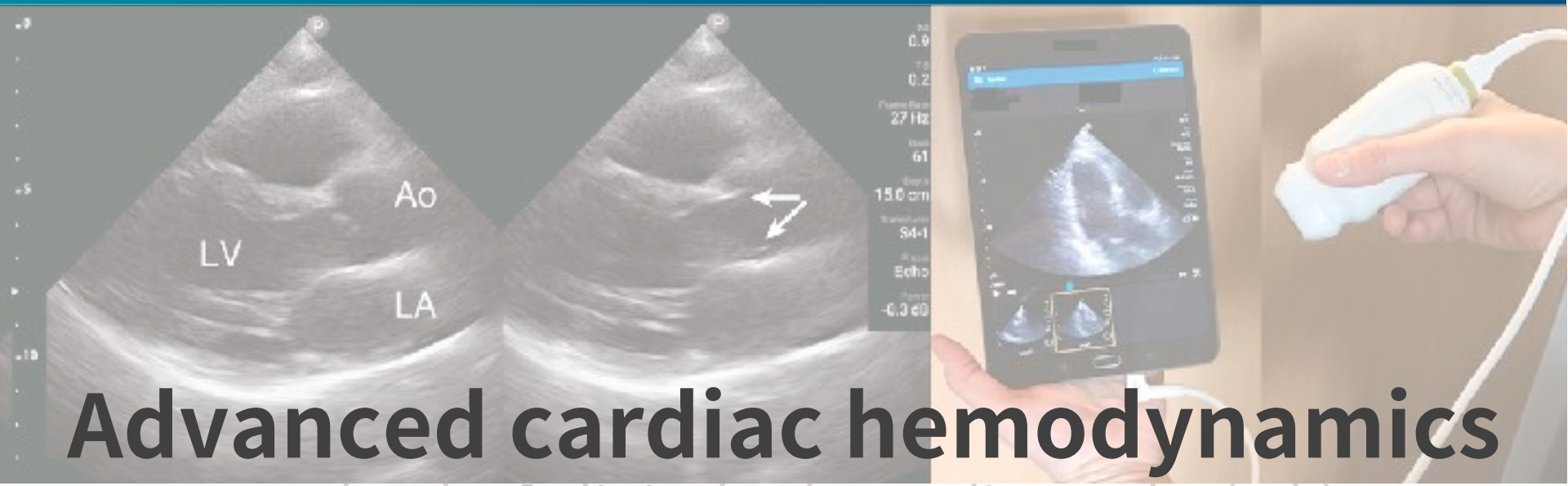
衛生福利部雙和醫院
(委託臺北醫學大學興建經營)
Taipei Medical University - Shuang Ho Hospital,
Ministry of Health and Welfare



Advanced cardiac hemodynamics

Textbook of Clinical Echocardiography (7th)

陳國智醫師 雙和醫院急診醫學科

juice119@gmail.com

POCUSacademy.com

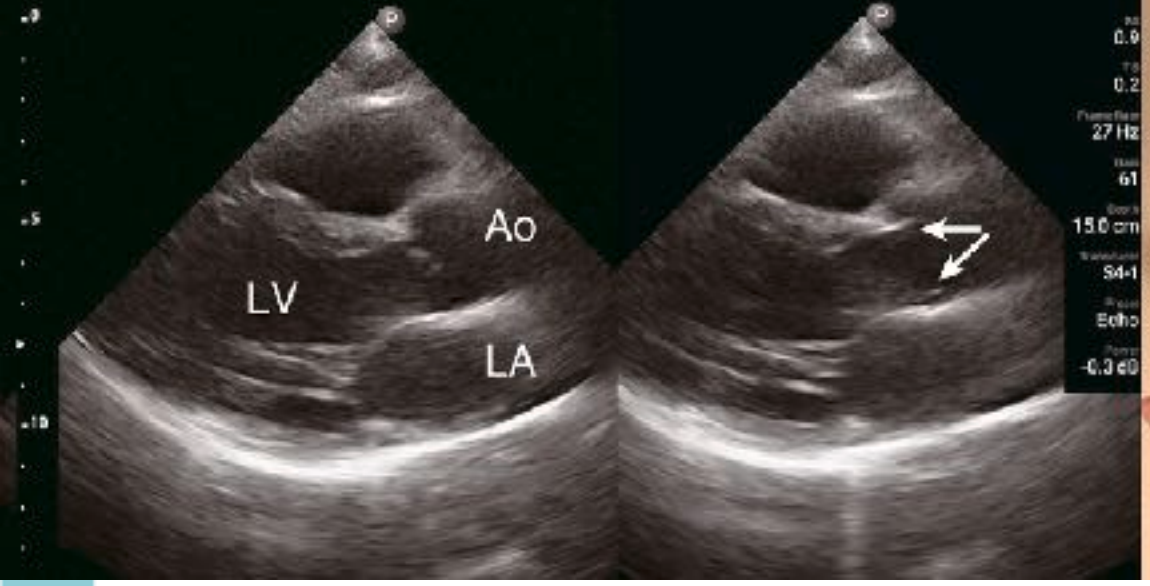
Core Applications (2023 ACEP Emergency Ultrasound Guidelines)
15項急診超音波核心應用

陳國智醫師

- Aorta
- DVT
- Trauma
- Thoracic/Airway
- Cardia/HD assessment

- Procedural Guidance
- US-guided NB
- Testicular
- Ocular
- Skin & Soft tissue

- Hepatobiliary
- Urinary tract
- Pregnancy
- Bowel
- MSK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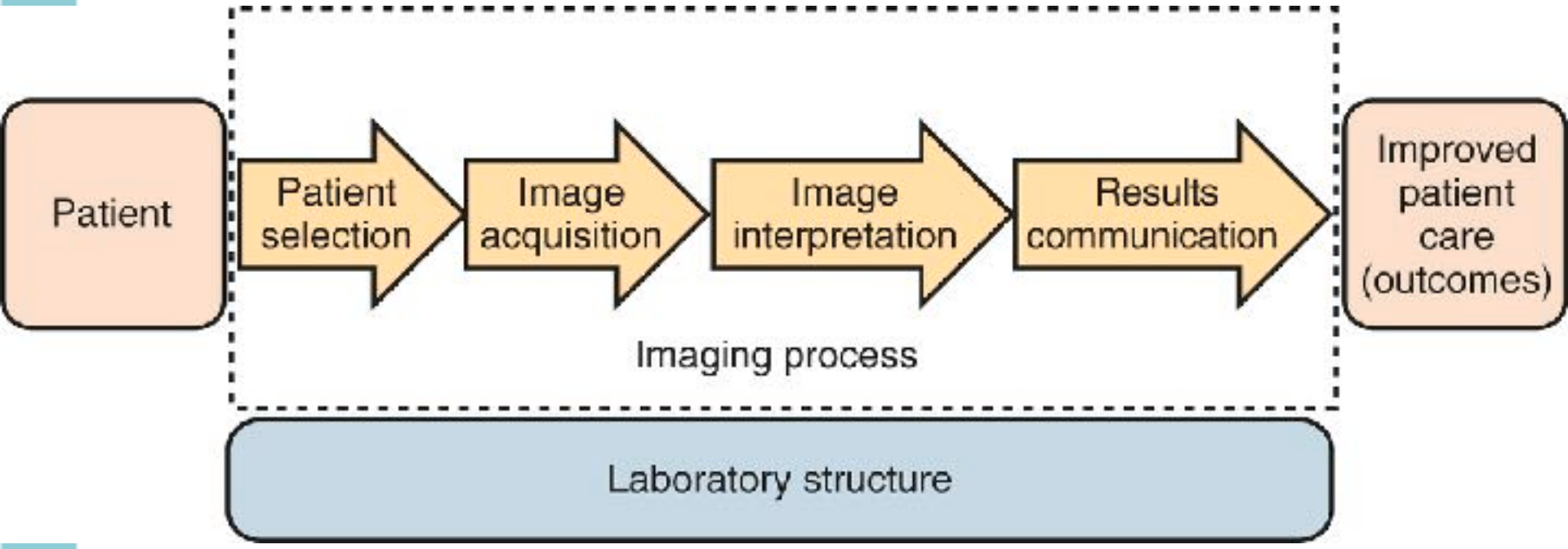
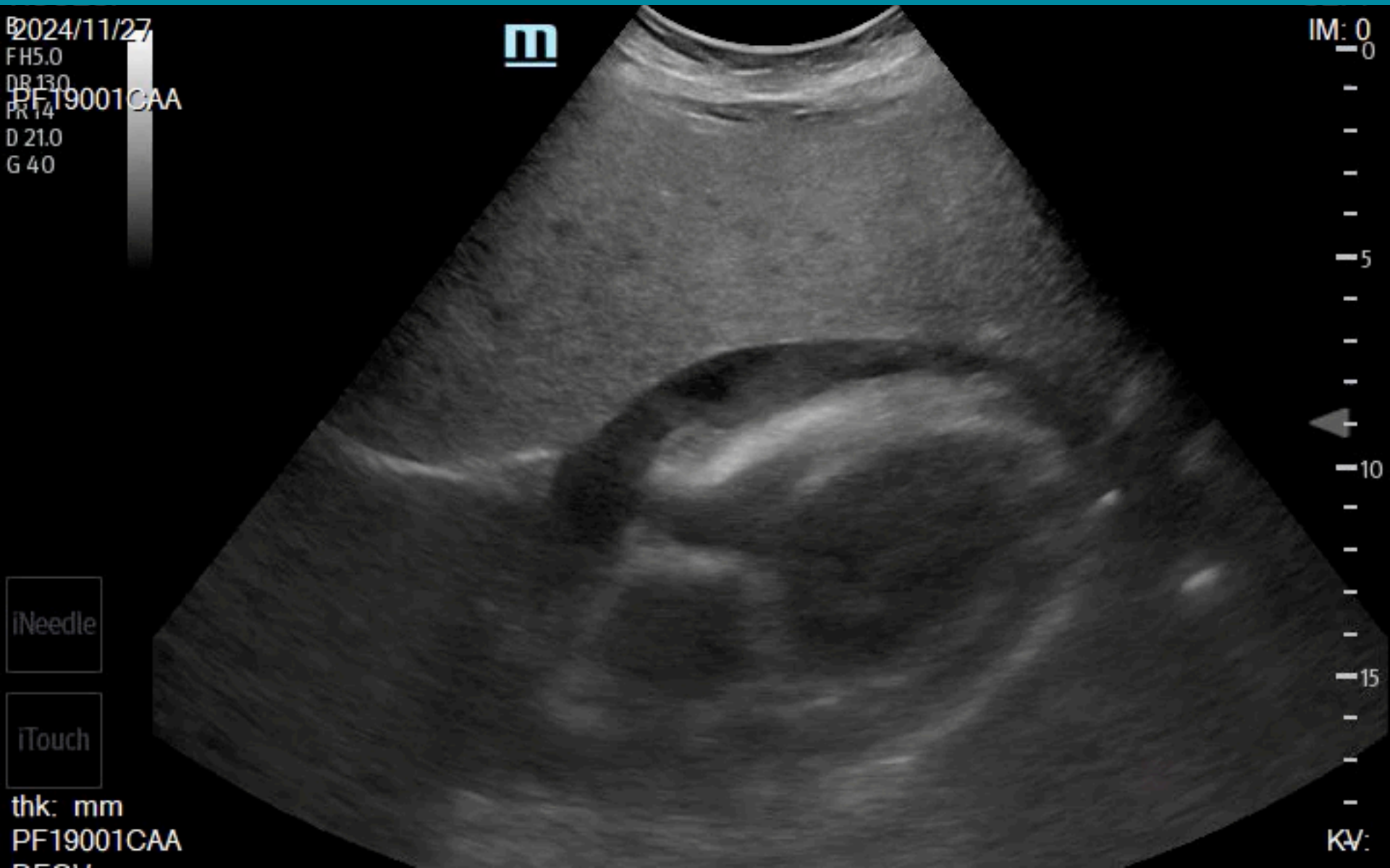

Patient
Patient selection
Image acquisition
Image interpretation
Results communication
Improved patient care (outcomes)
Imaging process
Laboratory structure

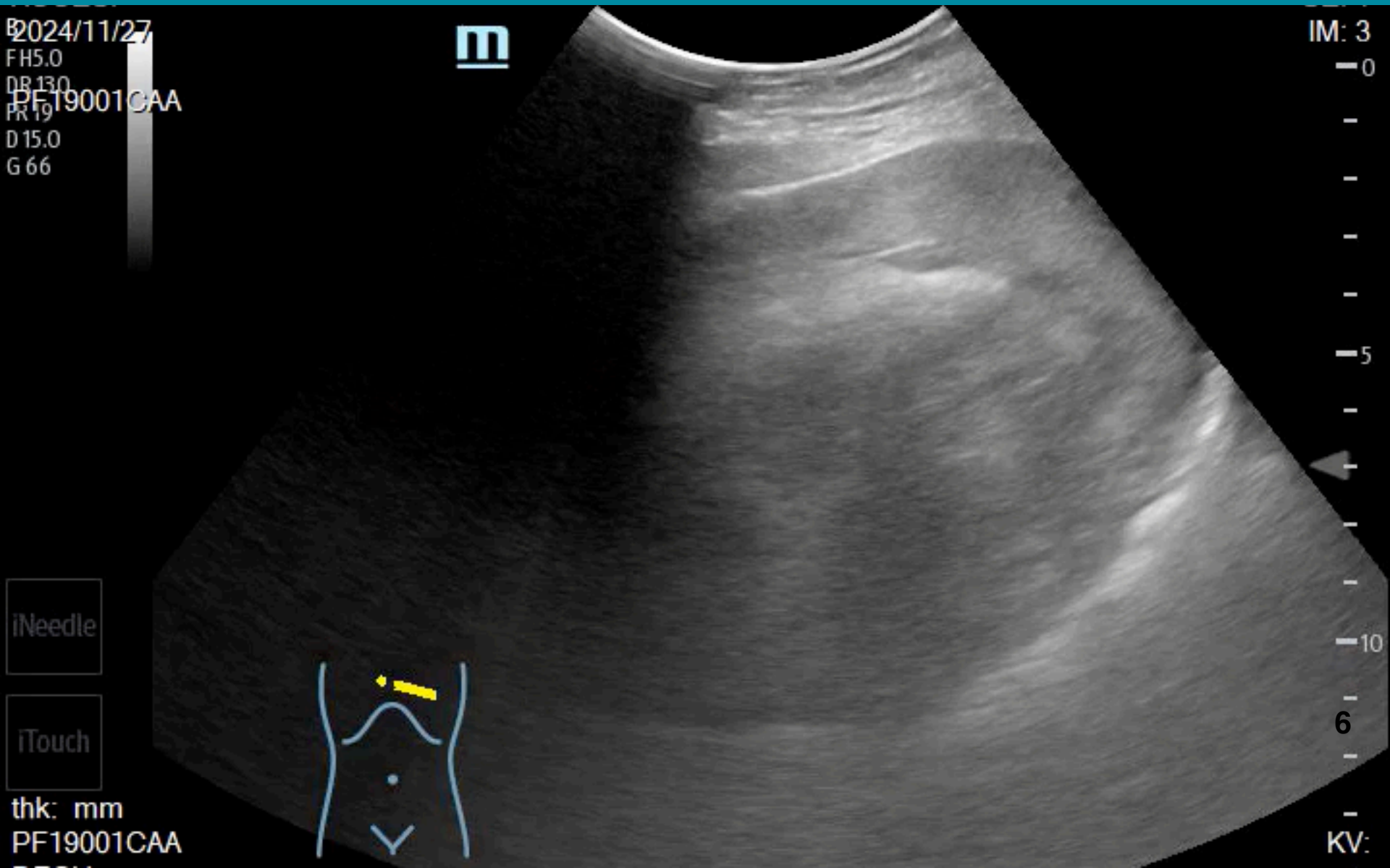
Cardiac US exam types

		PROCEDURAL GUIDANCE			
	Diagnostic Echocardiogram	**Cardiac Surgery**	**Interventional Procedures**	**Electrophysiology Procedures**	**Point of Care Echocardiography**
Purpose of imaging	Diagnose and measure disease severity, evaluate progression or response to therapy, integrate with clinical information and other imaging approaches	Comprehensive perioperative exam and/or procedure guidance (baseline data, measure results, detect complications)	Direct catheter and device positioning, evaluate procedure results, detect complications	Direct catheter and device positioning, detect complications	Immediate patient triage and management or monitoring cardiac parameters
Clinical setting	Any inpatient or outpatient location under the auspices of a structured echocardiography laboratory[a]	Operating room	Interventional suite or hybrid operating room	Electrophysiology laboratory	Inpatient bedside, emergency department or outpatient clinic
Health care provider	Images recorded by cardiac sonographer and interpreted by cardiologist with expertise in echocardiography	Interventional echocardiographer or cardiac anesthesiologist with expertise in echocardiography	Interventional echocardiographer, interventional cardiologist or anesthesiologist[b]	Clinical cardiac electrophysiologist or anesthesiologist[b]	Physician with limited training in echocardiography who provides direct care to the patient
Ultrasound modalities	All echocardiographic modalities as appropriate	TEE Epicardial	TEE ICE TTE	TEE ICE TTE	TTE, primarily 2D imaging and color Doppler
Documentation	Formal written report in medical record	Results integrated into anesthesiology procedure note	Results integrated into interventional procedure report	Results integrated into EP procedure report	Results reported in clinical progress note
Quality improvement	Long-term PACS storage of digital images documenting entire study	Long-term PACS storage of representative digital images	Optional long-term PACS storage of representative images	Optional long-term PACS storage of representative images	Images typically not recorded, although key images may be saved for CQI

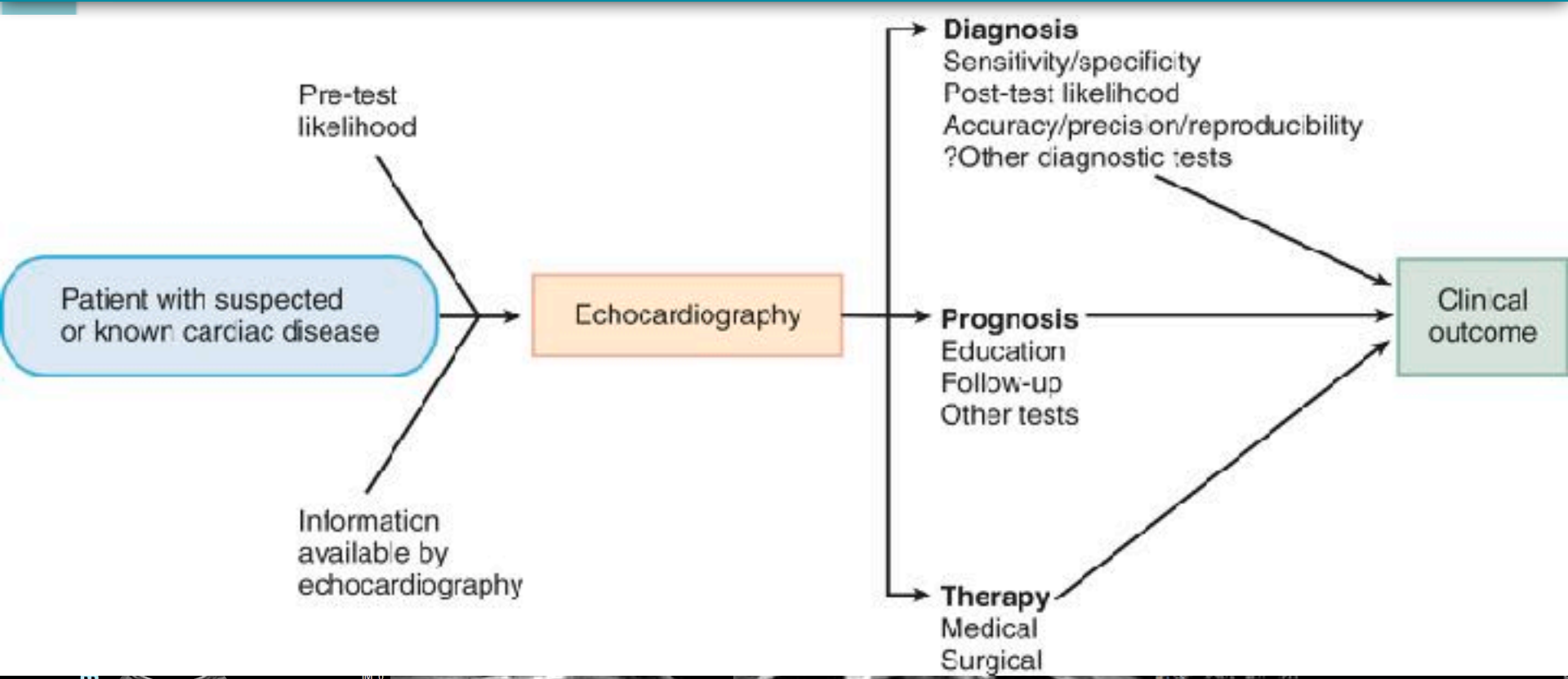
64F, dizziness with profound shock

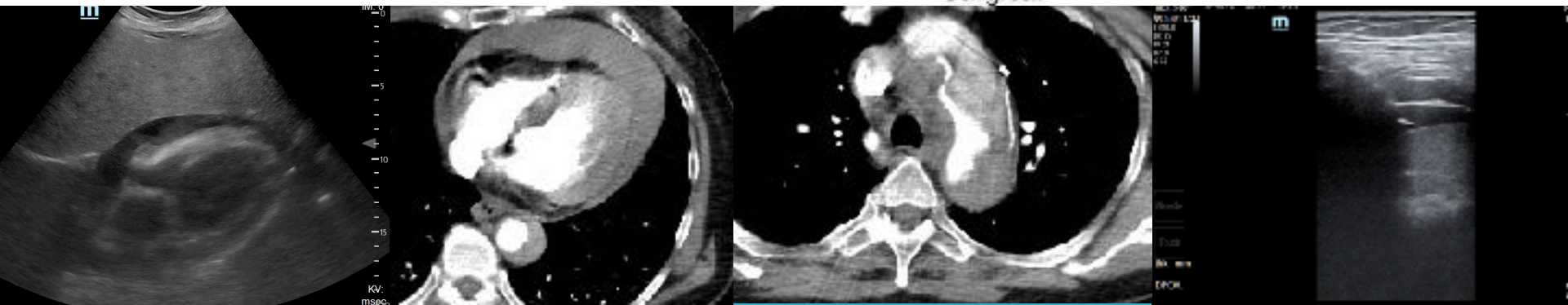


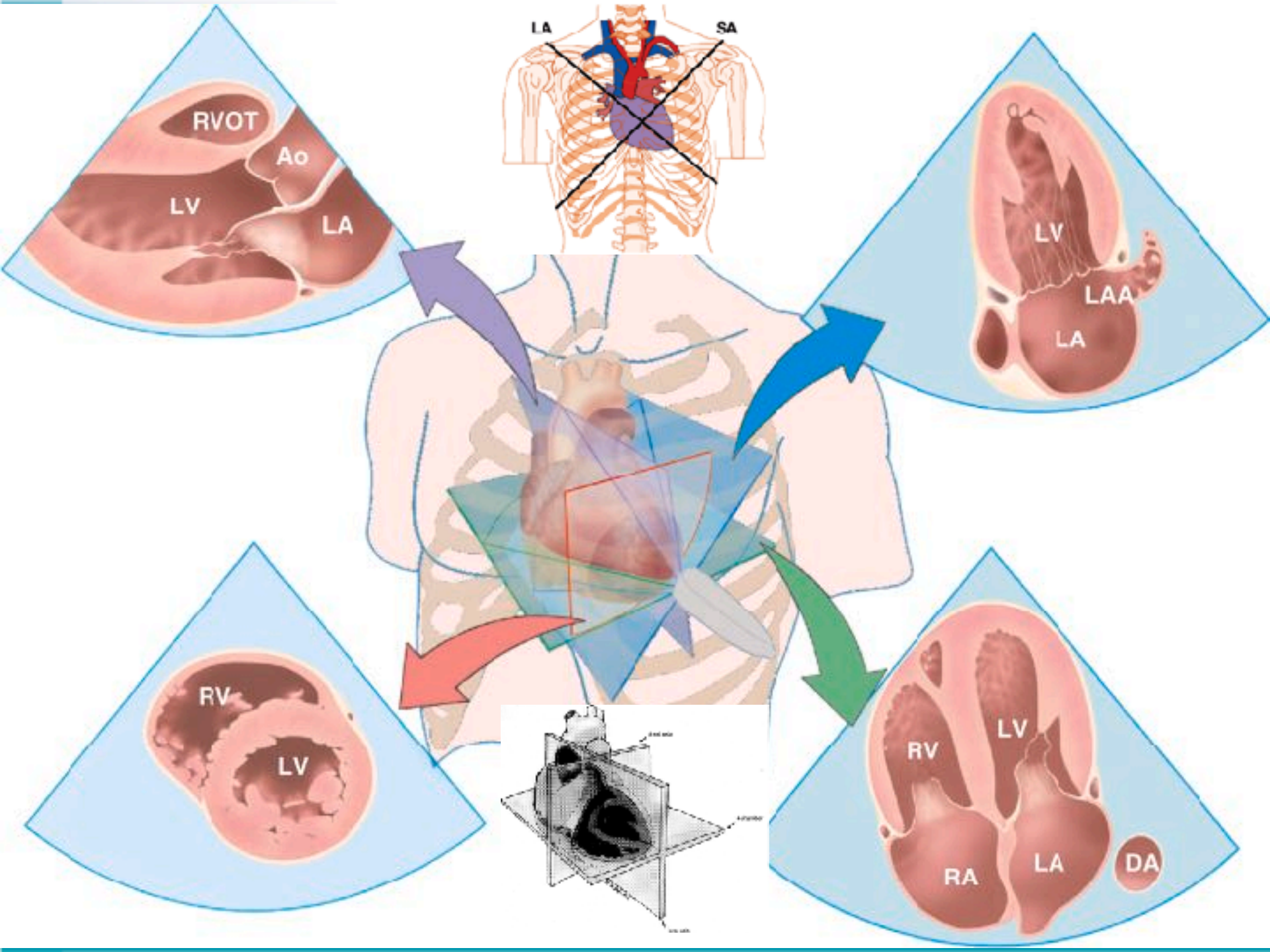
Hemopericardium (Type A dissection)



Impact of POCUS



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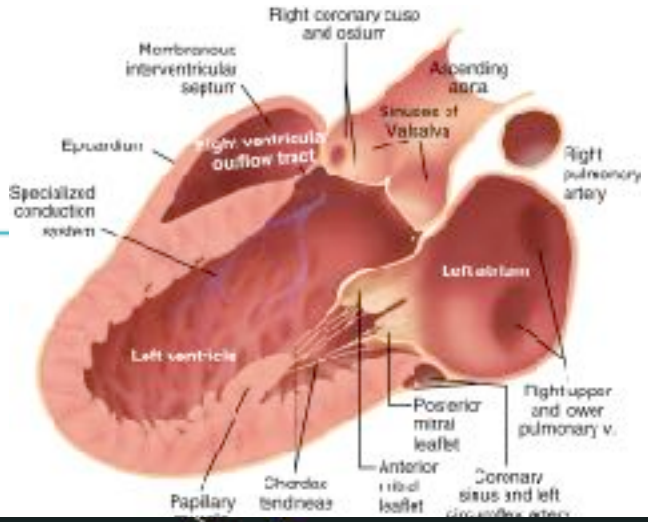
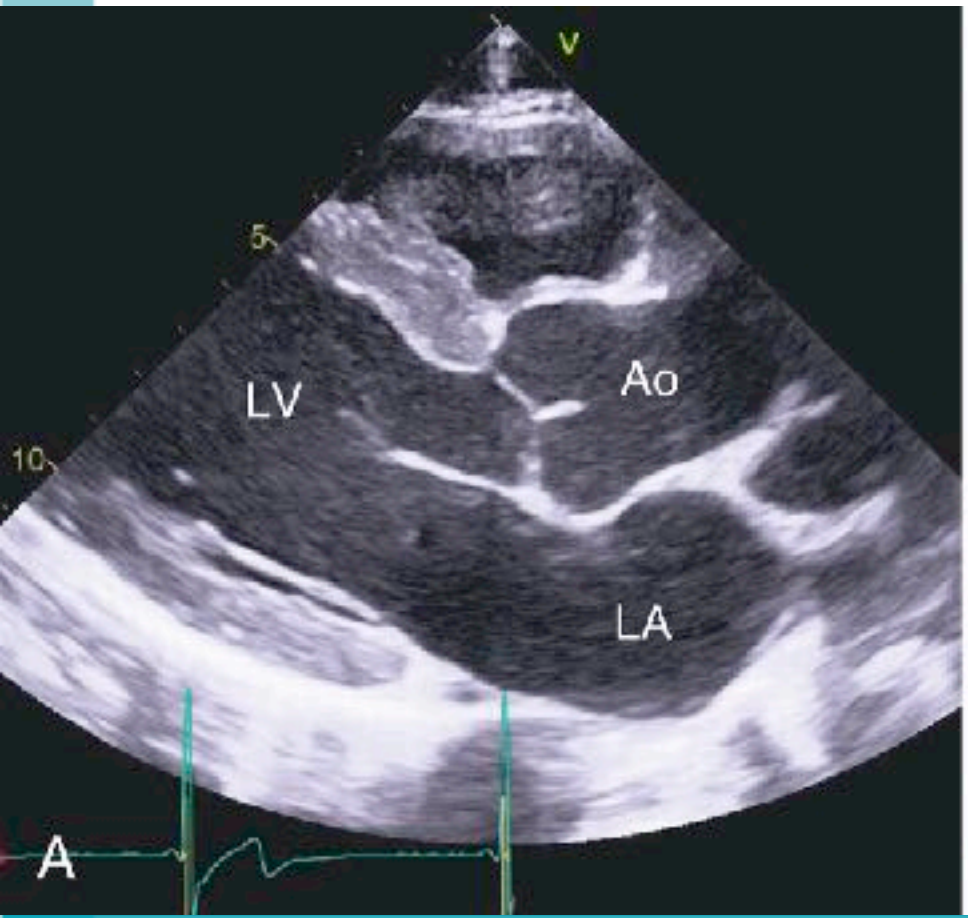
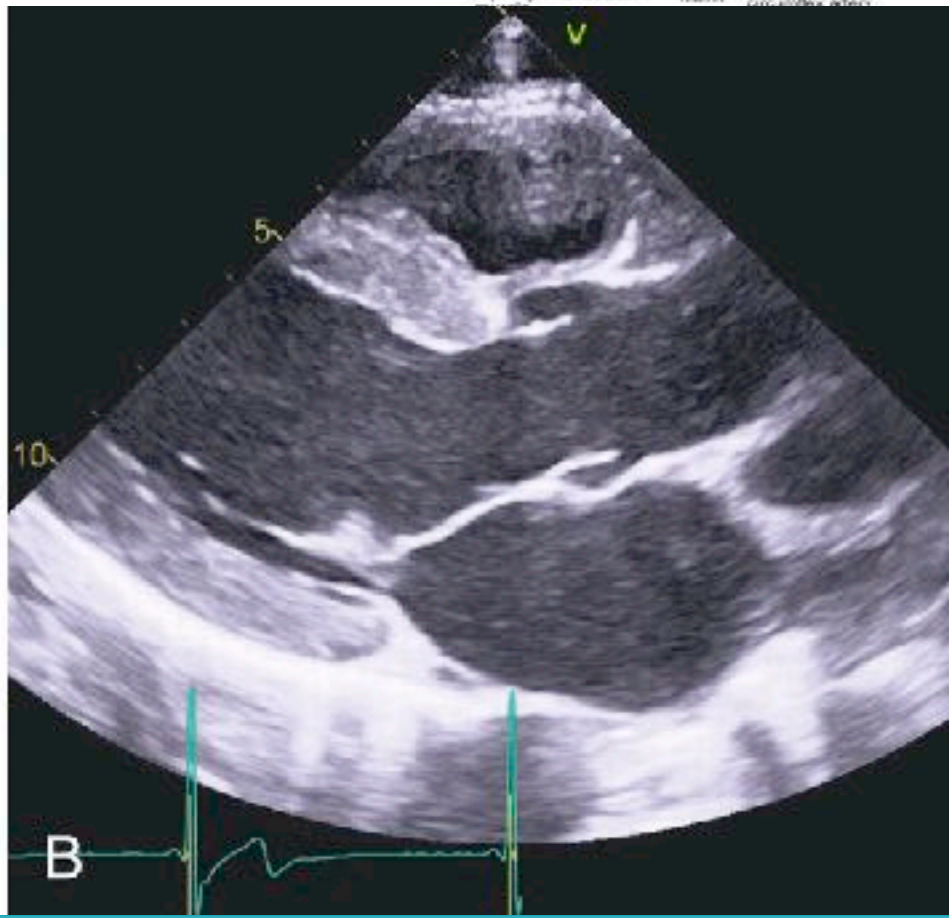
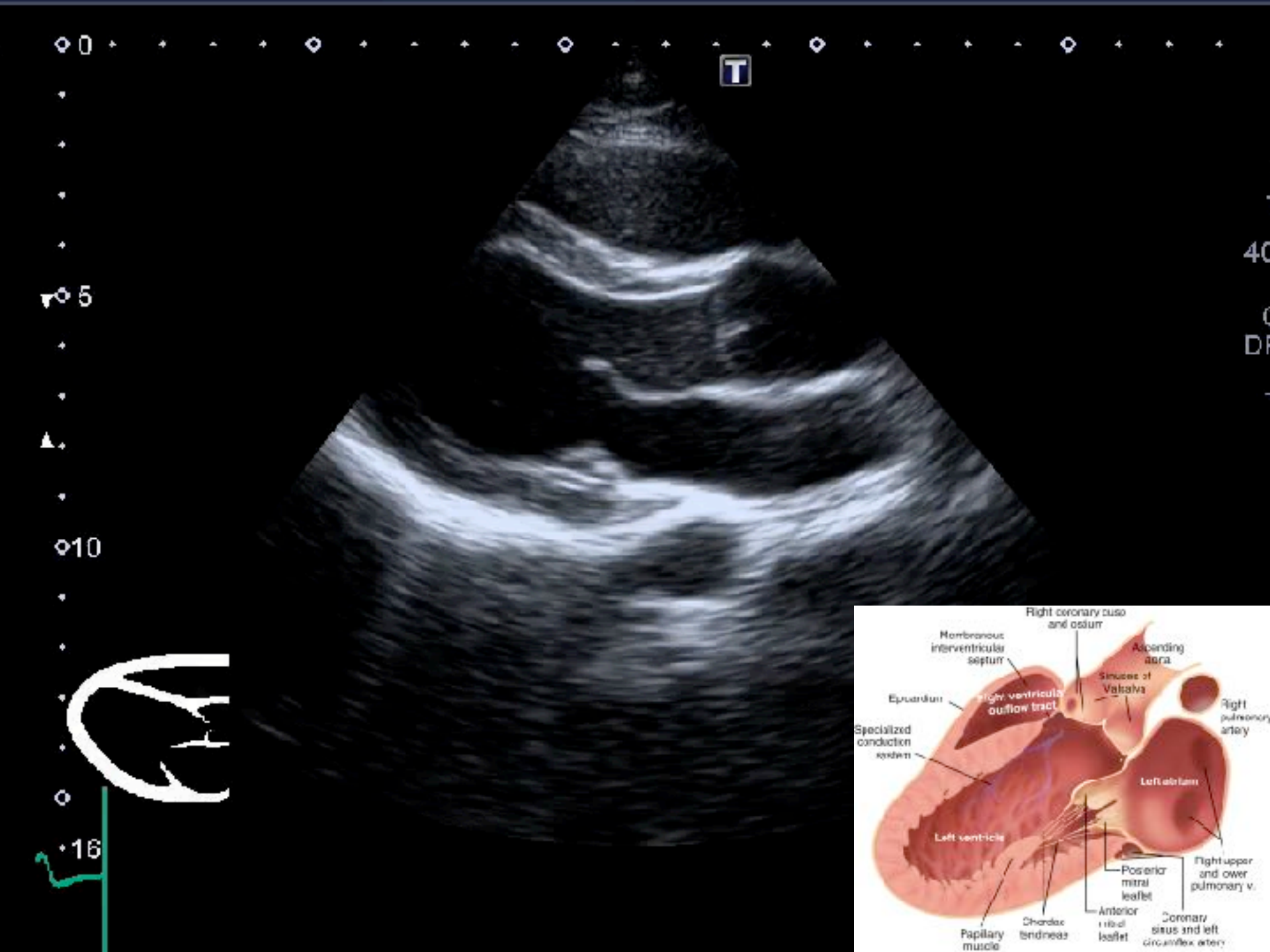
PSLA
(R shoulder)





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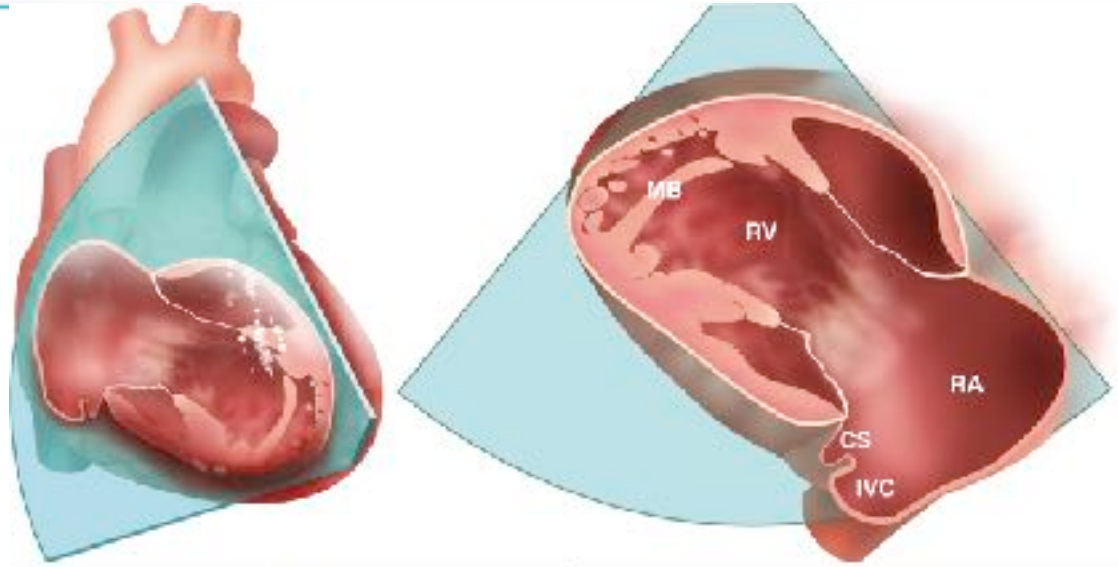
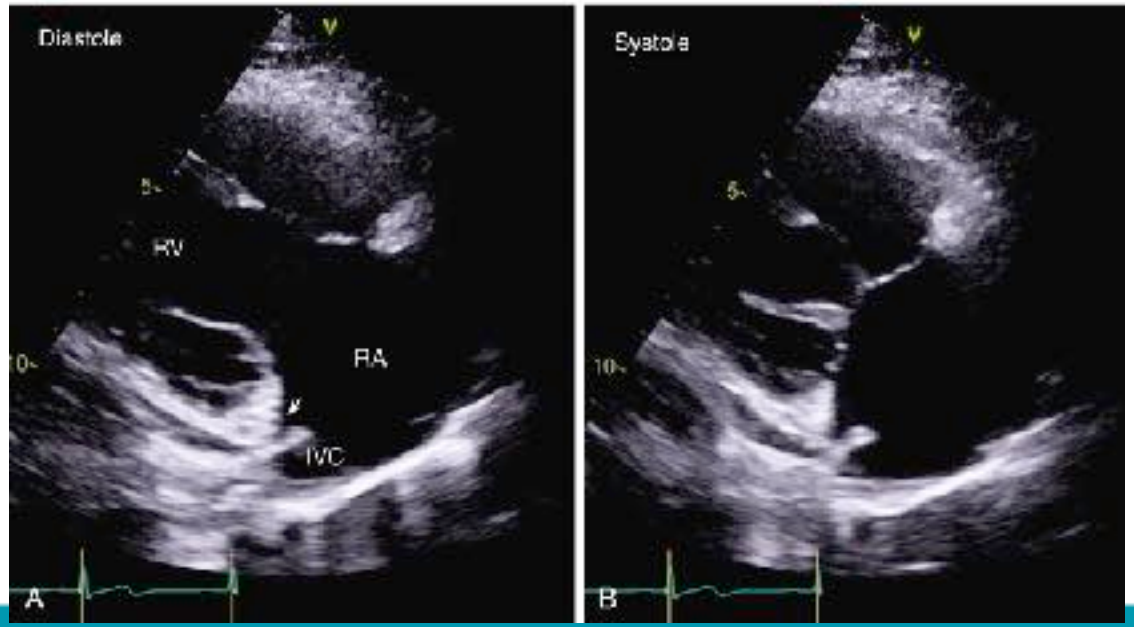
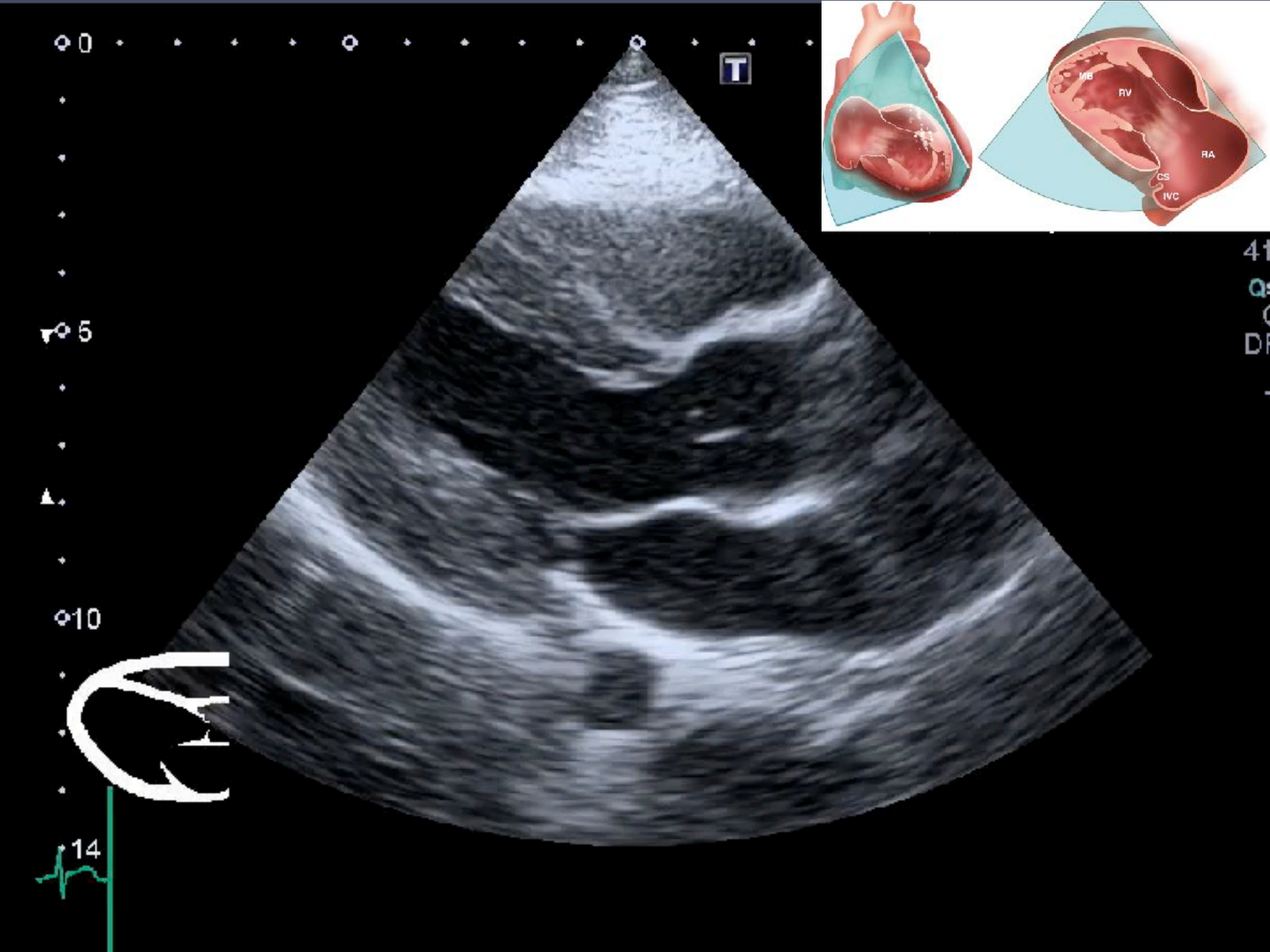
Right coronary cusp and ostium
Membranous interventricular septum
Ascending aorta
Sinuses of Valsalva
Epicardium
Right ventricular outflow tract
Right pulmonary artery
Specialized conduction system
Left atrium
Left ventricle
Posterior mitral leaflet
Right upper and lower pulmonary v.
Anterior mitral leaflet
Coronary sinus and left circumflex artery
Papillary muscle
Chordae tendineae

RV inflow view



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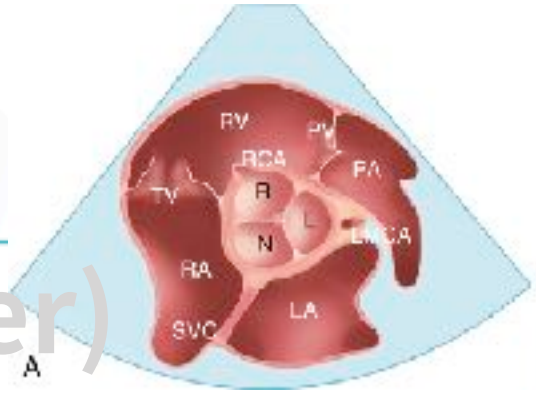
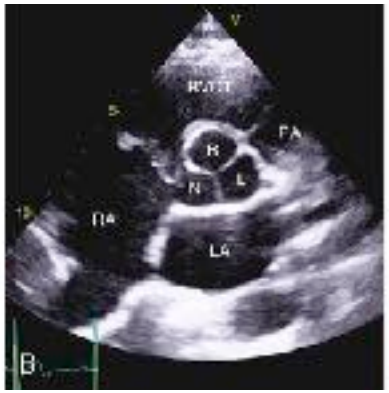
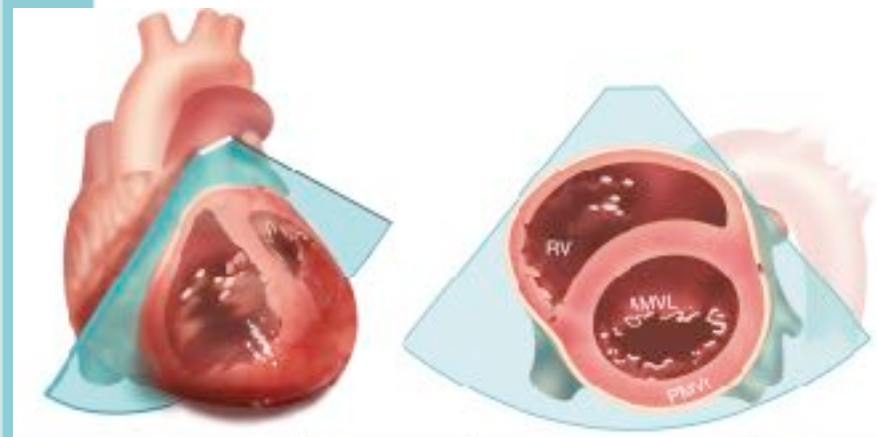
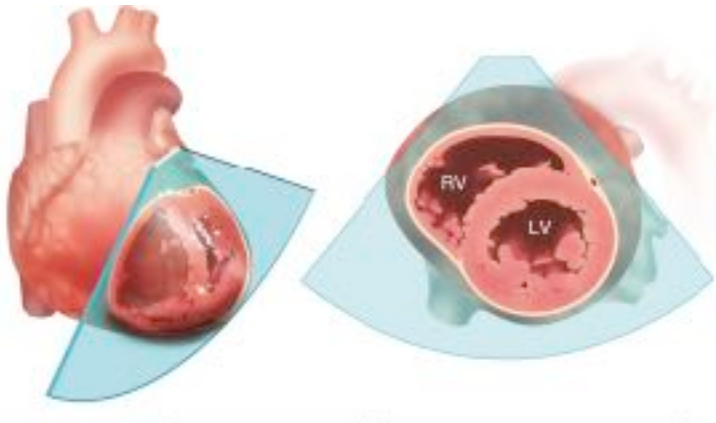
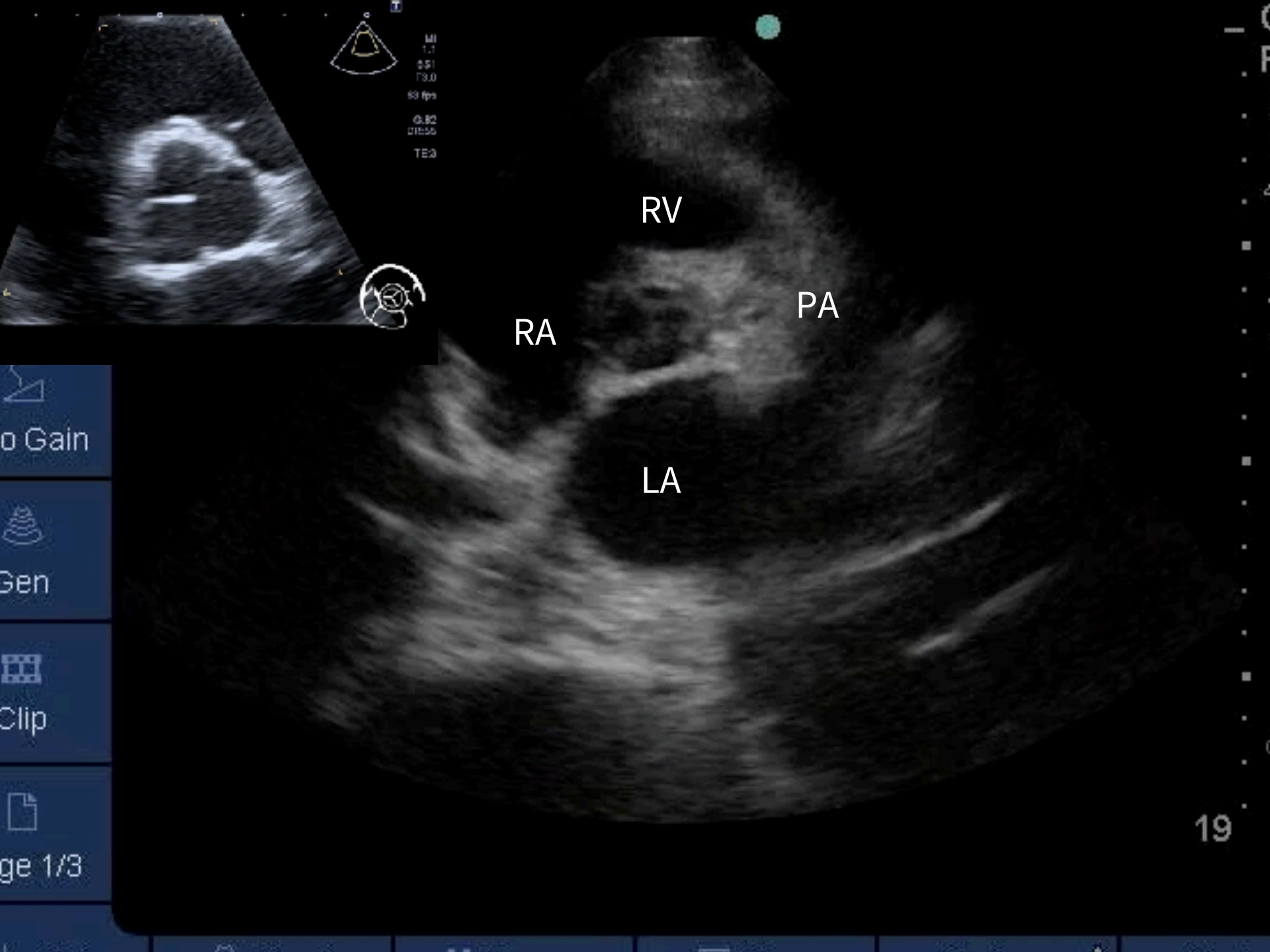
PSSA (L shoulder)







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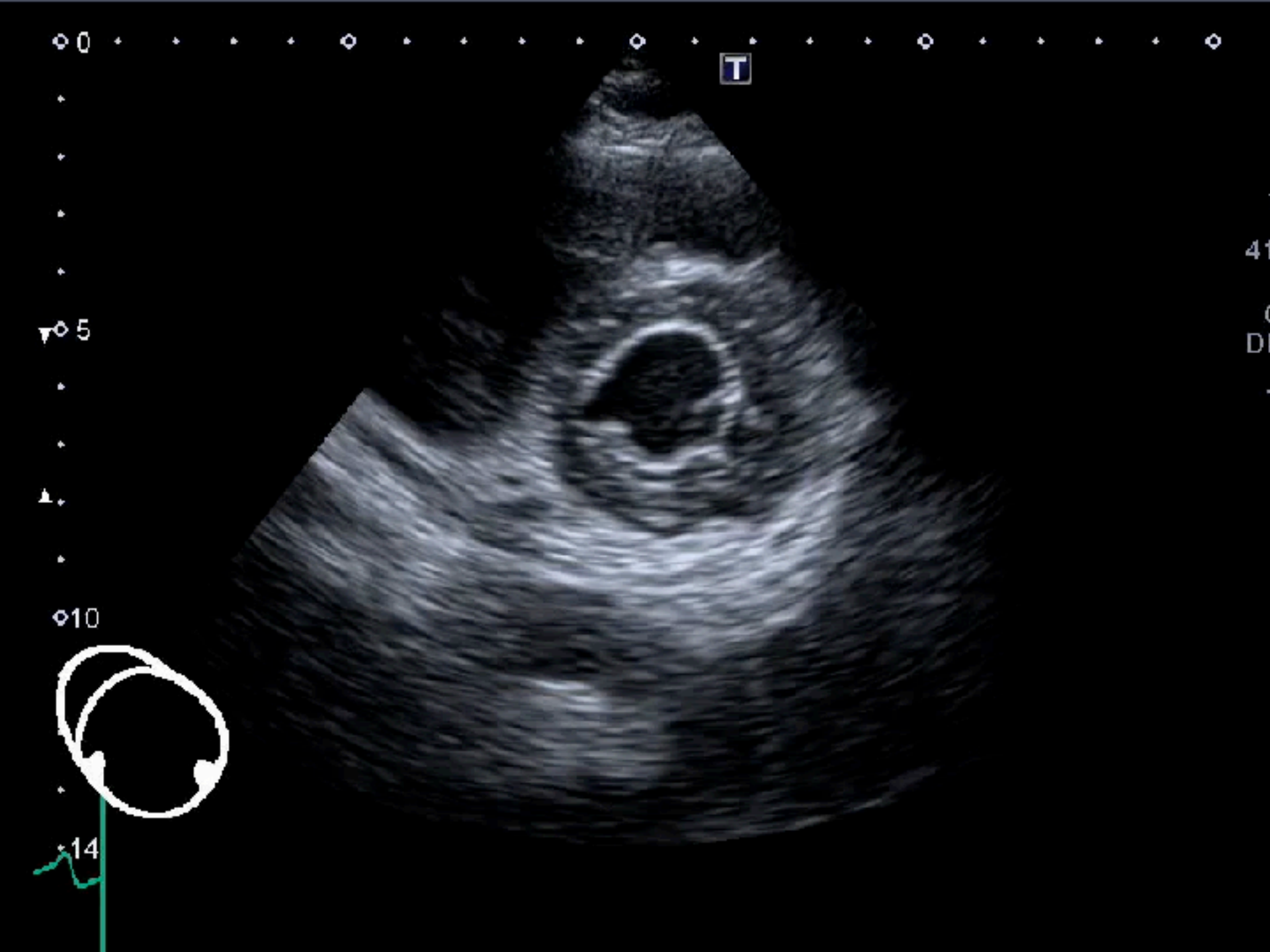
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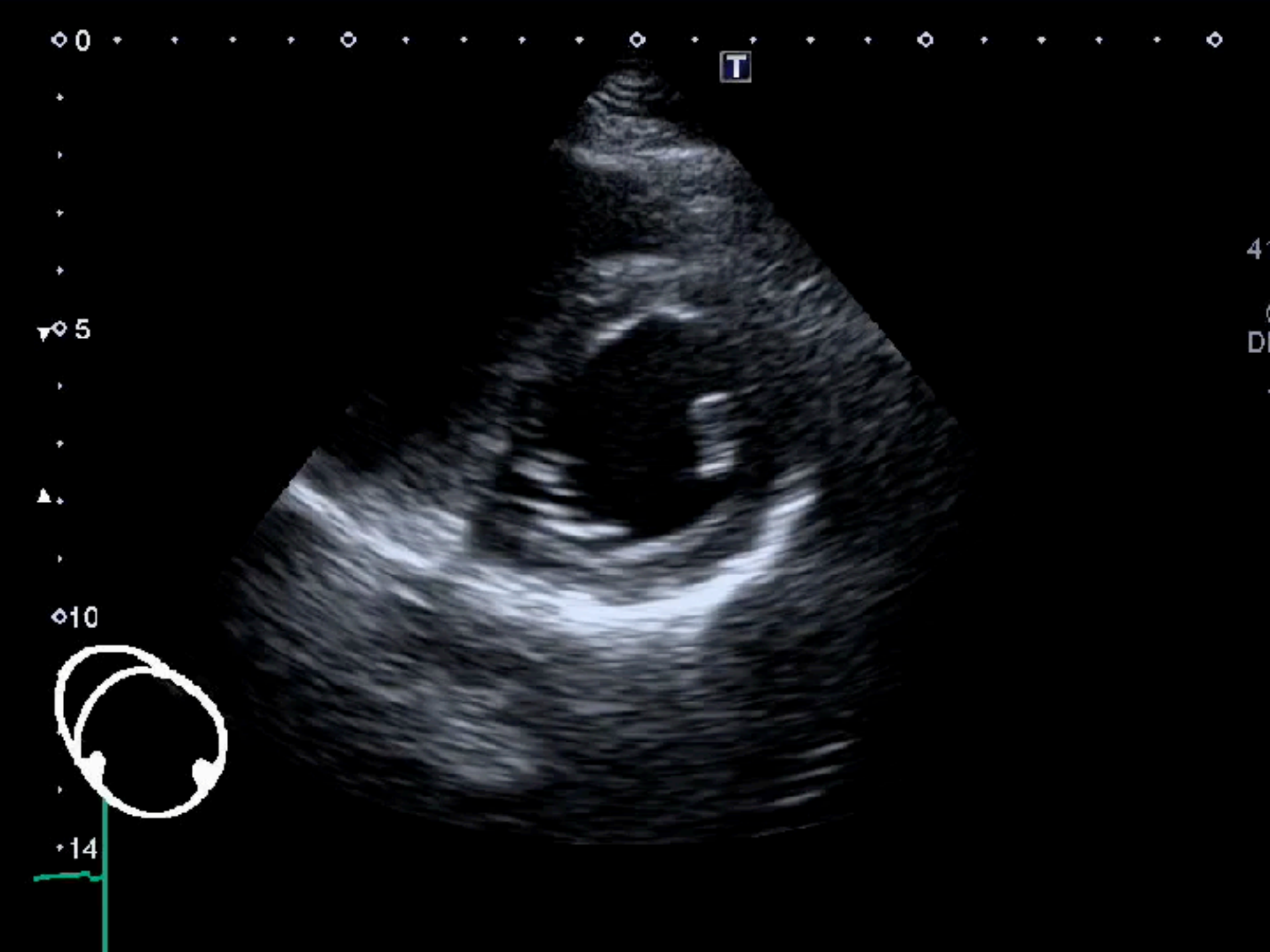
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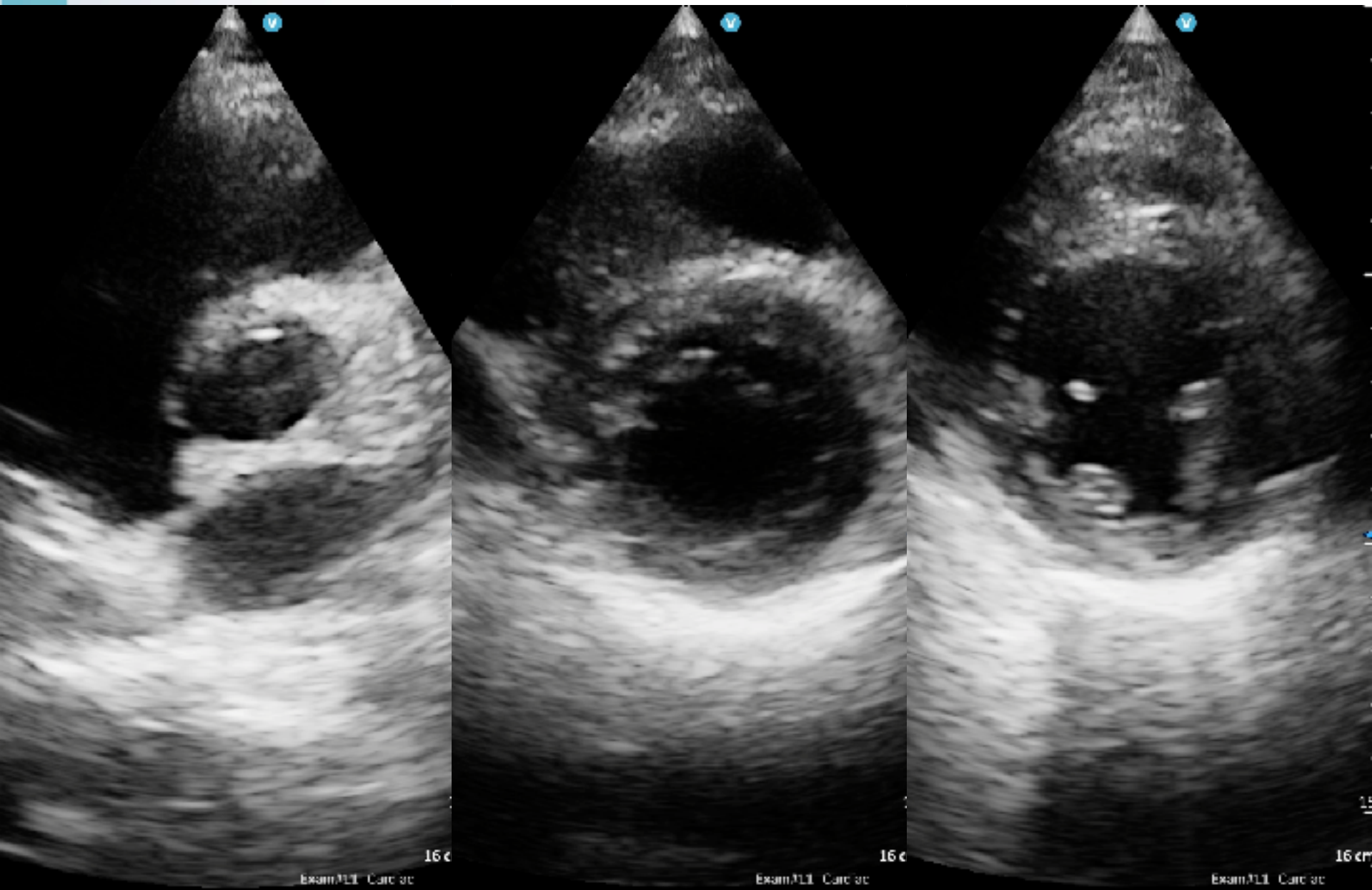
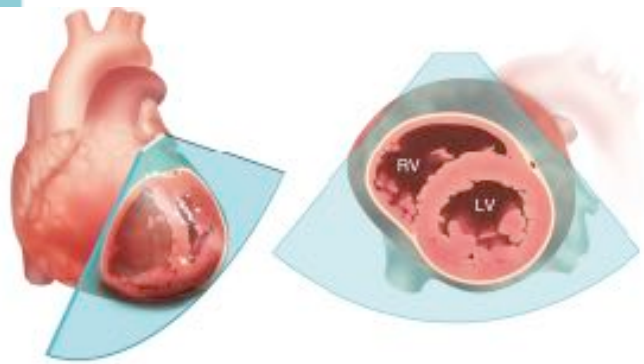
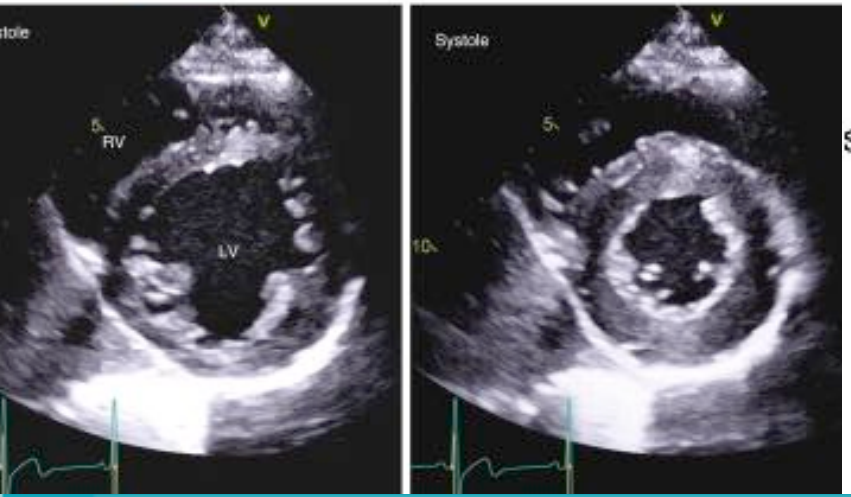
PSSA

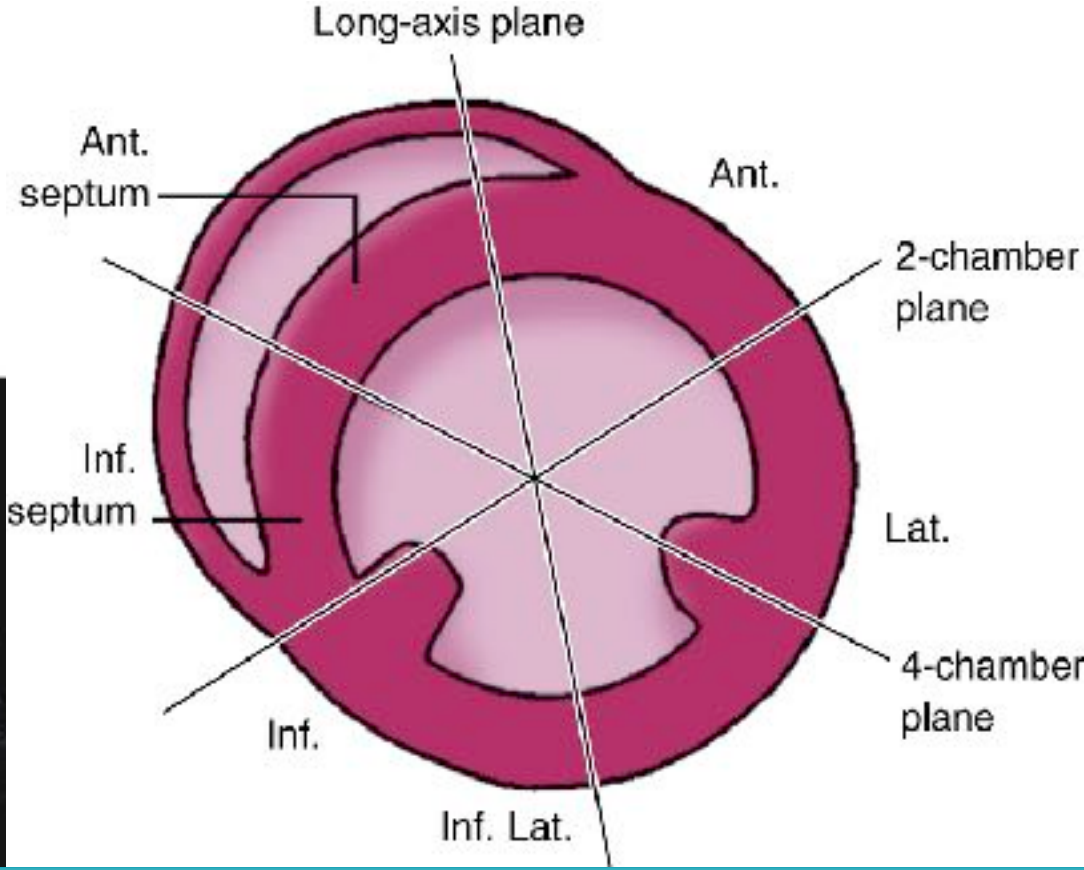


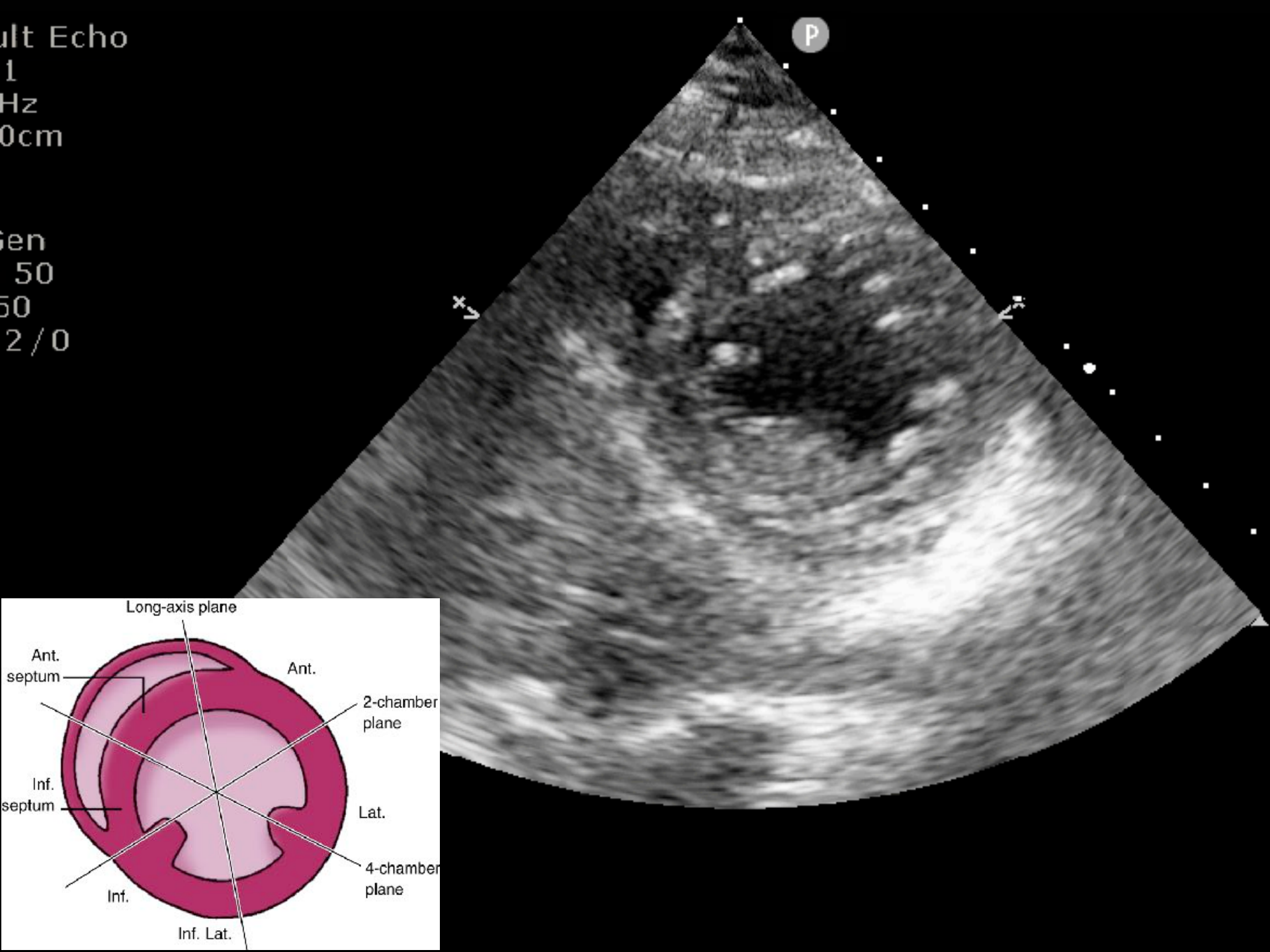
PSSA

Papillary muscle level: RWMA





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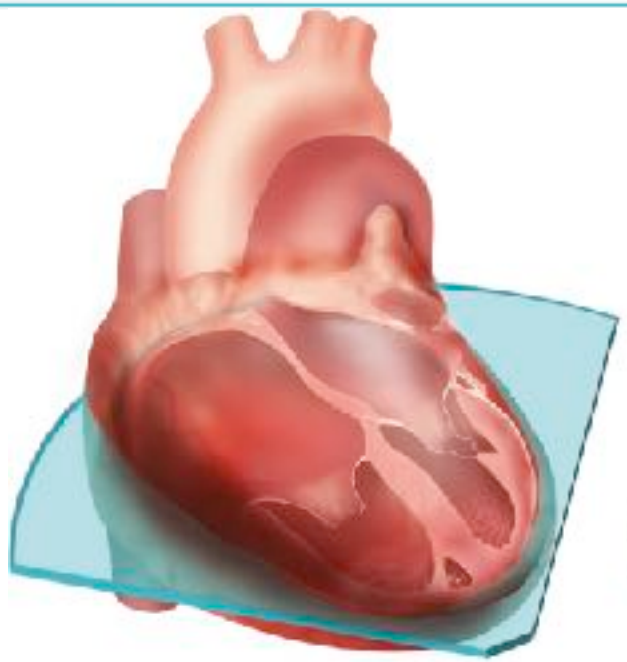
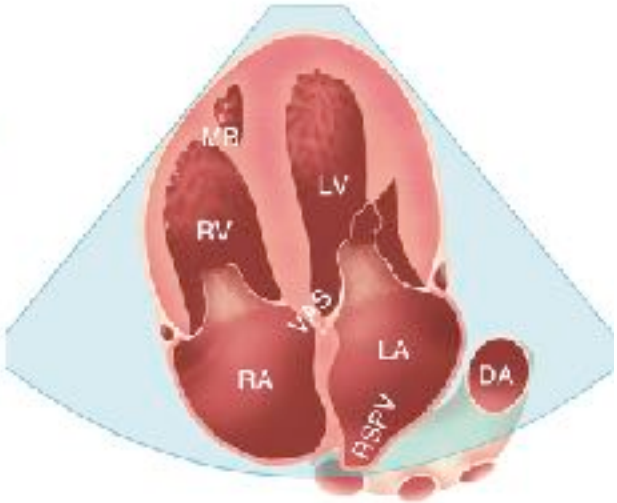
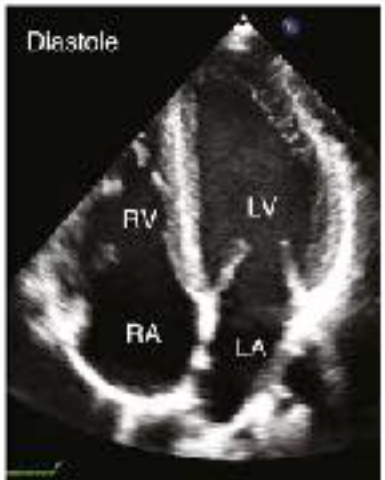
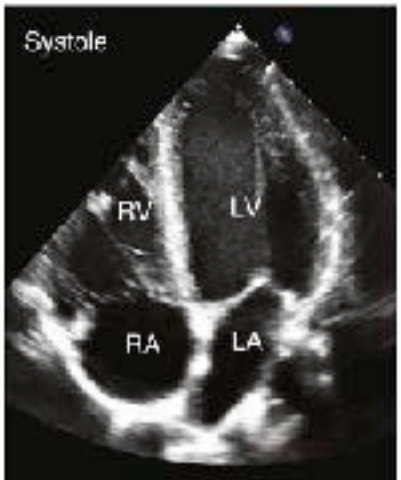
Apical 4 chamber view

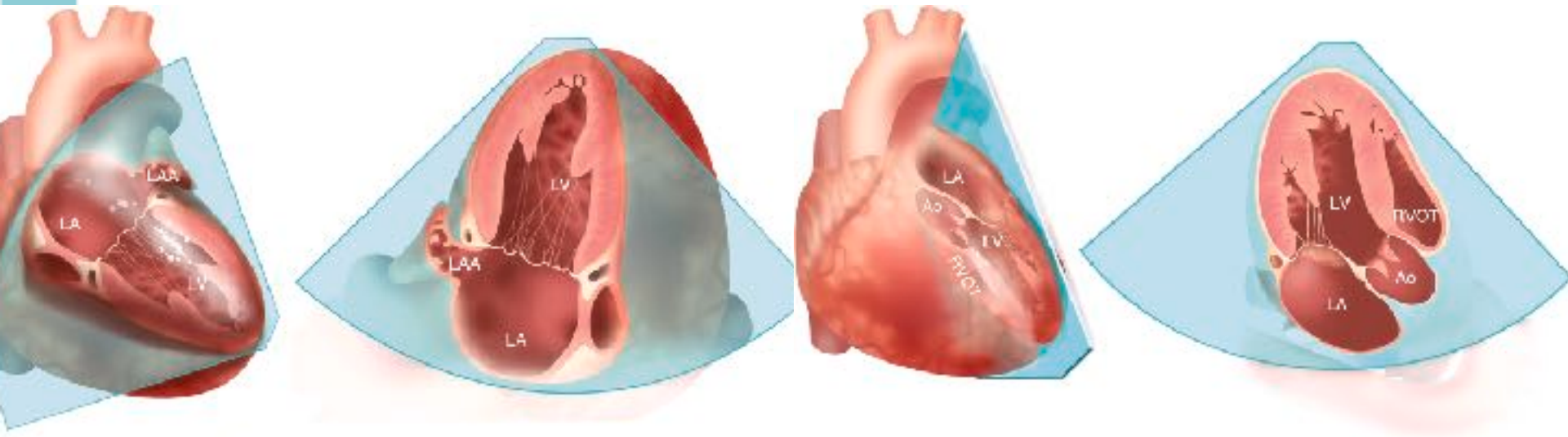


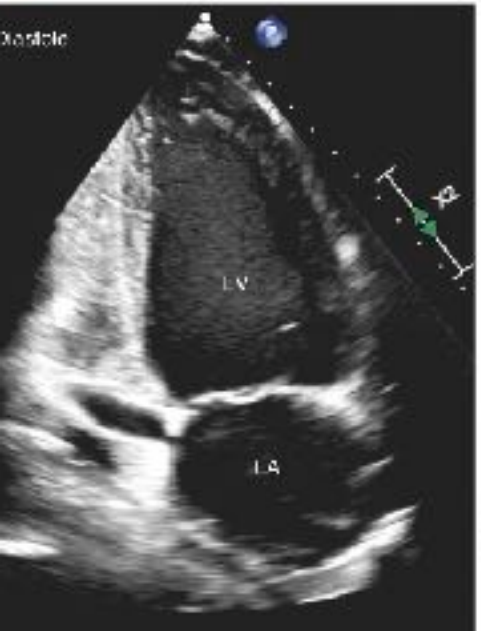


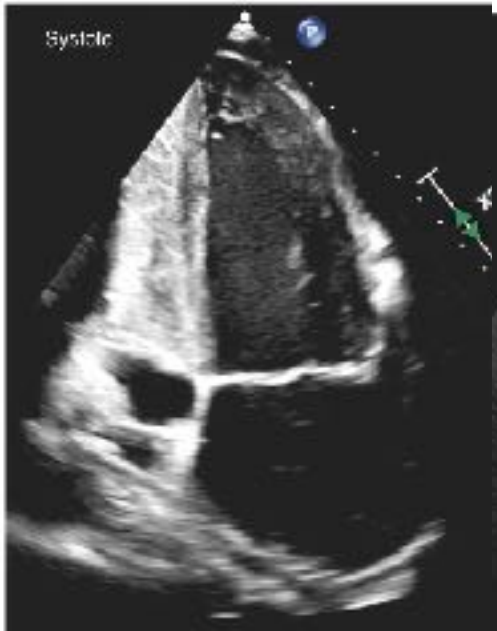


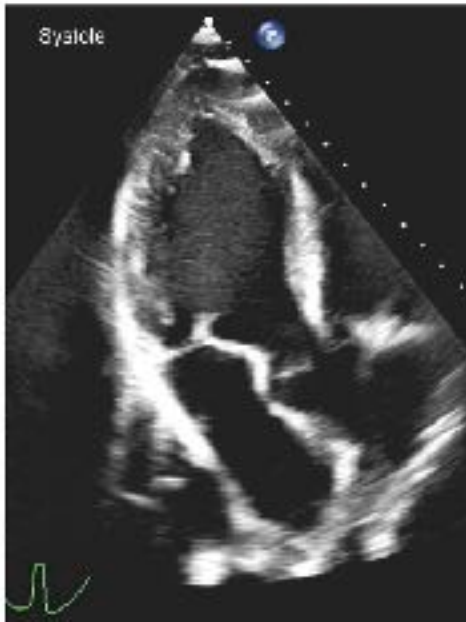


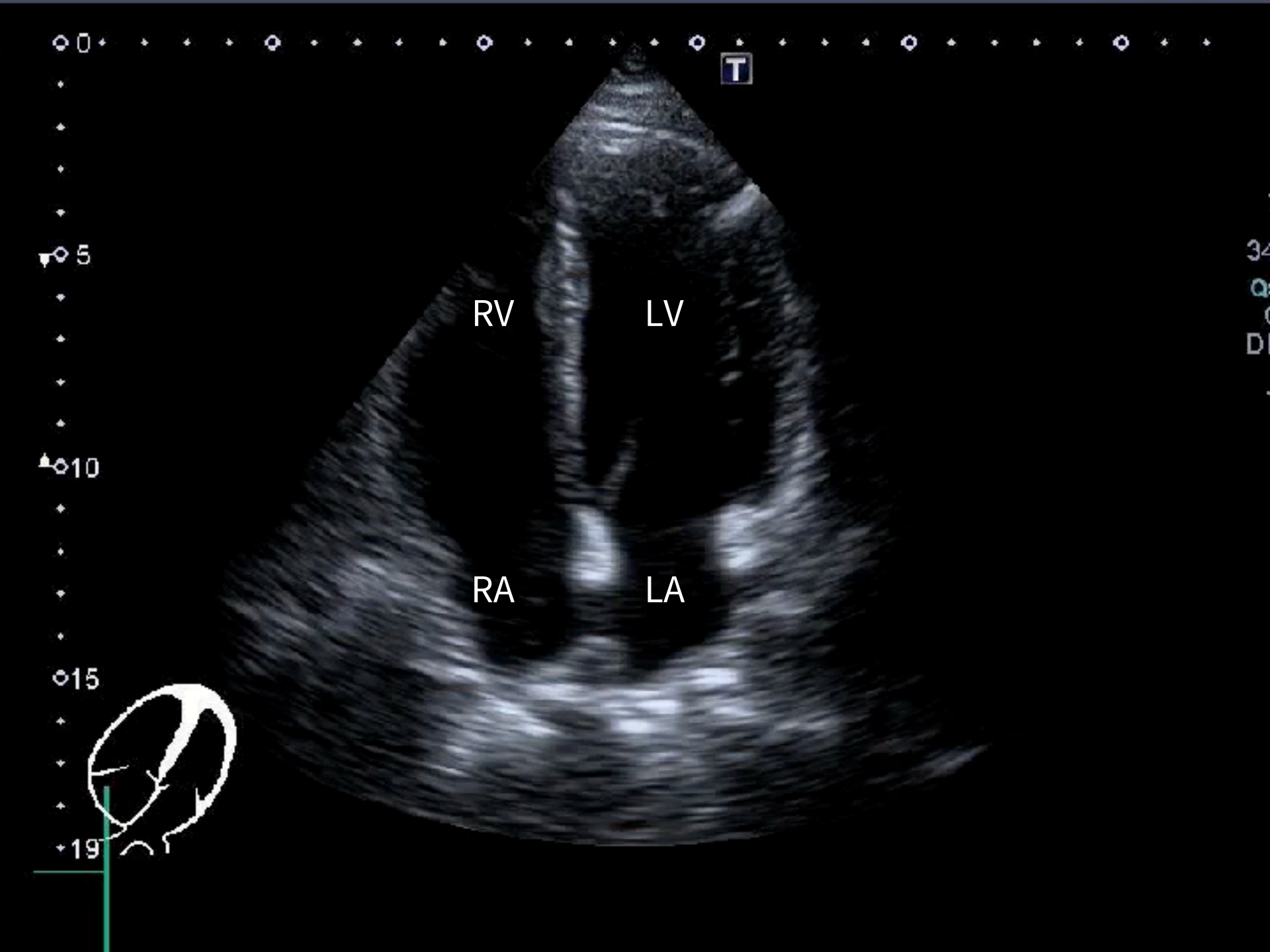
Apical 2 (60°)/3 (120°) chamber view










RV
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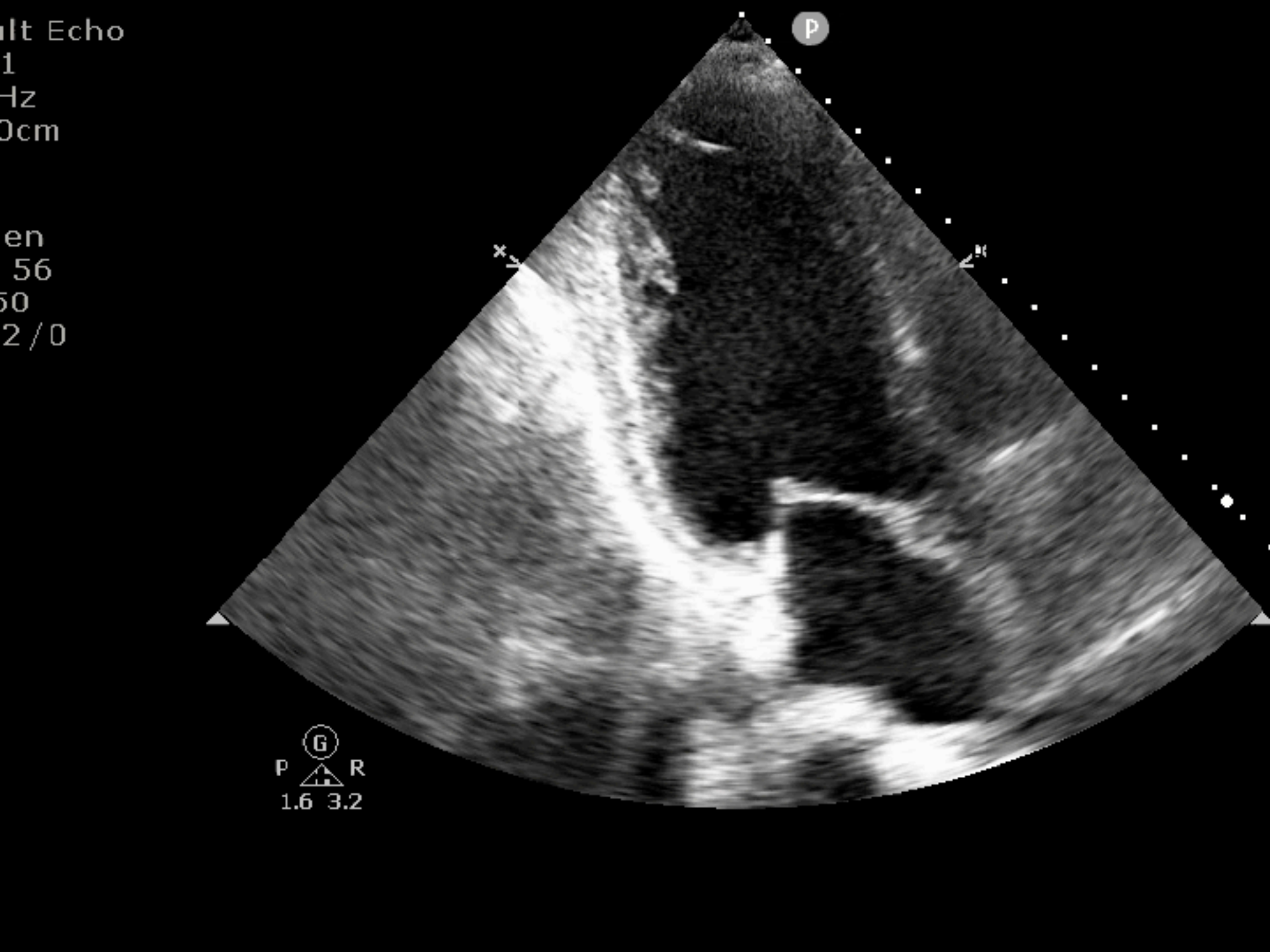
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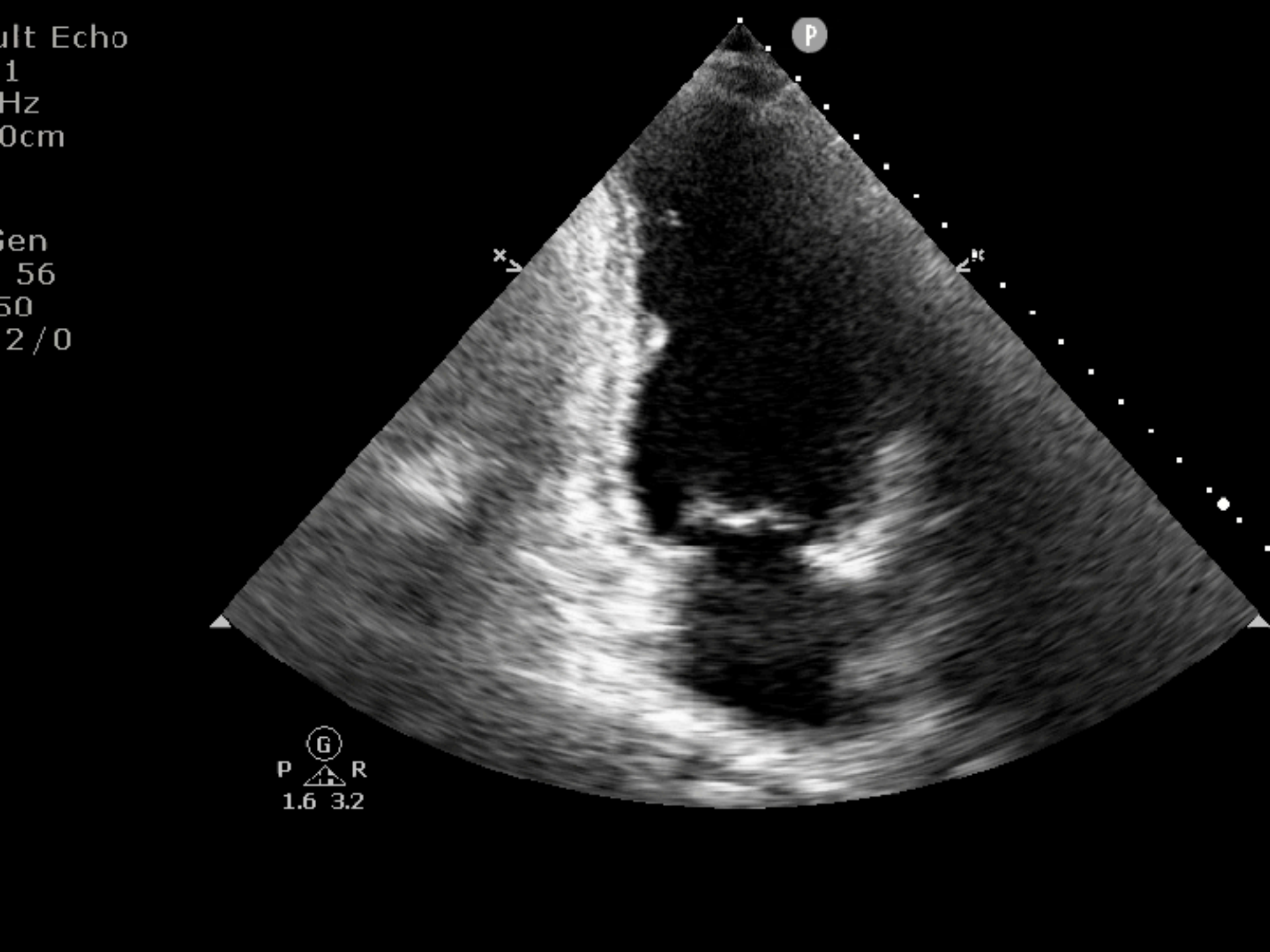
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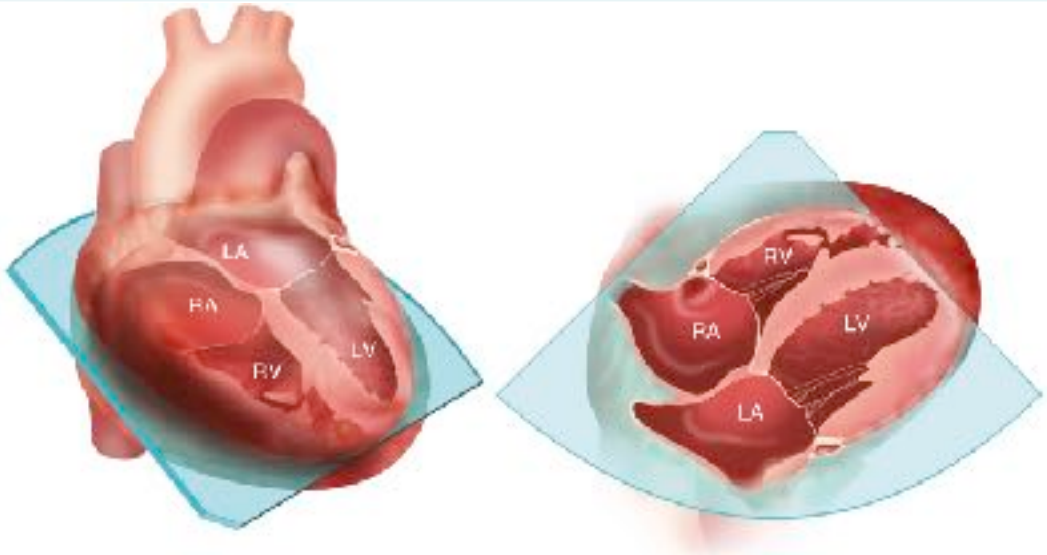
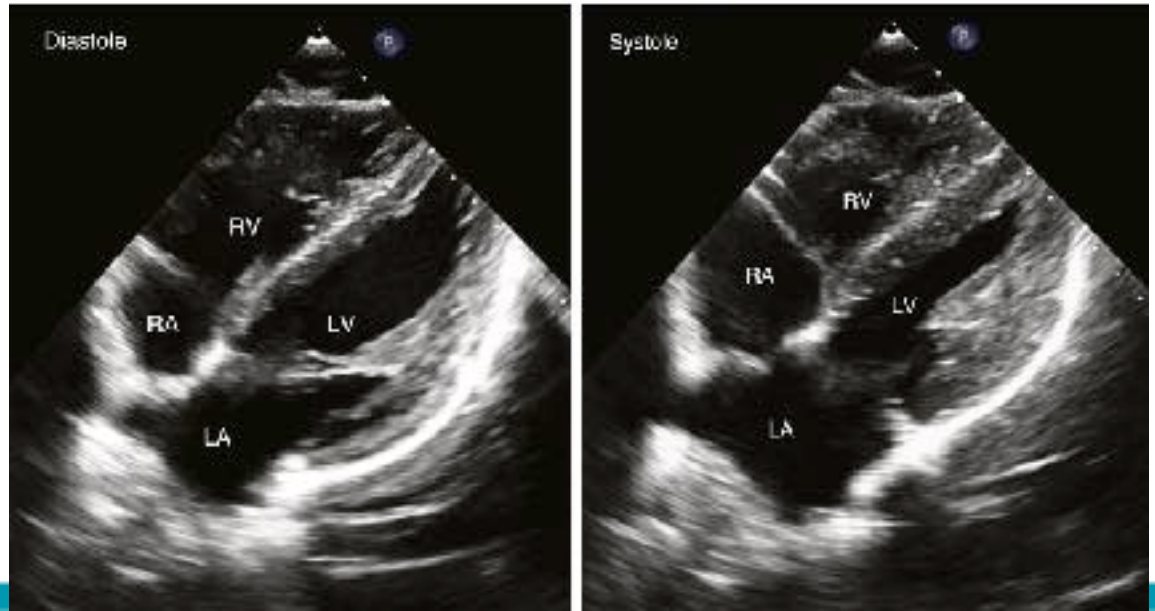
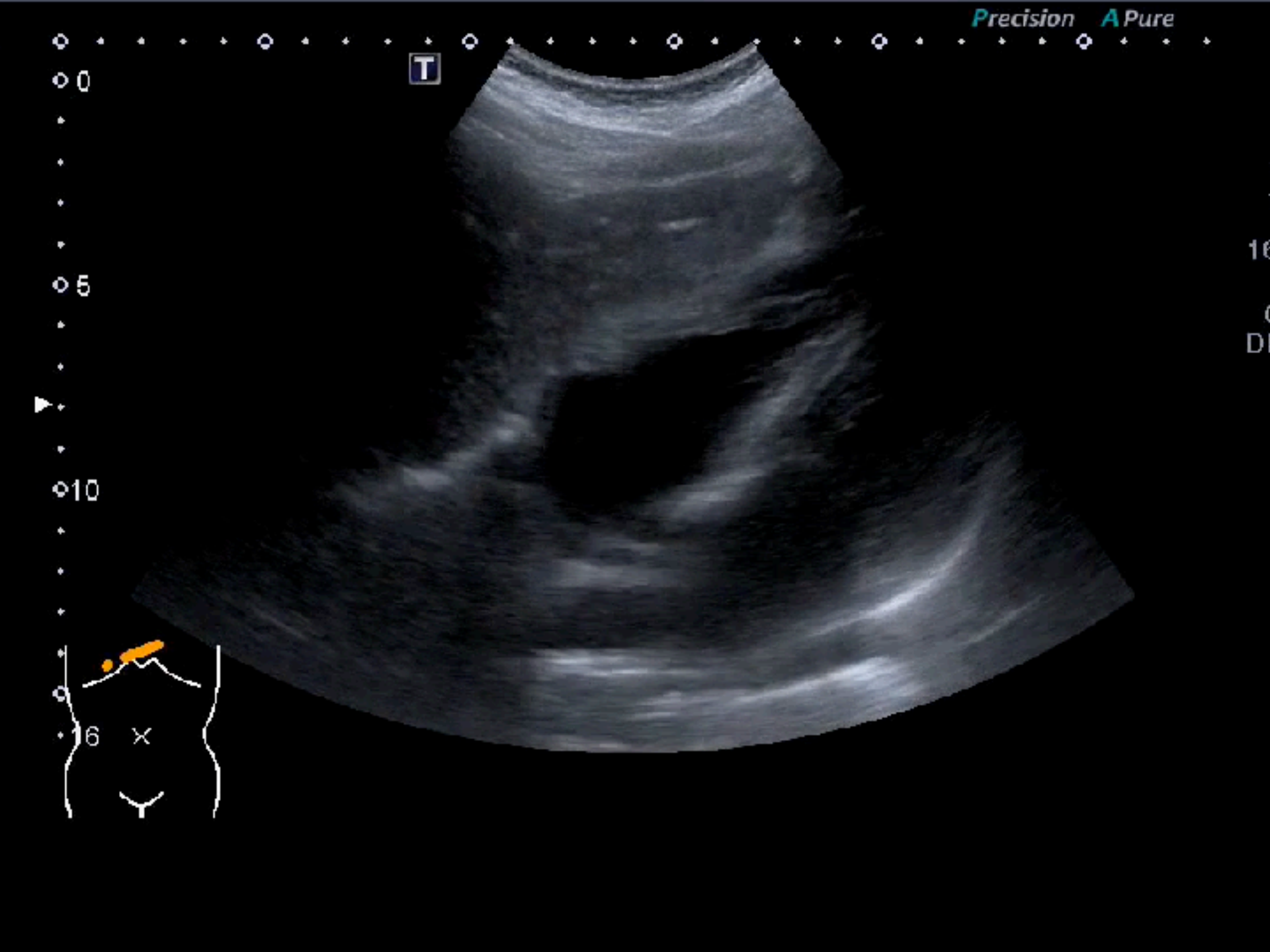
Subcostal 4 chamber



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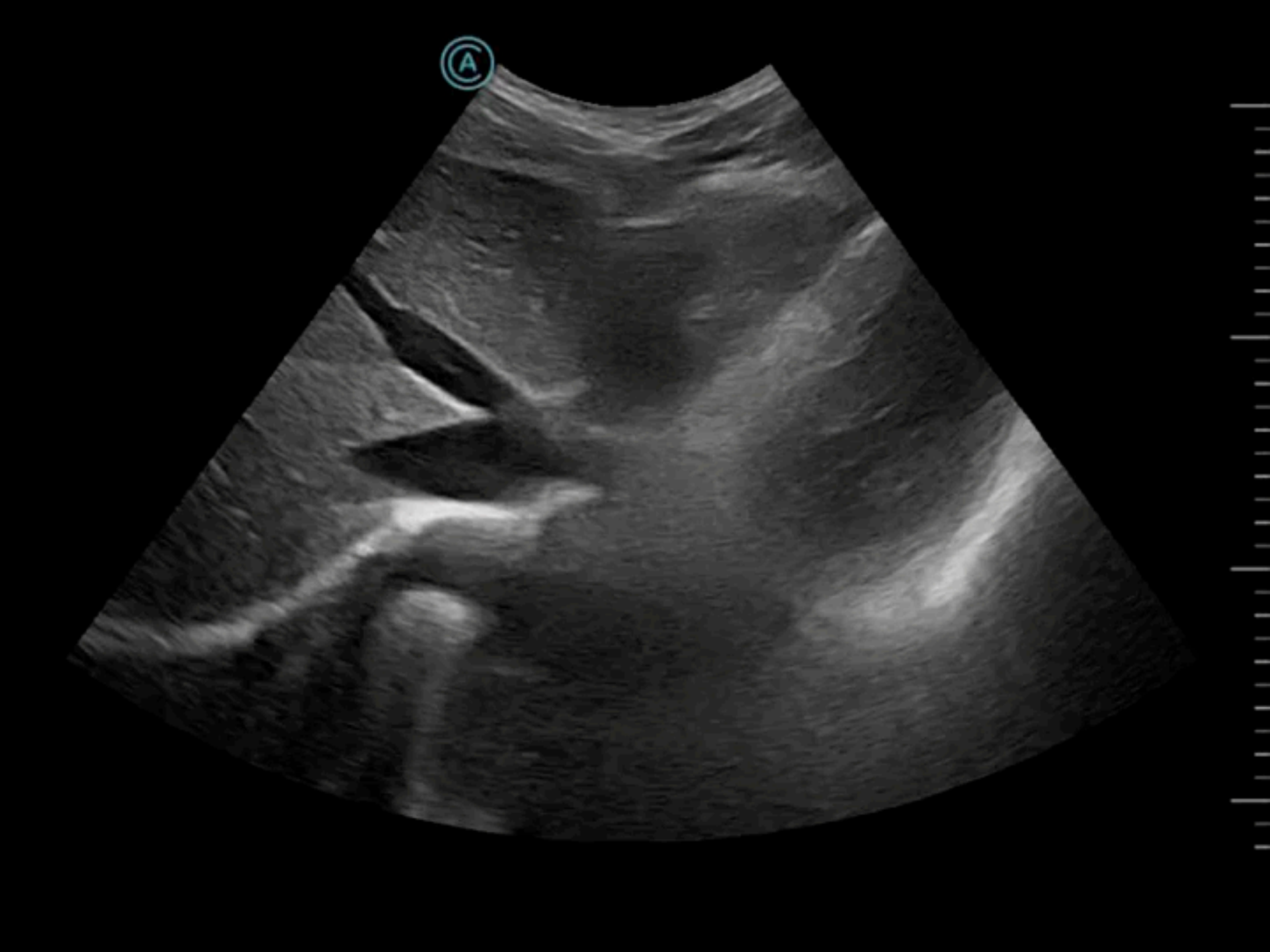
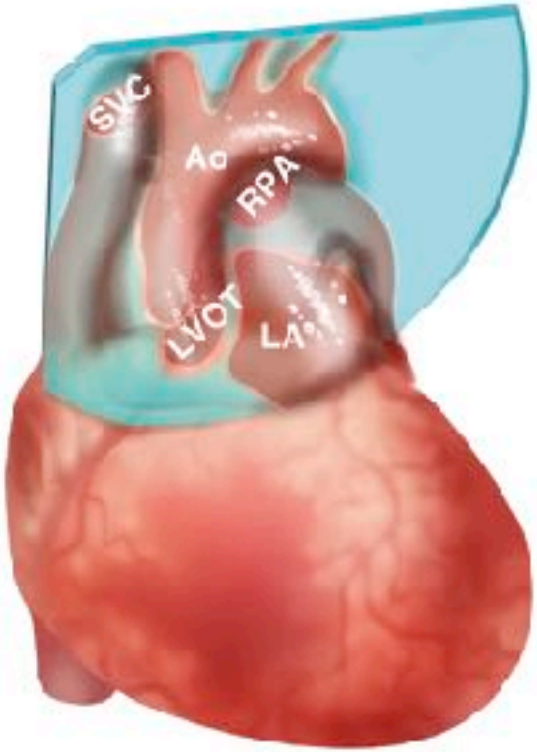
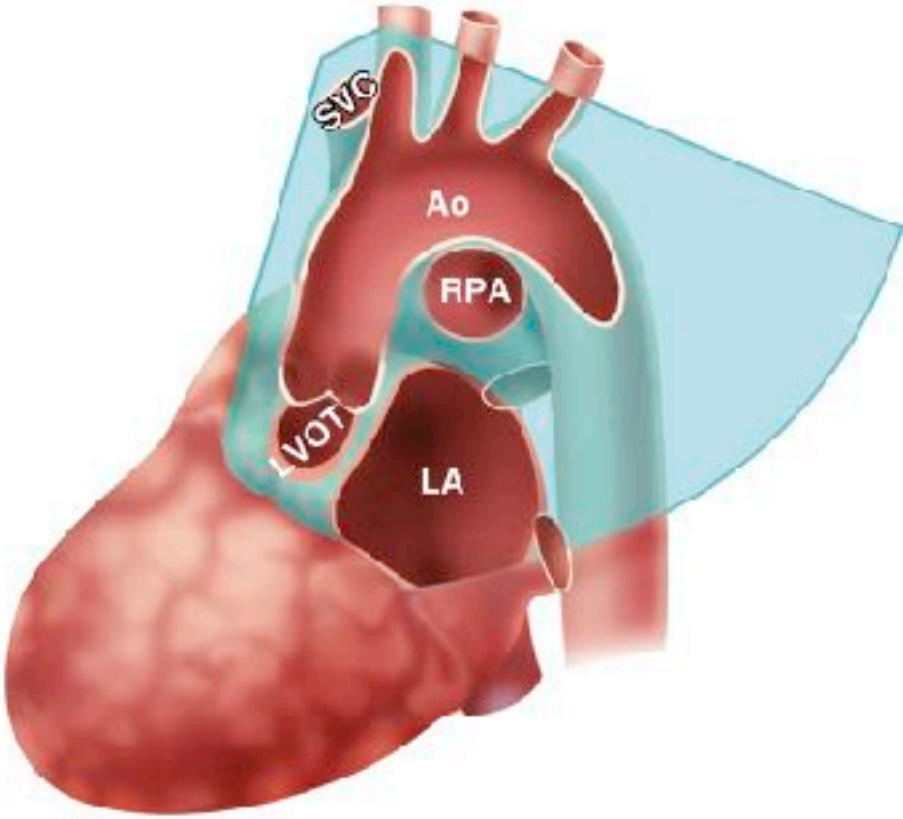
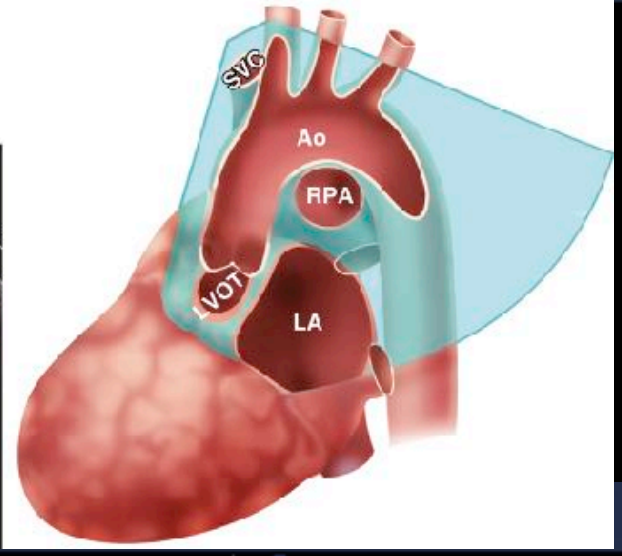


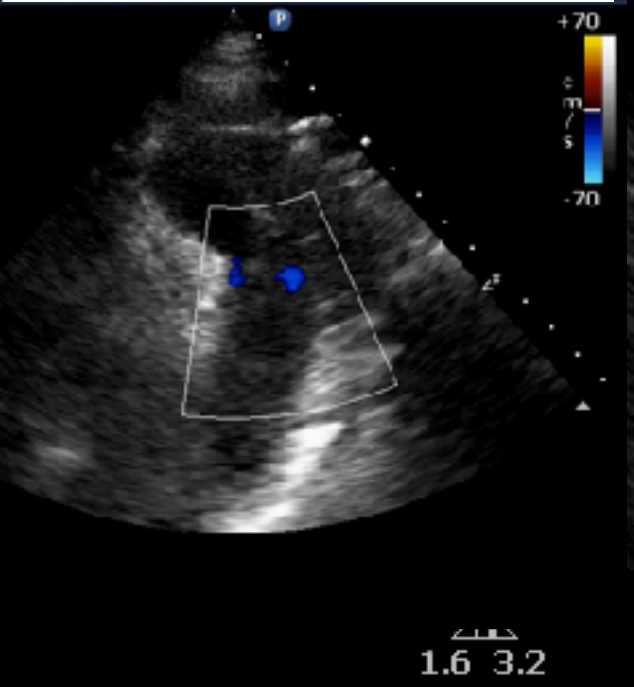

A

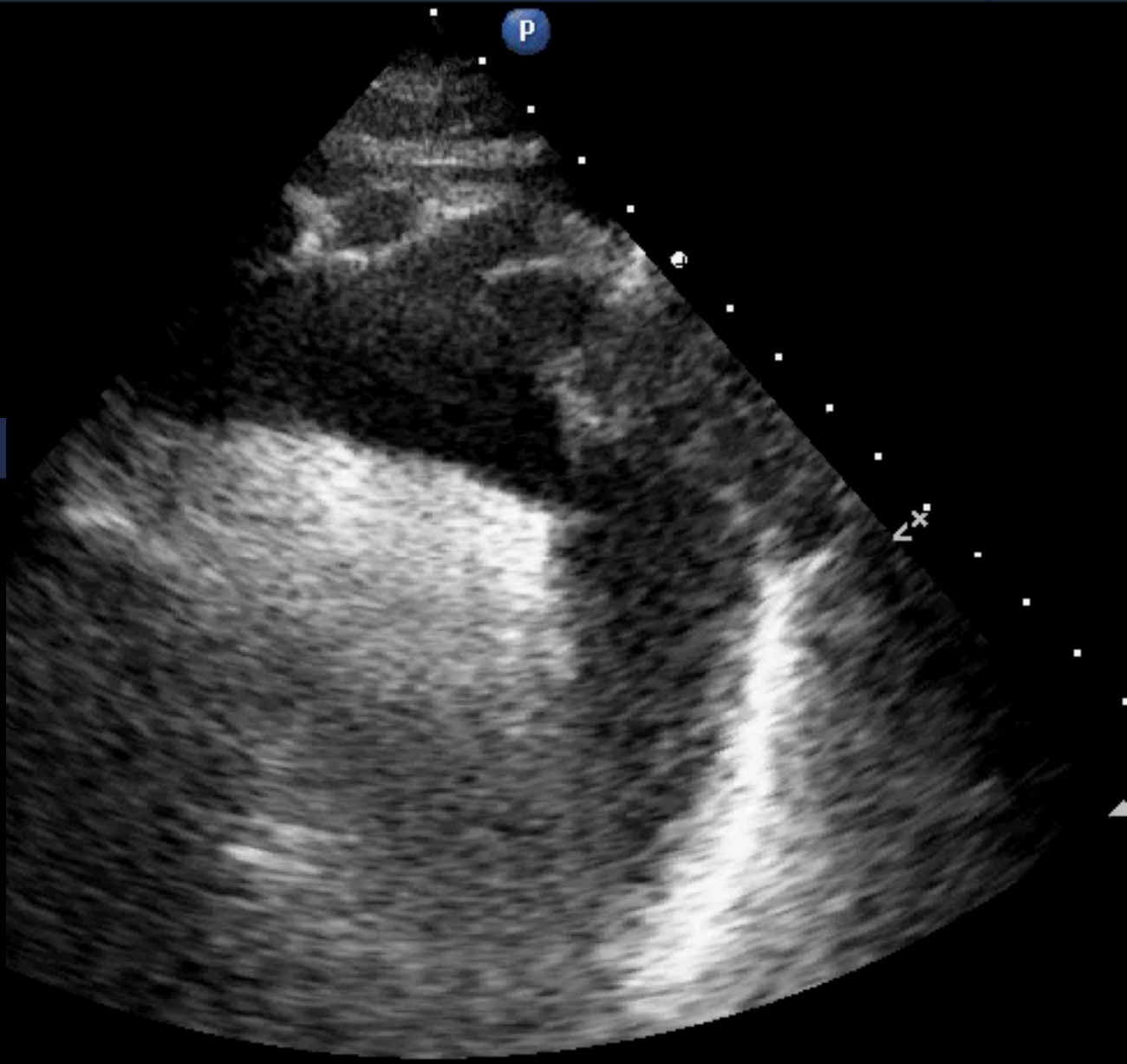
Suprasternal notch view











1.6 3.2

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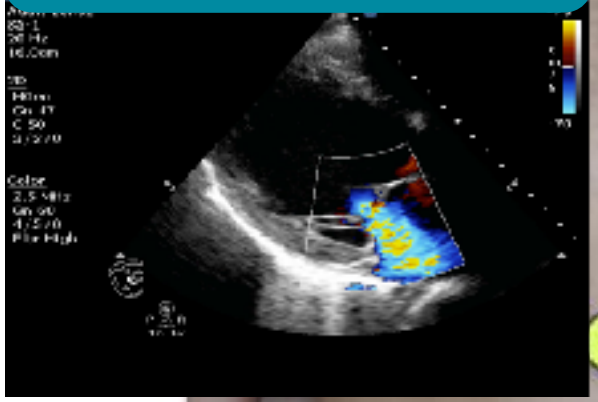
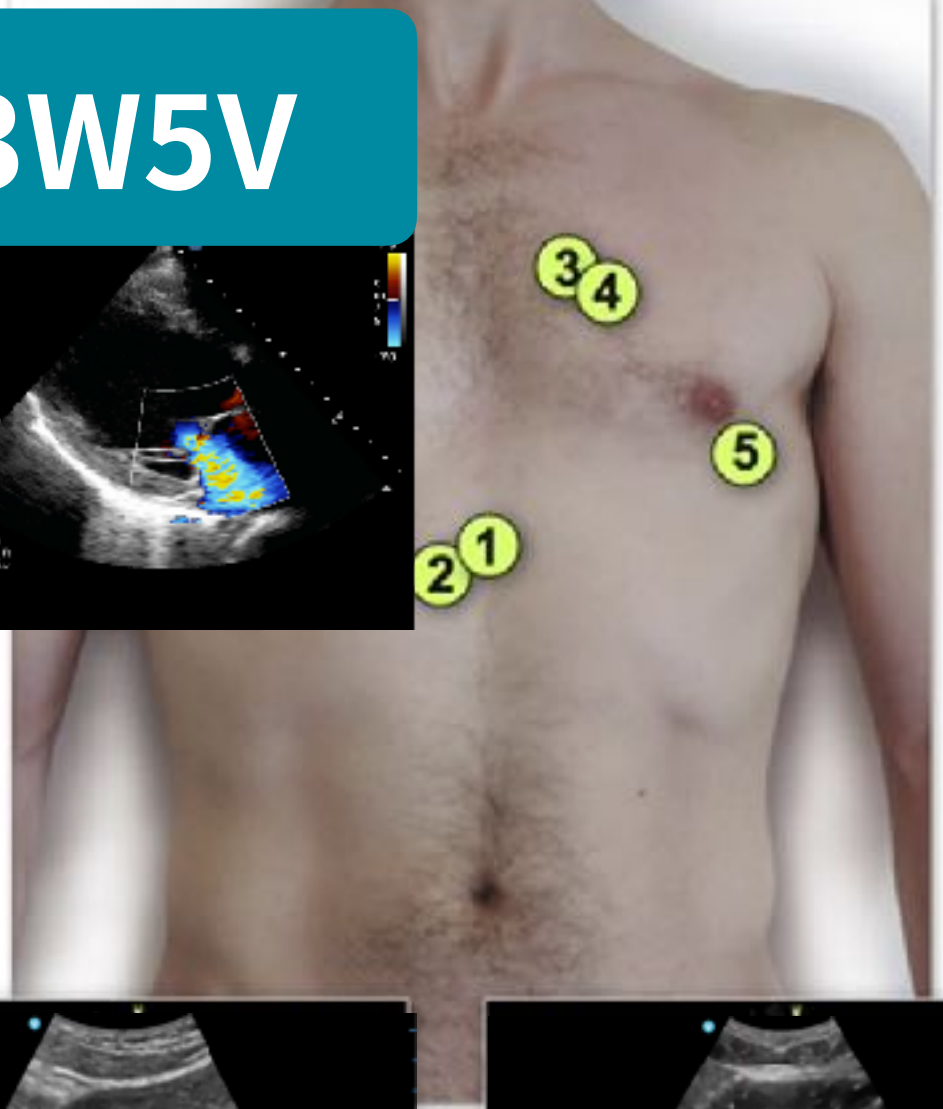
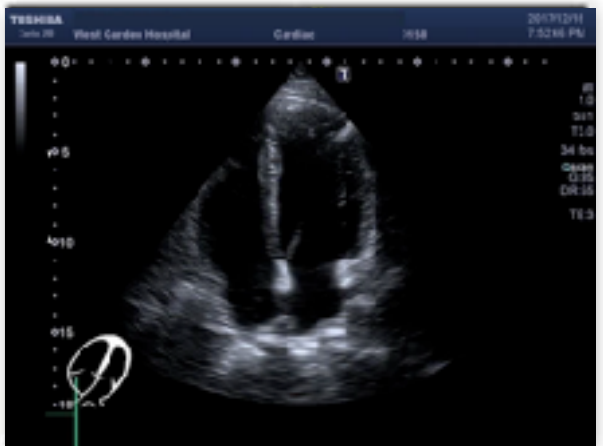




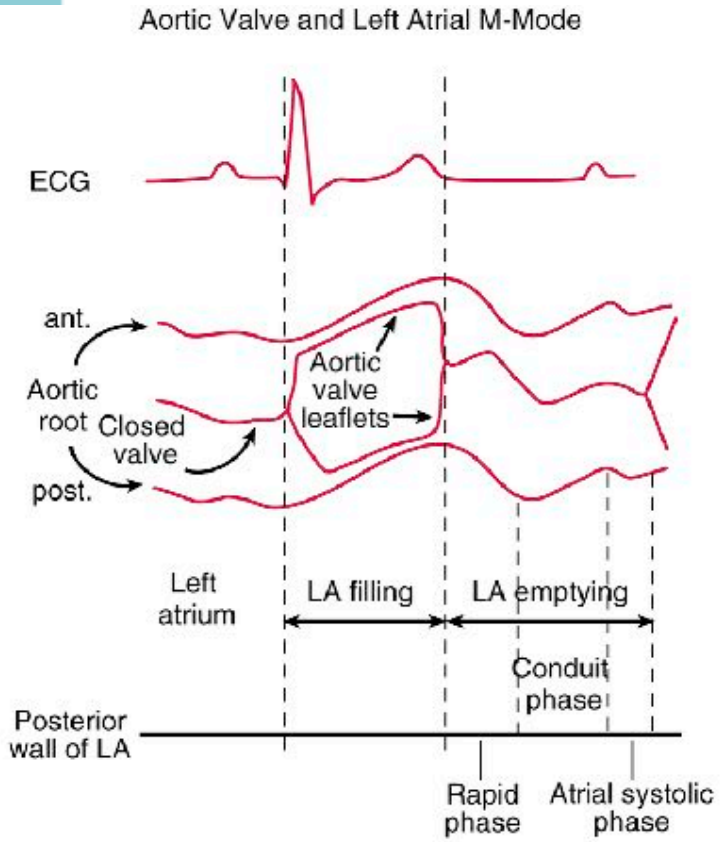


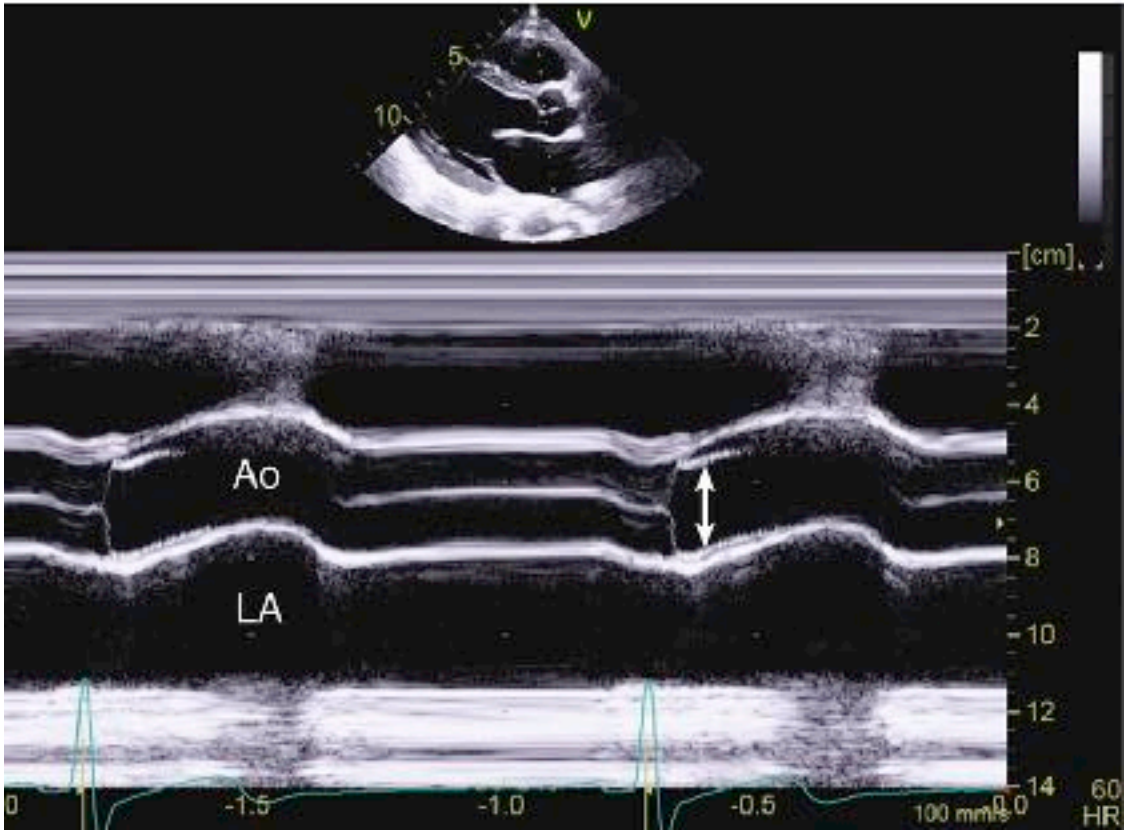
Goal of POCUS

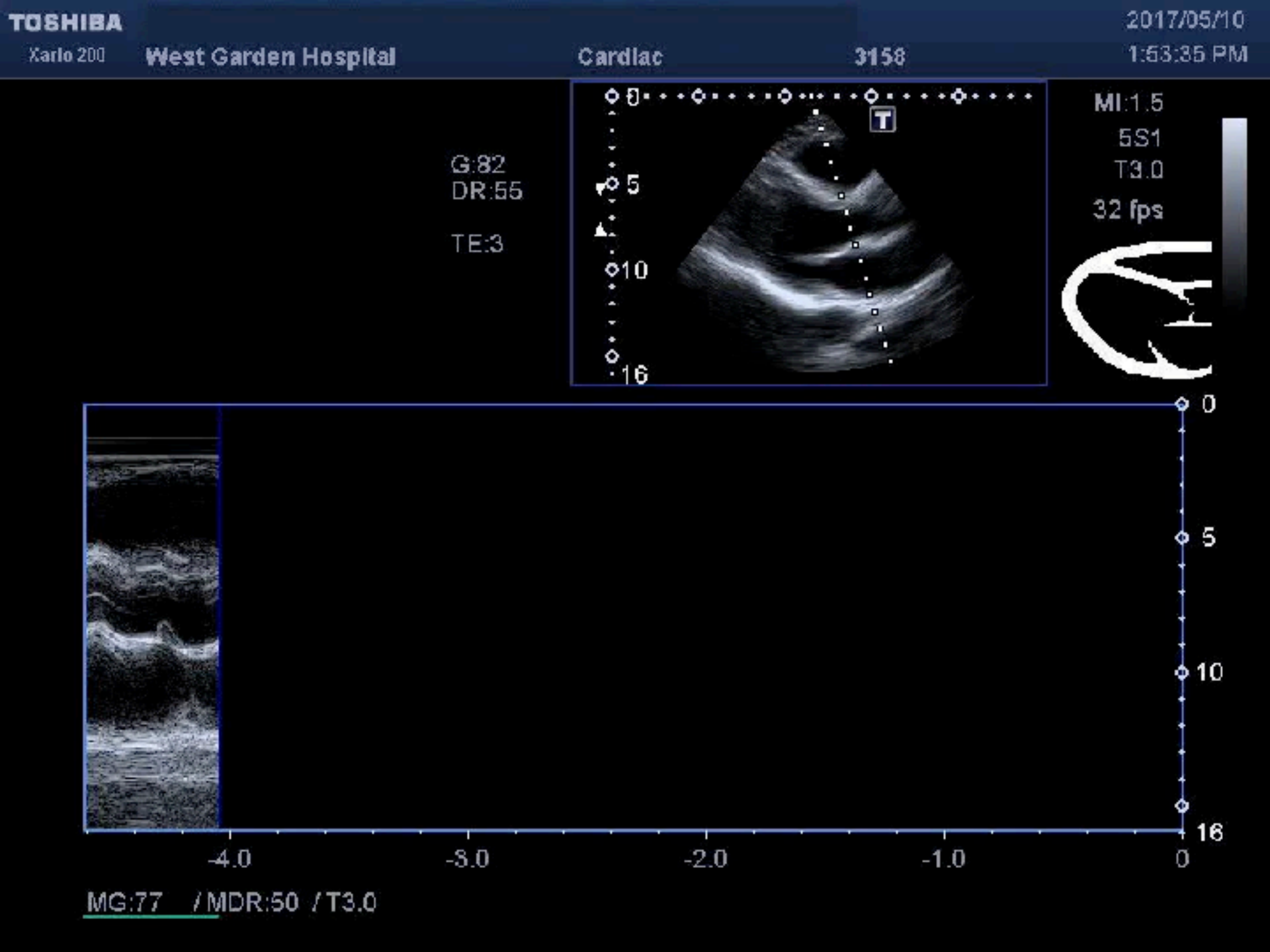
Diagnostic Target	Goals of POCUS	Imaging Views	Limitations
LV size and function	• Estimate overall LV systolic function (normal, mildly, moderately, or severely reduced). • Estimate LV size (relative to size of aortic root).	• Parasternal long- and short-axis views of LV • Apical 4-chamber	• Quantitative measurement of LV ejection fraction is rarely possible. • Evaluation of regional wall motion requires considerable expertise but may be suggested by FoCUS findings.
RV size and function	• Estimate RV systolic function. • Detect RV dilation.	• Apical 4-chamber view • Subcostal view	• Complex RV shape limits evaluation of size and systolic function.
Pericardial effusion	• Detect pericardial effusion. • Estimate effusion size (small, moderate, large).	• Parasternal • Apical • Subcostal	• Loculated effusions may be missed. • Tamponade physiology is a clinical diagnosis that should be considered for all moderate or large effusions.
Volume status	• Evaluate central venous pressure.	• IVC size and respiratory variation from subcostal view (RA pressure)	• Unreliable in ventilated patients
Other	• More complex anatomic and physiologic abnormalities may be suspected on a POCUS study.	• All views	• A diagnostic echocardiogram is recommended when regional wall motion abnormalities are a concern, to evaluate for aortic disease, valve stenosis, or regurgitation, or to estimate pulmonary pressures.

FoCUS, Focused cardiac ultrasound; *IVC*, inferior vena cava.
From McConnaughey S, Otto CM: Focused cardiac ultrasound at the bedside. In Otto CM, editor: *The practice of clinical echocardiography*, ed 6, Philadelphia, 2022, Elsevier, pp 234–249.

Aortic valve & Left atrium (4cm)

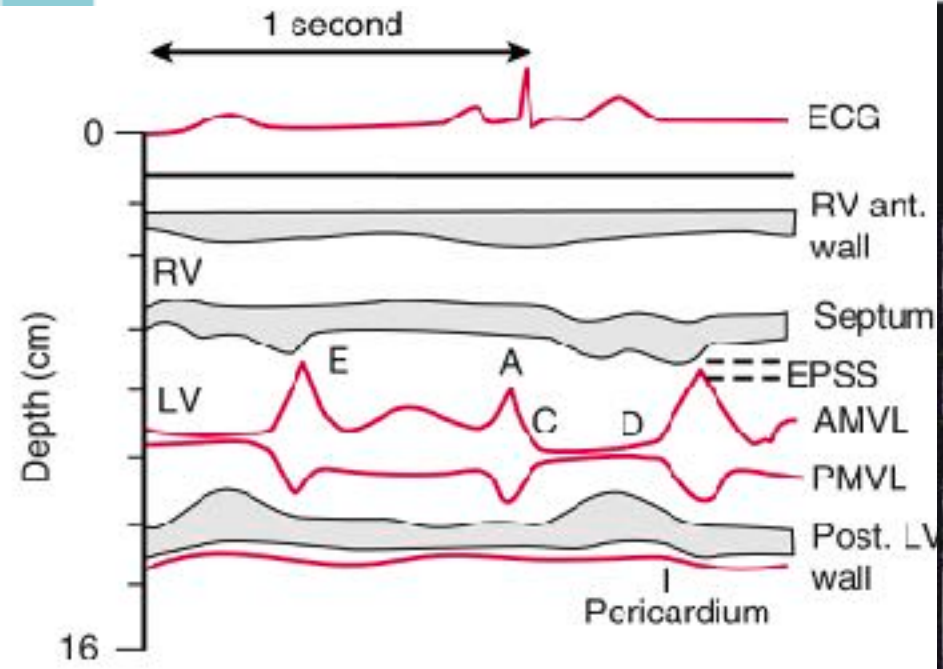


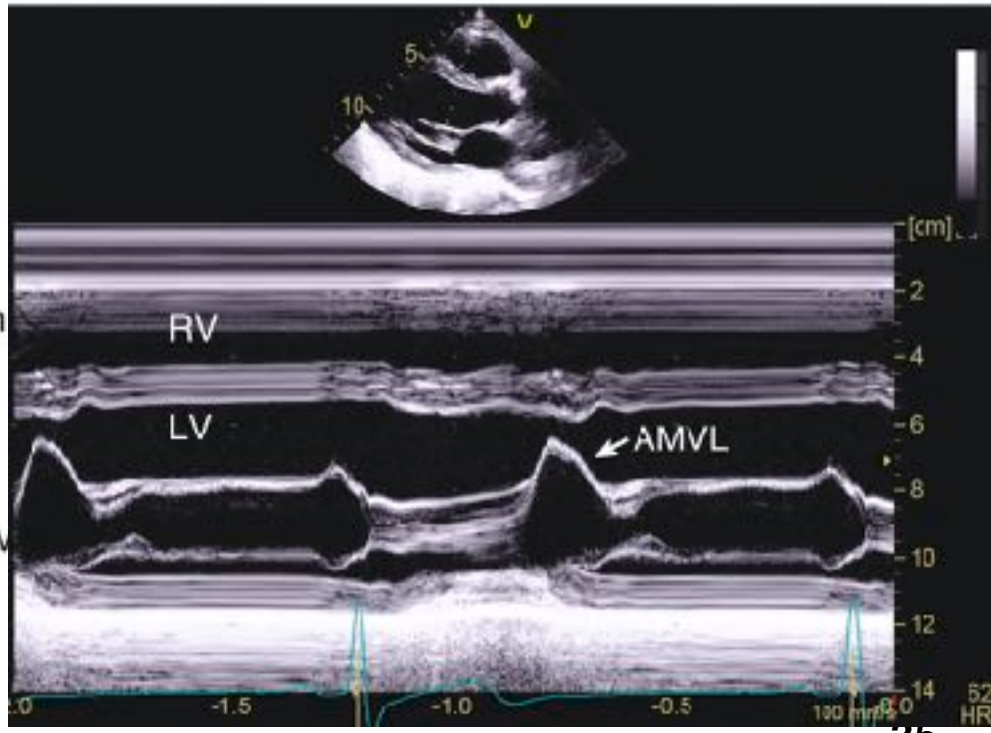



TOSHIBA
Xario 200
West Garden Hospital
Cardiac
3158
2017/05/10
1:53:35 PM
G:82
DR:55
TE:3
MI:1.5
5S1
T3.0
32 fps
0
5
10
16
0
5
10
16
-4.0
-3.0
-2.0
-1.0
0
MG:77
/MDR:50
/T3.0

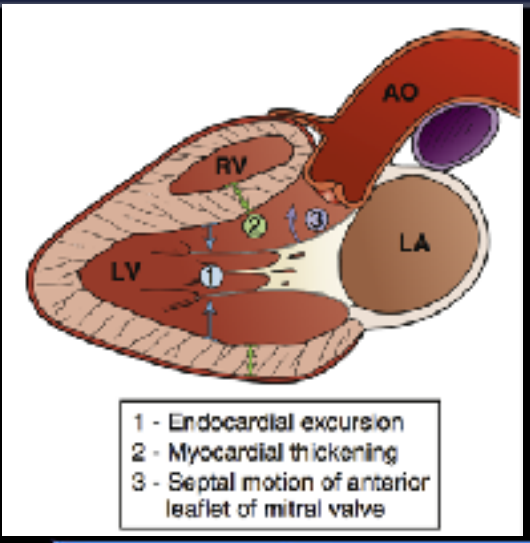
Mitral valve

EPSS: E-point to septal separation



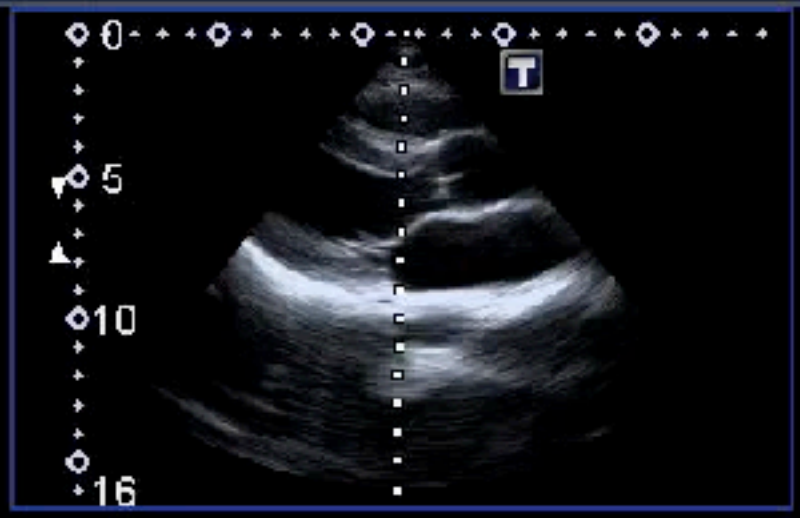


E-point septal separation **>7mm** : LVEF < 30%



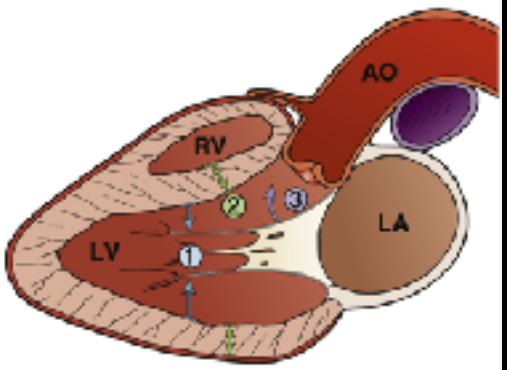
G:82
DR:55

TE:3



MI:1.5
5S1
T3.0
32 fps

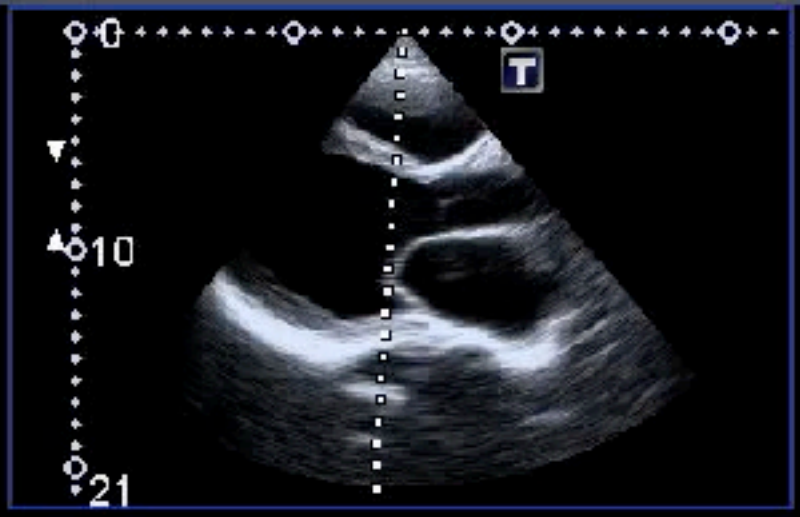
MG:77 / MDR:50 / T3.0



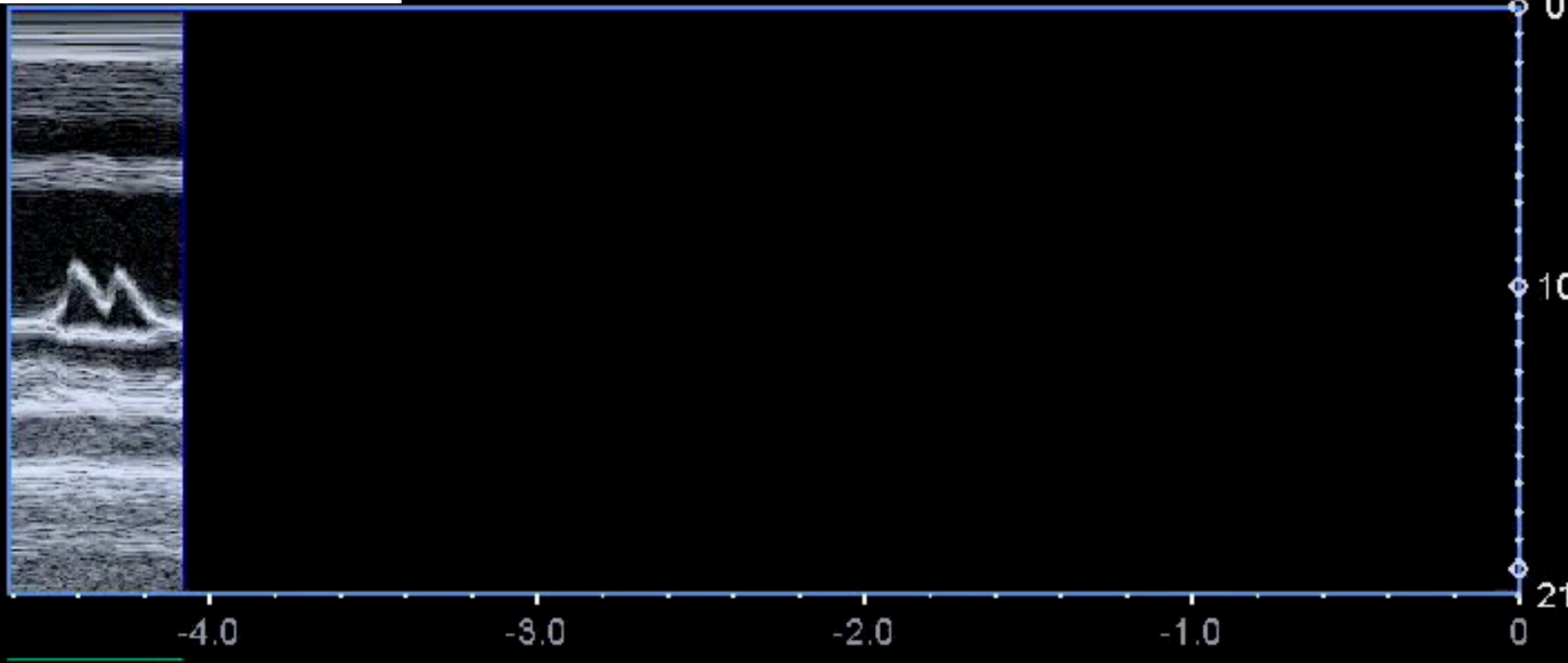
1 - Endocardial excursion
2 - Myocardial thickening
3 - Septal motion of anterior leaflet of mitral valve

Qscan
G:95
DR:55

TE:3



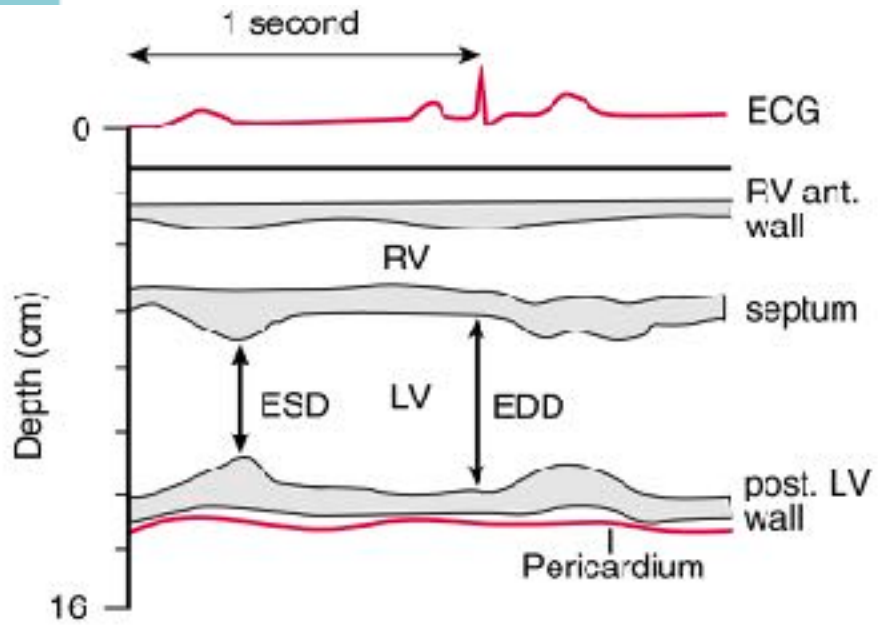
MI:1.5
5S1
T3.0
19 fps

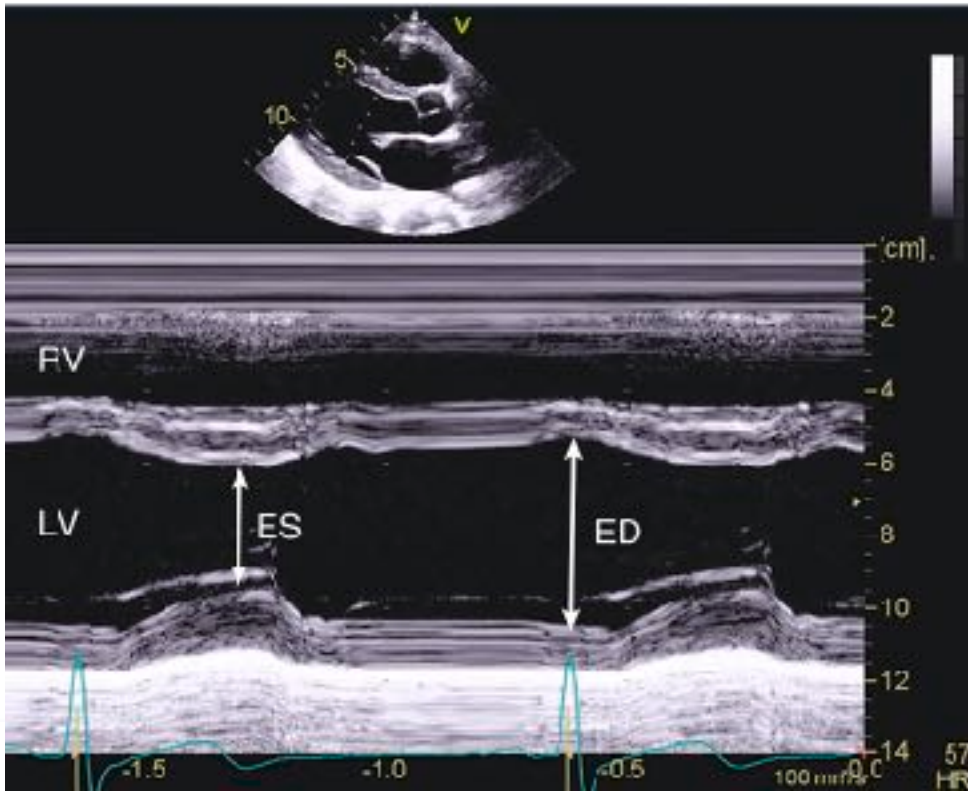


Qscan:90 / MDR:50 / T3.0

Left ventricle dimension

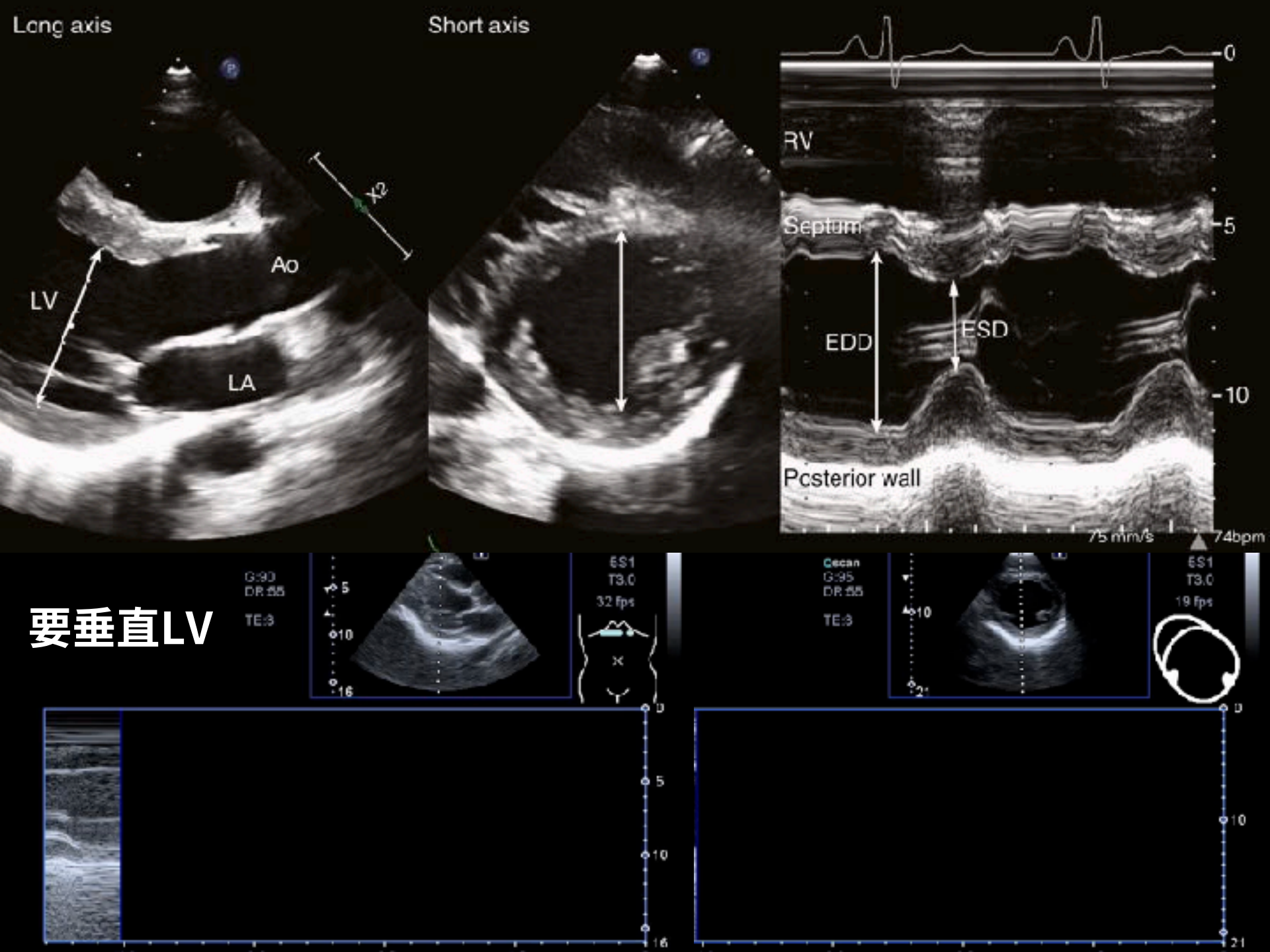
EF ~ 2FS / RV free wall motion

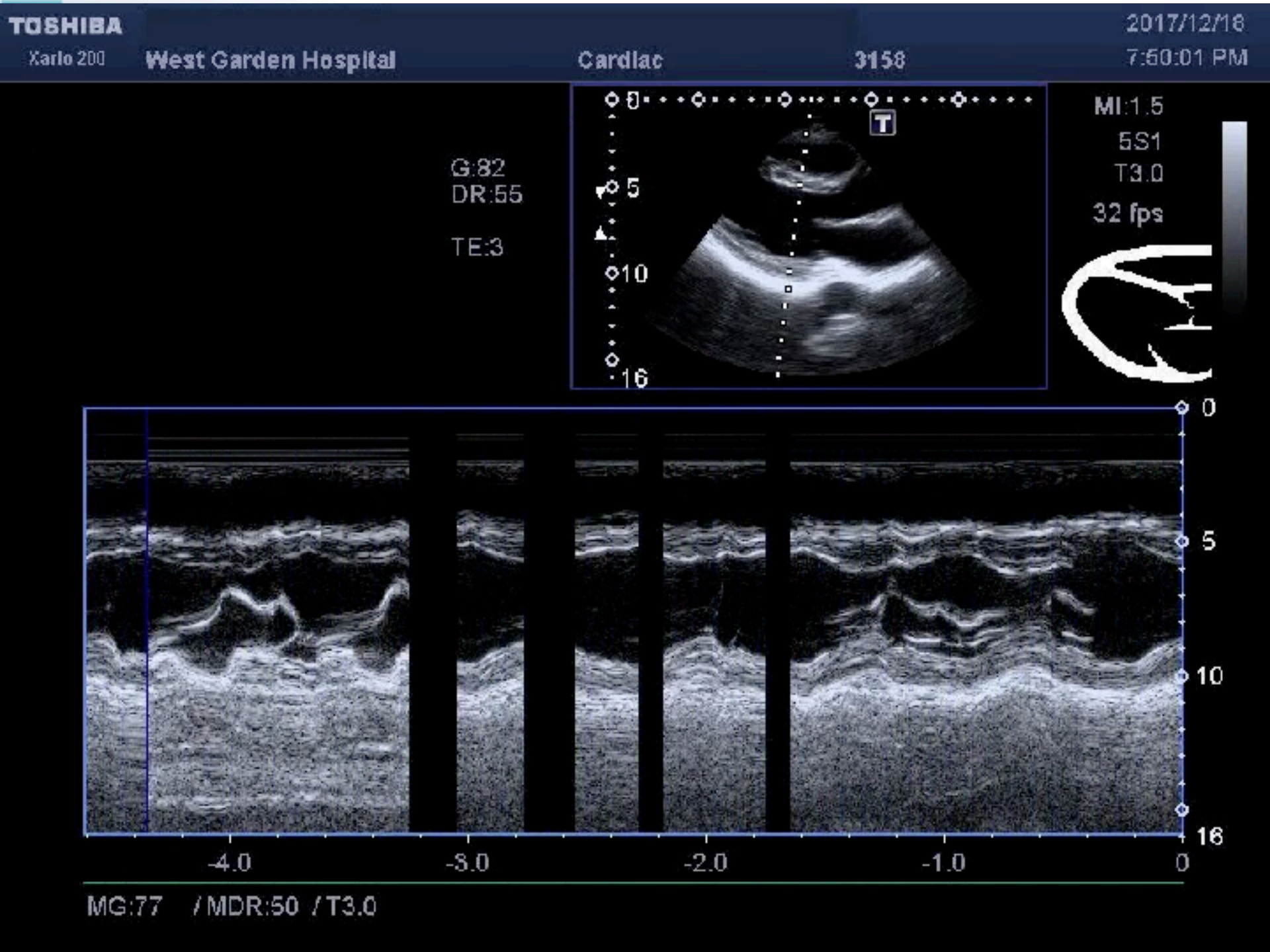


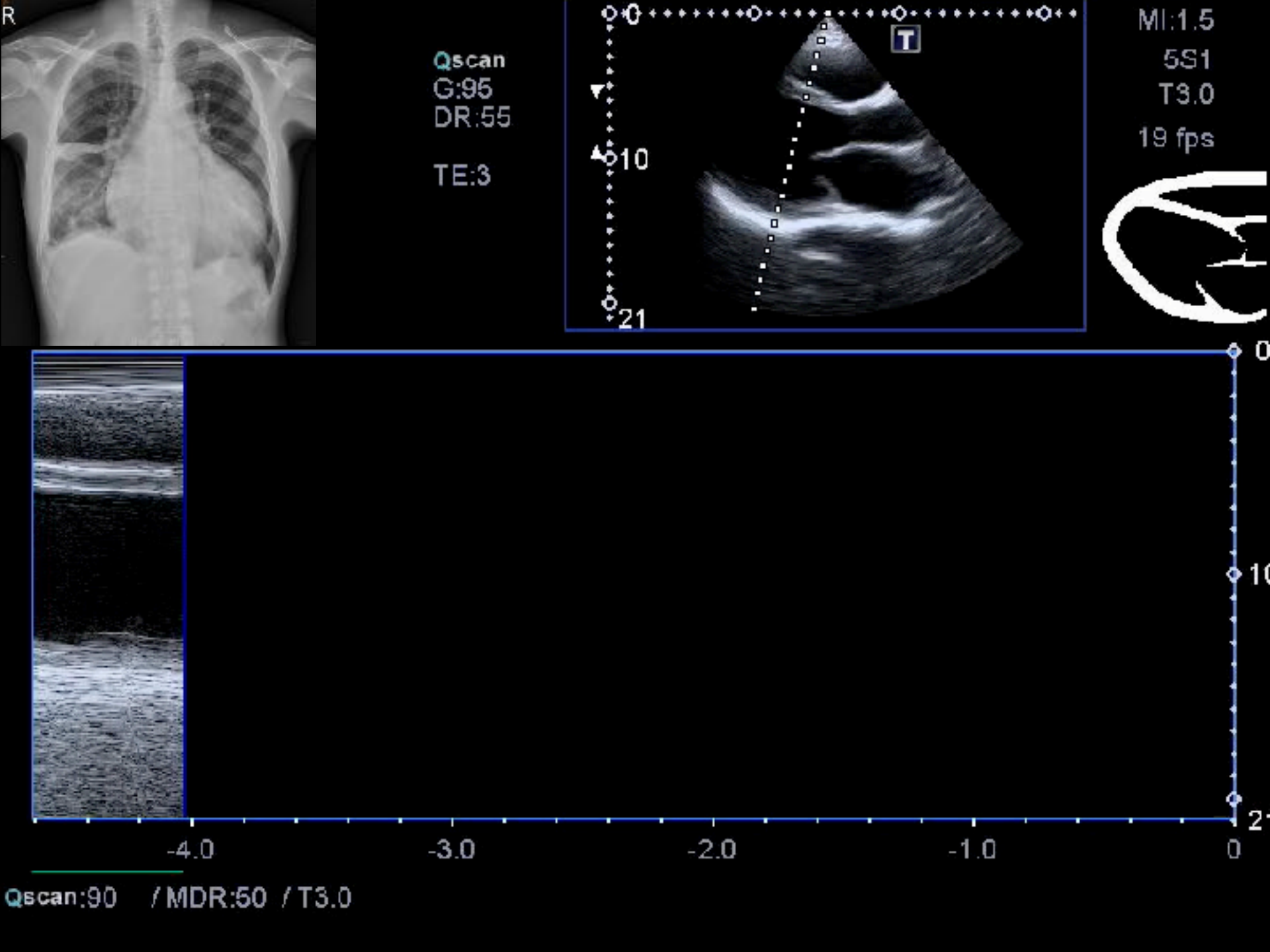


FS: fractional shortening

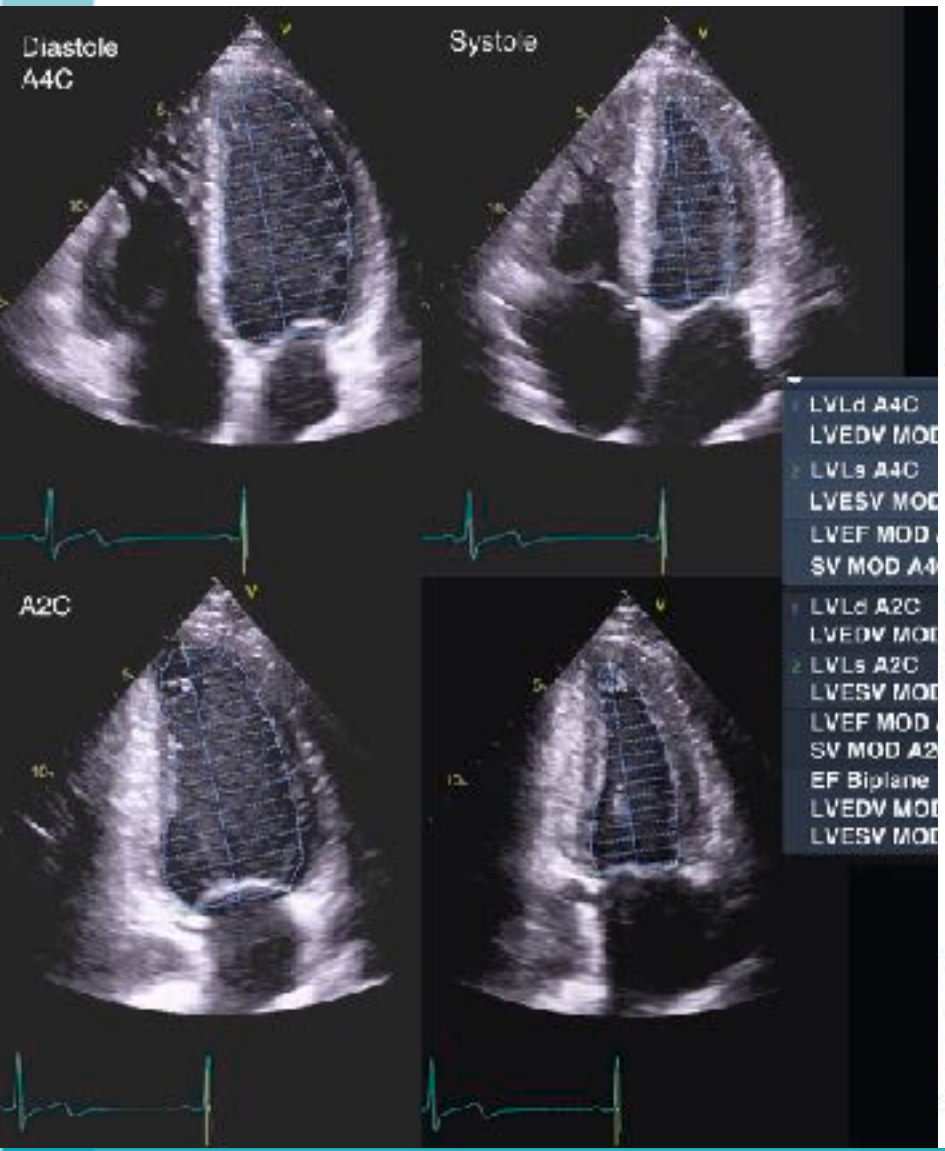
(LVIDd-LVIDs) / LVIDd * 100% (25 ~ 45%)

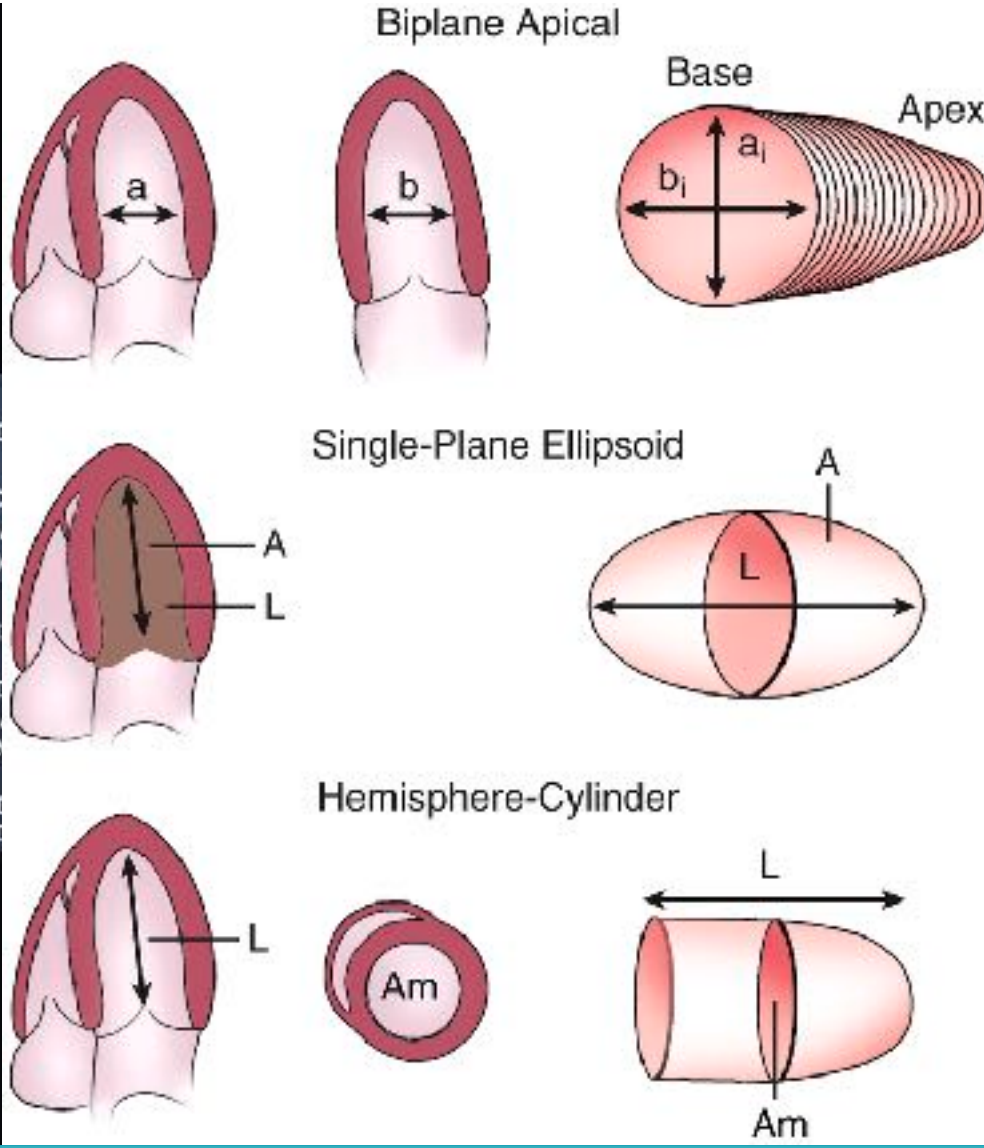

Long axis
Short axis
LV
Ao
LA
x2
RV
Septum
EDD
ESD
Posterior wall
0
5
10
75 mm/s
74bpm
要垂直LV


TOSHIBA
Xario 200
West Garden Hospital
Cardiac
3158
2017/12/16
7:50:01 PM
G:82
DR:55
TE:3
MI:1.5
5S1
T3.0
32 fps
0
5
10
16
0
5
10
16
-4.0
-3.0
-2.0
-1.0
0
MG:77 / MDR:50 / T3.0


R
Qscan
G:95
DR:55
TE:3
0
10
21
T
MI:1.5
5S1
T3.0
19 fps
0
10
2
-4.0
-3.0
-2.0
-1.0
0
Qscan:90 / MDR:50 / T3.0

2D LV
Volume calculation (ER耗時)



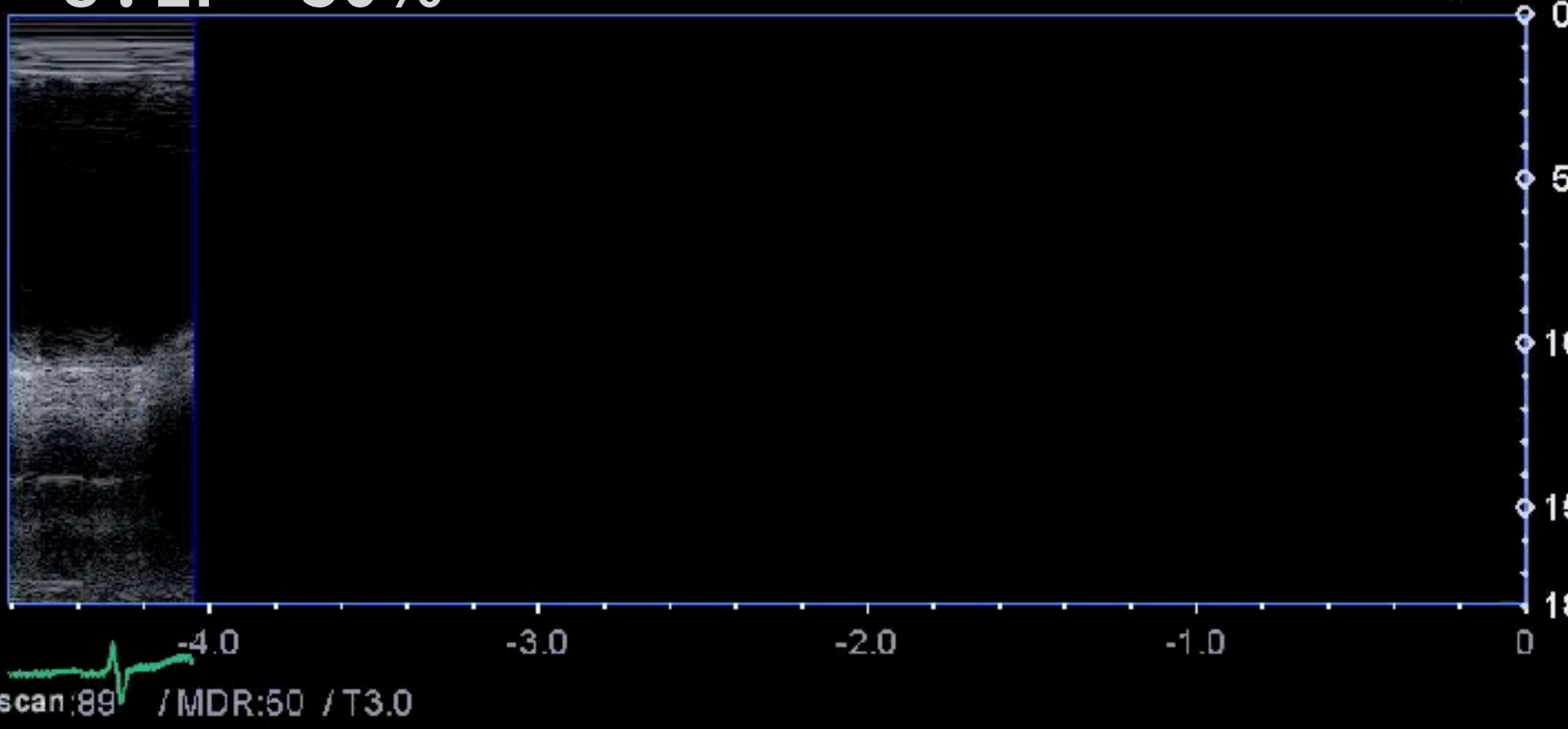


MAPSE

12-15 mm

> 10 : preserved LV

< 8 : EF < 50%



MAPSE

Question

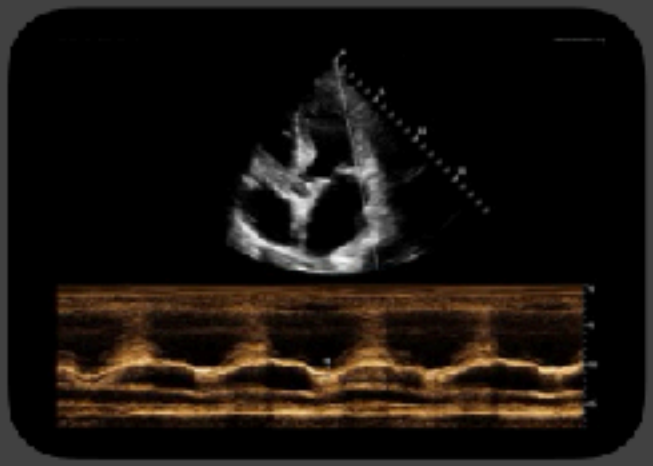
Does an emergency physician (EP) measured MAPSE predict a decreased LVEF compared to reference comprehensive echo?

Methods

Single center, prospective observational cohort. Convenience sample of ED patients with expected acute heart failure. Comprehensive echo done within past 12 months or 3 months after ED visit.

1° outcome: Performance of EP measured MAPSE <8mm for detecting <50% LVEF on comprehensive echo

2° outcomes: Inter-rater reliability, test performance compared to EPSS and visual estimation, correlation with cardiac biomarkers.



Results

	Sensitivity	Specificity	+LR	-LR
MAPSE	42%	89%	3.9	0.65

Inter-rater reliability of MAPSE was 96.7%.

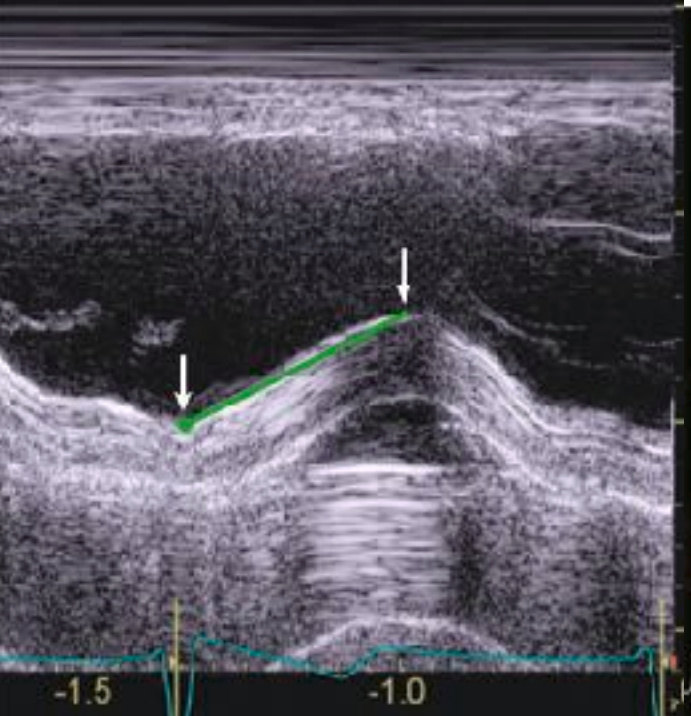
When EPSS, MAPSE, & visual estimation were all abnormal, MAPSE was 94% specific.

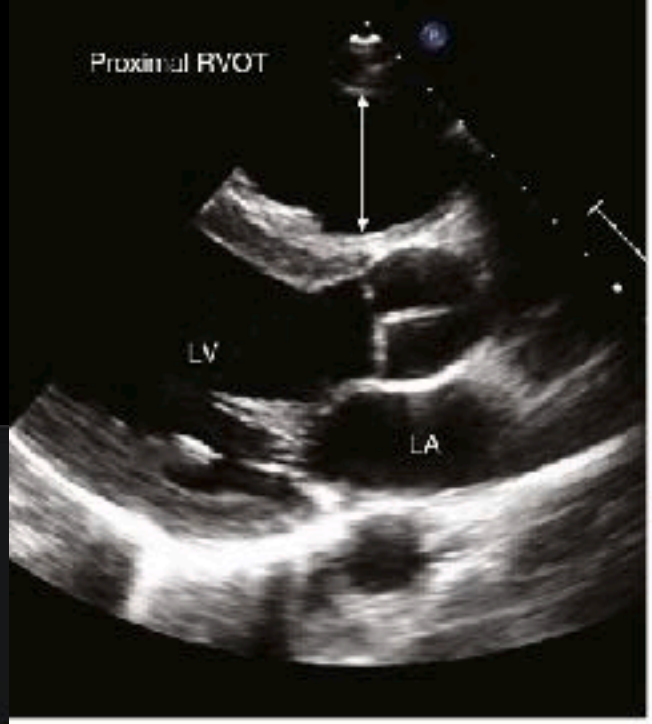
N=61

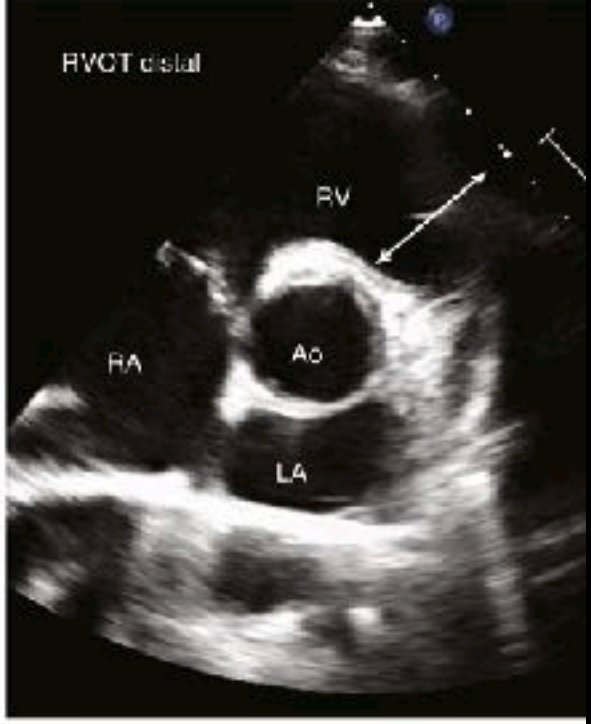
Schick AL, Kaine JC, Al-Sadhan NA, Lin T, Baird J, Bahit K, Dwyer KH. Focused cardiac ultrasound with mitral annular plane systolic excursion (MAPSE) detection of left ventricular dysfunction. Am J Emerg Med. 2023 Jun;68:52-58. doi: 10.1016/j.ajem.2023.03.018. Epub 2023 Mar 11. PMID: 36933331.

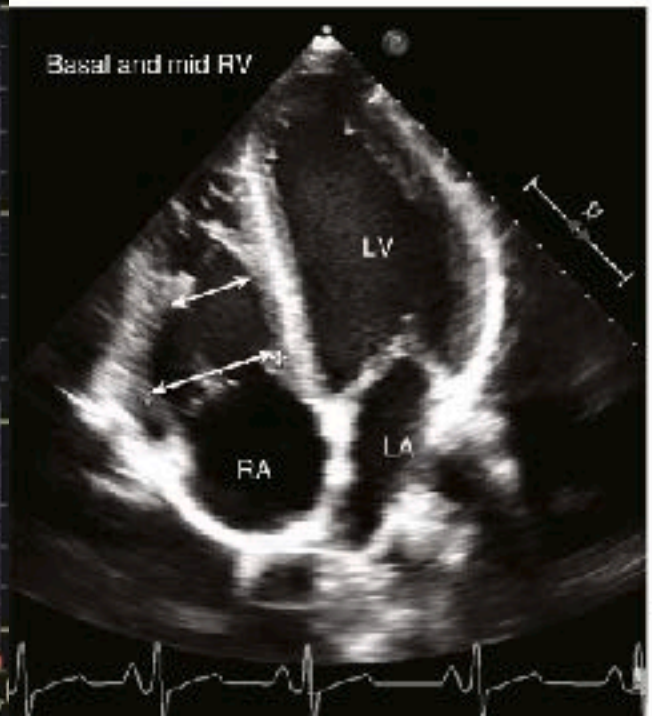
TAPSE

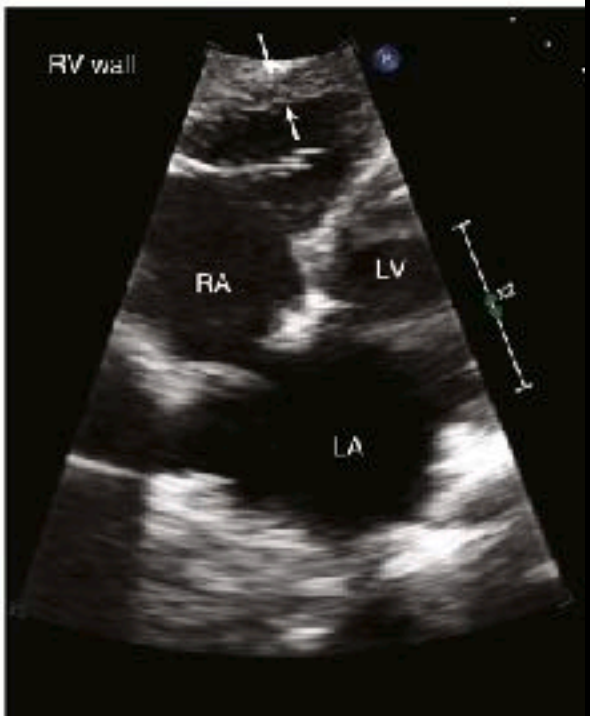
Tricuspic annular plane systolic excursion



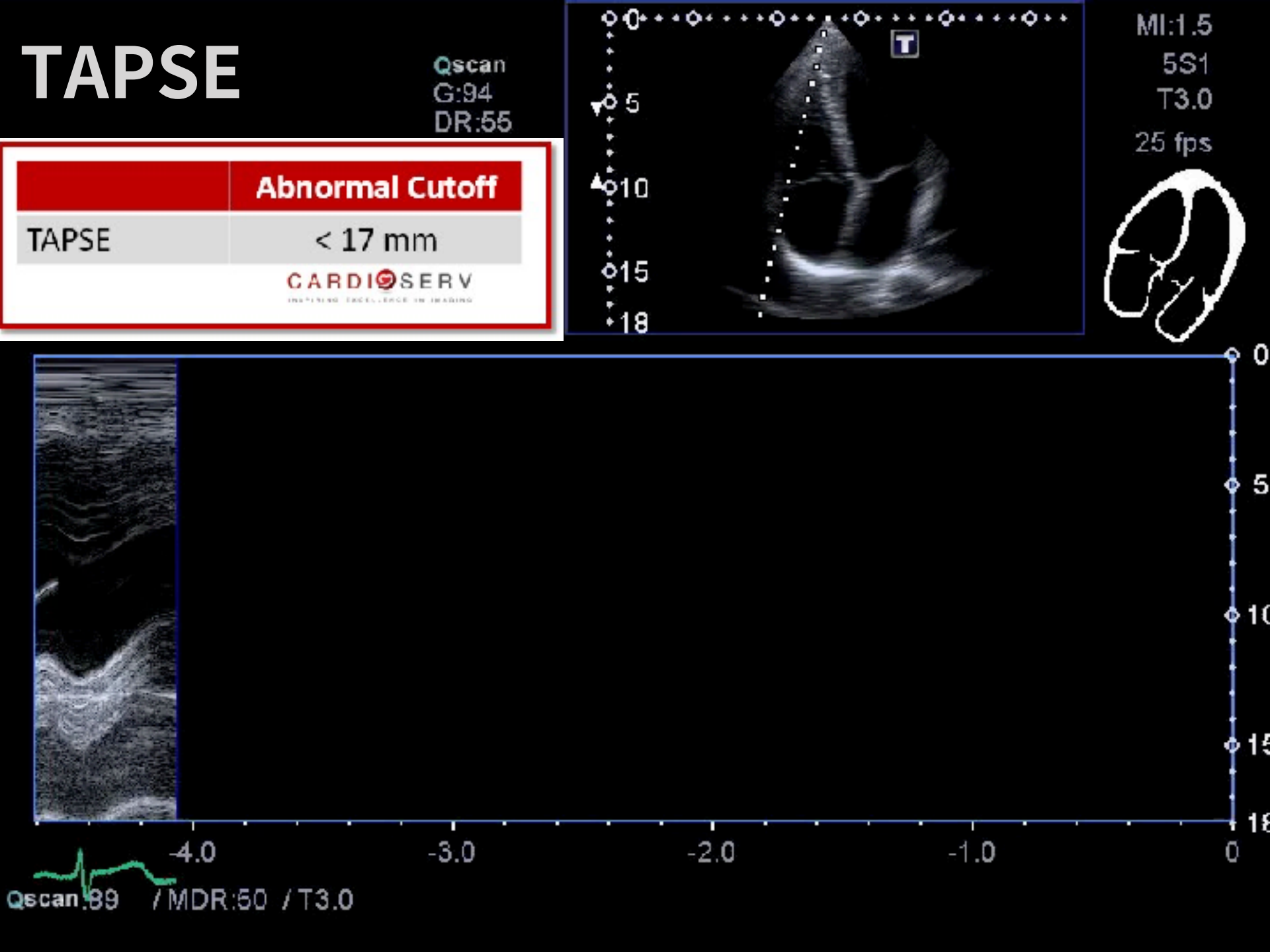


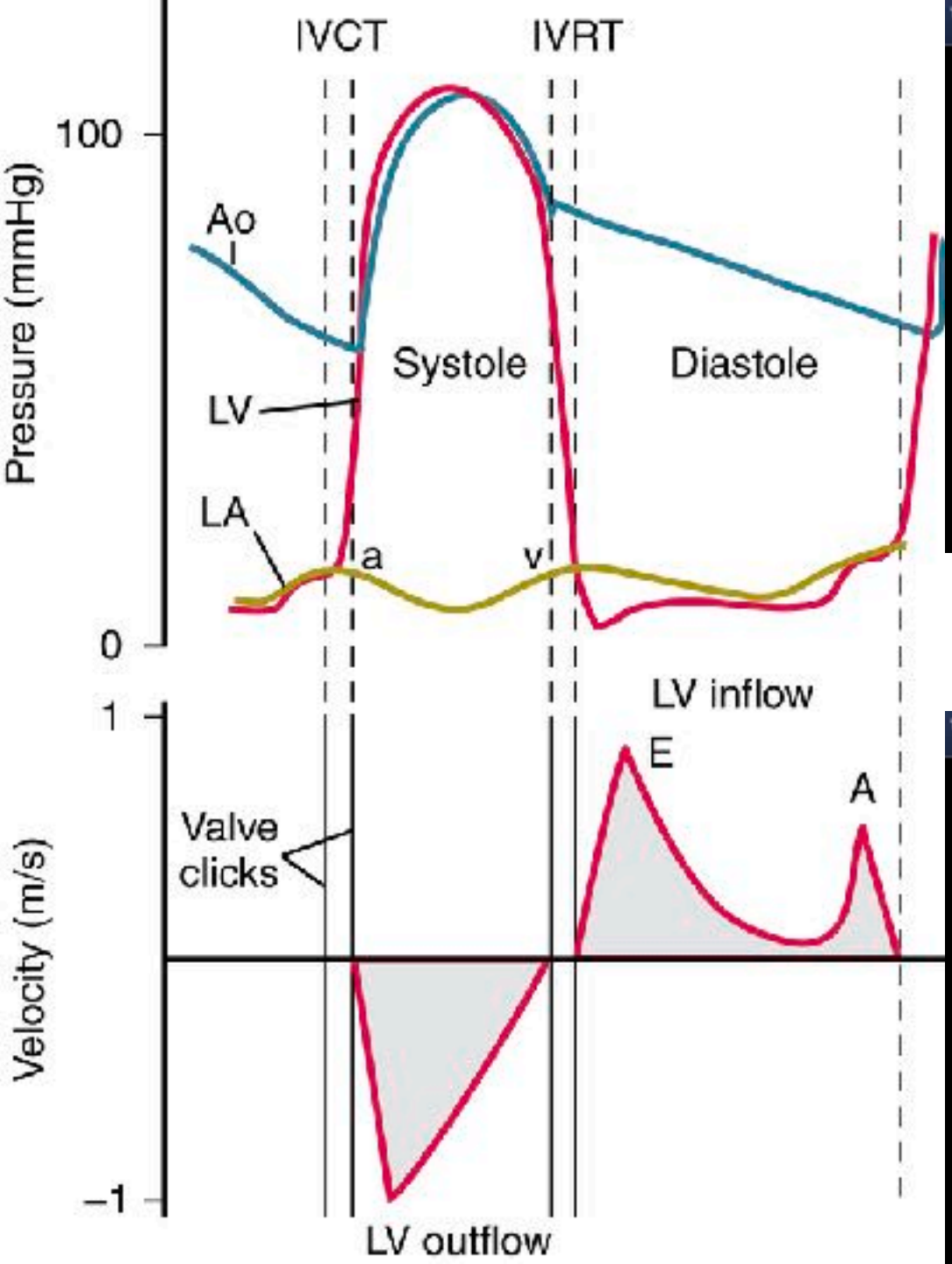




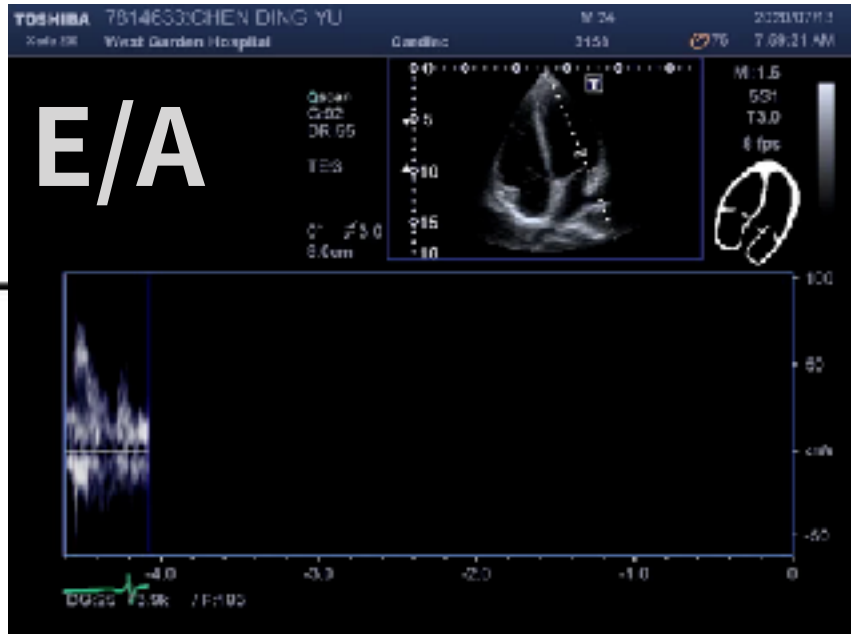


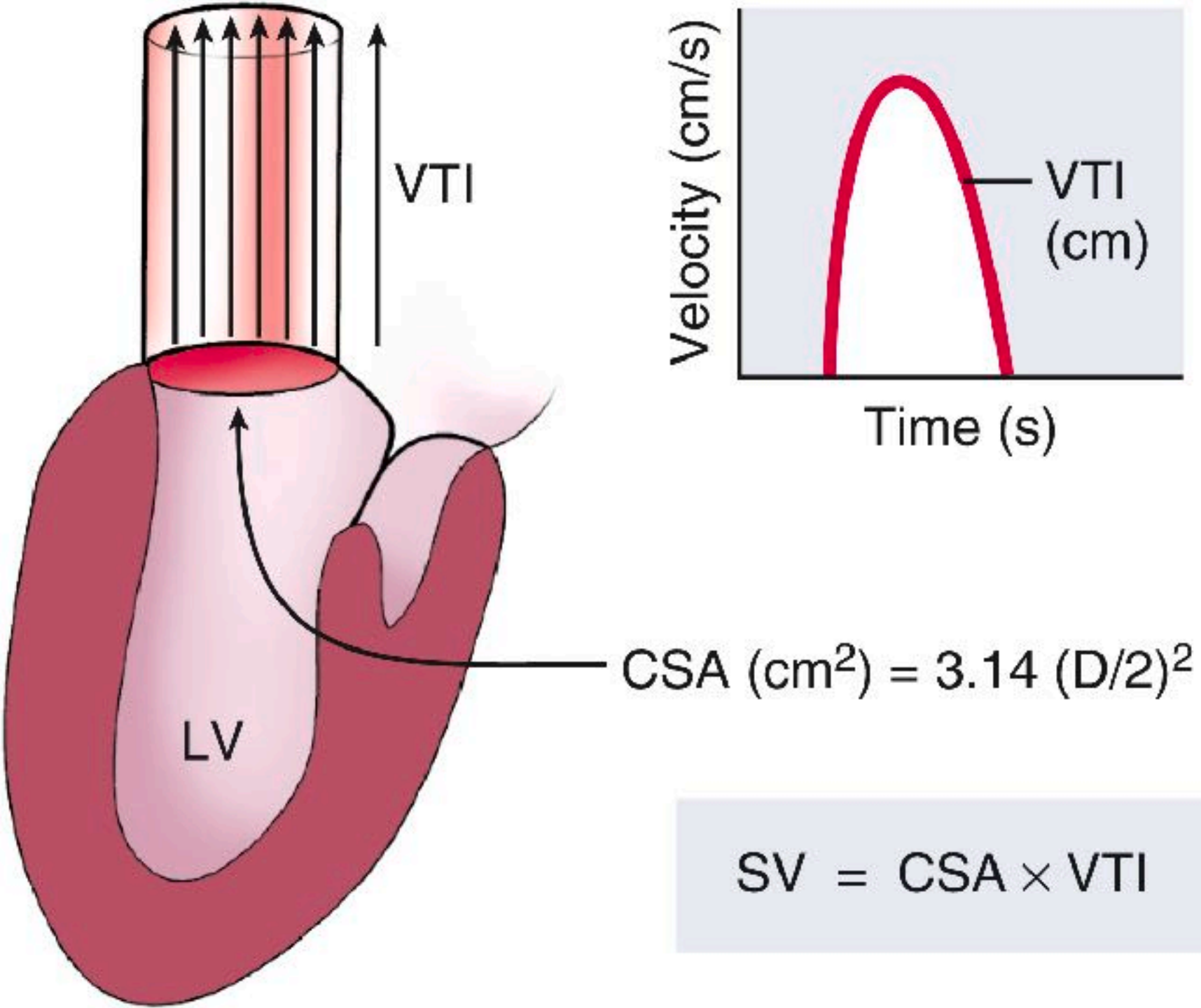
TAPSE


Qscan
G:94
DR:55
Abnormal Cutoff
TAPSE
< 17 mm
CARDIOSERV
0
5
10
15
18
T
MI:1.5
5S1
T3.0
25 fps
0
5
10
15
18
-4.0
-3.0
-2.0
-1.0
0
Qscan 89 / MDR:50 / T3.0

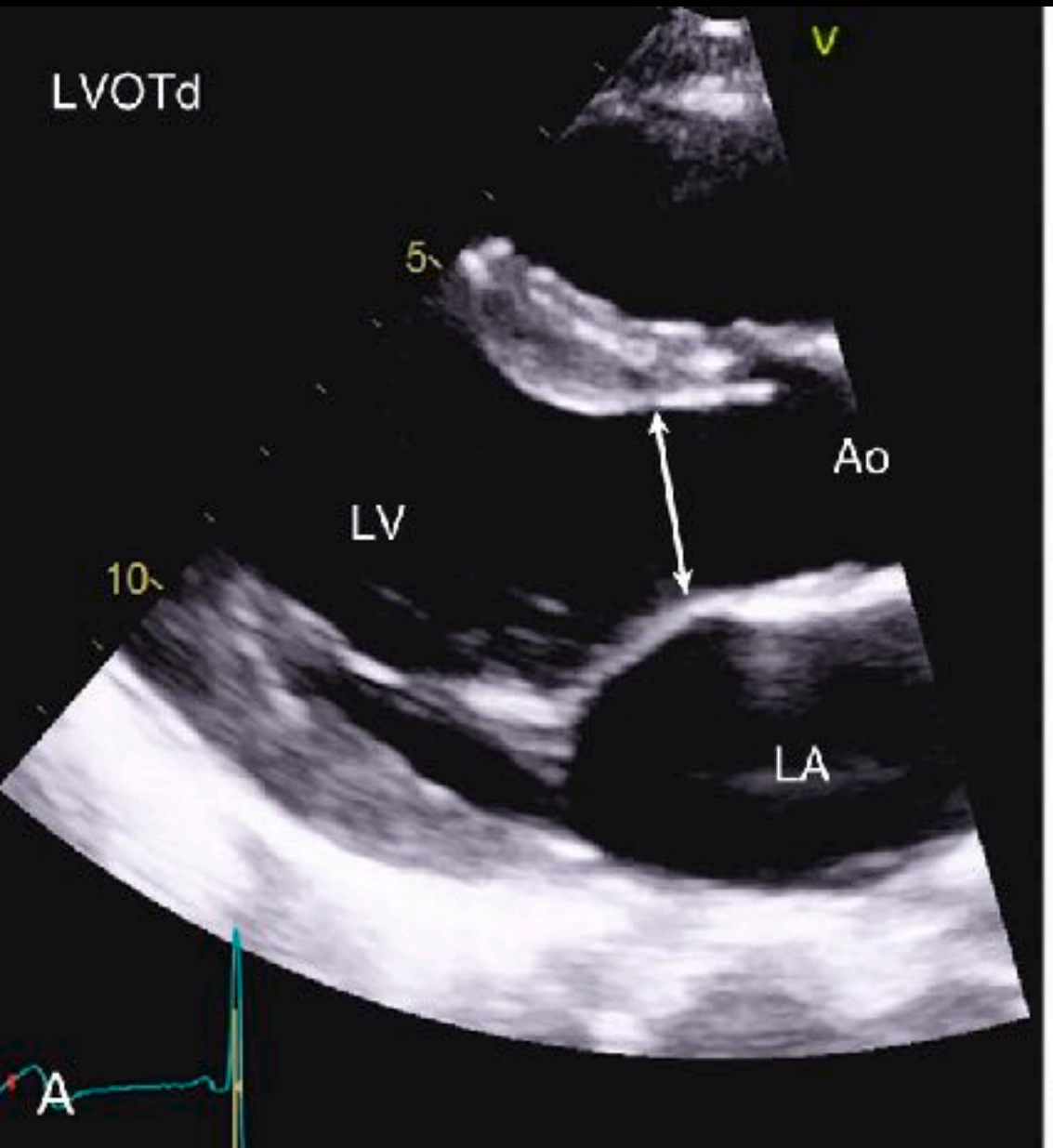

IVCT
IVRT
100
0
Pressure (mmHg)
Ao
Systole
Diastole
LV
LA
a
v
1
−1
Velocity (m/s)
LV inflow
E
A
Valve clicks
LV outflow

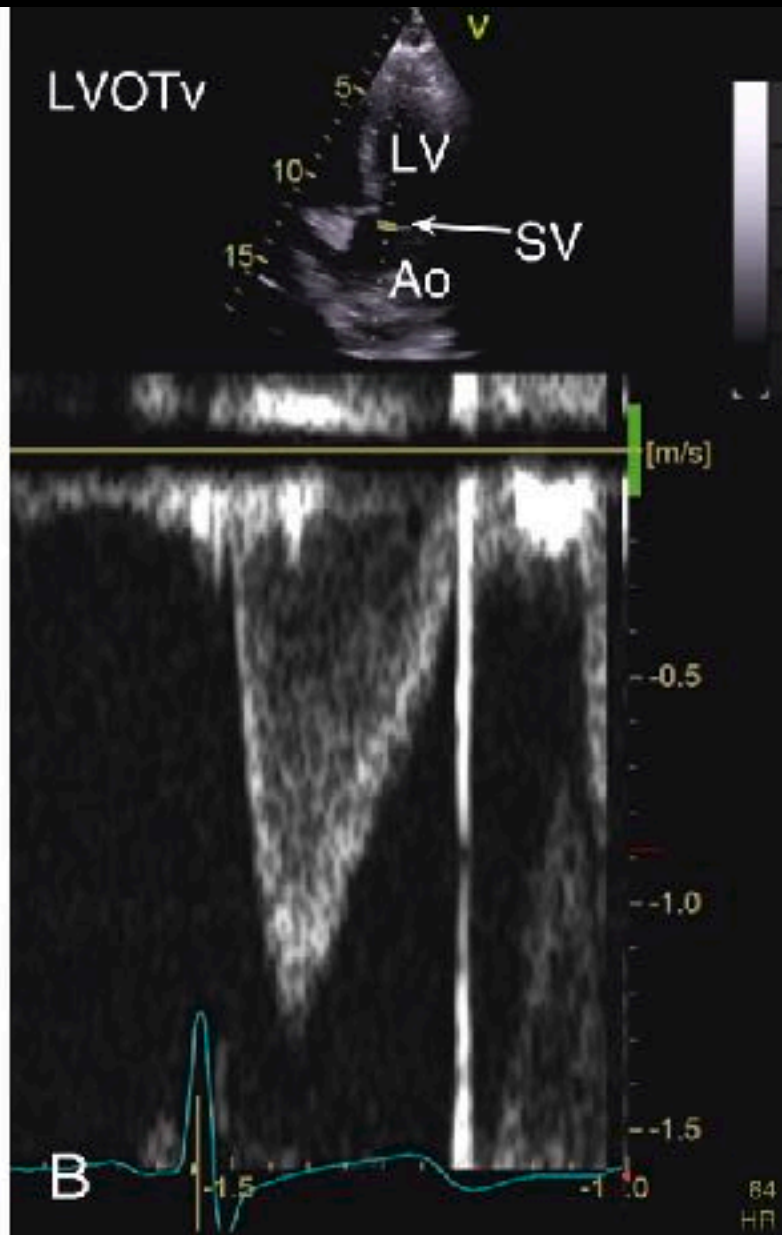

VTI


E/A

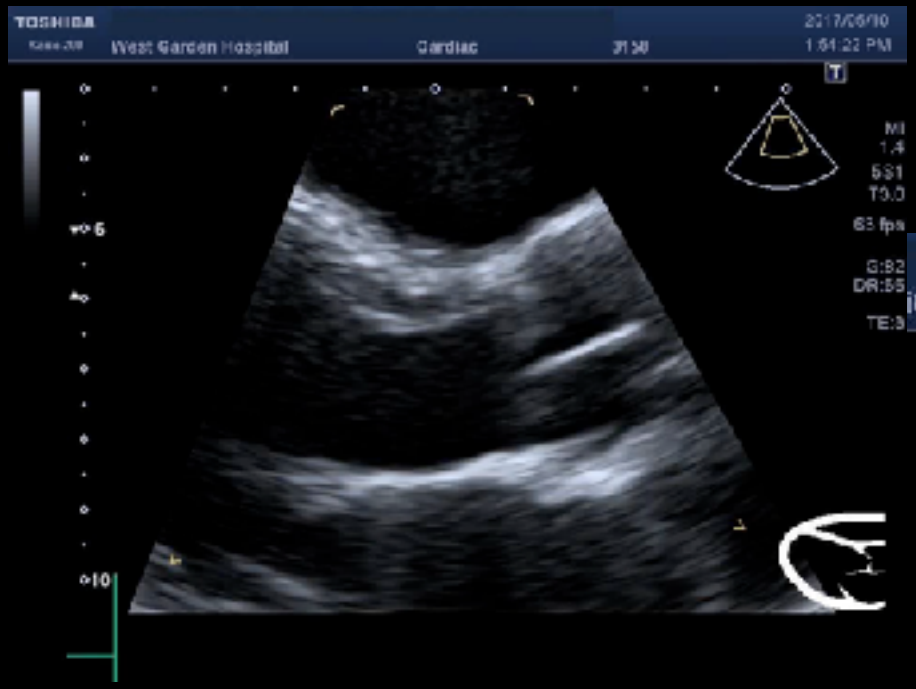

VTI
Velocity (cm/s)
VTI
(cm)
Time (s)
CSA (cm²) = 3.14 (D/2)²
LV
SV = CSA × VTI

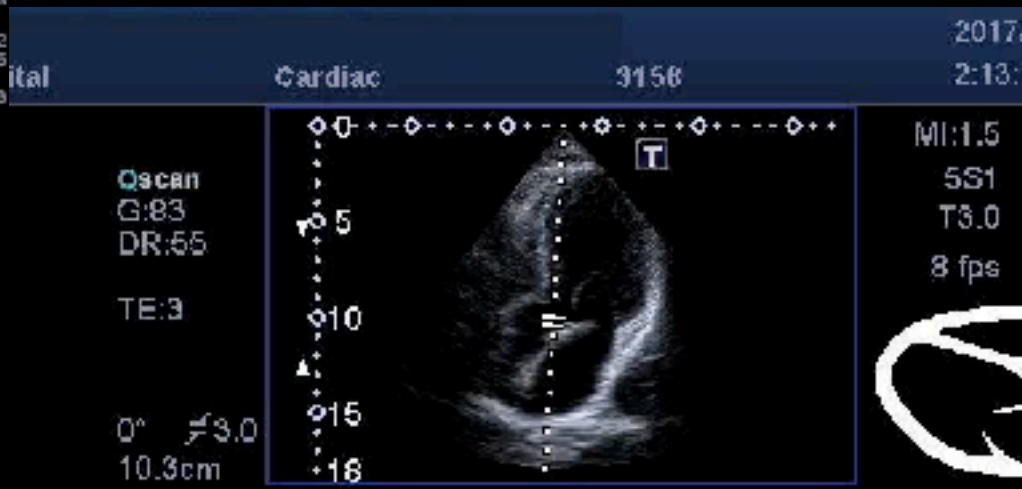
CO = SV * HR = (CSA * VTI) * HR

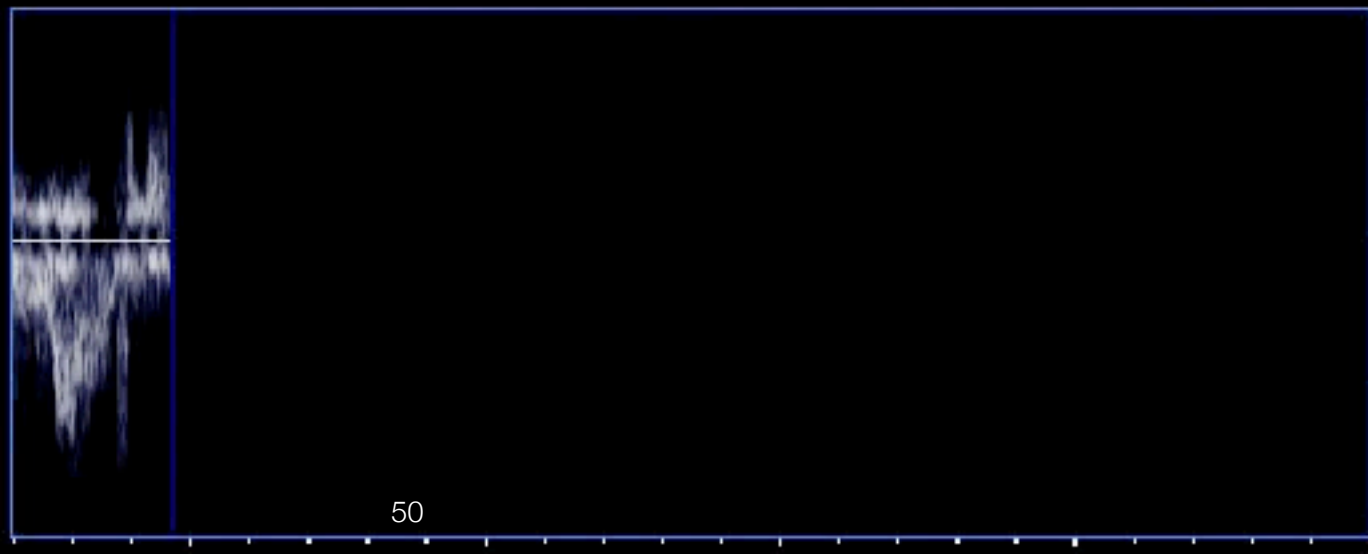




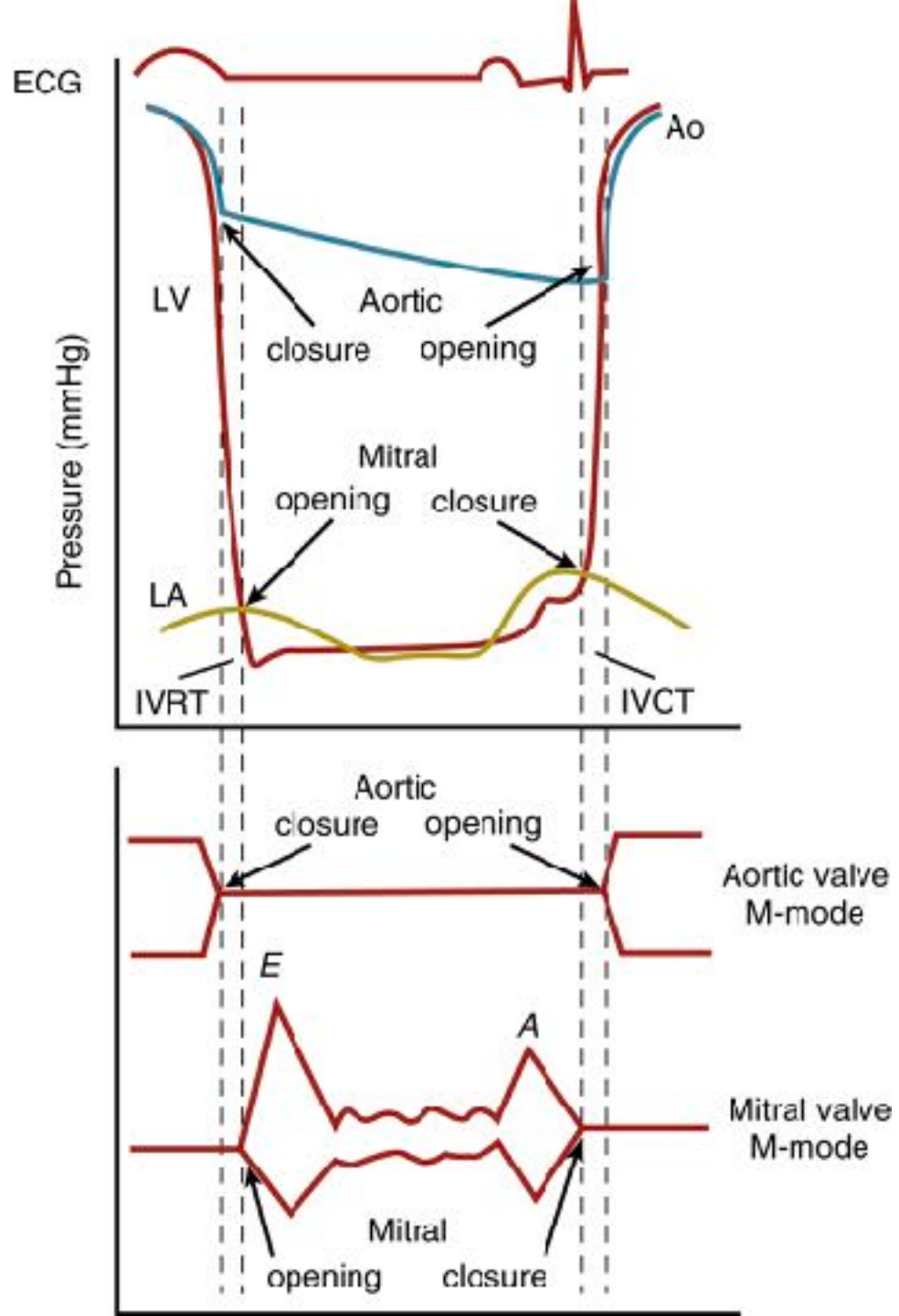
CO = SV * HR = (CSA * VTI) * HR



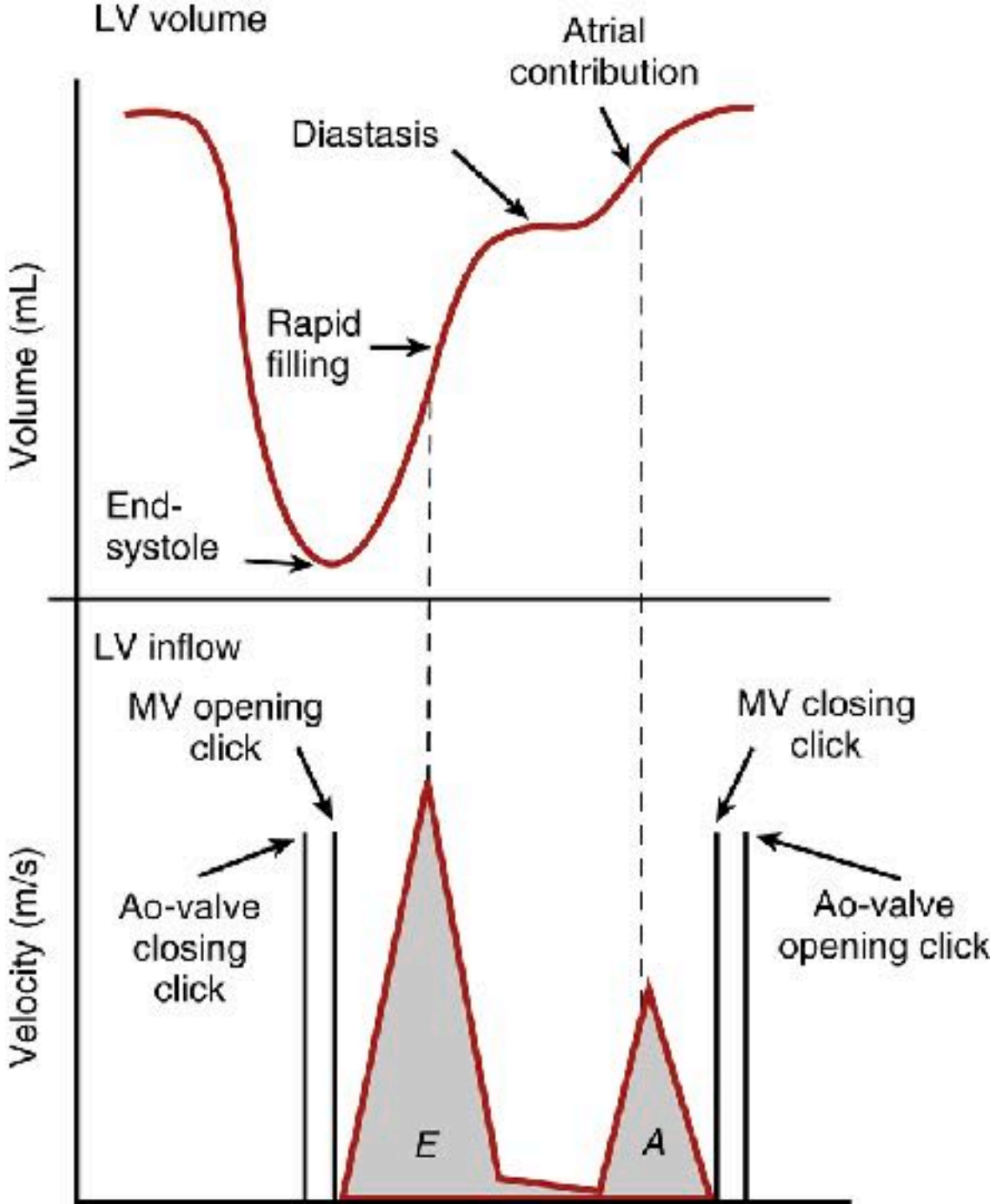




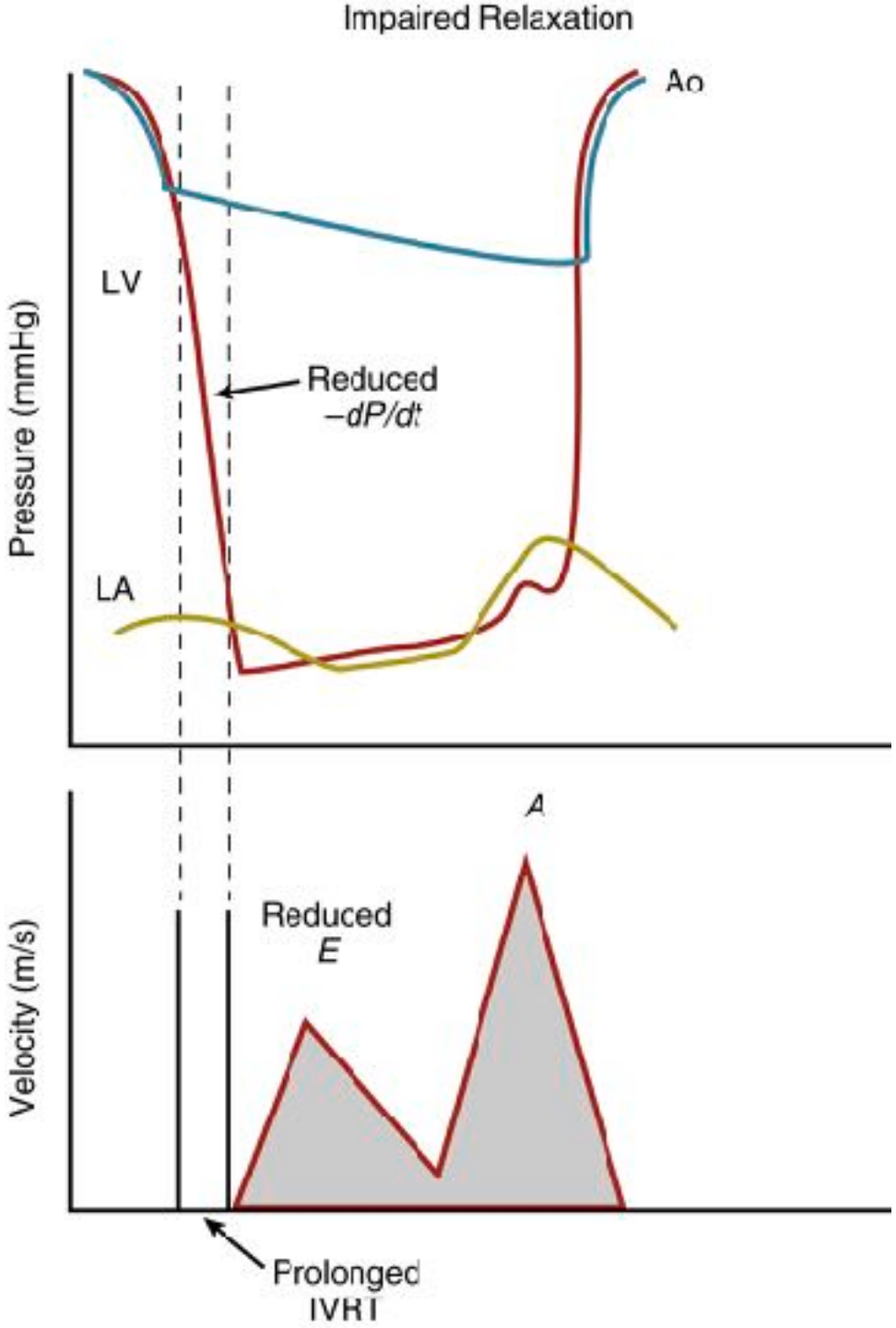
Diastolic Pressure Curve



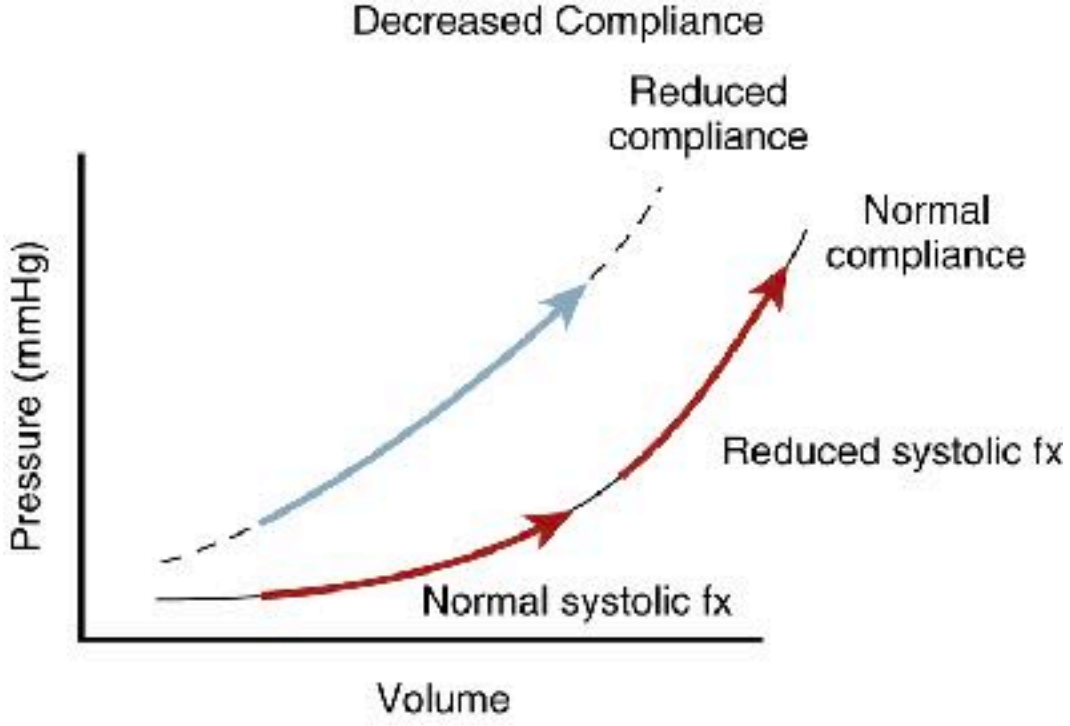
Diastolic Filling Curve

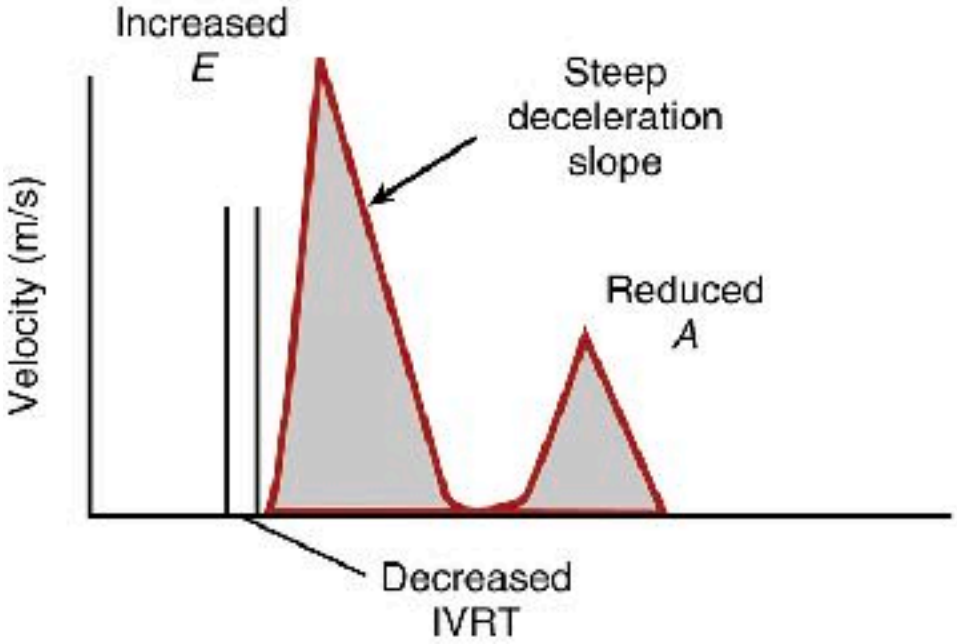


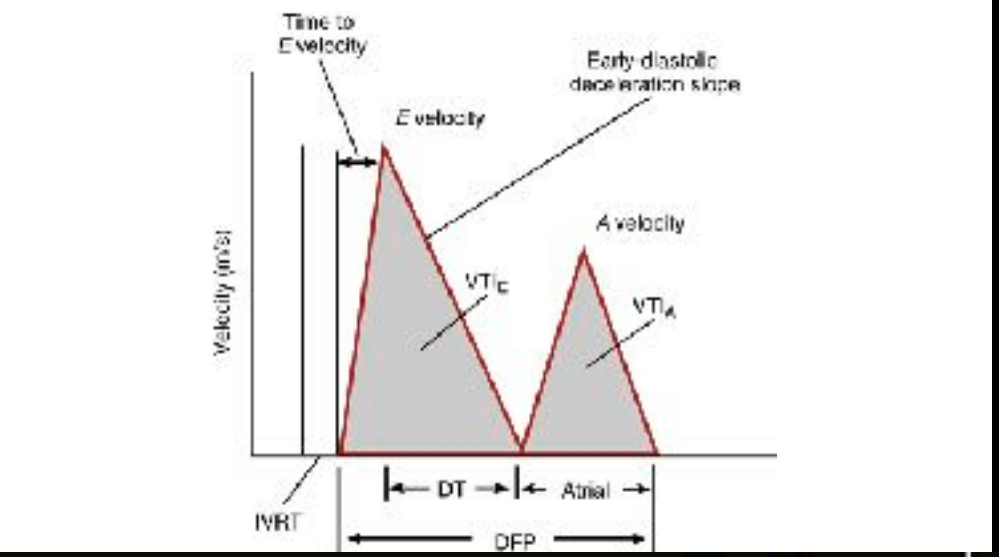
Impaired LV Relaxation

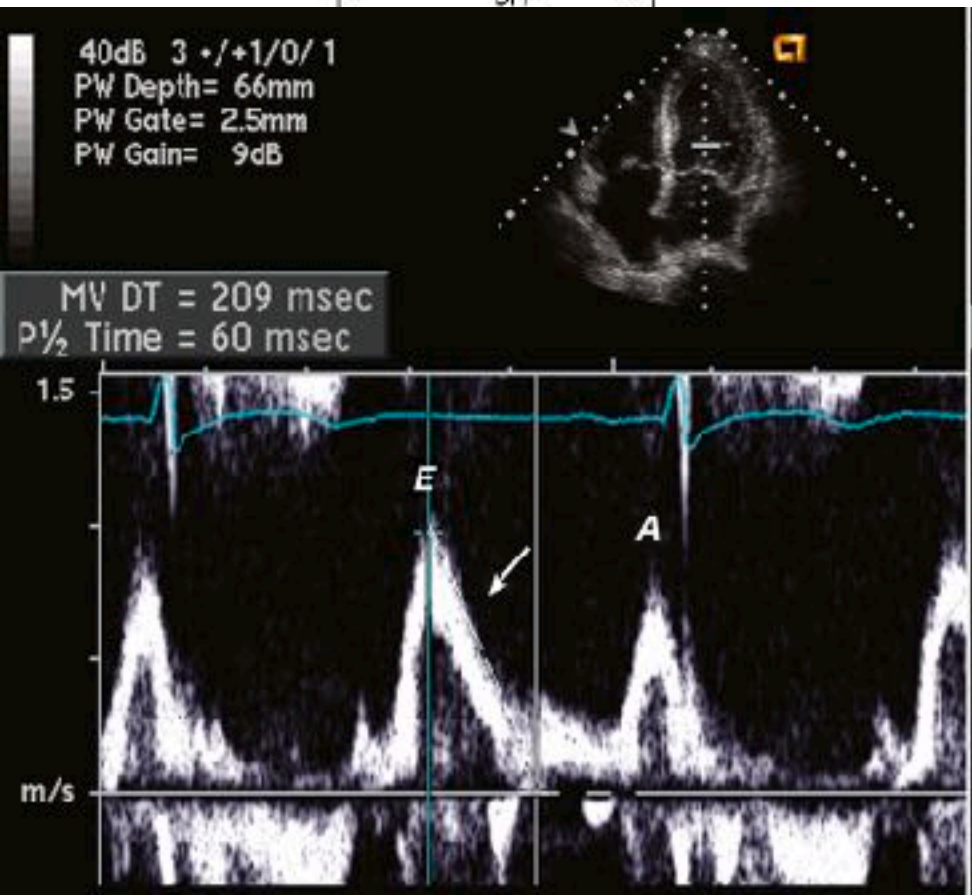


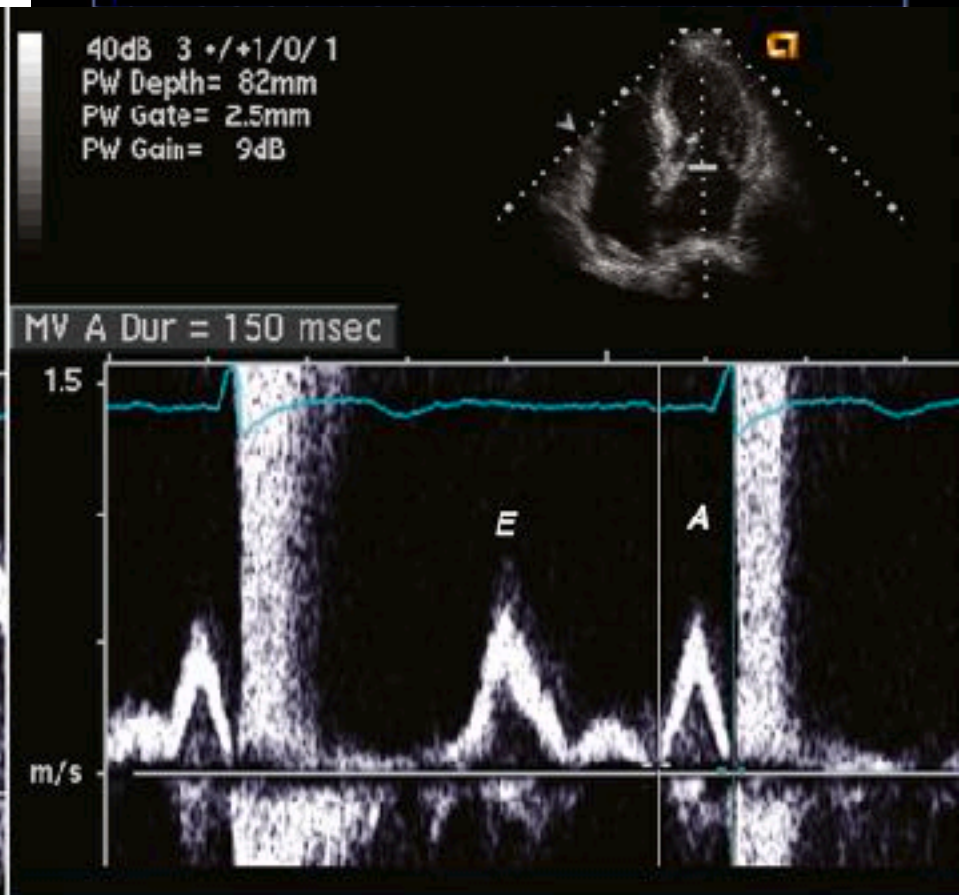
Reduced Diastolic Compliance



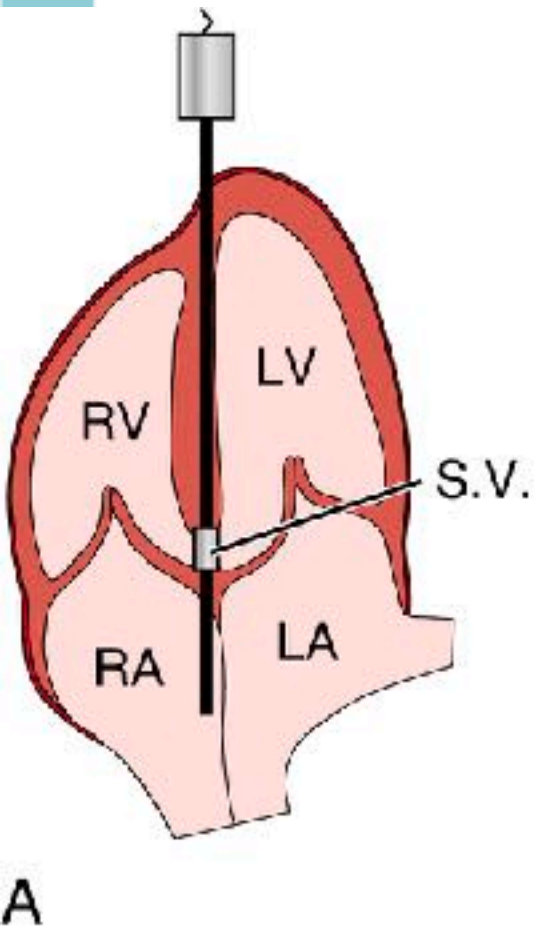


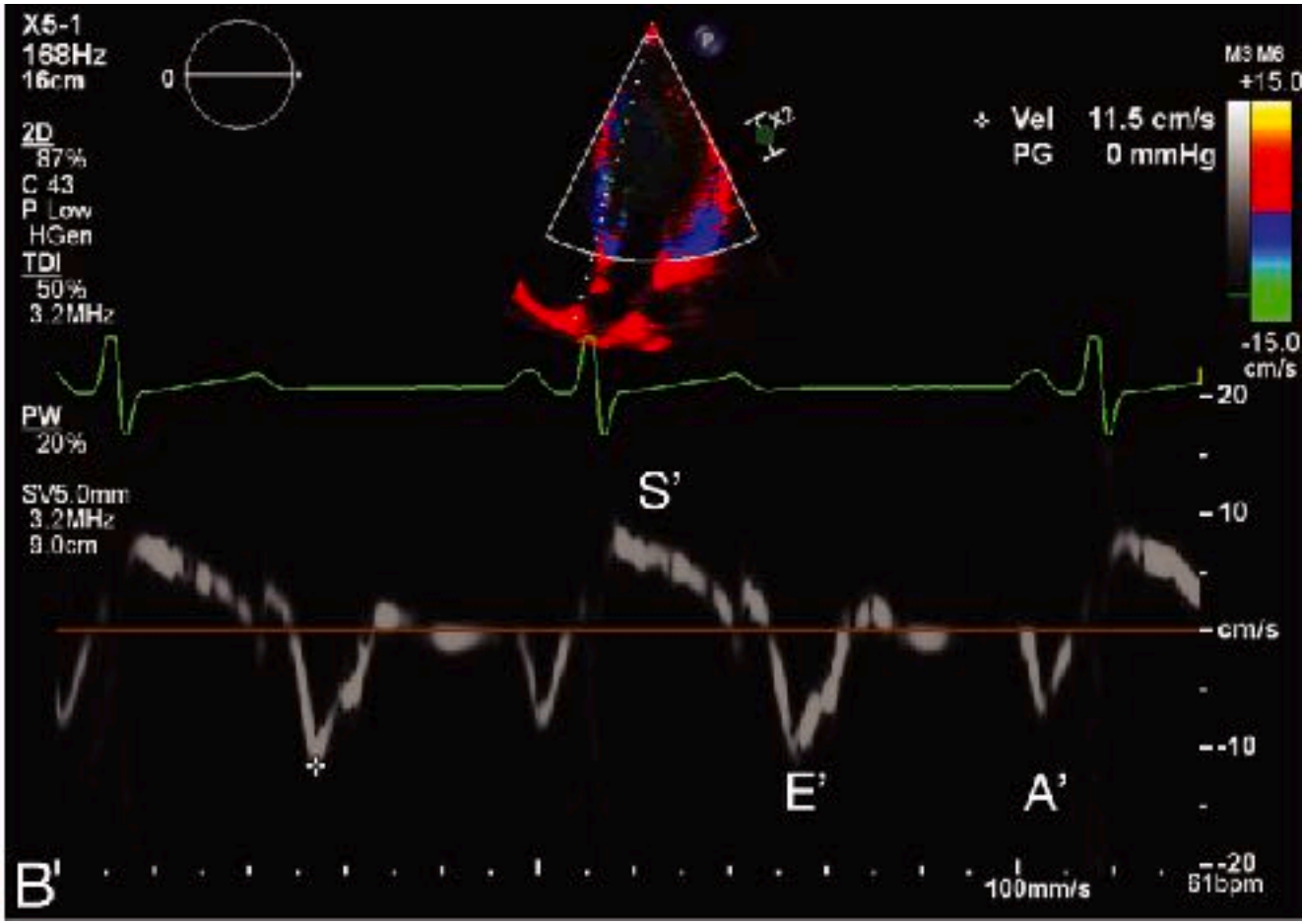

Time to E velocity
Early diastolic deceleration slope
E velocity
A velocity
VTI$_E$
VTI$_A$
Velocity (m/s)
IVRT
DT
Atrial
DFP

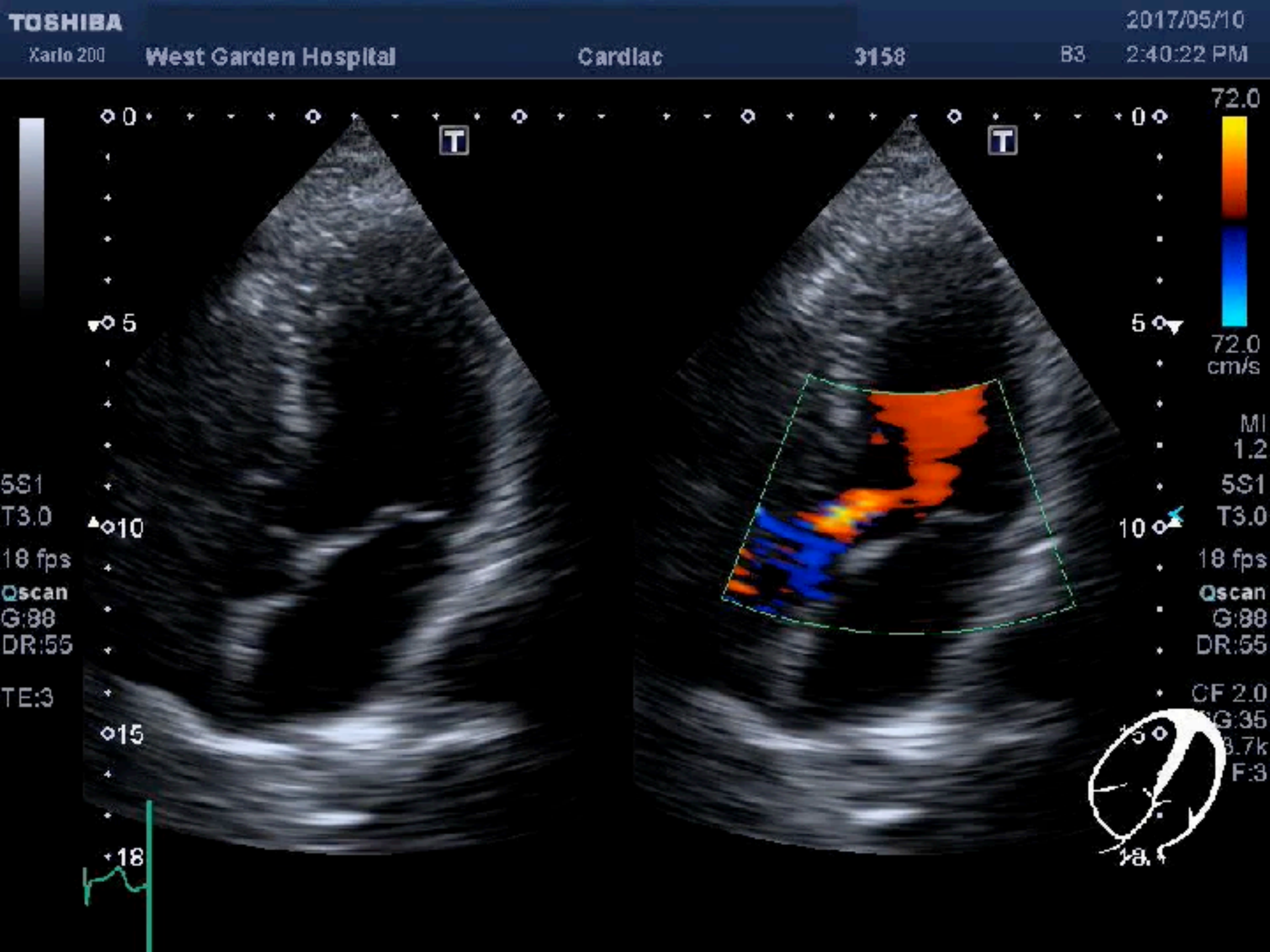

40dB 3 •/+1/0/ 1
PW Depth= 66mm
PW Gate= 2.5mm
PW Gain= 9dB
MV DT = 209 msec
P½ Time = 60 msec
1.5
E
A
m/s

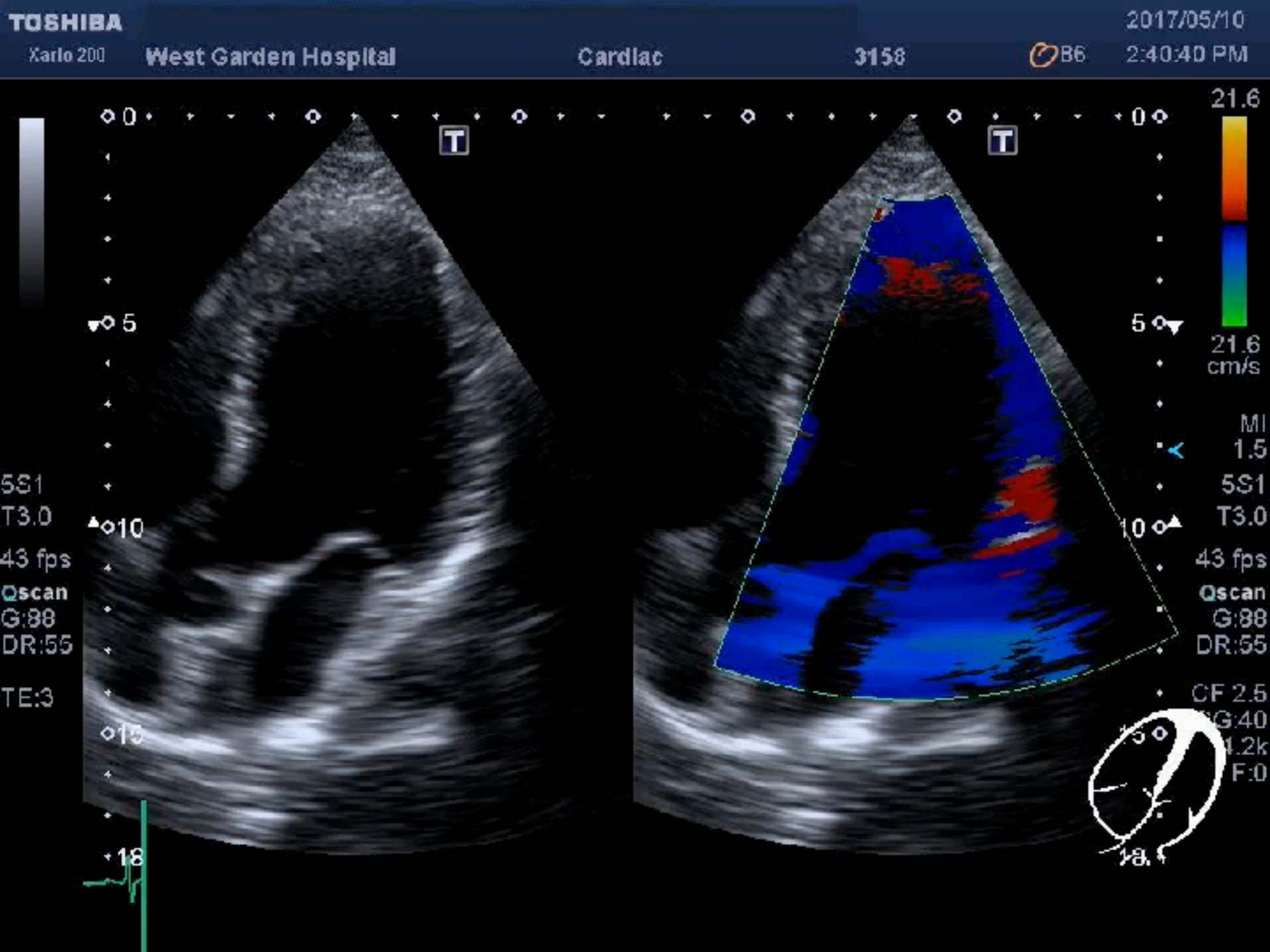

40dB 3 •/+1/0/ 1
PW Depth= 82mm
PW Gate= 2.5mm
PW Gain= 9dB
MV A Dur = 150 msec
1.5
E
A
m/s

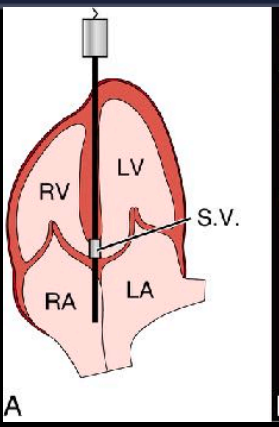
Tissue Doppler imaging

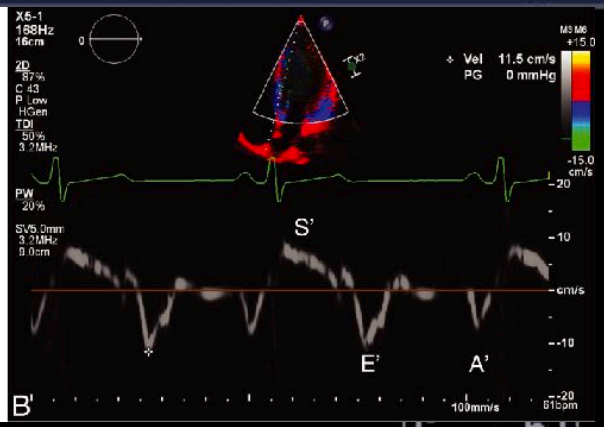


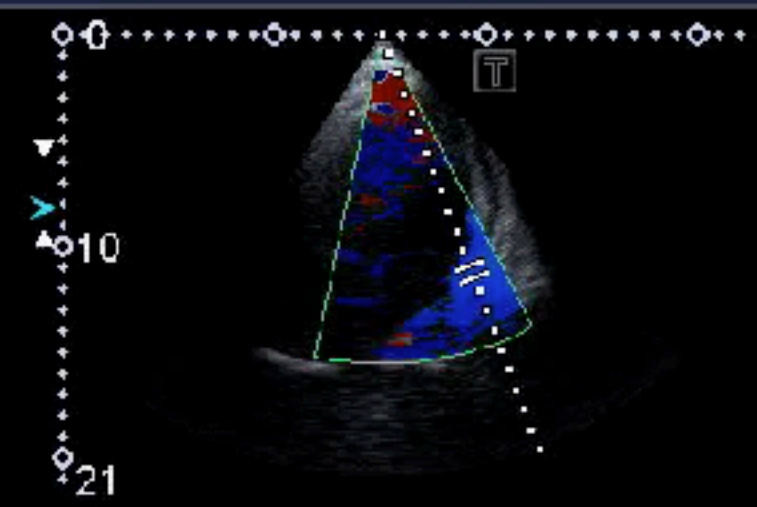



TOSHIBA
Xario 200
West Garden Hospital
Cardiac
3158
B3
2017/05/10
2:40:22 PM
72.0
72.0
cm/s
MI
1.2
5S1
T3.0
18 fps
Qscan
G:88
DR:55
TE:3
CF 2.0
F:3


TOSHIBA
Xario 200
West Garden Hospital
Cardiac
3158
B6
2017/05/10
2:40:40 PM
21.6
21.6
cm/s
MI
1.5
5S1
T3.0
43 fps
Qscan
G:88
DR:55
TE:3
CF 2.5
G:40
F:0


RV
LV
S.V.
RA
LA
A


X6-1
188Hz
16cm
2D
87%
C 43
P Low
HGen
TDI
50%
3.2MHz
Vel 11.5 cm/s
PG 0 mmHg
PW
20%
S'
E'
A'
B'
100mm/s


MI:1.0
5S1
T3.0
36 fps
10
21
12.1cm

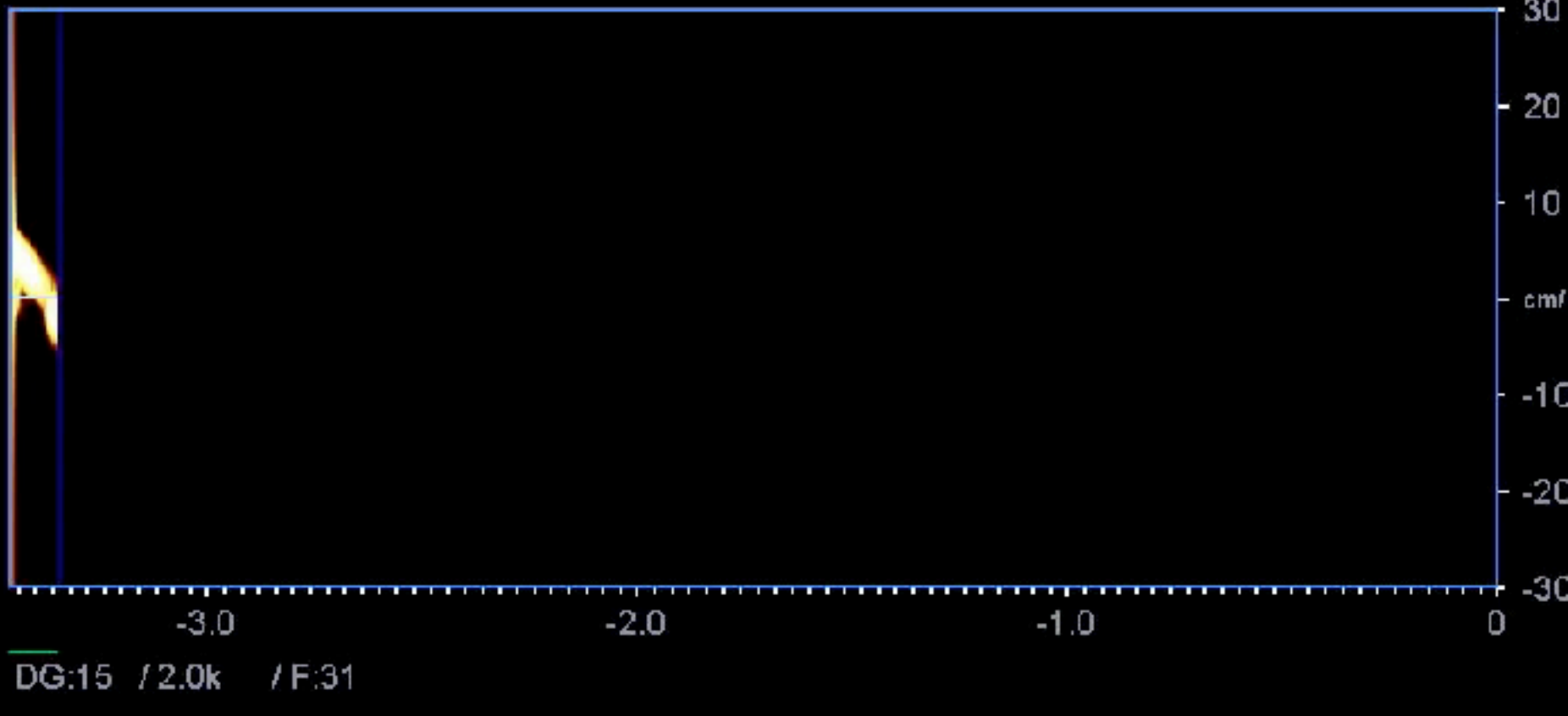

30
20
10
cm/
-10
-20
-30
-3.0
-2.0
-1.0
0
DG:15 / 2.0k / F:31

TABLE 7.4 Classification of Diastolic Dysfunction (Key Measures Highlighted)

	Normal	Mild (Grade I)	Moderate (Grade II)	Severe* (Grade III)
Pathophysiology		↓ Relaxation and normal LVEDP	↓ Relaxation and ↑ LVEDP	↓ Compliance and ↑↑ LVEDP
E/A ratio†	≥0.8	<0.8	>0.8 to <2.0‡	≥2.0
Valsalva Δ*E/A*		<0.5	≥0.5	≥0.5
DT (ms)	150–200	>200	150-200	<150
E' velocity (cm/s)	≥10	<8	<8	<5
E/E' ratio	≤10	≤10	10–14	>14
IVRT (ms)	50–100	≥100	60–100	≤60
PV S/D	≅1	S > D	S < D	S ≪ D
PV_a (m/s)	<0.35	<0.35§	≥0.35	≥0.35
a_{dur}-A_{dur} (ms)	<20	<20§	≥30	≥30
LA volume index	<34 mL/m²	Mildly enlarged	Moderately enlarged	Severely enlarged

*An additional grade of irreversible severe dysfunction is characterized by the absence of a decrease in *E* velocity with the strain phase of the Valsalva maneuver.

†Only the *yellow* rows are included in the American Society of Echocardiography guidelines, plus consideration of tricuspid regurgitant jet velocity. In the absence of other causes for elevated pulmonary pressures, a tricuspid regurgitant velocity of greater than 2.8 m/s is consistent with moderate to severe LV diastolic dysfunction.

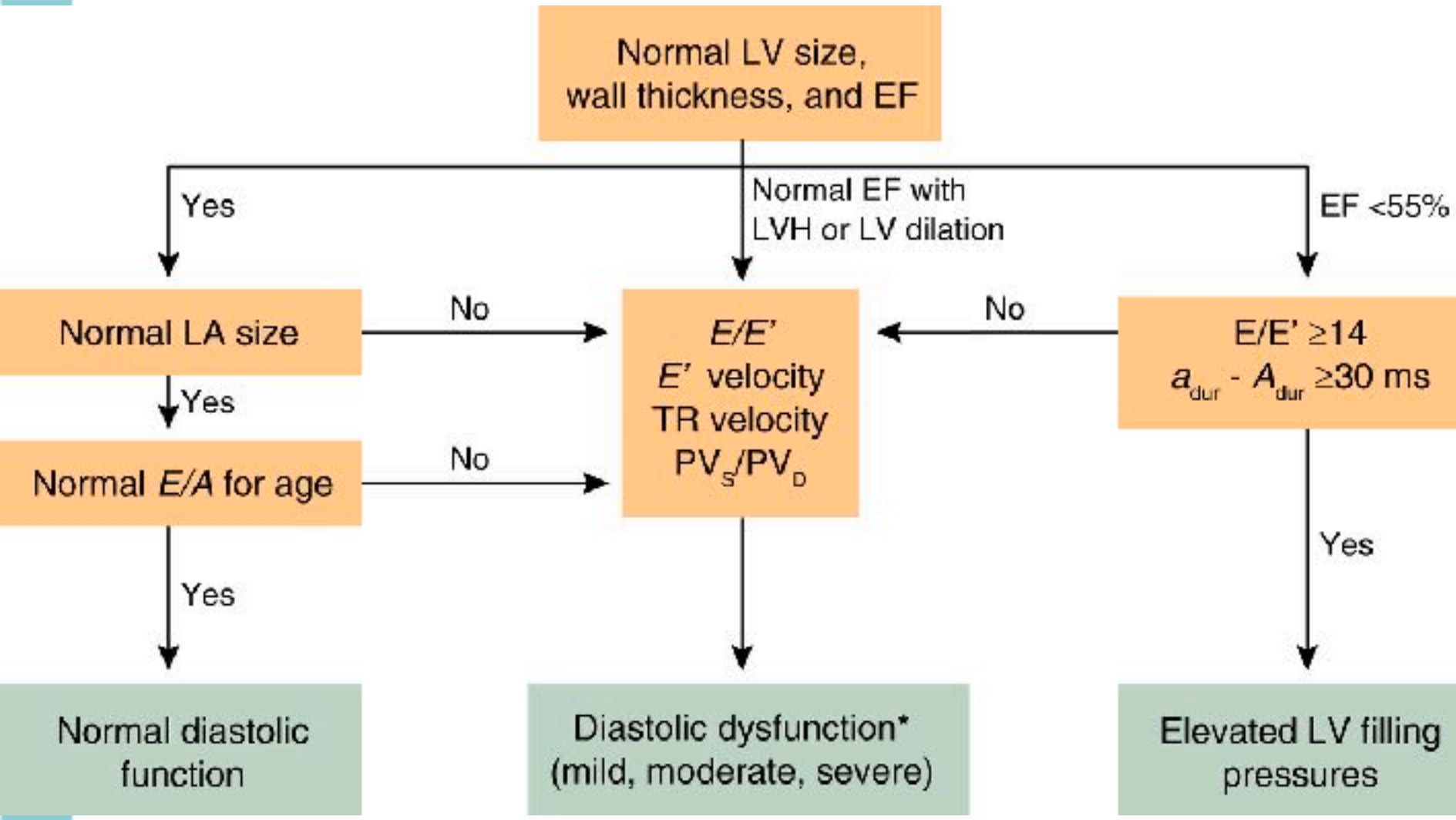
‡*E/A* with the Valsalva maneuver is <1.

§Pulmonary vein *a* duration and velocity may be increased if filling pressures are elevated.

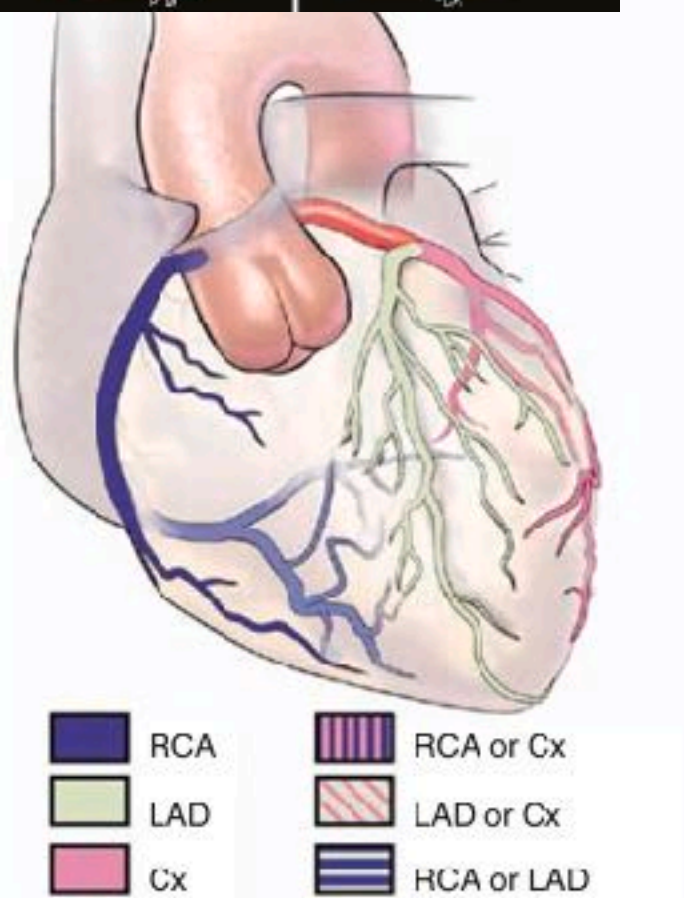
A, Late diastolic ventricular filling velocity with atrial contraction; *DT*, deceleration time; *E*, early diastolic peak velocity; *E'*, early diastolic tissue Doppler velocity; *IVRT*, isovolumic relaxation time; *LVEDP*, LV end-diastolic pressure; *PV*, pulmonary vein.

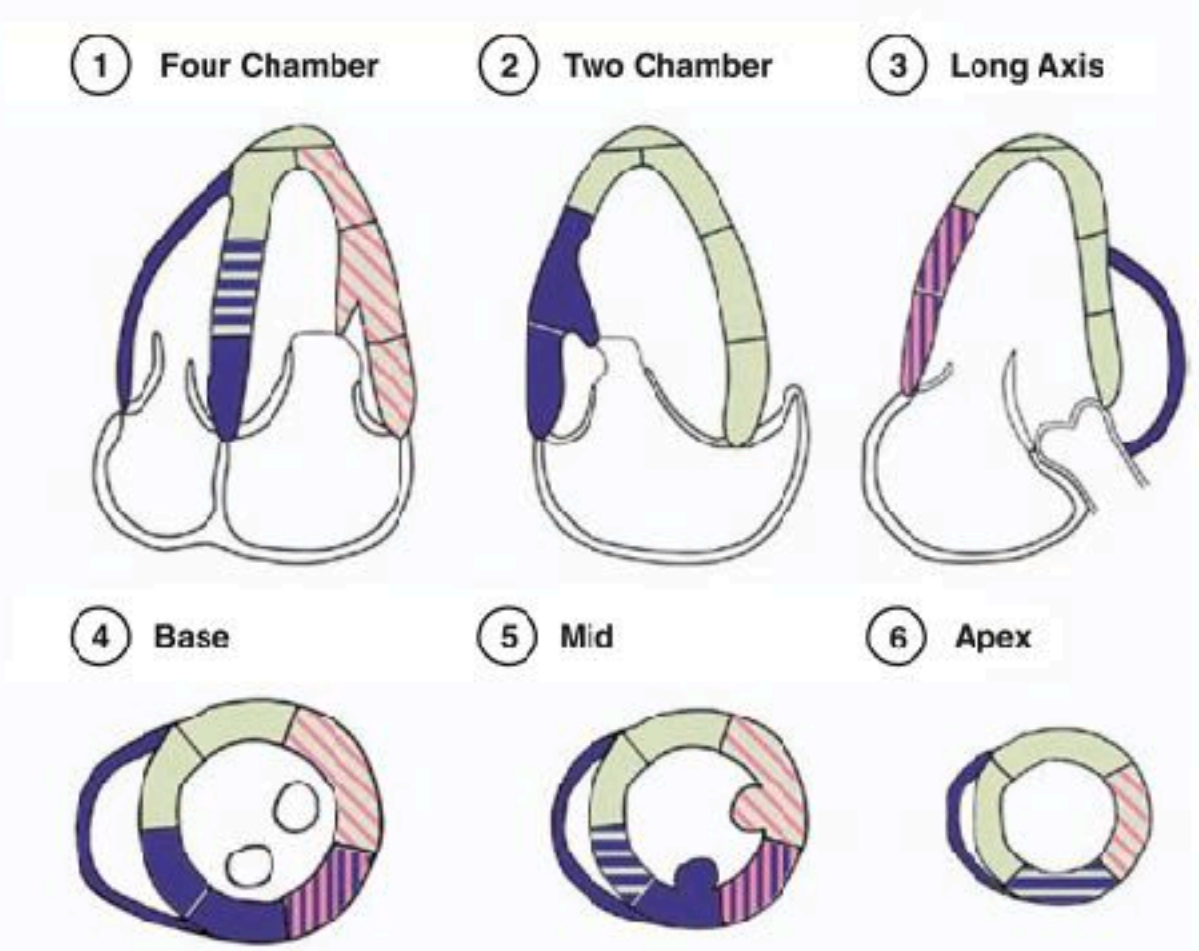
Data from Nagueh SF, Smiseth OA, Appleton CP, et al: [ASE guidelines], *J Am Soc Echocardiogr* 29:277–314, 2015; Rakowski H, Appleton C, Chan KL, et al: [Canadian consensus guidelines], *J Am Soc Echocardiogr* 9:736–760, 1996; Yamada H, Goh PP, Sun JP, et al: [Canadian consensus guidelines], *J Am Soc Echocardiogr* 15:1238–1244, 2002; Redfield MM, Jacobsen SJ, Burnett JC Jr, et al: Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic, *JAMA* 289:194–202, 2003; Lester SJ, Tajik AJ, Nishimura RA, et al: Unlocking the mysteries of diastolic function: deciphering the Rosetta Stone 10 years later, *J Am Coll Cardiol* 51:679–689, 2008.

Diastolic dysfunction approach

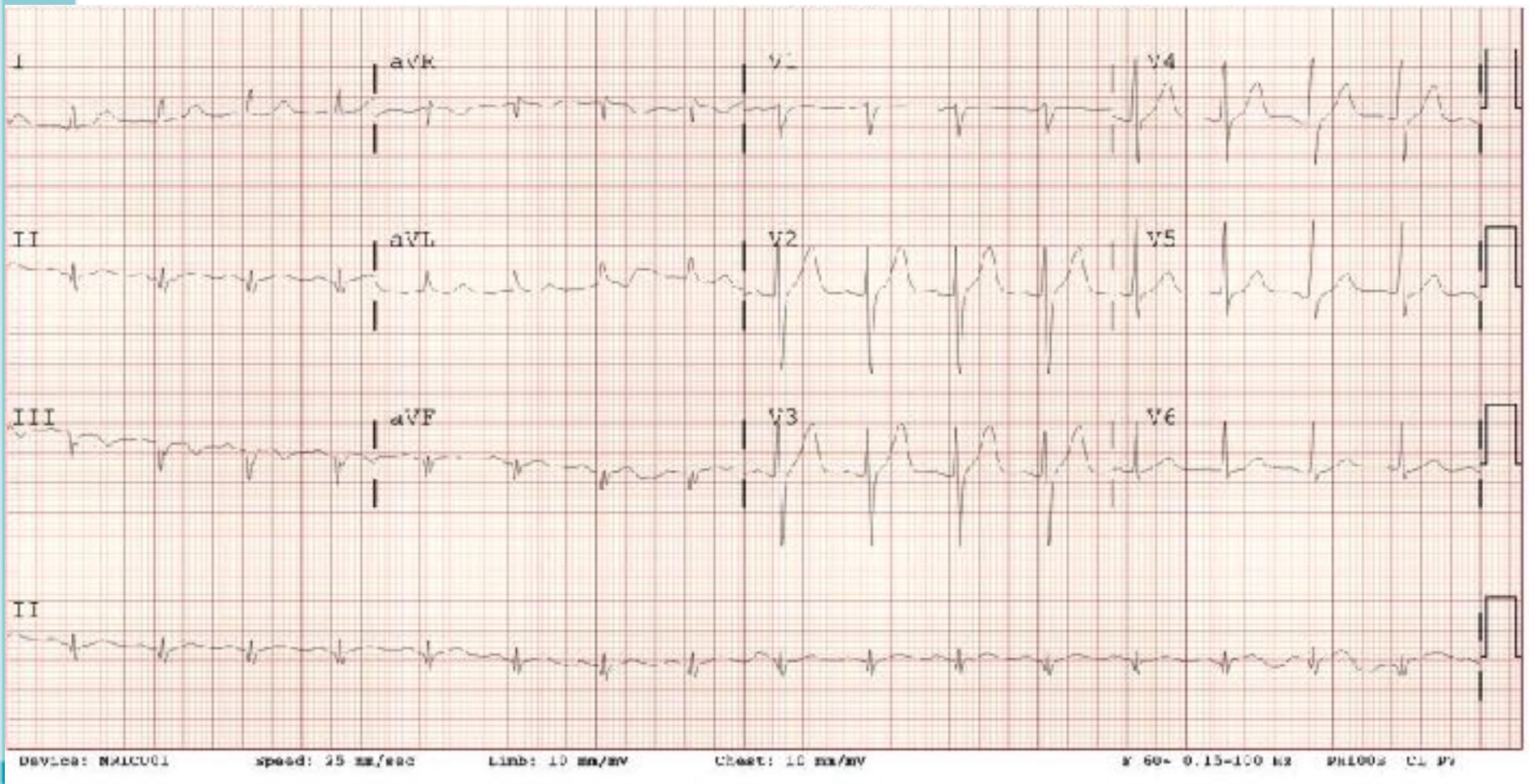


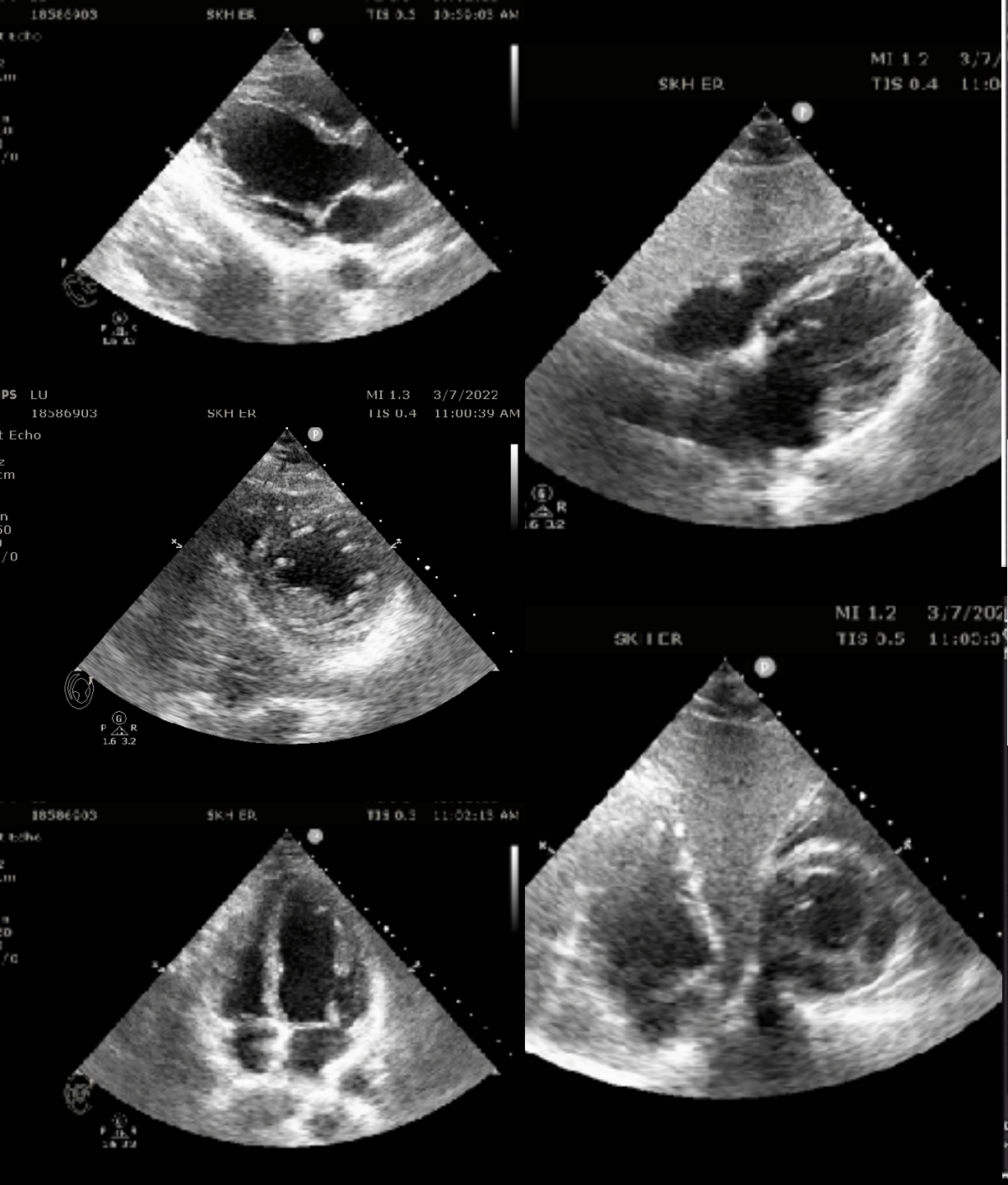
Coronary artery & Segments





39M,
chest pain & cold sweating

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TIS 0.4
MI 1.3
3/7/2022
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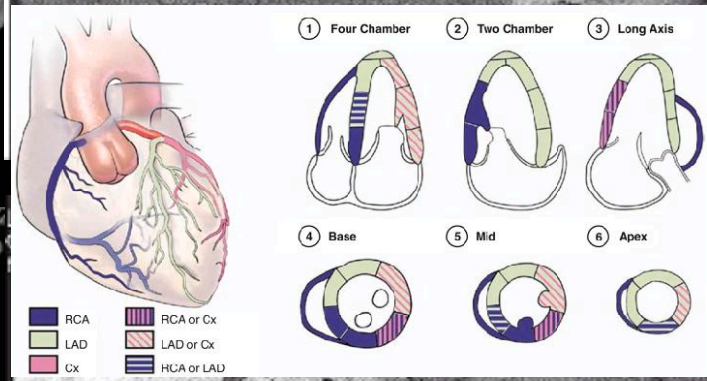
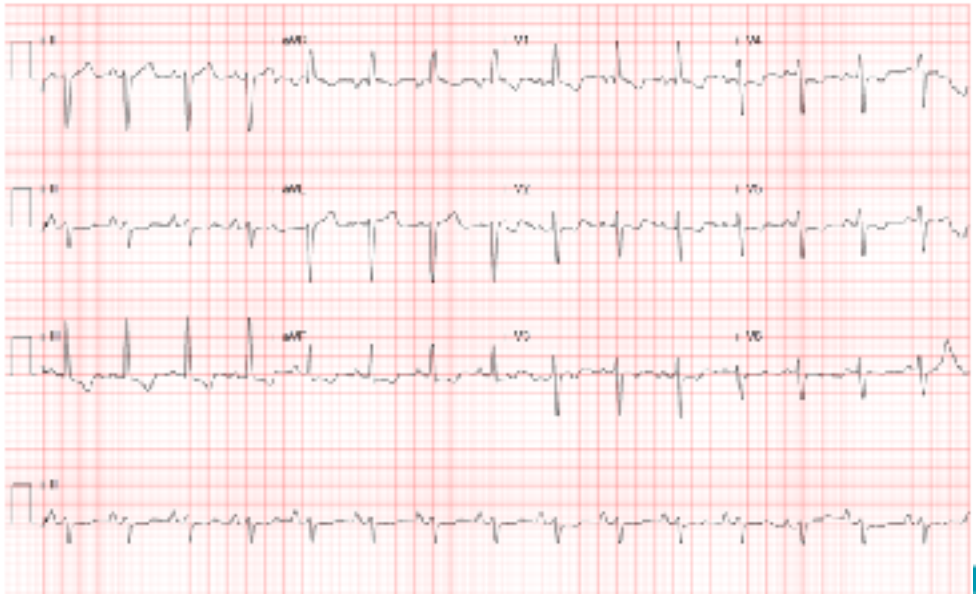
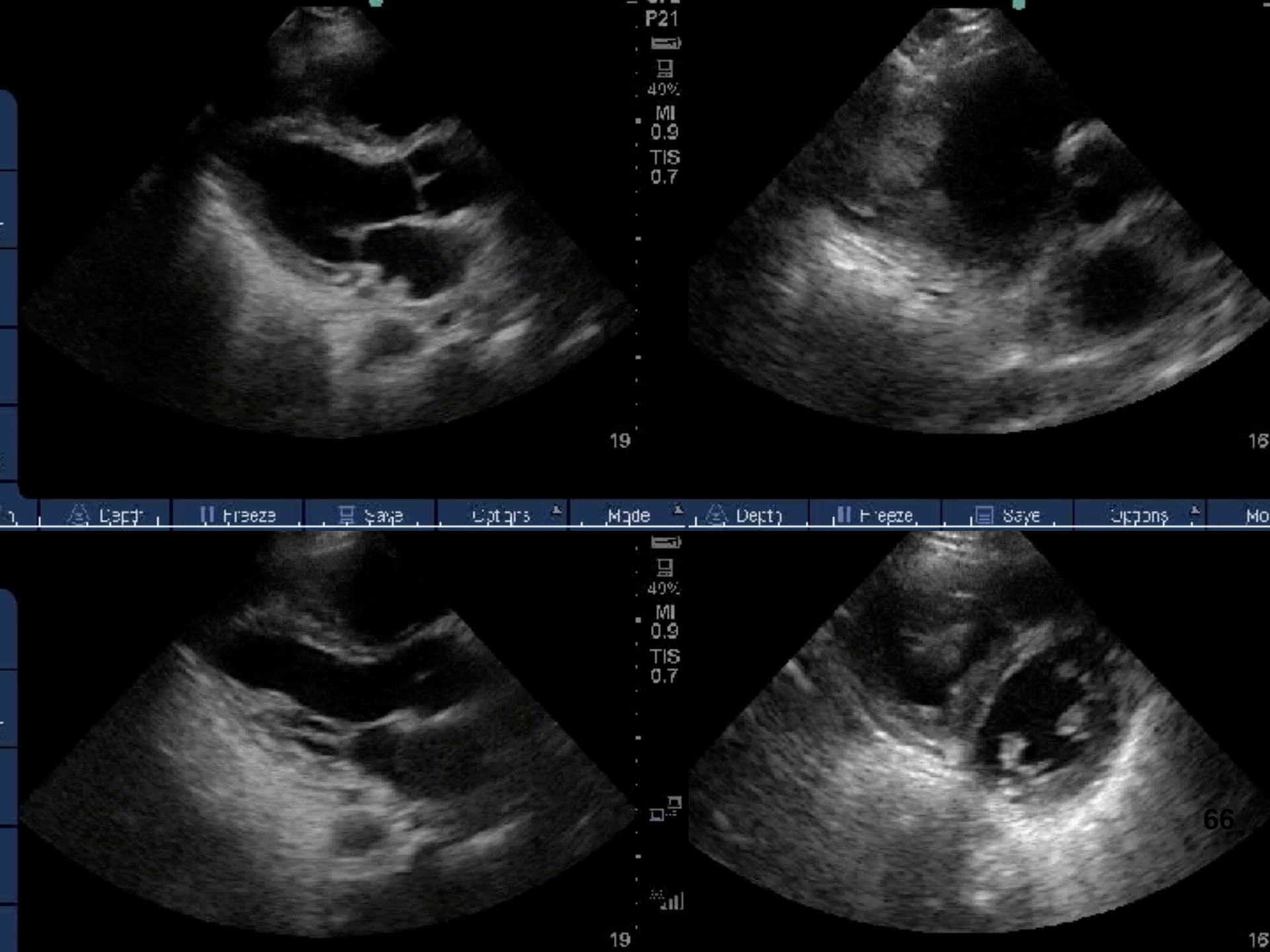
TIS 0.4
11:00:39 AM
Echo
SKH ER
MI 1.2
TIS 0.5
SKH ER
SKH ER


1 Four Chamber
2 Two Chamber
3 Long Axis
4 Base
5 Mid
6 Apex
RCA
LAD
Cx
RCA or Cx
LAD or Cx
RCA or LAD


240
11:54:13

43M, interstitial lung dx, SOB 土長轉回

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40%
MI
0.9
TIS
0.7
19
16
Depth
Freeze
Save
Options
Mode
Depth
Freeze
Save
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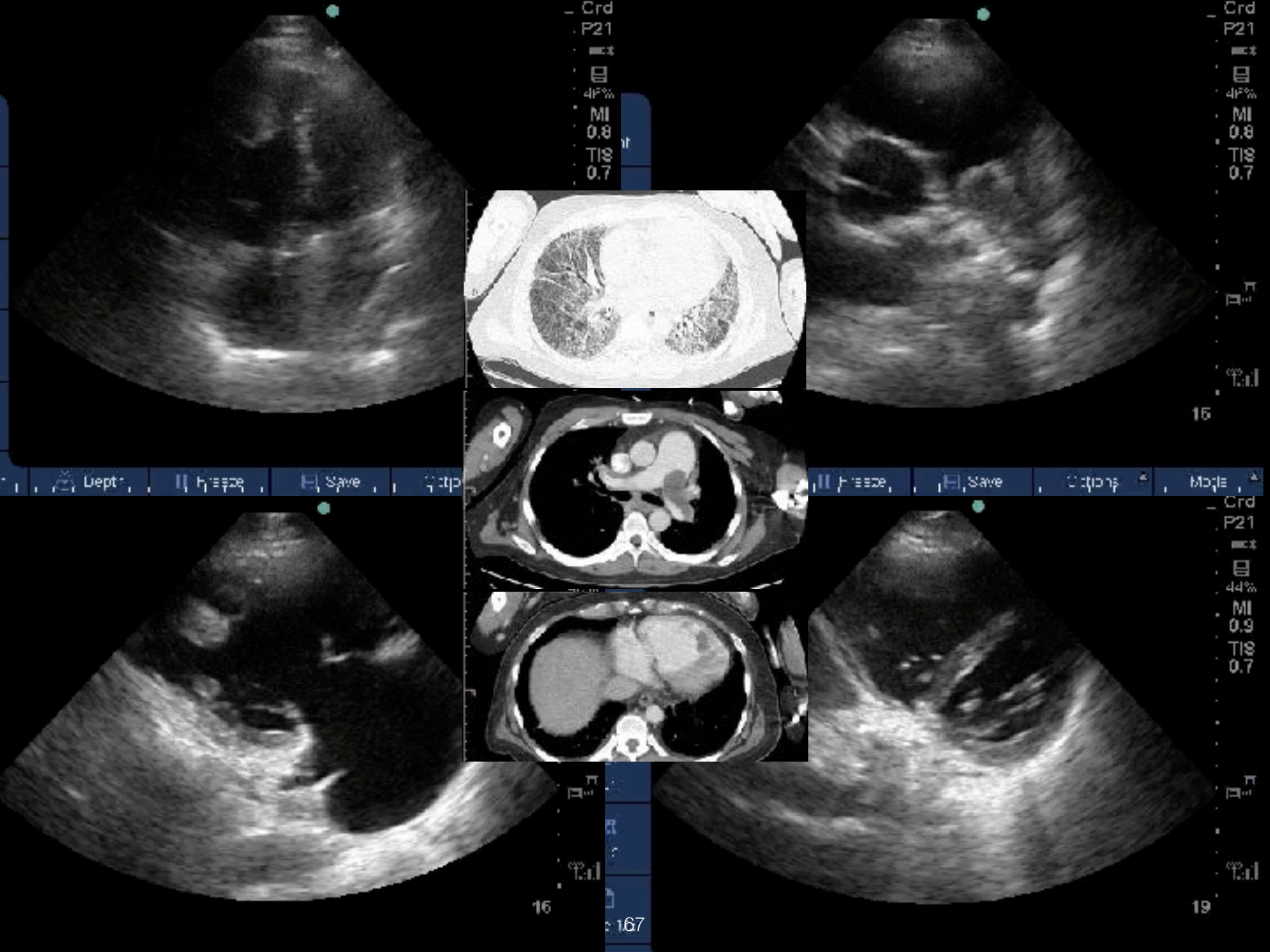
Mo
40%
MI
0.9
TIS
0.7
19
16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MI
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TIS
0.7
Crd
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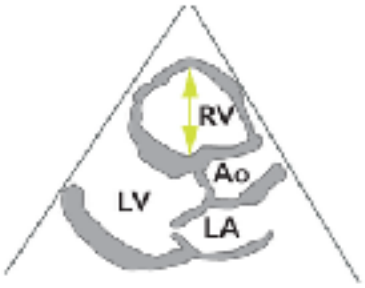
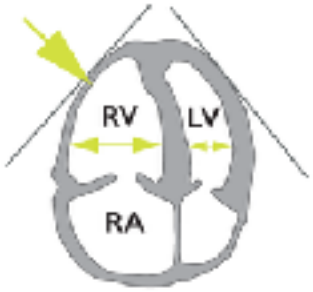
MI
0.8
TIS
0.7
Freeze
Save
Freeze
Save
Crd
P21
MI
0.9
TIS
0.7
16
19

60 / 60 rule : 94% specific for PE



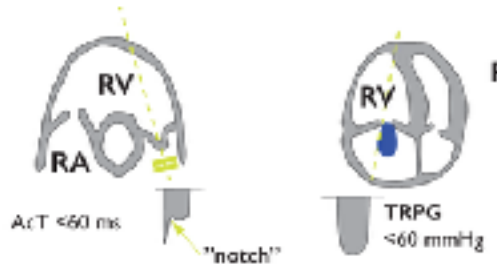
A. Enlarged right ventricle, parasternal long axis view



B. Dilated RV with basal RV/LV ratio >1.0, and McConnell sign (arrow), four chamber view

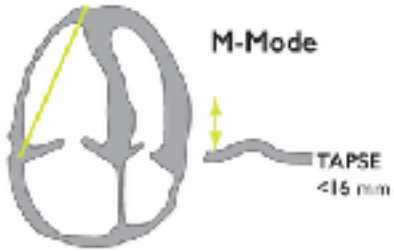
C. Flattened intraventricle septum (arrows) parasternal short axis view

D. Distended inferior vena cava with diminished inspiratory collapsibility, subcostal view

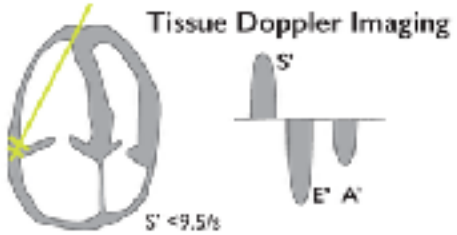


E. 60/60 sign: coexistence of acceleration time of pulmonary ejection <60 ms and midsystolic "notch" with mildy elevated (<60 mmHg) peak systolic gradient at the tricuspic valve

F. Right heart mobile thrombus detected in right heart cavities (arrow)



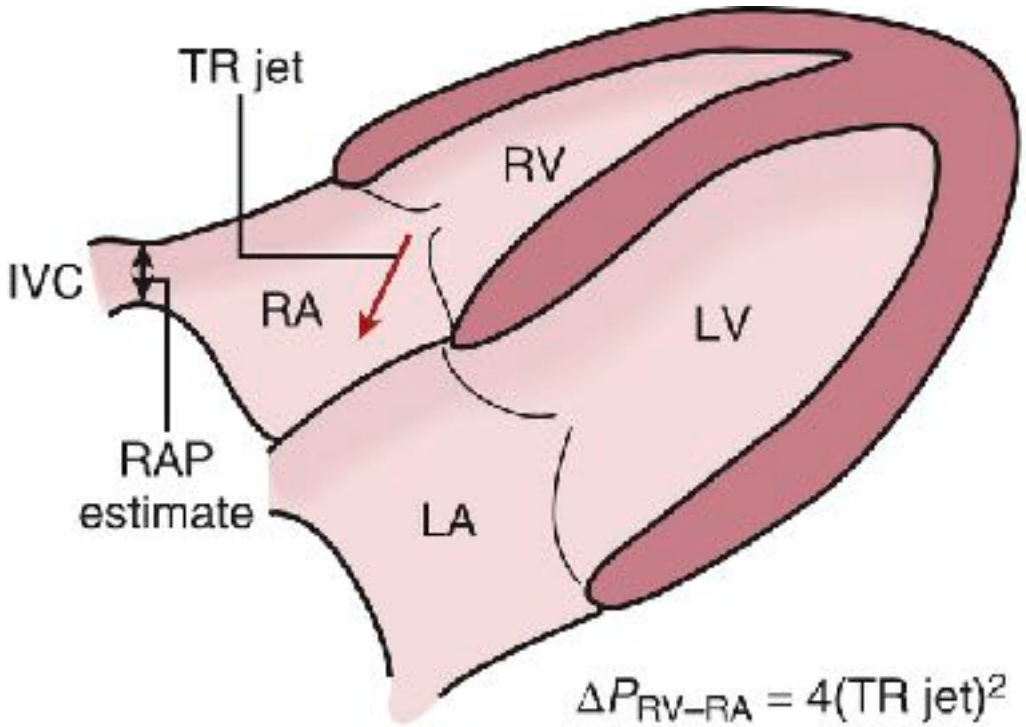
G. Decreased tricuspid annular plane systolic excursion (TAPSE) measured with M-Mode (<16 mm)



H. Decreased peak systolic (S') velocity of tricuspid annulus (<9.5 cm/s)

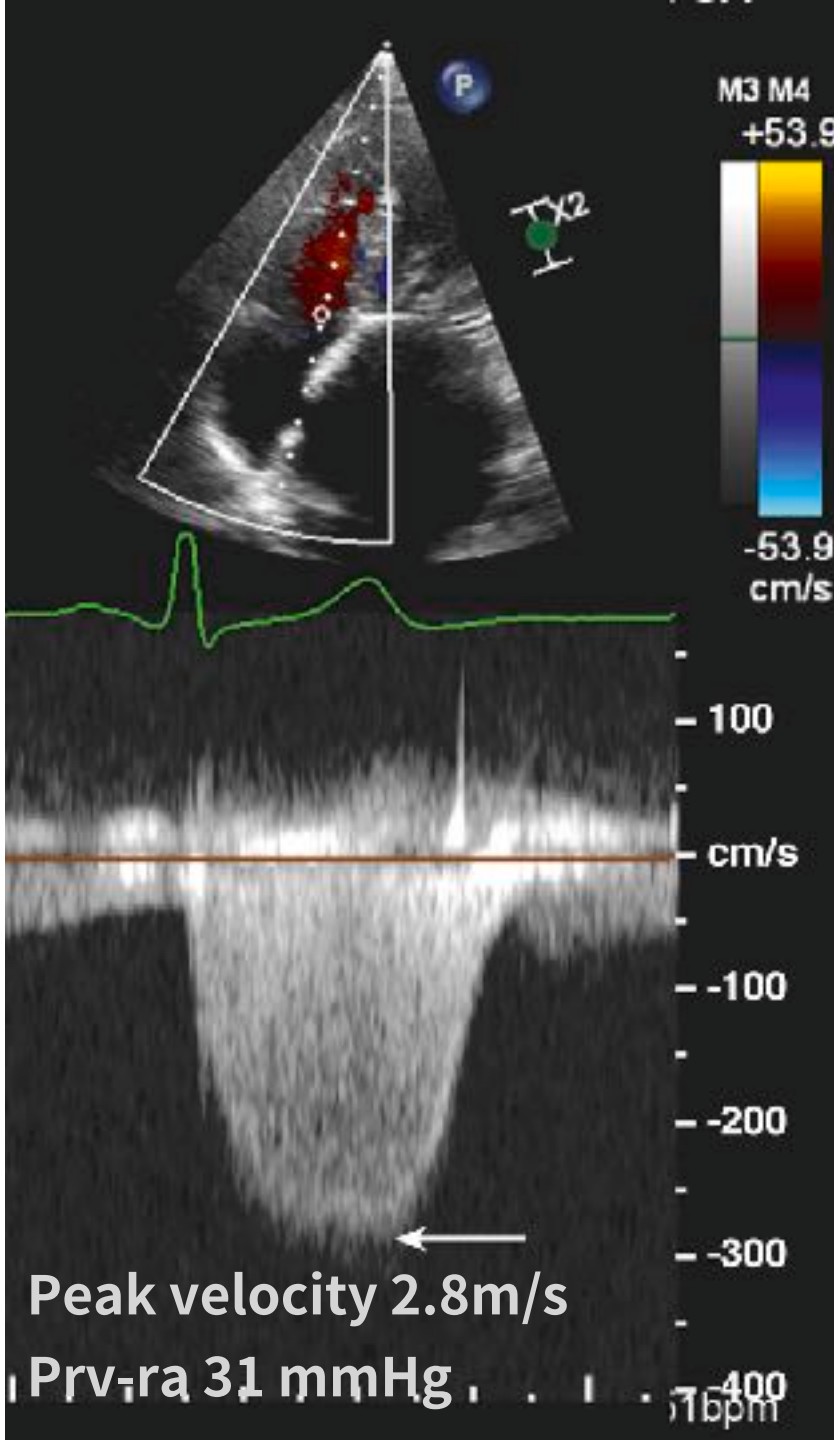
ESC 2019

Pulmonary artery pressure Measurement

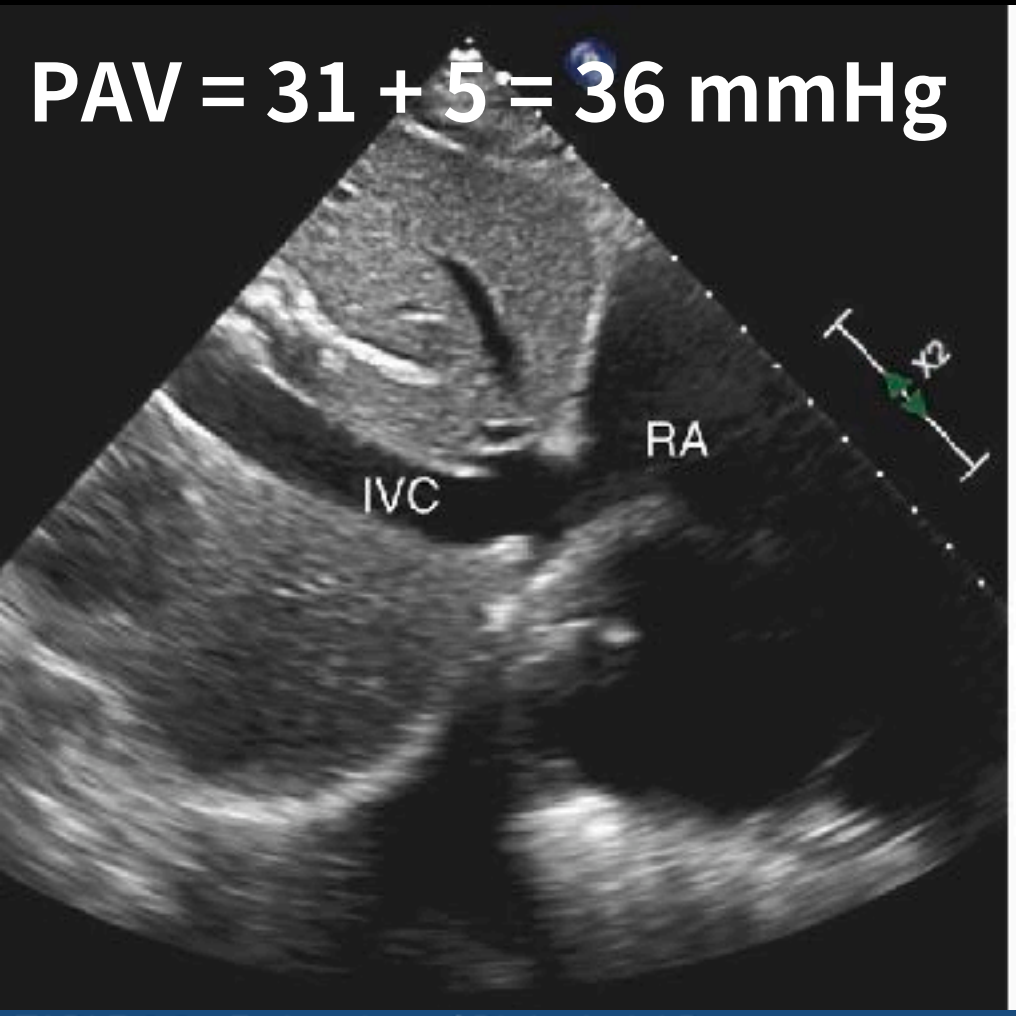


$\Delta P_{RV-RA} = 4(\text{TR jet})^2$

$\text{PAP} = \Delta P_{RV-RA} + \text{RAP}$



PAV = 31 + 5 = 36 mmHg



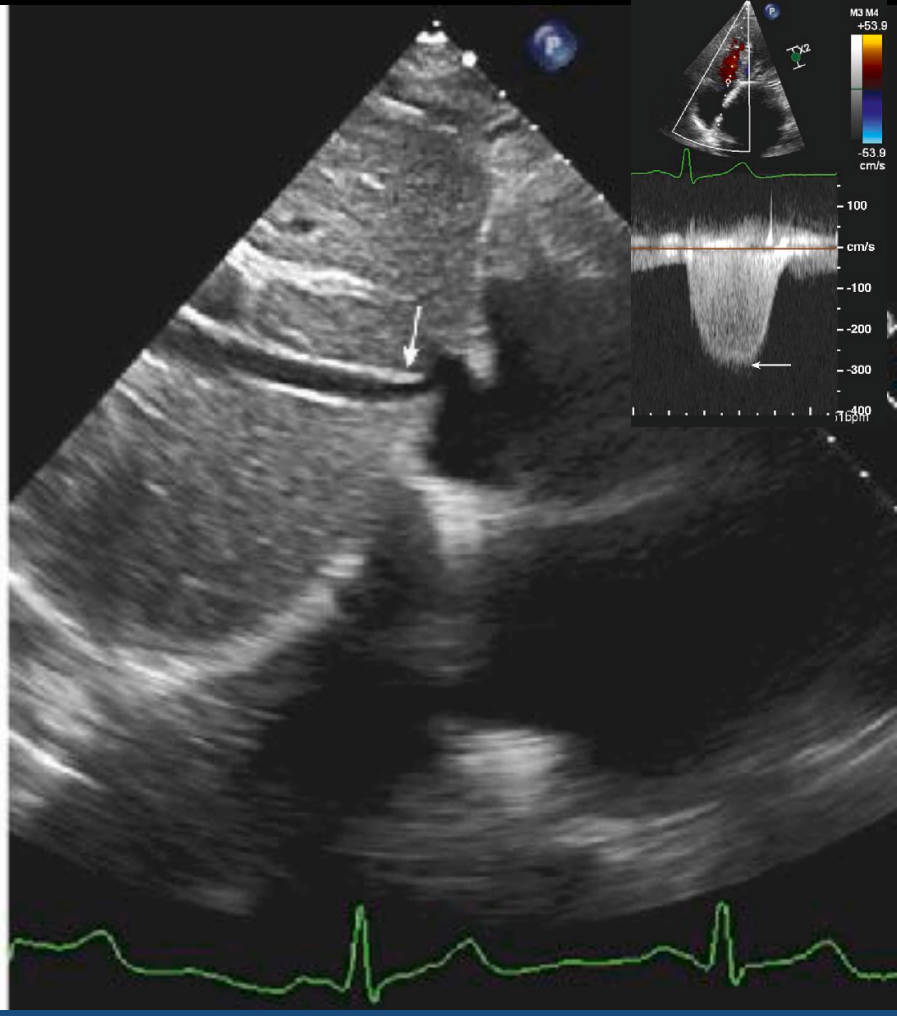
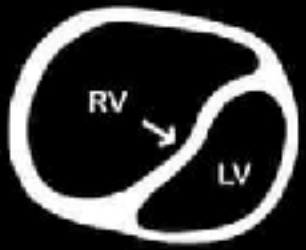


TABLE 6.6 Estimation of Right Atrial Pressure

		RA PRESSURE ESTIMATE	
IVC Diameter*	Change With Sniff	Range Estimate†	ASE Guidelines‡
Normal (≤2.1 cm)	Decrease > 50%	0–5 mmHg	3 mmHg
Normal (≤2.1 cm)	Decrease ≤ 50%	5–10 mmHg	8 mmHg§
Dilated (>2.1 cm)	Decrease > 50%	10–15 mmHg	
Dilated (>2.1 cm)	Decrease ≤ 50%	15–20 mmHg	15 mmHg

Increased RV:LV Size Ratio

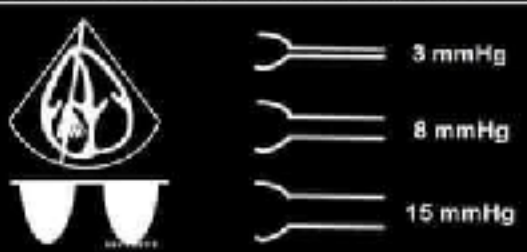
Abnormal Septal Motion



McConnell's Sign

Tricuspid Regurgitation

Elevated Pulmonary Artery Systolic Pressure



$PASP = (4 \times TRV_{max}^2) + RAP > 35\ mmHg$

Decreased TAPSE

Decreased S'

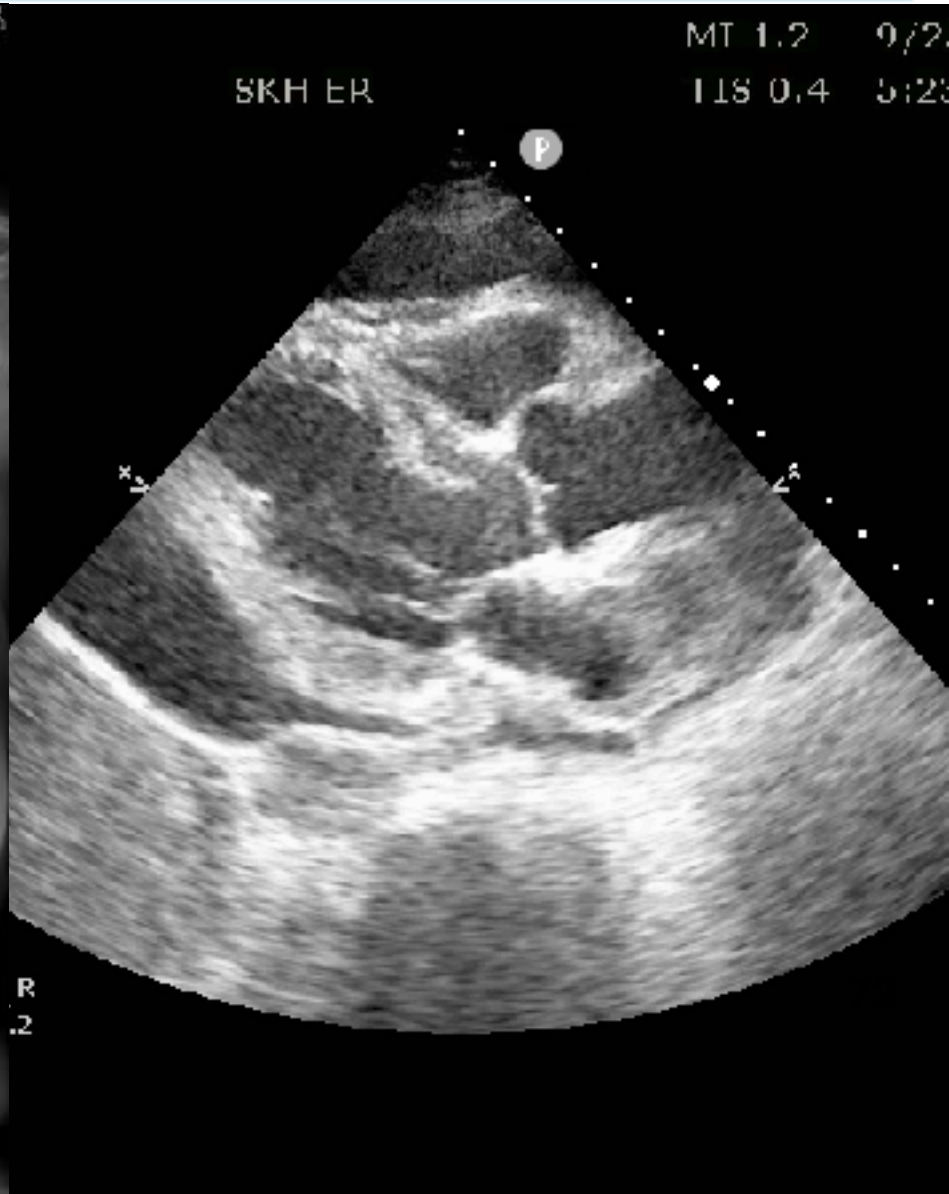
Pulmonary Artery Mid-Systolic Notching

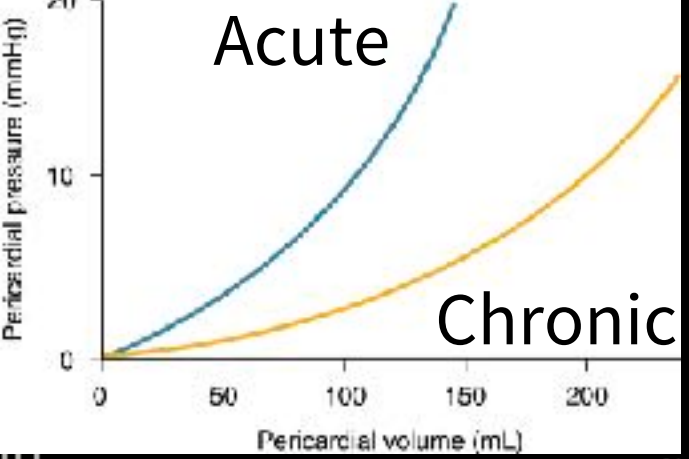
60/60 Sign

$(4 \times TRV_{max}^2) < 60\ mmHg$ PAAT < 60 ms

Speckle Tracking: Decreased Free Wall Strain

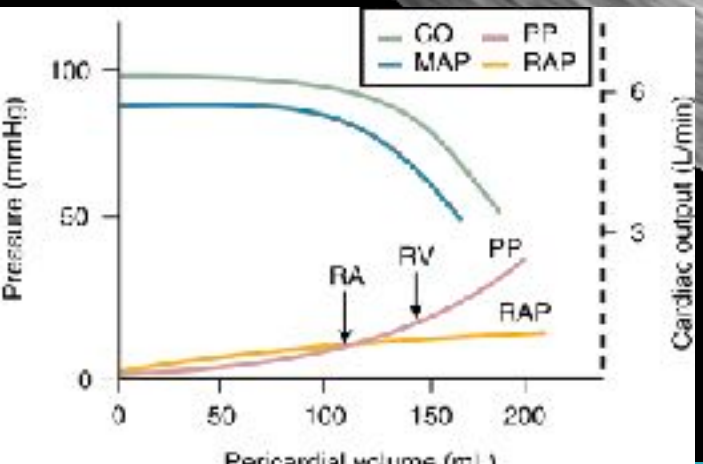
70F, dyspnea

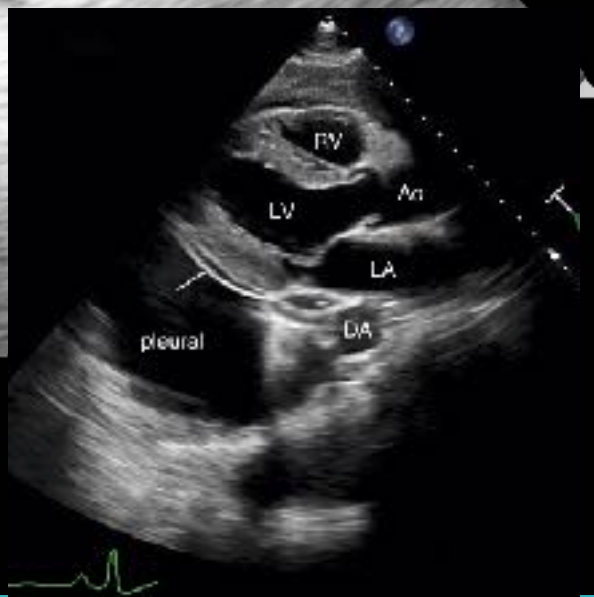




2 / 0

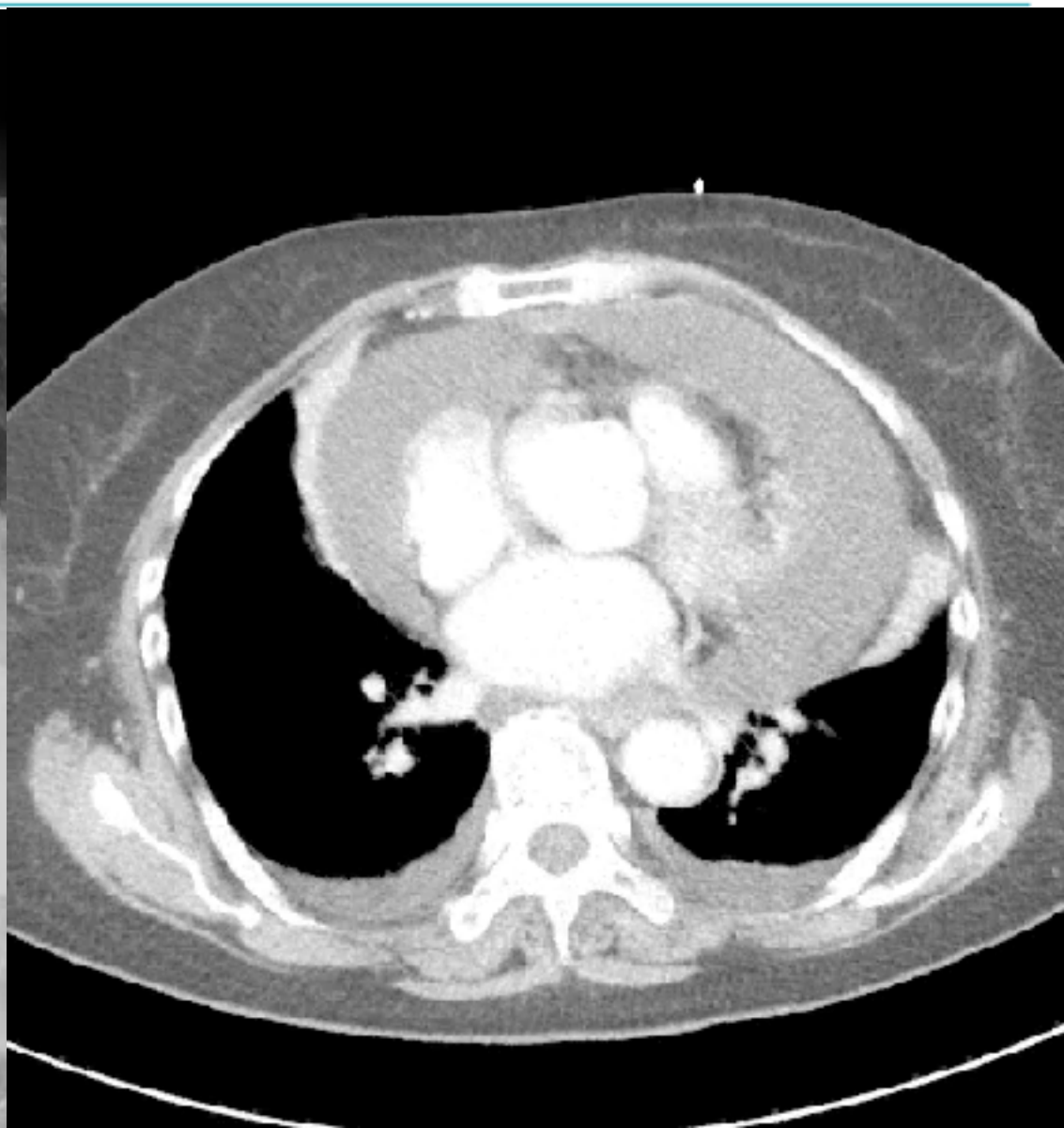
RA systolic collapse
RV diastolic collapse
IVC engorgement
Resp flow variation (MV)

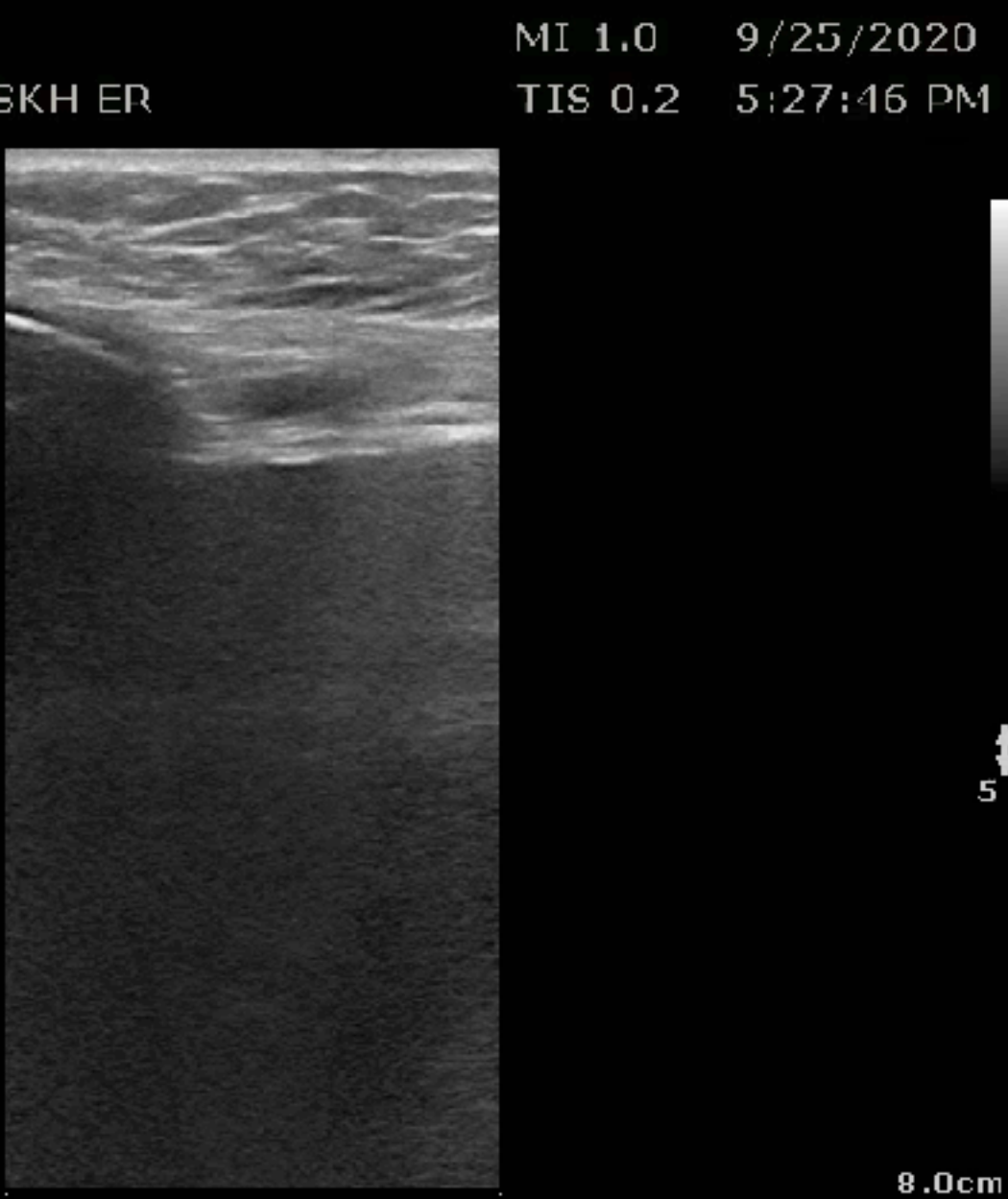


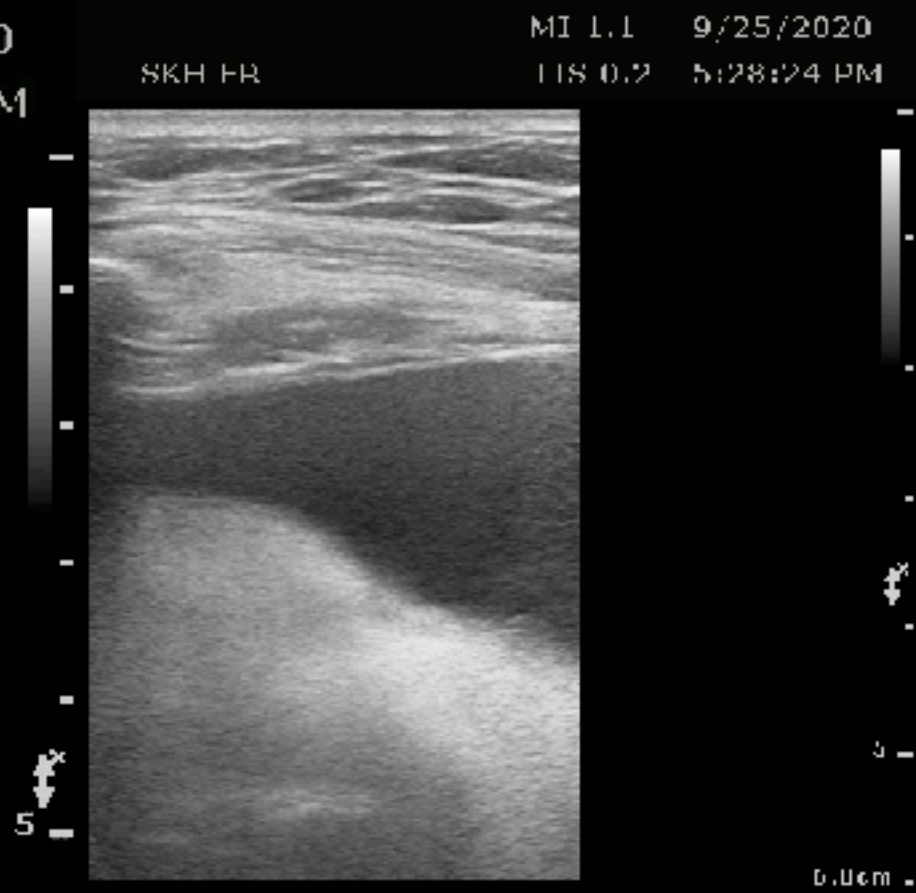



0205
SKII ER
TIS 0.4
5:24:26
21630205
SKII ER
TIS 0.1
5:25:
Adult Echo
S5-1
28 Hz
19.0cm
2D
HGen
Gn 50
D 50
0/2/0
MI 1.2
0205
SKII ER
TIS 0.
74

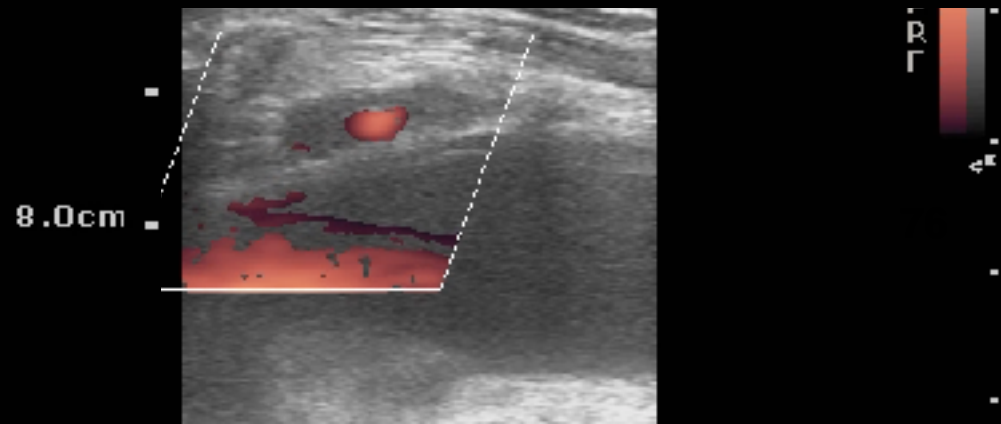
CT scan for evaluation



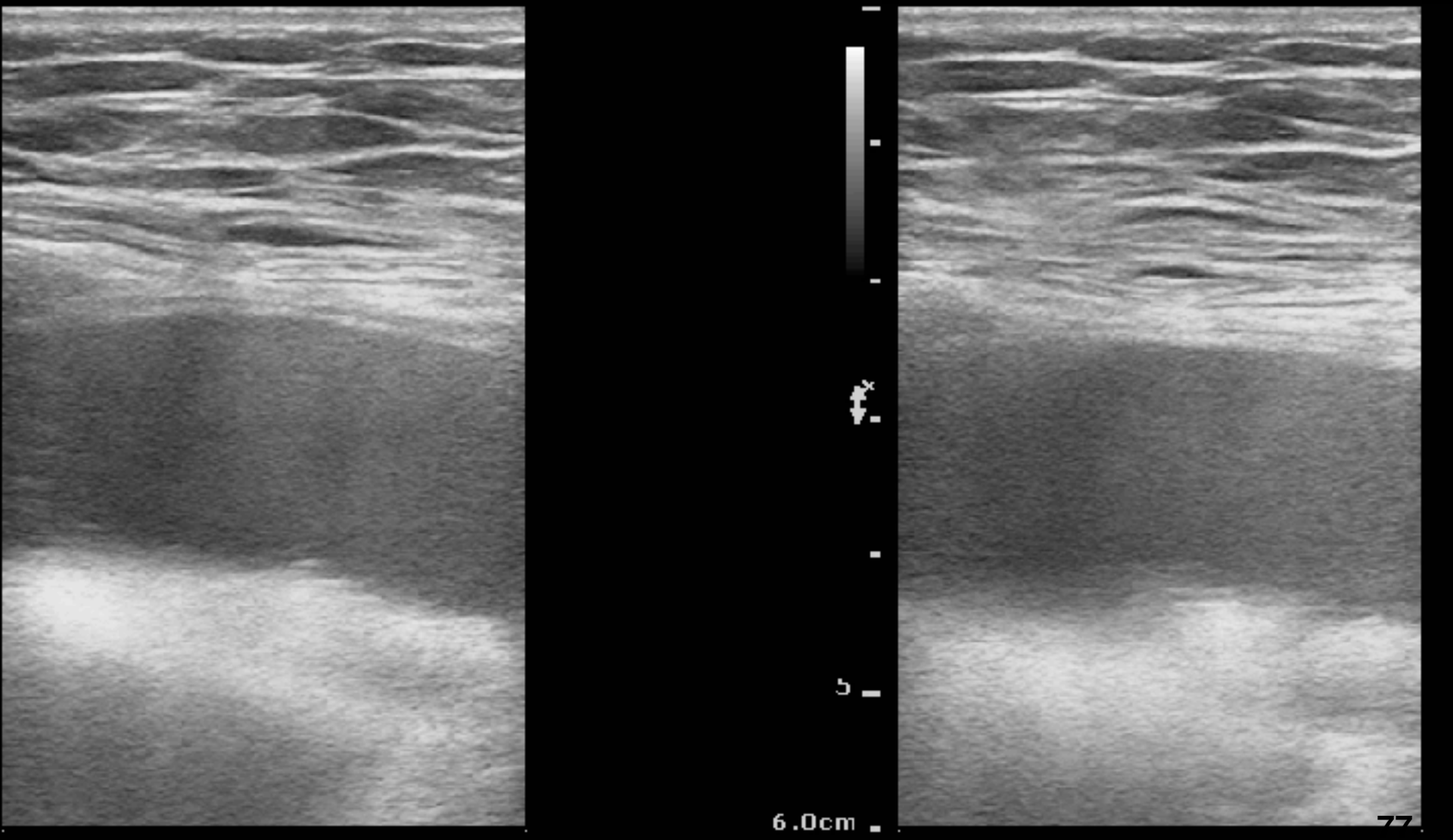


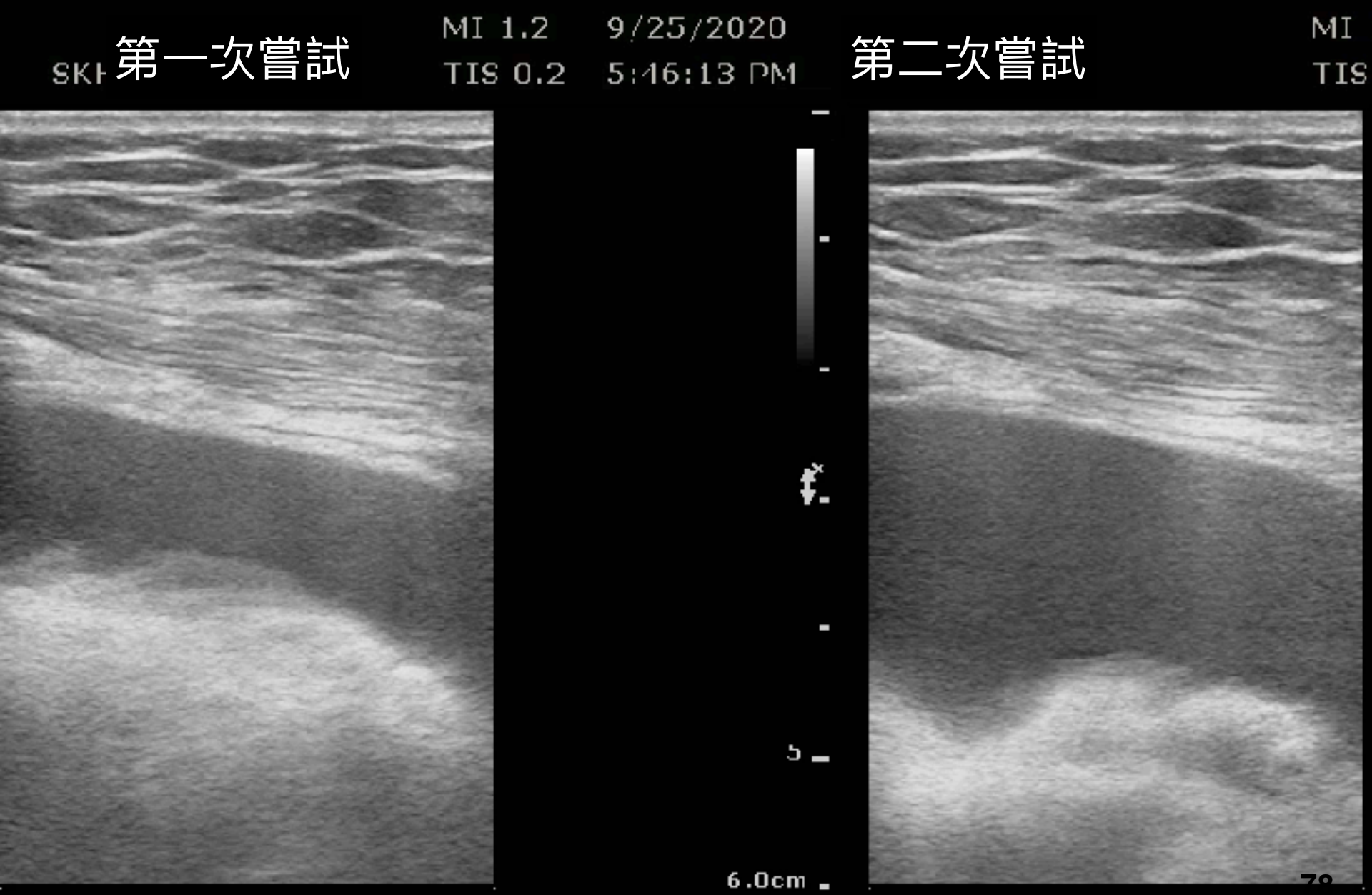


避開Internal thoracic artery

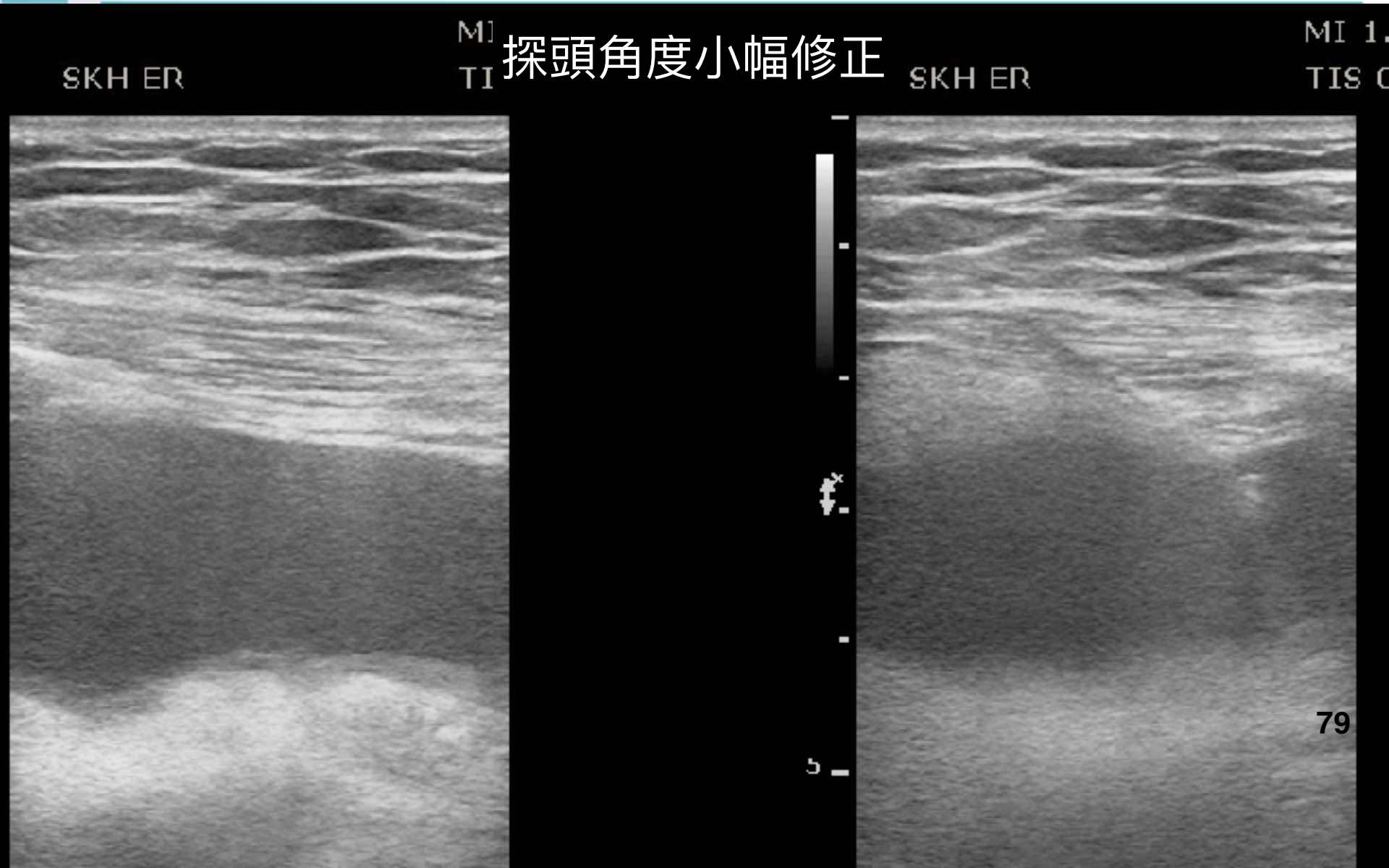


利用心肌長針施打局部麻醉，同時掌握入針角度和路線

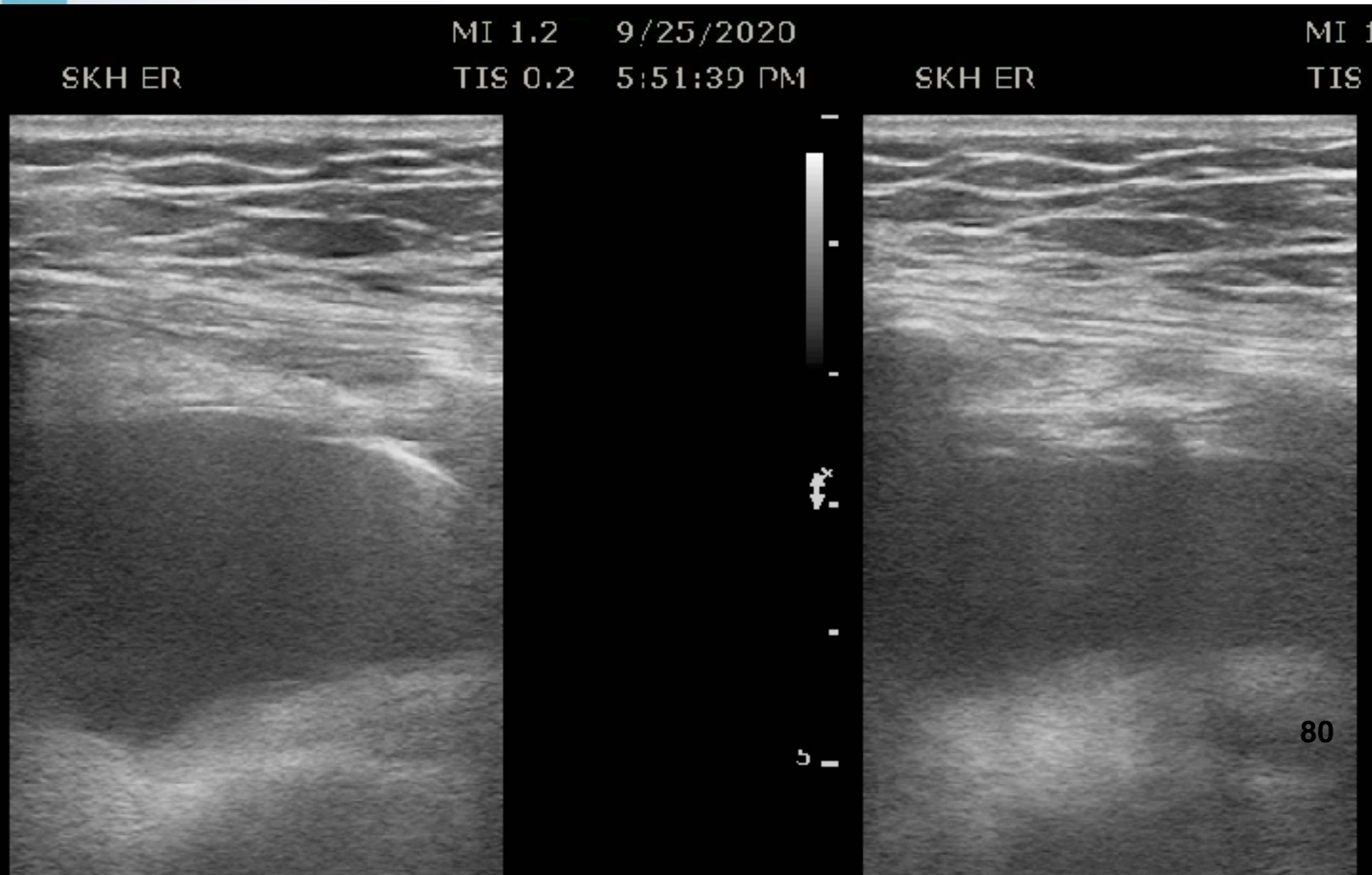



第一次嘗試
MI 1.2
TIS 0.2
9/25/2020
5:16:13 PM
第二次嘗試
MI
TIS
5
6.0cm

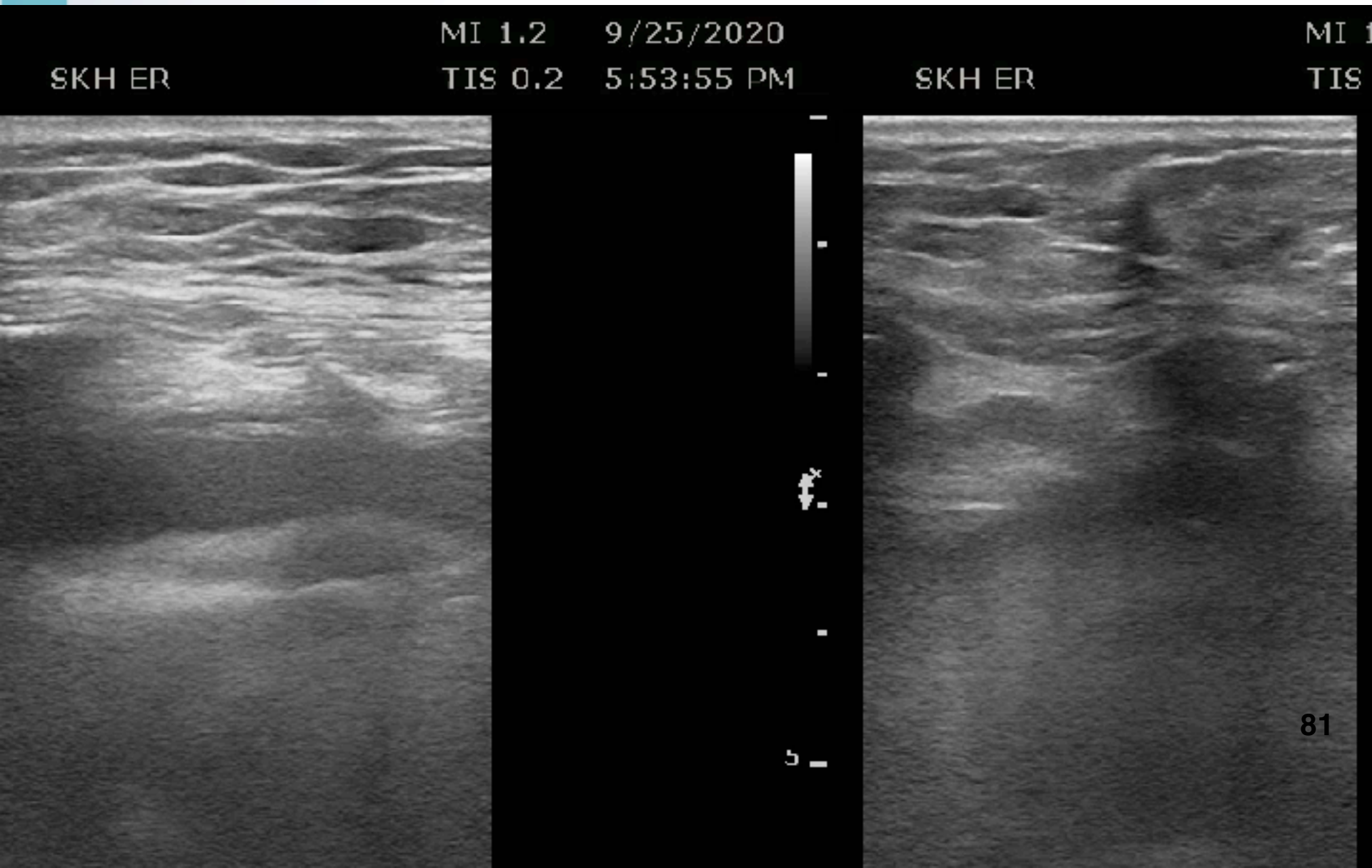
CVC引導硬針置放



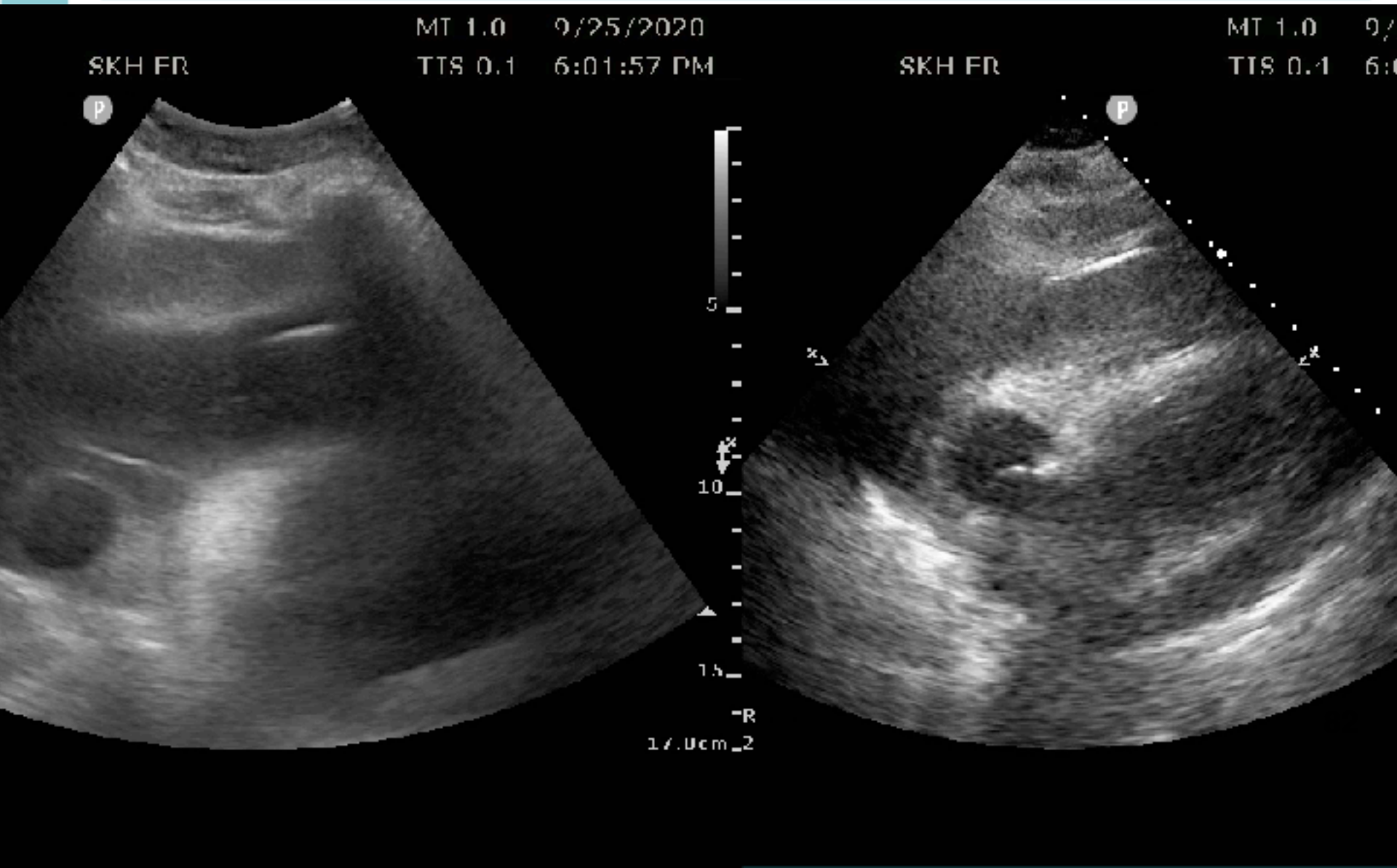
依序放入導線和CVC



Trace CVC catheter



CVC catheter visible

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TIS 0.4
9/25/2020
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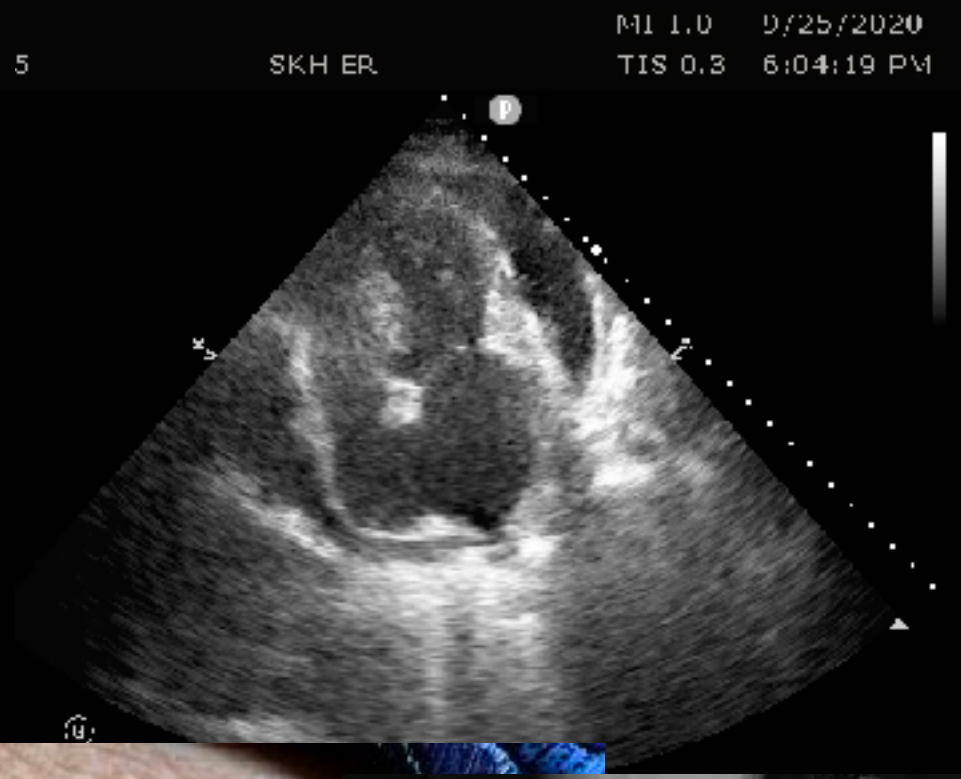
5
SKH ER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9/25/2020
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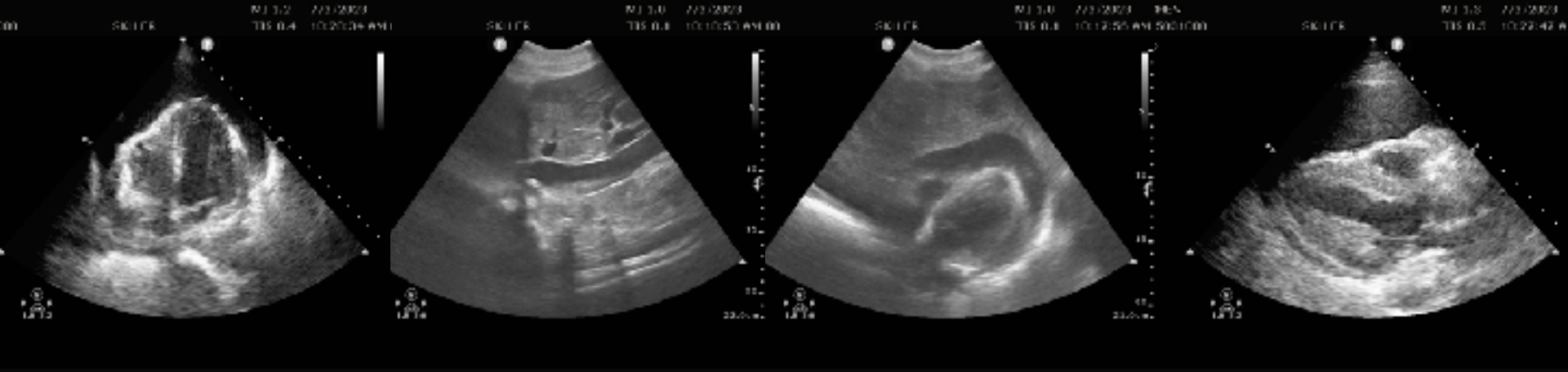
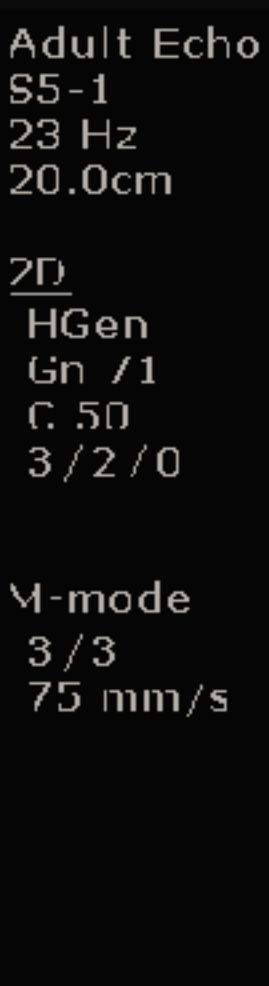
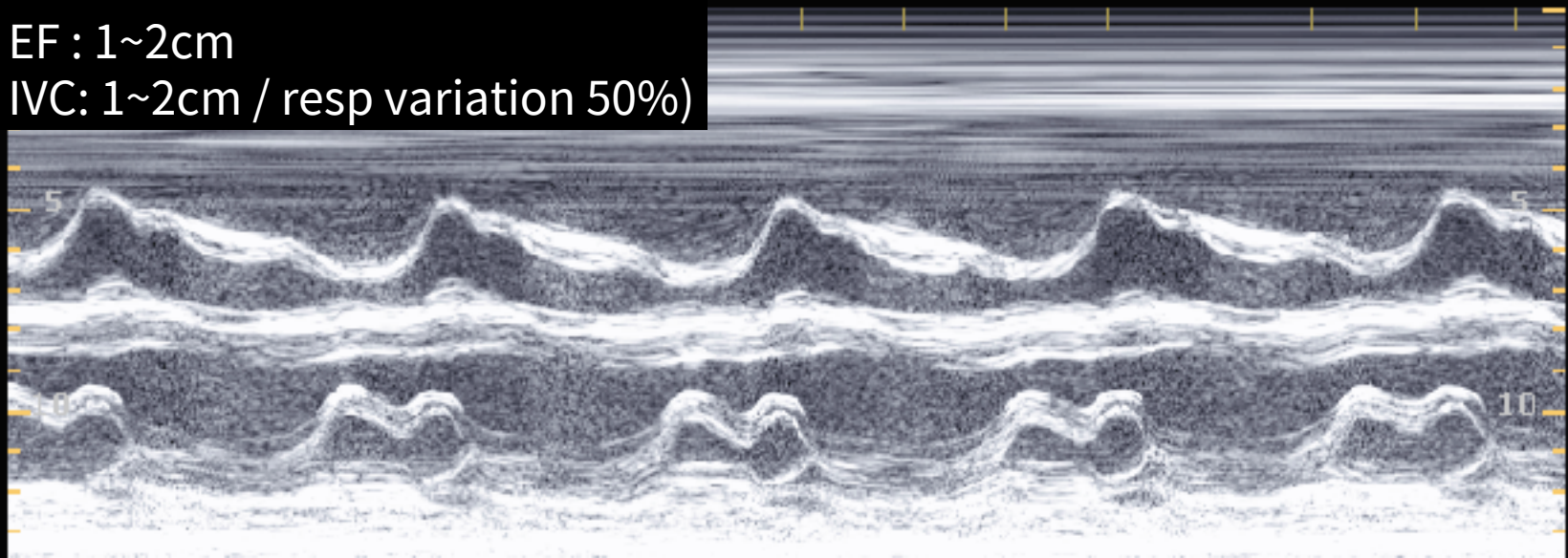
SKH ER

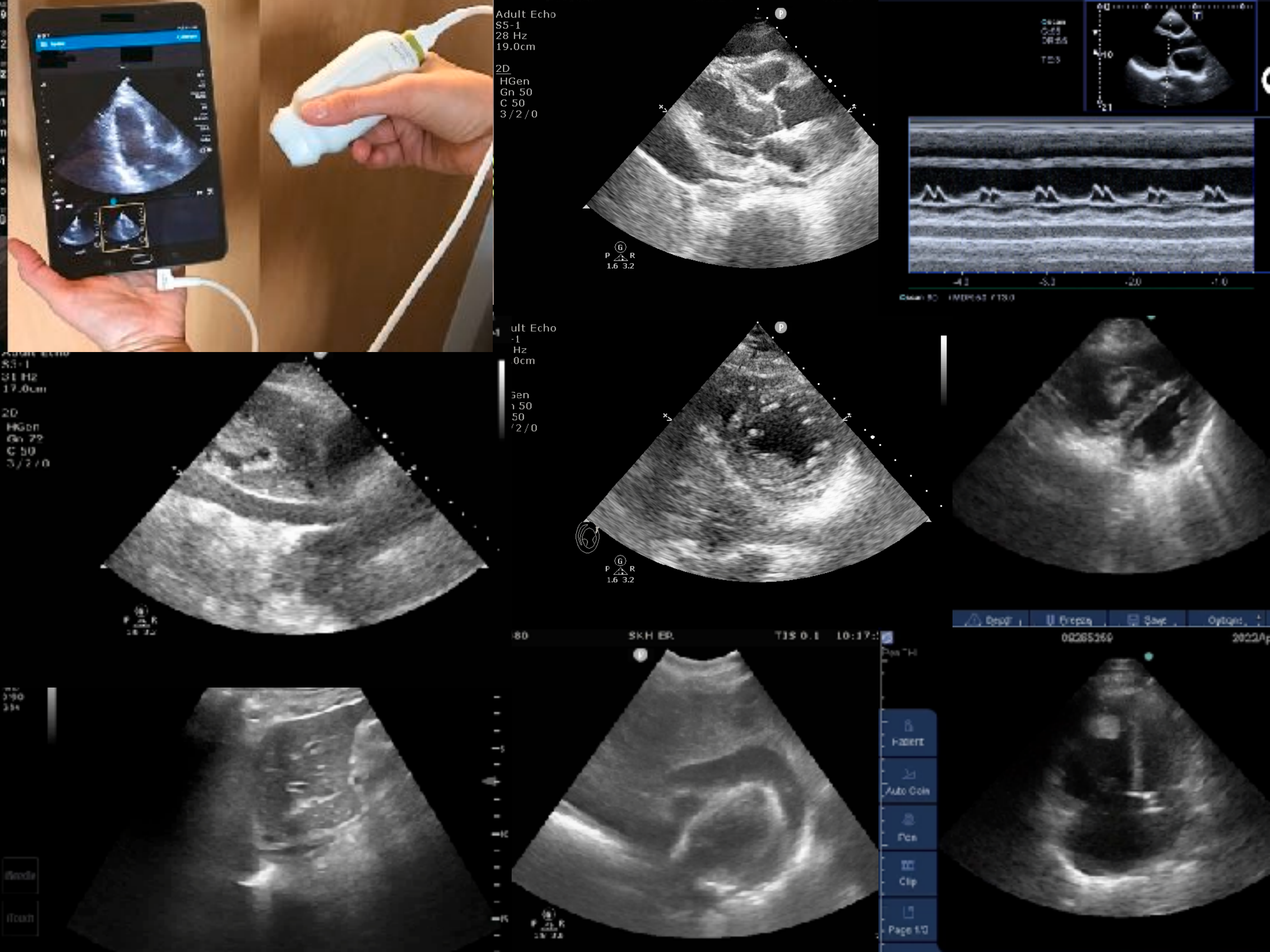

L





EF : 1~2cm
IVC: 1~2cm / resp variation 50%)





Adult Echo
S5-1
28 Hz
19.0cm
2D
HGen
Gn 50
C 50
3/2/0
P R
1.6 3.2
SKH ER
TIS 0.1
Freeze
Save
Auto Gain
Clip