Assessment of Right Ventricle, Tricuspid Valve, and Pulmonary Artery Pressures

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GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

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(J Am Soc Echocardiogr 2010;23:685-713.)

Importance of RV Dysfunction in Various Disease States

- Primary Pulmonary Arterial Hypertension
- Pulmonary Thromboembolism
- Secondary
  - Left heart failure
  - Left sided valve diseases
  - Myocardial infarction with RV involvment
- Congenital Heart Diseases
- ARVD/Other Systemic Diseases

2D Assessment
Right ventricle

- Structurally complex cavity:
  - crescent shape
  - irregular endocardial surface due to heavy trabeculation: difficult to delineate endocardial border
  - location behind the sternum: inadequate image quality
- Fits no simple geometric figure:
  - failure to standardize RV volume determination
- RV size estimation requires integration of multiple views and qualitative and quantitative assessment

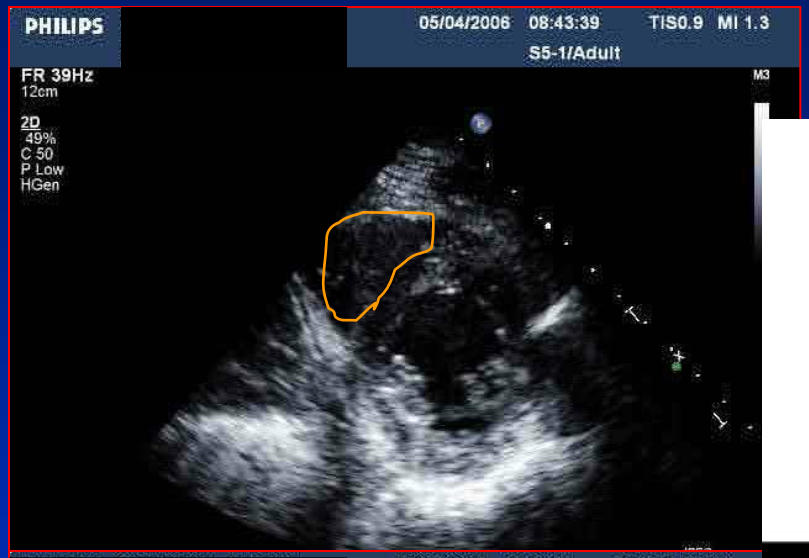
Table 2 Chamber dimensions

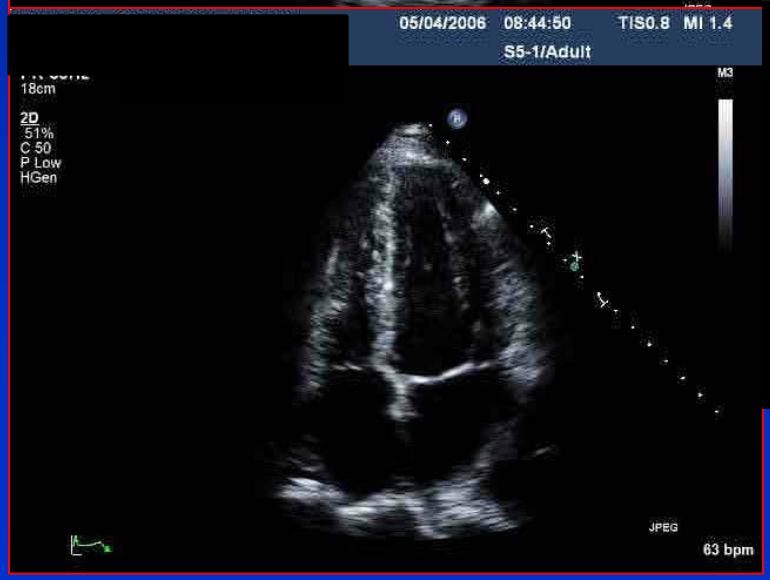
Dimension	Studies	n	LRV (95% CI)	Mean (95% CI)	URV (95% CI)
RV mid cavity diameter (mm) (Figure 7, RVD2)	12	400	20 (15-25)	28 (23-33)	35 (30-41)
RV basal diameter (mm) (Figure 7, RVD1)	10	376	24 (21-27)	33 (31-35)	42 (39-45)
RV longitudinal diameter (mm) (Figure 7, RVD3)	12	359	56 (50-61)	71 (67-75)	86 (80-91)
RV end-diastolic area (cm^2) (Figure 9)	20	623	10 (8-12)	18 (16-19)	25 (24-27)
RV end-systolic area (cm^2) (Figure 9)	16	508	4 (2-5)	9 (8-10)	14 (13-15)
RV end-diastolic volume indexed (mL/m^2)	3	152	44 (32-55)	62 (50-73)	80 (68-91)
RV end-systolic volume indexed (mL/m^2)	1	91	19 (17-21)	33 (31-34)	46 (44-49)
3D RV end-diastolic volume indexed (mL/m^2)	5	426	40 (28-52)	65 (54-76)	89 (77-101)
3D RV end-systolic volume indexed (mL/m^2)	4	394	12 (1-23)	28 (18-38)	45 (34-56)
RV subcostal wall thickness (mm) (Figure 5)	4	180	4 (3-4)	5 (4-5)	5 (5-6)
RVOT PLAX wall thickness (mm) (not shown)	9	302	2 (1-2)	3 (3-4)	5 (4-6)
RVOT PLAX diameter (mm) (Figure 8)	12	405	18 (15-20)	25 (23-27)	33 (30-35)
RVOT proximal diameter (mm) (Figure 8, RVOT-Prox)	5	193	21 (18-25)	28 (27-30)	35 (31-39)
RVOT distal diameter (mm) (Figure 8, RVOT-Distal)	4	159	17 (12-22)	22 (17-26)	27 (22-32)
RA major dimension (mm) (Figure 3)	8	267	34 (32-36)	44 (43-45)	53 (51-55)
RA minor dimension (mm) (Figure 3)	16	715	26 (24-29)	35 (33-37)	44 (41-46)
RA end-systolic area (cm^2) (Figure 3)	8	293	10 (8-12)	14 (14-15)	18 (17-20)

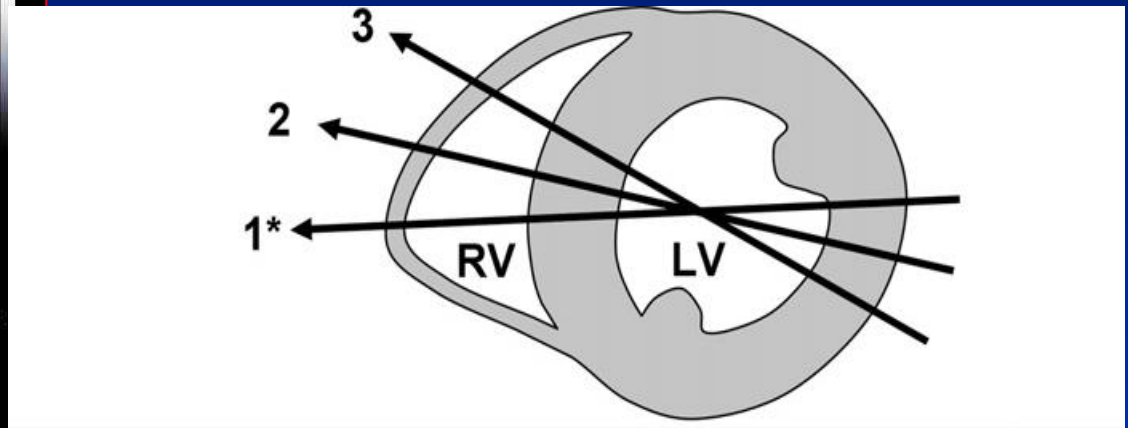
CI, Confidence interval; *LRV*, lower reference value; *PLAX*, parasternal long-axis; *RA*, right atrial; *RV*, right ventricular; *RVD*, right ventricular diameter; *RVOT*, right ventricular outflow tract; *3D*, three-dimensional; *URV*, upper reference value.

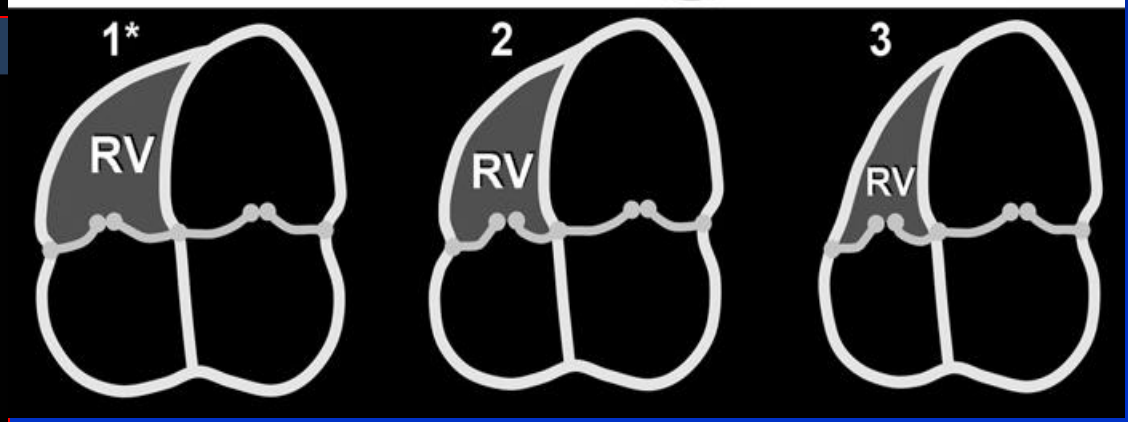
Right ventricle

Normal dimensions



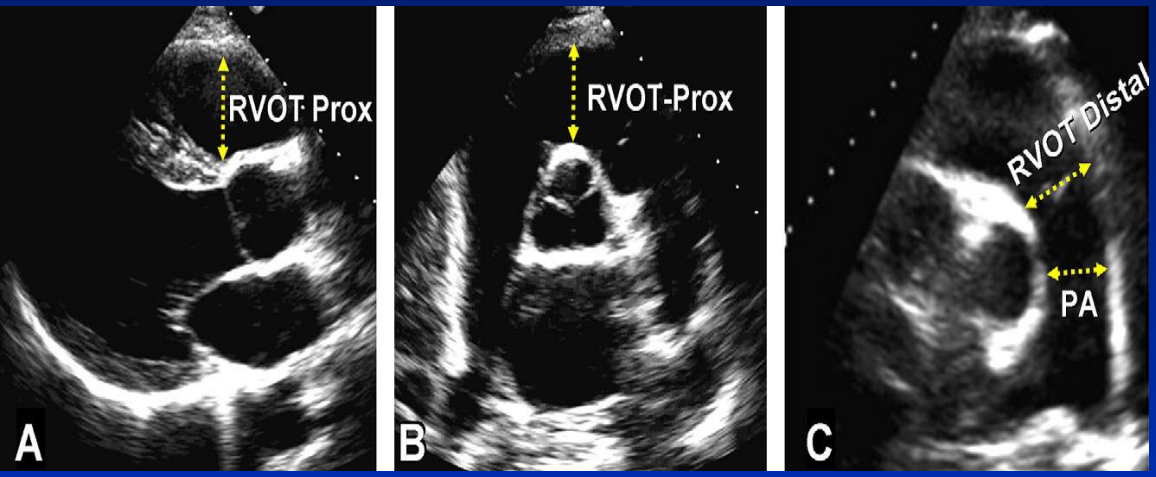


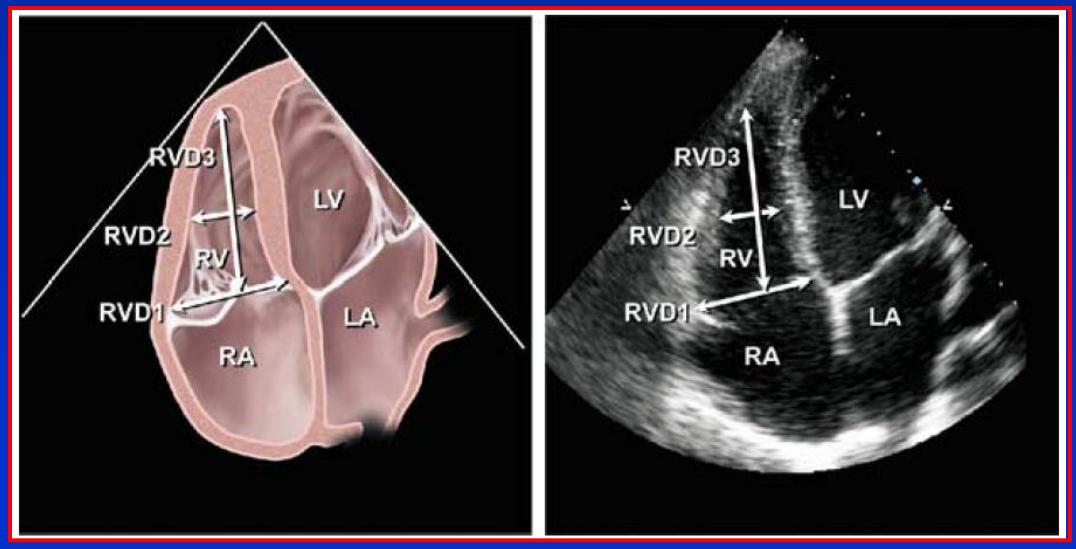




Right ventricle

Linear dimensions

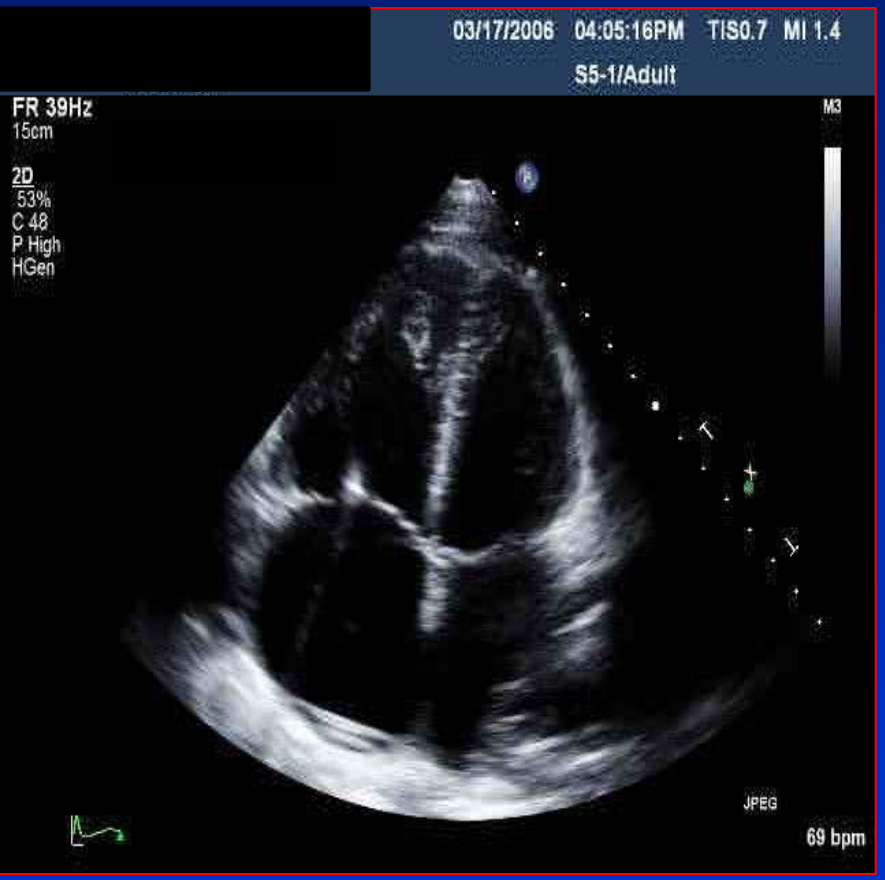




- PLAX RVOT : 3.3 cm
- PSAX RVOT : 2.7cm
- **Basal diameter 4.2 cm**
- Mid level diameter 3.5 cm
- Longitudinal dimension 8.6 cm

Right ventricle

Dilatation

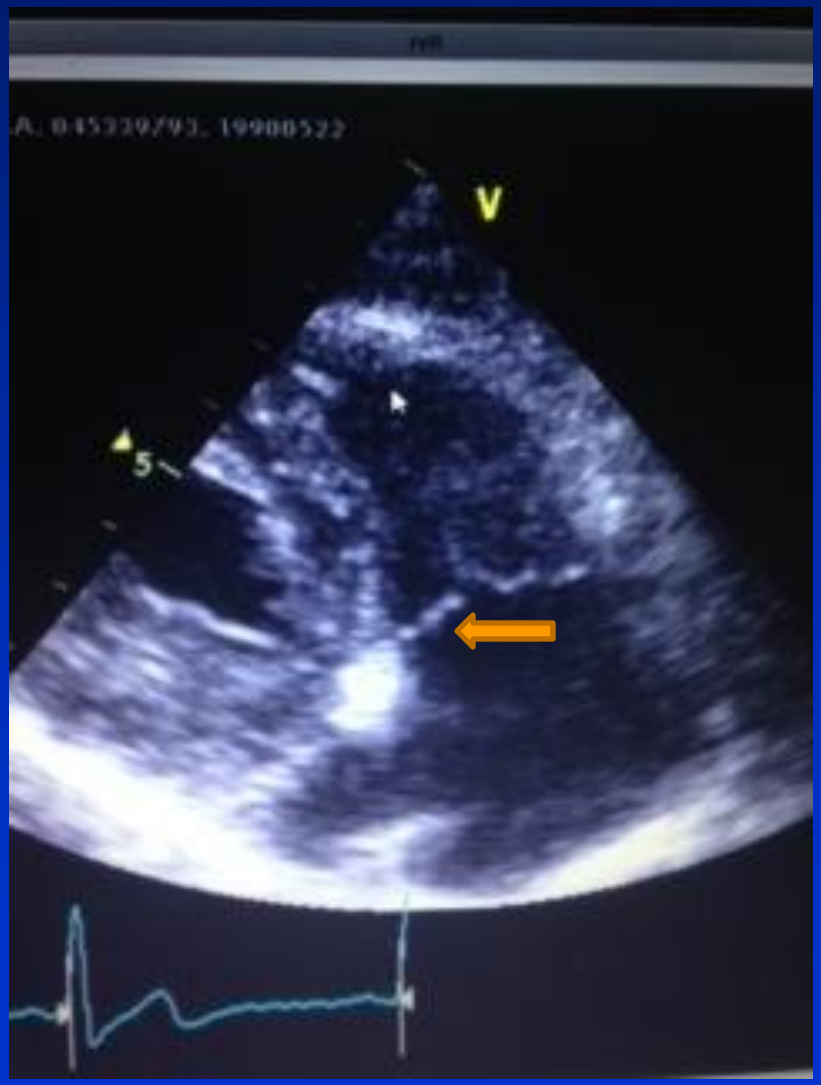


Normal RV < 2/3 LV

RV dilatation:

- Linear dimensions
- Mild: enlarged but RV area<LV area
- Moderate: RV area=LV area
- Severe: RV area>LV area

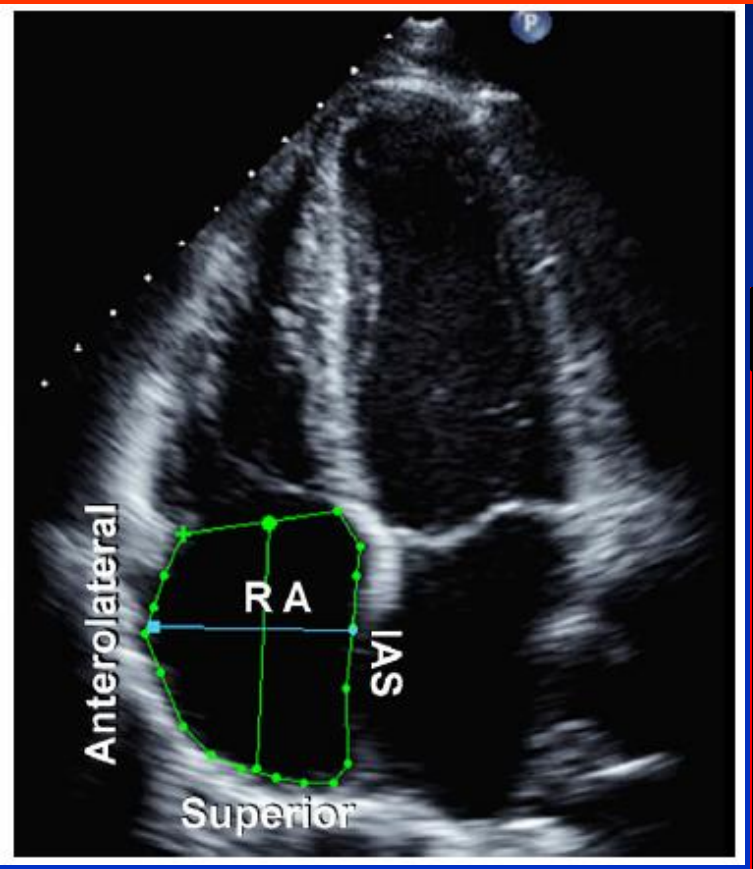
What structure is this?



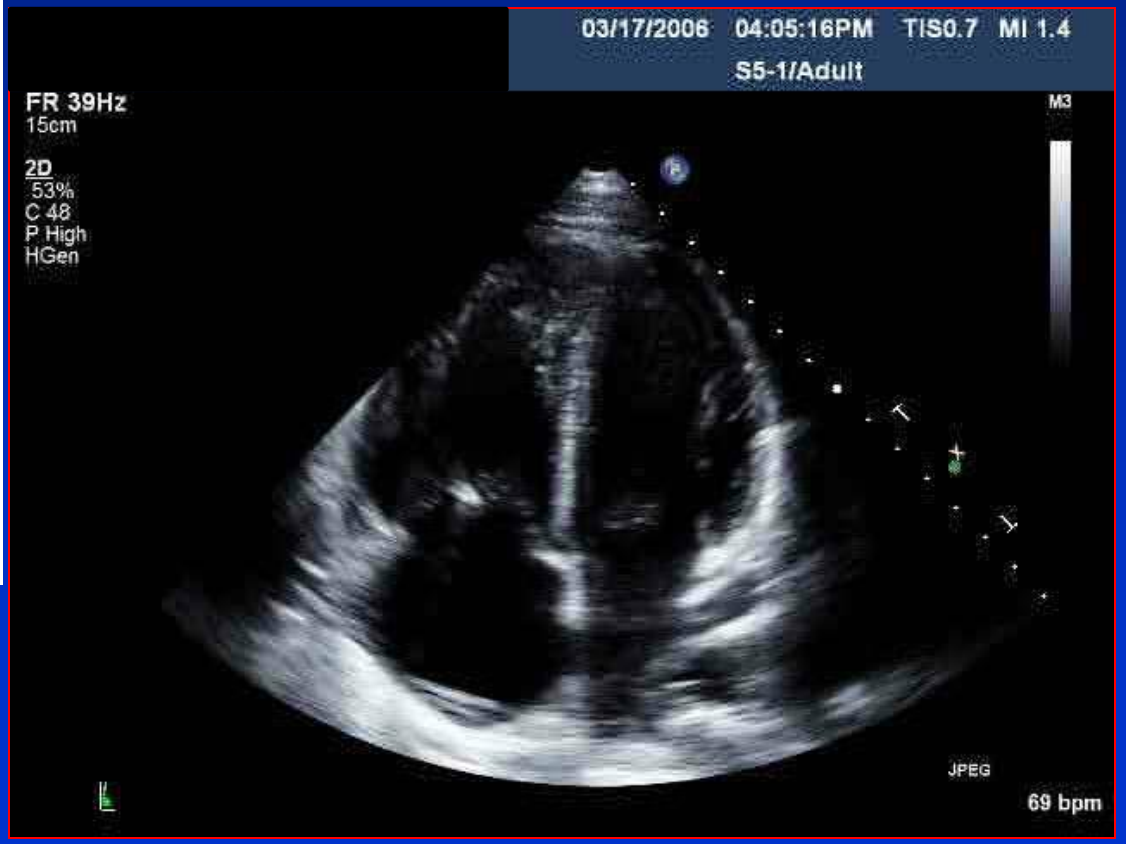
- Anterior leaftlet
- Posterior leaflet
- Septal leaflet
- Ostium of CS
- Ostium of IVC
- Eustachian Valve

2D Assessment

Right atrial size



- Major-axis (vertical line) <5.3cm
- Minor-axis (horizontal line) <4.4cm
- ***RA area<18cm2***

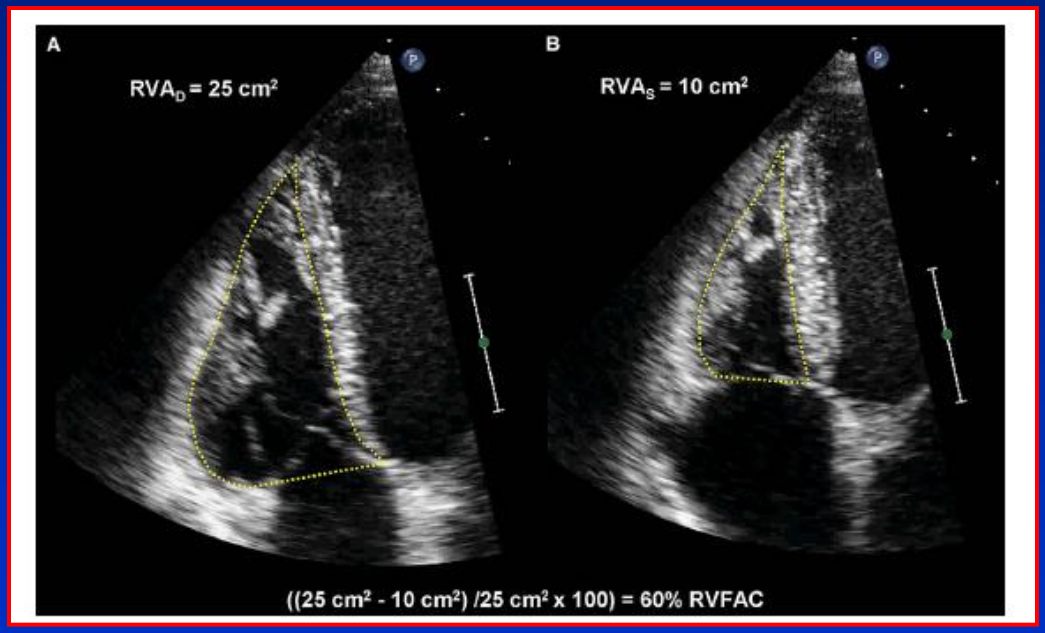


RV function

- Subjective:
  - thickening of the RV wall and inward motion of the RV free wall in multiple views
  - integrate findings from various views
- RV fractional area change
- Tricuspid annular descent (TAPSE)
- Tissue Doppler
- Tei Index

RV function

RV fractional area change



- RV fractional area change=

$$\frac{\text{RVD area-RVS area}}{\text{RVD area}}$$

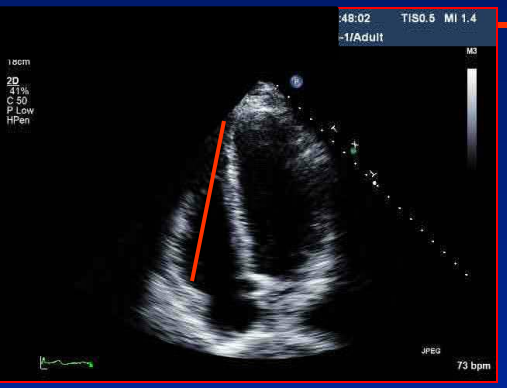
-Normal: >35%

- Relatively high correlations (0.69–0.88) between echo and MRI estimated RV size

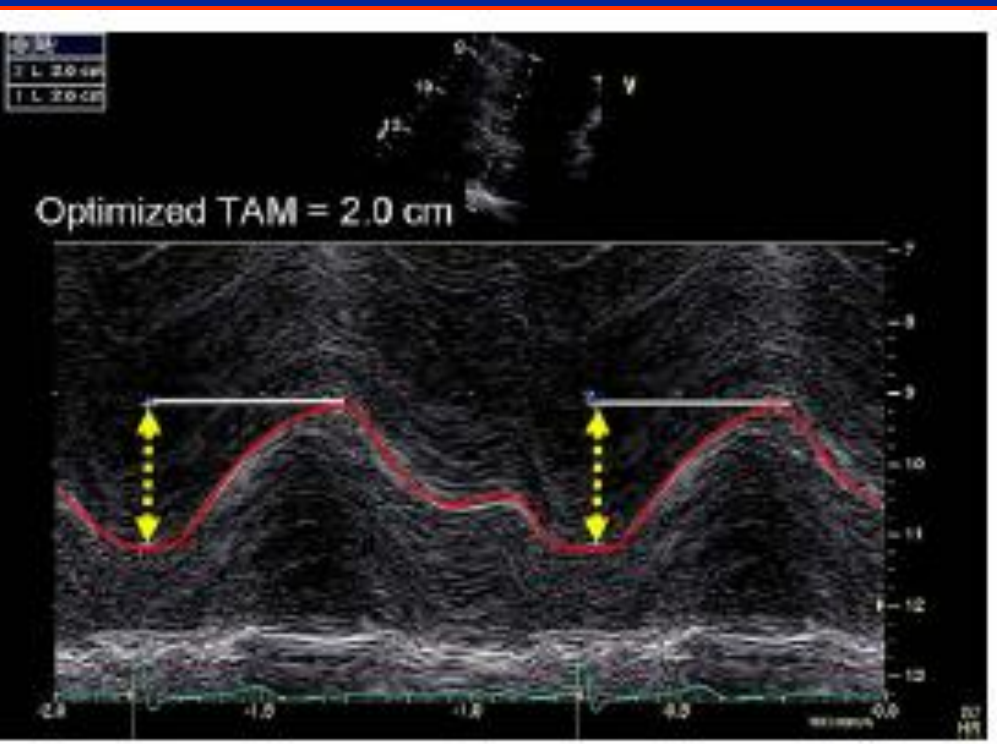
- RV tracing may be improved using intravenous contrast agents.

RV function

Tricuspid annular descent



- RV ejects blood primarily by shortening of the longitudinal axis



Tricuspid annular plane systolic excursion (TAPSE index) measured in apical 4-chamber view and M-mode cursor through lateral tricuspid annulus

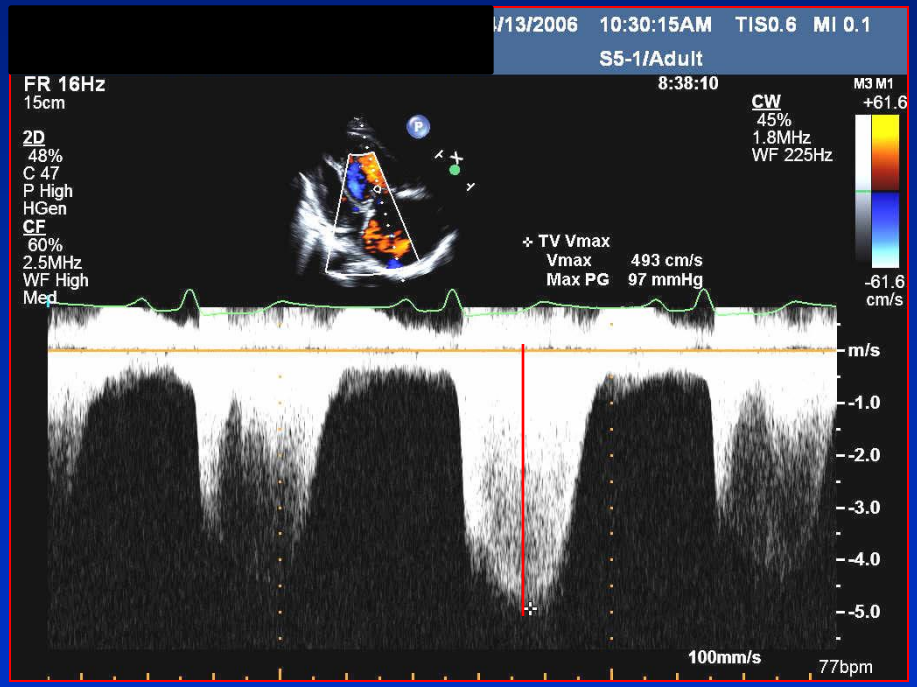
Normal>16 mm

Pulmonary Hypertension
Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP
2. Pulmonary vascular resistance
3. RVOT TVI

Doppler Assessment

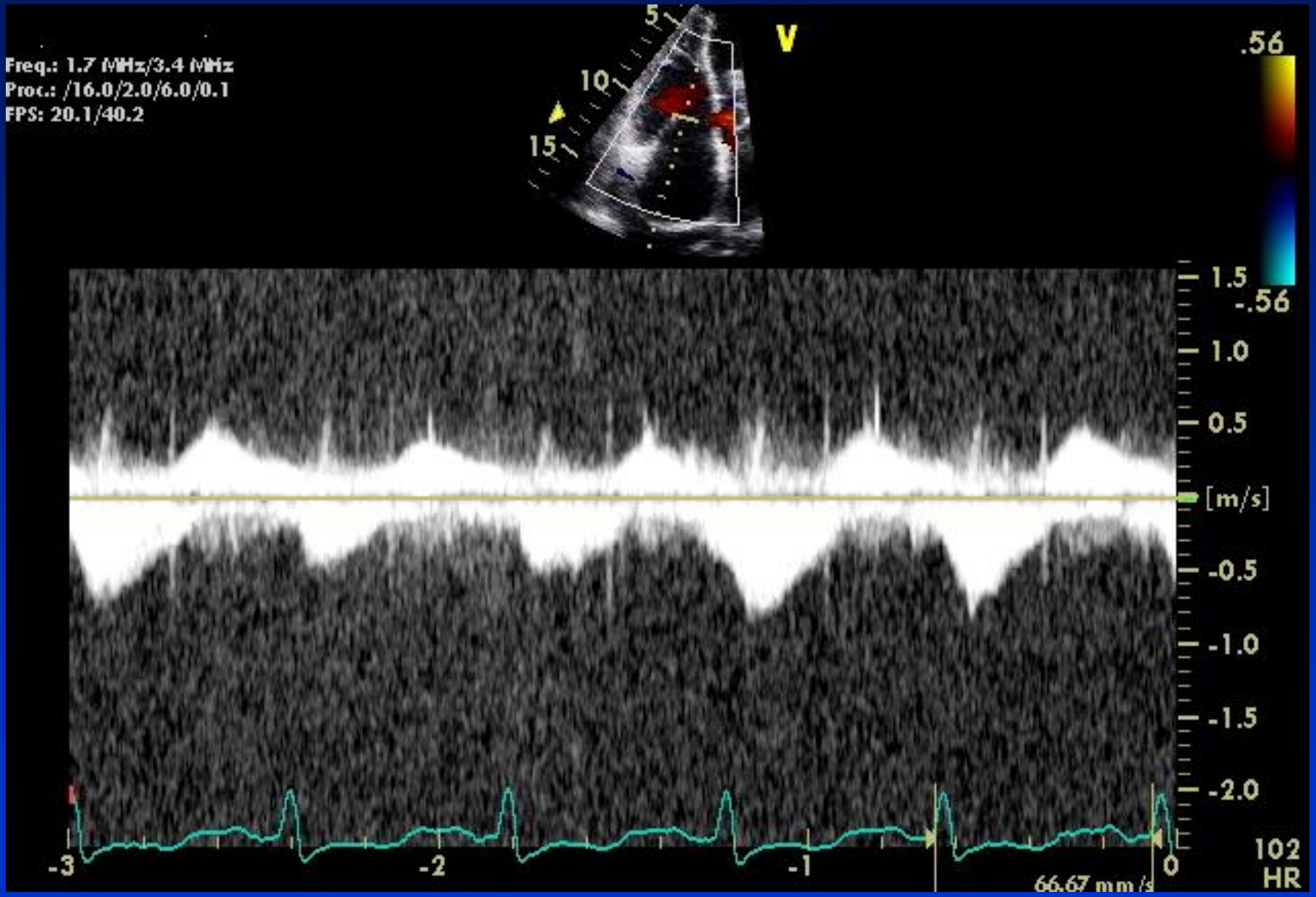
Pulmonary artery systolic pressure



- Peak TR velocity
  - Measured with continuous wave Doppler
  - reflects RV to RA pressure difference during systole

    $RVSP\text{-}RAP = 4(V_{Tr})^2$

    $RVSP = 4(V_{Tr})^2 + RAP$
  - In the absence of pulmonic stenosis: RVSP=PASP
- Good correlation between echo and RHC derived PAP


Freq.: 1.7 MHz/3.4 MHz
Proc.: /16.0/2.0/6.0/0.1
FPS: 20.1/40.2
5
10
15
V
.56
1.5
-.56
1.0
0.5
[m/s]
-0.5
-1.0
-1.5
-2.0
-3
-2
-1
0
66.67 mm/s
102
HR

Doppler Assessment

Pitfalls in obtaining accurate PASP

Inaccurate RAP estimate

Presence of pulmonic stenosis (RVSP≠PASP)

Severe TR: Doppler envelope may be cut off because of early equalization of RV and RA pressures > underestimation of PASP

Over-estimation when given saline to enhance TR

Pulmonary Hypertension

Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP
2. Pulmonary vascular resistance
3. RVOT TVI

Doppler Assessment

Pulmonary artery (end) diastolic pressure

Pulmonary regurgitant velocity reflects PA to RV pressure difference during diastole

$PADP\text{-}RVDP = 4(V_{PI})^2$

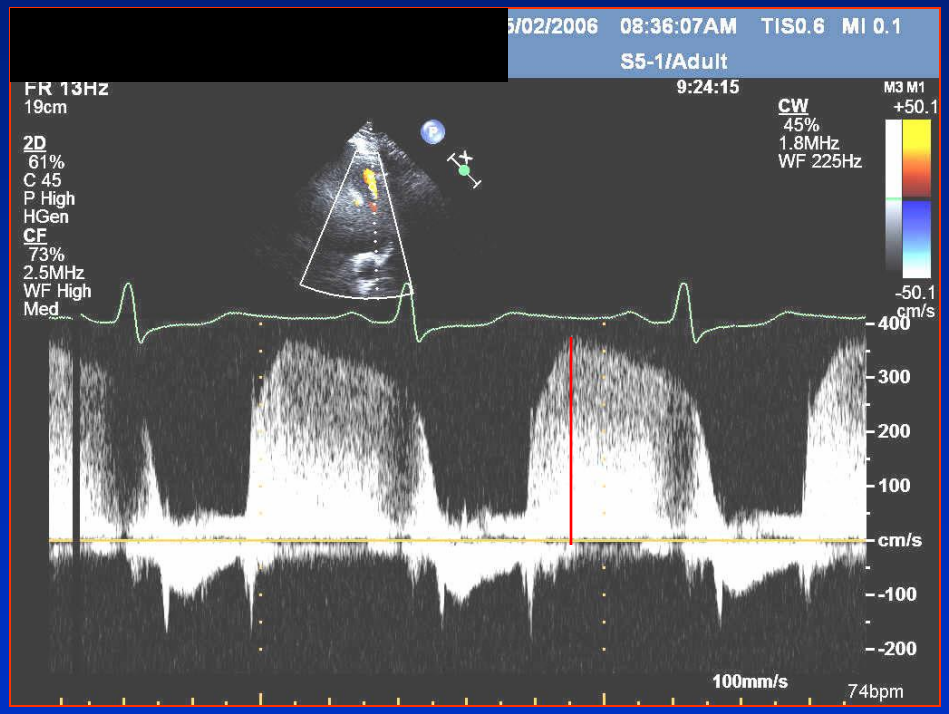
$PADP = 4(V_{PI})^2 + RAP$

Pulmonary Hypertension
Doppler Assessment

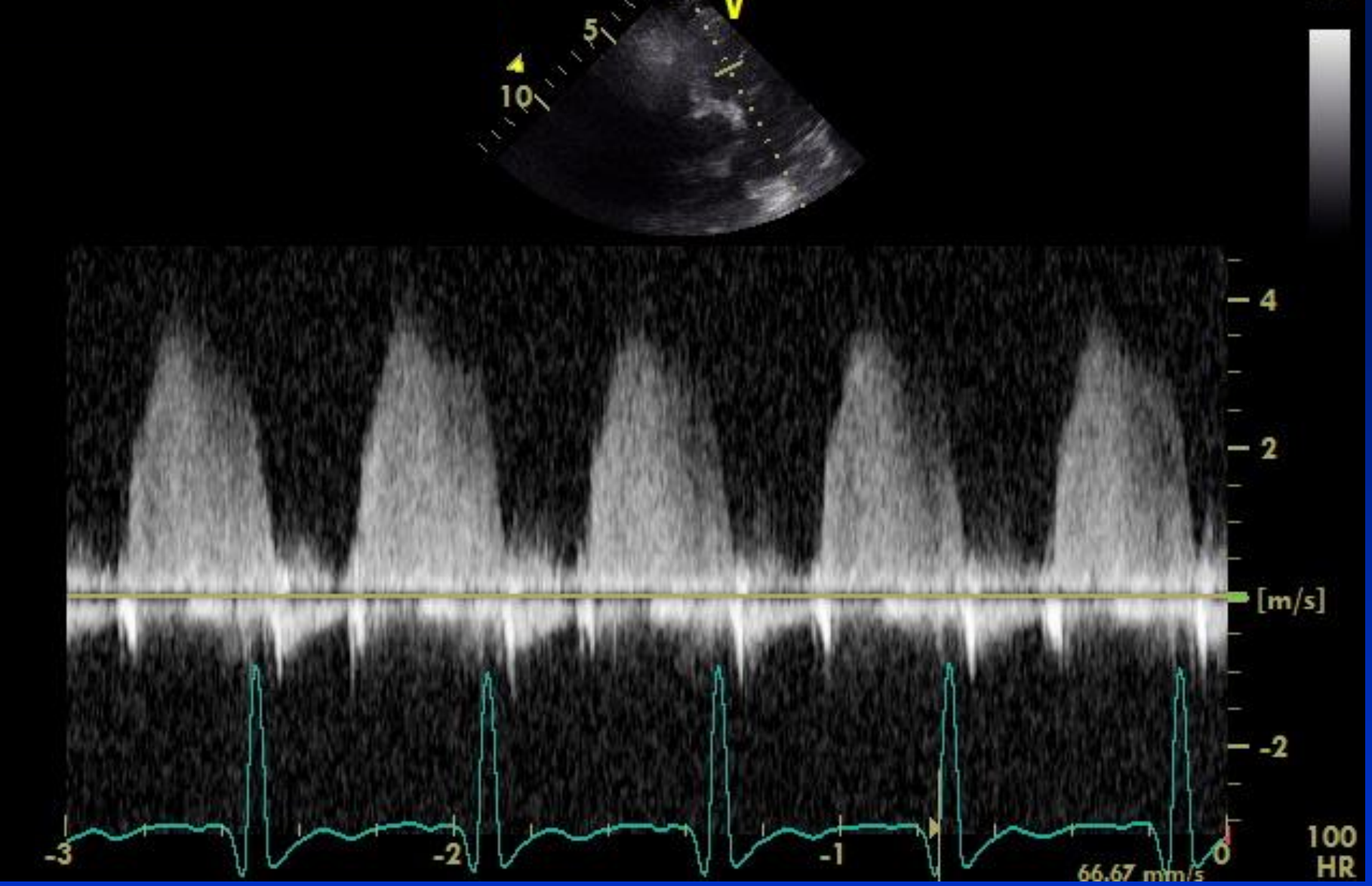
1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP
2. Pulmonary vascular resistance
3. RVOT TVI

Doppler Assessment

Mean pulmonary artery pressure



- Mean PAP= $4(V_{peak\ PI})^2 + RAP$



What is SPAP?? Assuming peak and end PI velocities are 3.75m/s and 3m/s, RAP 15

Pulmonary Hypertension

Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP
2. Pulmonary vascular resistance
3. RVOT TVI

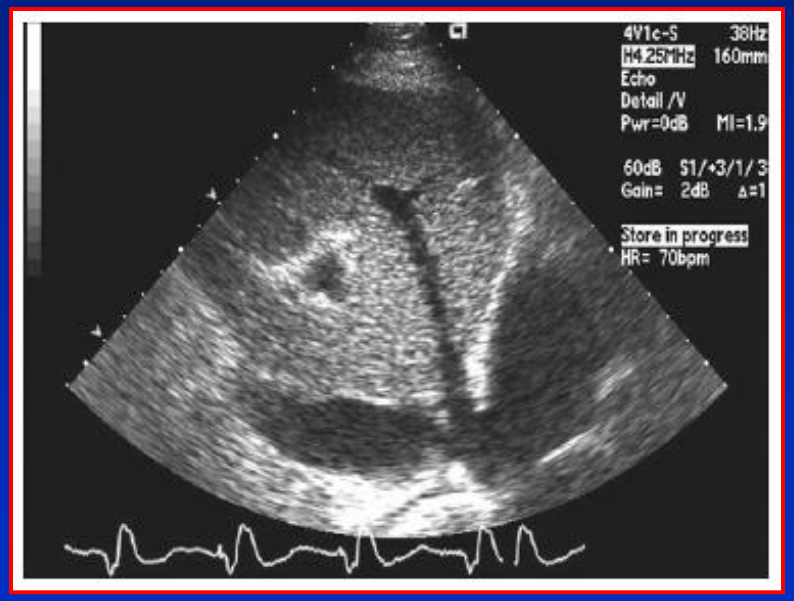
Doppler Assessment

Right atrial pressure

- IVC diameter
- IVC collapsibility
- Hepatic venous Doppler

Right atrial pressure

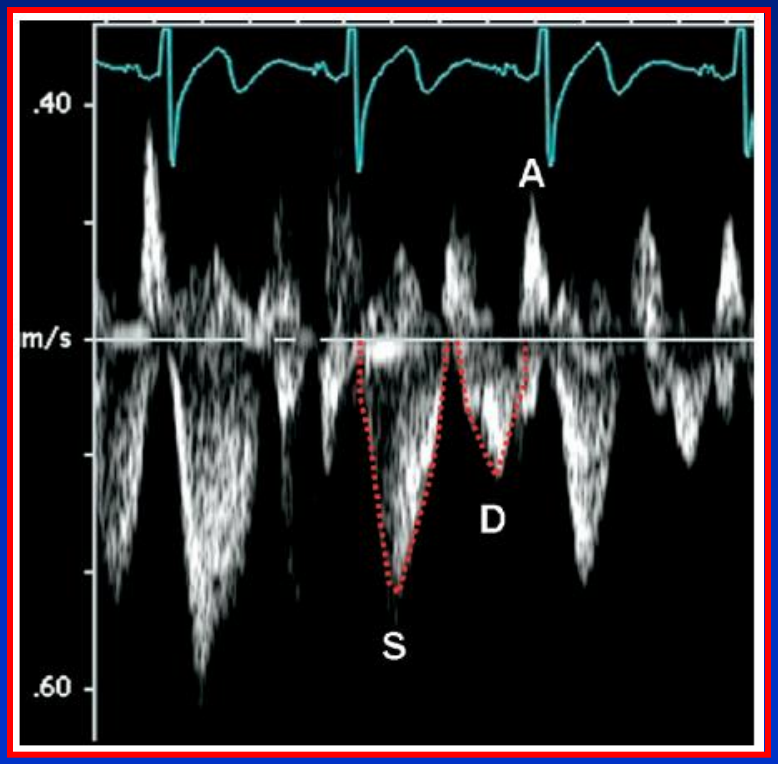
IVC Diameter and Collapsibility



- Imaged supine position; subcostal view.
- IVC diameter
  - best measured between 5 and 30 mm from the IVC and RA junction.
- IVC should be captured for 3-5 beats during quiet respiration and during a “sniff” maneuver.
- IVC diameter varies with respiration, with minimal size at end inspiration.

Right atrial pressure

Hepatic venous Doppler



- PW Doppler cursor placed in hepatic vein parallel to flow
- Waves:
  - Systolic forward flow
  - Diastolic forward flow pulse
  - Atrial systole; reversal of flow
- Increase in RAP: pressure gradient between the hepatic veins and the RA decreases, thus lowering the forward systolic flow.

New 2010 Guidelines to Estimate RAP

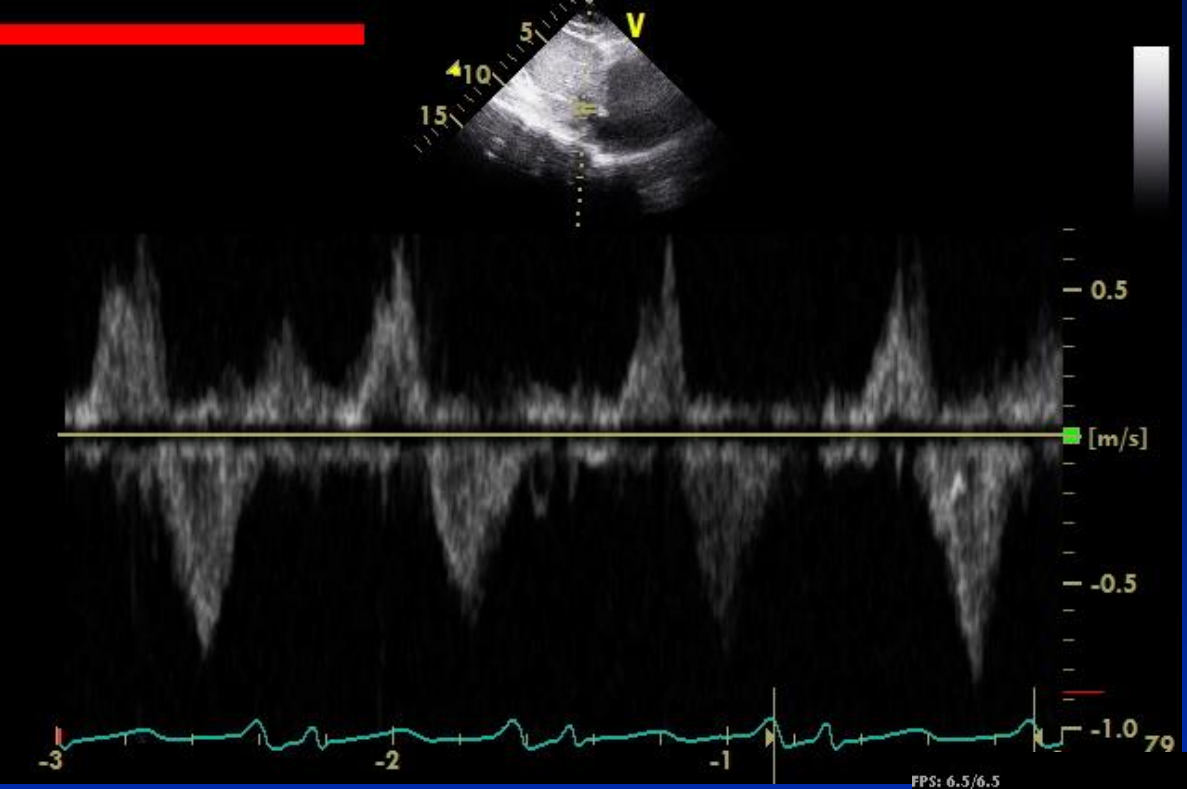
veins (Figure 4). **For simplicity and uniformity of reporting, specific values of RA pressure, rather than ranges, should be used in the determination of SPAP. IVC diameter ≤ 2.1**

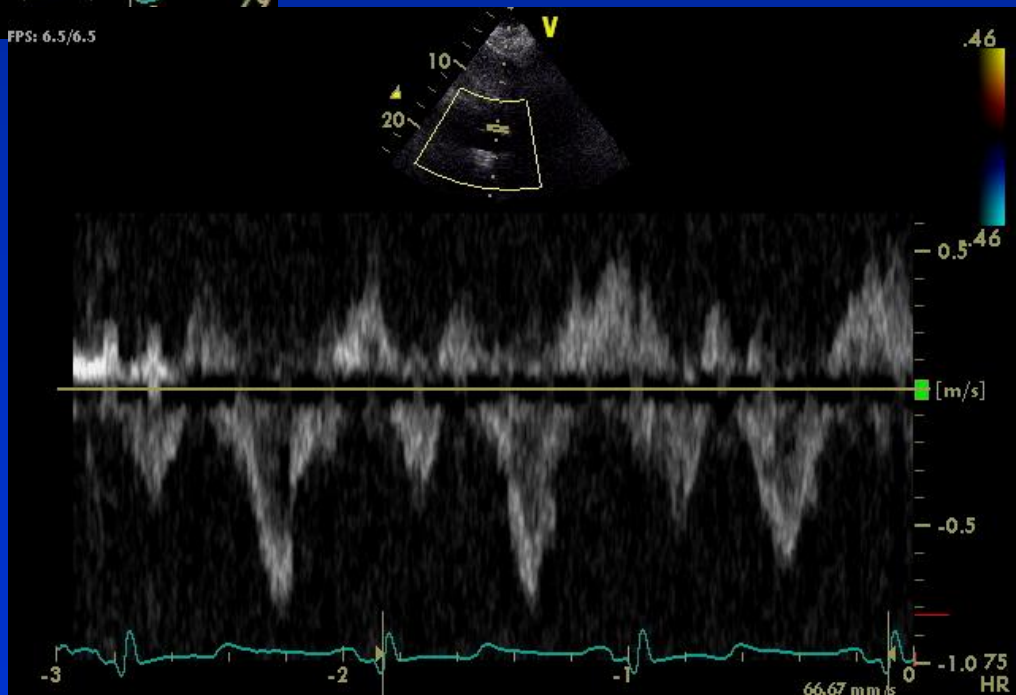
Table 3 Estimation of RA pressure on the basis of IVC diameter and collapse

Variable	Normal (0-5 [3] mm Hg)	Intermediate (5-10 [8] mm Hg)		High (15 mm Hg)
IVC diameter	≤2.1 cm	≤2.1 cm	>2.1 cm	>2.1 cm
Collapse with sniff	>50%	<50%	>50%	<50%
Secondary indices of elevated RA pressure				• Restrictive filling • Tricuspid E/E' > 6 • Diastolic flow predominance in hepatic veins (systolic filling fraction < 55%)

RA Pressure
Exceptions

- Atrial fibrillation
  - Use IVC diameter and collapsibility only.
- Ventilated patients
  - dilated IVC does not correlate with RAP
  - if < 1.2cm, 100% specific for RAP < 10mmHg
- Young patients/athletes
  - IVC may be dilated and systolic wave may be blunted in setting of normal RAP


V
5
10
15
0.5
[m/s]
-0.5
-1.0
79
-3
-2
-1


FPS: 6.5/6.5
V
10
20
.46
.46
0.5
[m/s]
-0.5
-1.0
75
HR
-3
-2
-1
0
66.67 mm/s

Pulmonary Hypertension

Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP
2. Pulmonary vascular resistance
3. RVOT TVI

Question

- How do you calculate pulmonary vascular resistance?
  A. PASP-CVP/CO
  B. Mean PAP-PCWP/CO
  C. MAP-CVP/CO
  D. PCWP-Mean PAP/CO

Doppler Assessment
Pulmonary vascular resistance

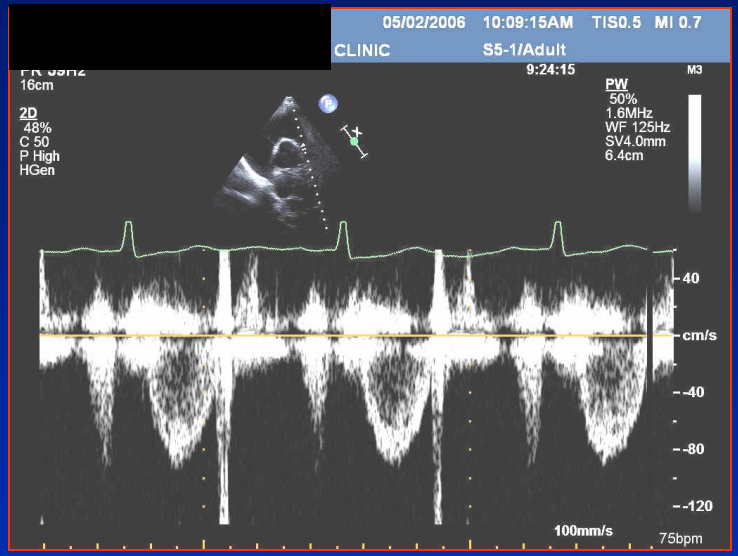
- Distinguishing high PAP due to increased pulm flow versus from pulm HTN due to elevated PVR.
- Heart/liver transplant eval.
- CHF
- Congenital heart disease

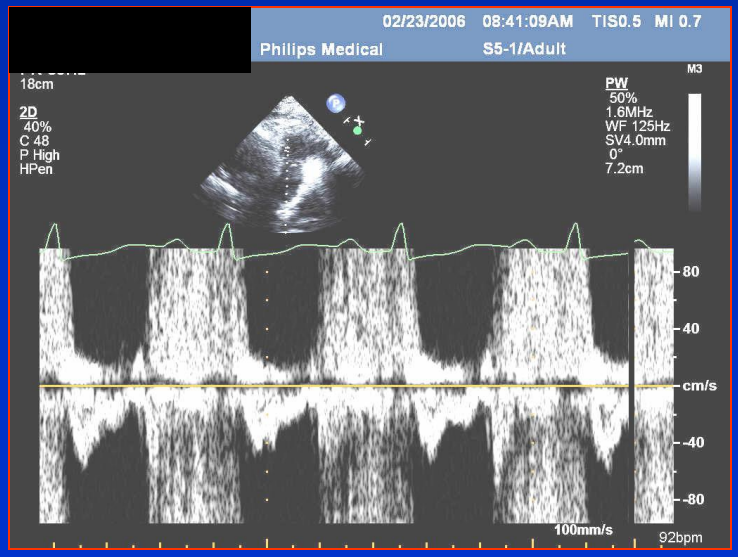
- PVR = [Mean Pulmonary Artery Pressure – PCWP] / CO

- PVR (woods units) can be estimated using: TR peak velocity / RVOT TVI x10 + 0.16

Doppler Assessment

RVOT TVI





- Normal:
  - pulm flow contour is symmetric
  - peak velocity occurs in mid-systole (137 +/- 24 msec).

- Pulmonary HTN:
  - Pulmonary hypertension: mid-systolic notching of RVOT TVI.
  - Peak velocity occurs earlier in systole (97 +/- 20 msec).
  - Pulmonary artery flow acceleration time (AT): measured using PW in RVOT from onset of flow to peak velocity.

PA flow acceleration time

- **AT inversely correlates to mean PAP**.
- As PAP increases, acceleration time decreases (normal > 120 msec).
- **If ACT < 90 msec → PAP is > 60 mmHg**
- mPAP = 79 – (0.45 x RVOT AT in msec)
  - If HR<60 or>100 then time must be adjusted

Question

- In which setting can the ACT time be normal despite significant pulmonary hypertension?
  A. Severe PI
  B. Peripheral pulmonary artery stenosis
  C. Elevated RVEDP
  D. Significant RV dysfunction

Question

Which of the following is true?

A. In the setting of pulmonic stenosis, pulmonary artery systolic pressure (sPAP) can be estimated as:

$sPAP=4v^2+RAP$ (v=peak TR jet velocity)

B. In the presence of a VSD, sPAP can be calculated as LVSP- $4v^2$ (v=peak velocity of flow through VSD)

C. PA diastolic pressure can be calculated as $4v^2+RAP$ (v=peak early diastolic pulmonary regurgitant velocity).

D. RVOT acceleration time can be used to calculate sPAP.

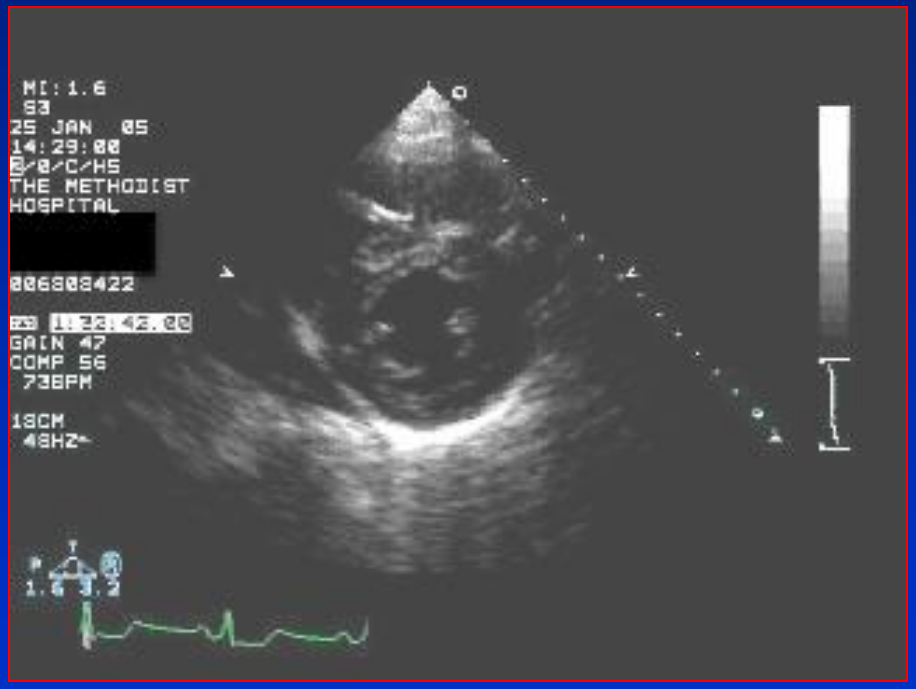
Pulmonary Hypertension

2D Assessment

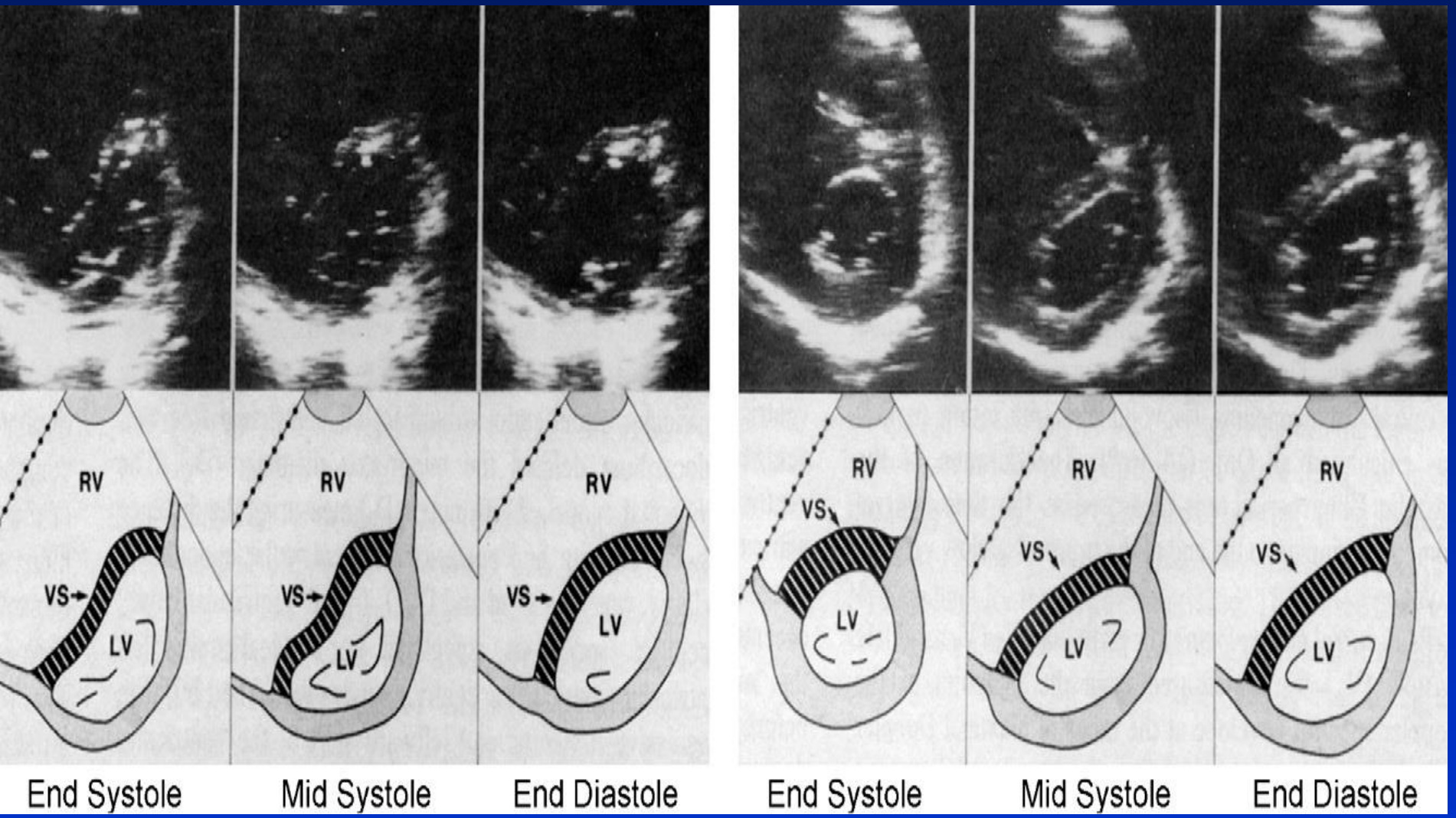
1. RA size
2. RV size
3. Septal flattening

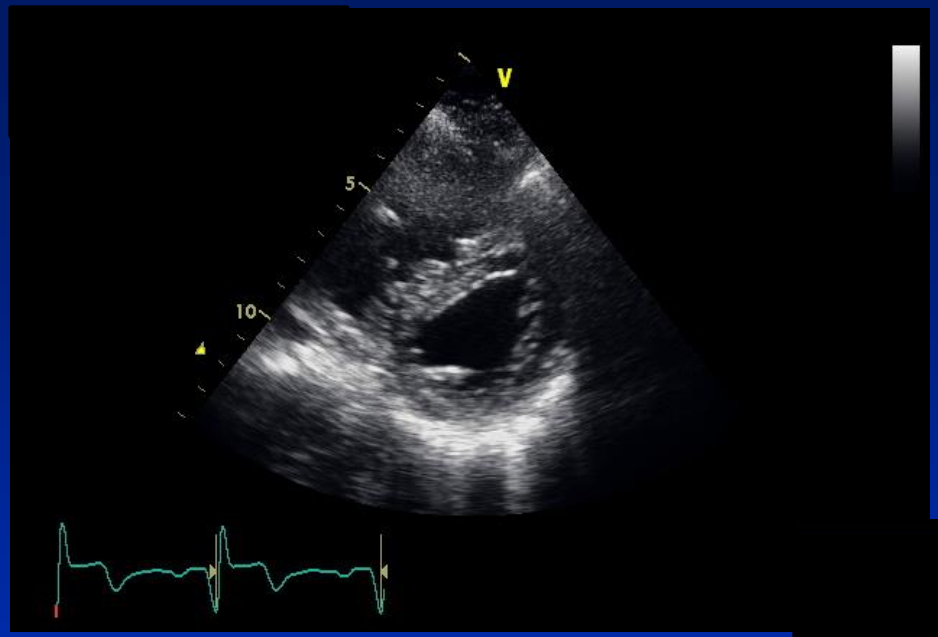
Interventricular septum

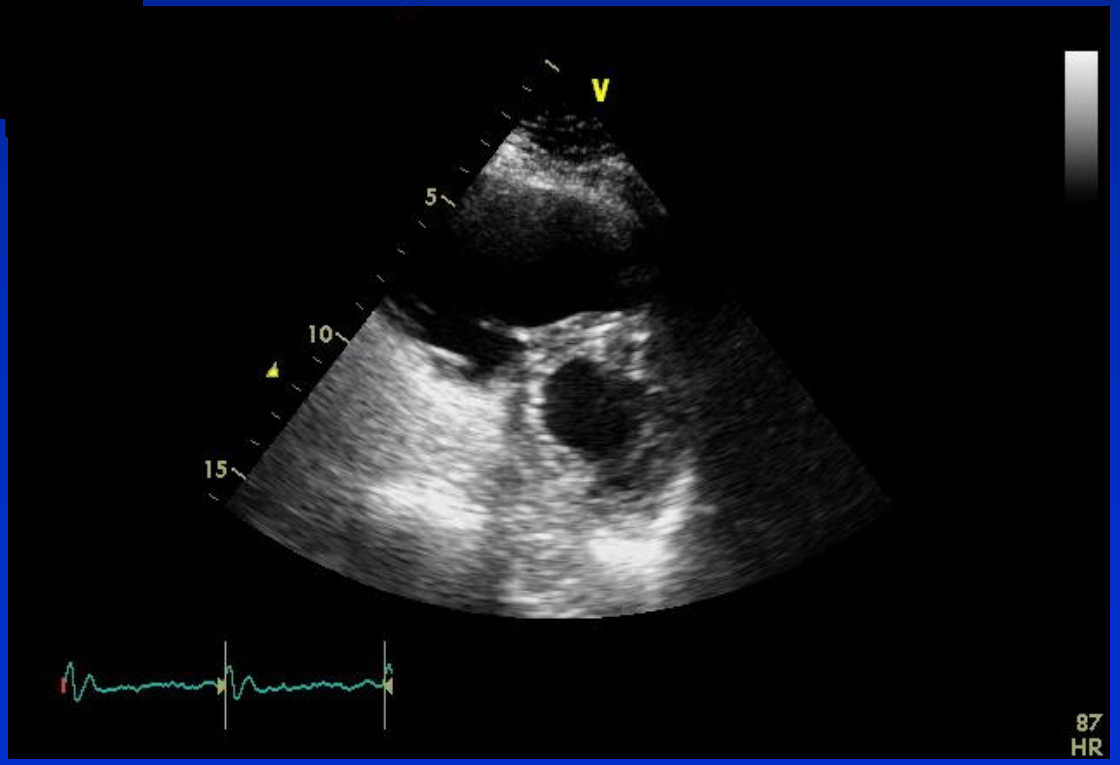
Normal motion

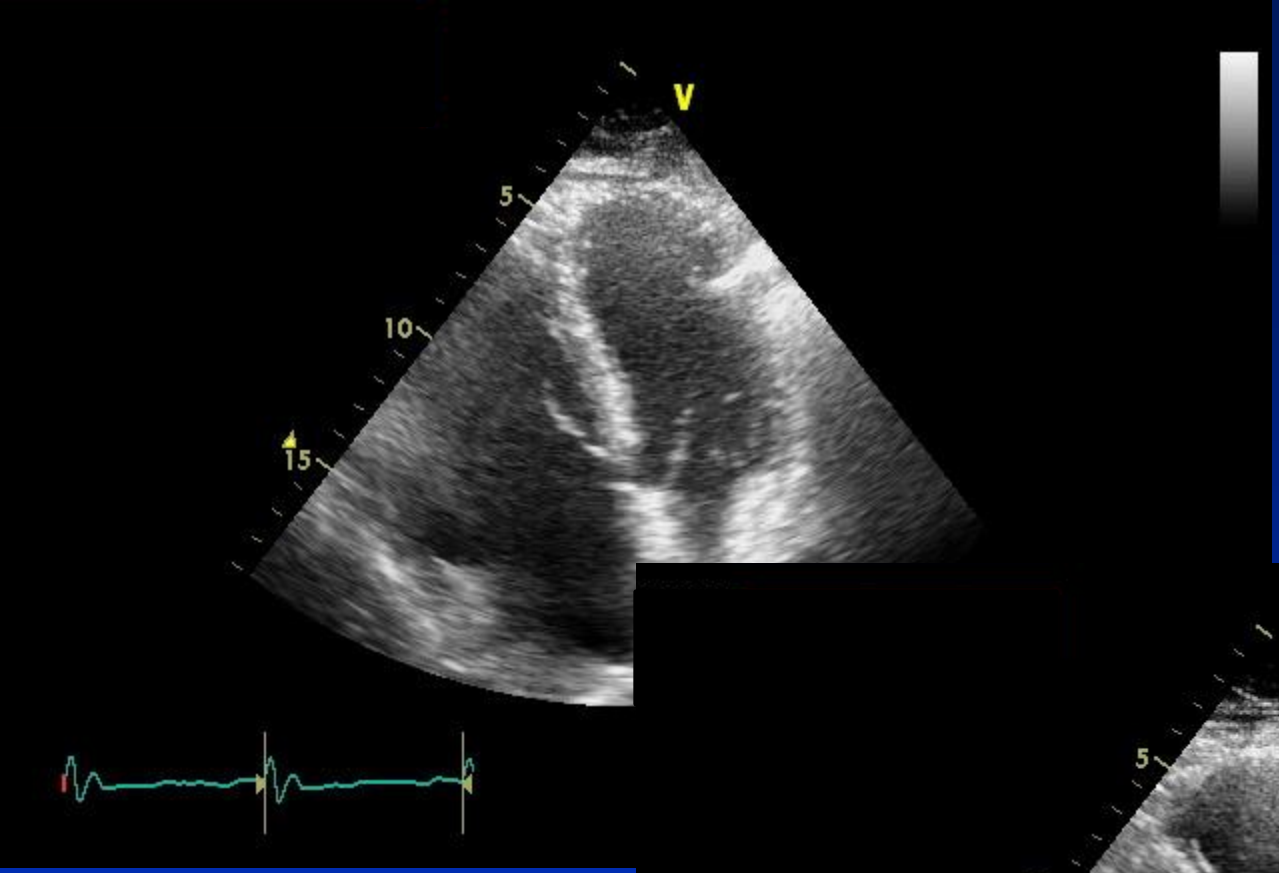


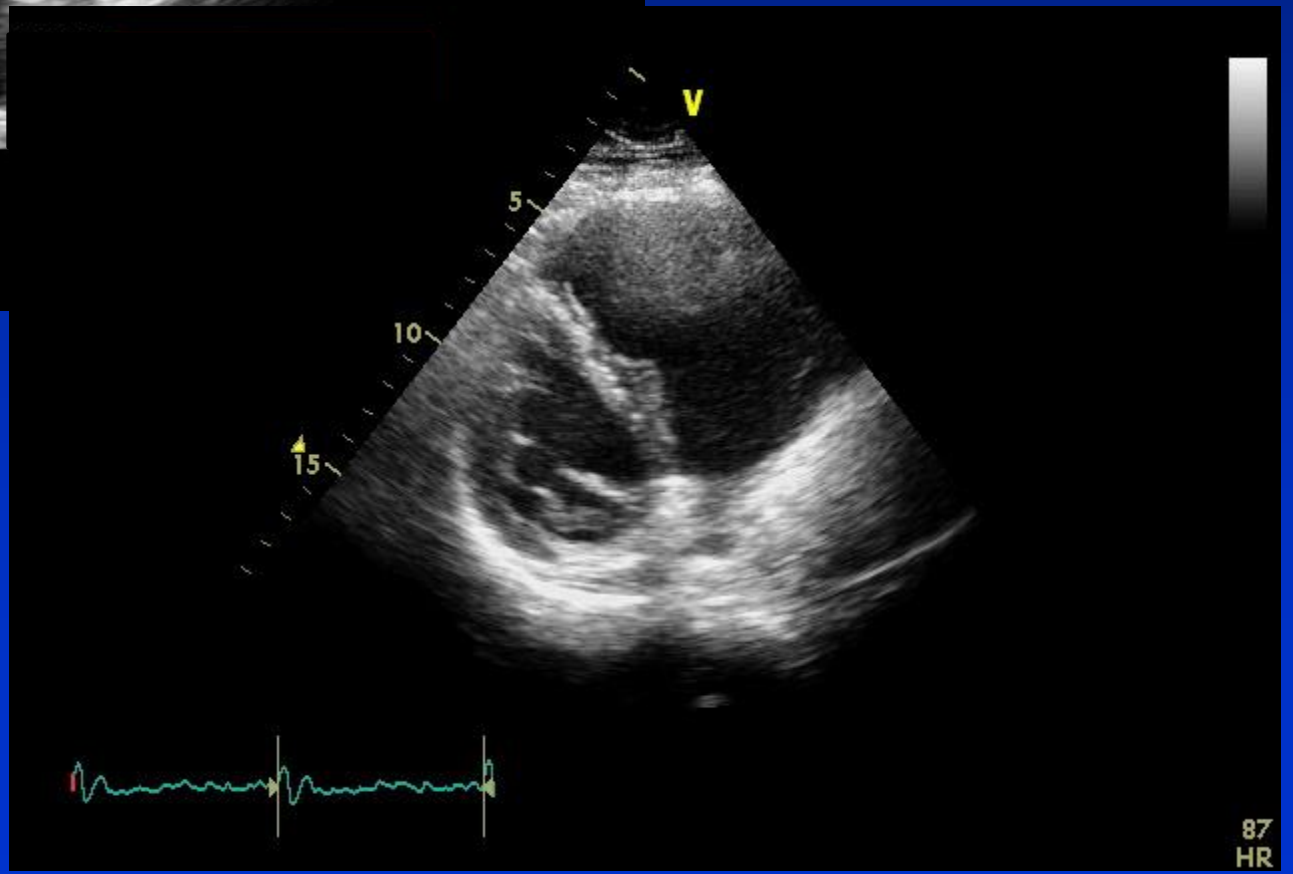
- LV maintains a round shape throughout the cardiac cycle
- Reflects higher pressures in the LV compared to the RV in systole and diastole

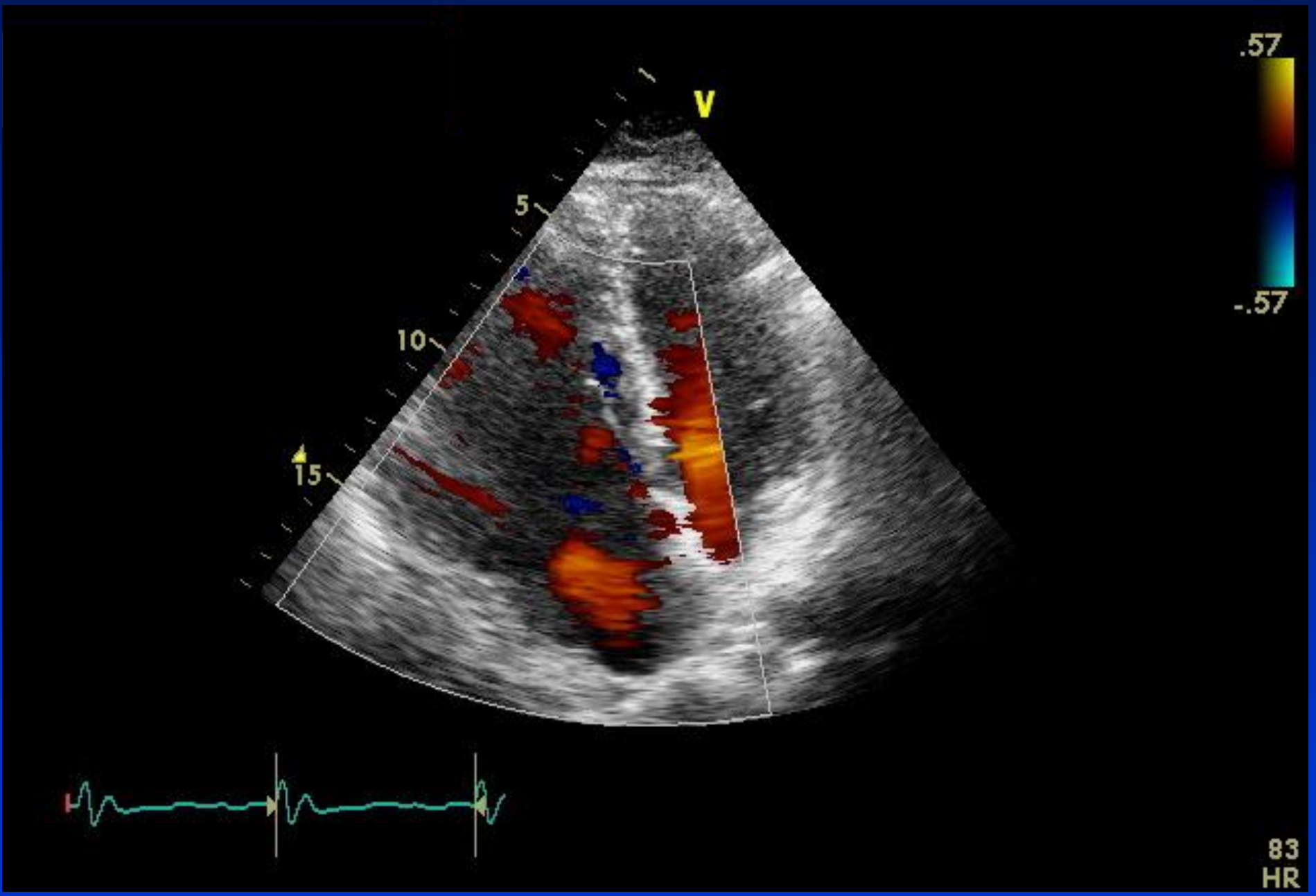

RV
VS
LV
RV
VS
LV
RV
VS
LV
RV
VS
LV
RV
VS
LV
RV
VS
LV
End Systole
Mid Systole
End Diastole
End Systole
Mid Systole
End Diastole

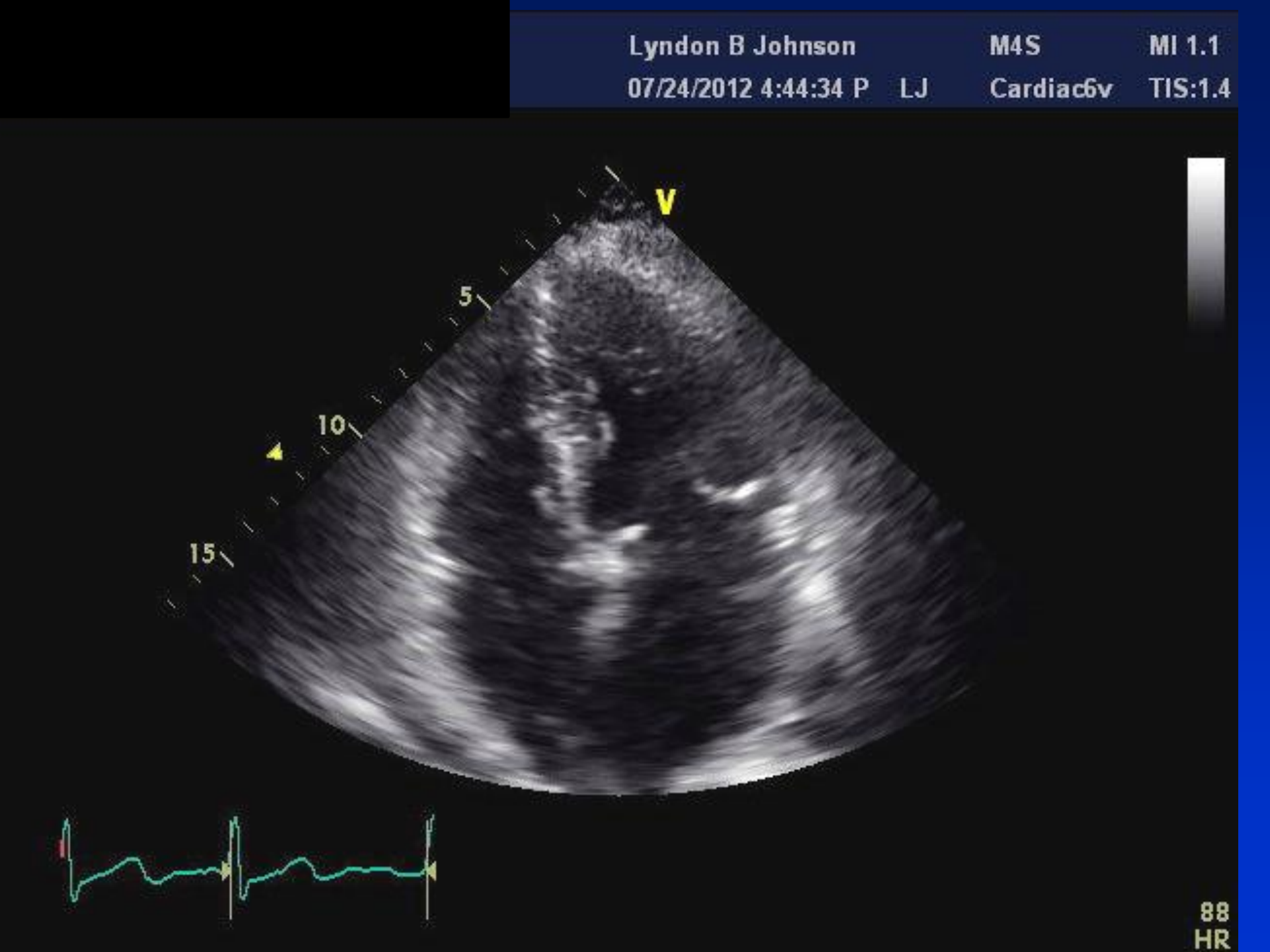

V
5
10

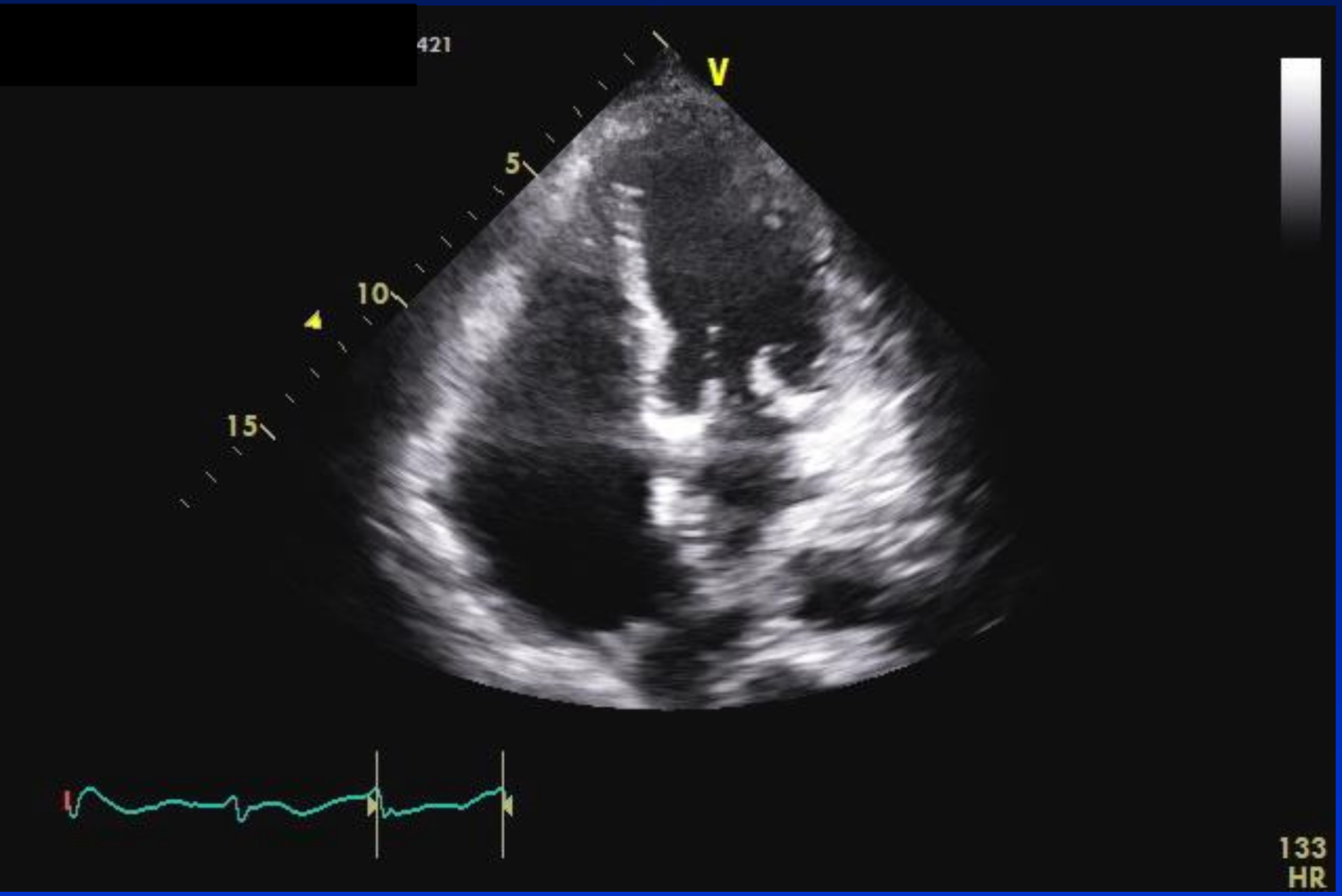

V
5
10
15
87
HR

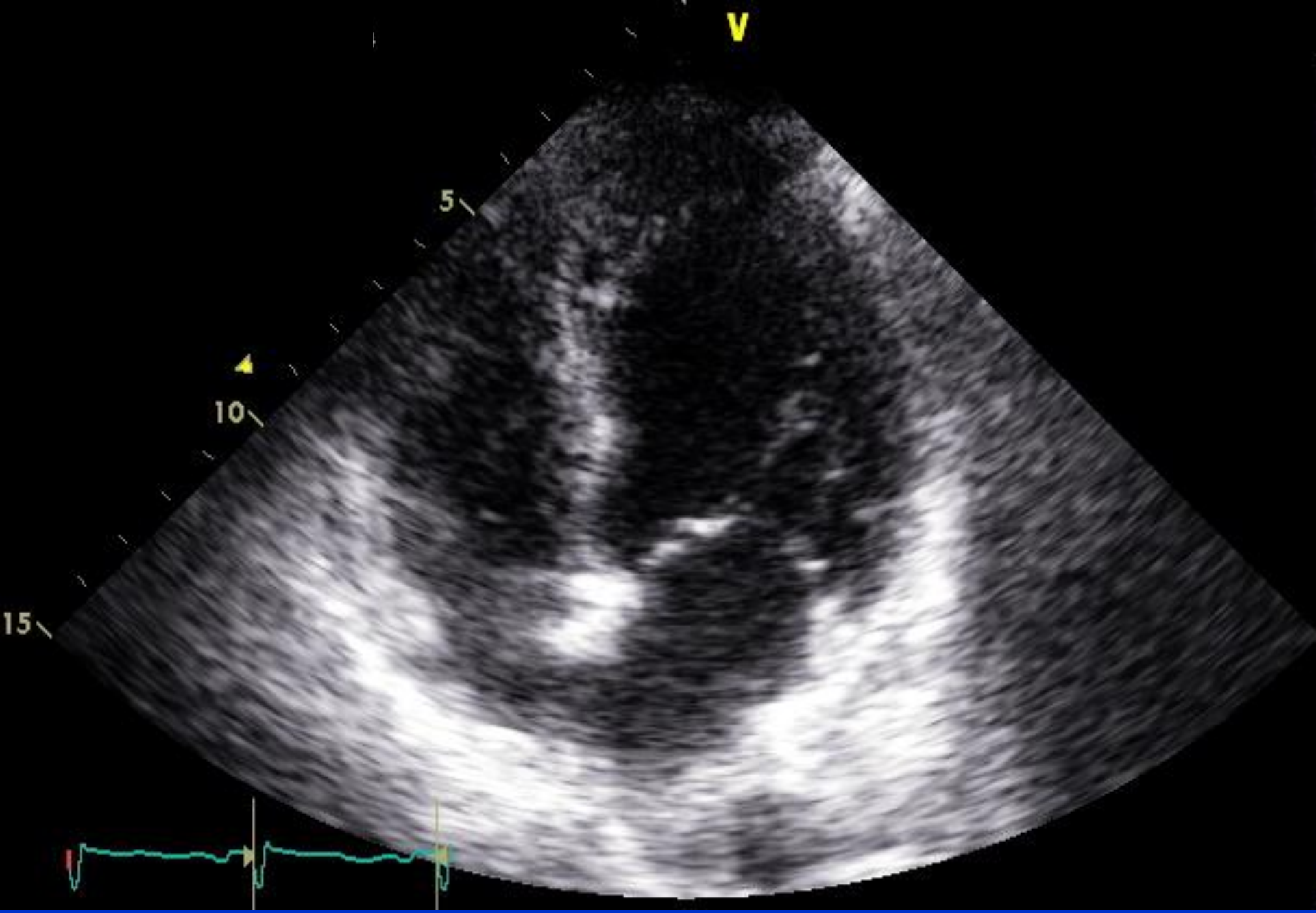

V
5
10
15

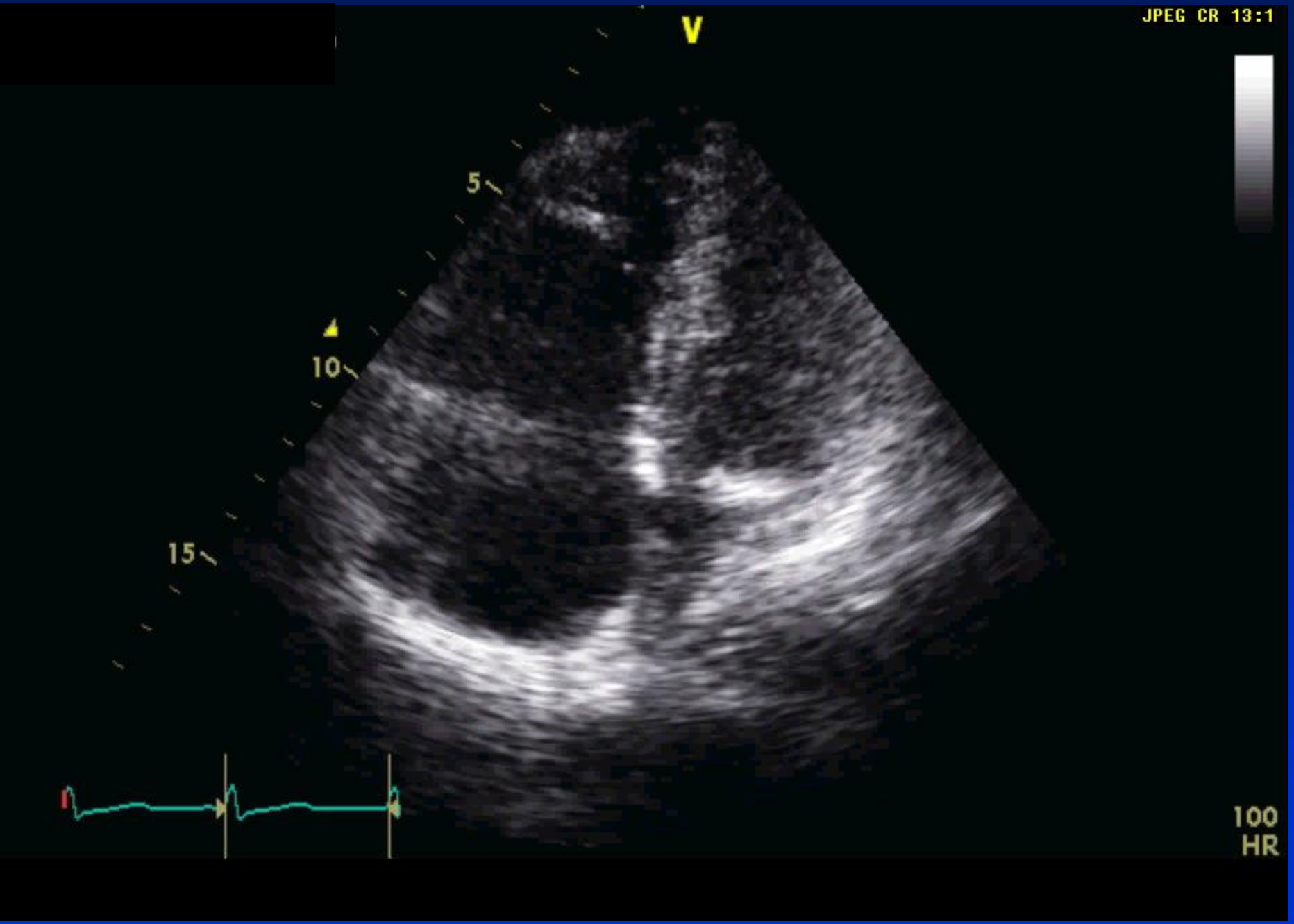

V
5
10
15
87
HR

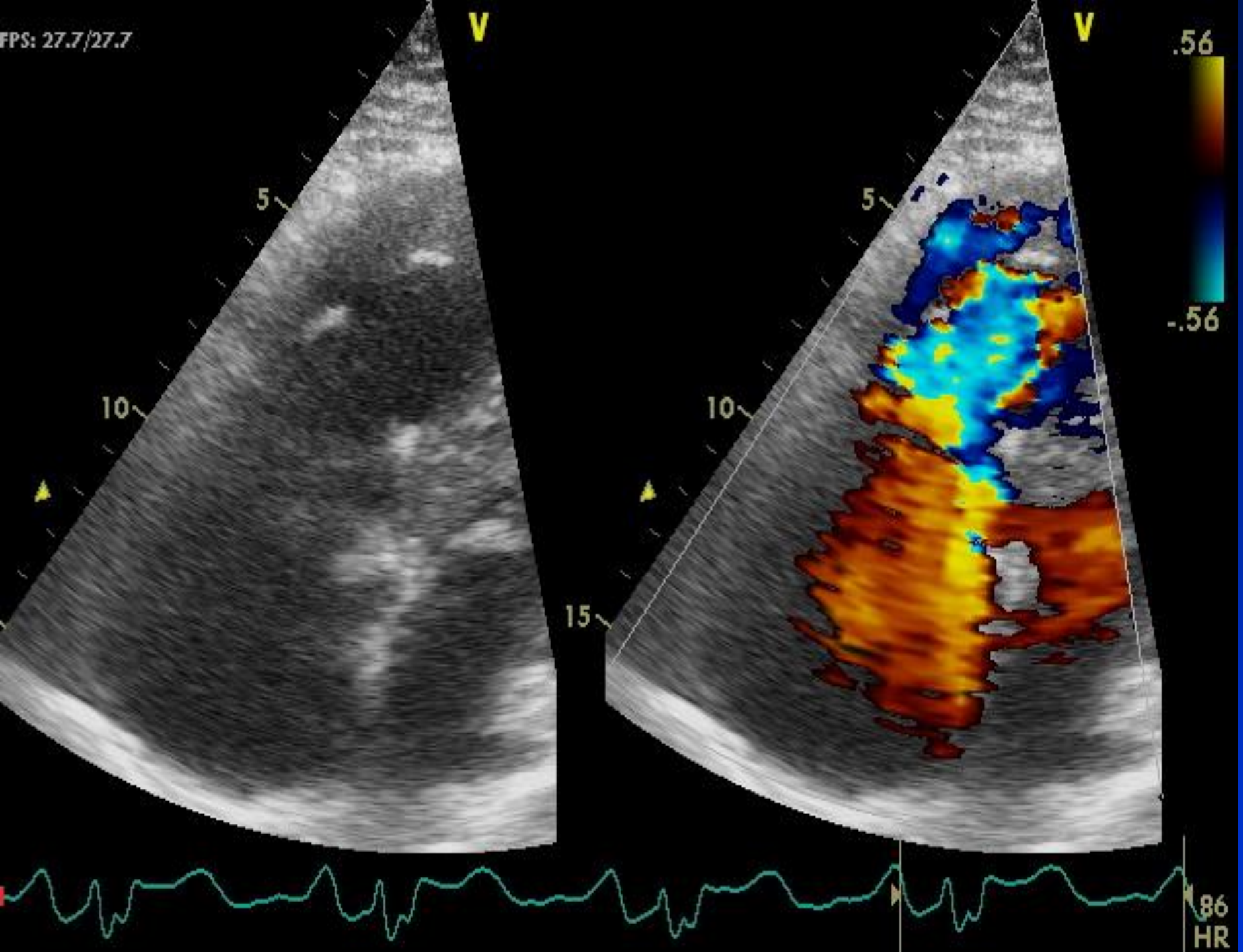

.57
-.57
V
5
10
15
83
HR

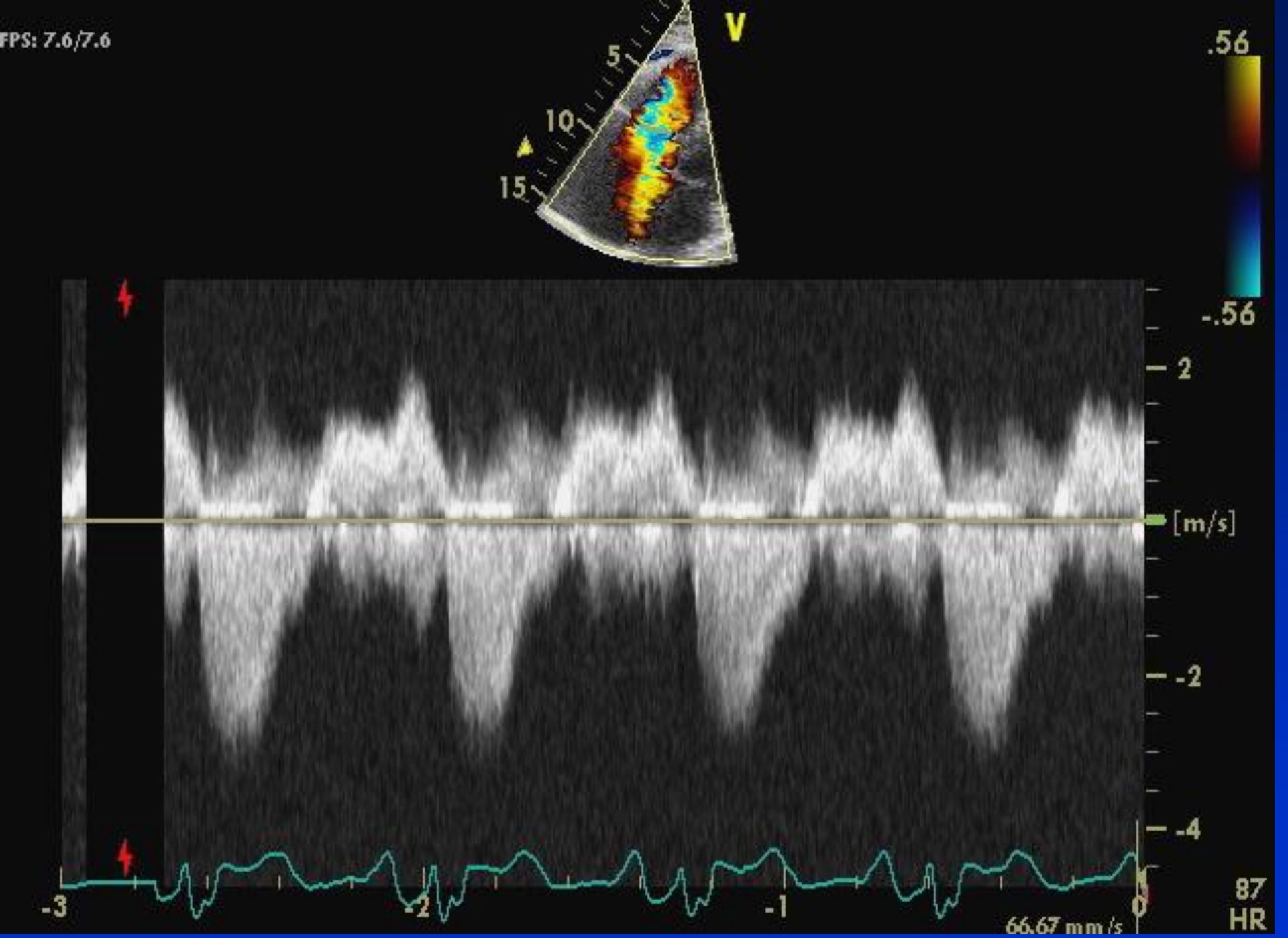

Lyndon B Johnson
M4S
MI 1.1
07/24/2012 4:44:34 P
LJ
Cardiac6v
TIS:1.4
V
5
10
15
88
HR


421
V
5
10
15
133
HR


V
5
10
15


JPEG CR 13:1
V
5
10
15
100
HR


FPS: 27.7/27.7
V
5
10
15
V
5
10
.56
-.56
86
HR


FPS: 7.6/7.6
V
5
10
15
.56
-.56
2
[m/s]
-2
-4
-3
-2
-1
0
66.67 mm/s
87
HR

Pulmonary Hypertension Question

Which of the following is not prognostic indicator of survival in PHTN?

A. Presence and size of pericardial effusion

B. Elevated Tei index

C. RA size

D. RVOT TVI AT<62ms

E. TR severity

F. Pulmonary artery pressure

Thank You !