Valvular Regurgitation: Can We Do Better Than Colour Doppler?

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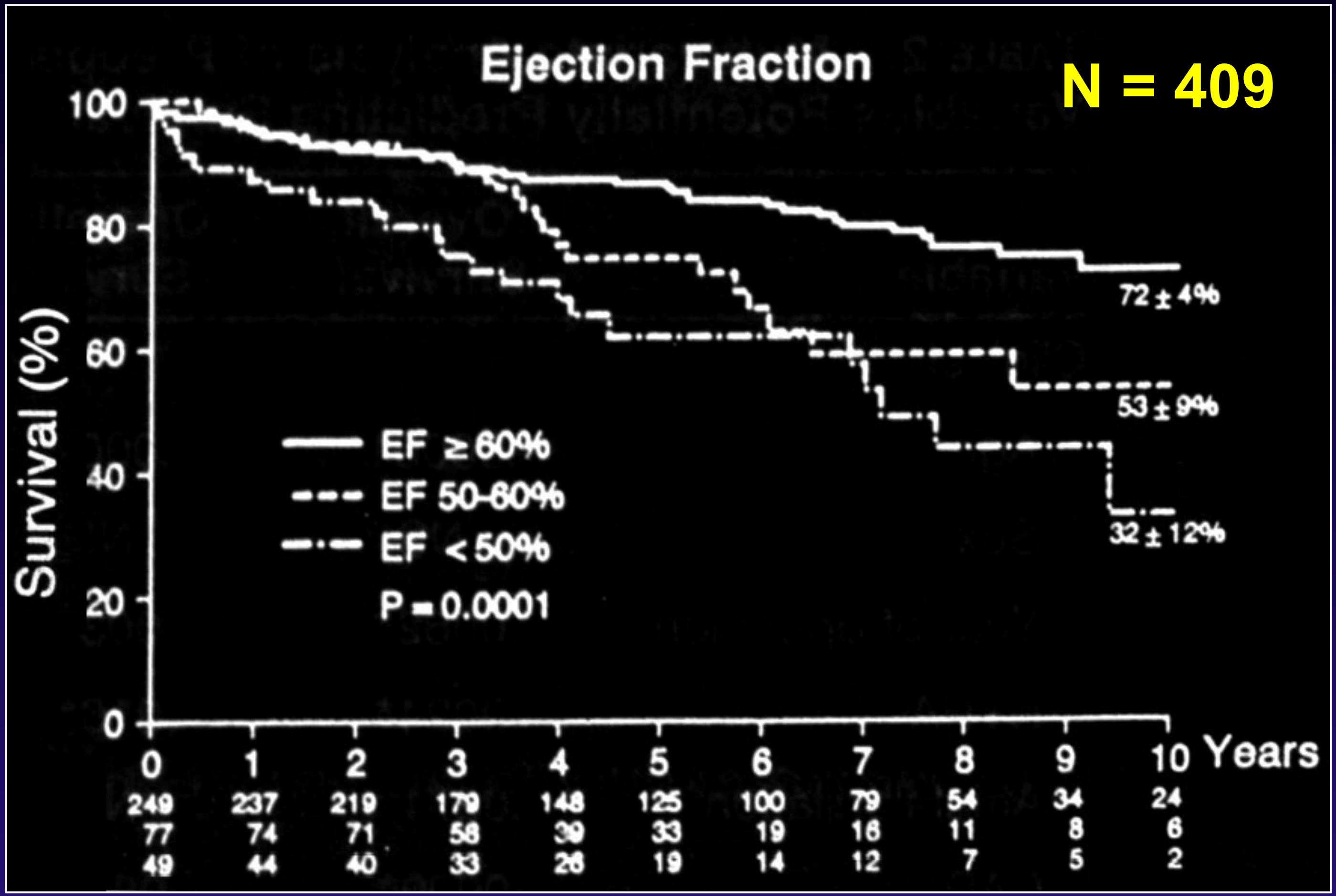
Valvular Regurgitation

- Valve regurgitation volume loads the ventricles
- Chronic volume loading may lead to ventricular dysfunction
- Irreversible ventricular dysfunction may precede the development of symptoms
- ie You may miss the boat if you wait for symptoms

Mitral Regurgitation
Impact of pre-op LVEF

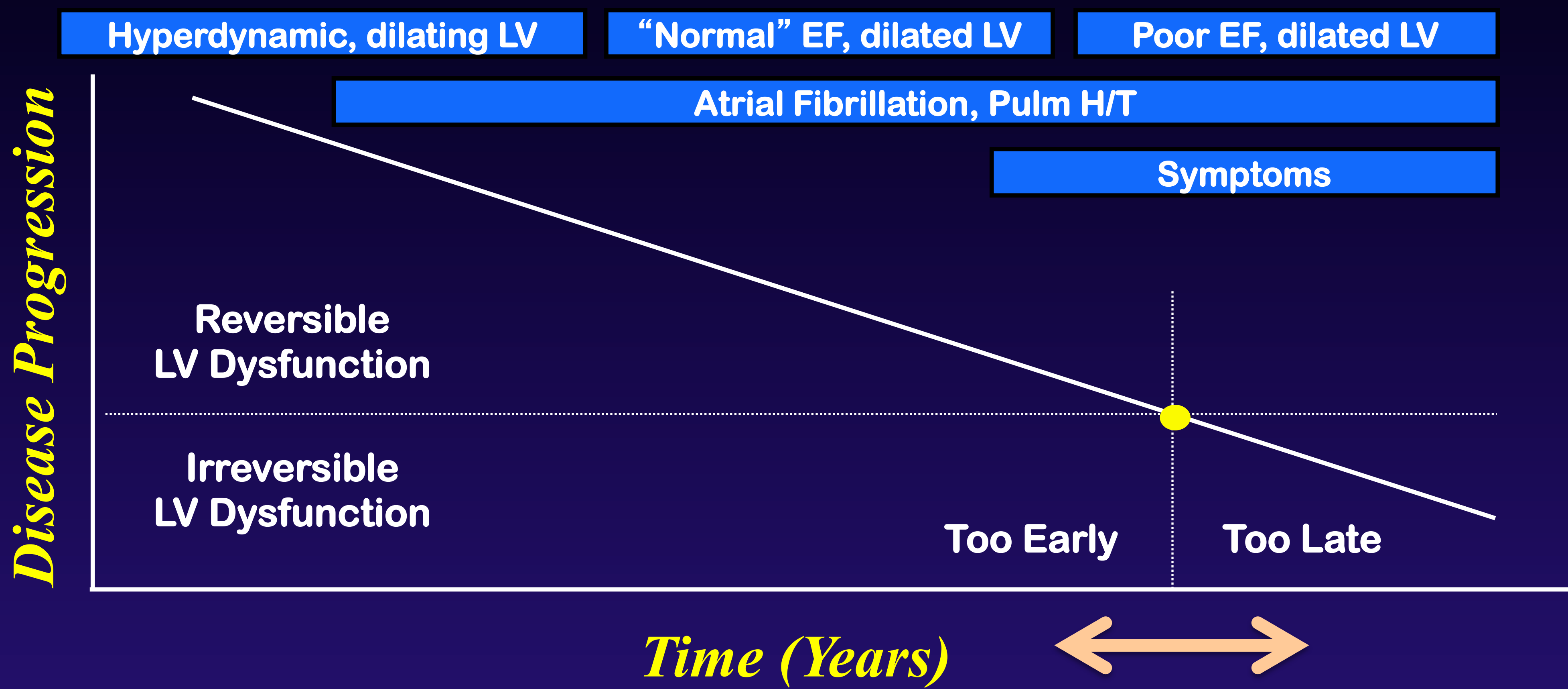


Enriquez-Serrano, *Circulation* 1994;90:830

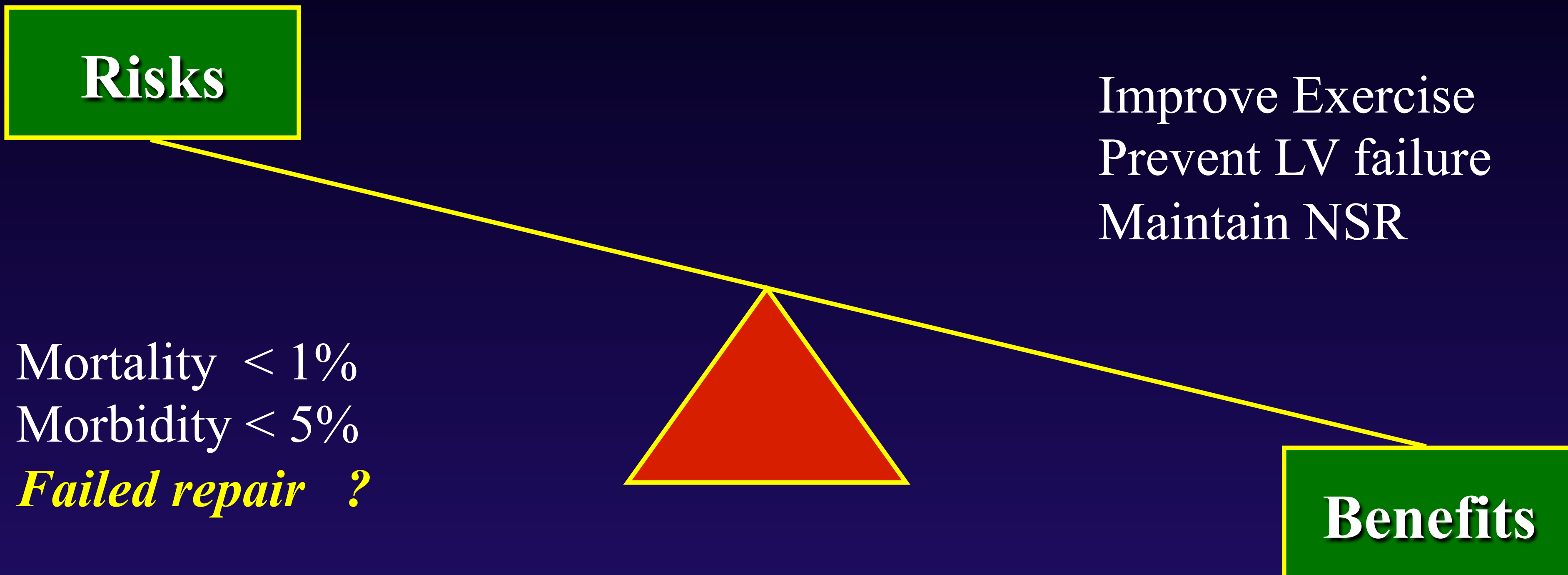
Key Clinical Decisions

- Is the mitral regurgitation clinically significant?
  - How severe?
- Is the patient symptomatic?
- Is ventricular function affected?
- If regurgitation is severe, but the patient is asymptomatic – when is the right time for surgery?
- If regurgitation is not severe – how do we monitor this in the future?

Optimal timing for surgery



When to operate?



Echo Assessment of Regurgitation

- Assessing the mechanism of regurgitation
- Determining the severity of regurgitation:
  - qualitative and quantitative
- Assessing the hemodynamic consequences of regurgitation
  - LV size and function, LA size, PA pressure

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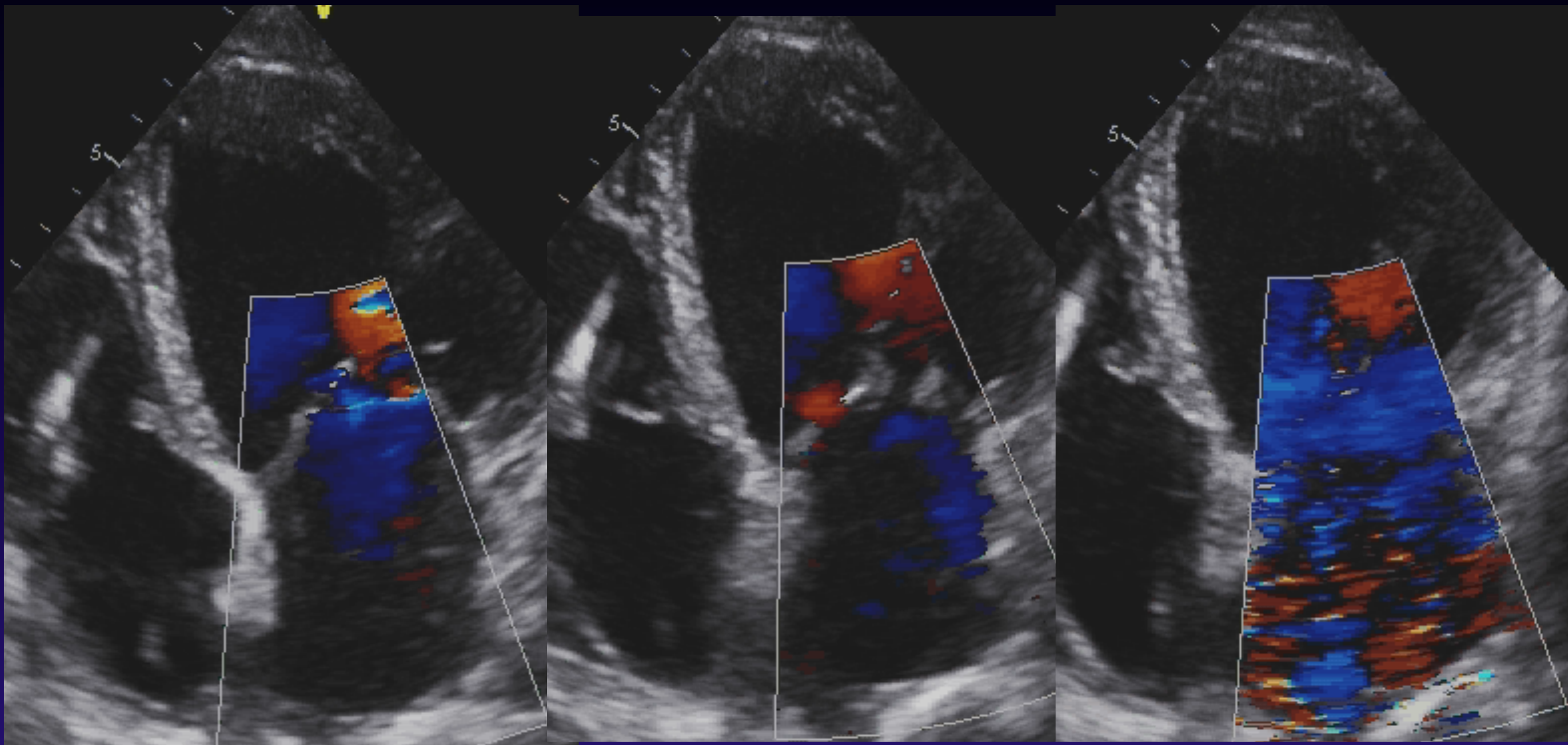
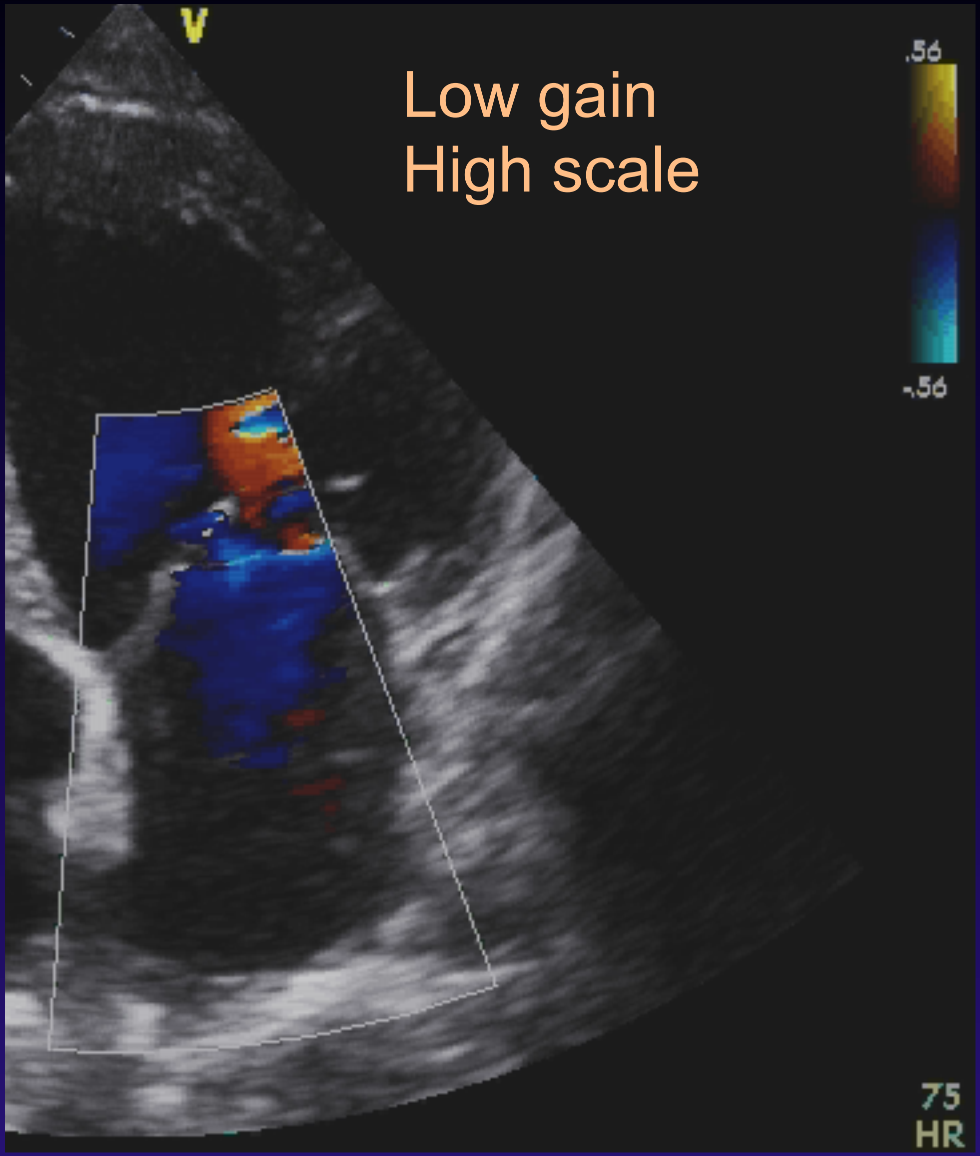
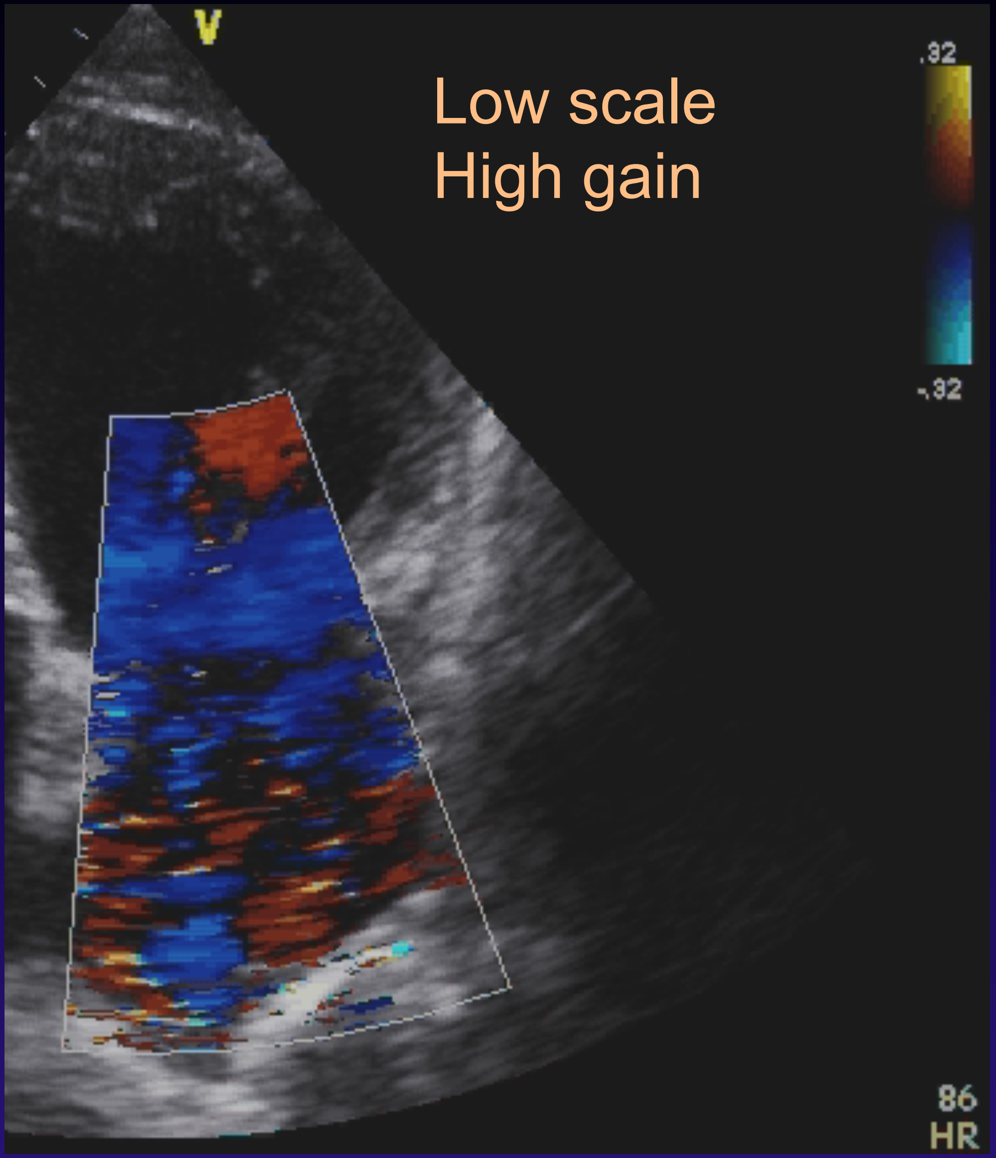
Who Has The Most Regurgitation?



It’s The Same Patient



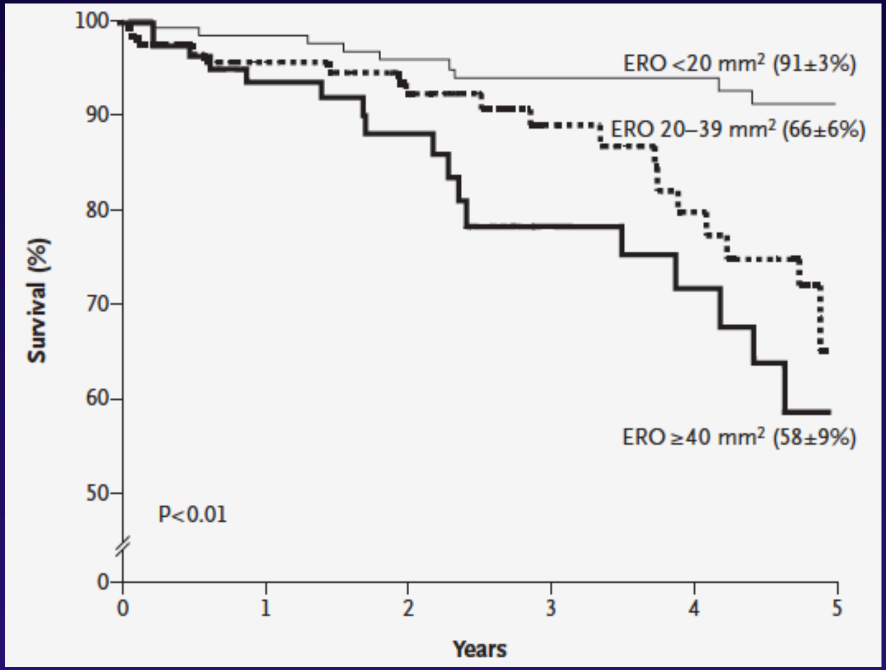


Factors Which Affect Regurgitant Jet Size

- Instrumentation
  - Doppler frequency, Nyquist limit, gain
- Eccentricity leading to jet distortion
- Haemodynamics – driving pressure
- Chamber compliance

Valvular Regurgitation

- Severity of regurgitation is a key determinant of the load on the ventricle
- The size of the regurgitant orifice affects prognosis



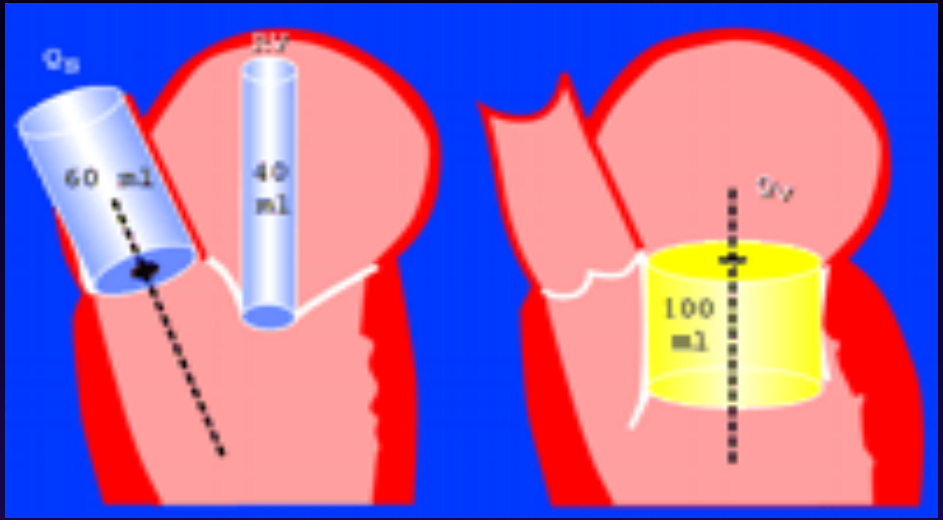
Enriquez-Serrano, *NEJM* 2005 352:875

Quantitative Measures Of Valve Regurgitation

- Vena Contracta Size
  - 2d
  - 3d
- Regurgitant Orifice Area
  - PISA
  - Volumetric Flow

Key Quantitative Parameters

- Regurgitant Volume
  - the volume of blood which flow backwards through the leaky valve
- Regurgitation Fraction
  - the percentage of the total stroke volume which flow backwards
- (Effective) Regurgitant Orifice Area
  - the effective area of the leak



RV = 40 ml

RF = 40%

Quantitative Assessment Of The Mitral Valve

Vena Contracta Width

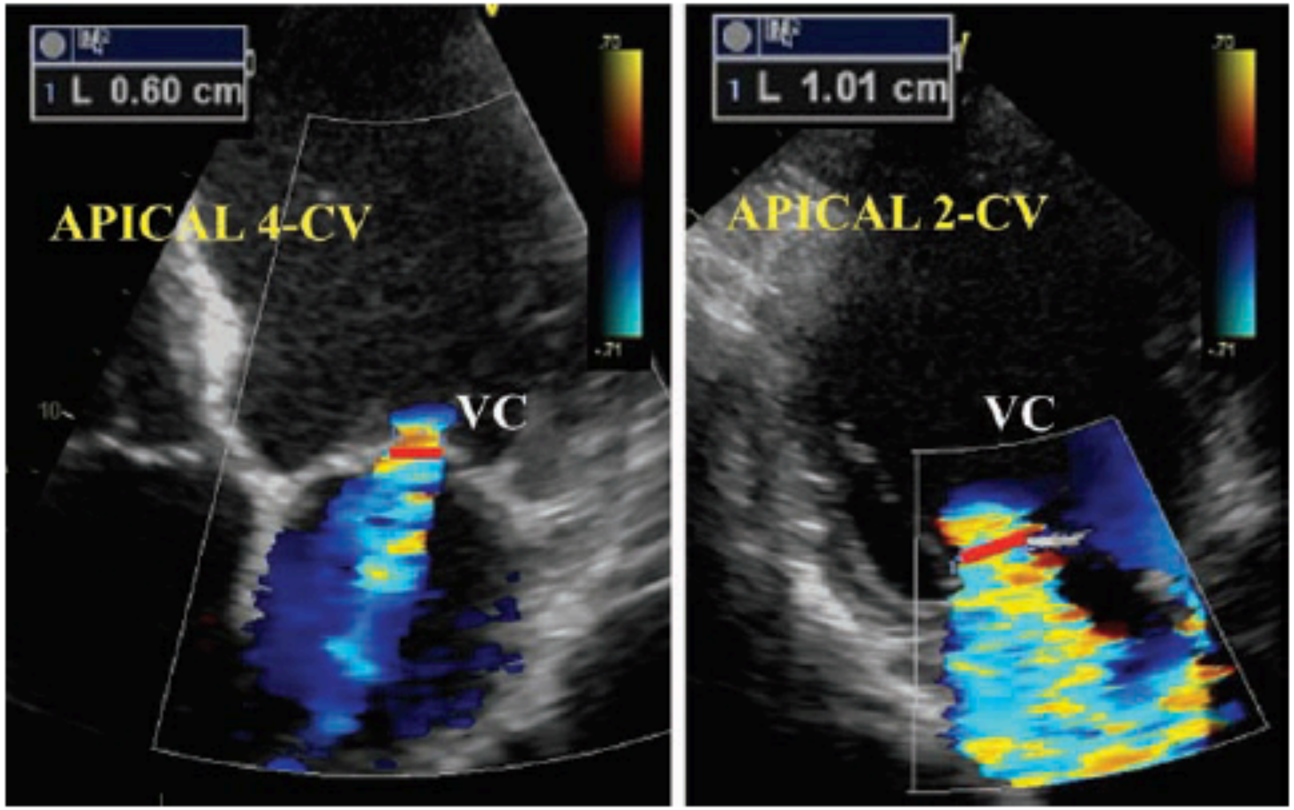


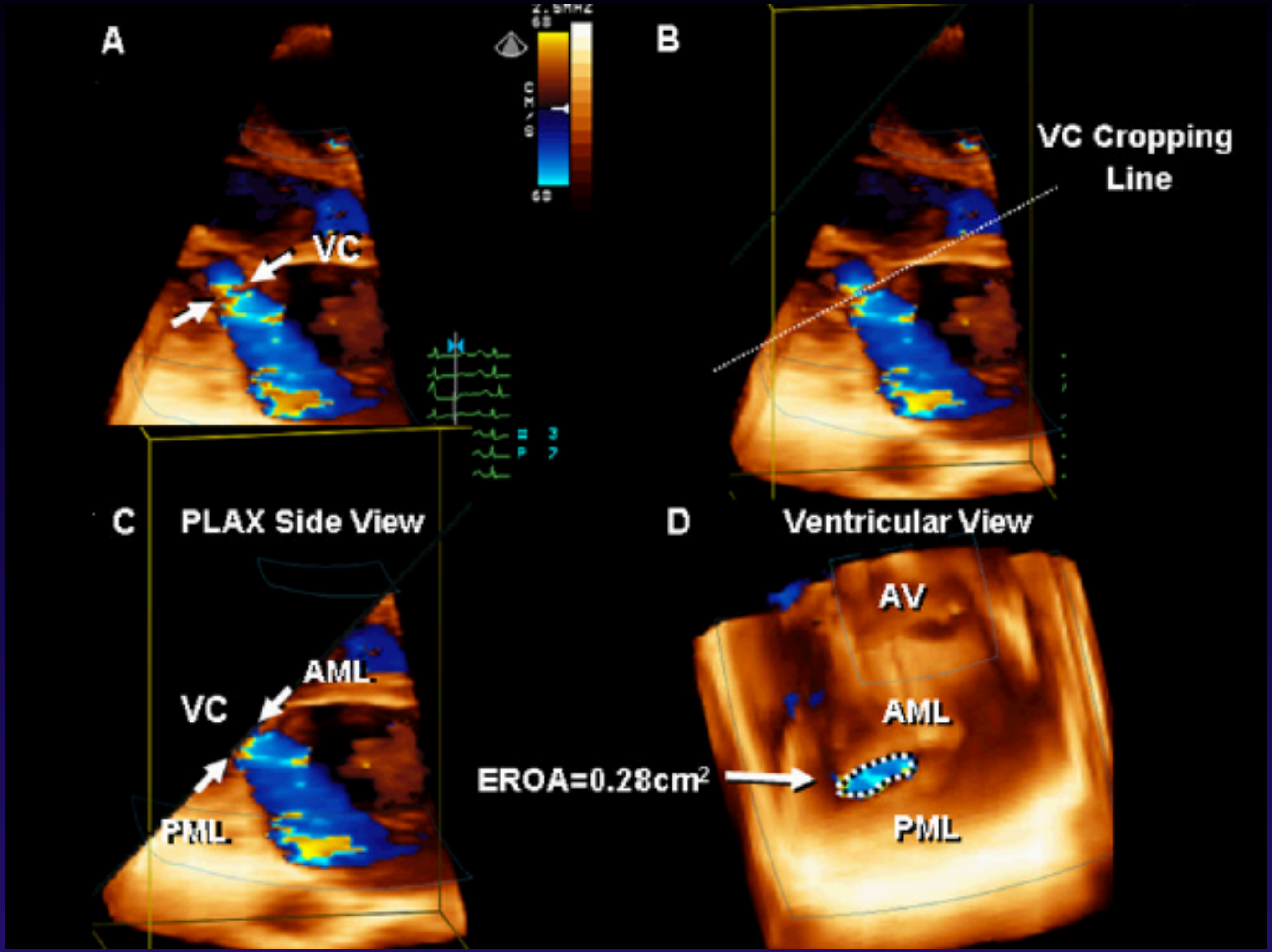
Figure 23 Semi-quantitative assessment of MR severity using the vena contracta width (VC) obtained from the apical four-chamber and two-chamber views (CV) in a patient with ischaemic functional MR. The mean vena contracta is calculated (6+10/2 = 8 mm).

Lancellotti, *EHJ-CVI* 2013 14:611

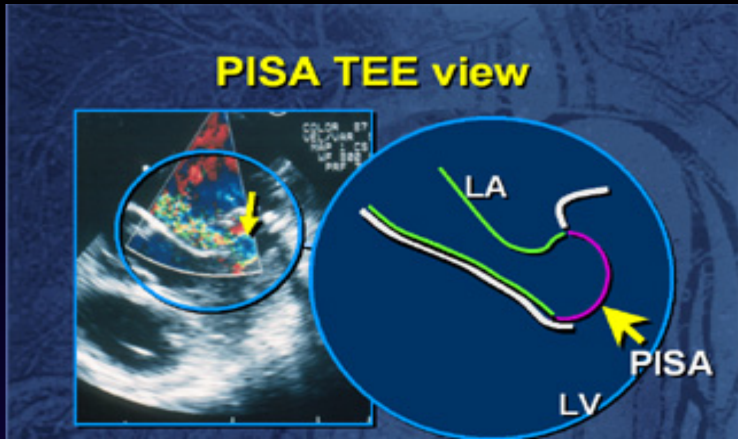
Vena Contracta Width

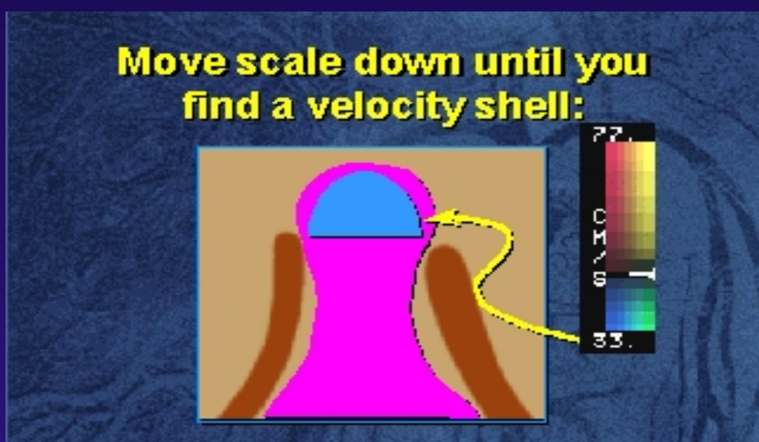
- Remains valid with eccentric jets
- Can be technically challenging
- Problematic with multiple jets
- ?Benefit with 3-D vena contracta

Vena Contracta by 3-D

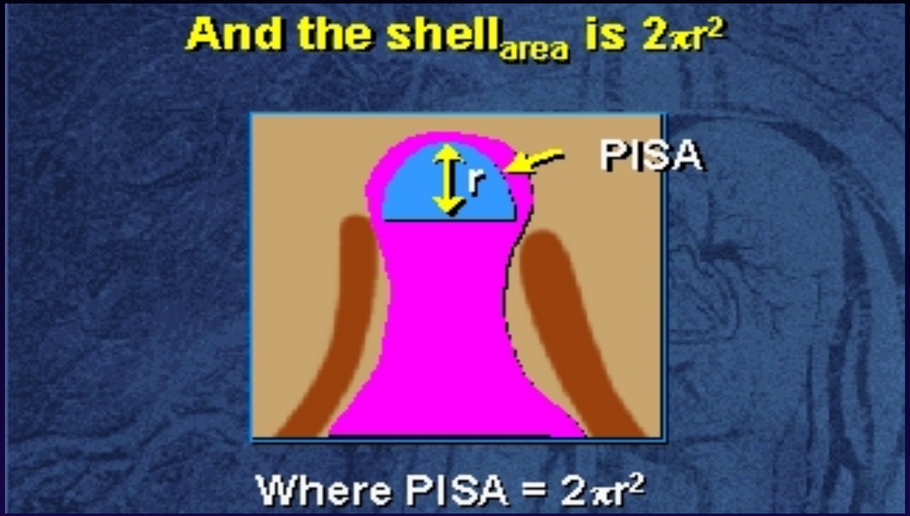


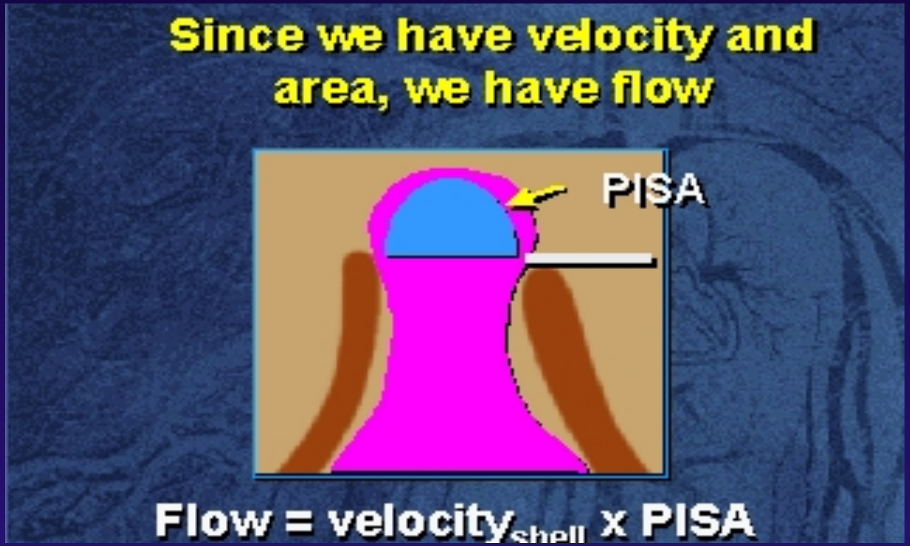
Yosefy *Am J Card* 2009 104:978





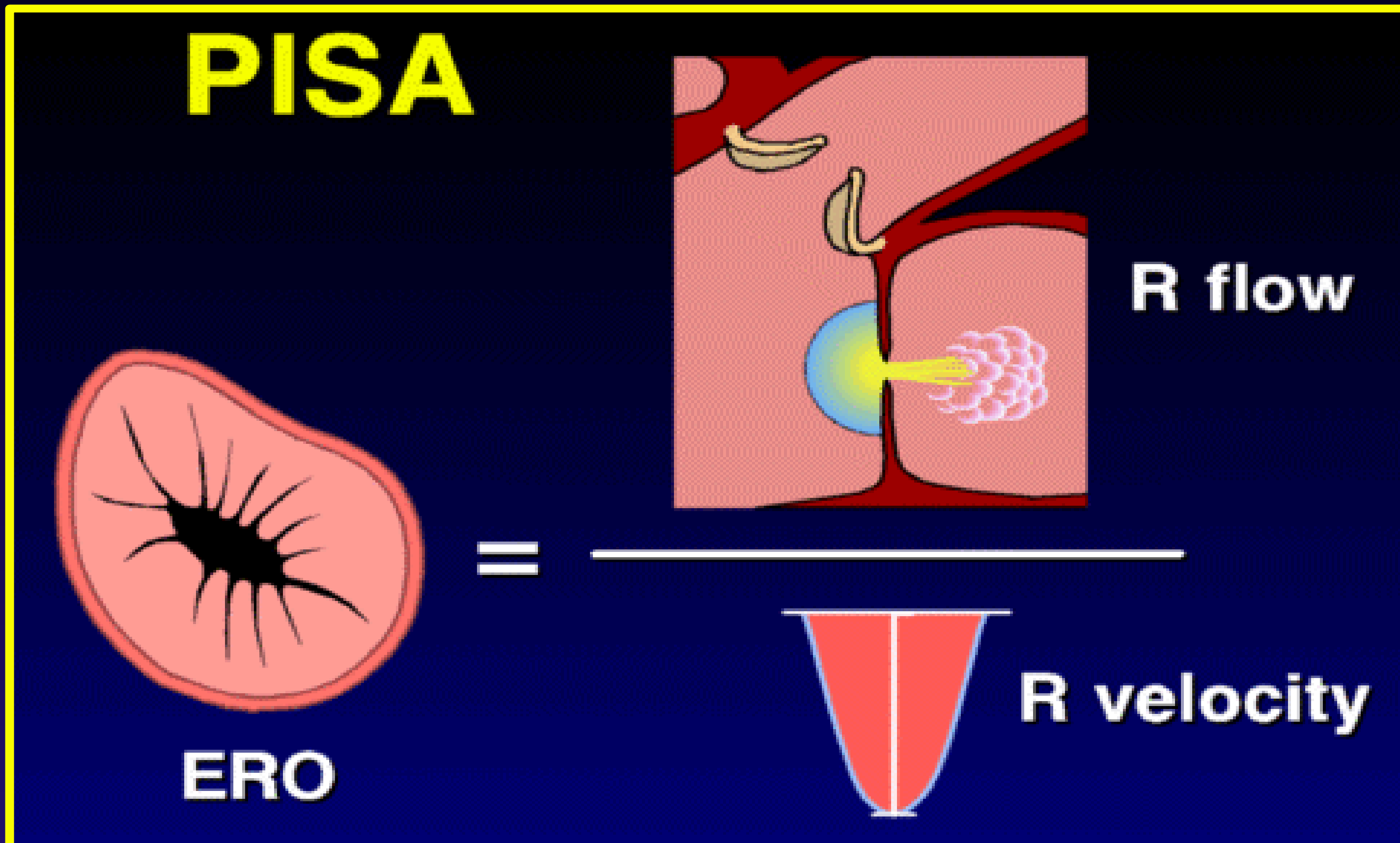
- Proximal Isovelocity Surface Area
  - Blood converges towards orifice.
  - Doppler flow imaging reveals concentric hemispheric shells, representing isovelocity surfaces.
  - As blood accelerates towards orifice, *velocity aliasing* occurs, and distinct red-blue interface occurs at shell boundary.
    - The velocity is equal to the *Nyquist limit*.
    - Adjust the Nyquist limit to optimise shell size.
    - Calculate shell surface area = $2\pi r^2$





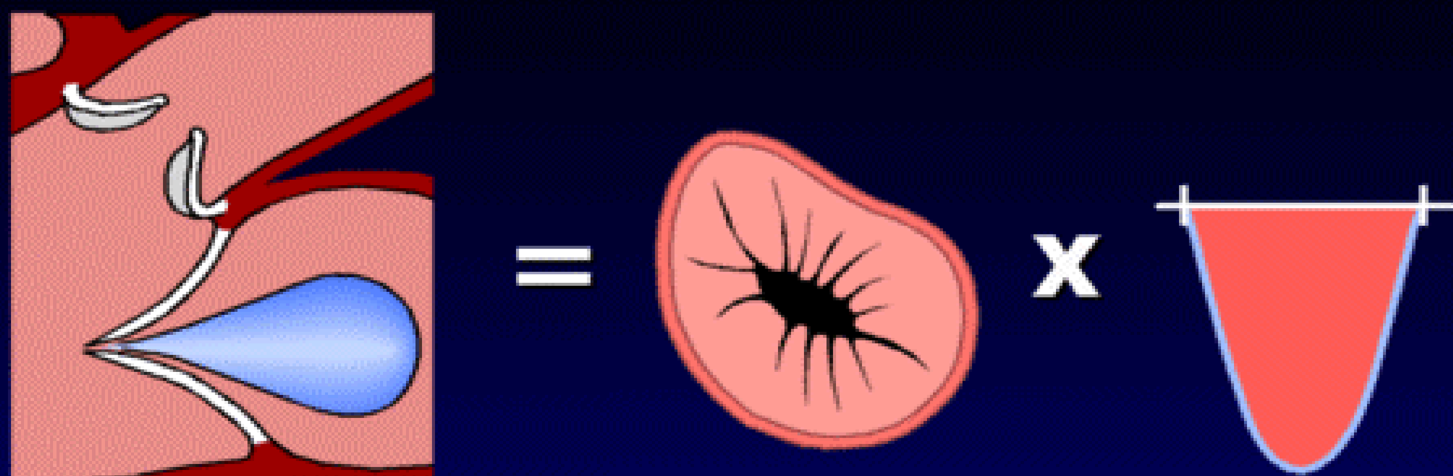
- Flow rate through any given shell equals flow rate through orifice (continuity equation).
  - FR = aliasing velocity x 6.28 x r^2 (PISA).
- Flow rate = ERO x $velocity_{jet}$
  - $Velocity_{jet}$ obtained by CW.
  - ERO – effective regurg orifice area
- ERO = Flow rate ÷ $velocity_{jet}$
- Regurg. vol. = ERO x TVI_{MR}

Regurgitant orifice



Regurgitant volume

PISA



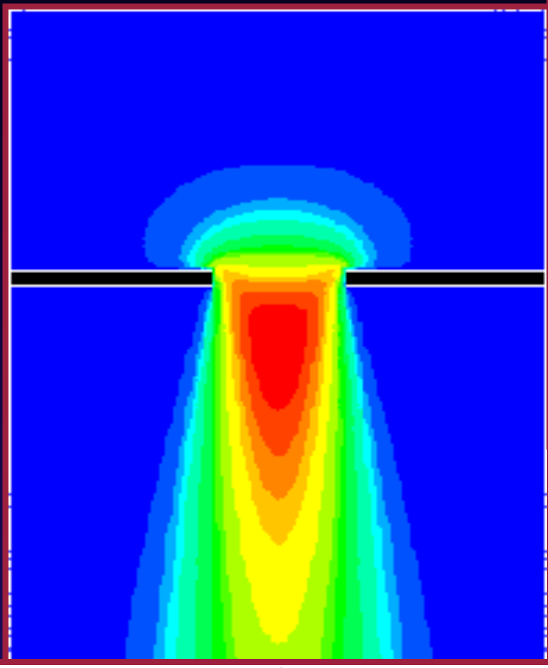
R volume = ERO x RTVI

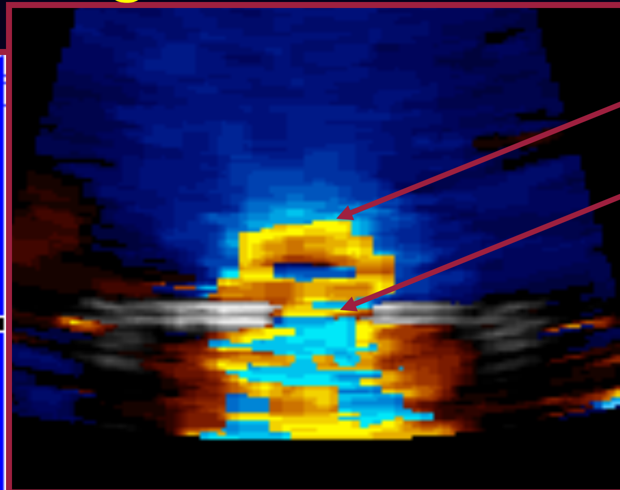
Limitations of PISA Method

- Irregular orifice shape – may be helped by 3-D
- Flattening of the contours near the orifice.
  - Loss of hemispheric shape.
- Constraint of flow by proximal structures.
  - Affects ability to form hemisphere.
- Uncertainty in localising regurgitant orifice.
  - An issue as you square the area in the PISA formula.
- Variability in regurgitant orifice through cardiac cycle.
- Multiple jets

Sources of Error with PISA

Contour Flattening Near the Orifice



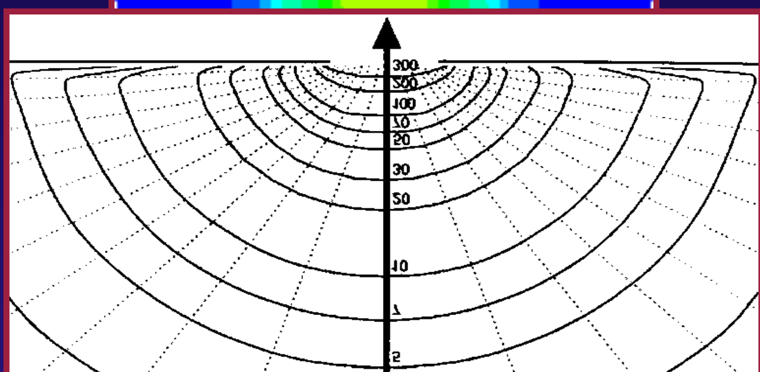


Contour velocity: v_a

Orifice velocity: v_0

Conventional PISA

$$Q = 2\pi r^2 v_a$$

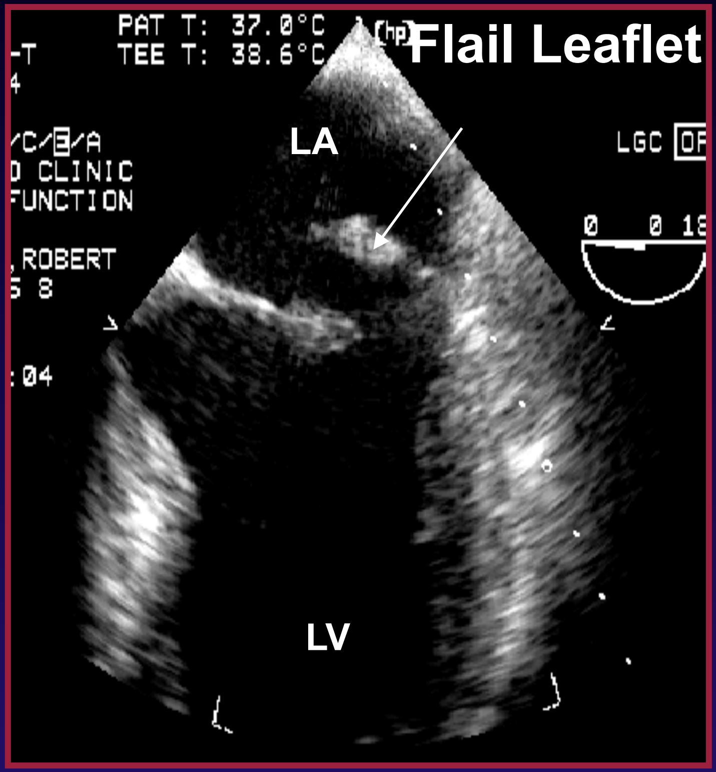


Flow underestimated by v_a/v_0

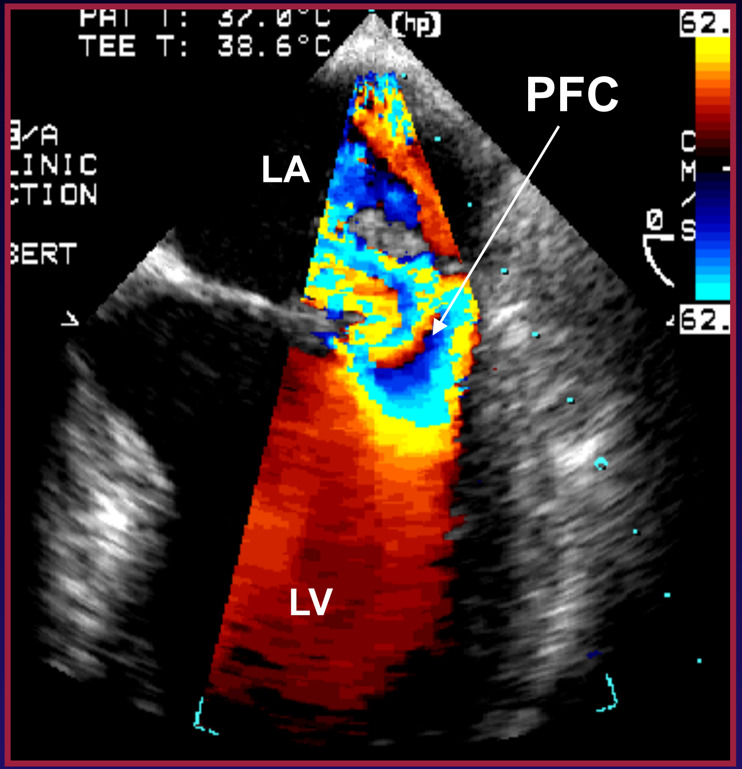
Ensure the hemisphere is large enough to minimize this

Sources of Error with PISA

Proximal Flow Constraint by Surrounding Structures



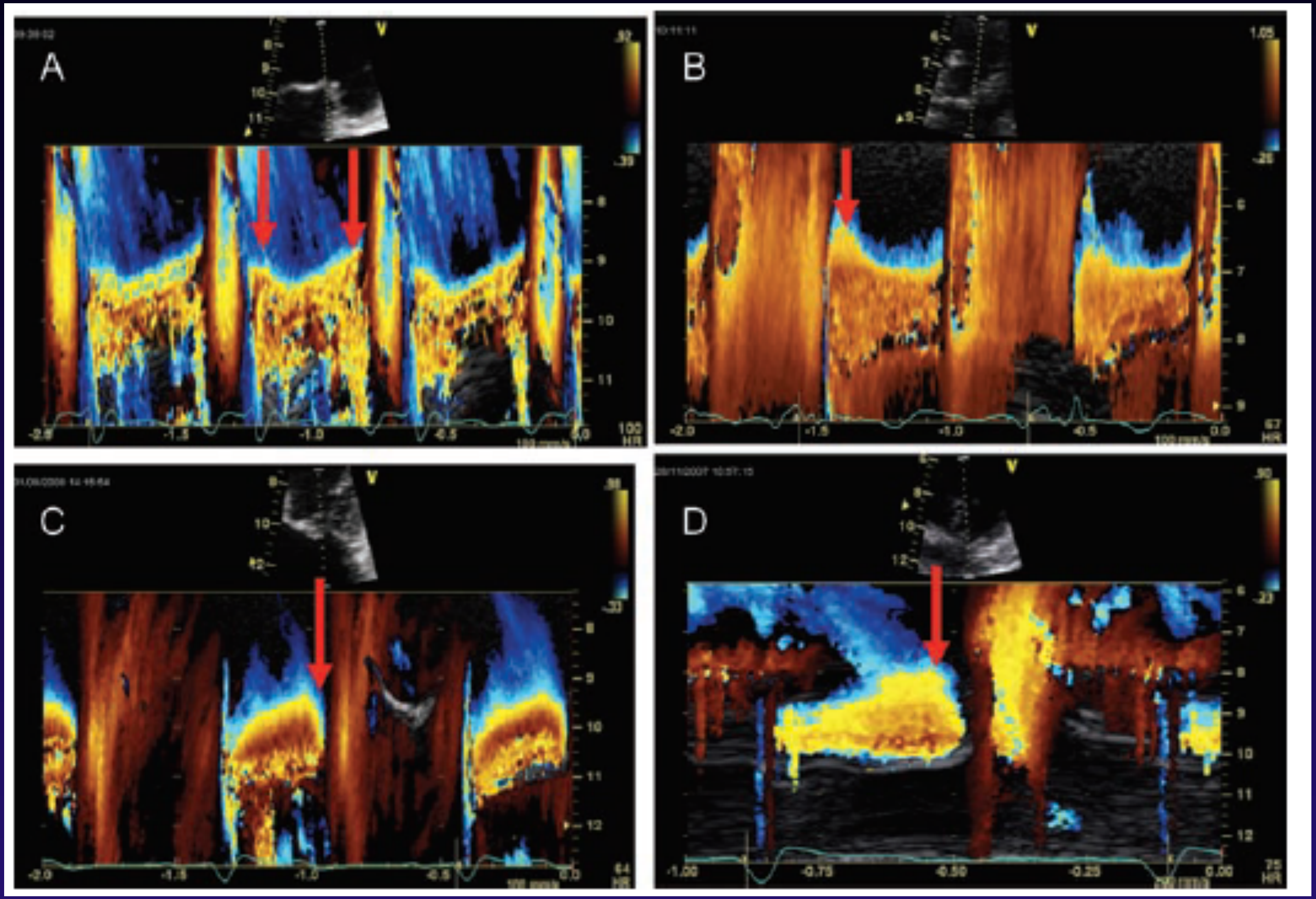
Flail Leaflet



Wall Constraint

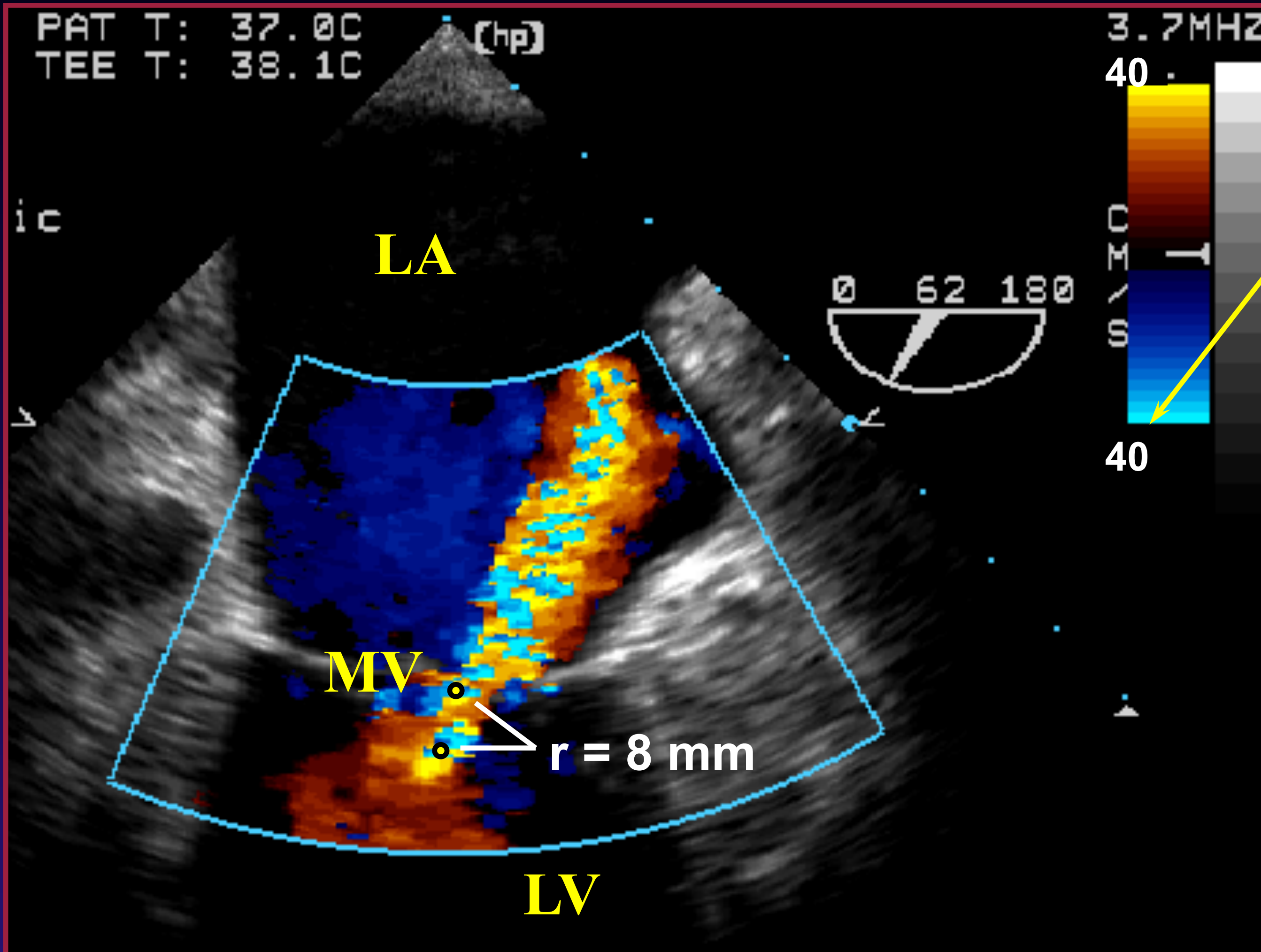
Sources of Error with PISA

Variable Orifice Size



Lancellotti, *EHJ-CVI* 2013 14:611

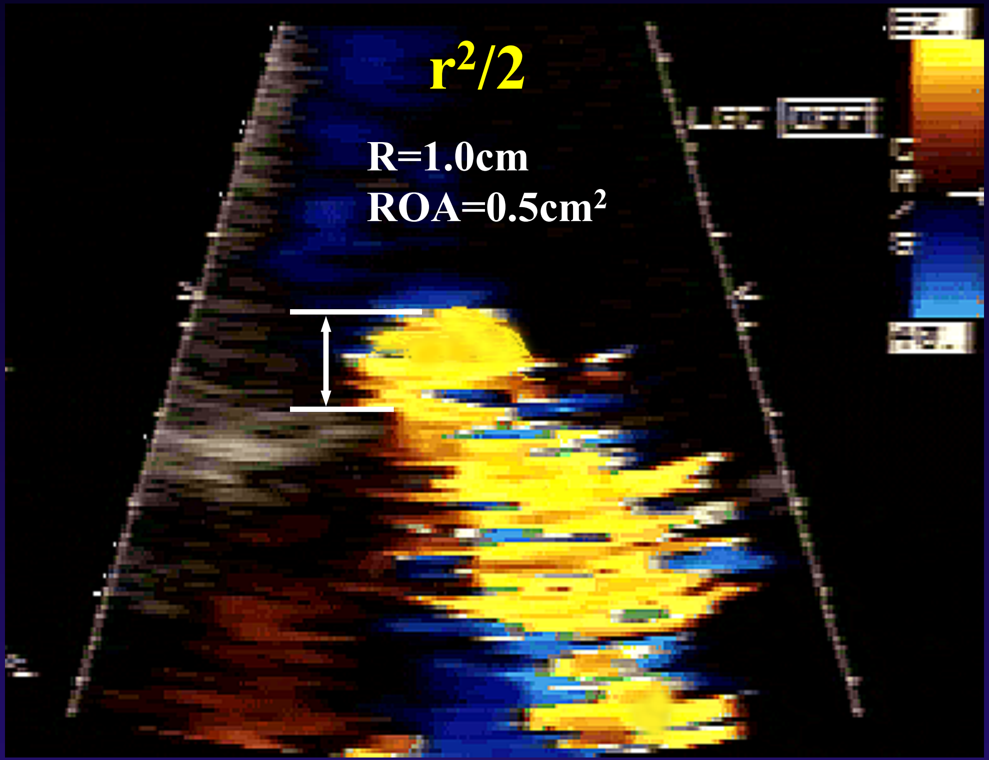
Measurement of Mitral ROA
Simplified PISA Formula

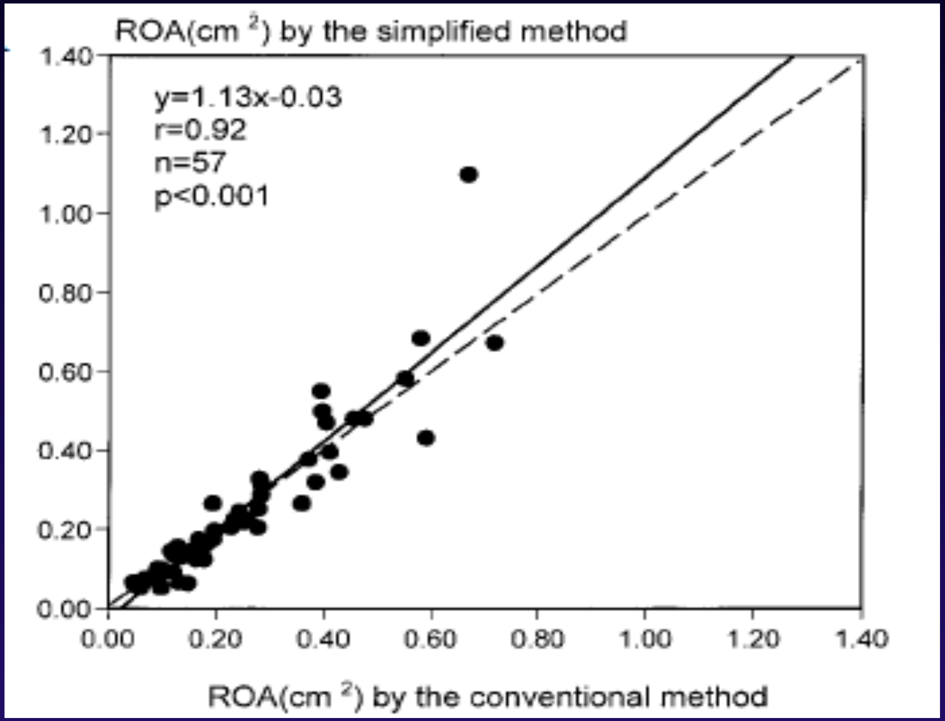


- *Assume LV-LA Δp is 100 mmHg*
- *Set aliasing velocity to 40 cm/sec*
- *Then ROA = $r^2/2$*

ROA = $8^2/2$ = 32 mm^2

ROA by Simplified PISA Method: $r^2/2$



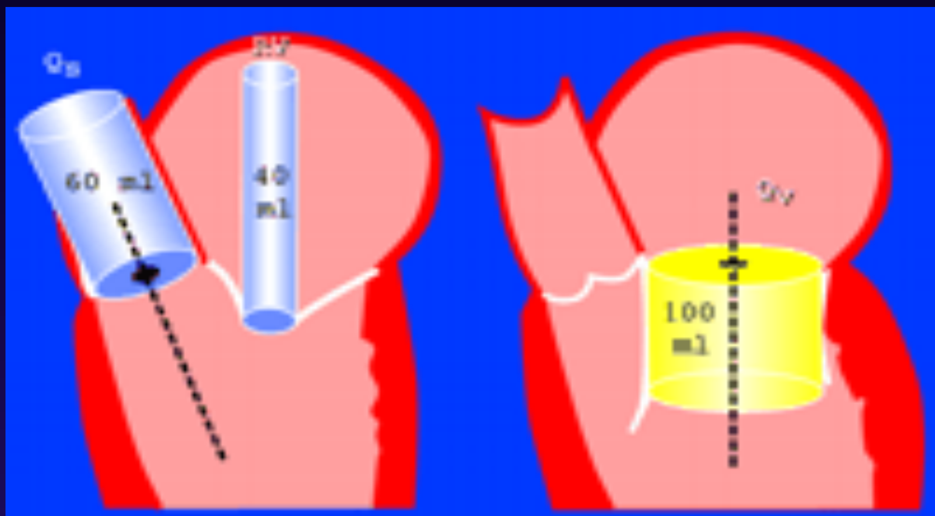


Pu, Prior et al., *JASE* 2001 14:180

What Is Our Reference Method?

- Echo Studies
  - Volumetric Flow
- MRI Studies
  - Volumetric Flow

Quantitative Assessment of MR - Volumetric Flow



Mitral annulus

LVOT - Beware of AR

- Measure SV in 2 regions, one of which includes the regurgitant volume.
- Difference b/n these two SVs is the regurgitant volume through the valve.
  - Area of the LVOT x VTI
  - Mitral annular area x VTI

  Or

  - LV stroke volume
    - LVEDV-LVESV (3-d or Simpson's biplane)
- Regurg. flow rate (ml/s), fraction (%), orifice area.

Improving Accuracy & Usability

- Volumetric flow not often used
  - Time-consuming

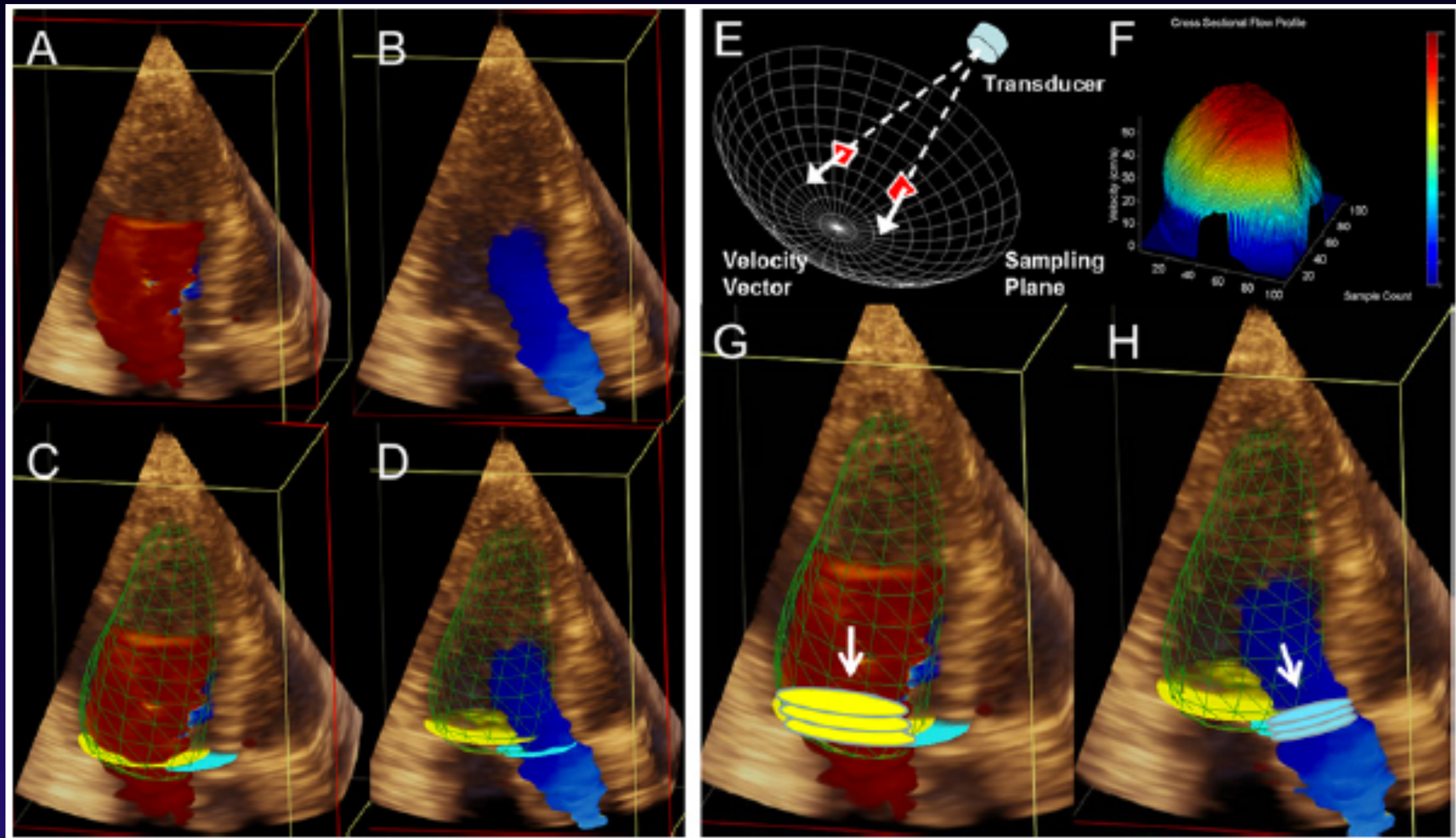
LVOT diameter—by LVOT TVI). This calculation is inaccurate in the presence of significant AR.

Key point: The Doppler volumetric method is a time-consuming approach that is not recommended as a first-line method to quantify MR severity.

Anterograde velocity of mitral inflow: mitral to aortic TVI ratio. In the absence of mitral stenosis, the increase in the transmitral flow

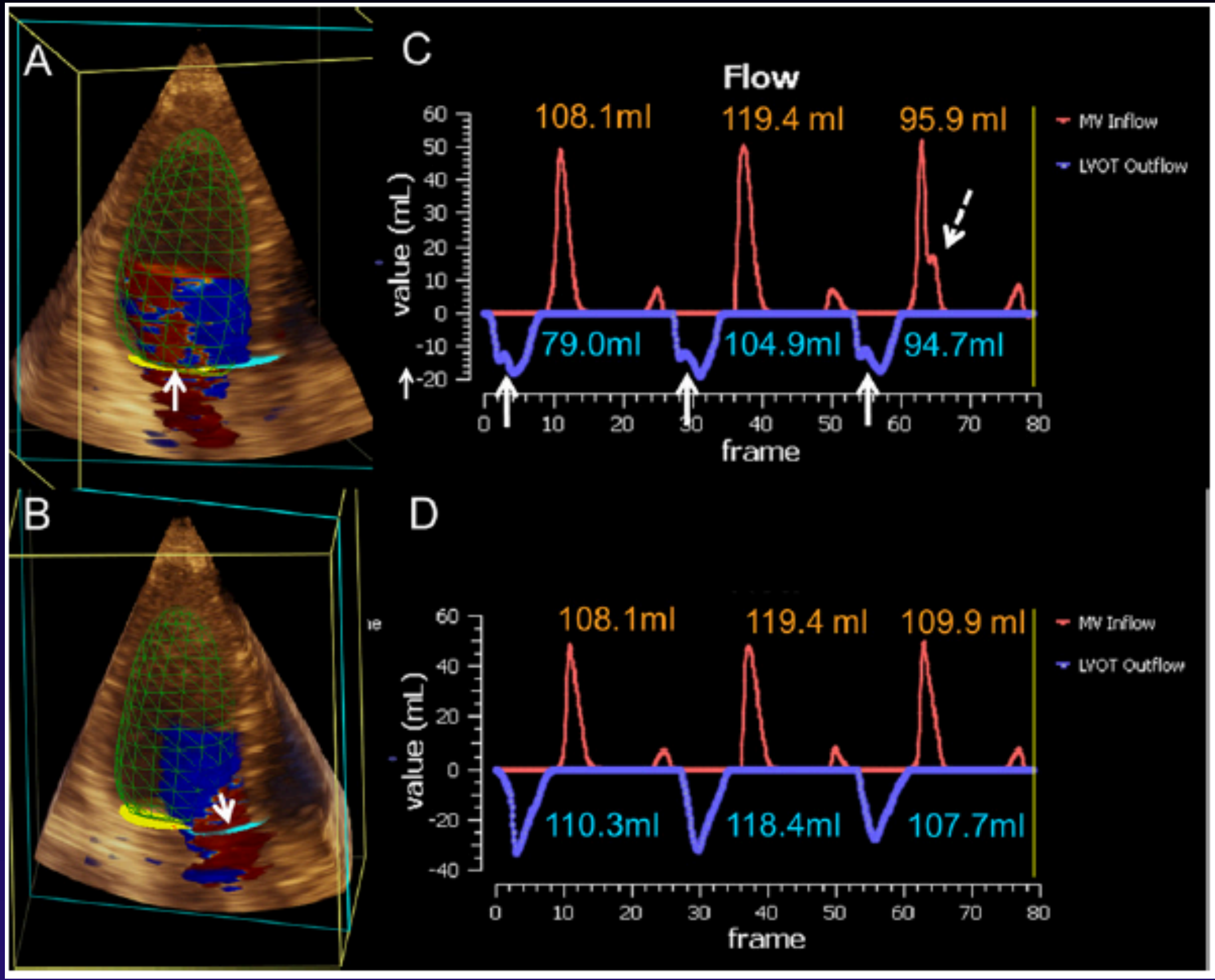
Lancellotti, *EHJ-CVI* 2013 14:611

Simultaneous MV and LVOT flow - Real Time Colour Flow Doppler



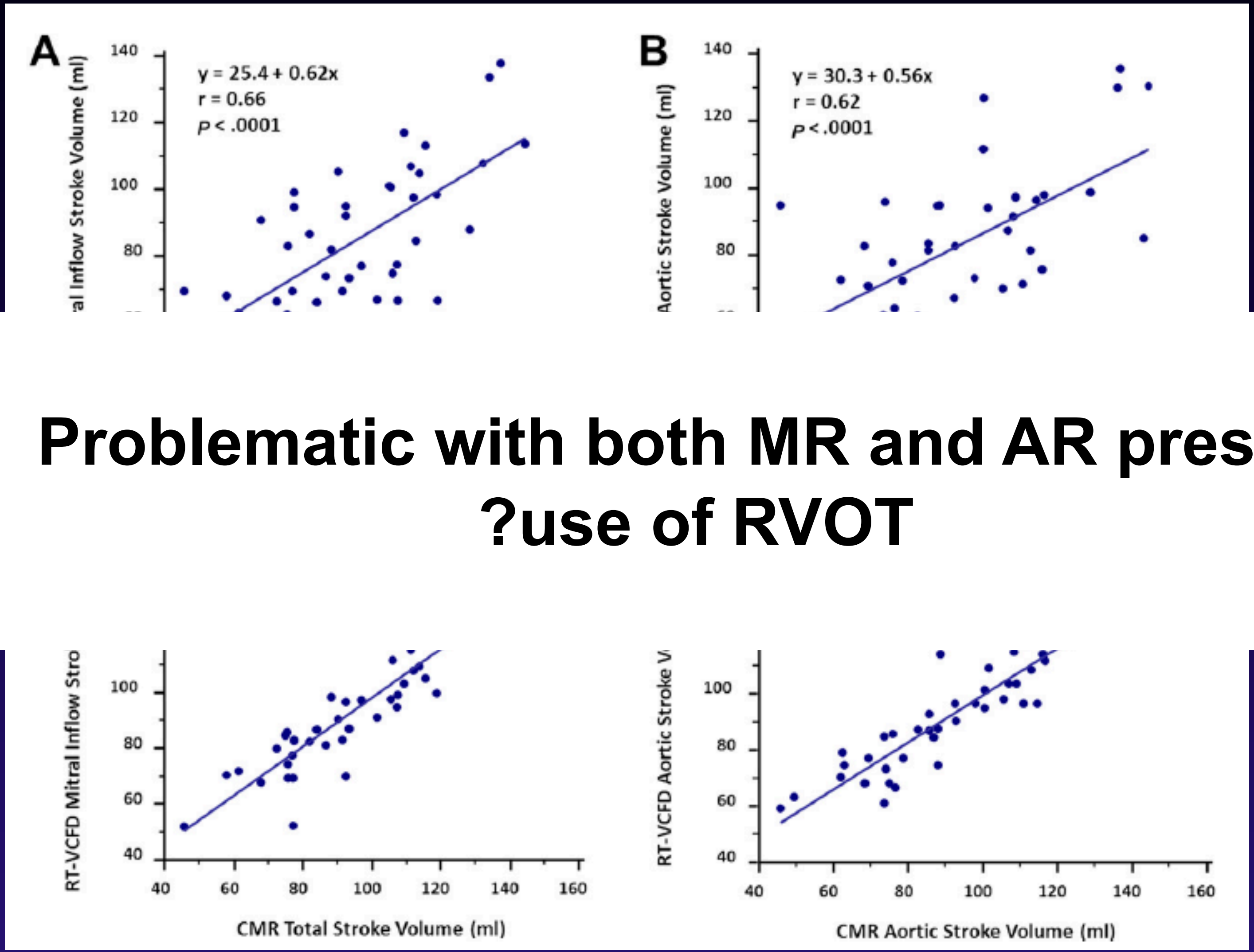
Thavendiranathan, *JASE* 2012 25:1

Simultaneous MV and LVOT flow



Thavendiranathan, *JASE* 2012 25:1

RT-CFD More Accurate Than 2-D



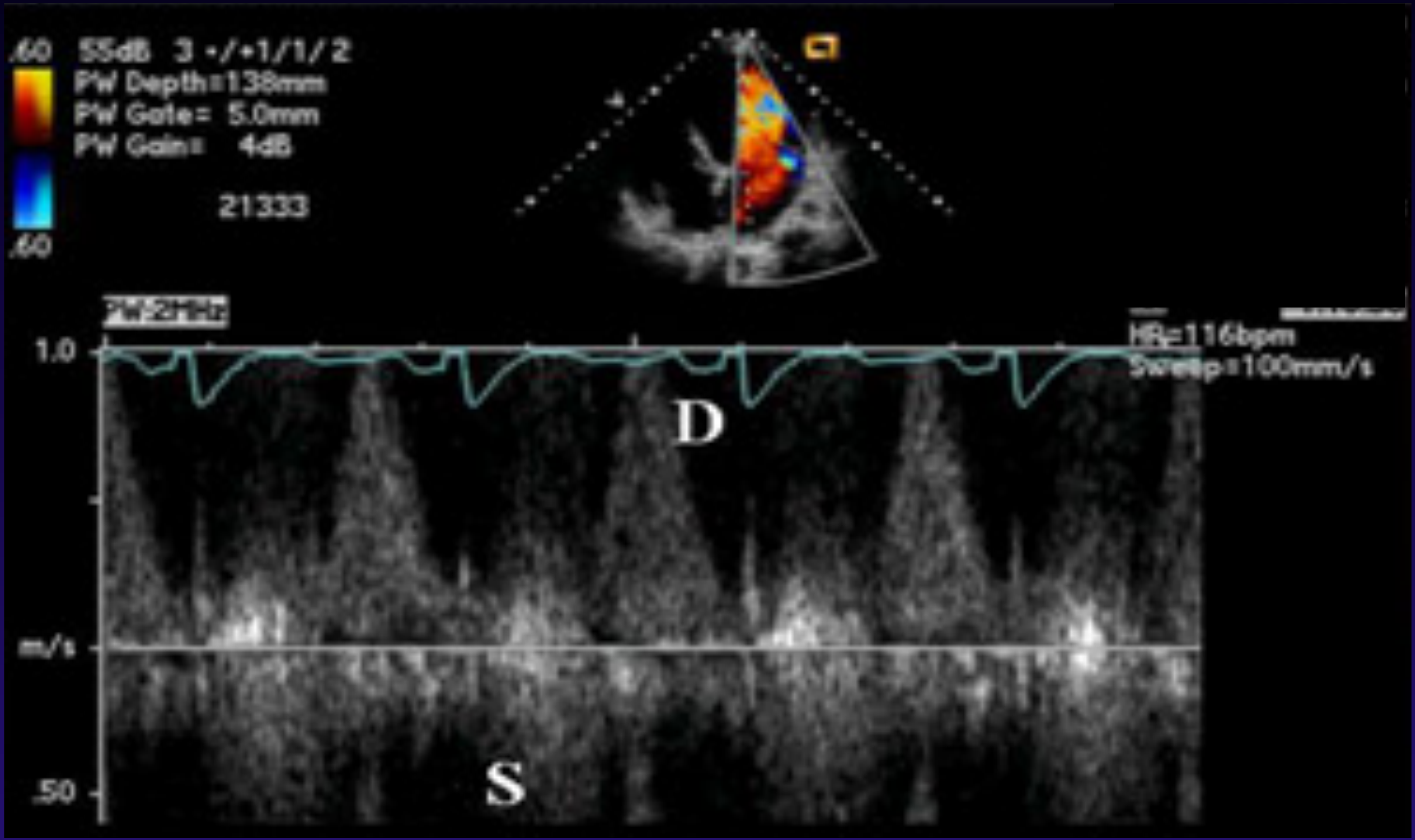
Problematic with both MR and AR present
?use of RVOT

Thavendiranathan, *JASE* 2012 25:1

Use All The Available Information

- Pulmonary vein flow
- Mitral inflow characteristics
- CW of the MR jet
  - Signal intensity
  - Shape of the signal

Systolic flow reversal in pulmonary veins

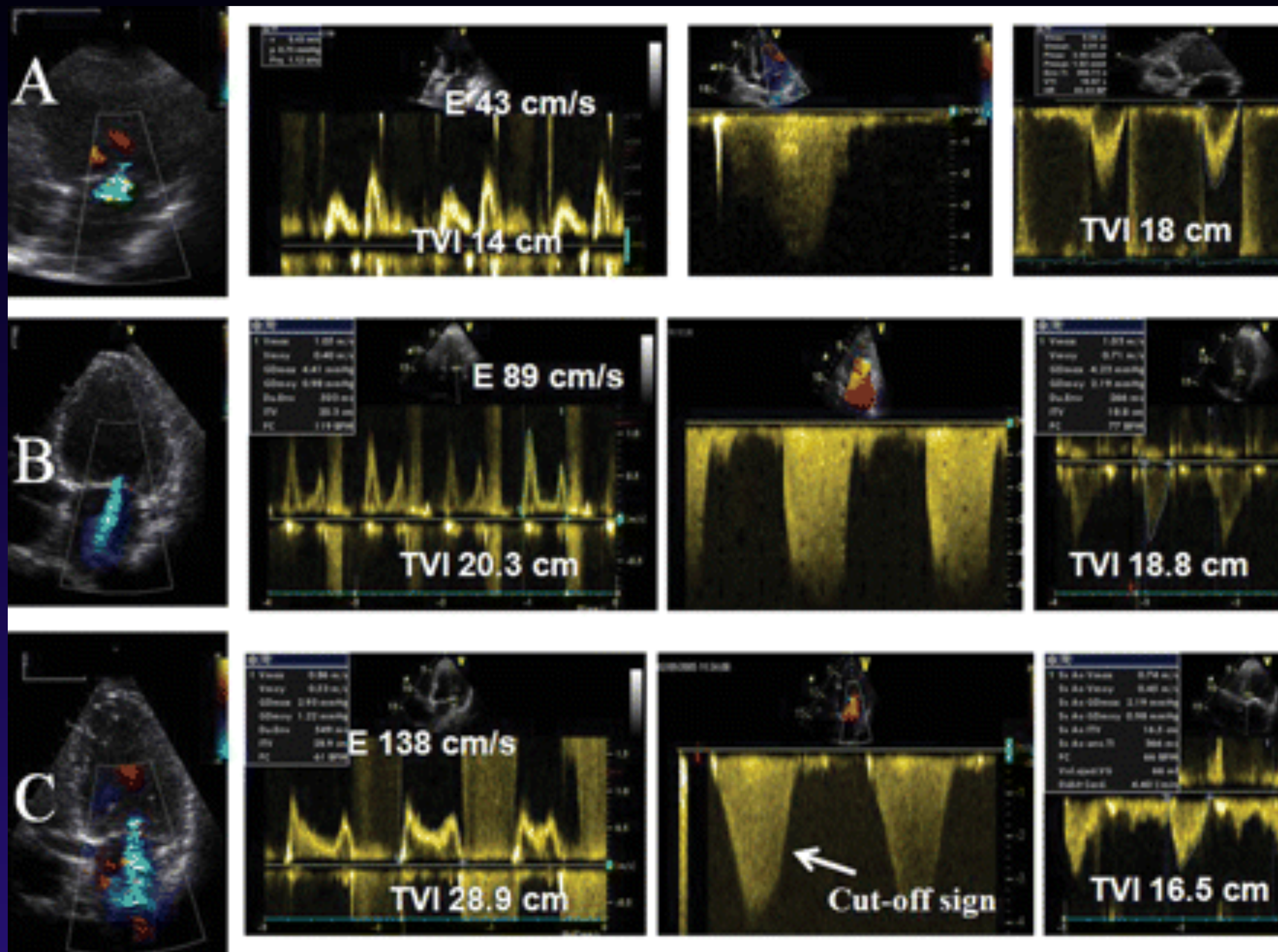


Mitral CW and PW Doppler

MILD

MOD

SEVERE



Lancellotti, *EHJ-CVI* 2010 11:307

Key Cut-off Values for MR

	Mild	Moderate		Severe
		Mod	Mod Severe	
VC width	< 0.3	0.3 – 0.69		≥ 0.7
R Vol (ml/beat)	< 30	30 - 44	45 - 59	≥ 60
R Fract (%)	< 30	30 - 39	40 – 49	≥ 50
EROA (cm^2)	< 0.2	0.20 – 0.29	0.30 – 0.39	≥ 0.4

Zoghbi, *JASE* 2003 16:777

Aortic Regurgitation

- JET AREA AND JET LENGTH ARE NOT WELL CORRELATED WITH SEVERITY
- Quantification can be more difficult

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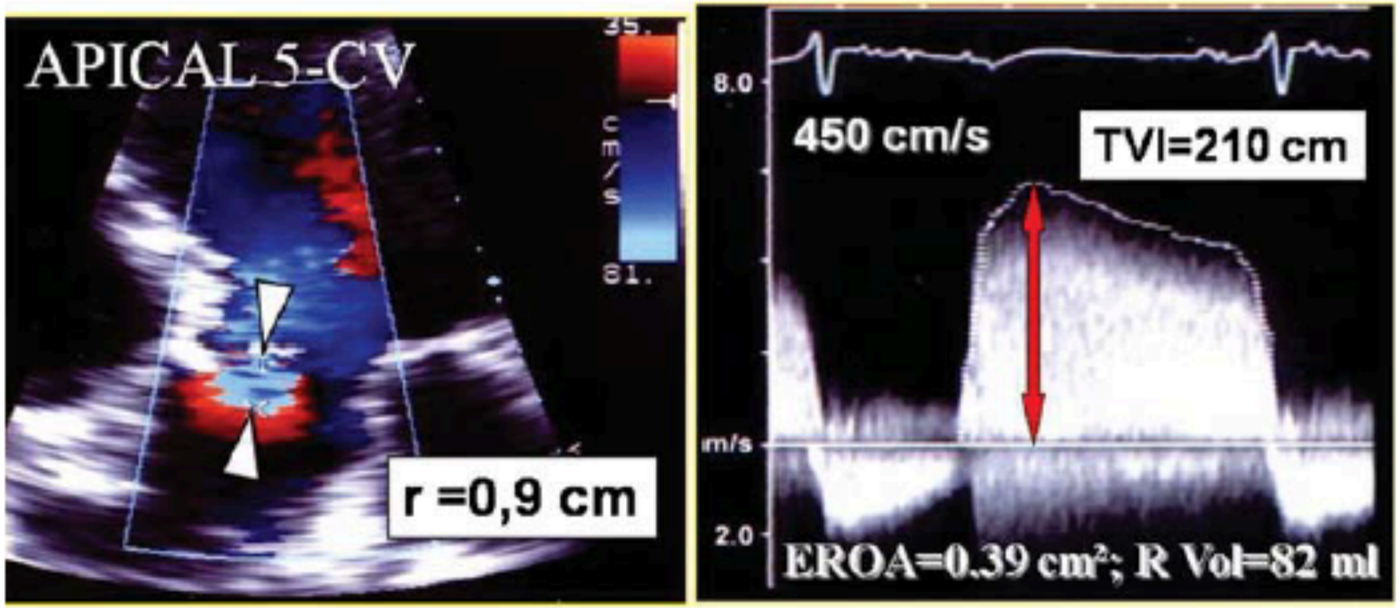
Use of PISA in Aortic Regurgitation

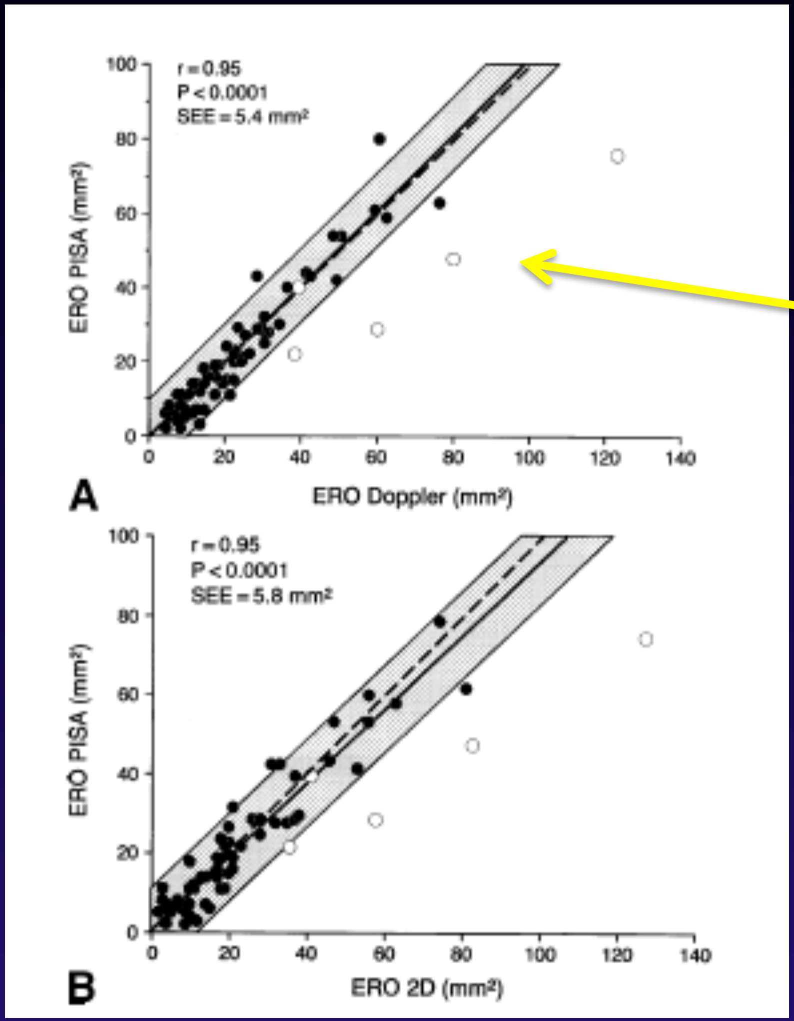


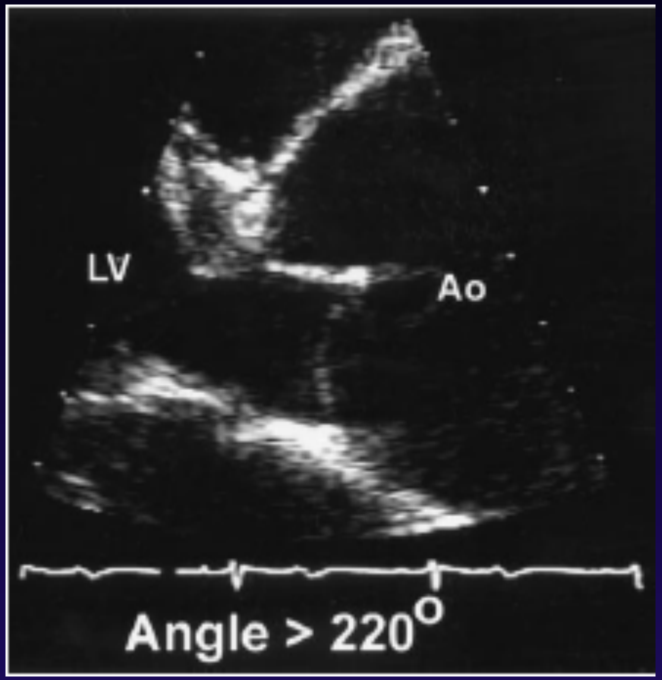
ERO = Flow/Peak velocity = 178/450 = 0.39 cm^2

R Vol = EROA × TVI = 0.39 cm^2 × 210 cm = 82 mL

Lancellotti, *EHJ-CVI* 2010 11:223

Use of PISA in Aortic Regurgitation

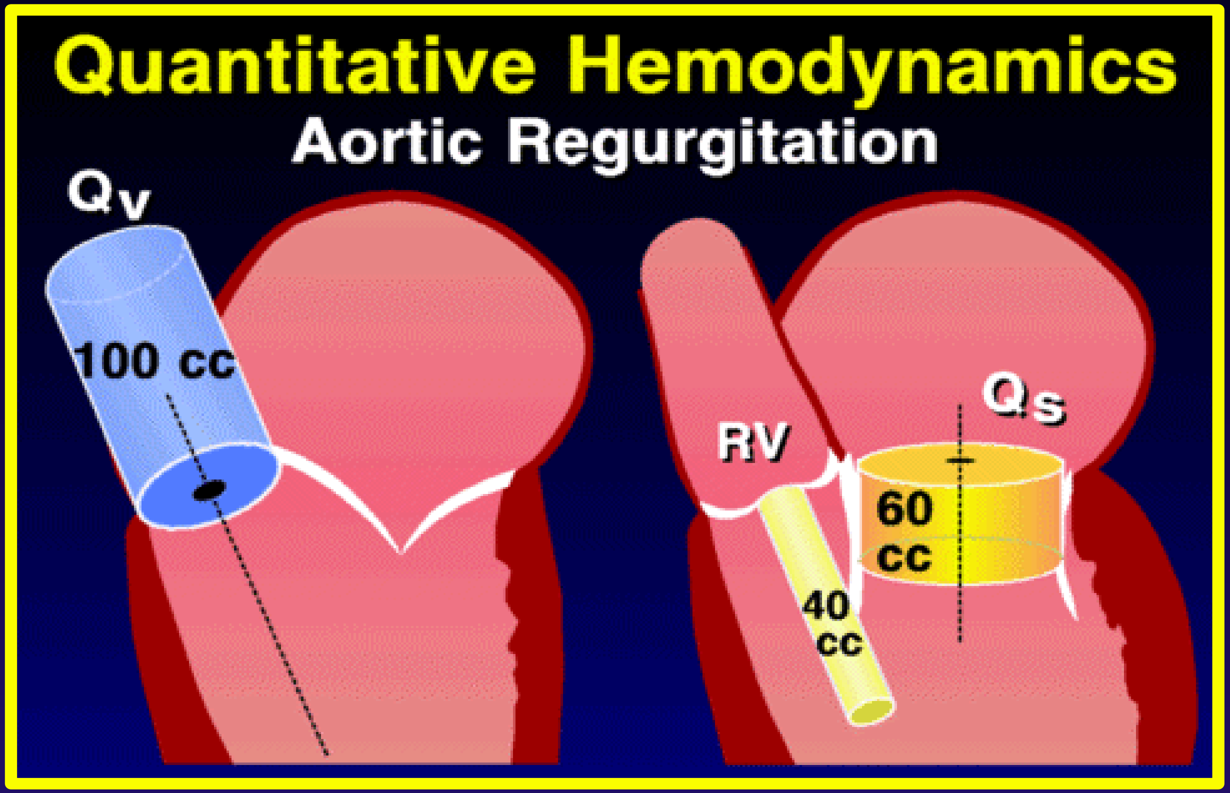




Underestimation with tented valves

Tribouilloy, *JACC* 1998 32:1032

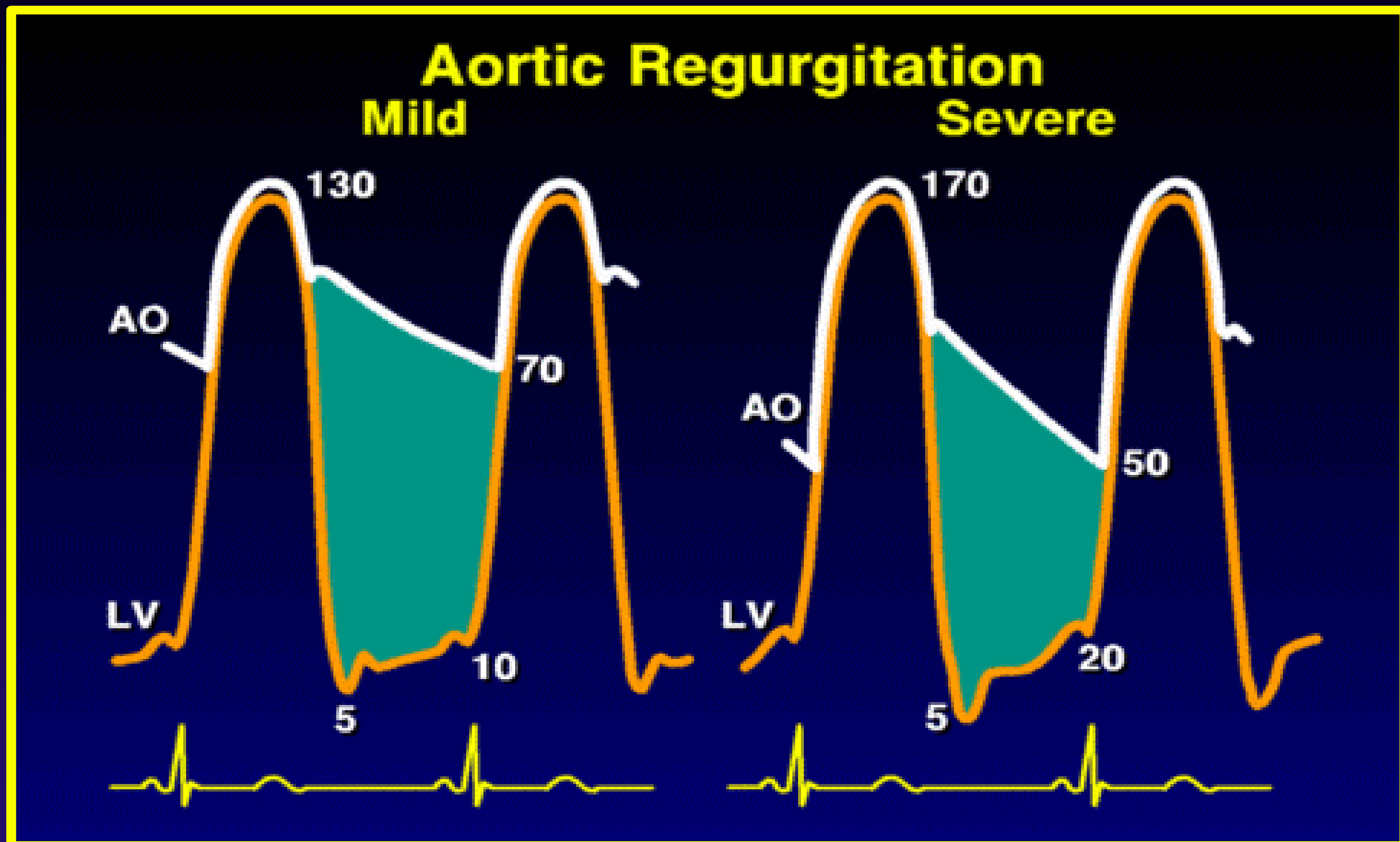
Volumetric Flow in Aortic Regurgitation



Additional Parameters

- AR pressure half-time
- Diastolic flow reversal
  - Upper descending aorta
  - Abdominal aorta

AR and Pressure Half-time



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		Mod	Mod Severe	
VC width	< 0.3	0.3 – 0.60		≥ 0.6
R Vol (ml/beat)	< 30	30 - 44	45 - 59	≥ 60
R Fract (%)	< 30	30 - 39	40 – 49	≥ 50
EROA (cm^2)	< 0.1	0.10 – 0.19	0.20 – 0.29	≥ 0.3

Zoghbi, *JASE* 2003 16:777

Tricuspid Regurgitation

- Many parallels with MR
- Vena contracta width can be used
- PISA can be used
  - an EROA $\geq 40\ mm^2$ indicates severe TR
  - R Vol > 45 ml suggests severe TR
- Other parameters suggesting severe TR
  - systolic flow reversal in the hepatic veins
  - V wave cut-off sign

ASE Guidelines for Native Valve Regurgitation

AMERICAN SOCIETY OF ECHOCARDIOGRAPHY REPORT

Recommendations for Evaluation of the Severity of Native Valvular Regurgitation with Two-dimensional and Doppler Echocardiography

A report from the American Society of Echocardiography's Nomenclature and Standards Committee and The Task Force on Valvular Regurgitation, developed in conjunction with the American College of Cardiology Echocardiography Committee, The Cardiac Imaging Committee Council on Clinical Cardiology, the American Heart Association, and the European Society of Cardiology Working Group on Echocardiography, represented by:

William A. Zoghbi, MD, Maurice Enriquez-Sarano, MD, Elyse Foster, MD, Paul A. Grayburn, MD, Carol D. Kraft, RDMS, Robert A. Levine, MD, Petros Nihoyannopoulos, MD, Catherine M. Otto, MD, Miguel A. Quinones, MD, Harry Rakowski, MD, William J. Stewart, MD, Alan Waggoner, MHS, RDMS, and Neil J. Weissman, MD

- ? Time for a new version

Zoghbi, *JASE* 2003 16:777

EACVI Guidelines 2013

Estimation of the severity of valvular regurgitation: recommendations

1. The colour flow area of the regurgitant jet is not recommended to quantify the severity of valvular regurgitation.

2. Both VC measurement and the PISA method are recommended to evaluate the severity of regurgitation when feasible.

3. Adjunctive parameters should be used when there is discordance between the quantified degree of regurgitation and the clinical context.

Lancellotti, *EHJ-CVI* 2013 14:611

Summary

- Accurate assessment of valvular regurgitation is important for clinical decision making
- Colour flow jet area is NOT recommended
- Quantitative measures are preferable
- PISA continues to be useful in selected cases
- Real-time 3D colour flow Doppler may become a method of choice for future quantification