Acute Pulmonary Embolism

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Pulmonary Embolism

- Pulmonary embolism (PE) is a relatively common cardiovascular emergency

- By occluding the pulmonary arterial bed it may lead to acute life-threatening but potentially reversible RV failure

- PE is a difficult diagnosis that may be missed because of non-specific clinical presentation

- However, early diagnosis is fundamental, since immediate treatment is highly effective

European Heart Journal (2008) 29, 2276–2315

Pathophysiology

- The consequences of acute PE are primarily haemodynamic and become apparent when 30–50% of the pulmonary arterial bed is occluded by thromboemboli

- Sudden death may occur, usually in the form of electromechanical dissociation

- Or, the patient presents with syncope and/or systemic hypotension, which might progress to shock and death due to acute **RV failure**

- Rightward bulging of the IVS may further compromise the cardiac output as a result of **diastolicLV dysfunction**

European Heart Journal (2008) 29, 2276–2315

Diagnosis

- Chest X-ray is usually abnormal, and the most frequent findings (plate-like atelectasis, pleural effusion or elevation of a hemidiaphragm) are nonspecific.
- But Chest X-ray is useful in excluding other causes of SOB and chest pain
- PE is associated with hypoxaemia, but up to 20% of patients have normal PaO_2 and a normal alveolar-arterial oxygen gradient [$D(A\text{-}a)O_2$]
- ECG signs of RV strain, such as T-wave inversion in V1–V4, a QR pattern in V1, the classic S1Q3T3 type and RBBB, may be helpful
- Normal D-dimer levels renders acute PE or DVT unlikely, (the negative predictive value of D-dimer is high)

Massive PE

- Suspected PE with high mortality risk
- Thromboembolic occlusion of >30-50% pulmonary arterial bed
- Acute increase of pulmonary vascular resistance
- Acute right heart failure
- Raised pulmonary pressures
- Reduced RV function

Massive PE

- Non-specific clinical presentation
- Risk markers:
  - -Shock/Hypotension
  - **-RV dysfunction**
  - -Myocardial injury (cardiac troponin T or I +ve)

PE and Echocardiography

- **Role of Echo in "massive" PE**
  - Review standard 2D right heart views
  - Recognising normal right heart structures
  - Screening for right heart thrombi/masses
  - Detecting right heart dysfunction
  - Assessing pulmonary artery pressures
  - TDI Indices

PE and Echocardiography

- **Advantages:**

-Bedside diagnostic test in acutely unwell/ unstable patients

-Immediate results

- **Disadvantages:**

-Indirect signs

-Limited sensitivity (-ve result cannot exclude PE)

Role of Echo in "Massive" PE

- Screen for right heart thrombi in transit
- Differential diagnosis:
  - cardiogenic shock
  - acute valvular dysfunction
  - tamponade
  - aortic dissection
- Detect indirect signs which are highly suggestive of PE

PE and Echocardiography

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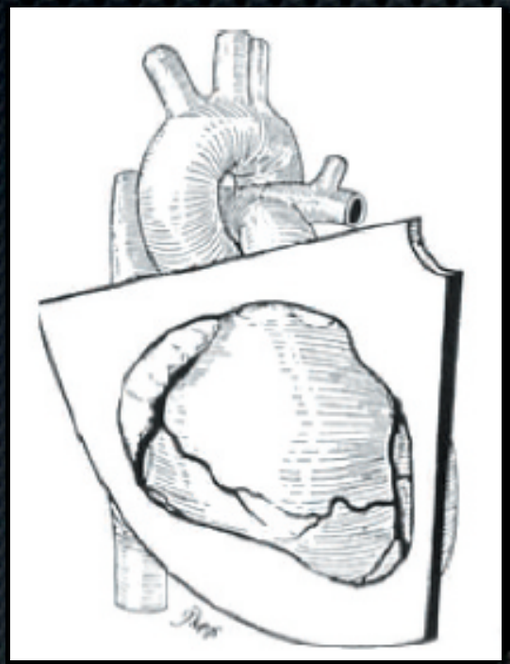
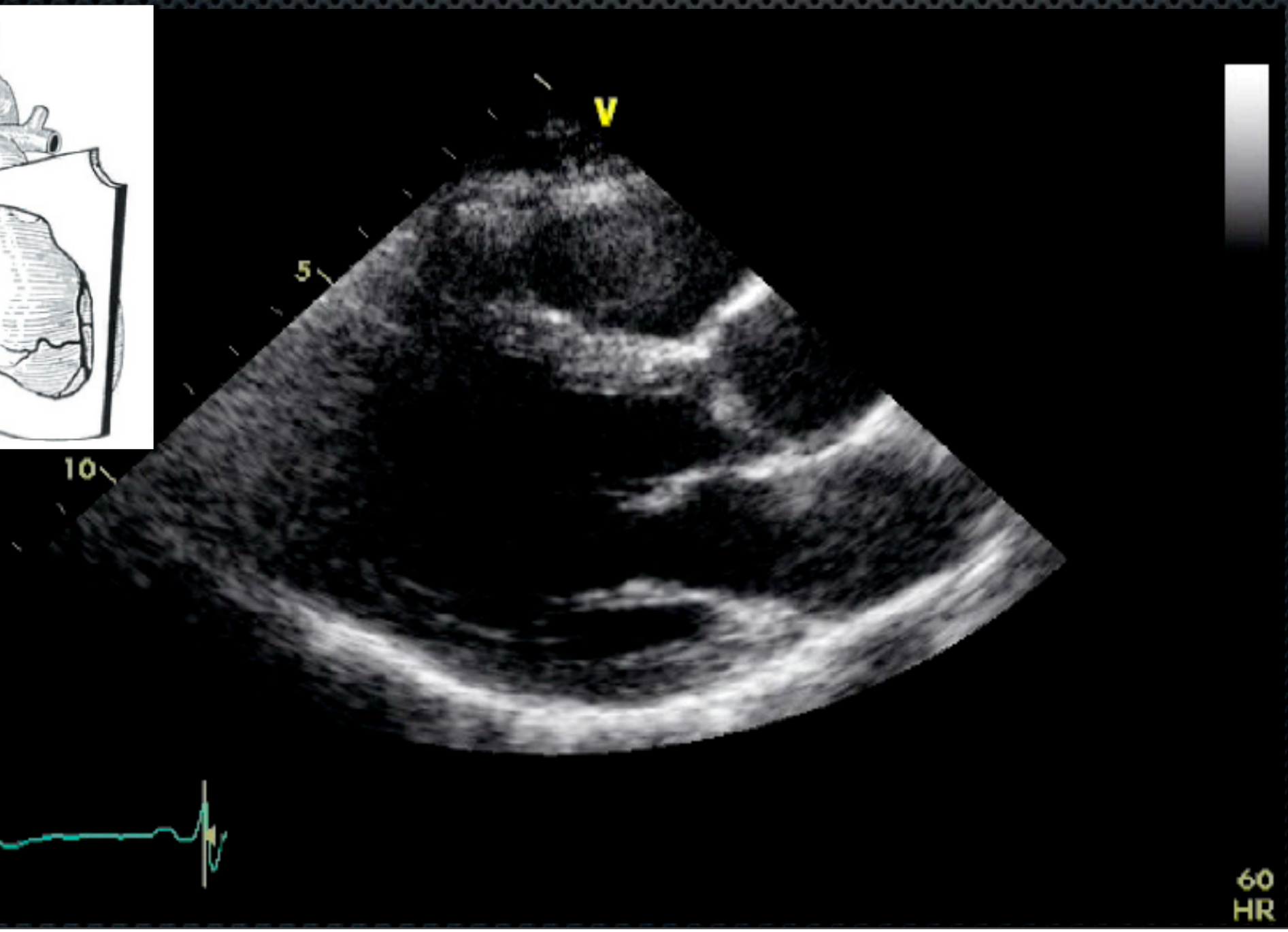
2D Right Heart Views

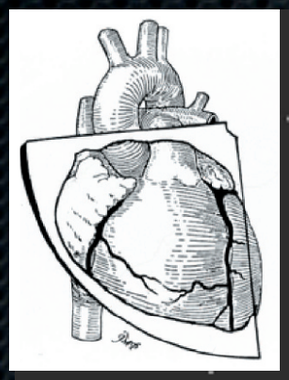
PLAX - RVOT





2D Right Heart Views

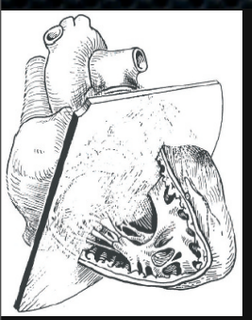
PLAX RV iflow

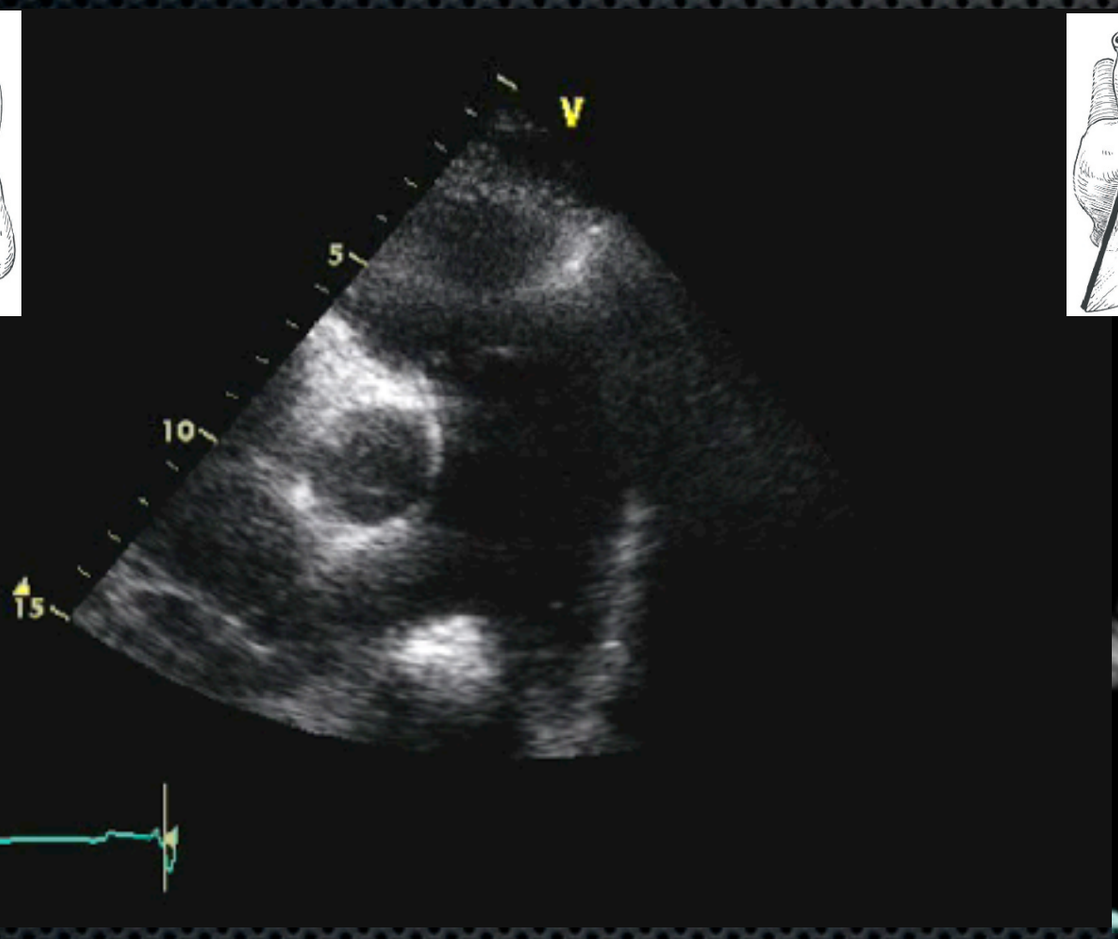


PLAX RV outflow

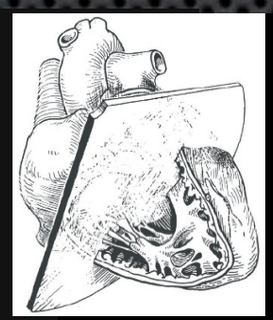
2D Right Heart Views

PSAX - Pulmonary artery



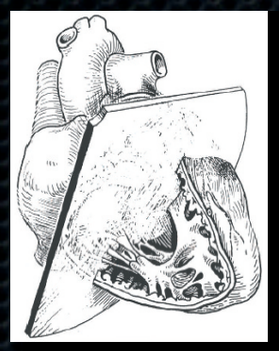


PSAX - Ao/LA

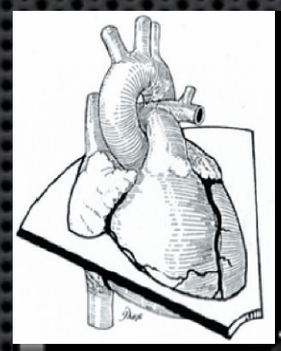


2D Right Heart Views

PSAX - LV

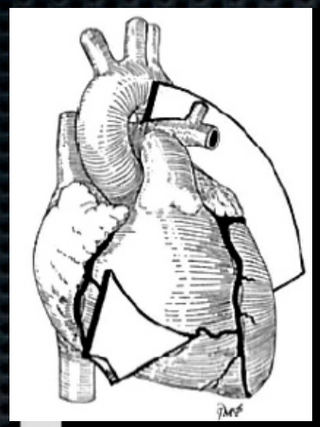


AP 4C



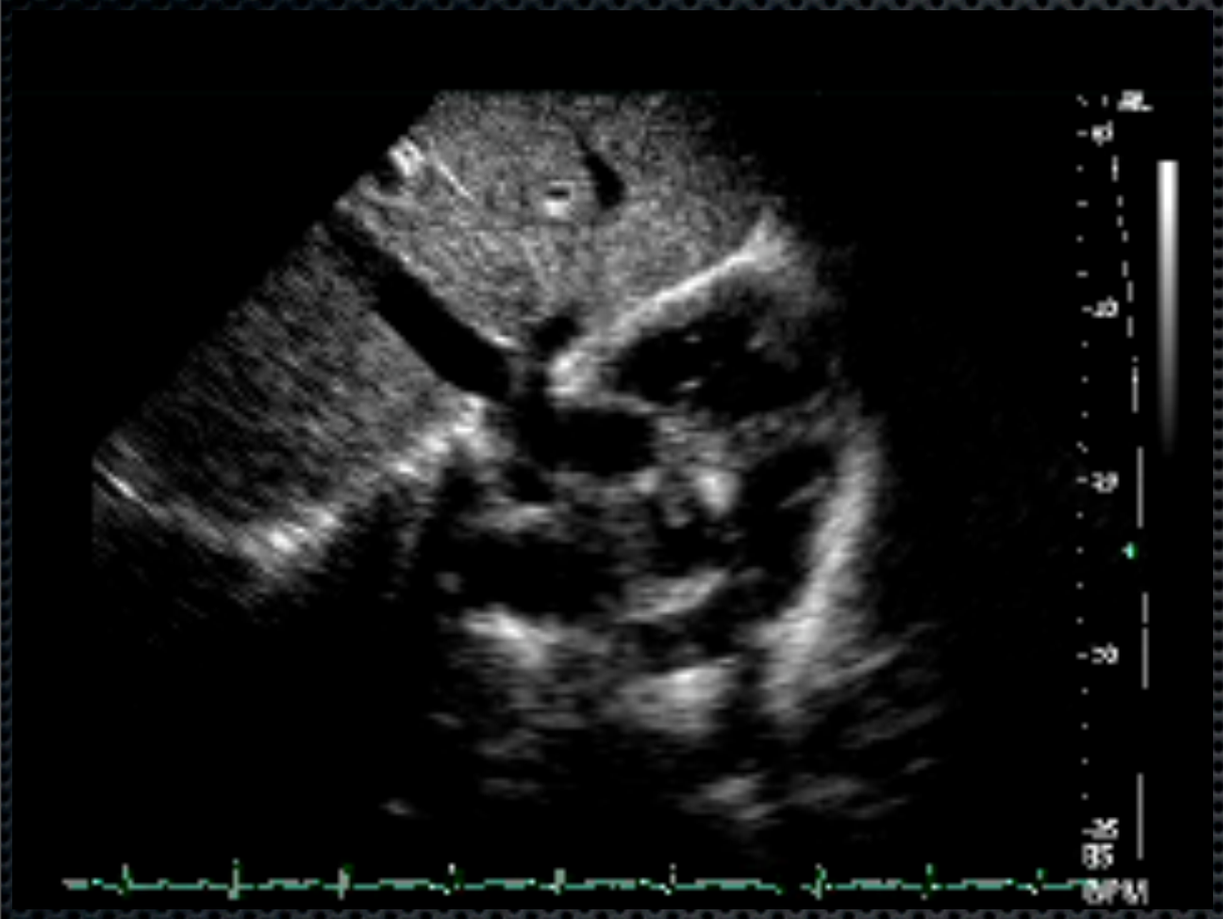
2D Right Heart Views

Sub-costal 4C

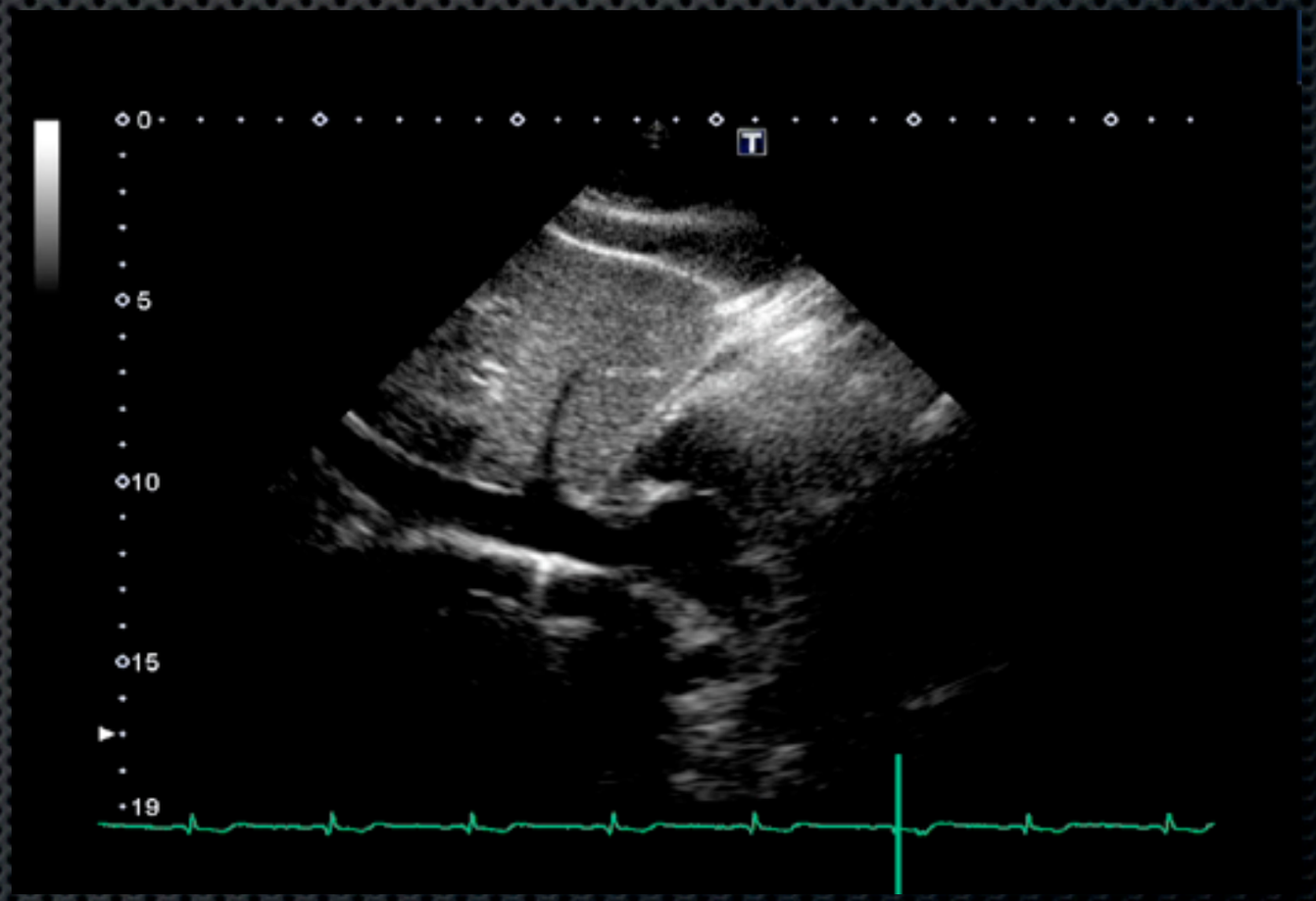


2D Right Heart Views

Sub-costal SAX



Sub-costal SAX - Bicaval



PE and Echocardiography

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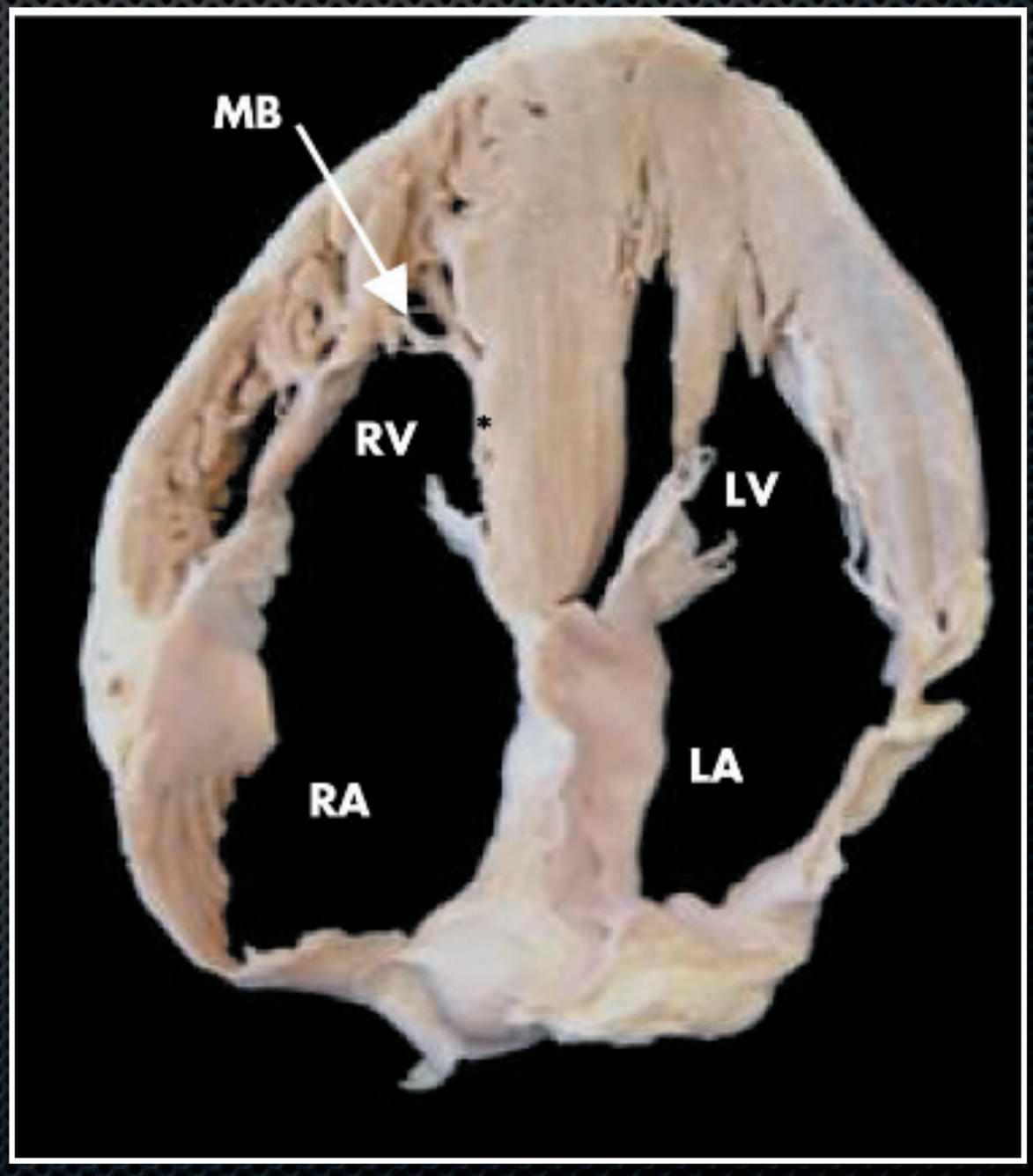
Normal Right Heart Structures

The Moderator Band



Normal Right Heart Structures

The Moderator Band

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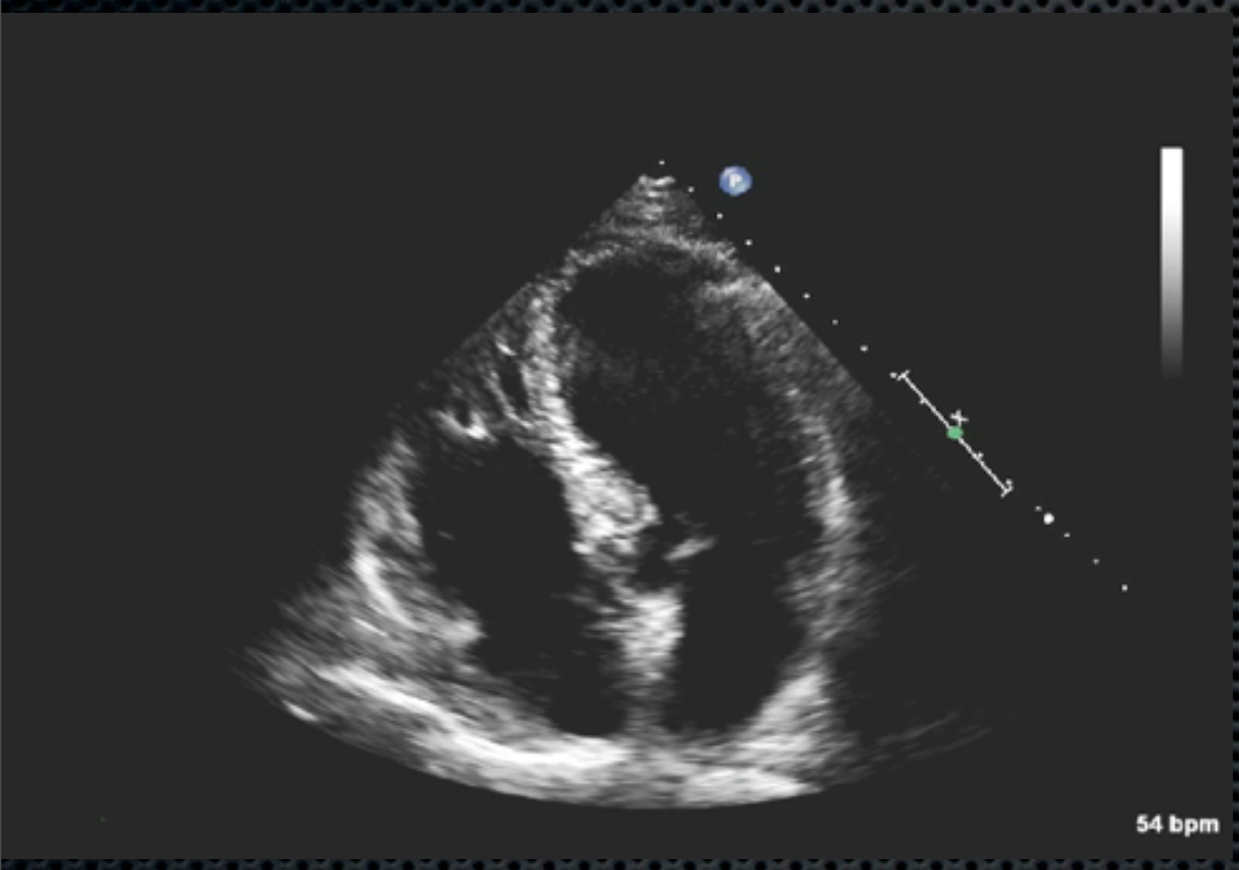
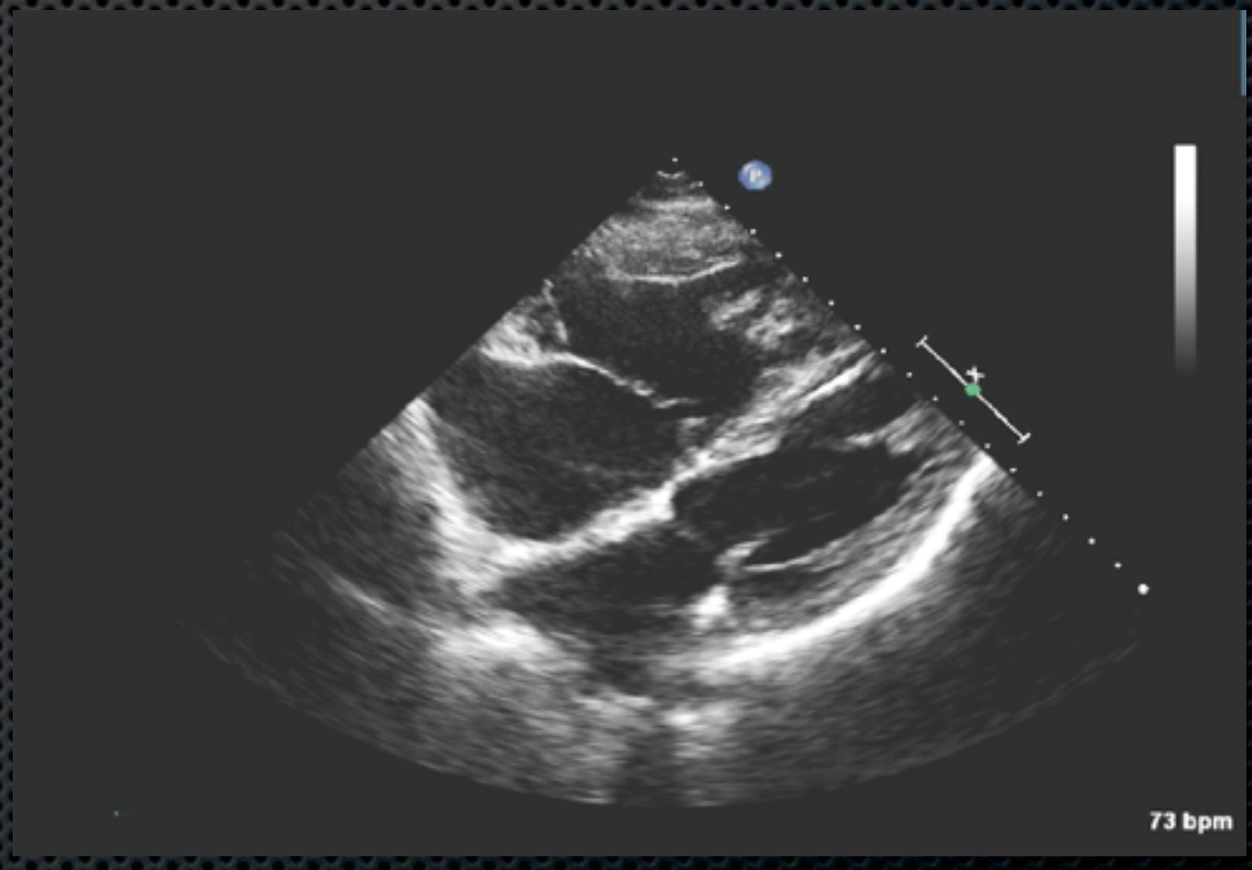
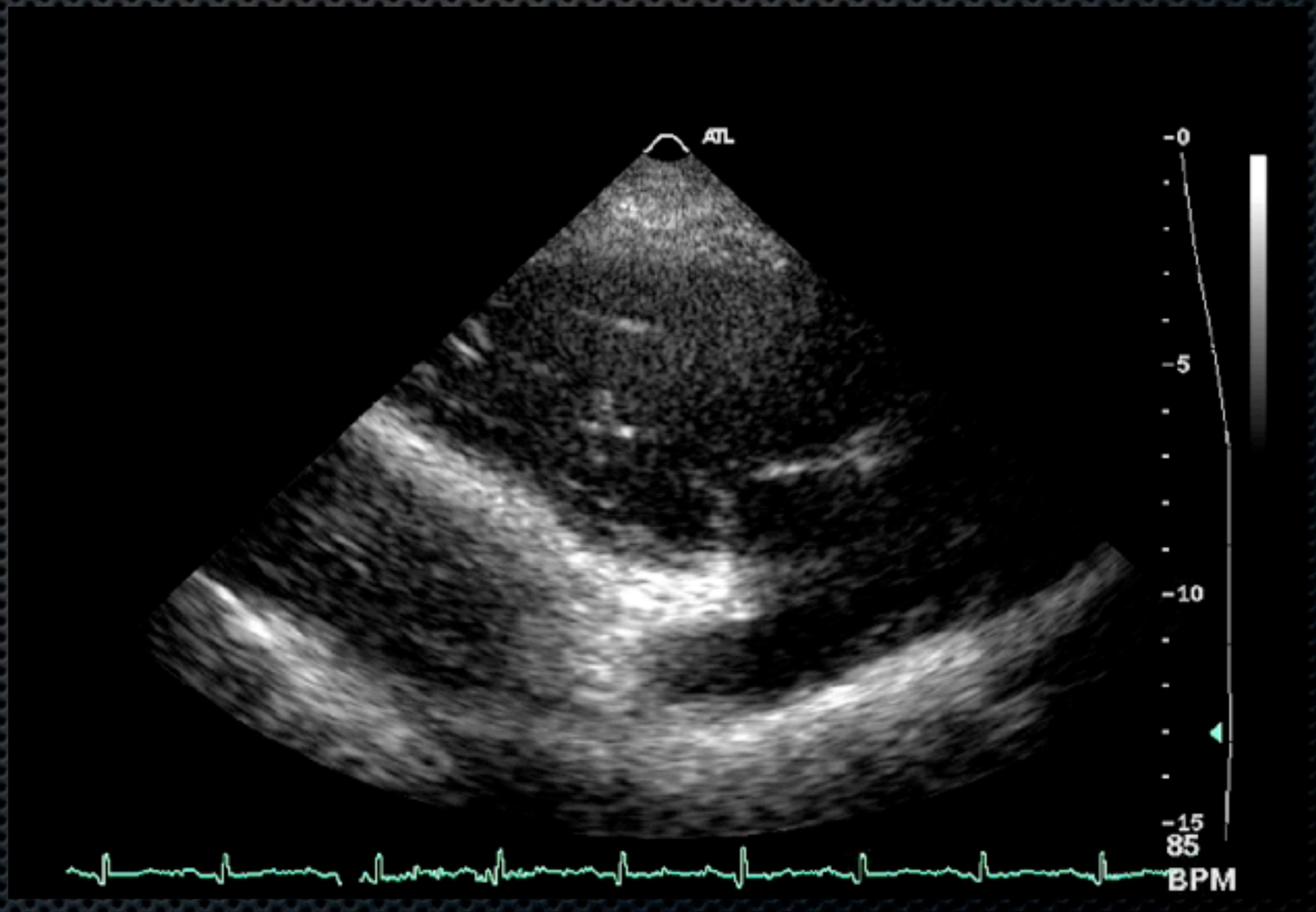


Sub-costal 4C



Normal Right Heart Structures

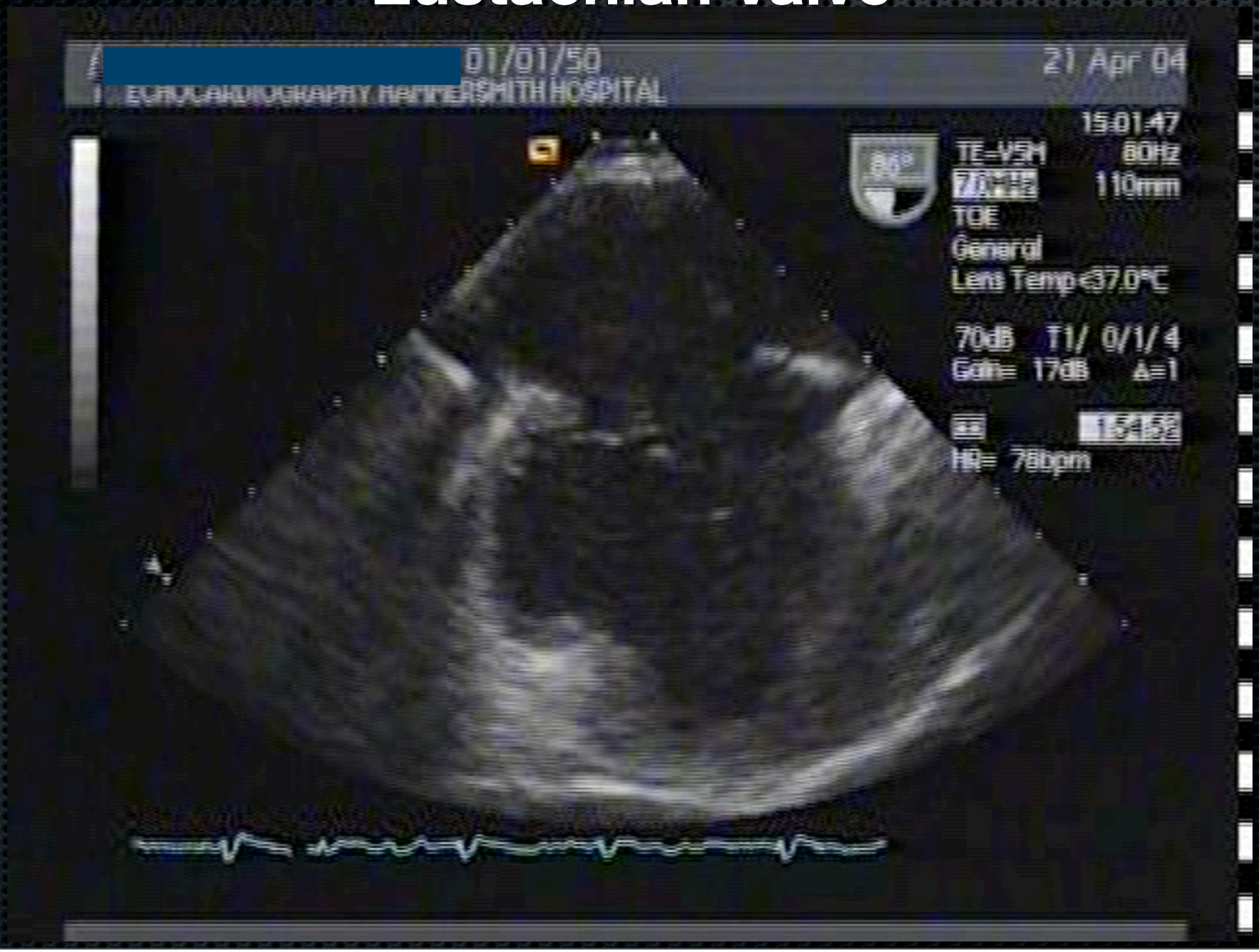
Eustachian Valve



PLAX RV Inflow tract

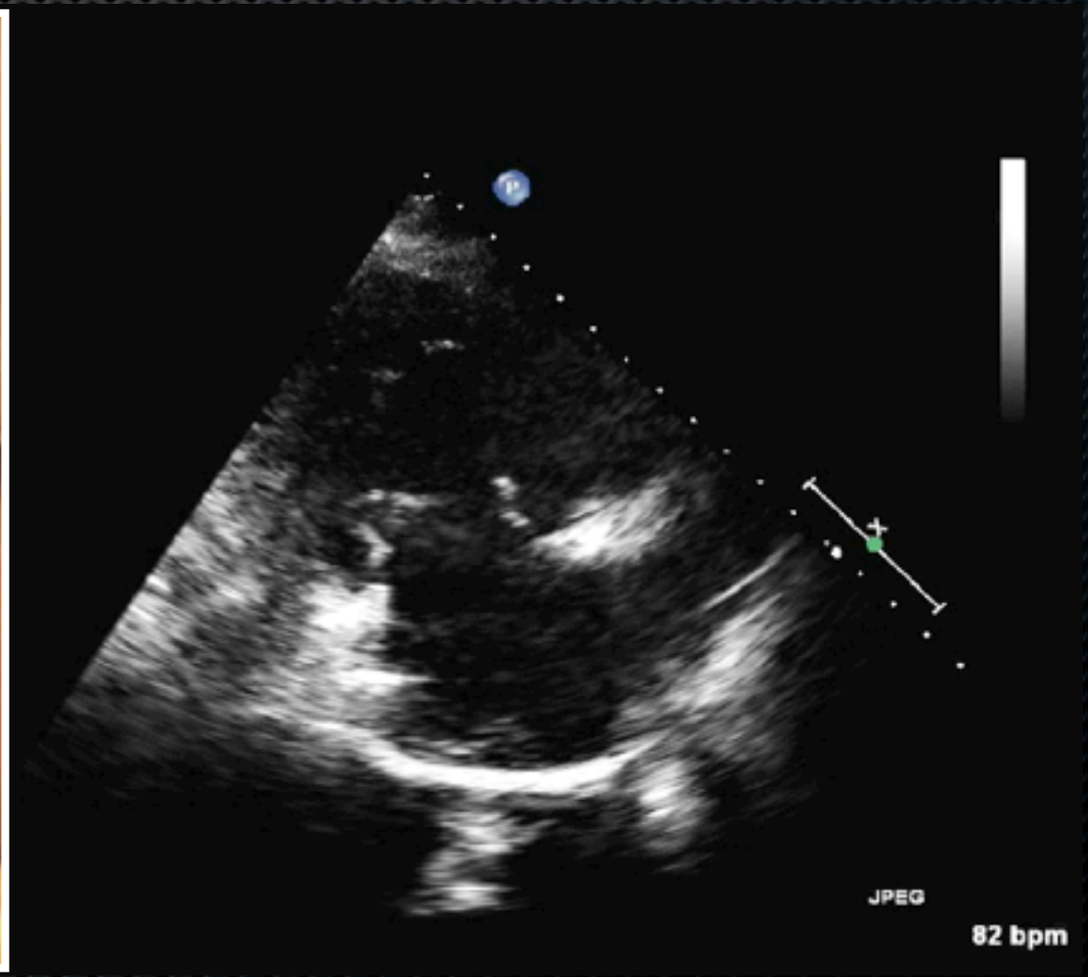
Normal Right Heart Structures

Eustachian Valve



Normal Right Heart Structures

Chiari Network



PLAX RV Inflow tract

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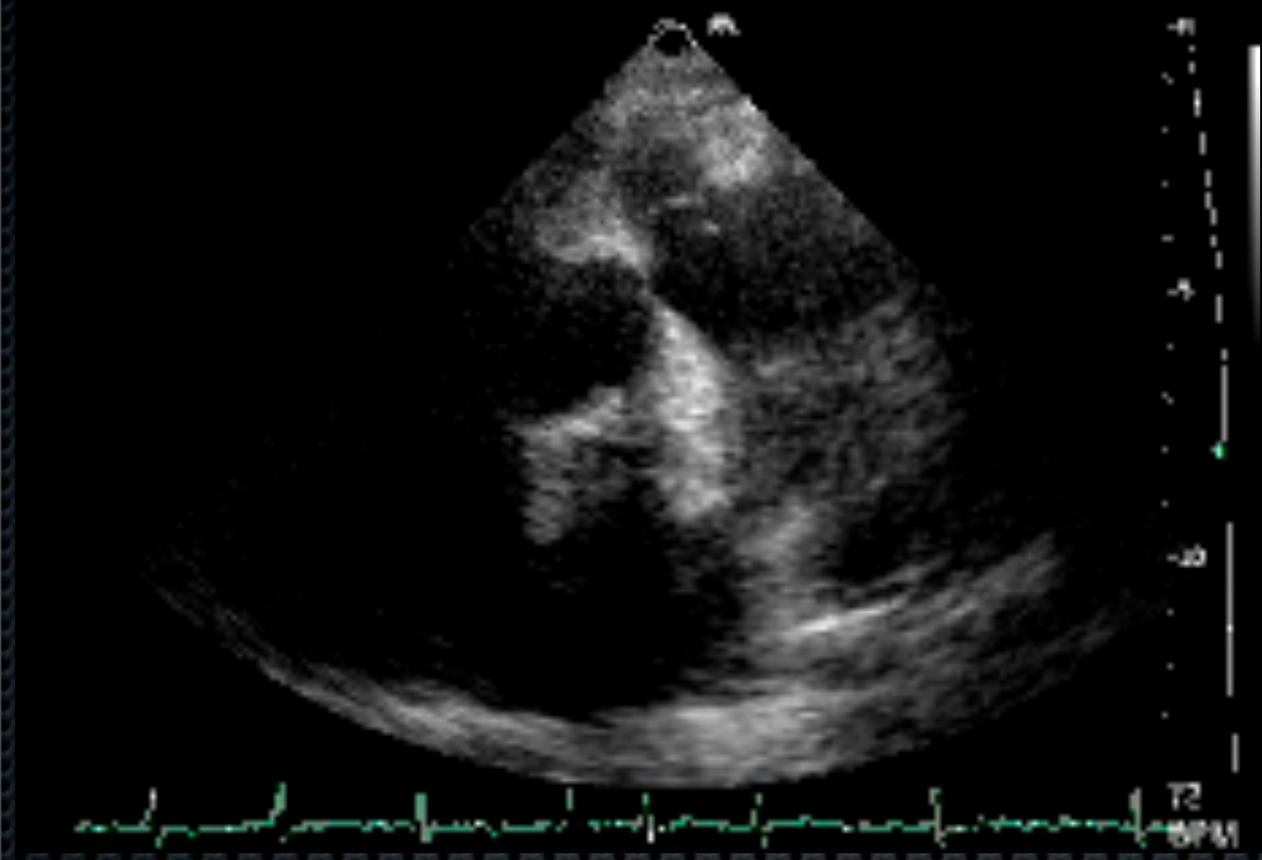
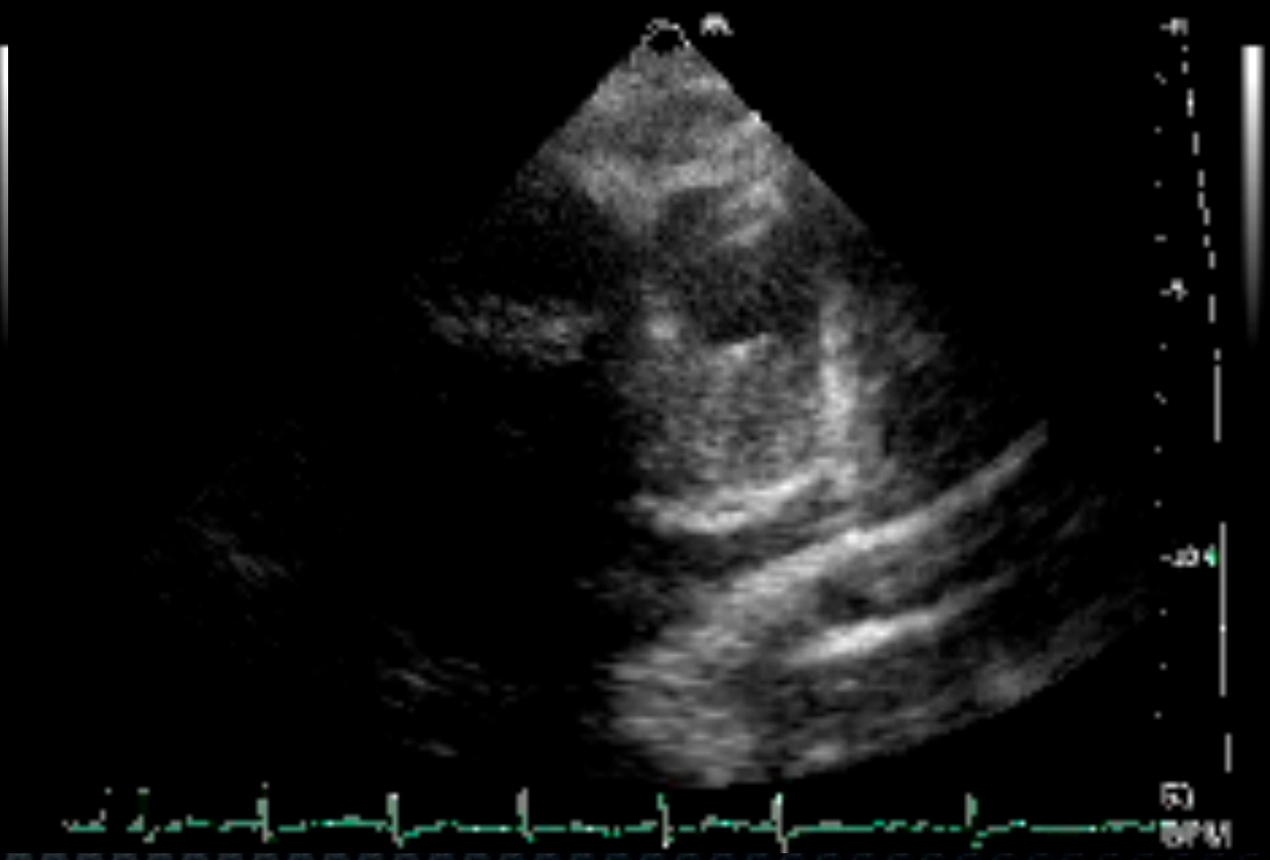
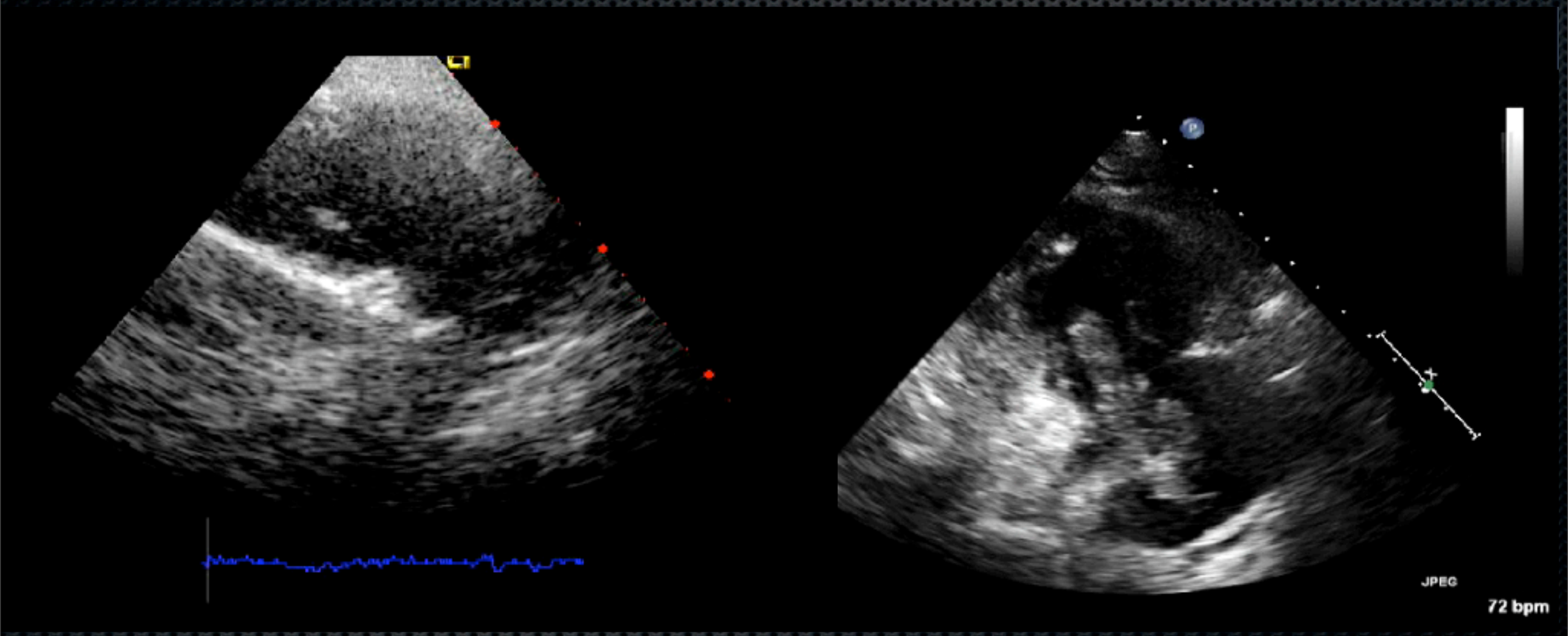
Right Heart Masses / Thrombi

PSAX - Pulmonary Artery





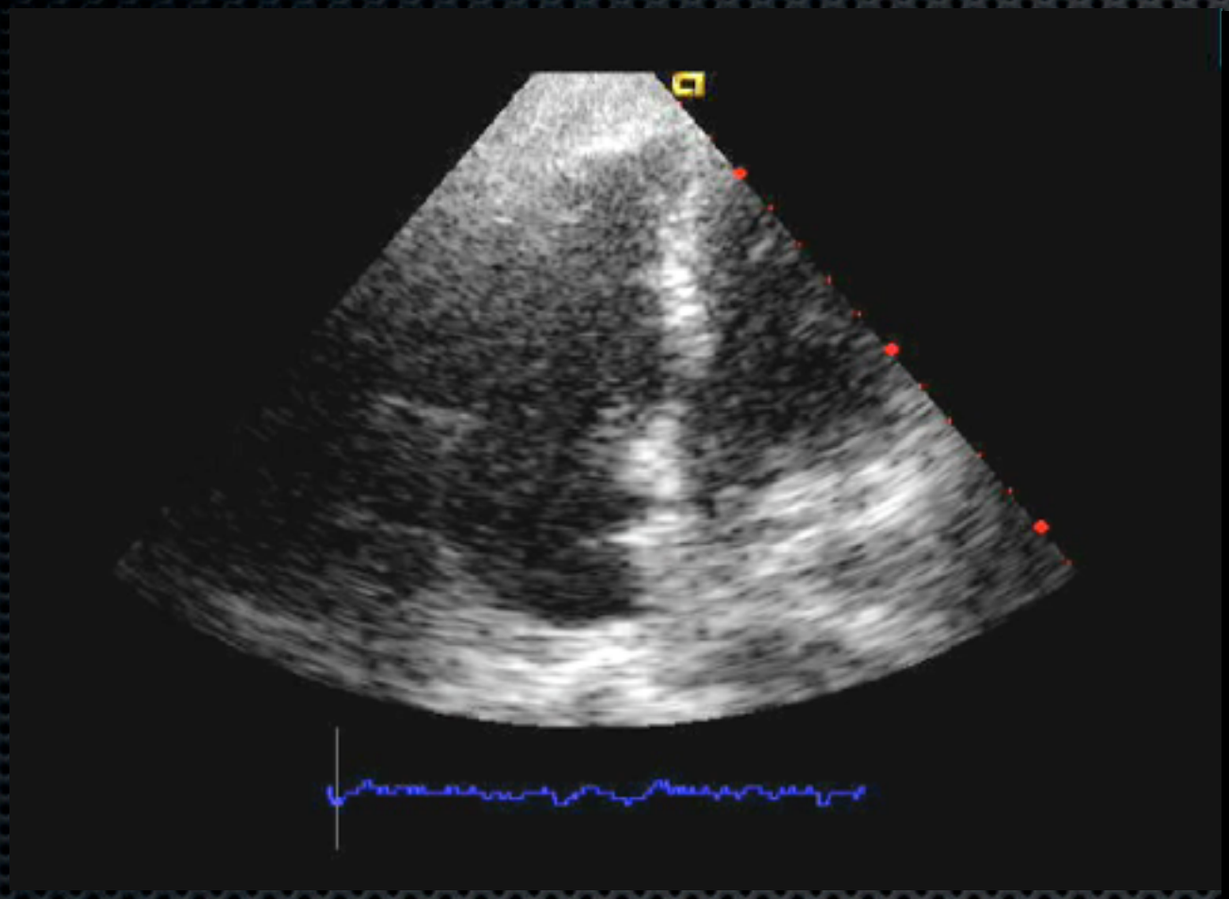
Right Heart Masses / Thrombi

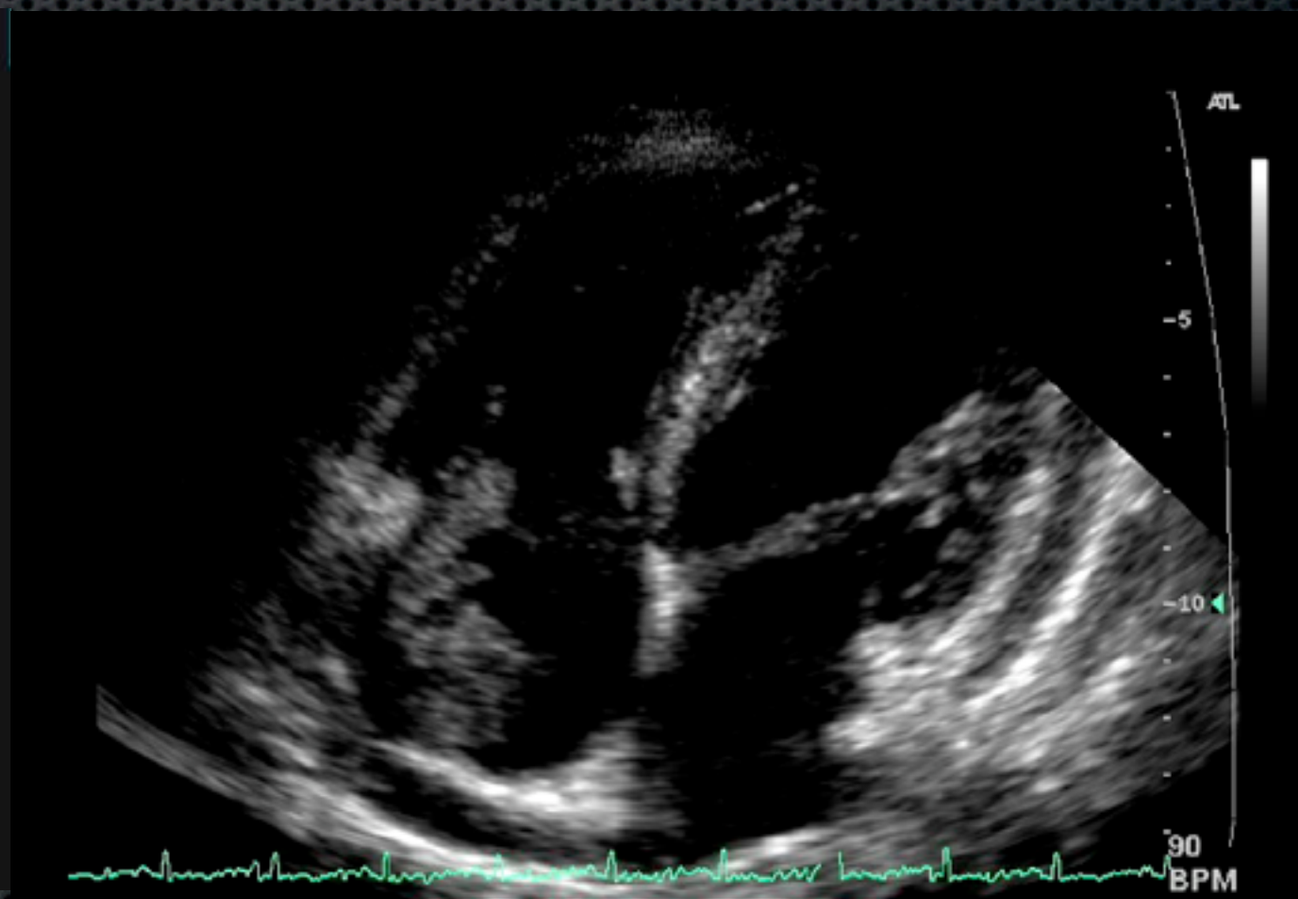


PLAX RV inflow tract

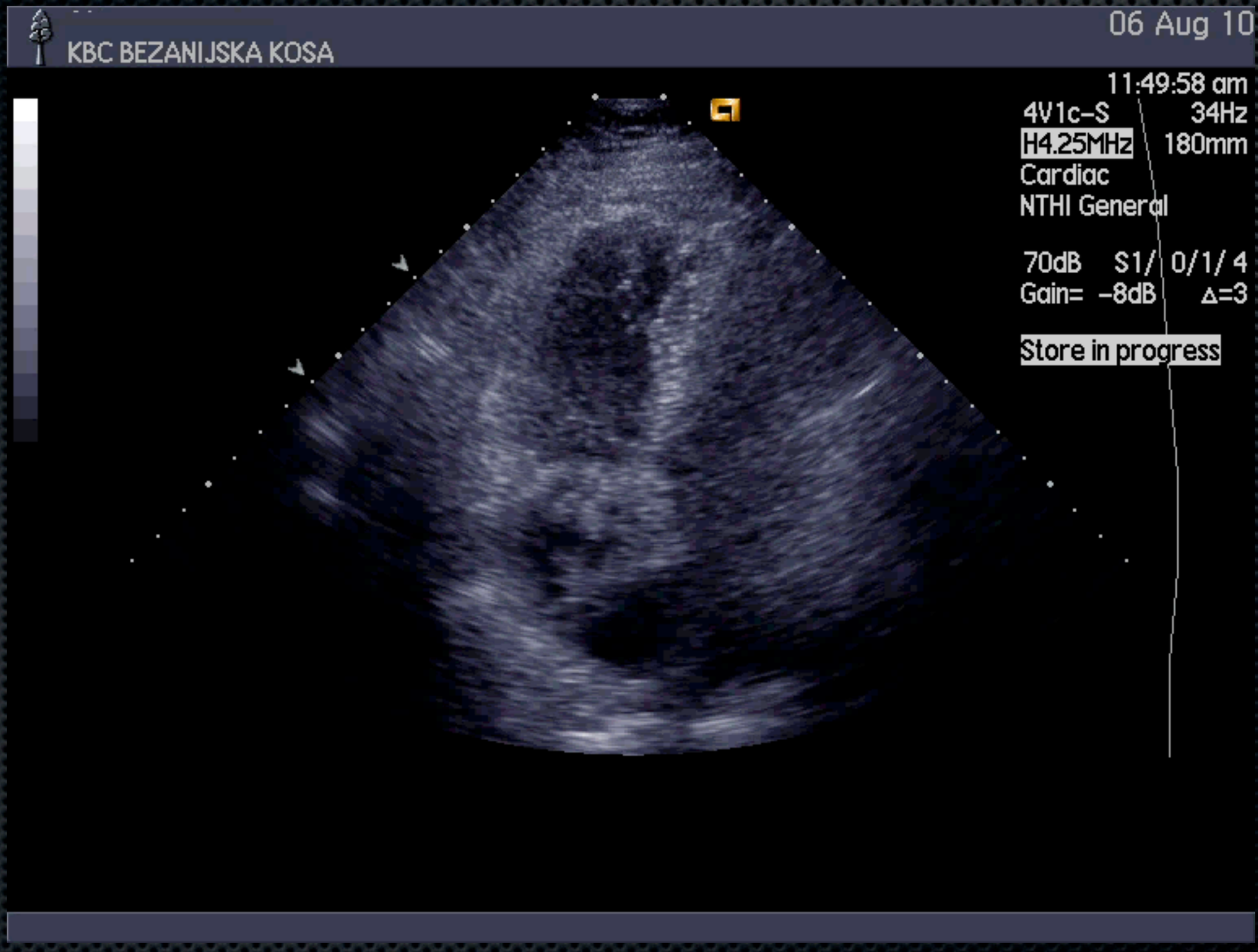
Right Heart Masses / Thrombi

AP 4C



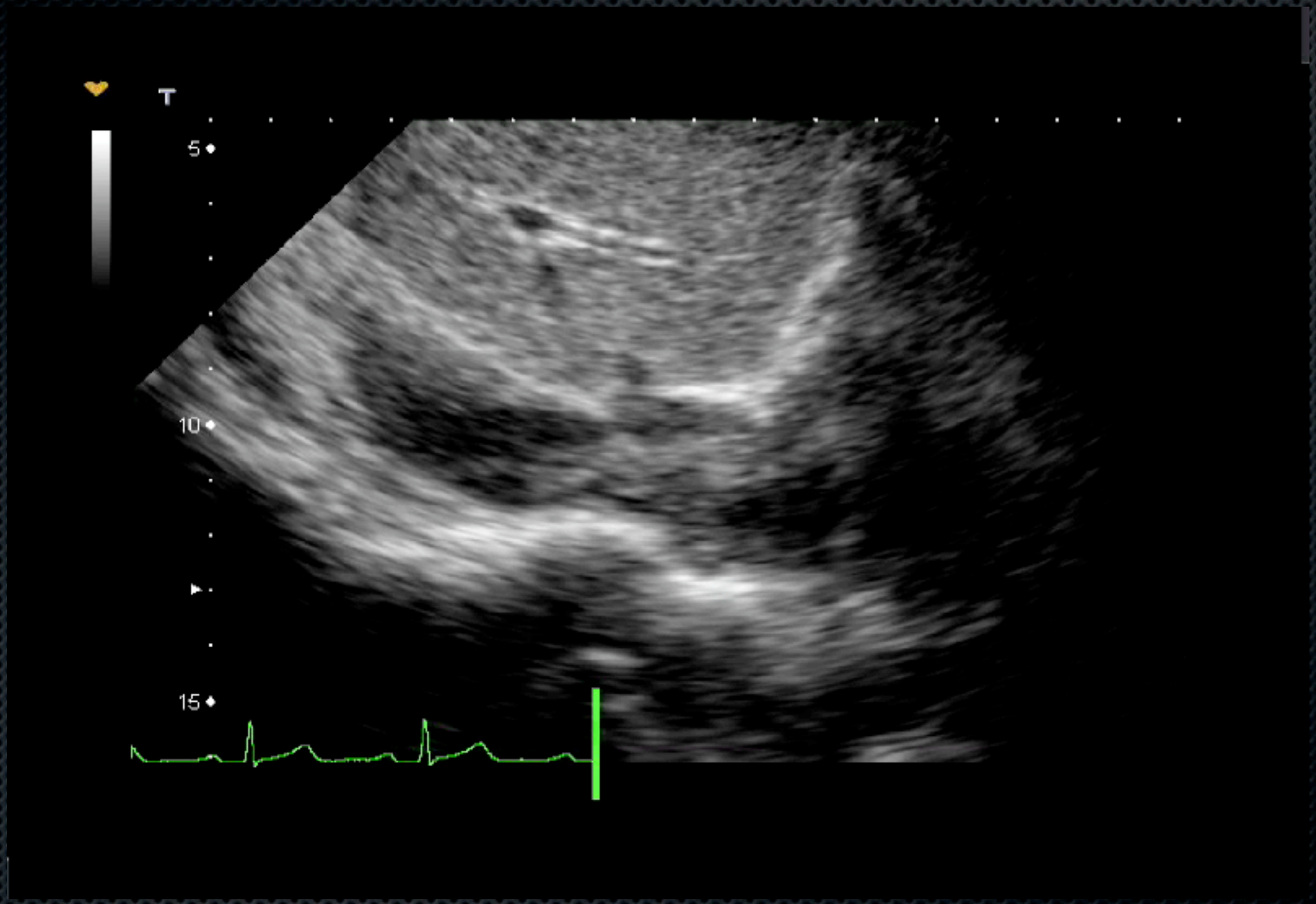


Right Heart Masses / Thrombi



Courtesy of A. Djokovic

Right Heart Masses / Thrombi



Sub-costal SAX

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RV Dysfunction

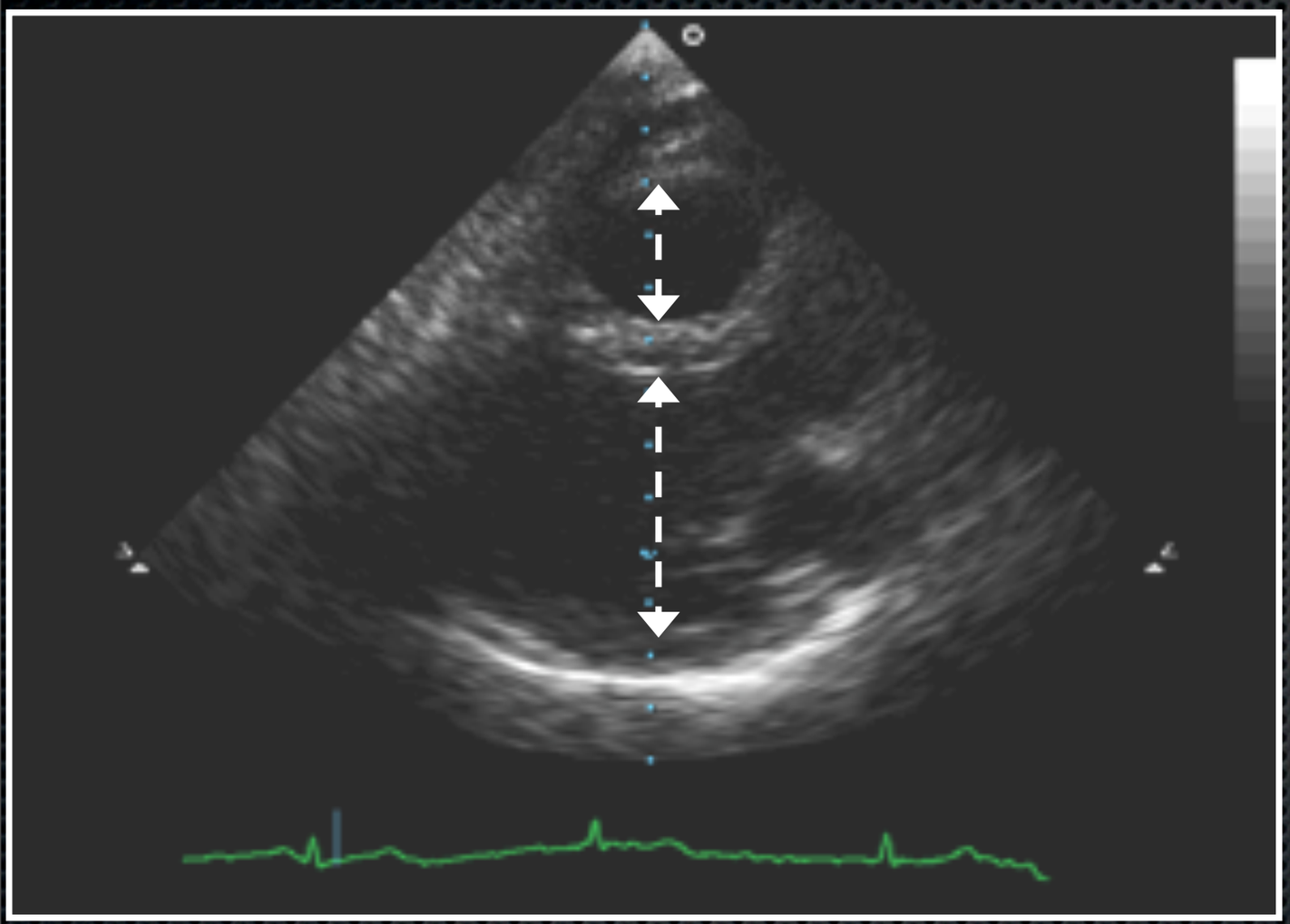
Echocardiographic criteria for diagnosis of PE

- **RV Dilatation**
  - -increased RV/LVEDD ratio
- **RV impairement (depressed contractility)**
  - -McConnell sign
- **Pressure overload**
- **Raised pulmonary systolic pressure**
  - -increased TR velocity
  - -decreased pulmonary acceleration time
- **Disturbed RV ejection pattern**
  - -60/60 sign
- **Impaired myocardial performance**
  - -RV MPI and V Index

RV Dilatation

Normal

PLAX



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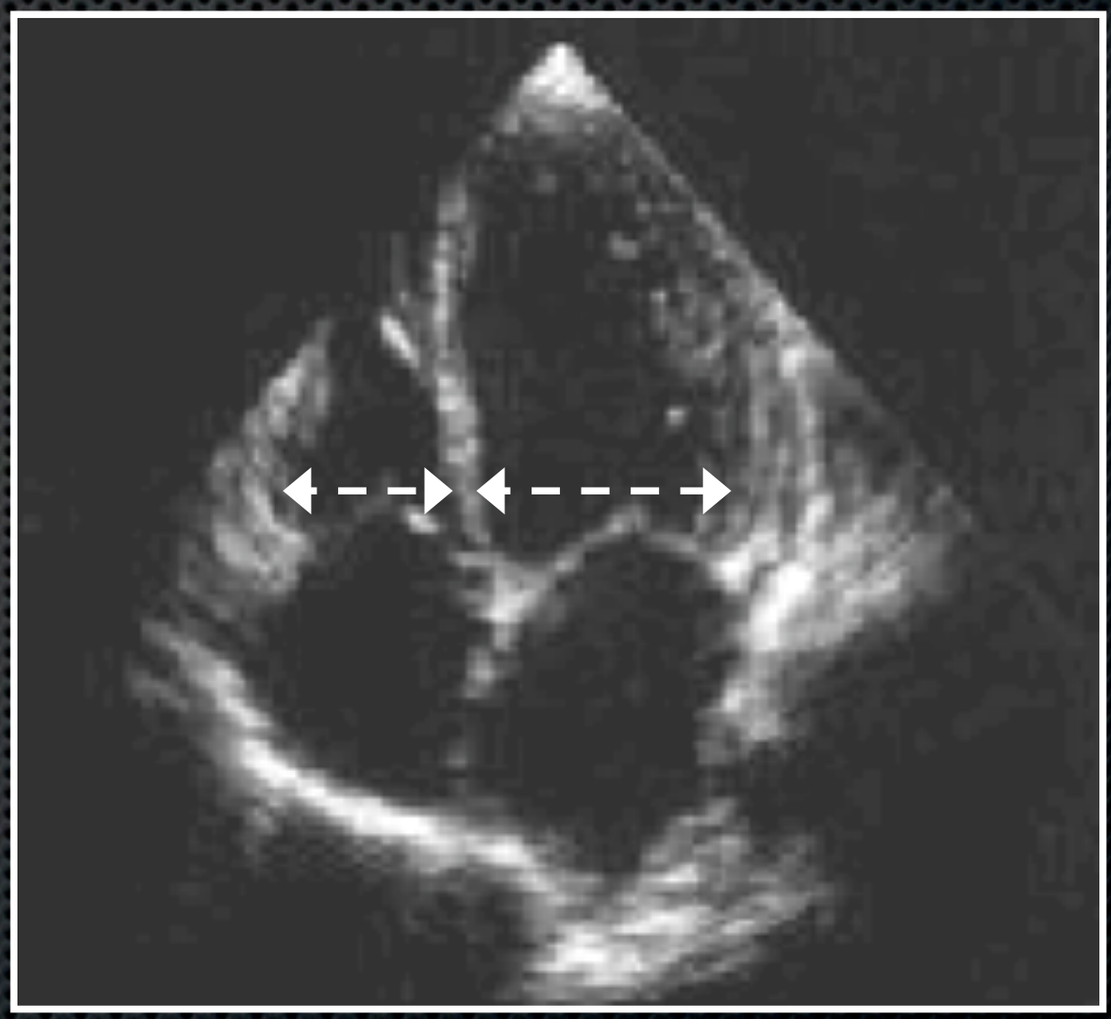
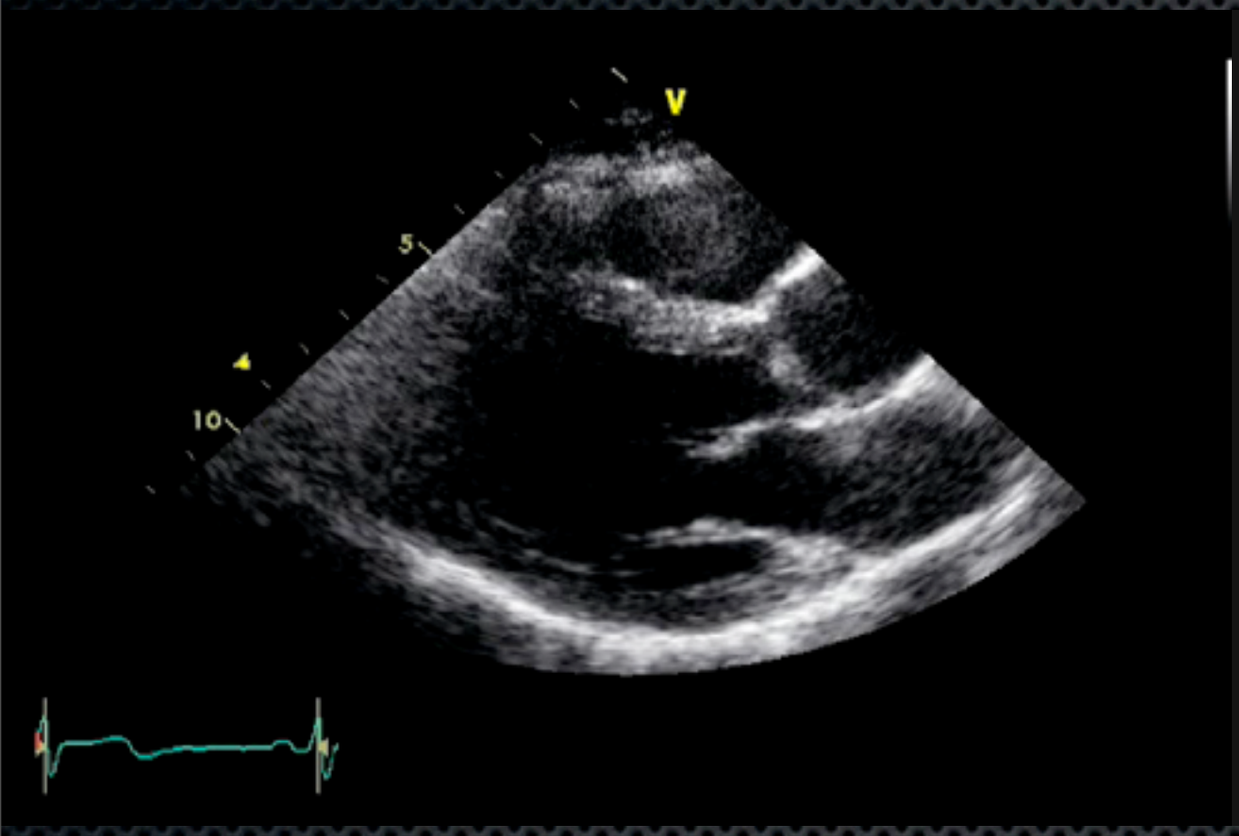


- Relative RV:LV ratio 1:3
- RV/LV EDD >0.55

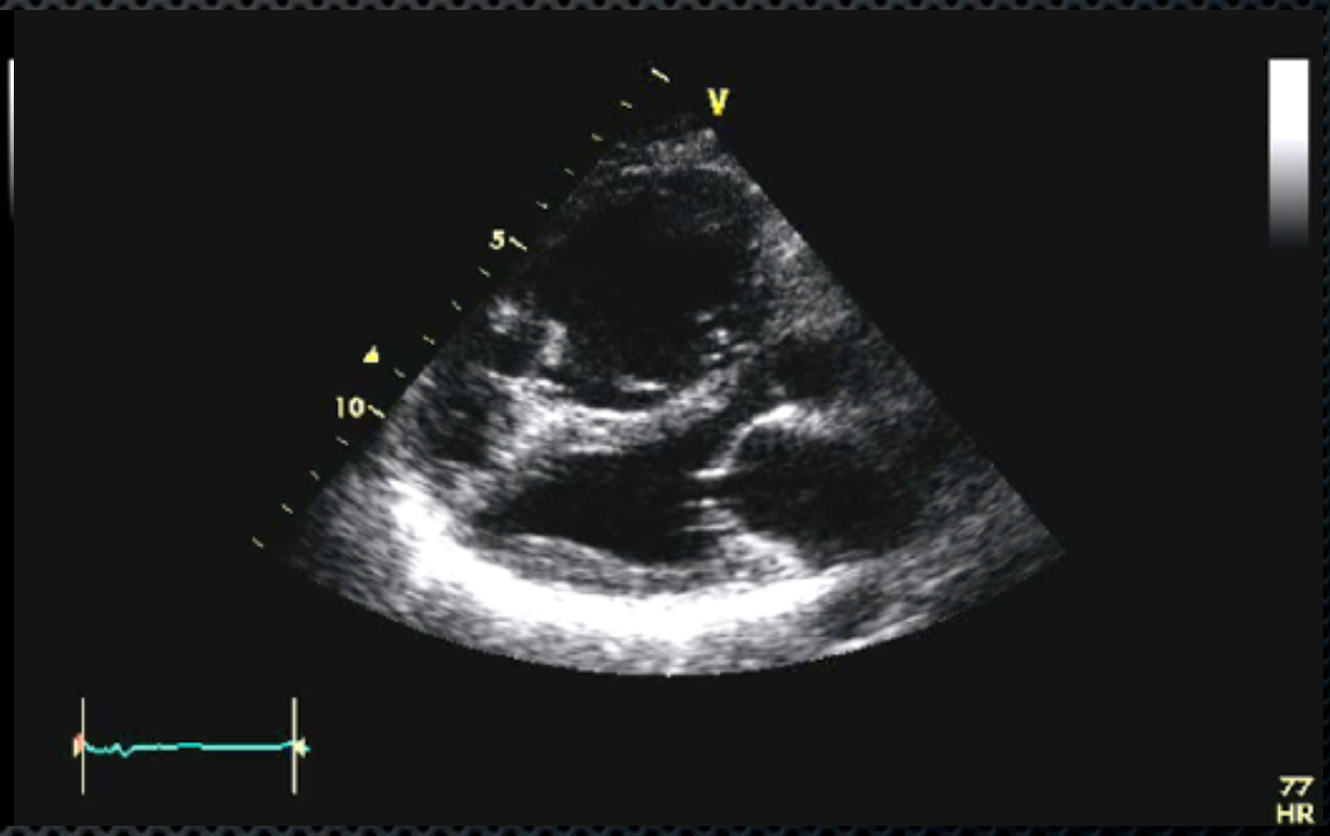
(Nazeyrollas P et al. Euro Heart J 1996:17:779 – 786)

RV Dilatation

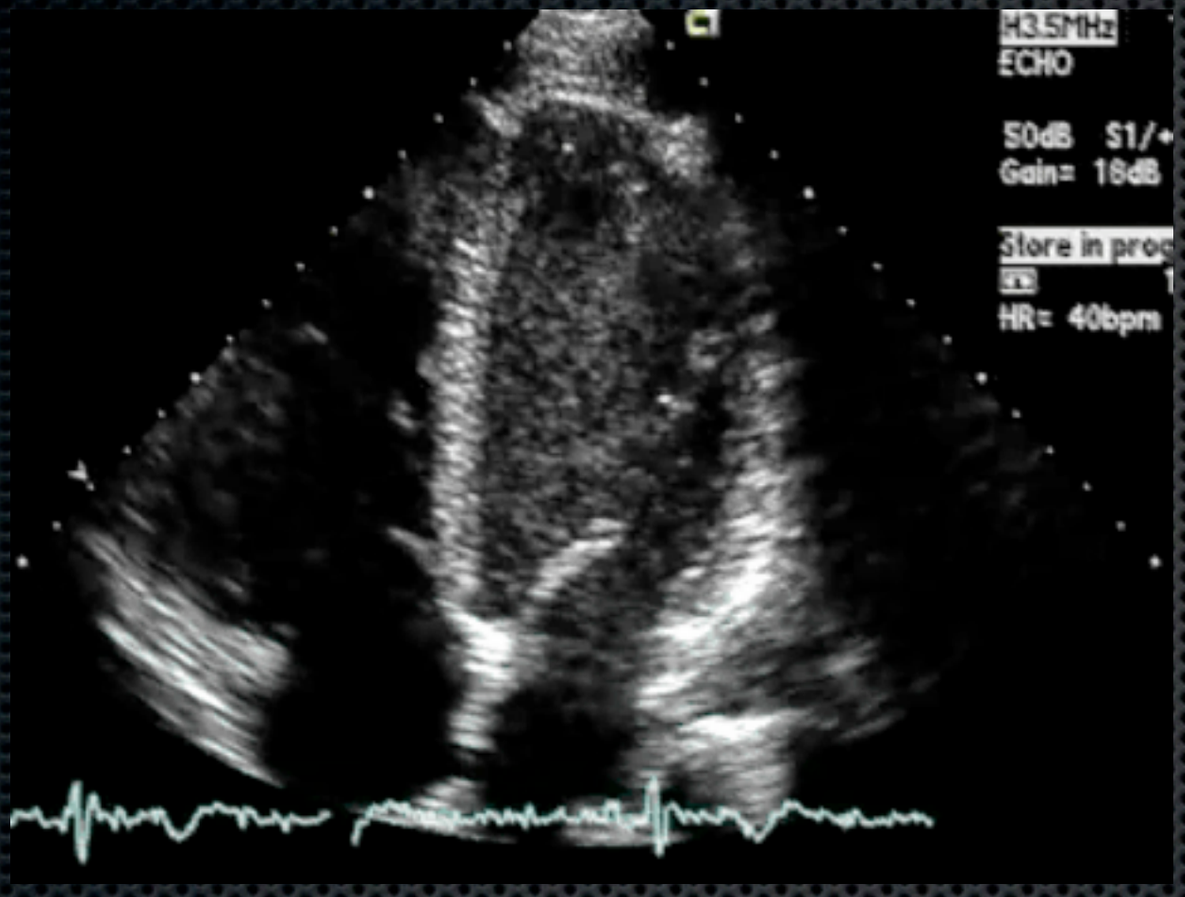
Normal

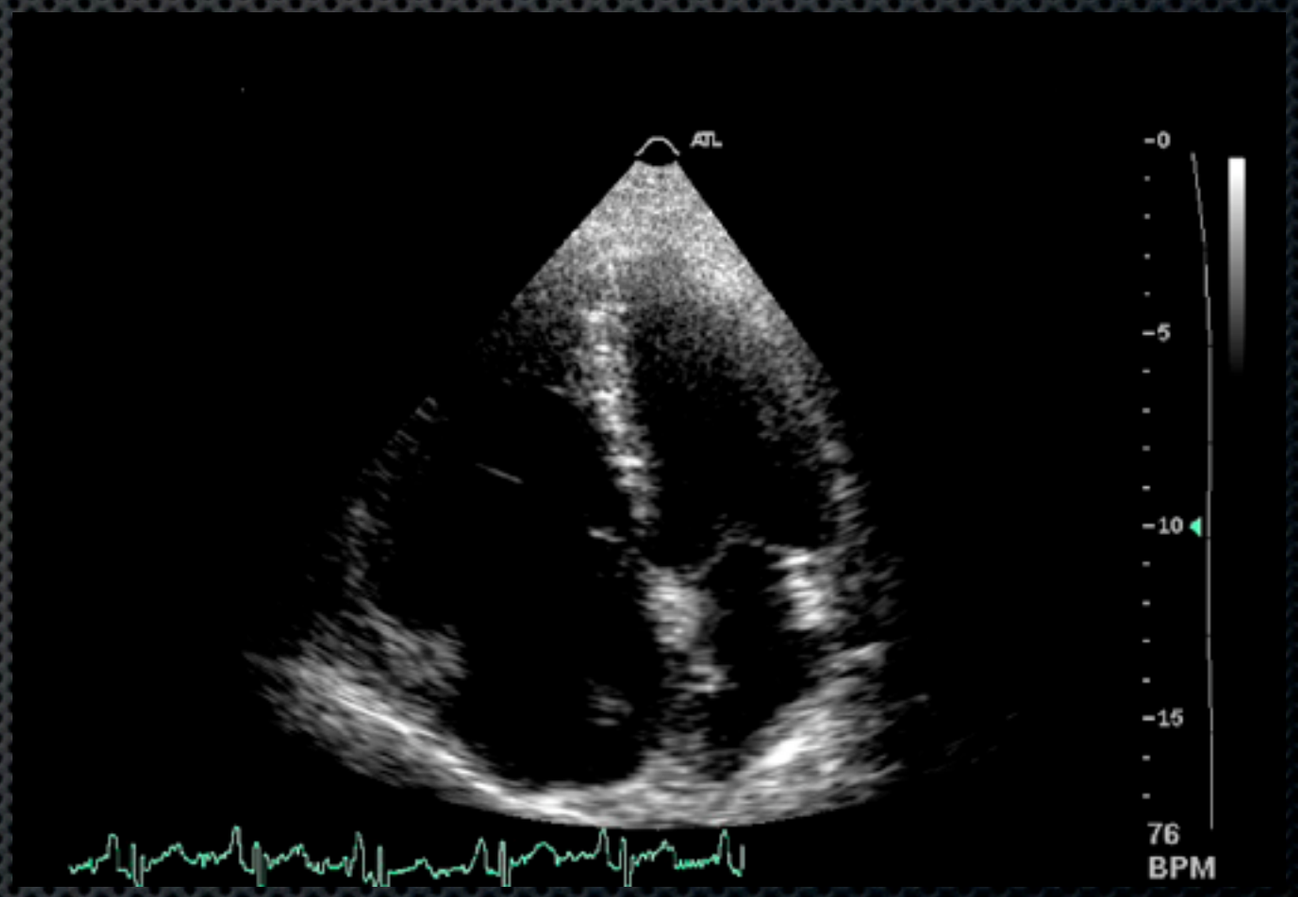


Dilated



RV Dilatation





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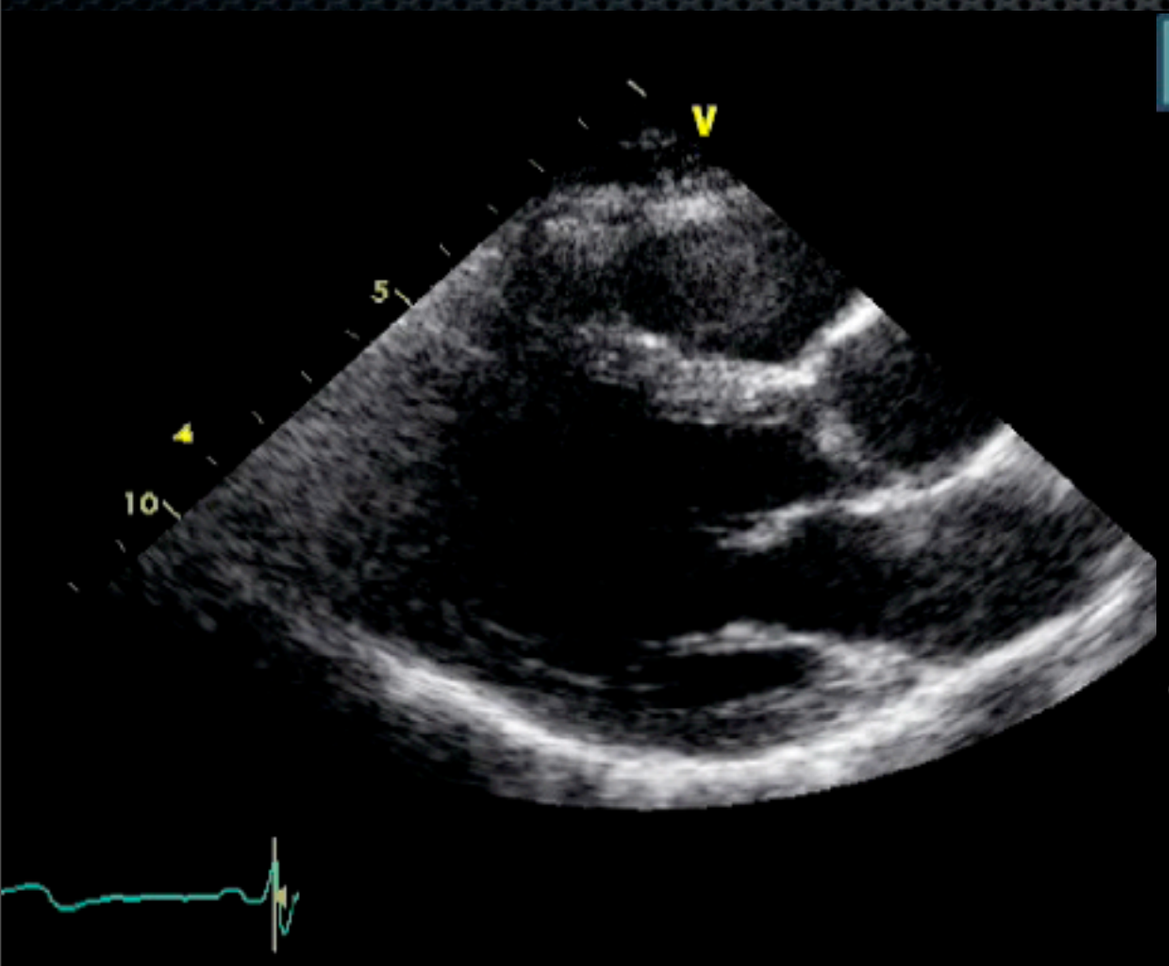
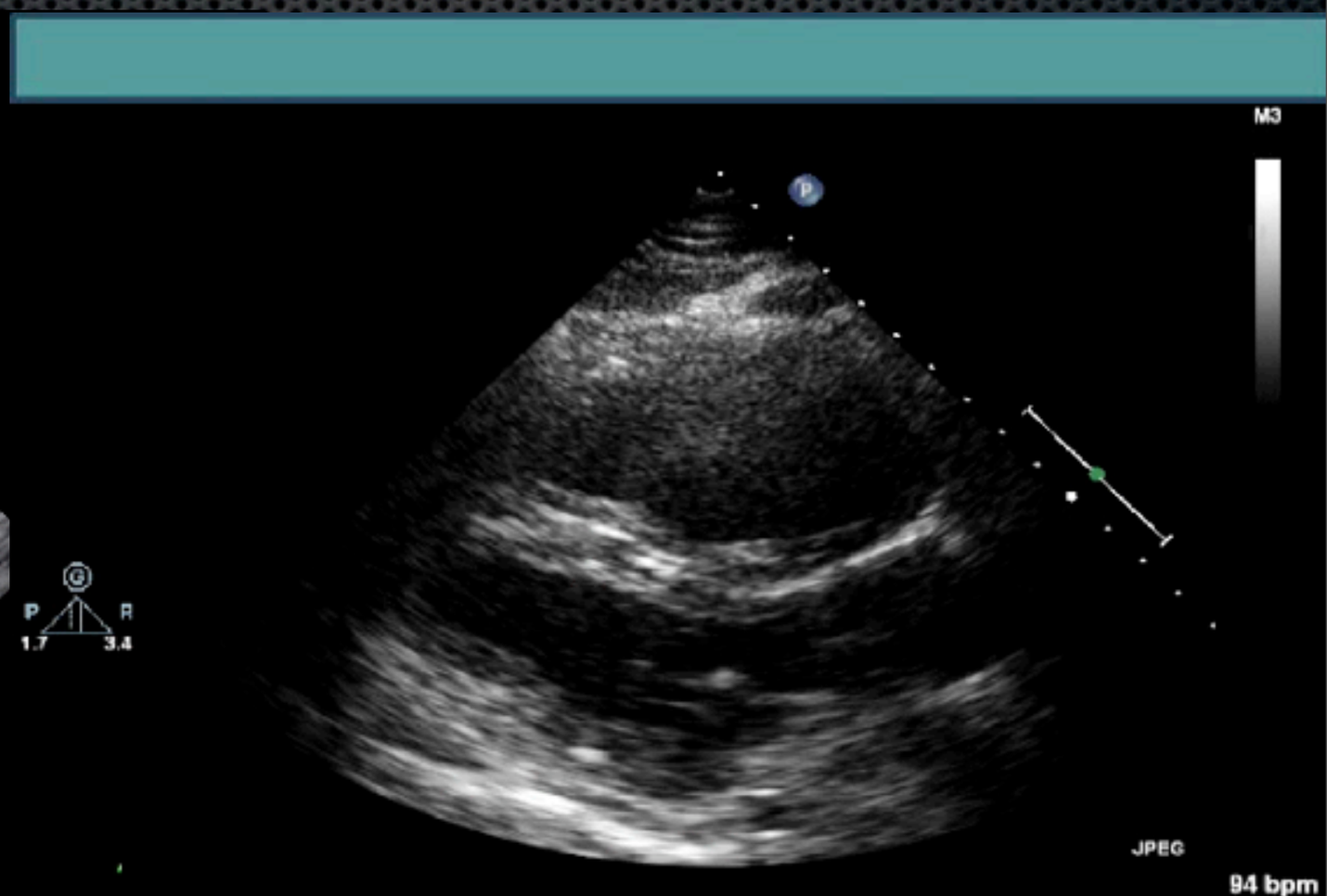
RV Impairment

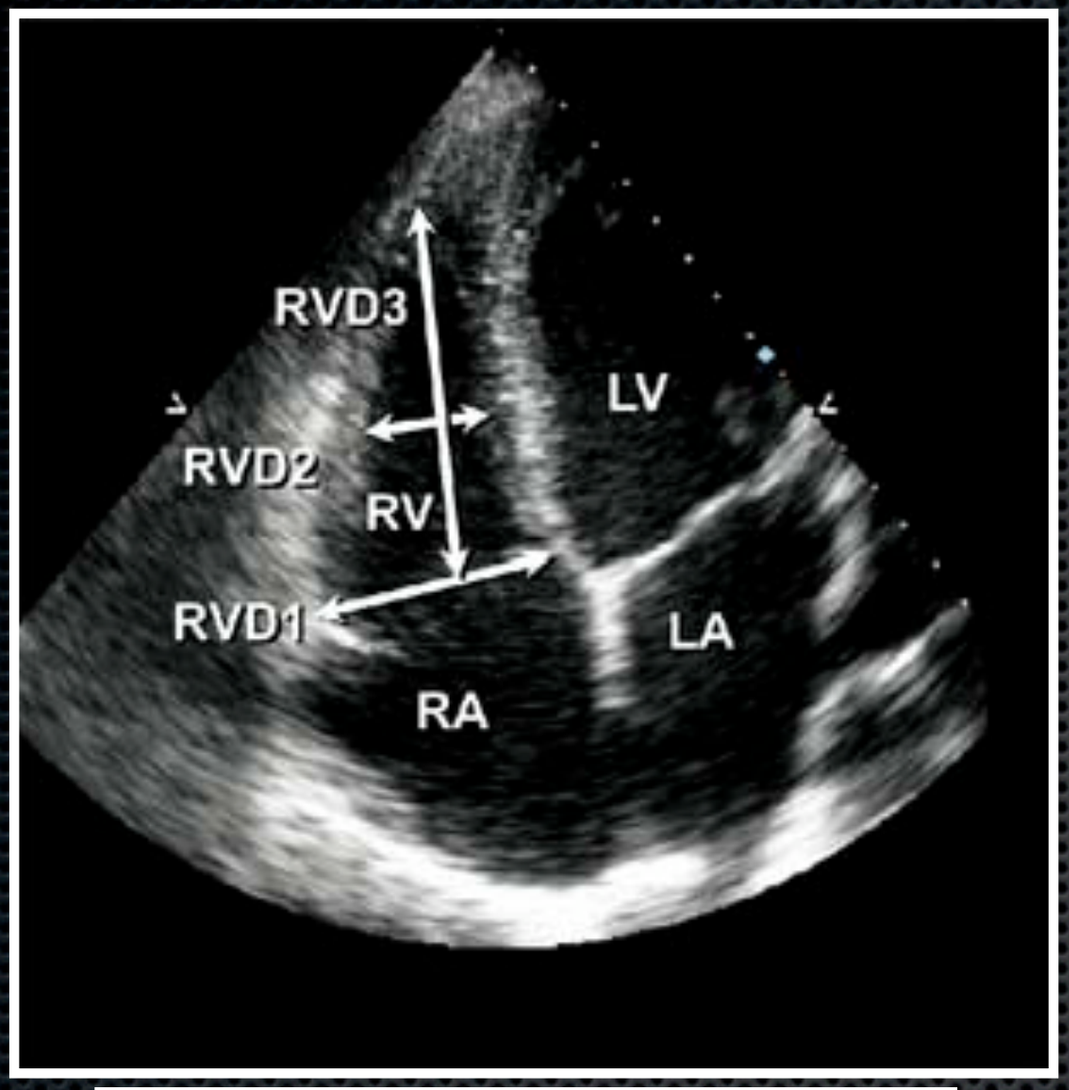
Normal

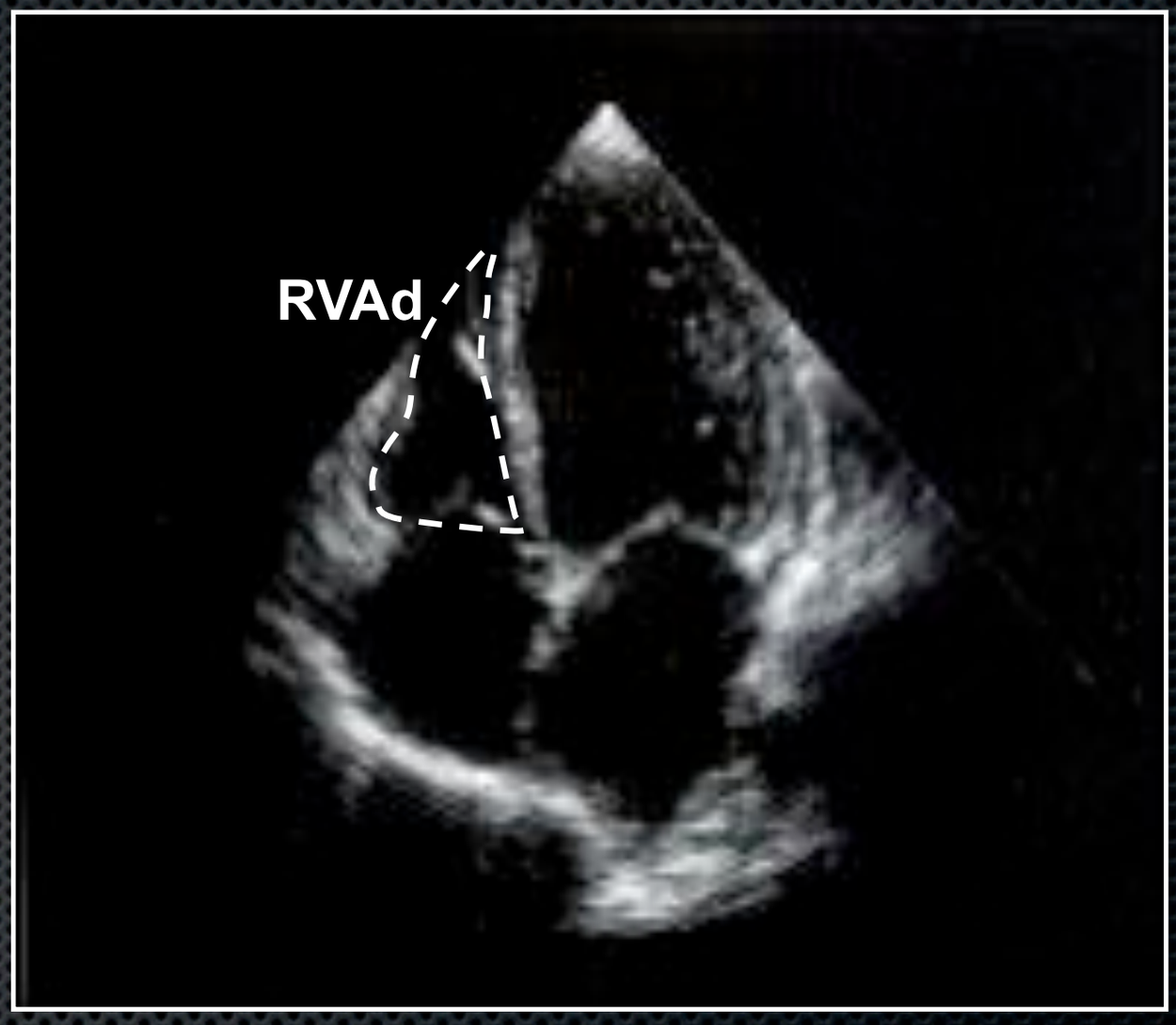


Severe



Quantification of RV size





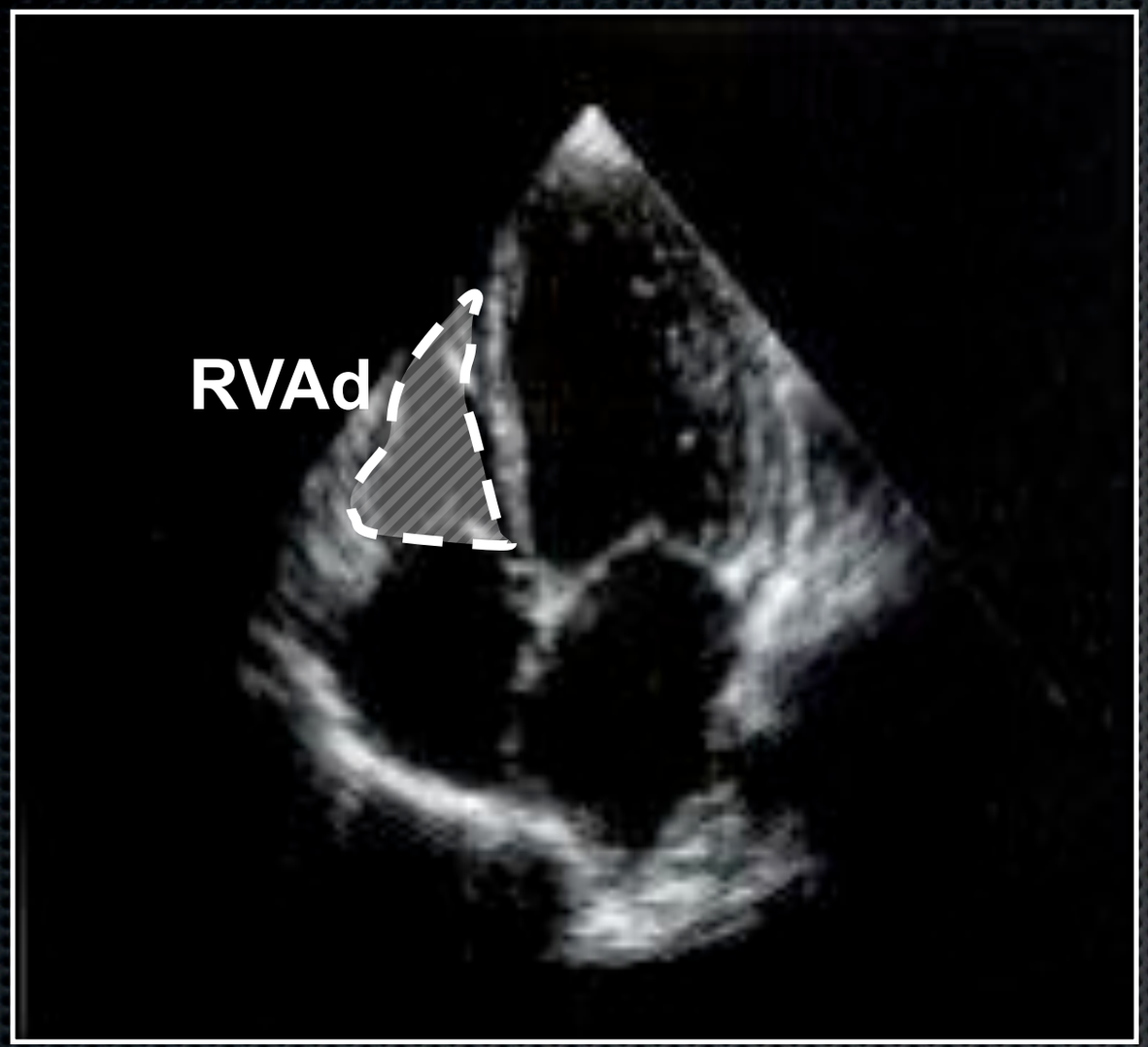
Reference Range*	
RVD1	2.7 – 3.3 cm
RVD2	2.0 – 2.8 cm
RVD3	7.1 – 7.9 cm
RVAd	11 – 28 cm^2

Clinical application:

- Practical
- Reproducible ?

(Lang RM et al. J Am Soc Echo 2005; 18:1440 – 1463)

RV Fractional Area Change

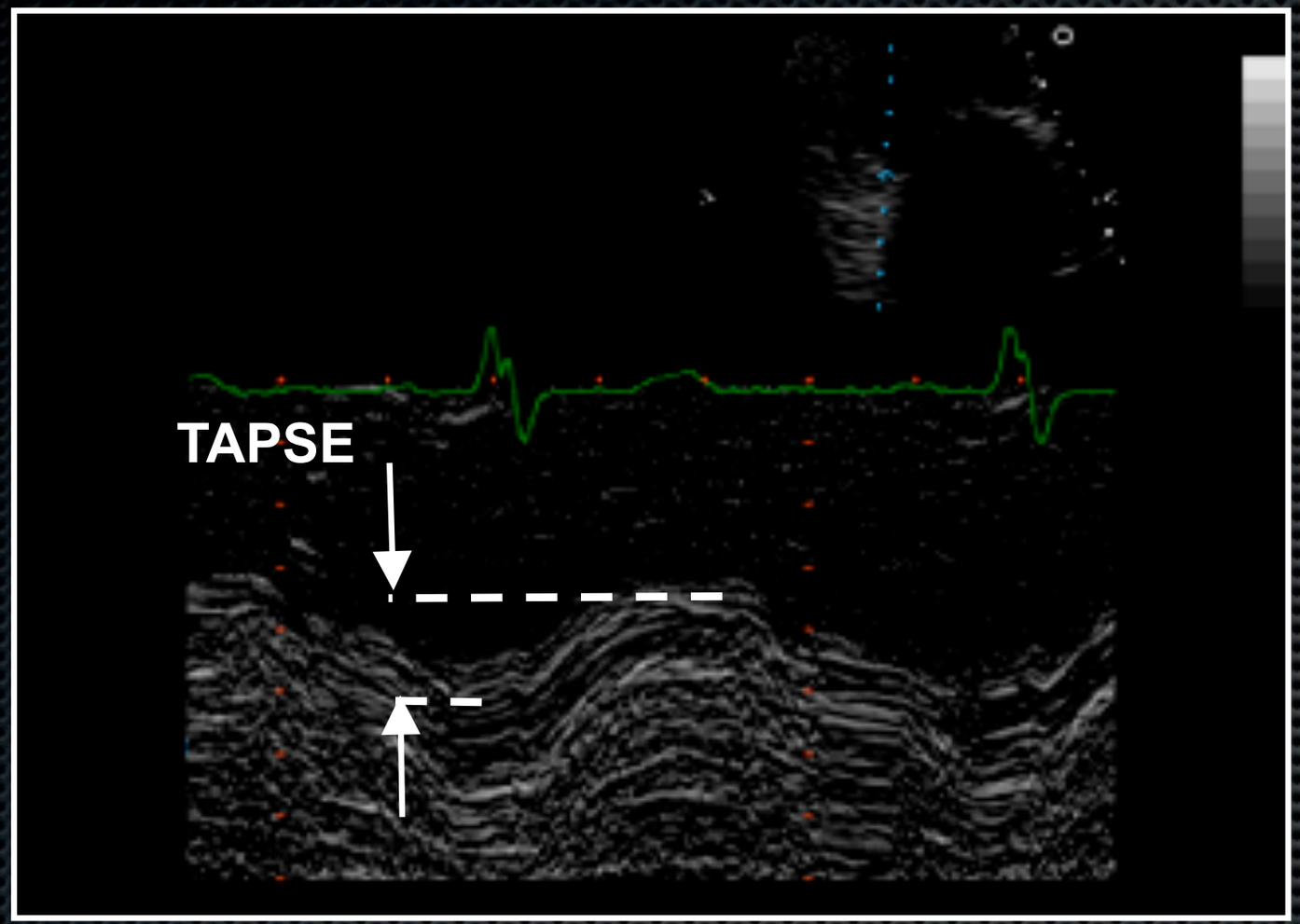


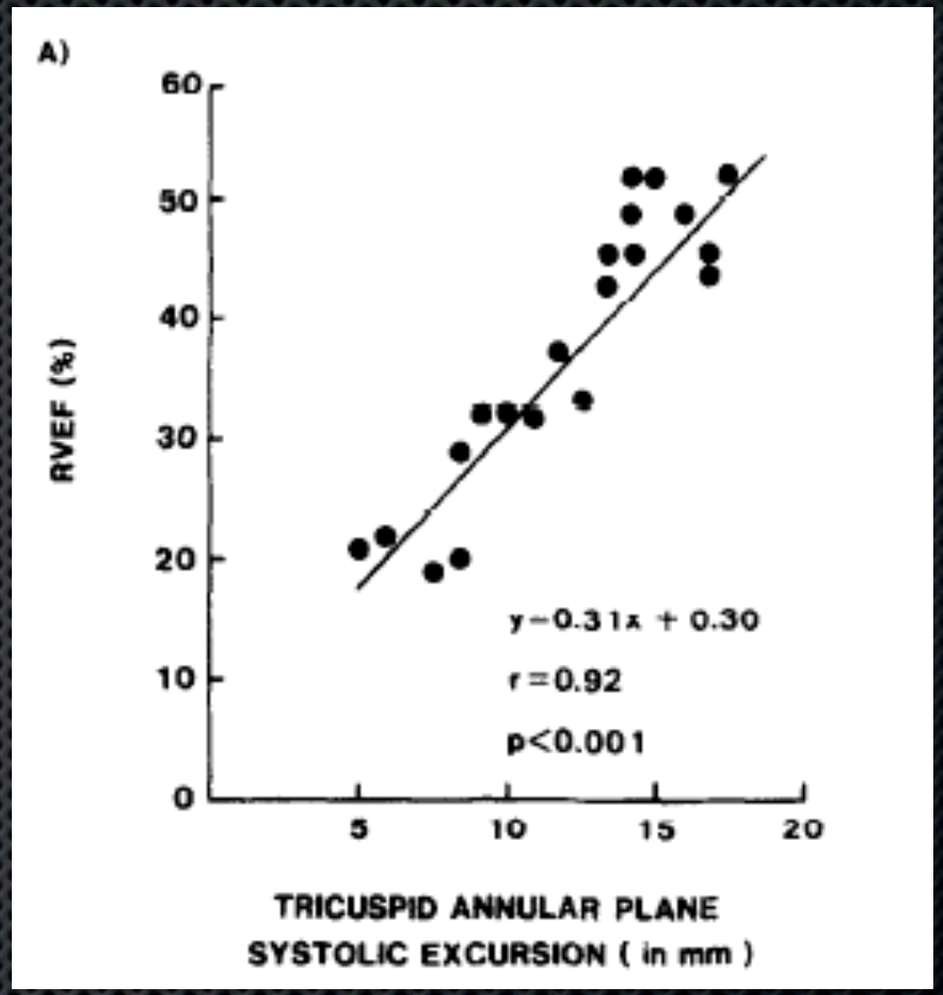
$$RVFAC = \left(\frac{RVAd - RVAs}{RVAd}\right) x100$$

	Normal
RVAd(cm^2):	11 – 28
RVAs (cm^2):	7.5 – 16
RV FAC (%):	32 – 60

- Good correlation of RV FAC with RVEF from cMRI
- Utilised in numerous studies
- Feasible in clinical practice?

TAPSE





Normal:	1.6 – 2.0 cm
Mild:	1.1 – 1.5 cm
Moderate:	0.6 – 1.0 cm
Severe:	<0.50 cm

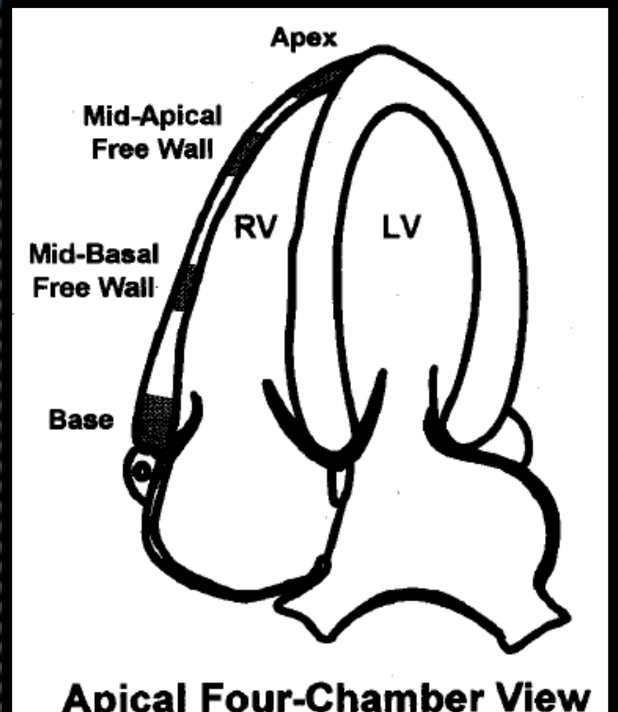
- Good correlation with RVEF
- Simple
- Reproducible
- But load dependant

(Kaul S et al. Am Heart J 107:526-31, 1984)

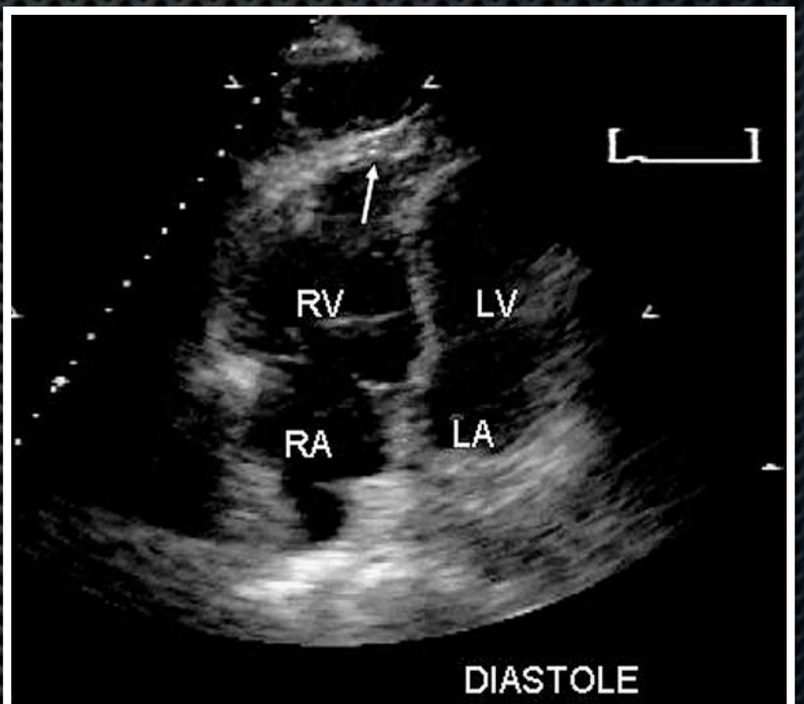
McConnell Sign

'Distinct regional RV dysfunction':

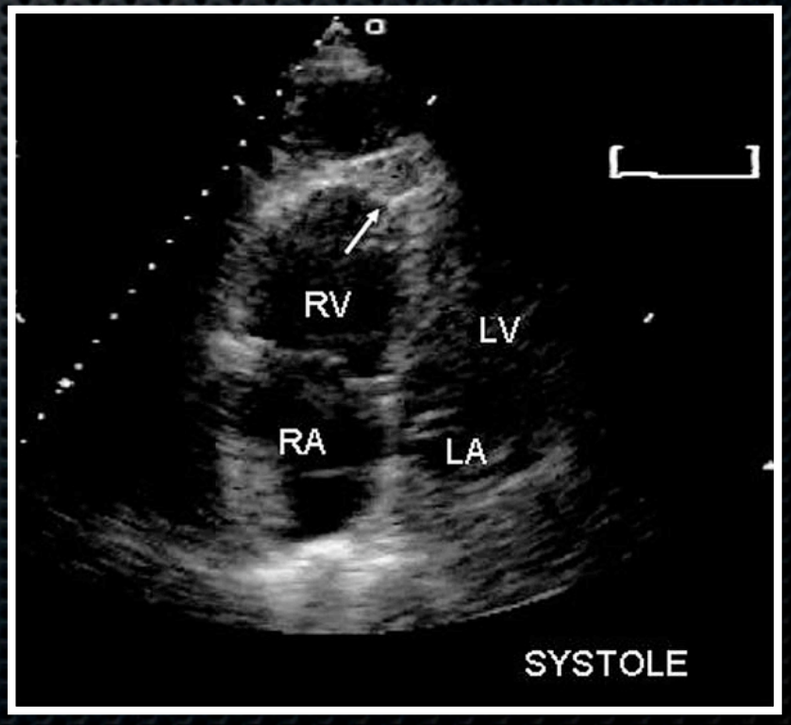
- Mid-free wall hypokinesia/akinesia
- Normal apical motion
- Not seen in chronic PHT
- But also seen in acute RV infarction



Apical Four-Chamber View



	Patients without known previous cardiorespiratory diseases (n = 46)	Patients with known previous cardiorespiratory diseases (n = 54)
	McConnell sign	McConnell sign
Specificity (%)	100	100
Sensitivity (%)	19	20
PPV (%)	100	100
NPV (%)	35	40

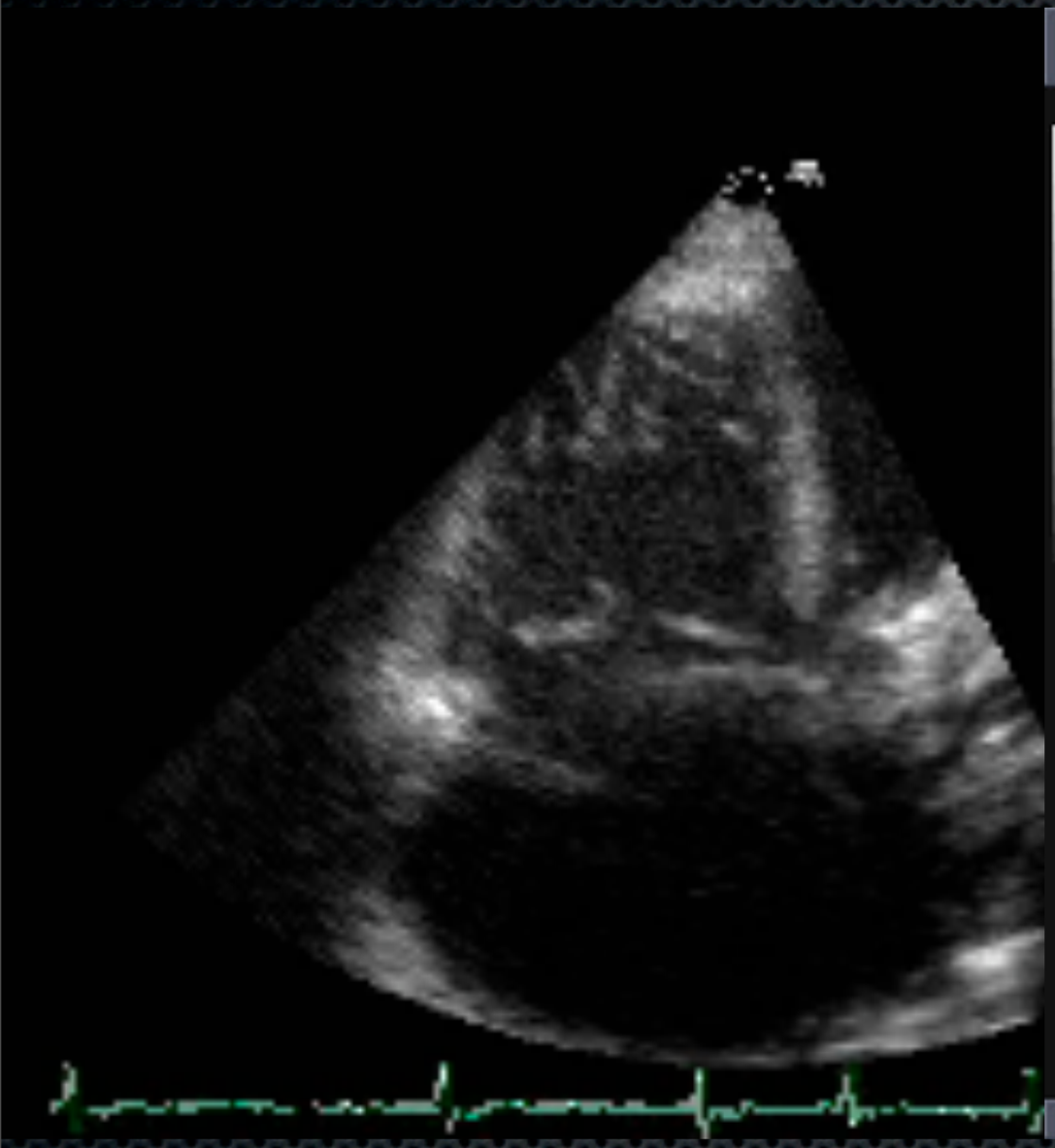


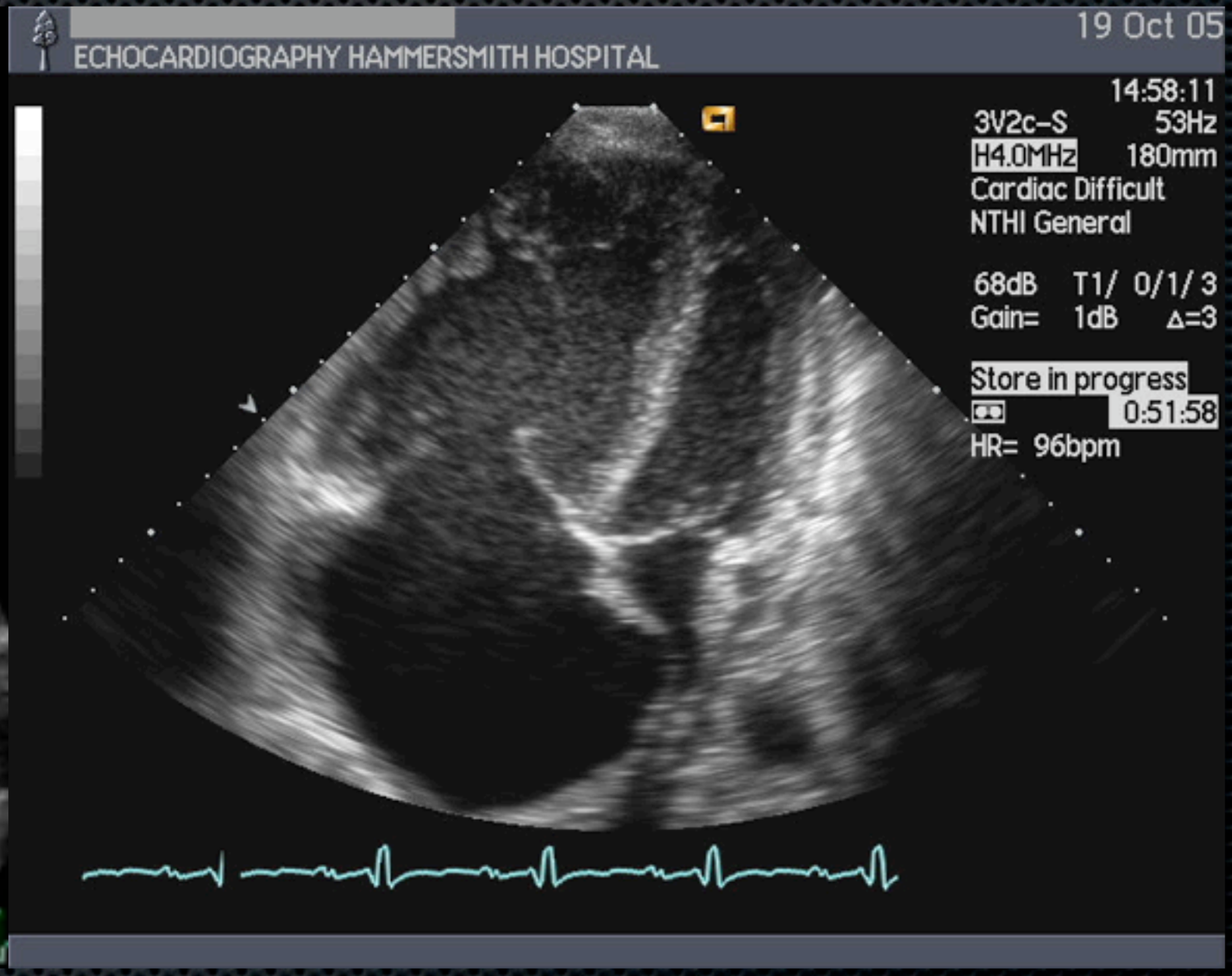
McConnell et al. Am J Cardiol 1996;78:469-473)

McConnell Sign

Acute PE

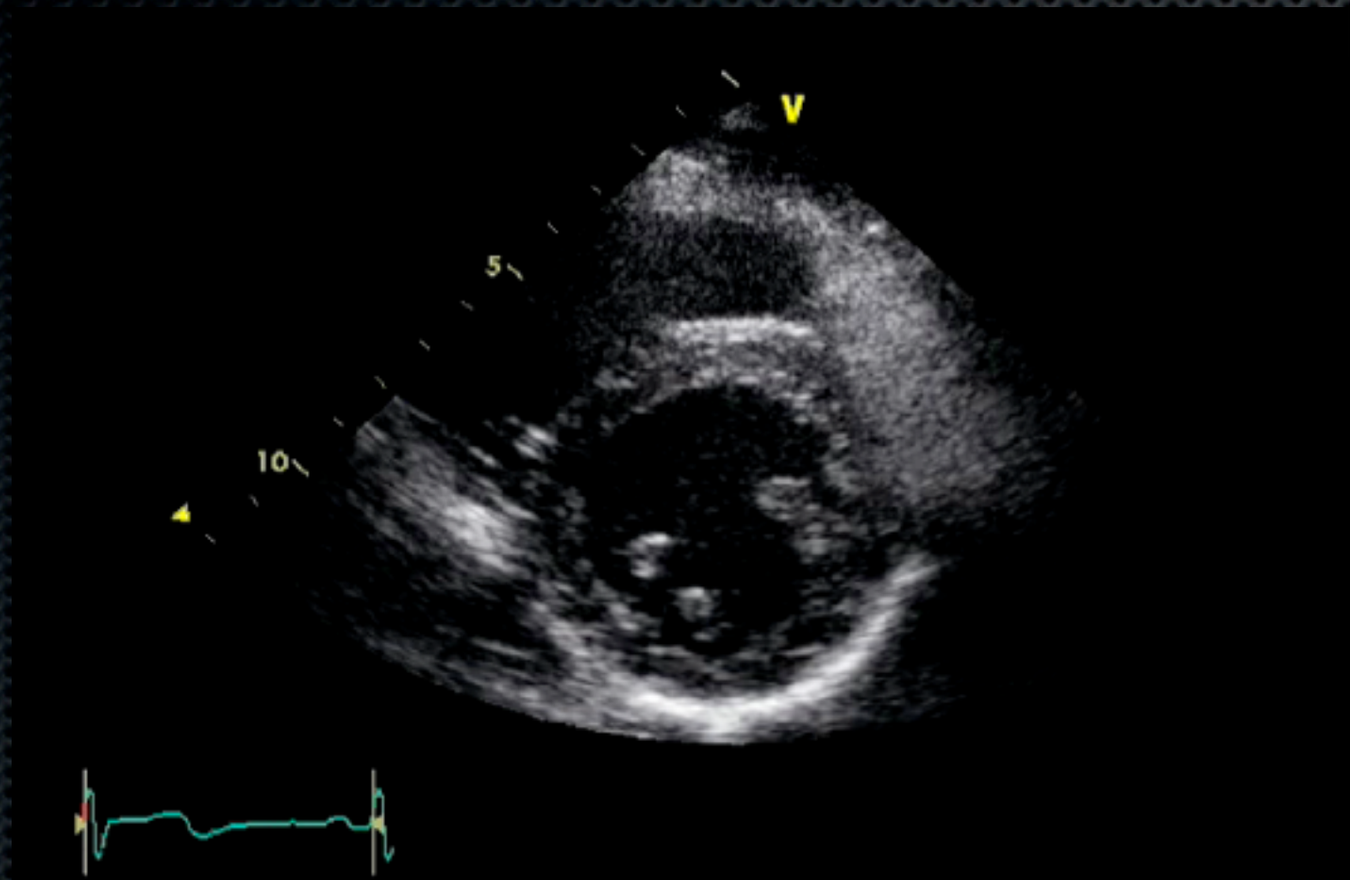
CTEPH



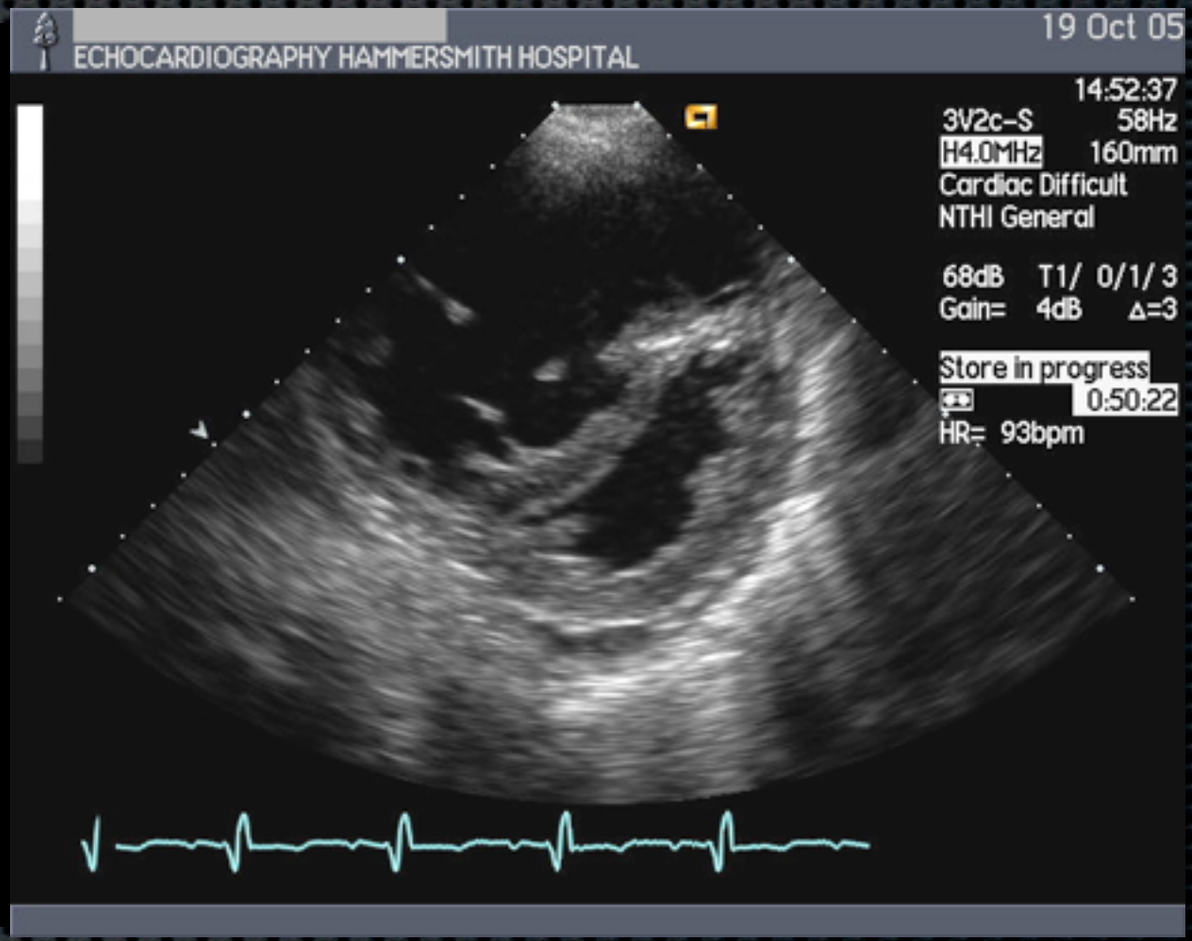


RV Pressure Overload

Normal



RV Pressure overload



- Pressure loading = systolic ‘D’ shaped LV
- Volume loading = diastolic ‘D’ shaped LV + TR/PR or L- R shunt
- ↑diastolic pressure = diastolic ‘D’ shaped LV + RV impairment

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Assessing Pulmonary Artery Pressures

$$\Delta P = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) + \int_1^2 \frac{d\bar{v}}{dt}\, x d\bar{s} + R(\bar{v})$$

Gradient=convective acceleration + flow acceleration + viscous friction

ΔP = pressure difference(mmHg)

V_1 = proximal velocity (m/s)

V_2 = distal velocity (m/s)

ρ = density of fluid (g/cm^3)

$d\bar{V}$ = change in velocity over time (dt)

ds = distance over pressure decrease

R = viscous resistance in the vessel

$\bar{V}$ = velocity of blood flow

Assessing Pulmonary Artery Pressures

$$\Delta P = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) + \int_1^2 \frac{d\bar{v}}{dt} x d\bar{s} + R(\bar{v})$$

Gradient=convective acceleration + flow acceleration + viscous friction

ΔP = pressure difference(mmHg)

V_1 = proximal velocity (m/s)

V_2 = distal velocity (m/s)

ρ = density of fluid (g/cm^3)

$d\bar{V}$ = change in velocity over time (dt)

ds = distance over pressure decrease

R = viscous resistance in the vessel

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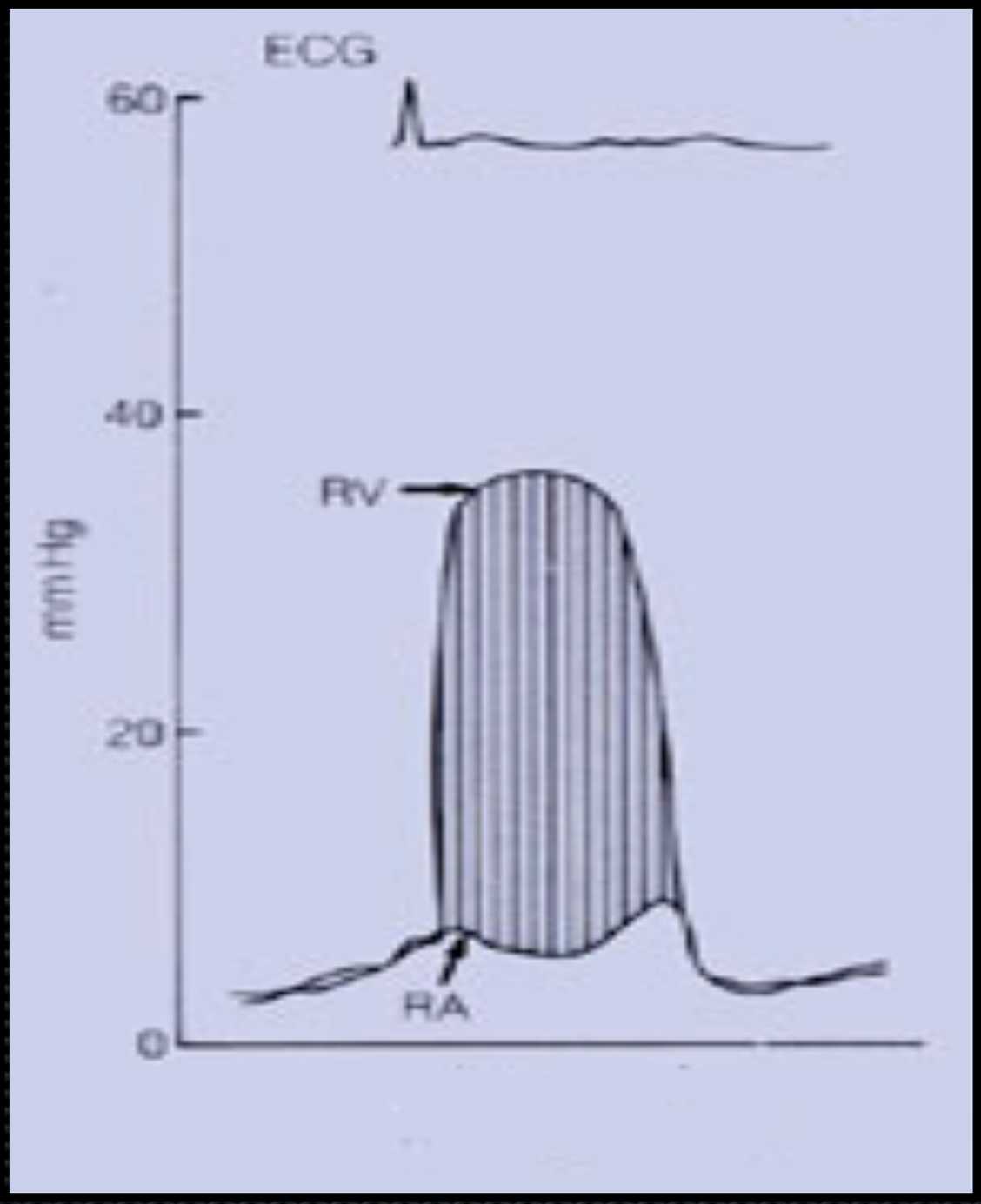
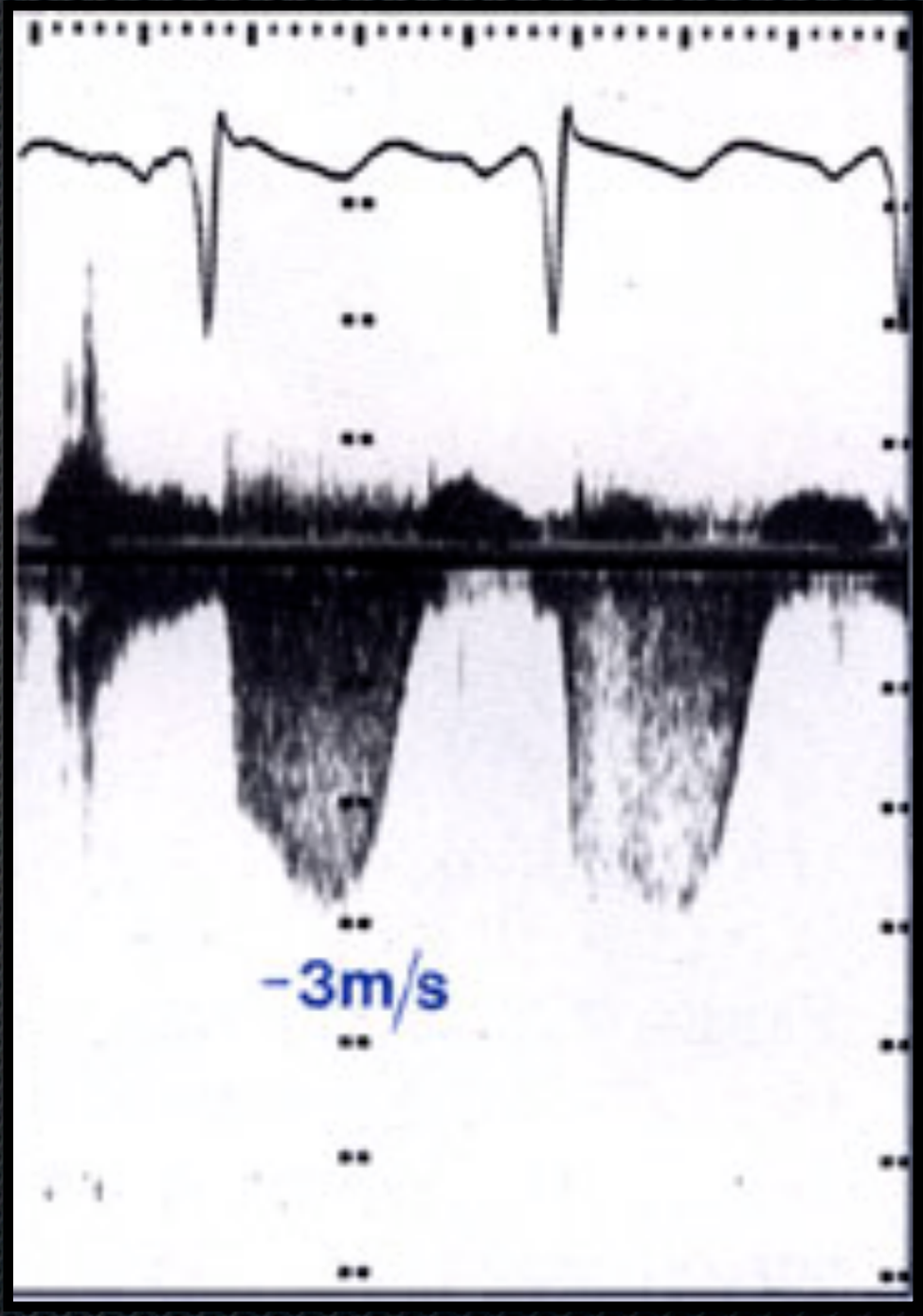
$$\Delta P = 4\left(V_2^2 - V_1^2\right)$$

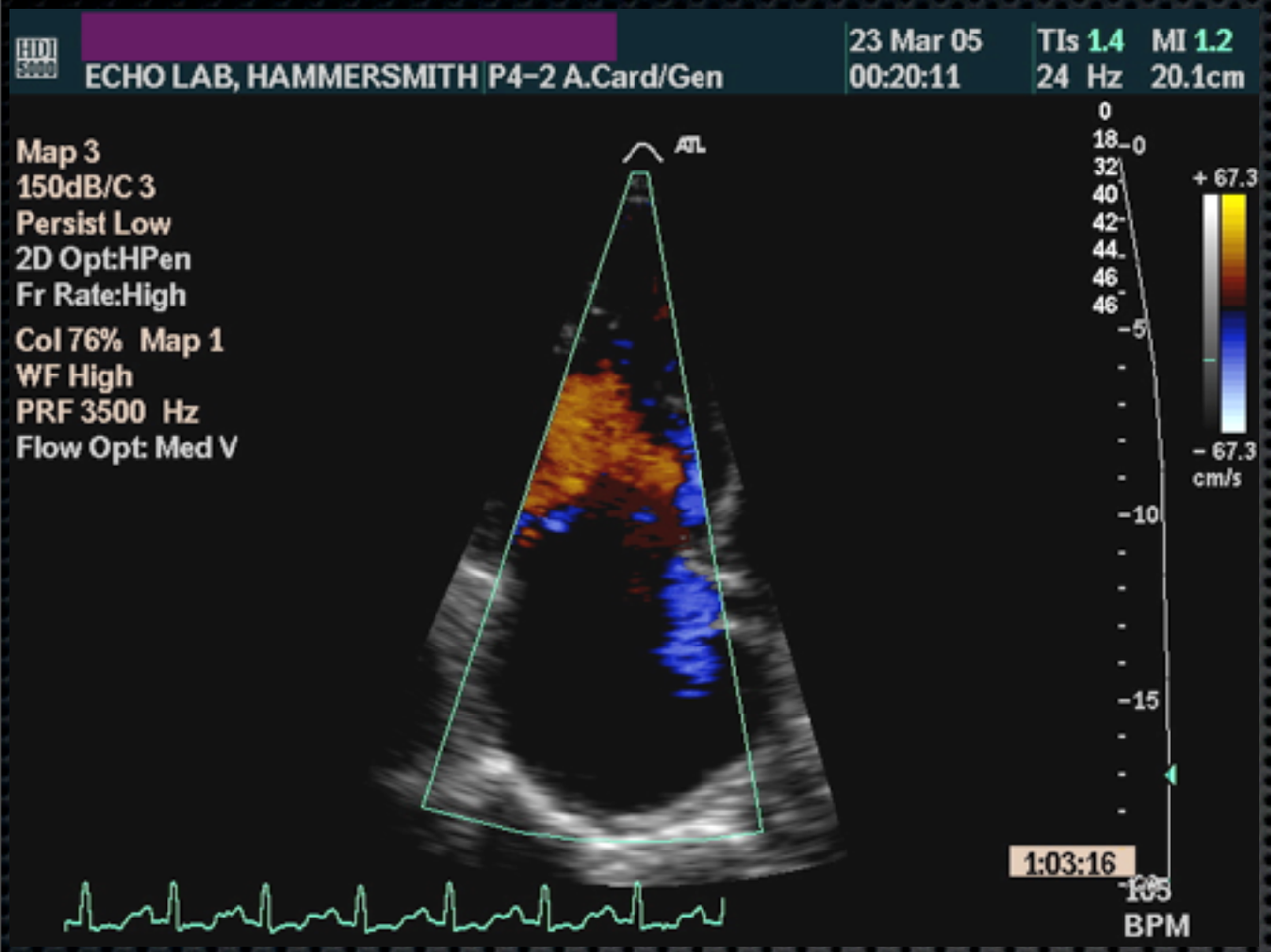
Measurement of RV Systolic Pressure

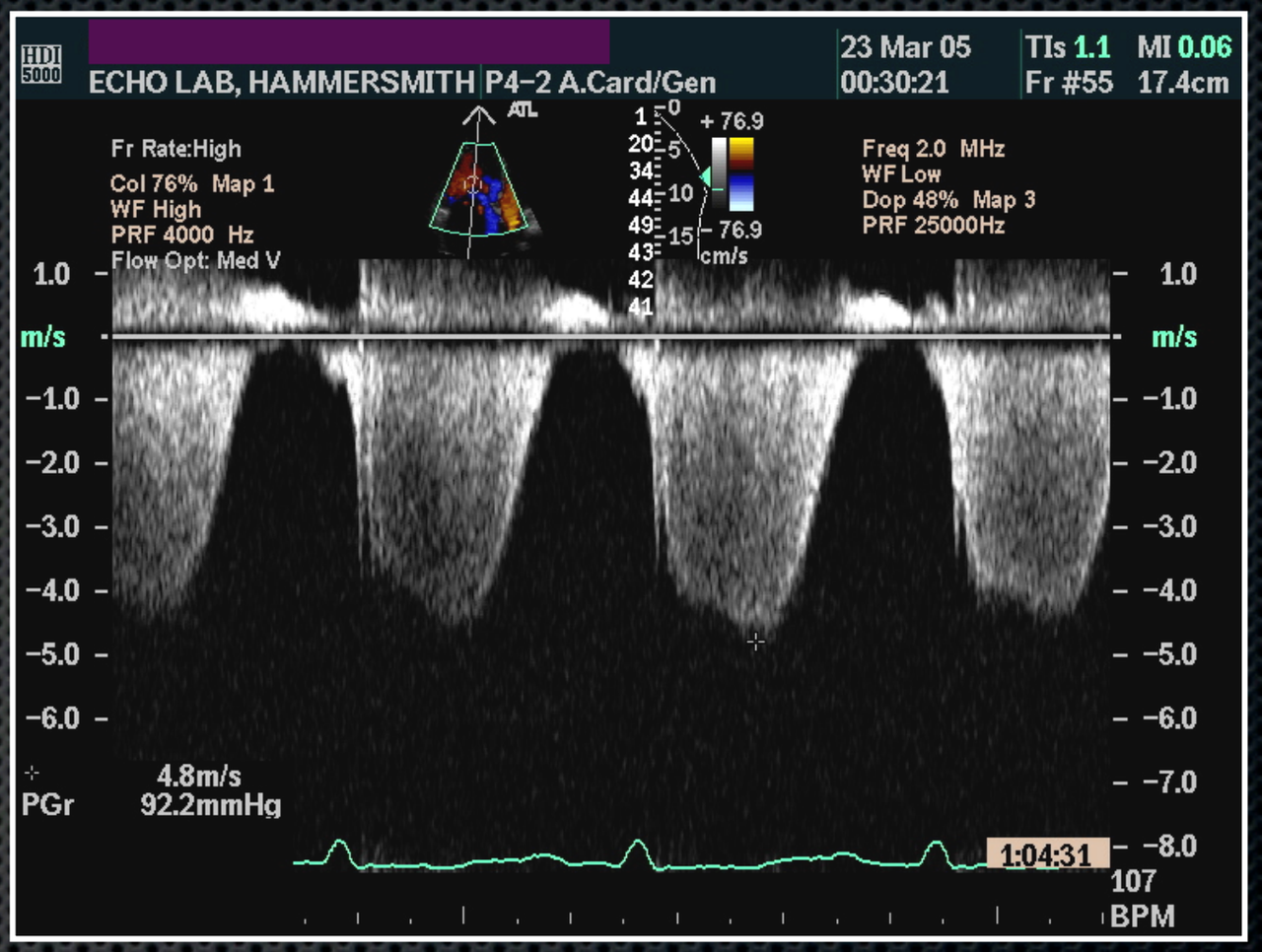




$$RV\ SP = 4(TR\ V_{Max})^2 + \text{estimated RAP}$$

RV Systolic Pressure



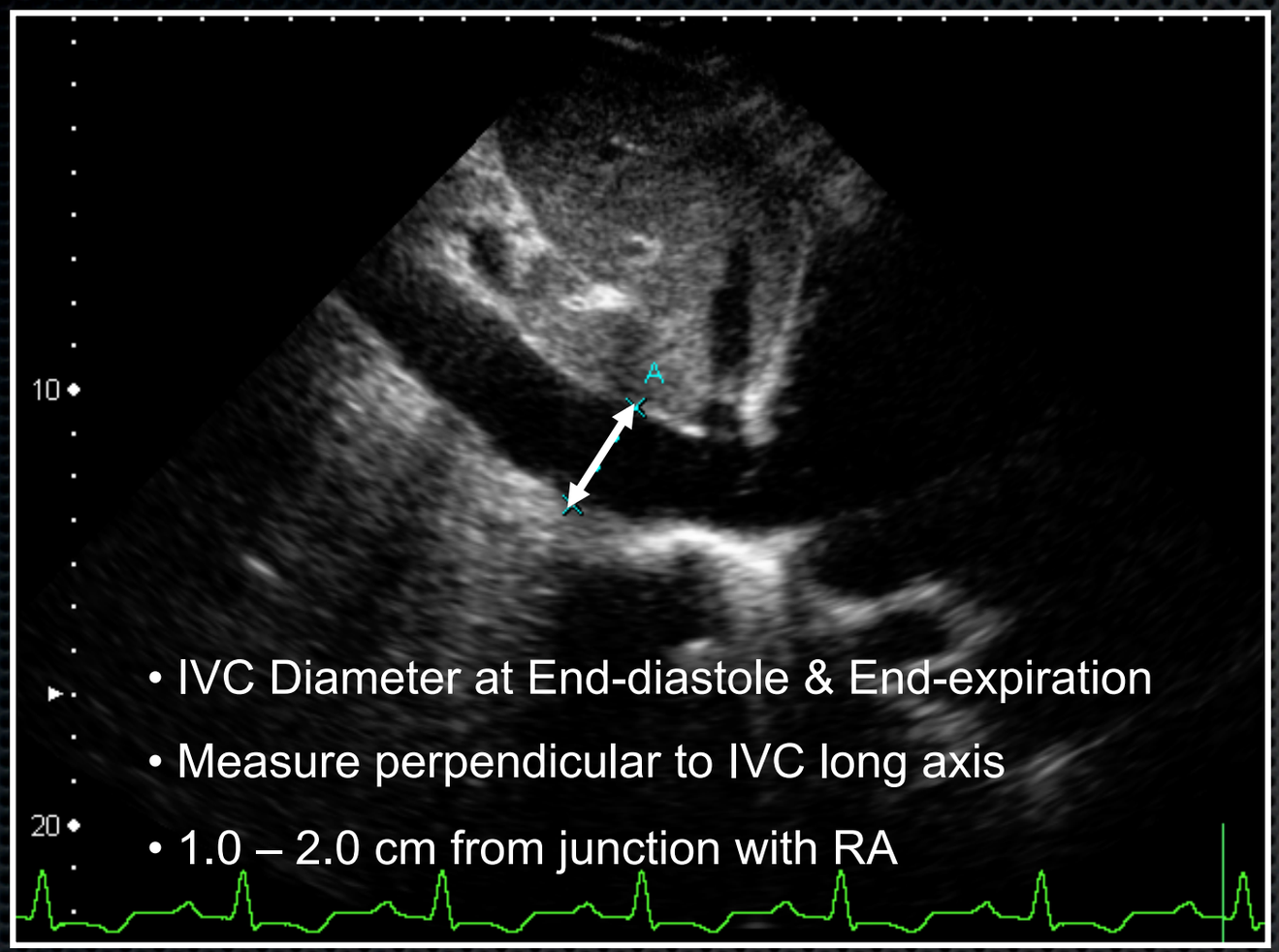


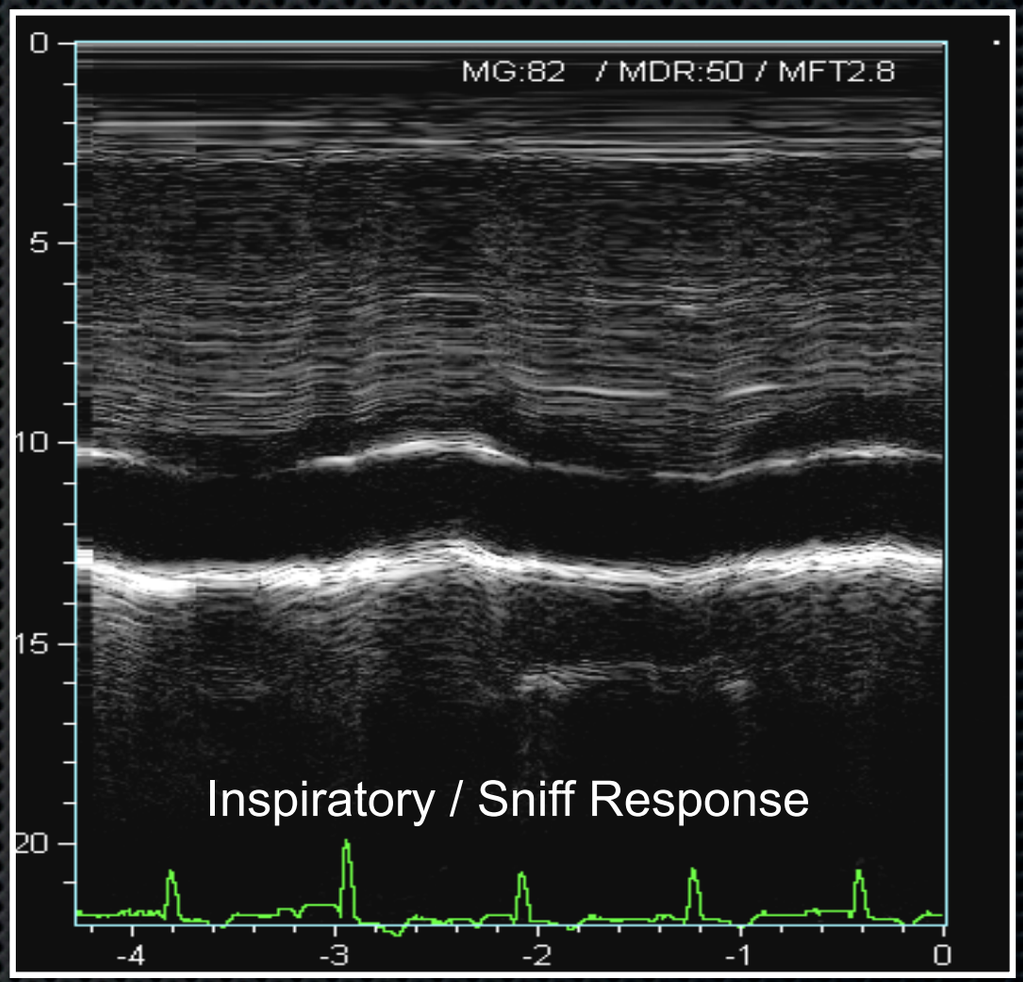
RV systolic pressure = $4(\text{TR } V_{MAX})^2$ + estimated RAP

RVSP (mmHg) :	PHT Grade:
35 – 55	Mild
55 – 85	Moderate
>85	Severe

(Circulation 70:657-662, 1984)

Mean RA Pressure

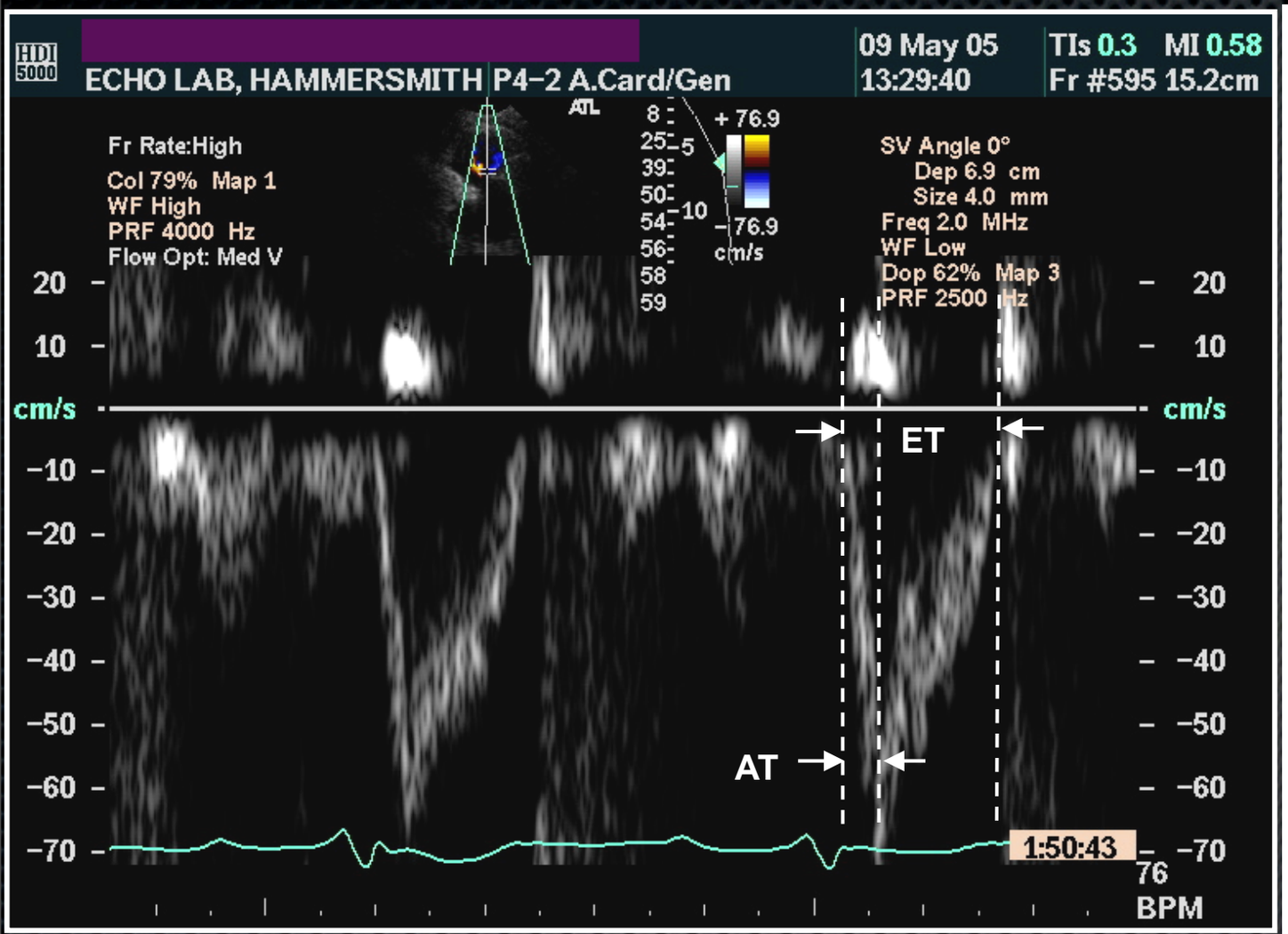


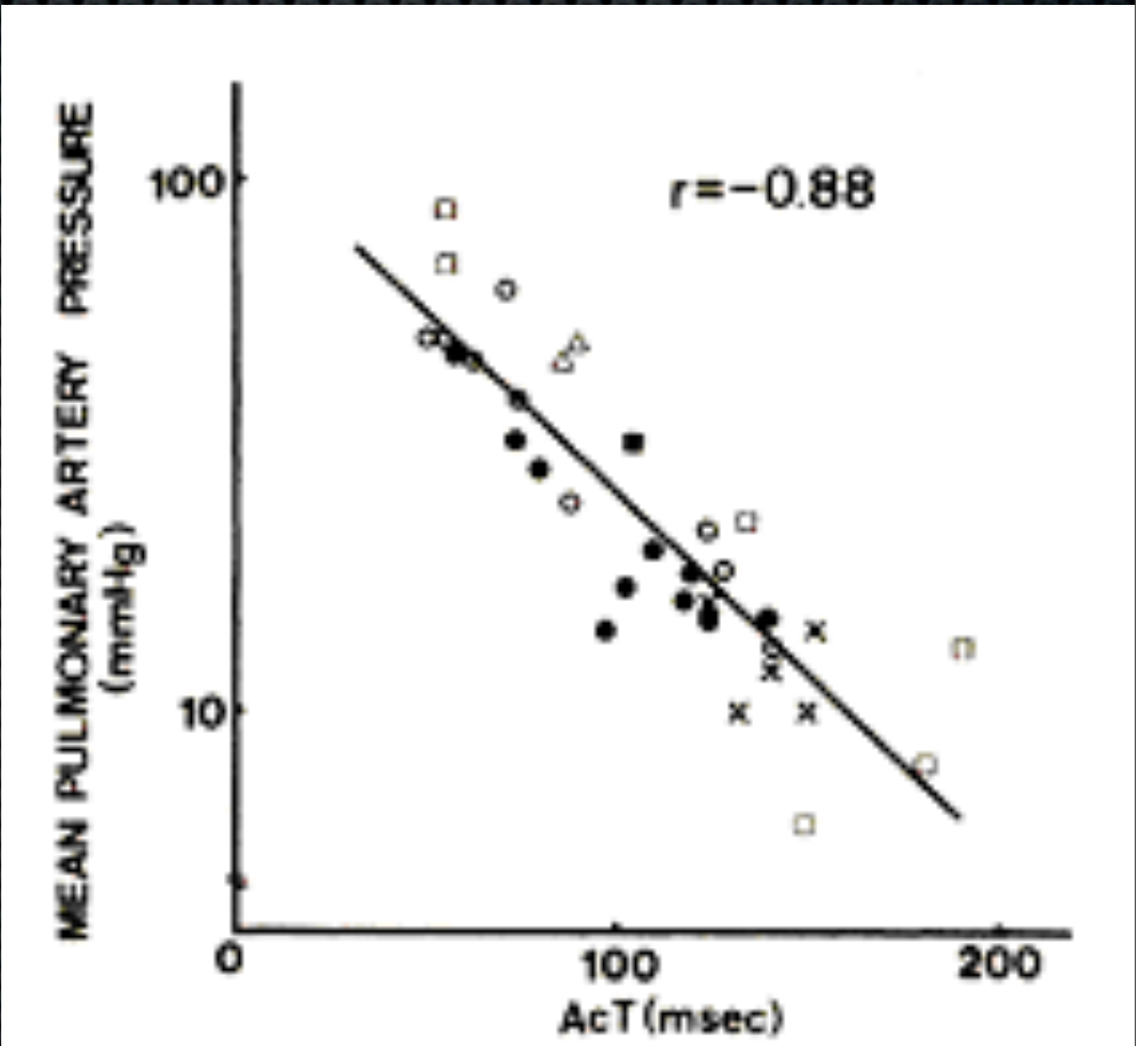


Mean RAP (mmHg)	IVC ∅ (mm)	IVC Inspiratory Collapse
0 – 5	< 15	Complete
5 – 10	15 – 25	> 50%
10 – 15	15 – 25	< 50 %
15 – 20	> 25	< 50 %
> 20	>25	No change

(Ommen SR. et al. Clin Proc 75: 24-9, 2000)

RVOT Acceleration Time

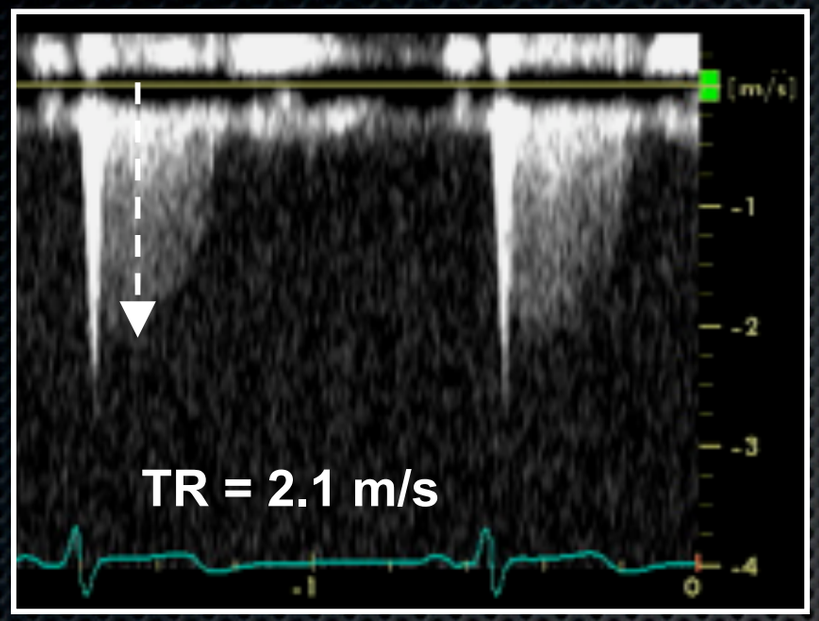


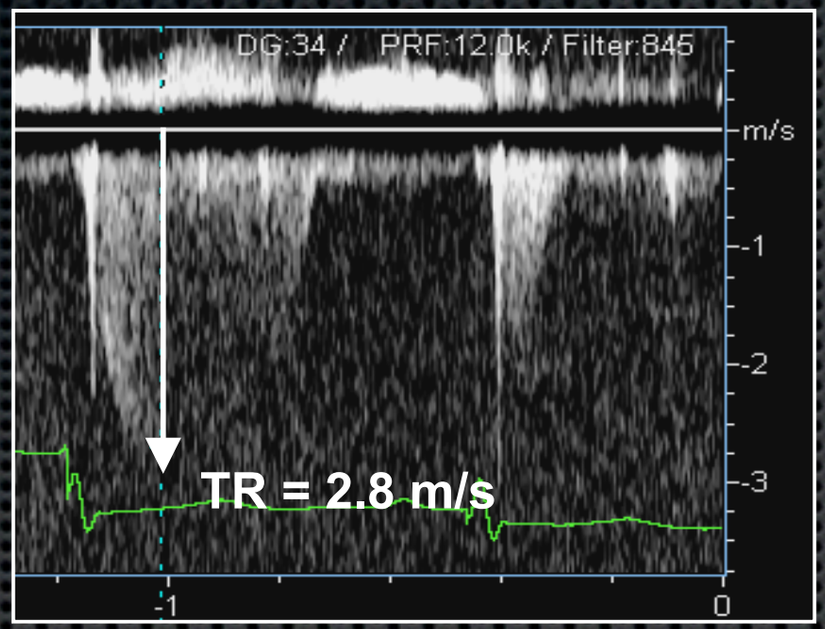


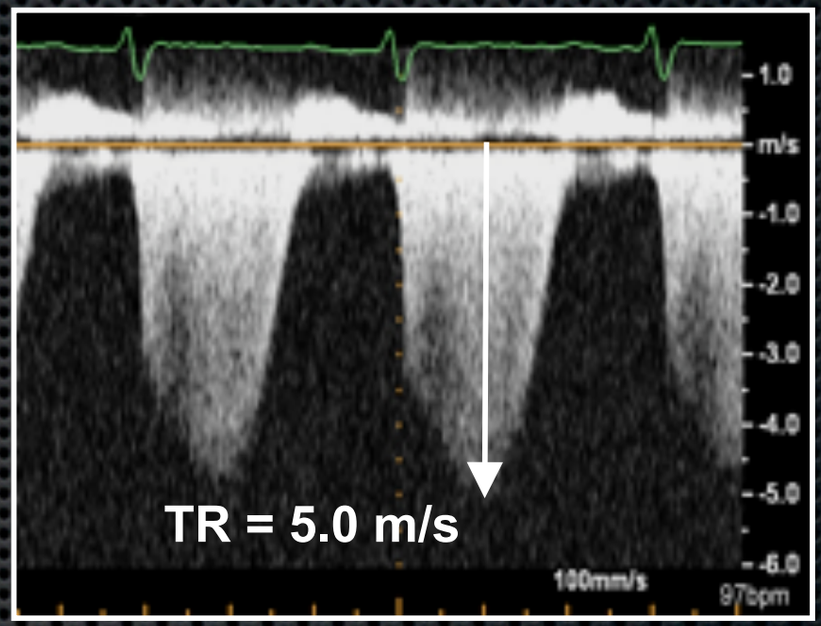
- Normal AT ≥140 ms
- Correlates with RVSP, MPAP and PVR

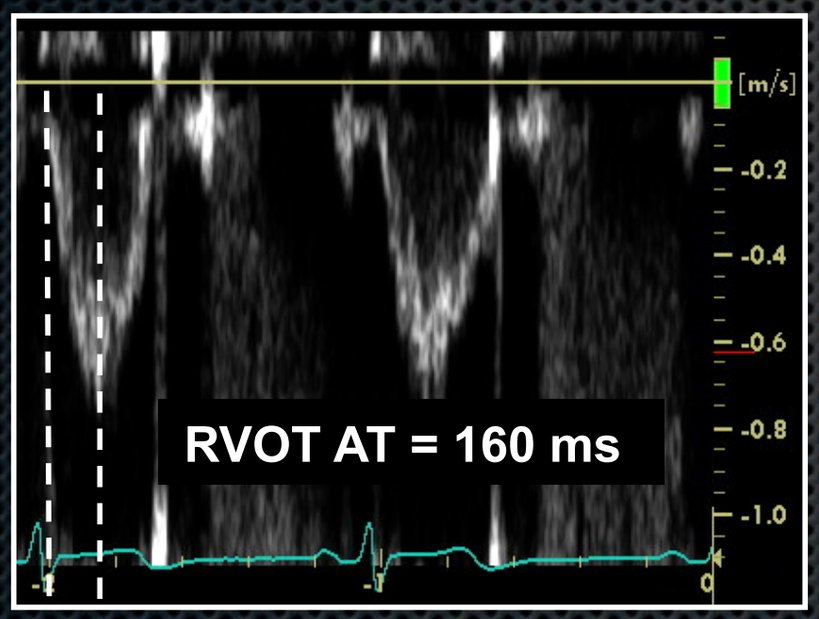
(Kitabake A. et al. Circulation 68:302-309, 1983)

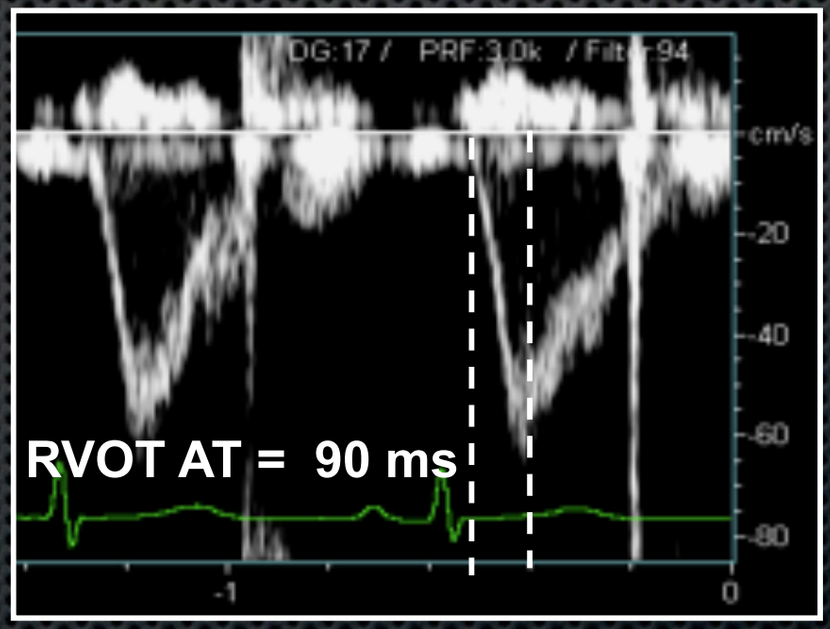
RVOT Acceleration Time

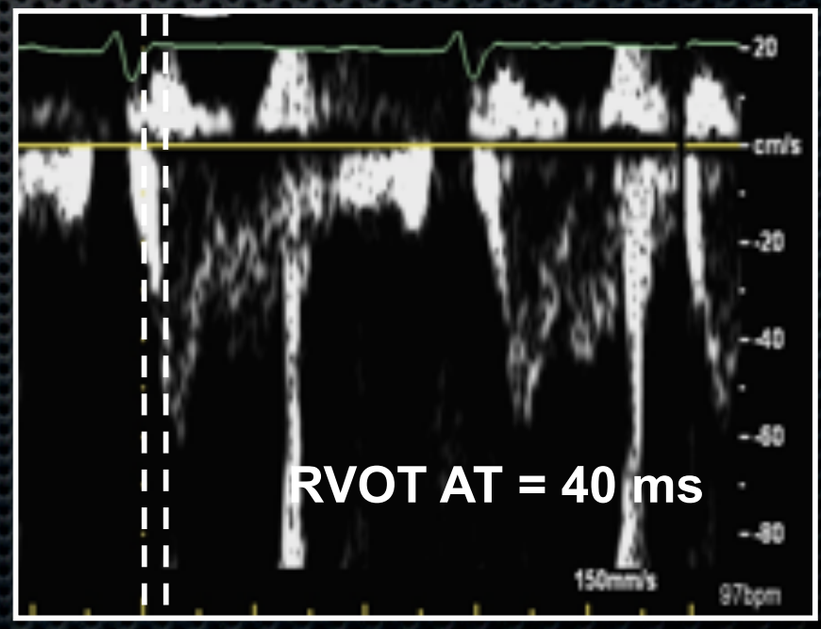




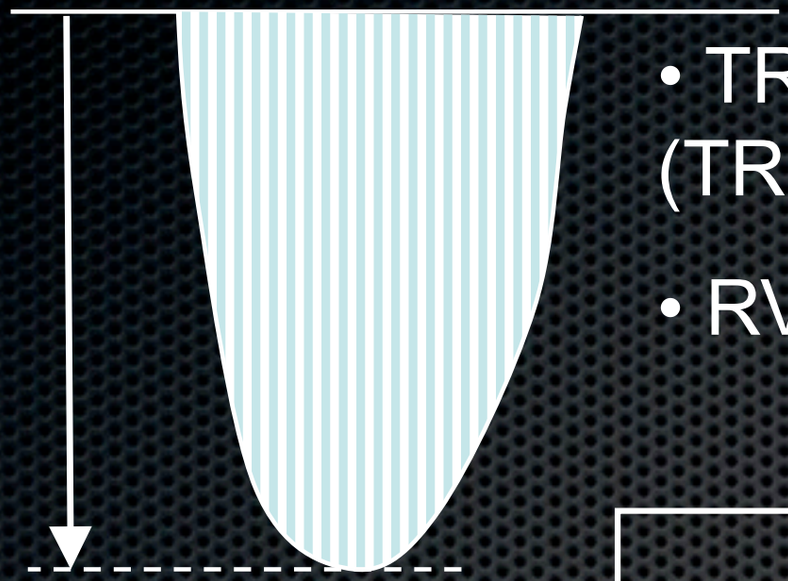




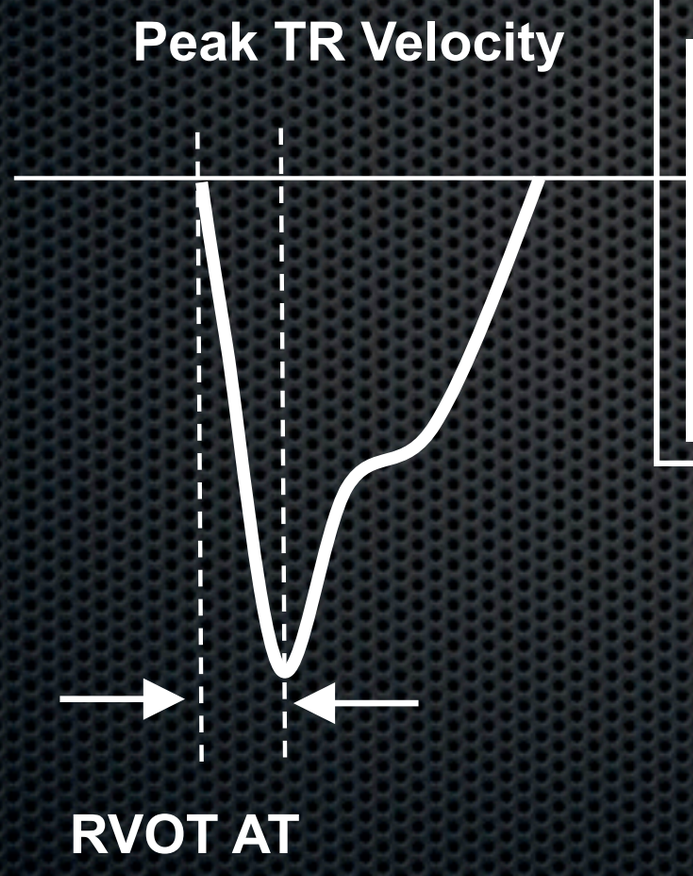




60/60 Sign



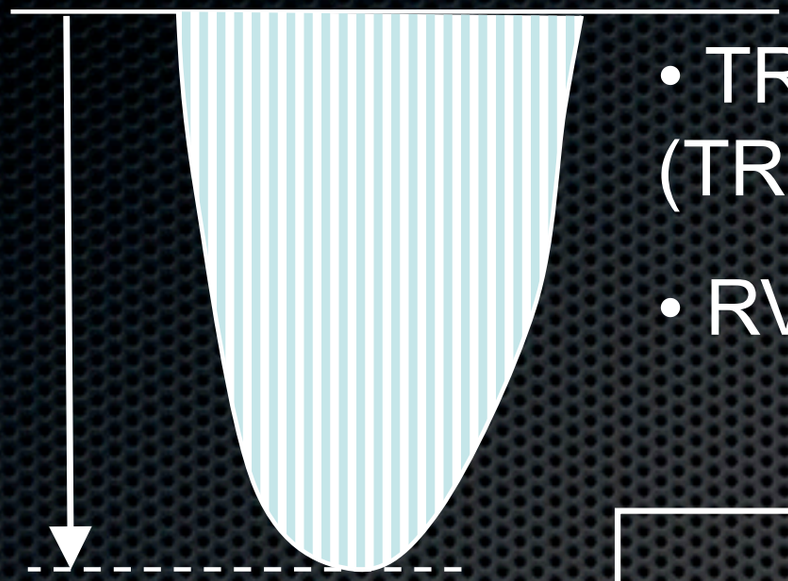
- TR peak pressure gradient ≥30 and ≤ 60 mmHg (TR V_{max} ≥ 2.7 and ≤ 3.9 m/s)
- RVOT acceleration time ≤60 ms



	Patients without known previous cardiorespiratory diseases (n = 46)	Patients with known previous cardiorespiratory diseases (n = 54)
	60/60 sign	60/60 sign
Specificity (%)	100	89
Sensitivity (%)	25	26
PPV (%)	100	82
NPV (%)	37	40

(Kurzyna M et al. Am J Cardiol 2002;90:507-511)

60/60 Sign



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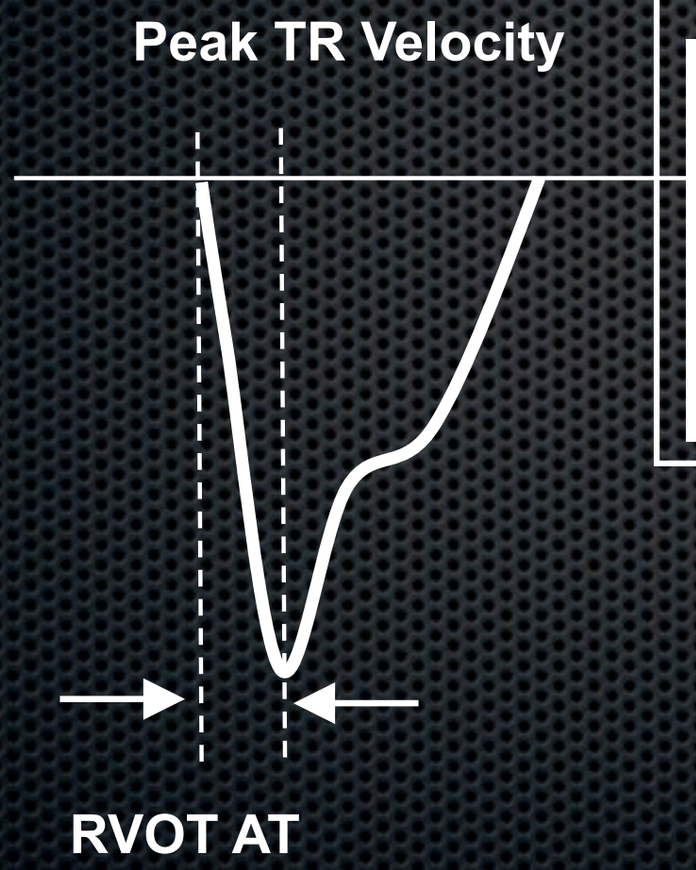

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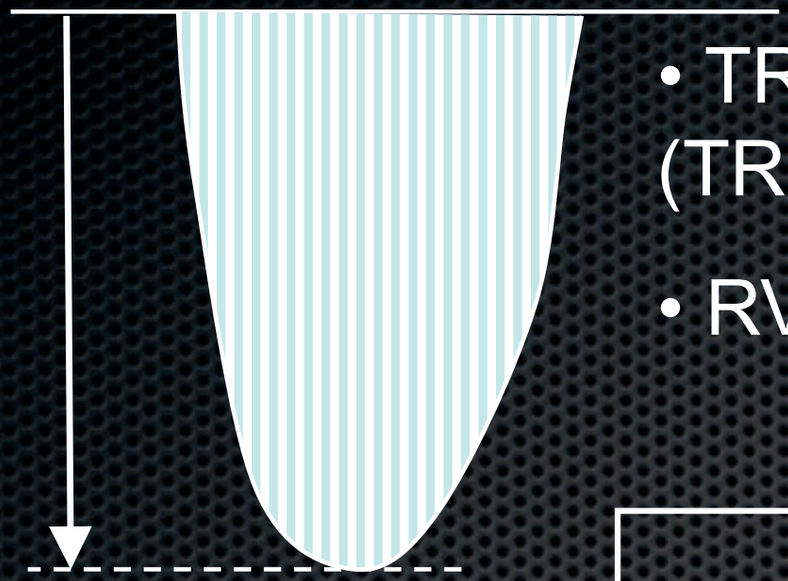

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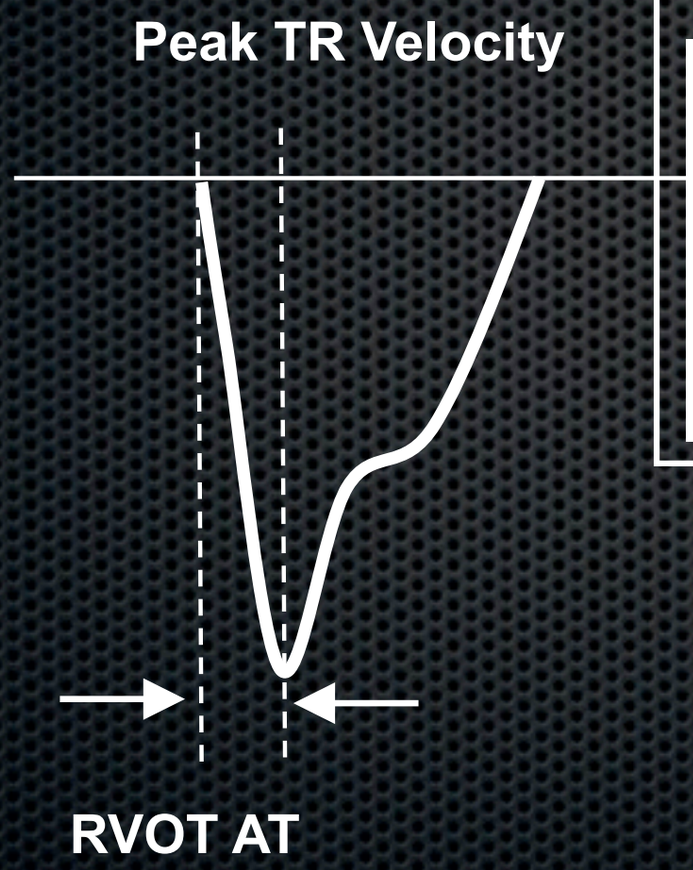

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PE and Echocardiography

- Role of Echo in “massive” PE
- Review standard 2D right heart views
- Recognising normal right heart structures
- Screening for right heart thrombi/masses
- Detecting right heart dysfunction
- Assessing pulmonary artery pressures
- **TDI Indices**

Myocardial Performance Index

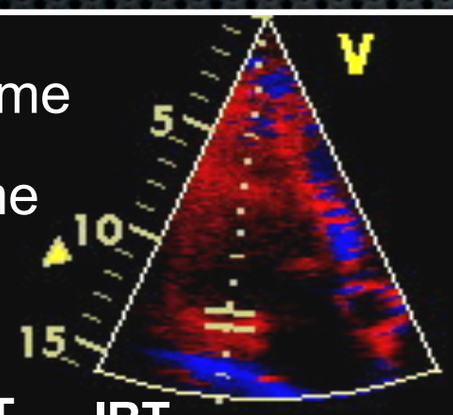
ICT = Isovolumetric contraction time

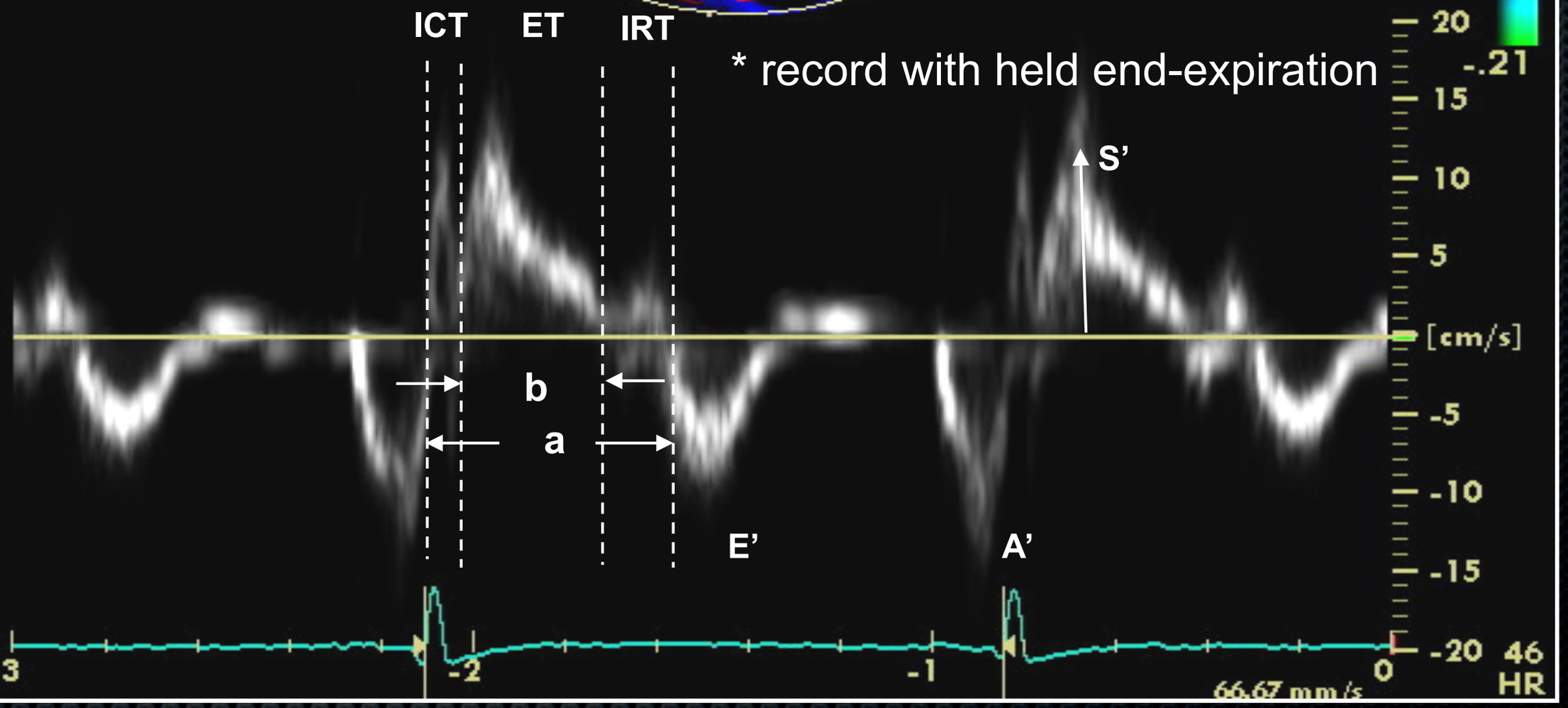
IRT = Isovolumetric relaxation time

ET = Ejection Time

MPI = ICT+IRT/ET

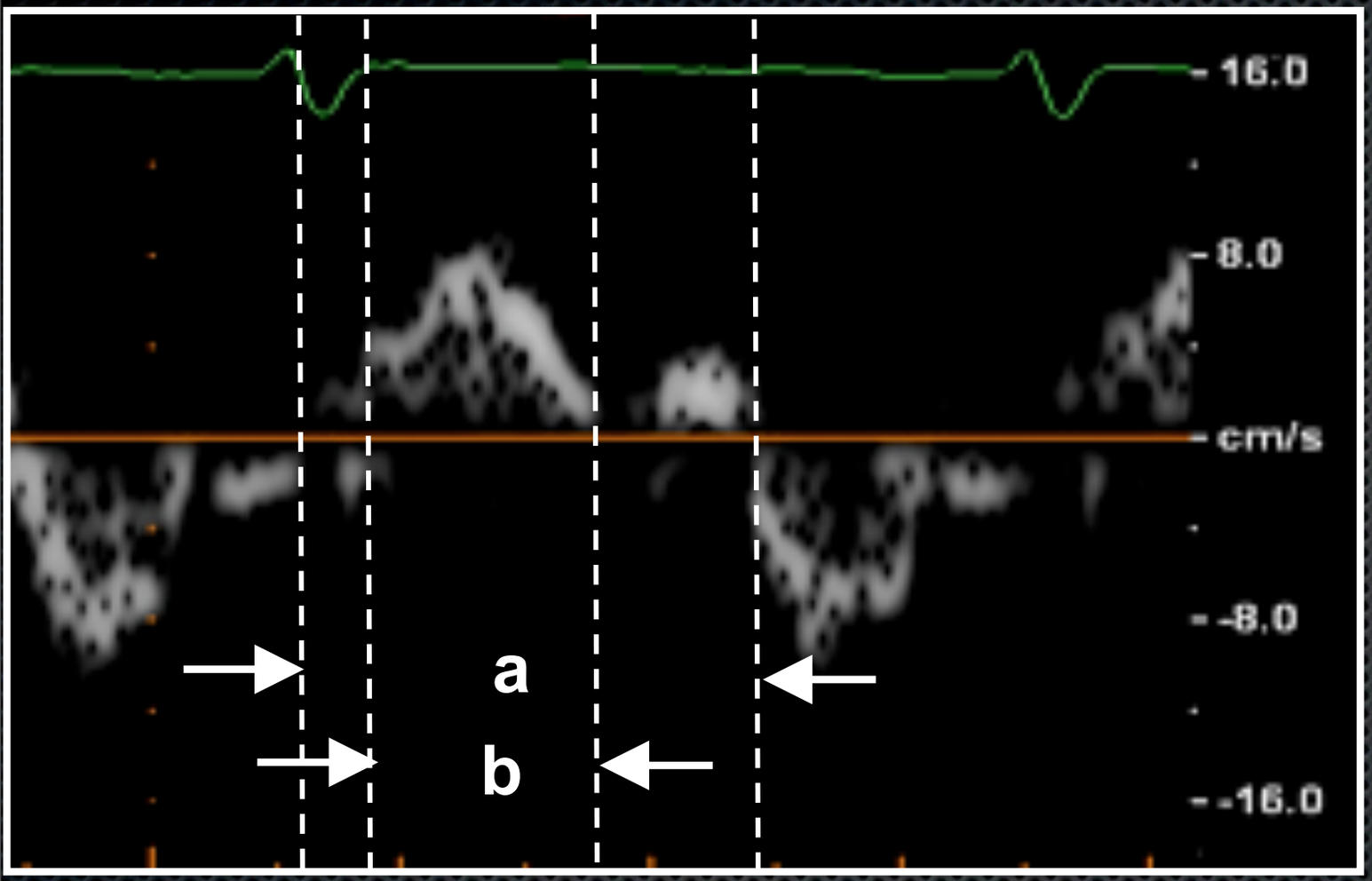
= a – b/b



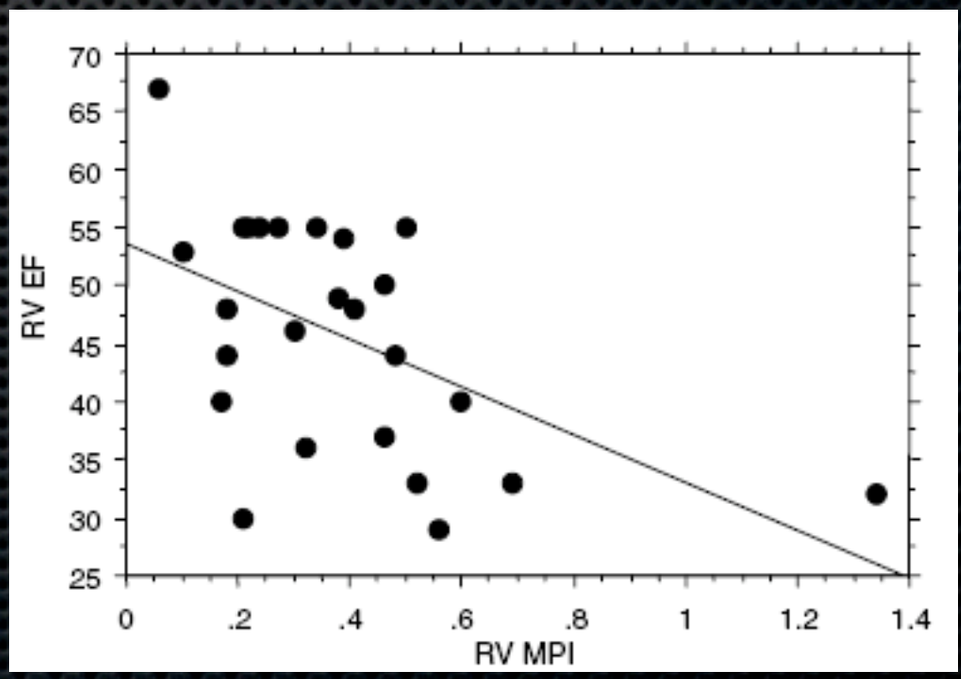


(Tei, C. et al J ASE 9:838-847, 1996)

RV function from MPI



RV Function:	MPI:
Normal	< 0.32
Mild	0.32 – 0.49
Moderate	0.50 – 0.75
Severe	> 0.75



- Independent of chamber geometry
- Not applicable in AF and significant TR

(Pavan K. Karnati. et al. Echocardiography. 25:381-385, 2008)

Diagnostic value of three echo signs suggesting the presence of acute PE

	Patients without known previous cardiorespiratory disease			Patients with known previous cardiorespiratory disease		
	RV overload	60/60 sign	McConnell sign	RV overload	60/60 sign	McConnell sign
Specificity	78	100	100	21	89	100
Sensitivity	81	25	19	80	26	20
PPV	90	100	100	65	82	100
NPV	64	37	35	36	40	40

European Heart Journal (2008) 29, 2276–2315

Risk stratification according to expected pulmonary embolism-related early mortality rate

PE-related early MORTALITY RISK		RISK MARKERS			Potential treatment implications
		CLINICAL (shock or hypotension)	RV dysfunction	Myocardial injury	
HIGH >15%		+	(+)[a]	(+)[a]	Thrombolysis or embolectomy
NON HIGH	Intermediate 3–15%	–	+	+	Hospital admission
			+	–	
			–	+	
	Low <1%	–	–	–	Early discharge or home treatment

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			–	+	
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Prognostic significance of RV dysfunction by Echo in Acute PE

Author	N	patients	Echo criteria	Early mortality
Goldhaber et al	101	normotensive	RV Hypo & Dilatation	4.3 vs 0%
Ribeiro et al	126	normotensive & hypotensive	**RVD**	12.8 vs 0%
Kasper et al	317	normotensive & hypotensive	RV>30mm or TI>2.8m/s	13 vs 0.9
Grifoni et al	162	BP≥100mmHg	• **RV> 30mm** • **RV/LV>1** • **Paradox IVS** • **AcT≤90ms or** • **TIPG>39mmHg**	4.6 vs 0%
Kucher et al	1035	BP≥90mmHg	**RVD**	16.3 vs 9.4%

European Heart Journal (2008) 29, 2276–2315

Suspected high-risk PE

In high-risk PE, emergency CT or bedside echo is recommended for diagnostic purpose **I C**

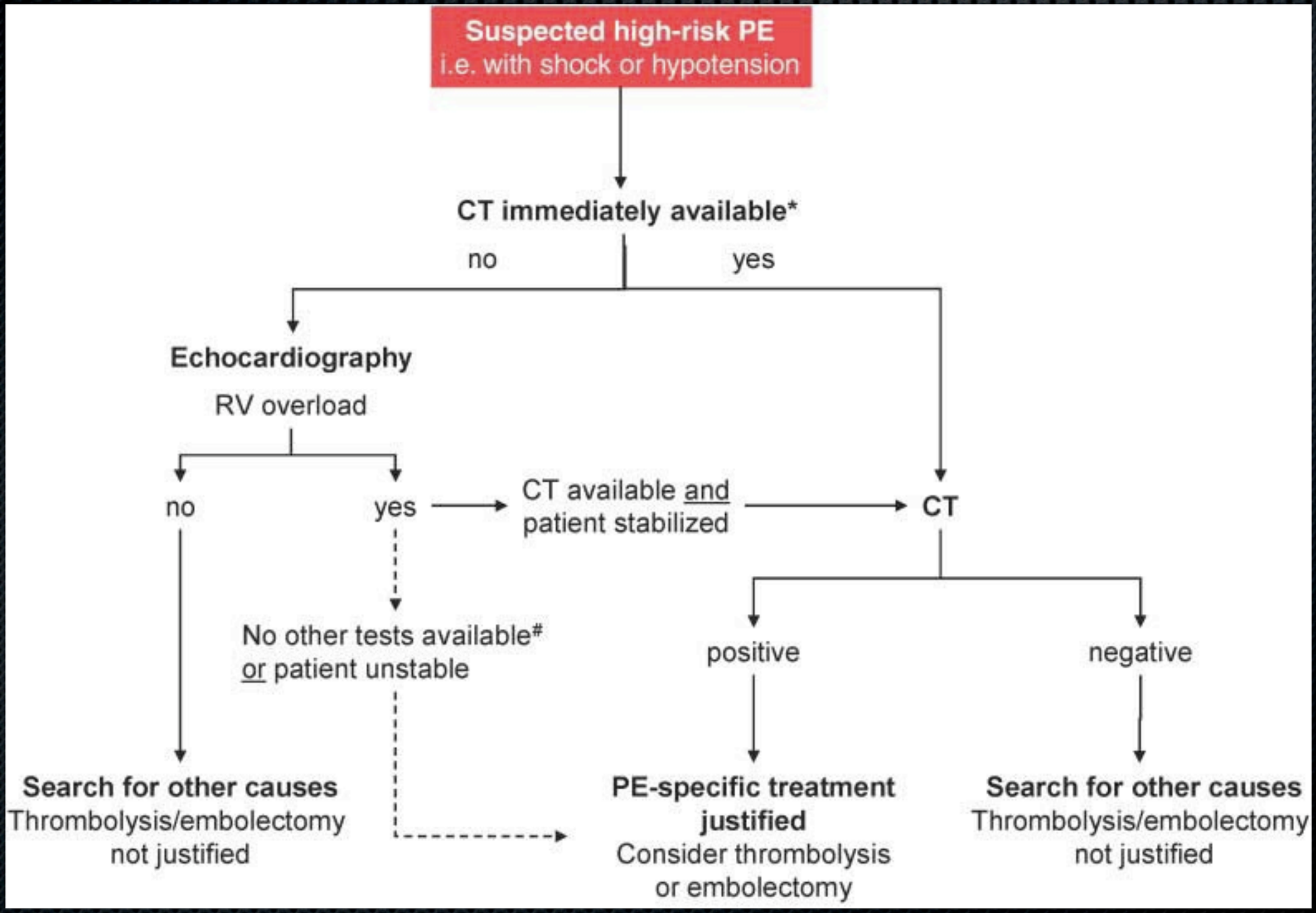
Suspected non high-risk PE

D-dimer is recommended in emergency department patients to reduce the need for unnecessary imaging **I A**

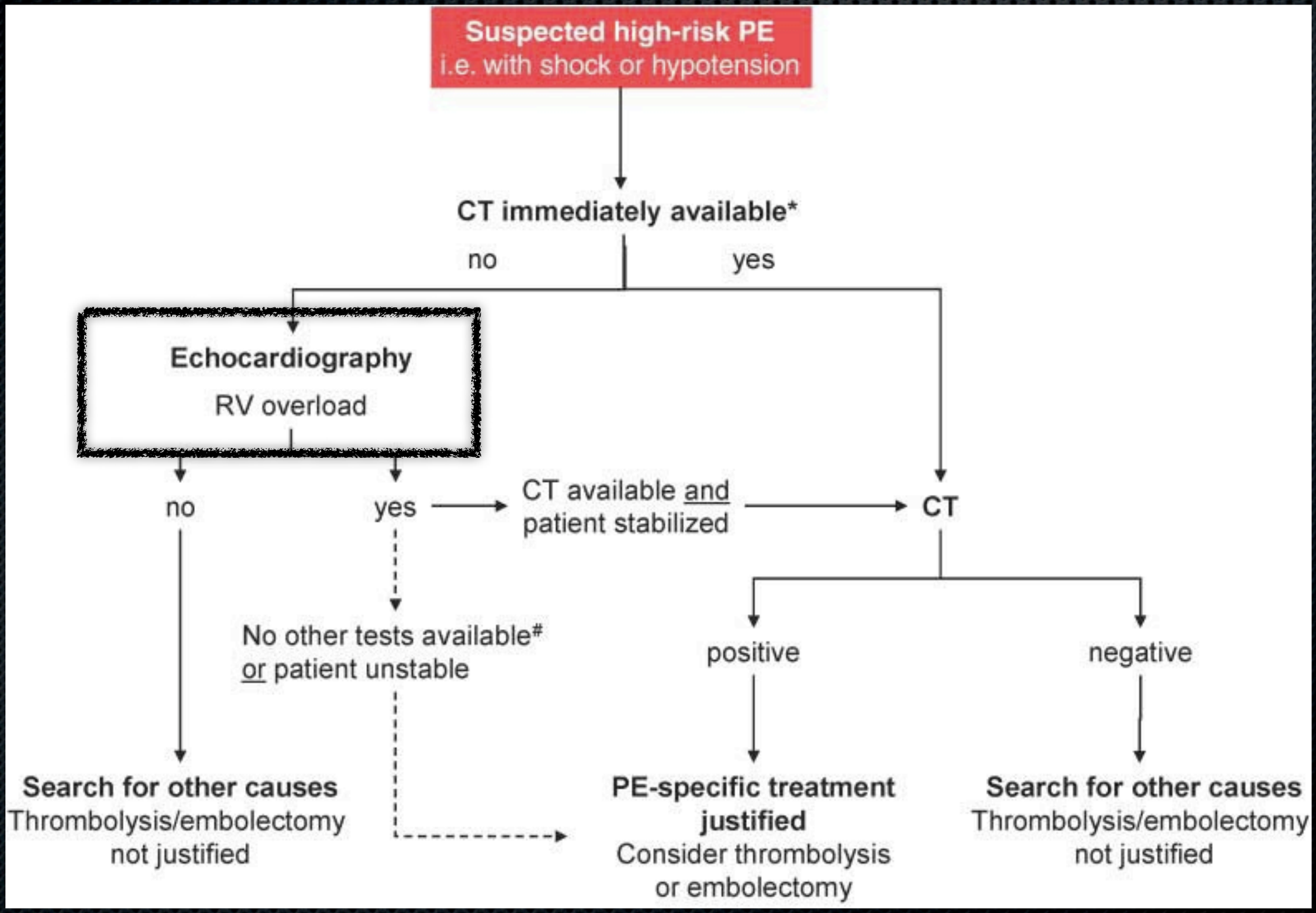
Systematic use of echocardiography for diagnosis in haemodynamically stable, normotensive patients is not recommended **III C**

European Heart Journal (2008) 29, 2276–2315

ESC Diagnostic Algorythm



ESC Diagnostic Algorythm



ESC Diagnostic Algorythm Summary

- Screen for right heart thrombi in transit
- Differential diagnosis
- Detect indirect signs highly suggestive of PE
  - -RV Dilatation (RV:LV ratio)
  - -RV dysfunction (McConnel Sign)
  - -RV pressure overload
  - -Raised PAP (TR velocity/RVOT AT)
  - -60/60 sign
  - -MPI?
- All indirect signs have limited sensitivity and/or specificity


Thank you!
petros@imperial.ac.uk

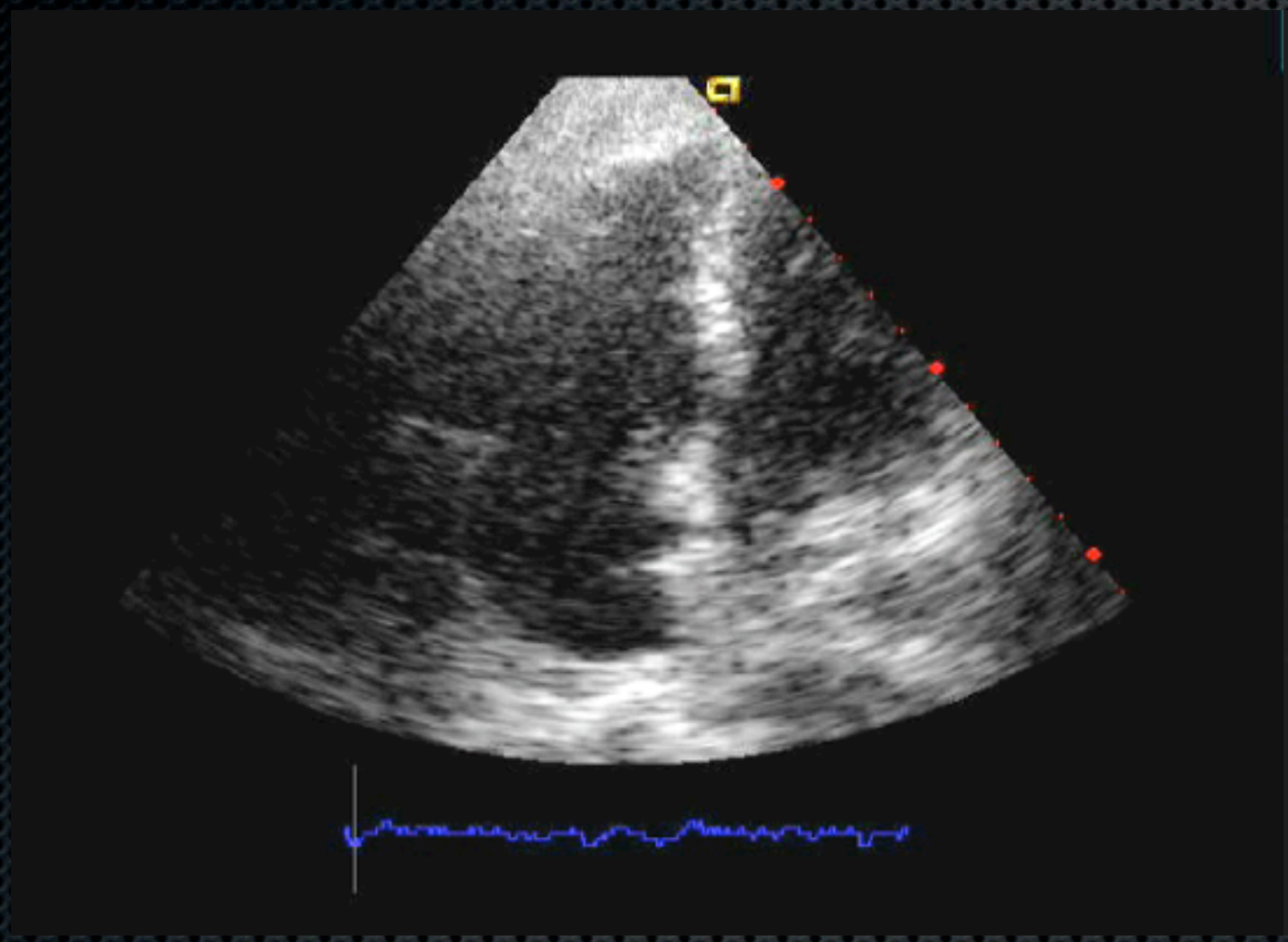
Principal markers useful for risk stratification in acute pulmonary embolism

Clinical Markers	Shock Hypotension
Markers of RV Dysfunction	•RV dilatation, Hypokinesis or pressure overload on echocardiography •BNP or NT-proBNP elevation •Elevated tight heart pressure at RHC
Markers of Myocardial injury	Cardiac troponin T or I positive

European Heart Journal (2008) 29, 2276–2315

McConnell Sign

Acute PE



CTEPH