diastolic LV dimension > 6.5 cm

…or rapid progression/deterioration of indices

Quantitation of Aortic Regurgitation: *Echocardiographic Approaches*

- **Qualitative**
- **Semi-Quantitative**
  - "Guess-timating" Regurgitant Orifice
- *(Somewhat More)* **Quantitative**
  - Based on volumetric calculations

Quantitation of Aortic Regurgitation: *Echocardiographic Approaches*

Table 4 Qualitative and quantitative parameters useful in grading aortic regurgitation severity

	Mild	Moderate	Severe
Structural parameters			
LA size	Normal*	Normal or dilated	Usually dilated**
Aortic leaflets	Normal or abnormal	Normal or abnormal	Abnormal/flail, or wide coaptation defect
Doppler parameters			
Jet width in LVOT –Color Flow[ζ]	Small in central jets	Intermediate	Large in central jets; variable in eccentric jets
Jet density–CW	Incomplete or faint	Dense	Dense
Jet deceleration rate –CW (PHT, ms)[ψ]	Slow > 500	Medium 500-200	Steep < 200
Diastolic flow reversal in descending aorta –PW	Brief, early diastolic reversal	Intermediate	Prominent holodiastolic reversal
Quantitative parameters[φ]			
VC width, cm[ζ]	< 0.3	0.3-0.60	> 0.6
Jet width/LVOT width, %[ζ]	< 25	25-45 / 46-64	≥ 65
Jet CSA/LVOT CSA, %[ζ]	< 5	5-20 / 21-59	≥ 60
R Vol, ml/beat	< 30	30-44 / 45-59	≥ 60
RF, %	< 30	30-39 / 40-49	≥ 50
EROA, cm^2	< 0.10	0.10-0.19 / 0.20-0.29	≥ 0.30

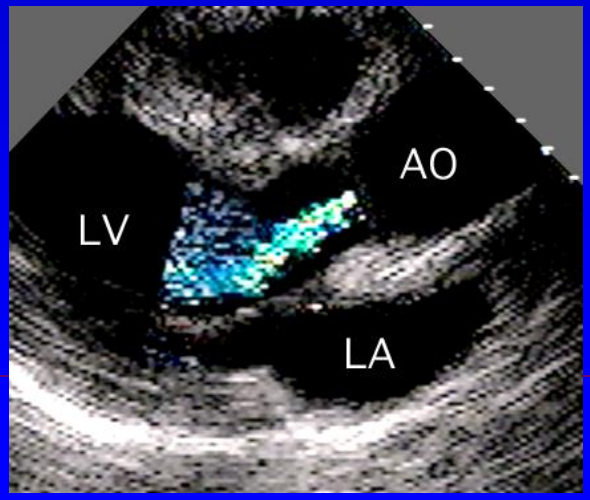
Zoghbi et al. JASE (2003) 16:777-802.

Semi-Quantitative:
Jet Width vs. LVOT Diameter

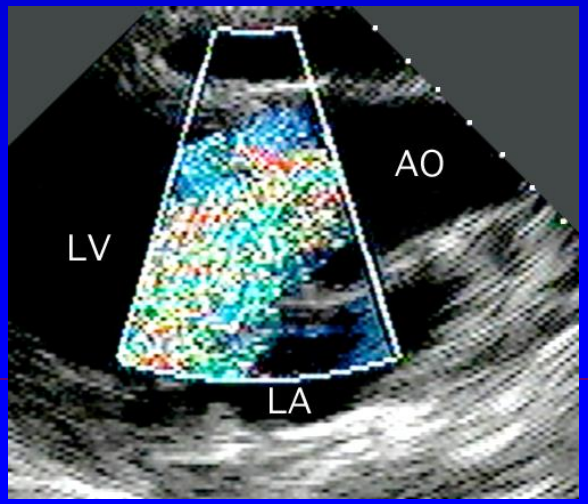
- Parasternal long axis
- TEE longitudinal plane

<25% = mild
25-64% = moderate
≥65% = severe

AR / LVOT = 29%
Moderate AR

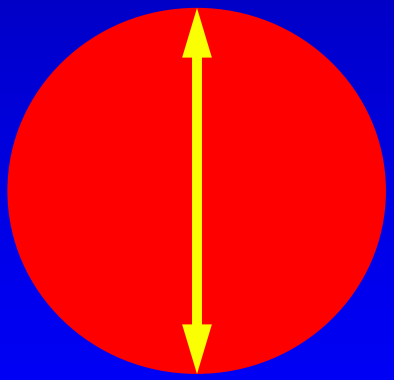


AR / LVOT = 73%
Severe AR



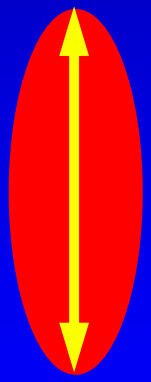
We’se gots problems:

What we THINK we are measuring



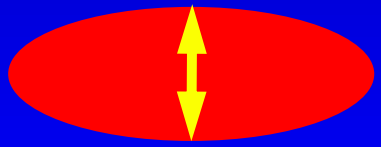
BUT…

What if??

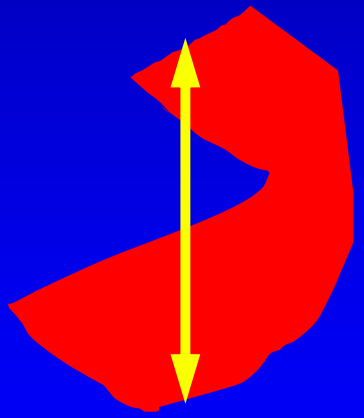


OR…

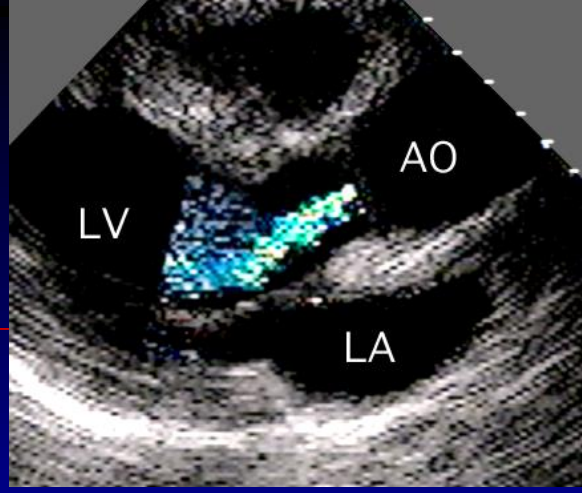
Worse yet…



?????



Semi-Quantitative:
Jet Width vs. LVOT diam



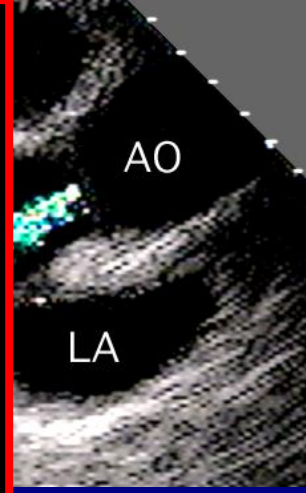
Mild	Moderate		Severe
	Mild–Moderate	Moderate–Severe	
< 25%	25–45%	46–64%	≥ 65%

Zoghbi et al. JASE (2003) 16:777-802.

Sem
Jet

Pitfalls:

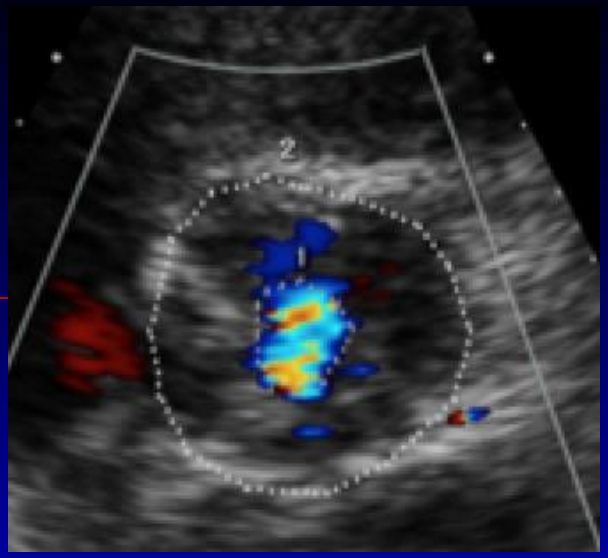
- Measuring too far down in LVOT
- Low Nyquist limits
- Excessive color Doppler gains
- Eccentrically-directed jets
- Eccentric origin of jets
- Variation of flow (width)
- Blood pressure dependent



M			ere
	Mild–Moderate	Moderate–Severe	
< 25%	25–45%	46–64%	≥ 65%

Zoghbi et al. JASE (2003) 16:777-802.

Semi-Quantitative:
Jet Area vs. Ao Root Area



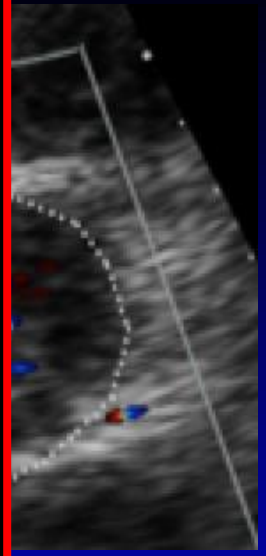
Mild	Moderate		Severe
	Mild–Moderate	Moderate–Severe	
< 5%	5–20%	21–59%	≥ 60%

Zoghbi et al. JASE (2003) 16:777-802.

Sem
Jet A

Pitfalls:

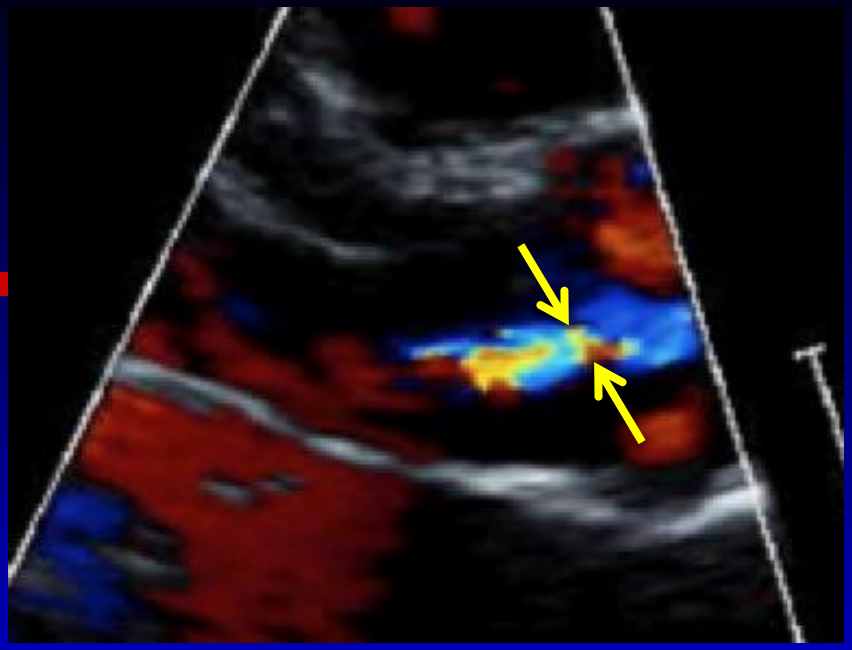
- Measuring below the valve
- Low Nyquist limits
- Excessive color Doppler gains
- Multiple jets
- Variation of flow (width)
- Blood pressure dependent



M			ere
	Mild–Moderate	Moderate–Severe	
< 5%	5–20%	21–59%	≥ 60%

Zoghbi et al. JASE (2003) 16:777-802.

Semi-Quantitative: *Vena Contracta*



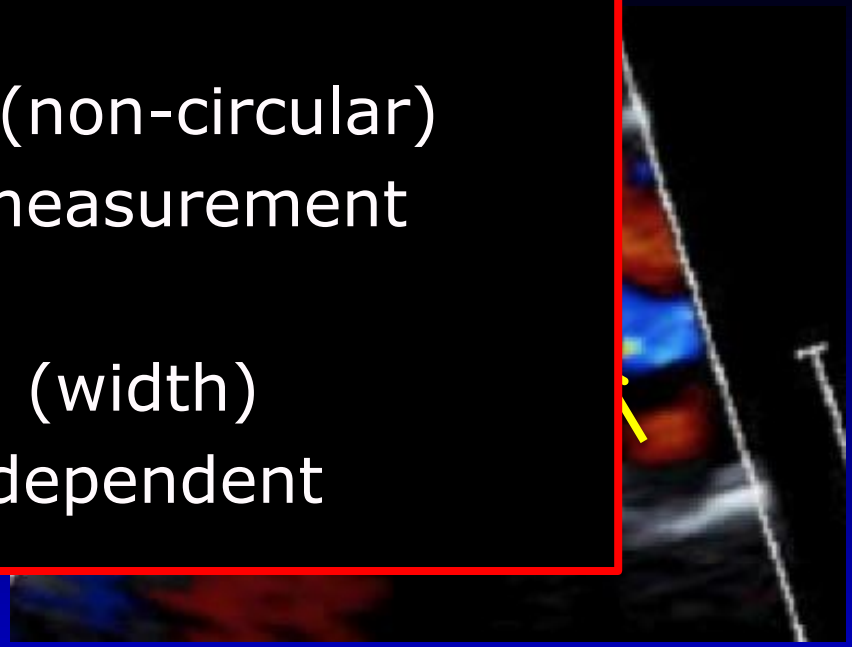
Mild	Moderate	Severe
< 0.3 cm	0.3–0.60 cm	> 0.6 cm

Zoghbi et al. JASE (2003) 16:777-802.

Sem
Vena

Pitfalls:

- Eccentric origin (non-circular)
- Imprecision of measurement
- Multiple Jets
- Variation of flow (width)
- Blood pressure dependent

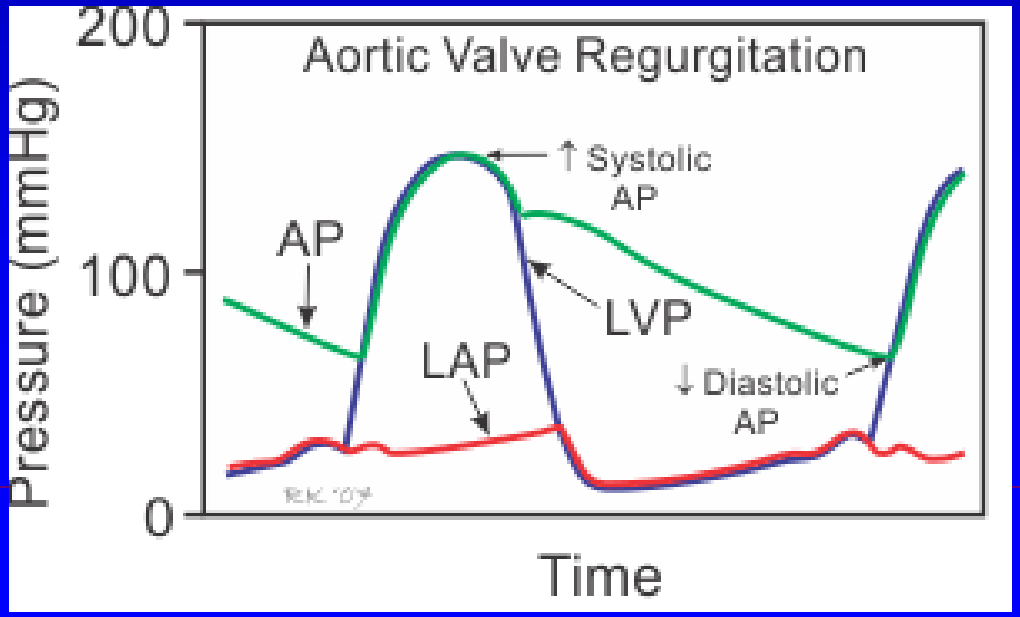


Mild	Moderate	Severe
< 0.3 cm	0.3–0.60 cm	> 0.6 cm

Zoghbi et al. JASE (2003) 16:777-802.

Continuous Wave Doppler
Slope of Diastolic Spectral Envelope

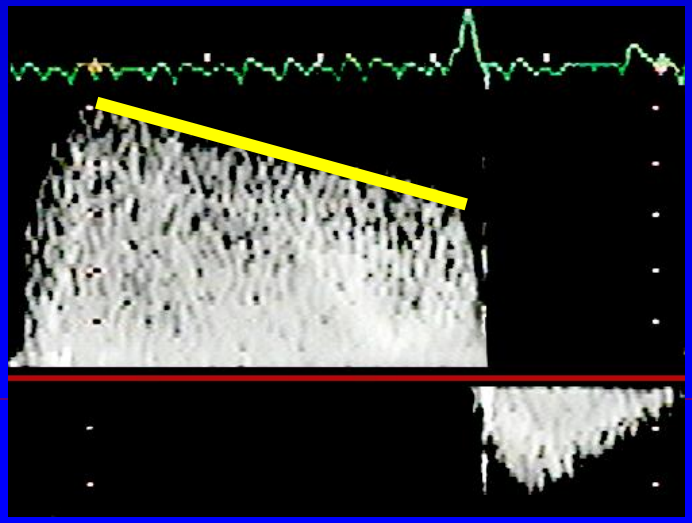
- Decrease in Ao - LV pressure gradient
  - Fall in velocity during diastole
  - Flat slope = minimal ↓ diastolic gradient
    = mild AR



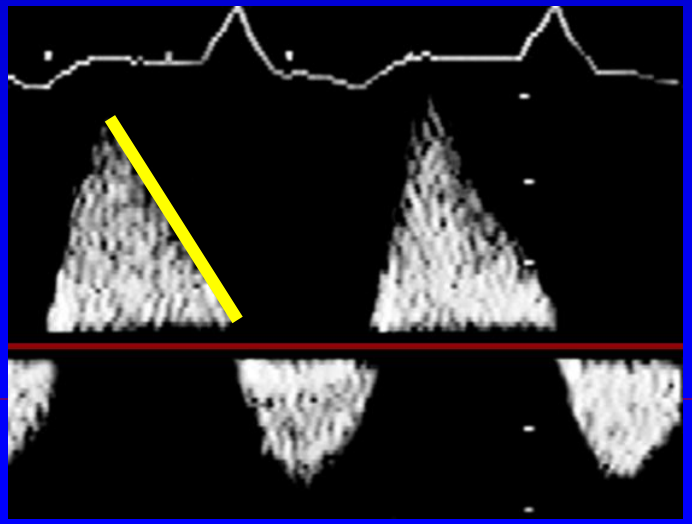
Continuous Wave Doppler
Slope of Diastolic Spectral Envelope

- Decrease in Ao - LV pressure gradient
  - Fall in velocity during diastole
  - Flat slope = minimal ↓ diastolic gradient
    = mild AR

<2.0 m/sec^2 = mild



>3.5 m/sec^2 = severe



Semi-Quantitative:
Diastolic CW Doppler Slope

AR jet	Mild	Moderate	Severe
Deceleration Slope (m/sec^2)	**< 2**	**2 – 3.5**	**> 3.5**
Pressure Half-time (msec)	**> 500**	**500-200**	**< 200**

Zoghbi et al. JASE (2003) 16:777-802.

Sem
Dias

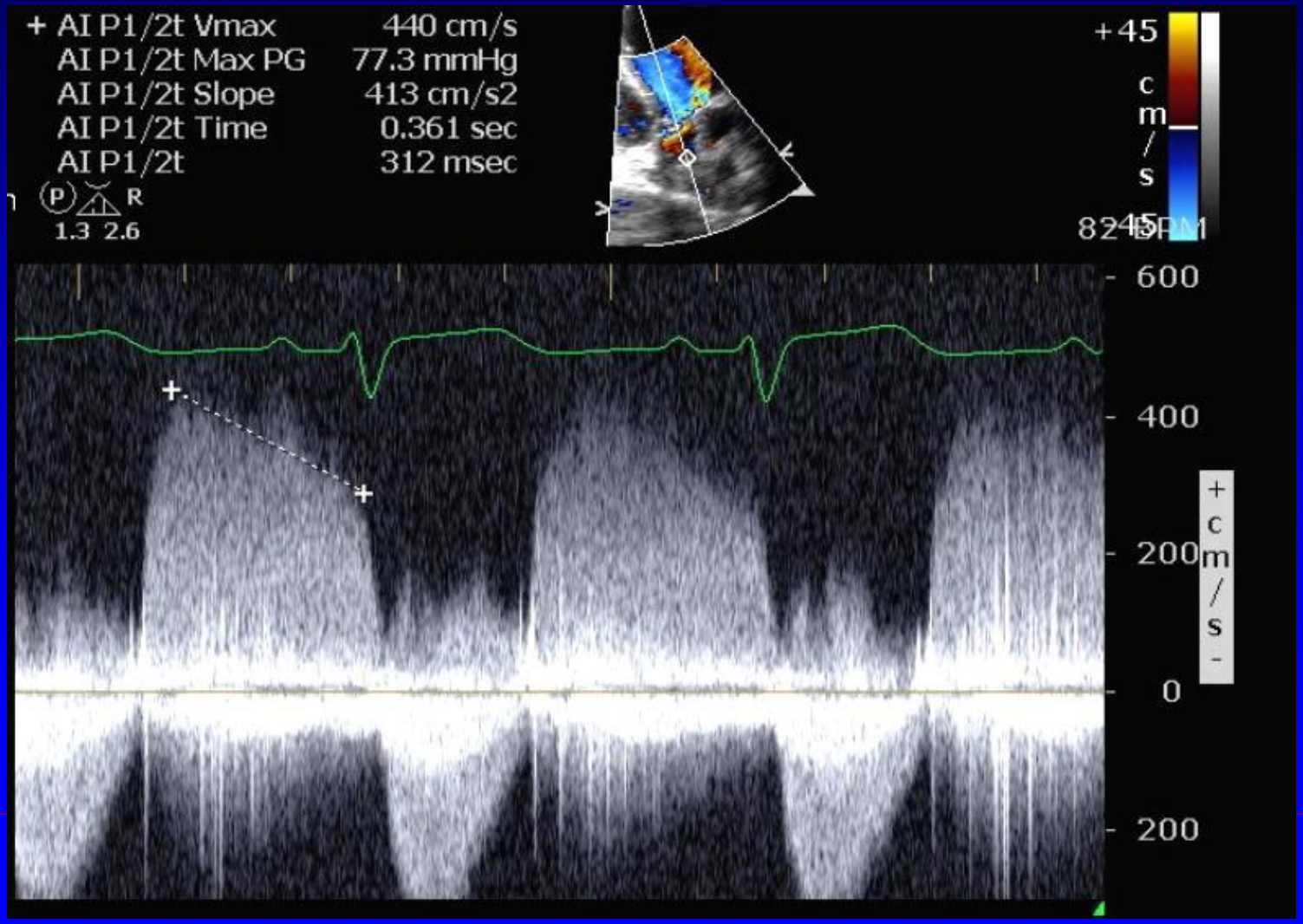
Pitfalls:

- Poor (fuzzy) Doppler envelope
- Some severe AR have long $P_{½}$
- Low SVR decreases $P_{½}$
- Severe MR decreases $P_{½}$
- Restrictive filling decreases $P_{½}$

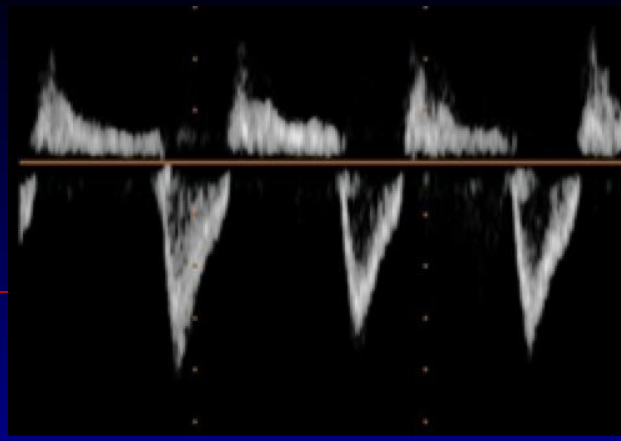
A			evere
Deceleration Slope (m/sec^2)	**< 2**	**2 – 3.5**	**> 3.5**
Pressure Half-time (msec)	**> 500**	**500-200**	**< 200**

Zoghbi et al. JASE (2003) 16:777-802.

Don’t let this happen to you!!



Qualitative Doppler:
Desc. Aorta Flow Reversal



Mild	Moderate	Severe
Brief, Early Diastolic	**Intermediate, Early-Mid Diastolic**	**Prominent, Holodiastolic**

Zoghbi et al. JASE (2003) 16:777-802.

Quantitative Doppler for AR
Volumetric Calculations

Can also use mitral inflow instead

- **Regurgitant volume**
  - $SV_{LVOT} - SV_{RVOT}$
  - $\{[\pi/4 * (LVOT_{diam})^2]*VTI_{LVOT}\} - \{[\pi/4 * (RVOT_{diam})^2]*VTI_{RVOT}\}$
- **Regurgitant Fraction**
  - RF = Regurgitant Volume / SV_{LVOT}
- **Effective Regurgitant Orifice Area**
  - EROA = Regurgitant volume/VTI_{AR}

Quantitative Doppler for AR
Volumetric Calculations

- Benefits:
  - Correlates well with CMR volumetrics
  - Multiple jets no problem
  - Spectral flow better than color Doppler

- Pitfalls:
  - Use of mitral inflow requires too many assumptions
  - Measuring RVOT flow and dimensions difficult
  - Presence of AS confounds (LVOT acceleration)
  - Inaccurate with >moderate MR or PR/PS

Quantitative Doppler *Regurgitant Volume*

Mild	Moderate		Severe
	Mild–Moderate	Moderate–Severe	
< 30 cc	30–44 cc	45–59 cc	≥ 60 cc

Zoghbi et al. JASE (2003) 16:777-802.

Quantitative Doppler *Regurgitant Fraction*

Mild	Moderate		Severe
	Mild–Moderate	Moderate–Severe	
< 30%	30–39%	40–49%	≥ 50%

Zoghbi et al. JASE (2003) 16:777-802.

Quantitative Doppler
Regurgitant Orifice Area

Mild	Moderate		Severe
	Mild–Moderate	Moderate–Severe	
< 10 mm^2	10–19 mm^2	20–29 mm^2	≥ 30 mm^2

Zoghbi et al. JASE (2003) 16:777-802.

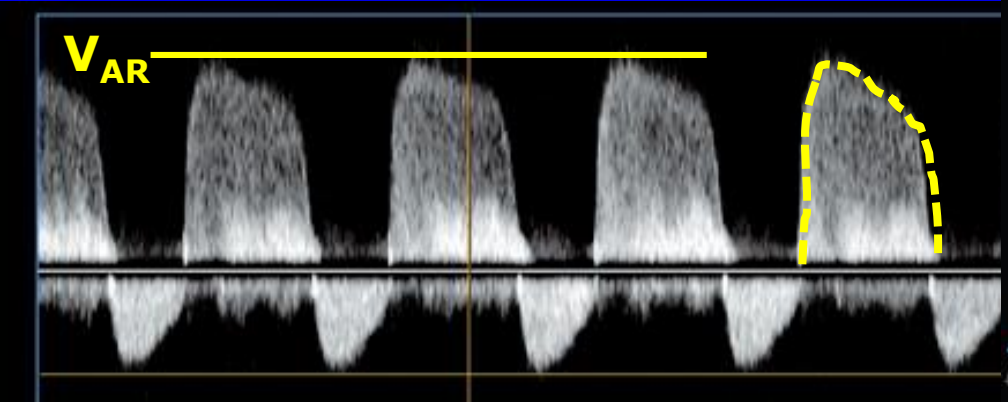
Quantitative Doppler for AR
PISA is Possible (…but unlikely)

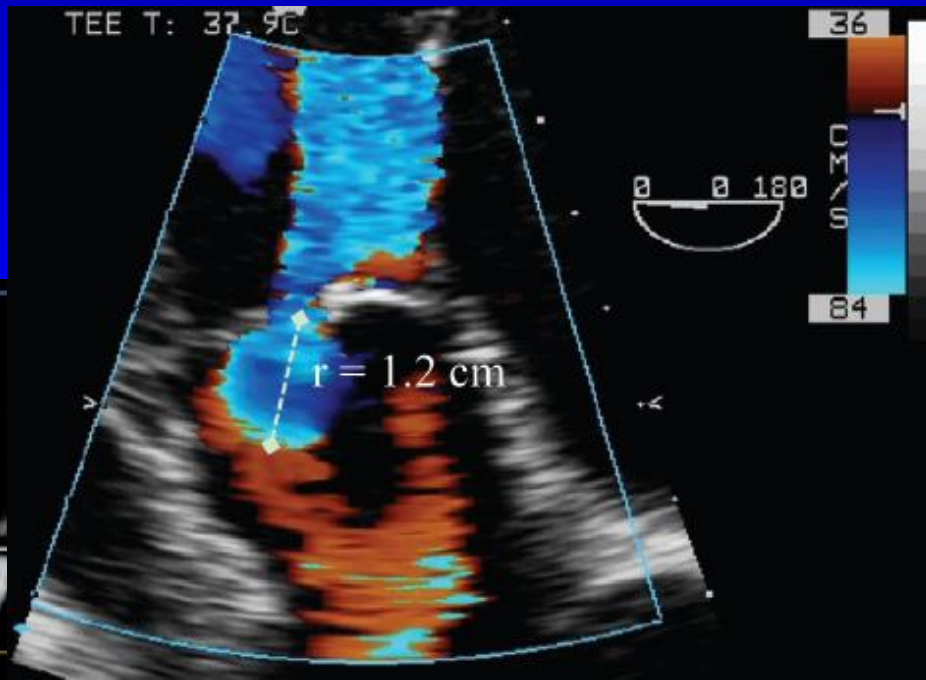
$$\text{Surface Area}_{alias} * \text{Vel}_{alias} = \text{EROA}_{AR} * \text{Vel}_{AR}$$

$$[2\pi * r_{alias}^2] * \text{Vel}_{alias} = \text{EROA}_{AR} * \text{Vel}_{AR}$$

Regurgitant volume =

$$\text{EROA} * \text{VTI}_{AR}$$





WHY DO WE CARE ABOUT THIS??

Timing of Surgical Intervention

Appropriate Patient Follow Up

Passing Echo Board Exams

Aortic Regurgitation: *Summary*

- Progressive, asymptomatic disease
  - Rate of progression varies individually
  - Close clinical and echo follow up essential
- Medical treatment options are limited
- Symptoms indicate need for surgery
- Severity of AR and LV functional indices
  - **KEY** parameters in asymptomatic patients

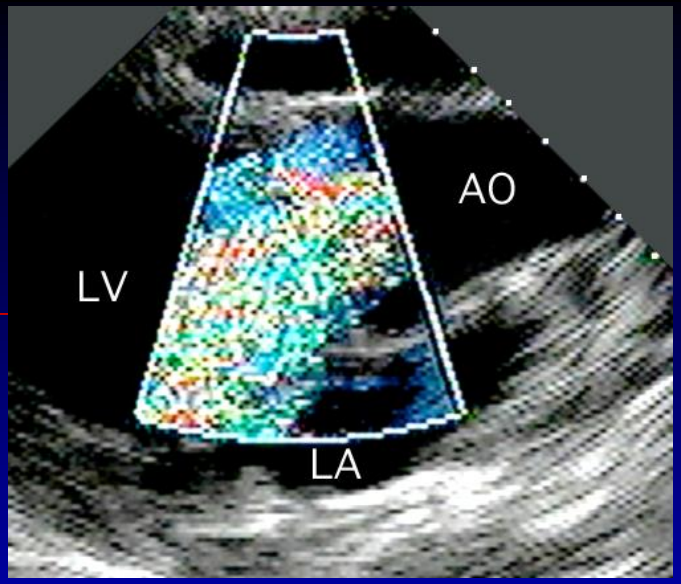
Aortic Regurgitation: *Summary*

- An **INTEGRATIVE** approach is required

	Mild	Moderate		Severe
Specific signs for AR severity	• Central Jet, width < 25% of LVOT[ζ] • Vena contracta < 0.3 cm[ζ] • No or brief early diastolic flow reversal in descending aorta	Signs of AR>mild present but no criteria for severe AR		• Central Jet, width ≥ 65% of LVOT[ζ] • Vena contracta > 0.6cm[ζ]
Supportive signs	• Pressure half-time > 500 ms • Normal LV size*	Intermediate values		• Pressure half-time < 200 ms • Holodiastolic aortic flow reversal in descending aorta • Moderate or greater LV enlargement**
Quantitative parameters[ψ]				
R Vol, ml/beat	< 30	30-44	45-59	≥ 60
RF, %	< 30	30-39	40-49	≥ 50
EROA, cm^2	< 0.10	0.10-0.19	0.20-0.29	≥ 0.30

Zoghbi et al. JASE (2003) 16:777-802.

Review Question #1



- Possible reasons that this color Doppler evaluation may overestimate AR include:

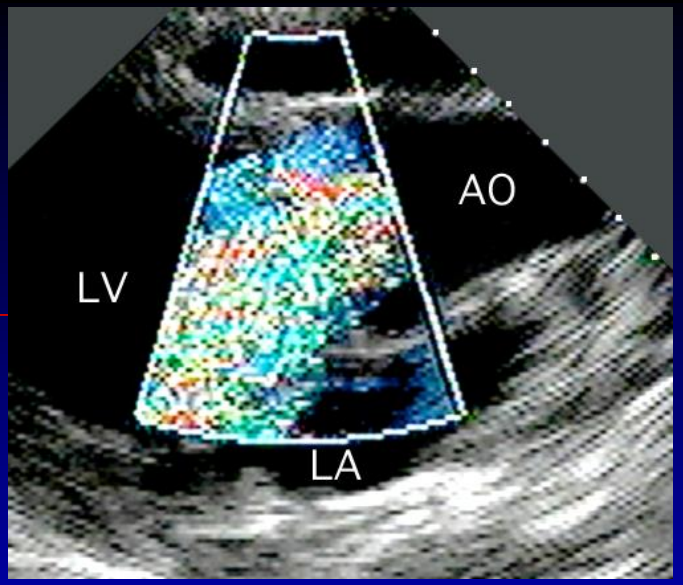
A. Low color Doppler gain setting

B. Use of too small a color Doppler sector

C. Low Nyquist velocity setting

D. High pulse repetition frequency (PRF)

Review Question #1 Answer:



- Possible reasons that this color Doppler evaluation may overestimate AR include:

A. Low color Doppler gain setting

B. Use of too small a color Doppler sector

C. Low Nyquist velocity setting

D. High pulse repetition frequency (PRF)

Review Question #2

- Which condition may lead to over-estimation of AR severity by deceleration slope (or P1/2) of diastolic Continuous Wave (CW) Doppler:

A. Advanced restrictive myocardial disease

B. Severe mitral valve stenosis

C. Severe aortic valve stenosis

D. Low Nyquist limit setting

Review Question #2

- Which condition may lead to over-estimation of AR severity by deceleration slope (or P1/2) of diastolic Continuous Wave (CW) Doppler:

A. Advanced restrictive myocardial disease

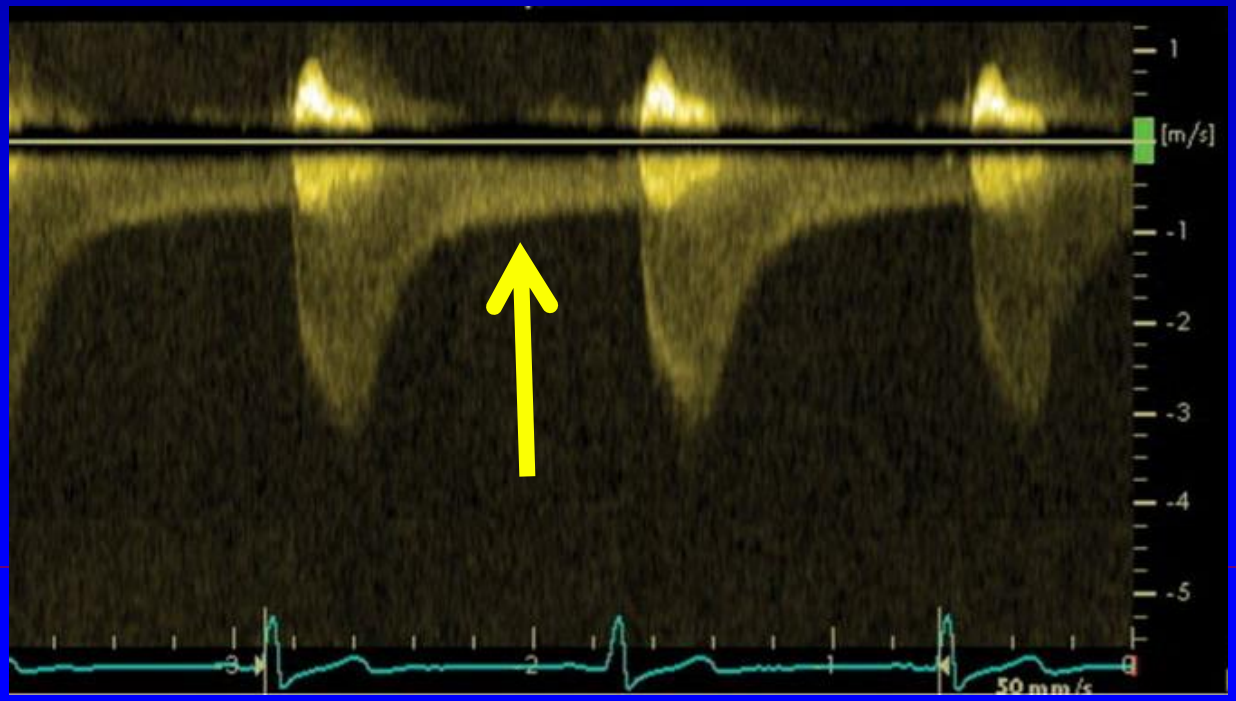
B. Severe mitral valve stenosis

C. Severe aortic valve stenosis

D. Low Nyquist limit setting

Review Question #3

- A continuous wave Doppler cursor is placed at the junction of the aortic arch and proximal descending aorta, just beyond the left subclavian artery. The following is obtained:



Review Question #3

- The etiology of the diastolic Doppler flow indicated by the arrow is:

A. Stenosis of the left subclavian artery

B. Severe aortic regurgitation

C. Moderate aortic regurgitation

D. Severe coarctation of the aorta

Review Question #3

- The etiology of the diastolic Doppler flow indicated by the arrow is:

A. Stenosis of the left subclavian artery

B. Severe aortic regurgitation

C. Moderate aortic regurgitation

D. Severe coarctation of the aorta

Thank You!