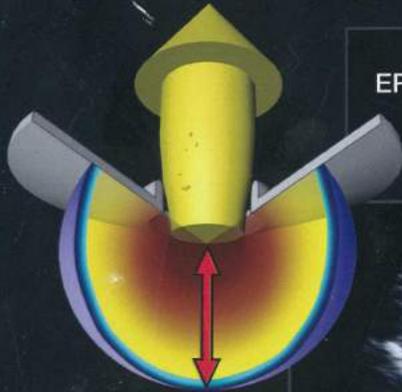




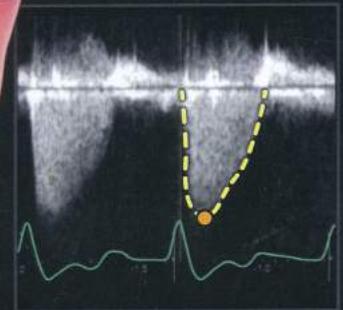
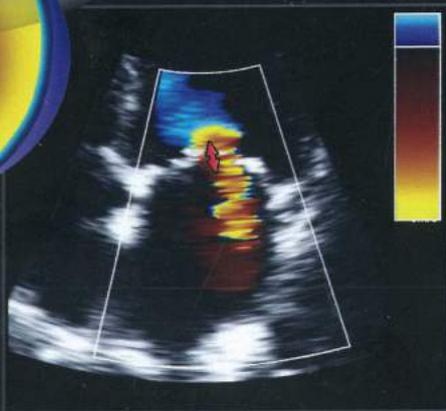
ASE

American Society of  
Echocardiography

# Echocardiography Formula Review Guide: Native Valves and Intracardiac Pressures



$$ERO = \frac{\text{Reg flow}}{V_{\text{Max}}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{\text{Max}}}$$



Akhil Narang, MD (Chair); Gerard Aurigemma, MD, FASE;  
Nadia El Hangouche, MD; Kalie Kebed, MD; Roberto M. Lang, MD, FASE;  
Steven Lester, MD, FASE; Hemalatha Narayanasamy, MBBS, MD;  
Matthew W. Parker, MD, FASE; Brent White, MD.

Adapted from:

Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice. J Am Soc Echocardiogr 2009; 22: 1-23.

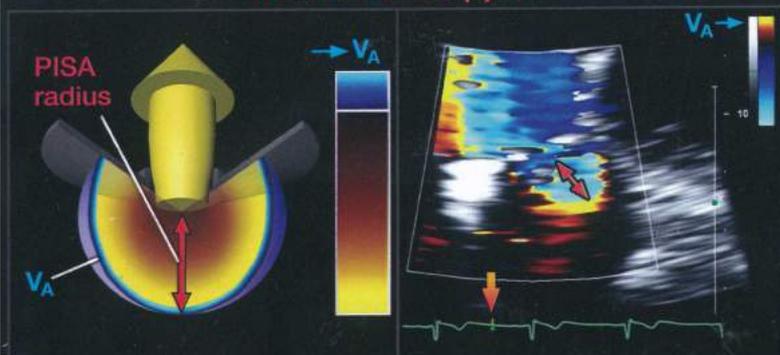
Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation: A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017; 30: 303-371.

Recommendations on the Echocardiographic Assessment of Aortic Valve Stenosis: A Focused Update from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr 2017; 30: 372-392.

Design and illustration by [medmovie.com](http://medmovie.com)

# Aortic Regurgitation: Flow Convergence Method (PISA)

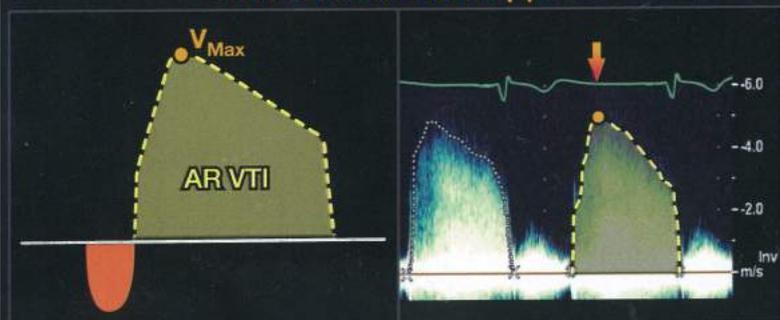
## Color Flow Doppler



- A. Align beam  
B. Zoom  
C. Nyquist limit →  
D. Draw radius ↕

- $r$  = Radial distance from orifice (cm)  
 $v_A$  = Aliasing velocity at radial distance ( $r$ ) (cm/s)  
 $v_{Max}$  = Peak velocity of AR jet (cm/s)  
 ↓ = Note: the PISA radius ( $r$ ) is to be measured at the same time point in the cardiac cycle as  $v_{Max}$   
 $VTI$  = VTI of AR jet (cm)  
 $ERO$  = Effective regurgitation orifice area (cm<sup>2</sup>)  
 $RVol$  = Regurgitant volume (mL/beat)  
 $RF$  = Regurgitant fraction (%)

## Aortic Valve CW Doppler



- F. Measure AR VTI  
G. Measure AR Max Velocity

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times v_A$$

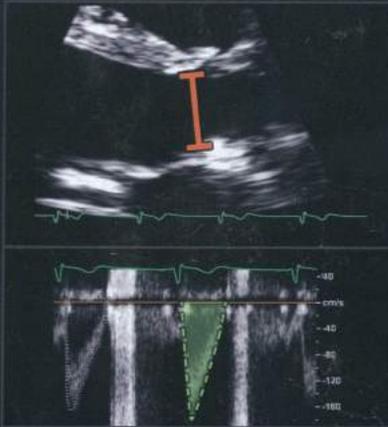
$$ERO = \frac{\text{Reg flow}}{v_{Max}} = \frac{2 \times \pi \times r^2 \times v_A}{v_{Max}}$$

$$RVol = ERO \times VTI \quad RF = \frac{RVol}{LVOT \text{ stroke volume}}$$

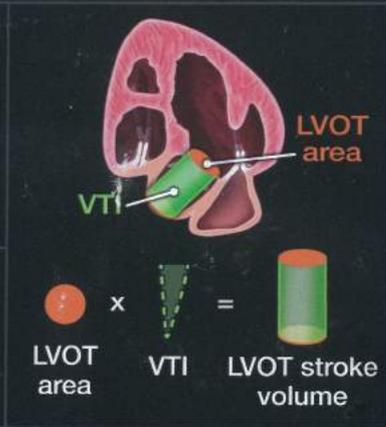
	Mild	Moderate	Severe
EROA (cm <sup>2</sup> )	< 0.10	0.11 - 0.29	≥ 0.30
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

# Aortic Regurgitation: Continuity Method

LVOT Diameter



LVOT Stroke Volume



LVOT diameter in mid systole (cm)

PW Doppler at LVOT (VTI) (cm)

MV annulus diameter in mid diastole (cm)

PW Doppler at the level of MV annulus (VTI) (cm)

EROA = Effective regurgitation orifice area (cm<sup>2</sup>)

RVol = Regurgitant volume (mL/beat)

RF = Regurgitant fraction (%)

$$RVol = \text{LVOT SV} - \text{Mitral valve SV}$$

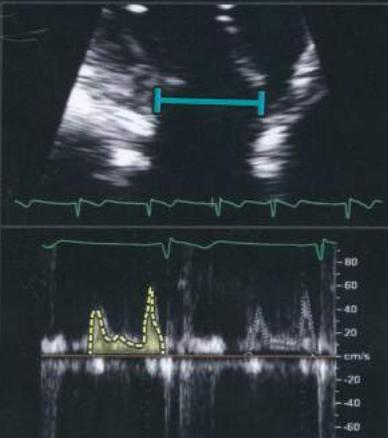
$$RVol = (\text{LVOT area} \times \text{LVOT VTI}) - (\text{MV area} \times \text{MV VTI})$$

$$RVol = \left\{ \pi \times \left( \frac{\text{LVOT diameter}}{2} \right)^2 \times \text{LVOT VTI} \right\} - \left\{ \pi \times \left( \frac{\text{MV annulus diameter}}{2} \right)^2 \times \text{MV VTI} \right\}$$

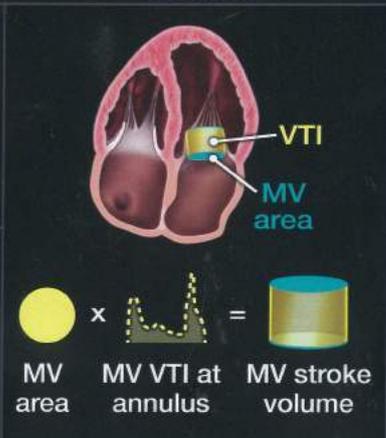
$$EROA (\text{cm}^2) = \frac{RVol}{AR VTI}$$

$$RF (\%) = \frac{RVol}{LVOT SV}$$

MV Annulus Diameter



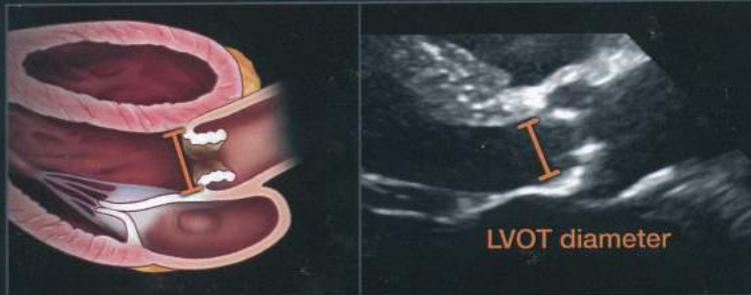
Mitral Valve Stroke Volume



	Mild	Moderate	Severe
EROA (cm <sup>2</sup> )	< 0.10	0.11 - 0.29	≥ 0.30
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

# Aortic Stenosis

## LVOT Diameter



$$A1 \times V1 = A2 \times V2$$

$$A2 = \frac{A1 \times V1}{V2}$$



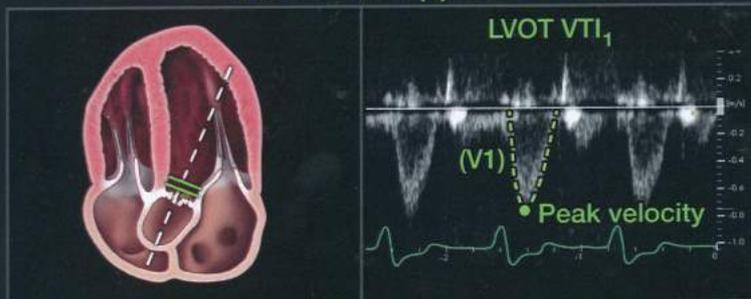
$$A1 = \text{LVOT area (cm}^2\text{)}$$

$$A2 = \text{AV area (cm}^2\text{)}$$

$$VTI_1 = \text{LVOT VTI (cm)}$$

$$VTI_2 = \text{AV VTI (cm)}$$

## LVOT PW Doppler

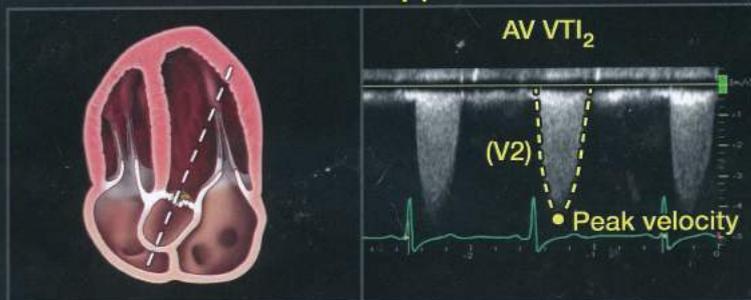


$$\text{AV area} = \frac{\text{LVOT area} \times \text{LVOT VTI}}{\text{AV VTI}}$$

$$\text{AV area} = \frac{\pi \times \left( \frac{\text{LVOT diameter}}{2} \right)^2 \times \text{LVOT VTI}}{\text{AV VTI}}$$

$$\text{Velocity time integral ratio (dimensionless index)} = \frac{\text{LVOT VTI}}{\text{AV VTI}}$$

## AV CW Doppler

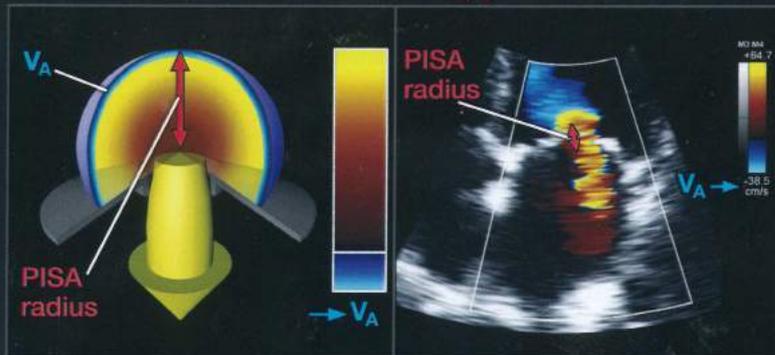


## Grading AS Severity

	Mild	Moderate	Severe
Peak velocity (m/s)	2.6 - 2.9	3.0 - 4.0	≥ 4.0
Mean gradient (mmHg)	< 20	20 - 40	≥ 40
AVA (cm <sup>2</sup> )	> 1.5	1.0 - 1.5	< 1.0
Indexed AVA (cm <sup>2</sup> /m <sup>2</sup> )	> 0.85	0.60 - 0.85	< 0.6
Dimensionless index	> 0.50	0.25 - 0.50	< 0.25

# Mitral Regurgitation: Flow Convergence Method (PISA)

## Color Flow Doppler



- A. Align beam  
B. Zoom  
C. Variance off  
D. Nyquist limit →  
E. Draw radius ↕

$r$  = Radial distance from orifice (cm)

$V_A$  = Aliasing velocity at radial distance ( $r$ ) (cm/s)

$V_{Max}$  = Peak velocity of MR jet (cm/s)

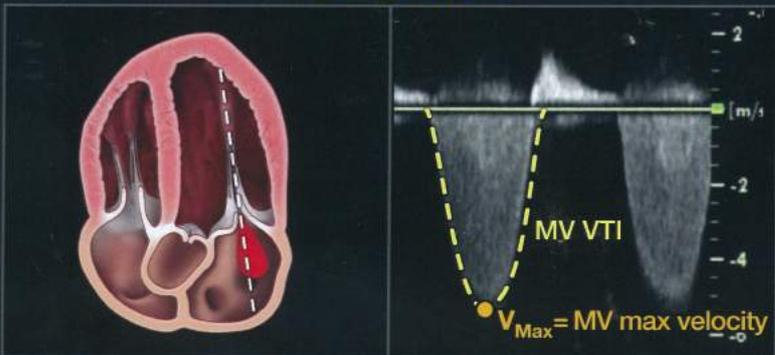
$VTI$  = VTI of MR jet (cm)

ERO = Effective regurgitant orifice (cm<sup>2</sup>)

RVol = Regurgitant volume (mL/beat)

RF = Regurgitant fraction (%)

## MV CW Doppler



- F. Measure MV VTI  
G. Measure MV max velocity

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

$$ERO = \frac{\text{Reg. flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$

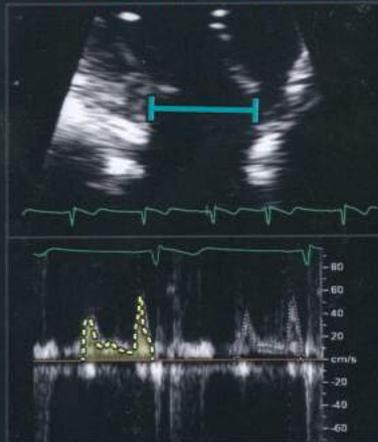
$$RVol = ERO \times VTI \quad RF = \frac{RVol}{\text{Stroke volume}^*}$$

\* Calculated as forward stroke volume (either using transmitral inflow or the sum of LVOT flow and RVol)

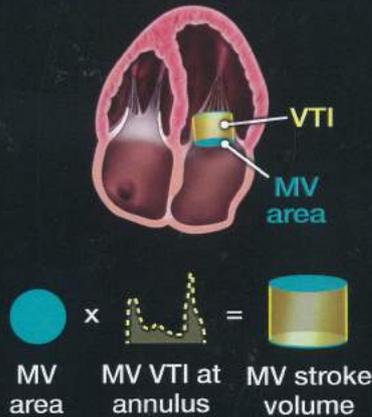
	Mild	Moderate	Severe
EROA (cm <sup>2</sup> )	< 0.20	0.20 - 0.39	≥ 0.40
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

# Mitral Regurgitation: Continuity Method

## MV Annulus Diameter



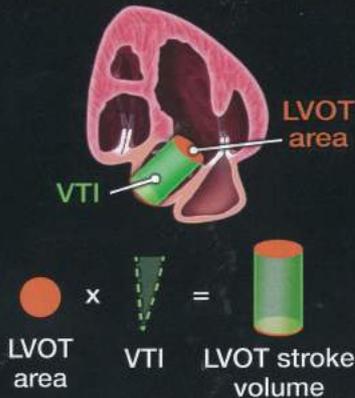
## Mitral Valve Stroke Volume



## LVOT Diameter



## LVOT Stroke Volume



LVOT diameter in mid systole (cm)

PW Doppler at LVOT (VTI) (cm)

MV annulus diameter in mid diastole (cm)

PW Doppler at the level of MV annulus (VTI) (cm)

EROA = Effective regurgitation orifice area (cm<sup>2</sup>)

RVol = Regurgitant volume (mL/beat)

RF = Regurgitant fraction (%)

$$RVol = \text{Mitral valve SV} - \text{LVOT SV}$$

$$RVol = (\text{MV area} \times \text{MV VTI}) - (\text{LVOT area} \times \text{LVOT VTI})$$

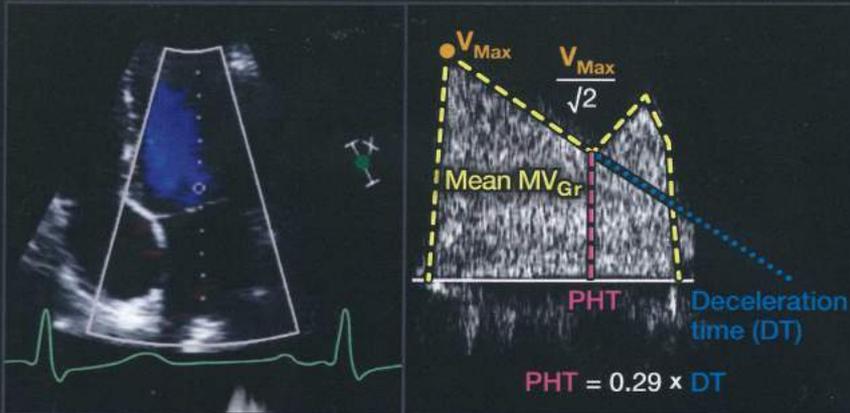
$$RVol = \left\{ \pi \times \left( \frac{\text{MV annulus diameter}}{2} \right)^2 \times \text{MV VTI} \right\} - \left\{ \pi \times \left( \frac{\text{LVOT diameter}}{2} \right)^2 \times \text{LVOT VTI} \right\}$$

$$EROA \text{ (cm}^2\text{)} = \frac{RVol}{MR \text{ VTI}} \quad RF \text{ (\%)} = \frac{RVol}{MV \text{ SV}}$$

	Mild	Moderate	Severe
EROA (cm <sup>2</sup> )	< 0.20	0.20 - 0.39	≥ 0.40
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

# Mitral Stenosis

## Continuous Flow Doppler



## Mean Mitral Valve Gradient ( $MV_{Gr}$ )

Obtained by tracing **Mean  $MV_{Gr}$**  (mmHg) from the mitral valve continuous flow Doppler.

- Valid for HR 60-80 bpm
- Average multiple cardiac cycles (5 - 10) in atrial fibrillation

## Pressure Half Time (PHT)

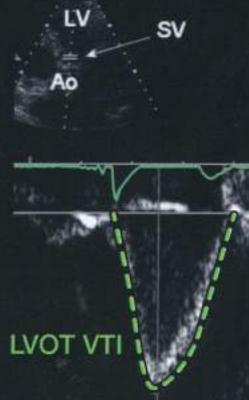
$$MVA (cm^2) = \frac{220}{PHT}$$

PHT validated in rheumatic mitral stenosis and less accurate in calcific mitral stenosis, atrial septal defect, significant aortic regurgitation, altered ventricular compliance (diastolic dysfunction), or after mitral balloon valvuloplasty.

## LVOT Diameter



## Pulsed Wave Doppler of the LVOT



Continuity Equation:  $SV_{LVOT} = SV_{MV}$

$$LVOT_{Area} = \pi \times \left( \frac{LVOT \text{ diameter}}{2} \right)^2$$

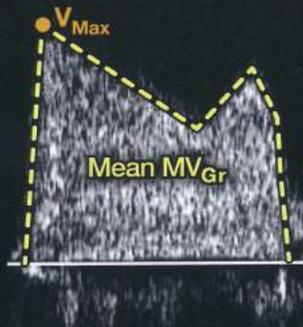
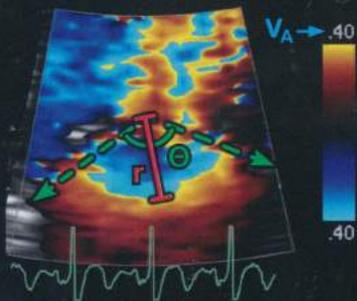
$$MVA (cm^2) = LVOT_{Area} \times \frac{LVOT \text{ VTI}}{MV \text{ VTI}}$$

Assumes stroke volume through mitral valve is equal to stroke volume through LVOT. Inaccurate if either significant aortic or mitral regurgitation.

# Mitral Stenosis

## Color Flow Doppler

## Continuous Flow Doppler



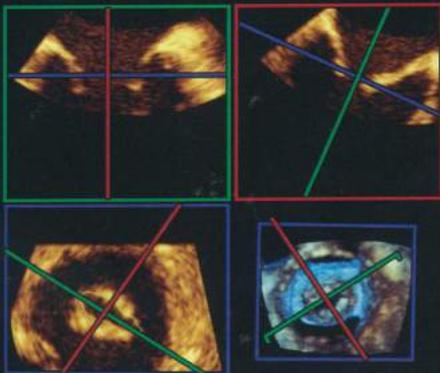
- $r$  = Radial distance from orifice (cm)
- $V_A$  = Aliasing velocity at radial distance ( $r$ ) (cm/s)
- $V_{Max}$  = Peak velocity of MS jet (m/s)
- Mean  $MV_{Gr}$**  = Mean mitral valve gradient (mmHg)
- $\theta$  = Angle of funnel shaped MV orifice

## Planimetry 2D

## Planimetry 3D



Direct tracing of the MV orifice including opened commissures at the MV leaflet lips in mid diastole.



Parasternal short axis view

$$\text{PISA flow rate} = 2 \pi r^2 \times V_A$$

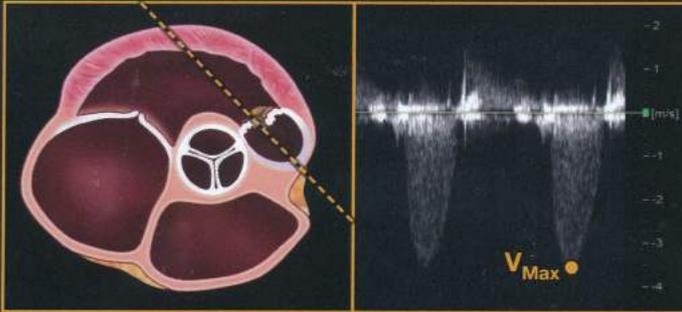
$$\text{MVA} = \frac{\text{PISA flow rate}}{V_{Max}} \times \frac{\theta}{180}$$

## Grading MS Severity

	Mild	Severe
<b>Mean <math>MV_{Gr}</math></b> (mmHg)	< 5	> 10
<b>PHT</b> (ms)	145 - 150	> 220
<b>MVA</b> (cm <sup>2</sup> )*	> 1.5 - 4.0	< 1.0

\* MVA can be calculated by planimetry, continuity equation, or by PISA.

# Pulmonic Stenosis



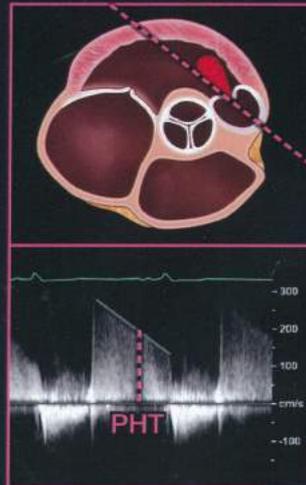
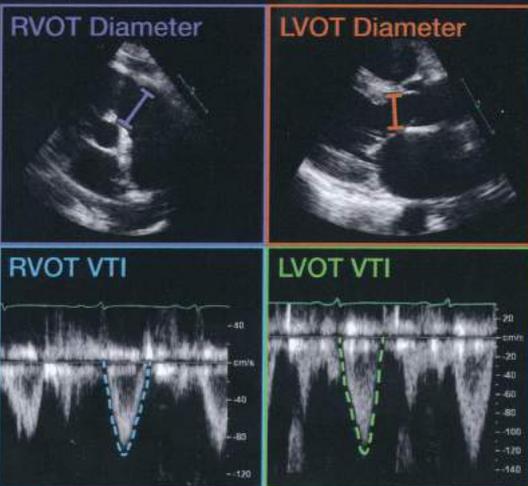
$$\text{PV CW Doppler : } \Delta P_{\text{Max}} = 4(\text{PV } V_{\text{Max}})^2$$

	Mild	Moderate	Severe
Peak Velocity (m/s)	< 3	3 - 4	> 4
Peak Gradient (mmHg)	< 36	36 - 64	> 64

# Pulmonic Regurgitation

CW Doppler Pressure  
Half-Time (PHT)

Regurgitant Volume and Fraction



$$SV_{\text{RVOT}} = \pi \times \left( \frac{\text{RVOT diameter}}{2} \right)^2 \times \text{RVOT VTI}$$

$$SV_{\text{LVOT}} = \pi \times \left( \frac{\text{LVOT diameter}}{2} \right)^2 \times \text{LVOT VTI}$$

$$\text{RVol (mL)} = SV_{\text{RVOT}} - SV_{\text{LVOT}}$$

$$\text{RF (\%)} = \frac{\text{RVol}}{\text{Stroke volume}_{\text{RVOT}}}$$

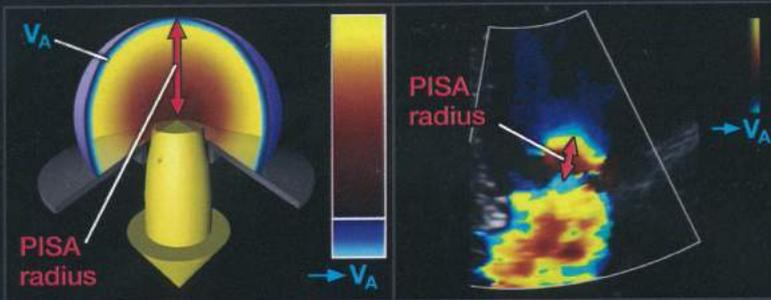
Findings Suggestive of Severe PR

**PHT** < 100 ms

**RF** > 40%

# Tricuspid Regurgitation: Flow Convergence Method (PISA)

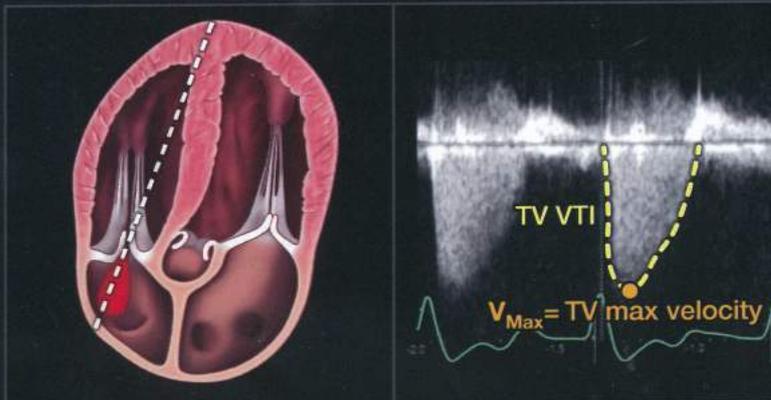
## Color Flow Doppler



- A. Align beam
- B. Zoom
- C. Variance off
- D. Nyquist limit →
- E. Draw radius ↕

- $r$  = Radial distance from orifice (cm)
- $V_A$  = Aliasing velocity at radial distance ( $r$ ) (cm/s)
- $V_{Max}$  = Peak velocity of TR jet (cm/s)
- $VTI$  = VTI of TR jet (cm)
- ERO = Effective regurgitant orifice (cm<sup>2</sup>)
- RVol = Regurgitant volume (mL/beat)

## TV CW Doppler



- F. Measure TV VTI
- G. Measure TV max velocity

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

$$ERO = \frac{\text{Reg. flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$

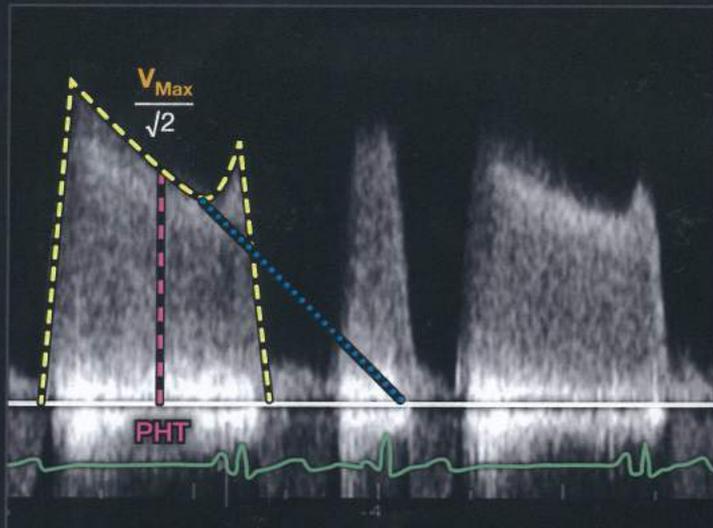
$$RVol = ERO \times VTI$$

	Mild	Severe
EROA (cm <sup>2</sup> )	< 0.20	≥ 0.40
RVol (mL)	< 30	≥ 45

# Tricuspid Stenosis

10

## CW Doppler Through the Tricuspid Valve



## Cut Off Values for Hemodynamically Significant Tricuspid Stenosis

Mean Gradient Pressure	$\geq 5$ mmHg
Pressure Half Time	$\geq 190$ ms
Inflow VTI	$> 60$ cm
Valve Area by Continuity Equation*	$\leq 1$ cm <sup>2</sup>

\* Use with caution as difficult to obtain accurate measurements of inflow volume through TV. In the absence of significant TR, one can use SV from either LVOT or RVOT.

# Heart Pressures

## Right Atrial Pressure (RAP)

RAP (mmHg)	0 - 5 (3)	5 - 10 (8)	10 - 20 (15)
IVC diameter (cm)	≤ 2.1	≤ 2.1	> 2.1
Collapse w/ sniff	> 50%	< 50%	> 50%

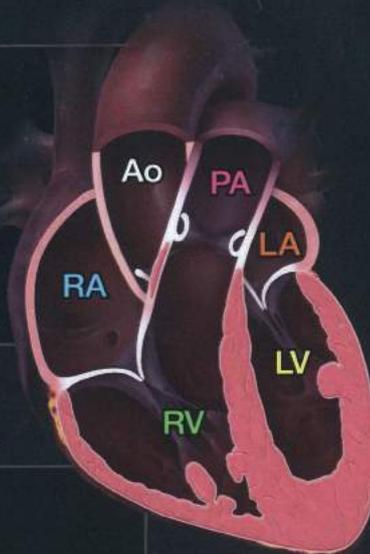
## Mean Pulmonary Artery Pressure (mPAP)

$$mPAP = \frac{1}{3} PASP + \frac{2}{3} PADP$$

$$mPAP = 4(PR_{Peak\ velocity})^2 + RAP$$

$$mPAP = Mean\Delta P_{(RV-RA)} + RAP$$

$$mPAP = 79 - (0.45 \times RVOT\ AcT)$$



## Right Ventricular Pressure

$$RVSP = 4(TRV_{Max})^2 + RAP$$

$$RVSP = SBP - 4(VSD_{Max})^2$$

$$RVEDP = LVEDP - 4(VSD_{Diastolic\ velocity})^2$$

## Pulmonary Artery Pressure

$$PASP = RVSP \text{ (if no PS)}$$

$$PASP = RVSP - PS_{Gradient}$$

$$PAEDP = 4(PR_{End-diastolic\ velocity})^2 + RAP$$

## Pulmonary Vascular Resistance (PVR)

$$PVR = 10 \frac{TR_{Peak\ systolic\ velocity}}{RVOT\ VTI} + 0.16$$

$$PVR = \frac{mPAP - mPCWP}{Cardiac\ output}$$

## Left Atrial Pressure (LAP)

$$LAP = \frac{E}{e} + 4$$

$$LAP = 1.24 \times \frac{E}{e} + 1.9$$

$$LAP = SBP - 4(MR\ V_{Max})^2$$

## Left Ventricle Pressure

$$LVSP = 4(MR_{Peak\ systolic\ velocity})^2 + LAP$$

$$LVEDP = DBP - 4(AR_{End\ diastolic\ velocity})^2$$

For ASE's complete guidelines:

[asecho.org/guidelines](http://asecho.org/guidelines)

To purchase educational products, including the complete  
line of ASE Guideline Posters, ASE Pocket Guidelines,  
and the ASE Guideline Reference book:

[ASEMarketPlace.com](http://ASEMarketPlace.com)



**ASE**

American Society of  
Echocardiography