ULTRASOUND
PROGRAM

Hemodynamic monitor in ICU

陳國智 西園醫院急診醫學科

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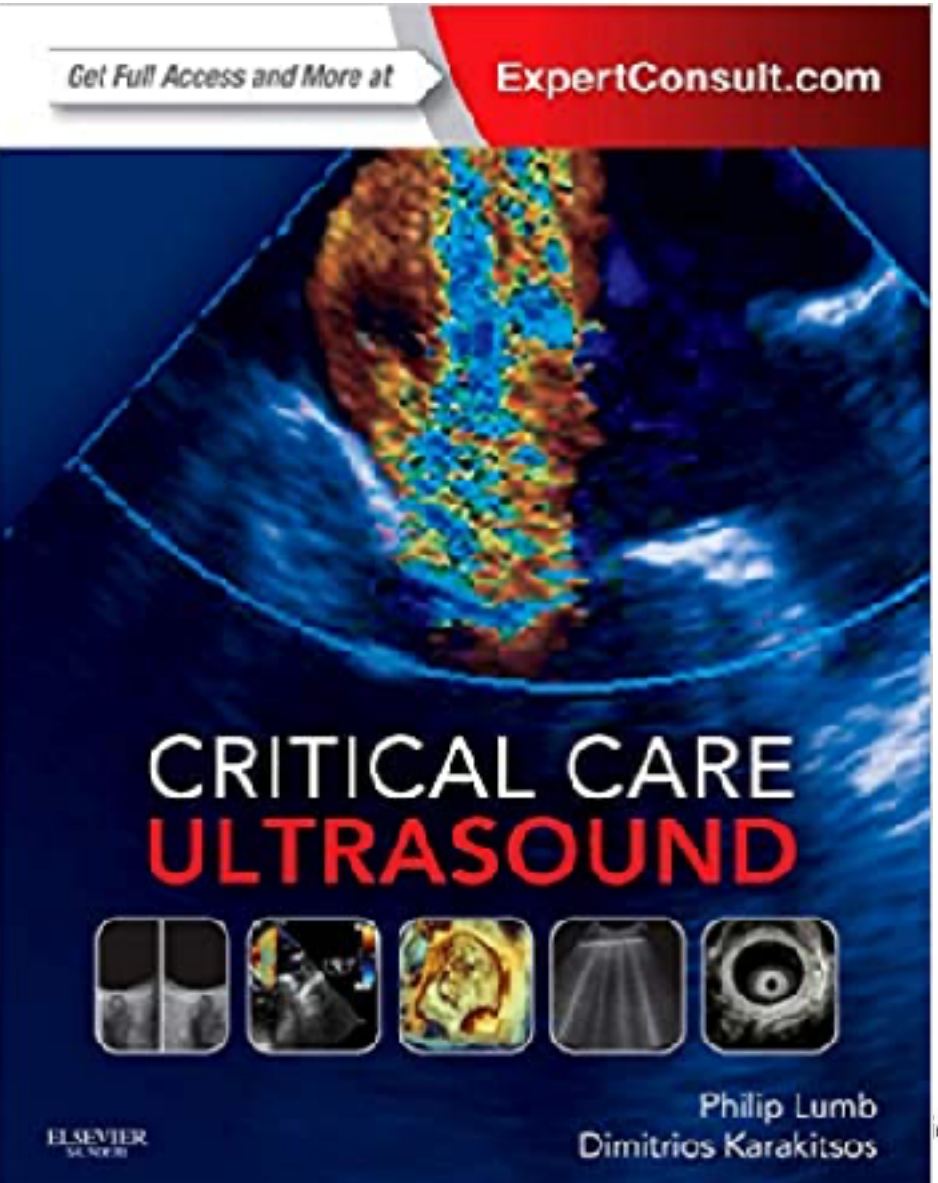

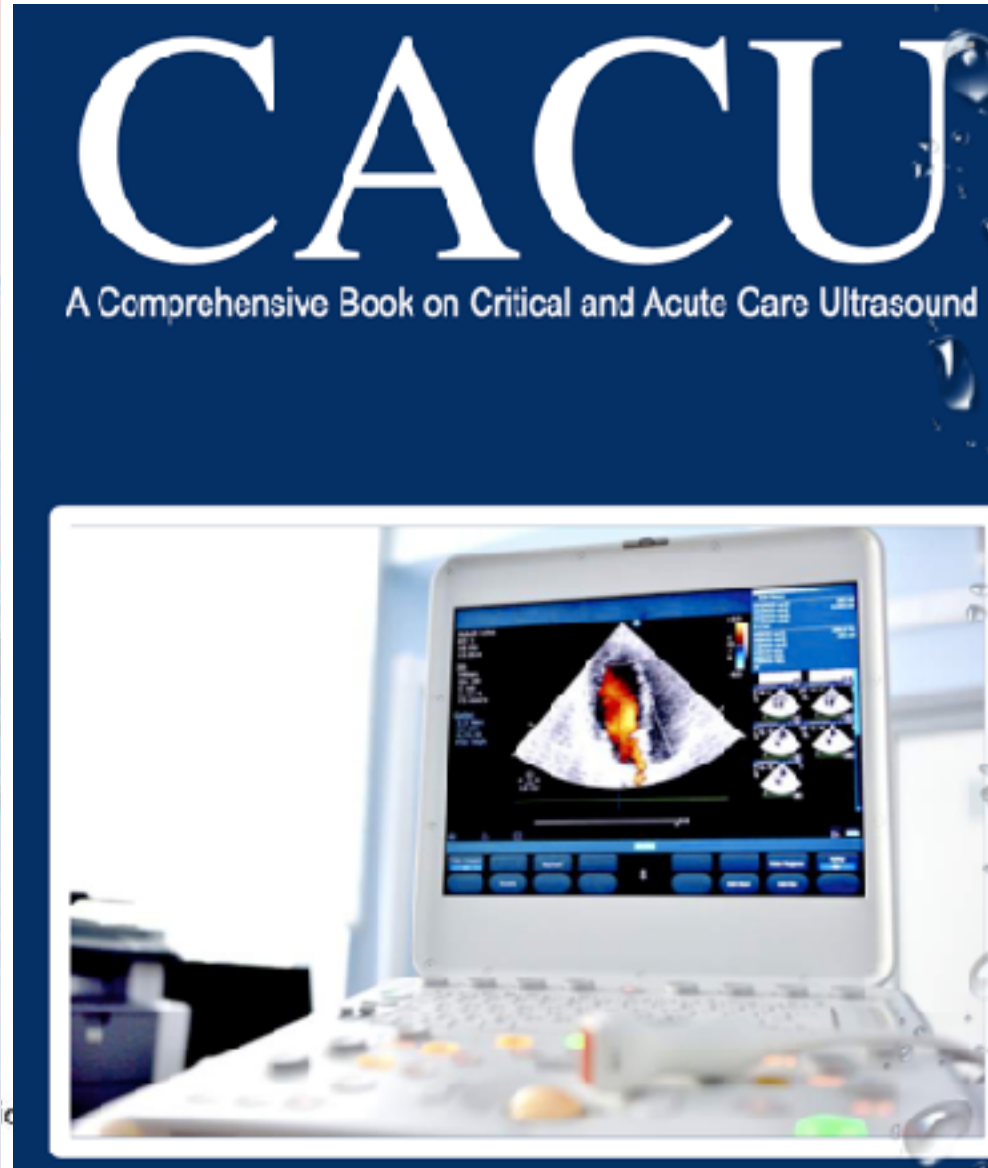

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RUSH for Shock

	Heart	IVC	FAST	Aorta	Pulmonary
Hypovolemic Shock	1. Hypercontractile 2. Small chamber size	Flat IVC	Peritoneal fluid	1. Aortic dissection 2. Aortic aneurysm	Pleural fluid
Cardiogenic Shock	1. Hypocontractile 2. Dilated heart	Distended IVC	Peritoneal fluid	Normal	1. Pulmonary edema 2. Pleural fluid
Obstructive Shock	1. Hypercontractile 2. Pericardial effusion 3. Tamponade 4. RV strain 5. Thrombus	Distended IVC	Normal	DVT	Absent lung sliding
Distributive Shock	1. Hypercontractile or 2. Hypocontractile	Flat or normal IVC	Peritoneal fluid (peritonitis)	Normal	Pleural fluid (empyema, pneumonia)

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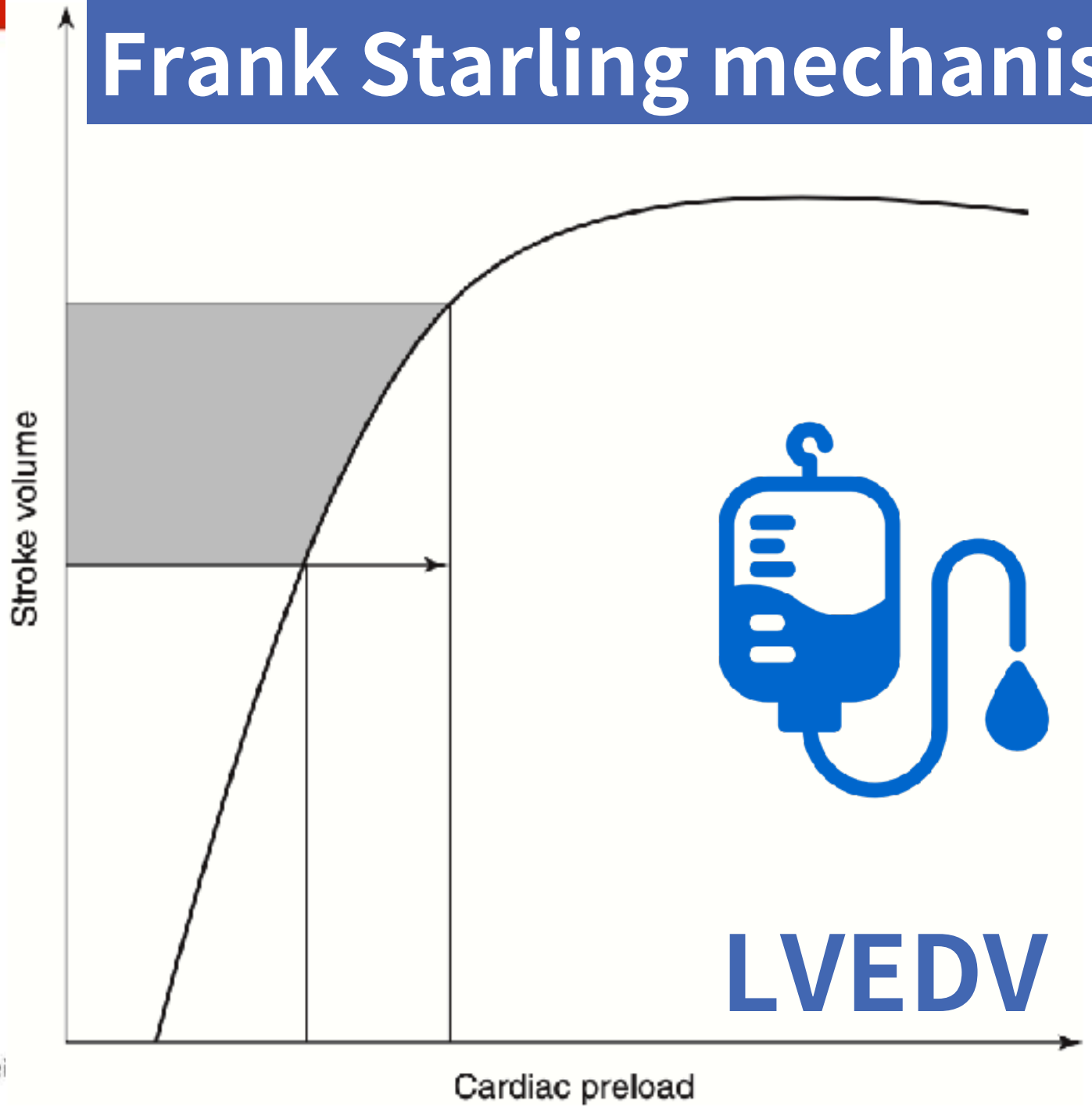
Shock Management

Taipei Medical University Center for Education in Medical Simulation

Frank Starling mechanism



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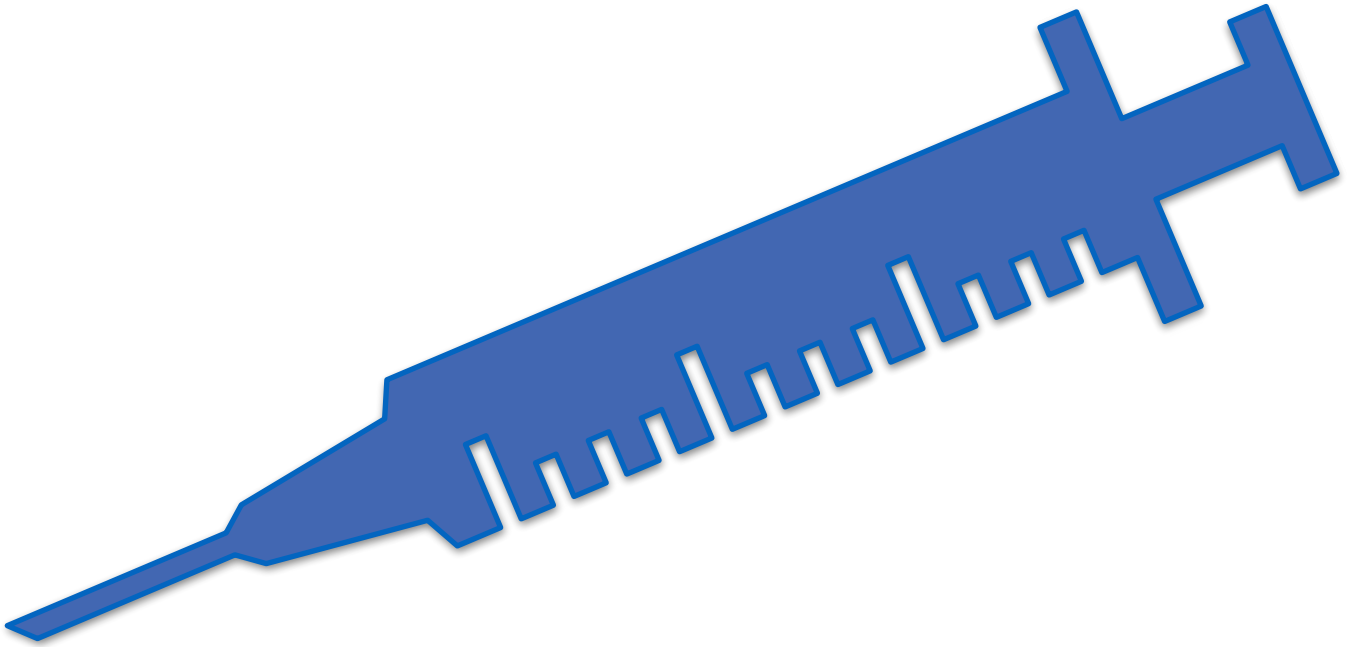
Fluid responsiveness



↑C.O. 10 - 15%

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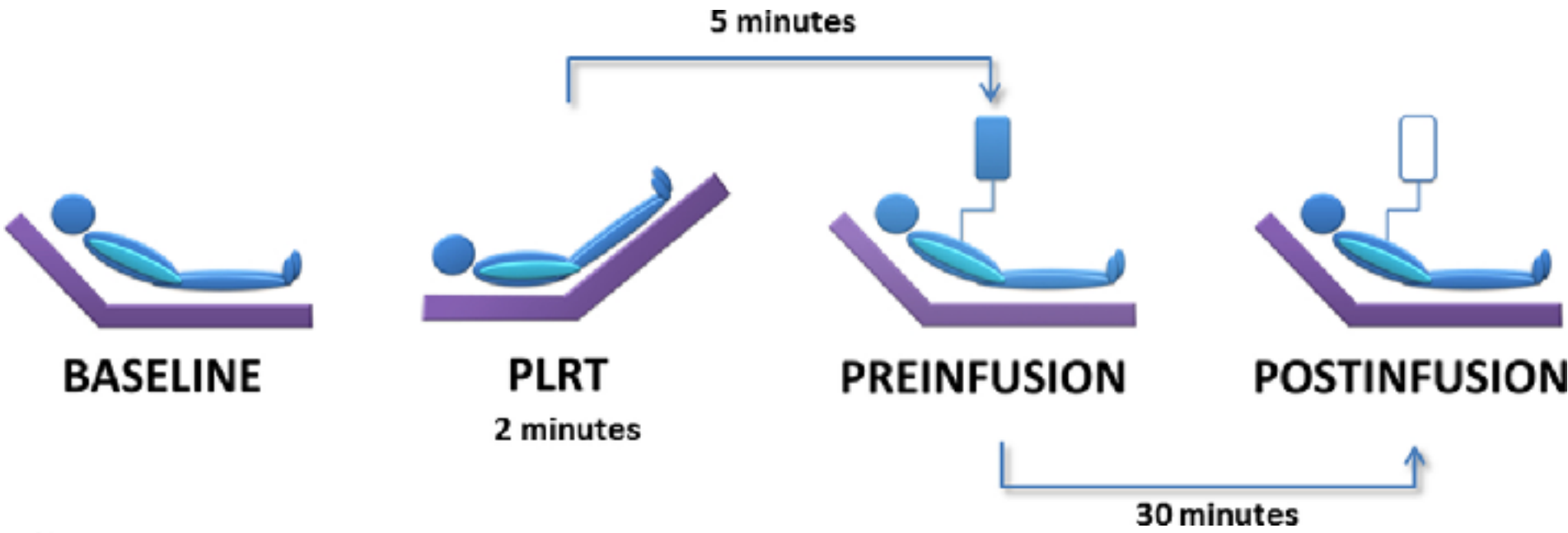
Passive Leg-Raising Test



Annals of Intensive Care 2012

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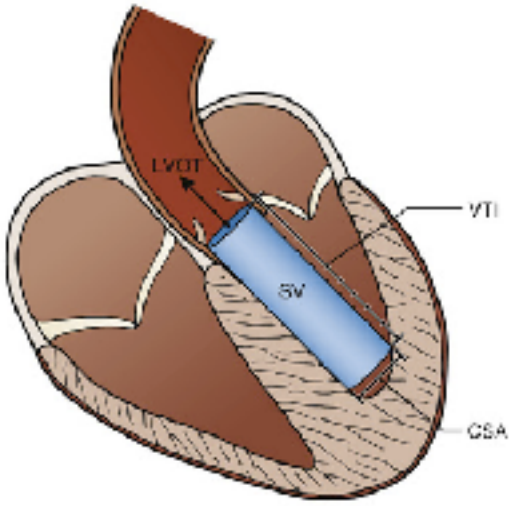
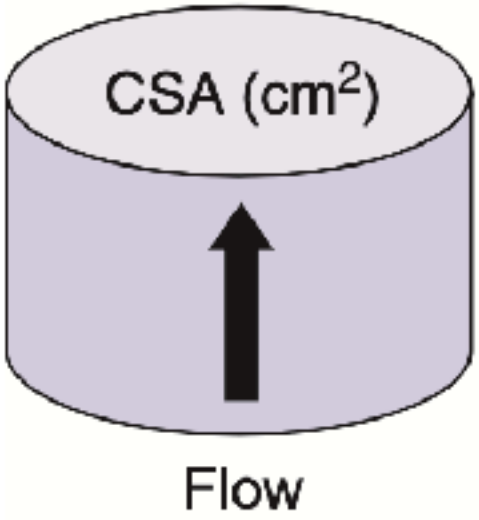
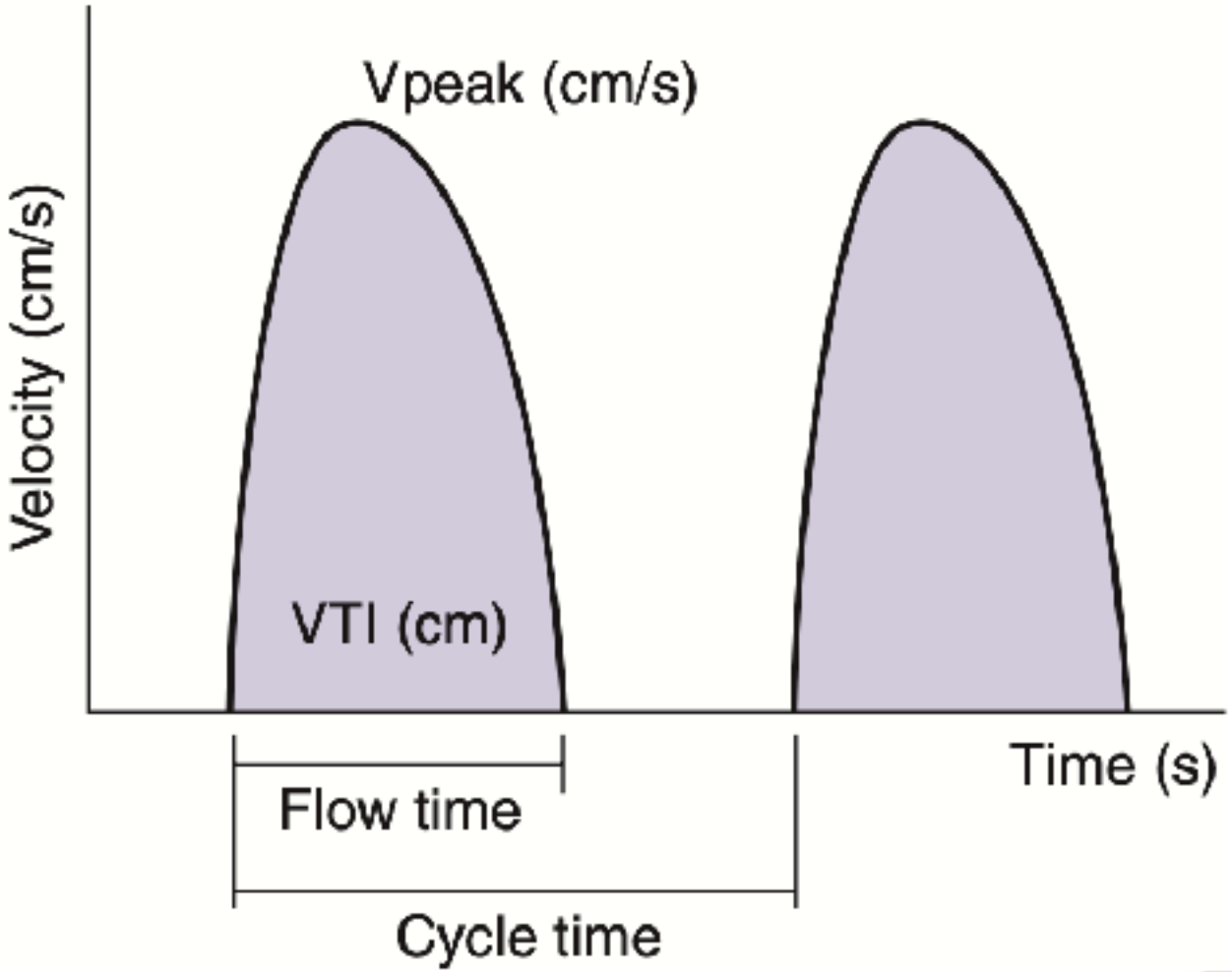
Techniques & Devices

Technique	Comment	Example of Device
Flow probe Doppler Electromagnetic	Sometimes used as a laboratory reference standard. Limited clinical application	
Fick method (O_2)	Requires a pulmonary artery catheter and metabolic cart. Often posed as the clinical reference standard but preconditions often not met in critical care	
Indirect Fick method (CO_2) Partial rebreathing technique	Partial rebreathing technique incorporating a number of mathematic assumptions, as well as changes in mechanically ventilated dead space, to remove the requirement for a pulmonary artery catheter	NiCO
Thermodilution	Pulmonary artery catheter (bolus or warm/semicontinuous)	
Transpulmonary indicator dilution Thermodilution Lithium Indocyanine green Dye dilution Pulsed dye densitometry		PICCO VolumeView LiDCO
Ultrasound indicator dilution (saline)	The indicator dilution curve is formulated from changes measured in ultrasound velocity (blood, 1560-1585; saline, 1533 m/sec)	COstatus
Esophageal Doppler		CardioQ HemoSonic WAKIe TO
Transcutaneous Doppler	May be applied to suprasternal (aortic valve) and parasternal (pulmonic valve) windows	USCOM
Arterial pressure waveform analysis		PICCO LiDCO Vigileo MostCare
Thoracic electrical bioimpedance		Lifegard TEBCO Hotman BioZ
Thoracic electrical bioreactance		NICOM



$$SV = CSA \times VTI$$





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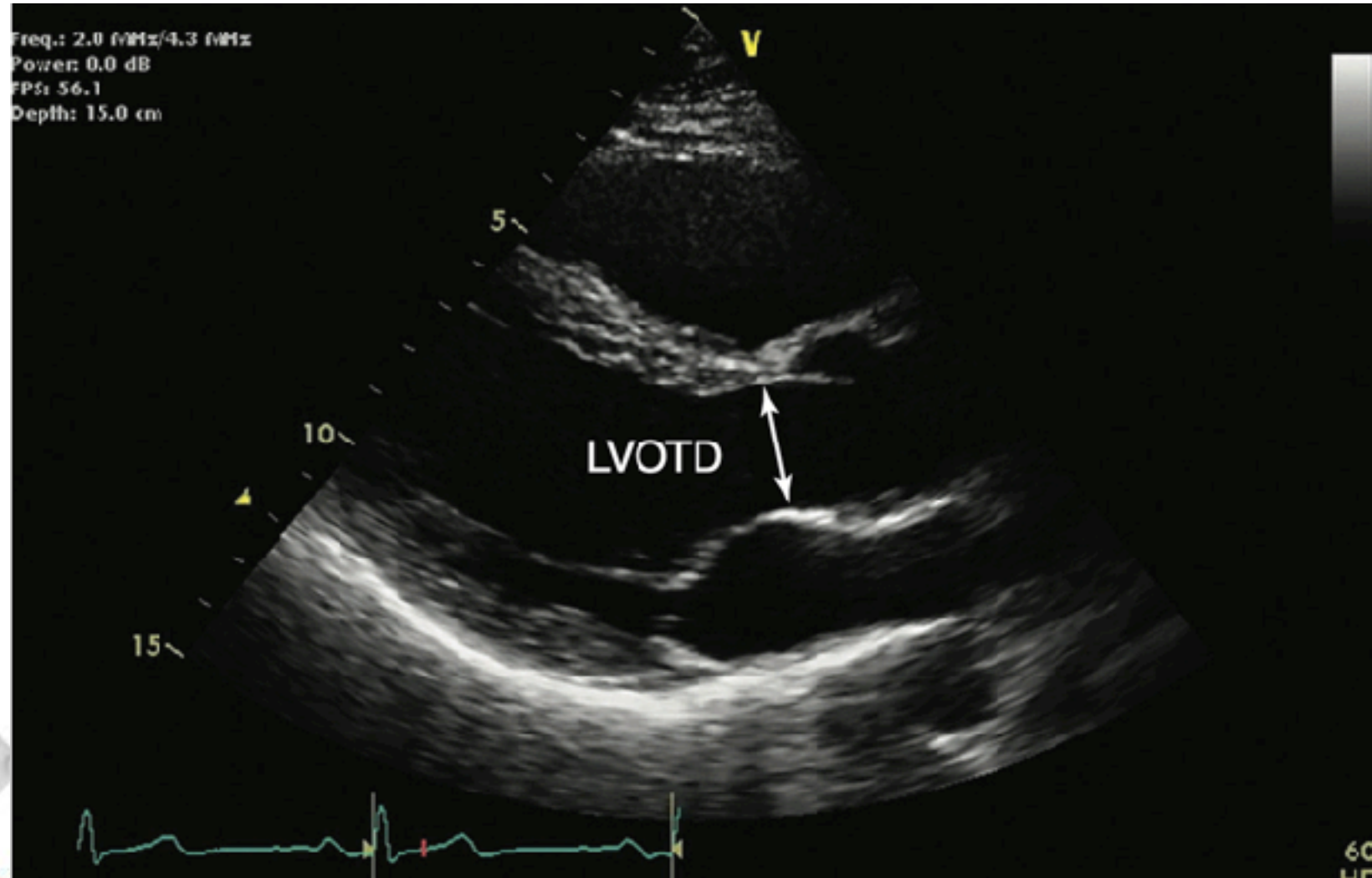
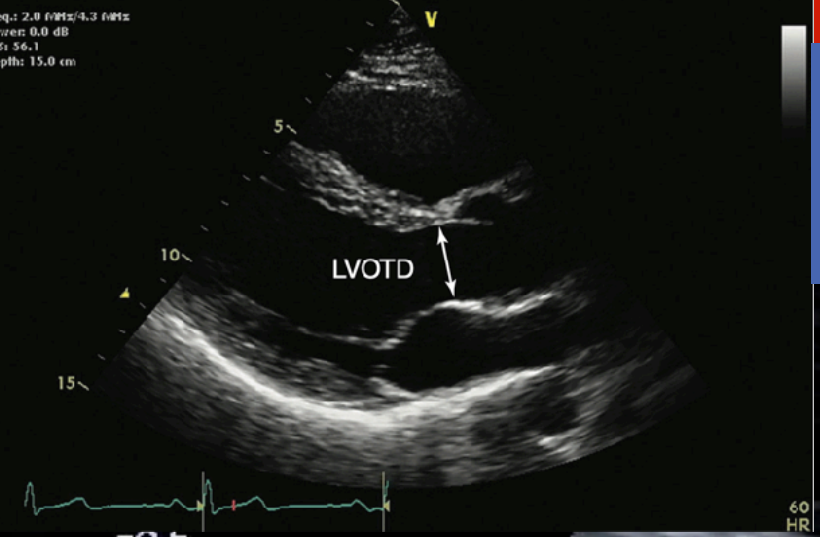
LV outflow tract



LVOT



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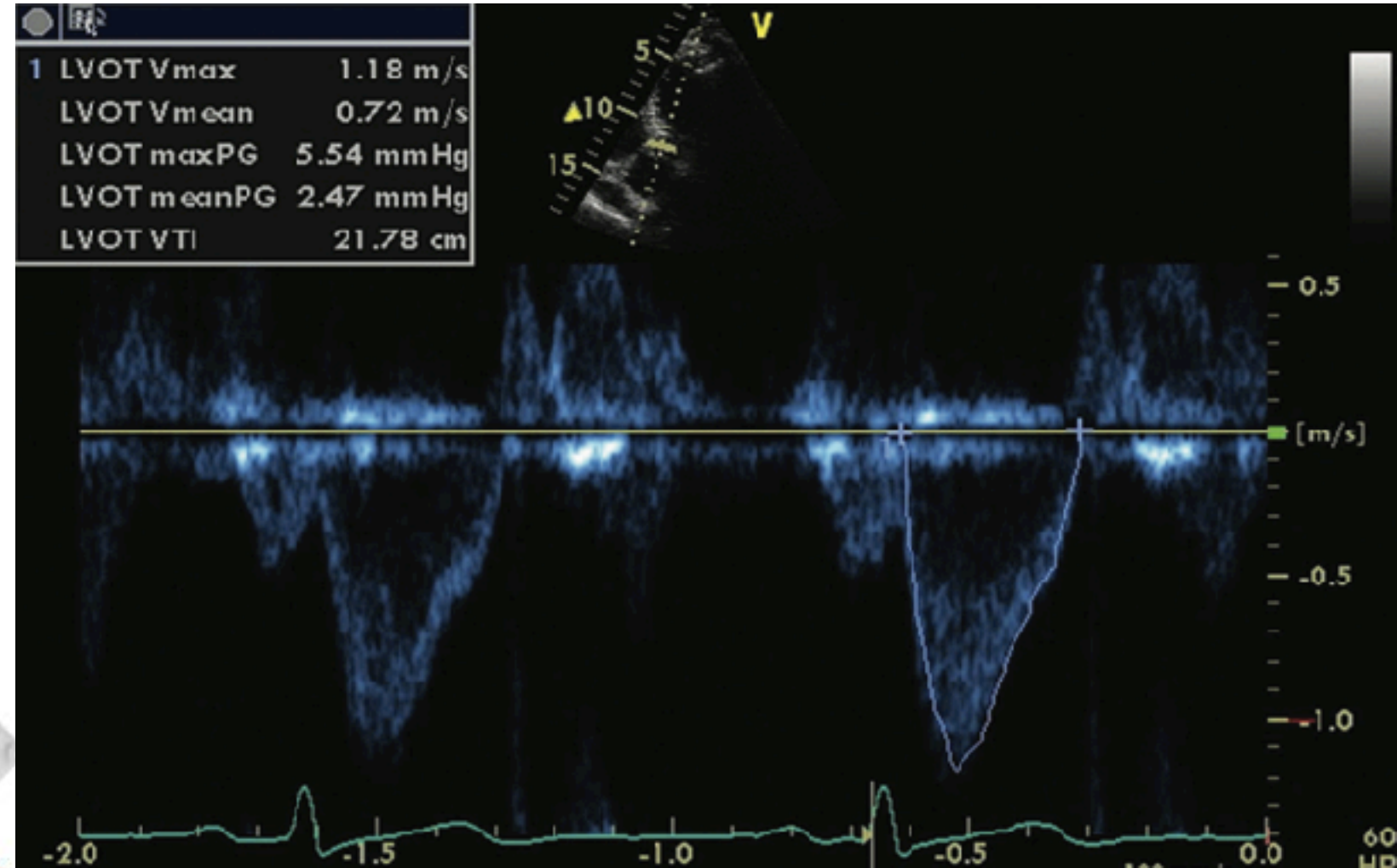
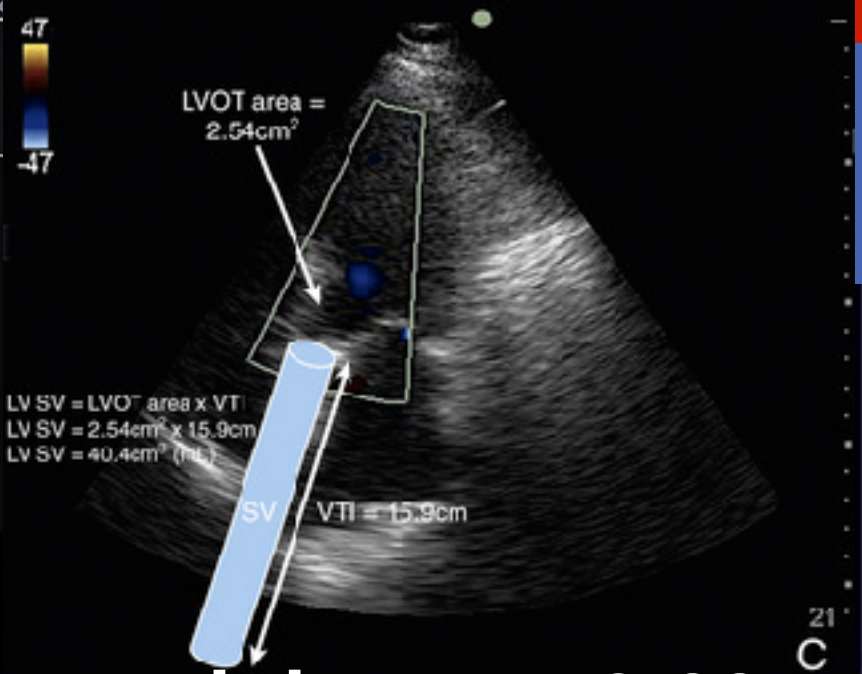
Velocity-time integral

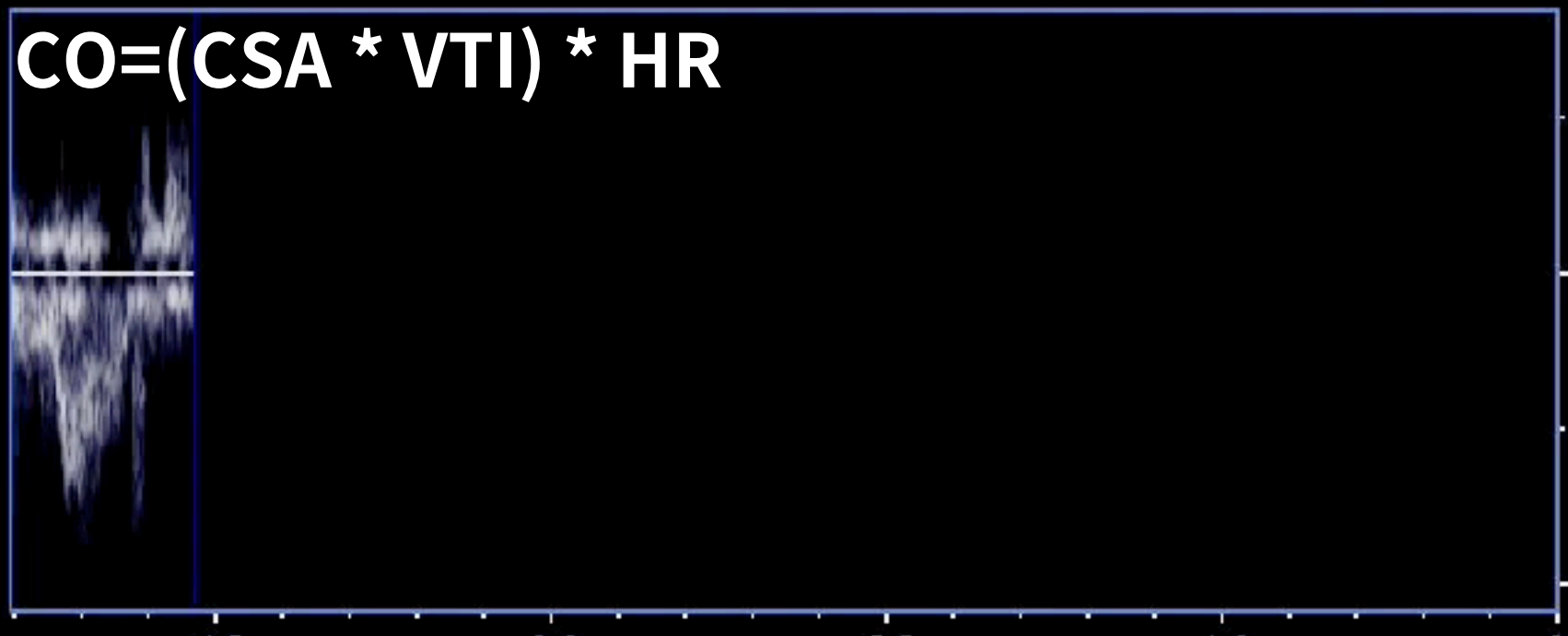


VTI



Adult VTI : 18-22cm

CO=(CSA * VTI) * HR



IVC : RV preload

Diameter 1~2 cm

Variation index: SB > 50% ; MV > 18%

IVC diameter (cm)	Collapse (%)	CVP (mean)mmH
<1	**> 50**	**0-5 (3)**
1-2	NA	5-10 (8)
>2	**<50**	**10-20 (15)**

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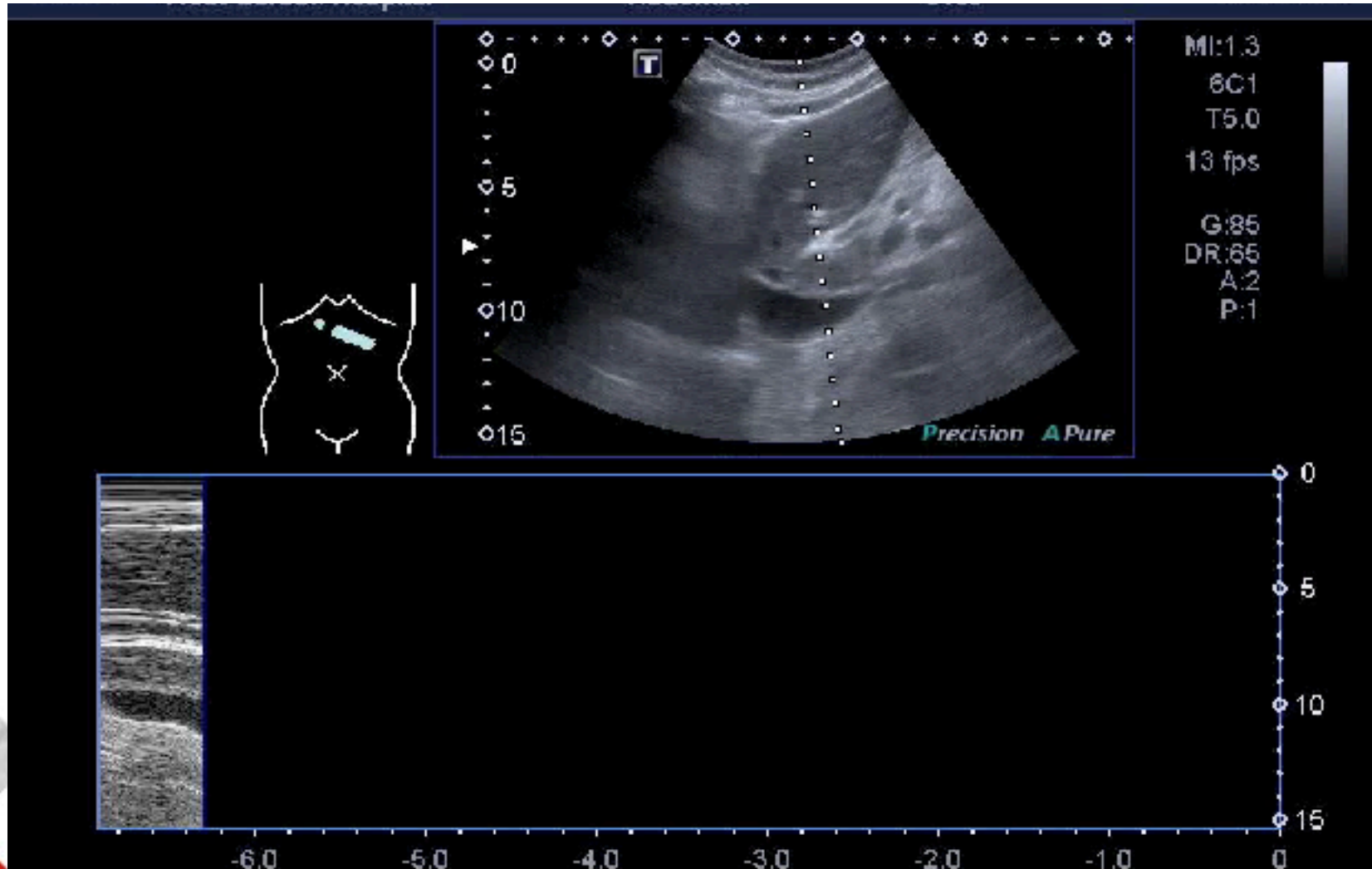
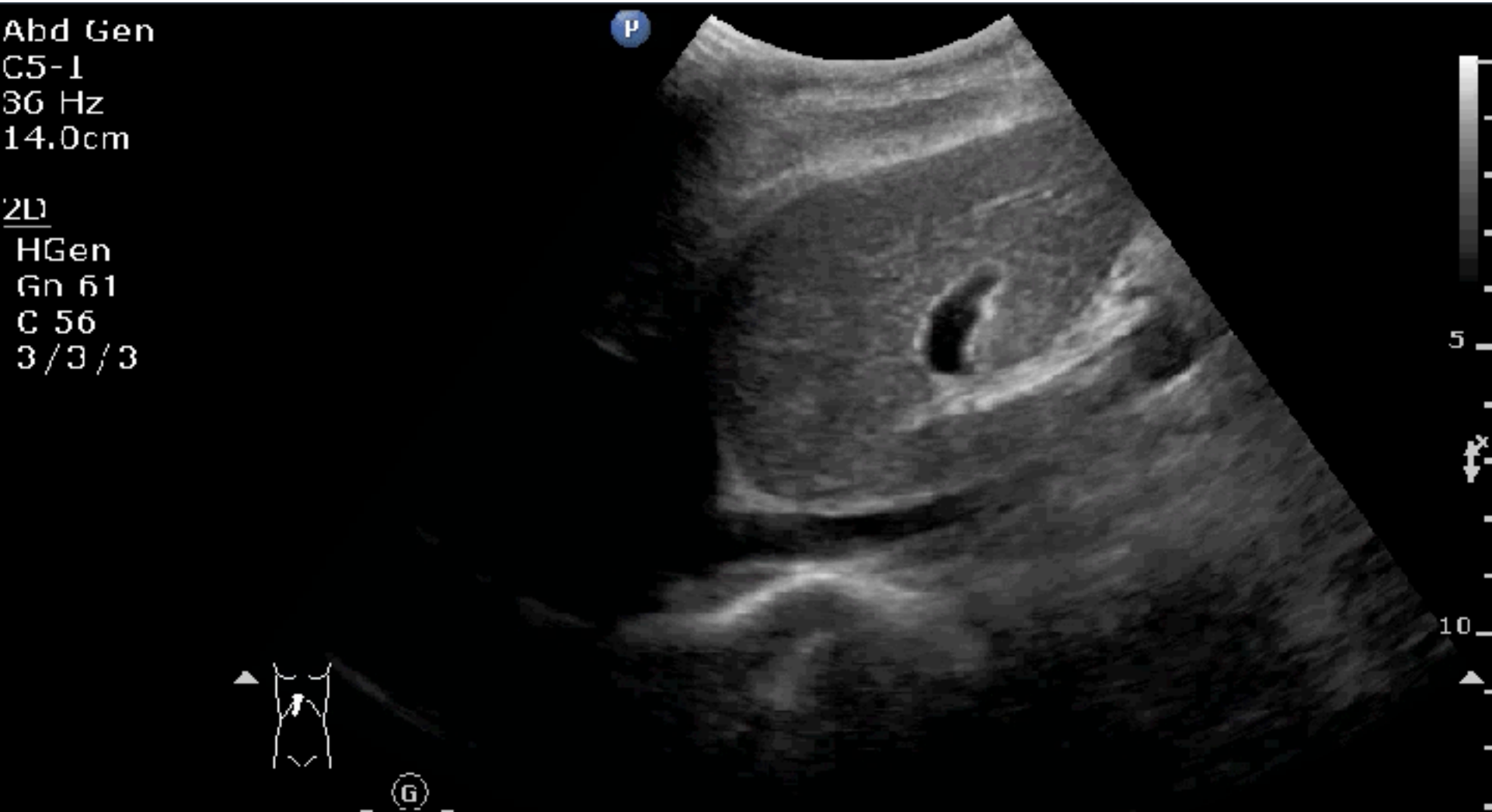
IVC variation



Fluid responder ?



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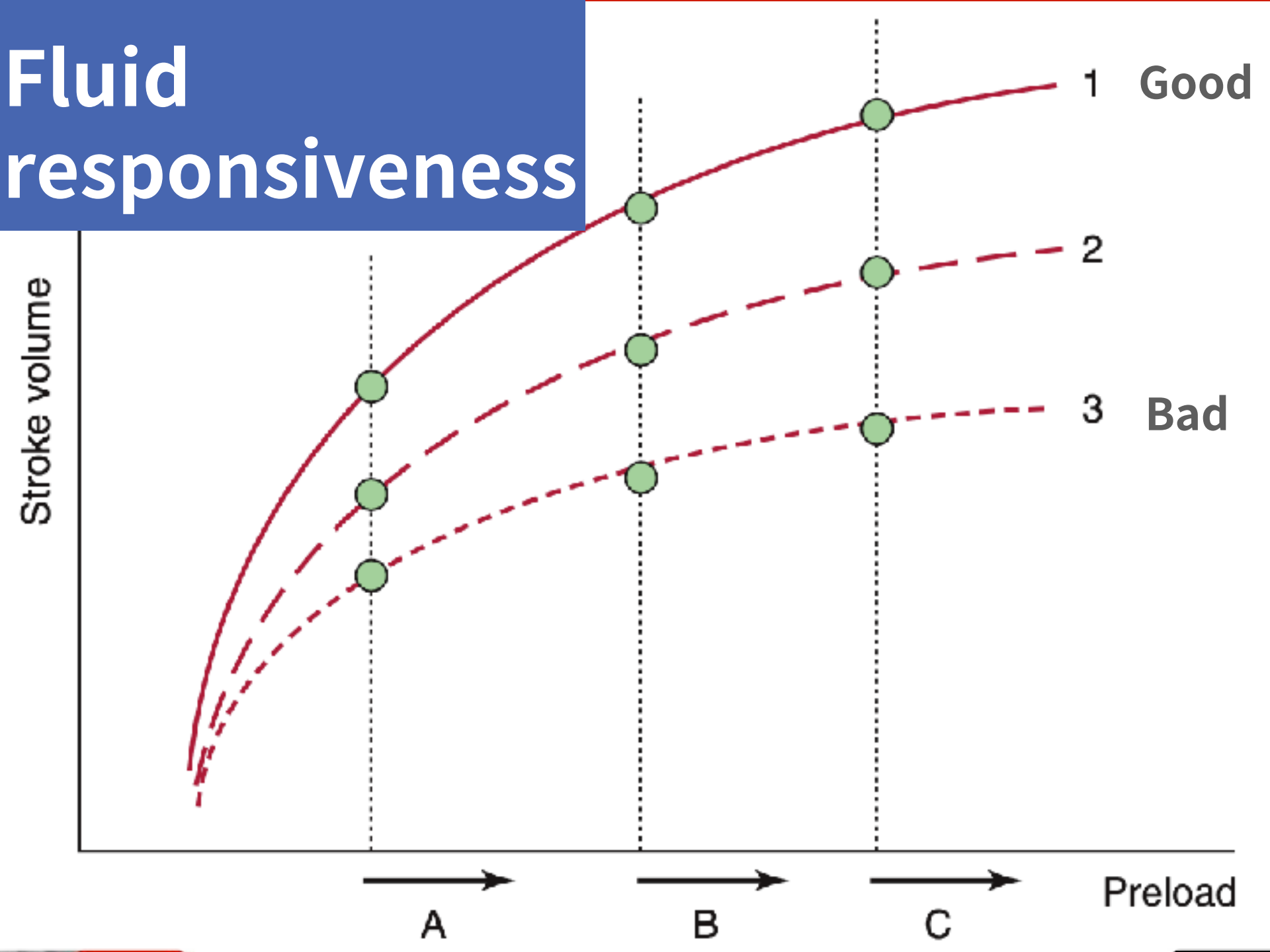
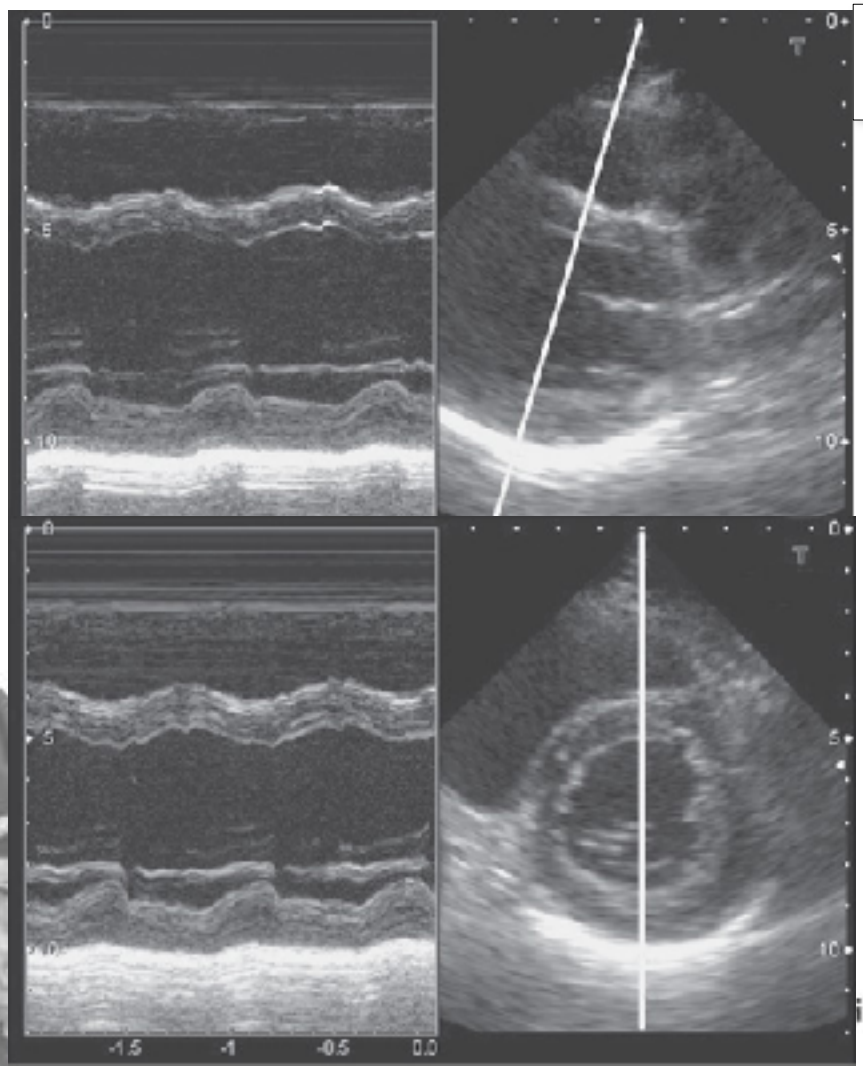
Fluid responder ?

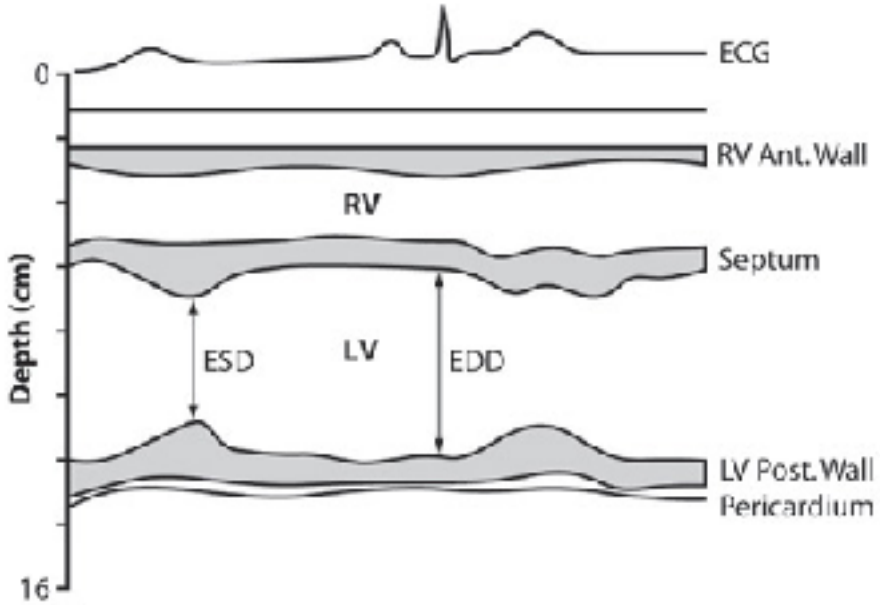
Fluid responsiveness



Fraction shortening



$$FS\ (\%) = 100 \times \frac{(LVEDD - LVESD)}{LVEDD}$$



NORMAL ≥ 30%

SEVERELY IMPAIRED < 20%

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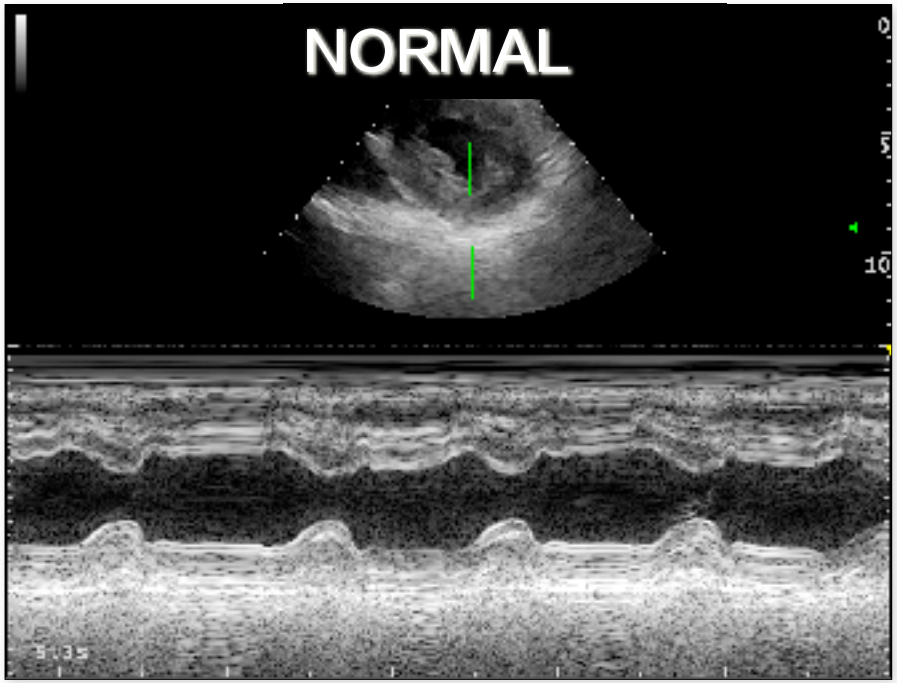
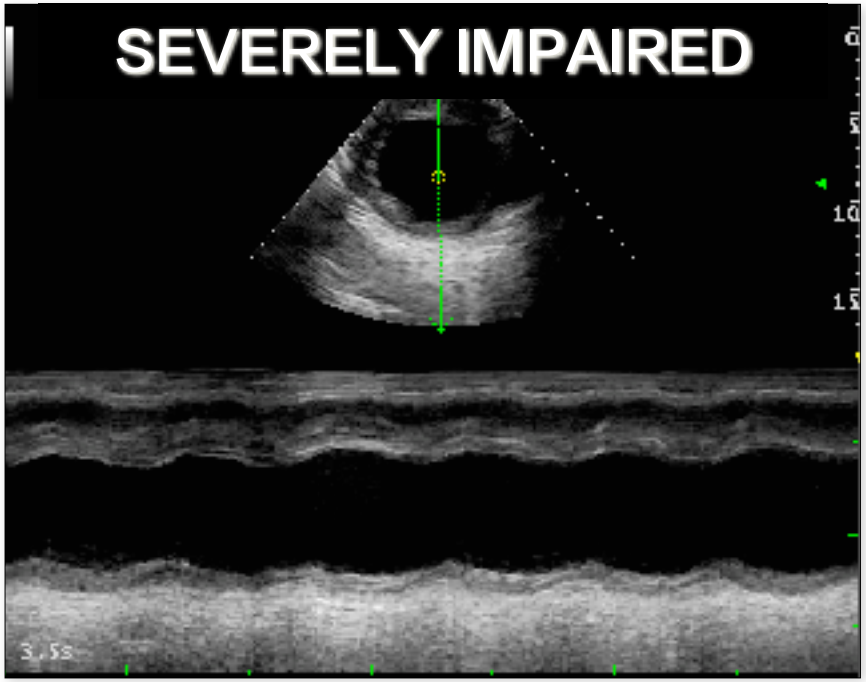
Fraction shortening





EF(%) ≈ FS(%) x 2 (ex. FS 30% ≈ EF 60%)

(Simplification of Teicholz method)

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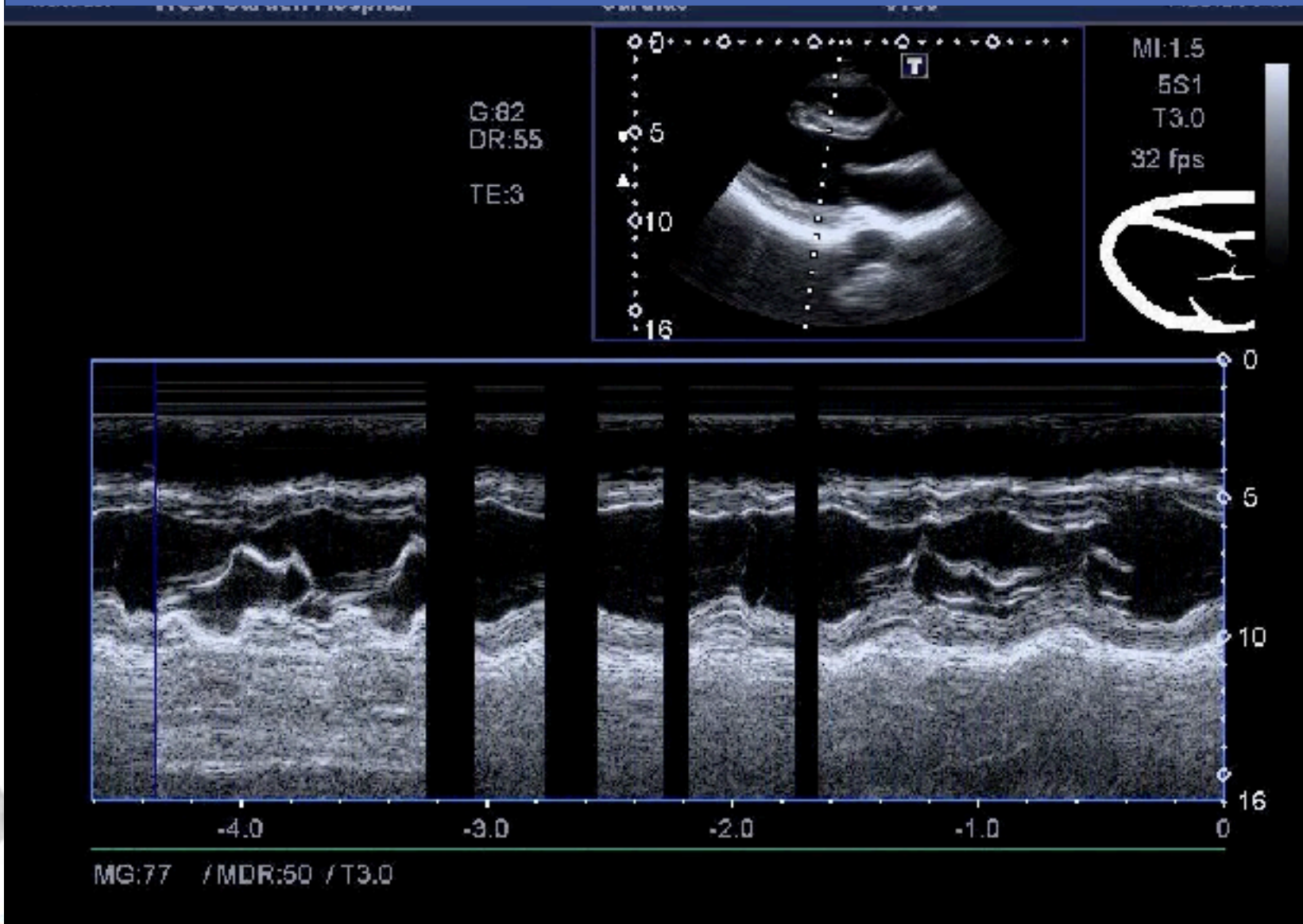
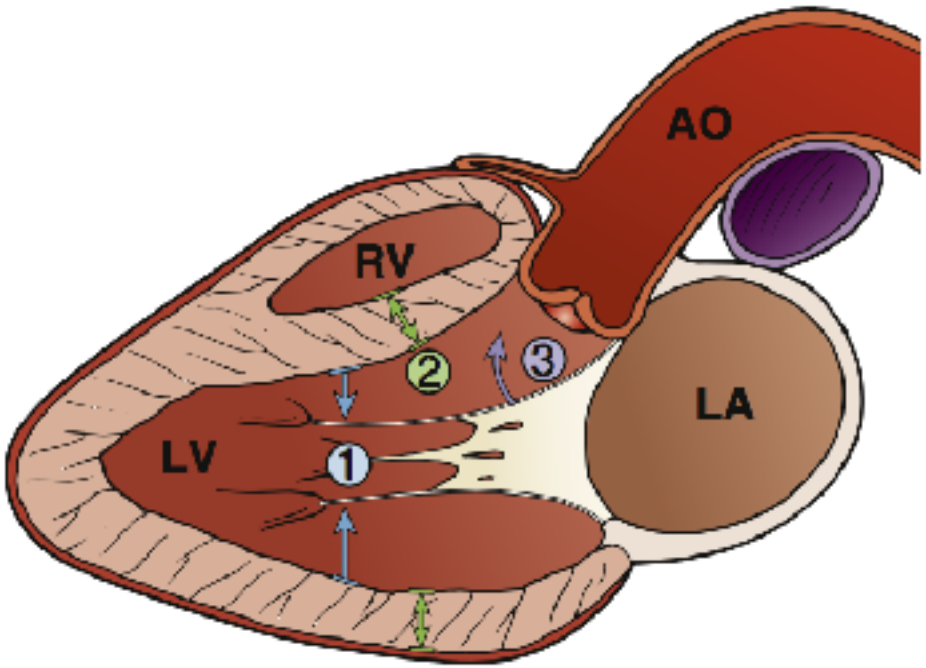
Fraction shortening

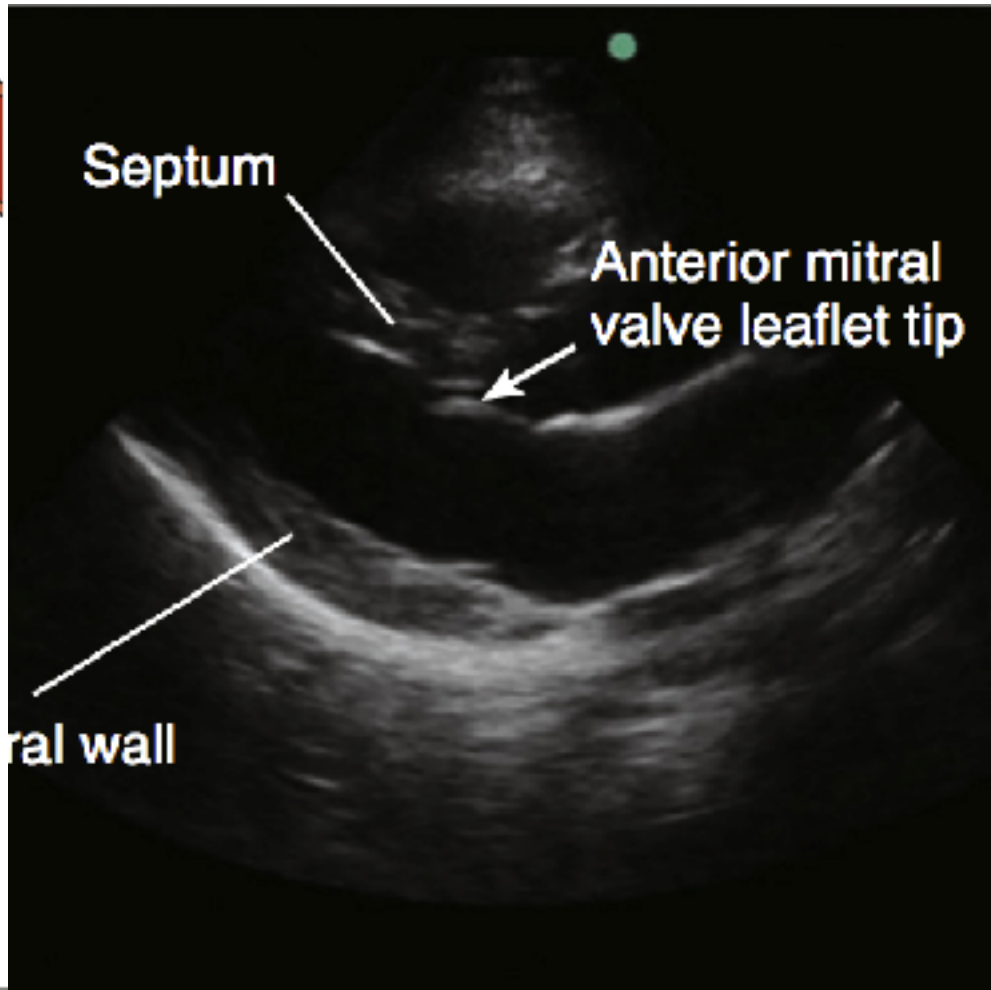


EPSS

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



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



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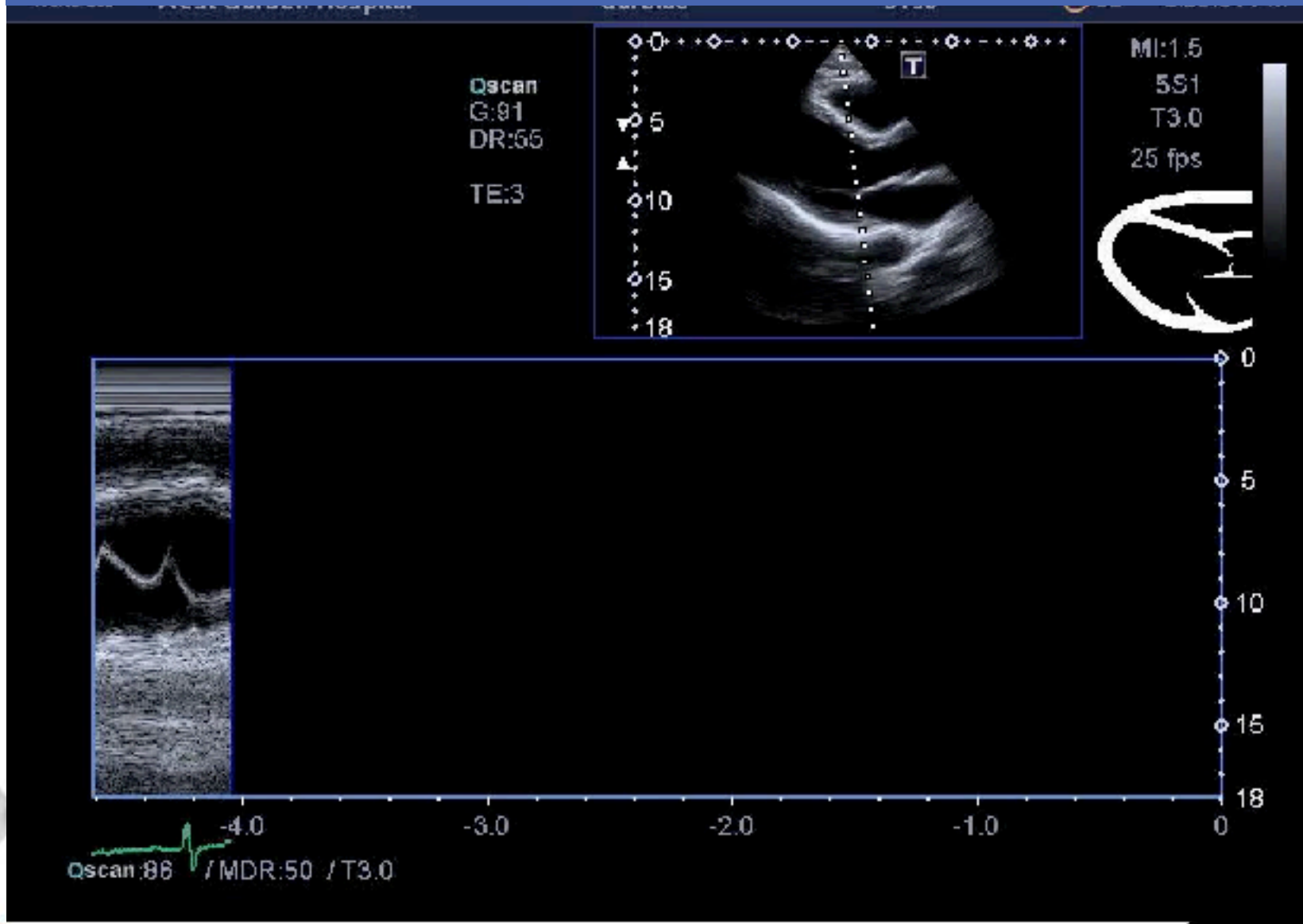
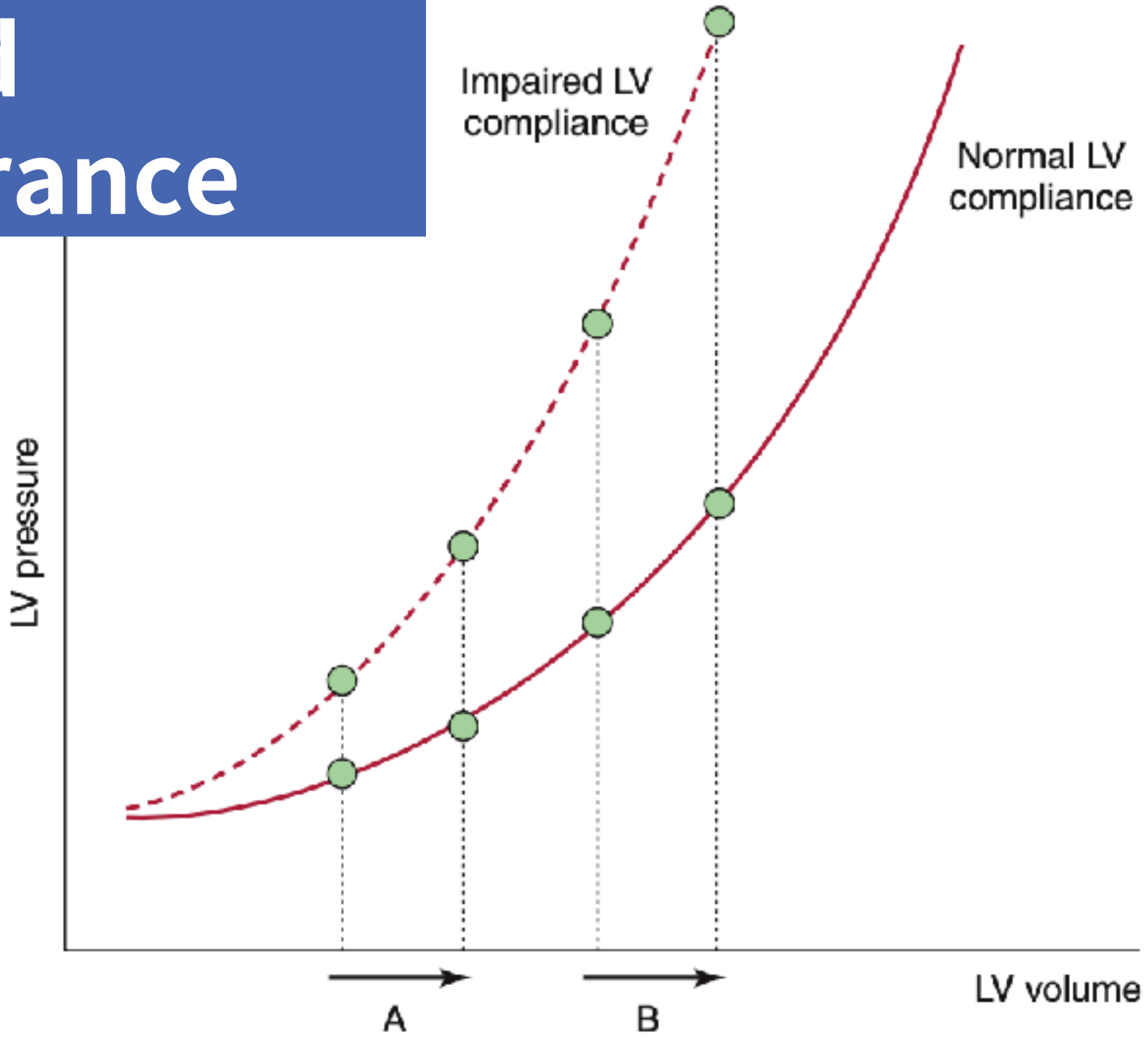
EPSS



Fluid tolerance



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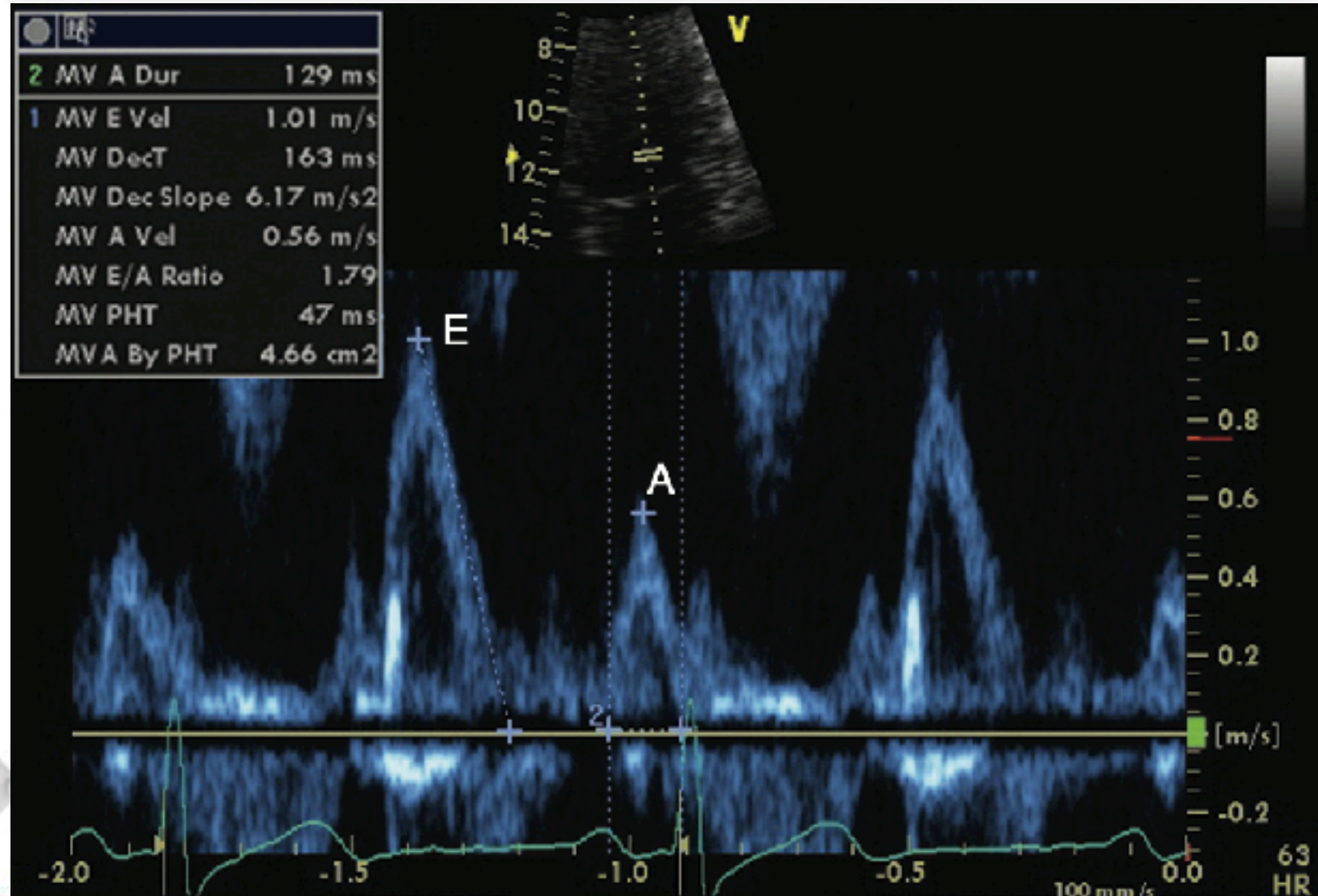
Mitral inflow Doppler



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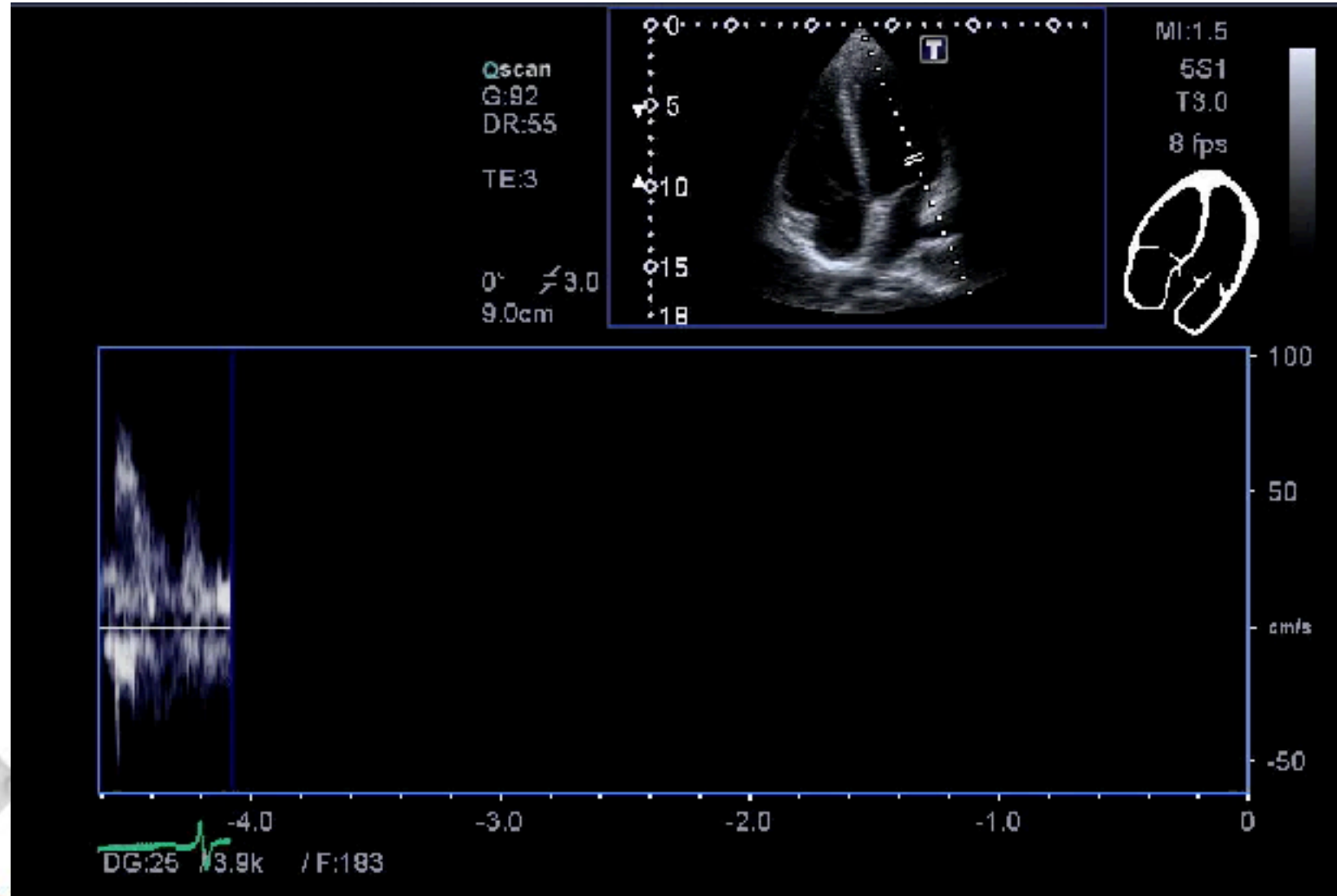
LV diastolic function



Algorithm for LV diastolic dysfunction

Septal and Lateral E′

Septal E′ ≥8, and
Lateral E′ ≥10, and
Left atrium < 34 ml/m^2

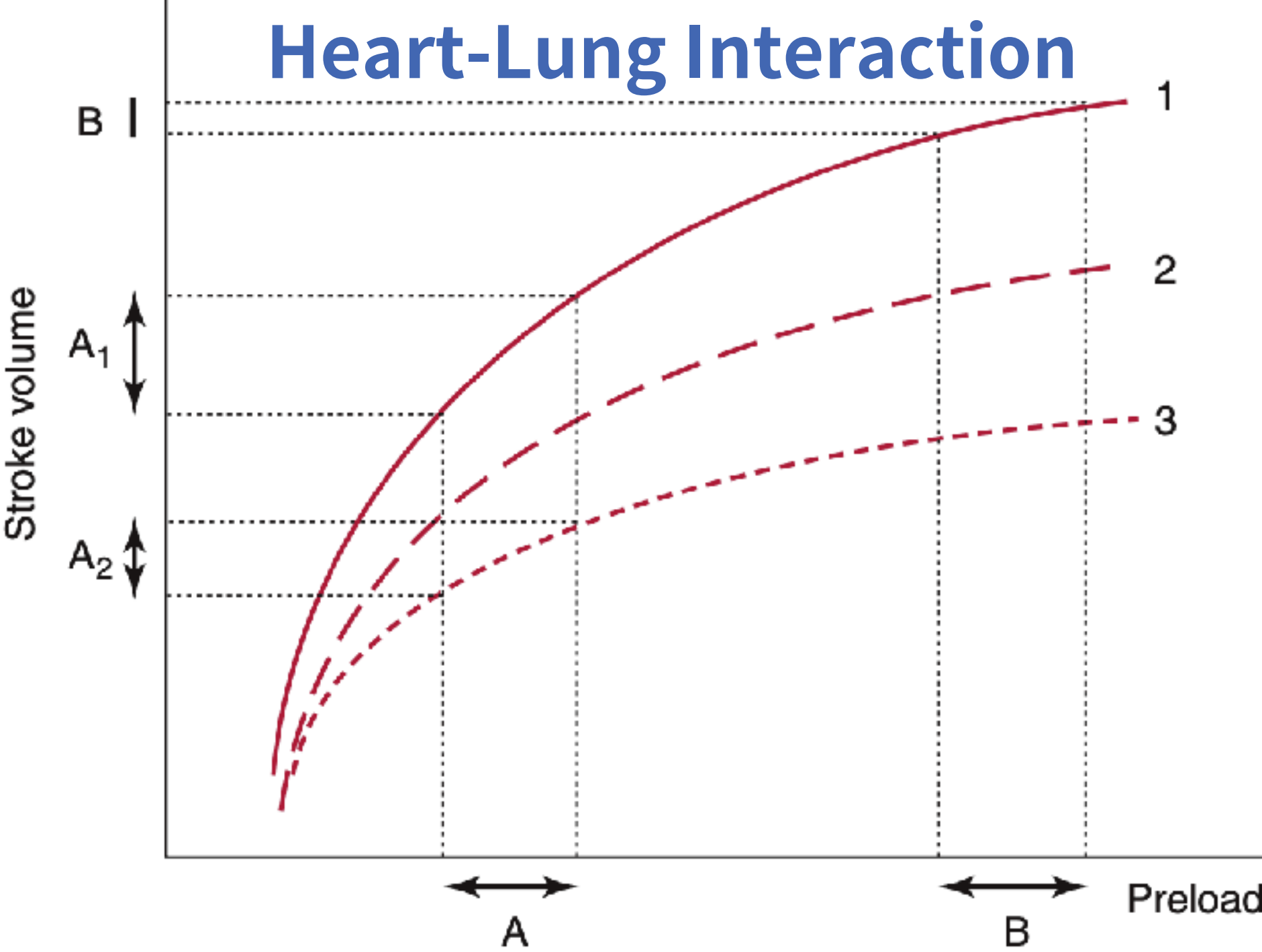
Septal E′ <8
Lateral E′ <10
Left atrium ≥ 34 ml/m^2

Normal function

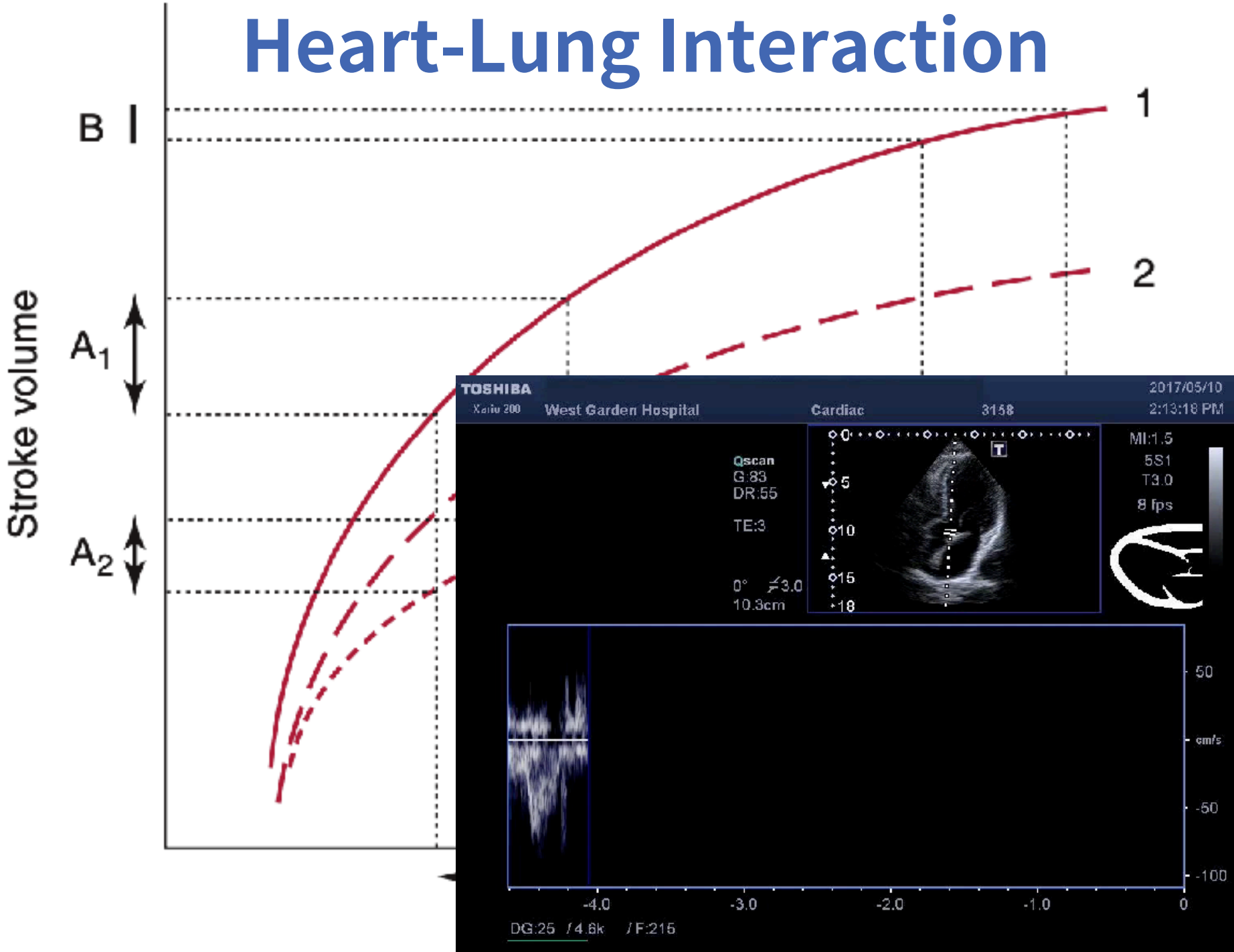
Diastolic dysfunction

Grade I:	Grade II:	Grade III:
E/A < 0.8	E/A < 0.8-1.5	E/A ≥ 2
DT > 200ms	DT > 160-200ms	DT < 160ms
Average E/E′ ≤ 8	Average E/E′ ≤ 9-12	Average E/E′ ≥ 13
Ar – A < 0ms	Ar – A ≥ 30ms	Ar – A ≥ 30ms

Heart-Lung Interaction



Heart-Lung Interaction



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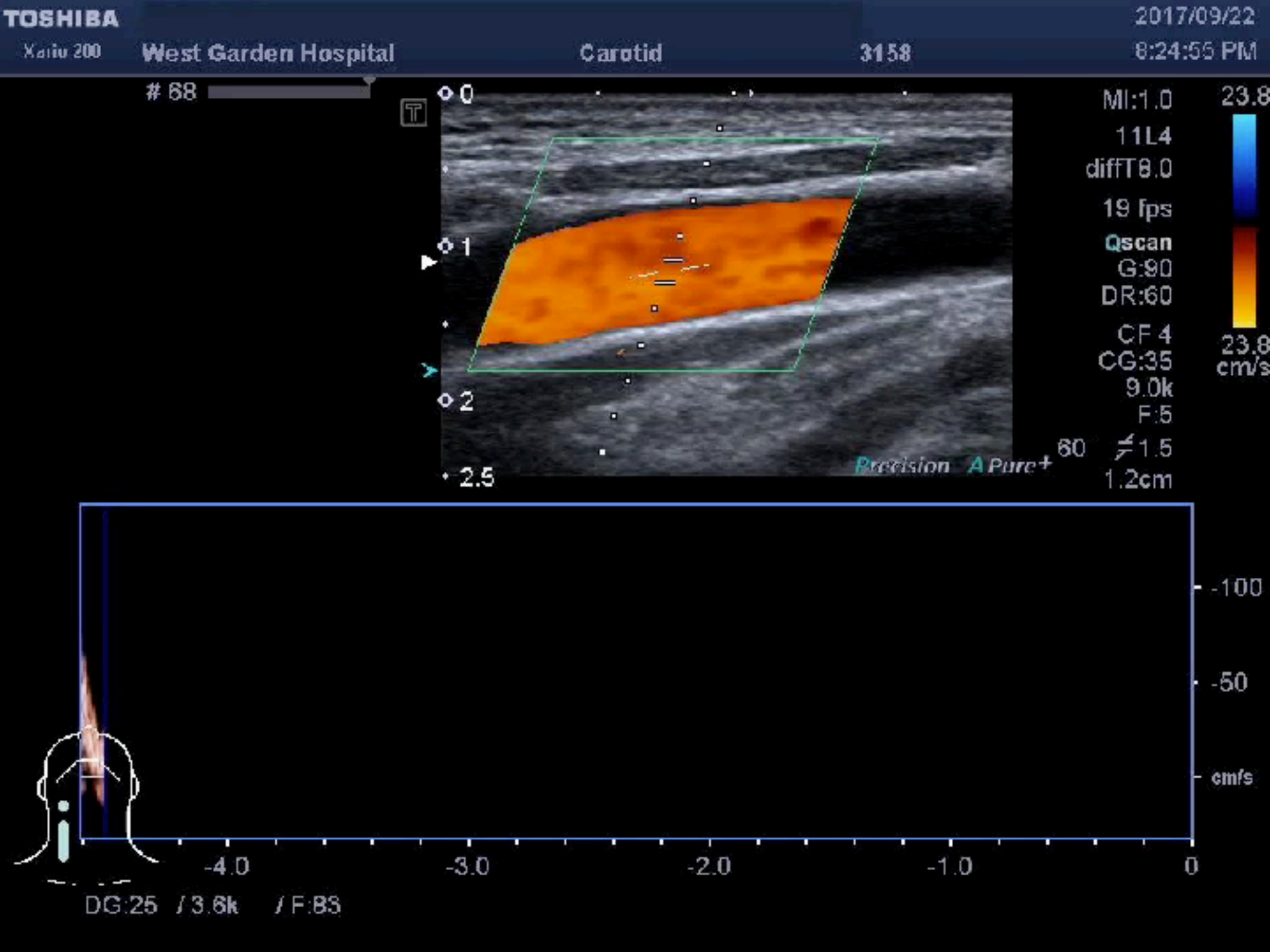
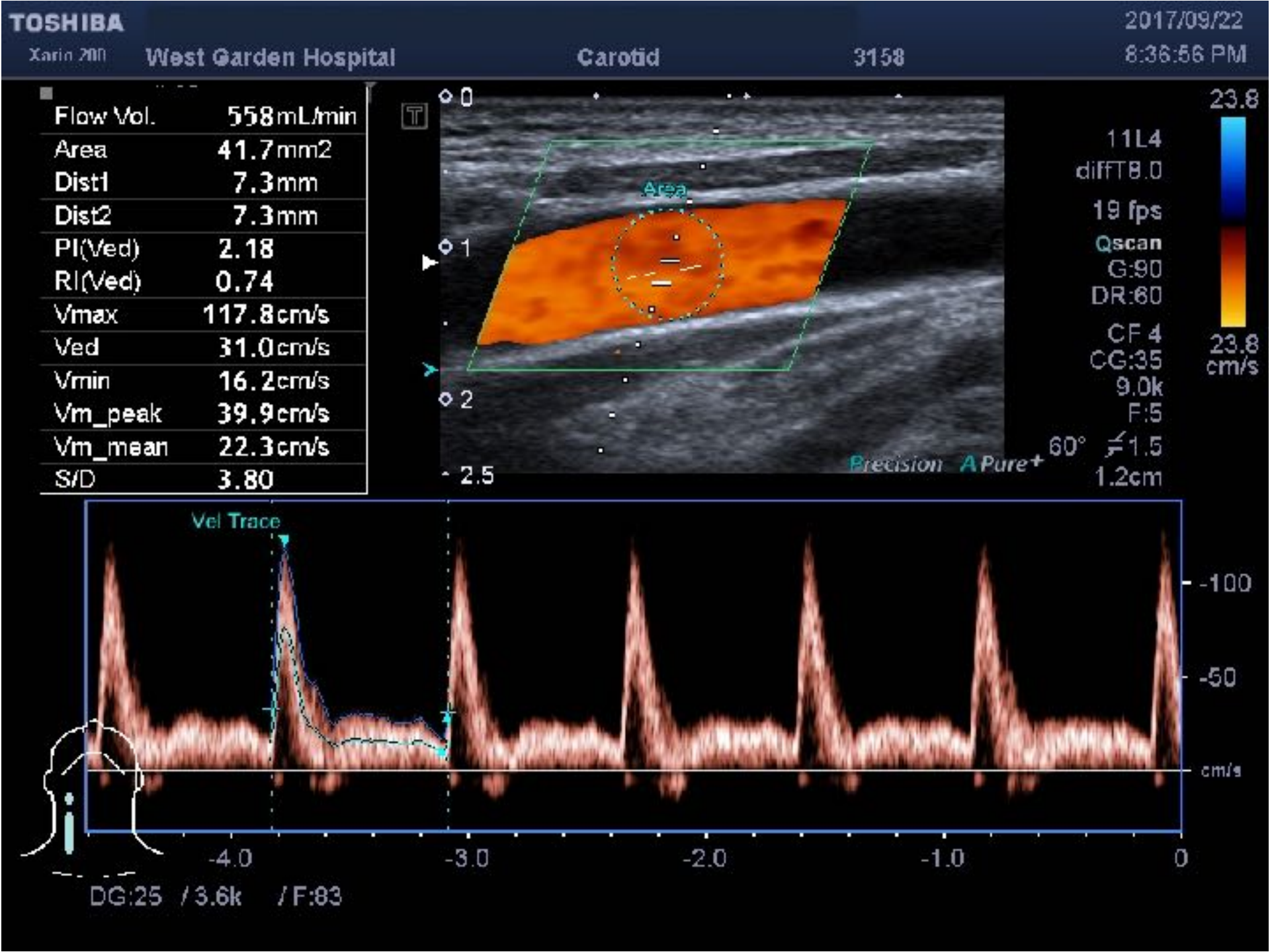
Carotid blood flow

$$\pi \times (\text{carotid diameter})^2/4 \times \text{VTI} \times \text{heart rate},$$


TOSHIBA
Xario 200
West Garden Hospital
Carotid
3158
2017/09/22
8:24:55 PM
68
0
1
2
2.5
MI:1.0
11L4
diffT8.0
19 fps
Qscan
G:90
DR:60
CF 4
CG:35
9.0k
F:5
1.5
1.2cm
60
Precision A Pure+
23.8
23.8
cm/s
-100
-50
cm/s
-4.0
-3.0
-2.0
-1.0
0
DG:25 / 3.6k / F:BS


TOSHIBA
Xario 200
West Garden Hospital
Carotid
3158
2017/09/22
8:36:56 PM
Flow Vol. 558mL/min
Area 41.7mm2
Dist1 7.3mm
Dist2 7.3mm
PI(Ved) 2.18
RI(Ved) 0.74
Vmax 117.8cm/s
Ved 31.0cm/s
Vmin 16.2cm/s
Vm_peak 39.9cm/s
Vm_mean 22.3cm/s
S/D 3.80
Area
0
1
2
2.5
Precision
APure+
11L4
diffT8.0
19 fps
Qscan
G:90
DR:60
CF 4
CG:35
9.0k
F:5
60°
1.5
1.2cm
23.8
23.8
cm/s
Vel Trace
-100
-50
cm/s
-4.0
-3.0
-2.0
-1.0
0
DG:25
/ 3.6k
/ F:83

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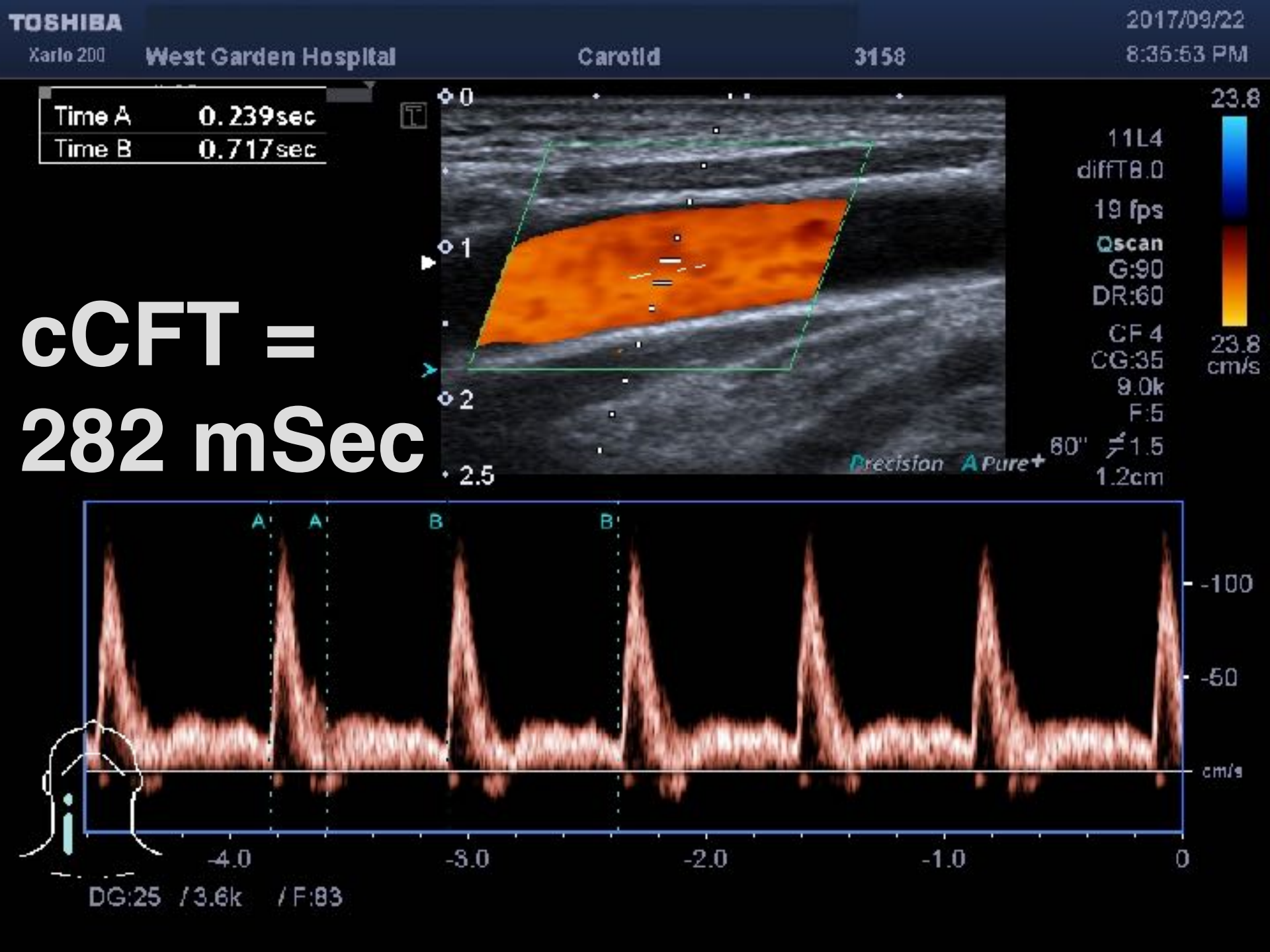
Corrected carotid flow time

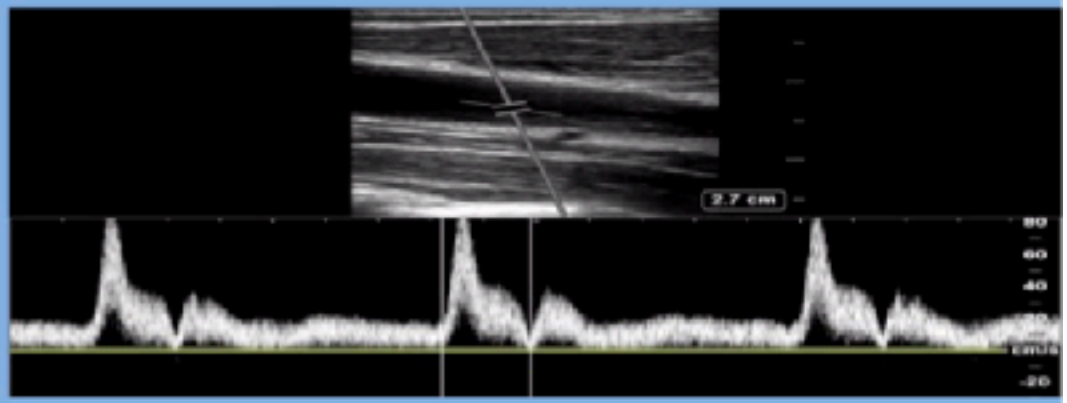
$$cCFT = \text{Systole time} / \sqrt{\text{cycle time}}$$


TOSHIBA
Xario 200
West Garden Hospital
Carotid
3158
2017/09/22
8:35:53 PM
Time A 0.239sec
Time B 0.717sec
11L4
diffT8.0
19 fps
Qscan
G:90
DR:60
CF 4
CG:35
9.0k
F:5
60"
1.5
1.2cm
Precision
A Pure+
23.8
23.8 cm/s
cCFT =
282 mSec
A
A
B
B
-100
-50
cm/s
-4.0
-3.0
-2.0
-1.0
0
DG:25
/3.6k
/F:83

ULTRASOUND PROGRAM

G.E.L.

CAROTID FLOW TIME



QUESTION:
Does the change in carotid corrected flow time (ccFT) by a passive leg raise predict fluid responsiveness in undifferentiated shock?

STUDY:
Prospective study of ICU patients in undifferentiated shock. Assessed ccFT vs NICOM. Responsiveness defined as ≥10% increase in stroke volume on the NICOM.

N=77

RESULTS

Using 7ms to define fluid responsiveness

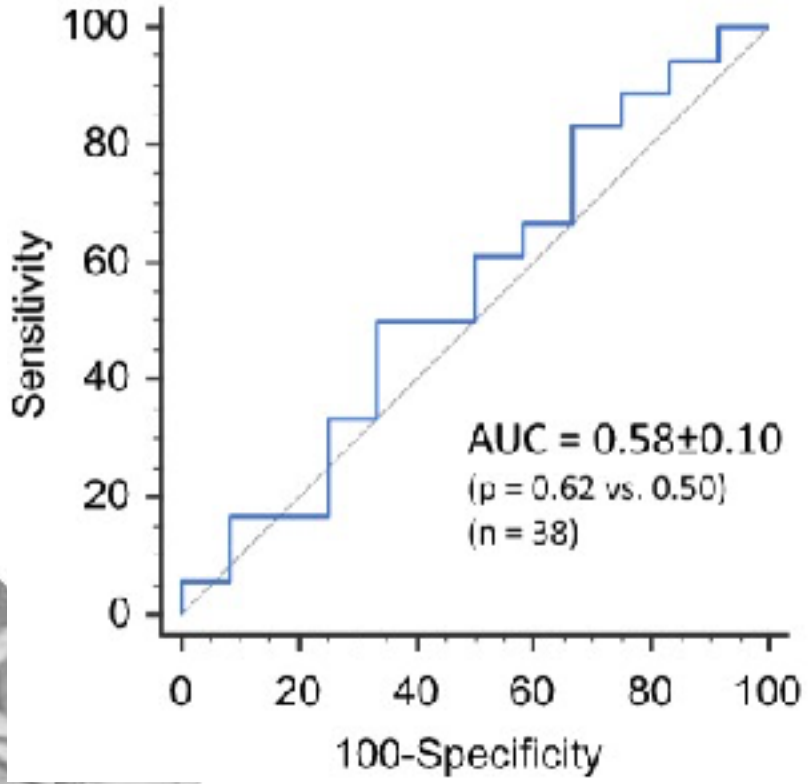
SENSITIVITY	SPECIFICITY
68%	96%

In undifferentiated shock patients, ccFT could identify fluid responders as defined by a noninvasive cardiac output device with an **AUC of 0.88.**

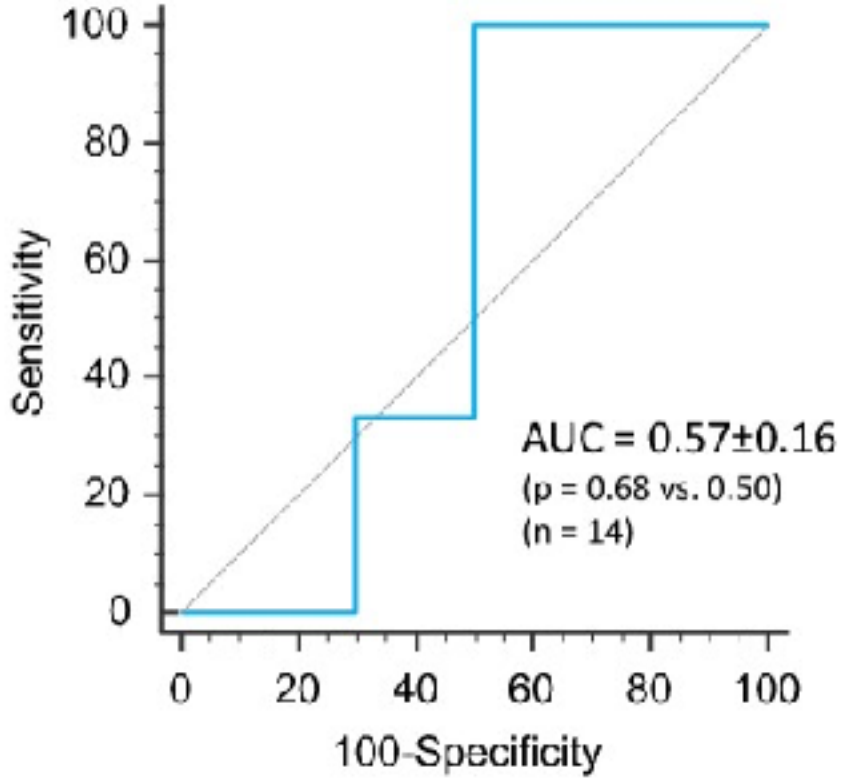
Barjaktarevic I, Toppen WE, Hu S et al. Ultrasound Assessment of the Change in Carotid Corrected Flow Time in Fluid Responsiveness in Undifferentiated Shock. Critical Care Medicine. 2018; 46(11): e1040-e1046

To detect a positive PLR test (increase in CI ≥ 10%)

Changes in carotid blood flow*



Changes in femoral blood flow



Ann Intensive Care. 2018; 8: 67.

TABLE 38-1 Ultrasound Indices Used to Predict Fluid Responsiveness

Index	Principle	Comments
STATIC INDICES		
Inferior vena cava diameter	Diameter inversely proportional to CVP and thus RV preload	Poor predictive value
LV area	LV area inversely proportional to LV preload	Poor predictive value. Kissing ventricles highly suggestive of a positive response to fluids
Mitral inflow pattern	Small E wave suggests low PAOP and thus low LV preload	Poor to moderate predictive value
Mitral inflow–to–mitral annulus ratio	Low E/Ea suggest low PAOP and thus low LV preload	Poor to moderate predictive value
DYNAMIC INDICES		
Respiratory variations in aortic flow	Mechanical ventilation induces cyclic changes in preload that result in cyclic changes in stroke volume only in preload-responsive patients	Well-validated physiologic concept. Excellent predictive value. Many limitations. Cutoff value 12%
Respiratory variations in superior vena cava diameter	Mechanical ventilation induces cyclic changes in preload that result in cyclic changes in superior vena cava diameter only in preload-responsive patients	Excellent predictive value. Cutoff value 35%. Validated in only 1 trial
Respiratory variations in inferior vena cava diameter	Respiration induces cyclic changes in preload that result in cyclic changes in inferior vena cava diameter only in preload-responsive patients	Good predictive value. Cutoff value 15-18% (with different formulas). Proposed but questioned in spontaneously breathing patients
Expiratory pause	Expiratory pause induces an abrupt increase in LV preload that results in an increase in stroke volume only in preload-responsive patients	Excellent predictive value. Cutoff value 12%. Validated in only 1 trial
Passive leg-raising test	Passive leg raising induces an abrupt increase in LV preload that results in an increase in stroke volume only in preload-responsive patients	Excellent predictive value. Cutoff value 12%. Validated in several trials. Also valid in spontaneously breathing patients. Cumbersome

CVP, Central venous pressure; *LV*, left ventricular; *PAOP*, pulmonary artery occlusion pressure; *RV*, right ventricular.

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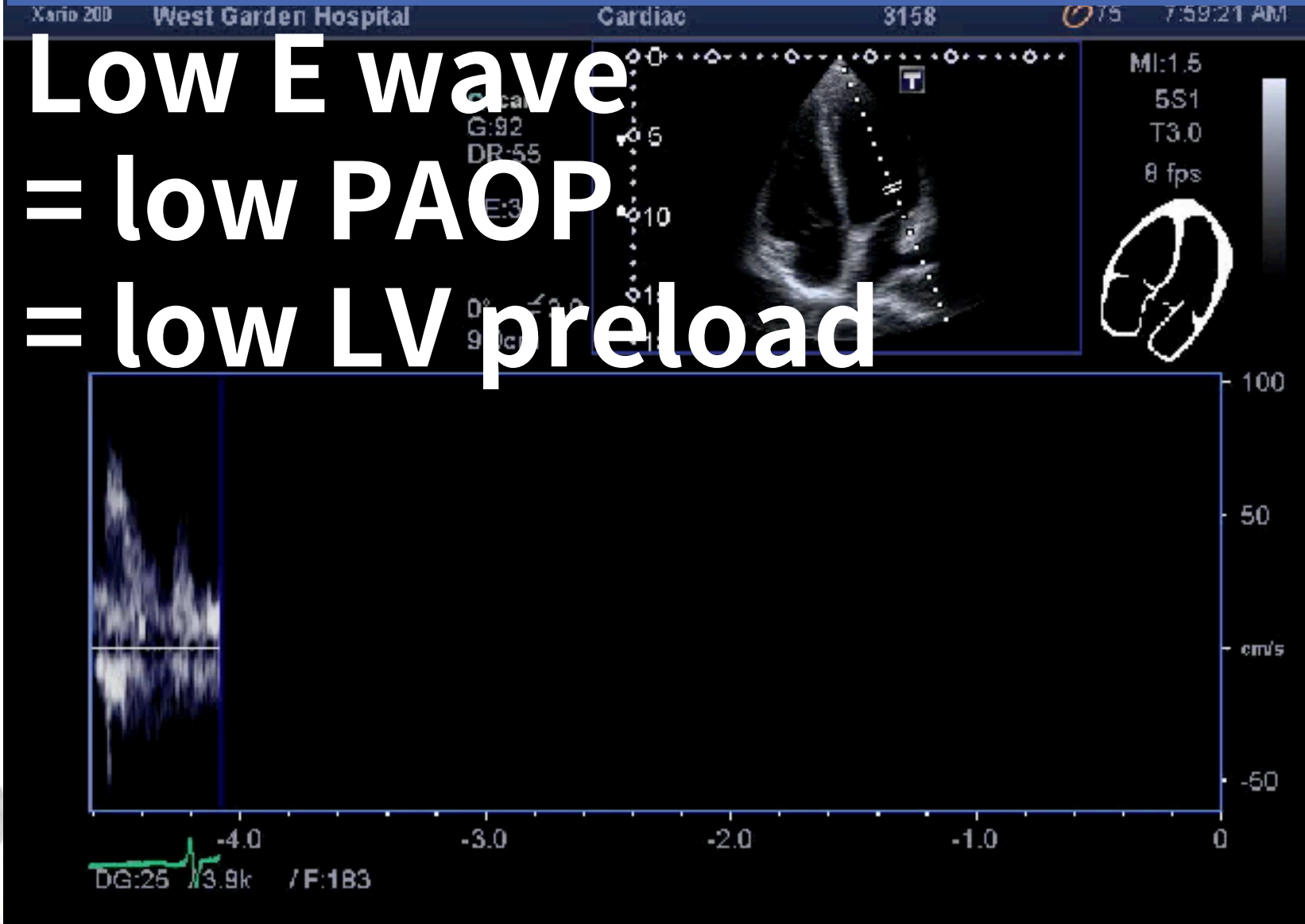
Mitral inflow pattern

Low E wave
= low PAOP
= low LV preload



ULTRASOUND
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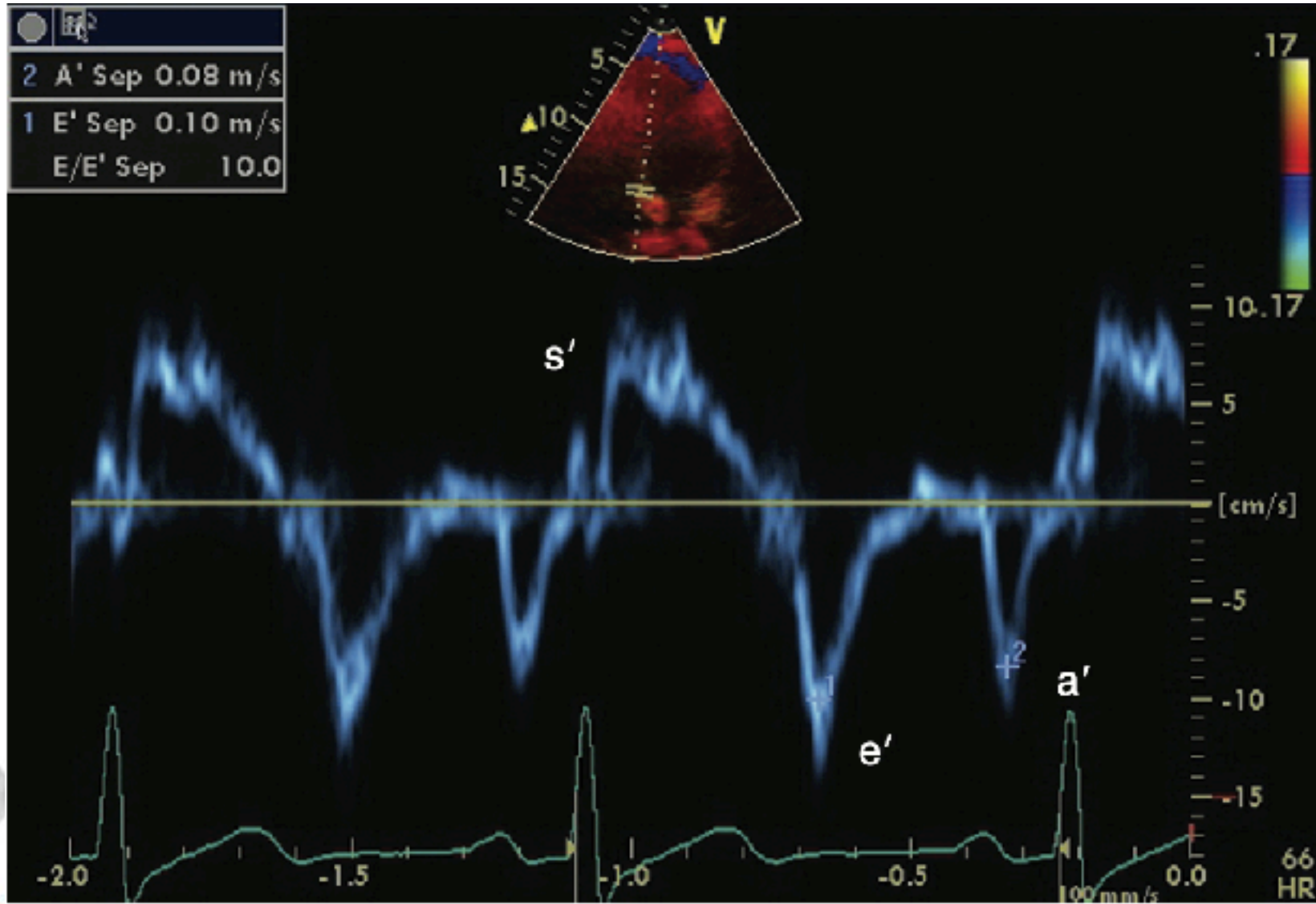
Tissue Doppler Image



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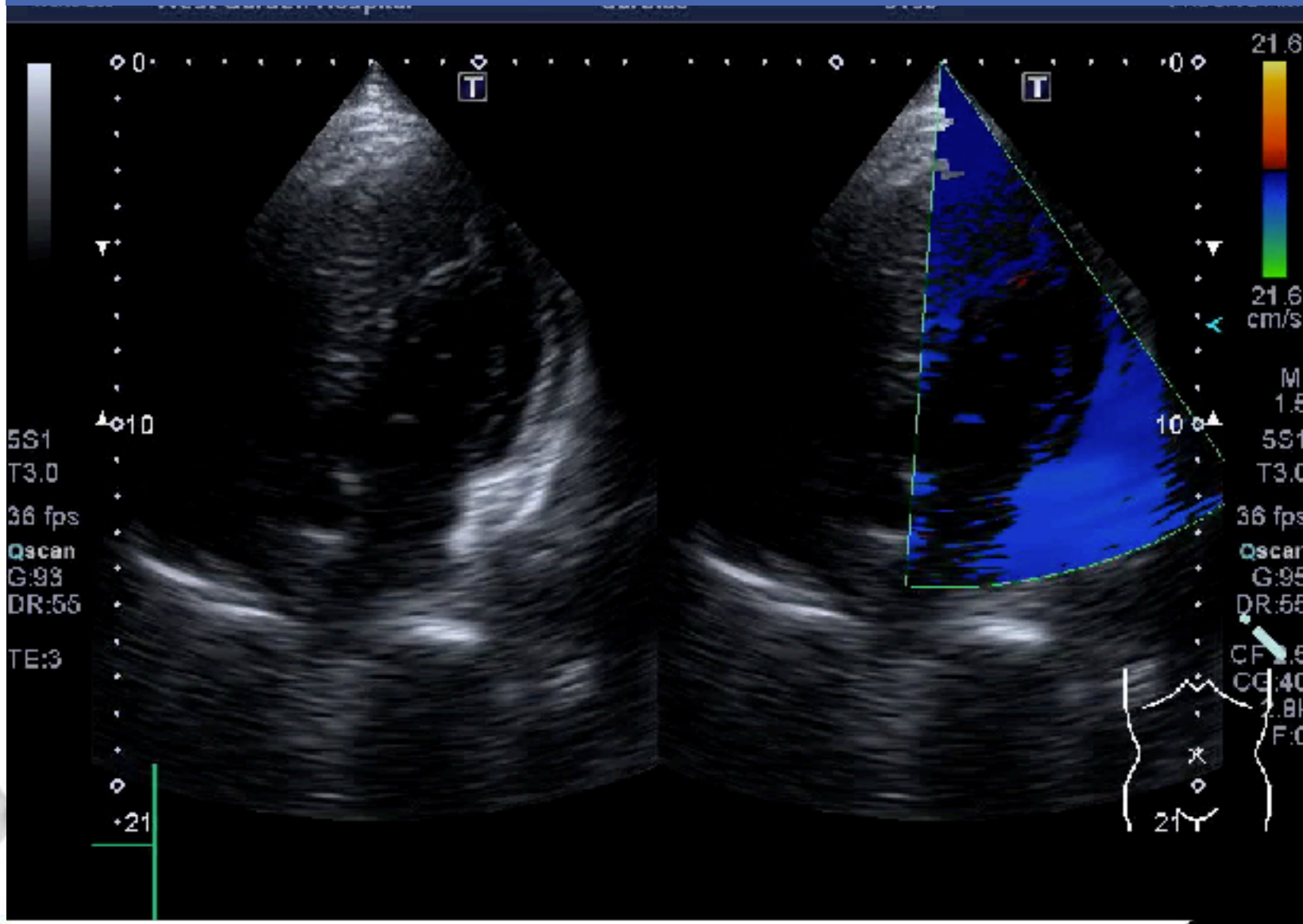
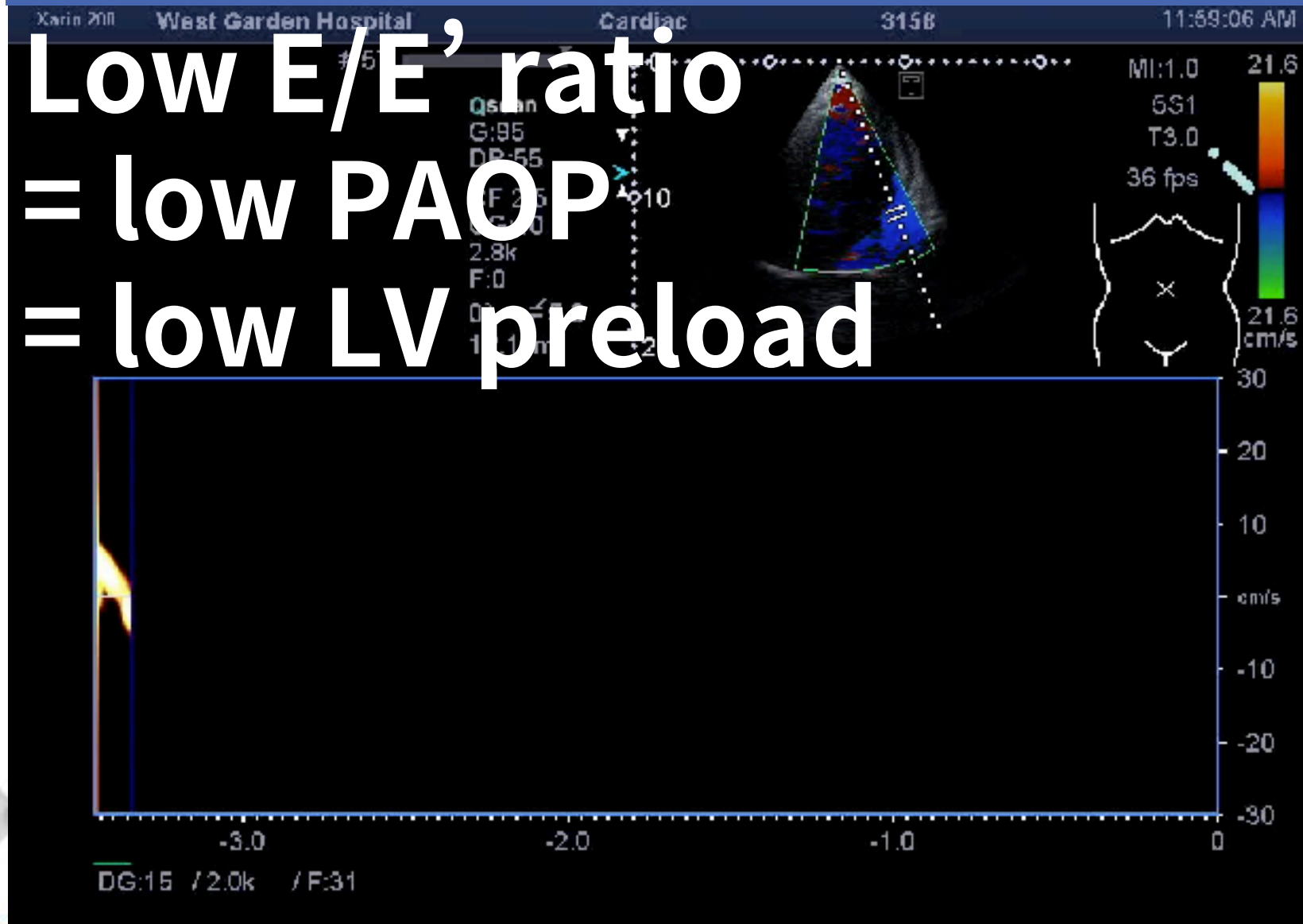
Tissue Doppler Image



ULTRASOUND PROGRAM

Tissue Doppler Image



Low E/E’ ratio
= low PAOP
= low LV preload

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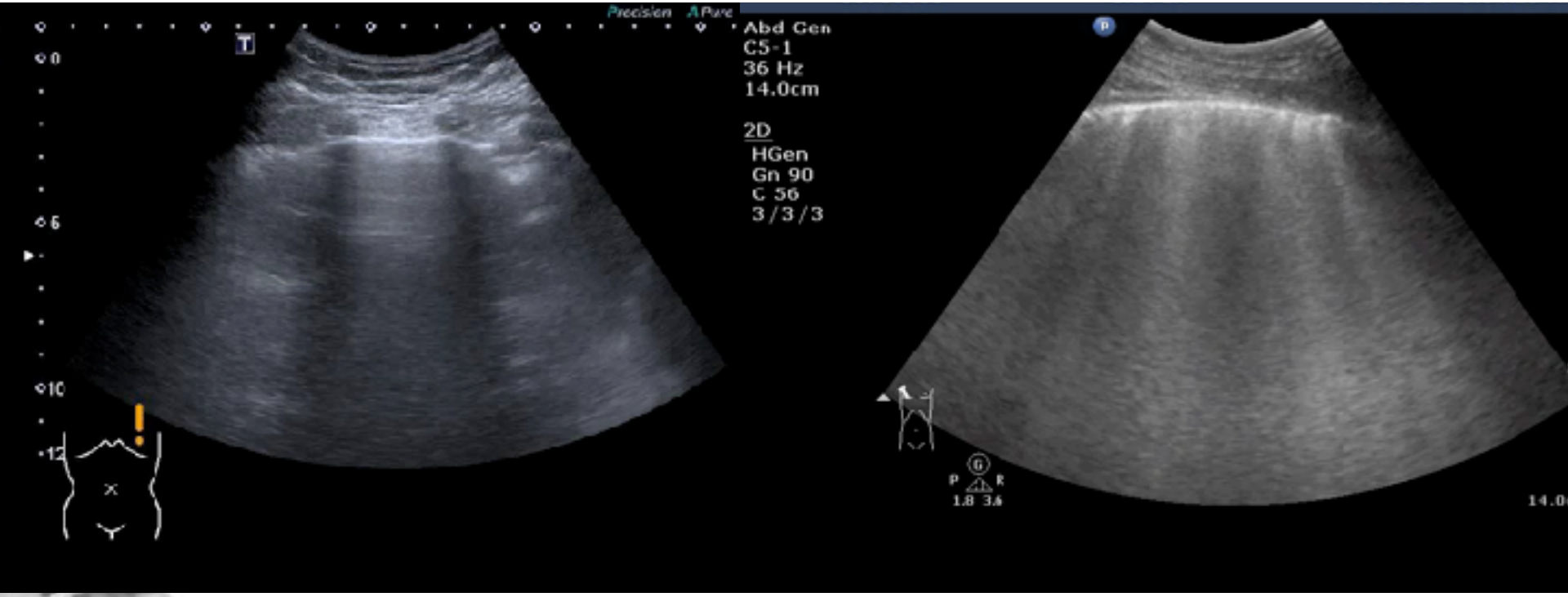
PROGRAM

Dry versus Wet



FALLS-protocol: lung ultrasound in hemodynamic assessment of shock

D. Lichtenstein
Service de Réanimation Médicale, Hôpital Ambroise-Paré, Université Paris-Ouest, France

Fluid Administration Limited by Lung Sonography

Heart, Lung and Vessels. 2013; 5(3): 142-147

The FALLS-protocol (Schematic decision tree)

Acute circulatory failure

Simple emergency cardiac Sonography → Tamponade, pulmonary embolism

Lung Ultrasound (BLUE-protocol) → Pneumothorax

Usually **Obstructive shock**

B-profile

A-profile

Usually **Cardiogenic shock** *

* Use SVC or IVC analysis etc if noncardiogenic pulmonary edema suspected

FALLS-protocol (fluid therapy) → Clinical improvement

No clinical improvement B-profile is generated

Usually **Hypovolemic shock**

Usually **Septic shock**

From Lichtenstein D, Expert Rev Respir Med 6(2):155-162

Obstructive

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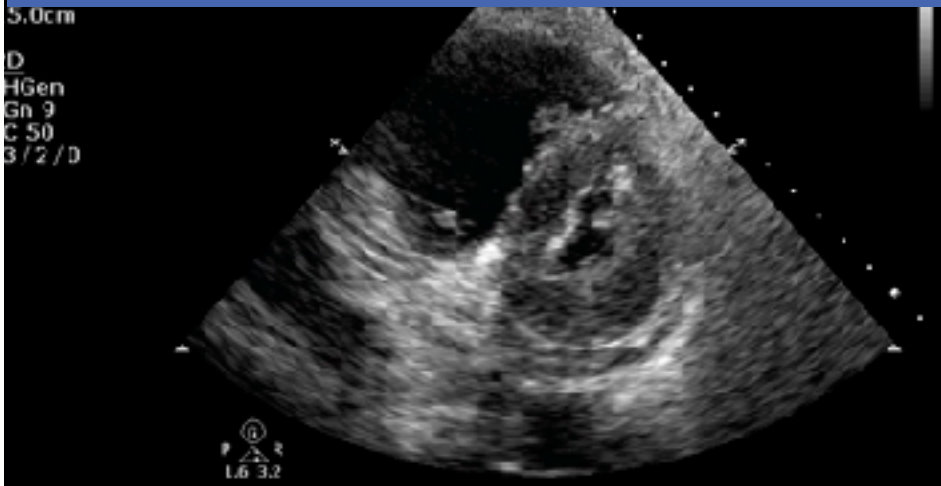
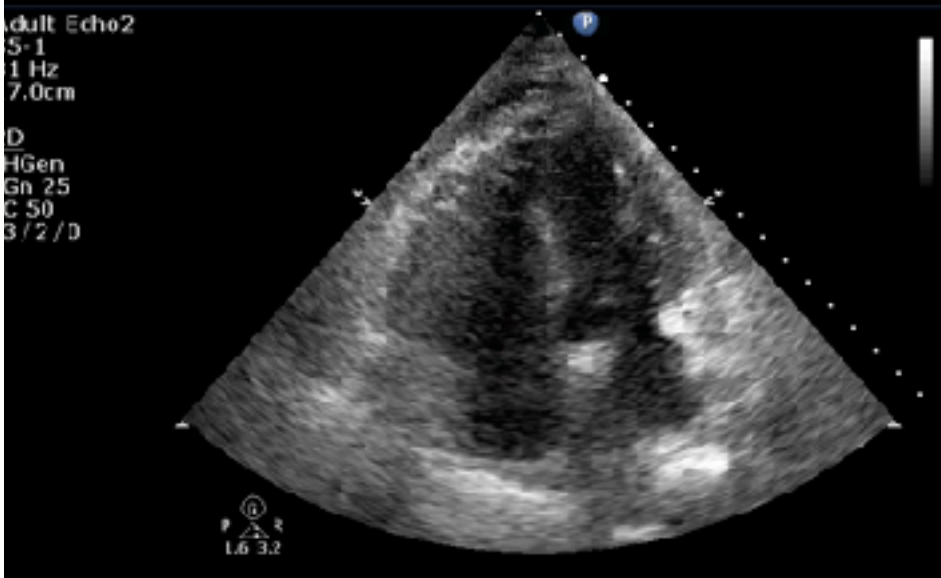
Obstructive





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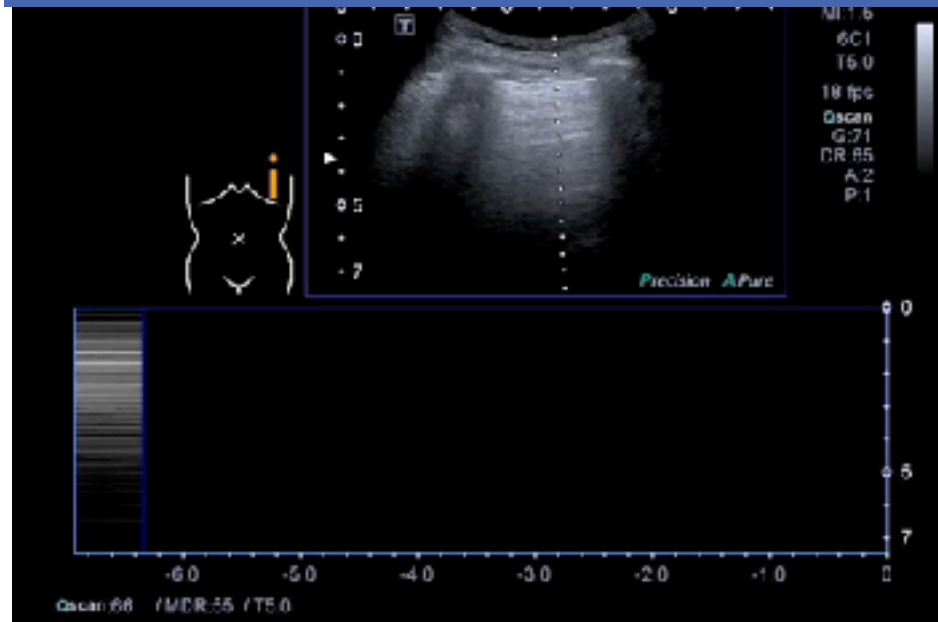
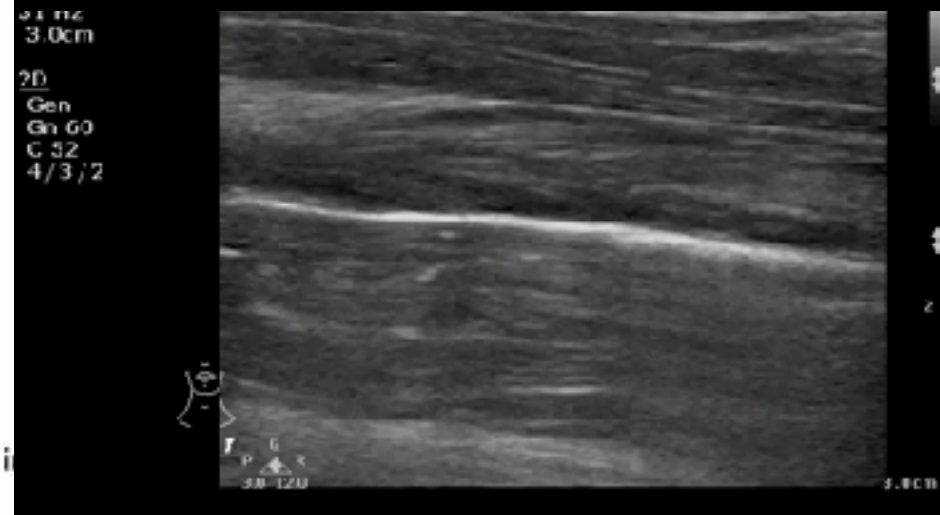
Obstructive





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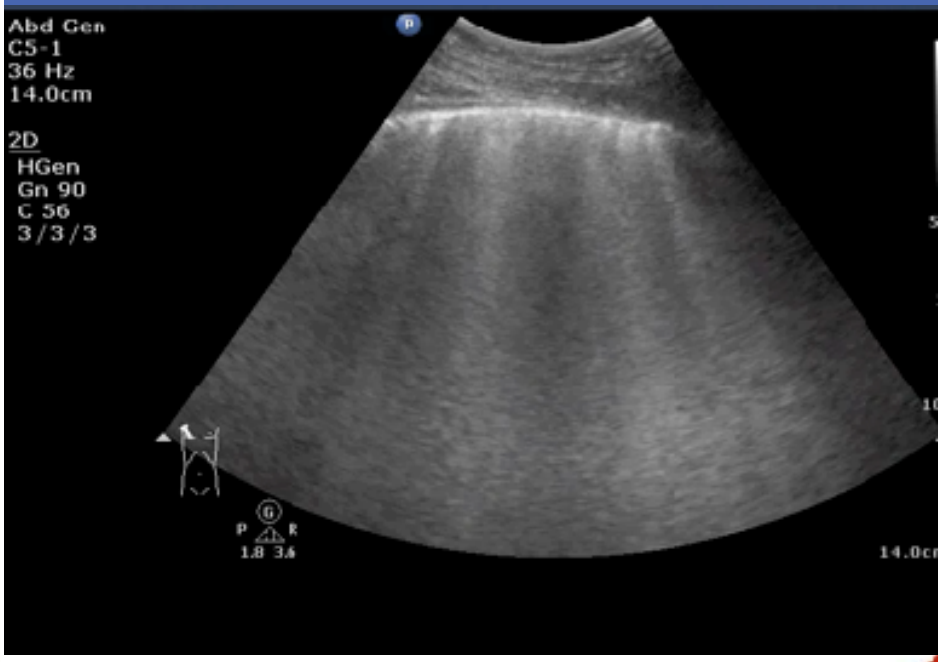
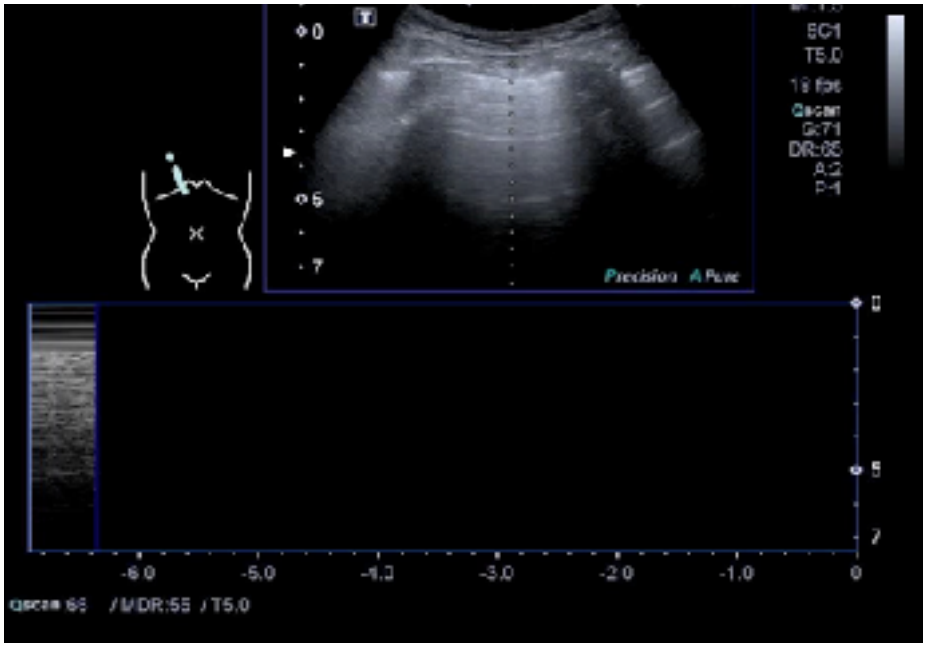
LV failure

Bilateral & Diffuse

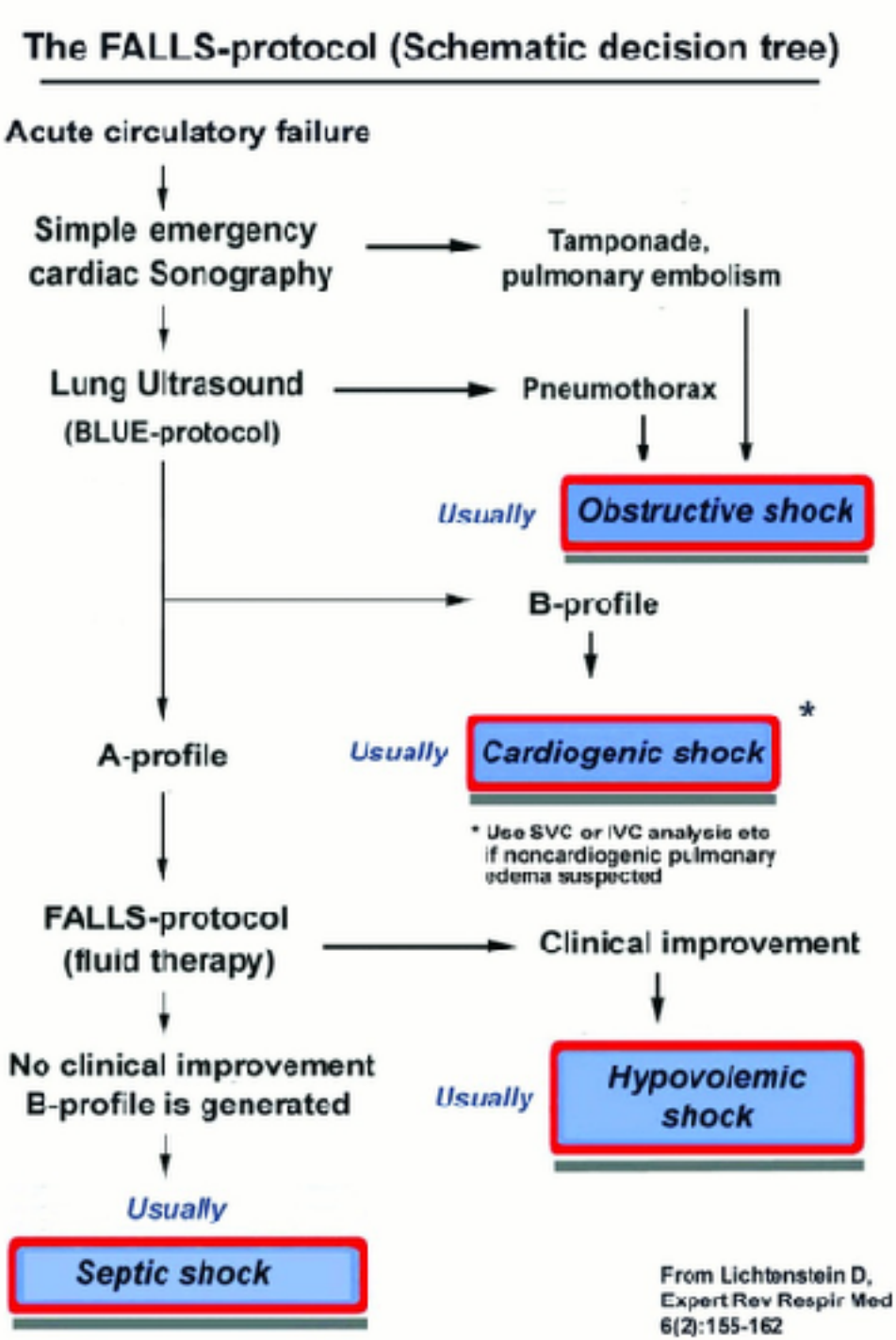


Hypovolemic

FALLS-responder



Search causes



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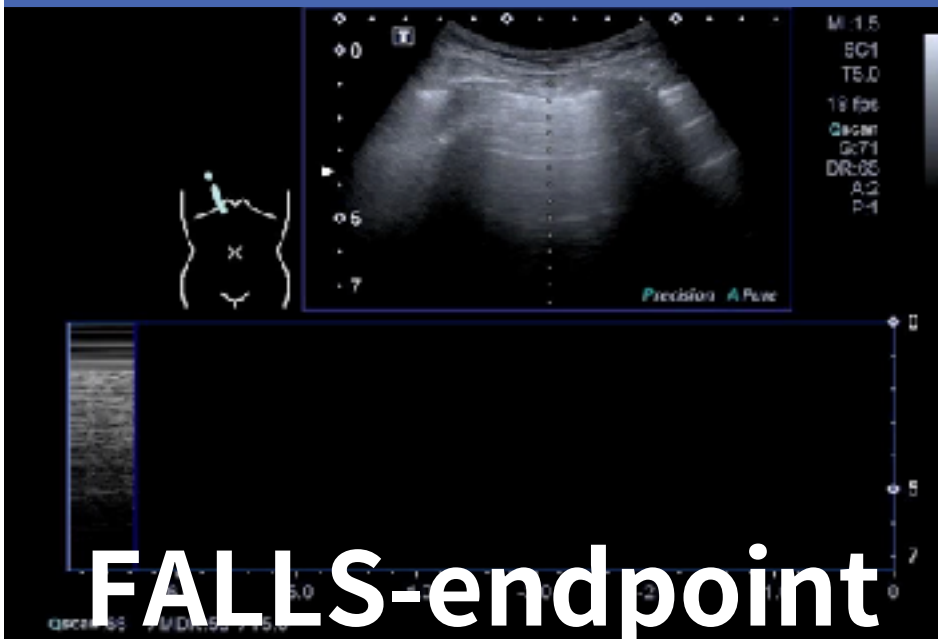
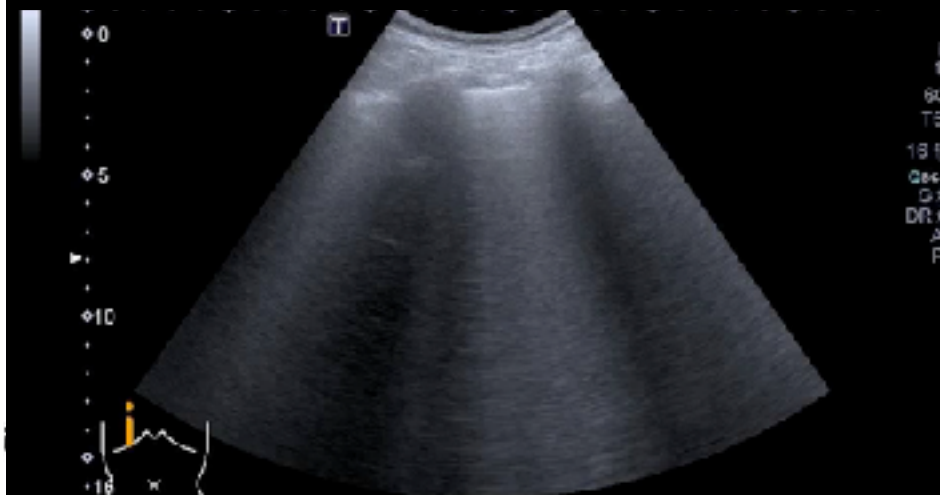
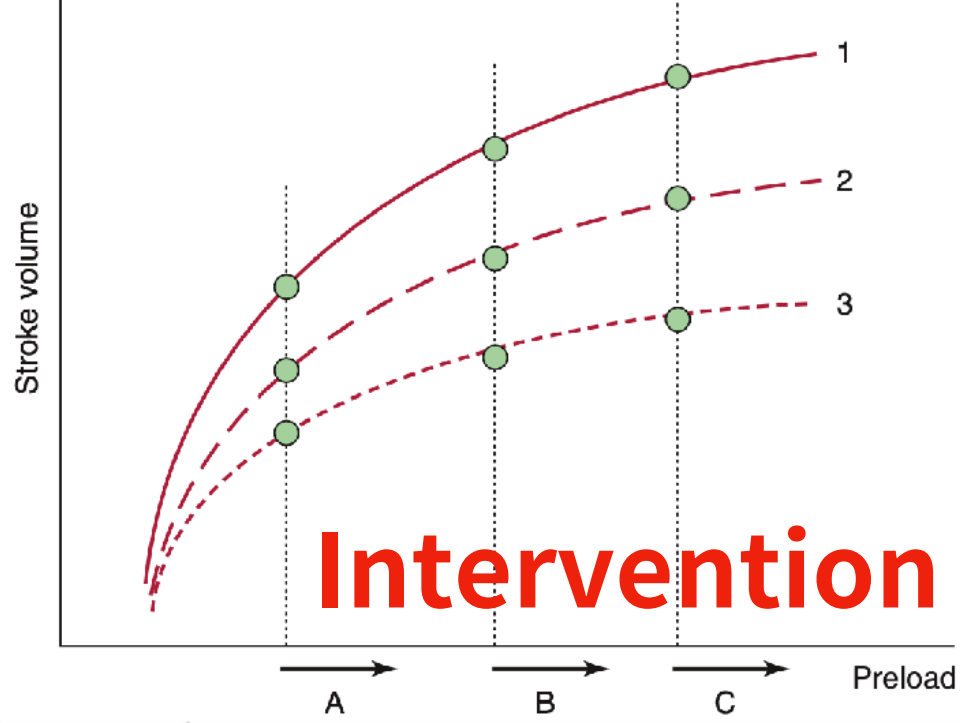
Distributive

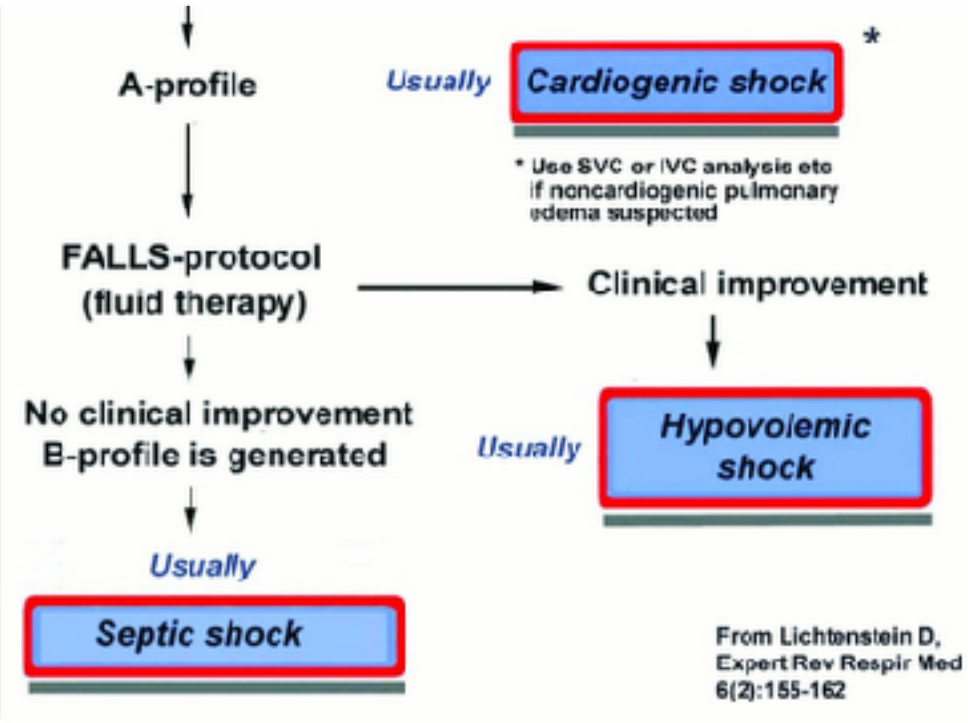


FALLS-endpoint

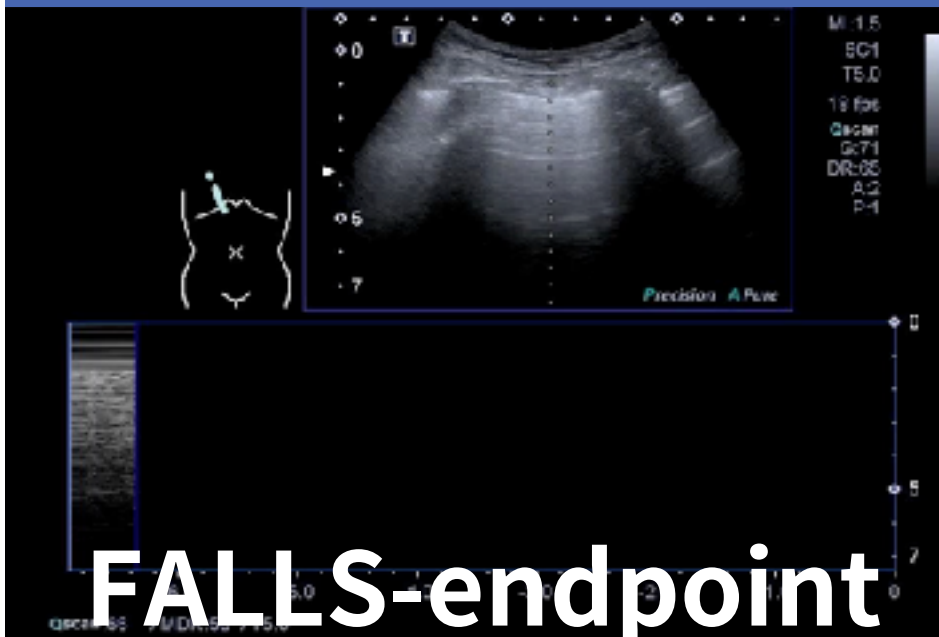




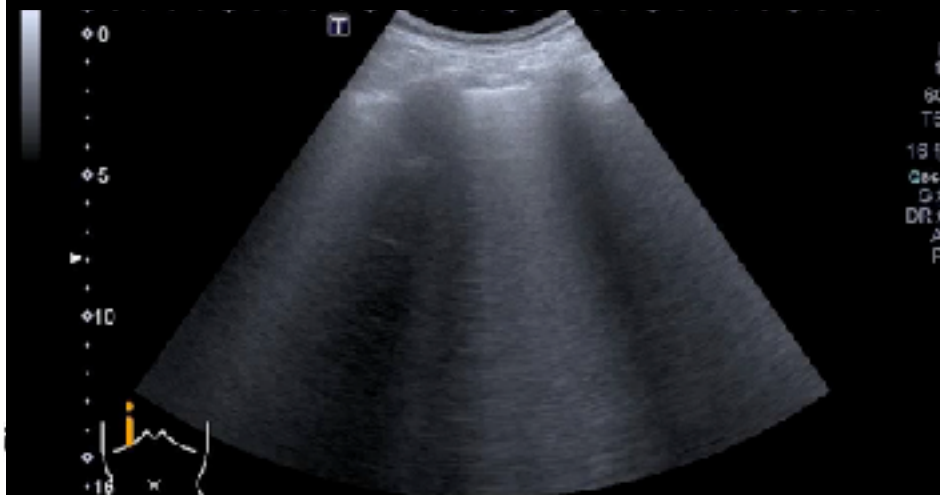
Intervention



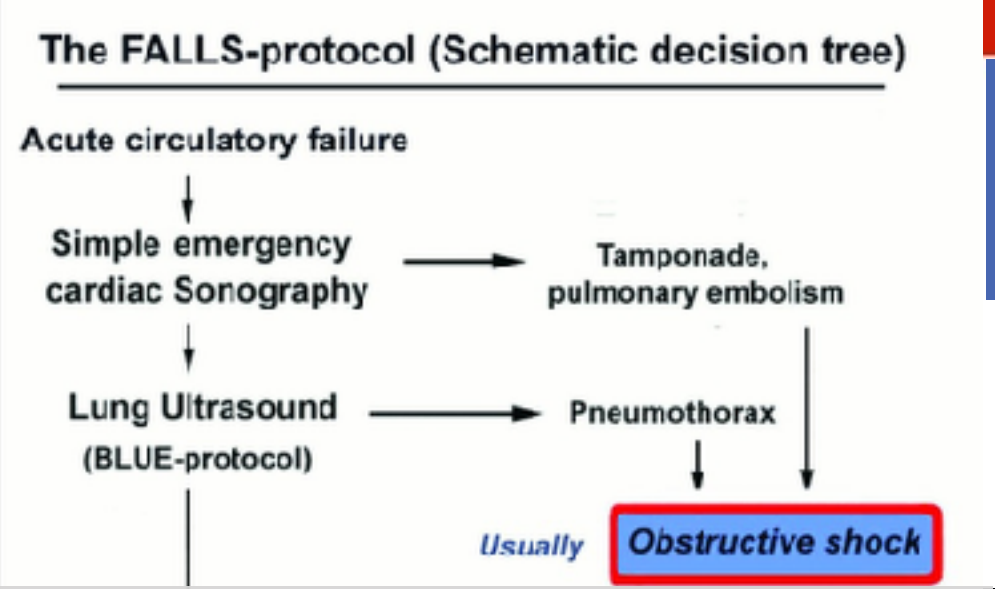
Distributive



FALLS-endpoint



Limitation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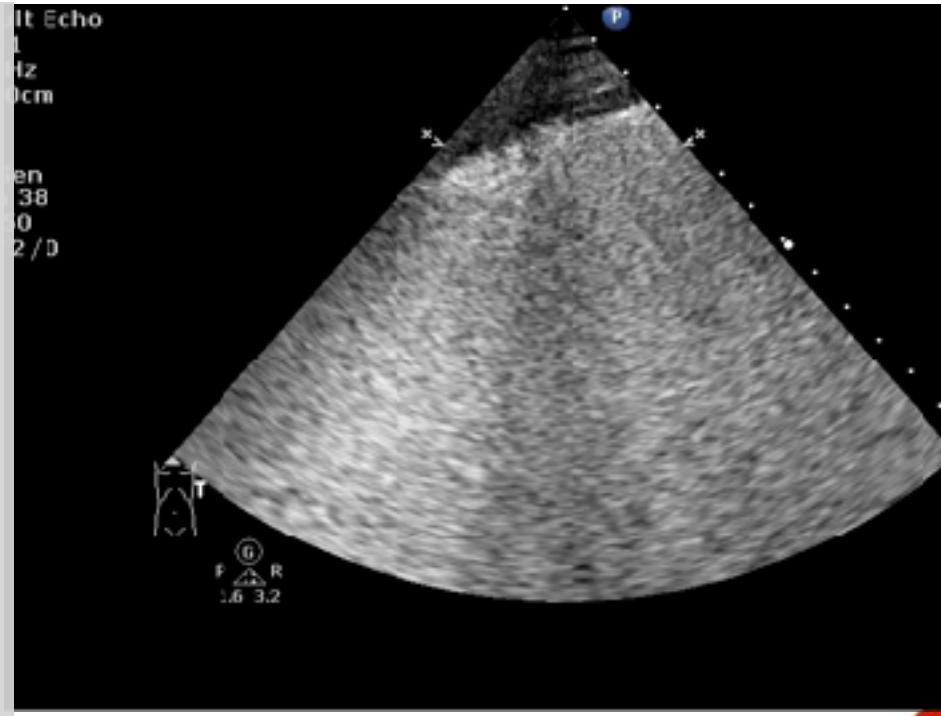
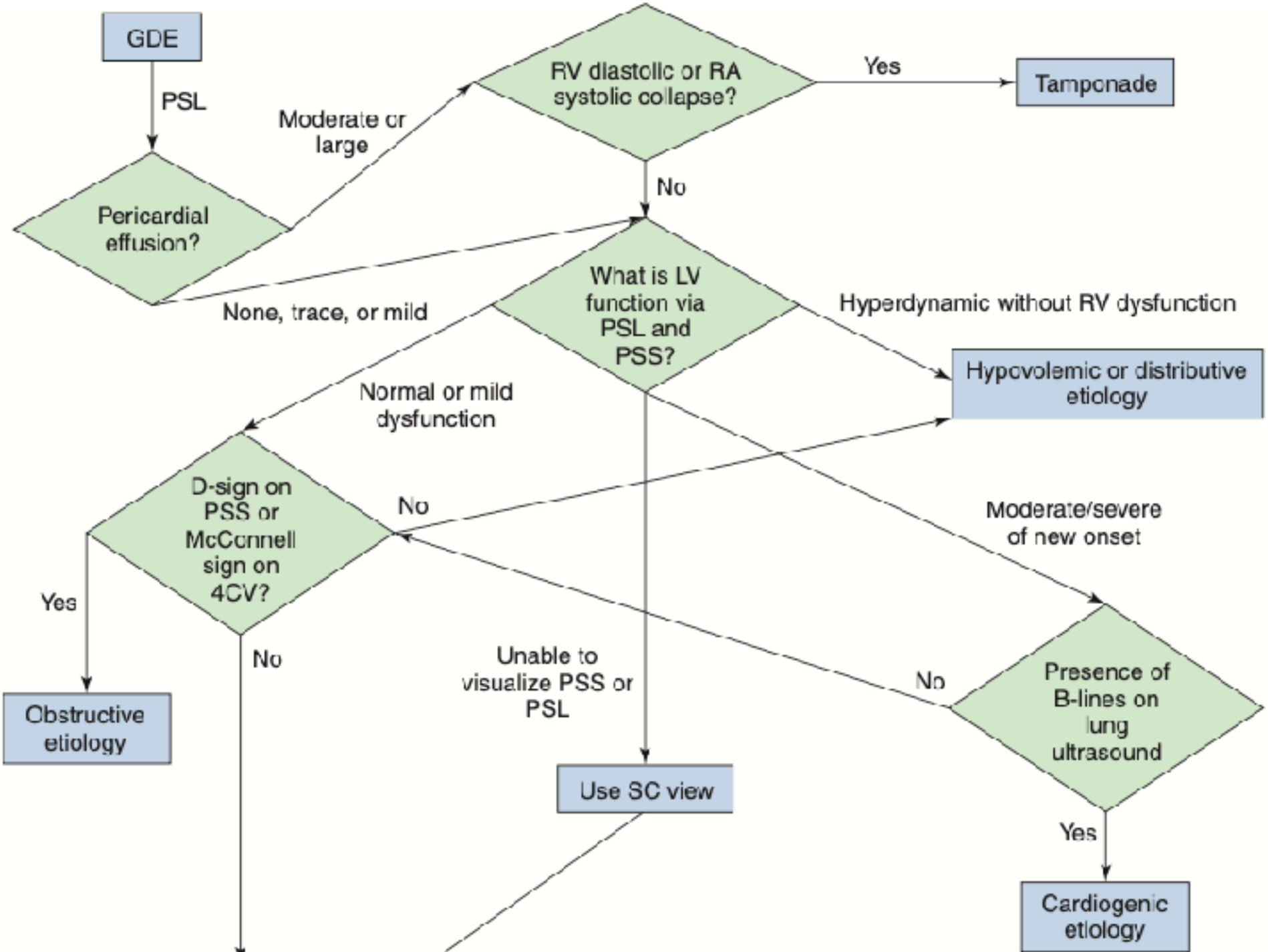
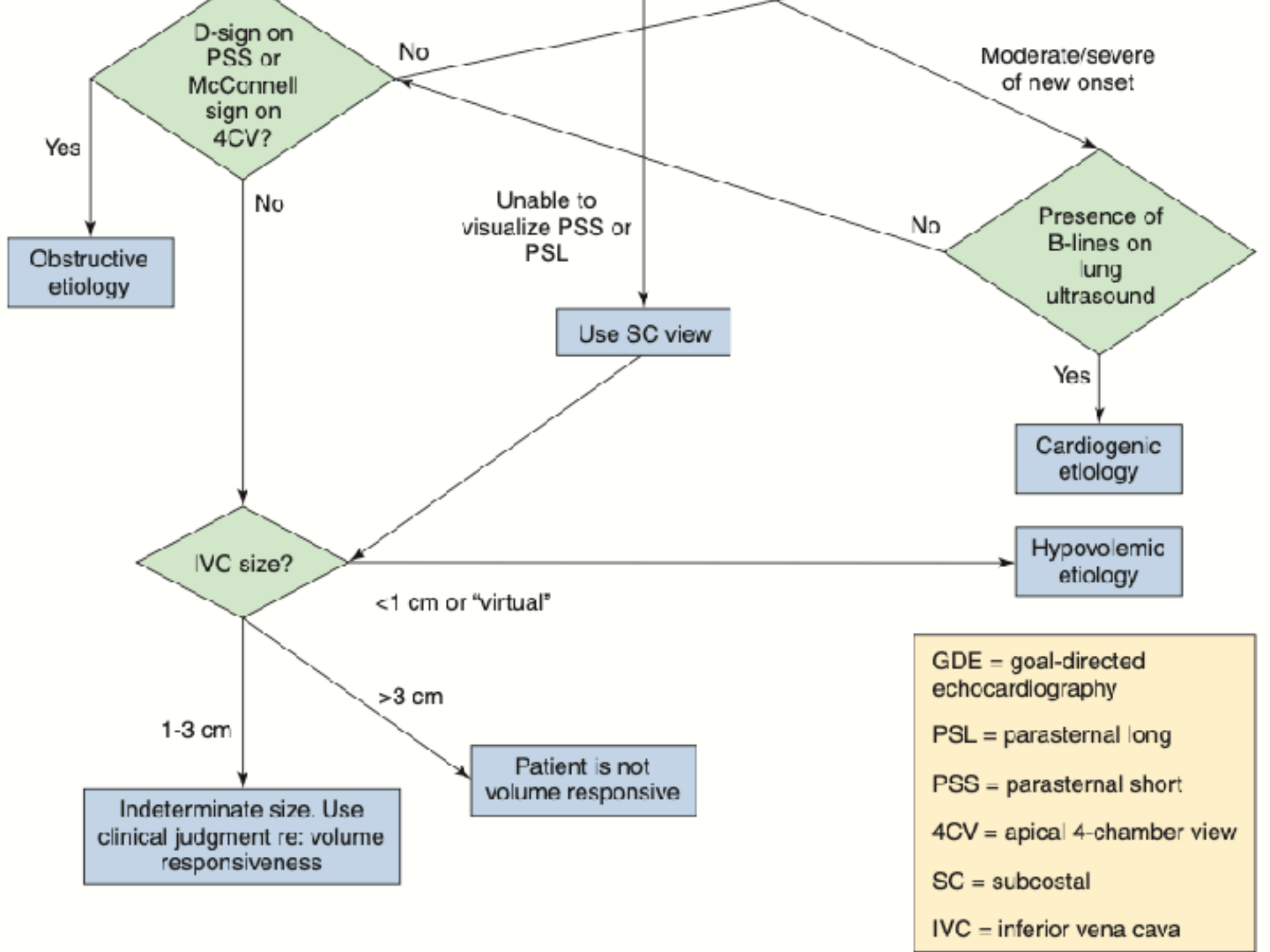
Pneumothorax
Usually
Obstructive shock




GDE
PSL
Pericardial effusion?
Moderate or large
RV diastolic or RA systolic collapse?
Yes
Tamponade
No
None, trace, or mild
What is LV function via PSL and PSS?
Hyperdynamic without RV dysfunction
Hypovolemic or distributive etiology
Normal or mild dysfunction
D-sign on PSS or McConnell sign on 4CV?
No
Moderate/severe of new onset
Yes
No
Obstructive etiology
Unable to visualize PSS or PSL
No
Presence of B-lines on lung ultrasound
Use SC view
Yes
Cardiogenic etiology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No
Moderate/severe of new onset
Yes
No
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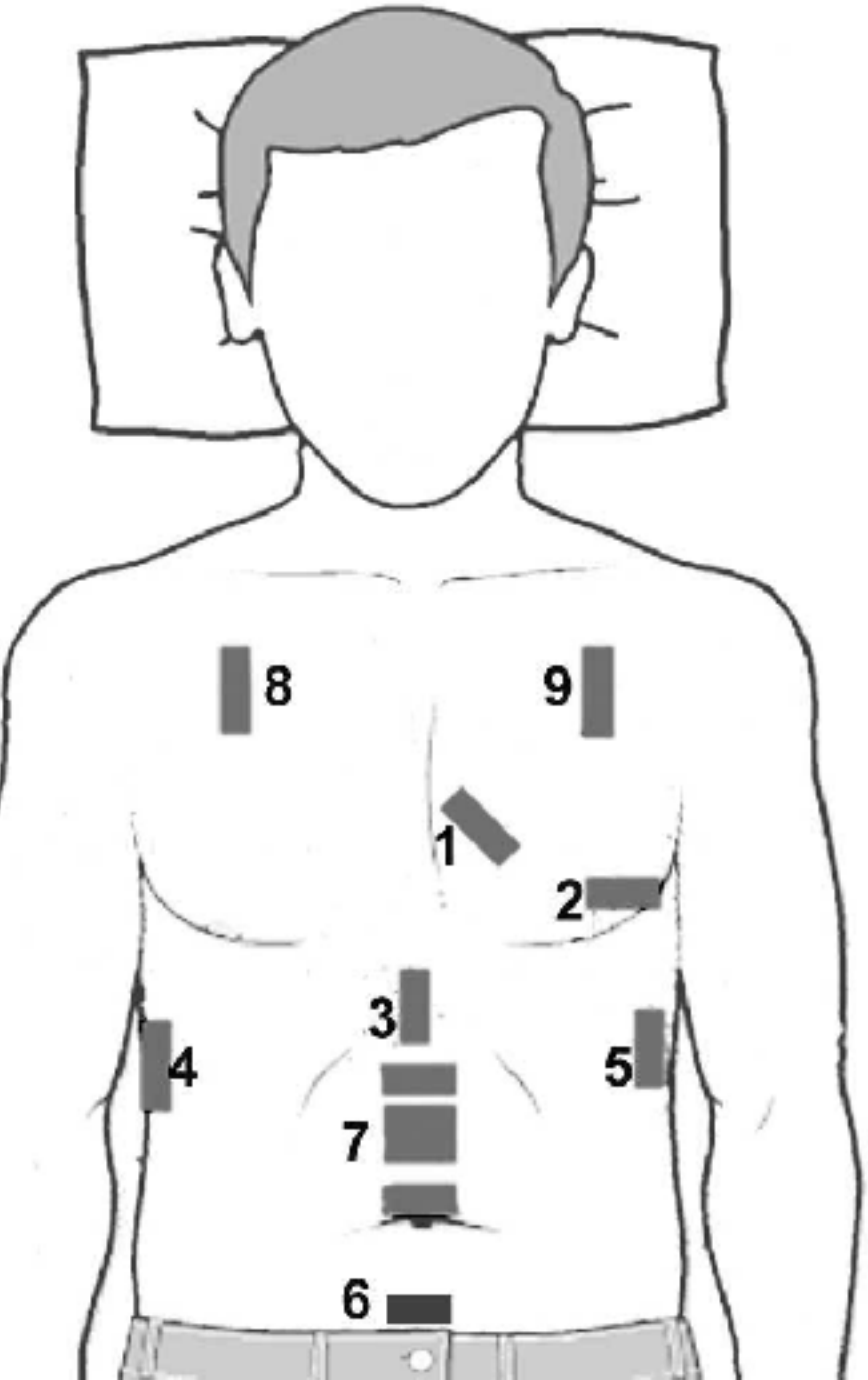
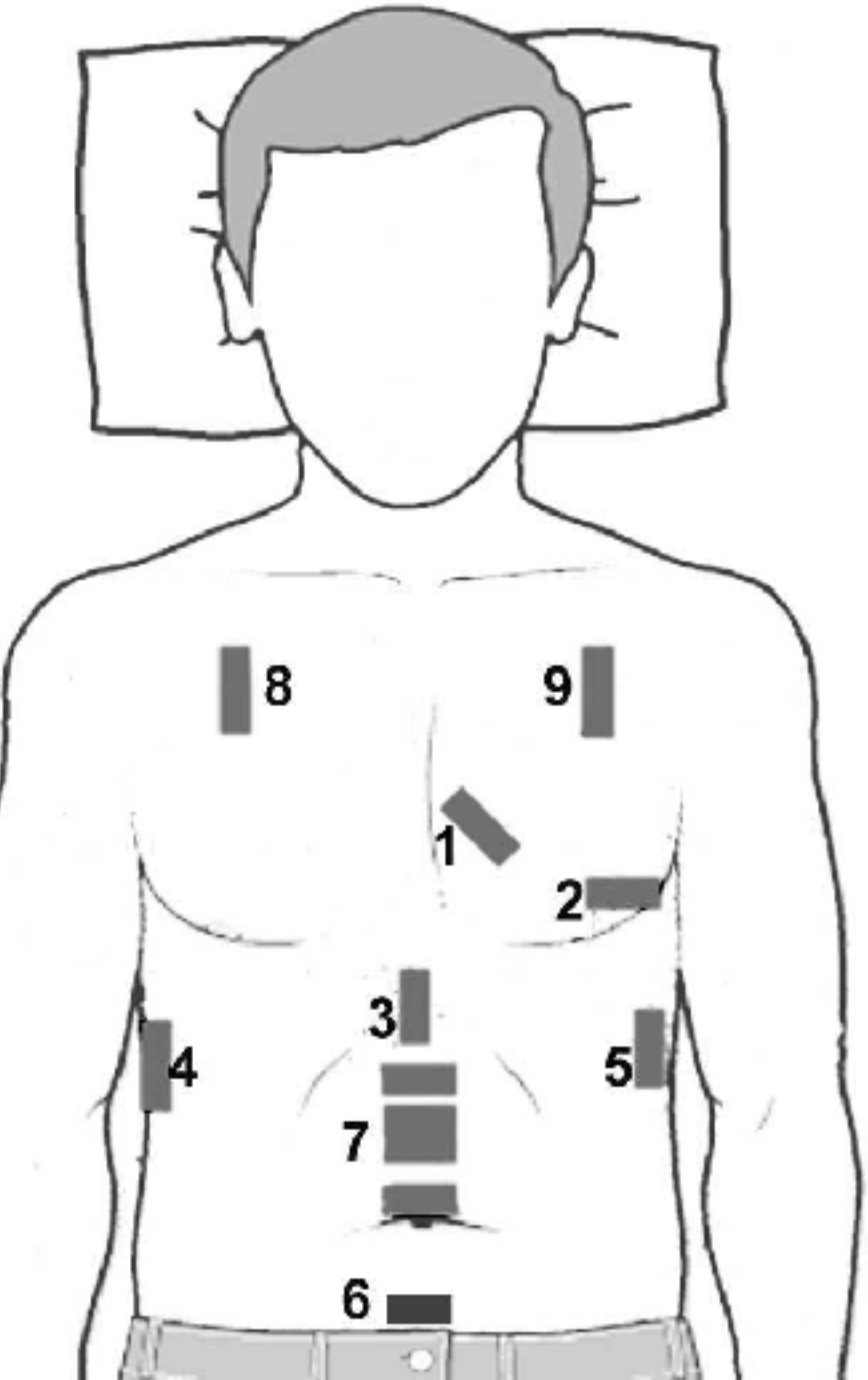
No
Presence of B-lines on lung ultrasound
Obstructive etiology
Use SC view
Yes
Cardiogenic etiology
IVC size?
Hypovolemic etiology
<1 cm or "virtual"
>3 cm
1-3 cm
Patient is not volume responsive
Indeterminate size. Use clinical judgment re: volume responsiveness
GDE = goal-directed echocardiography
PSL = parasternal long
PSS = parasternal short
4CV = apical 4-chamber view
SC = subcostal
IVC = inferior vena cava



RUSH(ed) Exam Sequencing

1. Parasternal Long Cardiac View
2. Apical Four-Chamber Cardiac View
3. Inferior Vena Cava View
4. Morison's with Hemothorax View
5. Splenorenal with Hemothorax View
6. Bladder View
7. Aortic Slide Views
8. Pulmonary View
9. Pulmonary View

Use Curvilinear Array for all Views
Add in a search for Ectopic Pregnancy and DVT depending on clinical circumstances



HI-MAP ED

Pump
Tank
Pipe

ULTRASOUND PROGRAM

RUSH for Shock

	Heart	IVC	FAST	Aorta	Pulmonary
Hypovolemic Shock	1. Hypercontractile 2. Small chamber size	Flat IVC	Peritoneal fluid	1. Aortic dissection 2. Aortic aneurysm	Pleural fluid
Cardiogenic Shock	1. Hypocontractile 2. Dilated heart	Distended IVC	Peritoneal fluid	Normal	1. Pulmonary edema 2. Pleural fluid
Obstructive Shock	1. Hypercontractile 2. Pericardial effusion 3. Tamponade 4. RV strain 5. Thrombus	Distended IVC	Normal	DVT	Absent lung sliding
Distributive Shock	1. Hypercontractile or 2. Hypocontractile	Flat or normal IVC	Peritoneal fluid (peritonitis)	Normal	Pleural fluid (empyema, pneumonia)

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Distributive Shock	1. Hypercontractile or 2. Hypocontractile	normal IVC	ritoneal fluid (peritonitis)	Normal	Pleural fluid (empyema, pneumonia)

有無
大小
強弱
左右

ULTRASOUND PROGRAM

RUSH for Shock

	Heart	IVC	FAST	Aorta	Pulmonary
Hypovolemic Shock	1. Hypercontractile 2. Small chamber	Flat IVC	Peritoneal fluid	1. Aortic dissection 2. Aortic	Pleural fluid
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Obstructive Shock					
Distributive Shock	1. Hypercontractile or 2. Hypocontractile	Flat or normal IVC	Peritoneal fluid (peritonitis)	Normal	Pleural fluid (empyema, pneumonia)

有無
大小
強弱
左右

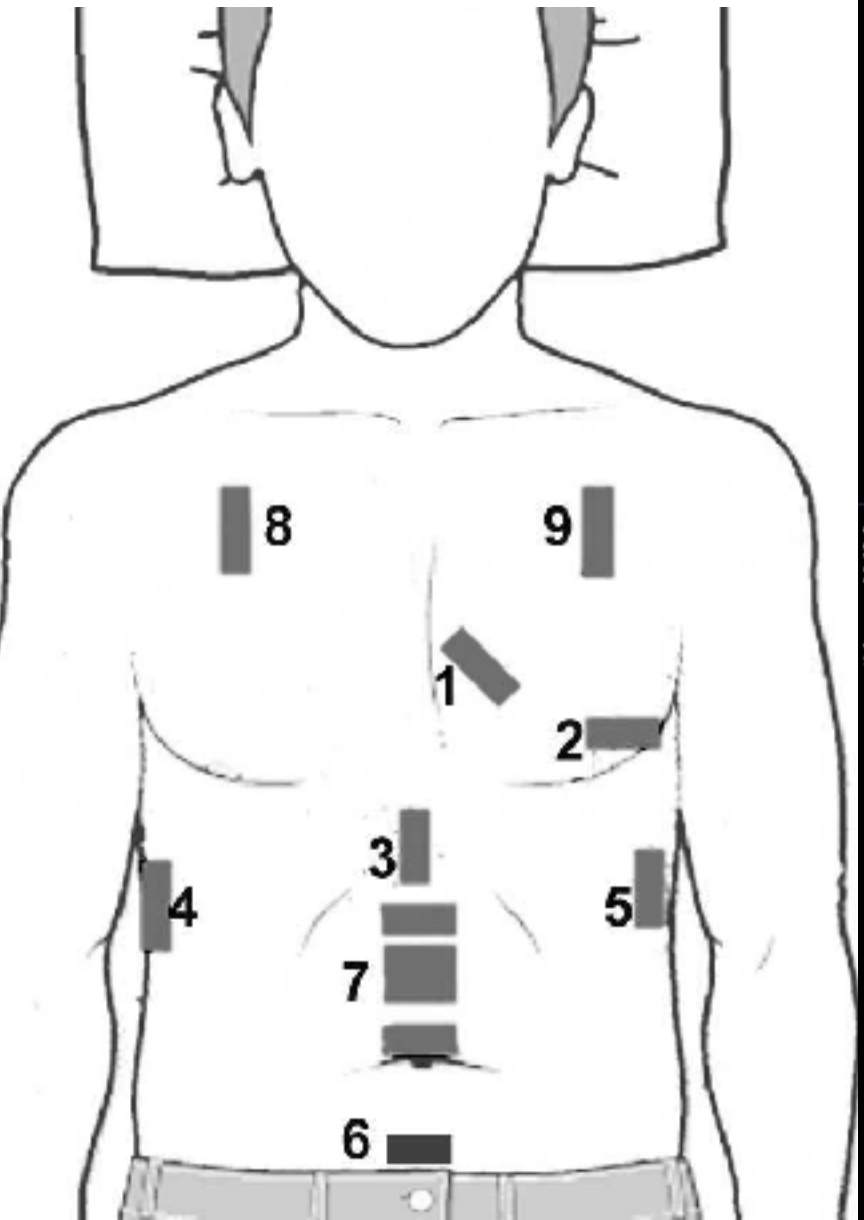
扁漲
變化

腹水
有無

3A
剝離
栓塞

氣胸
水腫
積水
肺炎

HI-MAPED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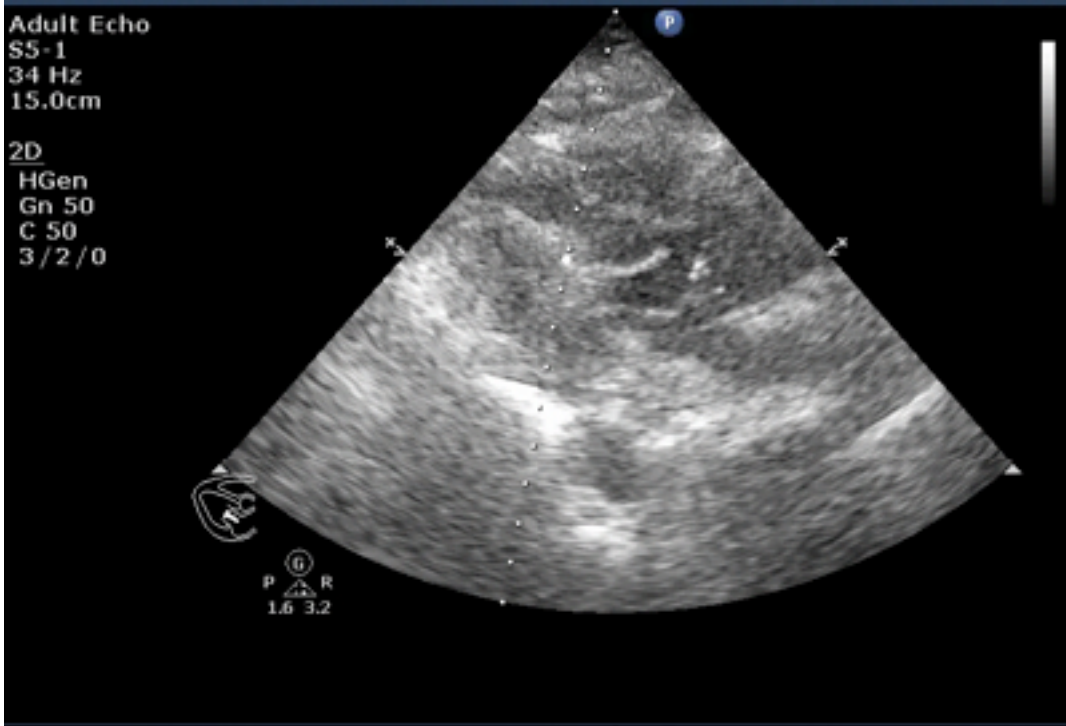
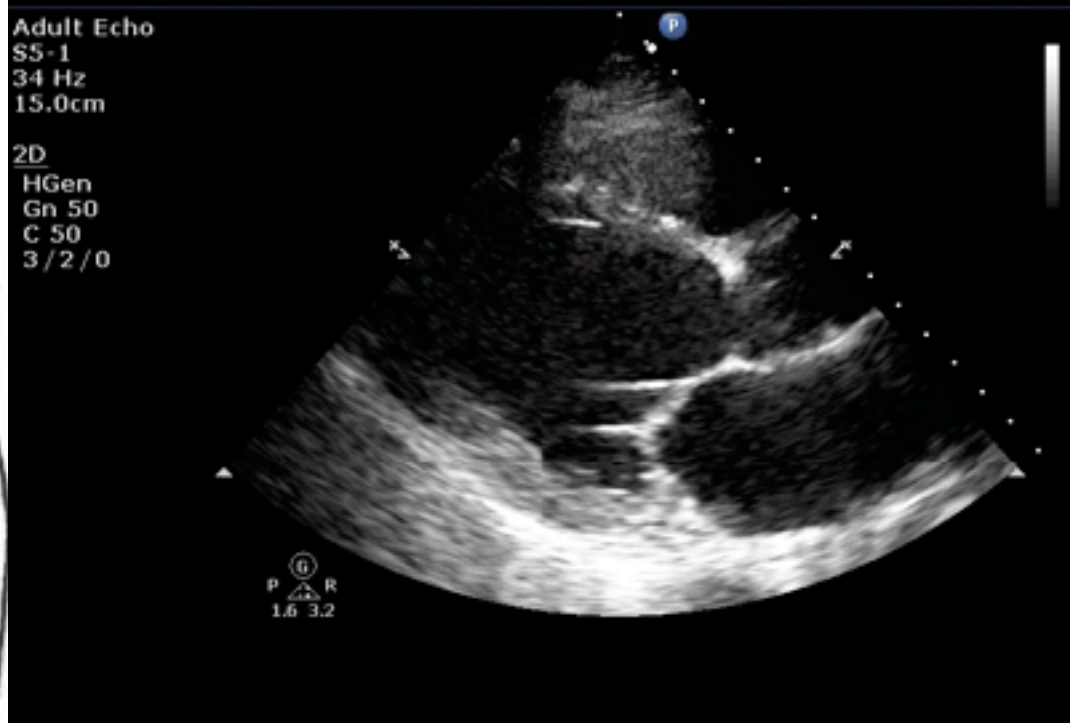
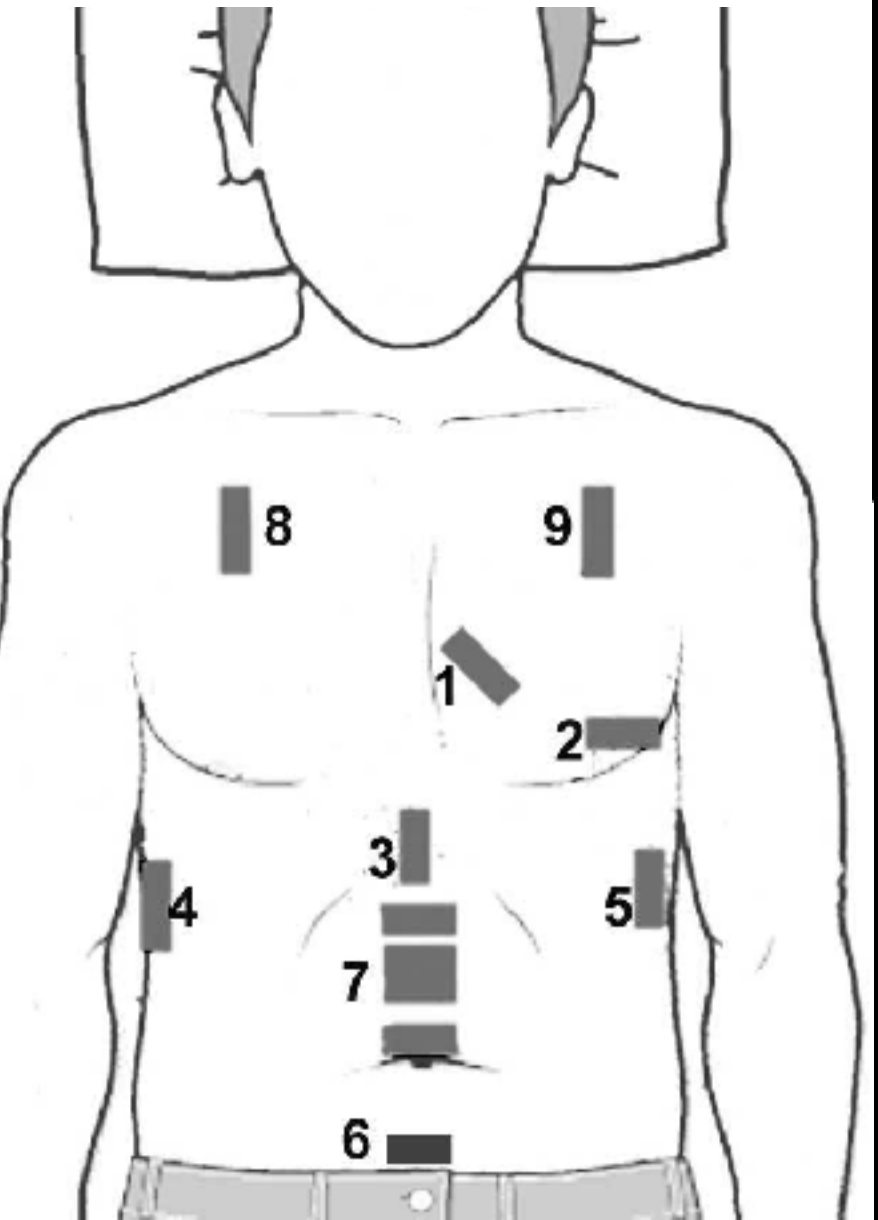

Adult Echo
S5-1
34 Hz
15.0cm
2D
HGen
Gn 50
C 50
3/2/0
P
R
1.6 3.2


Adult Echo
S5-1
34 Hz
15.0cm
2D
HGen
Gn 50
C 50
3/2/0
P
R
1.6 3.2

HI-MAPED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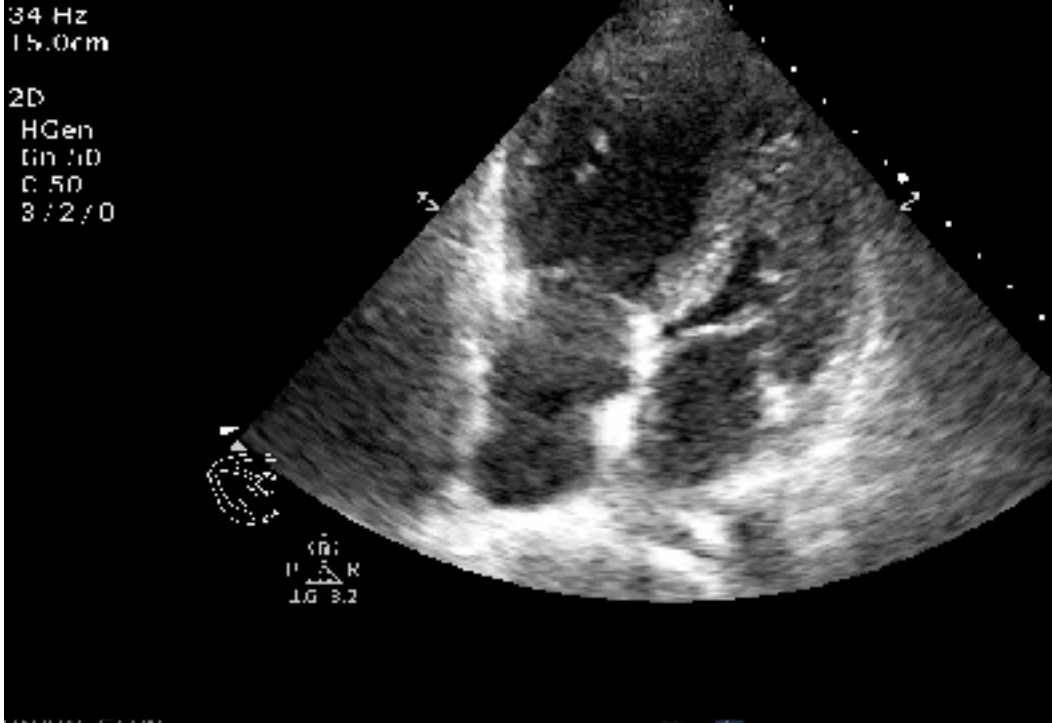
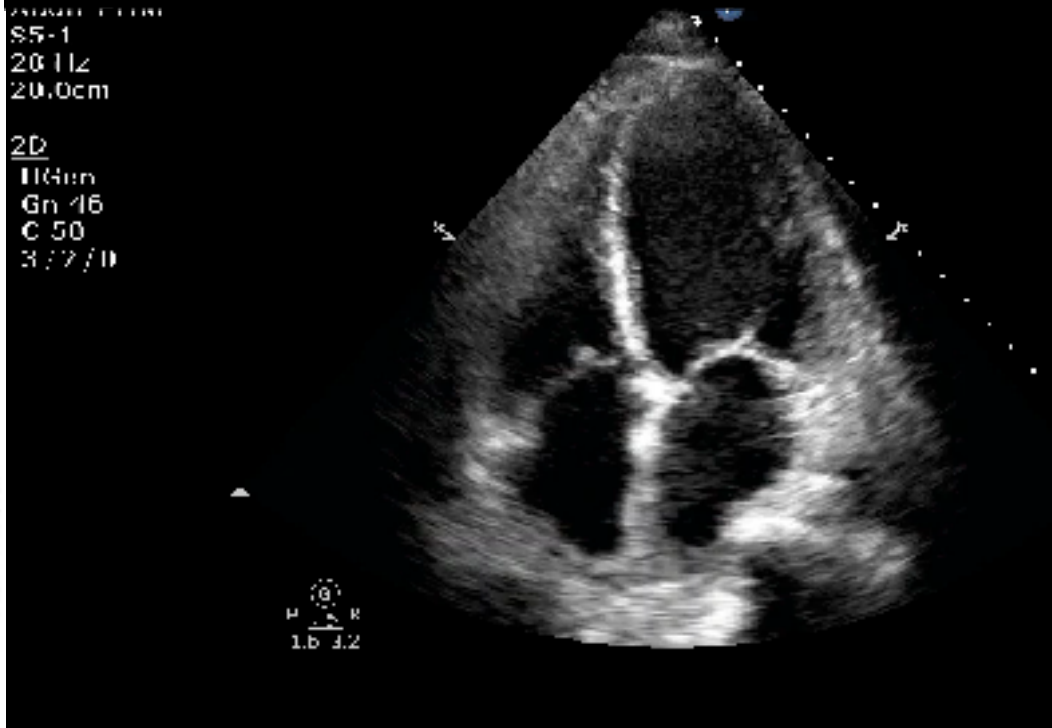
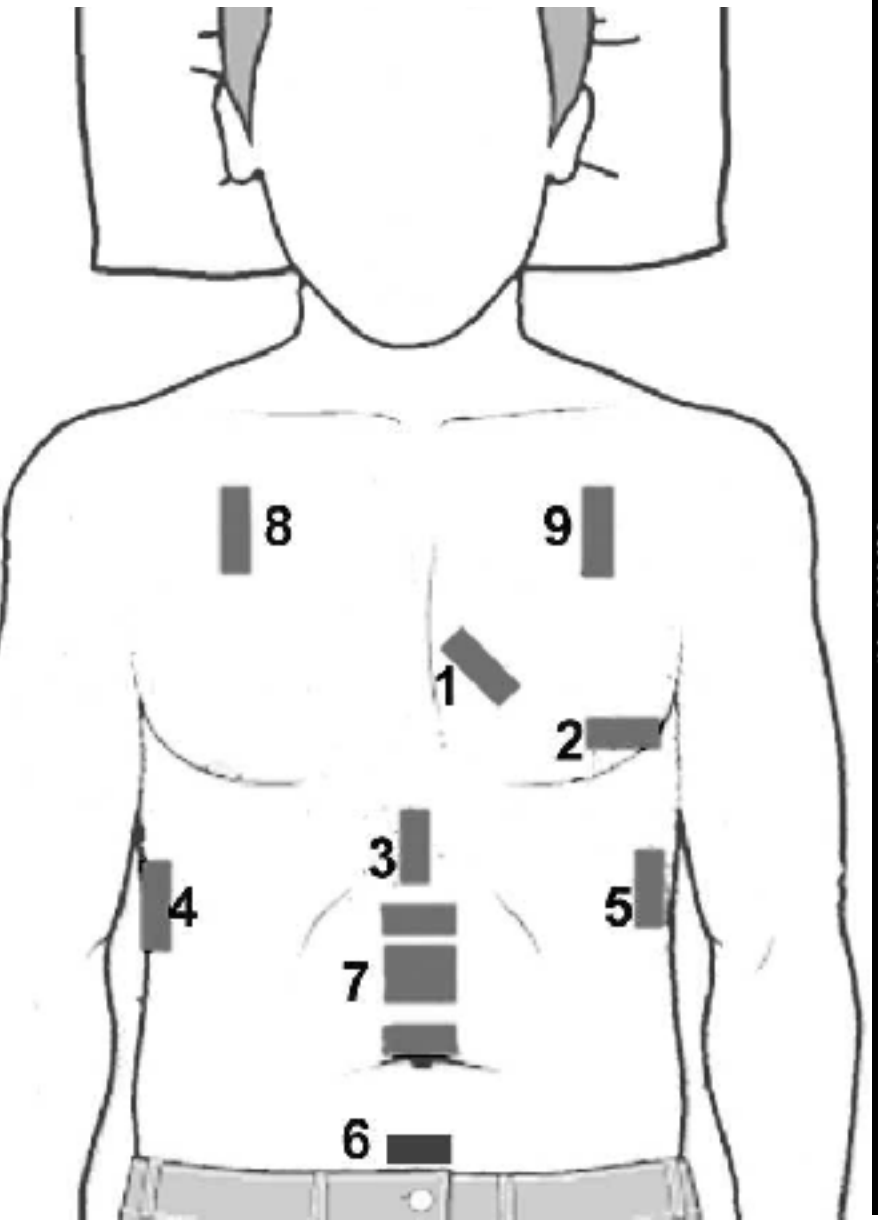

34 Hz
15.0cm
2D
HGen
Gn 50
C 50
3 / 2 / 0


S5-1
20 Hz
20.0cm
2D
HGen
Gn 46
C 50
3 / 2 / 0

HI-MAPED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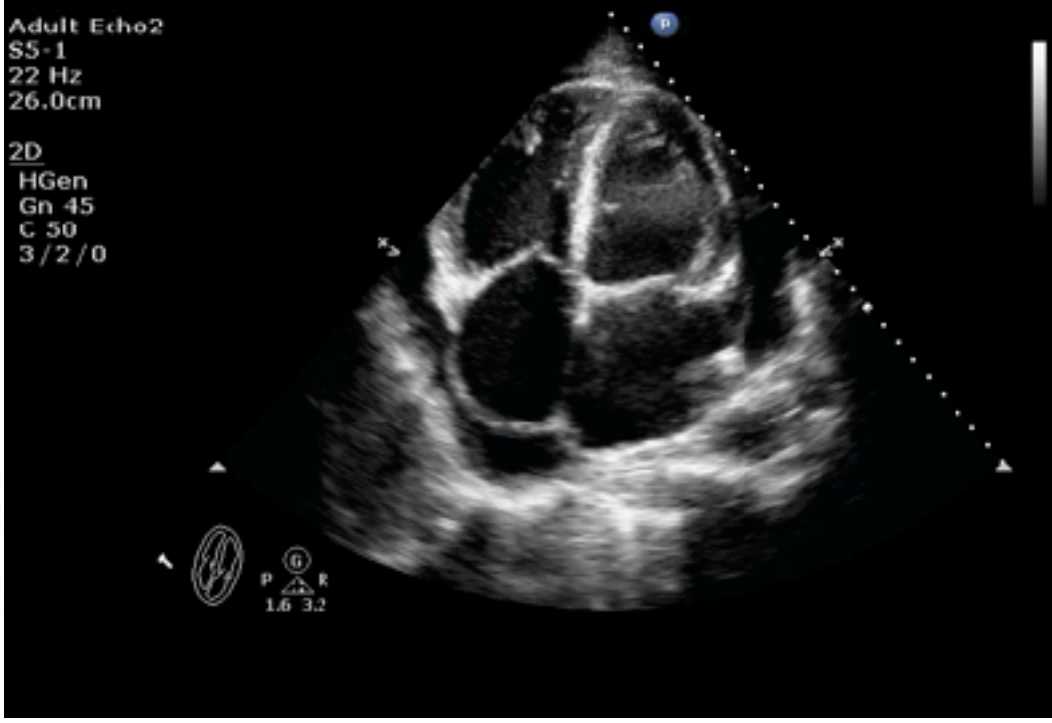
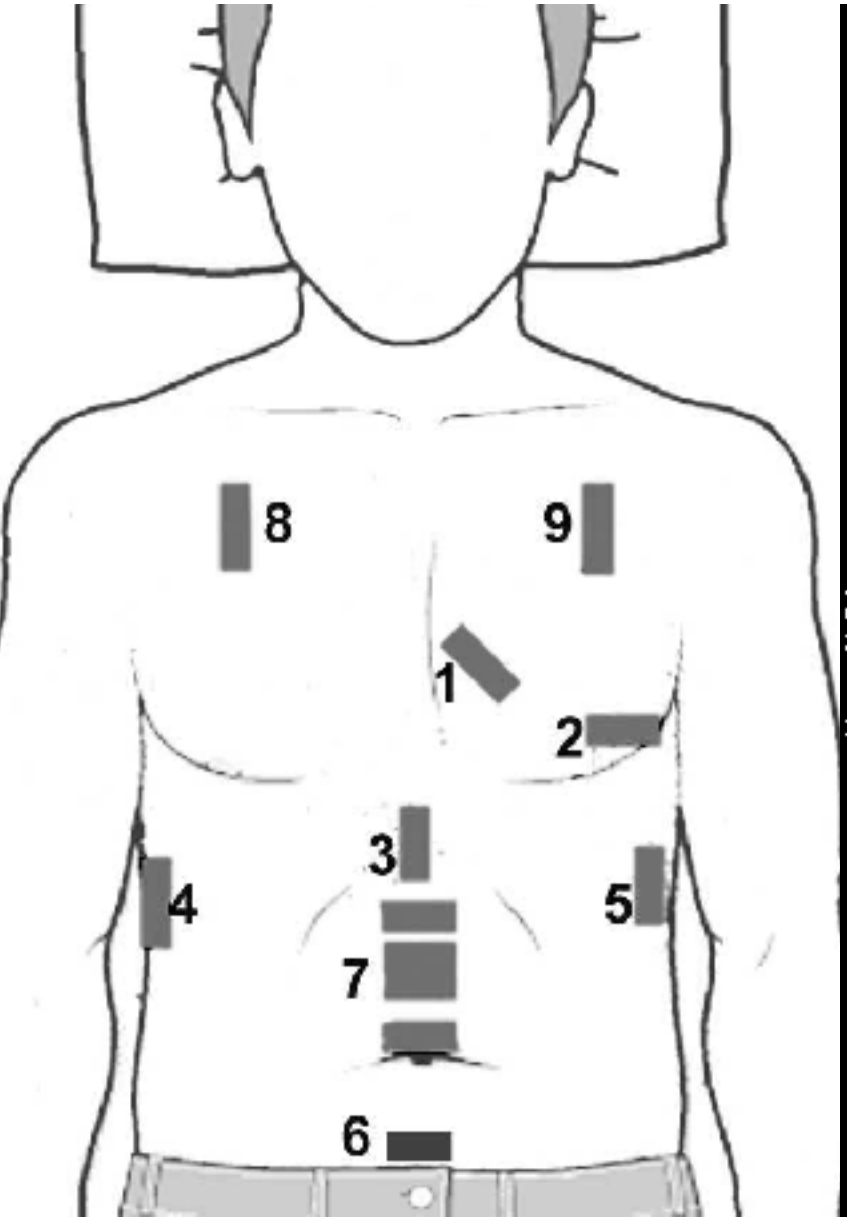
Abd Gen
C5-1
30 Hz
18.0cm
2D
HGen
Gn 100
C 56
3/3/3
5
10
15
P R
1.8 3.6
18.0cm


Adult Echo2
S5-1
22 Hz
26.0cm
2D
HGen
Gn 45
C 50
3/2/0
P R
1.6 3.2

HI-MAPED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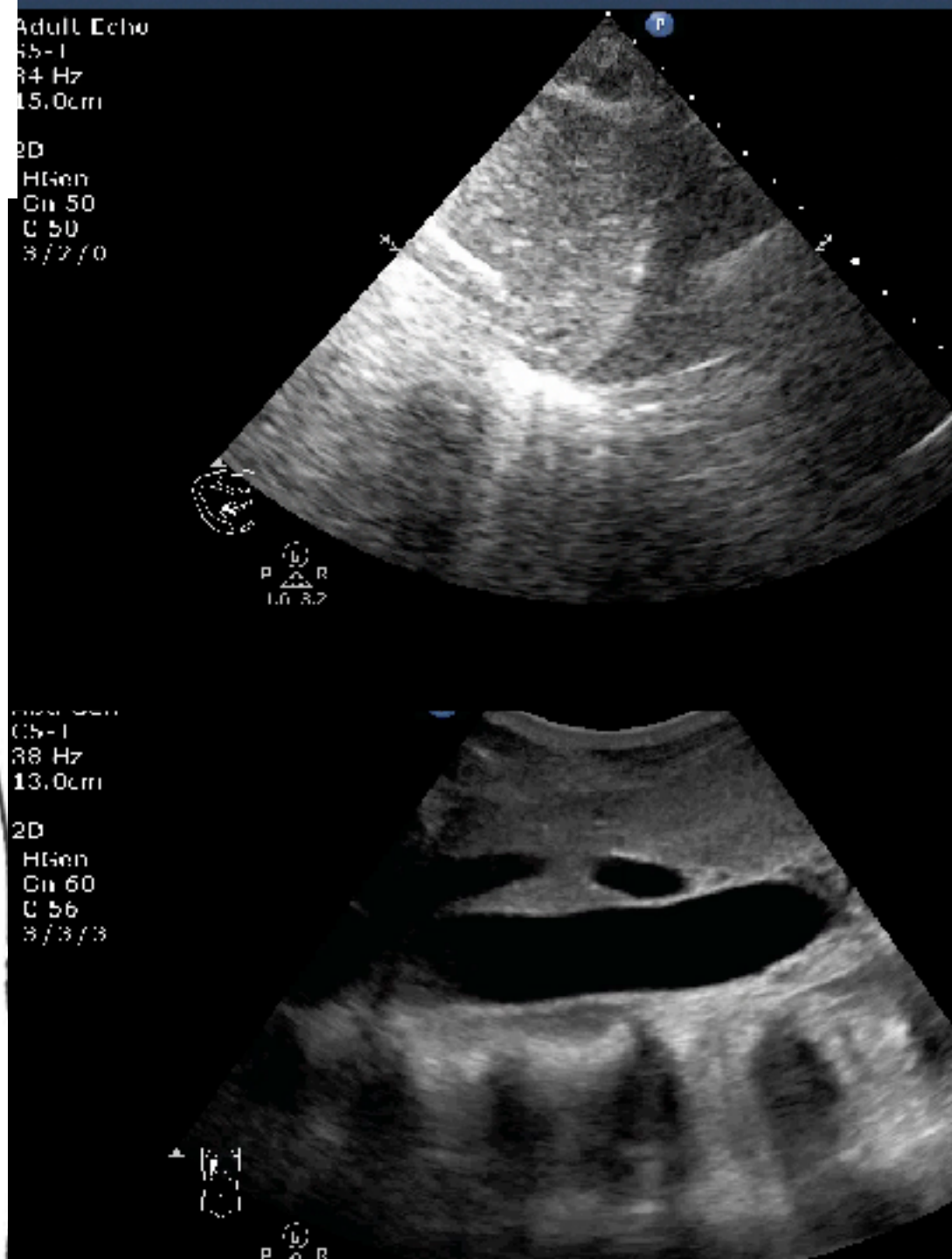
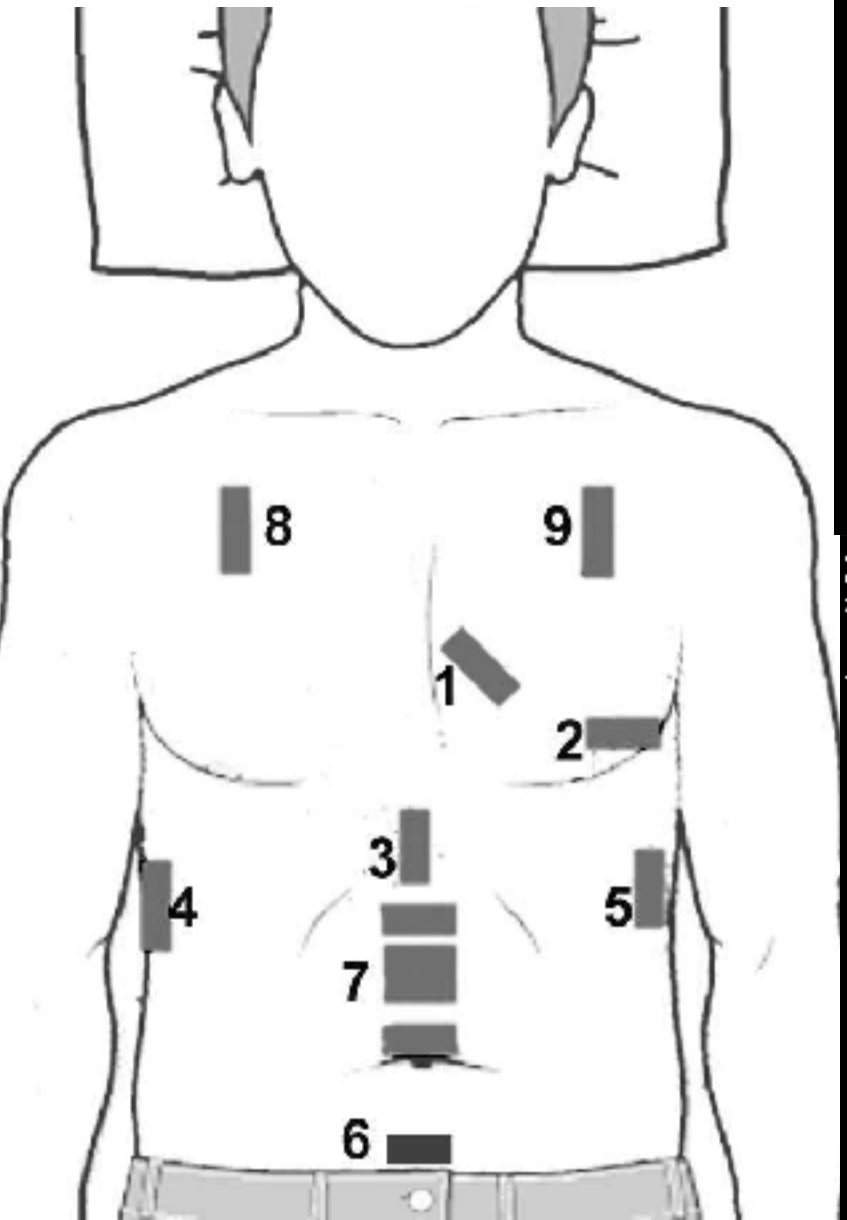

Adult Echo
C5-1
34 Hz
15.0cm
2D
HGen
Gn 50
C 50
3/2/0
C5-1
38 Hz
13.0cm
2D
HGen
Gn 60
C 56
3/3/3

HI-MAPED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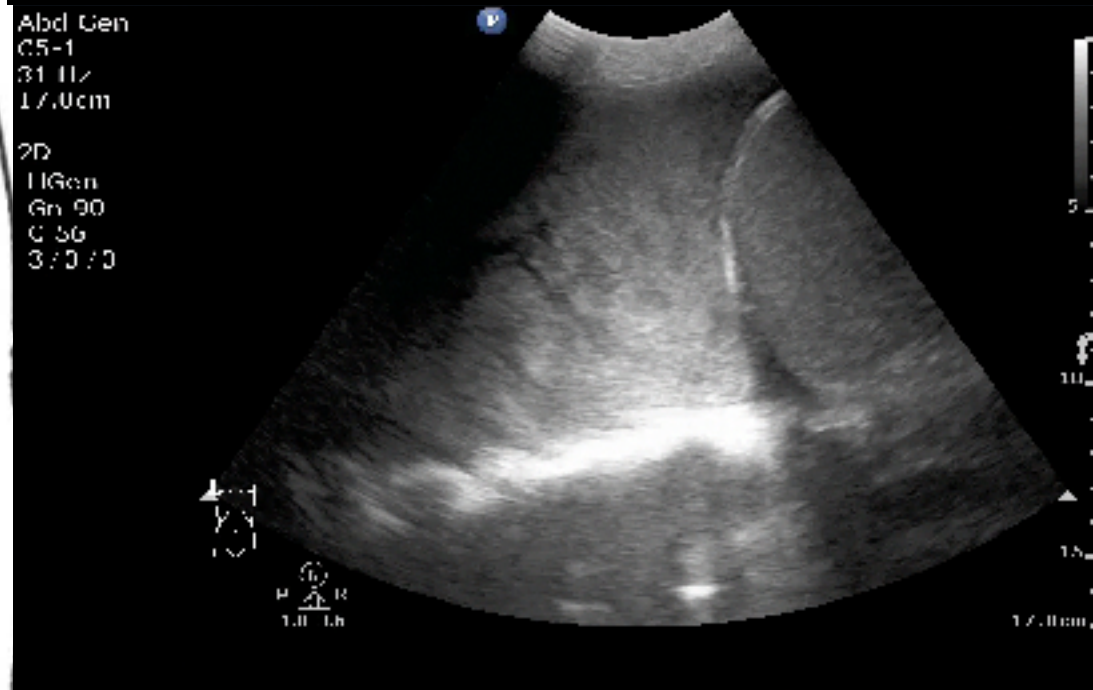
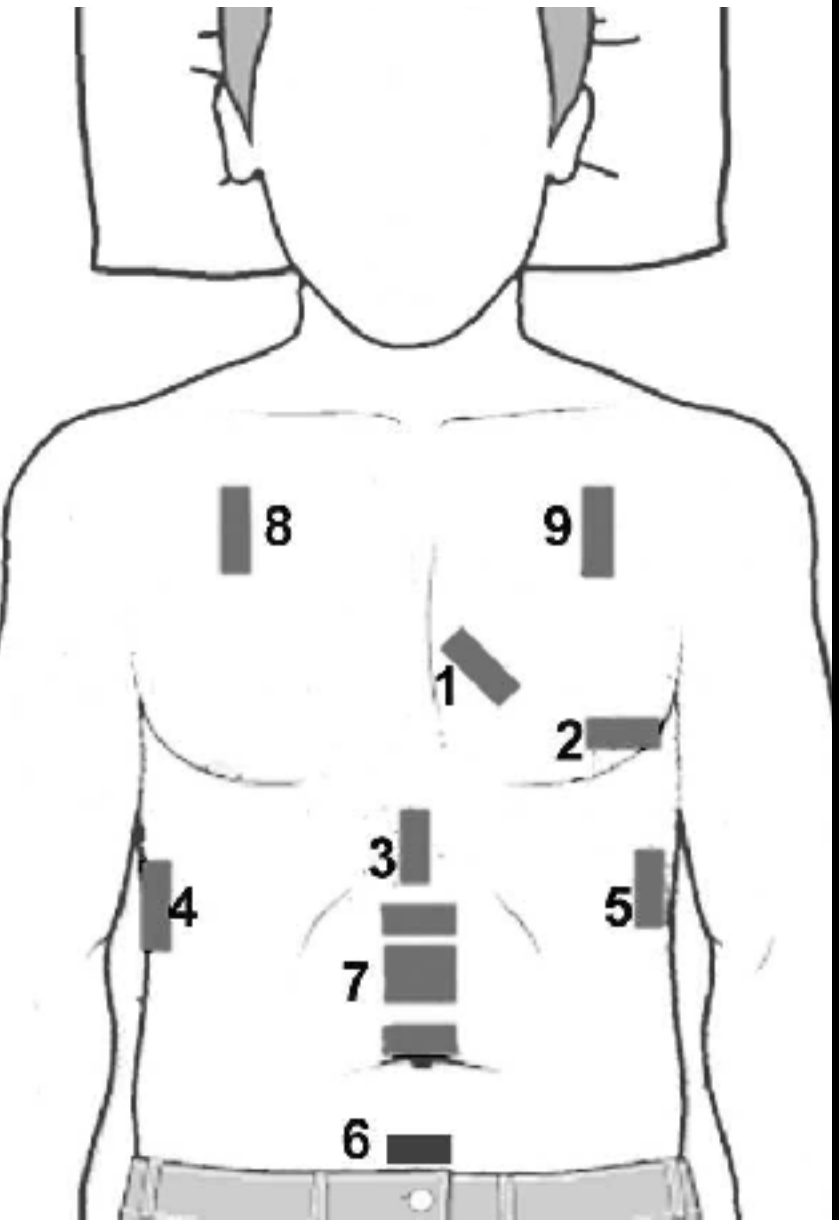
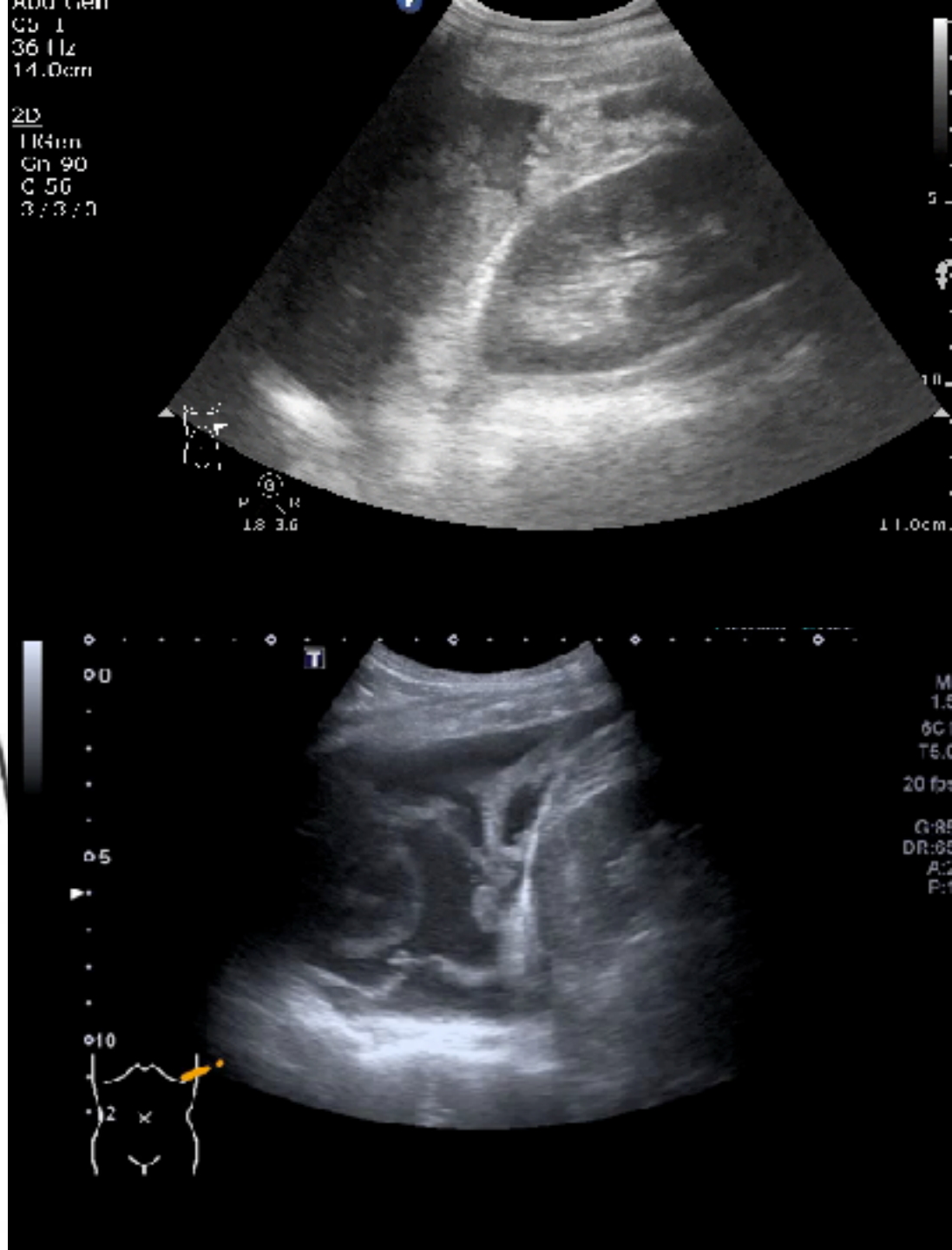
Abd Gen
38 Hz
13.0cm
2D
Gn 95
C 56
13.0cm

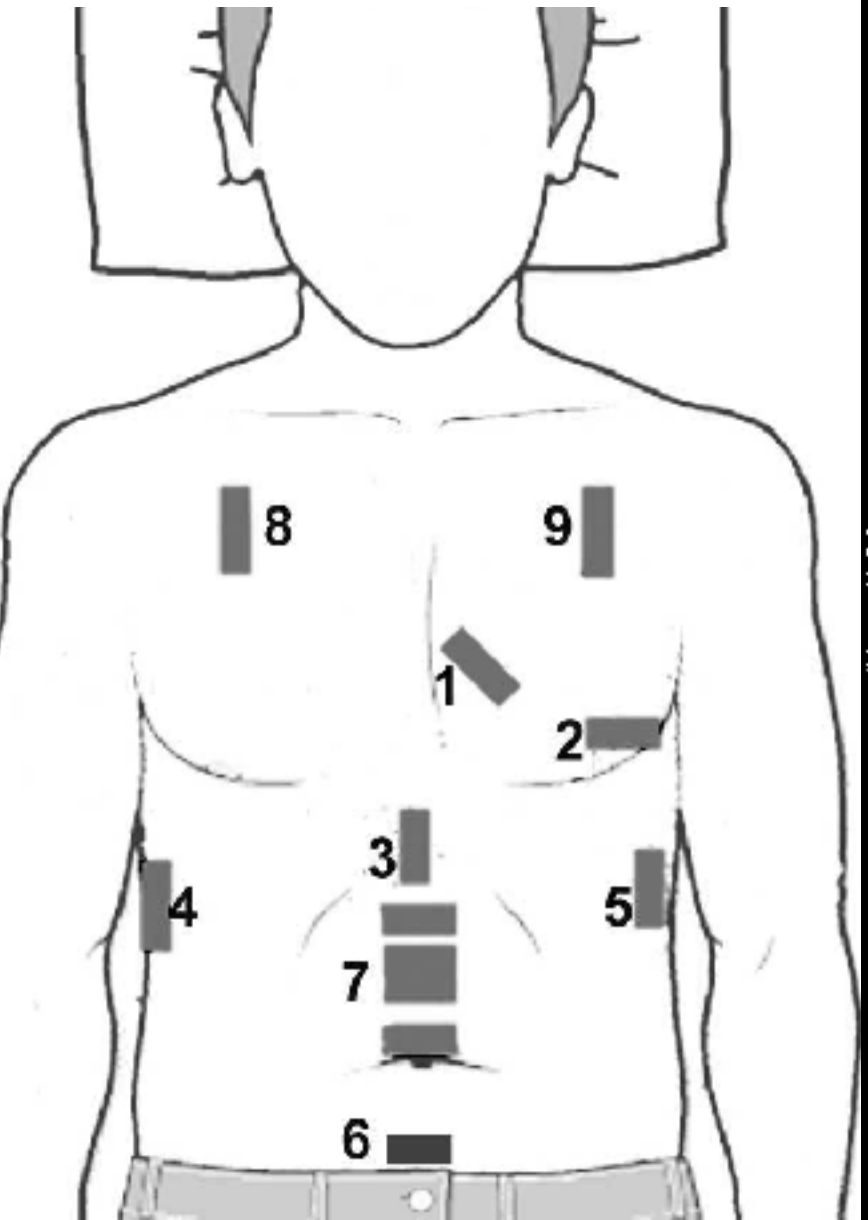

Abd Gen
C5-1
31 Hz
17.0cm
2D
Gn 90
C 56

HI-MAPED





HI-MAPED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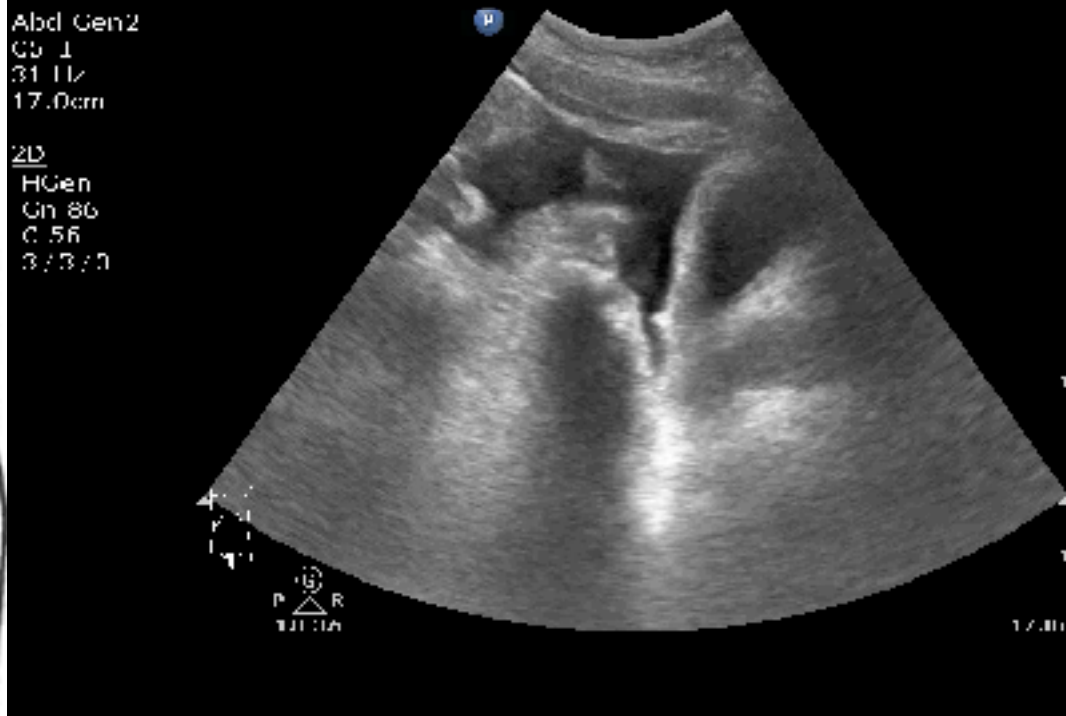
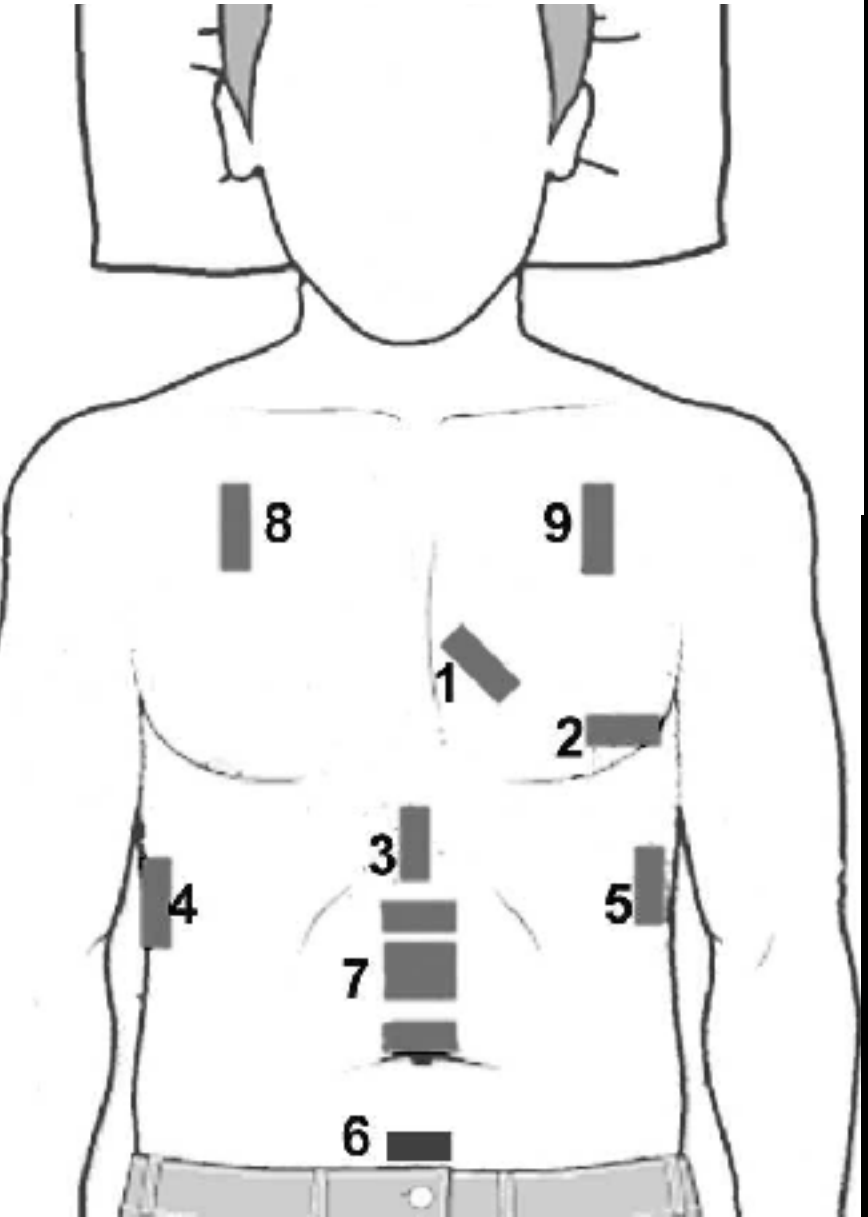
Abd Gen2
31 Hz
17.0cm
2D
HGen
Gn 86
C 56
3 / 3 / 0


Abd Gen2
31 Hz
17.0cm
2D
HGen
Gn 86
C 56
3 / 3 / 0

HI-MAPED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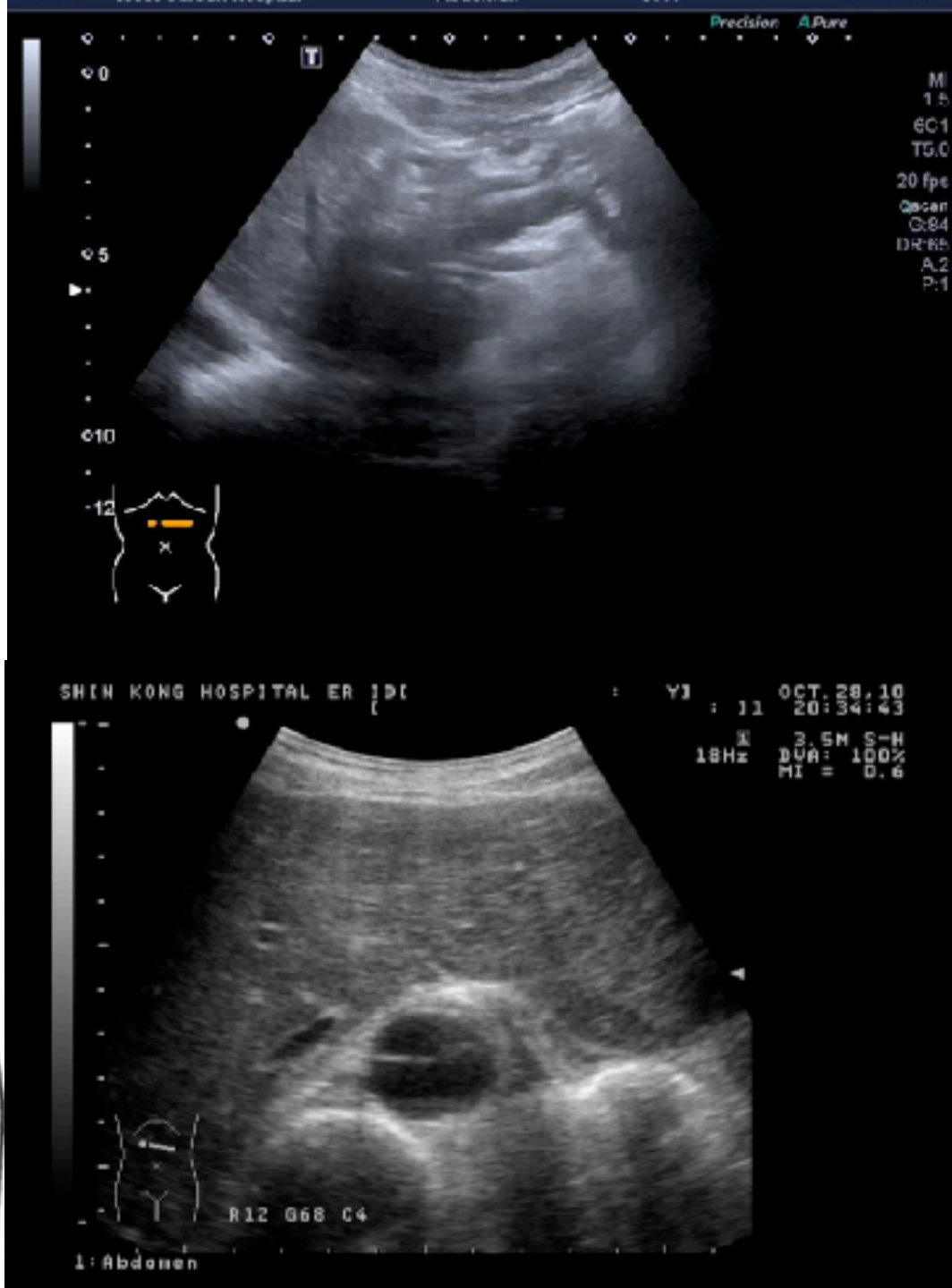
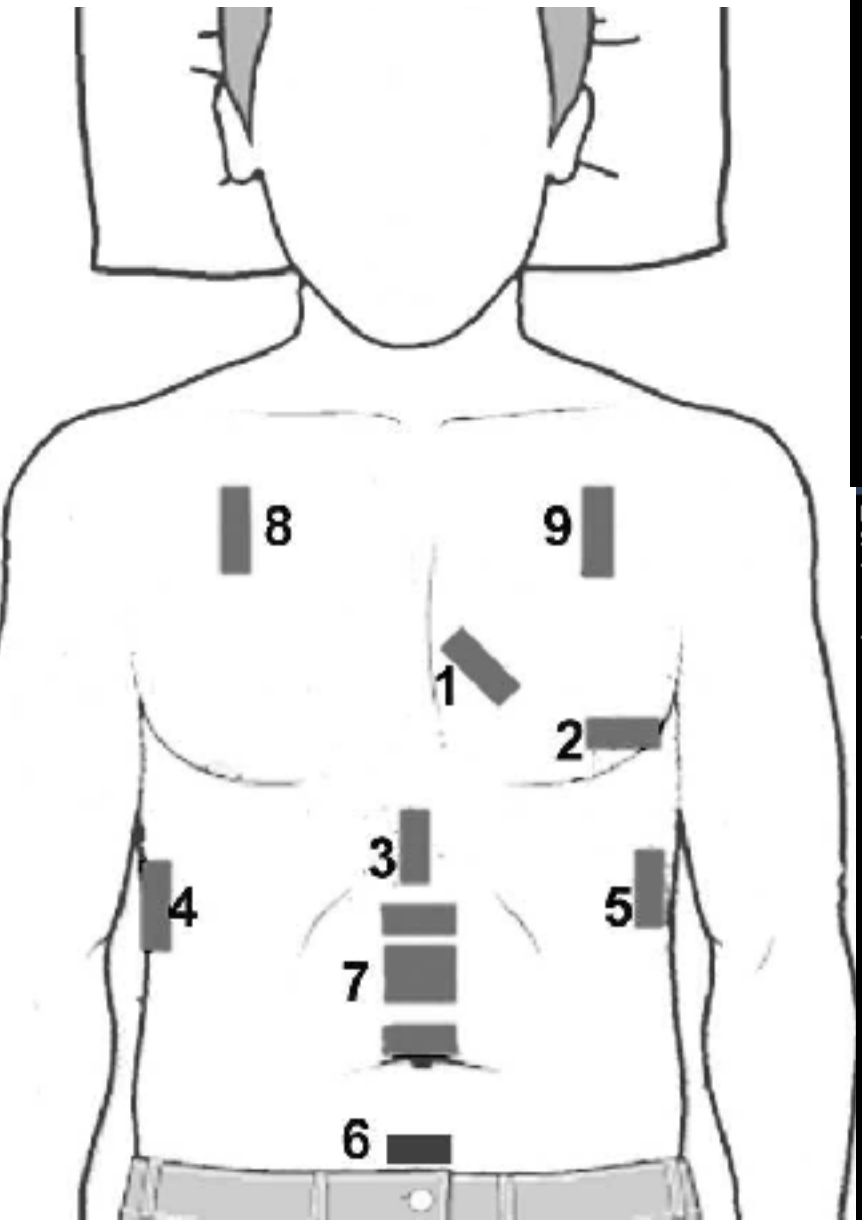

Precision
A.Pure
SHIN KONG HOSPITAL ER
OCT.28,10
20:34:43
R12 G68 C4
1:Abdomen

HI-MAPED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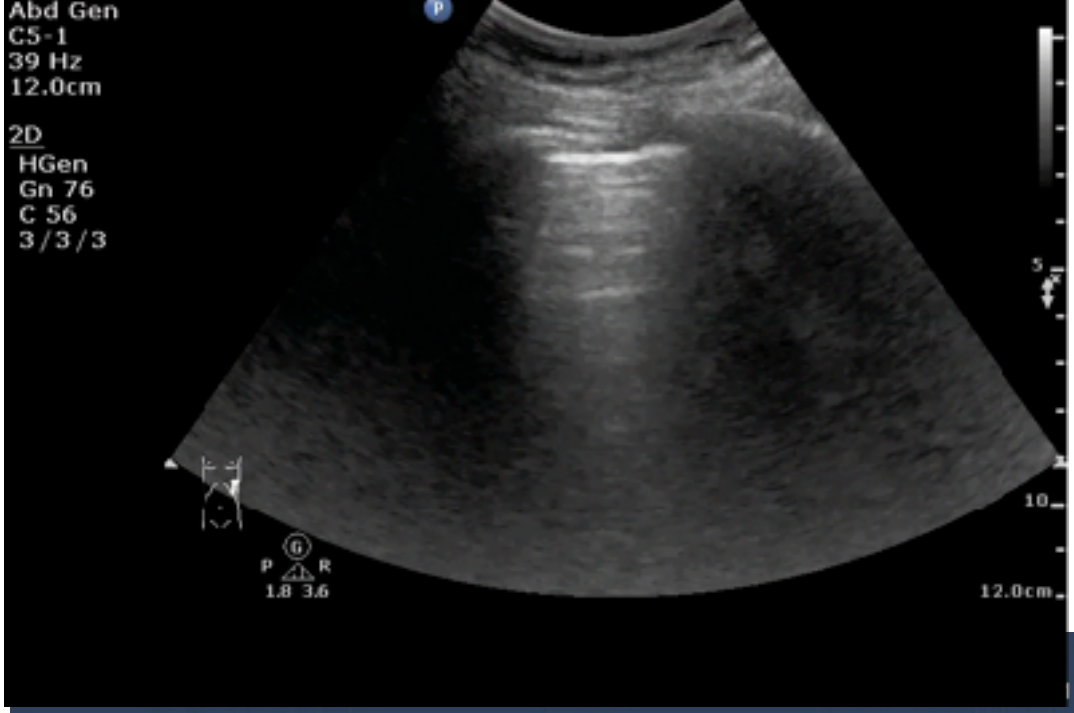
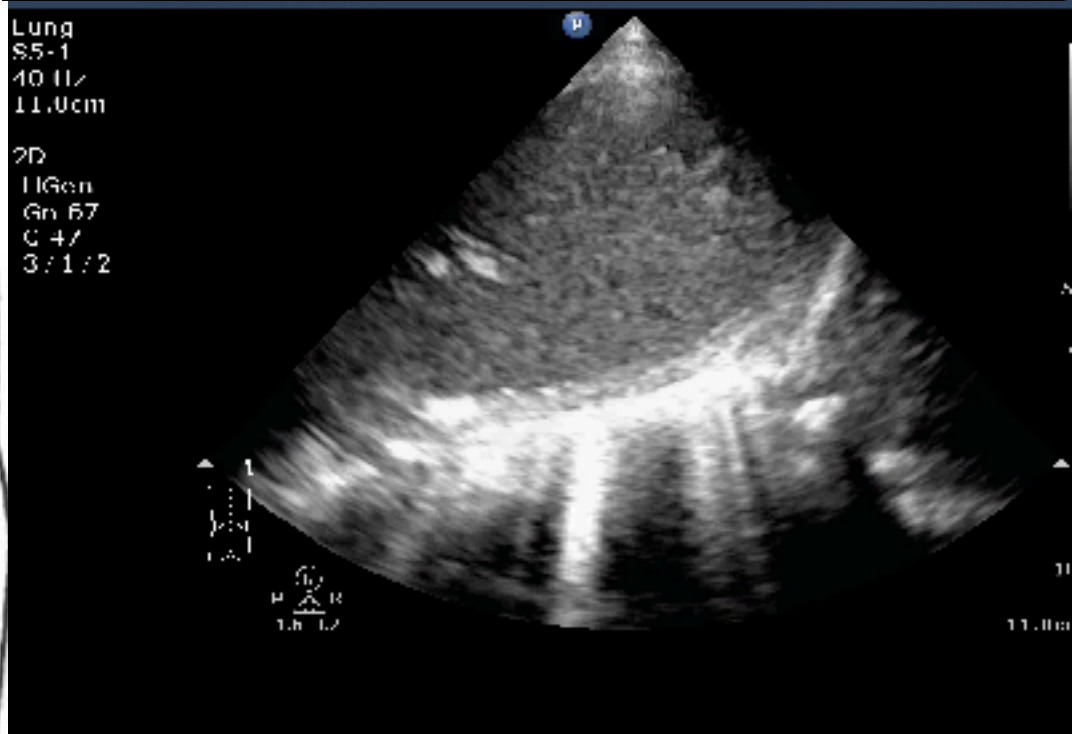
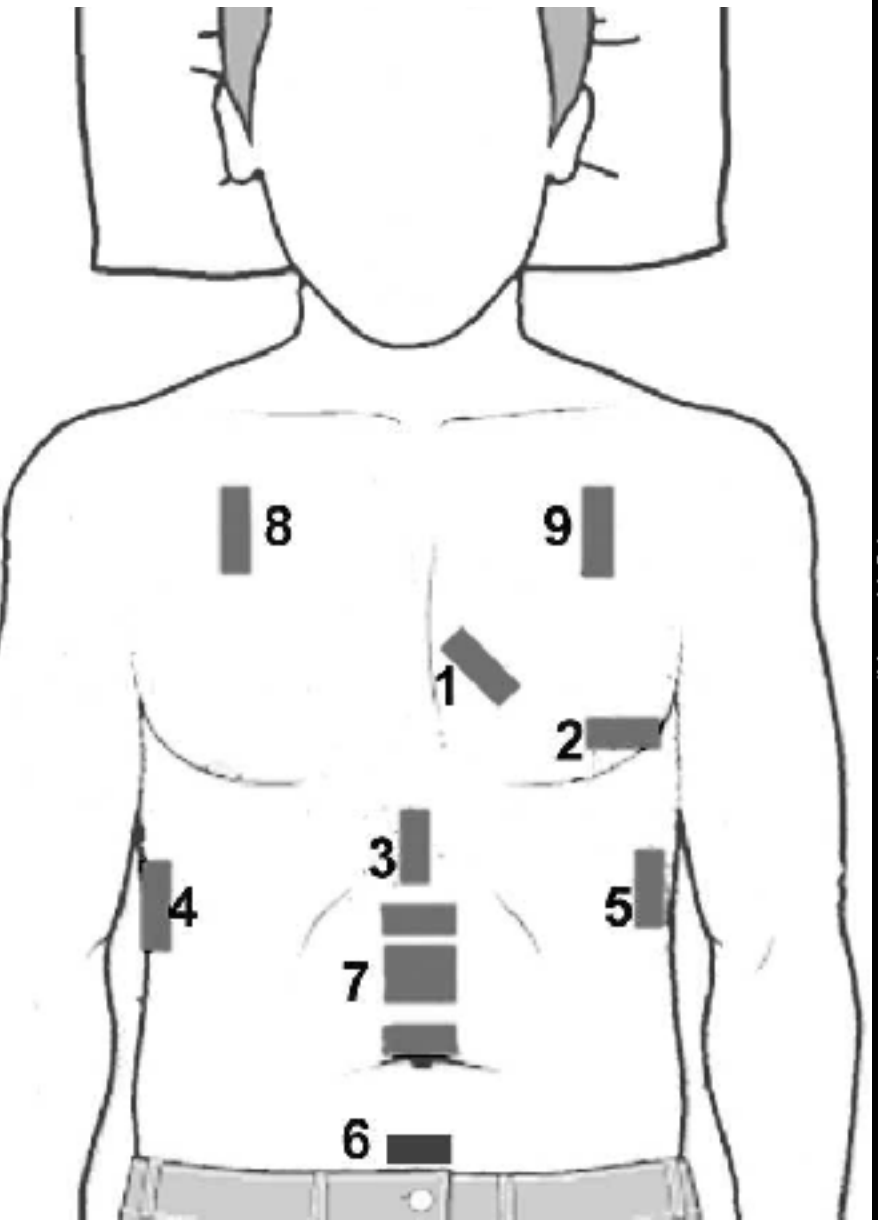
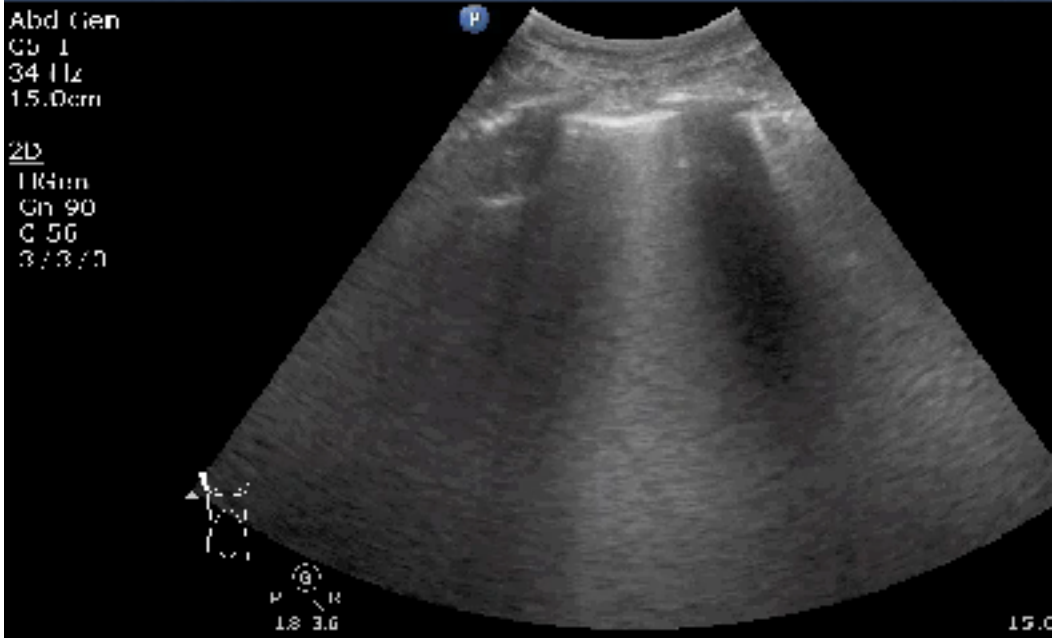
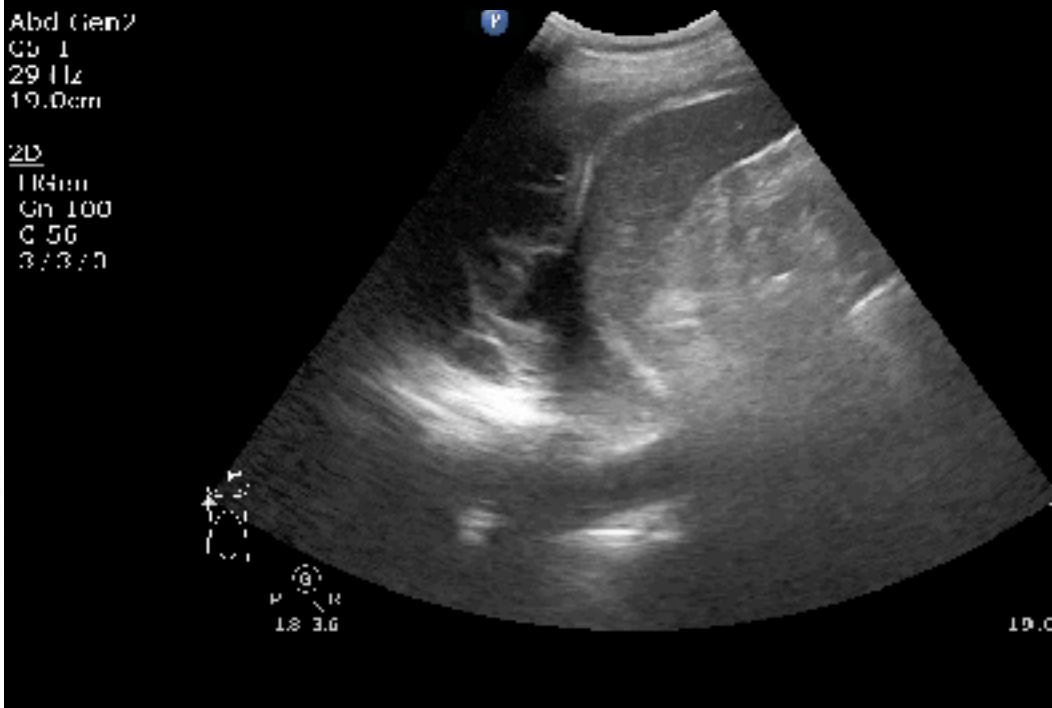

Abd Gen
C5-1
39 Hz
12.0cm
2D
HGen
Gn 76
C 56
3/3/3
P R
1.8 3.6
10
12.0cm


Lung
S5-1
40 Hz
11.0cm
2D
HGen
Gn 67
C 47
3/1/2

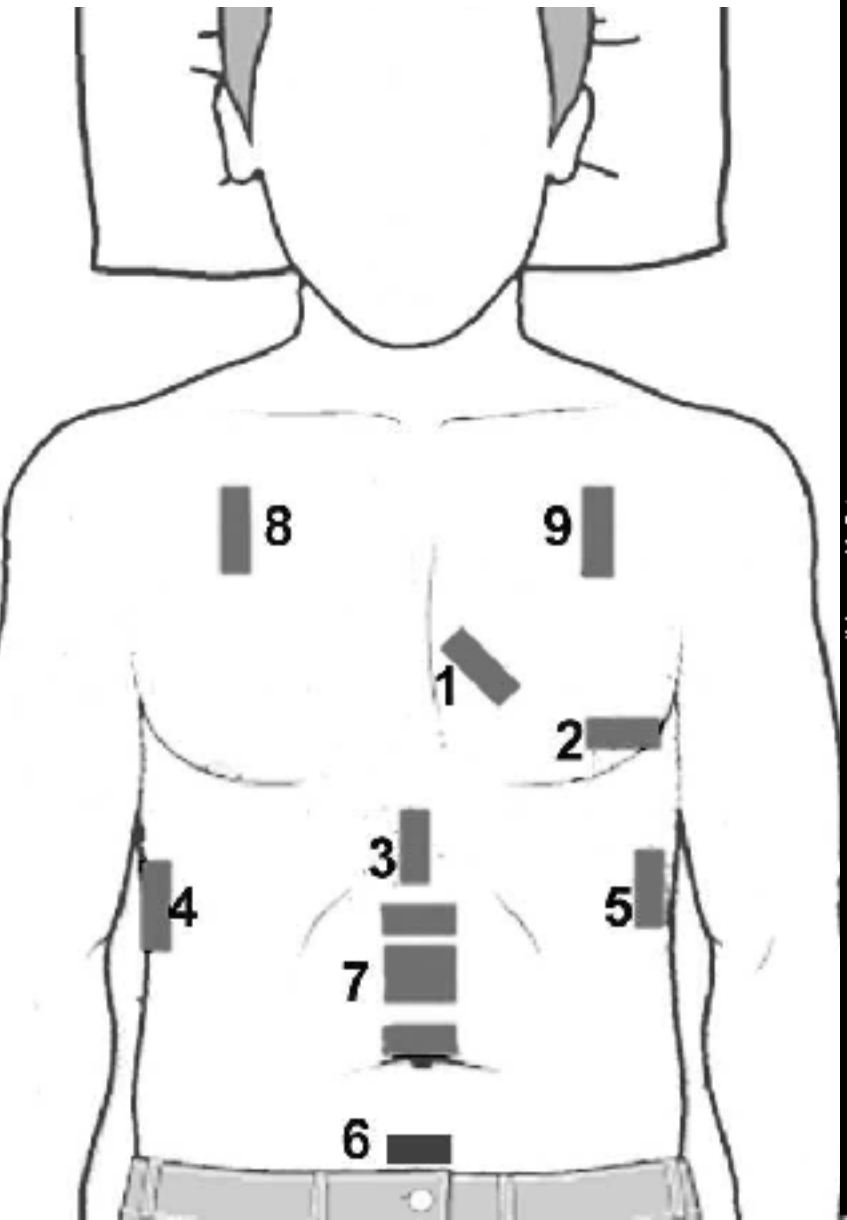
HI-MAPED

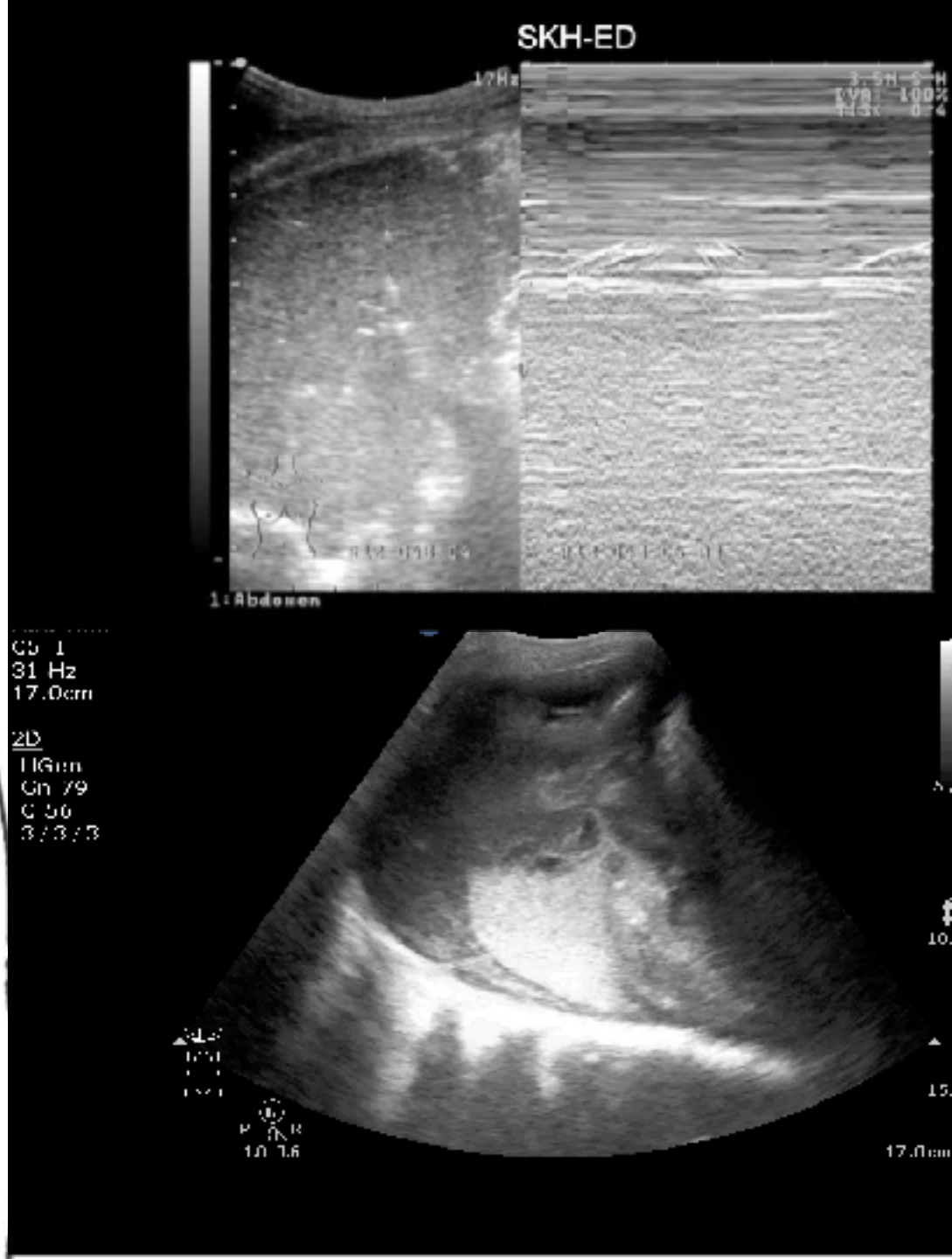

8
9
1
2
3
4
5
7
6


Abd Gen
C5 1
34 Hz
15.0cm
2D
THI=m
Gn 90
C 56
3/3/0
1.8 3.6

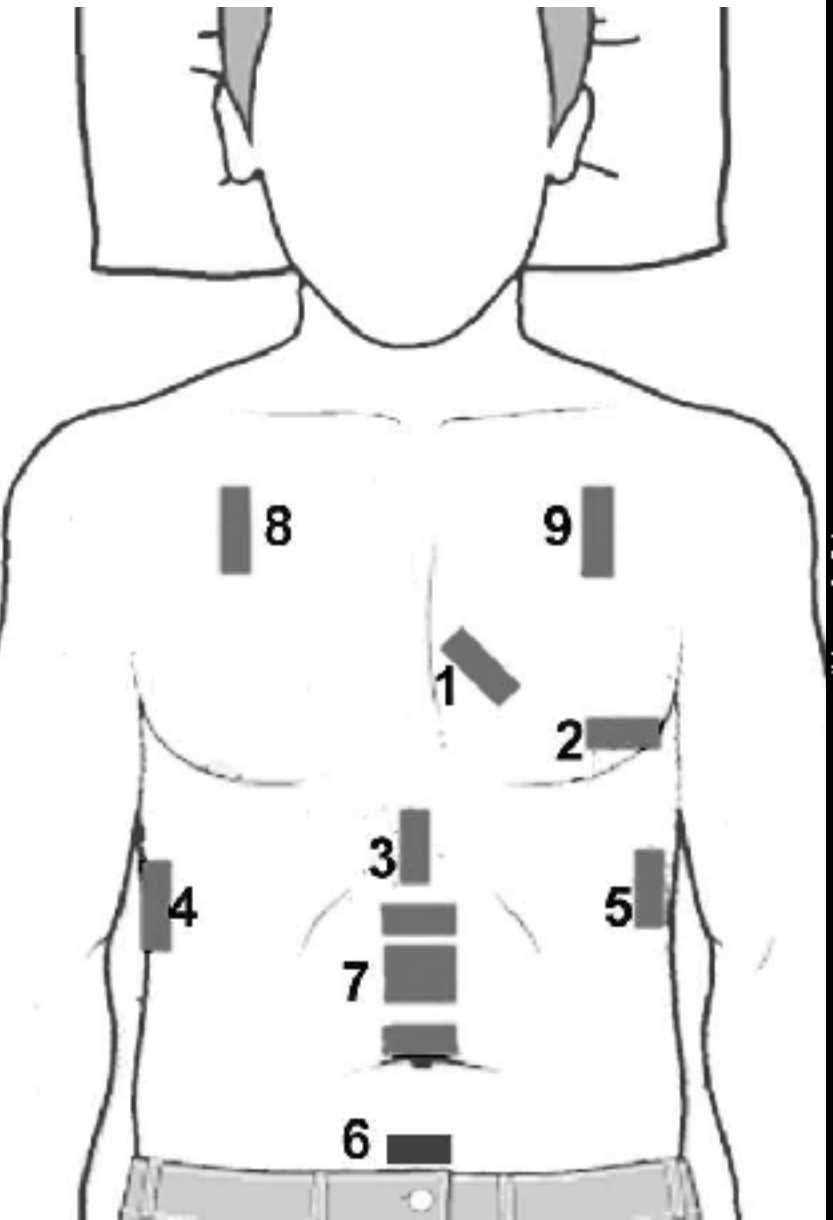

Abd Gen2
C5 1
29 Hz
19.0cm
2D
THI=m
Gn 100
C 56
3/3/0
1.8 3.6

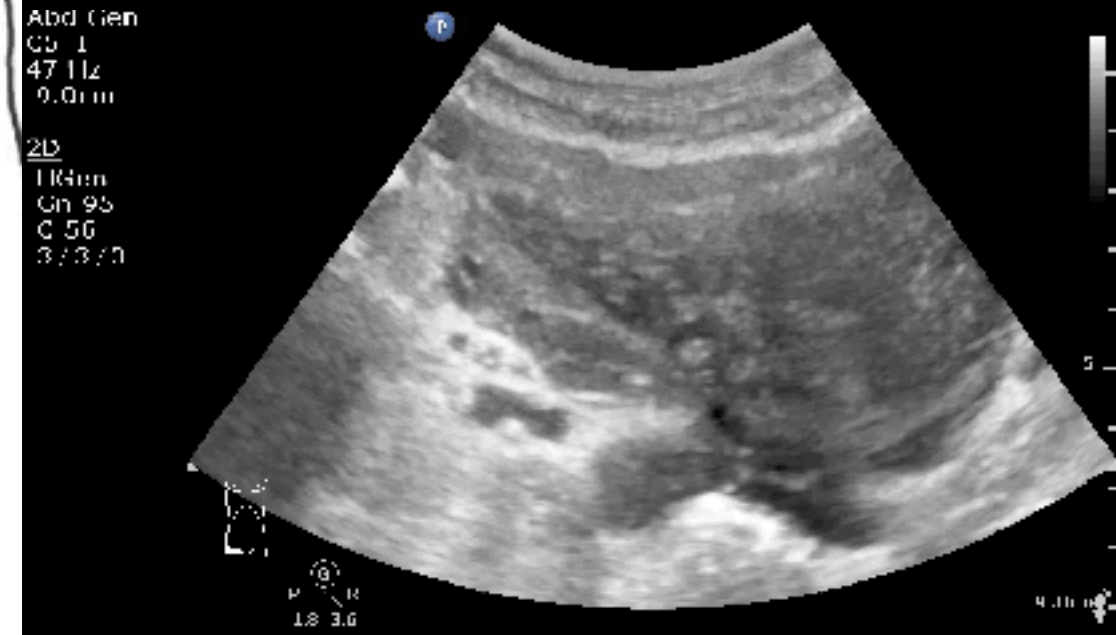
HI-MAP ED



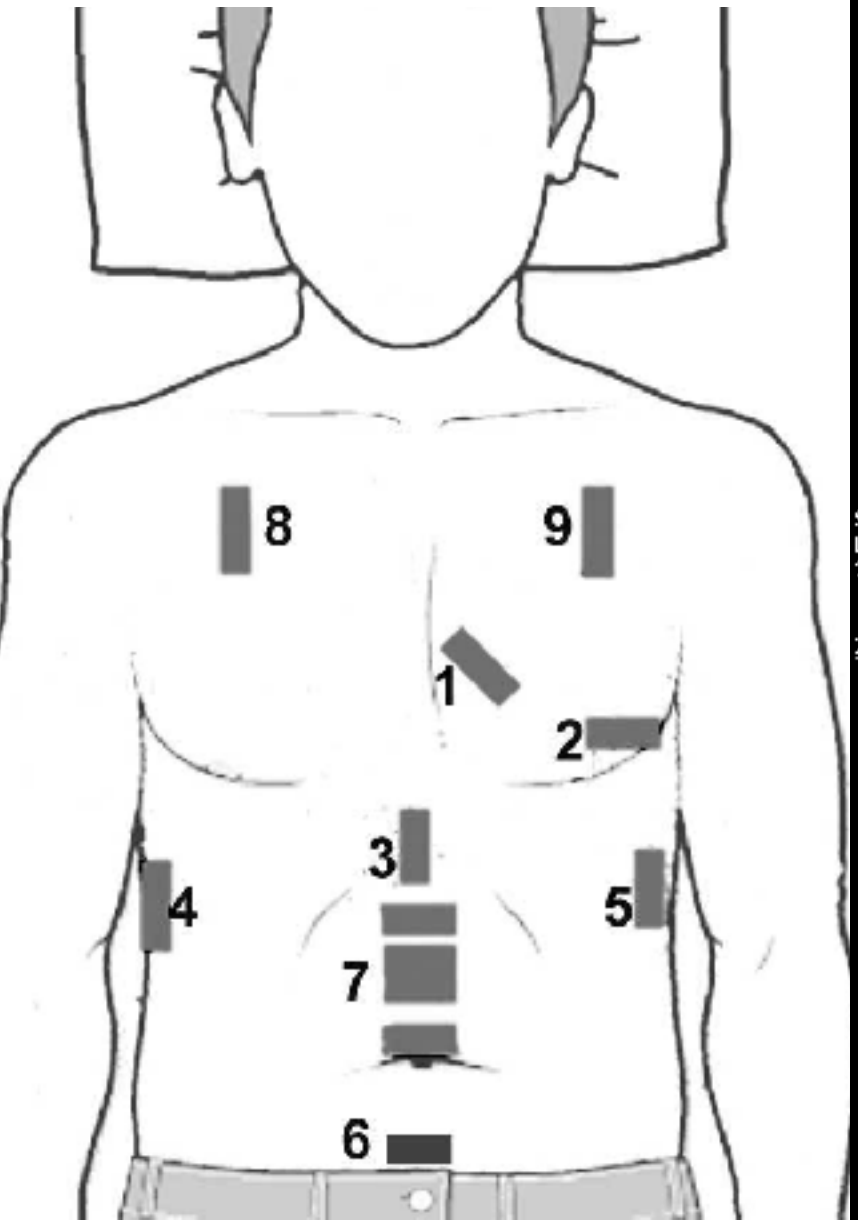


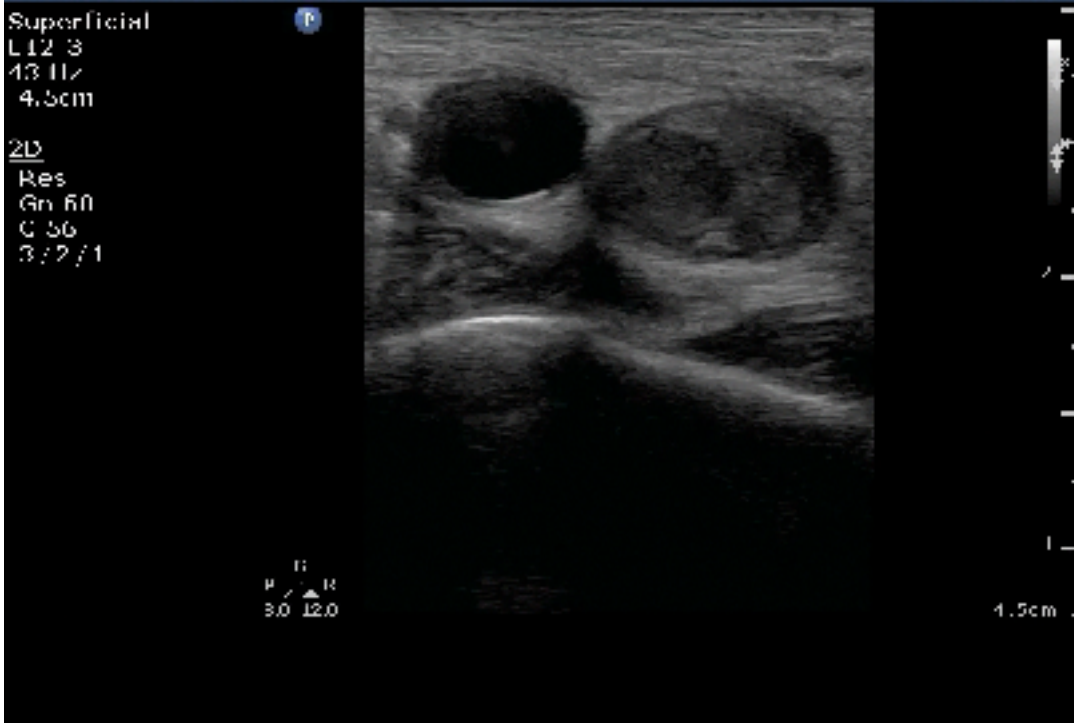
HI-MAPED





HI-MAPED

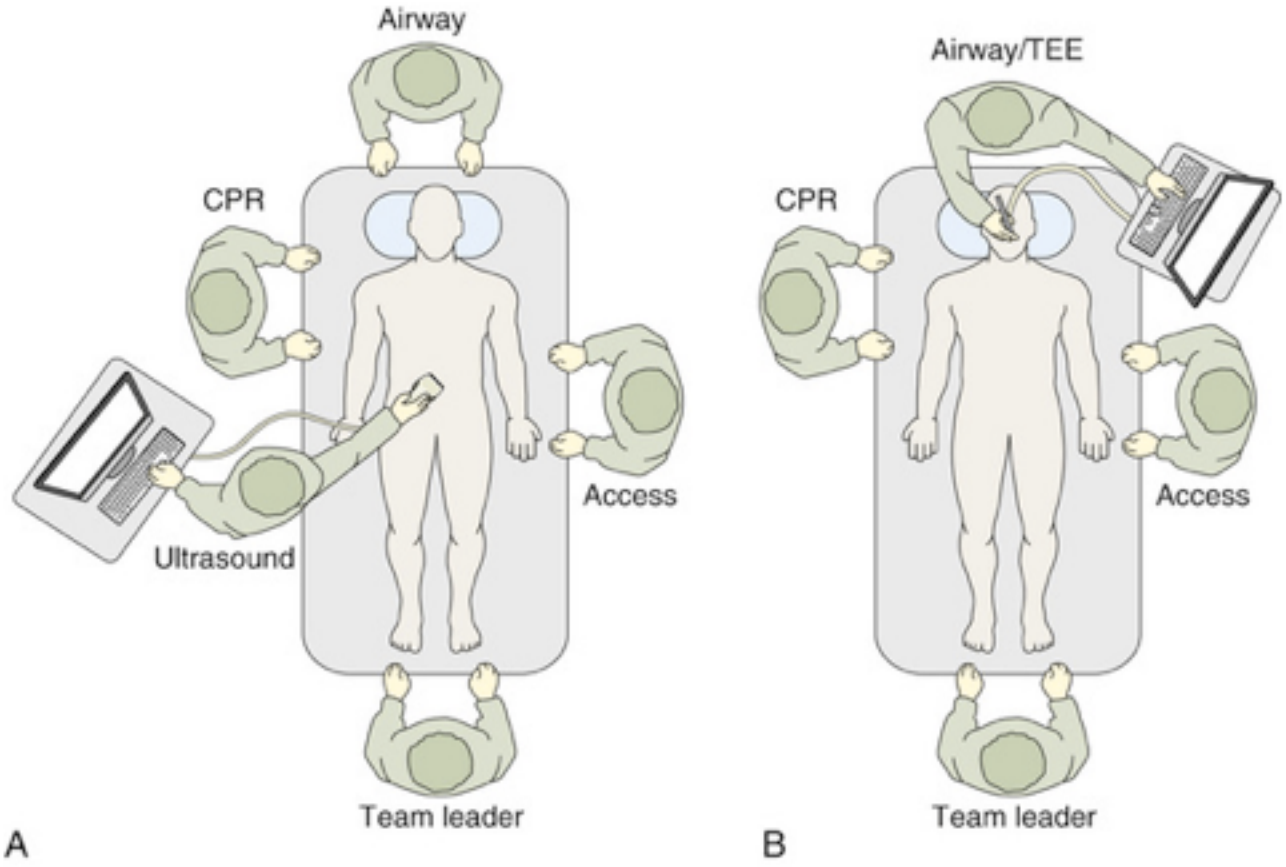

8
9
1
2
3
4
5
7
6


Superficial
L12-3
43 Hz
4.5cm
2D
Res
Gn 60
C 56
3/2/1
3.0 12.0
4.5cm


Superficial
L12-3
29 Hz
4.0cm
2D
Gen
Gn 65
C 52
4/3/2
3.0 12.0
4.0cm

ULTRASOUND PROGRAM

Resuscitation



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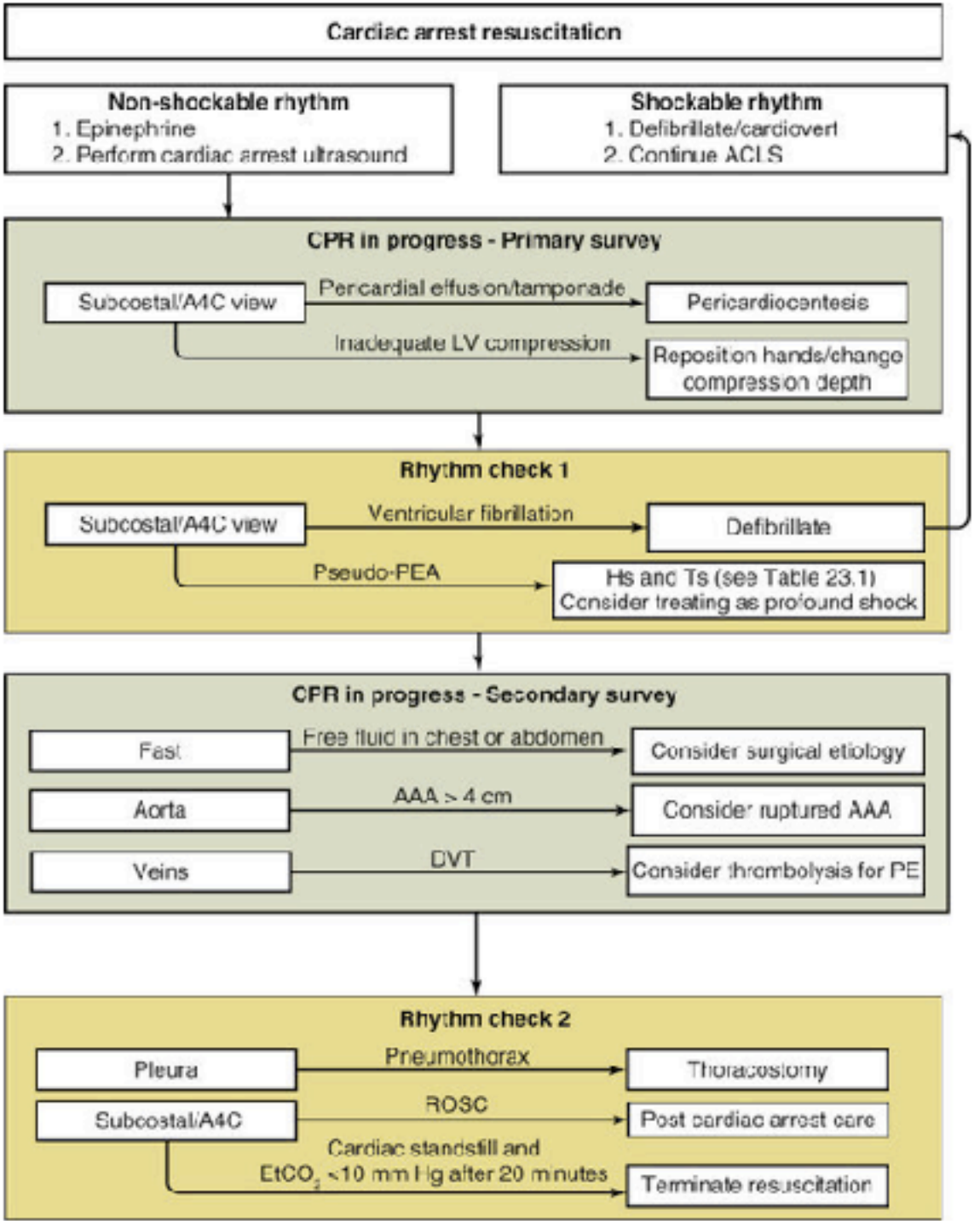
ULTRASOUND PROGRAM

Protocol

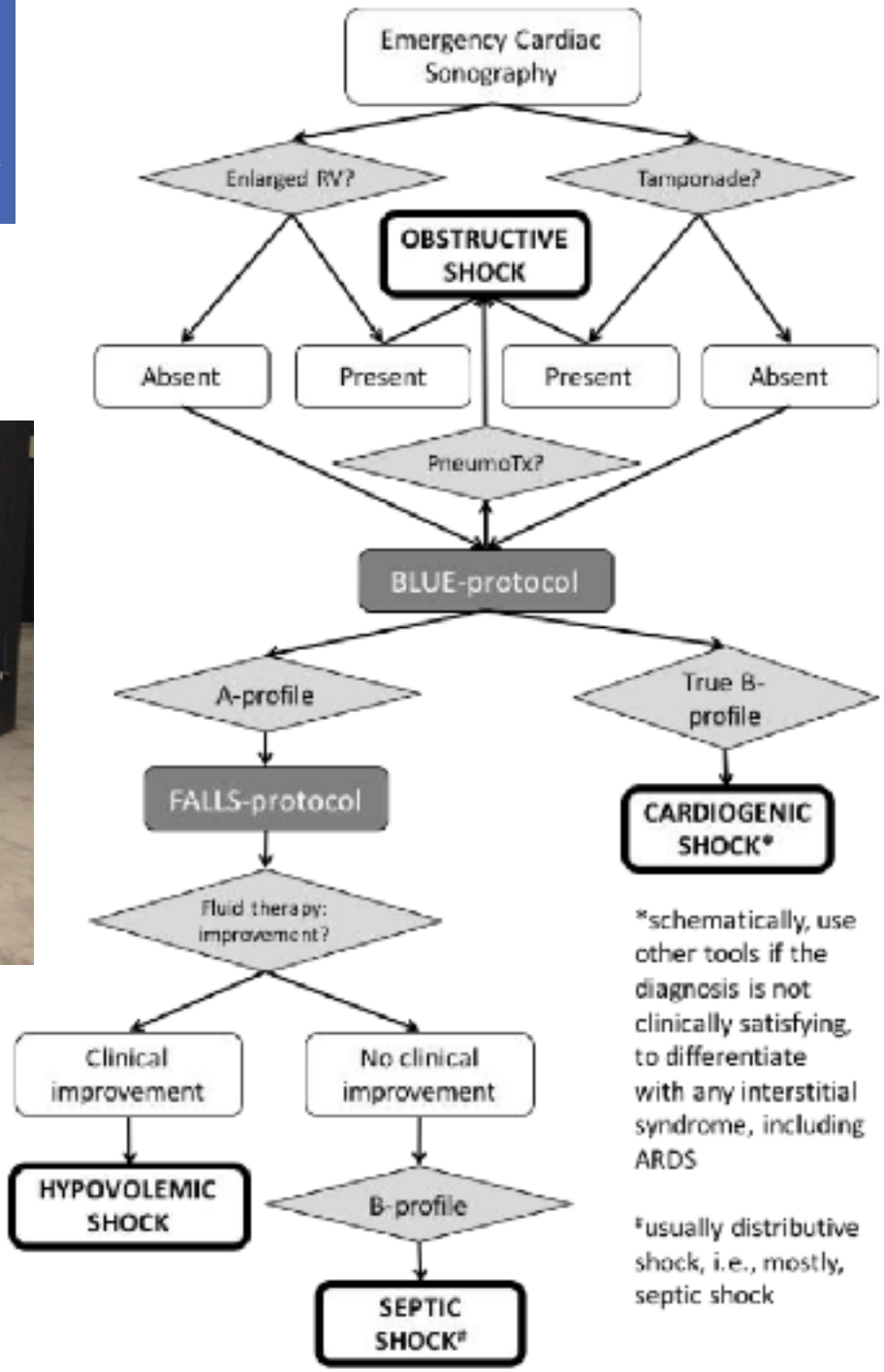
Hands-off

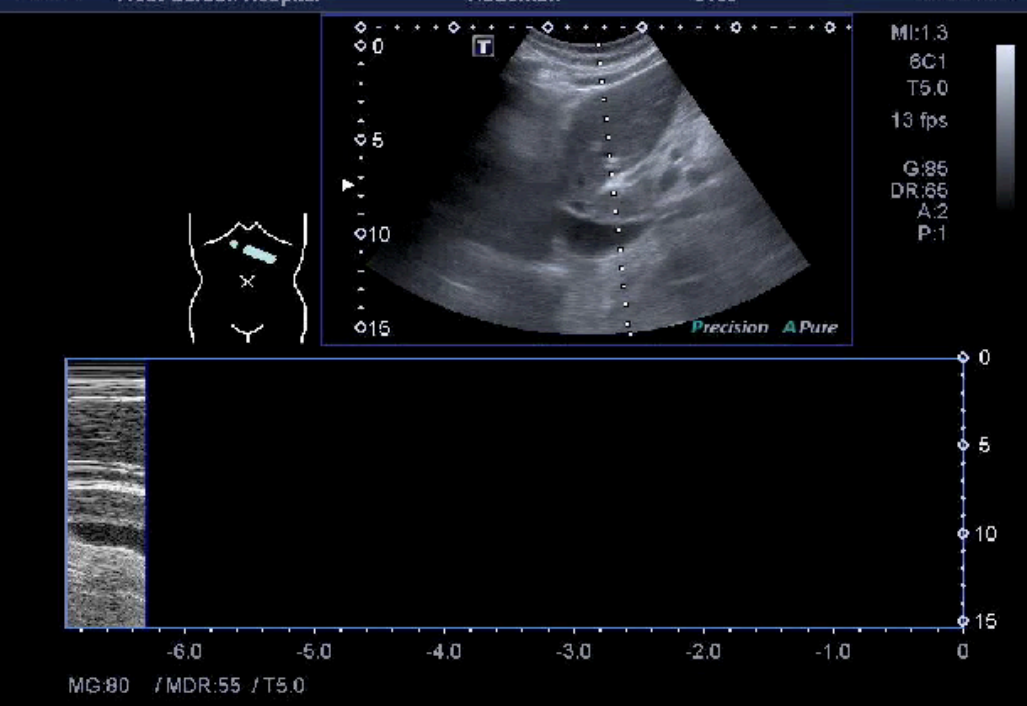
Taipei Medical University Conto

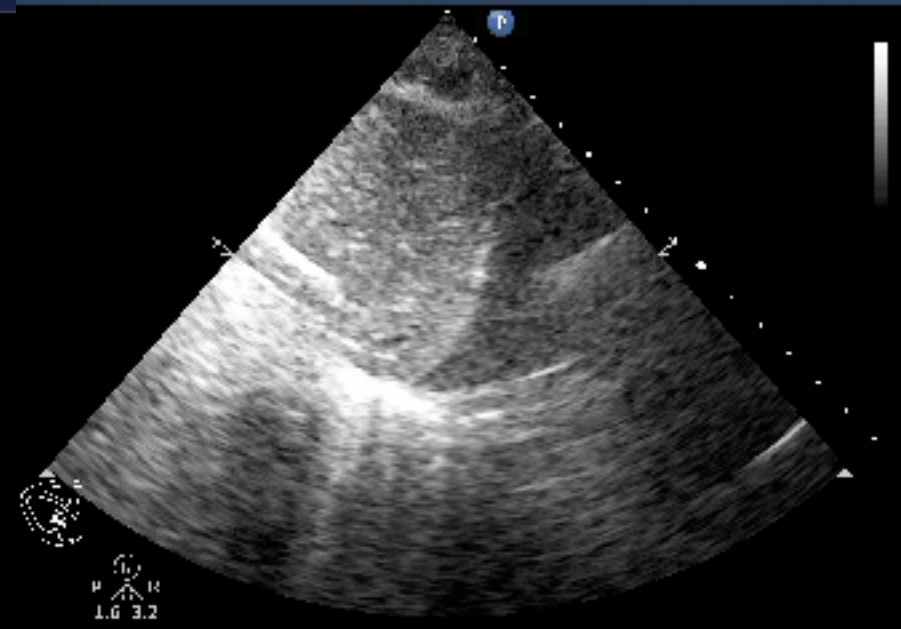


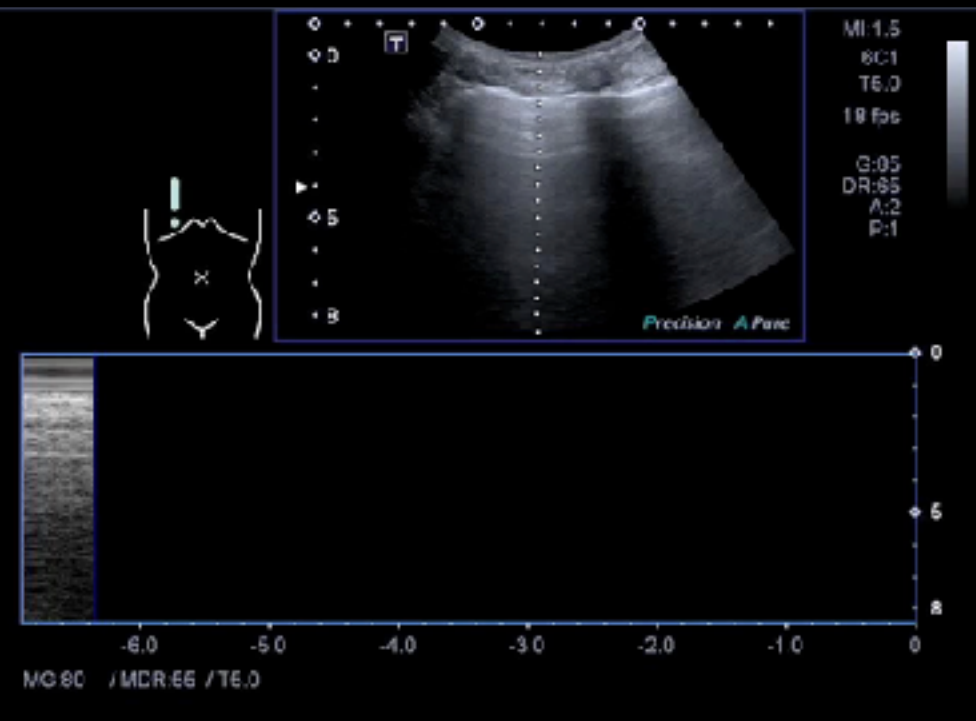
FALLS-protocol

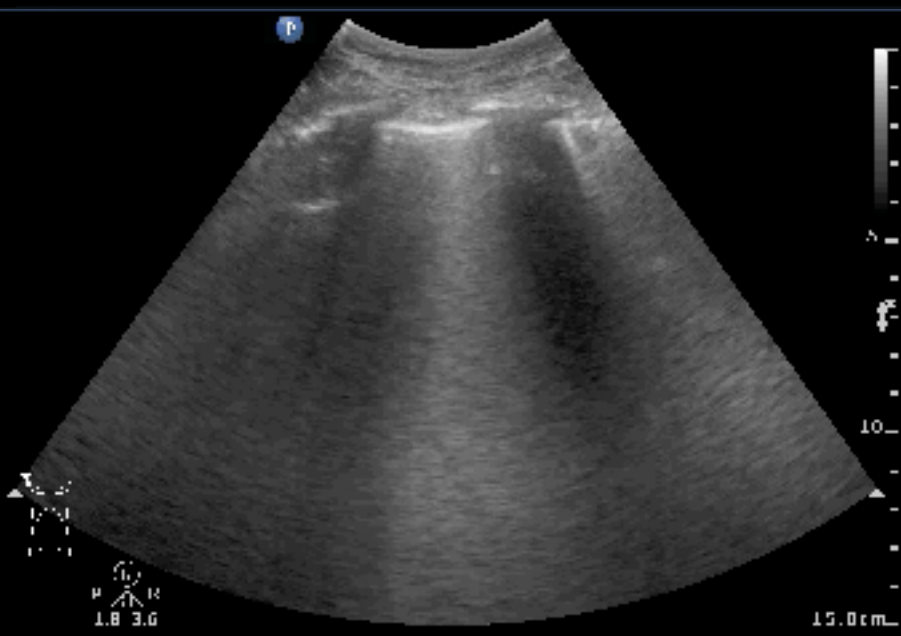
Taipei Medical University Center for Educat

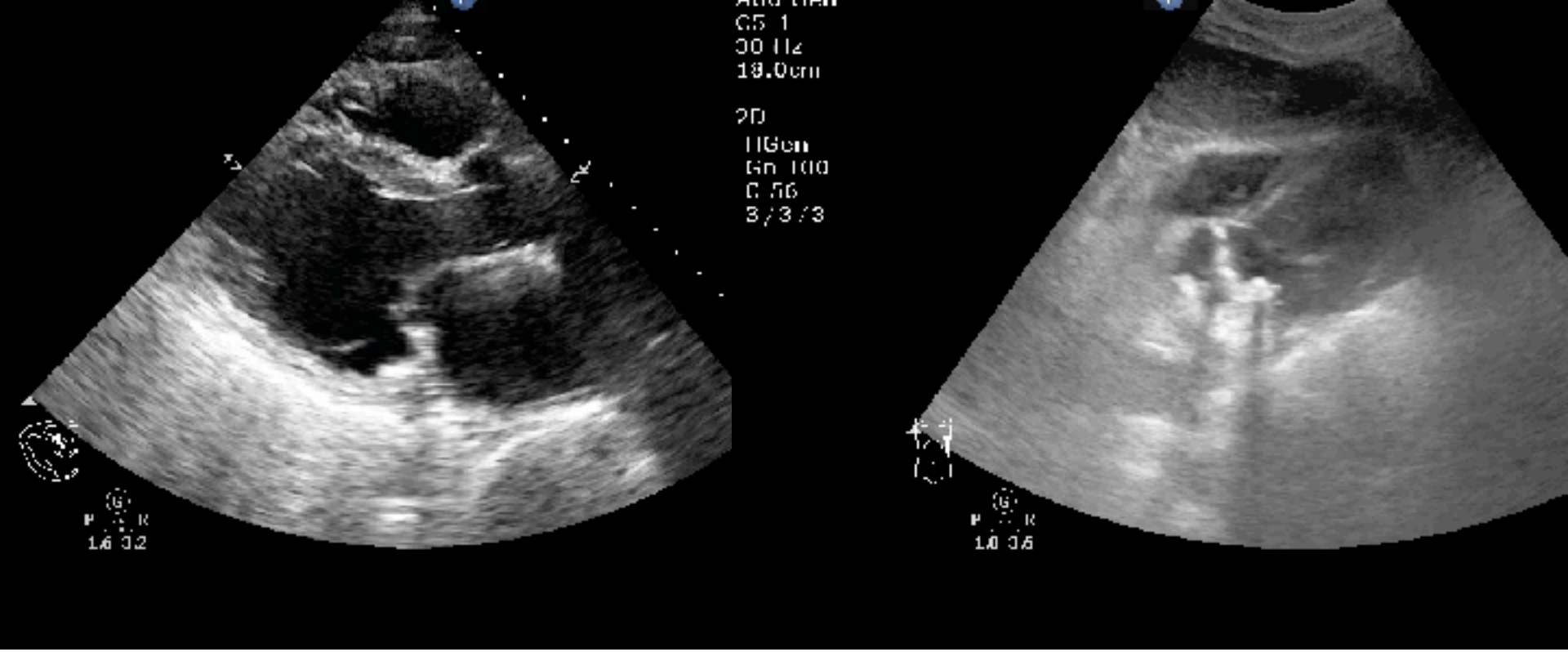



MI:1.3
6C1
T5.0
13 fps
G:85
DR:65
A:2
P:1
Precision A Pure
0
5
10
15
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0
MG:80 / MDR:55 / T5.0


1.6 3.2


MI 1.5
6C1
T6.0
18 fps
G:85
DR:65
A:2
P:1
Precision A Pure
0
5
8
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0


1.8 3.6
10
15.0cm



Medical University Center for Education in Medical Simulation

ULTRASOUND PROGRAM

Hemodynamic Management

IVC / Vein

Lung

Heart

HOLA: Holistic Approach

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