폐고혈압 평가를 위한 심초음파 이해하고 해석하기

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CATHOLIC MEDICAL CENTER

폐고혈압에서 심초음파의 적용

- 환자 찾아내기
  → 의심하고 심초음파 검사 시행하여 진단 하기

- 어떤 지표를 측정해야 하나?

- Rt heart catheterization을 대체할 수 있을까 ?

- 치료 반응 평가, 예후 예측

Echocardiographic Guideline

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.)

Keywords: Right ventricle, Echocardiography, Right atrium, Guidelines

J Am Soc Echocardiogr 2010;23:685-713

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

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The rapid technological developments of the past decade and the changes in echocardiographic practice brought about by these developments have resulted in the need for updated recommendations to the previously published guidelines for cardiac chamber quantification, which was the goal of the joint writing group assembled by the American Society of Echocardiography and the European Association of Cardiovascular Imaging. This document provides updated normal values for all four cardiac chambers, including three-dimensional echocardiography and myocardial deformation, when possible, on the basis of considerably larger numbers of normal subjects, compiled from multiple databases. In addition, this document attempts to eliminate several minor discrepancies that existed between previously published guidelines. (J Am Soc Echocardiogr 2015;28:1-39.)

Keywords: Adult echocardiography, Transthoracic echocardiography, Ventricular function, Normal values

J Am Soc Echocardiogr 2015;28:1-39

폐고혈압에서 심초음파의 적용

Right heart

Dimension

RV dimension
RA dimension
RVOT PLAX/PSAX
RV wall thickness
IVC demension

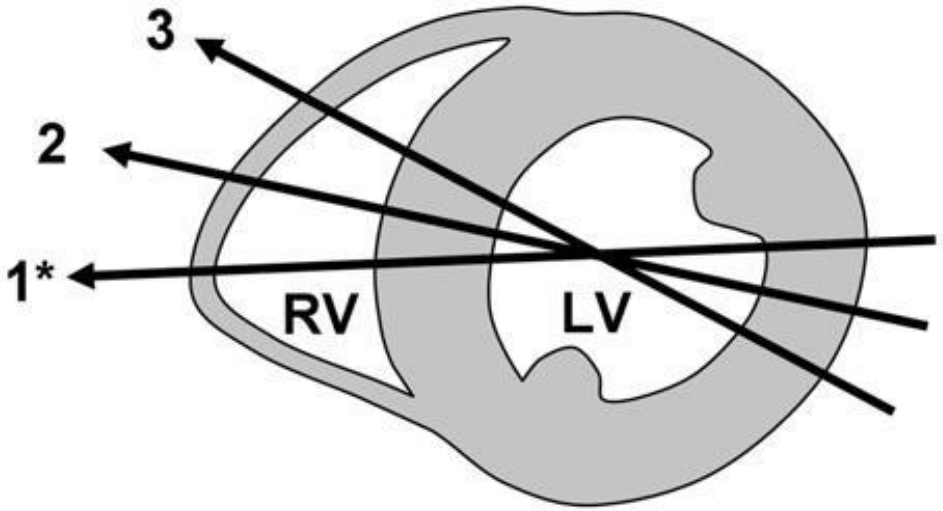
Systolic Function

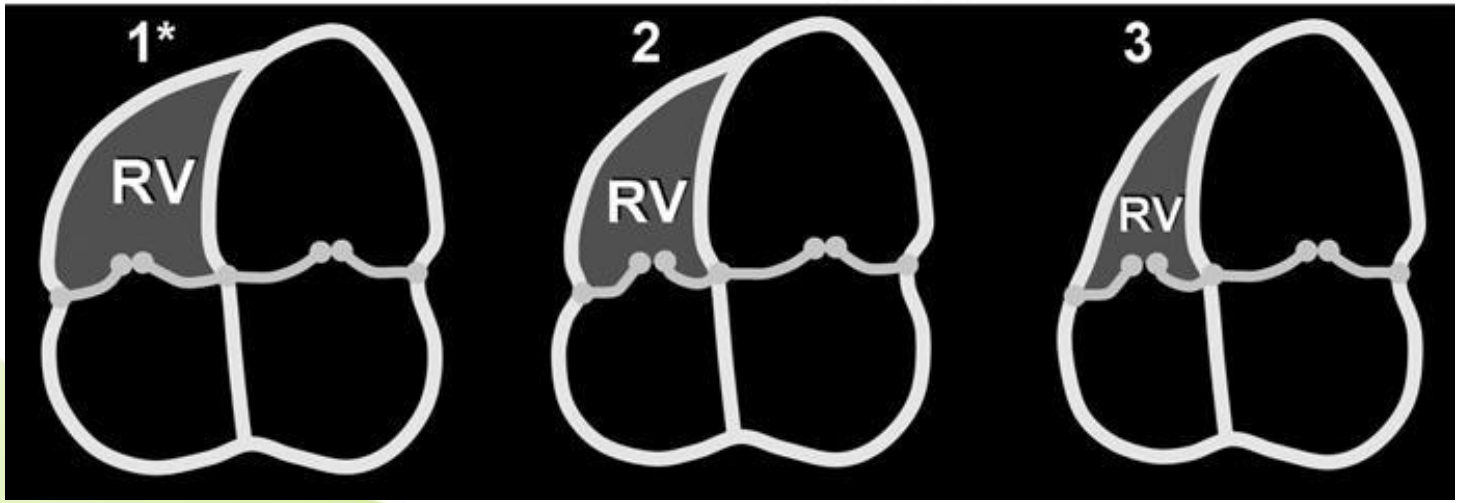
RIMP
TAPSE
2D FAC
S'
3D EF
Longitudinal strain

Pressure

Systolic PAP
Mean PAP
TR Vmax
PVR

RV Dimension





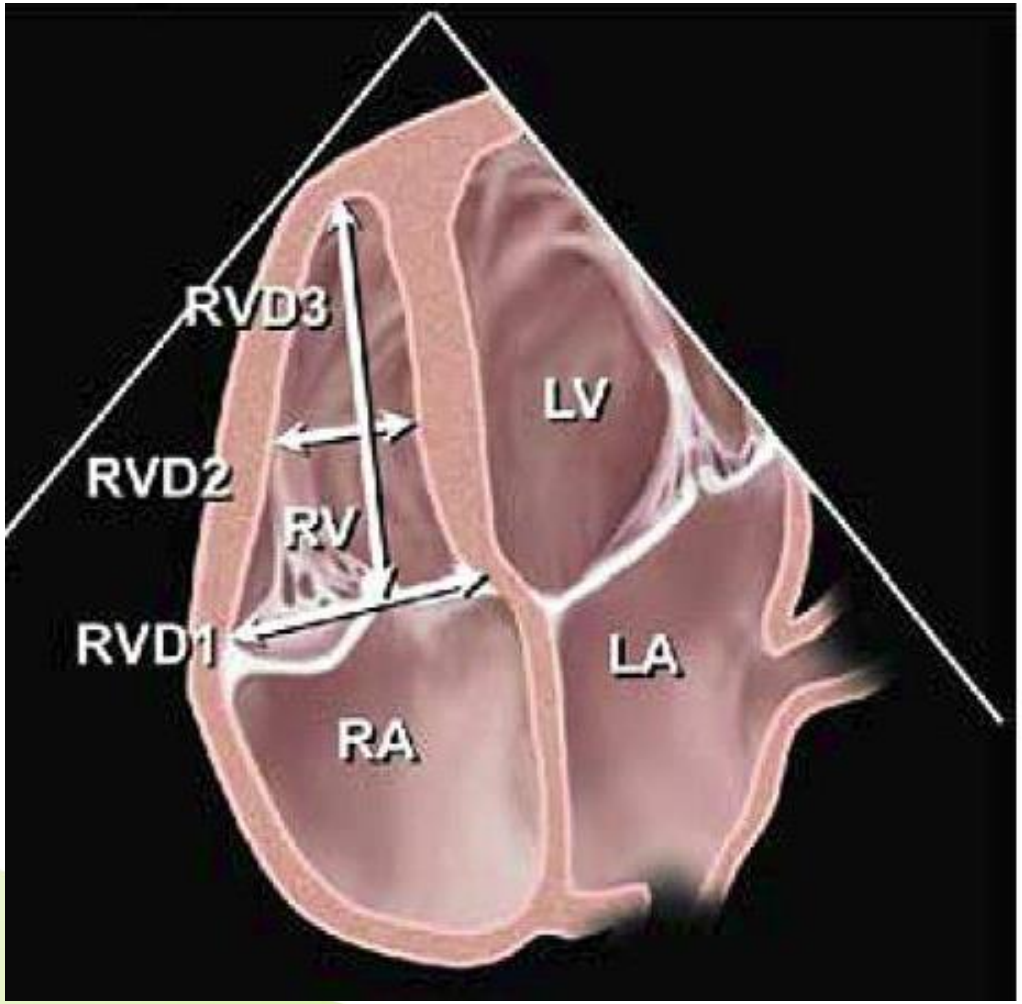
J Am Soc Echocardiogr 2010;23:685-713

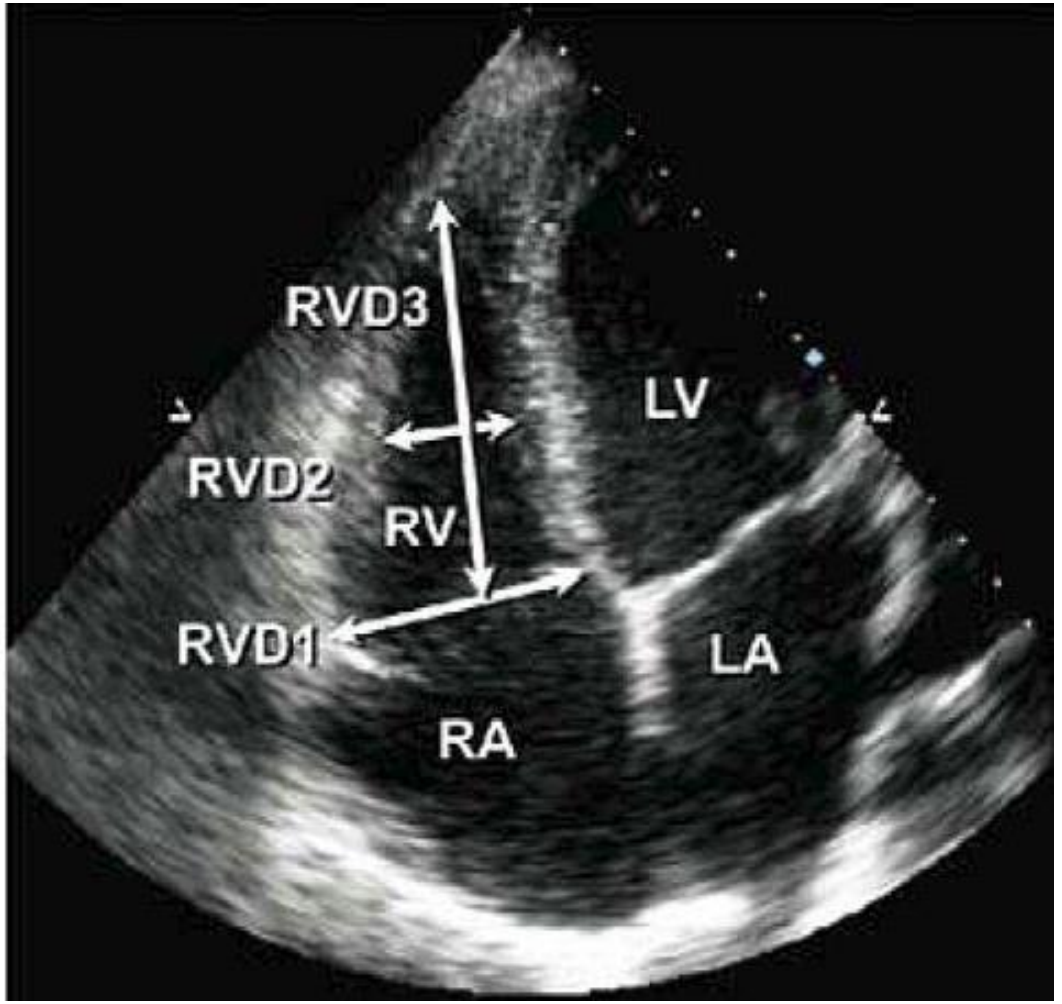
RV Dimension

RVD3 >86mm

RVD2 >35mm

RVD1 >42mm



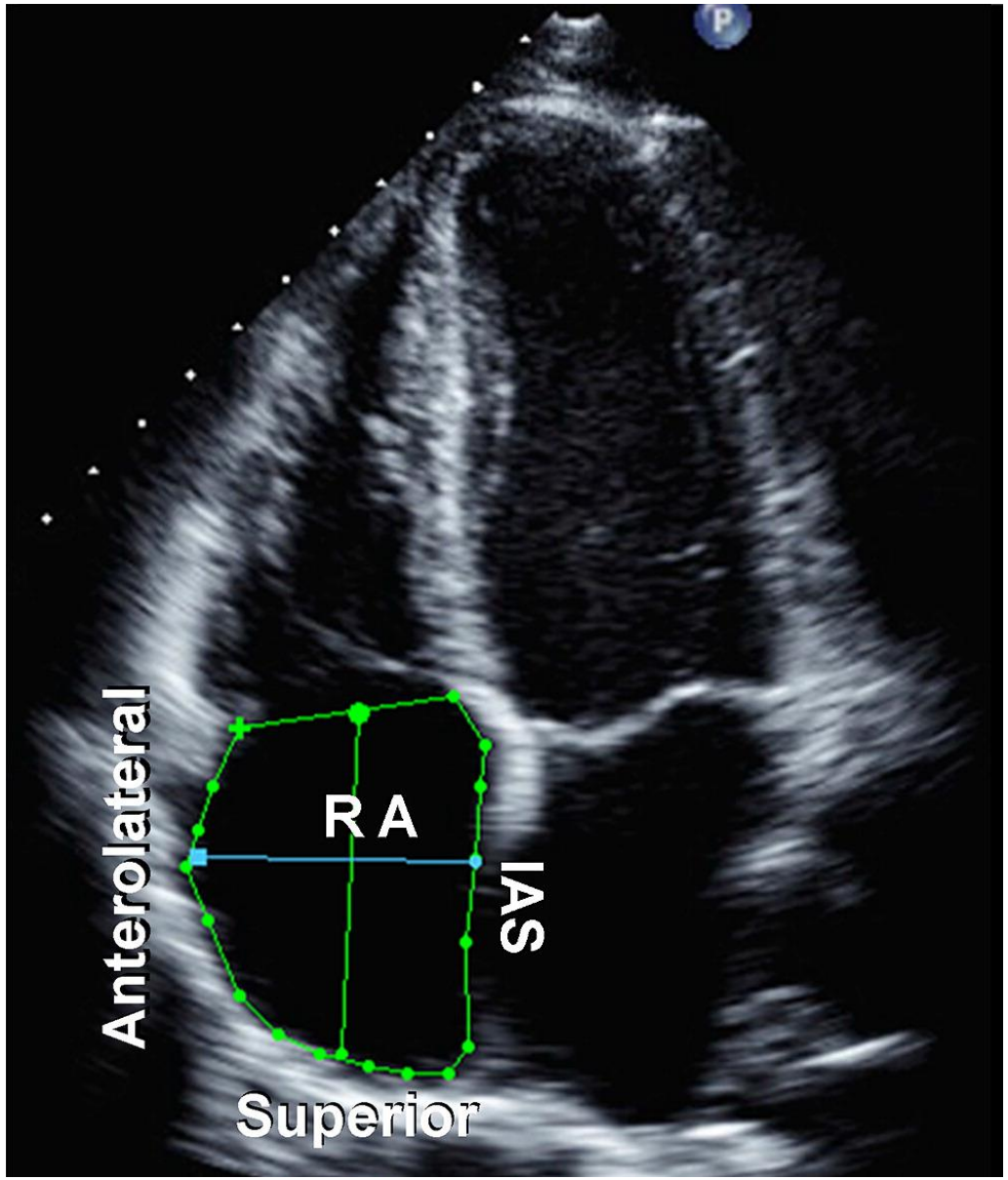


maximizing RV chamber size

J Am Soc Echocardiogr 2010;23:685-713

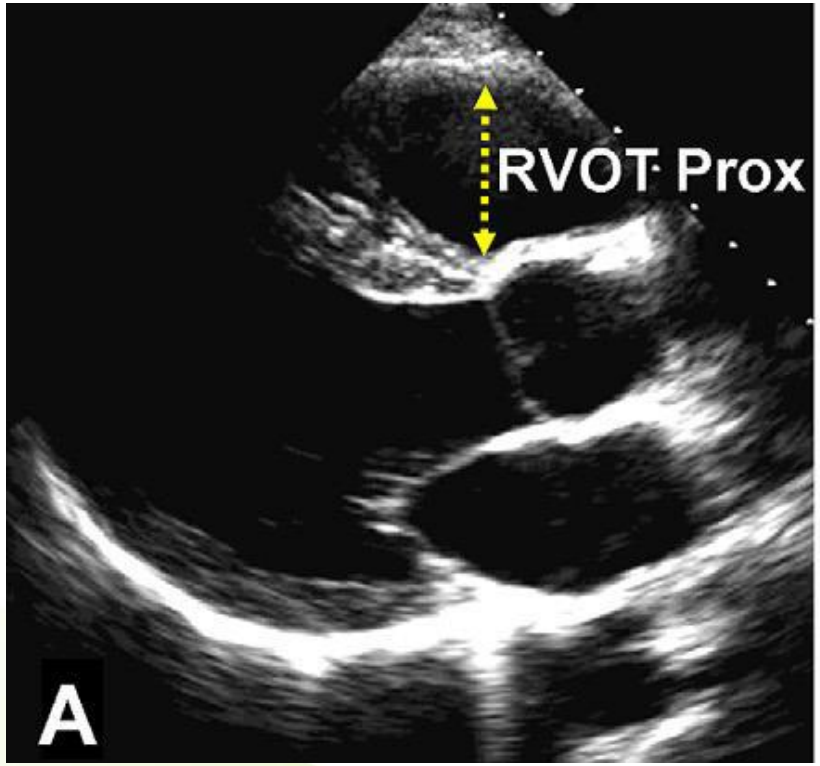
RA Dimension

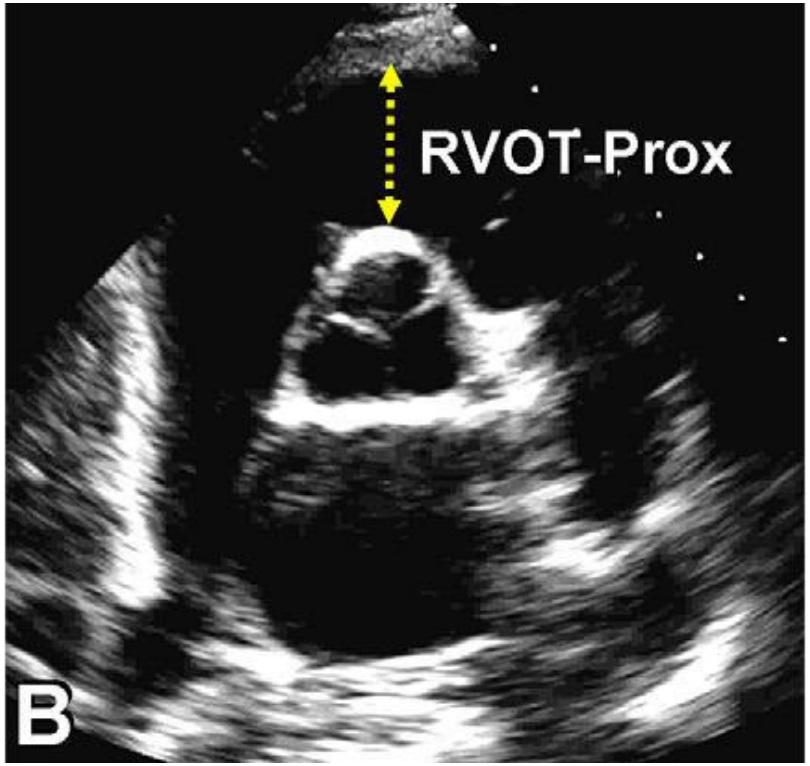
- RA area > 18 cm2,
- RA length (referred to as the major dimension) > 53 mm
- RA diameter (otherwise known as the minor dimension)
  > 44 mm indicate at end-diastole RA enlargement.

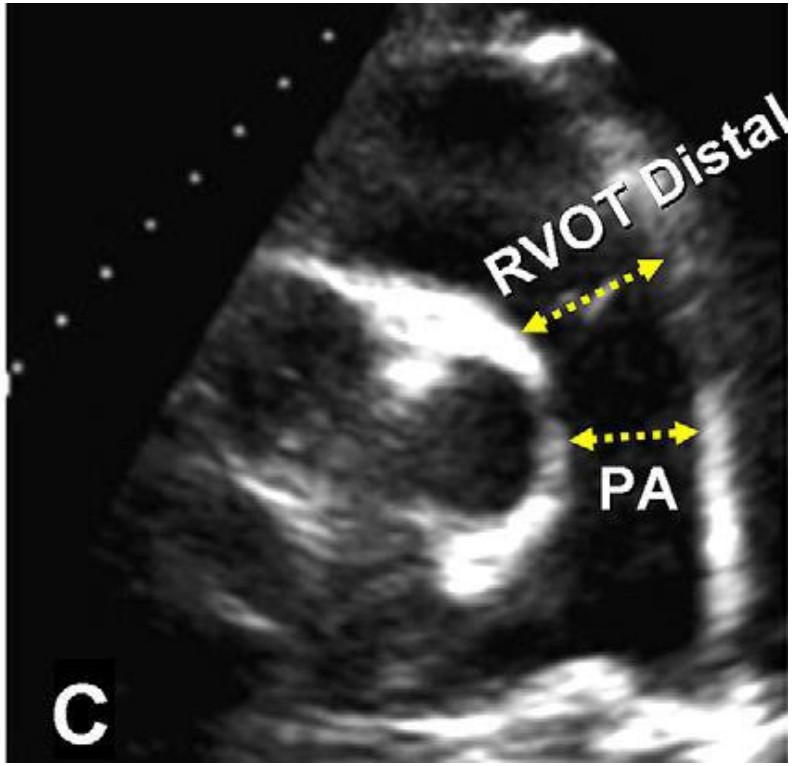


J Am Soc Echocardiogr 2010;23:685-713

RVOT PLAX/PSAX







33 mm

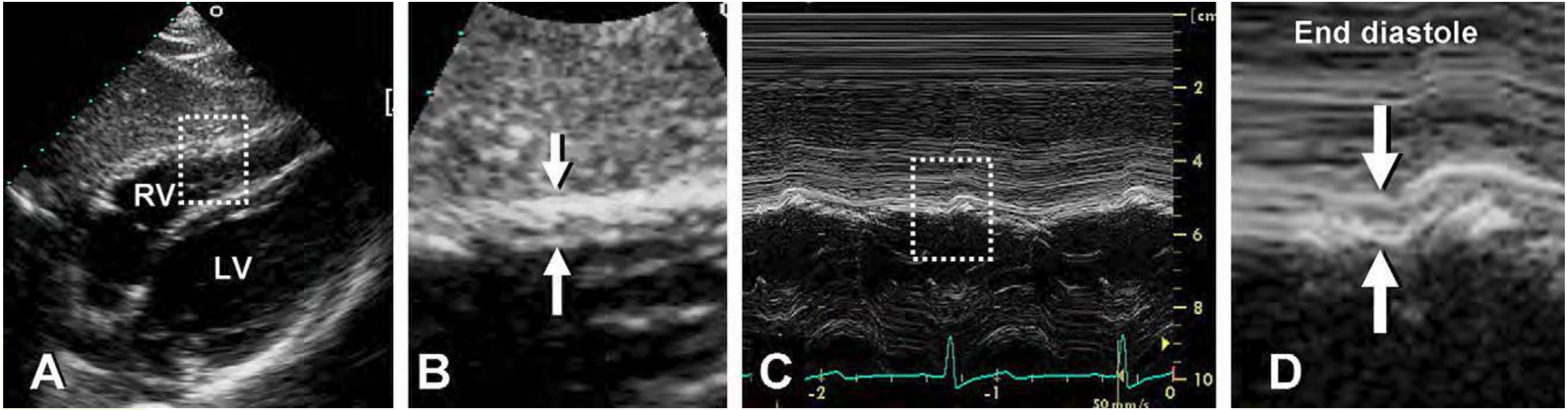
35 mm

27 mm

Upper reference value (95% CI)

J Am Soc Echocardiogr 2010;23:685-713

RV wall thickness



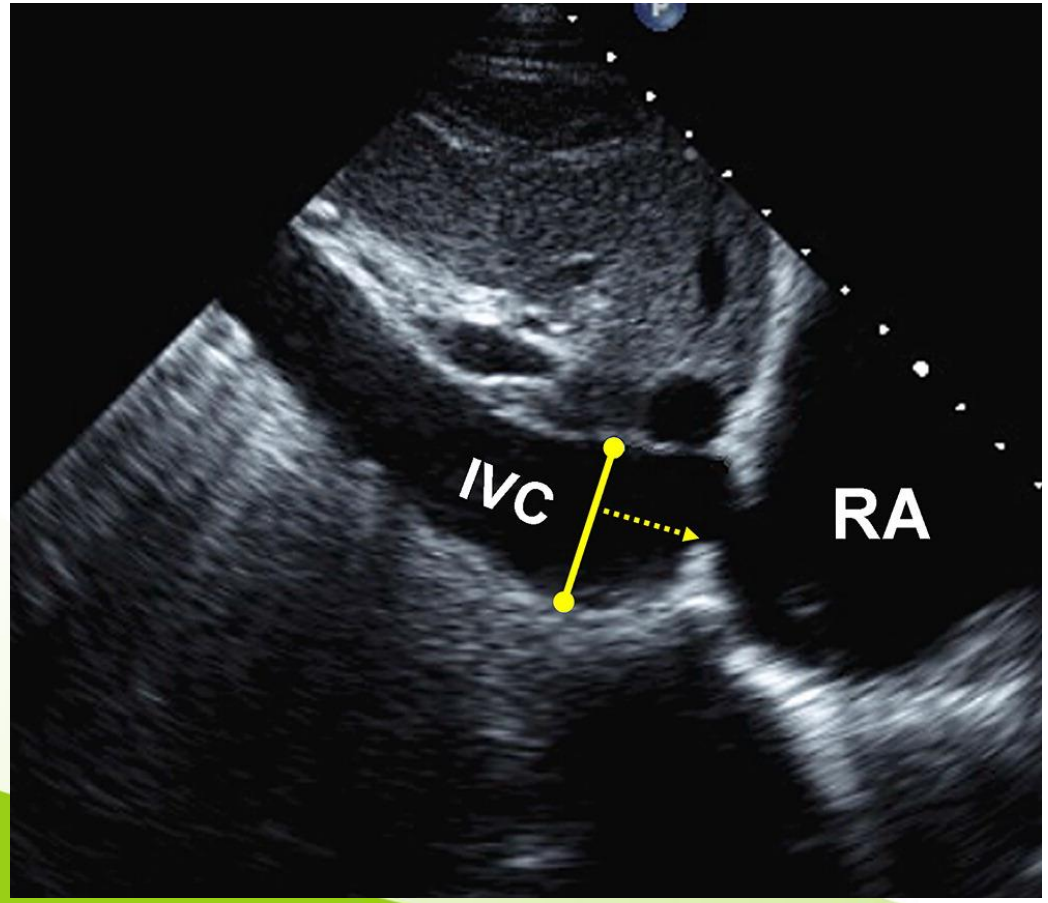
the normal cutoff of 0.5 cm

from either PLAX or subcostal windows

J Am Soc Echocardiogr 2010;23:685-713

IVC demension

Inspiratory response & RA pressure



Diameter	Inspiratory collapse	RA pressure
< 2.1 cm	≥ 50 %	3 (0-5) mmHg
≥ 2.1 cm	≥ 50 %	8 (5-10) mmHg
≥ 2.1 cm	< 50 %	15 (10-20) mmHg

J Am Soc Echocardiogr 2010;23:685-713

Right heart dimension

Valuable	Abnormal in 2010	Abnormal in 2015
RV dimension	>42 mm at base >35 mm at mid	>41 mm at base >35 mm at mid
RA dimension	>44 mm at end-diastole	2.4±0.3 cm/m2 in men 2.5±0.3 cm/m2 in women
RVOT PLAX distal diameter	>33 mm at end-diastole	>35 mm at end-diastole
RV wall thickness	>5 mm	>5 mm
IVC dimension	>2.1 cm	>2.1 cm

J Am Soc Echocardiogr 2010;23:685-713

J Am Soc Echocardiogr 2015;28:1-39

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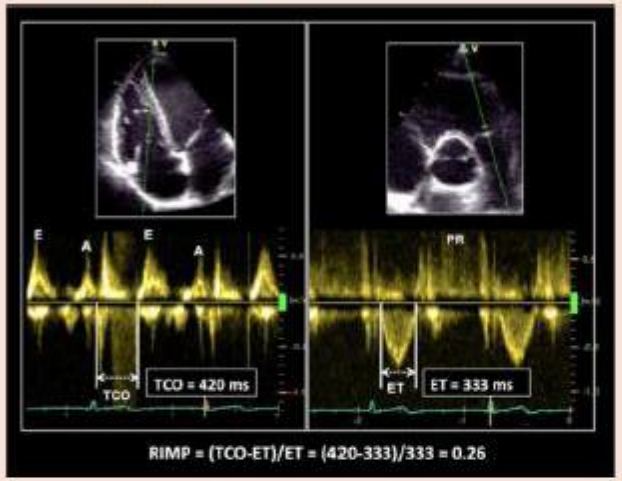
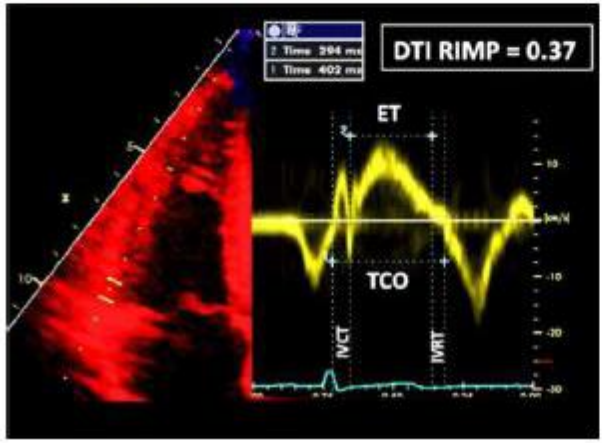
2D FAC
S'
3D EF
Longitudinal strain

Pressure

Systolic PAP
Mean PAP
TR Vmax
PVR

RIMP (RV Index of Myocardial Performance)

Echocardiographic imaging	Recommended methods	Advantages	Limitations
RV global function Pulsed Doppler RIMP 	RIMP (Tei index) by pulsed Doppler: RIMP = (TCO – ET)/ET	• Prognostic value • Less affected by heart rate	• Requires matching for R-R intervals when measurements are performed on separate recordings • Unreliable when RA pressure is elevated
Tissue Doppler RIMP 	RIMP by tissue Doppler: RIMP = (IVRT + IVCT)/ET = (TCO – ET)/ET	• Less affected by heart rate • Single-beat recording with no need for R-R interval matching	• Unreliable when RA pressure is elevated

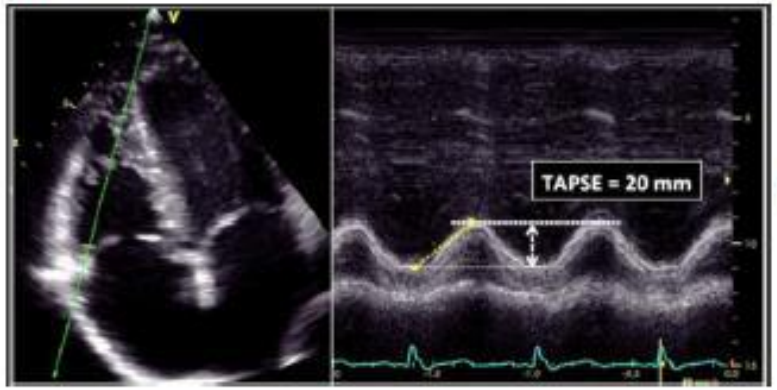
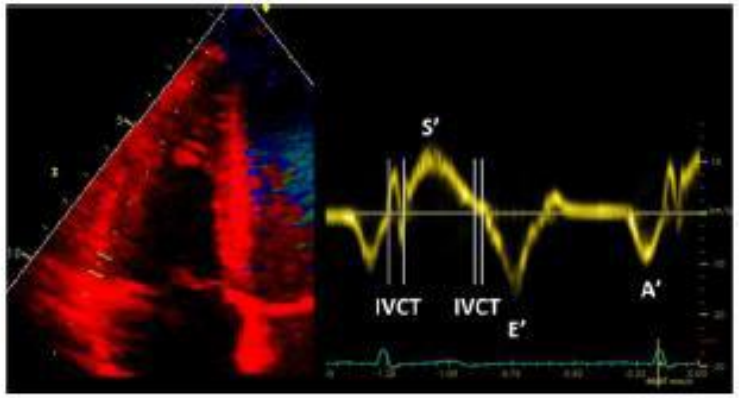
TCO: tricuspid valve closure-to-opening time

ET: Ejection time

IVCT: isovolumic contraction time

IVRT: isovolumic relaxation time

RV systolic function

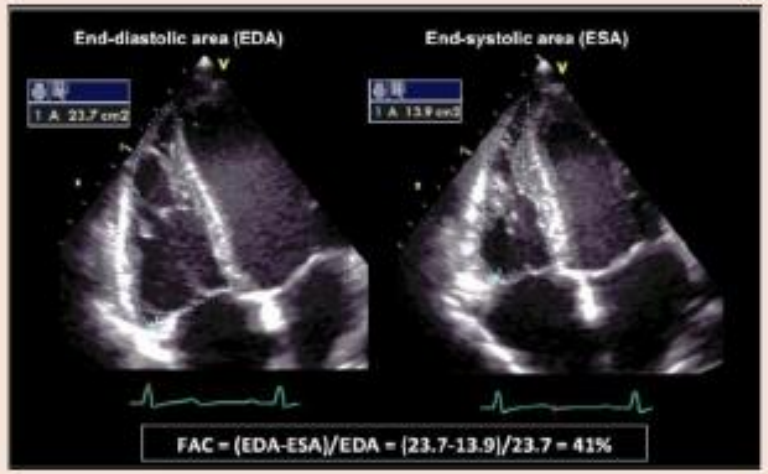
Echocardiographic imaging	Recommended methods	Advantages	Limitations
RV longitudinal systolic function TAPSE 	• Tricuspid annular longitudinal excursion by M-mode (mm), measured between end-diastole and peak systole • Proper alignment of M-mode cursor with the direction of RV longitudinal excursion should be achieved from the apical approach.	• Established prognostic value • Validated against radionuclide EF	• Angle dependency • Partially representative of RV global function*
Pulsed tissue Doppler S wave 	• Peak systolic velocity of tricuspid annulus by pulsed-wave DTI (cm/sec), obtained from the apical approach, in the view that achieves parallel alignment of Doppler beam with RV free wall longitudinal excursion	• Easy to perform • Reproducible • Validated against radionuclide EF • Established prognostic value	• Angle dependent • Not fully representative of RV global function, particularly after thoracotomy, pulmonary thromboendarterectomy or heart transplantation

J Am Soc Echocardiogr 2015;28:1-39

RV systolic function

RV global systolic function

FAC (Fractional Area Change)



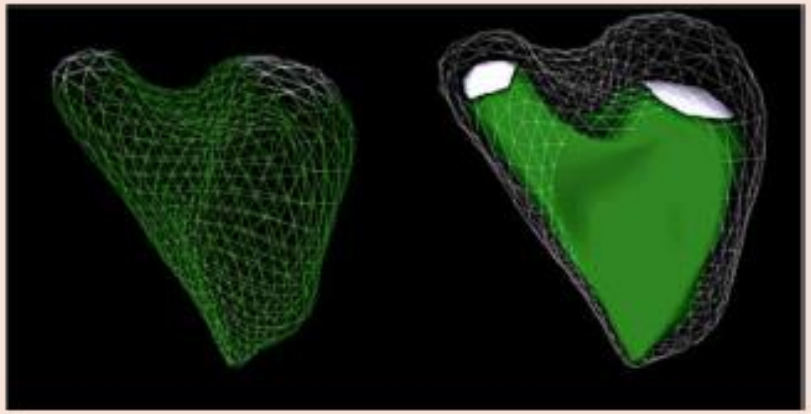
RV FAC in RV-focused apical four-chamber view:

$\text{RV FAC (\%)} = 100 \times (\text{EDA} - \text{ESA})/\text{EDA}$

- Established prognostic value
- Reflects both longitudinal and radial components of RV contraction
- Correlates with RV EF by CMR

- Neglects the contribution of RV outflow tract to overall systolic function
- Only fair inter-observer reproducibility

EF



Fractional RV volume change by 3D TTE:

$\text{RV EF (\%)} = 100 \times (\text{EDV} - \text{ESV})/\text{EDV}$

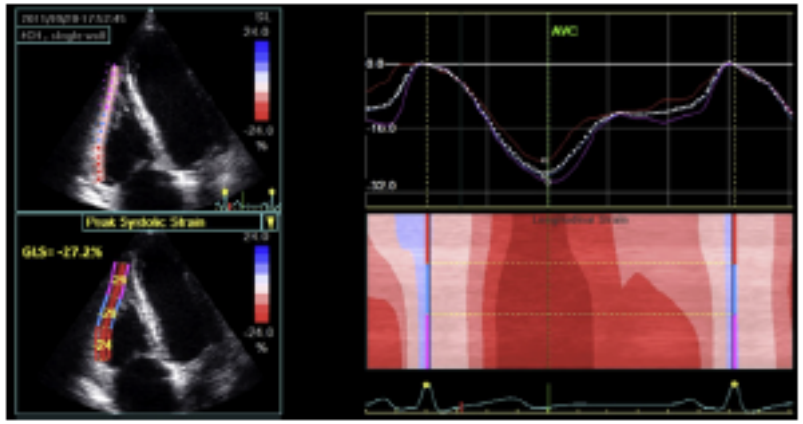
- Includes RV outflow tract contribution to overall function
- Correlates with RV EF by CMR

- Dependent on adequate image quality
- Load dependency
- Requires offline analysis and experience
- Prognostic value not established

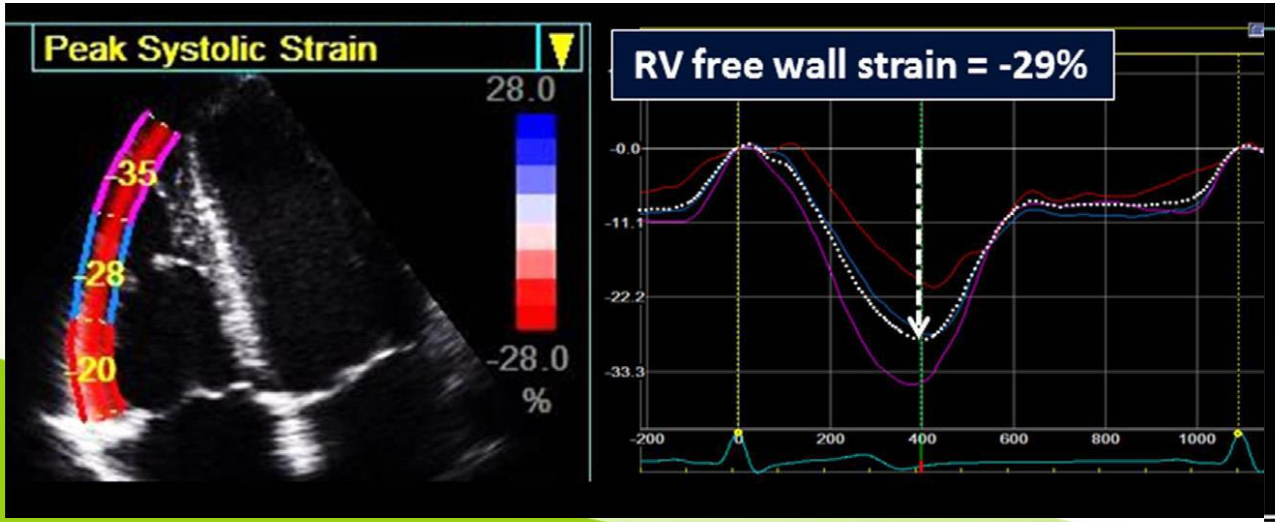
J Am Soc Echocardiogr 2015;28:1-39

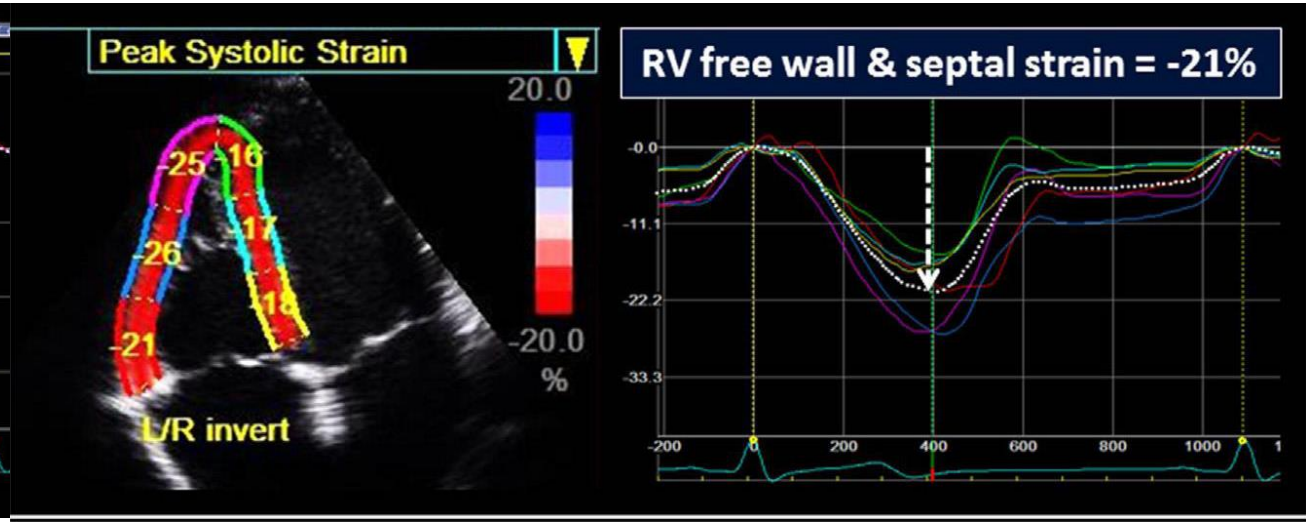
RV systolic function

GLS



- Peak value of 2D longitudinal speckle tracking derived strain, averaged over the three segments of the RV free wall in RV-focused apical four-chamber view (%)
- Angle independent
- Established prognostic value
- Vendor dependent





J Am Soc Echocardiogr 2015;28:1-39

RV systolic function

Valuable	Abnormal in 2010	Abnormal in 2015
RIMP	>0.40	>0.41
TAPSE	<16 mm	<17 mm
FAC	<35%	<35%
s’	<10 cm/s	<9.5 cm/s

J Am Soc Echocardiogr 2010;23:685-713

J Am Soc Echocardiogr 2015;28:1-39

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Systolic PAP
Mean PAP
TR Vmax
PVR

Pulmonary aretry pressure

Valuable	Method
Systolic PAP (RVSP)	RV-RA gradient + RA pressure 4x TR $Vmax^2$ + RA pressure
Mean PAP	1/3(SPAP) + 2/3(PADP) 79 – (0.45 x AT) ATs<120ms, 90 – (0.62 x AT) 4x(early PR velocity)^2 + RA pressure
PVR	(TR Vmax/RVOT TVI) x 10 + 0.16

J Am Soc Echocardiogr 2010;23:685-713

SPAP (RVSP)

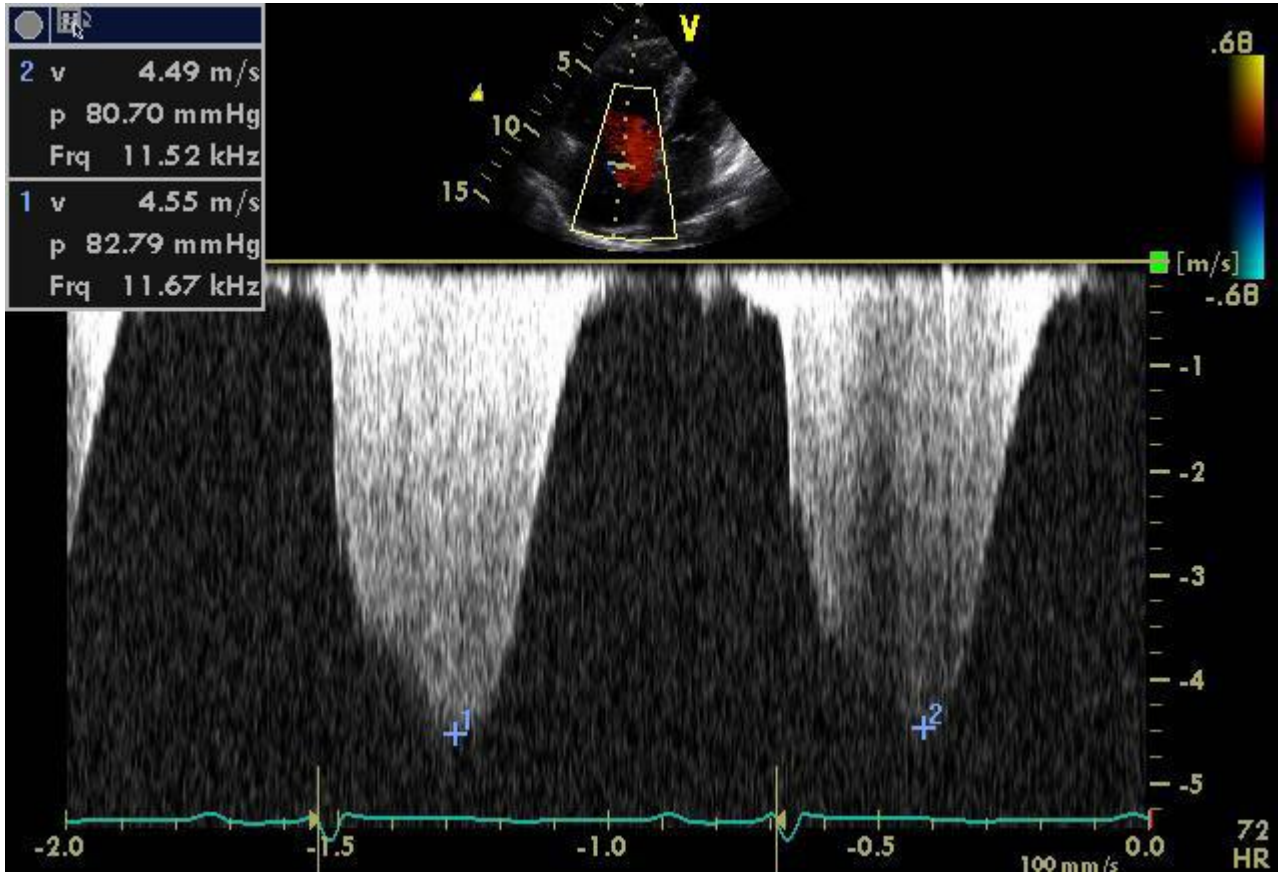
- Modified Bernoulli equation

  - Pressure gradient (Δ P) = 4 x v ^{2}
- RV systolic pressure

  = Δ P + RA pressure
- RV systolic pressure

  = PA systolic pressure

  (unless there is pulmonary stenosis)

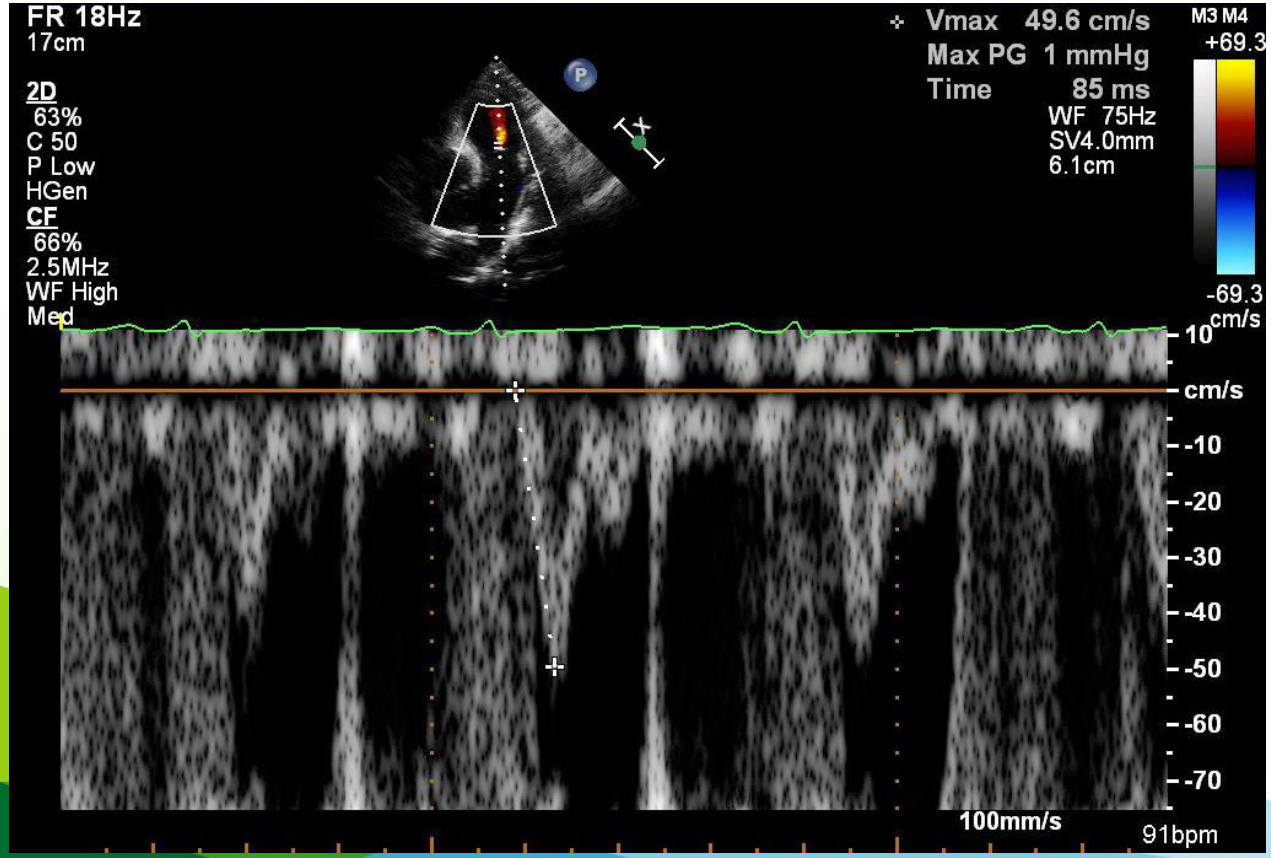


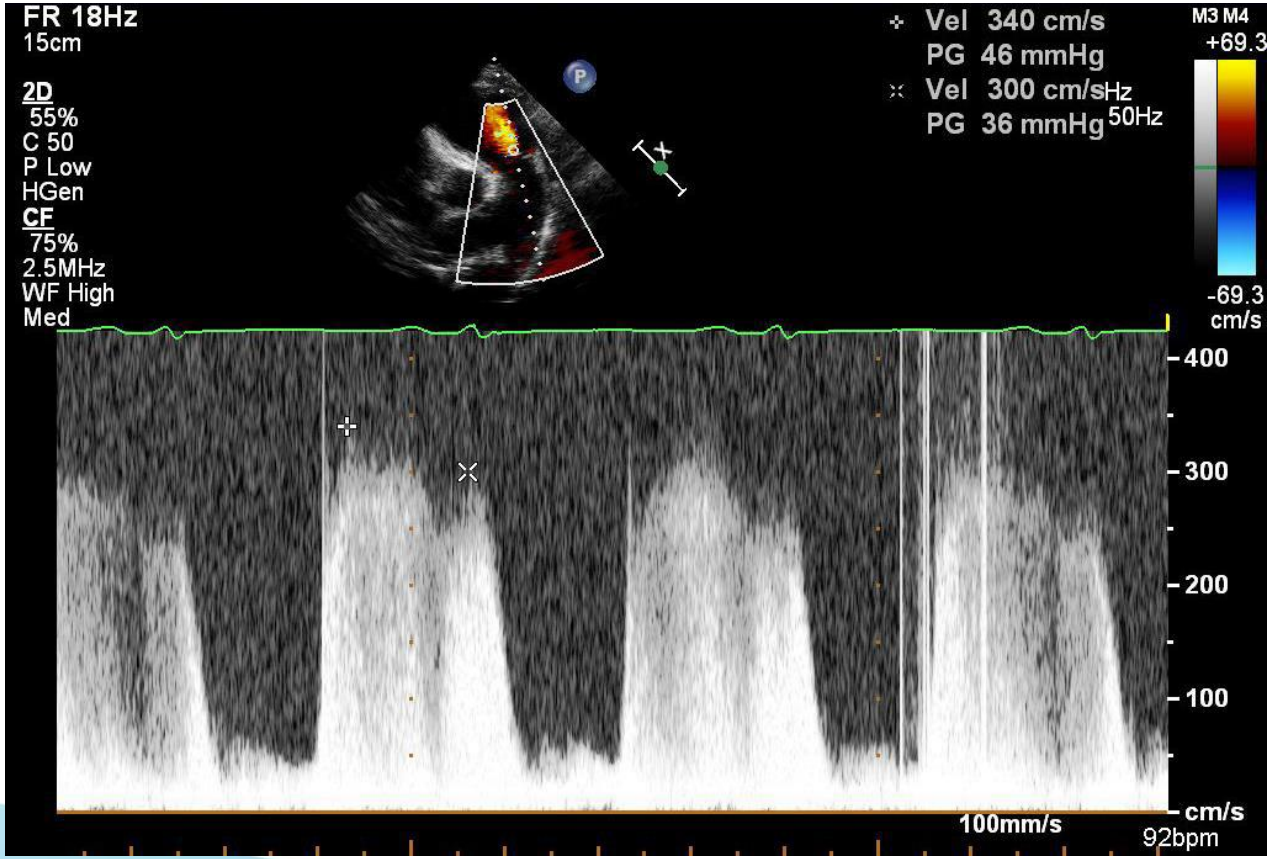
Mean PAP

Mean PAP = 90 – 0.62 x 85 = 37.3 mmHg

Mean PAP = 4 x 3.1^2 + 3 = 41.4 mmHg

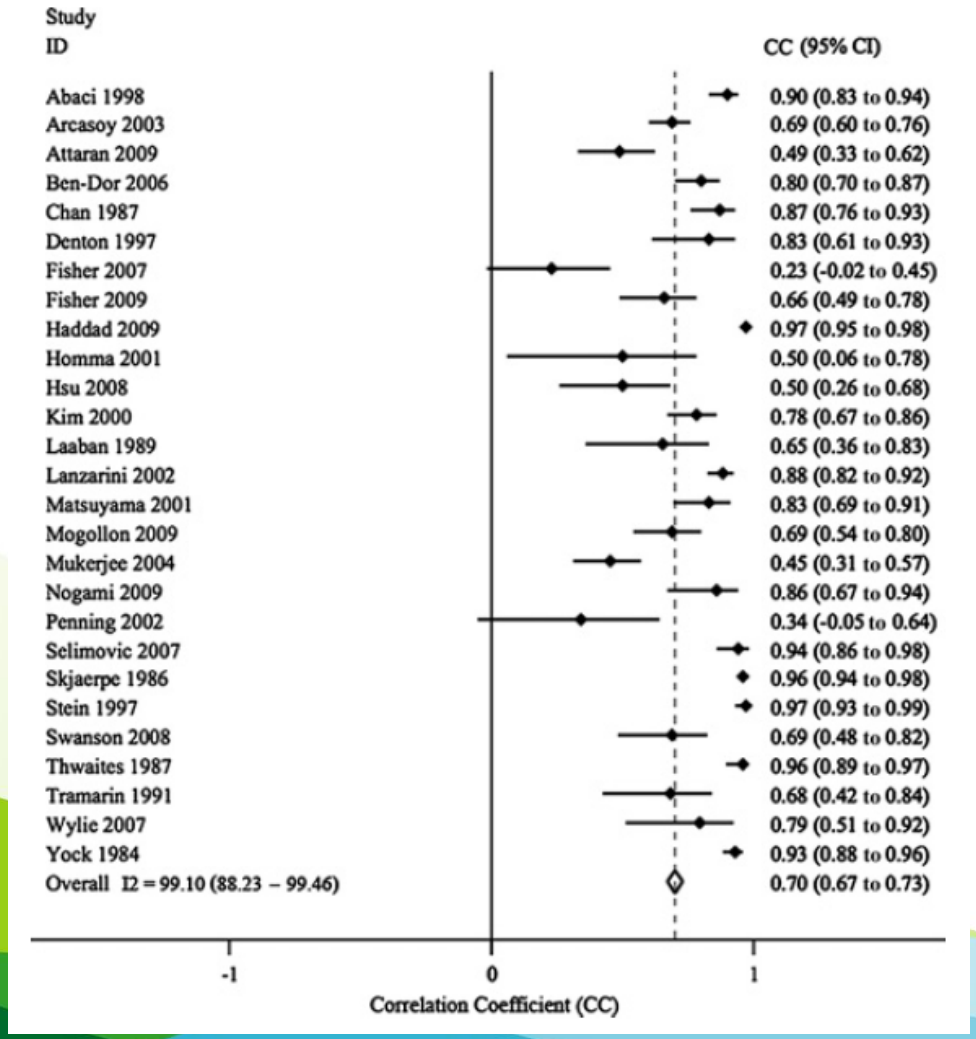
PAEDP = 4 x 2.9^2 + 3 = 36.6 mmHg

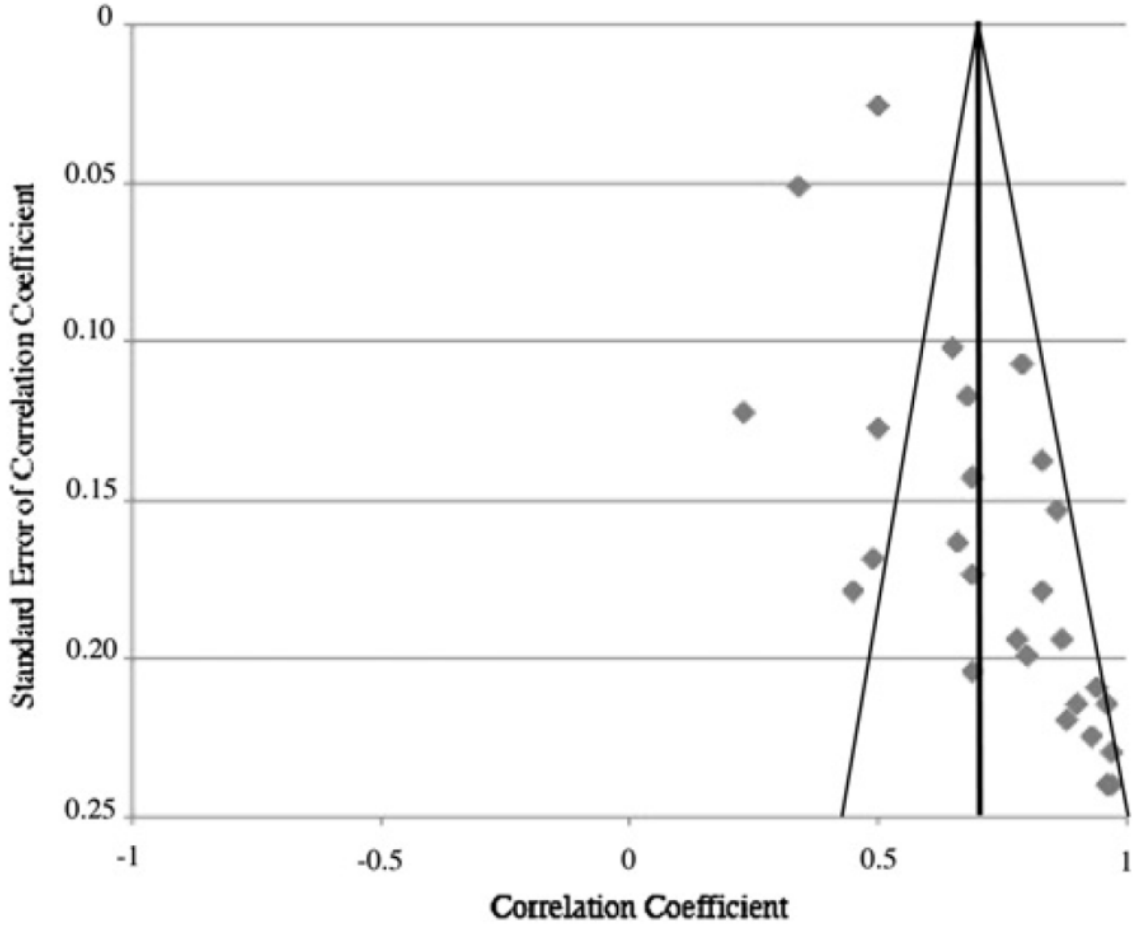




Non-invasive estimation of PAP

- Meta-analysis

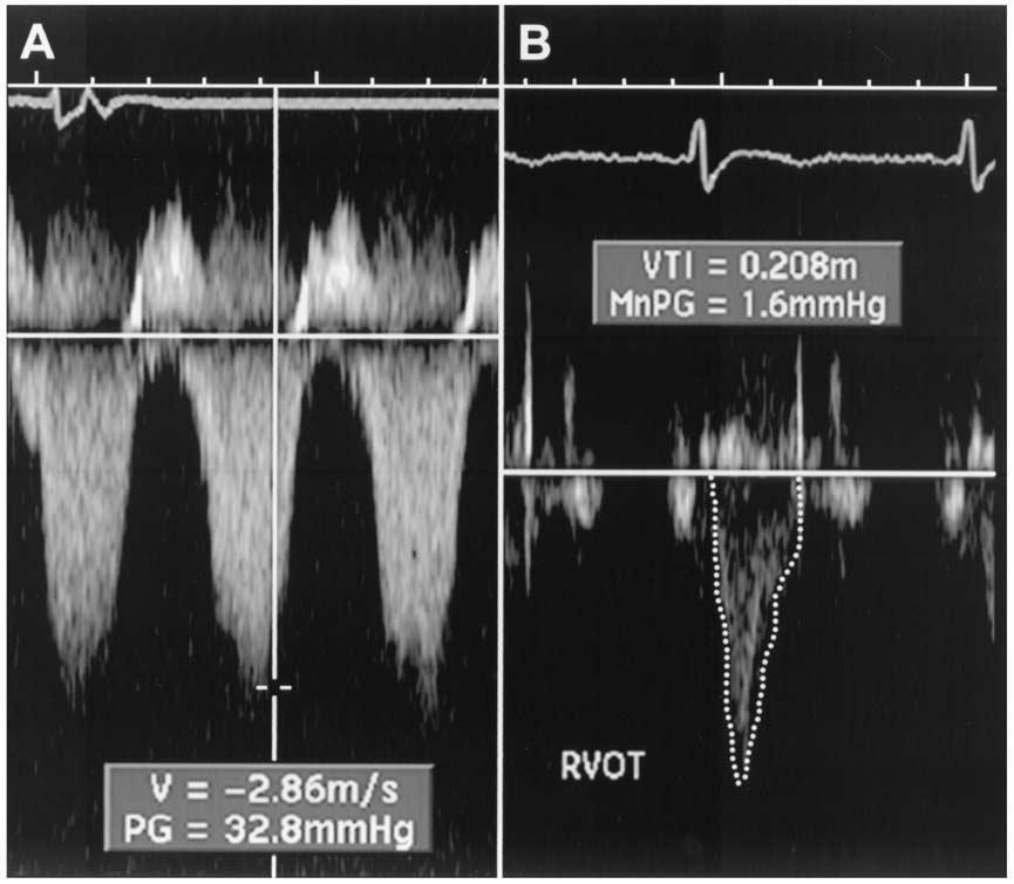




Janda et al. Heart 2011

PVR

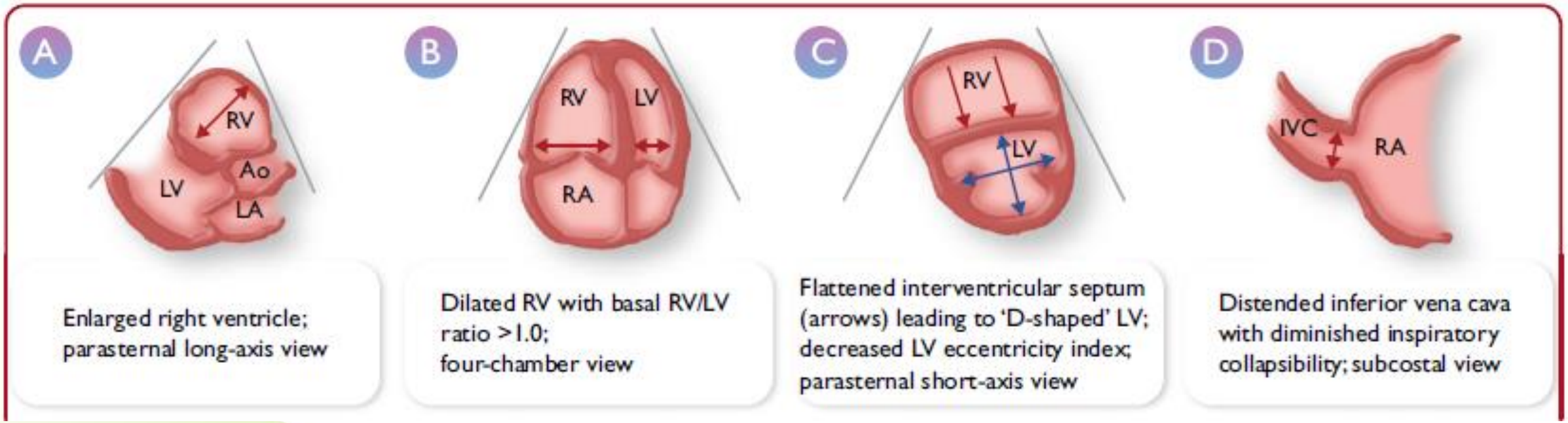
- PVR = (MPA - PCWP) / Cardiac output
- PVR (WU) = 10 x TRV / TVI_{RVOT} + 0.16



- TRV/TVI_{RVOT} = 2.86/20.8
  = 0.1375
- PVR_{ECHO} = 0.1375 x 10 + 0.16
  = 1.53 WU

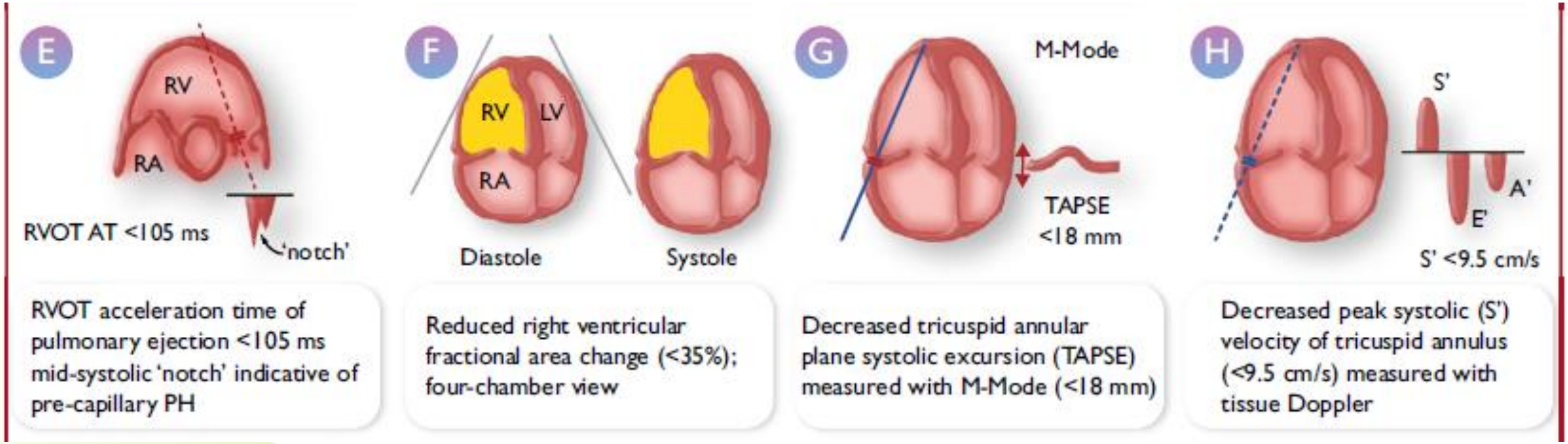
Abbas AE, J Am Coll Cardiol 2003;41:1021-7

Echocardiographic parameters in the assessment of pulmonary hypertension



European Heart Journal 2022;43,3618–3731

Echocardiographic parameters in the assessment of pulmonary hypertension



RVOT acceleration time of pulmonary ejection <105 ms mid-systolic 'notch' indicative of pre-capillary PH

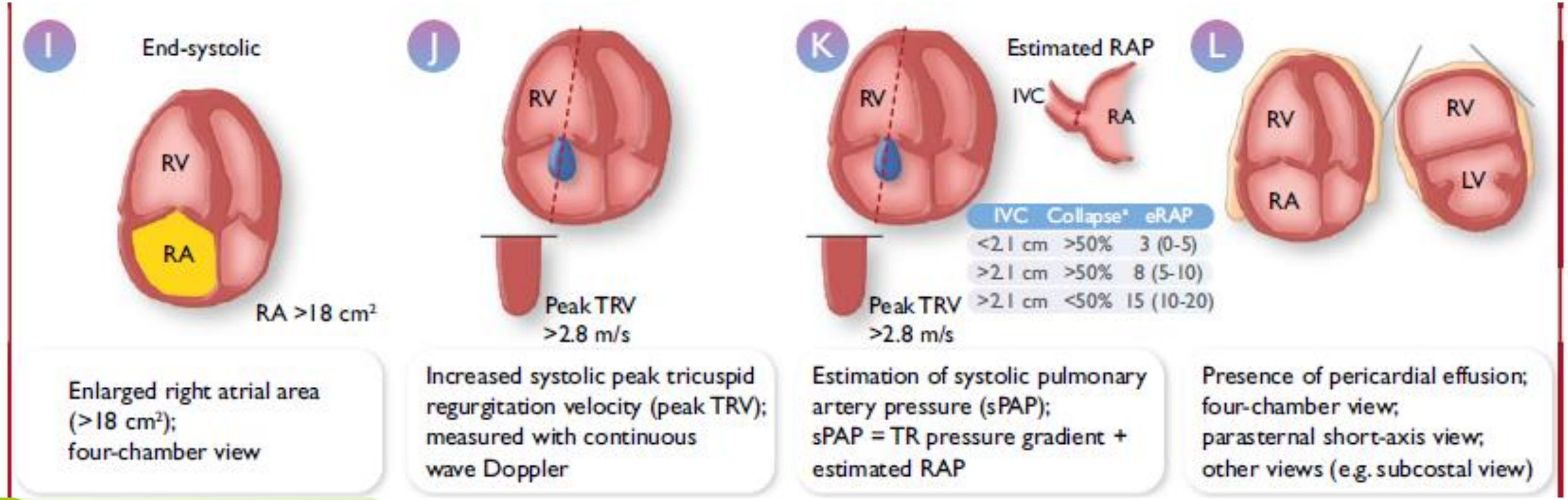
Reduced right ventricular fractional area change (<35%); four-chamber view

Decreased tricuspid annular plane systolic excursion (TAPSE) measured with M-Mode (<18 mm)

Decreased peak systolic (S') velocity of tricuspid annulus (<9.5 cm/s) measured with tissue Doppler

European Heart Journal 2022;43,3618–3731

Echocardiographic parameters in the assessment of pulmonary hypertension



Enlarged right atrial area (>18 cm²); four-chamber view

Increased systolic peak tricuspid regurgitation velocity (peak TRV); measured with continuous wave Doppler

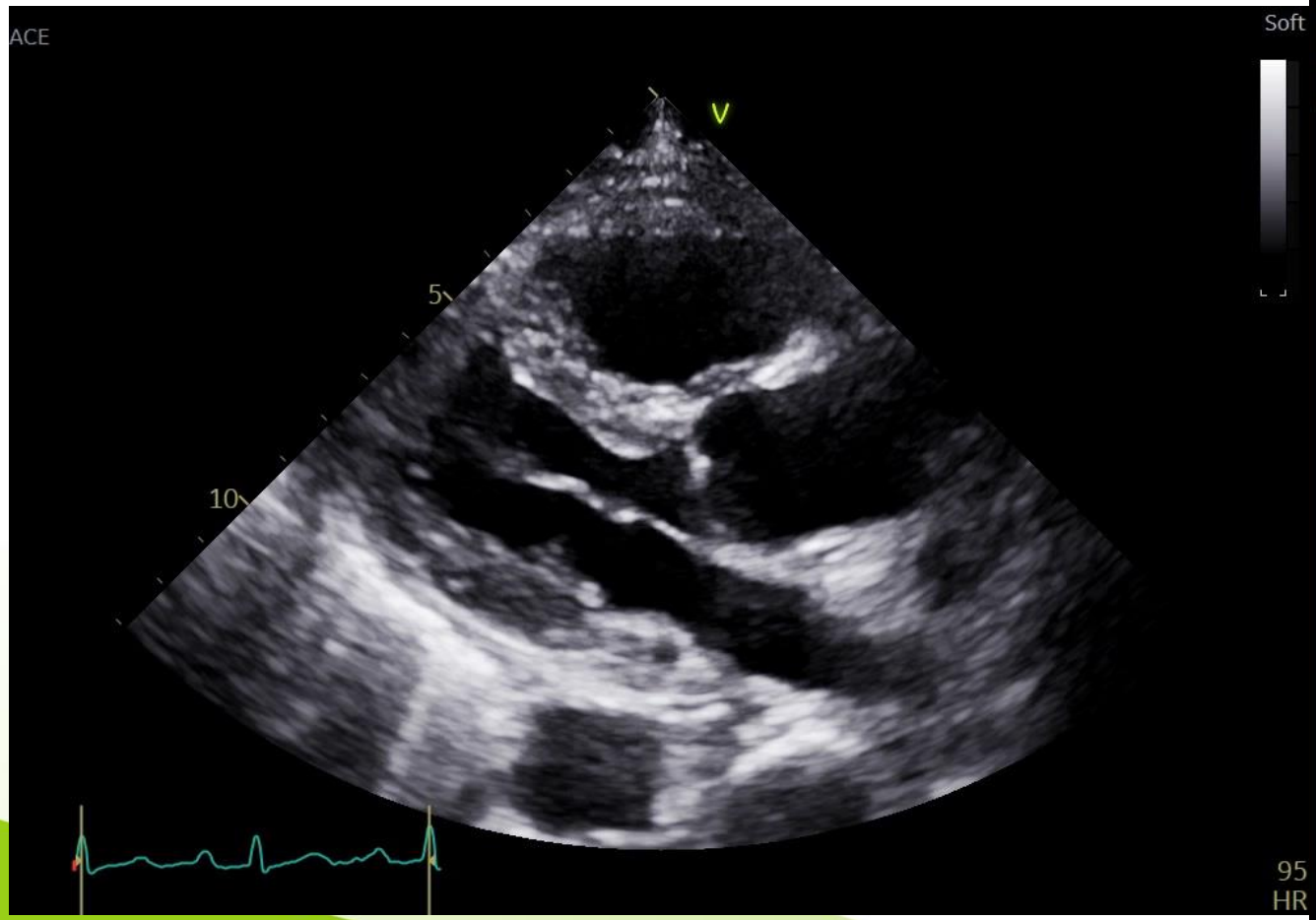
Estimation of systolic pulmonary artery pressure (sPAP); sPAP = TR pressure gradient + estimated RAP

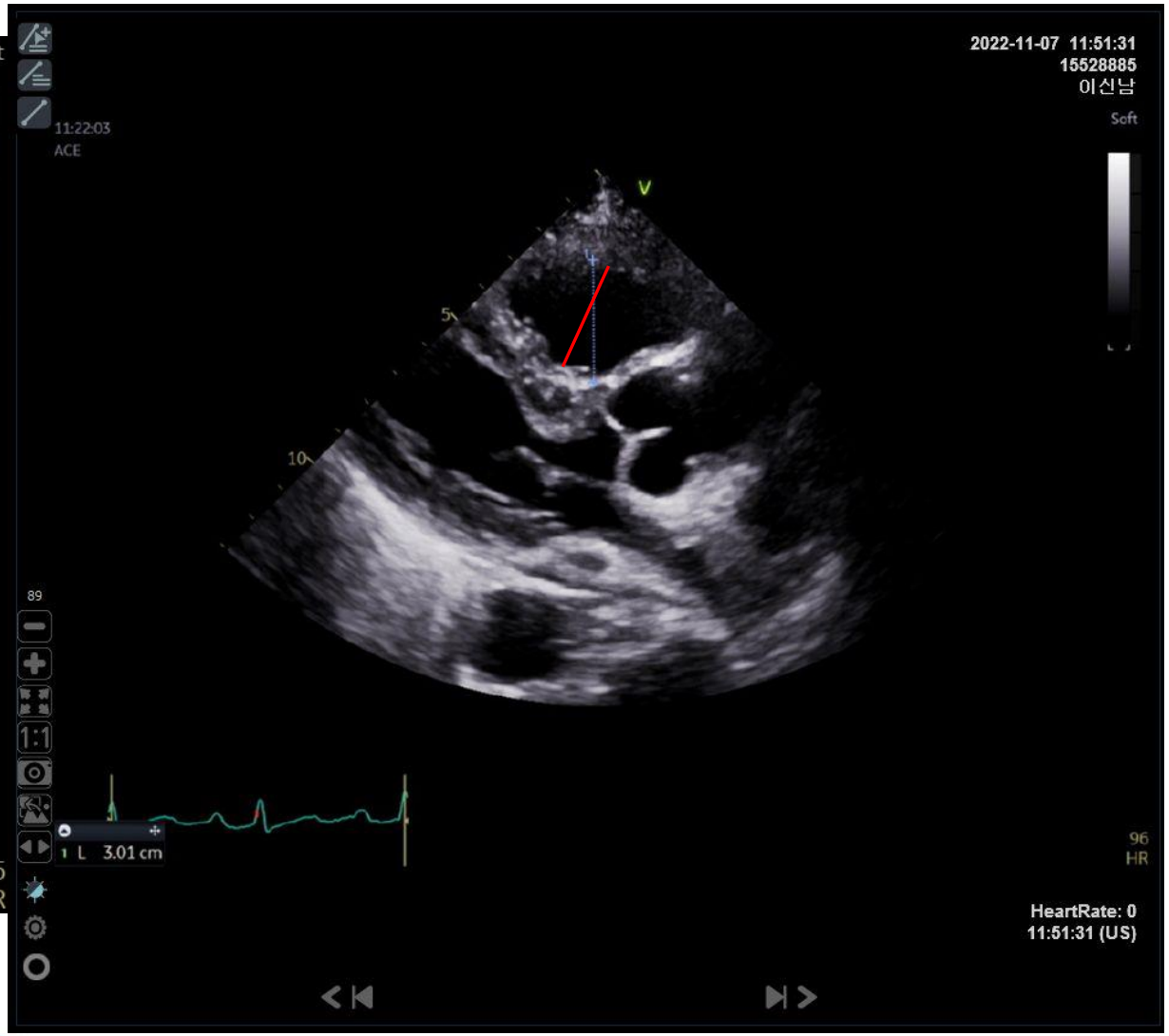
Presence of pericardial effusion; four-chamber view; parasternal short-axis view; other views (e.g. subcostal view)

European Heart Journal 2022;43,3618–3731

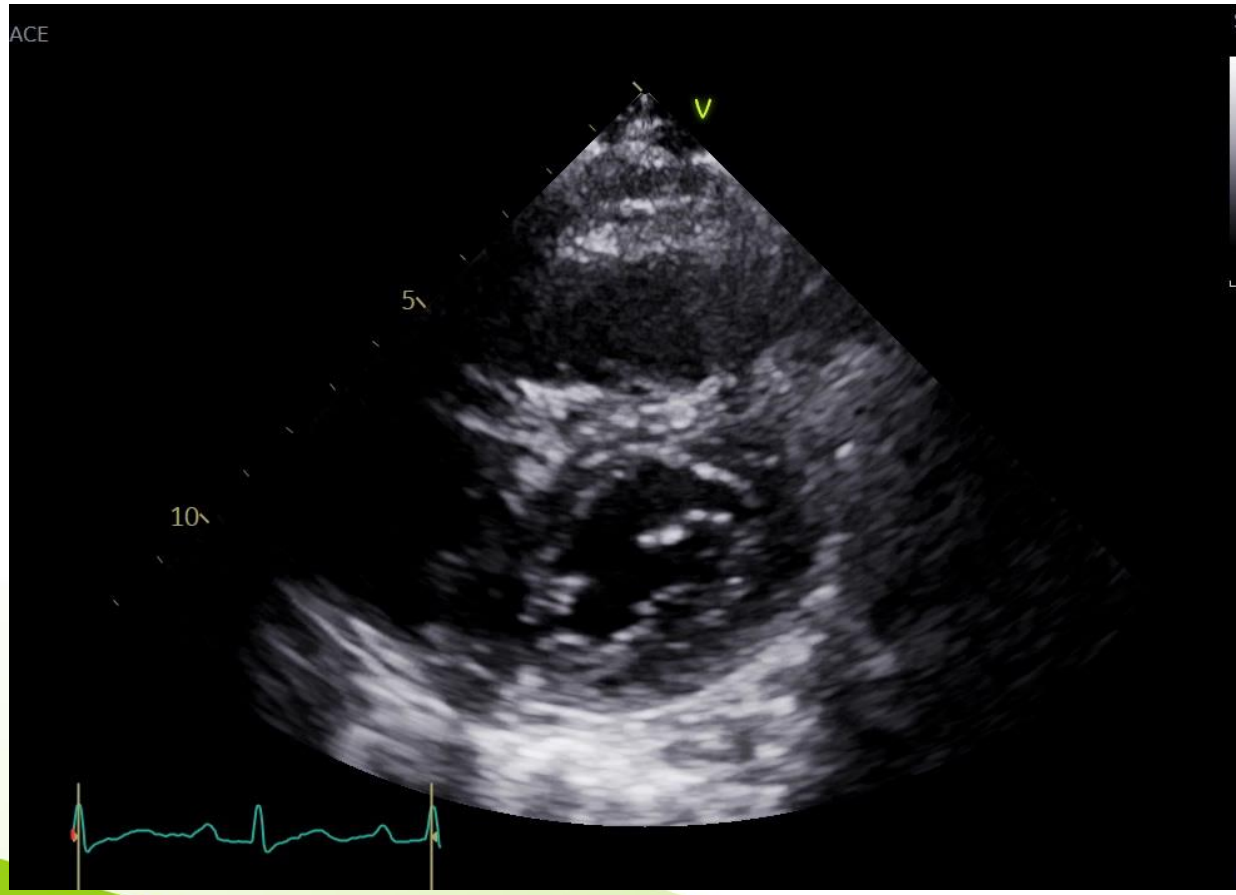
Case 1 M / 79 COPD

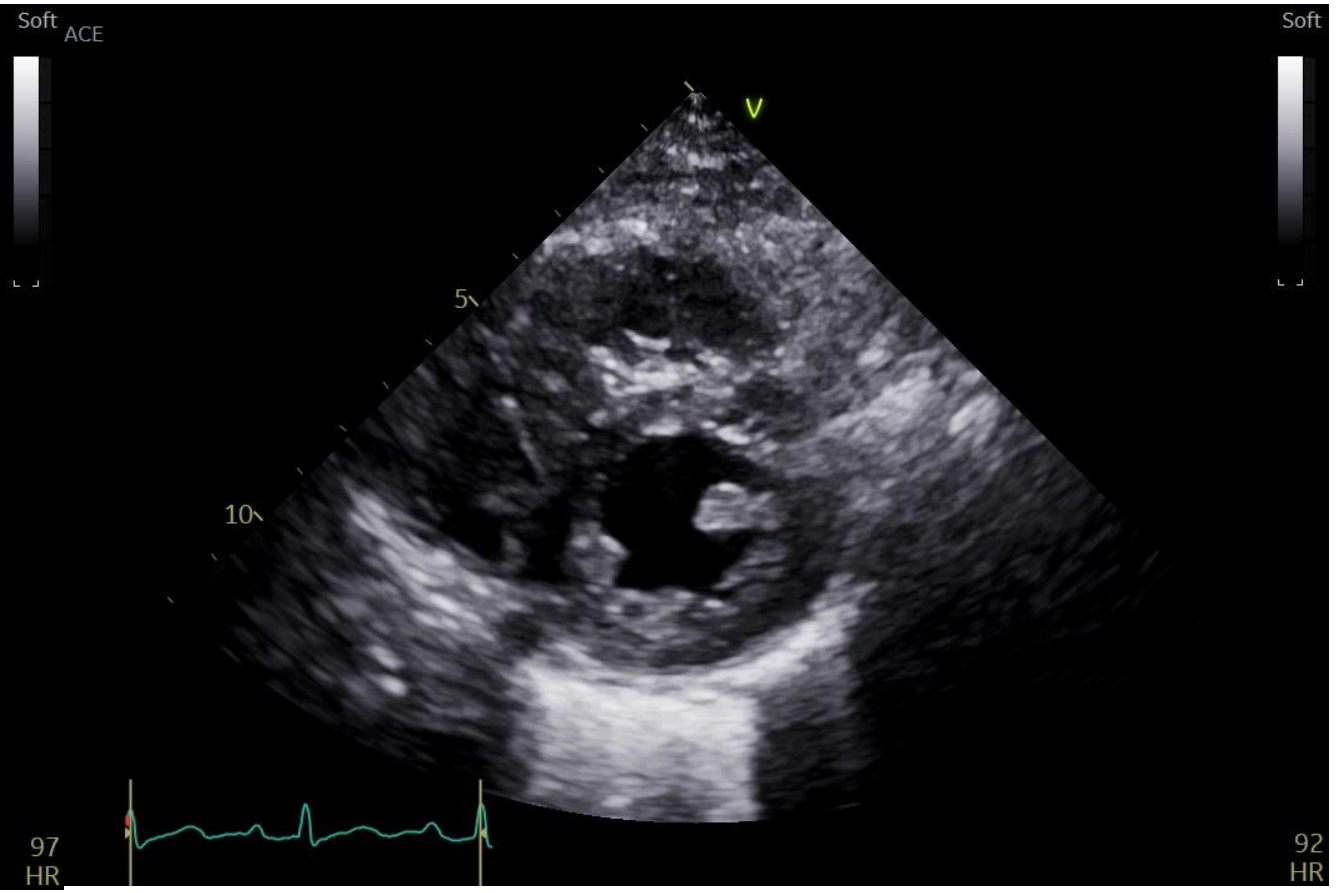
RVOT Prox 30.1 mm



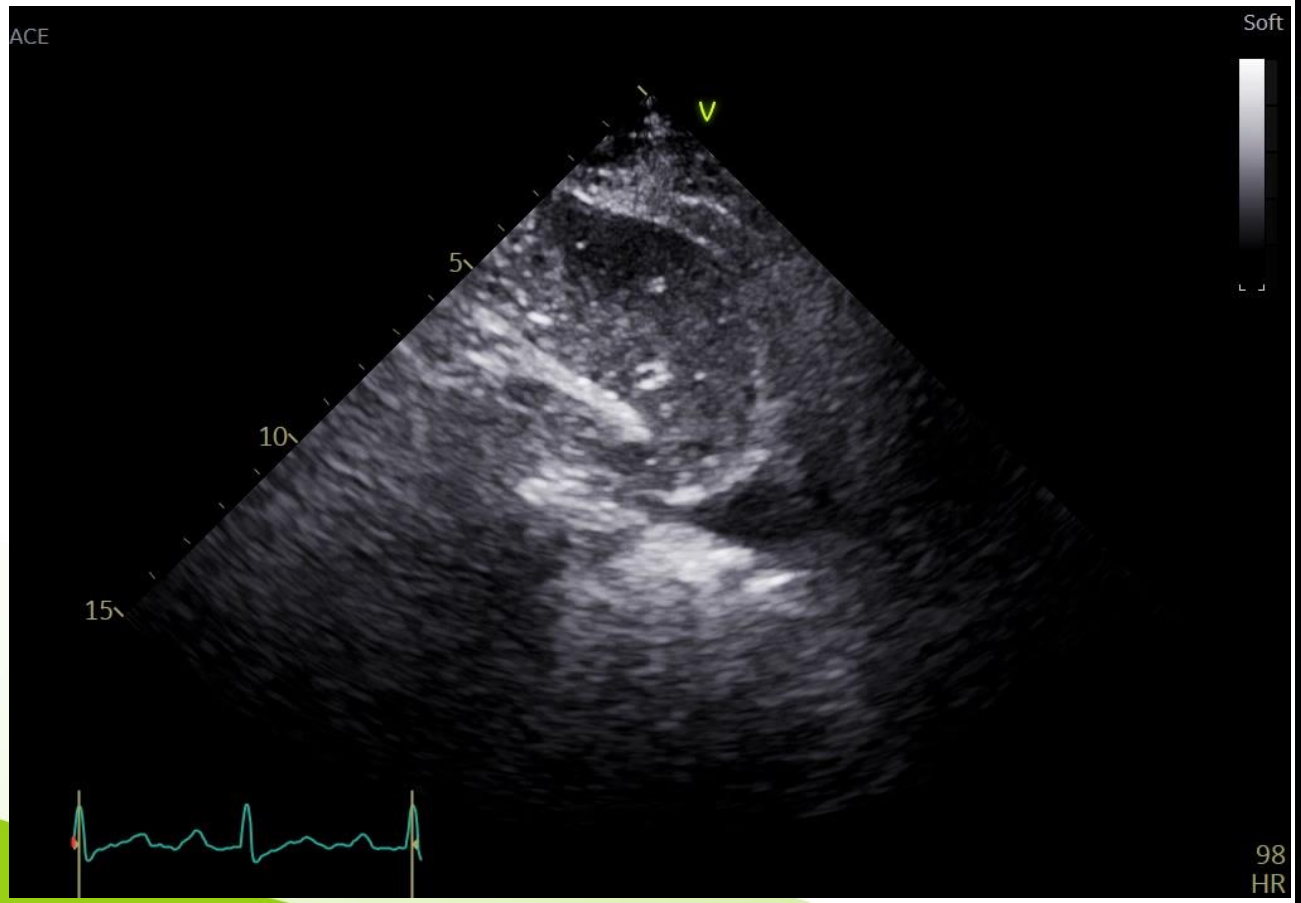


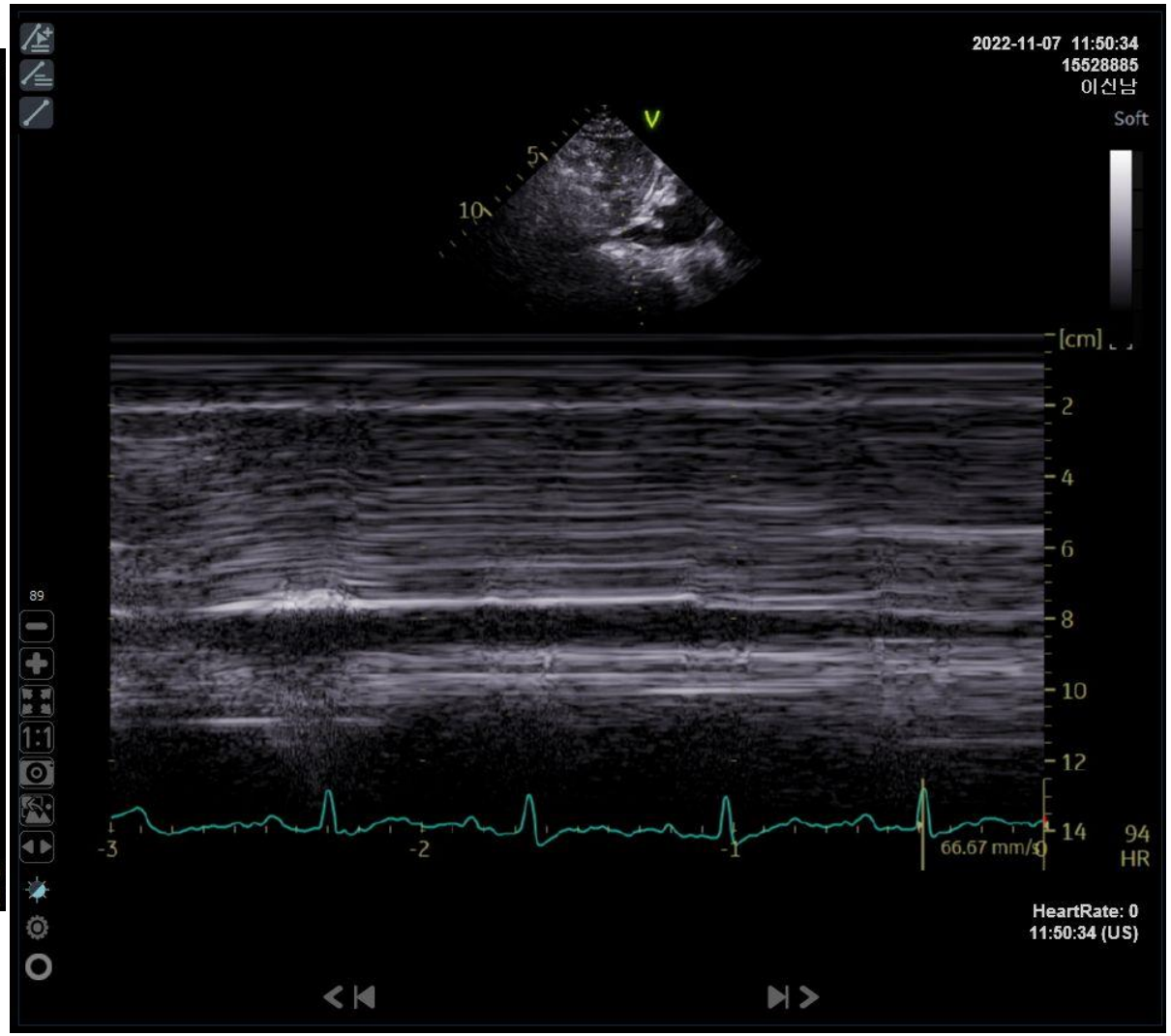
Case 1 M / 79 COPD





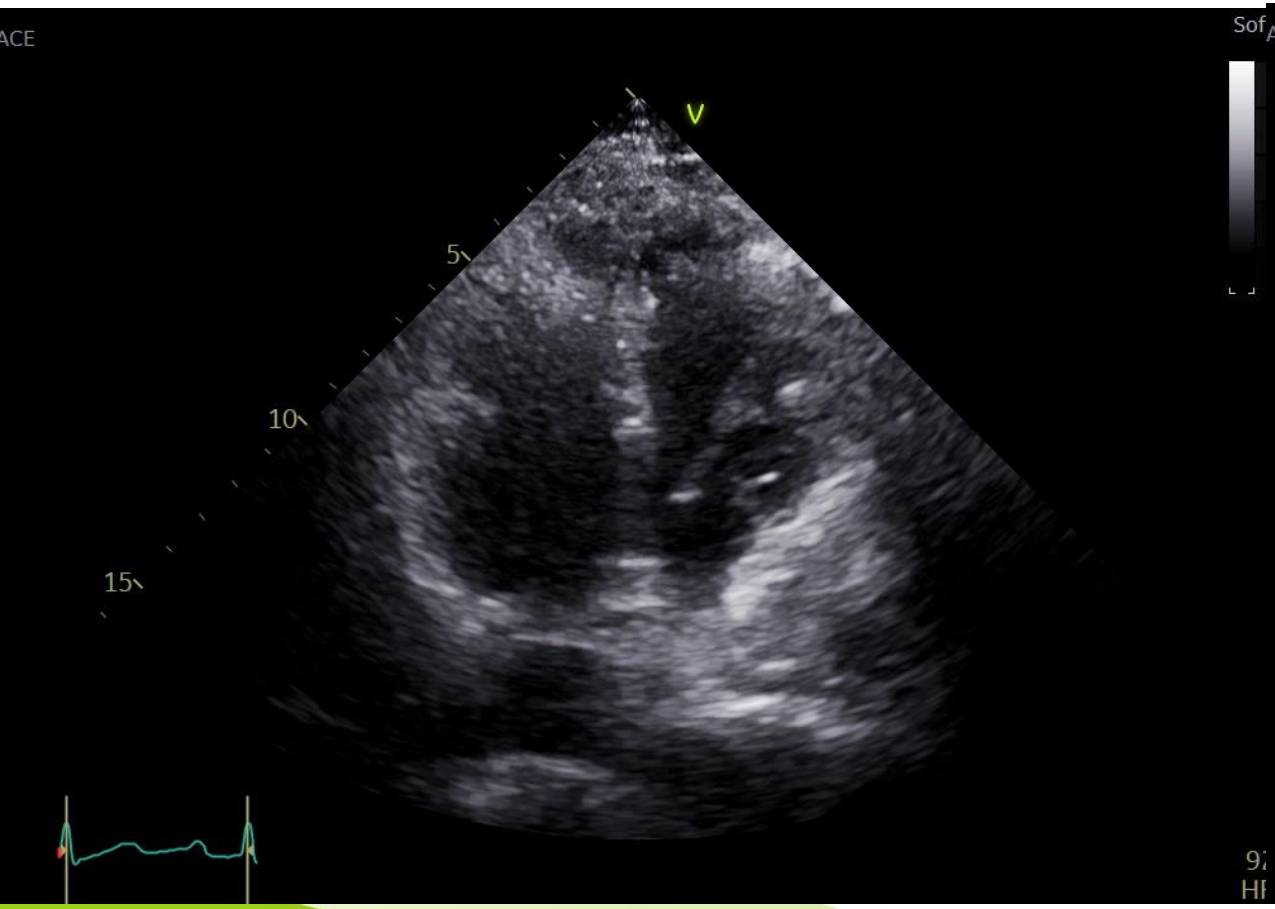
Case 1 M / 79 COPD

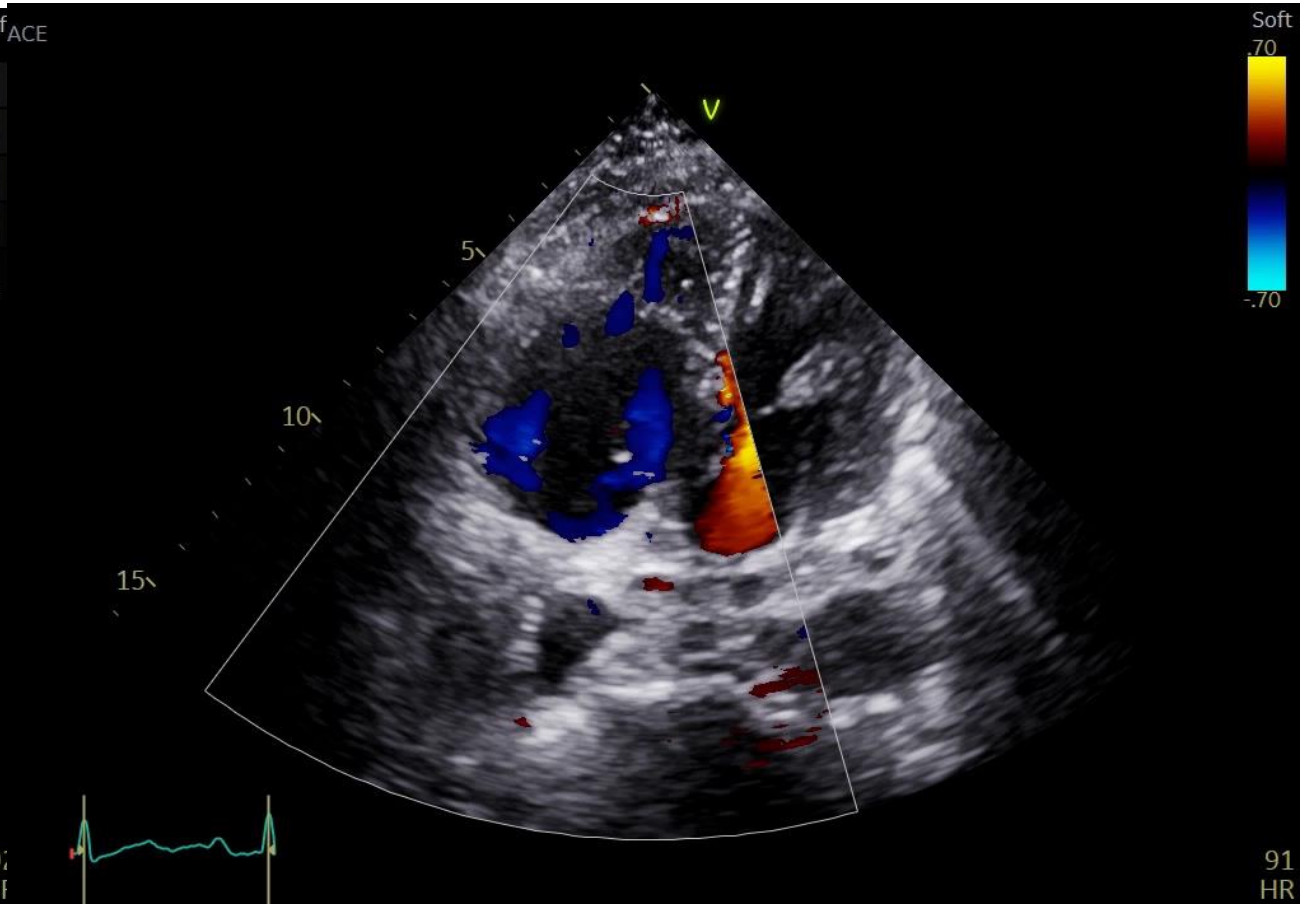




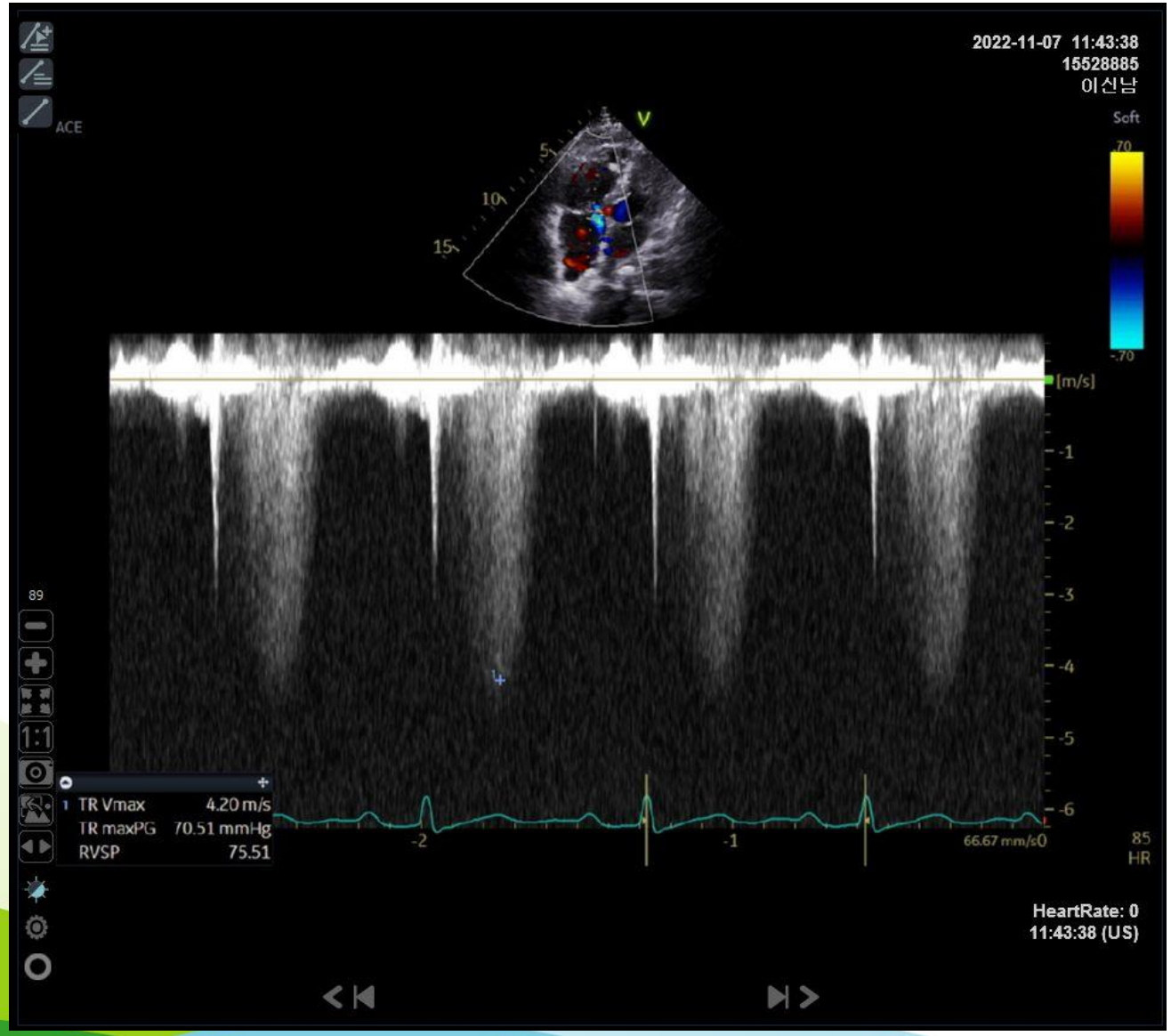
RAP 3 mmHg

Case 1 M / 79 COPD



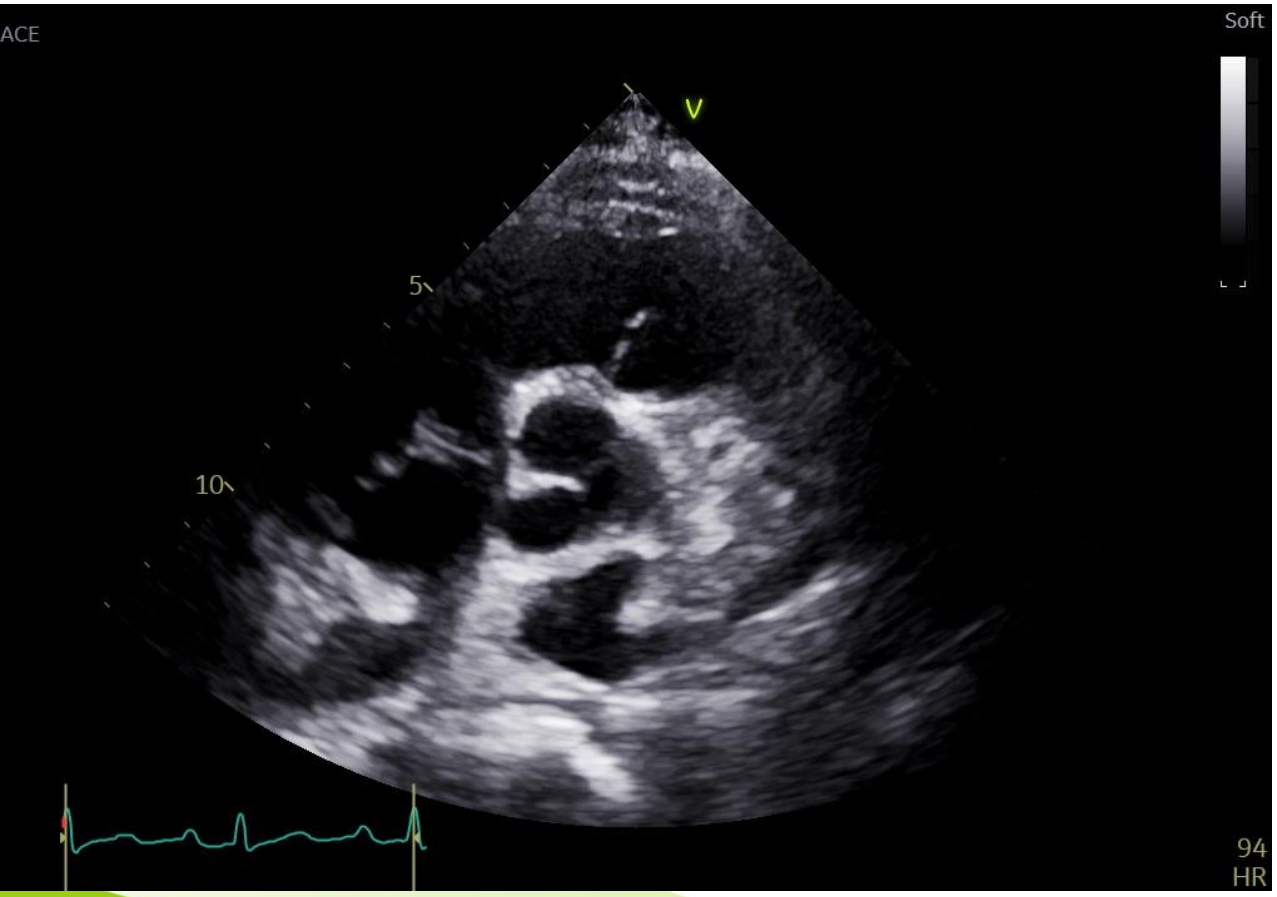


Case 1 M / 79 COPD

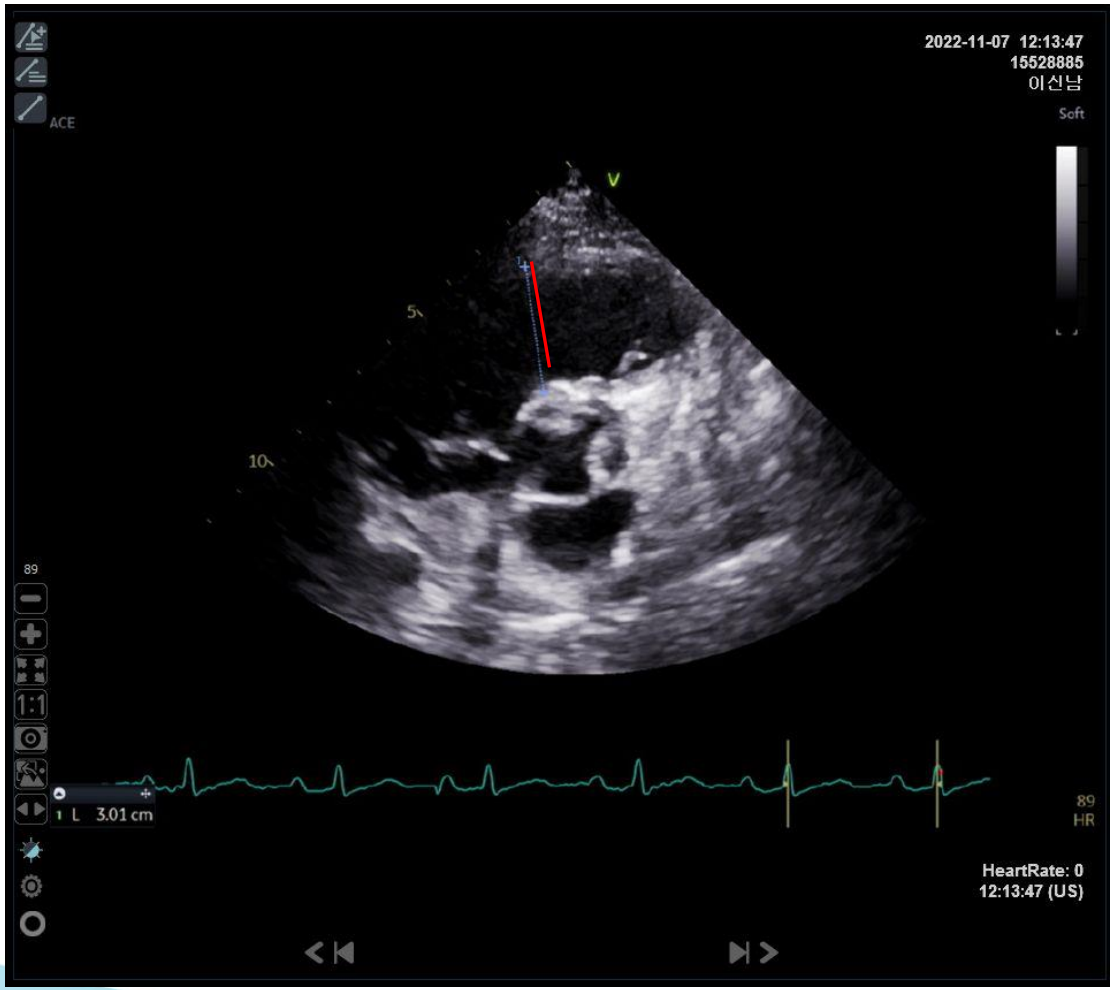


RVSP $4x4.2^2 + 3$
= 73.6 mmHg

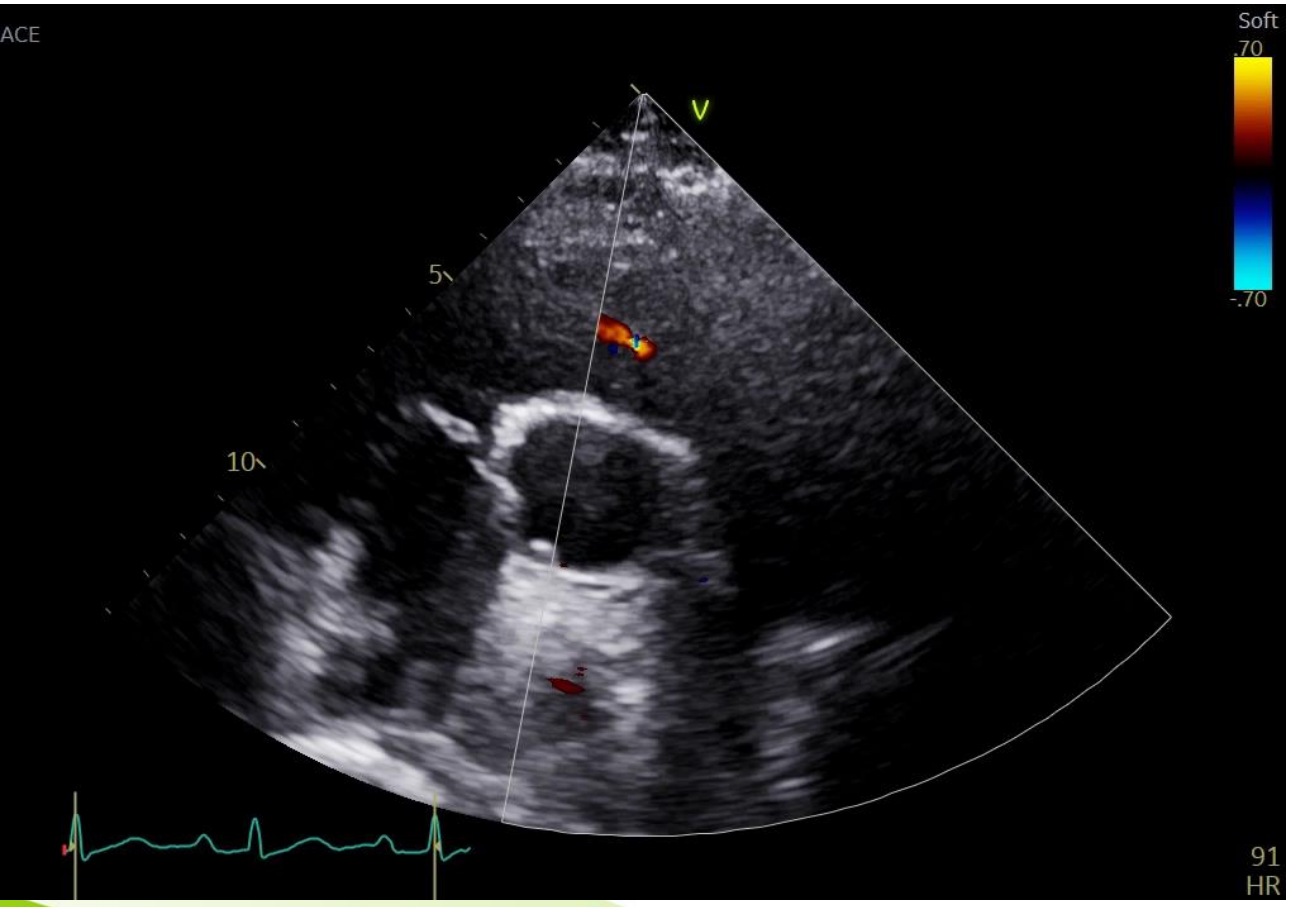
Case 1 M / 79 COPD

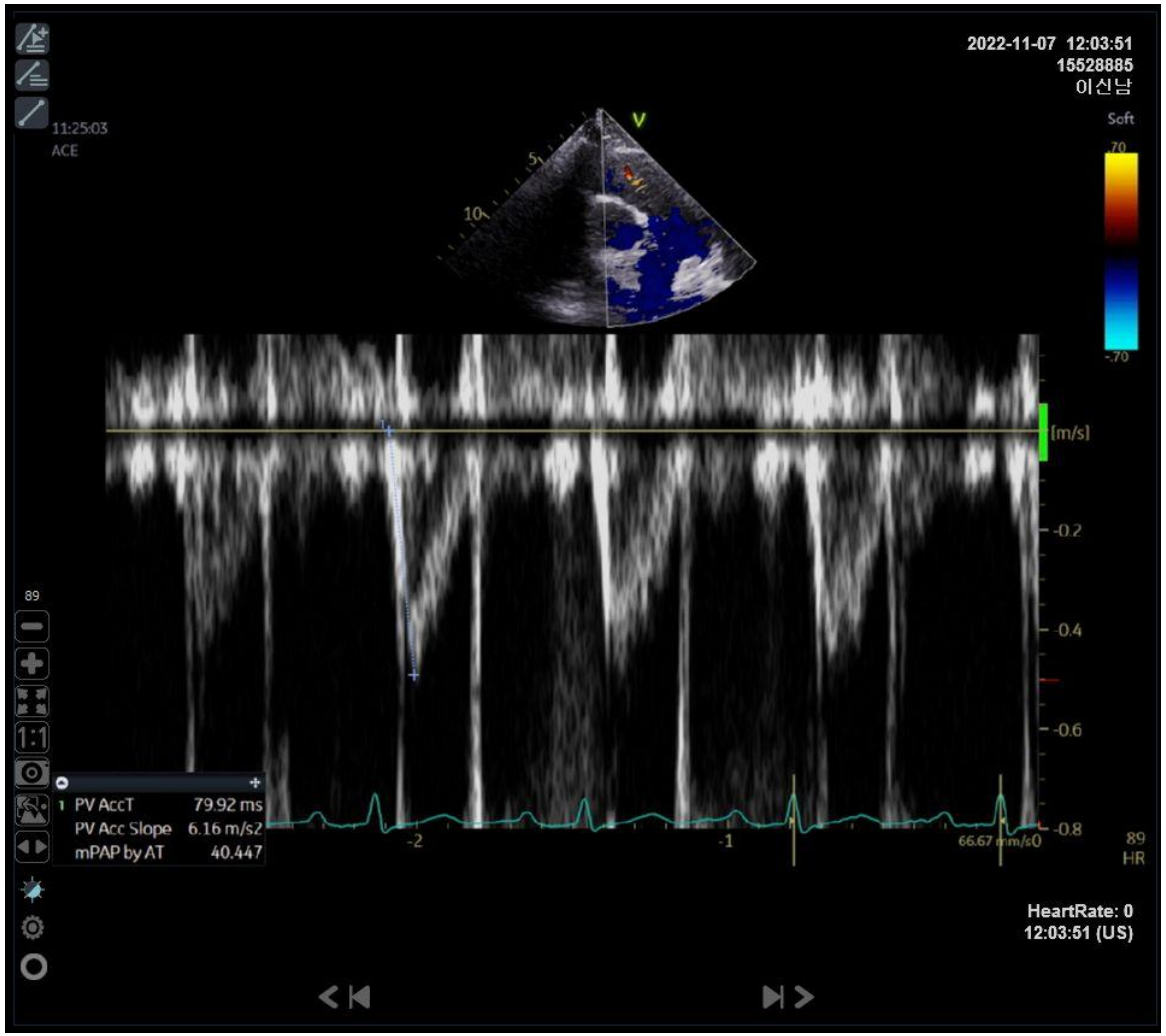


RVOT Prox 30.1mm



Case 1 M / 79 COPD

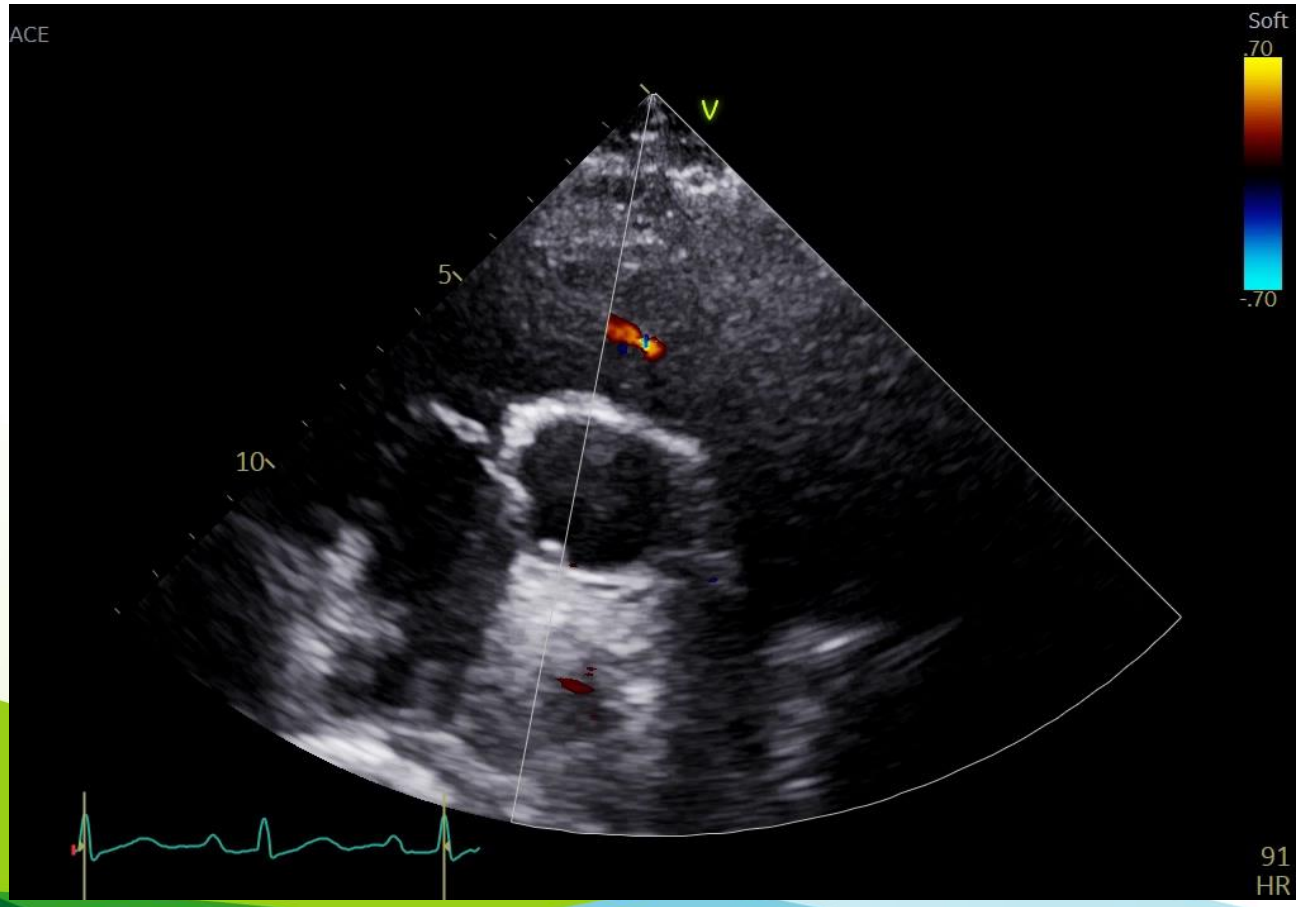


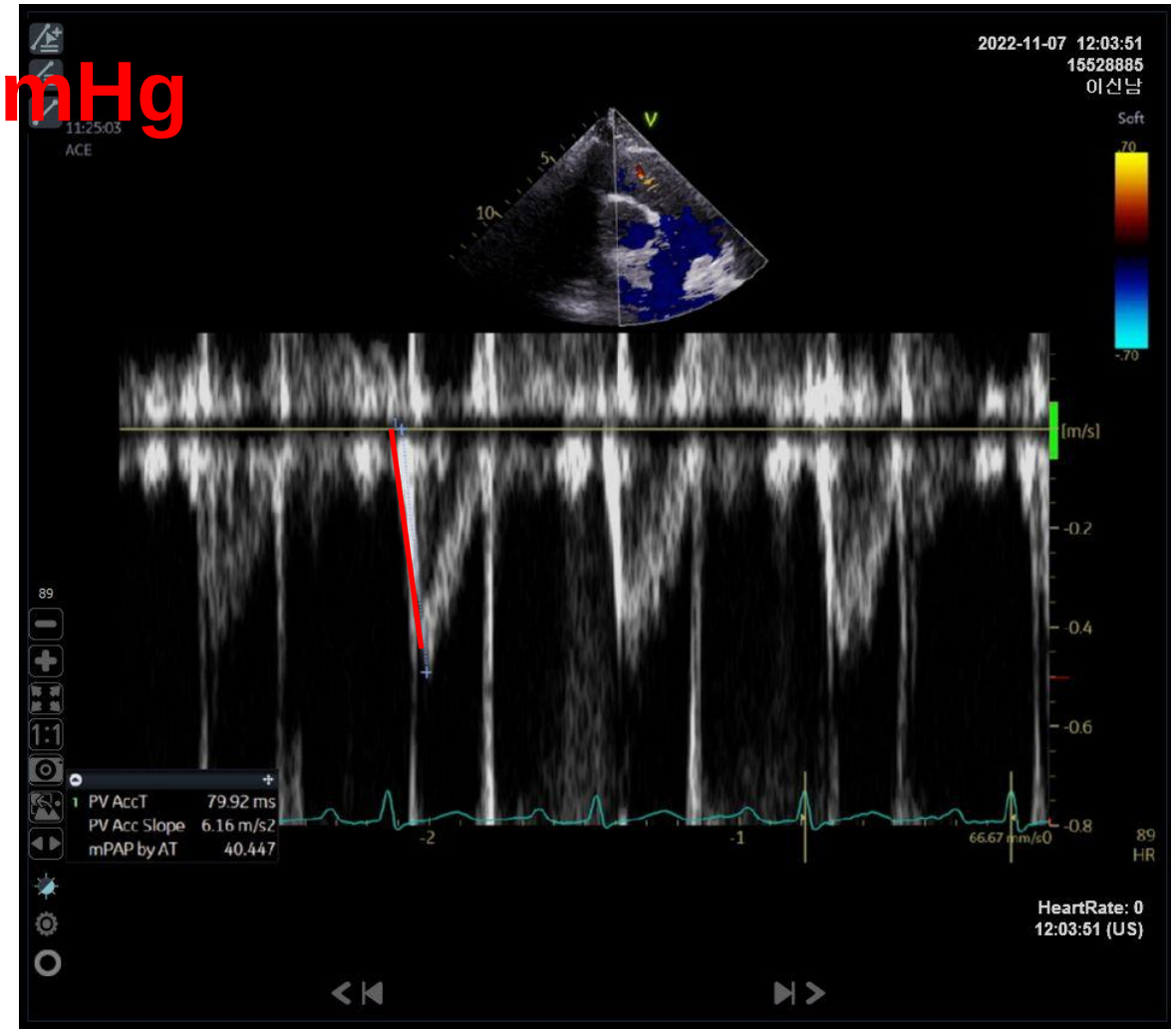


Case 1 M / 79 COPD

AT 79.9ms

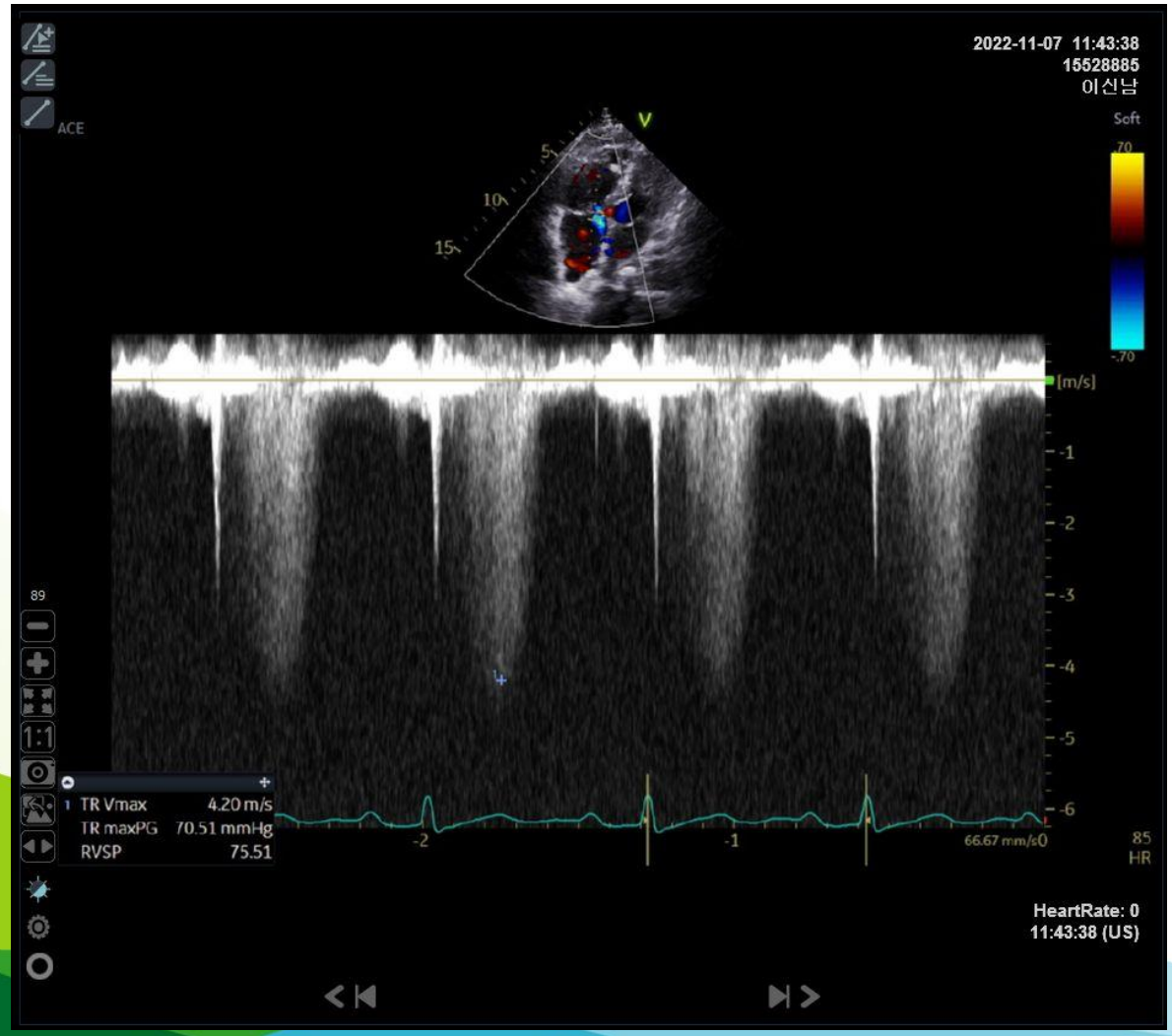
Mean PAP 90-0.62x79.9= 40.5mmHg

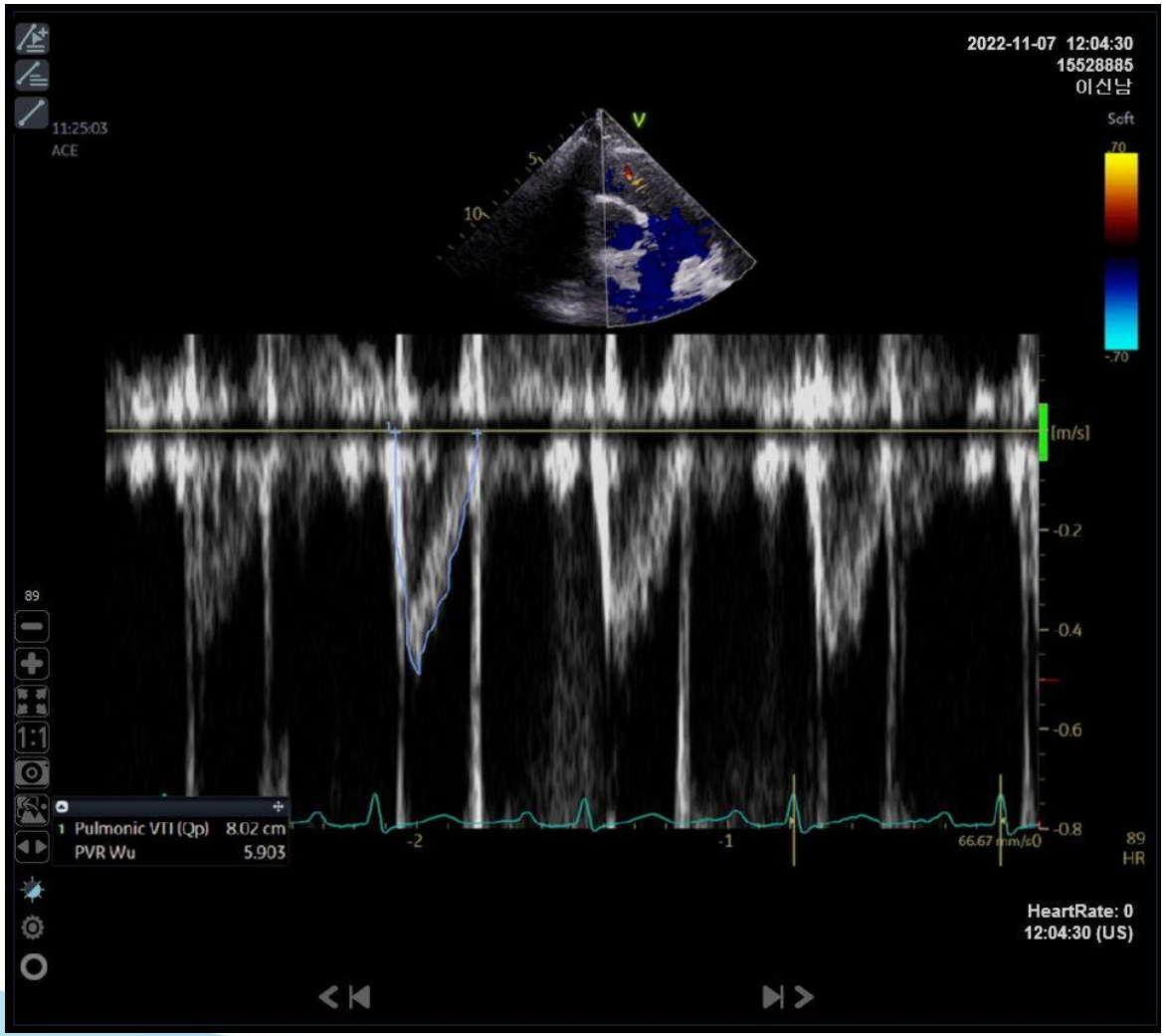




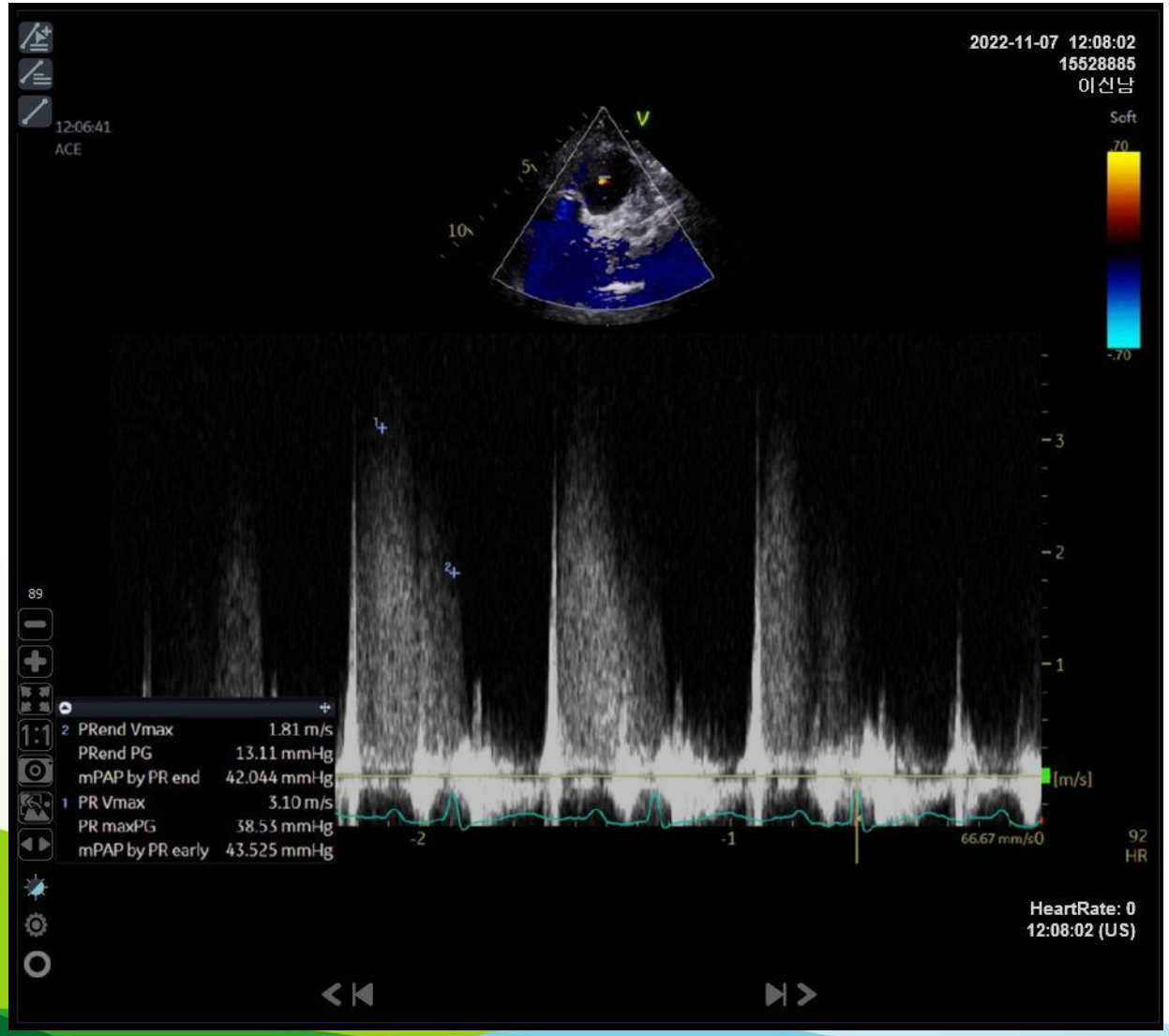
Case 1 M / 79 COPD

PVR= (TR Vmax/RVOT TVI) x 10 + 0.16= 5.9 WU





Case 1 M / 79 COPD



Mean PAP

= 4x(early PR velocity)^2 + RAP

= 4x3.1^2+3

= 41.4 mmHg

PAEDP

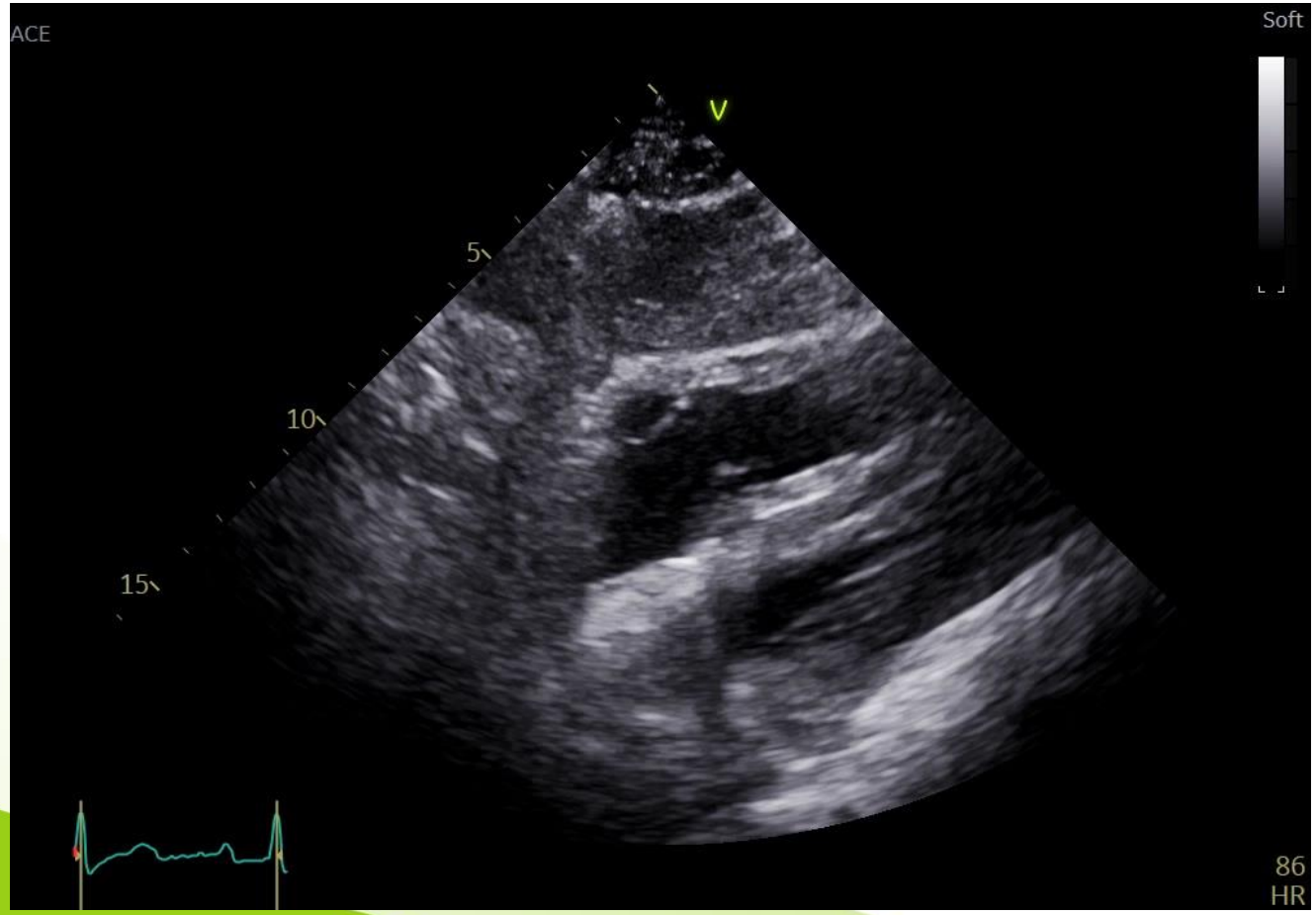
= 4xPREDV^2+RAP

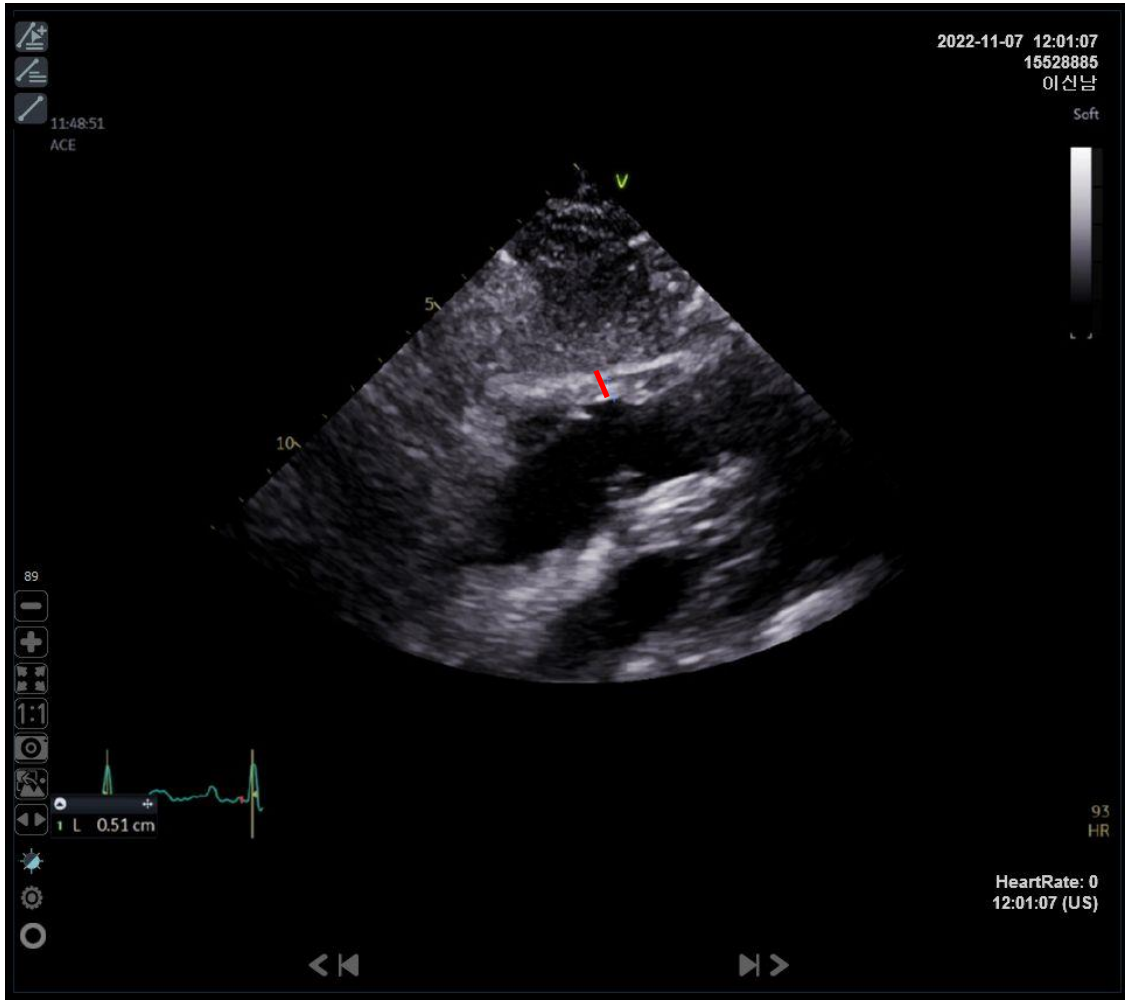
= 4x2.2^2 +3

= 22.4 mmHg

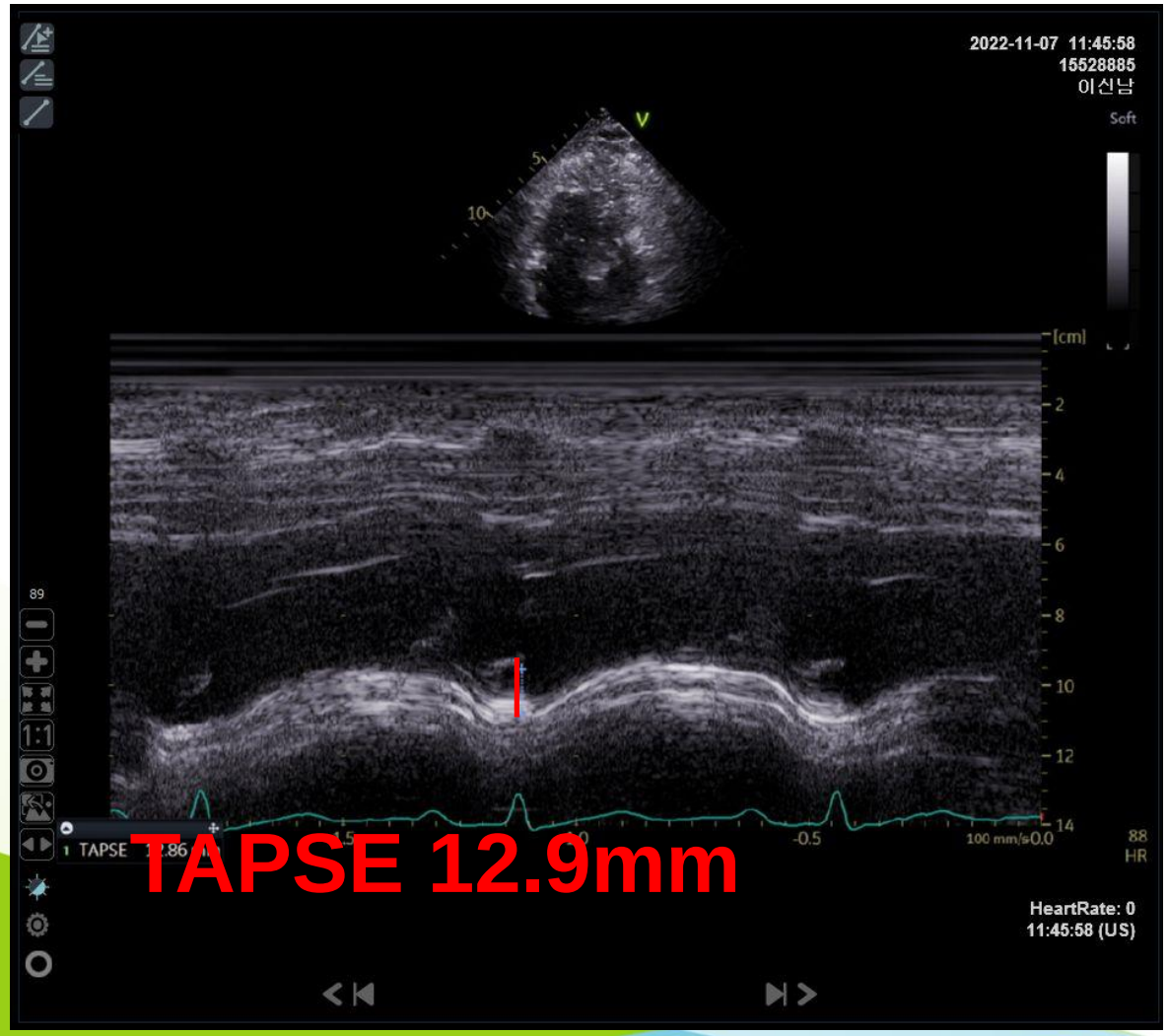
Case 1 M / 79 COPD

RV wall thickness 5.1mm

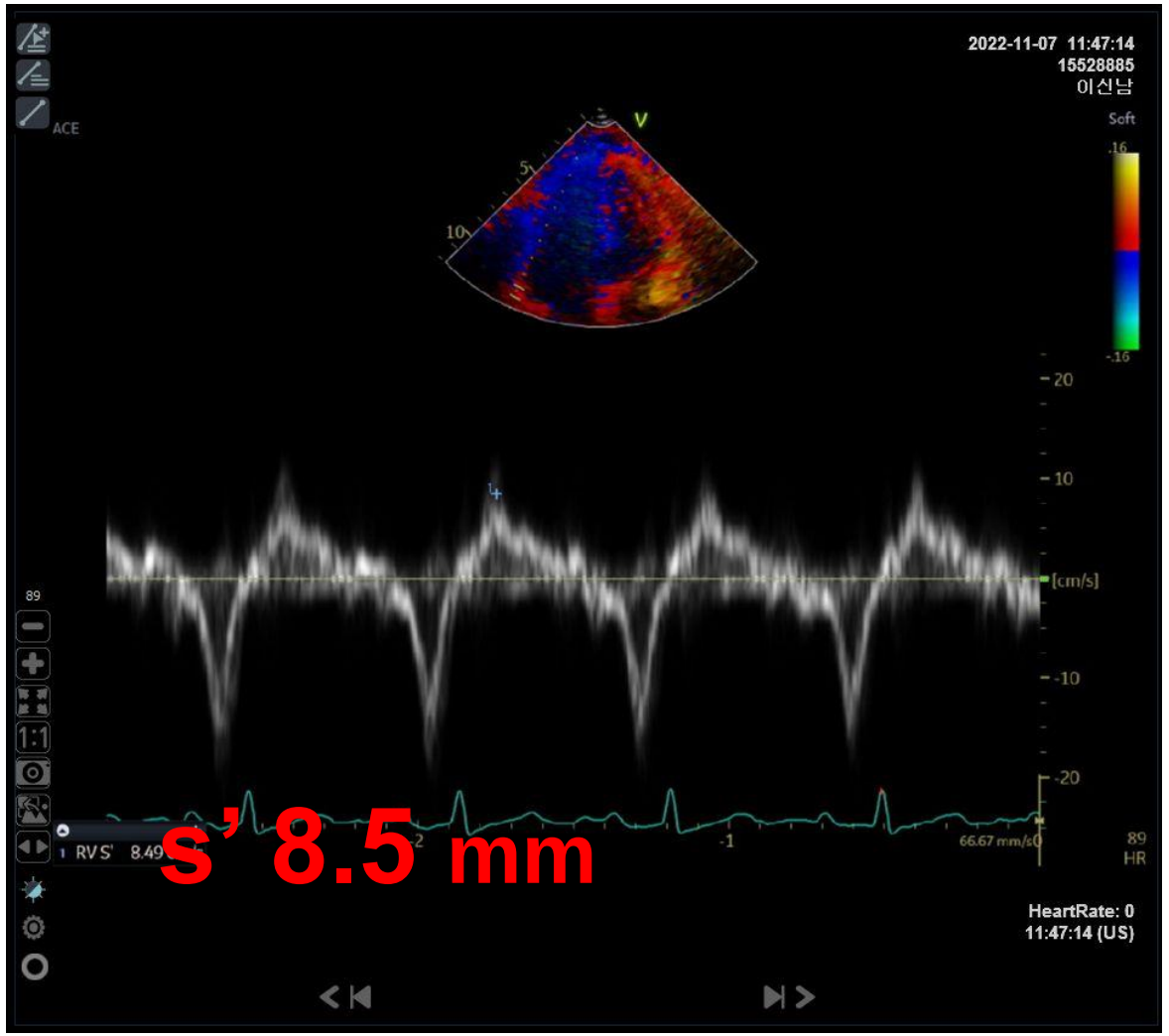




Case 1 M / 79 COPD

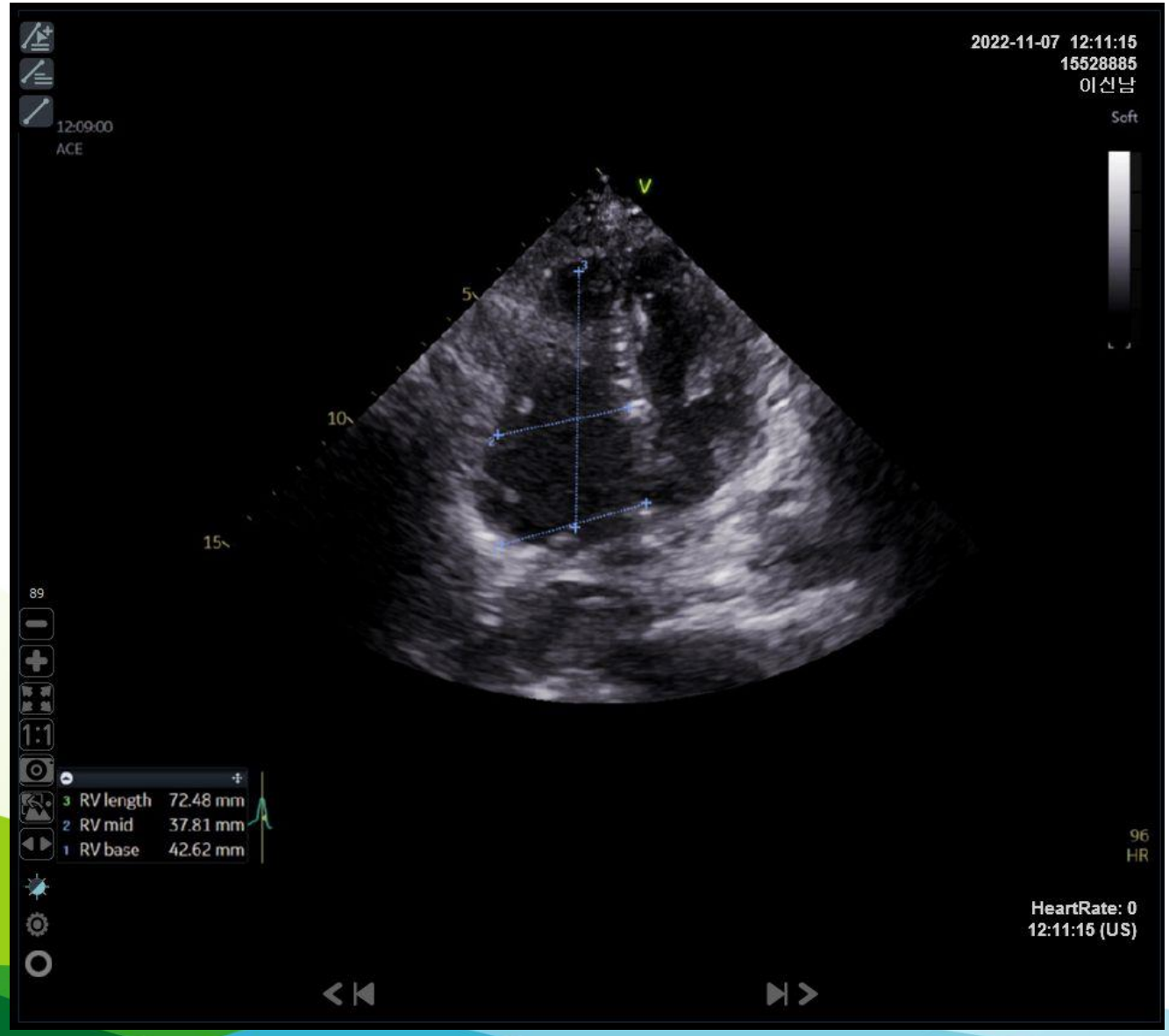


TAPSE 12.9mm



s' 8.5 mm

Case 1 M / 79 COPD



RVD3 72.5 mm
RVD2 37.8 mm
RVD1 42.6 mm

RV FAC 47.1%

Case 1 M / 79 COPD

- Group 3, pulmonary hypertension associated lung diseases
  - RV dimension 증가
  - RV systolic function 감소
  - SPAP, mean PAP, PVR 증가

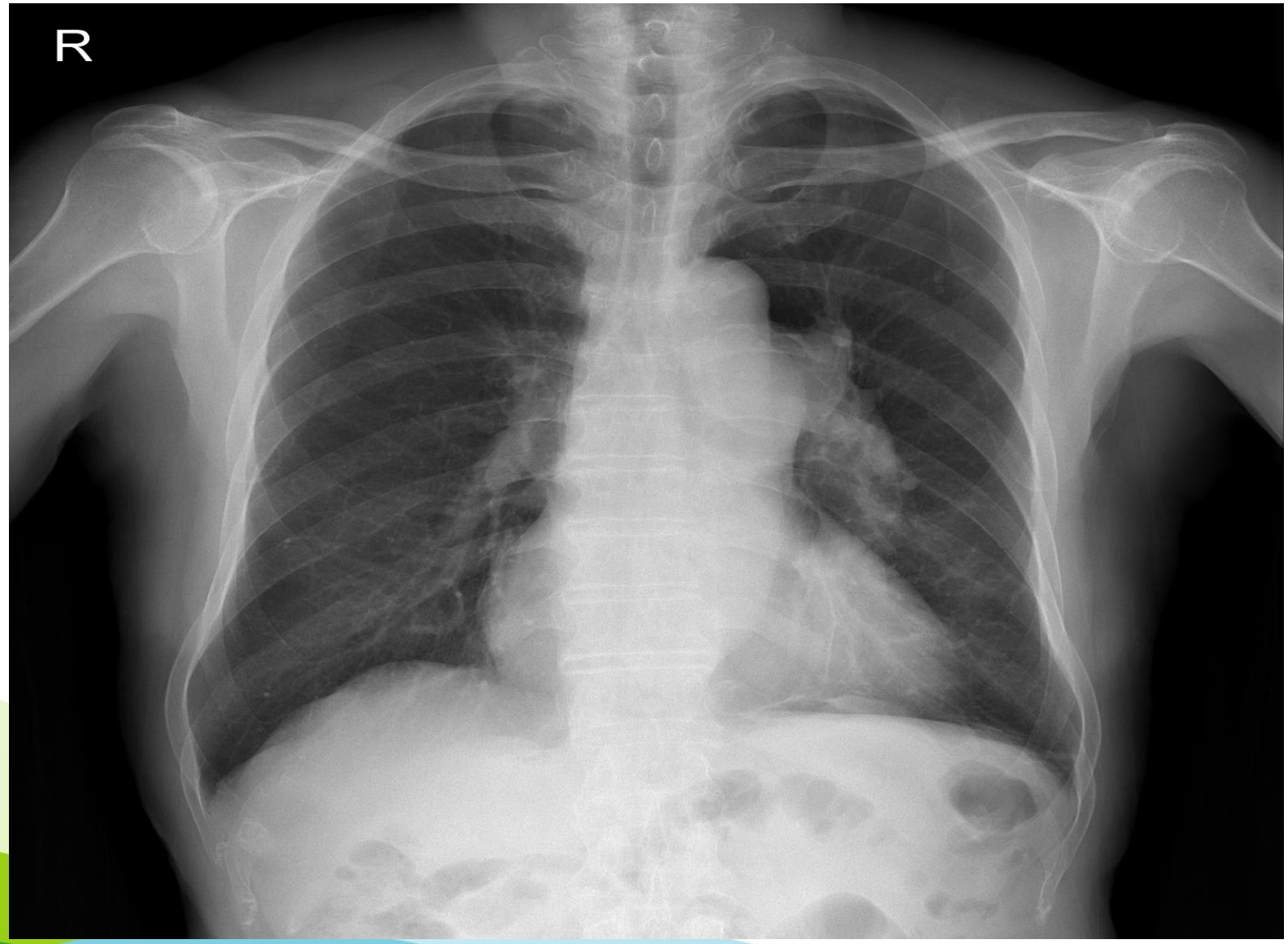
Case 2

- M / 81
- C.C : exertional dyspnea

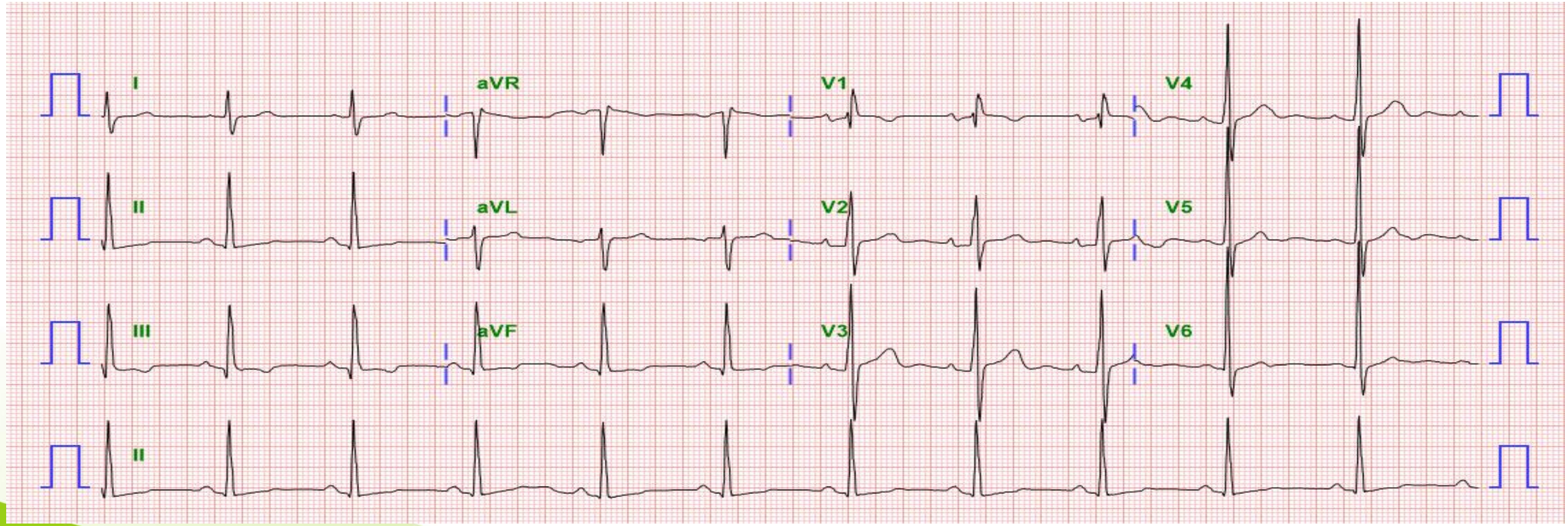
- P.I : 외과에서 Rt inguinal hernia 수술 예정으로
  평소 숨찬 증상 있어 순환기내과 외래 방문

- 159.5 cm 54.2 kg
- BP: 138/76 mmHg 65 bpm

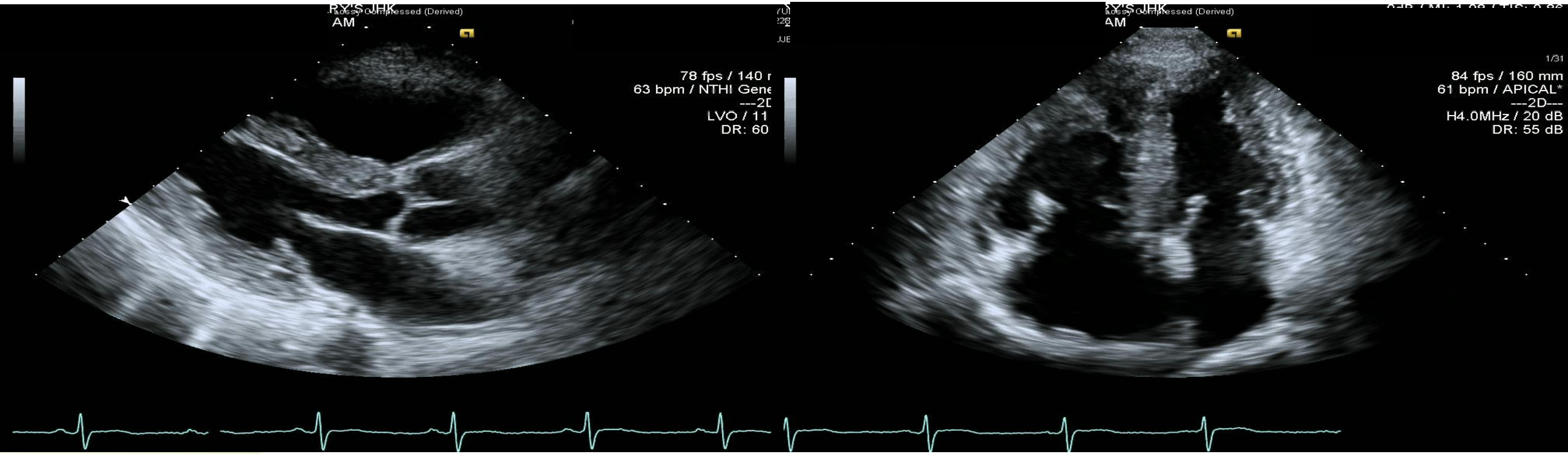
Chest PA



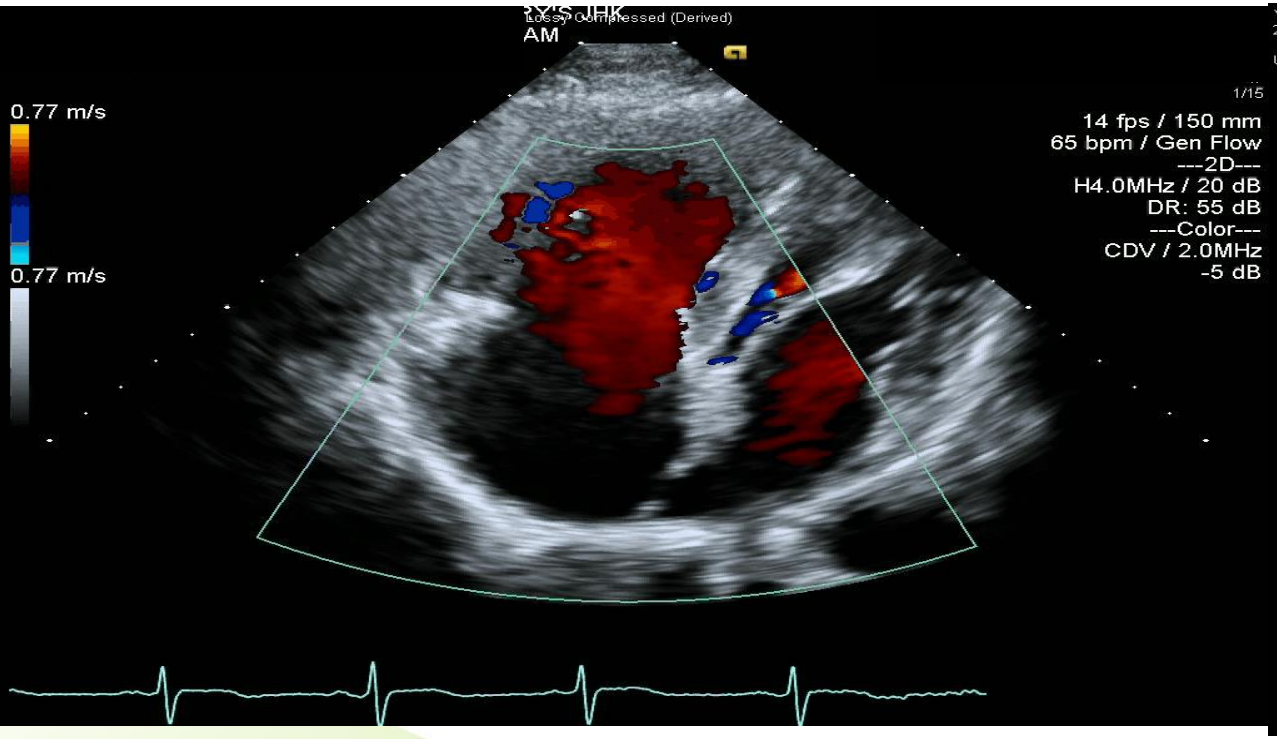
ECG

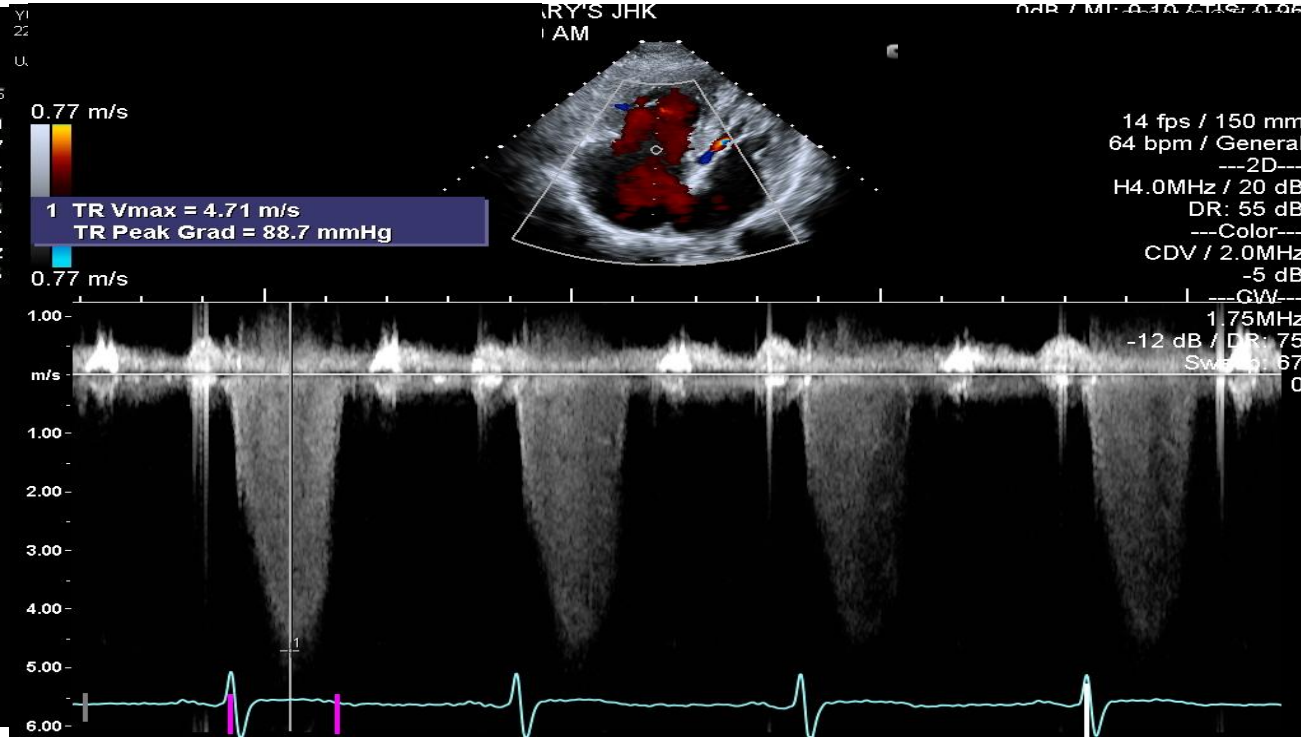


Echo

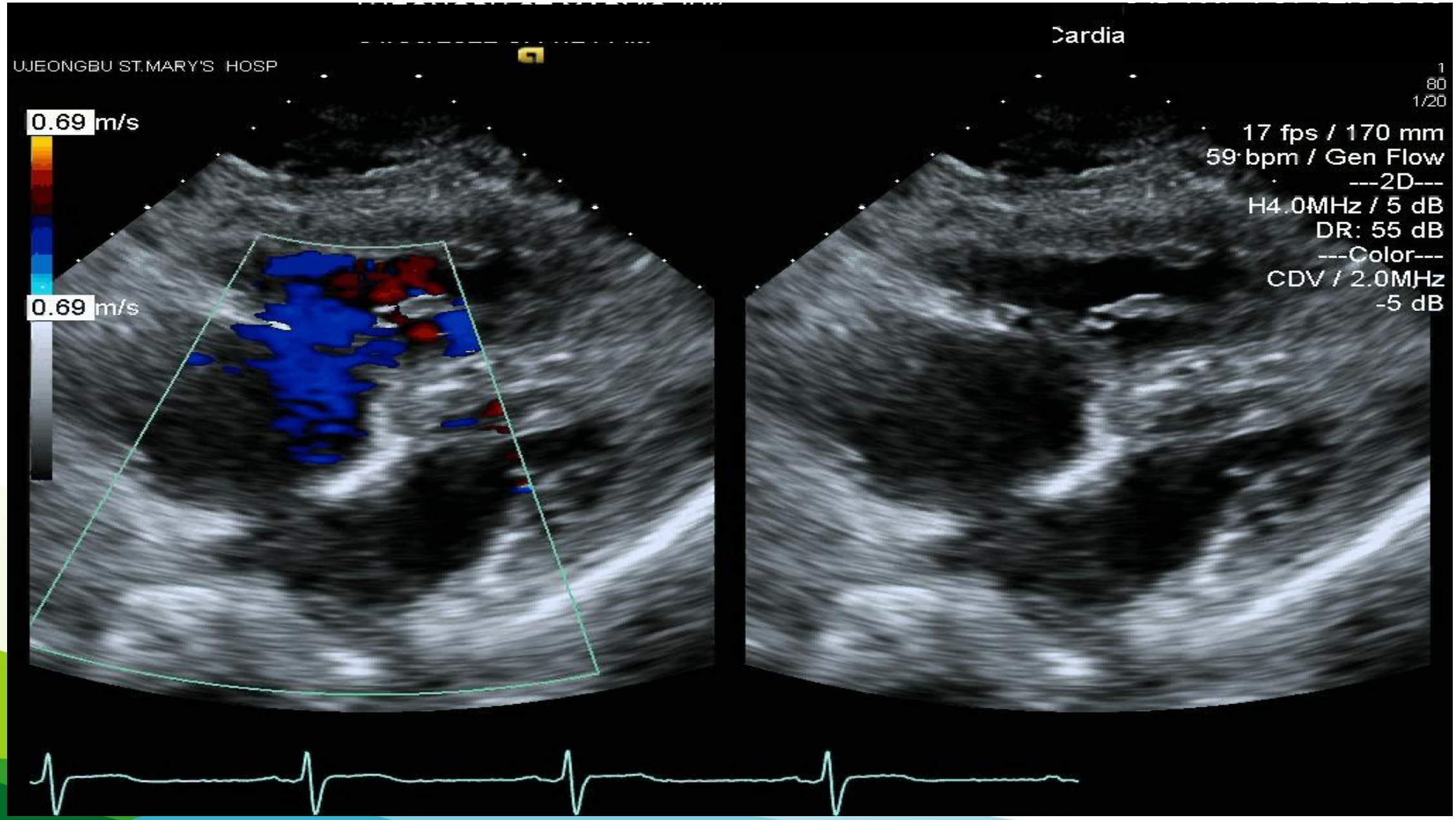

Lossy Compressed (Derived)
AM
78 fps / 140 r
63 bpm / NTHI Gene
---2D
LVO / 11
DR: 60
Lossy Compressed (Derived)
AM
1/31
84 fps / 160 mm
61 bpm / APICAL*
---2D---
H4.0MHz / 20 dB
DR: 55 dB

Echo

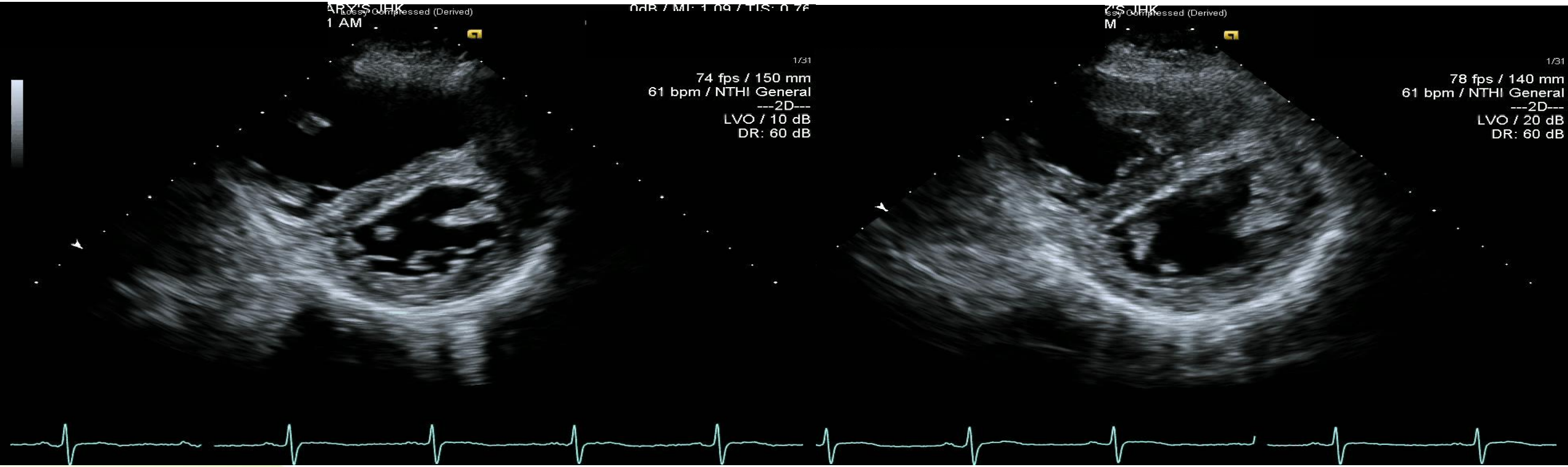

Lossy Compressed (Derived)
AM
0.77 m/s
0.77 m/s
14 fps / 150 mm
65 bpm / Gen Flow
---2D---
H4.0MHz / 20 dB
DR: 55 dB
---Color---
CDV / 2.0MHz
-5 dB


AM
0.77 m/s
1 TR Vmax = 4.71 m/s
TR Peak Grad = 88.7 mmHg
0.77 m/s
14 fps / 150 mm
64 bpm / Genera
---2D---
H4.0MHz / 20 dB
DR: 55 dB
---Color---
CDV / 2.0MHz
-5 dB
1.00
m/s
1.00
2.00
3.00
4.00
5.00
6.00

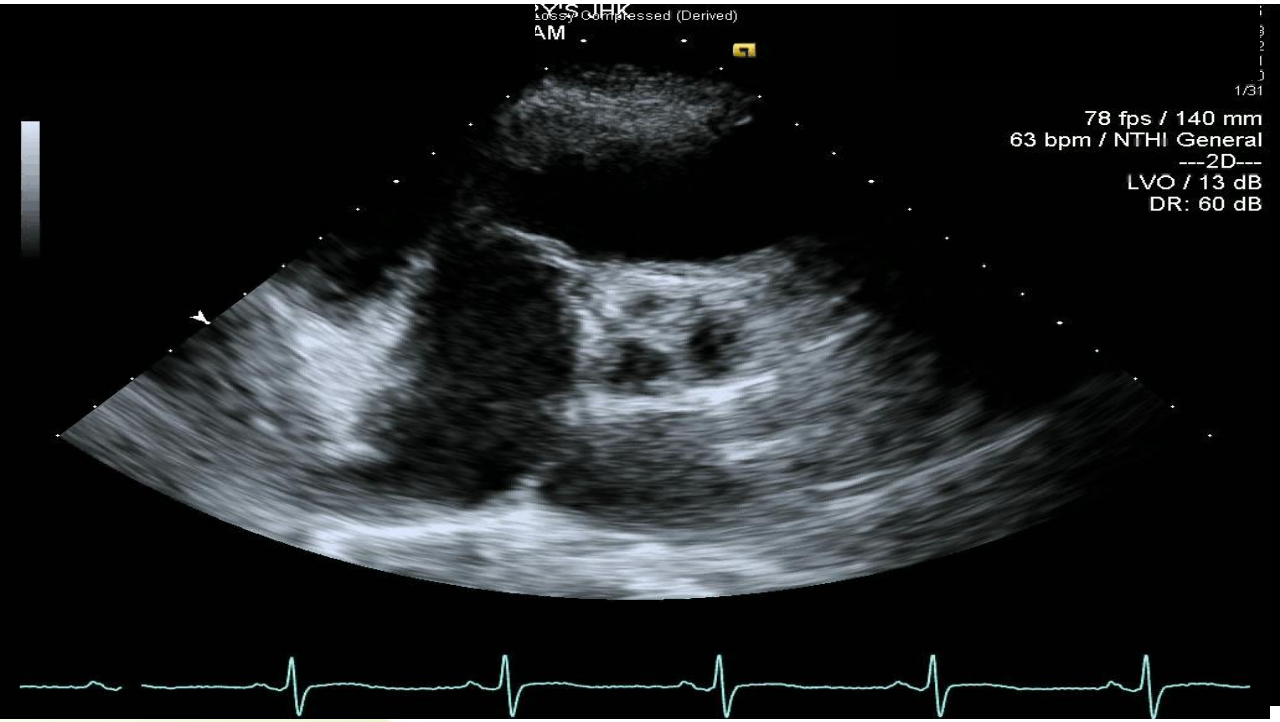
Echo


UJEONGBU ST.MARY'S HOSP
Cardia
0.69 m/s
0.69 m/s
1
80
1/20
17 fps / 170 mm
59 bpm / Gen Flow
---2D---
H4.0MHz / 5 dB
DR: 55 dB
---Color---
CDV / 2.0MHz
-5 dB

Echo

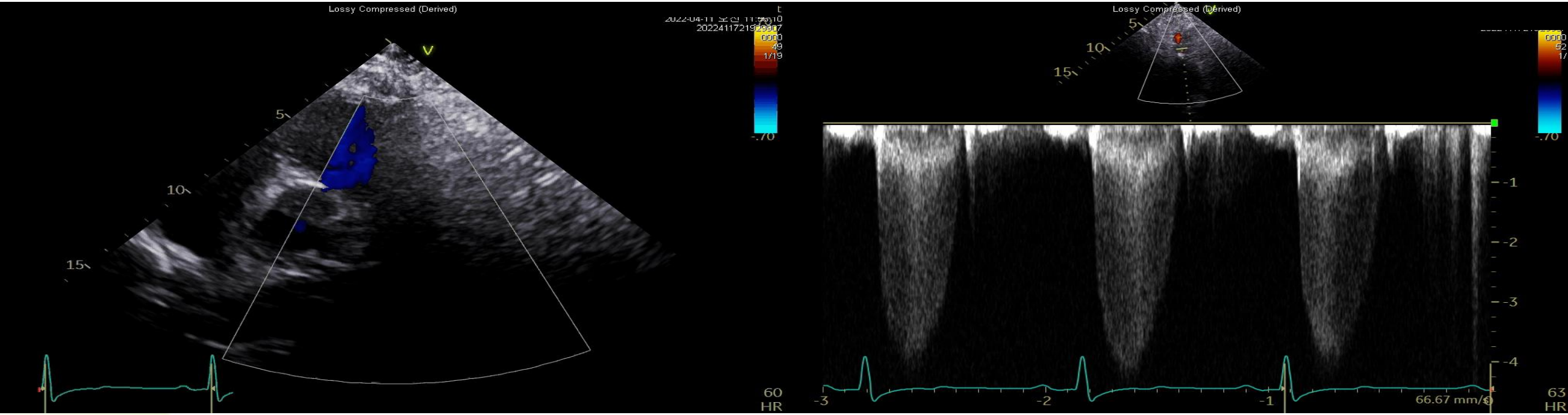

1 AM
74 fps / 150 mm
61 bpm / NTHI General
---2D---
LVO / 10 dB
DR: 60 dB
M
78 fps / 140 mm
61 bpm / NTHI General
---2D---
LVO / 20 dB
DR: 60 dB

Echo

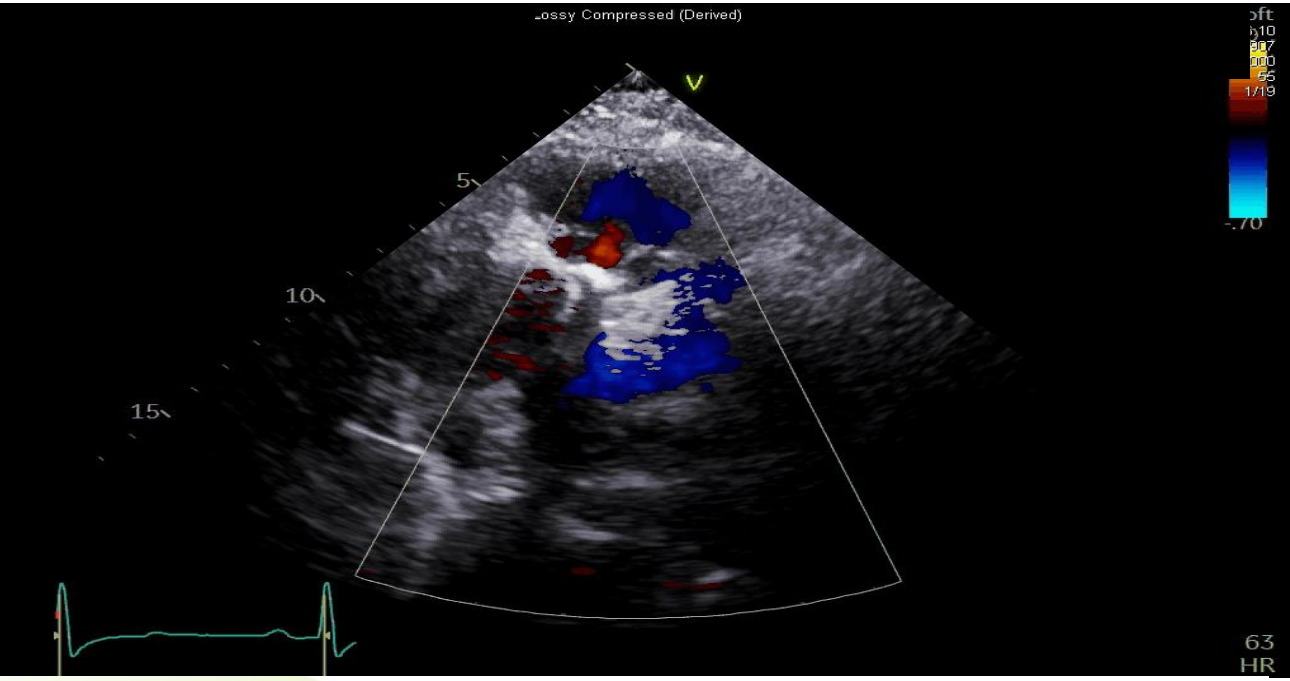

Lossy Compressed (Derived)
78 fps / 140 mm
63 bpm / NTHI General
---2D---
LVO / 13 dB
DR: 60 dB

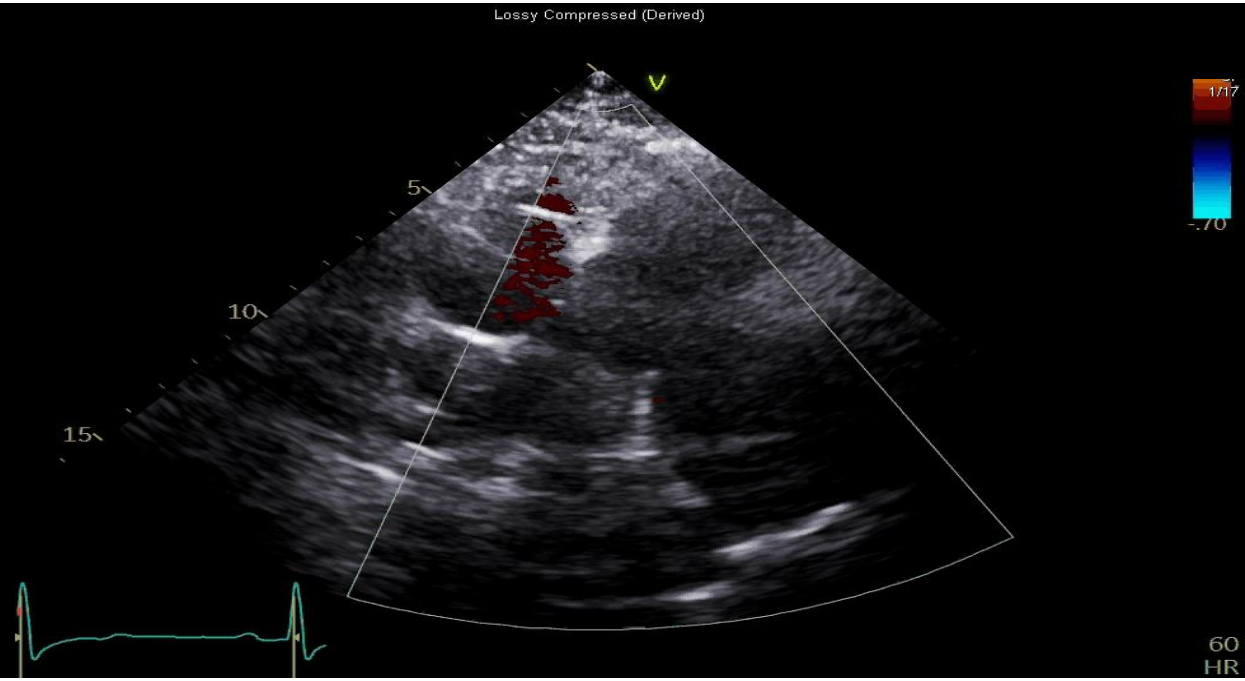

Lossy Compressed (Derived)
5
10
15
62
HR

Echo

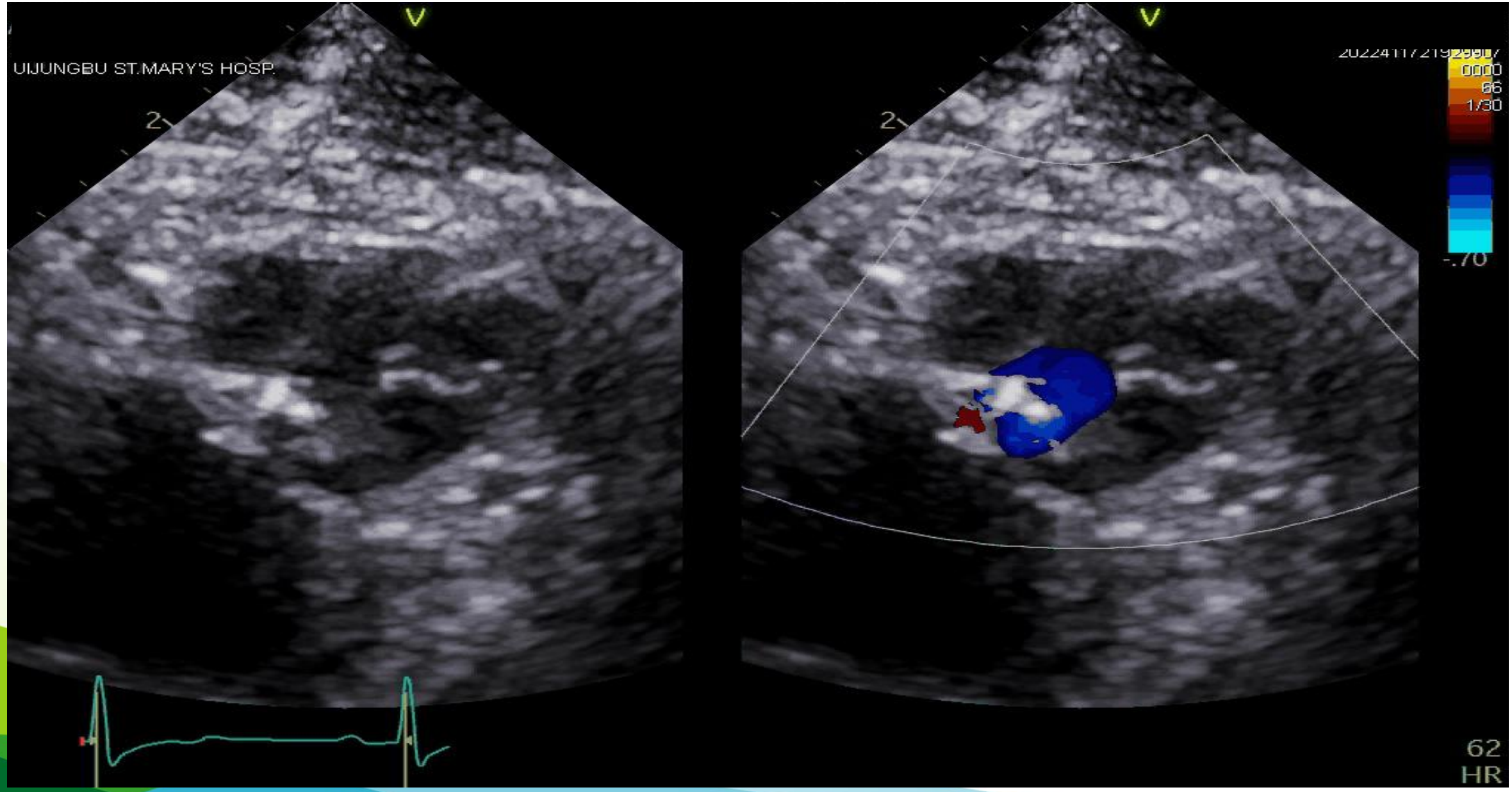

Lossy Compressed (Derived)
5
10
15
60
HR
Lossy Compressed (Derived)
5
10
15
-1
-2
-3
-4
-3
-2
-1
66.67 mm/s
63
HR

Echo

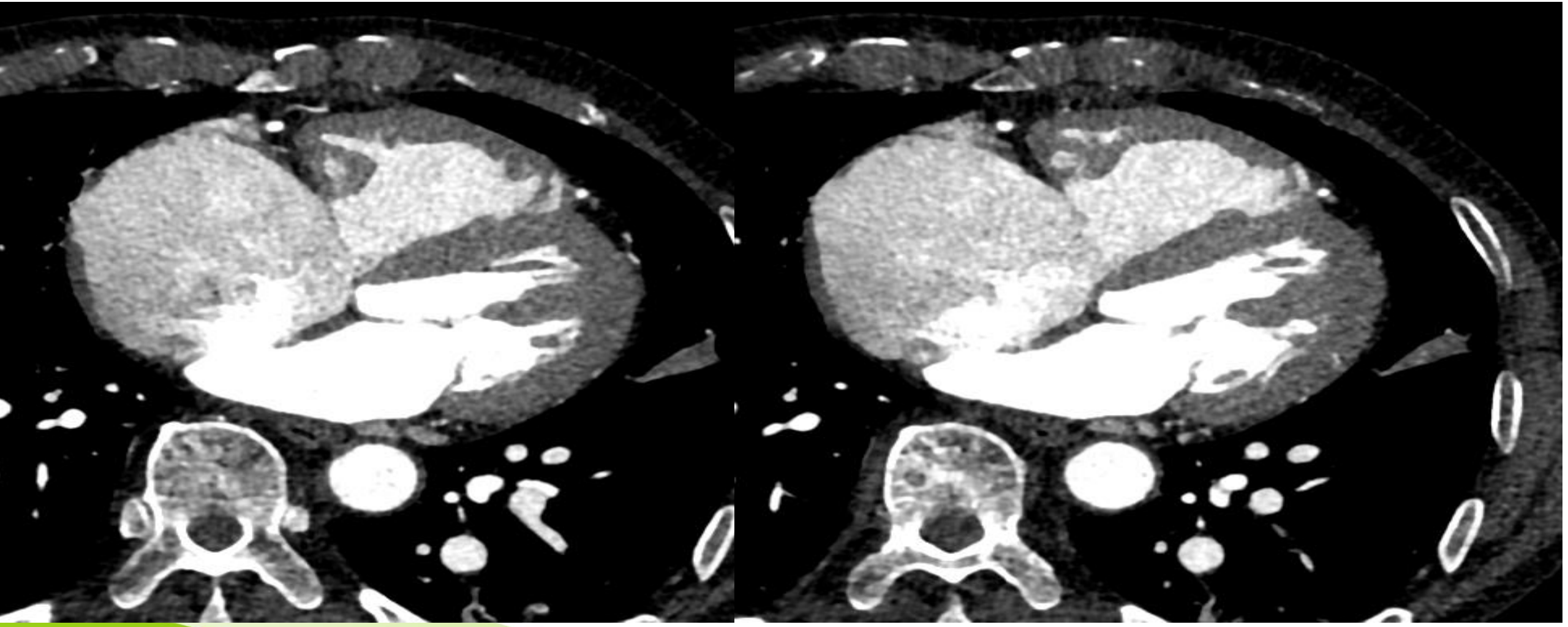

Lossy Compressed (Derived)
5
10
15
63
HR


Lossy Compressed (Derived)
5
10
15
60
HR

Echo

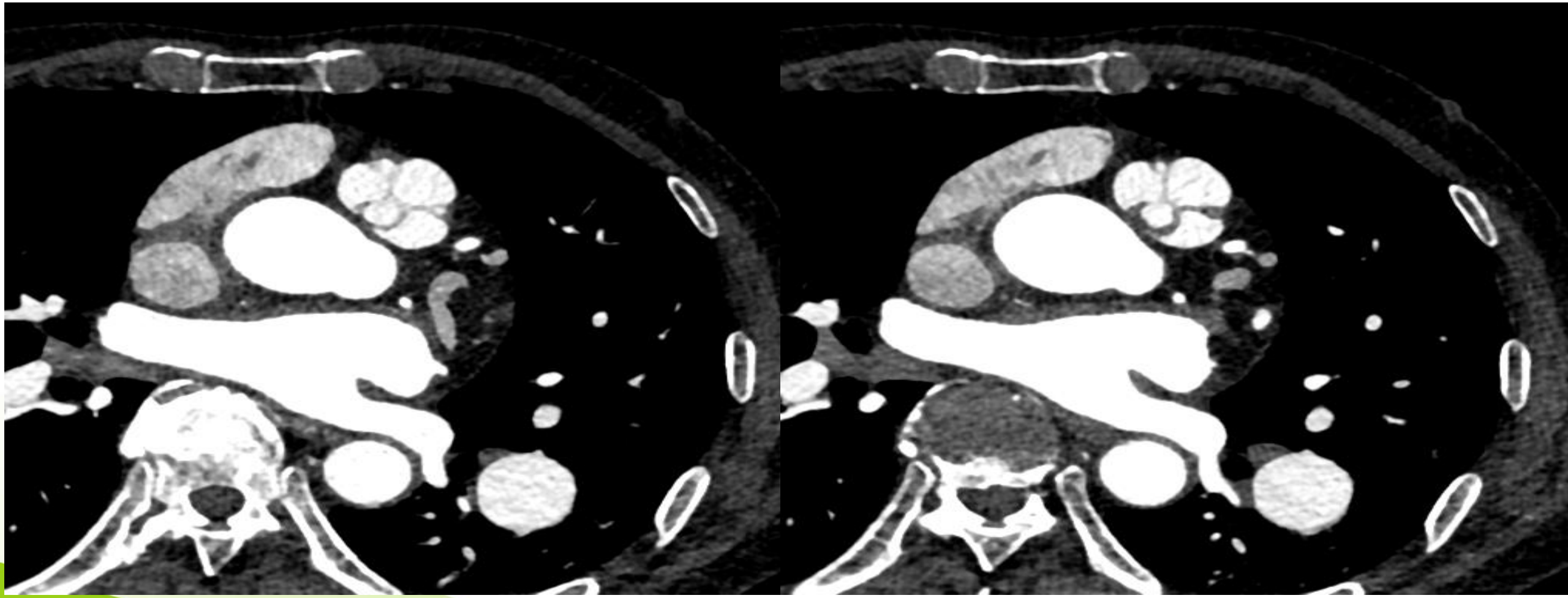


CT



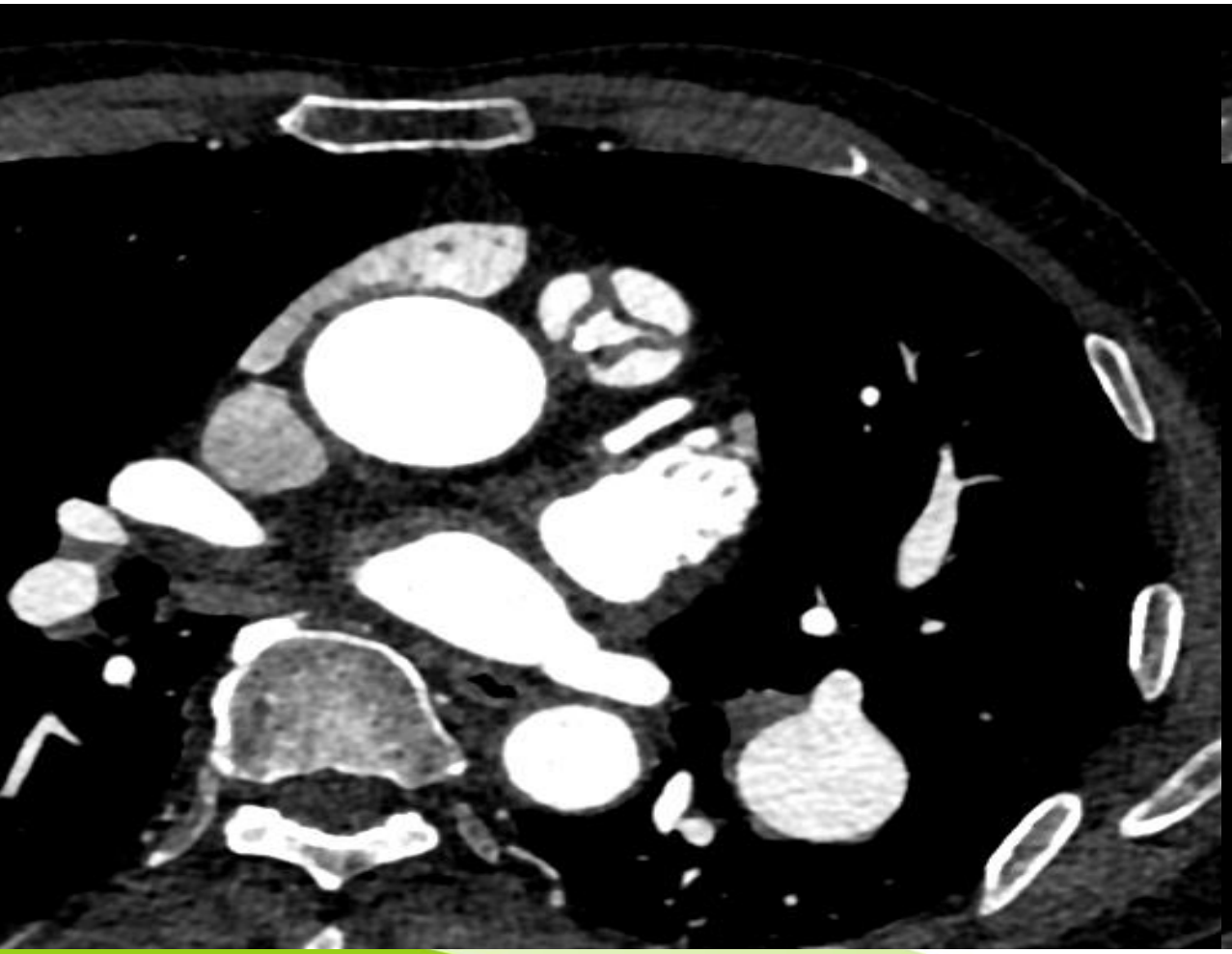
CT

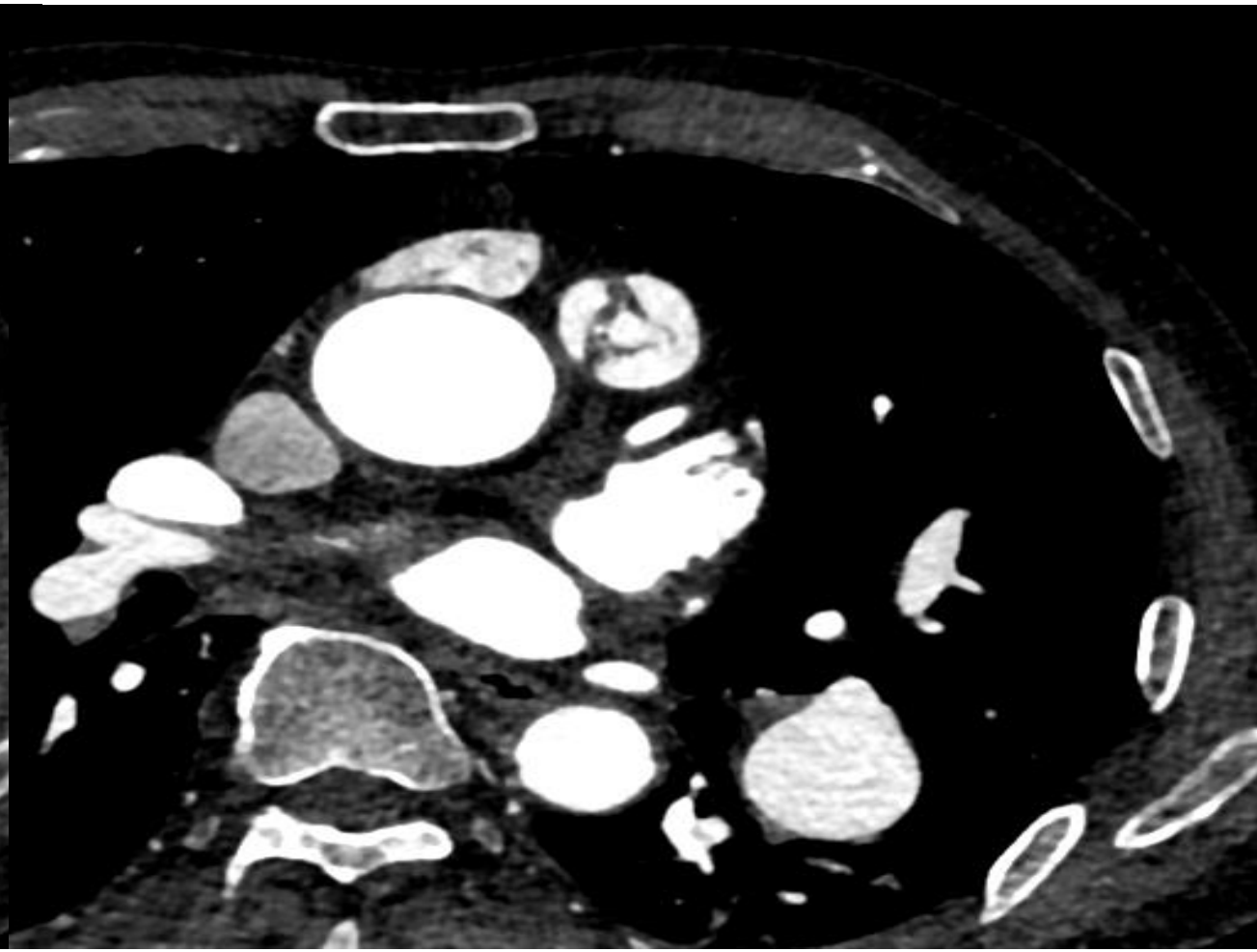
CT



CT

CT

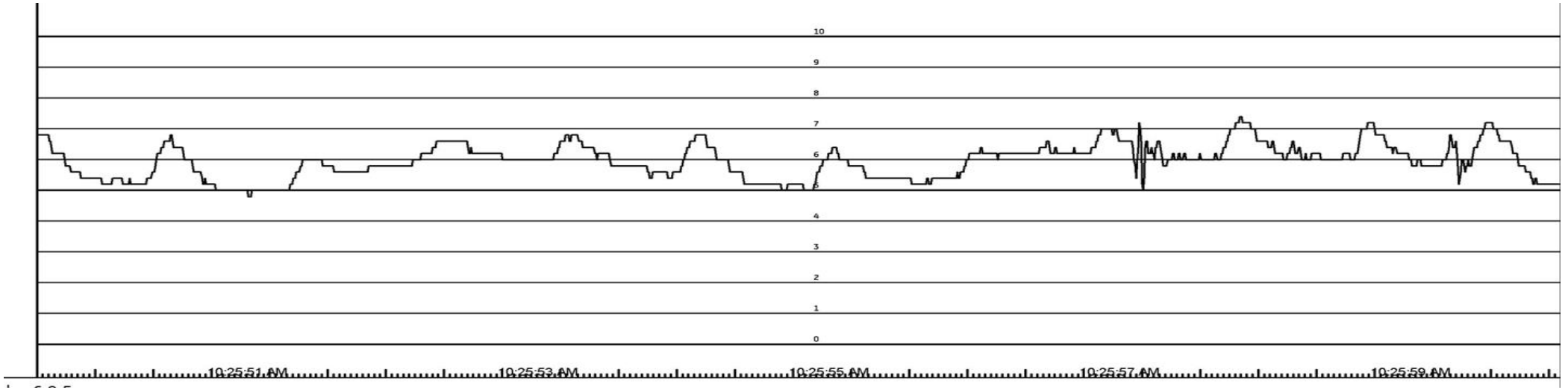




Rt heart catheterization

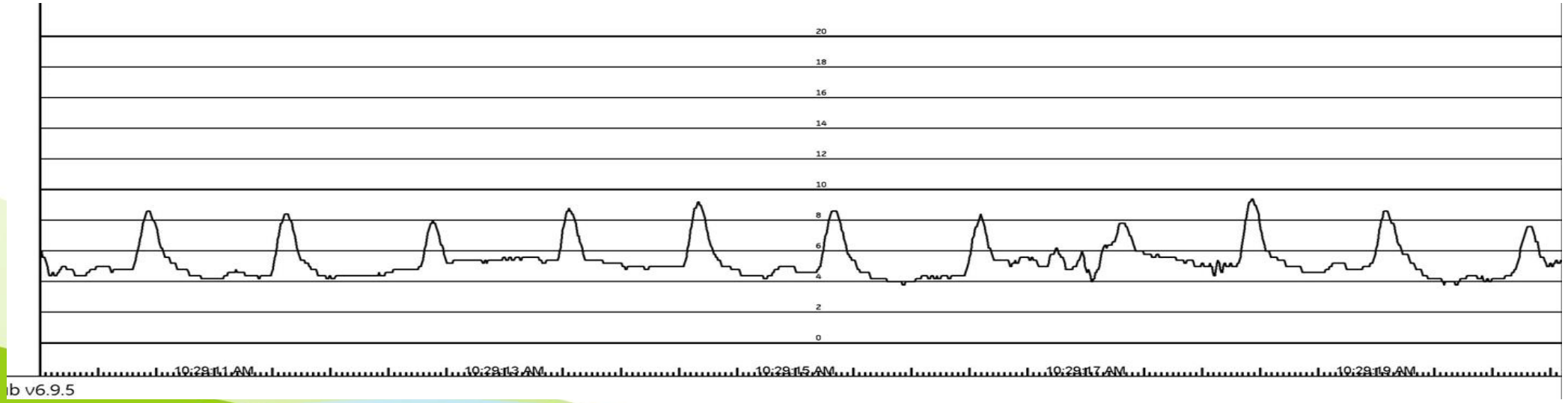
IVC

6mmHg



RA

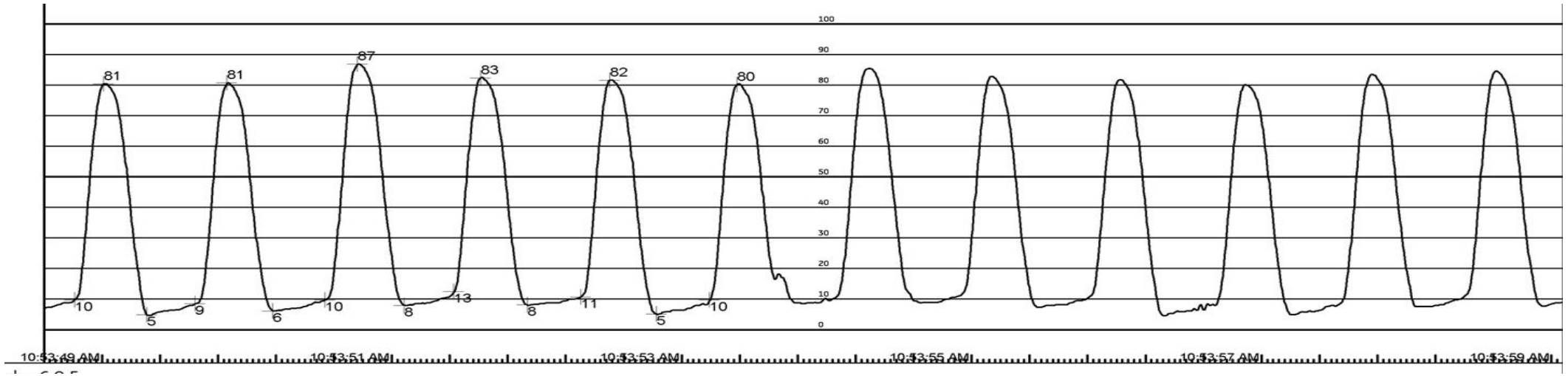
6mmHg



Rt heart catheterization

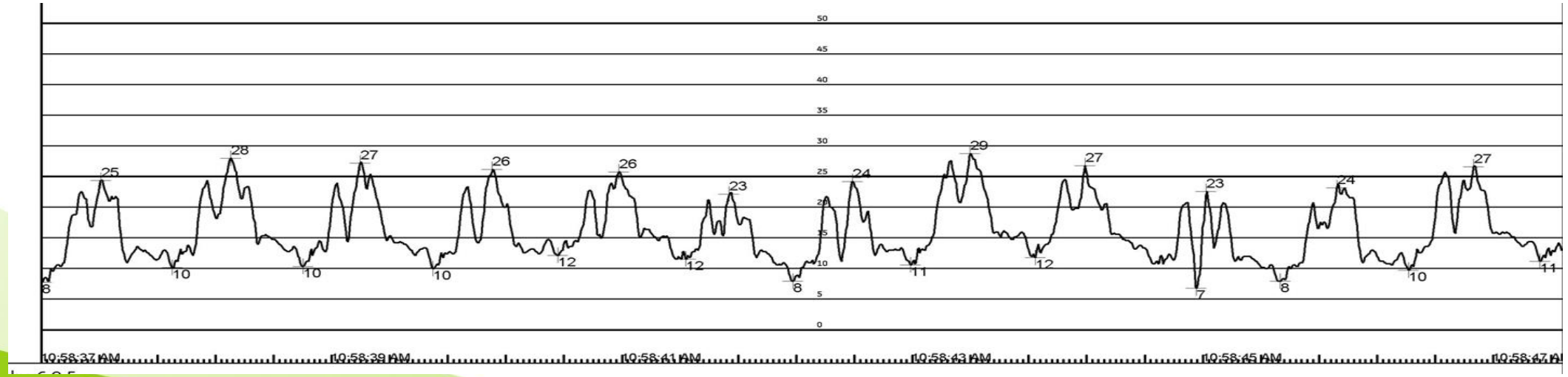
RV

83 /7 /11



PA

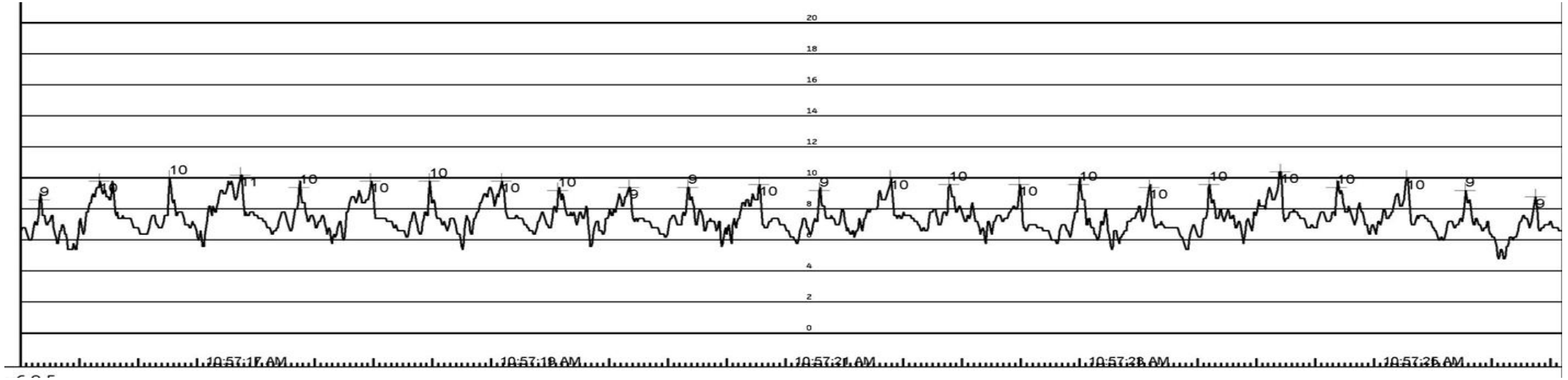
26/ 10 /16



Rt heart catheterization

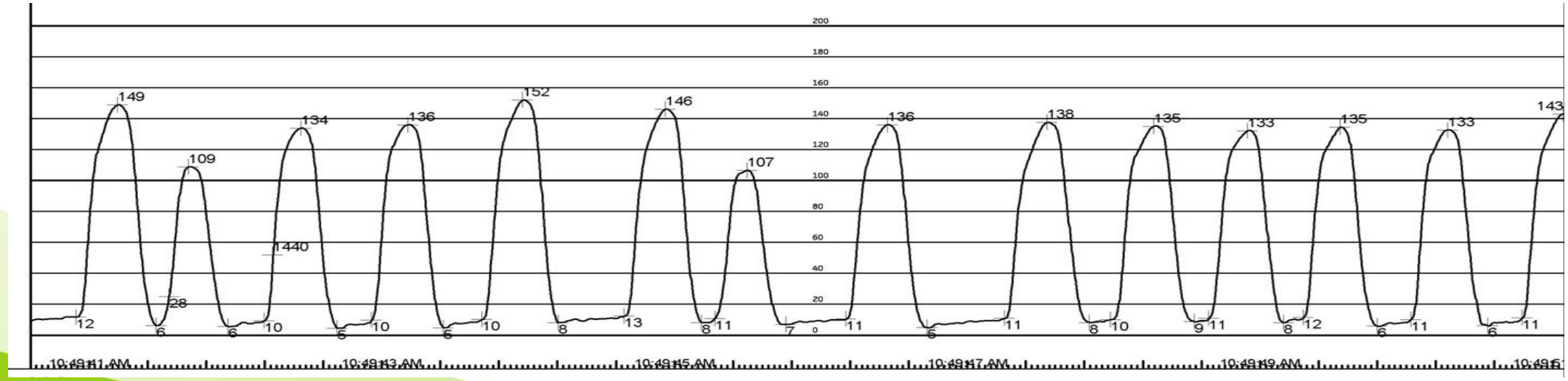
PAWP

8mmHg



LV

135 /7 /12



Rt heart catheterization

- Cardiac Output 3.13 L/min
- CO Index 2.01 L/min/m2
- PVR 2.23 WU
- SVR 27.8 WU
- Qp/Qs 1.29

Conclusion

- Moderate PS
- ASD
- No pulmonary hypertension

폐고혈압에서 심초음파의 적용

- 환자 찾아내기
  → 의심하고 심초음파 검사 시행하여 진단 하기

- 어떤 지표를 측정해야 하나?

- Rt heart catheterization을 대체할 수 있을까 ?

- 치료 반응 평가, 예후 예측

Thank You !