Comprehensive Hemodynamics
By Doppler Echocardiography.
The Echocardiographic Swan-Ganz Catheter.

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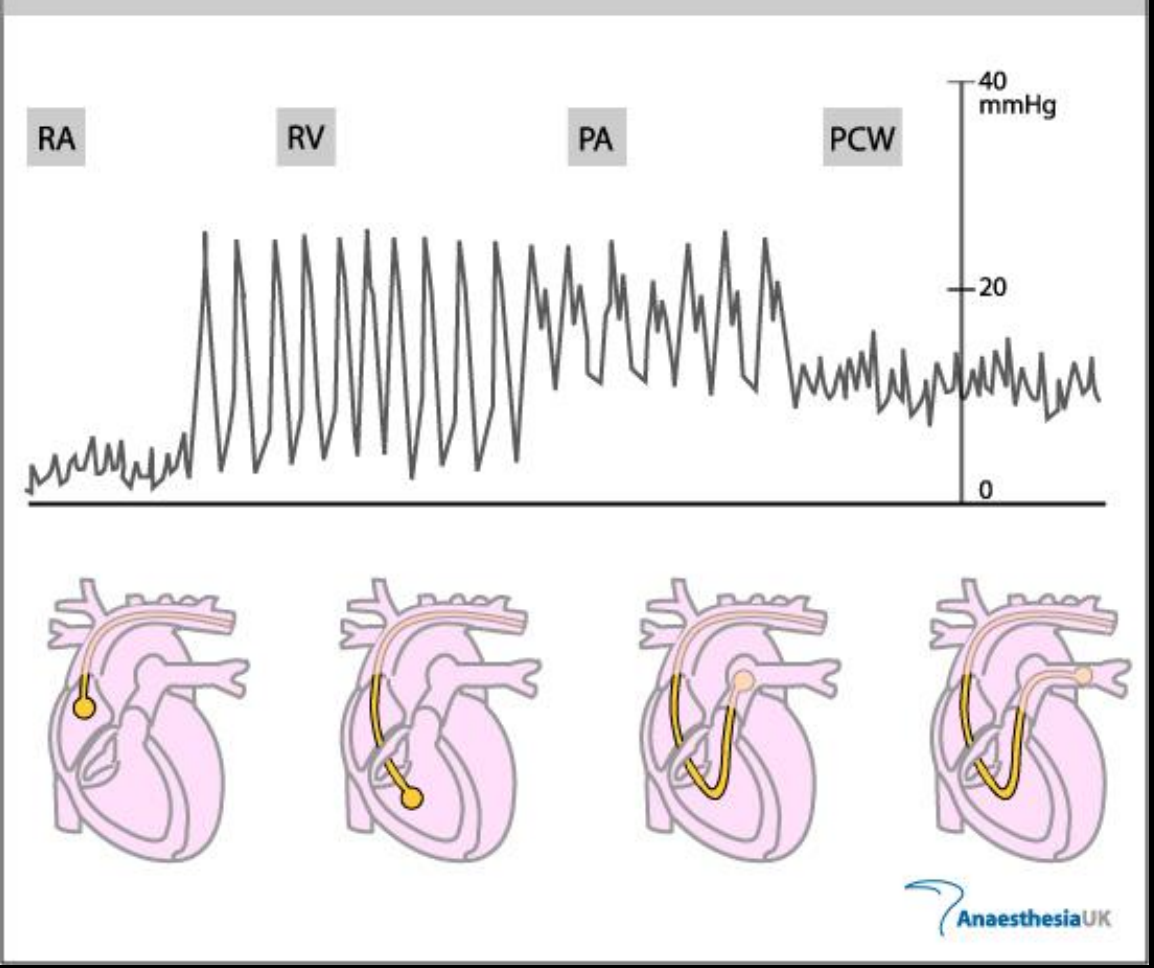
Mastering the use of Doppler:
The non invasive alternative to Swan-Ganz

No Dsclosures



PA Catheter

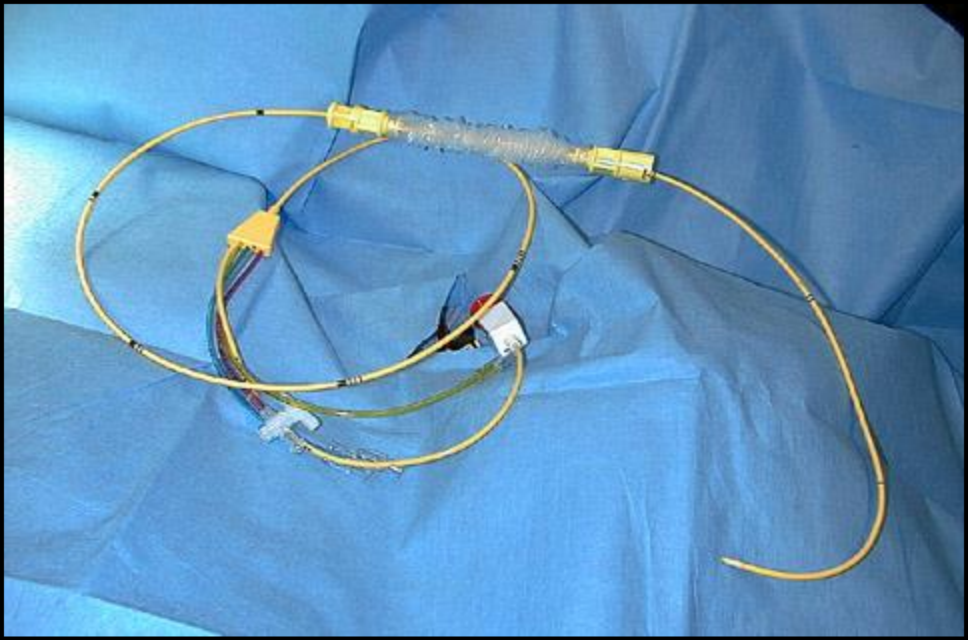
Gold standard of hemodynamic monitoring?

-Rt sided and PCW pressures. Volume status

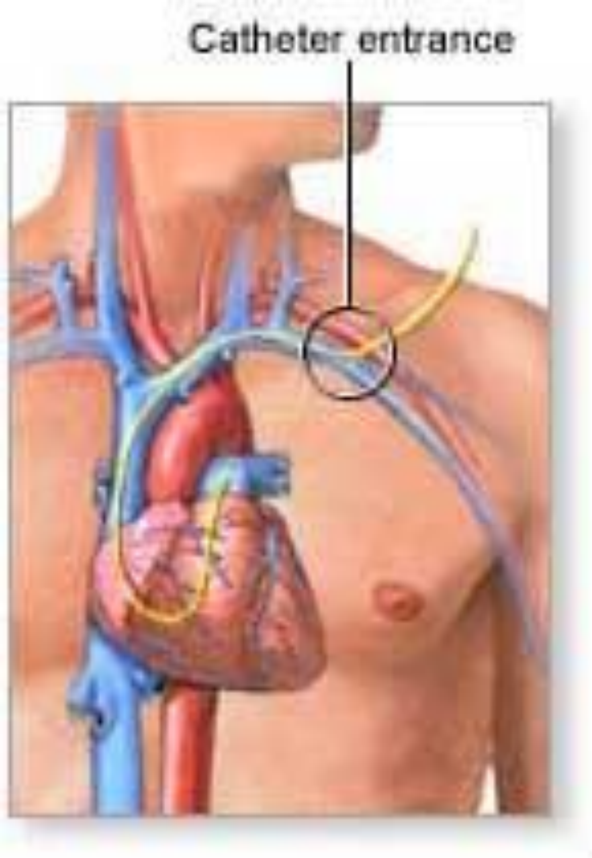
-Pulmonary blood flow and pulmonary vascular resistance

-Shunt location and magnitude

PA CATHETER:



No cardiac imaging- Unable to demonstrate
-Segmental or global wall motion
-Valvular anatomy
-Intracardiac masses and clots
-Pericadial effusion



PA Catheter- Complications

-Bleeding, hemothorax
-Clot formation and embolization
-Infection, sepsis, endocarditis
-PA perforation
-Arterial puncture, AV fistula, pseudoaneurysm
Left heart entry
-Pneumothorax
-Valvular tear
-Catheter knotting, Balloon rupture
-Ahrrythmia

AFTER RISK STRATIFICATION, PATIENTS MONITORED BY PA CATHETER HAD HIGHER MORTALITY AND MORBIDITY THAN PATIENT MONITORED BY ECHO

ECHOCARDIOGRAPHY

-Monitoring of chambers size , volume and motion
-Valve anatomy and pathology
- Intracardiac masses
- Pericardal abnormalities
-Blood flow, cardiac output and shunts
-Intracardiac pressures

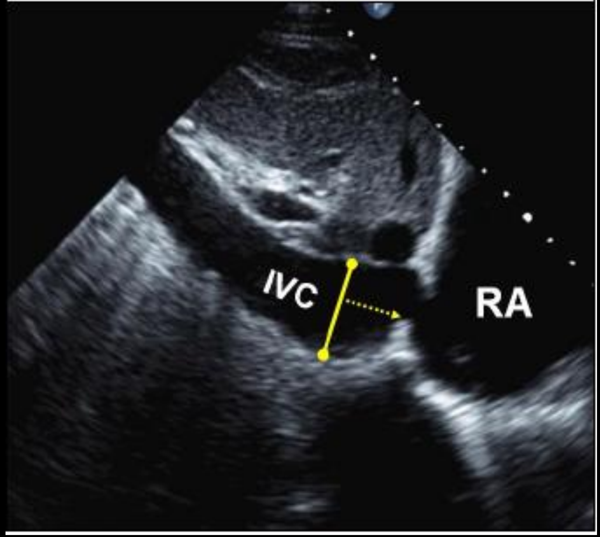
The Simplified Bernoulli Equation

$$\Delta P = 4V^2$$

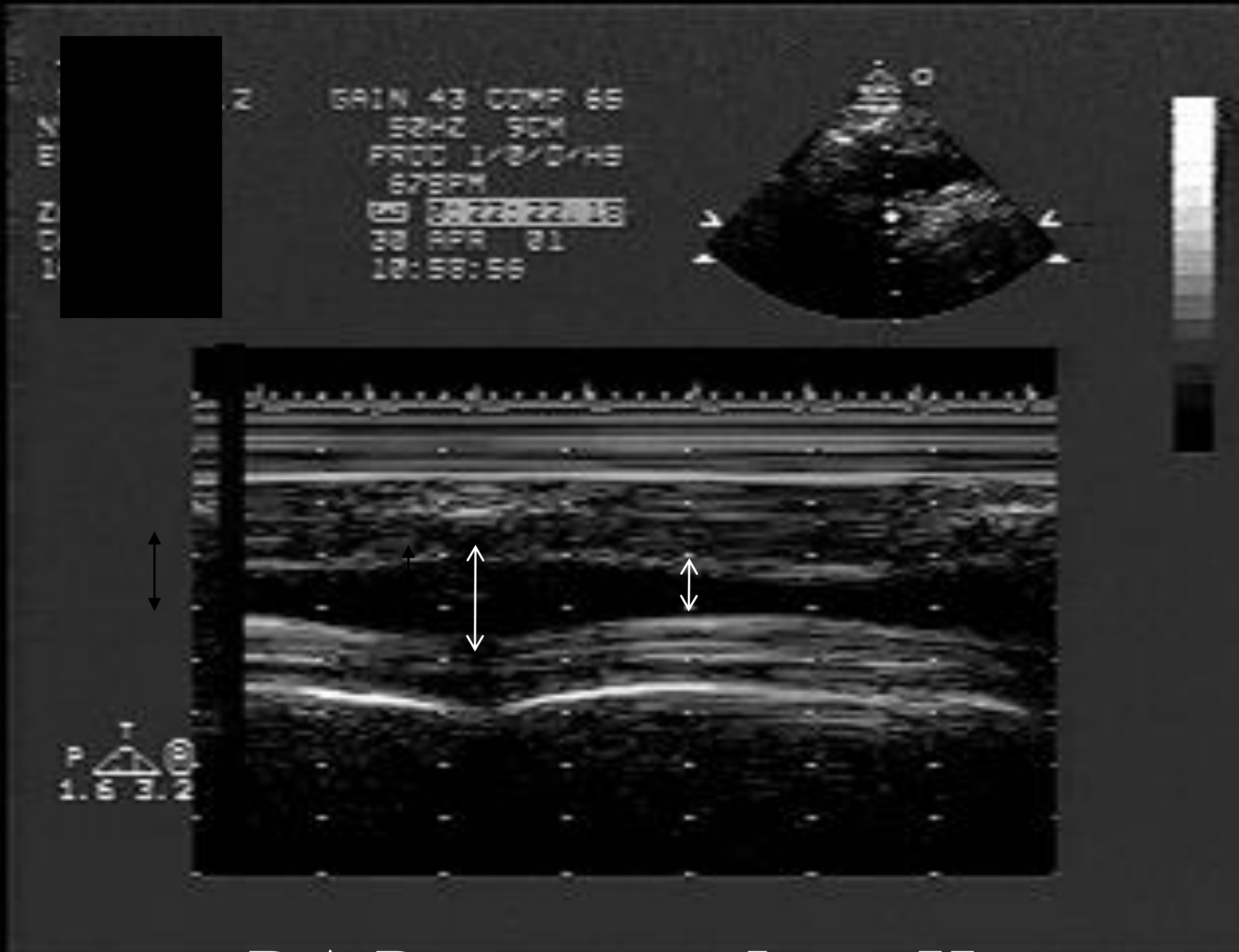
P = pressure (mm Hg)
V = velocity (m / sec)

Liv Hatle

IVC Dimensions



- IVC diameter ≤ 1.7 cm which collapses >50% with a sniff suggests RA pressure 0-5 mmHg
- IVC diameter > 1.7 cm which collapses <50% with a sniff suggests RA pressure 10-20 mmHg
- Scenarios where IVC diameter & collapse do not fit this paradigm, an intermediate value of 5-10 mmHg should be used.

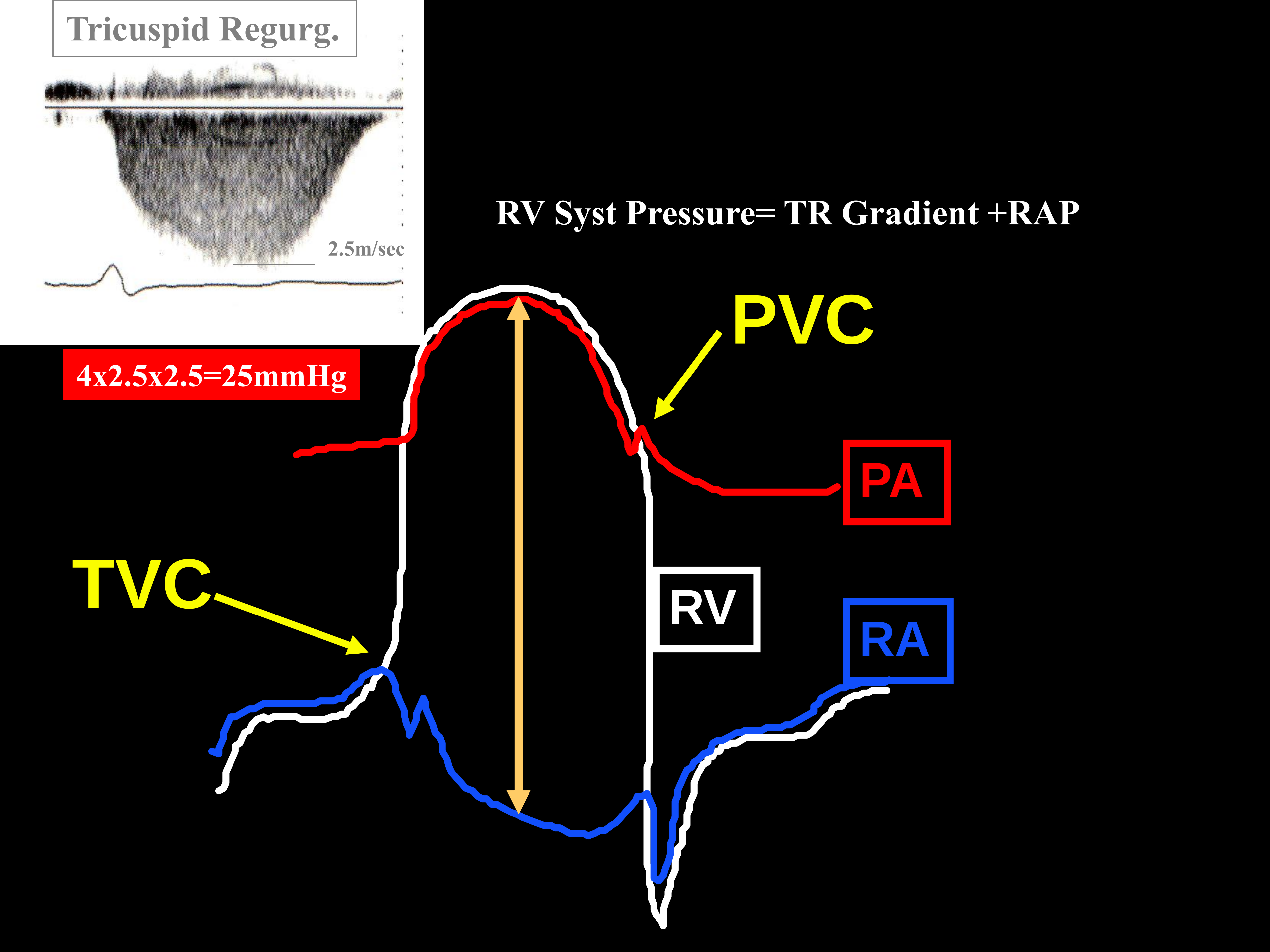


RA Pressure = 5 mmHg

Markedly elevated RA pressure (> 15 mm Hg)

Note: 1. Dilated IVC

2. Lack of respiratory variation



Tricuspid Regurg.
2.5m/sec
4x2.5x2.5=25mmHg
RV Syst Pressure= TR Gradient +RAP
PVC
PA
TVC
RV
RA

Evaluation of RV Systolic Pressure

RV systolic pressure =
TR gradient + RA pressure

Evaluation of RV Diastolic Pressure

In the absence of TS

RV diastolic pressure =
RA pressure

In the presence of TS

RV diastolic pressure =
RA pressure - TS gradient

Evaluation of PA Systolic Pressure

In the absence of PS

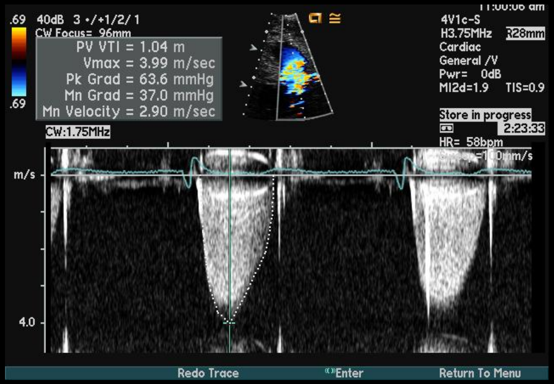
PA systolic pressure = RV systolic pressure

= TR gradient + RA pressure

In the presence of PS

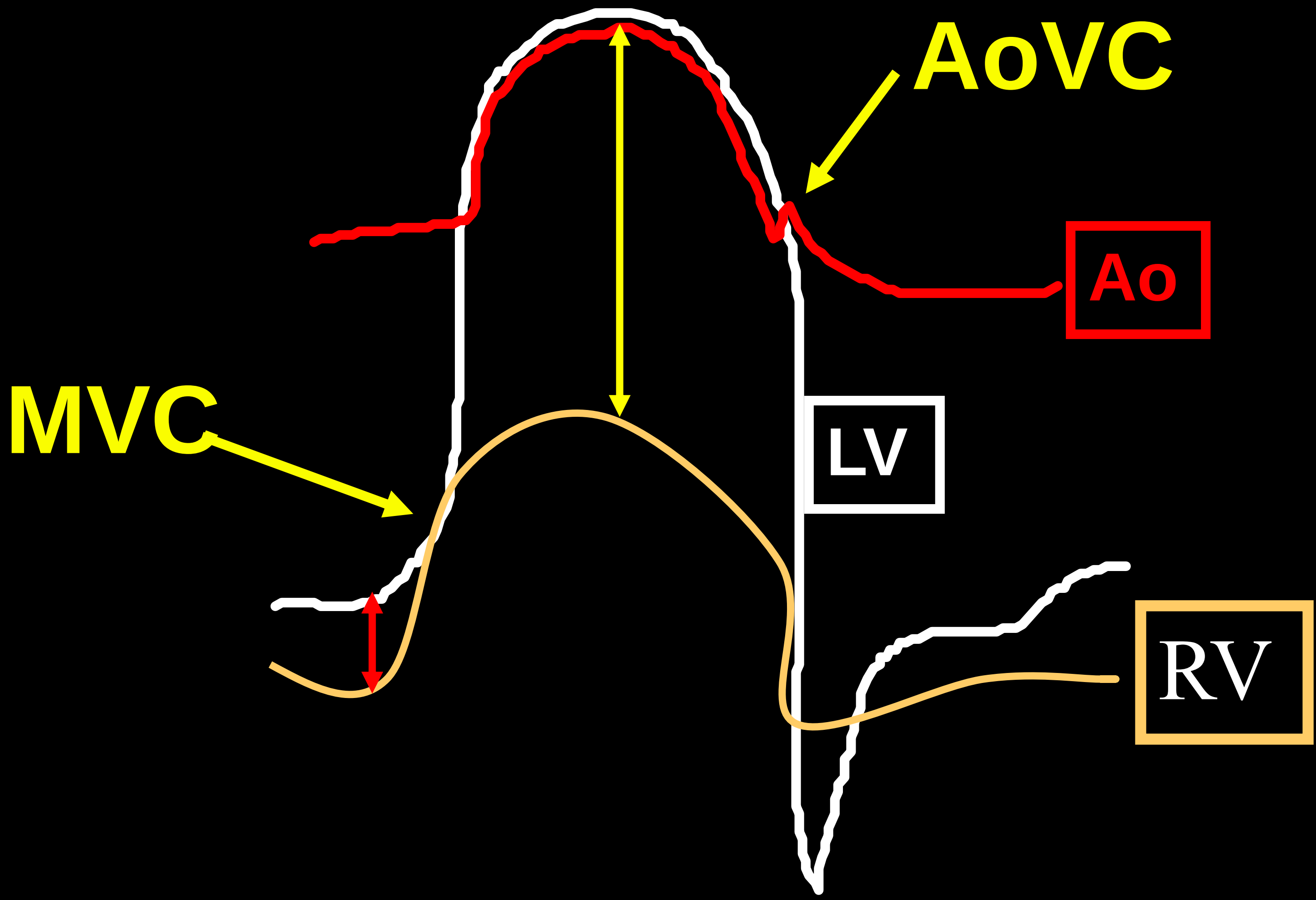
PA systolic pressure =

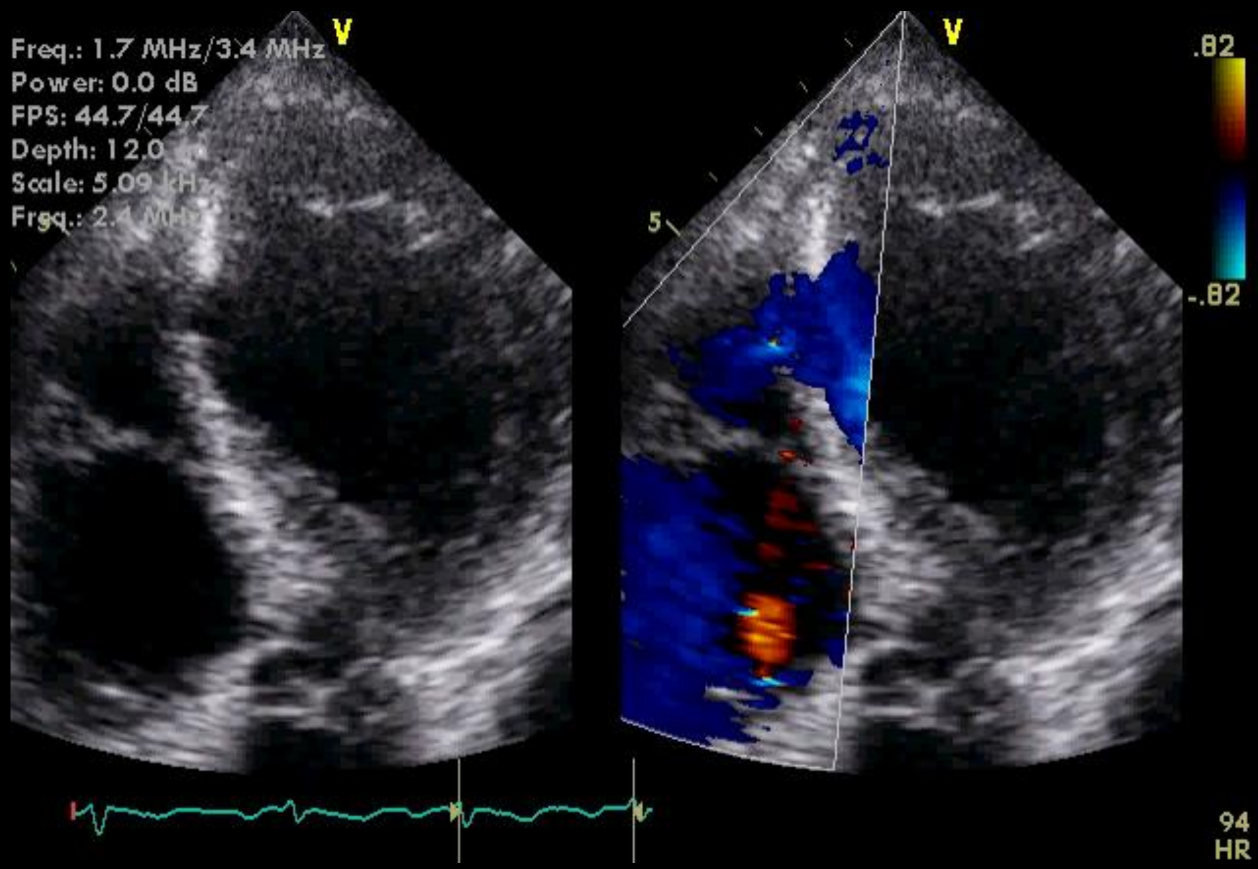
= RV systolic pressure - PS gradient



Pressure Gradients in VSD

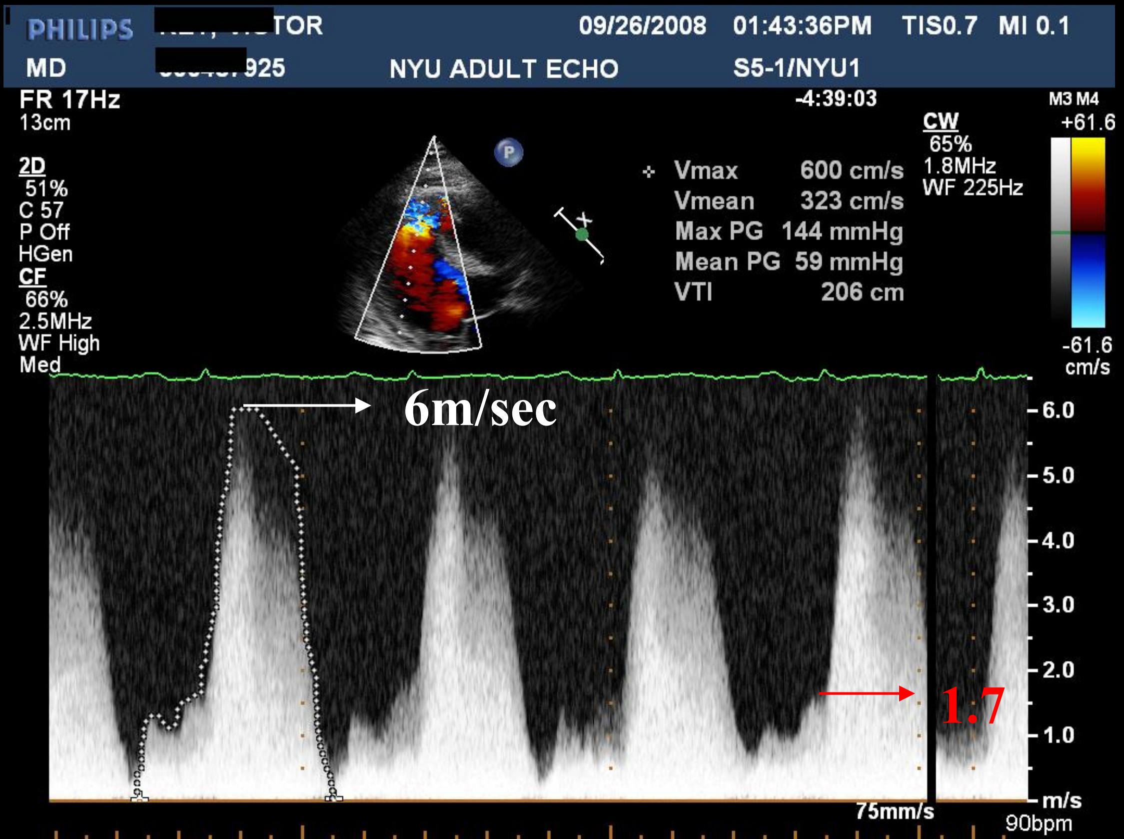
An alternative (non-TR based) way of estimating RV systolic pressure





67 y.o. with acute MI and heart failure

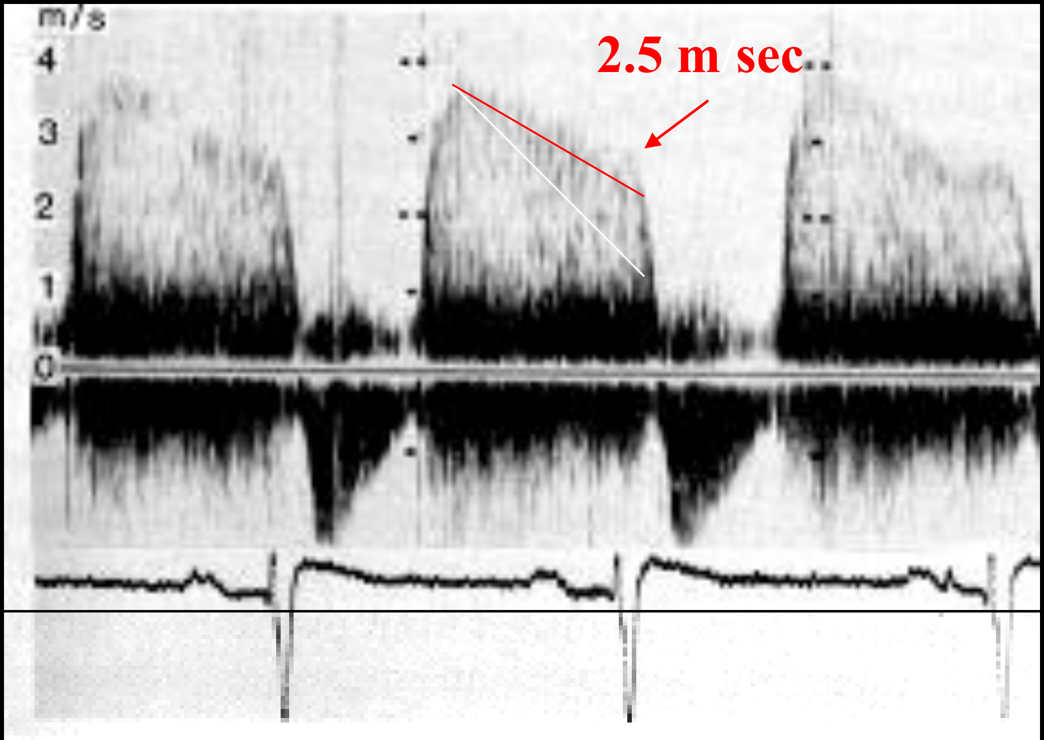
Post MI VSD
BP 175/70mmHg



LV-RV systolic gradient = 4x6x6=144mmHg

RV systolic pressure =
systolic BP - VSD gradient = 31 mmHg

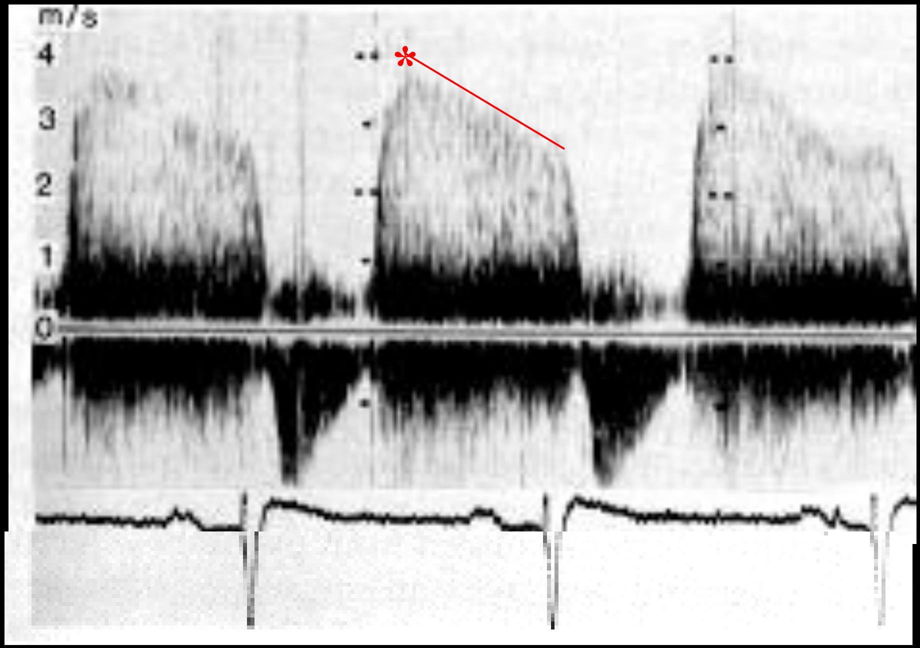
CW of Pulmonic Valve Flow



The study suggests:

1. Severe PS
2. Right heart failure
3. Pulmonary hypertension
4. Constrictive Pericarditis

CW of Pulmonic Valve Flow



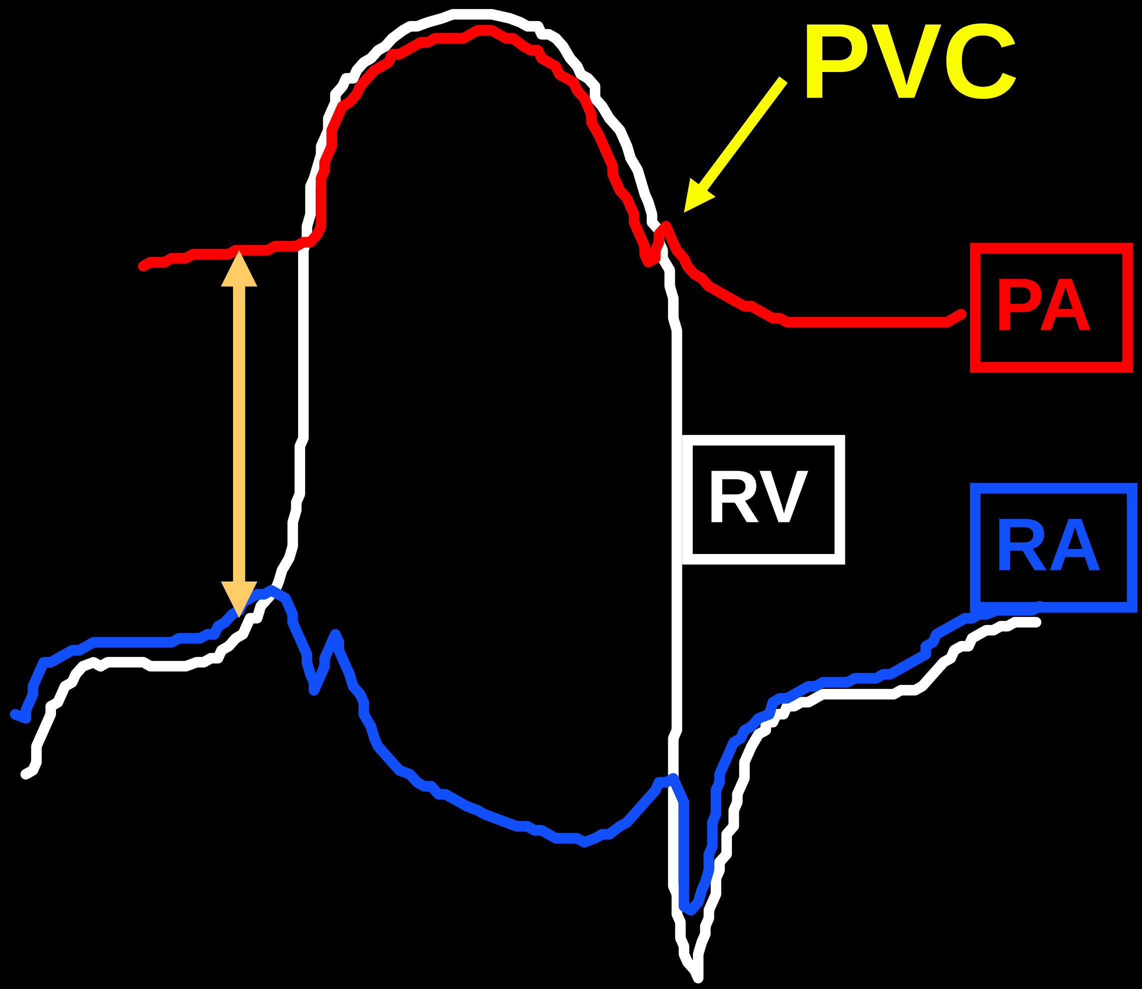
Pulmonary hypertension

Note the end-diastolic velocity of 2.5 m/sec, indicating an end diastolic gradient of 25 mmHg between the PA and RV

- **Mean PA pressure: $4V^2$ (Max PR Velocity)**

Evaluation of PA Diastolic Pressure

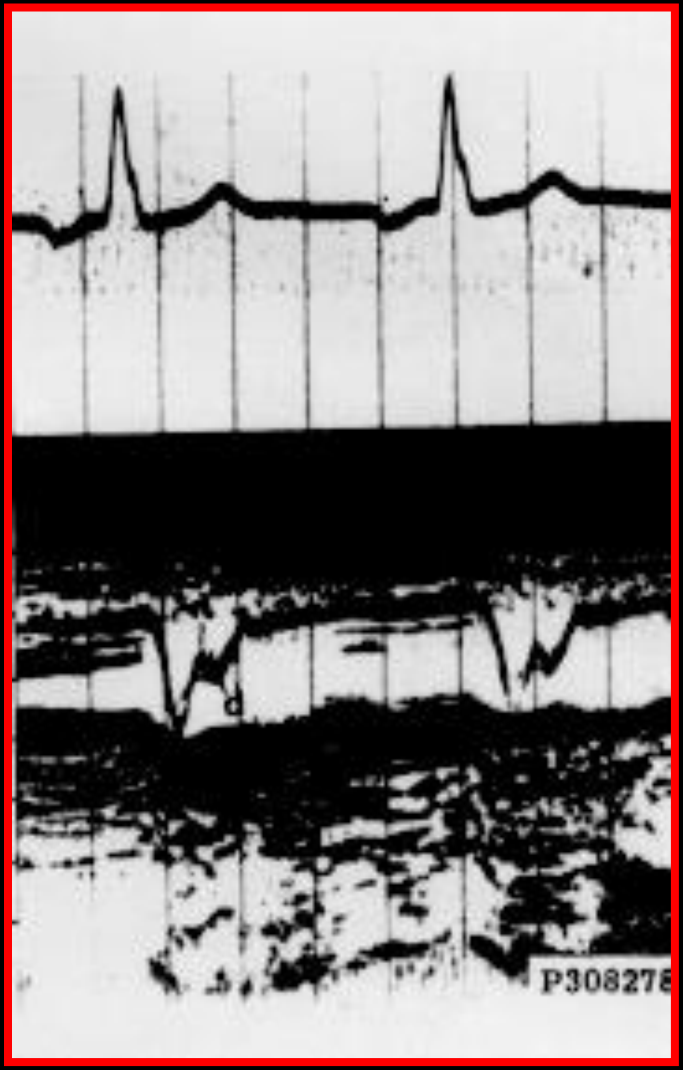
PA diastolic pressure =
PR gradient + RA(V) pressure



Pulmonary Artery Mean Pressure

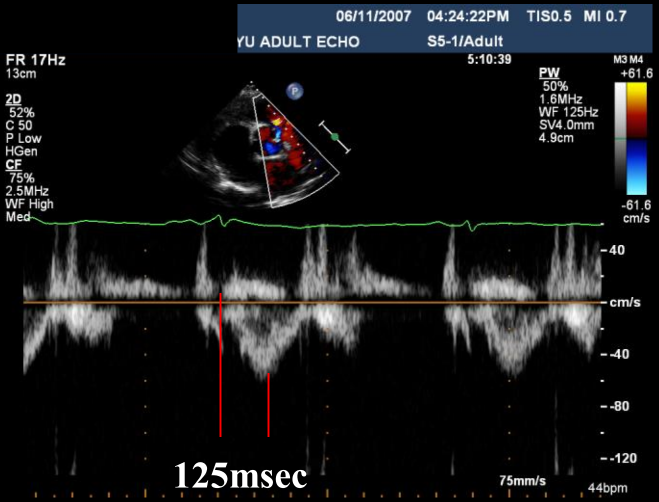
$$PA\ mean\ P = 0.6 \times PASP + 1.95\,mmHg$$

Severe PHT



1. No A wave
2. Systolic “flying W”
3. No diastolic posterior motion

RVOT Acceleration time



Mean PAP = 79 - (0.45 x AcT)

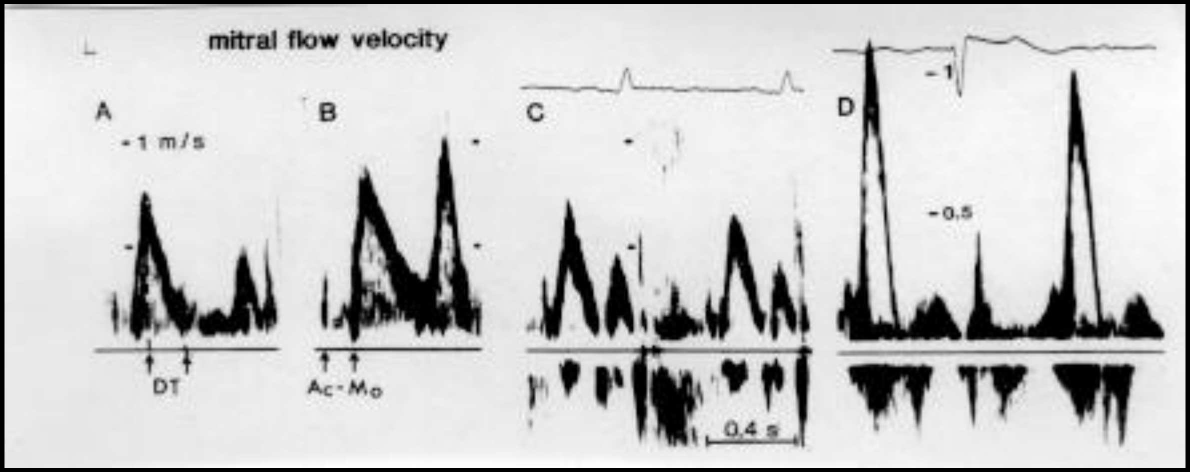
Normal AcT > 120msec

If AcT<90msec, peak PA systolic pressure is more than 60 mmHg

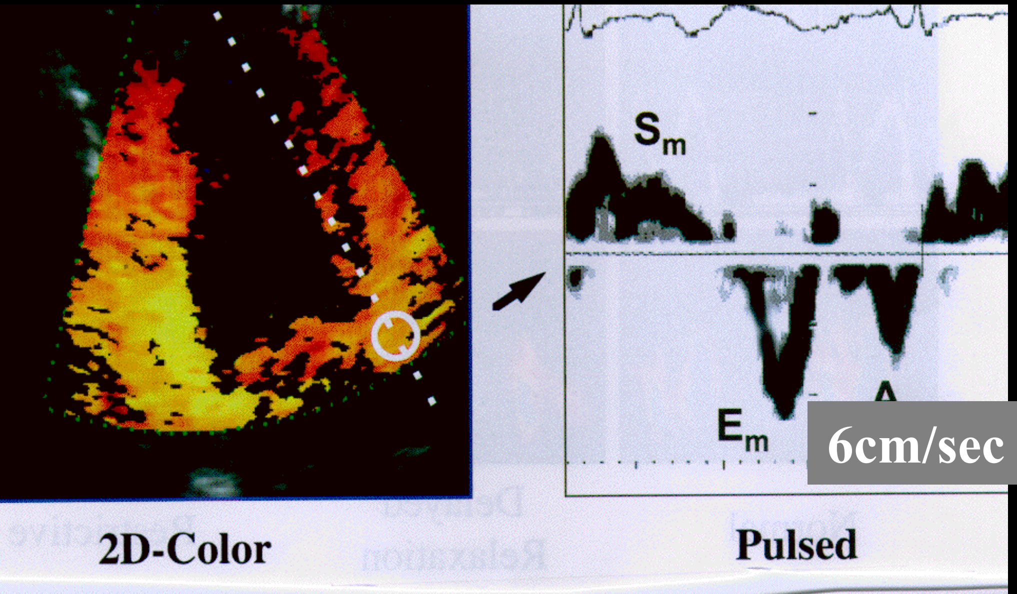
Mean PAP = 79 – (0.45 * 90) = 79 - 40 = 39 mmHg

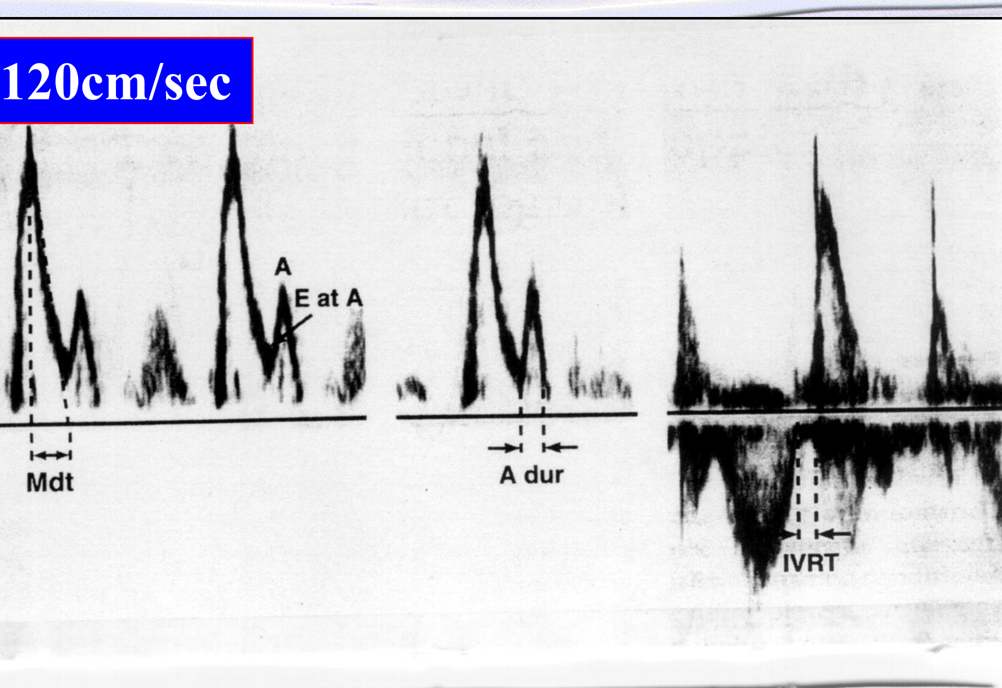
Evaluation of LA Pressure from transmitral and PV flow

A. Normal	6 - 12 mm Hg
B. Abnormal Relax.	8 - 14
C. Pseudonormal	15 - 22
D. Restrictive	> 22



Calculation of LA pressure





$LAP = 1.24[(E/e') + 1.9]$

Nagueh 1999

LAP = E/e' + 4

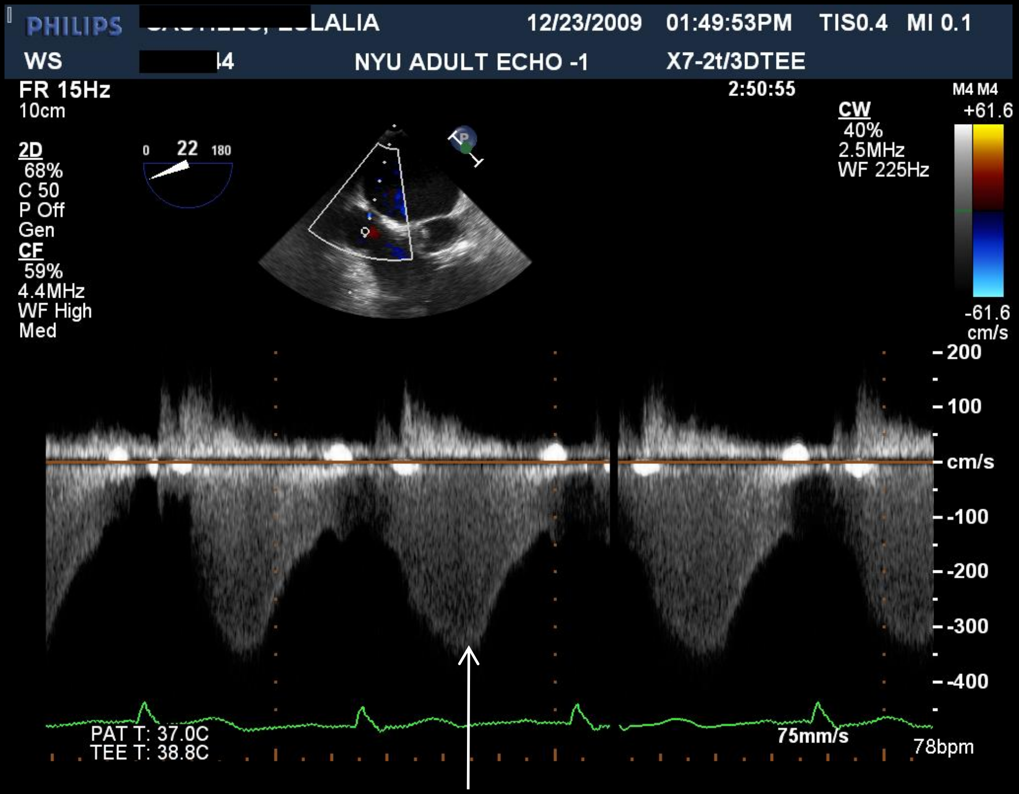
LAP= 120/6 + 4 = 24 mmHg

E/e' = 8: LA pressure nl

E/e' = 15: LA pressure high

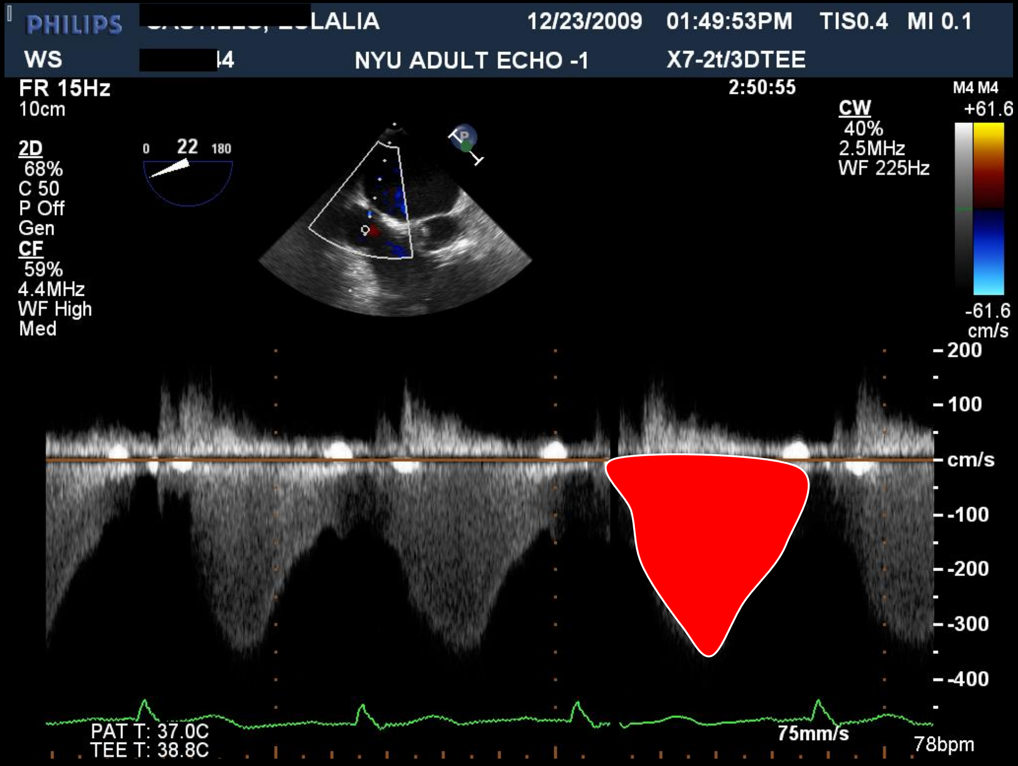
Patient with small ASD after Mitral Valvuloplasty
Estimated RA pressure 10mmHg. What is the peak LAP?

A) 10mmHg
B) 20mmHg
C) 35mmHG
D) 60mmHg



3.5m/sec

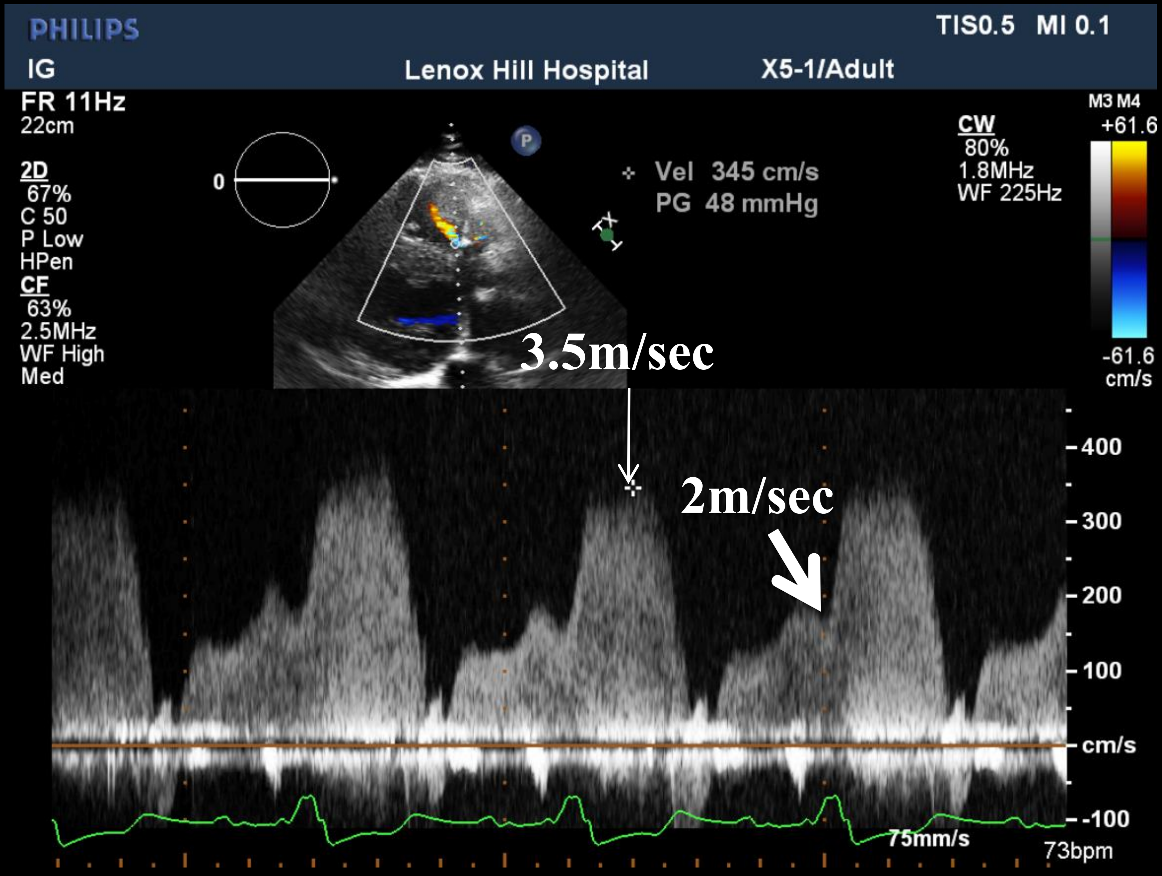
Calculation of LA pressure in a pt with ASD



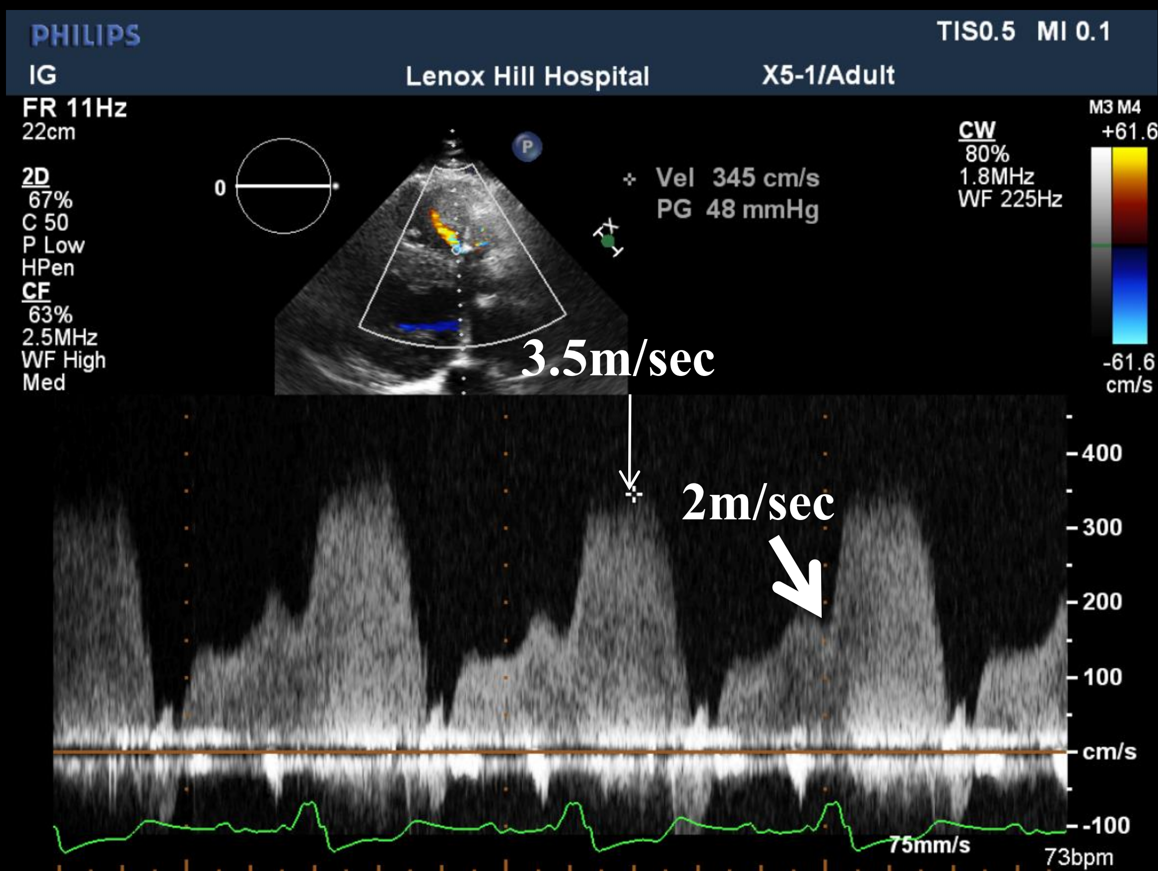
LAP=RAP(10)+ASD max gradient (50)= 10+50 = 60mmHg

POST MI VSD

The RA pressure is 10mmHg.
What is the LVEDP?



a) 12mmHg
b) 16mmHg
c) 26mmHg
d) 50mmHg



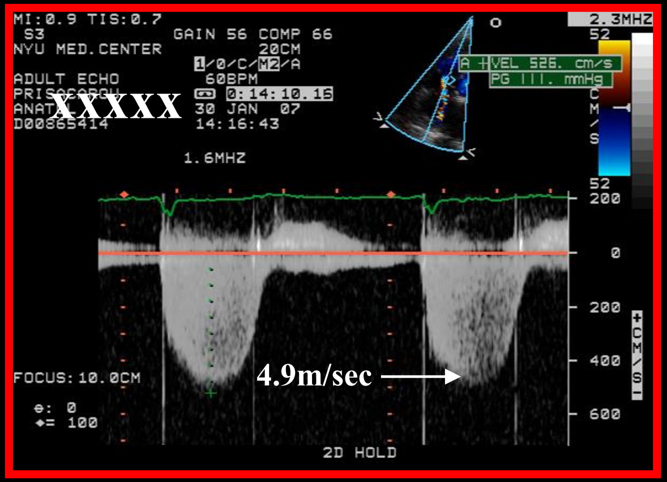
LVEDP = RV(RA) EDP+ End diastolic left to right gradient

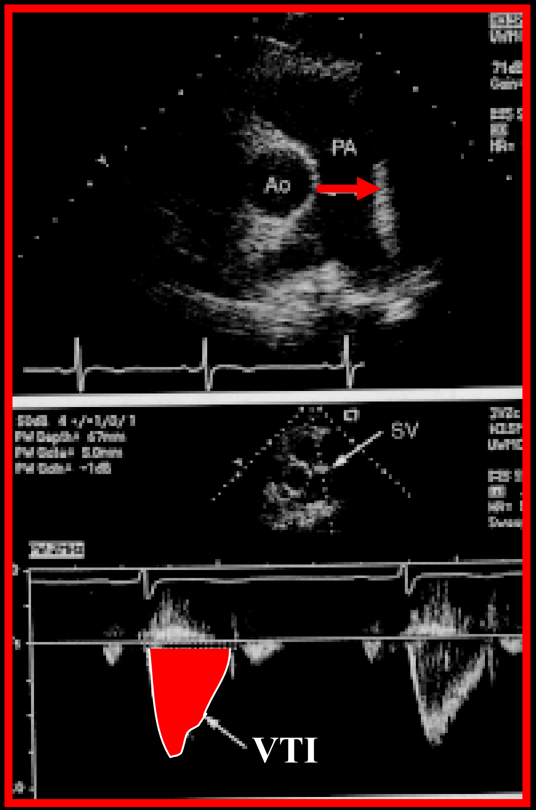
LVEDP= 10 + 16= 26mmHg

Pulmonary Vascular Resistance

Normal =2 Wood's units

PVR = (mean PAP- mean PCWP)/C.O.



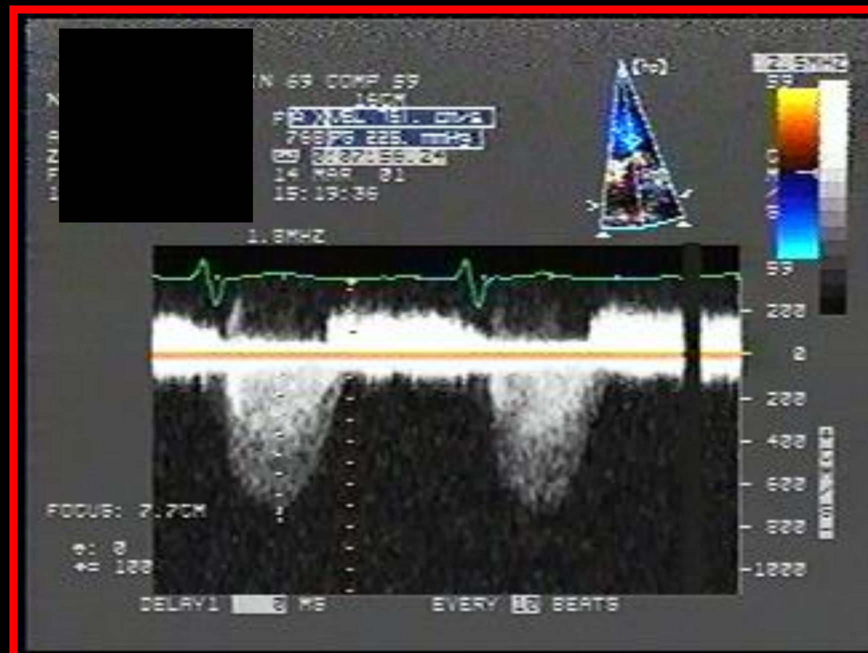


Another method

PVR= 10 (Peak TR Velocity/RVOT VTI + 0.16)

PVR=Wood's units
TR Velocity = m/sec
RVOT TVI = cm

CW of MR Jet in a pt with a BP of 120 / 80.
The MR velocity is 7.7 m / sec

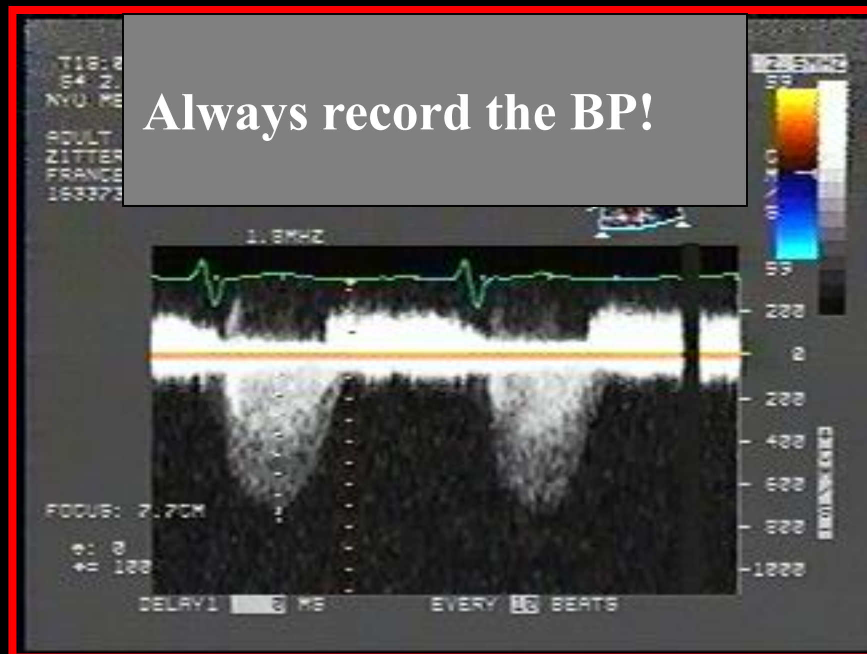


The most likely dx is:

1. Aortic Stenosis
2. Aortic Insufficiency
3. High Cardiac Output
4. Pulmonary Embolism

CW of MR Jet in a pt with a BP of 120 / 80

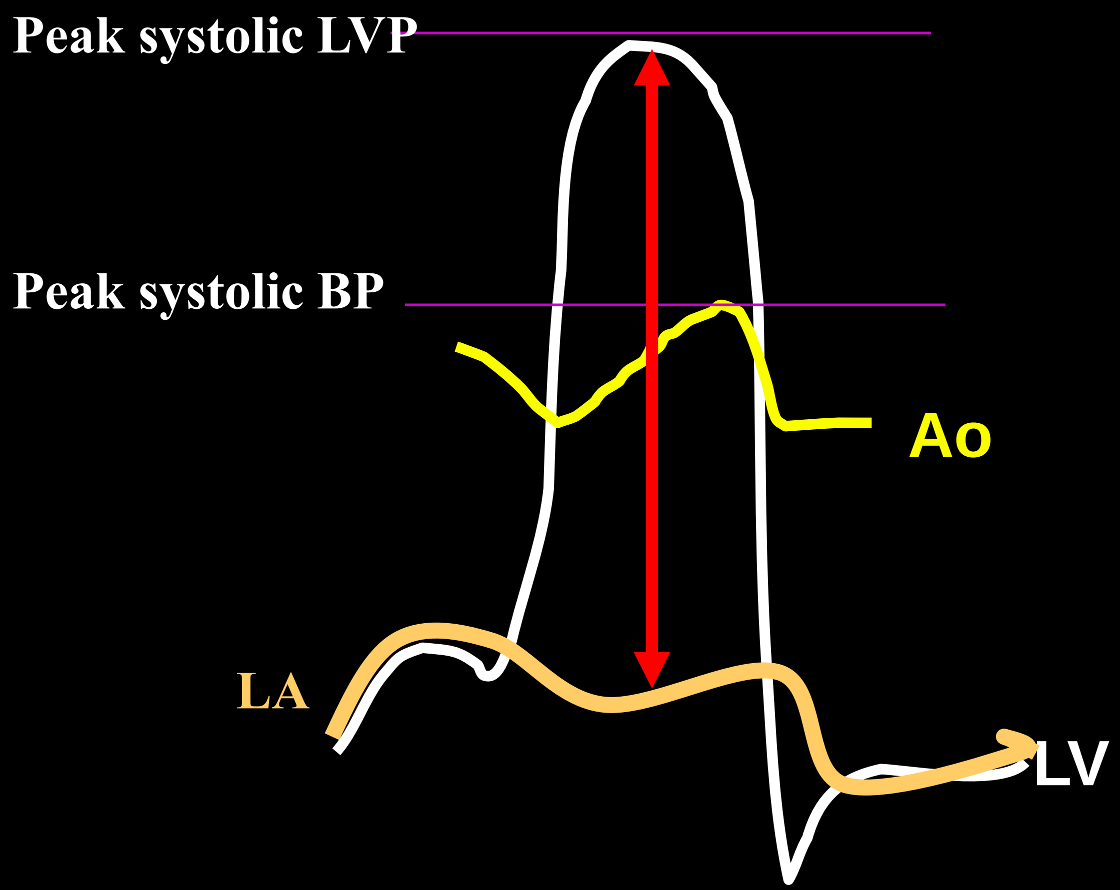
4x7.7x7.7=237mmHg



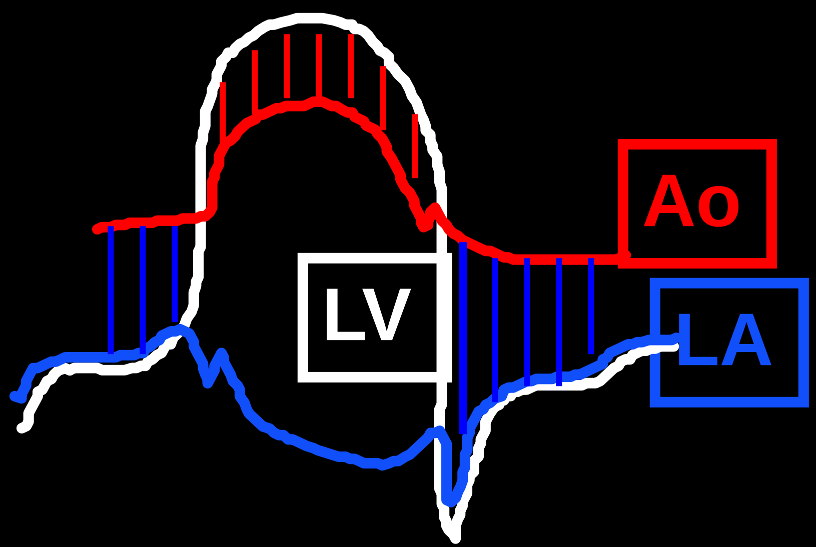
Aortic Stenosis

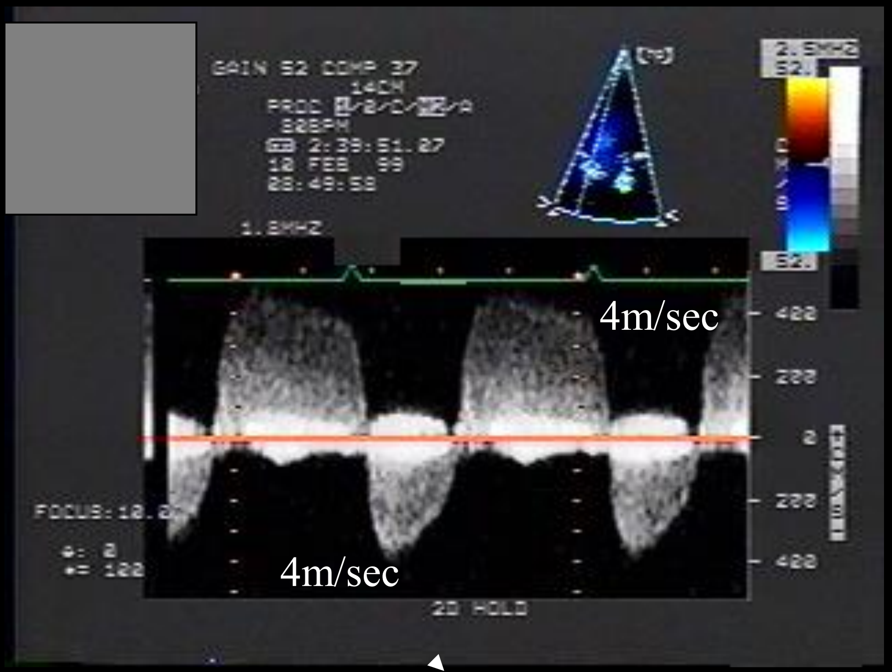
The velocity of the MR jet indicates a peak systolic LV-LA gradient of 237 mm Hg; Therefore the Aortic gradient is at least 120 mm Hg.

MR Velocity in AS



CW of Aortic Valve Flow
The BP is 150 / 80

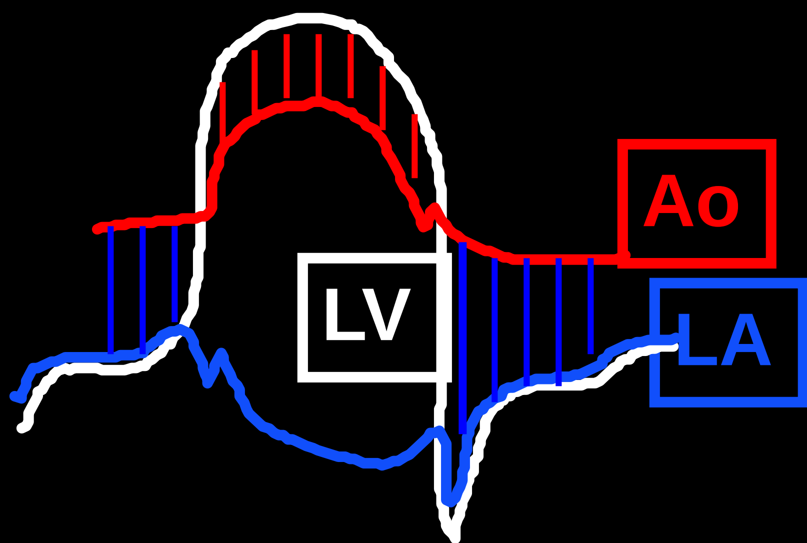


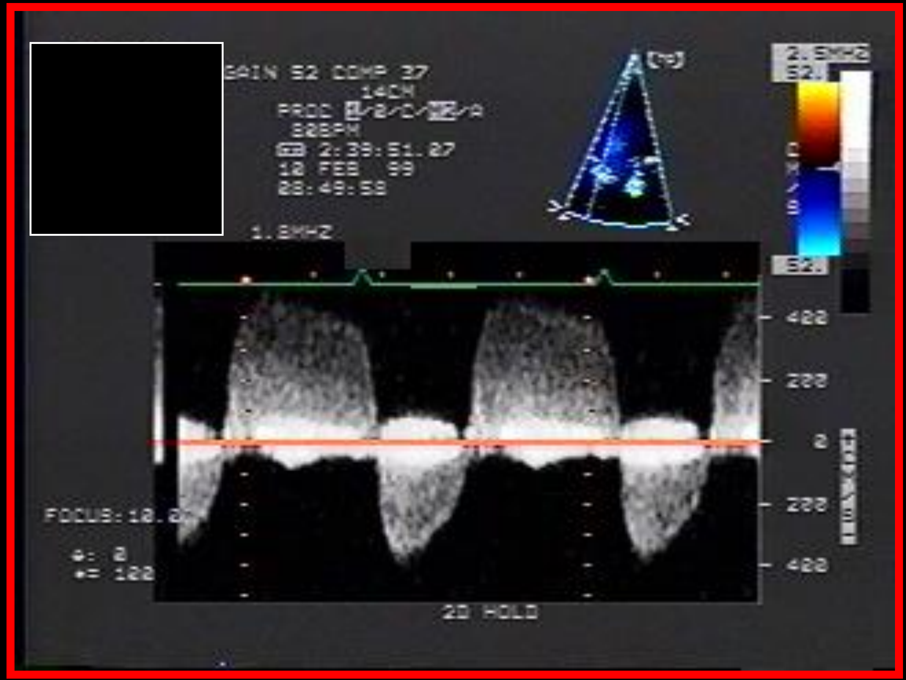


The LV pressure is:

1. 84 / 16
2. 214 / 44
3. 214/16
4. 195/16

CW of Aortic Valve Flow
The BP is 150 / 80





ANSWER:

4. 195/16

LV (sys)= Sys. BP (150) + 70%Ao gradient (45) = 195

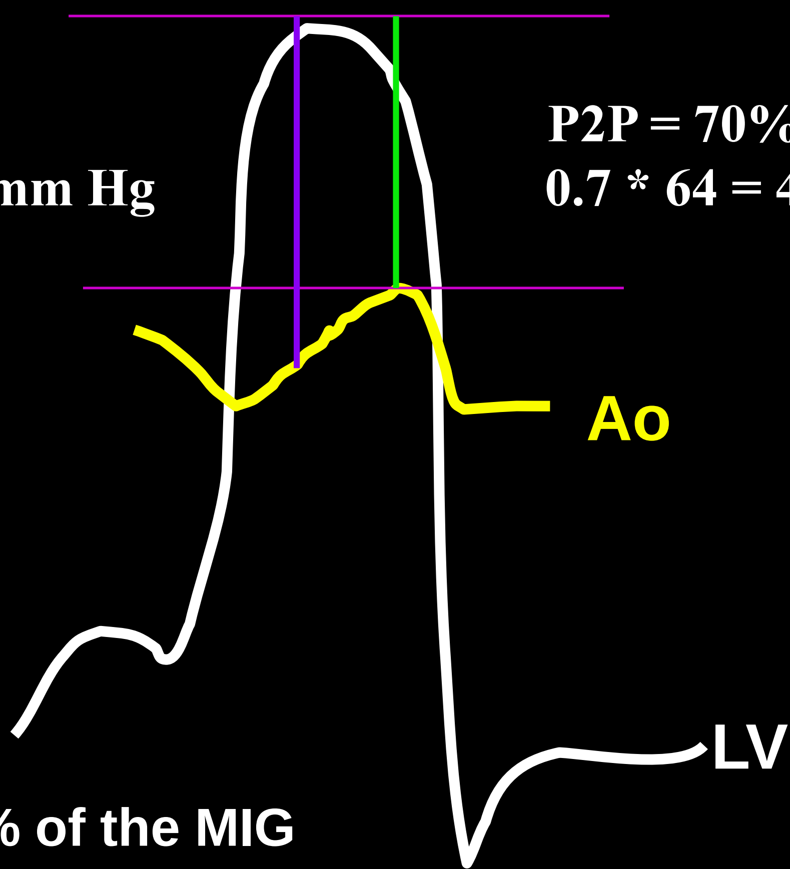
LV (dias) = Dias. BP (80) - Ao dias. Gradient (64) = 16

Aortic Valve Gradient

1. Peak - to - Peak Gradient (P2P)
2. Maximum Instantaneous Gradient (MIG)
3. Mean Gradient

MIG =
$(4 \text{ m/sec})^2 = 64$ mm Hg

P2P = 70% * MIG =
0.7 * 64 = 45 mm Hg



The P2P gradient is 70% of the MIG

Evaluation of LV Systolic Pressure

In pts without aortic valve disease:
LV systolic pressure = systolic BP

In pts with AS or LVOT obstruction:
LV systolic pressure = systolic BP
+ gradient

Evaluation of LV Diastolic Pressure

In pts with AR:

LV end-diastolic pressure =

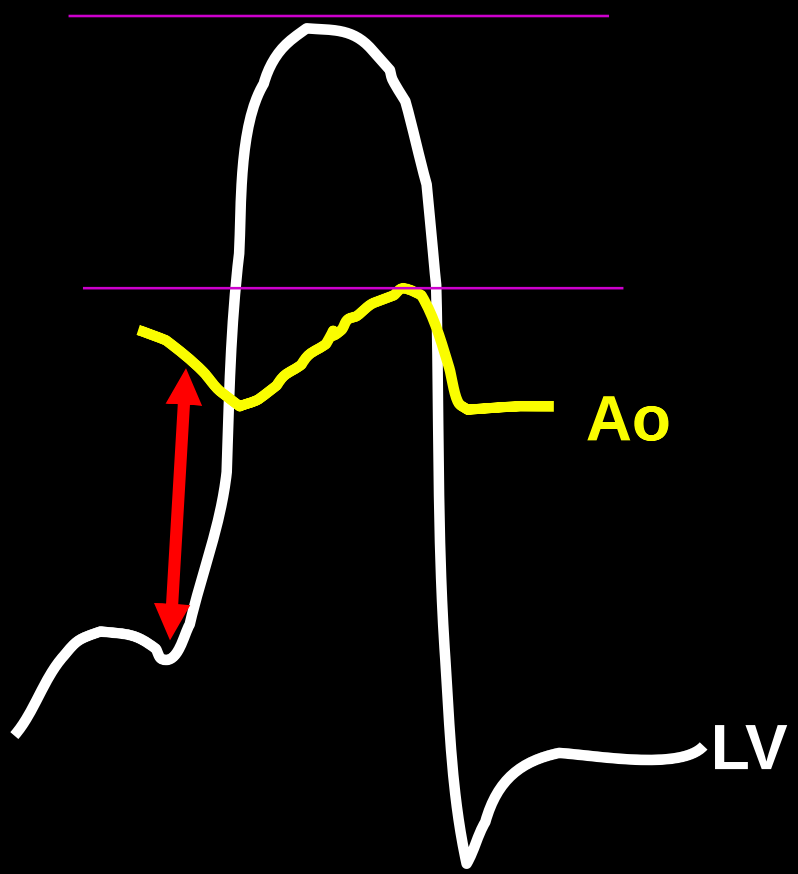
diastolic BP - AR gradient

In the absence of MS:

LVDP = (approx.) LA pressure

Calculation of LVEDP

Systemic diastolic BP - End Diastolic Aortic Gradient

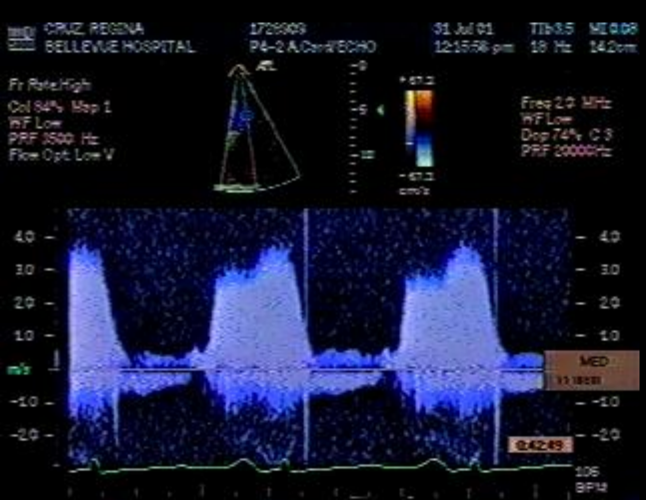


Estimating LA Pressure by E/e' May Be Inaccurate in:

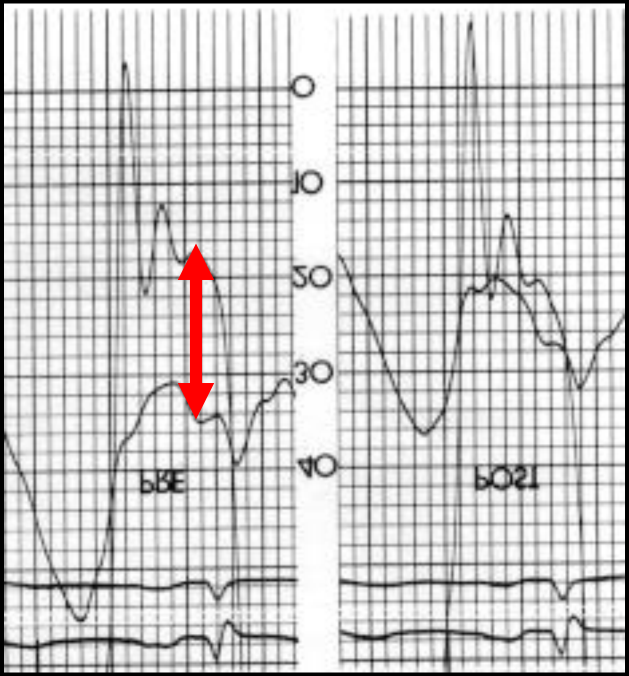
Mitral Stenosis
Mitral annular calcification
Prosthetic MV
Mitral regurgitation
Diffuse severe LV dysfunction

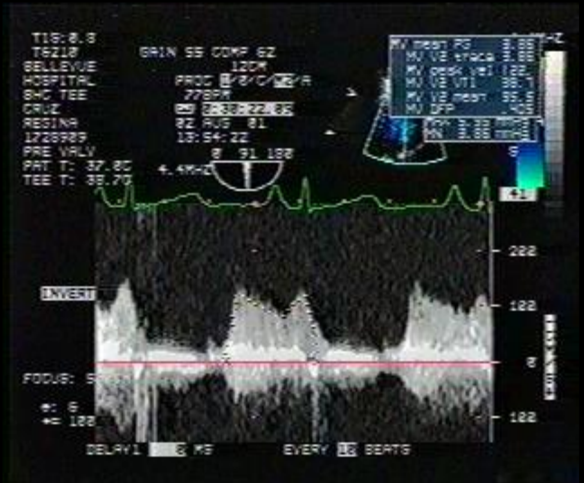
Evaluation of LA Pressure in pt with MS

In MS, LA diastolic pressure = LVDP + transmitral gradient



Mean MV gradient 16mmHg





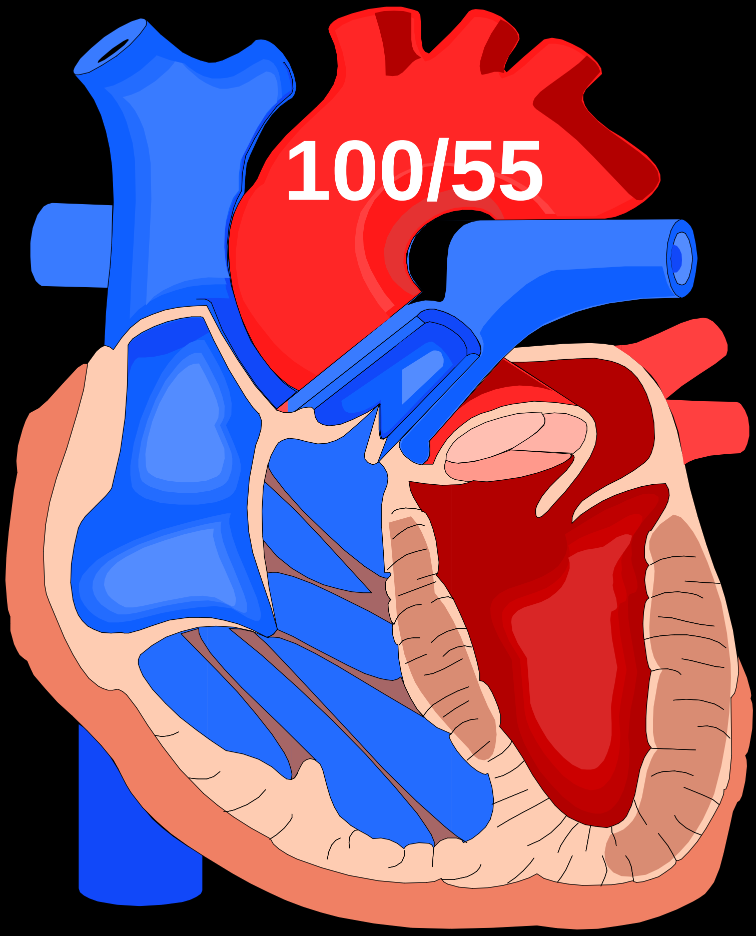
Mean MV gradient 4mmHg

Noninvasive Hemodynamic Study
63-Year-Old female with Dyspnea

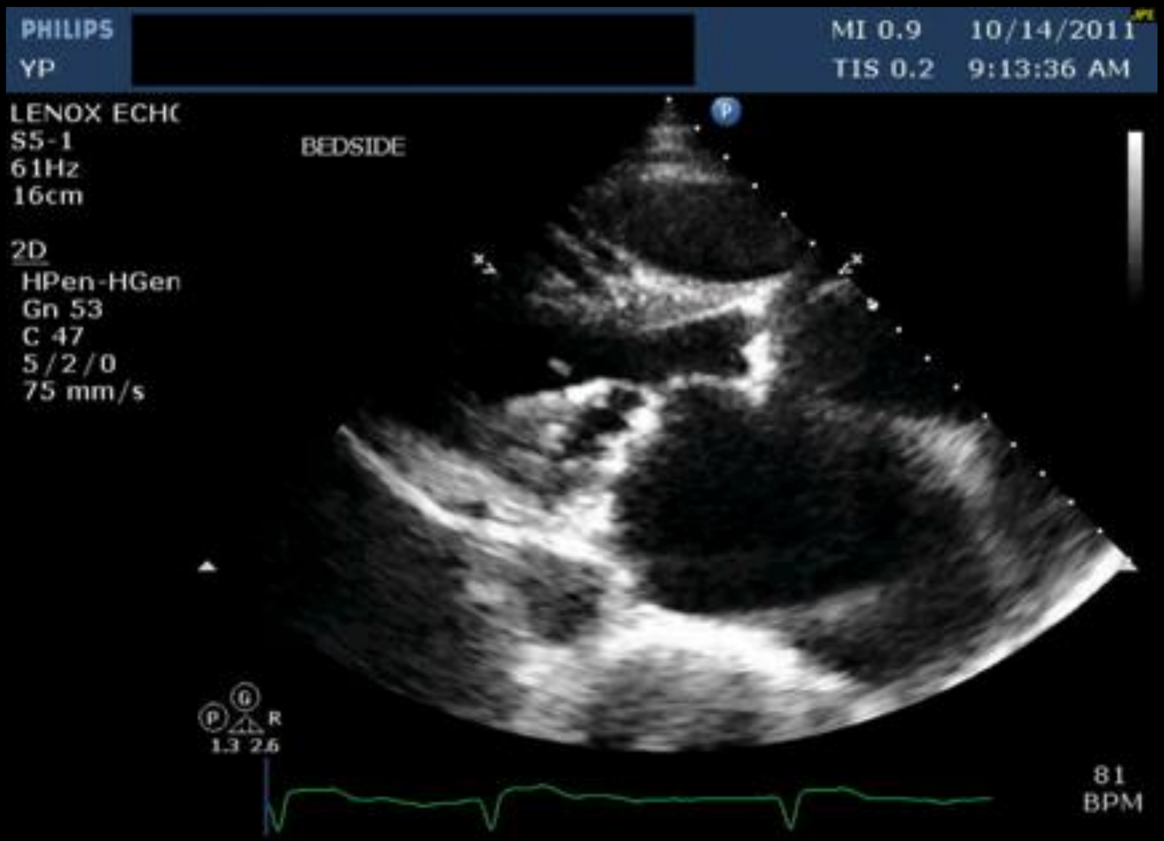
BP 100/55

Bibasilar rales

MS, AS, MR, TR murmurs



MMS + AS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10/14/2011
TIS 0.2
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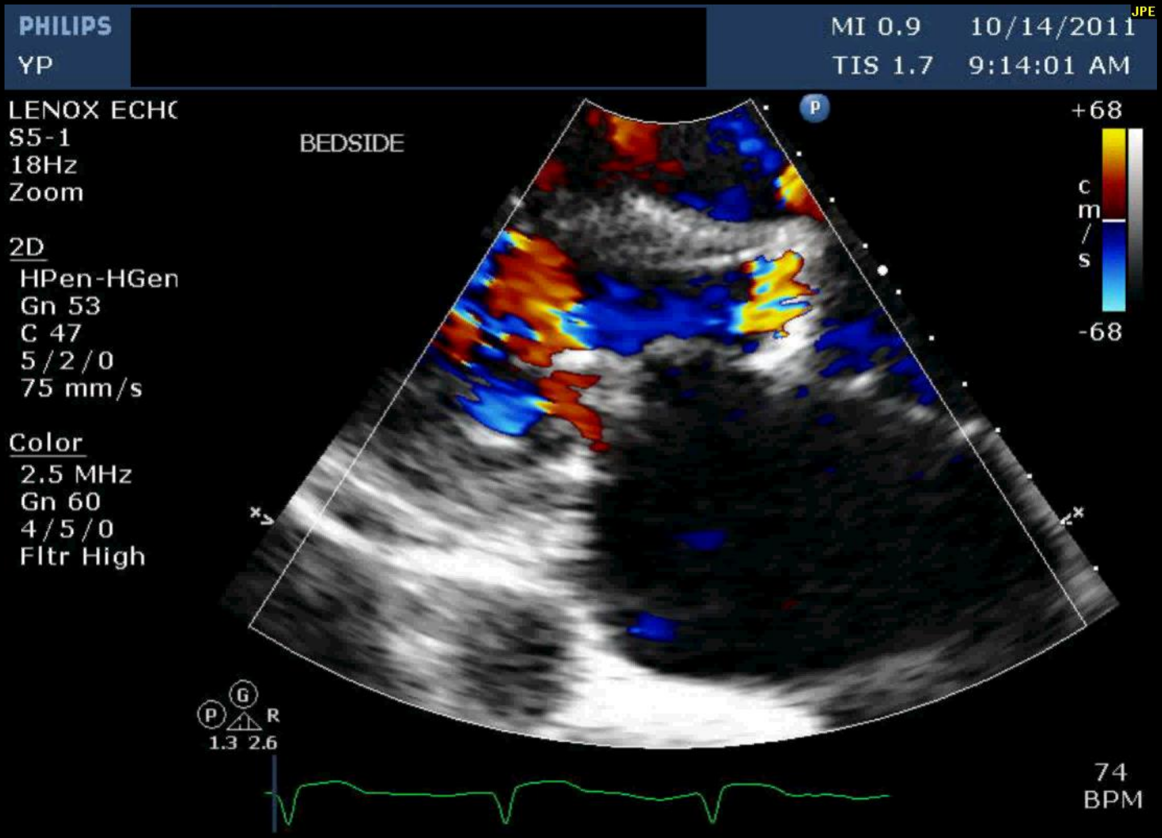
LENOX ECH
S5-1
61Hz
16cm
2D
HPen-HGen
Gn 53
C 47
5/2/0
75 mm/s
BEDSIDE
1.3 2.6
81
BPM

MMR + AR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LENOX ECH
S5-1
18Hz
Zoom
2D
HPen-HGen
Gn 53
C 47
5/2/0
75 mm/s
Color
2.5 MHz
Gn 60
4/5/0
Fltr High
BEDSIDE
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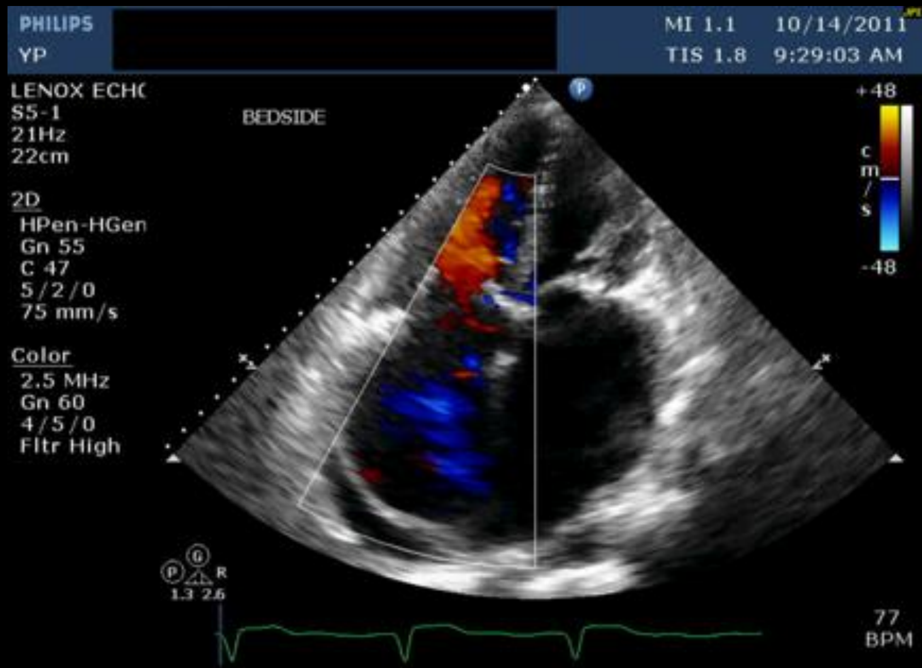
cm/s
-68
P
G
R
1.3 2.6
74
BPM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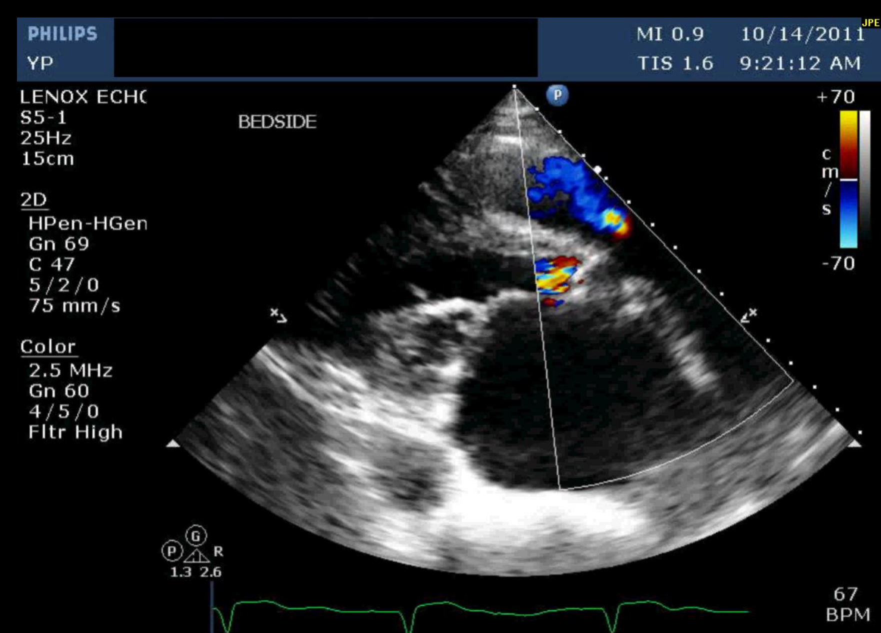
+48
cm/s
-48
77
BPM

TR + PR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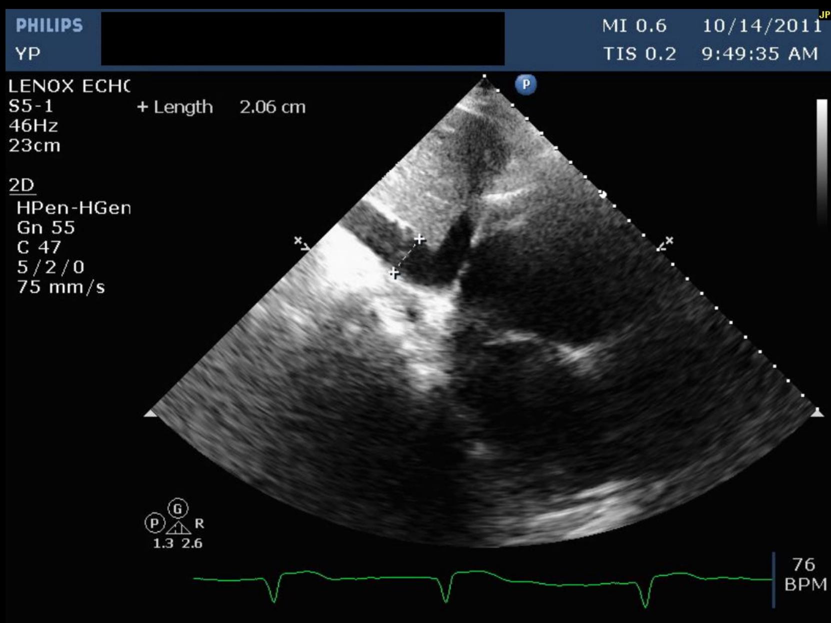
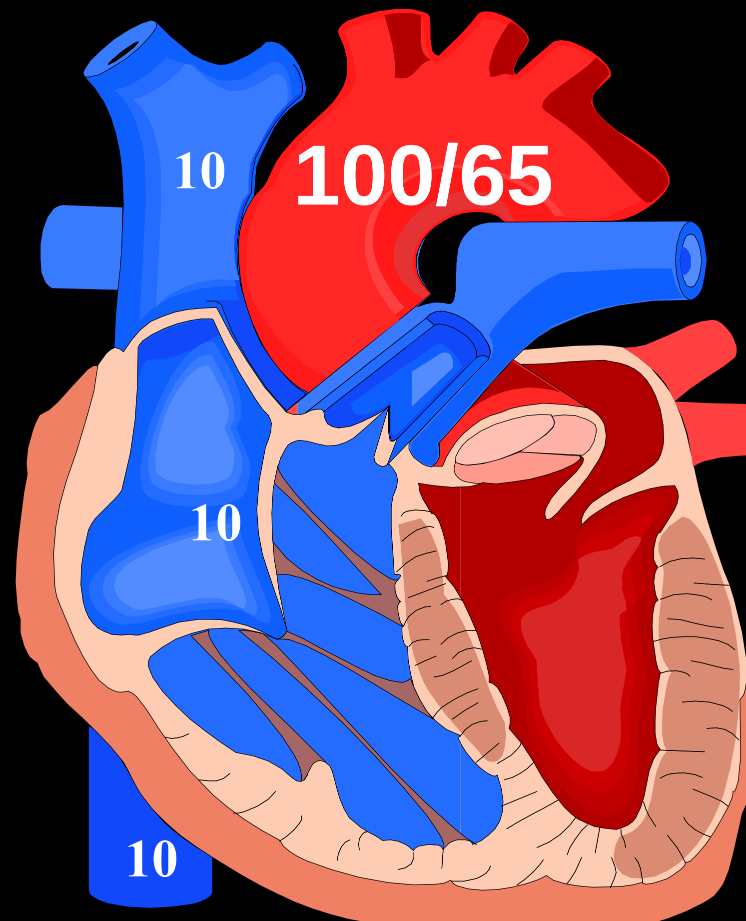
2D
HPen-HGen
Gn 69
C 47
5/2/0
75 mm/s
Color
2.5 MHz
Gn 60
4/5/0
Fltr High
BEDSIDE
+70
cm/s
-70
67
BPM

Normal IVC Size 2.0 cm

<50% Respiratory Variation





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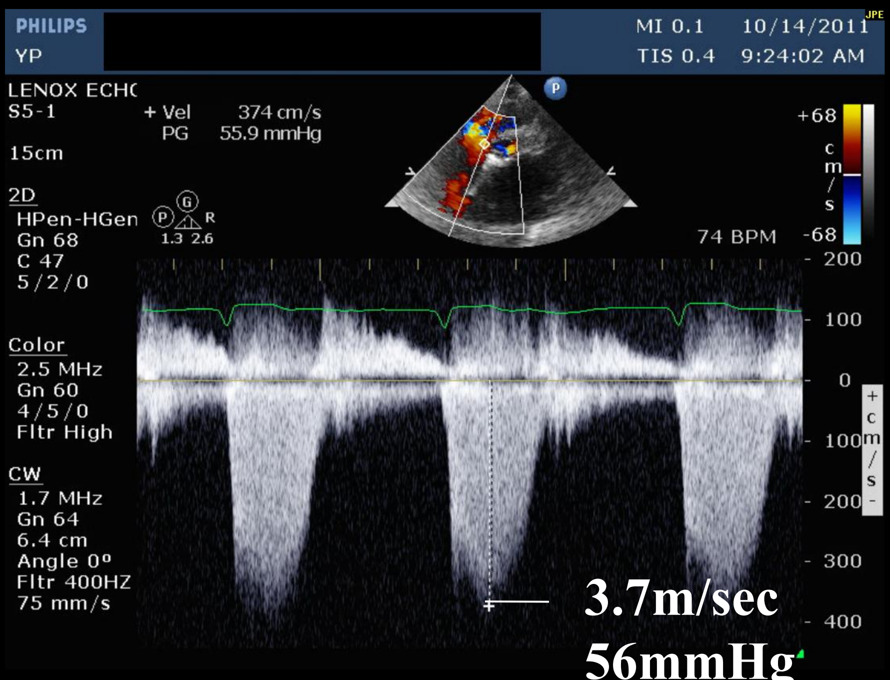
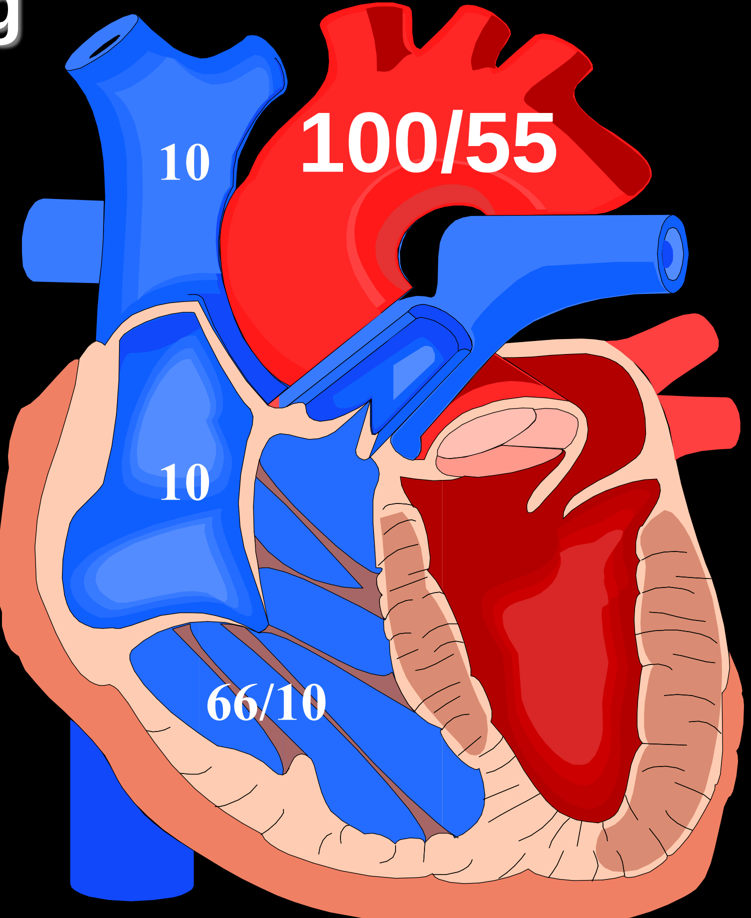
RV Pressures

RV systolic = RA pressure (10) + TR gradient (56) = 66 mm Hg



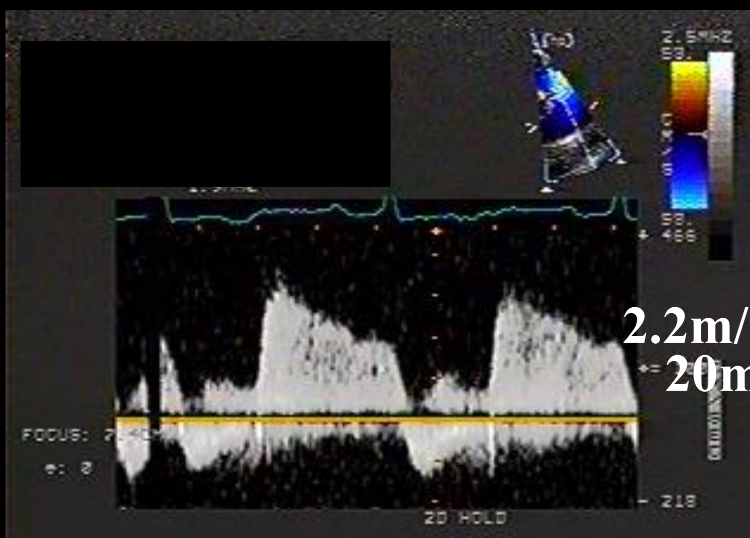


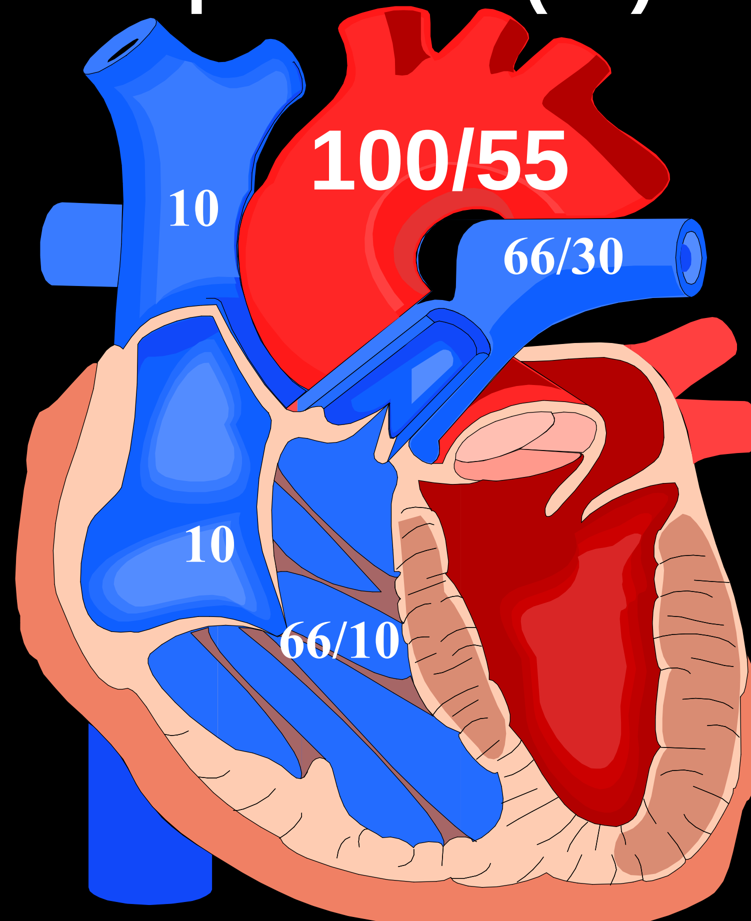
In the absence of TS

RV diastolic pressure = RA pressure

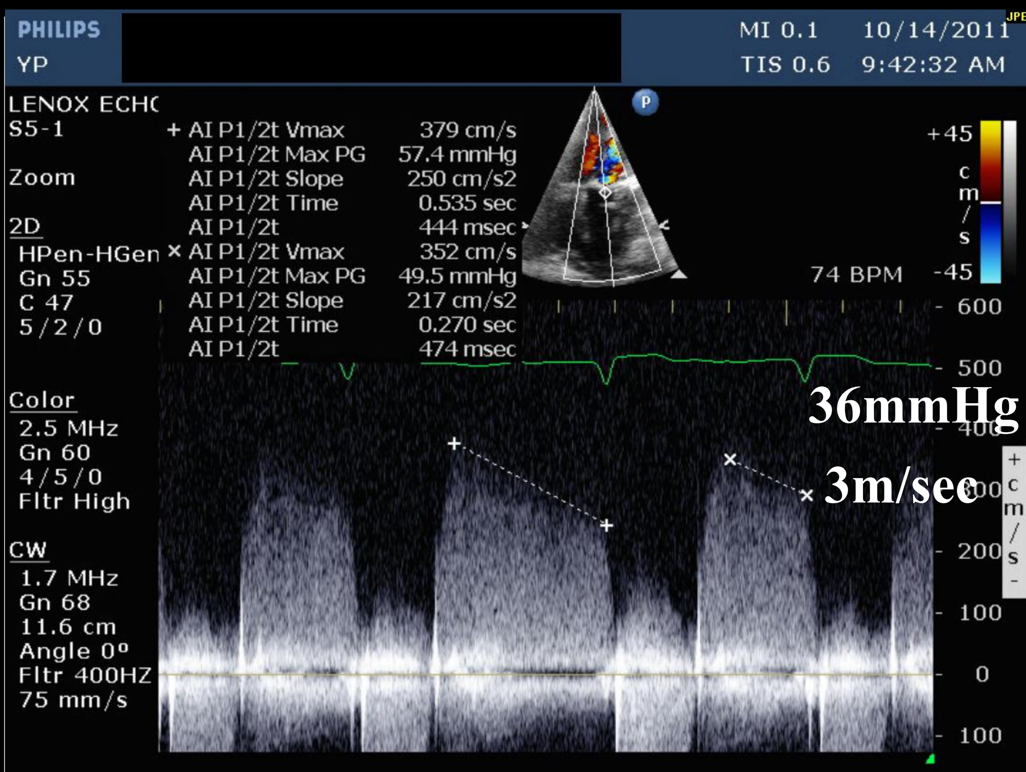
PA Pressure

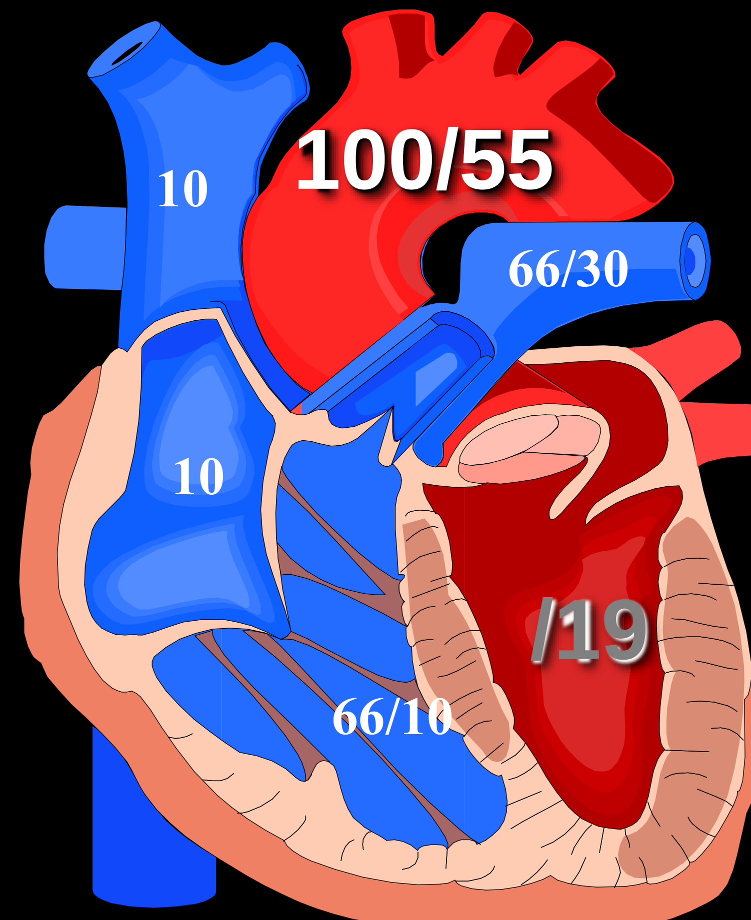
Systolic = RV systolic (66)
Diastolic = PR gradient (20) + RA pressure (10) = 30





LVEDP = aortic diastolic pressure (55) – AR gradient (36) = 19mmHg





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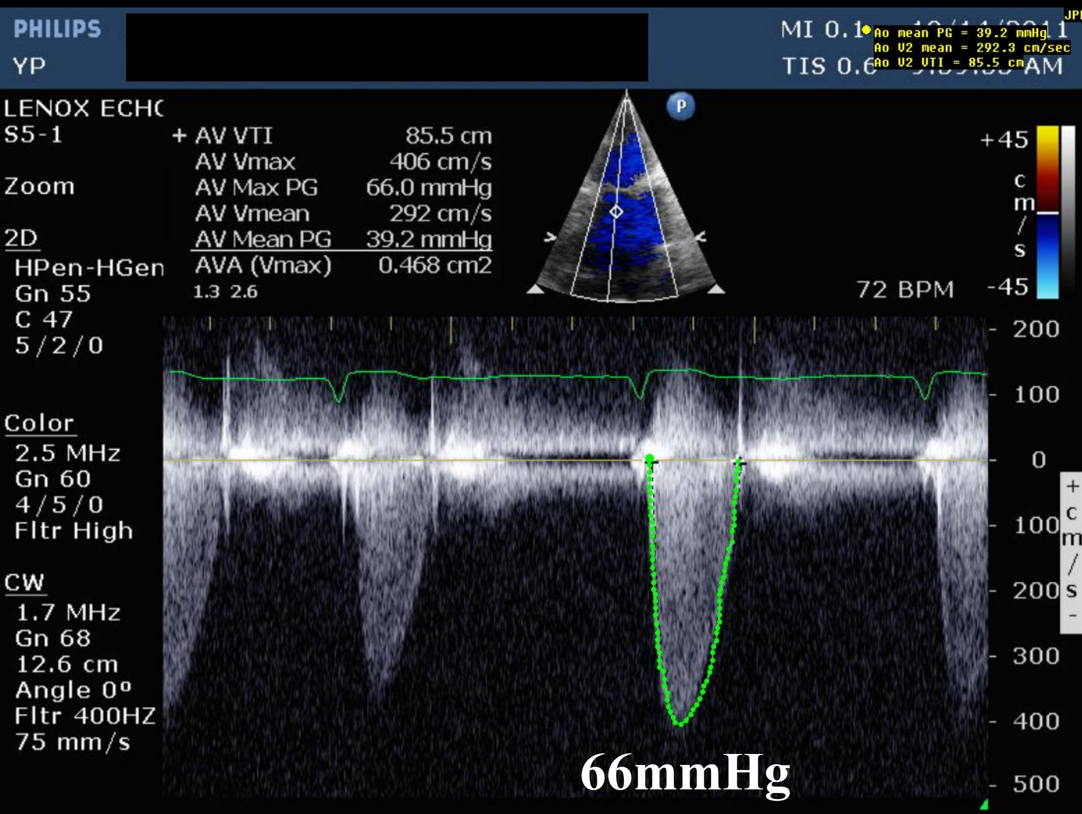
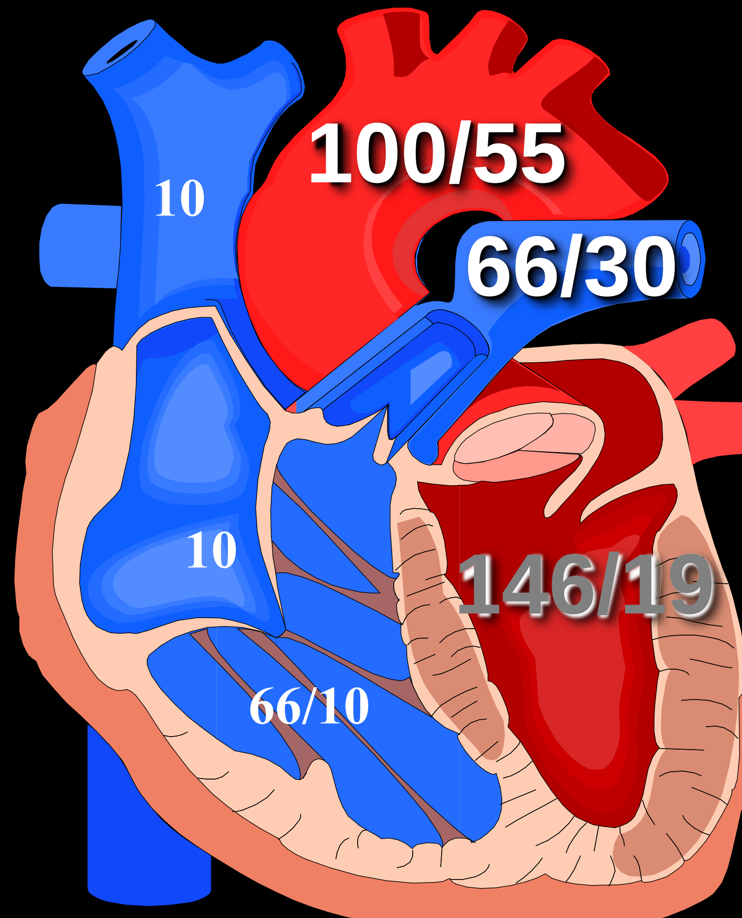
LV systolic pressure = aortic systolic pressure (100) + 70% of AV gradient (46) = 146mmHg

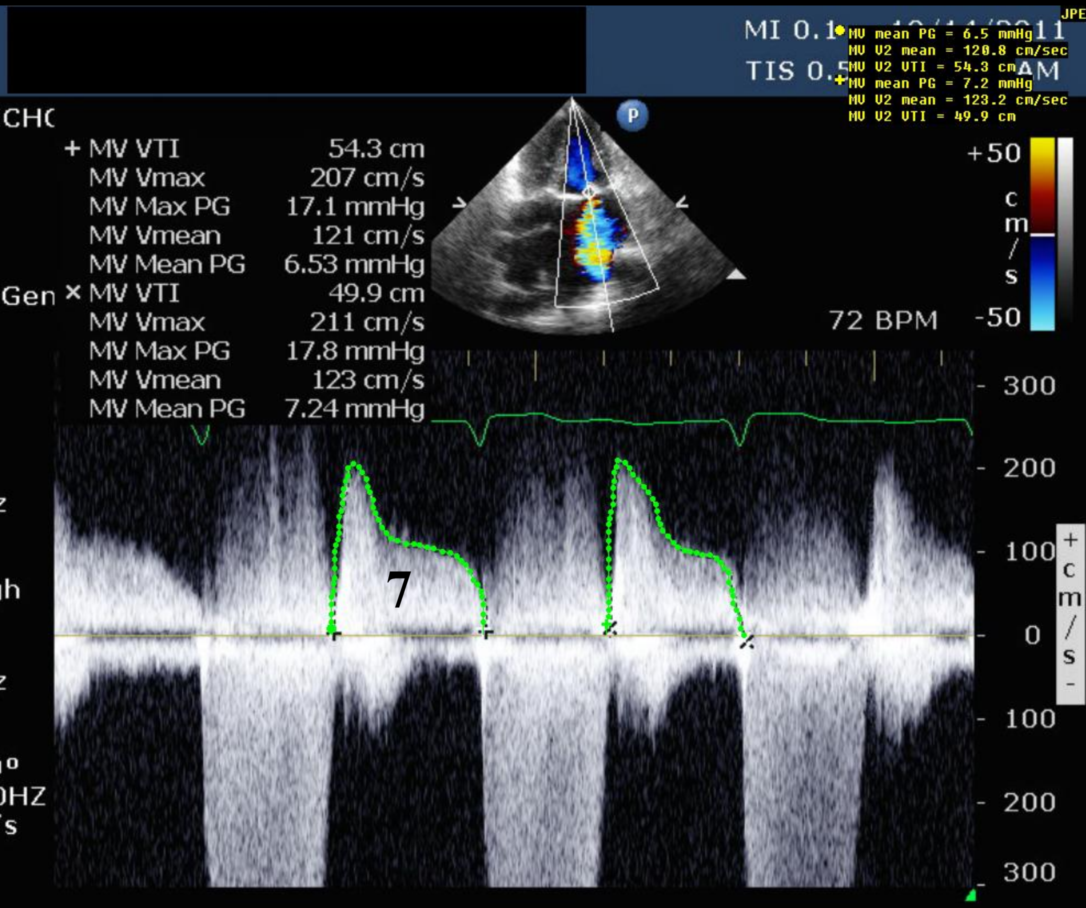


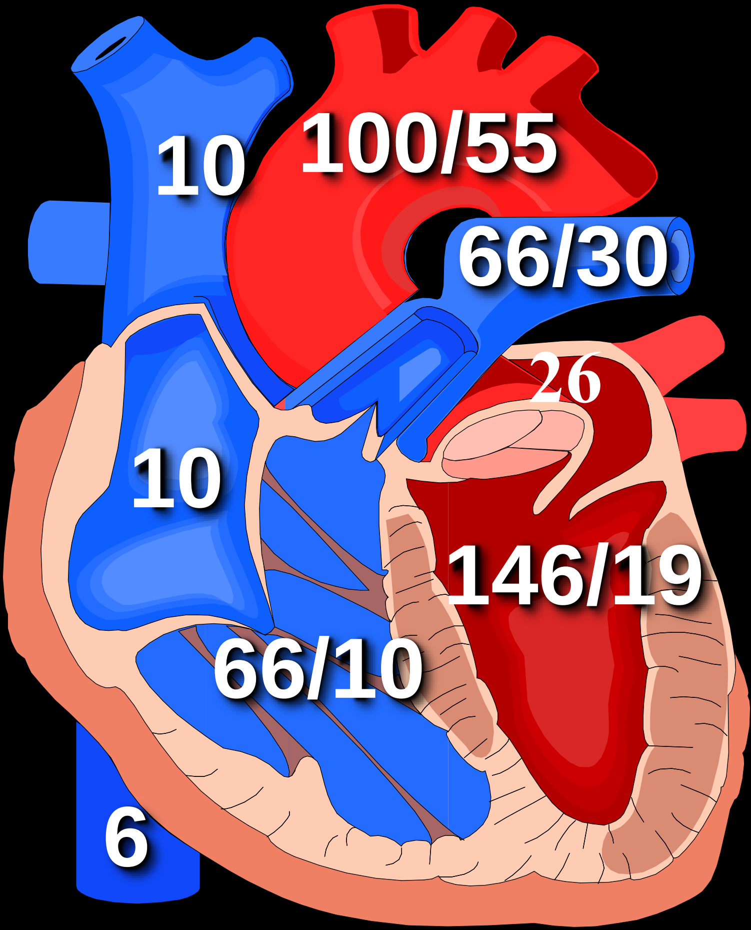


MIG

P2P = 0.7 * 66 = 46

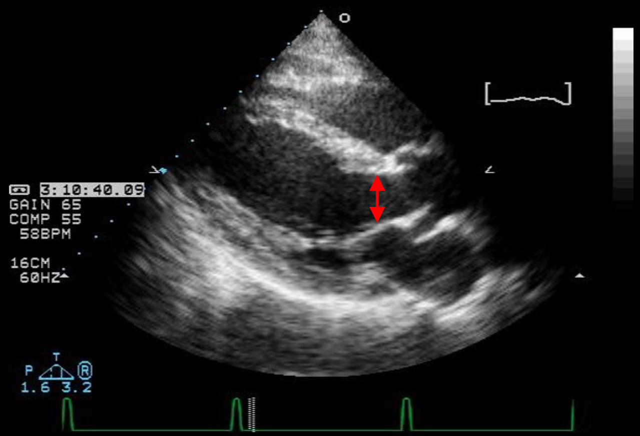
LA pressure = LV diastolic (19) + MV mean gradient (7) = 26mmHg

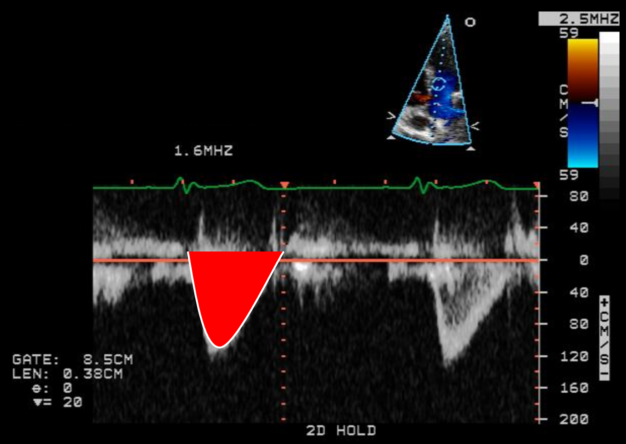




Calculation of Systemic Blood Flow

$$SBF = VTI_{LVOT} \text{ X } Area_{LVOT} \text{ X } HR$$





D = 2 cm

VTI = 24 cm

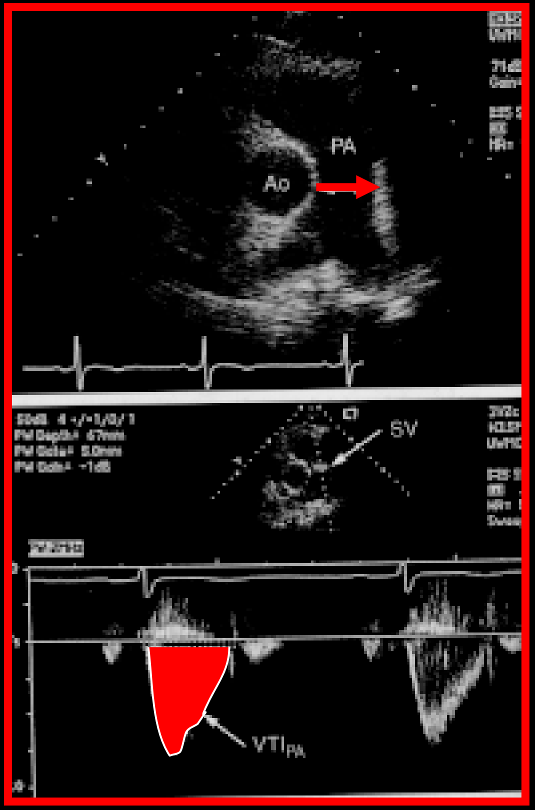
HR = 80

SBF= 6,000 cc

1 x 1 x 3.14 x 24 x 80

Calculation of Pulmonary Blood Flow

$$C.O. = VTI_{RVOT} \times Area_{RVOT} \times HR$$



Can also be calculated using RV inflow and TV VTI

Calculation of Shunts (ASD, VSD)

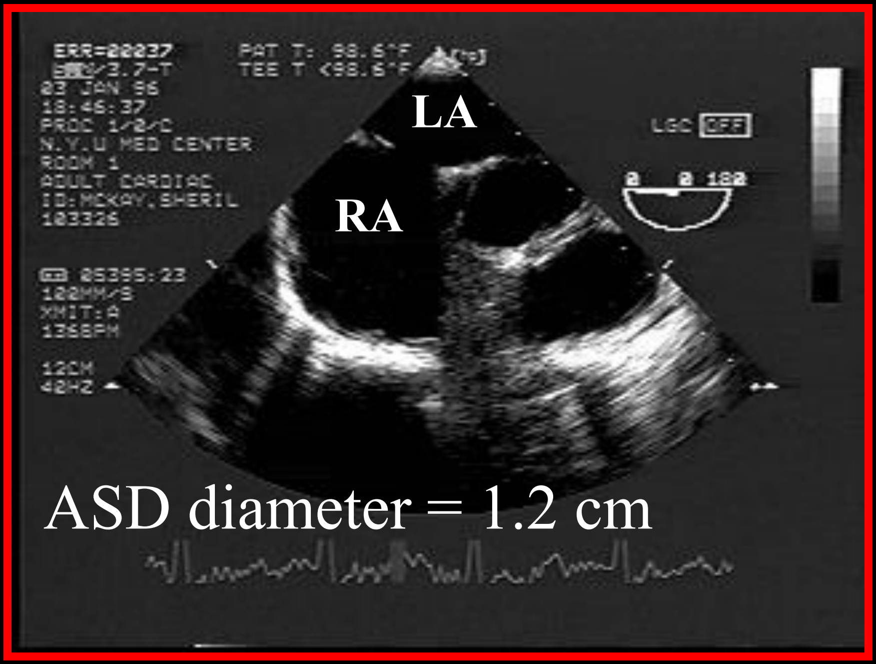
Shunt flow =

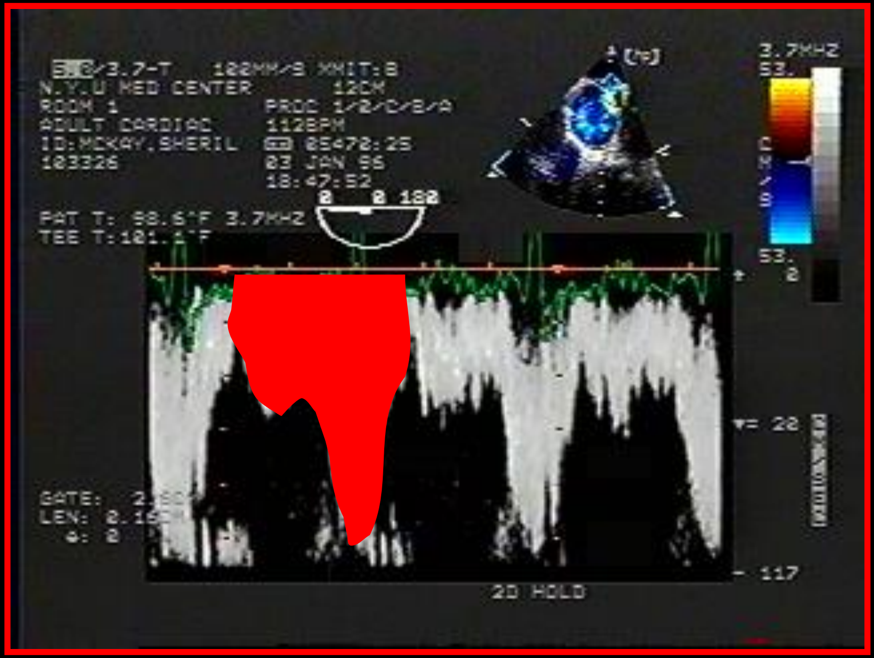
1. Pulmonary blood flow - systemic blood flow

- or -

2. ASD or VSD orifice area x Shunt VTI x HR

Calculation of ASD L-to-R Shunt





Shunt Flow = Orifice Area x VTI of shunt x HR

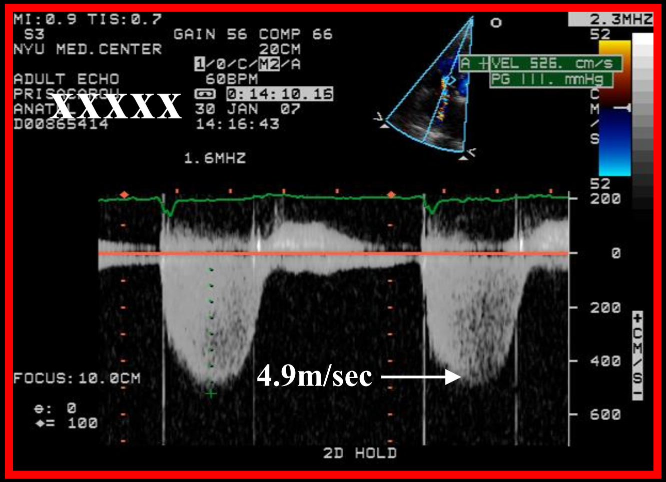
= 0.6 x 0.6 x 3.14 x 80 x 100 = 9L/min.

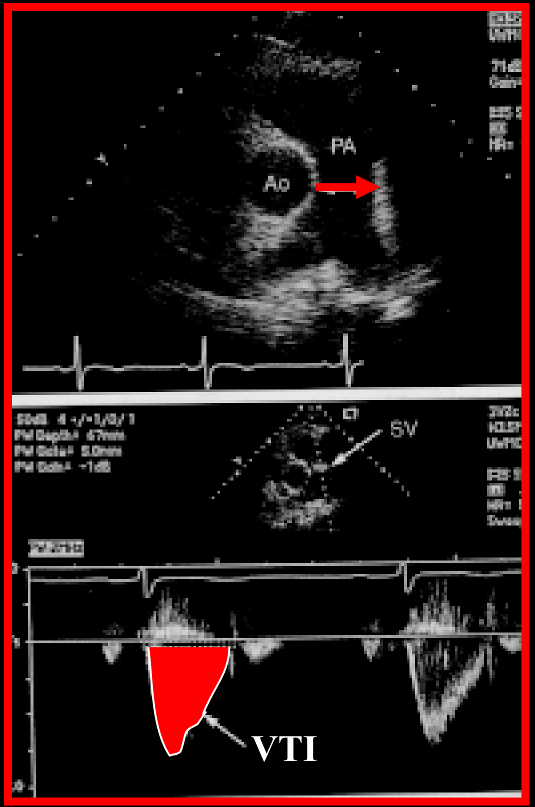
Real time, 3D TEE: Secundum ASD

Pulmonary Vascular Resistance

Normal =2 Wood's units

PVR = (mean PAP- mean PCWP)/C.O.





Another method

PVR= 10 (Peak TR Velocity/RVOT VTI + 0.16)

PVR=Wood's units
TR Velocity = m/sec
RVOT TVI = cm

Conclusions

Normal and abnormal hemodynamics can be evaluated non invasively by Doppler Echocardiography.

Invasive evaluation may be needed for details not seen on Echo, or when the clinical impression is not consistent with the echo-Doppler findings