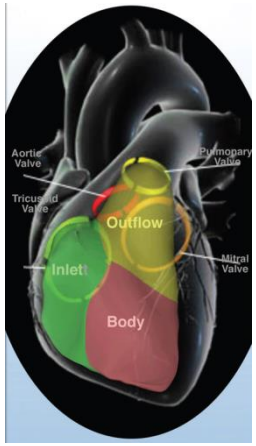
Echocardiographic Evaluation of the Right Ventricle



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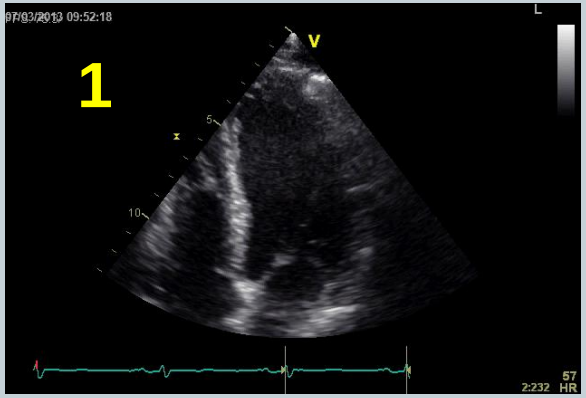
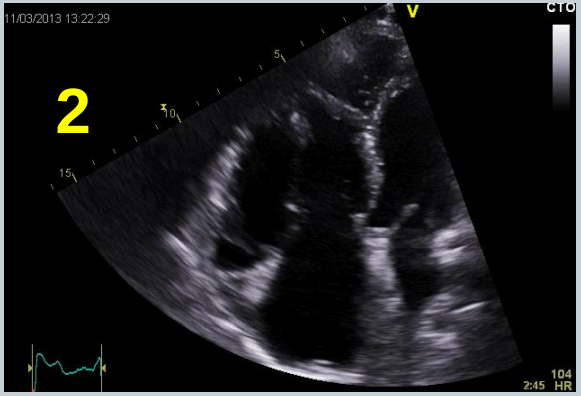
Question 1

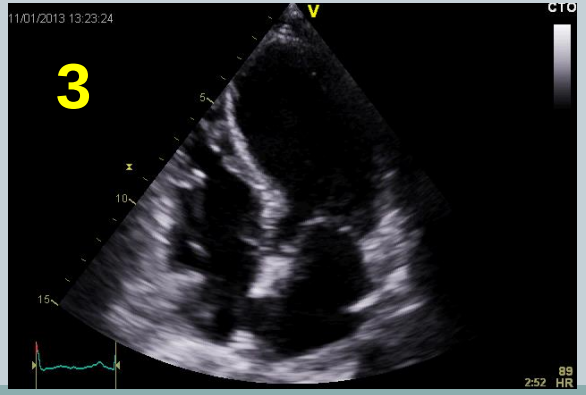
- A patient has the following quantitative measures of RV function. Which is NOT recommended to diagnose RV systolic dysfunction ASE guidelines
- A – Fractional area change of 30%
- B – TAPSE 15mm
- C- S' 8 cm/s
- D – Free wall strain by speckle tracking -17%
- E – MPI by pulsed Doppler of 0.5

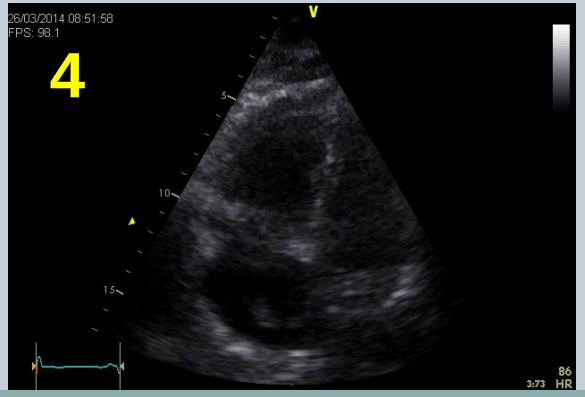
Question 2

- Of the clips below, which diagnosis is least likely to be represented









A – Acute Pulmonary Embolism

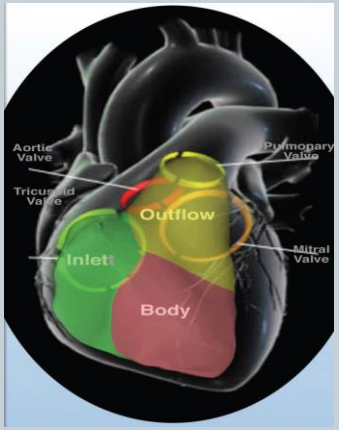
B – Pulmonary Arterial Hypertension

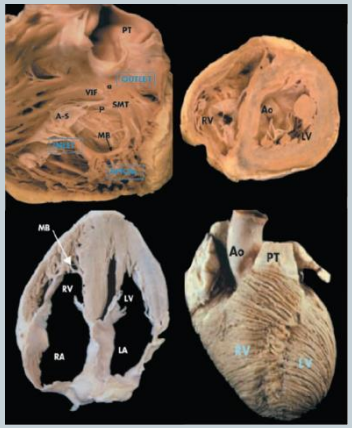
C- Atrial Septal Defect

D- RV infarction

E- Takotsubo Cardiomyopathy

Right Heart Anatomy

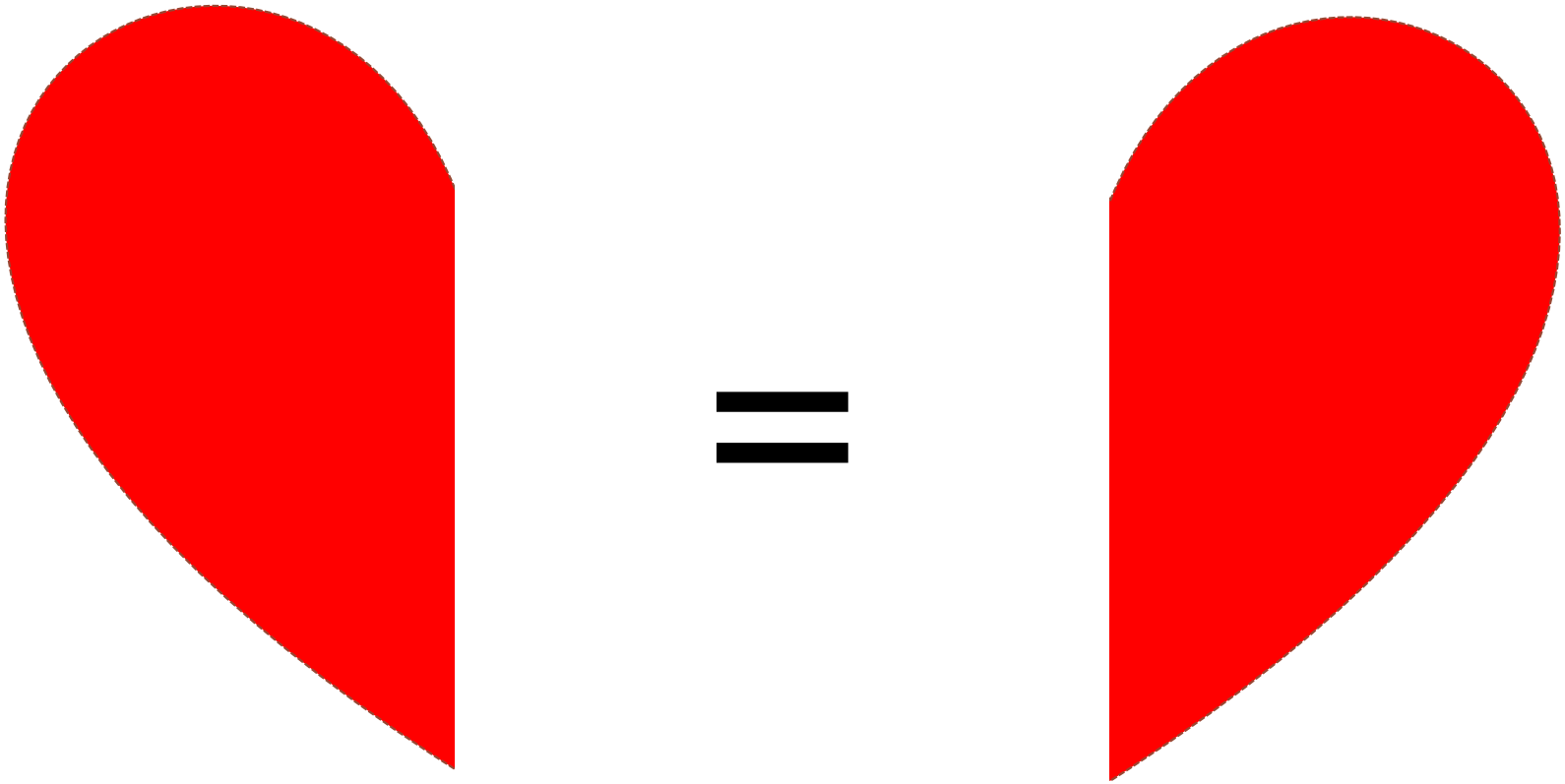




Haddad et al. Circulation 2008
Reproduced from Ho and Nihoyannopoulos Heart 2006

- Anterior Structure
- RA
- RV
  - inlet, body, infundibulum
- Tricuspid Valve
  - 3 leaflets, and papillary muscles
- Pulmonic Valve
- Longitudinal and circumferential fibers, but no spiral fibers

Stroke Volume R = Stroke Volume L



Who's Sicker?

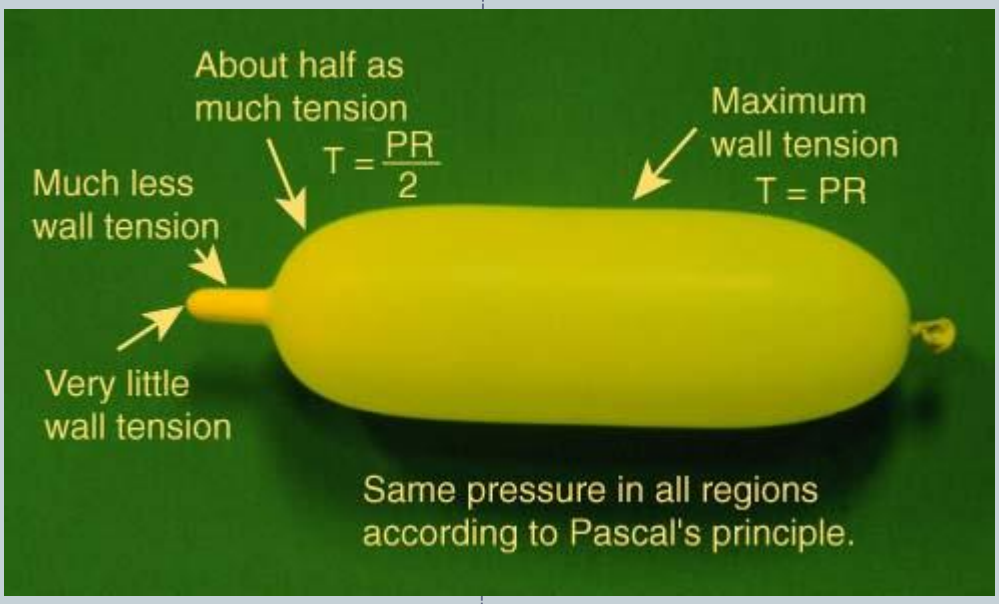
- Patient A - LVEDD 65mm, LVEF 20%, Moderate MR
- Patient B - LVEDD 36 mm, LVEF 60%, No MR
- Patient C - LVEDD 60 mm, LVEF 40-45%
- It depends

Fundamental Equations

- **Ohm's Law**
  V=I X R or P = Q X R

Laplace's Law
Wall Tension = (P X Radius) / M

This is a balloon



- http://hyperphysics.phy-astr.gsu.edu/hbase/ptens.html

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

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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JASE Jan 2015

Major Changes 2015

- RA volumes instead of area
- RV volumes and RVEF by 3D
  - Indexing by gender optional
- Minor changes in MPI, TAPSE, S’

Right Atrial Volume

>39 ml/m2 male
>33 ml/m2 female

- More representative of actual RA size than linear dimensions

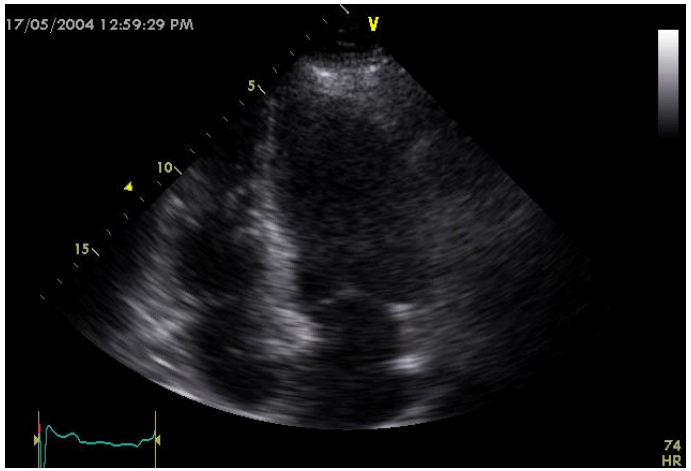
- Assumes a symmetrical shape of the cavity
- Single plane volume calculation may be inaccurate since it assumes that RA enlargement is symmetrical
- Normal values not well established

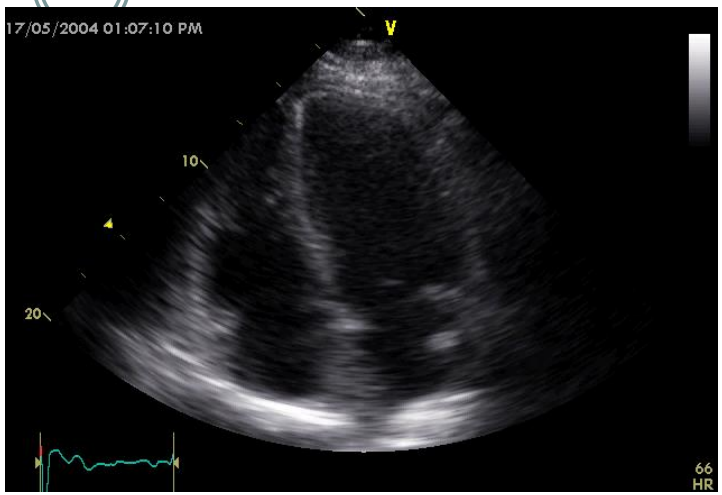
RV Size

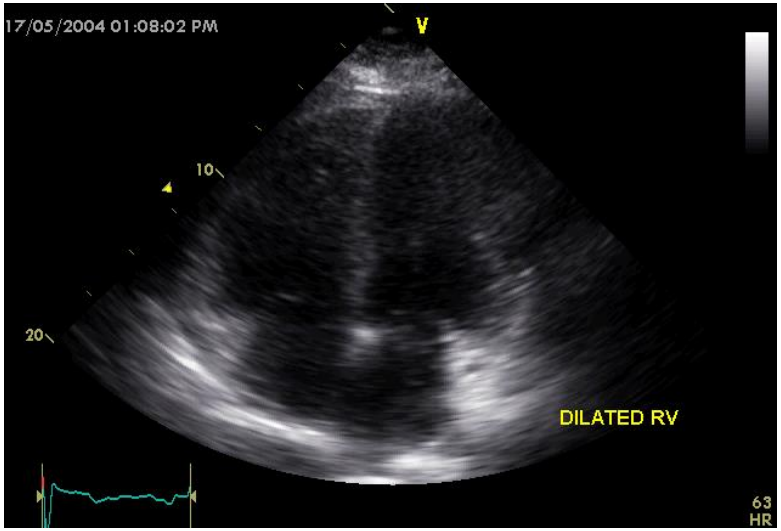

Wavelength
Multi-Purpose
Ultrasound Gel
500mL
NATIONAL THERAPY


Cor
Bovinum
Dexter

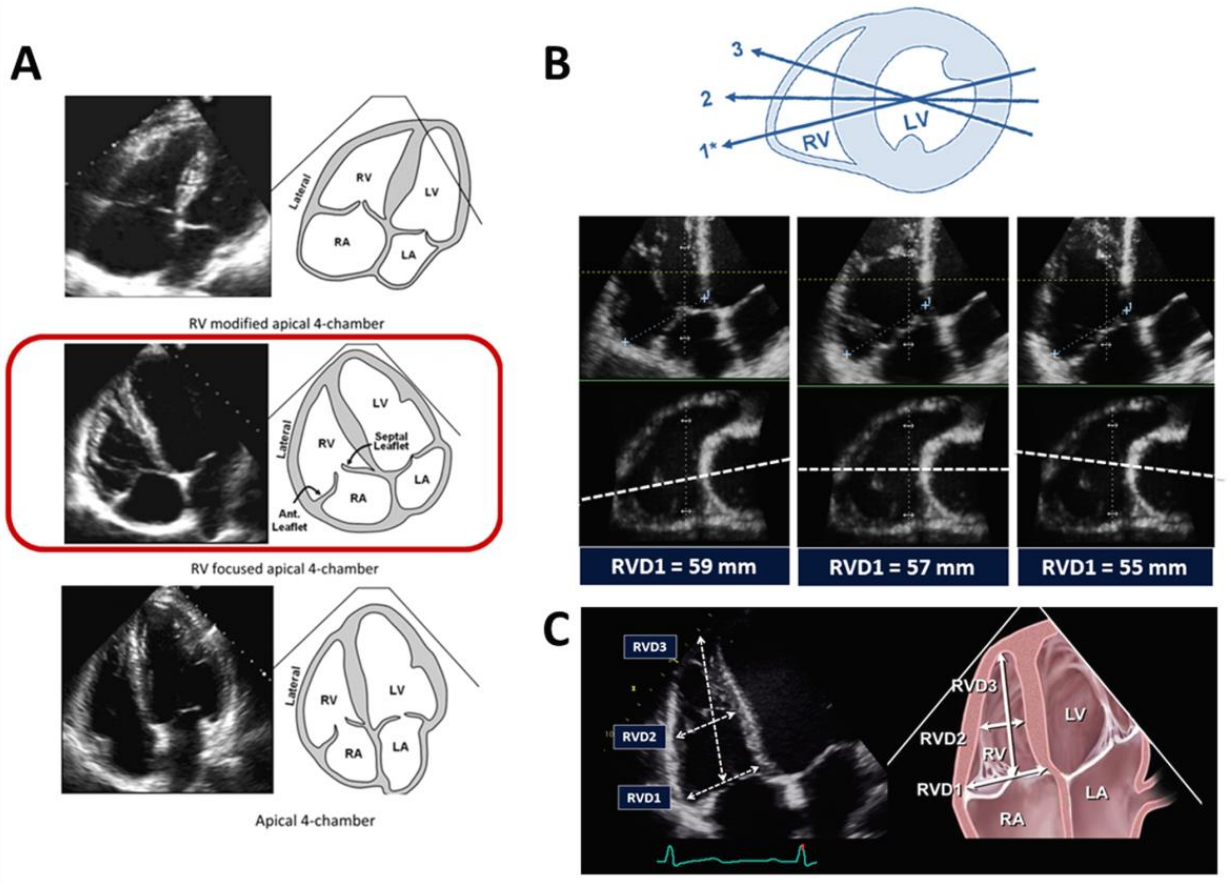
Small, Medium, or Large?







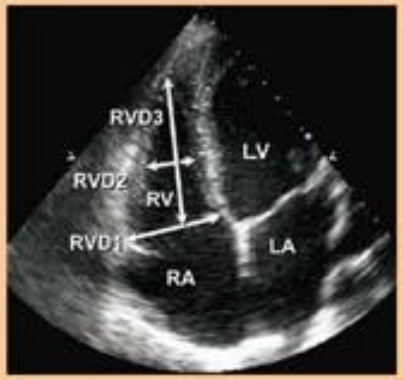
Courtesy of Dr. I. A. Sebag

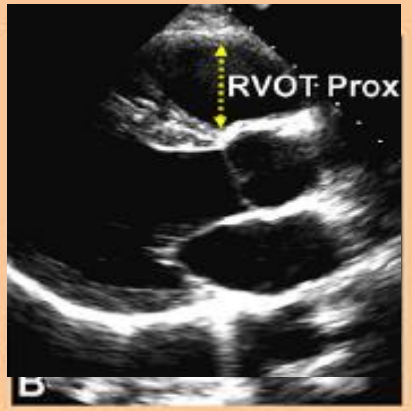


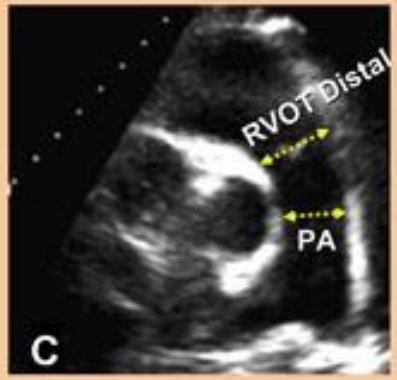
Courtesy Denisa Muraru

Measurements:

Chamber Quantification







Variable	Abnormal
A. RV Basal (RVD1)	> 4.2 cm
RV Mid (RVD2)	> 3.5 cm
RV Longitudinal (RVD3)	> 8.6 cm
B. RVOT PLAX proximal	> 3.3 cm
C. RVOT PSAX distal	> 2.7 cm

Table 8 Normal values for RV chamber size

Parameter	Mean ± SD	Normal range
RV basal diameter (mm)	33 ± 4	25-41
RV mid diameter (mm)	27 ± 4	19-35
RV longitudinal diameter (mm)	71 ± 6	59-83
RVOT PLAX diameter (mm)	25 ± 2.5	20-30
RVOT proximal diameter (mm)	28 ± 3.5	21-35
RVOT distal diameter (mm)	22 ± 2.5	17-27
RV wall thickness (mm)	3 ± 1	1-5
RVOT EDA (cm^2)		
Men	17 ± 3.5	10-24
Women	14 ± 3	8-20
RV EDA indexed to BSA (cm^2/m^2)		
Men	8.8 ± 1.9	5-12.6
Women	8.0 ± 1.75	4.5-11.5
RV ESA (cm^2)		
Men	9 ± 3	3-15
Women	7 ± 2	3-11
RV ESA indexed to BSA (cm^2/m^2)		
Men	4.7 ± 1.35	2.0-7.4
Women	4.0 ± 1.2	1.6-6.4

RV Base – 41mm

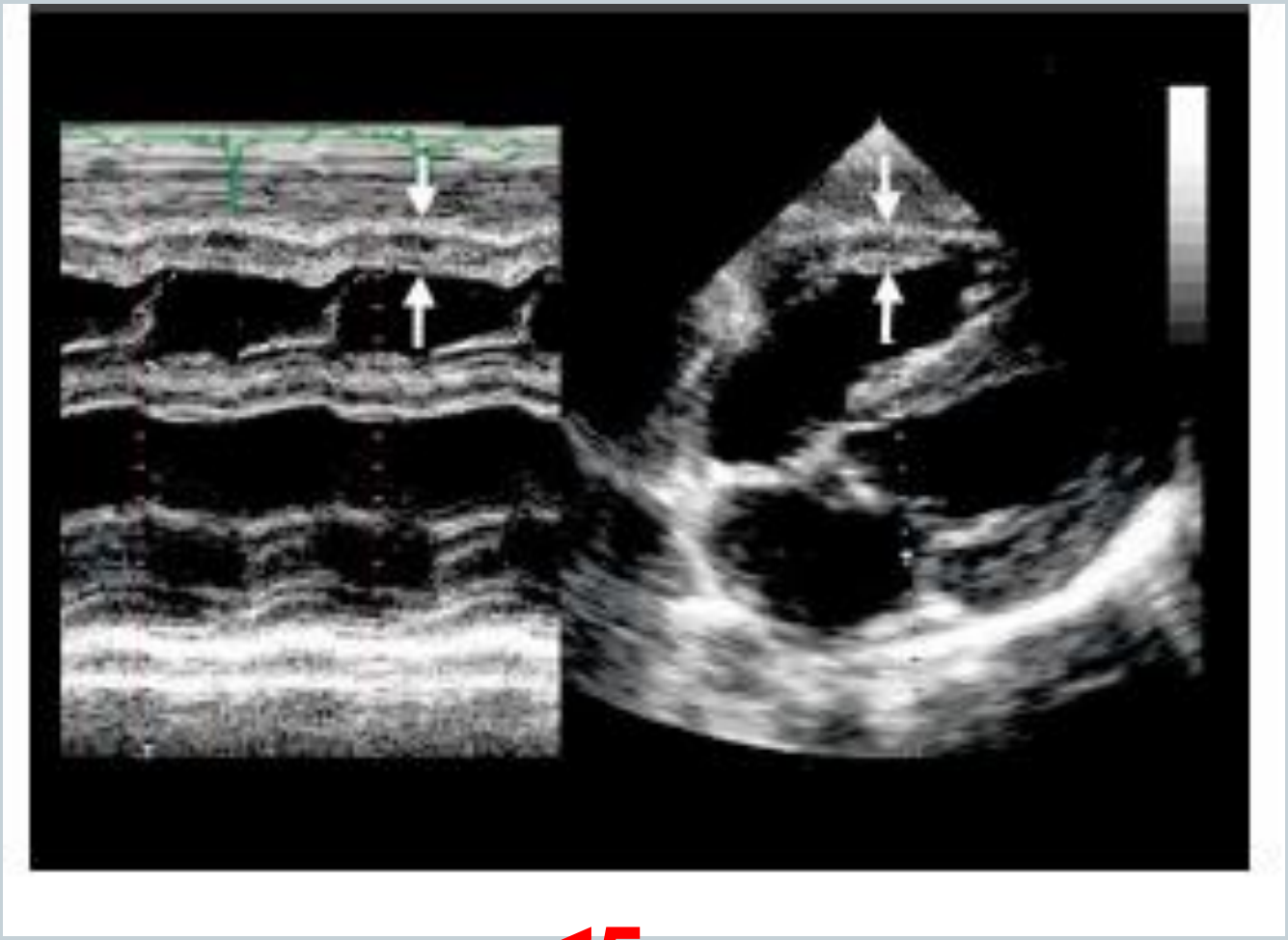
RV EDV indexed to BSA (mL/m^2)		
Men	61 ± 13	35-87
Women	53 ± 10.5	32-74
RV ESV indexed to BSA (mL/m^2)		
Men	27 ± 8.5	10-44
Women	22 ± 7	8-36

EDA, end-diastolic area; *ESA*, end-systolic area; *PLAX*, parasternal long-axis view; *RVOT*, RV outflow tract.

		RV EDV (mL/m^2)		RV ESV (mL/m^2)	
Age (y)	n (women, men)	Women	Men	Women	Men
<30	102 (45, 57)	53 (38, 78)	66 (42, 100)	20 (8, 45)	28 (16, 52)
30–39	96 (50, 46)	50 (38, 77)	58 (35, 85)	18 (11, 38)	23 (12, 38)
40–49	96 (53, 43)	50 (34, 65)	54 (36, 78)	18 (8, 27)	21 (11, 33)
50–59	88 (47, 41)	49 (37, 69)	53 (36, 76)	18 (11, 29)	19 (10, 37)
60–69	69 (39, 30)	46 (26, 64)	52 (37, 86)	17 (8, 26)	19 (10, 36)
≥70	37 (23, 14)	43 (25, 62)	54 (31, 68)	12 (7, 21)	18 (7, 28)

Data are expressed as median (5th, 95th percentile).

RV Wall Thickness



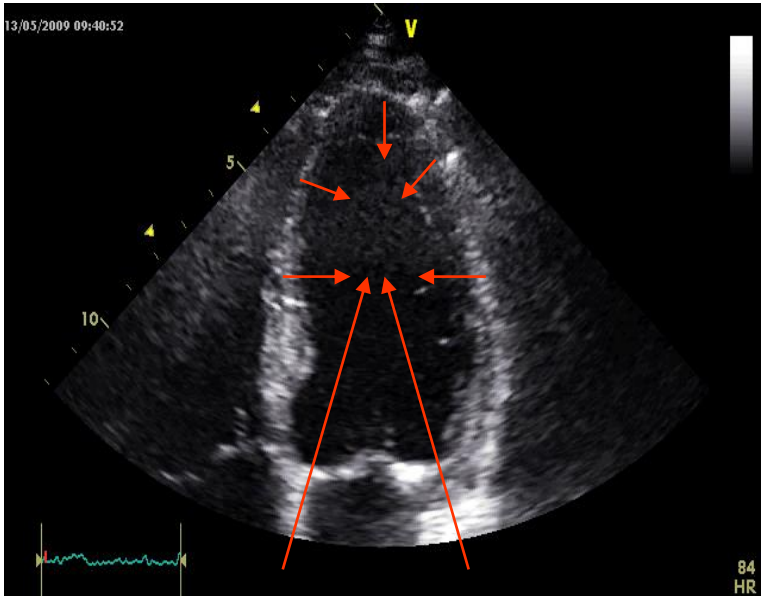
≤5mm

RV Systolic Function

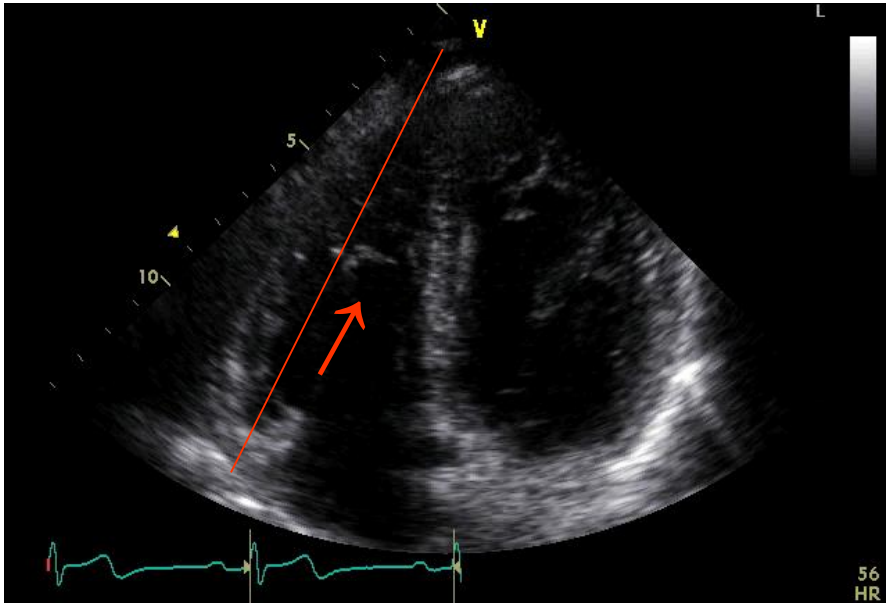
- Global
  - RV Ejection Fraction
  - RV Fractional Area Change %
  - Dp/dt
  - Myocardial Performance Index
  - 2D strain
- Regional
  - Tricuspid Annular Plane Systolic Excursion
  - S' (Doppler myocardial velocity in systole)

RV Contractile Pattern vs. LV

Left Ventricle

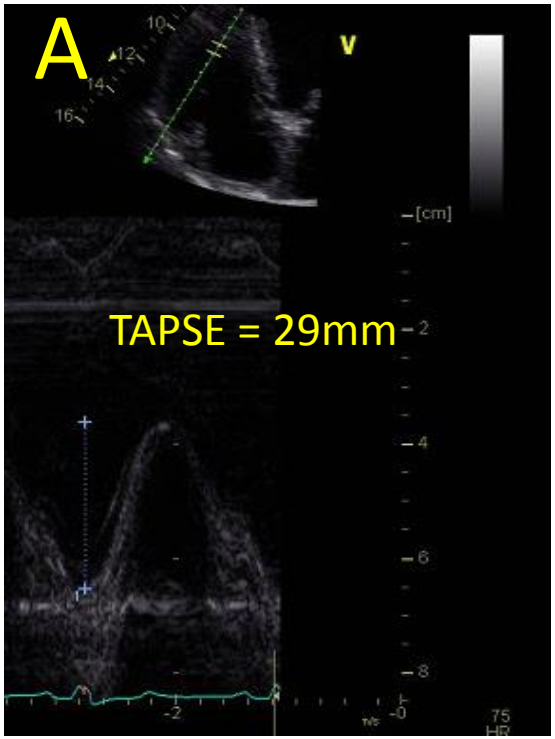


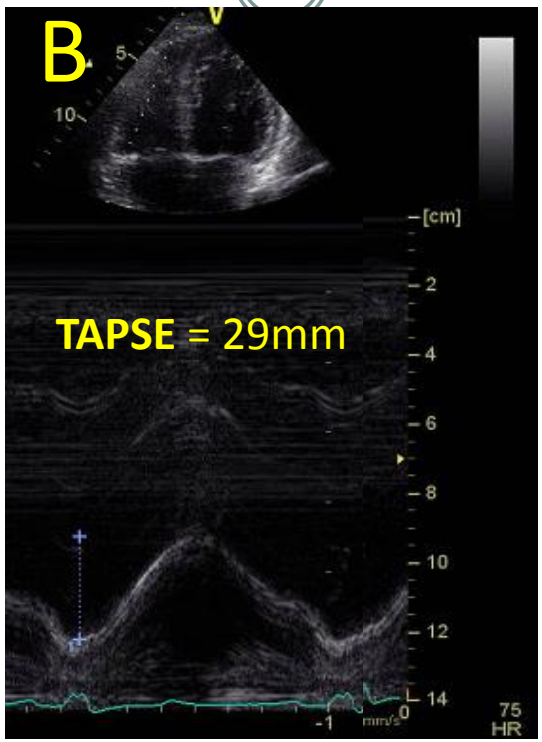
Right Ventricle



Courtesy – M-J Blais RDCS

TAPSE

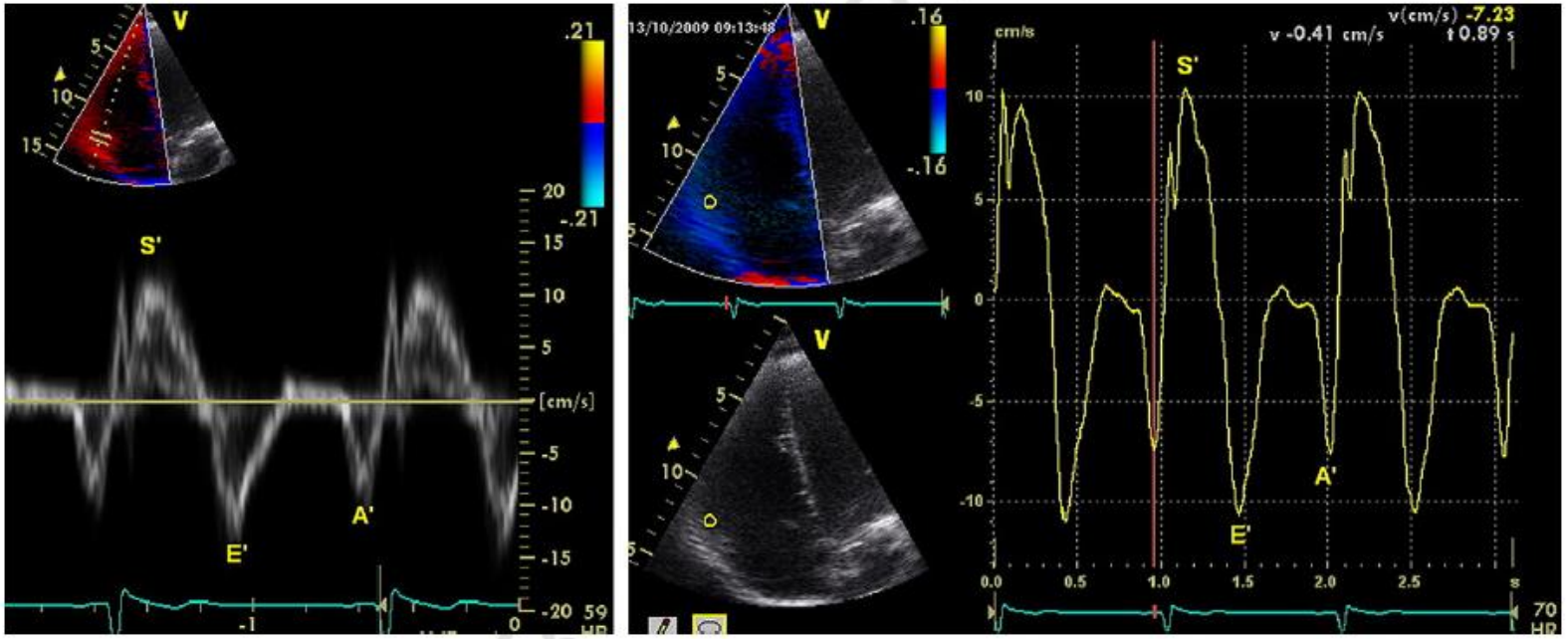




- √ Simple – align !
- √ Reproducible
- √ Prognostic

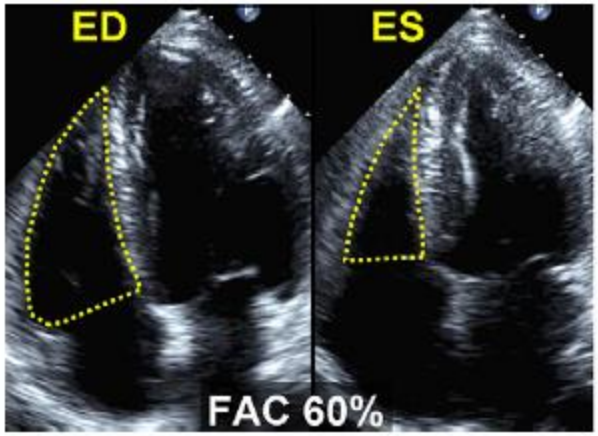
Abnormal TAPSE < 17 mm

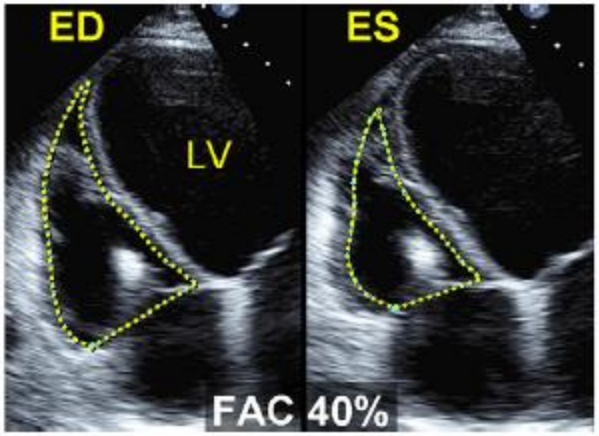
S’ (Tissue Doppler)

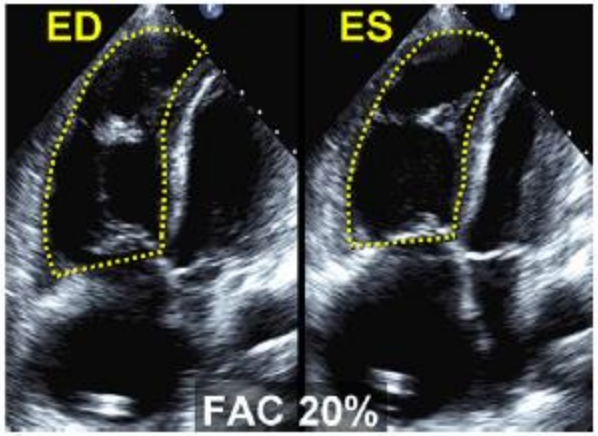


Abnormal Threshold < 9.5 cm/s

Fractional Area Change



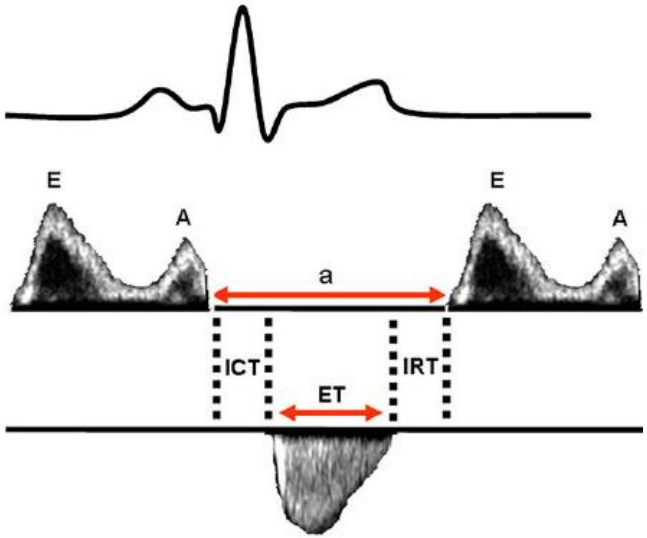




Recommendations: Two-dimensional Fractional Area Change is one of the recommended methods of quantitatively estimating RV function, with a lower reference value for normal RV systolic function of 35%.

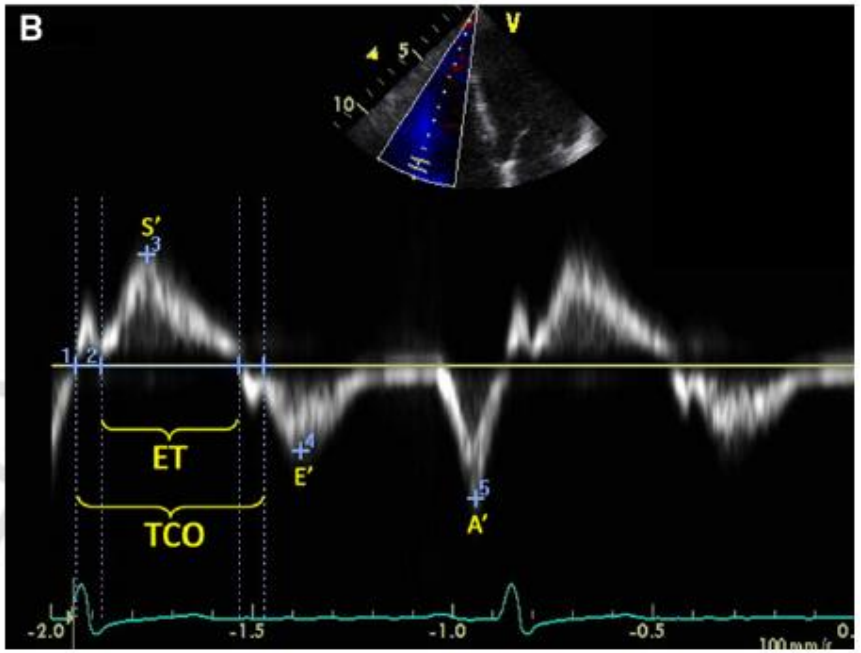
- √ Simple – standard A4c
- √ Reproducible – watch trabeculations
- √ Prognostic- PH, HF

Myocardial Performance Index



$$\text{RVMPI} = \frac{(\text{ICT} + \text{IRT})}{\text{ET}} = \frac{(a - \text{ET})}{\text{ET}}$$

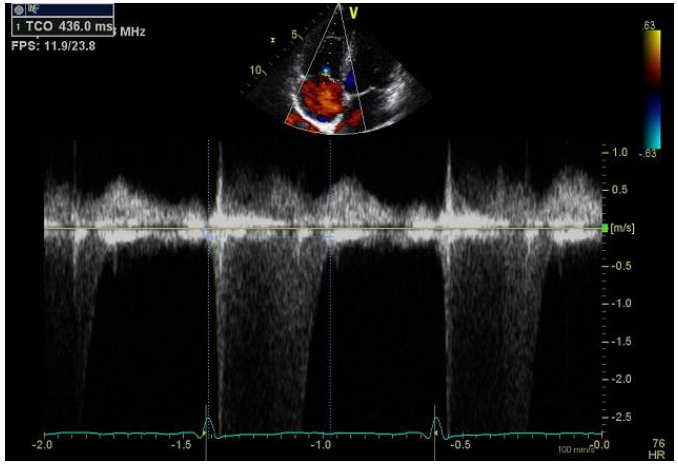
Horton et al. JASE 2009:22;776

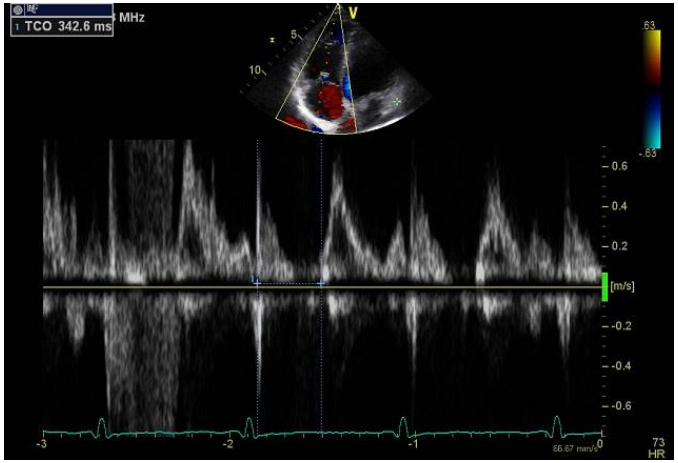


Abnormal **> 0.43 by Pulsed Doppler**
> 0.54 by Tissue Doppler

Caveats
-Pulsed Doppler – Different R-R intervals
-"Pseudonormal" with high RA pressure
-Preload dependant
-HR 60-100

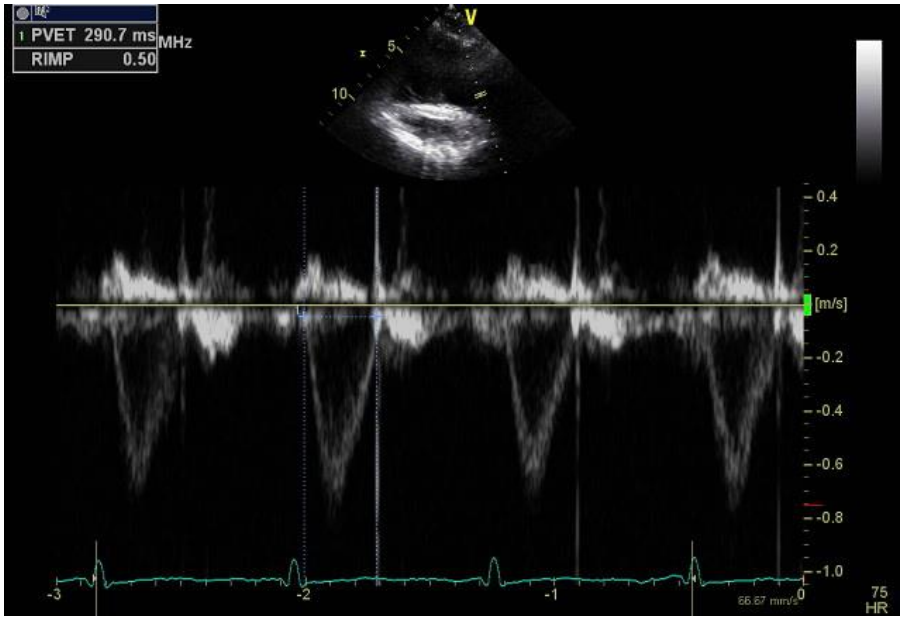
Closure-Opening time of Tricuspid Valve



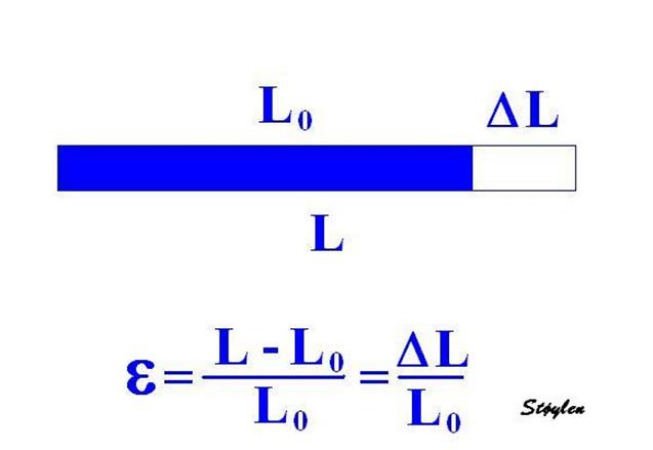


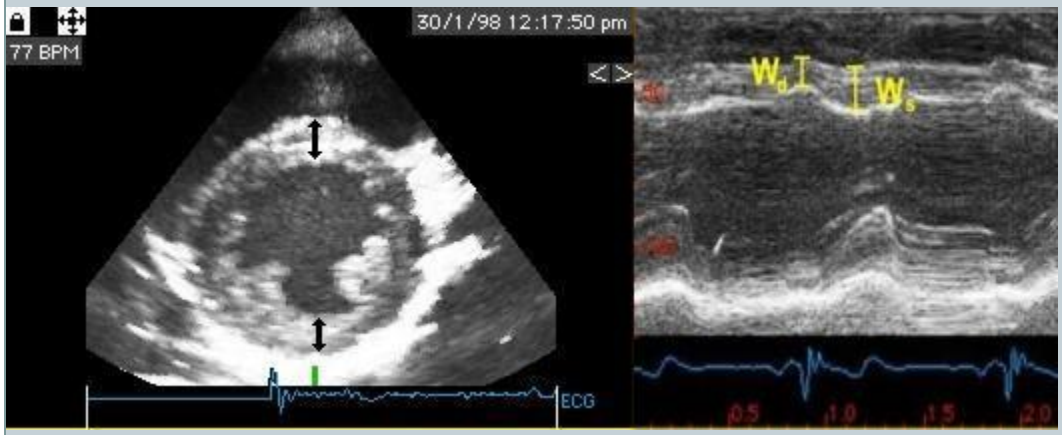
- small sample volume
- Leaflet tips

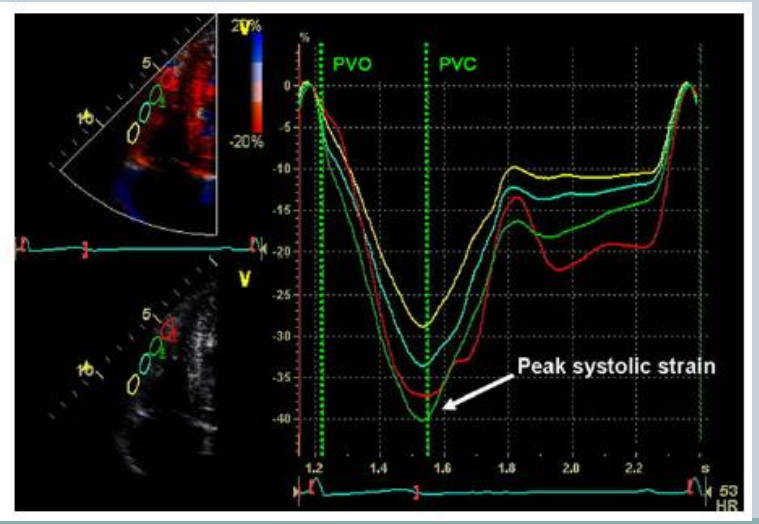
Measurement of ejection time



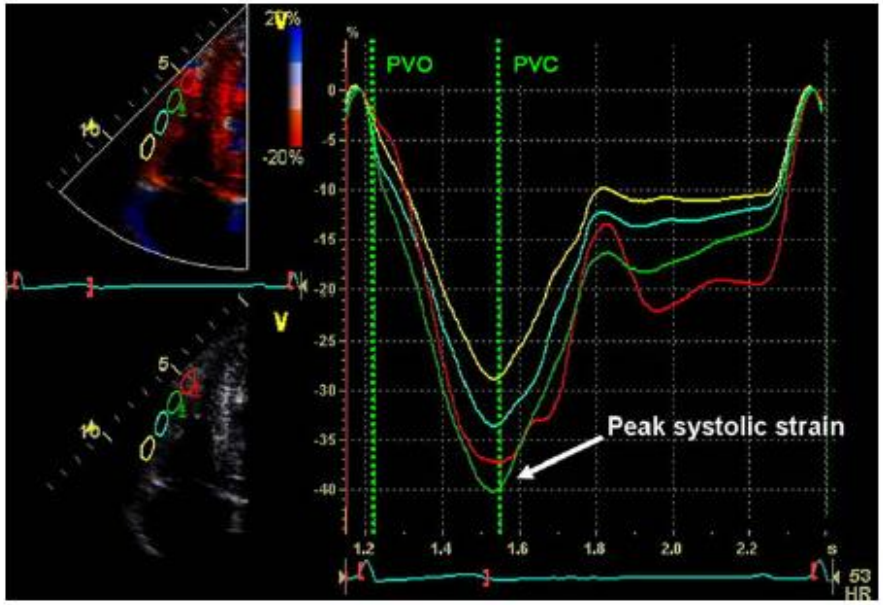
Strain


L_0
ΔL
L
$\varepsilon = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$
Stylen


77 BPM
30/1/98 12:17:50 pm
ECG
W_d
W_s


PVO
PVC
Peak systolic strain
HR

RV Strain

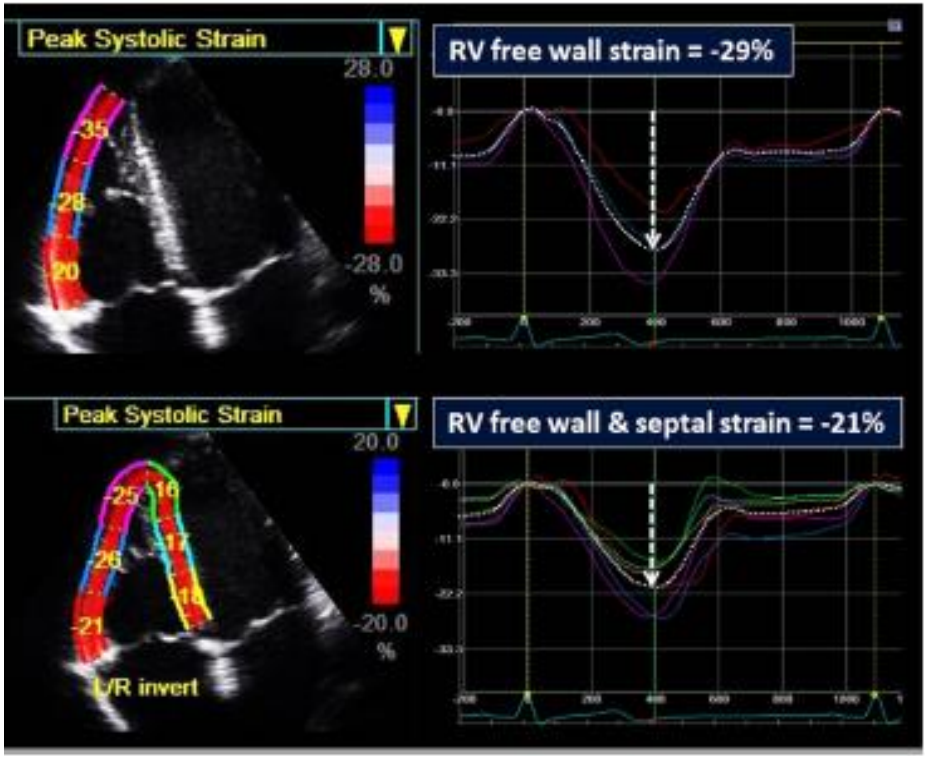


Horton et al. JASE 2009:22;776

Recommendations: The significant disadvantages listed above limit the clinical use of regional RV strain. Reference limits cannot be recommended, because of very wide confidence intervals both around the mean values and around the reference limits. Strain and strain rate remain research tools in experienced labs until their limitations can be overcome.

√ Simple
√ Reproducible
√ Prognostic

Strain – 2 D

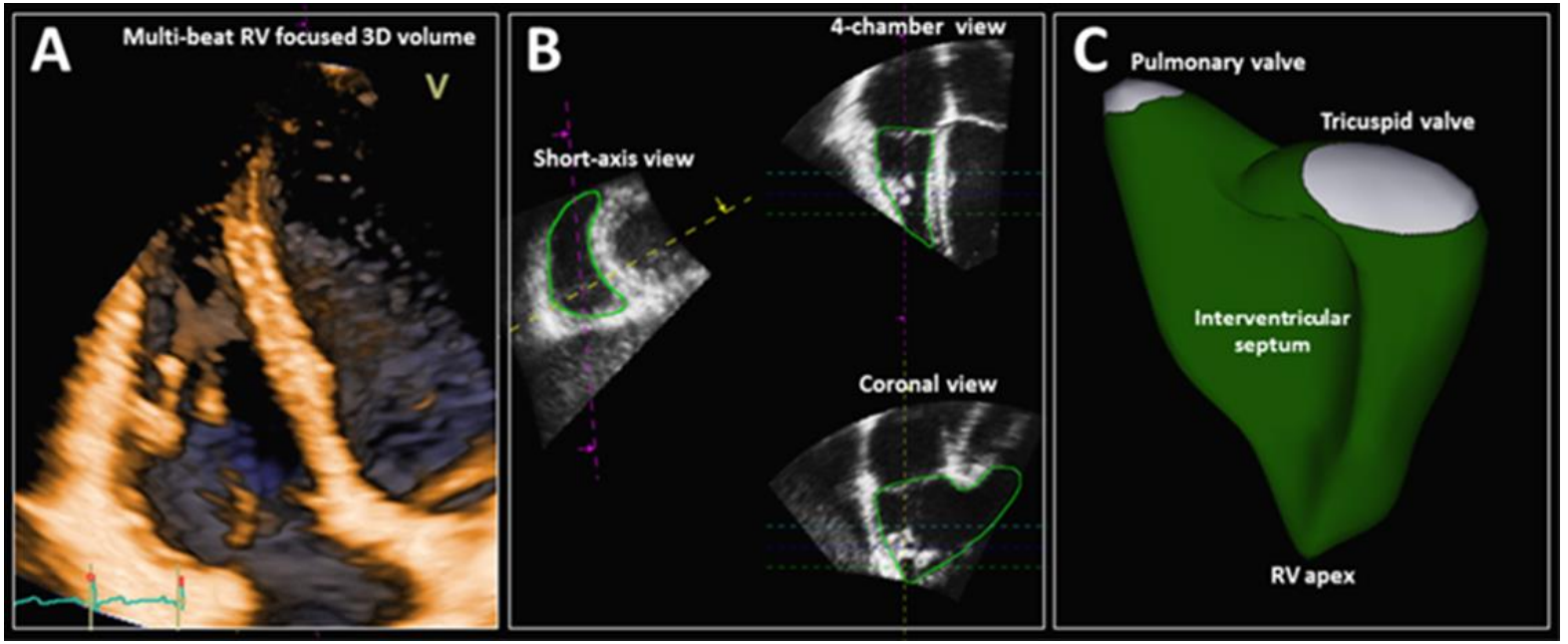


Abnormal Threshold < -20% **

Recommendations. Two-dimensional STE-derived strain, particularly of the RV free wall, appears to be reproducible and feasible for clinical use. Because of the need for additional normative data from large studies involving multivendor equipment, no definite reference ranges are currently recommended for either global or regional RV strain or strain rate.

RV Ejection Fraction

- Avantages
  - Widely accepted concept
  - Prognosticates in CHF, valvular heart disease, congenital heart disease
- Disadvantages
  - Many different techniques with broad differences and variability.
    - 2D vs. 3D, Rotation vs. Disk Summation
  - “Load Dependent"
  - Does not represent “contractility” when significant TR



√ Simple
√ Reproducible
√ Prognostic

RVEF higher in women - smaller volumes

Recommendation. In laboratories with appropriate 3D platforms and experience, 3DE-derived RV EF should be considered as a method of quantifying RV systolic function, with the limitations mentioned above. Roughly, an RV EF of <45% usually reflects abnormal RV systolic function, though laboratories may choose to refer to age- and gender-specific values.

	RV EF (%)	
Age (y)	Women	Men
<30	60 (43, 82)	56 (42, 68)
30–39	63 (50, 78)	60 (47, 74)
40–49	65 (49, 80)	59 (51, 75)
50–59	62 (46, 76)	62 (45, 74)
60–69	61 (50, 79)	63 (49, 79)
≥70	71 (57, 82)	65 (55, 76)

Summary

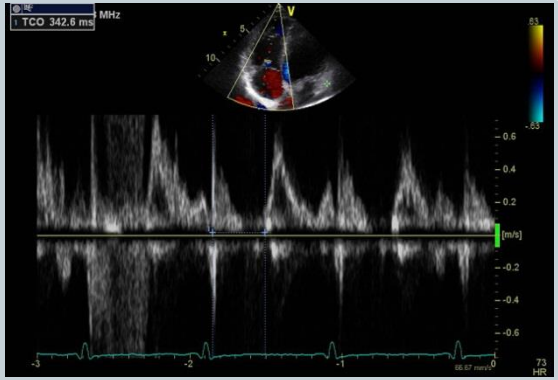
Recommended Methods and Normal References of Systolic Function

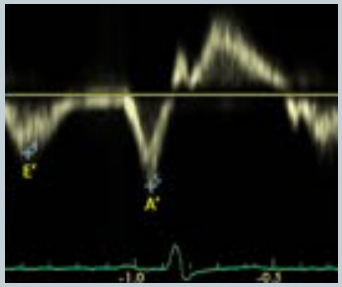
Table 10 Normal values for parameters of RV function

Parameter	Mean ± SD	Abnormality threshold
TAPSE (mm)	24 ± 3.5	<17
Pulsed Doppler S wave (cm/sec)	14.1 ± 2.3	<9.5
Color Doppler S wave (cm/sec)	9.7 ± 1.85	<6.0
RV fractional area change (%)	49 ± 7	<35
RV free wall 2D strain* (%)	−29 ± 4.5	>−20 (<20 in magnitude with the negative sign)
RV 3D EF (%)	58 ± 6.5	<45
Pulsed Doppler MPI	0.26 ± 0.085	>0.43
Tissue Doppler MPI	0.38 ± 0.08	>0.54
E wave deceleration time (msec)	180 ± 31	<119 or >242
E/A	1.4 ± 0.3	<0.8 or >2.0
e'/a'	1.18 ± 0.33	<0.52
e'	14.0 ± 3.1	<7.8
E/e'	4.0 ± 1.0	>6.0

MPI, Myocardial performance index.
*Limited data; values may vary depending on vendor and software version.

Diastolic Function





Diastolic Function

	E:A	E:E'	Deceleration Time	Additional Findings
Normal	0.8-2.1	<6	>120ms	-
Impaired Relaxation	<0.8	<6	>120ms	-
Pseudonormal	0.8-2.1	>6	>120ms	Diastolic flow predominance in HV
Restrictive	>2.1	>6	<120ms	Late diastolic antegrade flow in PA

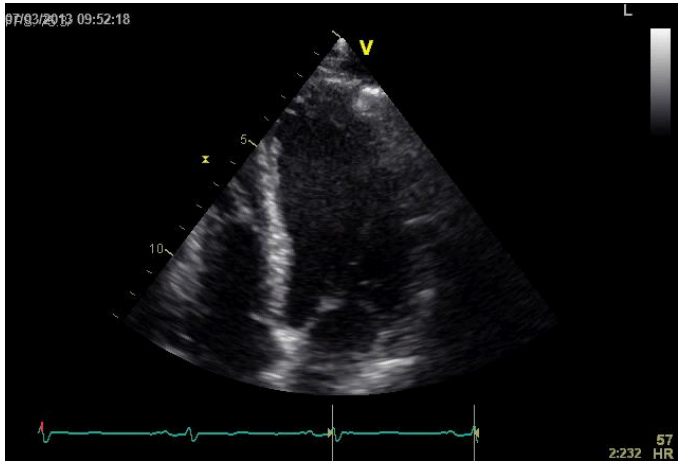
Recommendations: Measurement of RV diastolic function should be considered in patients with suspected RV impairment as a marker of early or subtle RV dysfunction, or in patients with known RV impairment as a marker of poor prognosis. Transtricuspid E/A ratio, E/E′ ratio, and RA size have been most validated and are the preferred measures(Table 6). Grading of RV diastolic dysfunction should be done as follows: tricuspid E/A ratio < 0.8 suggests impaired relaxation, a tricuspid E/A ratio of 0.8 to 2.1 with an E/E′ ratio > 6 or diastolic flow predominance in the hepatic veins suggests pseudonormal filling, and a tricuspid E/A ratio > 2.1 with a deceleration time < 120 ms suggests restrictive filling (as does late diastolic antegrade flow in the pulmonary artery). Further studies are warranted to validate the sensitivity and specificity and the prognostic implications of this classification.

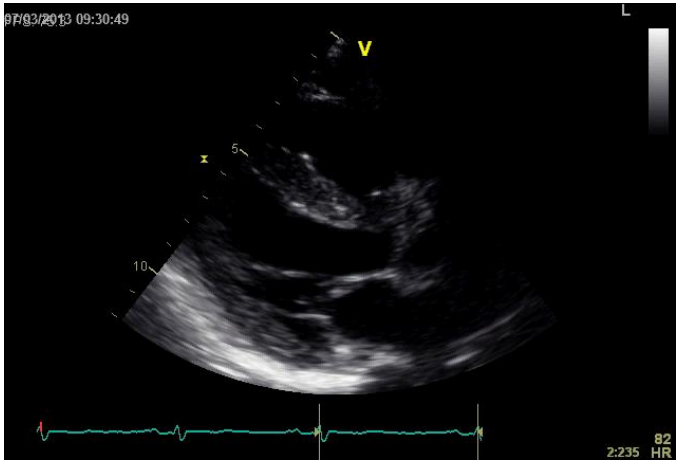
Right Heart Pathology – R > L

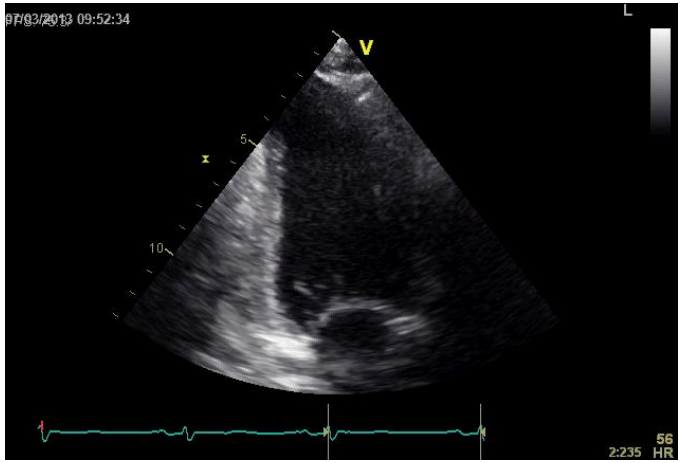
- Congenital vs. Acquired
- Myocardial
  - Cardiomyopathy – non-ischemic, ARVC , Takotsubo
  - Ischemic – RV infarction
- Valvular
  - TR – primary valvular, secondary
  - PR – usually congenital/post repair
- Post-Ventricular
  - PAH – pressure overload
  - Left-sided cardiomyopathy – pressure overload

RV infarction

- Associated with RCA occlusion
- Usually prox RCA but more subtle with more distal occlusion
- Will often recover quickly once artery open

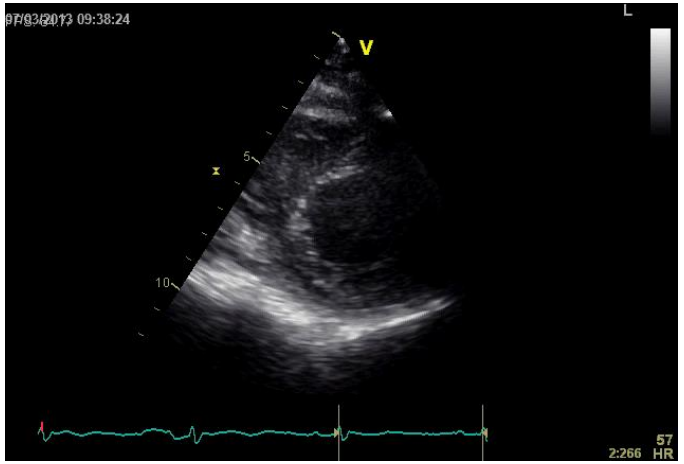


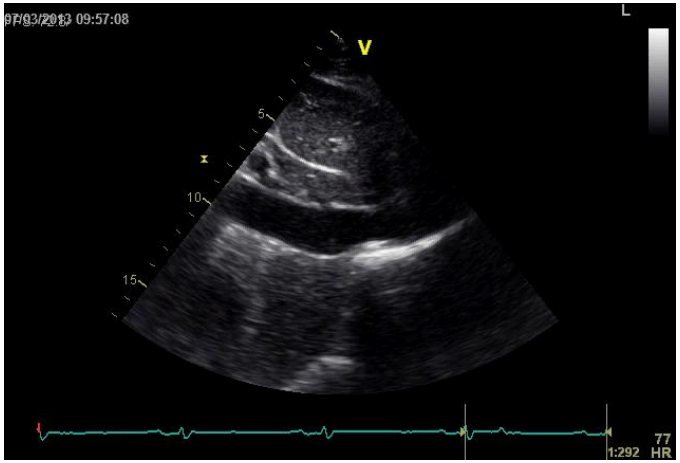


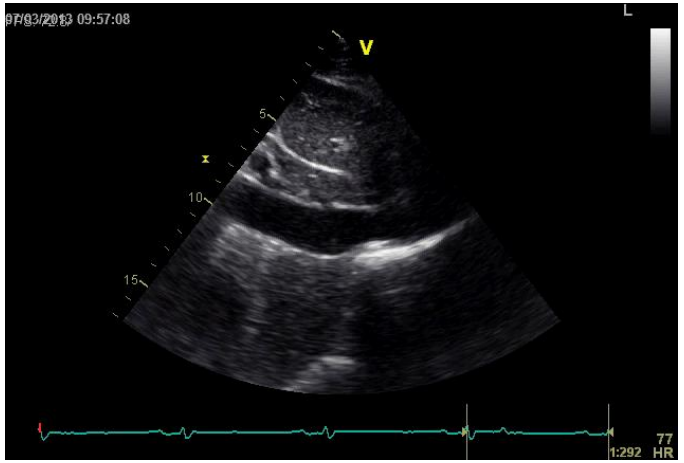


RV Infarction Tips

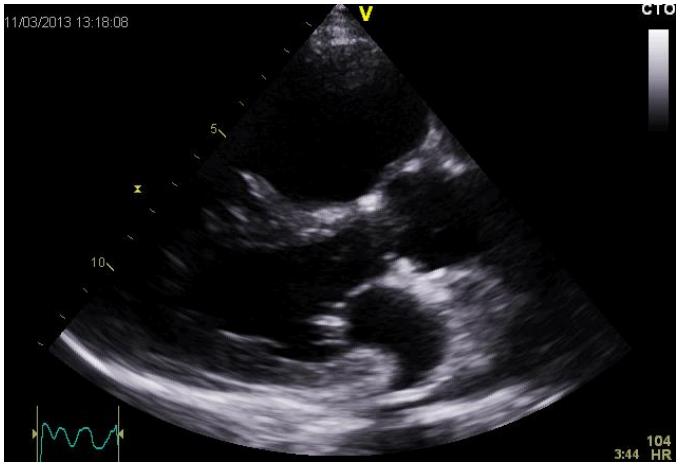
- Look at all views
- Look for IVC dilatation
- DDx Acute PE
- Look for inverted T







PAH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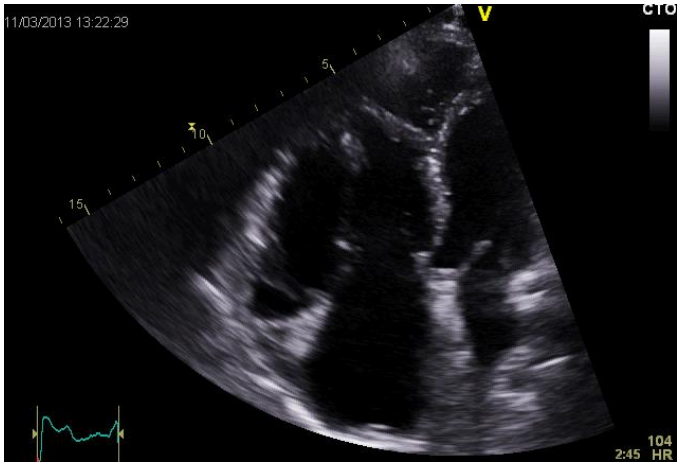
104
3:44 HR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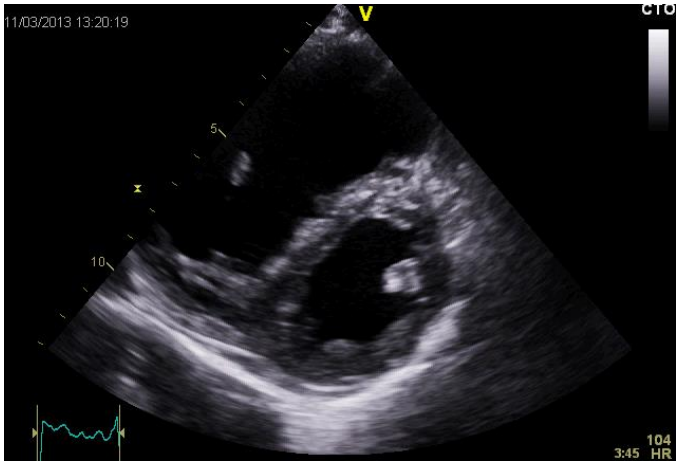
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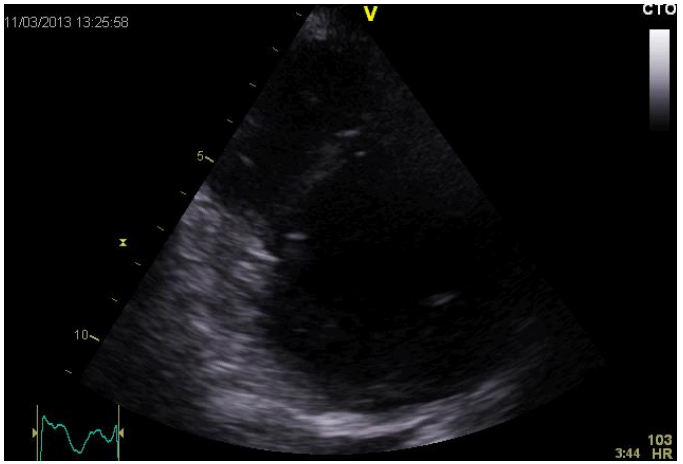
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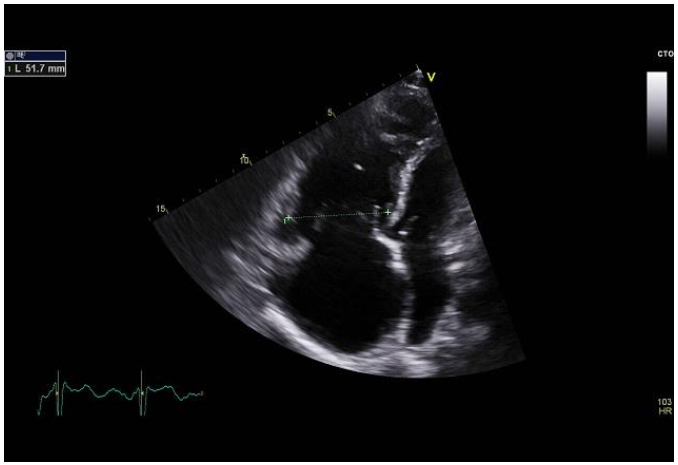
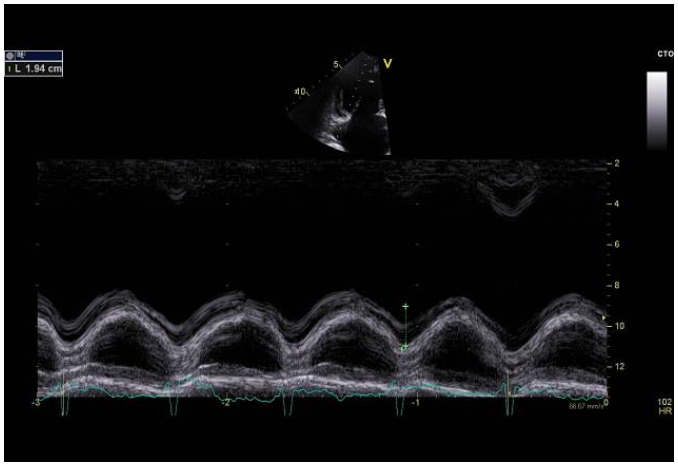
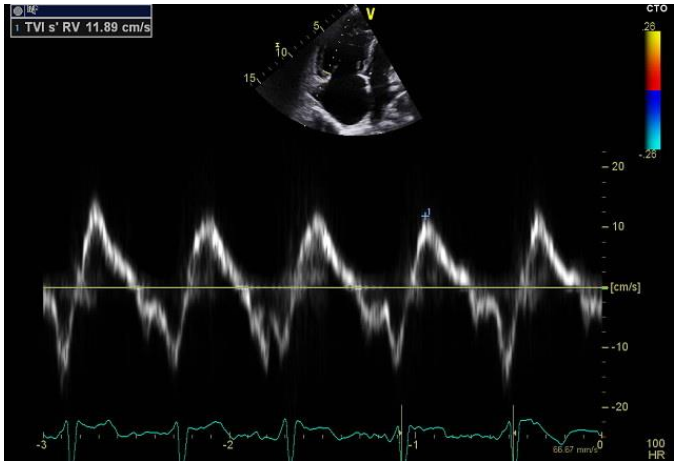
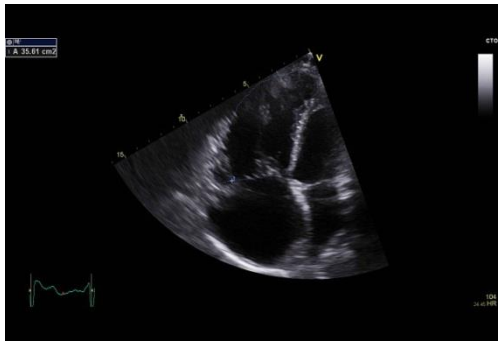
103
3:44 HR

RV systolic function





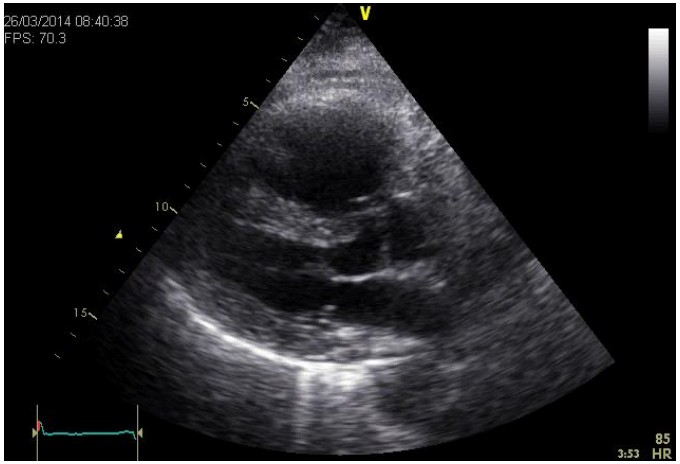


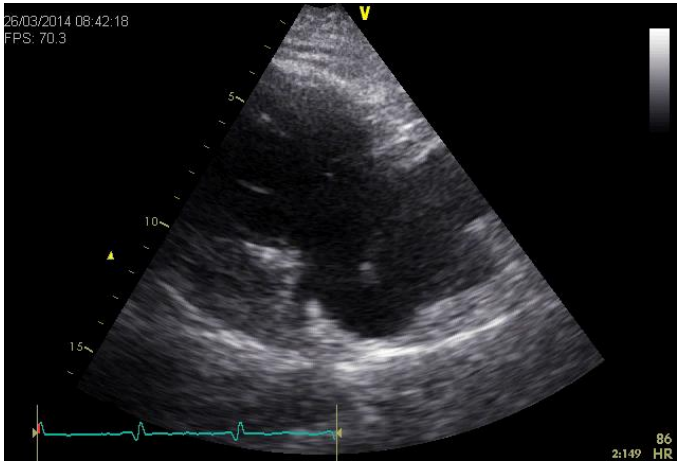


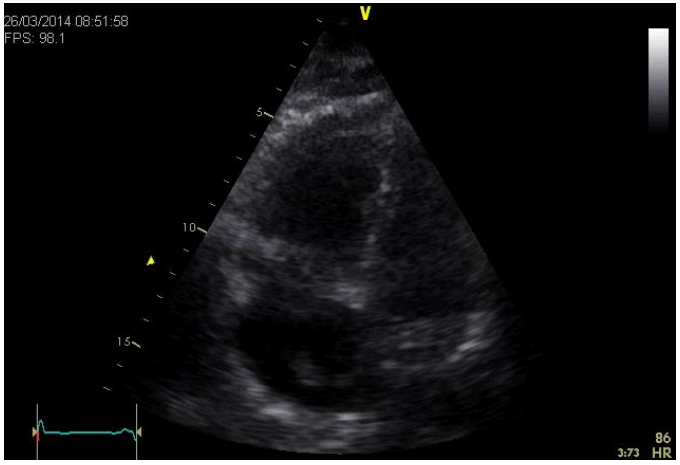
RVEDA RVESA

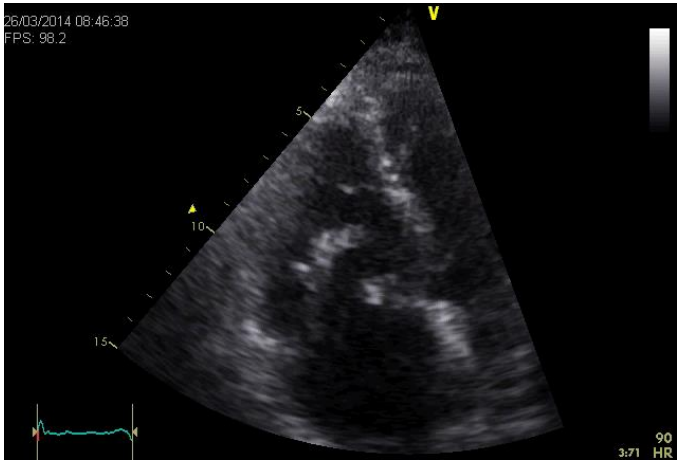
FAC = 20%

Acute Pulmonary Embolism

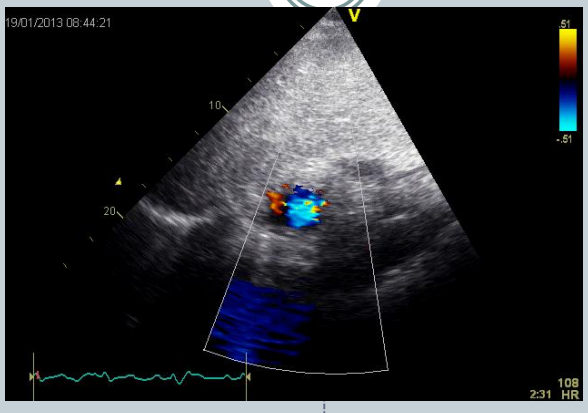


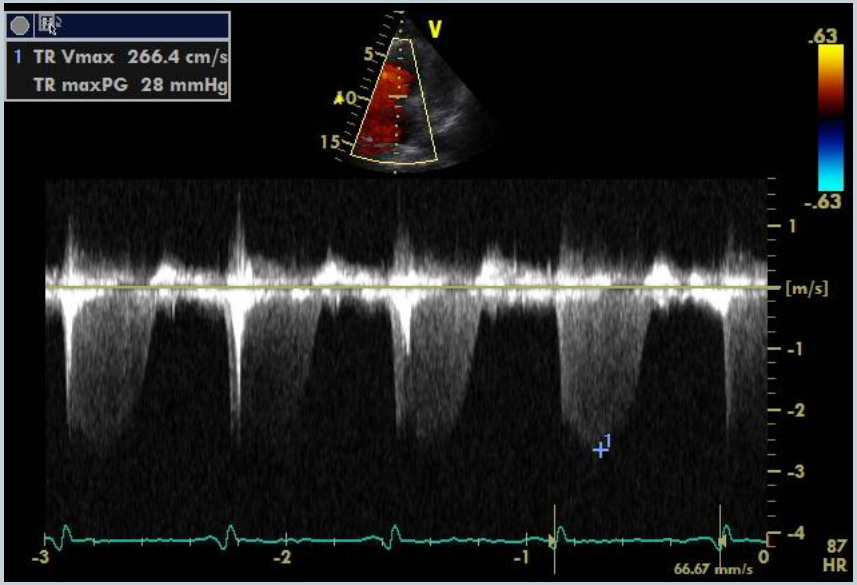


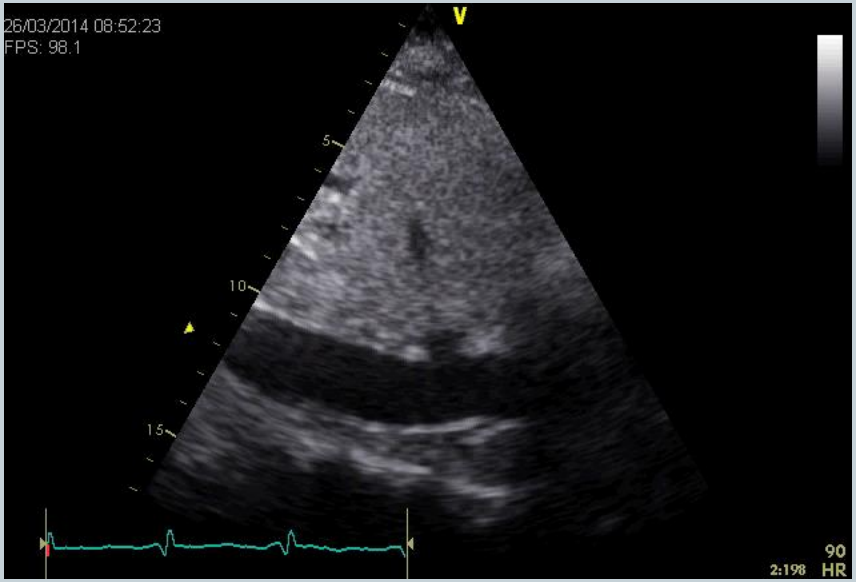




PE continued





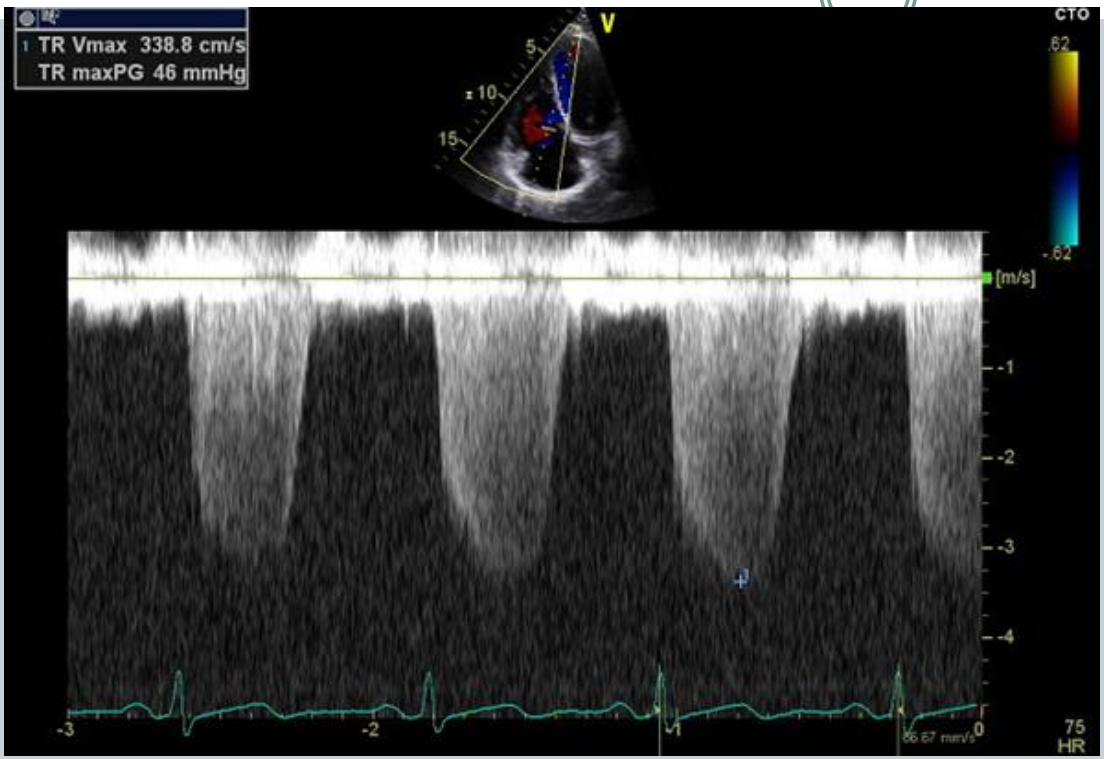


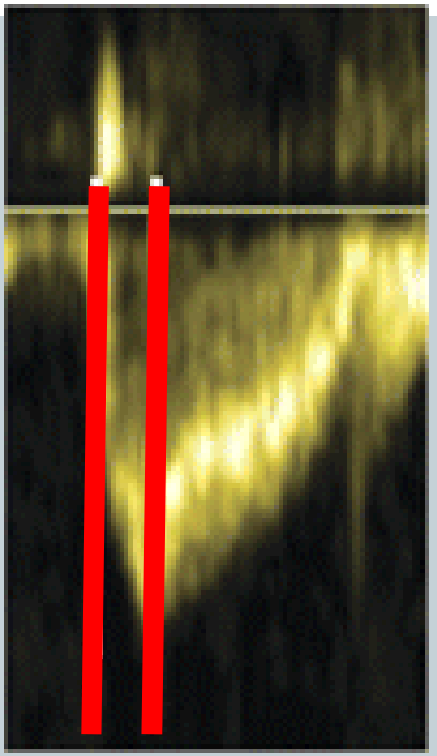
PE Echo Findings

- Present in 30-40%
- Increased RV size
- Decreased RV function
- New/worsened TR
- RV Thrombus/PE in transit
- Regional Wall Motion – McConnell's sign
- Increased PAP – mild or moderate, usually

- Prognostic info – RV dysfunction, Thrombus

60/60 Sign – Kurzyna AJC 2002





RV cannot acutely generate very high pressures
RVSP < 60 mmHg

When faced with high Impedance, ejection ends sooner
PA accel time < 60 msec

Perform and Report in All

- RV size – basal dimension – 41mm; RV volumes by 3D
- RA volume – if feasible – gender-specific
- RV systolic function - at least one of the following:
  - RVEF by 3D
  - Systolic Excursion velocity of the annulus [S'] - 9.5 cm/s
  - Fractional area change [FAC] – 35%
  - Tricuspid annular plane systolic excursion [TAPSE] 17 mm
  - with or without RV index of myocardial performance [RIMP] 0.43 0.54
- Systolic pulmonary artery pressure (SPAP) – 35-40mmHg with estimate of RA pressure on the basis of inferior vena cava (IVC) size and collapse 3,8,15 mmHg

In many conditions with right heart pathology add:

- Mean PA pressure (mPAP)

- INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE, INTEGRATE!!!!

Question 1

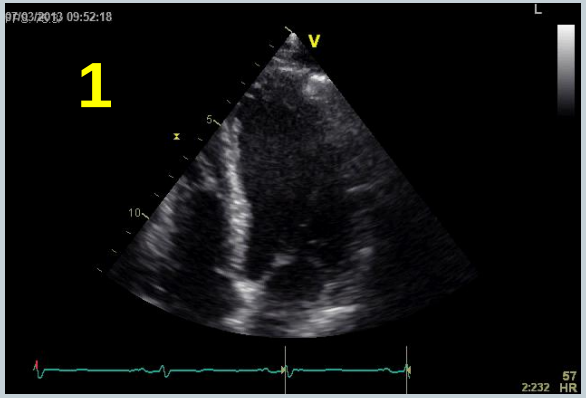
- A patient has the following quantitative measures of RV function. Which is NOT recommended to diagnose RV systolic dysfunction ASE guidelines
- A – Fractional area change of 30%
- B – TAPSE 15mm
- C- S' 8 cm/s
- D – Free wall strain by speckle tracking -17%
- E – MPI by pulsed Doppler of 0.5

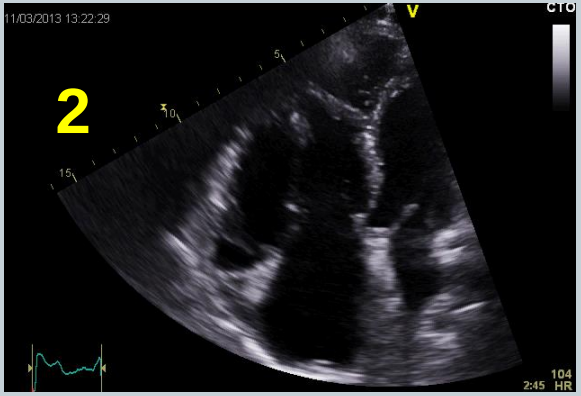
Answer - D

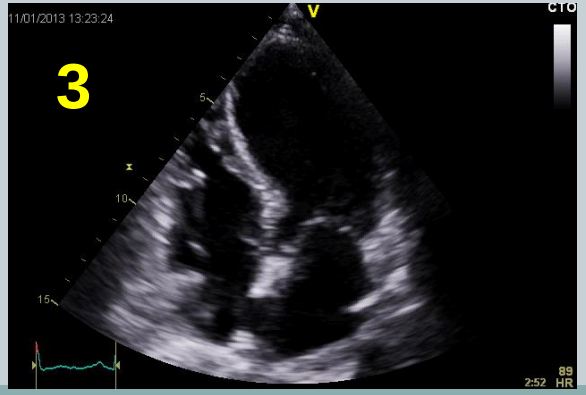
- All of the above indicate significant RV systolic dysfunction.
- Answer D – 2D strain by speckle tracking – is not one of the recommended methods to use in the routine exam owing to significant inter-vendor variability

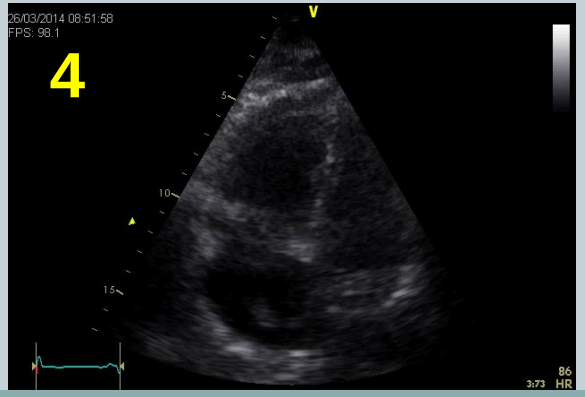
Question 2

- Of the clips below, which diagnosis is least likely to be represented









A – Acute Pulmonary Embolism

B – Pulmonary Arterial Hypertension

C- Atrial Septal Defect

D- RV infarction

E- Takotsubo Cardiomyopathy

Answer- C

- Choice C – ASD – usually demonstrates RV volume overload seen in multiple views, usually with preserved systolic function. An exception is the rare form associated with abnormal BMPR2 haplotype and PH representing fewer than 5% of ASDs, or those that present VERY late.
- 1 – RV infarct associated with inferior MI
- 2 – PAH
- 3 - Takotsubo
- 4 – Acute PE