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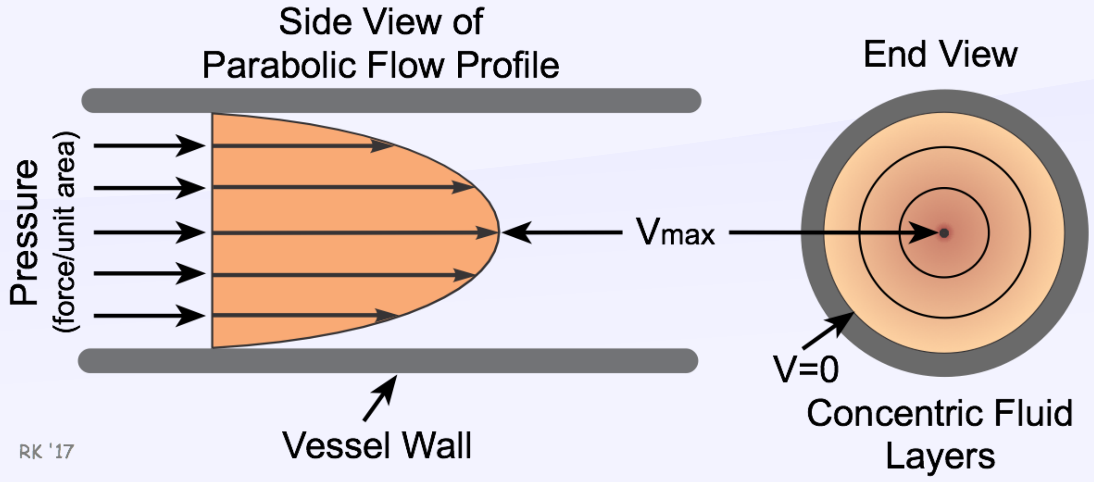
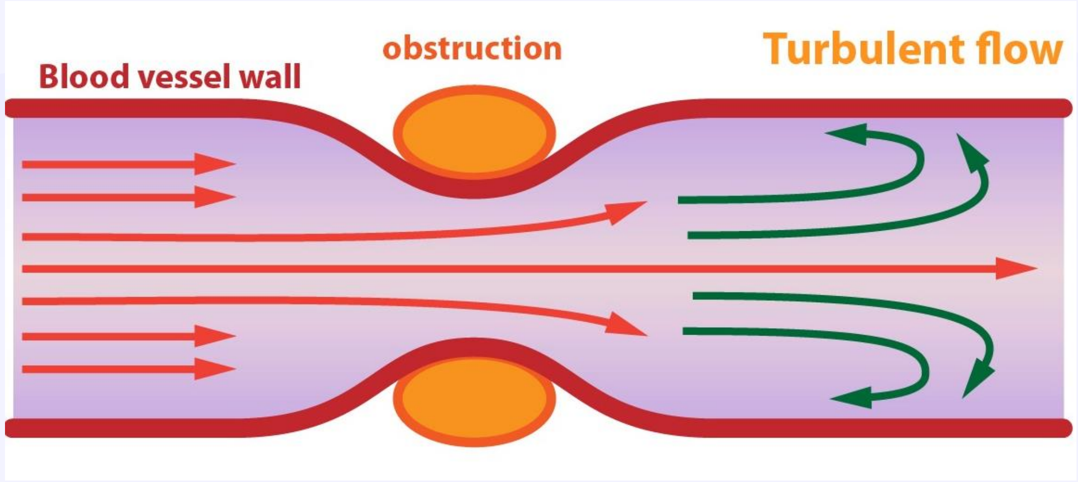
Basic Hemodynamics

September 4, 11 & 18, 2019
Department of Anesthesia and Pain Management- TGH, Toronto

Blood flow pattern in circulation system





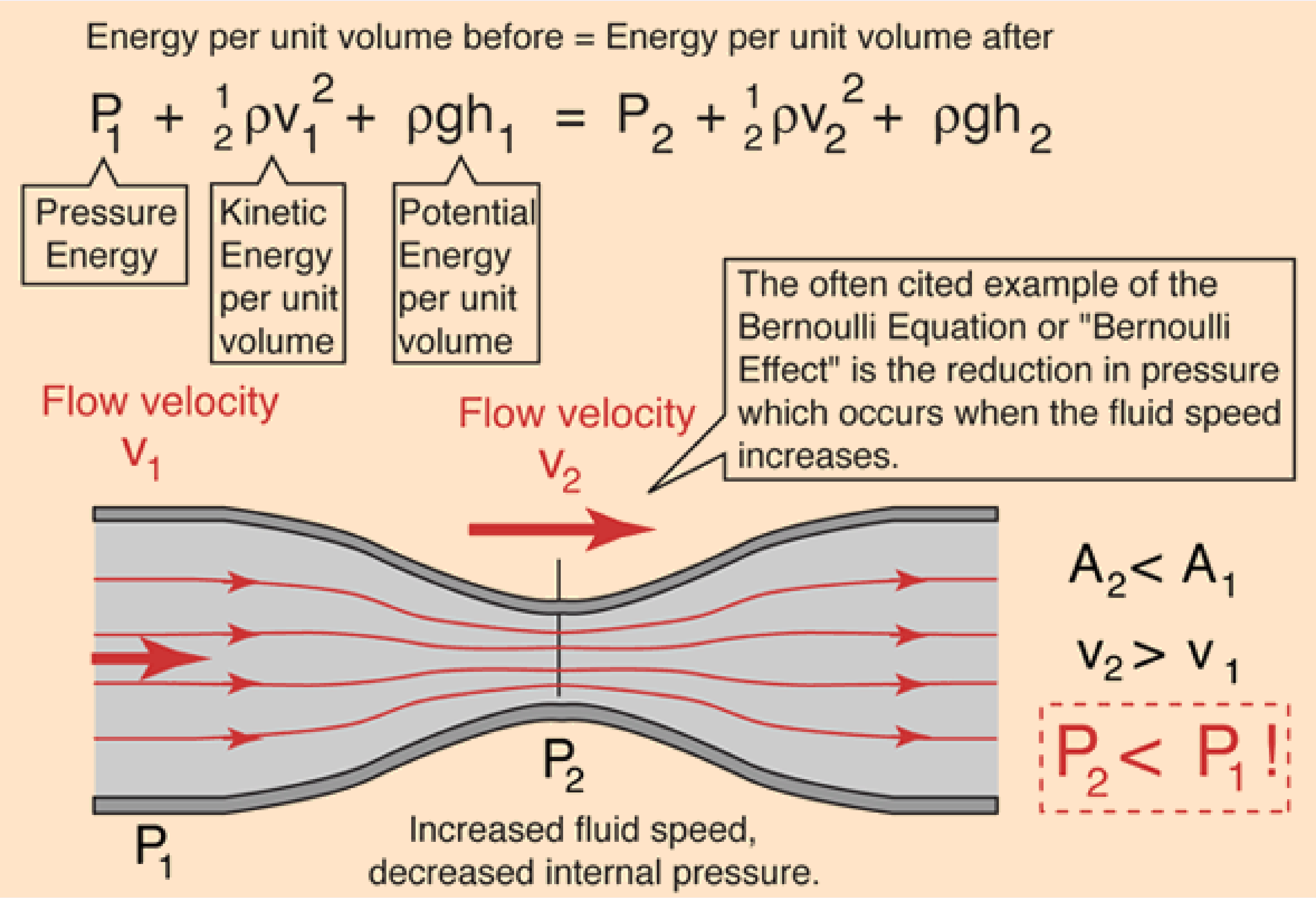
- Laminar flow
  - blood flows at a steady rate through a long, smooth blood vessel
  - flows in *streamlines*
  - each layer of blood remaining the same distance from the vessel wall
  - the central most portion of the blood stays in the center of the vessel

- Turbulent flow
  - blood flowing in all directions in the vessel and continually mixing within the vessel
  - When the rate of blood flow becomes too great
  - when it passes by an obstruction in a vessel
  - when it makes a sharp turn
  - when it passes over a rough surface
  - Increased resistance to blood flow

Daniel Bernoulli
1700- 1782
Swiss mathematician and physicist

BERNOULLI'S EQUATION

- Bernoulli's equation states that the sum of all forms of energy in a fluid flowing along an enclosed path is the same at any two points in that path. (Conservation of energy)
- **Assumptions**:
  - Flow is steady
  - Density is constant (incompressible)
  - Friction losses are negligible


Energy per unit volume before = Energy per unit volume after
$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$
Pressure Energy
Kinetic Energy per unit volume
Potential Energy per unit volume
The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.
Flow velocity v_1
Flow velocity v_2
$A_2 < A_1$
$v_2 > v_1$
$P_2 < P_1$!
P_2
P_1
Increased fluid speed, decreased internal pressure.

Bernoulli Equation

Conservation of Energy Principle

Relationship between Velocity and Pressure

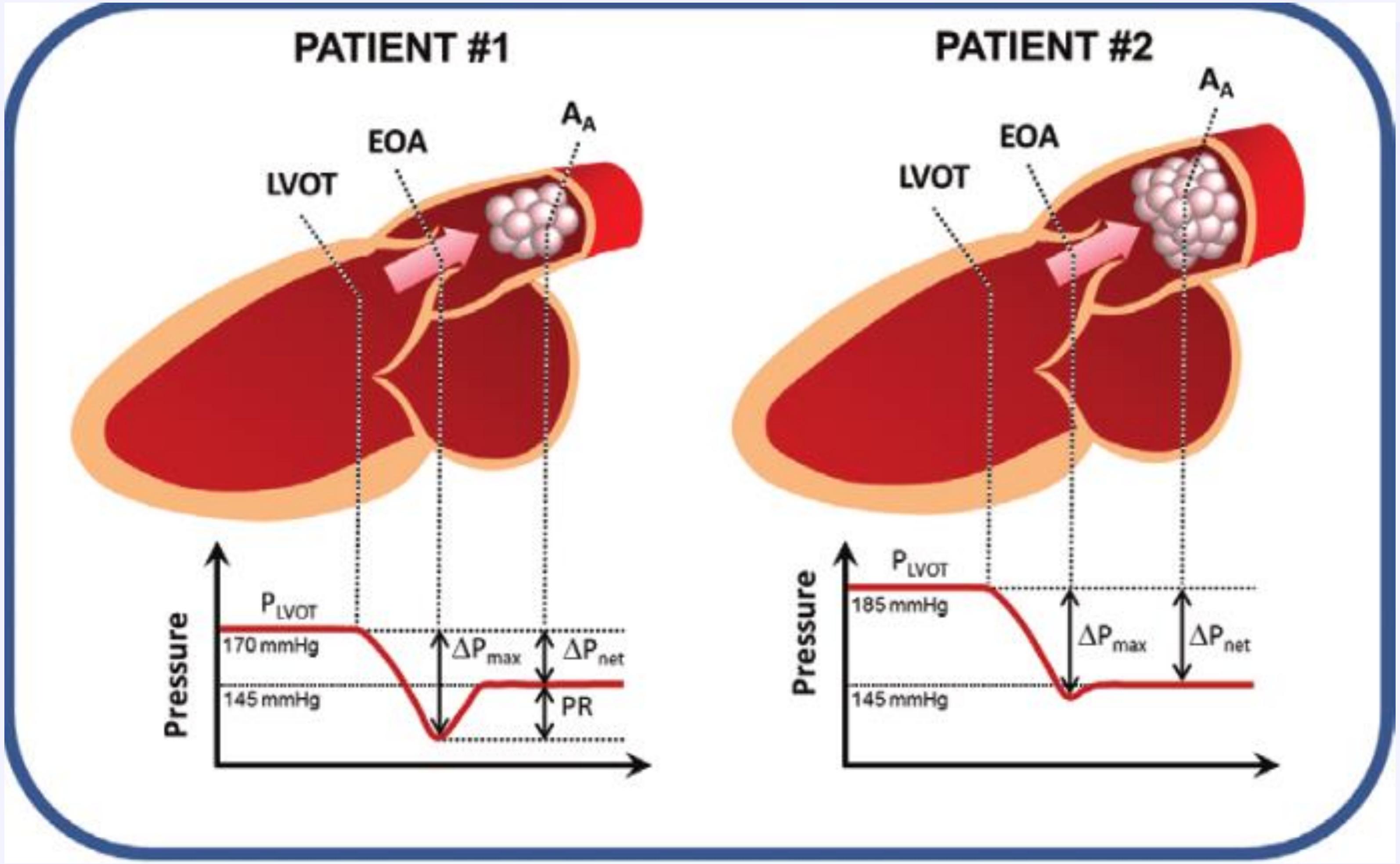
$$\Delta P = \tfrac{1}{2}\rho(V_2^2 - V_1^2) + \int_1^2 \frac{dv}{dt} \times ds + R(v)$$

convective acceleration — flow acceleration — viscous friction

Modified Bernoulli's Equation $\Delta P = 4\,(v_2^2 - v_1^2)$

Simplified Bernoulli's Equation $\Delta P = 4\,v^2$

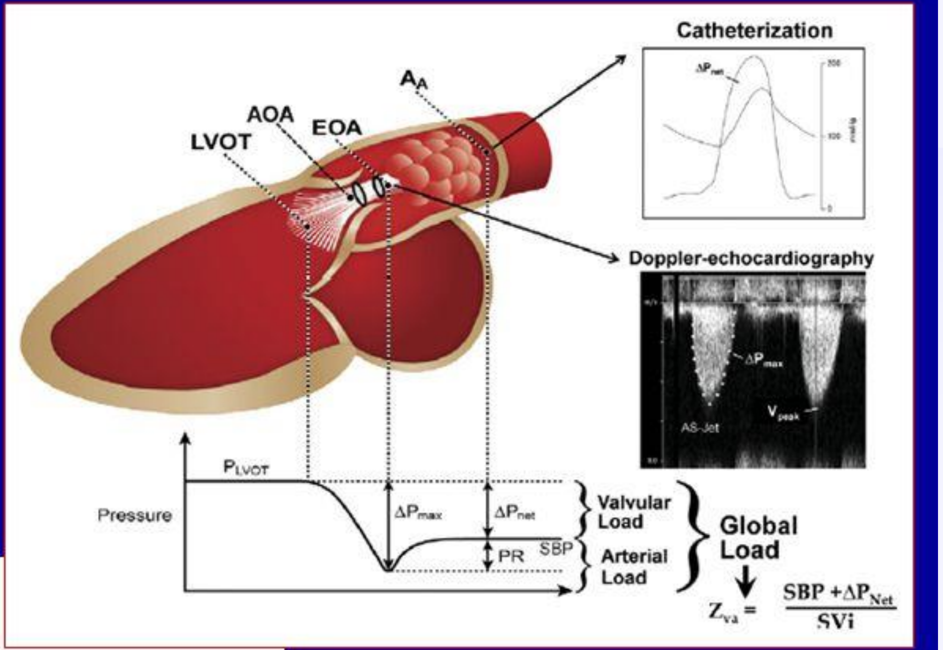
Pressure recovery phenomenon

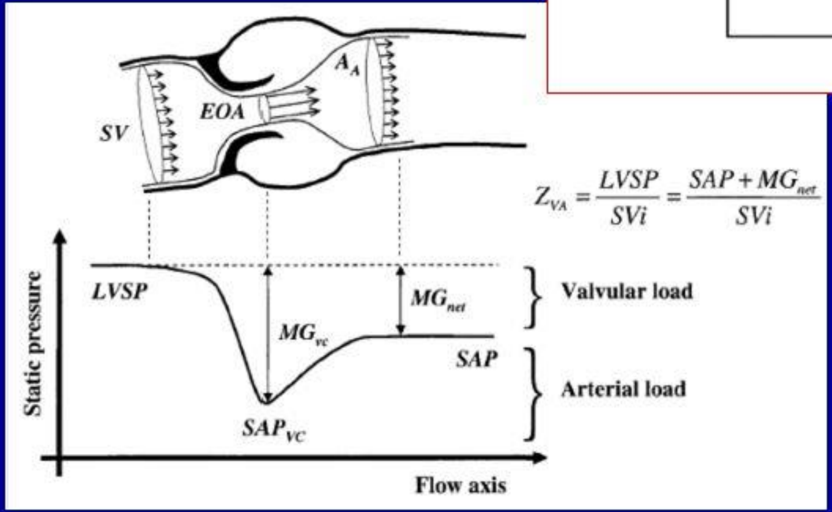


Pressure recovery phenomenon

- The phenomenon of pressure recovery in aortic stenosis is shown in previous slide.
- Two patients with same stroke volume and valve effective orifice area but different sizes of ascending area (2.0 cm diameter in patient # 1 vs 4.0 cm in patient # 2.
- Peak and mean gradient across the AoV measured by Doppler is the same in 2 patients but patient # 1 with the small aorta has a large amount of pressure recovery .
- Consequently, the net “irreversible” gradient (ΔP net; measured by catheter) in patient # 1 is lower than patient # 2. In other word, in patient # 1 Doppler is overestimating the gradient across the LVOT compared to cath.

Pressure recovery phenomenon





Gorlin Formula for calculation of aortic and mitral valves area

The Gorlin Valve Area Equation

(Basically a rearrangement of the Bernoulli equation)

General Equation:

$$A = \frac{F}{C\,(44.3)\sqrt{(P_1 - P_2)}}$$

Numerator term units
mL/sec

Aortic Valve

$$\text{Valve area} = \frac{\dfrac{\text{Cardiac Output}\,(\text{cm}^3/\text{min.})}{\text{Systolic ejection period}\,(\text{sec./min})}}{(C)(44.3)\sqrt{(\text{LV pressure} - \text{Ao pressure})}}$$

Mitral Valve

$$\text{Valve area} = \frac{\dfrac{\text{Cardiac Output}\,(\text{cm}^3/\text{min.})}{\text{Diastolic filling period}\,(\text{sec./min.})}}{(C)(44.3)\sqrt{(\text{LA pressure} - \text{LV pressure})}}$$

Gorlin R, Gorlin S: Hydraulic formula for calculation of the area of stenotic mitral valve, other cardiac valves and central circulatory shunts. Am Heart J 41:1, 1951

$$AVA = \frac{CO / (SEP \times HR)}{44.3 \times \sqrt{\text{Mean Gradient}}}$$

where:

AVA = aortic valve area in cm2 (normal = 2.5-3.5 cm2)
CO = cardiac output in mL/min
SEP = systolic ejection period/beat
HR = heart rate

Pressure recovery phenomenon

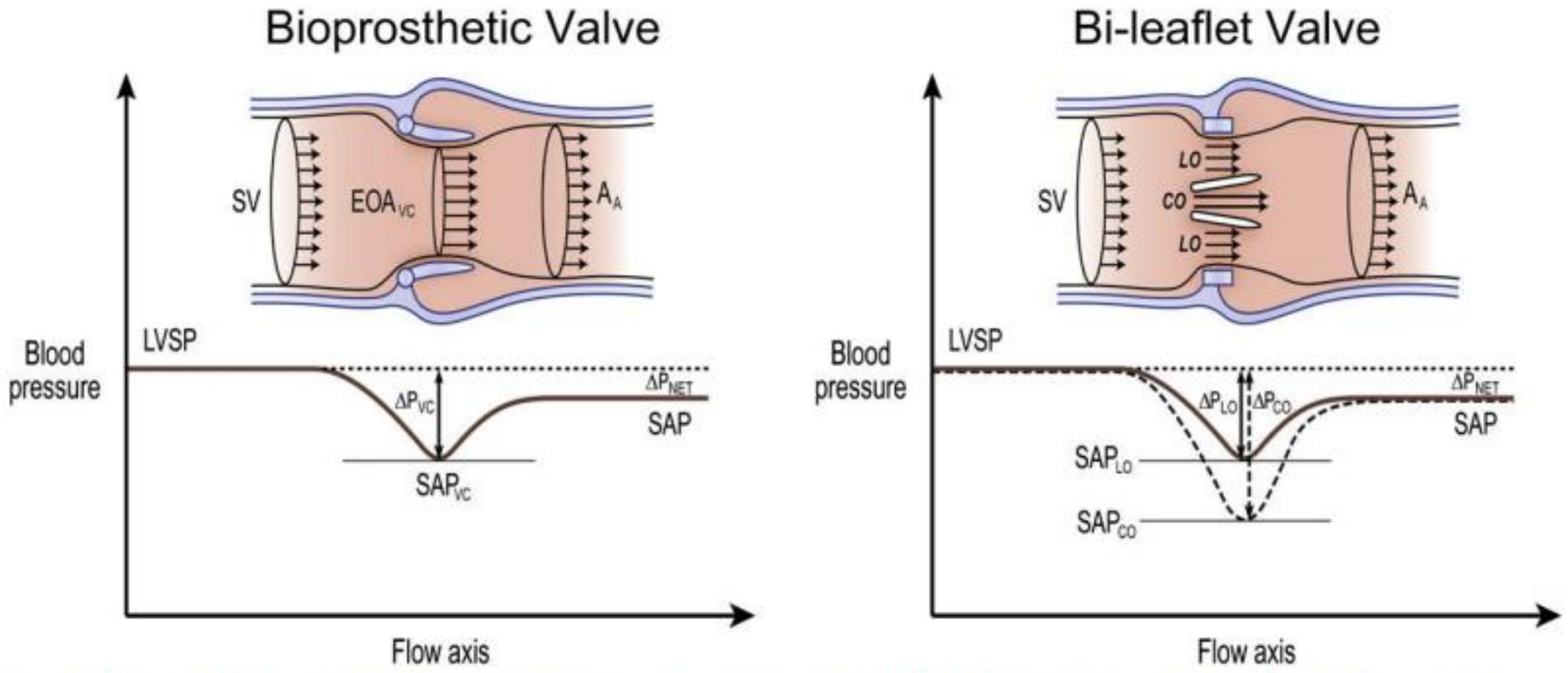
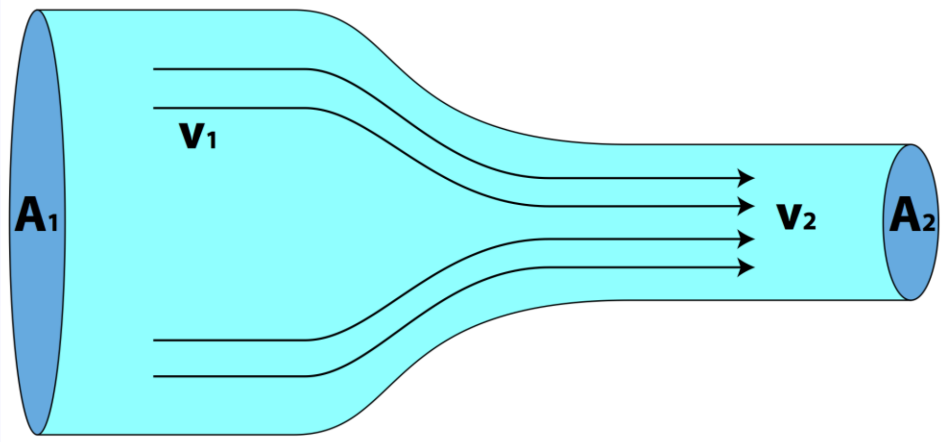


Figure 3 Schematic representation of velocity and pressure changes from the LVO tract to the ascending aorta (A_A) in the presence of a stented bioprosthesis and a bileaflet mechanical valve illustrating the phenomenon of pressure recovery. Because of pressure recovery, velocities are lower and systolic arterial pressure (SAP) is higher at the distal aorta than at the level of the vena contracta (VC). This is further exaggerated in the case of a bileaflet valve, in which the velocity is higher in the central orifice (CO) and thus pressure drop is higher at that level. Doppler gradients are estimated from maximal velocity at the level of the vena contracta and represent the maximal pressure drop, whereas invasive estimation of gradients usually reflect net pressure difference (ΔP) between LV systolic pressure (LVSP) and ascending aorta. *LO*, Lateral orifice; *SV*, stroke volume in LVO.

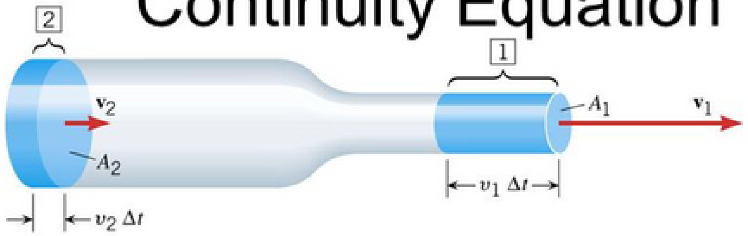
ASE guidelines, JASE 2009

Continuity equation



The conservation of the mass of fluid through two sections (be they A1 and A2) of a conduit (pipe) or tube of current establishes that the mass that enters is equal to the mass that leaves.

Continuity Equation

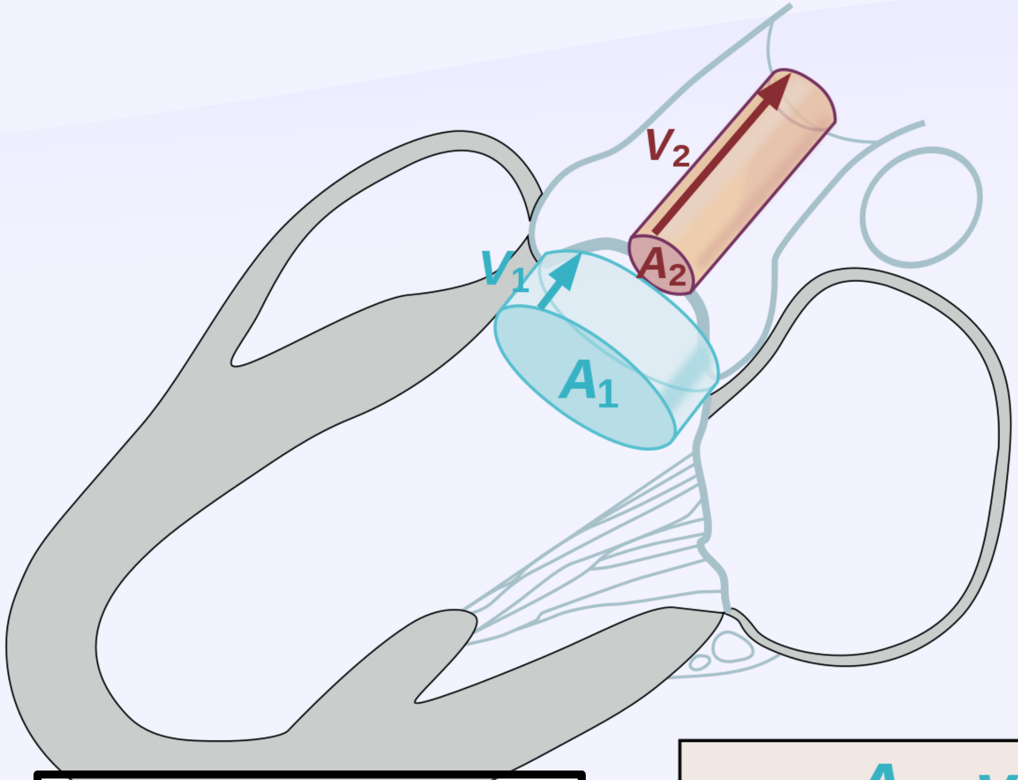


$$\rho_2 A_2 v_2 = \rho_2 A_1 v_1$$

Same, incompressable, fluid so roe drops out!

$$A_1 v_1 = A_2 v_2$$

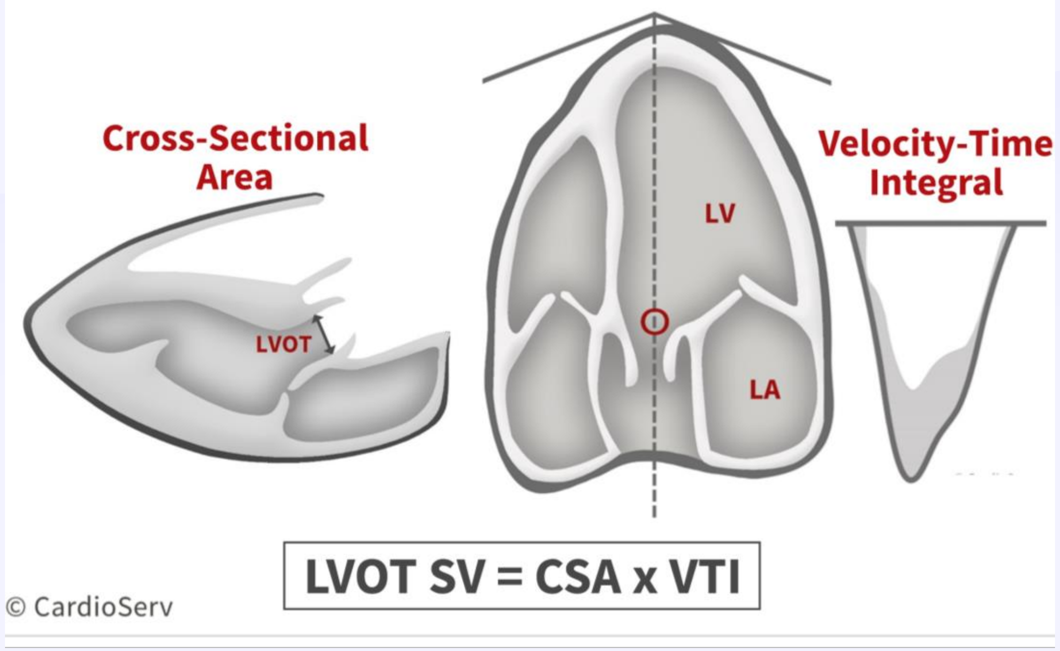
Continuity equation

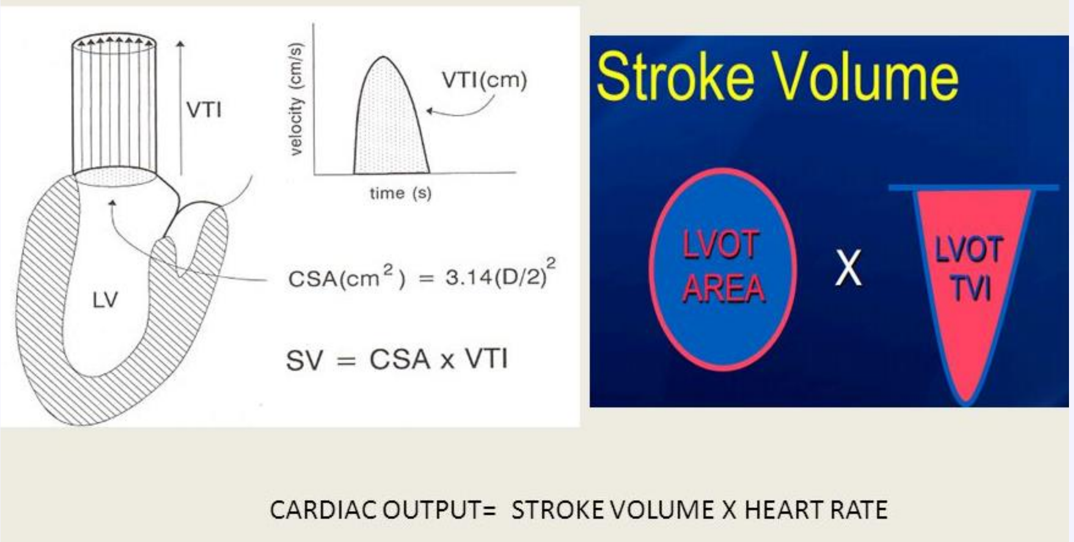


$$A2 = \frac{A1 \times LVOT\ VTI_1}{AoV\ VTI_2}$$

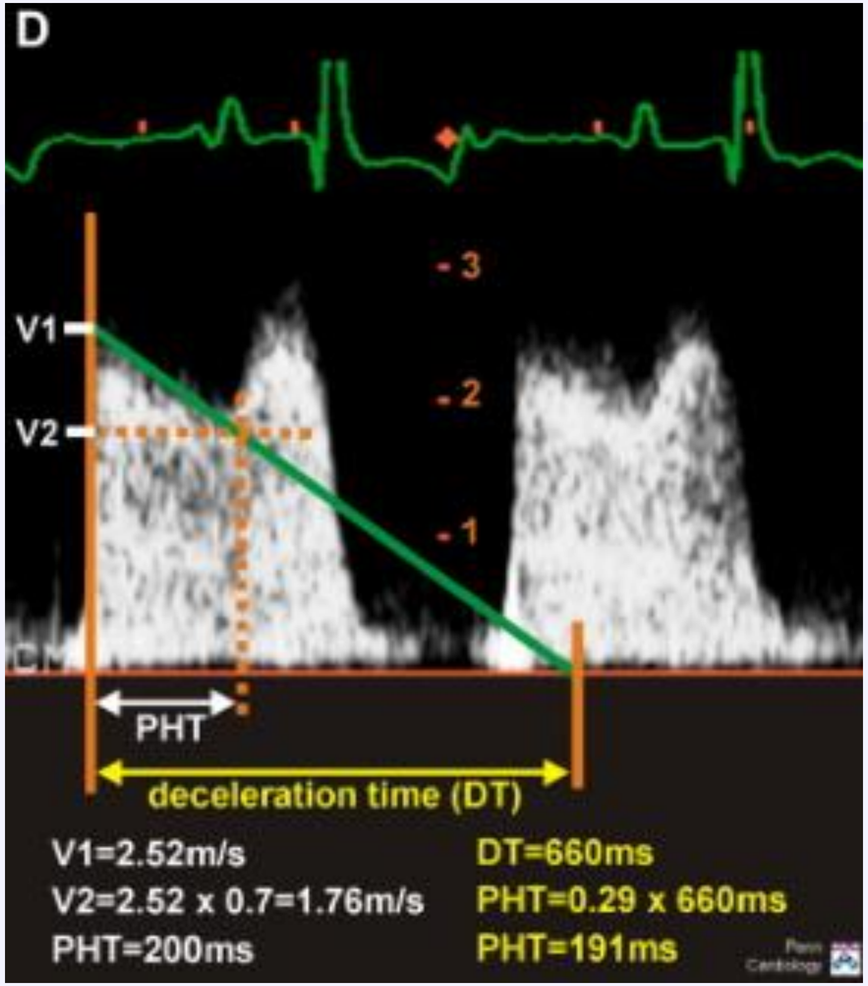
$$A_2 = \frac{A_1 \cdot v_1}{v_2}$$

Stroke volume & Cardiac output





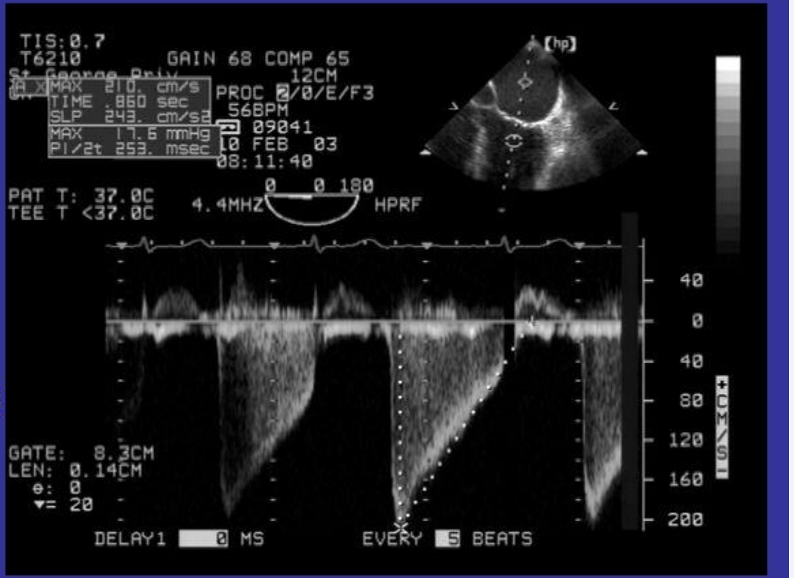
Pressure half time

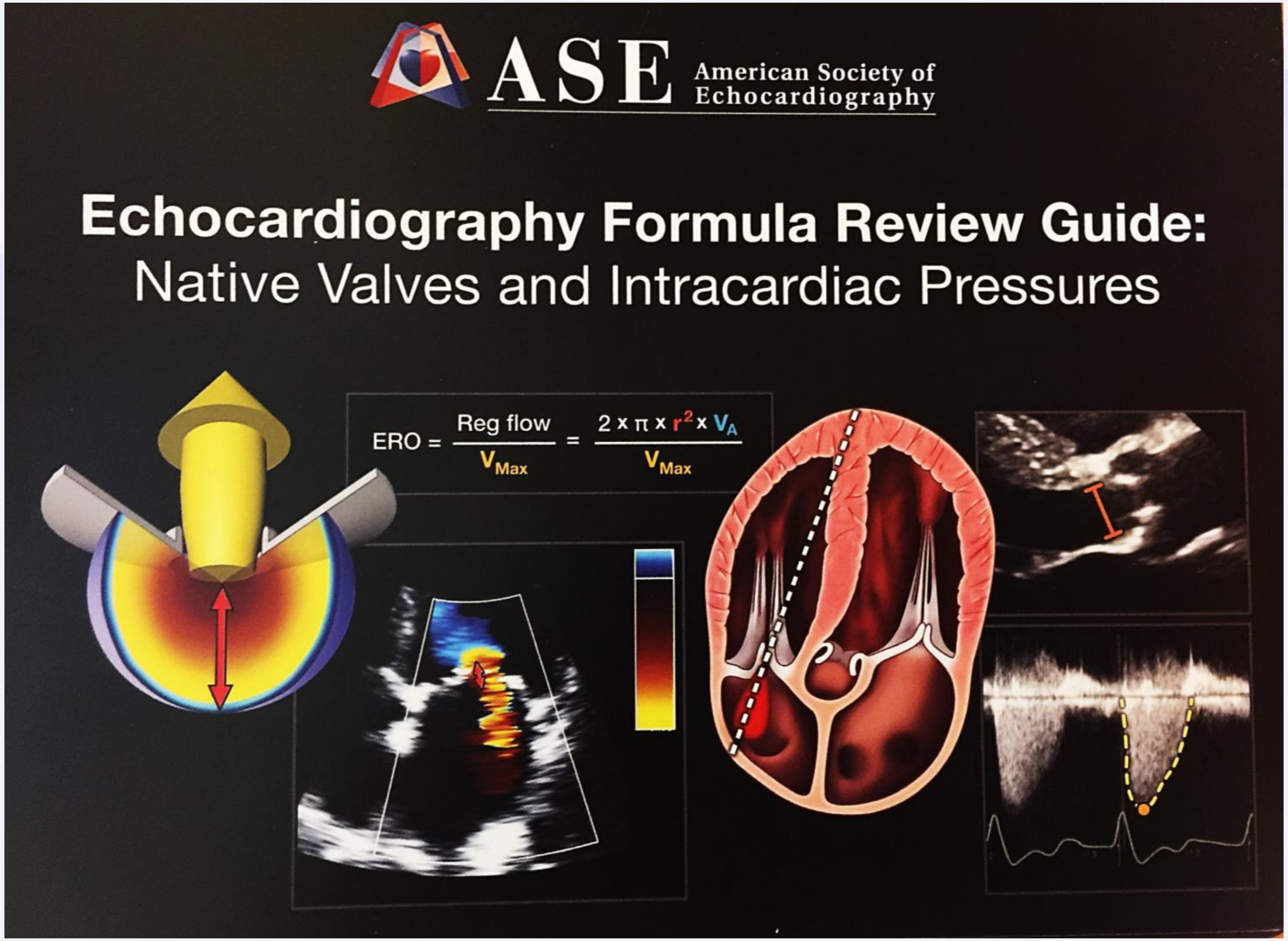


Doppler pressure half-time area

- The smaller the MV orifice, the slower the rate of pressure decline
- $T_{1/2}$= time for the peak transmitral pressure to halve (in msecs)
- Empiric formula:

  MVA= $220/T_{1/2}$
- Affected by ventricular compliance and cardiac output




ASE
American Society of Echocardiography
Echocardiography Formula Review Guide:
Native Valves and Intracardiac Pressures
ERO = Reg flow / V Max = 2 x π x r2 x VA / V 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.

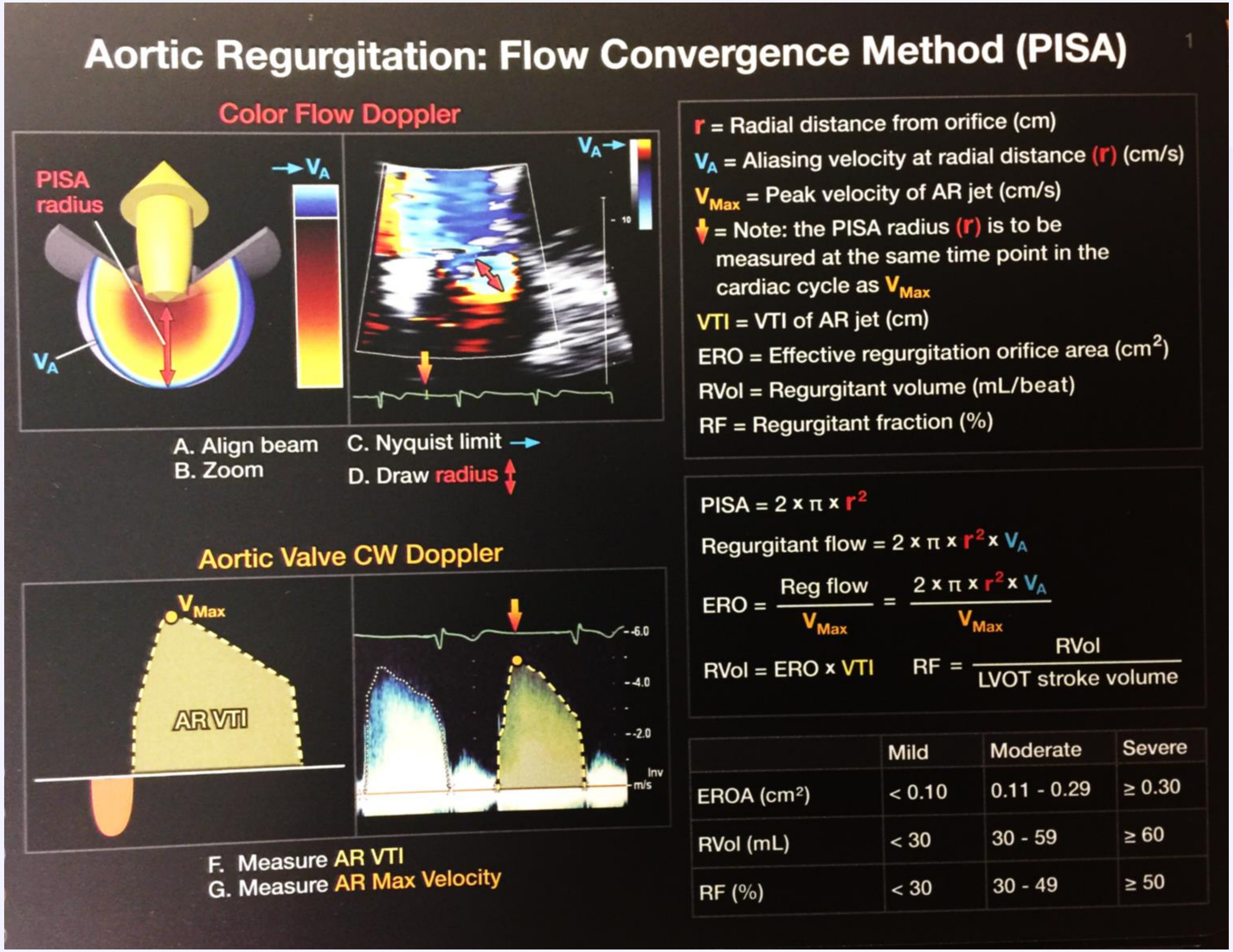
Adapted from:

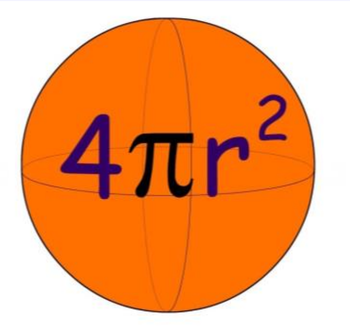
Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice. J Am Soc Echocardiogr 2009; 22: 1-23.

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.

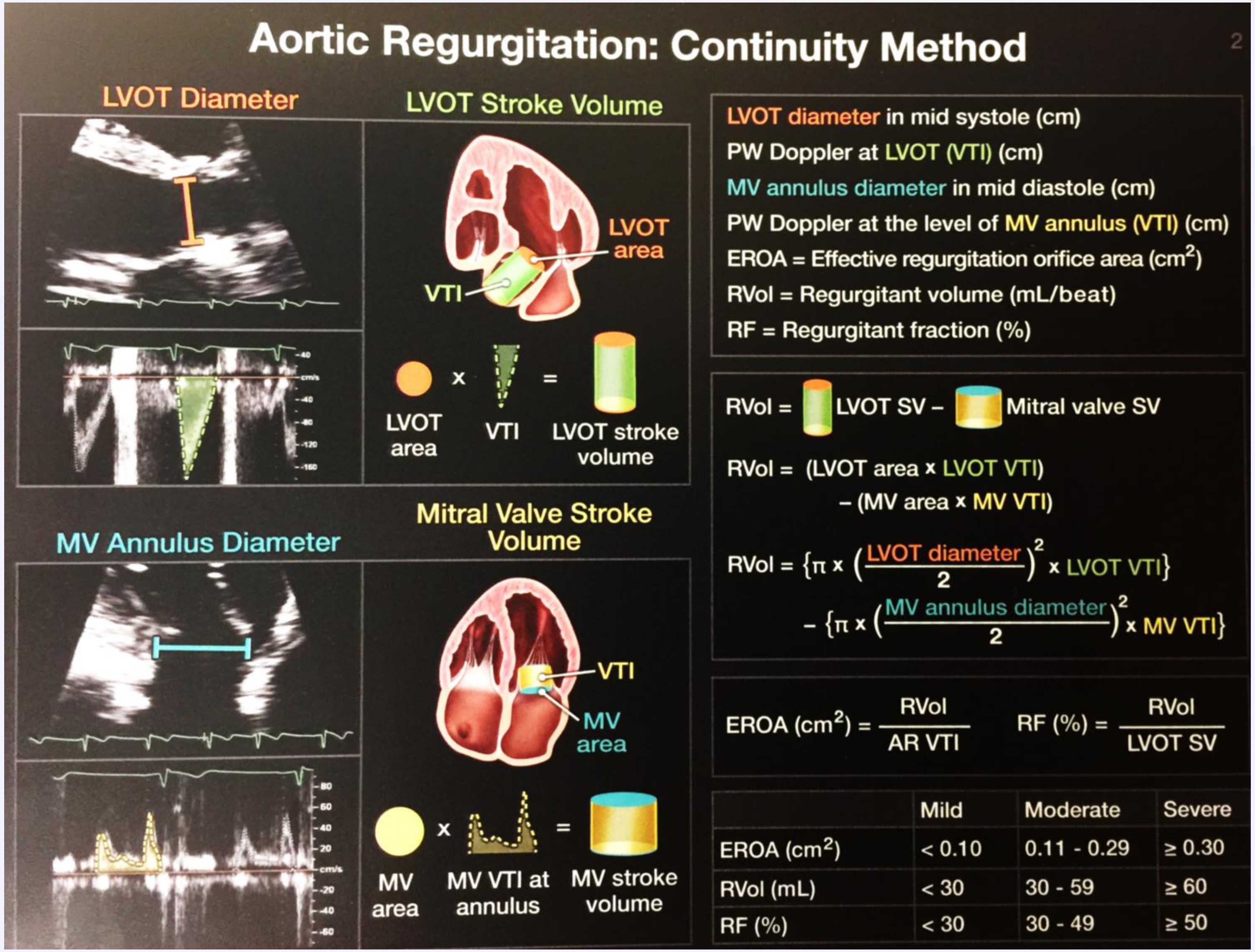
Recommendations on the Echocardiographic Assessment of Aortic Valve Stenosis: A Focused Update from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr 2017; 30: 372-392.

Design and illustration by medmovie.com

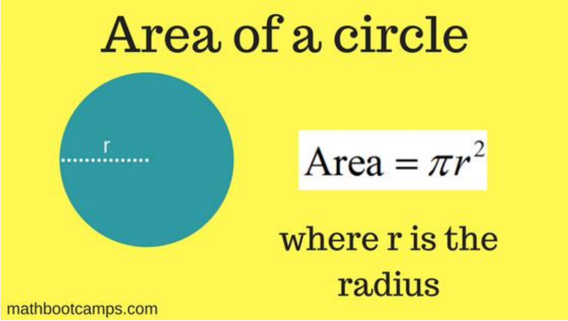


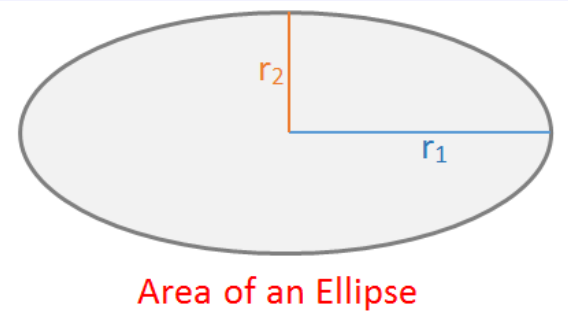


Surface area of a sphere



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



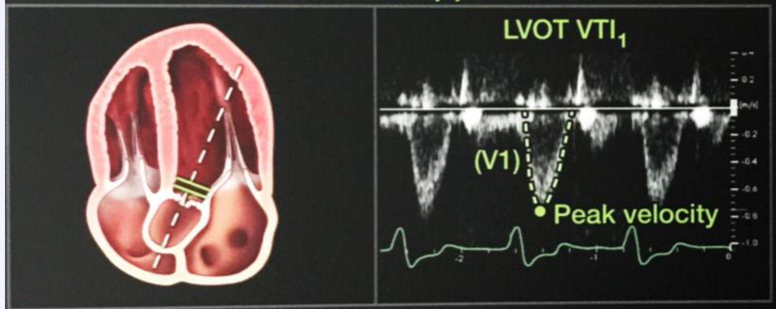


$$A = \pi \times r_1 \times r_2$$

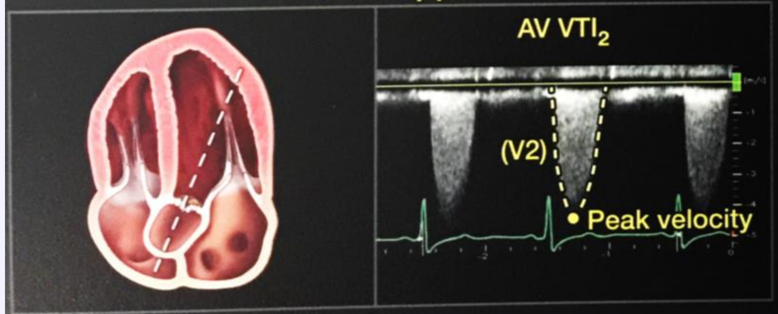
Aortic Stenosis

LVOT Diameter

LVOT PW Doppler

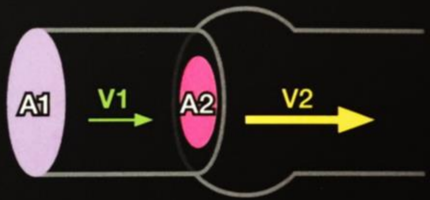


AV CW Doppler



$A1 \times V1 = A2 \times V2$

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



$A1$ = LVOT area (cm^2) $A2$ = AV area (cm^2)

VTI_1 = LVOT VTI (cm) VTI_2 = AV VTI (cm)

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

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

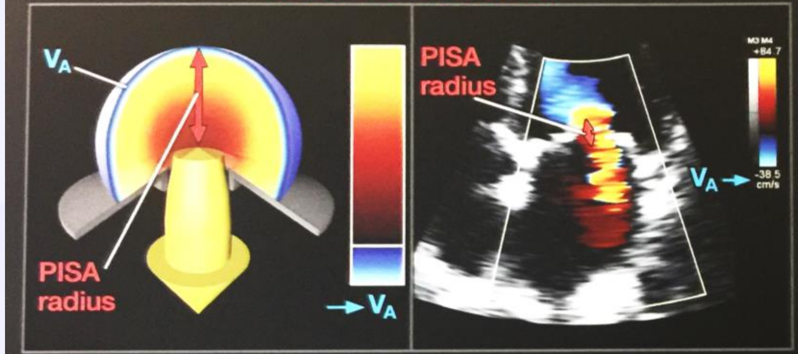
$$\text{Velocity time integral ratio (dimensionless index)} = \frac{\text{LVOT VTI}}{\text{AV VTI}}$$

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^2)	> 1.5	1.0 - 1.5	< 1.0
Indexed AVA (cm^2/m^2)	> 0.85	0.60 - 0.85	< 0.6
Dimensionless index	> 0.50	0.25 - 0.50	< 0.25

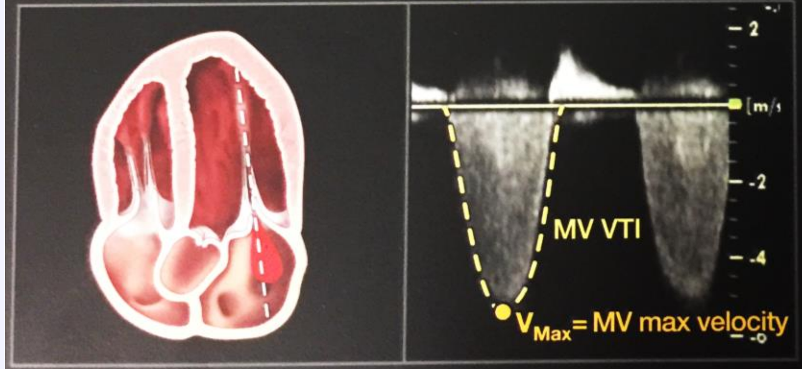
Mitral Regurgitation: Flow Convergence Method (PISA)

Color Flow Doppler



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

MV CW Doppler



F. Measure MV VTI
G. Measure MV max velocity

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^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

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

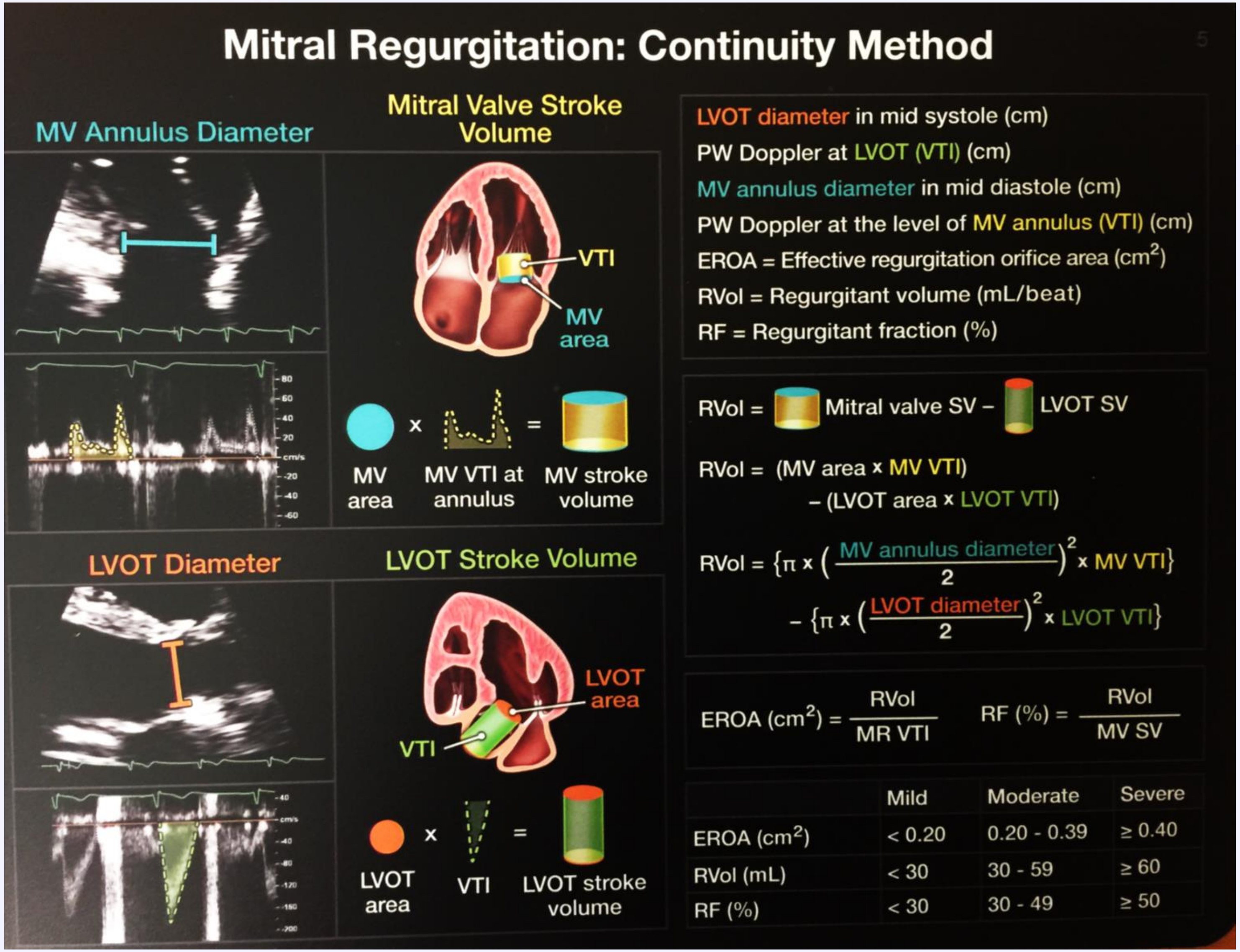
$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

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

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

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

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



Mitral Regurgitation: Continuity Method

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^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

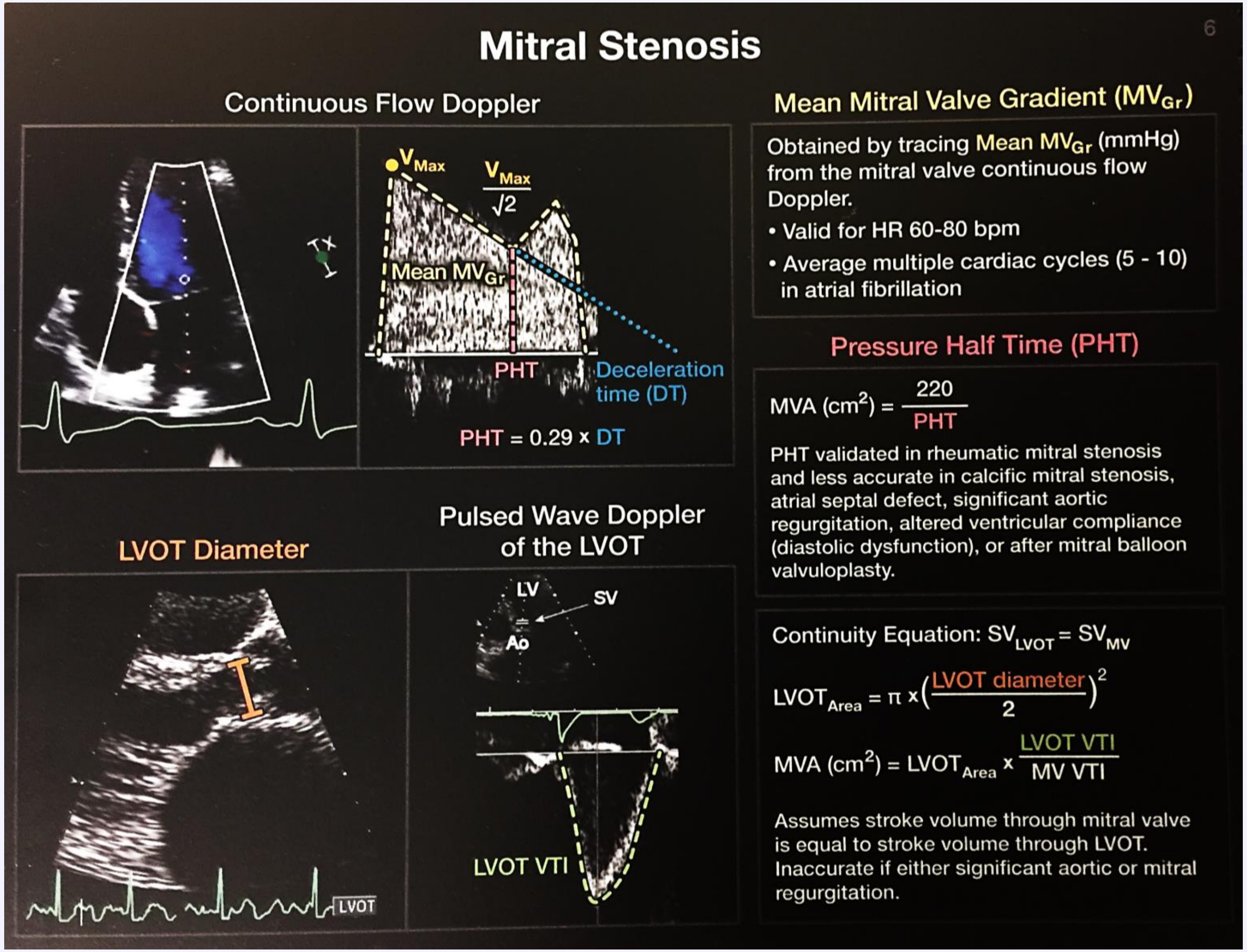
RVol = Mitral valve SV – LVOT SV

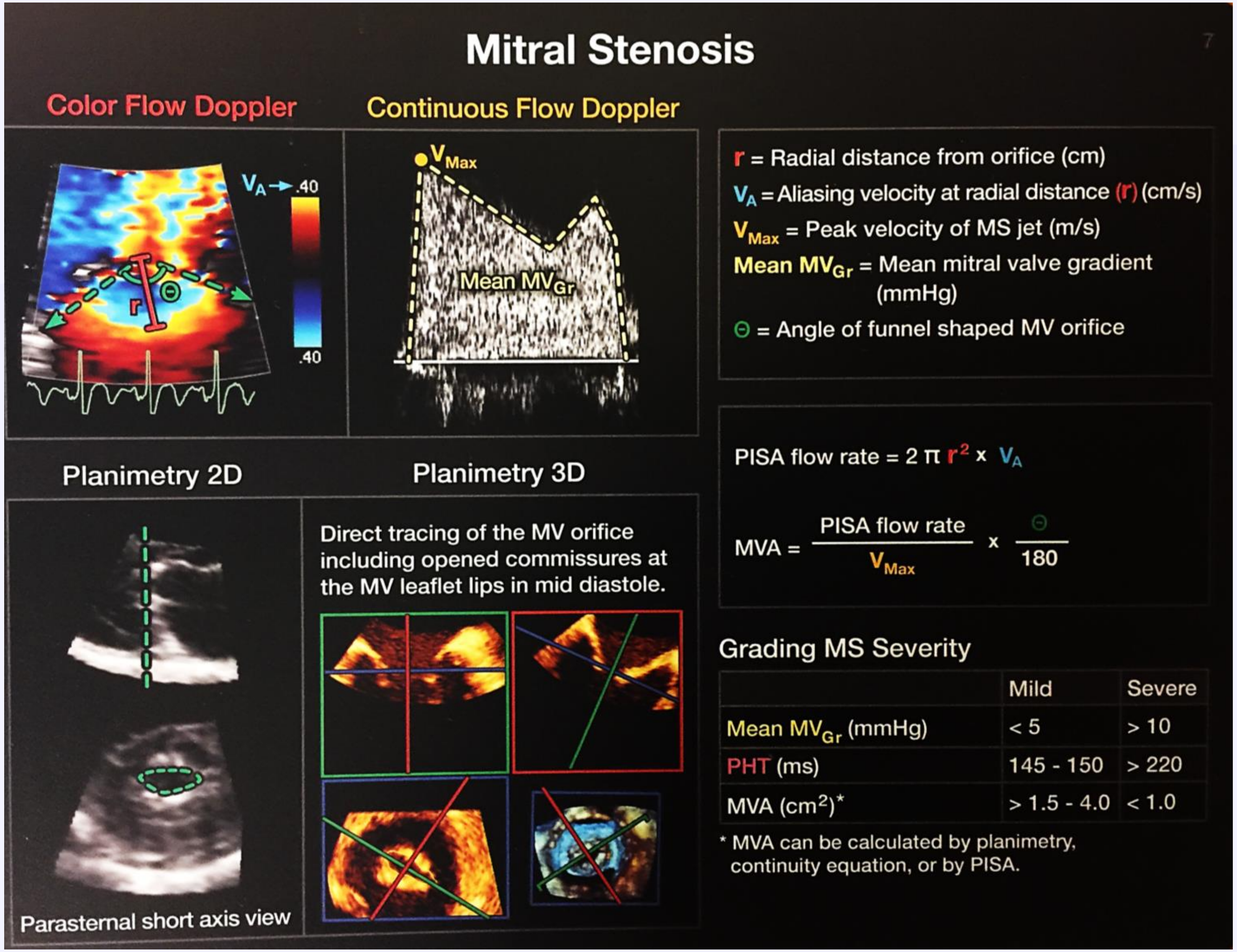
RVol = (MV area x MV VTI) – (LVOT area x LVOT VTI)

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

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

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


6
Mitral Stenosis
Continuous Flow Doppler
VMax
VMax / √2
Mean MVGr
PHT
Deceleration time (DT)
PHT = 0.29 x DT
Mean Mitral Valve Gradient (MVGr)
Obtained by tracing Mean MVGr (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 (cm2) = 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
LV
SV
Ao
LVOT VTI
LVOT
Continuity Equation: SVLVOT = SVMV
LVOTArea = π x (LVOT diameter / 2)2
MVA (cm2) = LVOTArea x LVOT VTI / MV VTI
Assumes stroke volume through mitral valve is equal to stroke volume through LVOT. Inaccurate if either significant aortic or mitral regurgitation.



Mitral Stenosis

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)

Θ = Angle of funnel shaped MV orifice

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

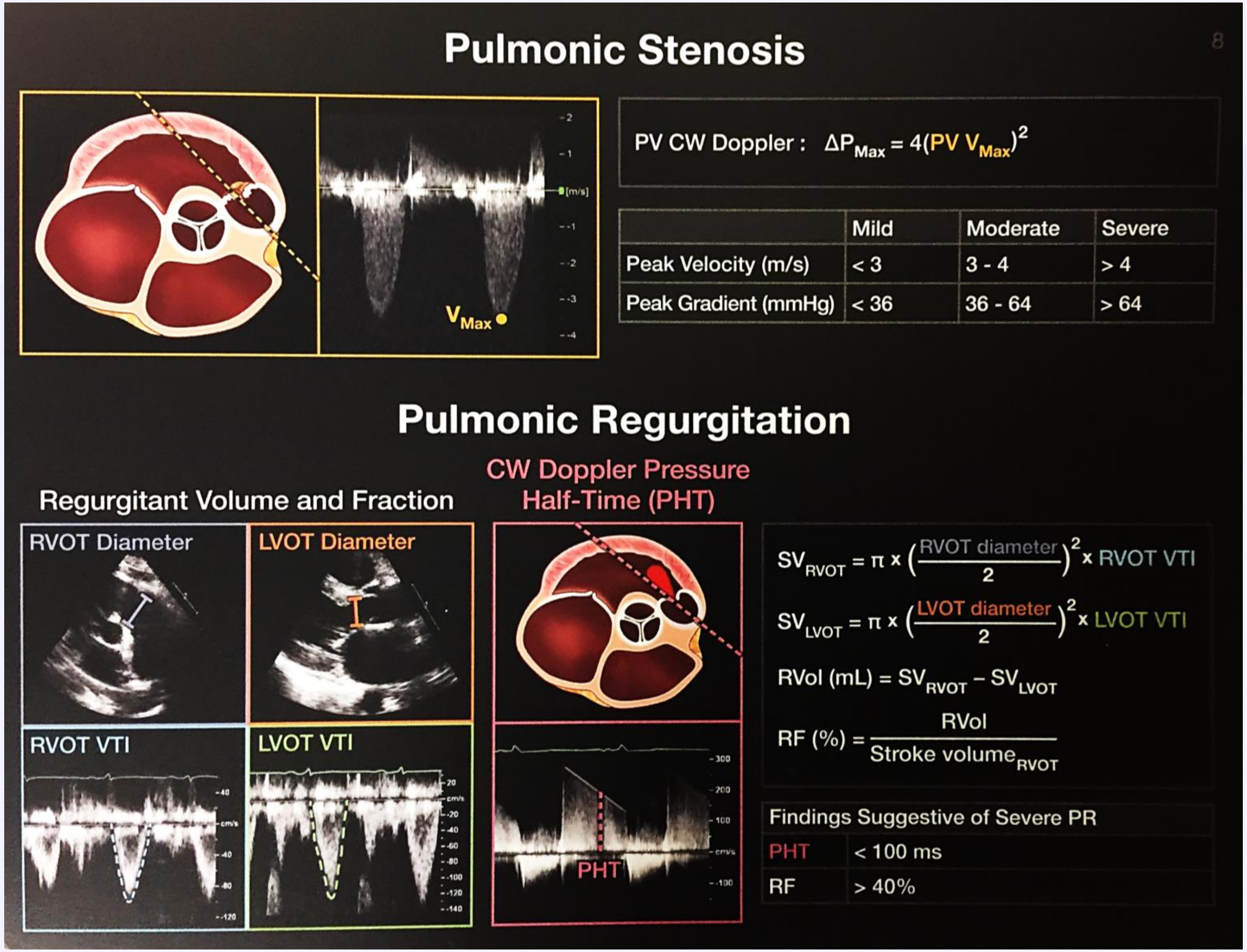
$$MVA = \frac{\text{PISA flow rate}}{V_{Max}} \times \frac{\Theta}{180}$$

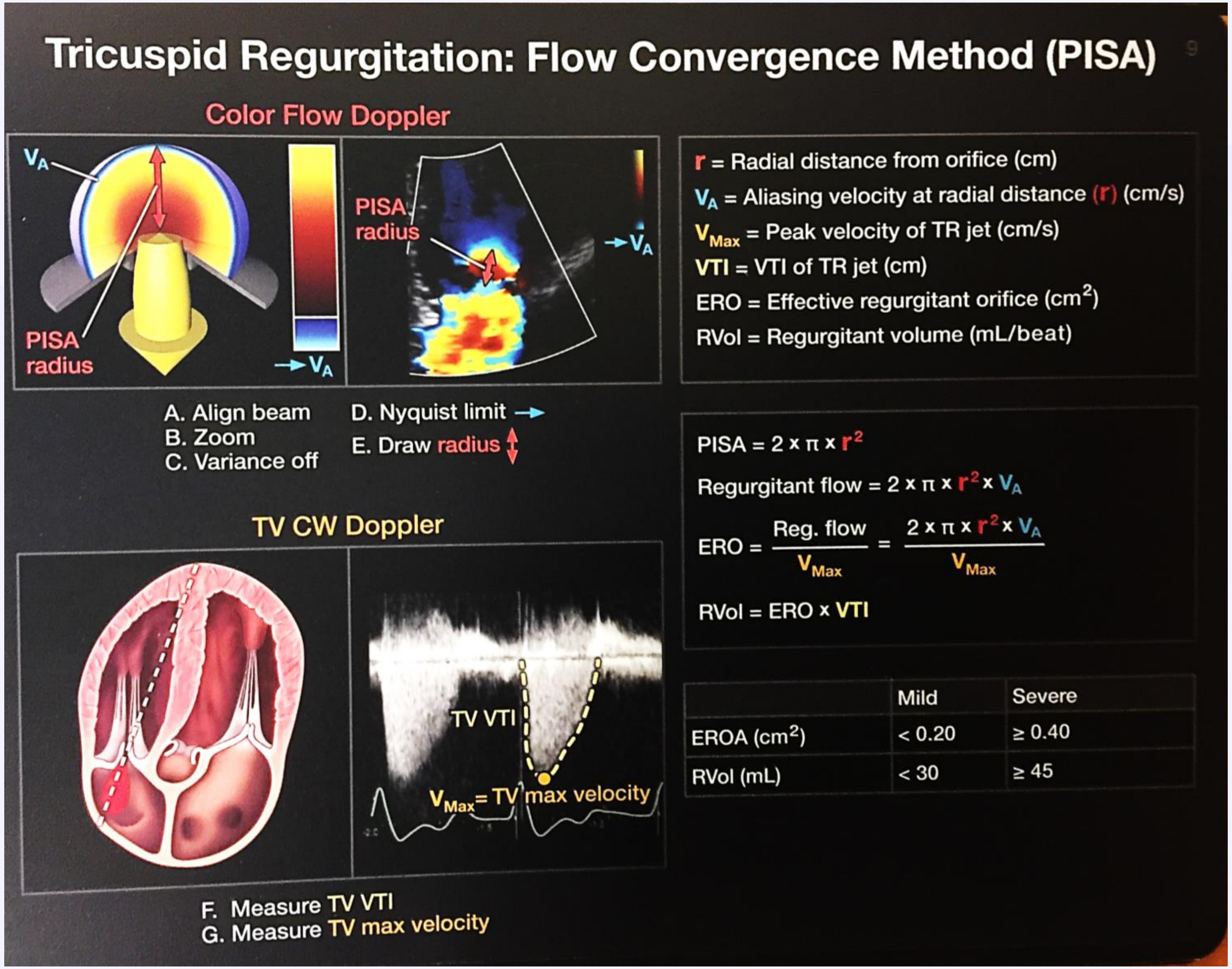
Direct tracing of the MV orifice including opened commissures at the MV leaflet lips in mid diastole.

Grading MS Severity

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

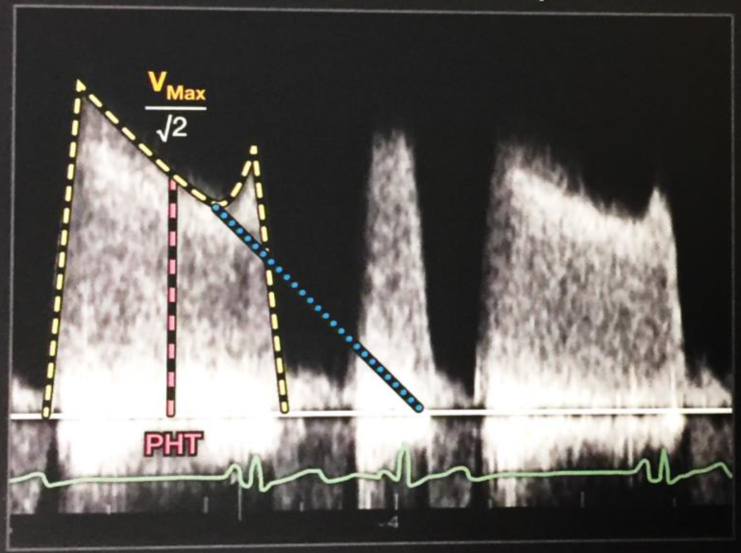
* MVA can be calculated by planimetry, continuity equation, or by PISA.


Pulmonic Stenosis
8
PV CW Doppler : ΔP_Max = 4(PV V_Max)^2
V_Max
Mild | Moderate | Severe
Peak Velocity (m/s) | < 3 | 3 - 4 | > 4
Peak Gradient (mmHg) | < 36 | 36 - 64 | > 64
Pulmonic Regurgitation
Regurgitant Volume and Fraction
CW Doppler Pressure Half-Time (PHT)
RVOT Diameter
LVOT Diameter
RVOT VTI
LVOT VTI
PHT
SV_RVOT = π x (RVOT diameter / 2)^2 x RVOT VTI
SV_LVOT = π x (LVOT diameter / 2)^2 x LVOT VTI
RVol (mL) = SV_RVOT − SV_LVOT
RF (%) = RVol / Stroke volume_RVOT
Findings Suggestive of Severe PR
PHT | < 100 ms
RF | > 40%


Tricuspid Regurgitation: Flow Convergence Method (PISA)
Color Flow Doppler
VA
PISA radius
→ VA
PISA radius
→ VA
A. Align beam
B. Zoom
C. Variance off
D. Nyquist limit →
E. Draw radius
r = Radial distance from orifice (cm)
VA = Aliasing velocity at radial distance (r) (cm/s)
VMax = Peak velocity of TR jet (cm/s)
VTI = VTI of TR jet (cm)
ERO = Effective regurgitant orifice (cm2)
RVol = Regurgitant volume (mL/beat)
PISA = 2 x π x r2
Regurgitant flow = 2 x π x r2 x VA
ERO = Reg. flow / VMax = 2 x π x r2 x VA / VMax
RVol = ERO x VTI
TV CW Doppler
TV VTI
VMax = TV max velocity
F. Measure TV VTI
G. Measure TV max velocity
Mild
Severe
EROA (cm2)
< 0.20
≥ 0.40
RVol (mL)
< 30
≥ 45

Tricuspid Stenosis

CW Doppler Through the Tricuspid Valve



Cut Off Values for Hemodynamically Significant Tricuspid Stenosis

Mean Gradient Pressure	≥ 5 mmHg
Pressure Half Time	≥ 190 ms
Inflow VTI	> 60 cm
Valve Area by Continuity Equation*	≤ 1 cm^2

* 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	> 2.1
Collapse w/ sniff	> 50%	< 50%	> 50%	< 50%

Mean Pulmonary Artery Pressure (mPAP)

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

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

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

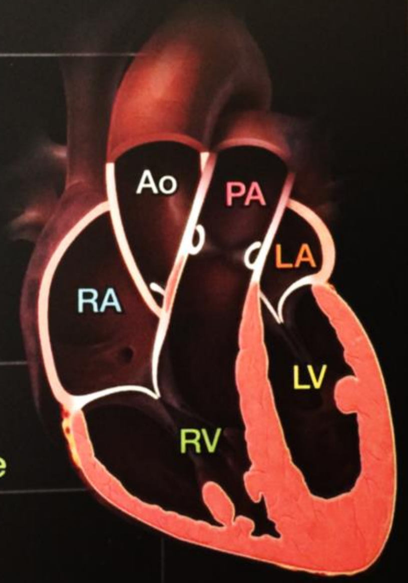
$$mPAP = 79 - (0.45 \times RVOT\ AcT)$$

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

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

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

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

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

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

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

Suggested reading materials

1. 2009 EAE/ASE, Echocardiographic assessment of valve stenosis: Recommendations for clinical practice. JASE 2009.
2. 2017 ASE/SCMR, Recommendations for noninvasive evaluation of native valvular regurgitation. JASE 2017.
3. 2017 EACVI/ASE, Recommendations on the echocardiographic assessment of aortic valve stenosis. JASE 2017.

Questions

Question 1

Which of the following statements about using Bernoulli's equation in Doppler echocardiography IS CORRECT?

A. This equation was described based on the law of conservation of the mass
B. Based on this equation when velocity of blood flow increase, blood pressure increases
C. Bernoulli's equation is not applicable if the blood flow is not steady
D. Simplified Bernoulli's equation should be used when we have combination of the aortic stenosis and coarctation of the aorta

Question 2

Which of the following statements about effect of pressure recovery phenomenon IS CORRECT?

A. Pressure recovery in a patient with aortic stenosis and dilated ascending aorta is more than narrow aorta
B. Overestimation of the Doppler gradient in a bioprosthetic aortic valve is more than mechanical double-disk AVR
C. In a patient with a long coarctation of the aorta, using Doppler echocardiography will overestimate the peak gradient
D. Peak Doppler gradient across the stenotic aortic valve is less than net gradient measured by catheter in the OR or Cath lab

Question 3

All of the following statements about blood flow pattern are correct EXCEPT:

A. Turbulent flow happens in a dilated tubular ascending aorta
B. Aortic regurgitation flow is an example of turbulent flow
C. In a patient without aortic stenosis, turbulent flow can happen in a hyper dynamic state
D. In a patient with dilated cardiomyopathy, blood flow inside the left ventricle in laminar

Question 4

Which of the following statements in using continuity equation in Doppler echocardiography IS CORRECT?

A. This equation is described based on the principle of conservation of the energy
B. Can be used in assessment of severity of aortic stenosis
C. Continuity equation can not be used for calculation of the aortic valve area if there is mixed lesion of aortic stenosis and regurgitation
D. Continuity equation can not be used for calculation of the aortic valve area if there is a combination of AS and coarctation of the aorta

Question 5

All of the following statements about assessment of degree of aortic regurgitation (AR) by PISA method are correct EXCEPT:

A. Nyquist limit colour bar should be moved towards regurgitant jet
B. Regurgitant volume more 60 ml/beat is compatible with (c/w) severe AR
C. EROA less than 0.10 cm2 is c/w mild AR
D. Regurgitant fraction more than 60% is c/w severe AR

Question 6

Which of the following statements in using continuity equation in assessment of degree of AR IS CORRECT?

A. LVOT VTI for calculation of stroke volume should be measured by PW Doppler
B. LVOT diameter should be measured at the mid diastole, same time of maximum AR
C. MV VTI should be measured at the level of the tips of mitral valve
D. EROA can be measured with dividing regurgitant volume by LVOT SV

Question 7

Which of the following statements in using echocardiography in assessment of degree of AR IS CORRECT?

A. Vena contracta in severe AR is more than 0.7 cm2
B. Pressure half time of AR jet in severe AR is between 200-500 ms
C. Jet width/LVOT width, central jet in severe AR is more than 65%
D. EROA of severe AR is more than 0.40 cm2

Question 8

Which of the following statements about assessment of degree of aortic stenosis by Doppler IS CORRECT?

A. LVOT diameter should be measured at end-diastole
B. Aortic valve area (AVA) is measured based on continuity equation
C. Calculation of AVA using LVOT and aortic VTI will give us aortic valve area at mid systole (peak opening)
D. Assumption to calculate cross sectional area of the LVOT is based on ellipsoid shape of LVOT

Question 9

All of the following statements about severe aortic stenosis (AS) by Doppler are correct EXCEPT:

A. Peak velocity across the aortic valve is more than 4.0 m/s
B. Indexed aortic valve area is less than 0.6 cm2/m2
C. Mean gradient across the aortic valve is more than 40 mmHg
D. Dimensionless Index is less than 0.35

Question 10

All of the following statements about assessment of degree of mitral regurgitation (MR) by PISA method are correct EXCEPT:

A. MR max. velocity should be measured in 4-chamber view in TEE
B. Colour bar of Nyquist limit should be moved towards LV apex in TEE
C. Stroke volume through the mitral inflow is equal to sum of LVOT flow and MR regurgitant volume
D. Regurgitant flow of MR is calculated in ml/s

Question 11

All of the following statements about assessment of degree of mitral regurgitation (MR) by PISA method are correct EXCEPT:

A. Regurgitant volume is calculated as EROA divided by MR VTI
B. EROA more than 0.40 cm2 is compatible with (c/w) severe MR
C. Regurgitant volume more than 60 ml/beat is c/w severe MR
D. Regurgitant fraction more than 50% is c/w severe MR

Question 12

All of the following statements about assessment of degree of mitral regurgitation (MR) by continuity method are correct EXCEPT:

A. MR VTI should be measured by PW positioning sample volume at the level of the mitral leaflets tip
B. Regurgitant volume is equal to difference between MV inflow stroke volume and LVOT stroke volume
C. EROA is calculated as regurgitant volume divided by MR VTI
D. Mitral inflow stroke volume is calculated based on assumption of circular shape of mitral annulus

Question 13

Which of the following statements about assessment of degree of mitral stenosis (MS) by PISA method in TEE IS CORRECT?

A. MS maximum velocity is measured at mid systole in TEE 4 chamber view
B. The angle of funnel shaped MV orifice should be measured at LV side to be used in MVA calculation
C. MVA is calculated as PISA flow rate multiply by MS maximum velocity
D. For measuring the radius (r) of the PISA by TEE, Nyquist limit colour bar should be moved towards the apex of the heart

Question 14

Which of the following statements about assessment of degree of MS by pressure half time method (PHT) IS CORRECT?

A. In significant AR, PHT method underestimates the mitral valve area
B. PHT is equal to mitral deceleration time divided by 0.29
C. PHT is defined as the time interval between the maximum mitral gradient in early diastole and the time point where the gradient is the half of the maximum initial value
D. PHT is defined as the time interval between the maximum mitral inflow velocity in early diastole and the time point where the velocity is the half of the maximum initial value

Question 15

All of the following statements about assessment of tricuspid regurgitation (TR) by PISA method are correct EXCEPT:

A. Effective regurgitant orifice area (EROA) measured by 2D PISA is larger than 3D PISA
B. TR maximum velocity should be measured in TEE 4 chamber view
C. EROA more than 0.40 cm2 is c/w severe TR
D. Regurgitant volume more than 45 ml/beat is c/w severe TR

Question 16

All of the following statements about echocardiographic assessment of tricuspid stenosis (TS) are correct EXCEPT:

A. Doppler tricuspid inflow VTI more than 60 cm is c/w severe TS
B. Mean diastolic gradient more than 5 mmHg is c/w severe TS
C. Tricuspid valve area by PHT less than 1.0 cm2 is c/w severe TS
D. PHT more than 190 ms is c/w severe TS

Question 17

In a patient with systemic blood pressure of 140/60 mmHg and moderate to severe AR, pulmonary capillary wedge pressure was measured at 24 mmHg. Which of the following statements IS CORRECT?

A. Left ventricular end diastolic pressure (LVEDP) is about 60 mmHg
B. AR jet early peak velocity by Doppler is about 3 m/s
C. AR jet peak velocity by Doppler is about 4 m/s
D. AR jet end diastolic velocity by Doppler is about 3 m/s

Question 18

In Doppler assessment of a patient with VSD and mitral regurgitation (MR), VSD LV to RV shunt maximum velocity was 5 m/s and MR jet peak velocity was 6 m/s. RVSP measured by TR velocity was 60 mmHg. What is your estimation about mean LA pressure?

A. Mean LA pressure is same as RVSP and is about 60 mmHg
B. Mean LA pressure in this patient can not be estimated without knowing the systolic blood pressure
C. Mean LA pressure is about 16 mmHg
D. Mean LA is about 26 mmHg.

Question 19

In Doppler assessment of pulmonary artery pressure (PAP) in a patient, RVOT acceleration time (RVOT AcT) was measured at 80 ms. RVSP measured by TR velocity was 63 mmHg. What is your estimation about PA diastolic pressure (PADP)?

A. PADP is about 33 mmHg
B. PADP is about 43 mmHg
C. PADP is half of RVSP which is about 31.5 mmHg
D. PADP can not be calculated without having IVC diameter

Question 20

In Doppler assessment of a patient with pulmonary hypertension and no PS, RVOT VTI was measured at 10 cm. TR maximum velocity was 4 m/s. IVC diameter was measured at 2.5 cm with 20% collapsibility. Which of the following statements IS CORRECT?

A. Pulmonary vascular resistance (PVR) in this patient is in normal range and pulmonary systolic pressure is about 64 mmHg
B. PA systolic pressure in this patient is about 80 mmHg and PVR is more than 4 Woods unit
C. PVR is in patient is 0.56 Woods and patient has severe RV dysfunction
D. This patient has severe pulmonary hypertension due to volume overloading

Correct Answers

1- C	9- D	17- D
2- C	10- B	18- C
3- A	11- A	19- A
4- B	12- A	20- B
5- D	13- D	
6- A	14- C	
7- C	15- A	
8- B	16- C	


Toronto
Thank you.