Ultrasound in the ICU: What Every Intensivist Should Know

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HARVARD MEDICAL SCHOOL

Learning objectives

- Discuss the utility and various applications of bedside ultrasound in the intensive care unit
- Provide a brief overview regarding the types of ultrasound intensivists should be familiar with including:
  - Cardiac
  - Thoracic
  - Abdominal
  - Vascular
  - Procedural

Society of Critical Care Medicine

The Intensive Care Professionals

Guidelines for the Appropriate Use of Bedside General and Cardiac Ultrasonography in the Evaluation of Critically Ill Patients—Part I: General Ultrasonography

Heidi L. Frankel, MD, FACS, FCCM, FCCP[1]; Andrew W. Kirkpatrick, MD, MHSC, FRSC, FACS[2]; Mahmoud Elbarbary, MD, PhD, MSc, EDIC[3,4,5]; Michael Blaivas, MD, FACEP, FAIUM[6]; Himanshu Desai, MD[7]; David Evans, MD, RDMS[8]; Douglas T. Summerfield, MD[9]; Anthony Slonim, MD, DrPH, FCCM[10]; Raoul Breitkreutz, MD[11,12]; Susanna Price, MD, PhD, MRCP, EDICM, FFICM, FESC[13]; Paul E. Marik, MD, FCCM, FCCP[14]; Daniel Talmor, MD, MPH, FCCM[15]; Alexander Levitov, MD, FCCM, FCCP, RDCS[7]

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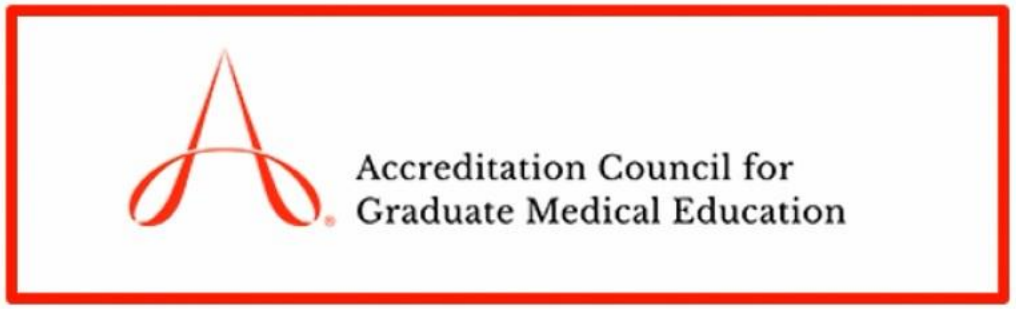


- Anesthesiology Critical Care Medicine
- Internal Medicine Critical Care Medicine
- Pulmonary Critical Care Medicine
- Surgical Critical Care

Benefits

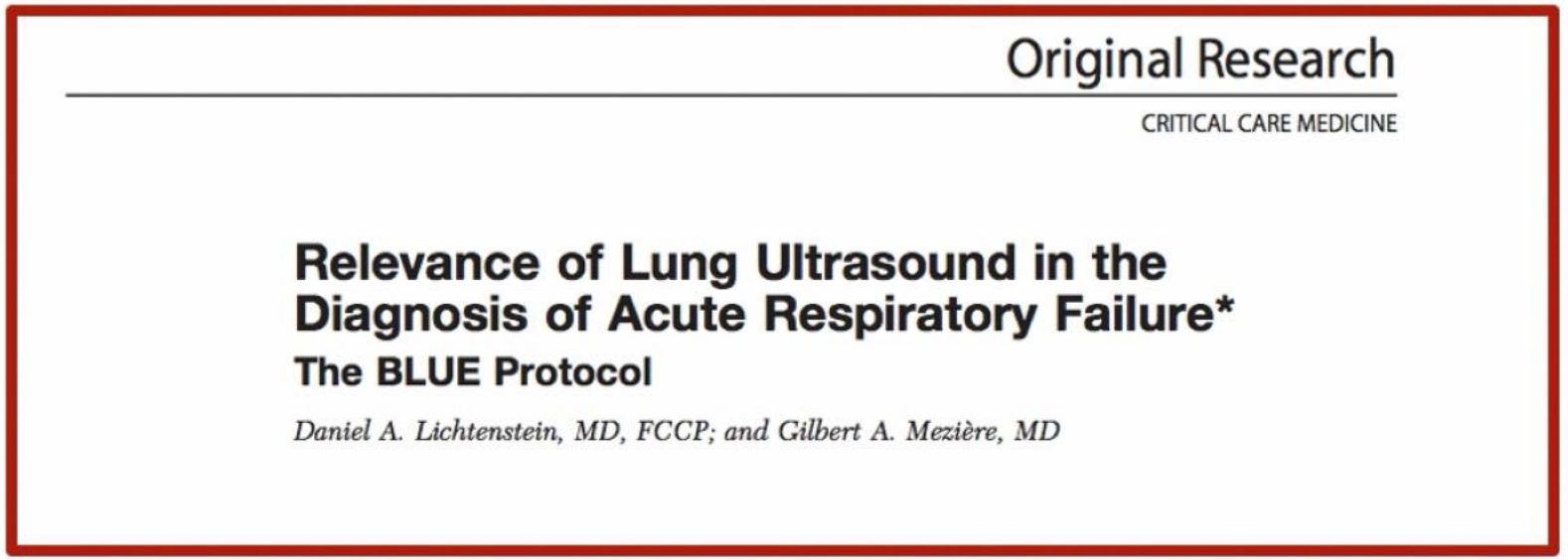
- Can be obtained real-time
- The treating physician is the one performing ad interpreting the scan, therefore they can incorporate other clinical data to understand the clinical scenario better
- Can be repeated as often as needed to monitor treatment effects

Pitfalls

- Inadequate views
- Operator dependent
- Incorrect interpretation

- Intensivists correctly identified:
  - normal LV function in 22 of 24 cases (92%)
  - abnormal LV function in 16 of 20 cases (80%)
- The K statistic for the agreement between intensivist and echocardiographer for any abnormality in LV function was 0.72

Chest. 2009 Jun;135(6):1416-20



- The use of the BLUE protocol would have provided correct diagnoses in 90.5% of cases

Chest. 2008 Jul;134(1):117-25

- Modified the admitting diagnosis in 32/125 patients (25.6%)
- Confirmed it in 73/125 patients (58.4%)
- Not effective in confirming or modifying it in 17/125 patients (13.6%)
- Missed it in 3/125 patients (2.4%)
- Prompted further testing in 23/125 patients (18.4%)
- Led to changes in medical therapy in 22/125 patients (17.6%)
- Led to invasive procedures in 27/125 patients (21.6%)

Anesthesiology. 2012 Oct;117(4):801-9

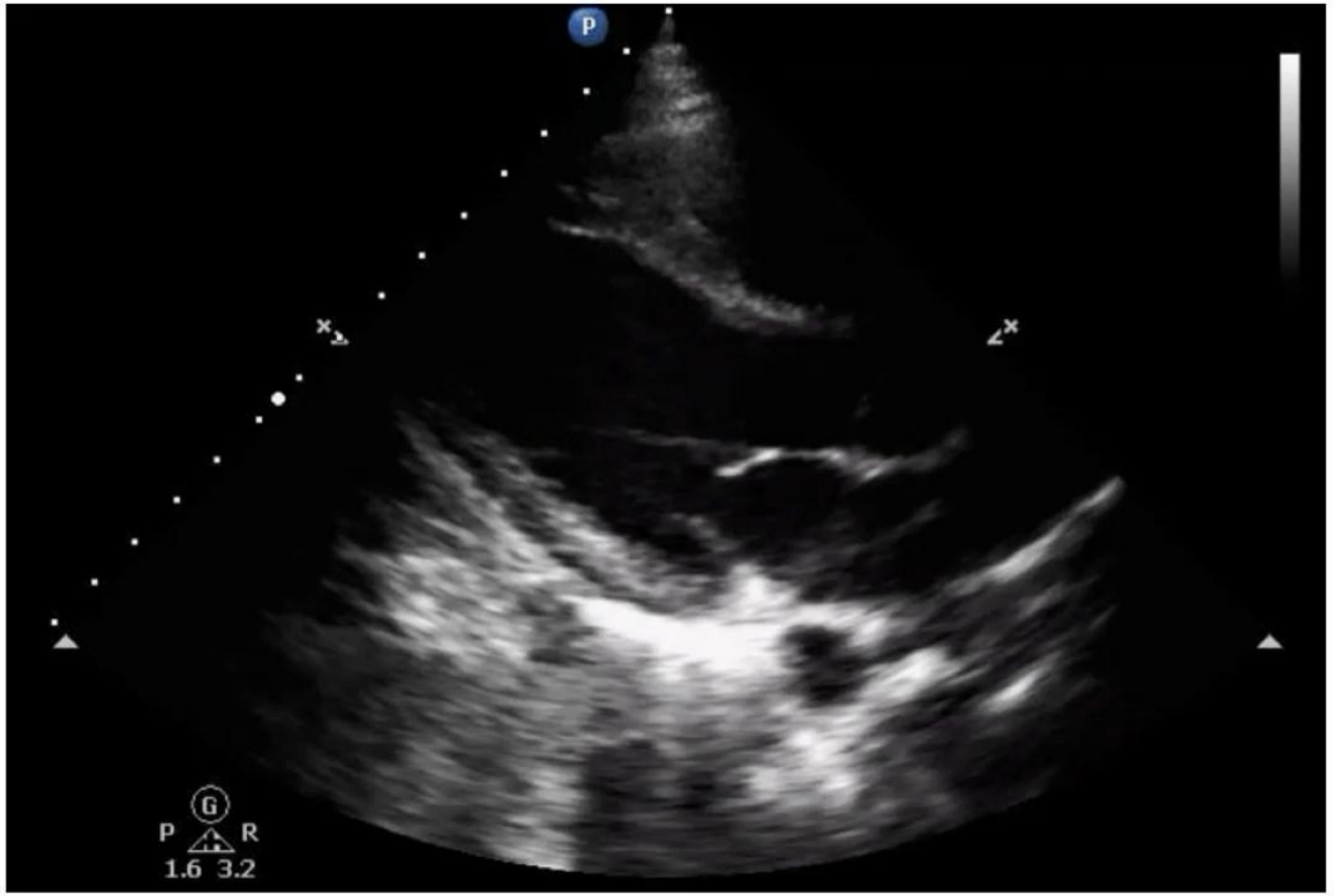
Critical Care Ultrasound

- Cardiac
  - Basic
  - Advanced
- Thoracic
  - Pleura
  - Lung
- Vascular
- Abdominal
- Procedural

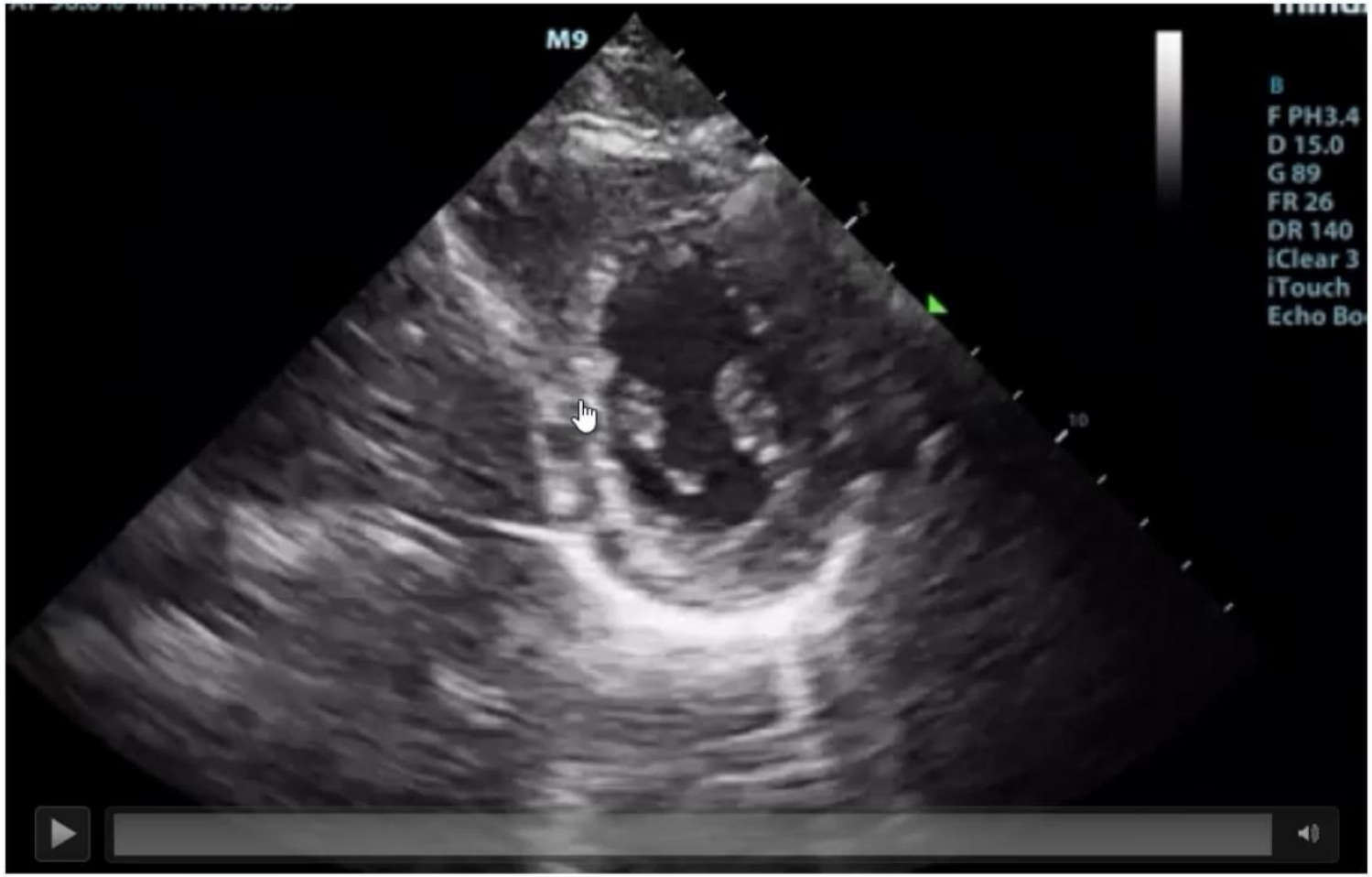
Basic critical care echocardiography

- Global LV size and function
- Global RV size and function
- Volume status, LV and RV filling, IVC variability and size
- Pericardial effusion
- Pericardial tamponade
- Gross valvular abnormalities

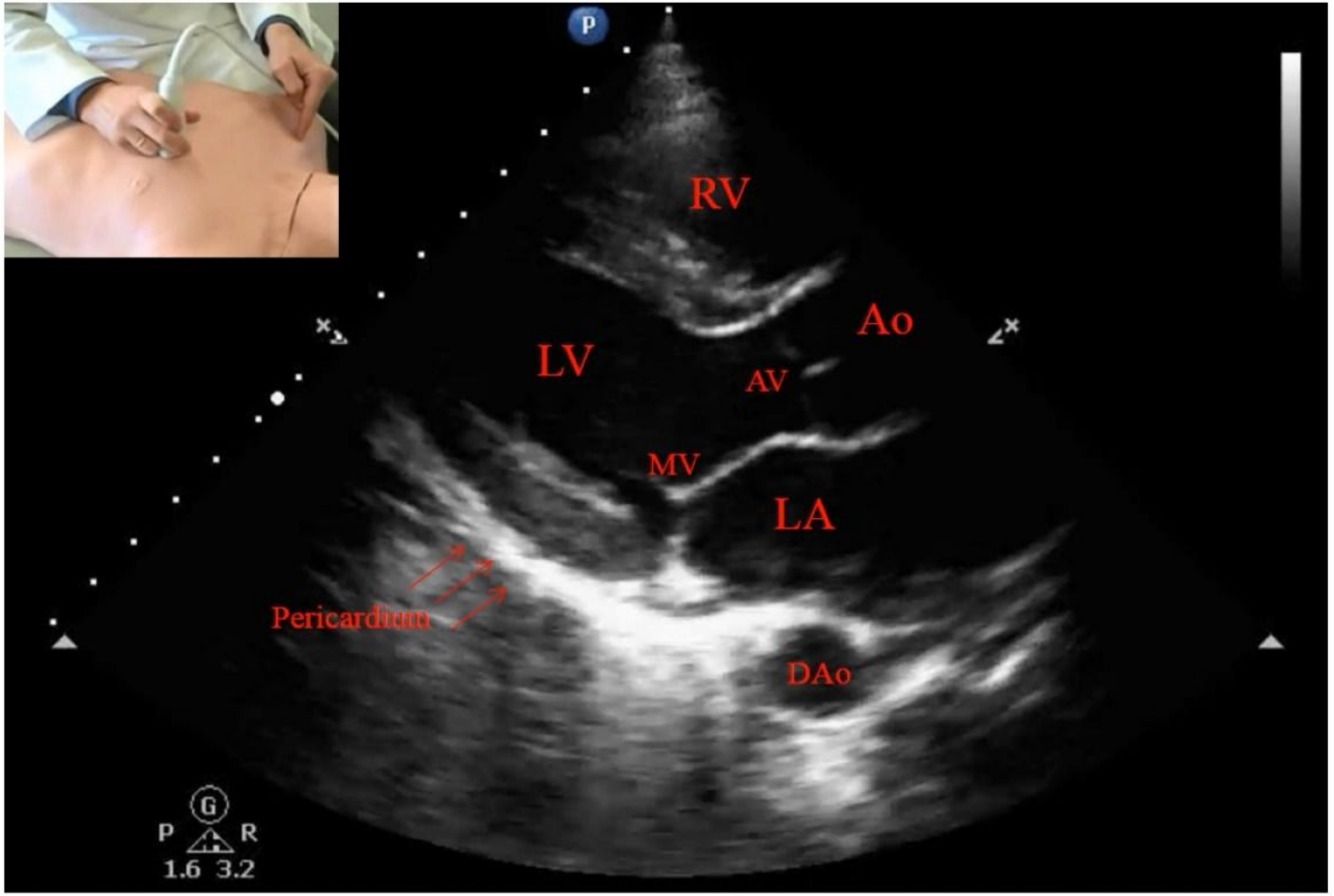
Parasternal long-axis



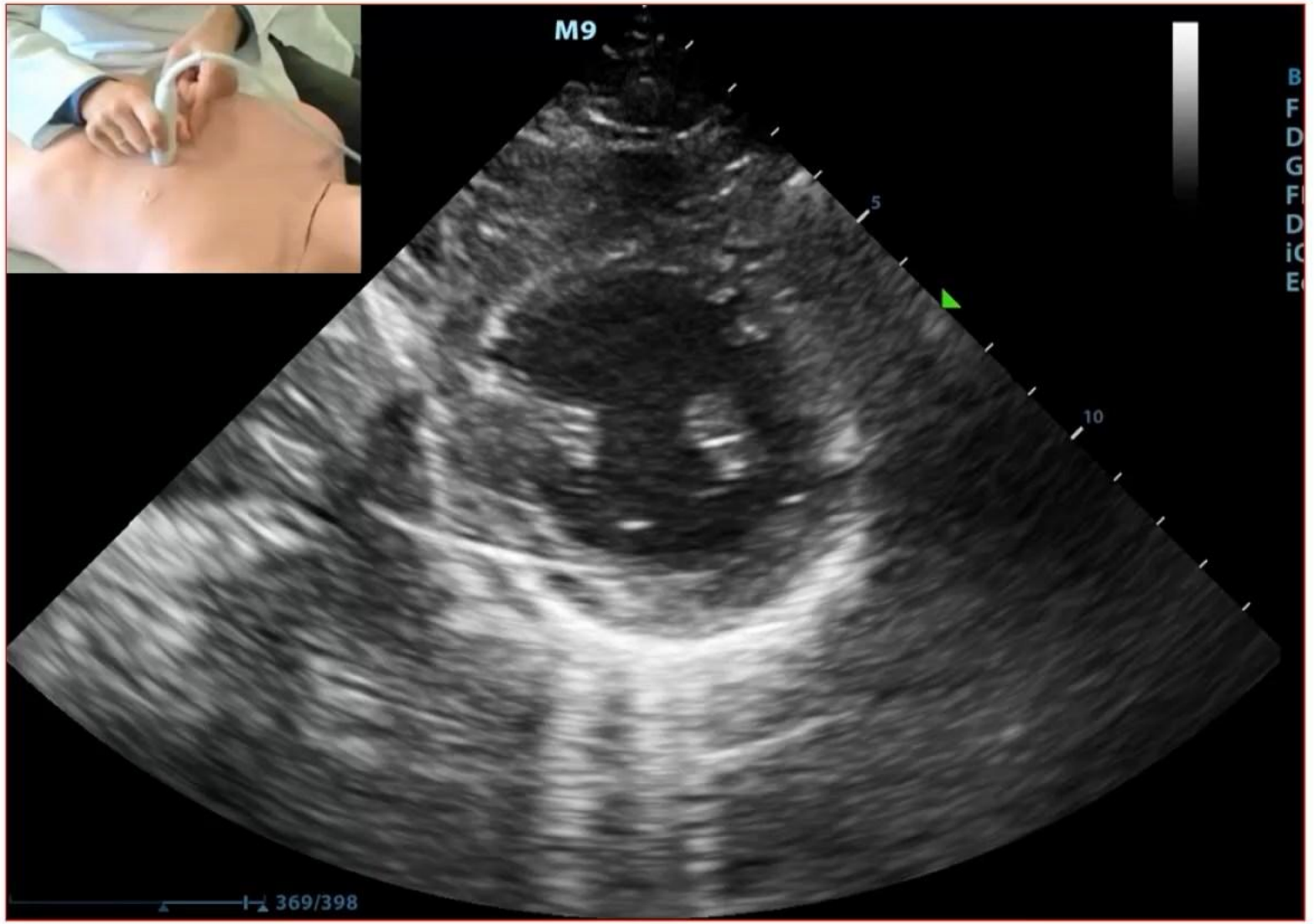
Parasternal long-axis



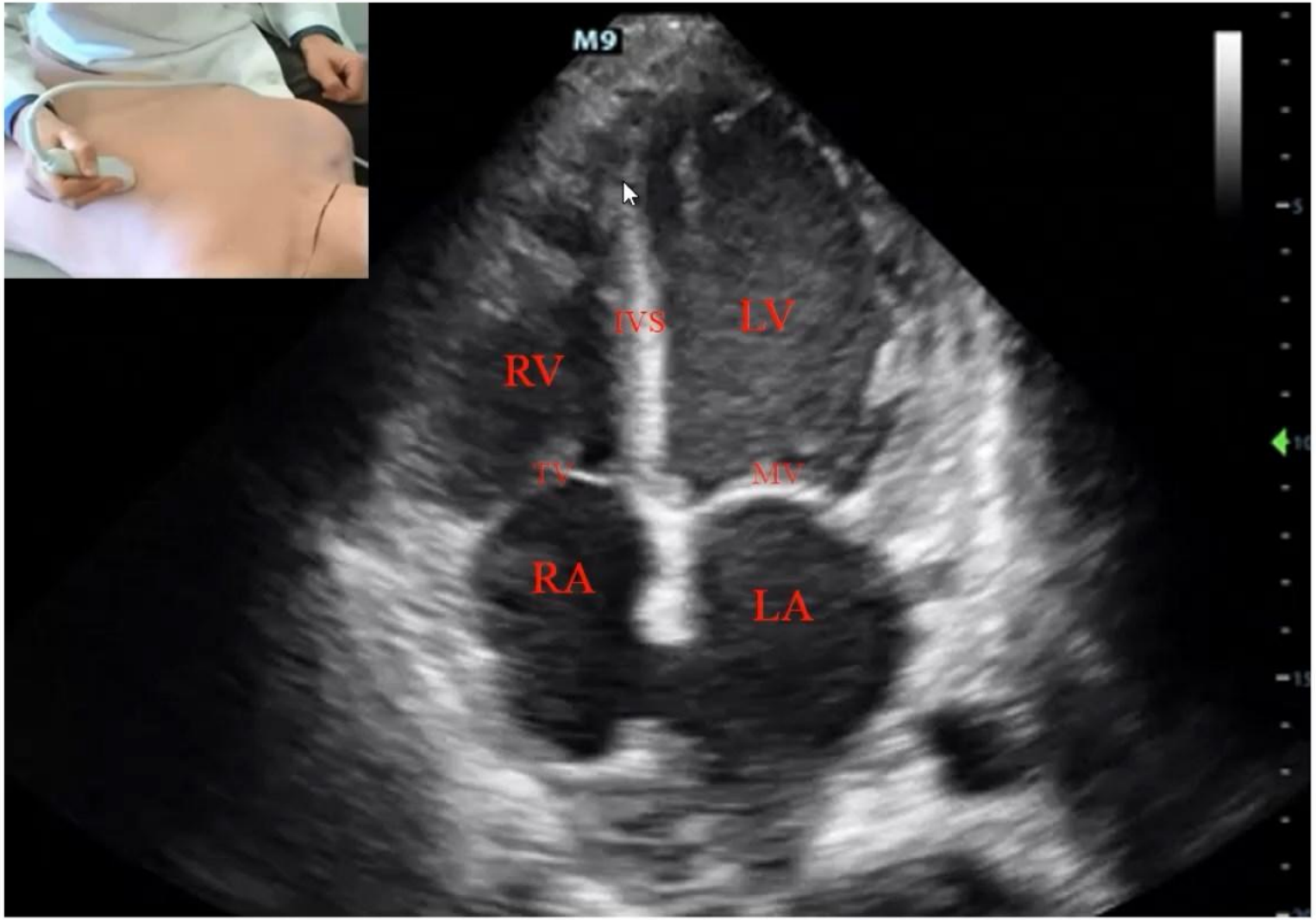
Parasternal long-axis



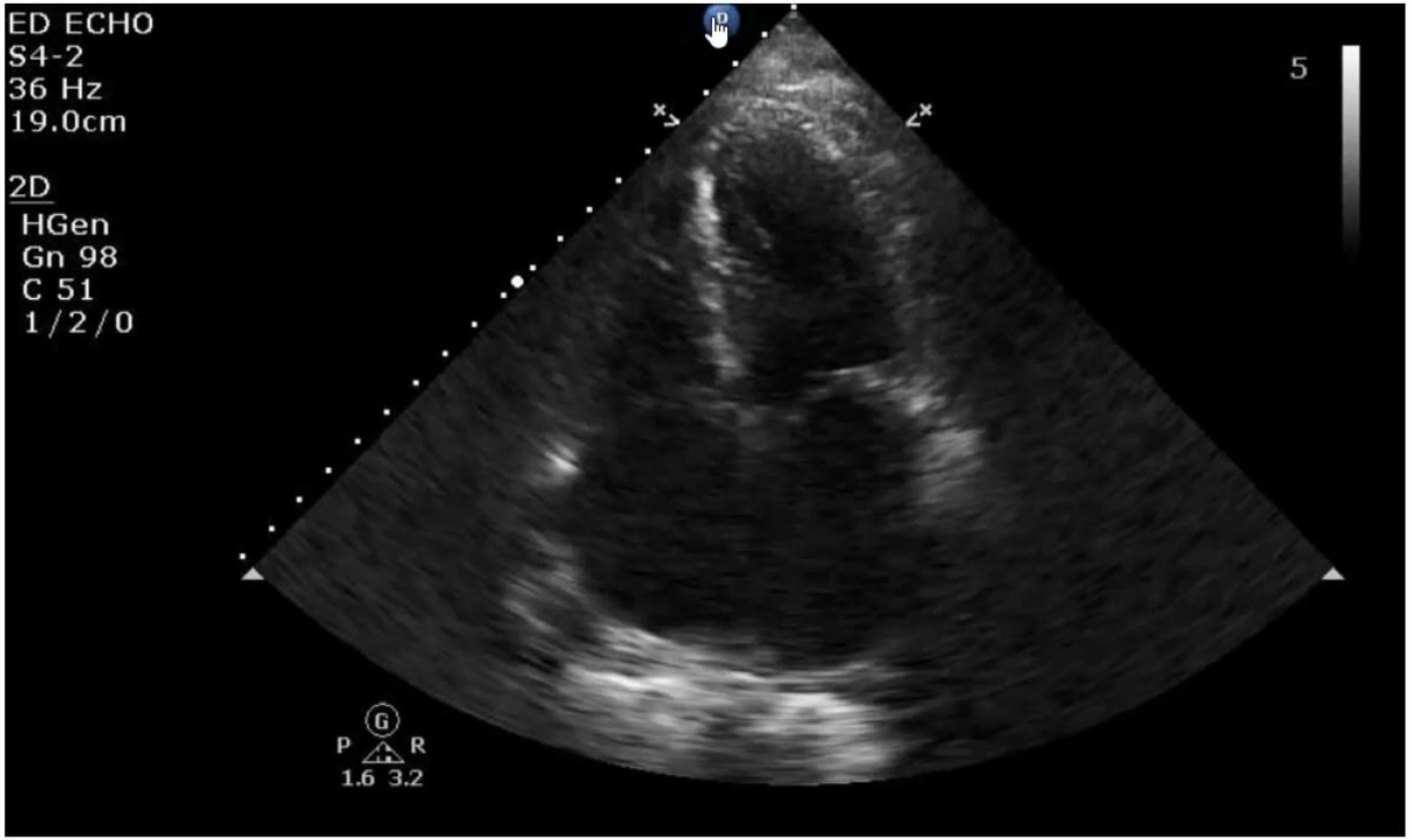
Parasternal short-axis



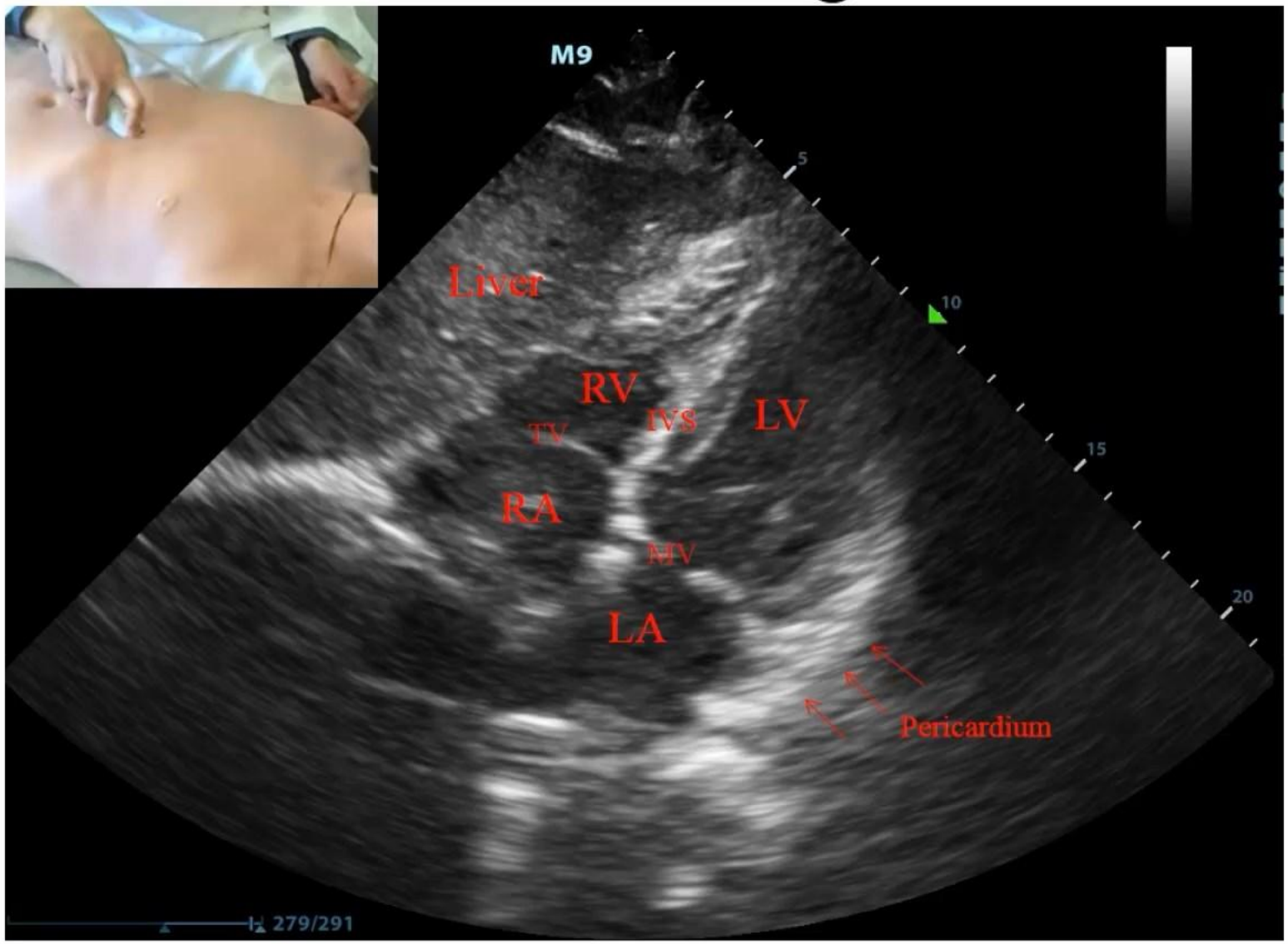
Apical 4-chamber



Apical 4-chamber

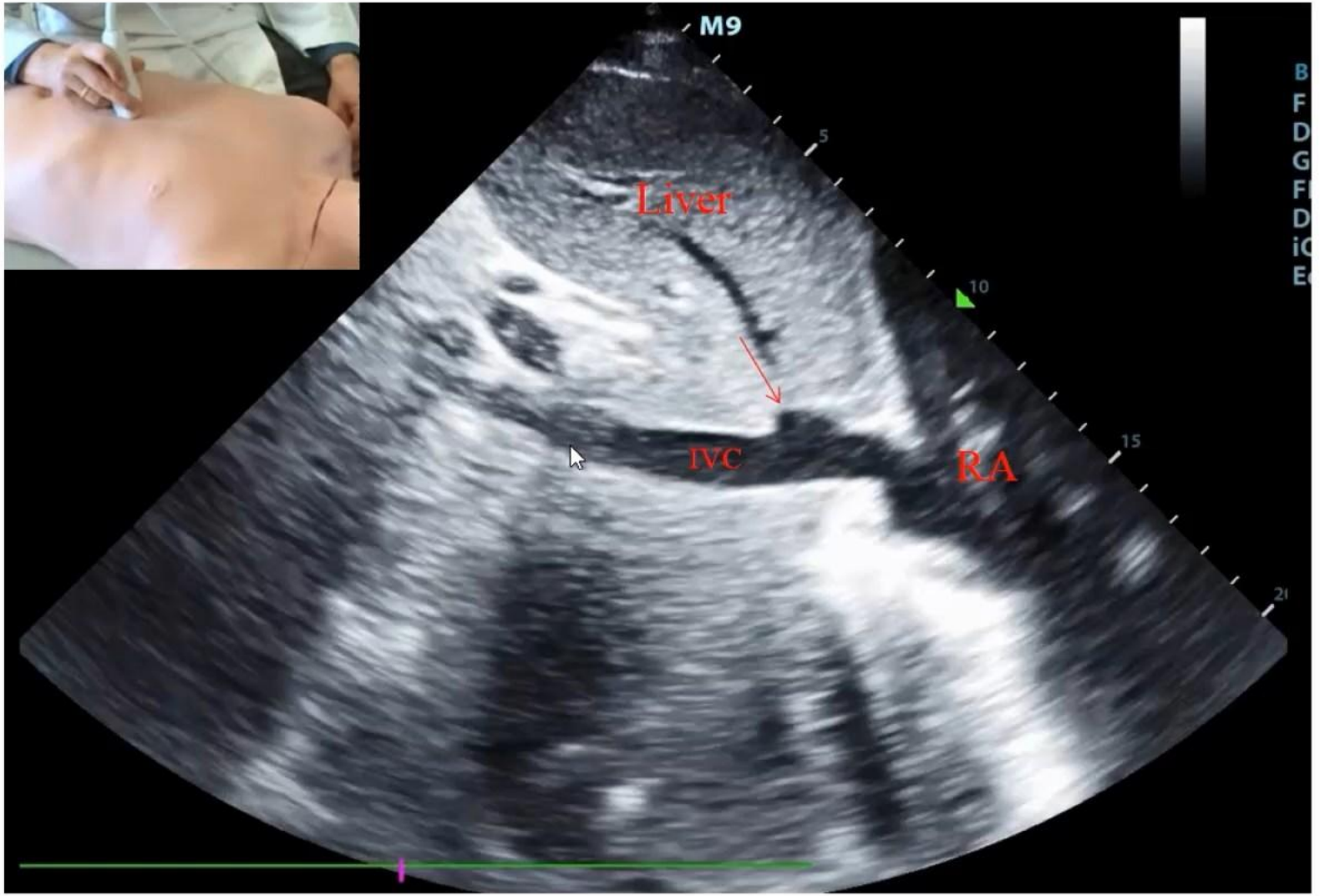


Subcostal long-axis



IVC

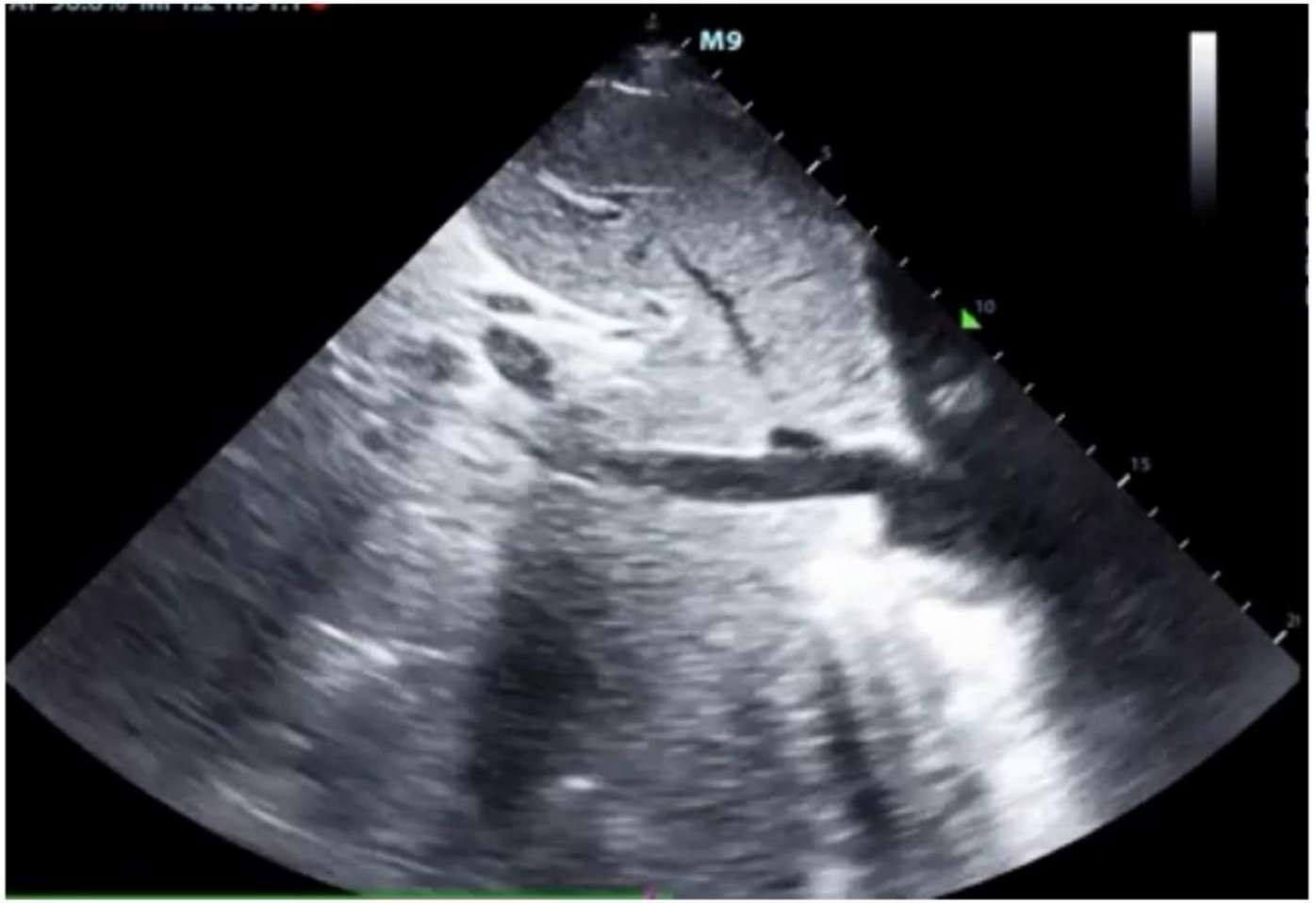
IVC



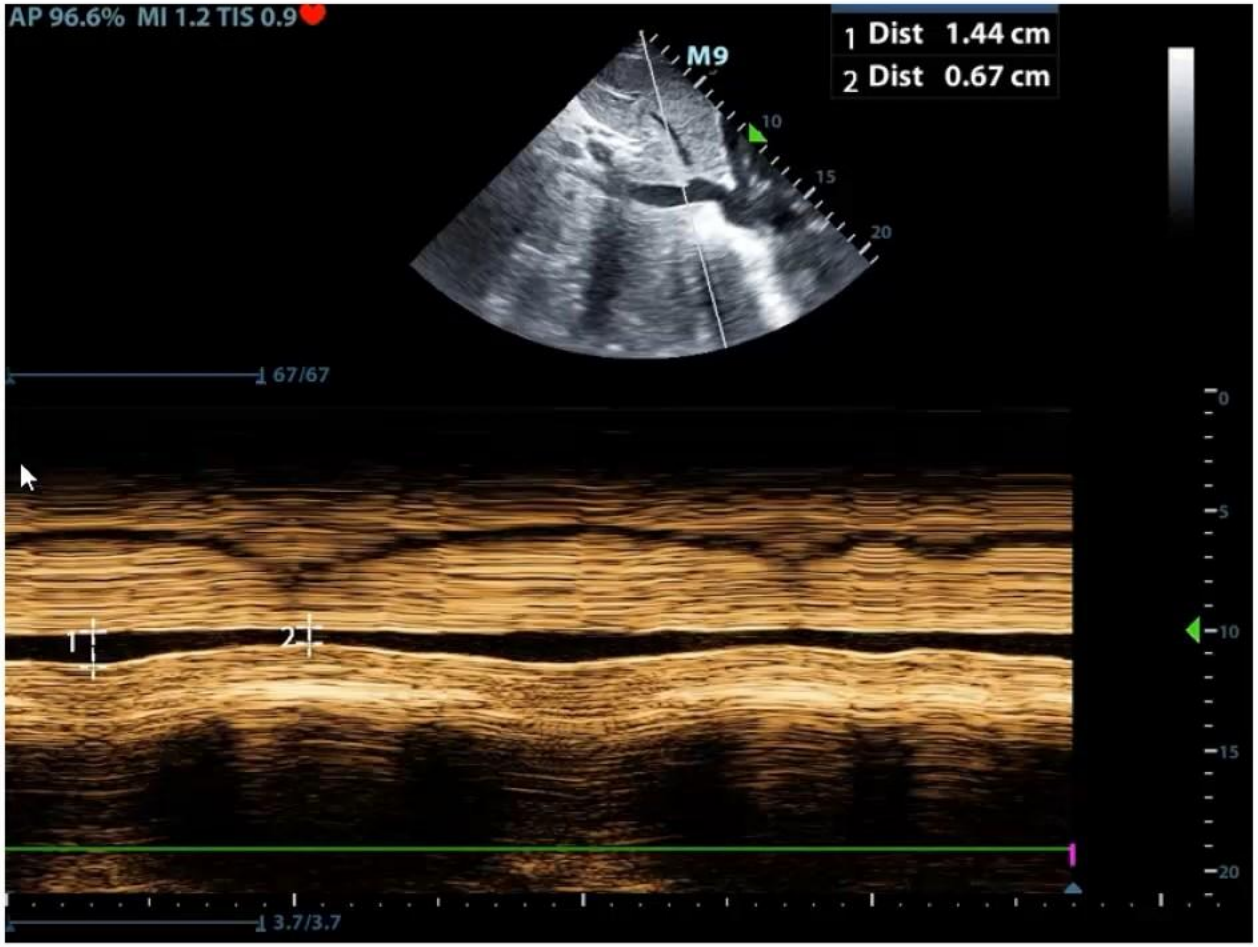
IVC evaluation for fluid responsiveness

- Best studied in mechanically ventilated, fully sedated patients without any spontaneous respirations
  - Respiratory variation greater then **12 – 18%** predicts volume responsiveness
- Spontaneously breathing patients
  - No great studies exist
  - However is a good estimate for CVP and some clinicians suggest:
    - **IVC < 2 cm**, greater than **50% collapse** with respiration suggests fluid responsiveness

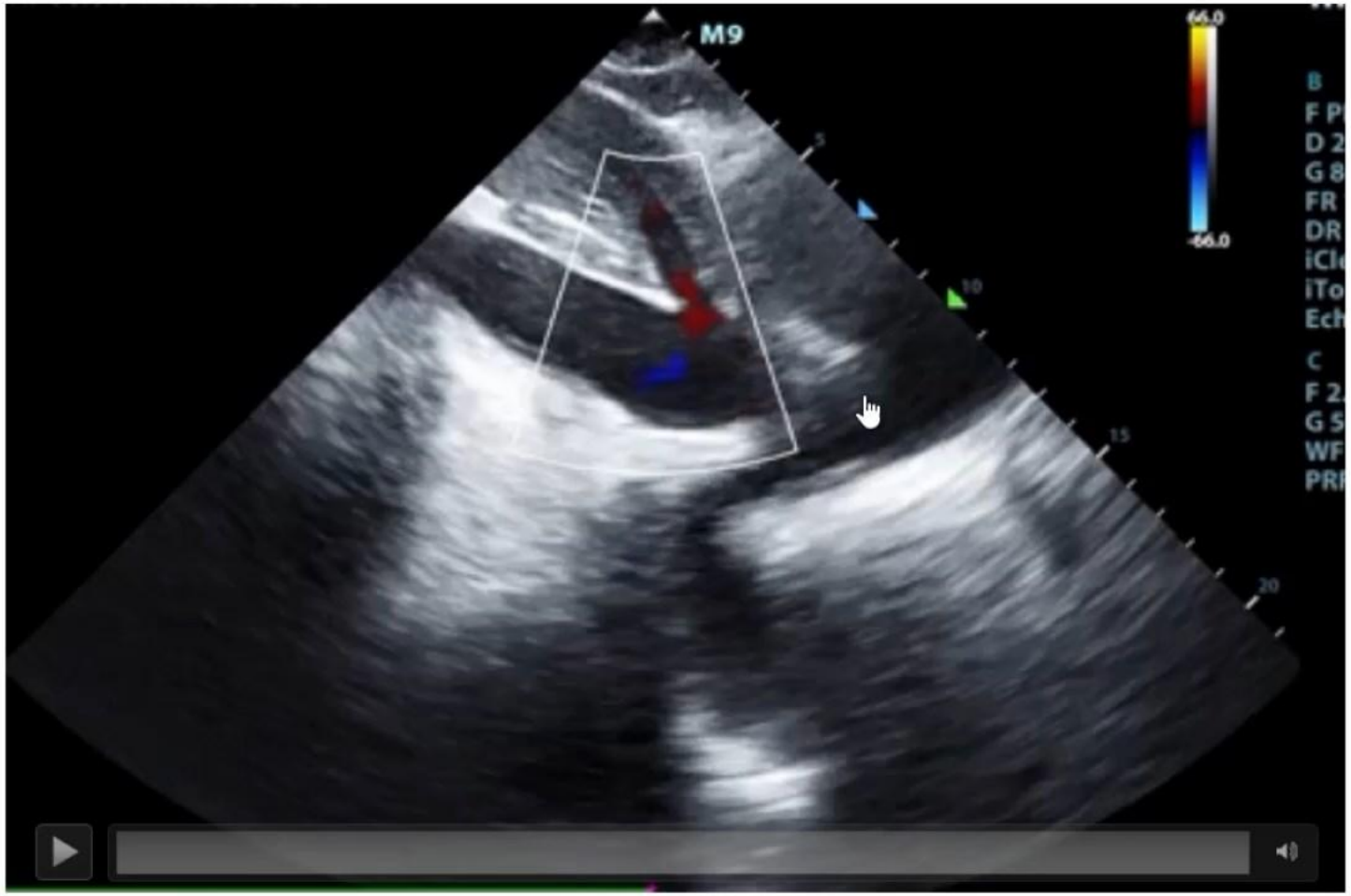
Hypovolemia



Hypovolemia

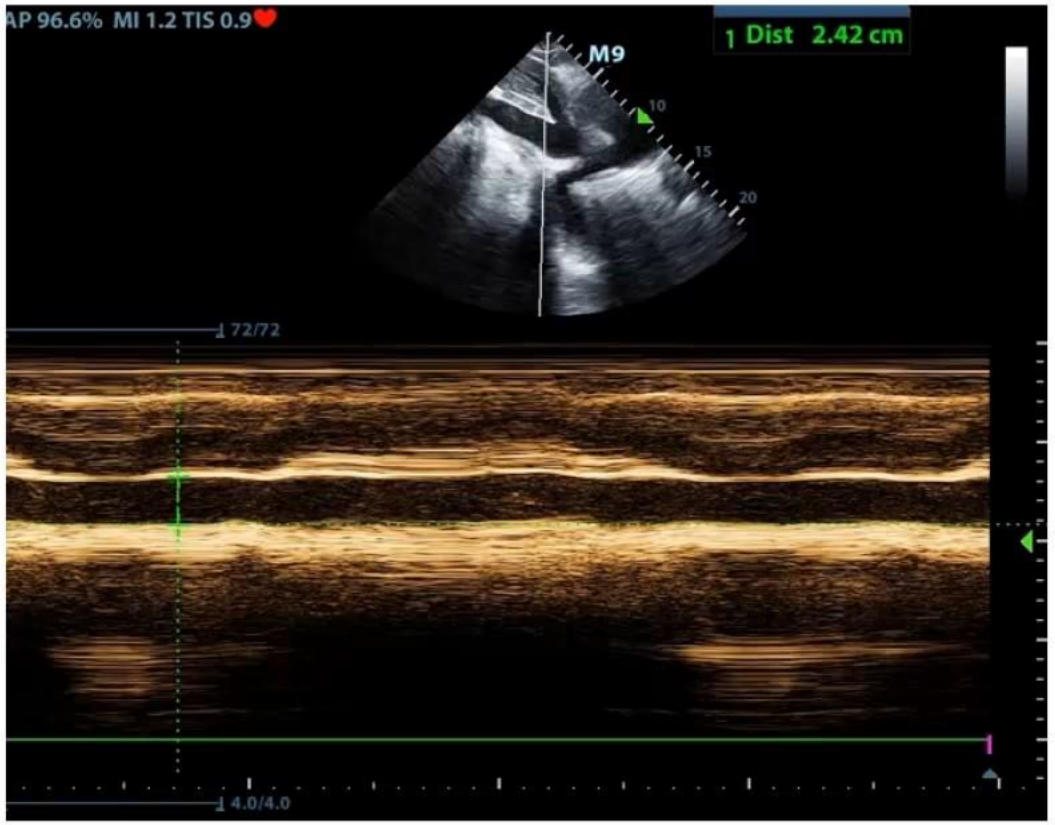


Volume overloaded IVC

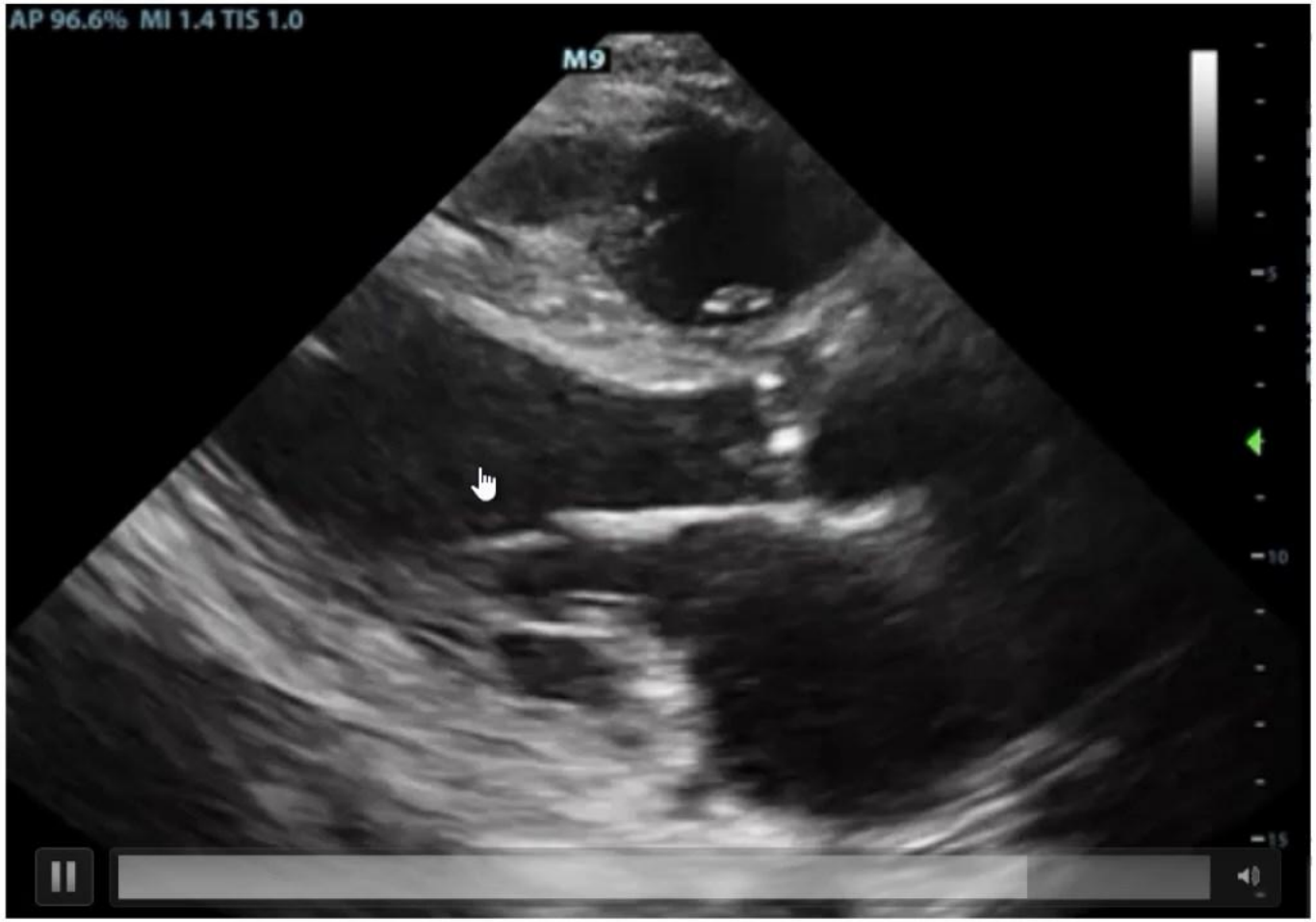


Volume overloaded IVC

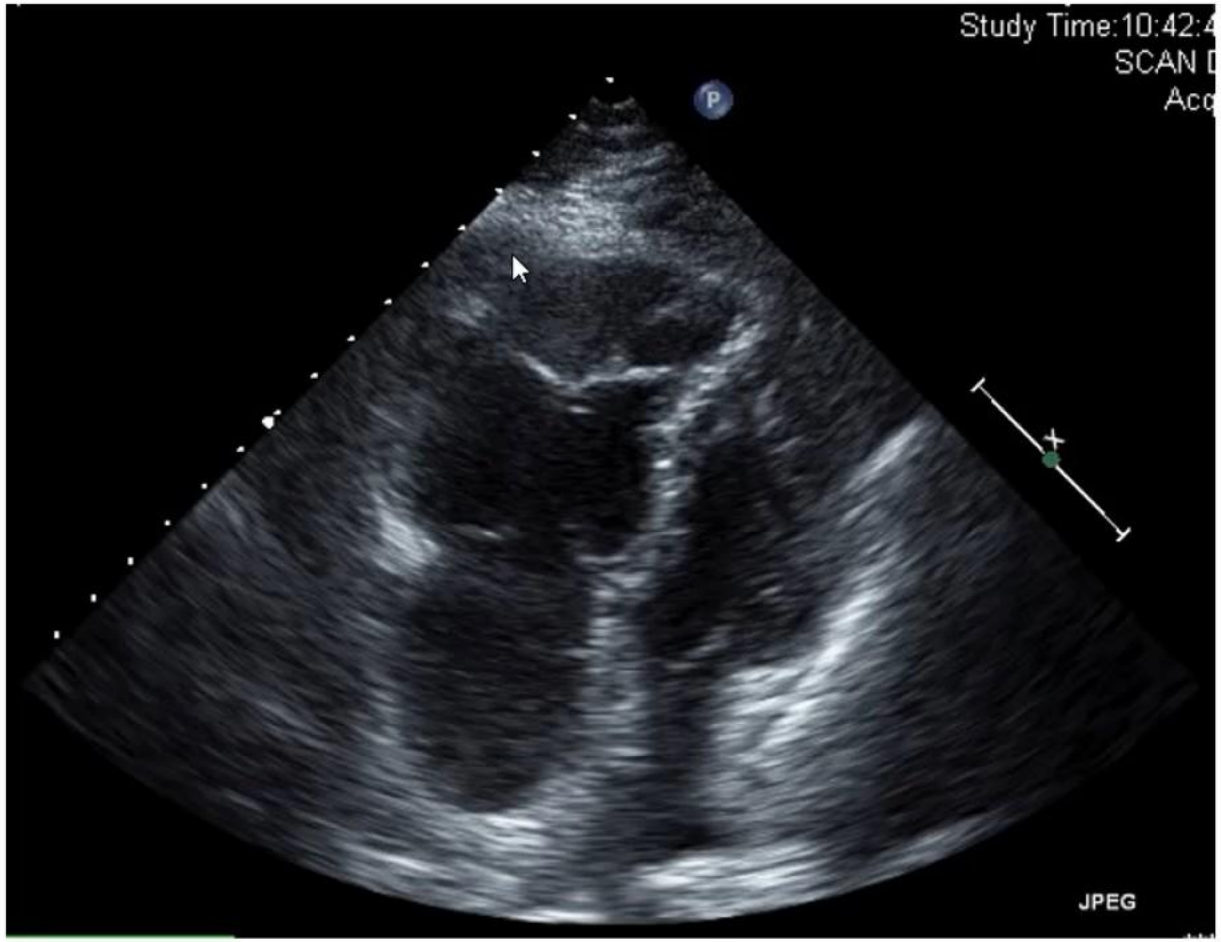
- > 2 cm
- No respiratory variation



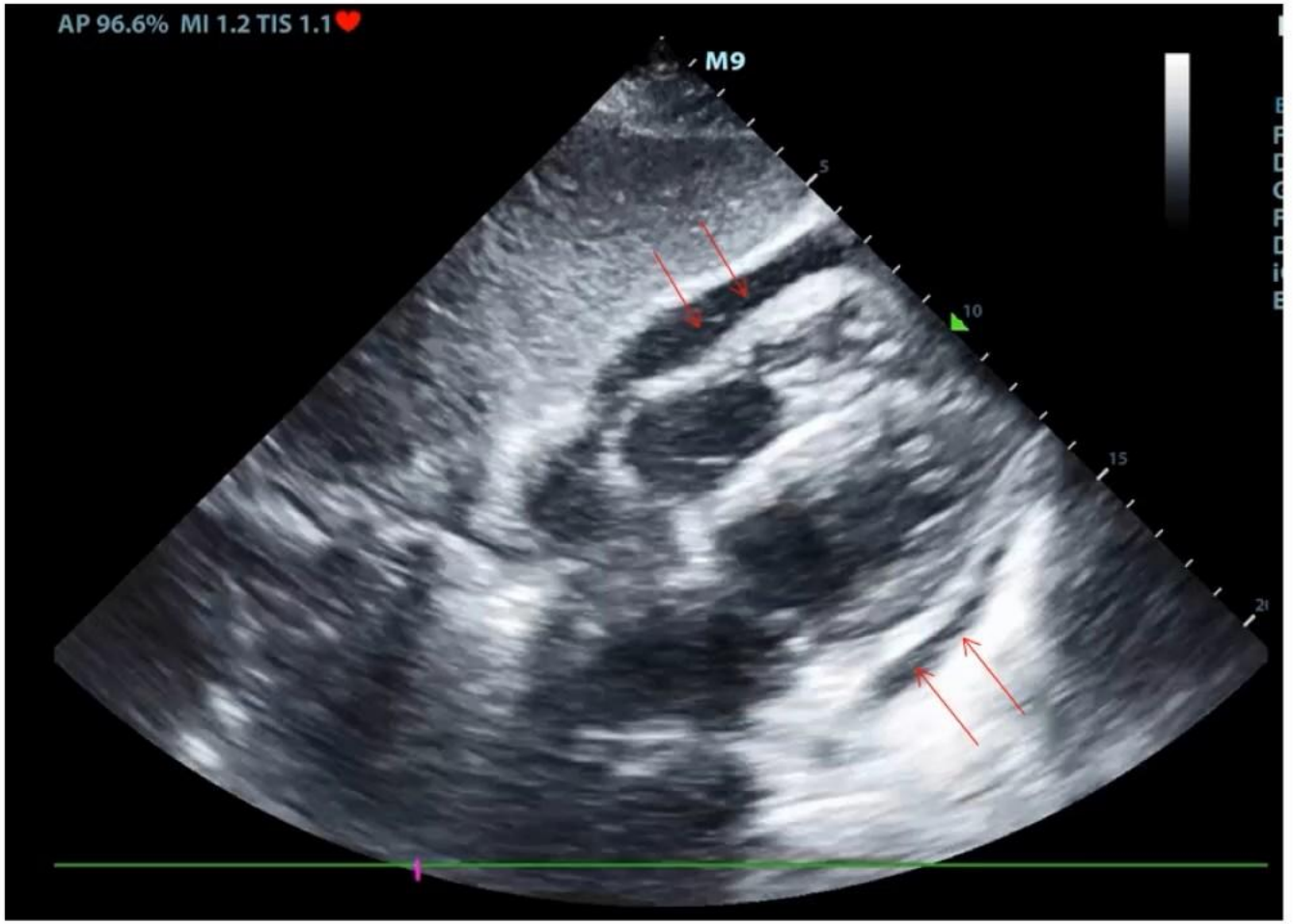
Depressed LV function



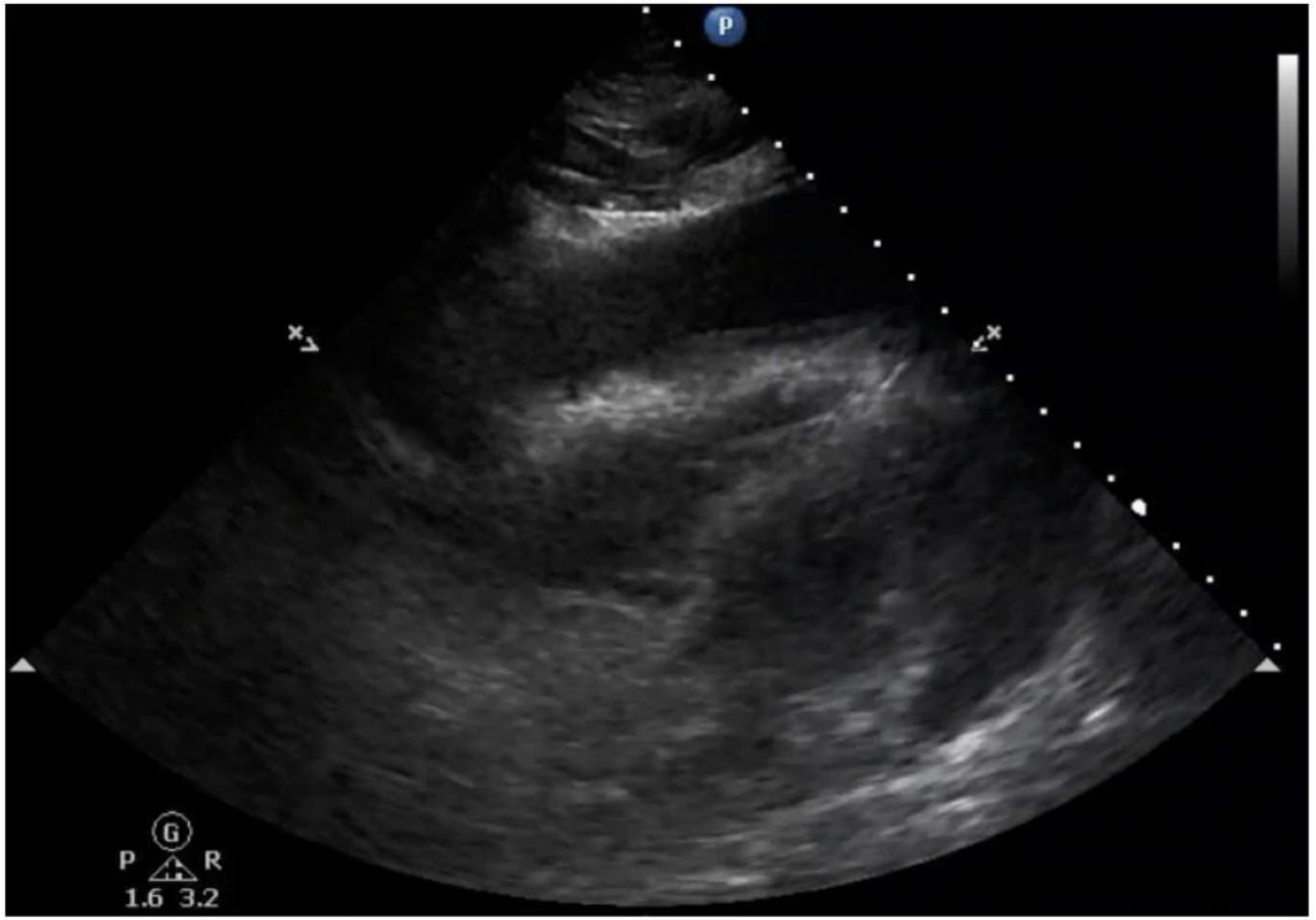
RV Strain



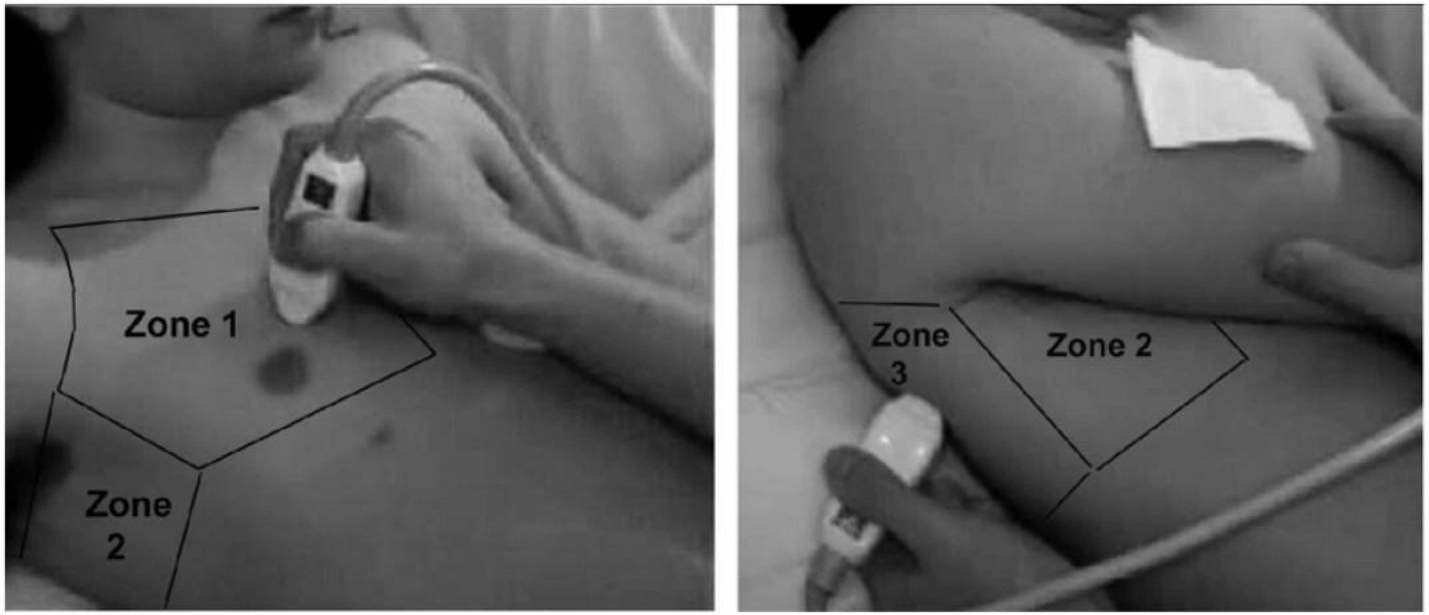
Pericardial Effusion



Tamponade

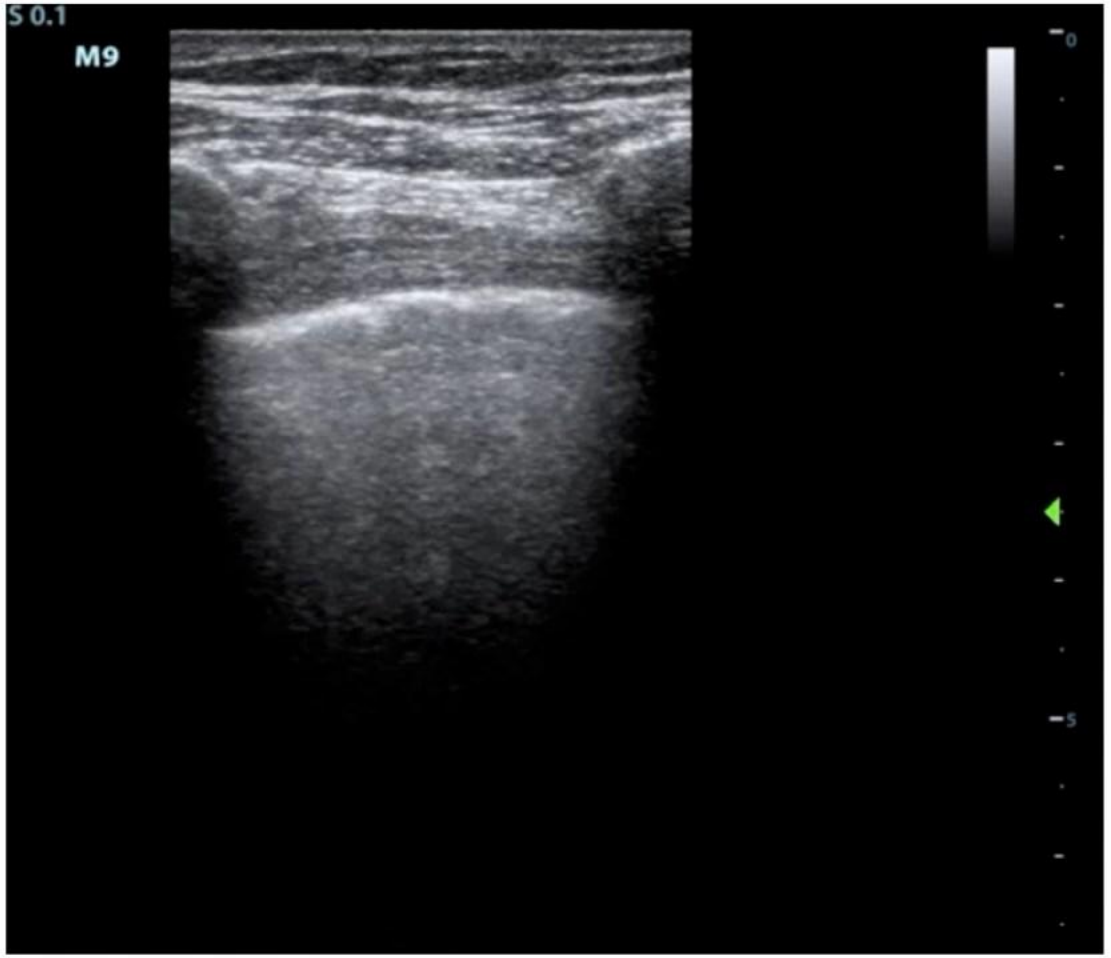


Basic views

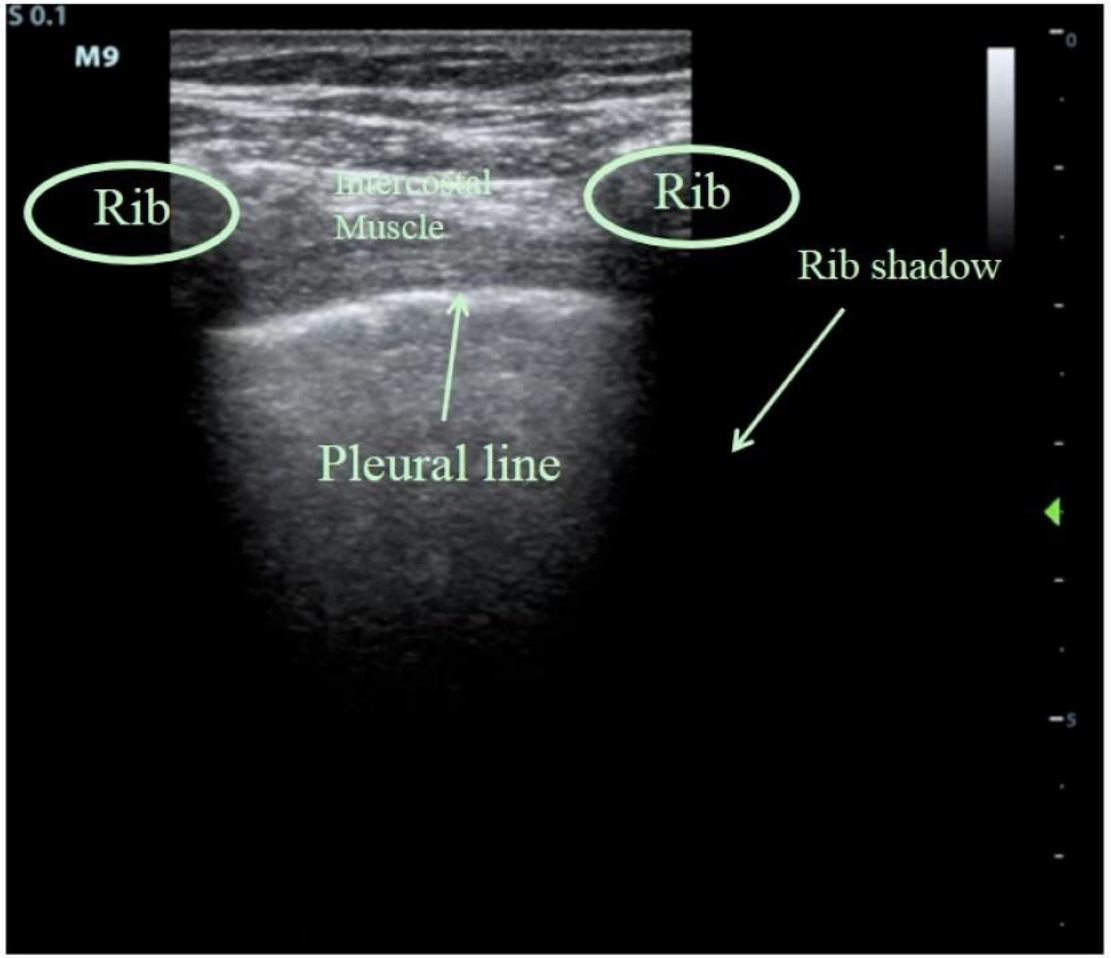


Chest. 2008 Jul;134(1):117-25

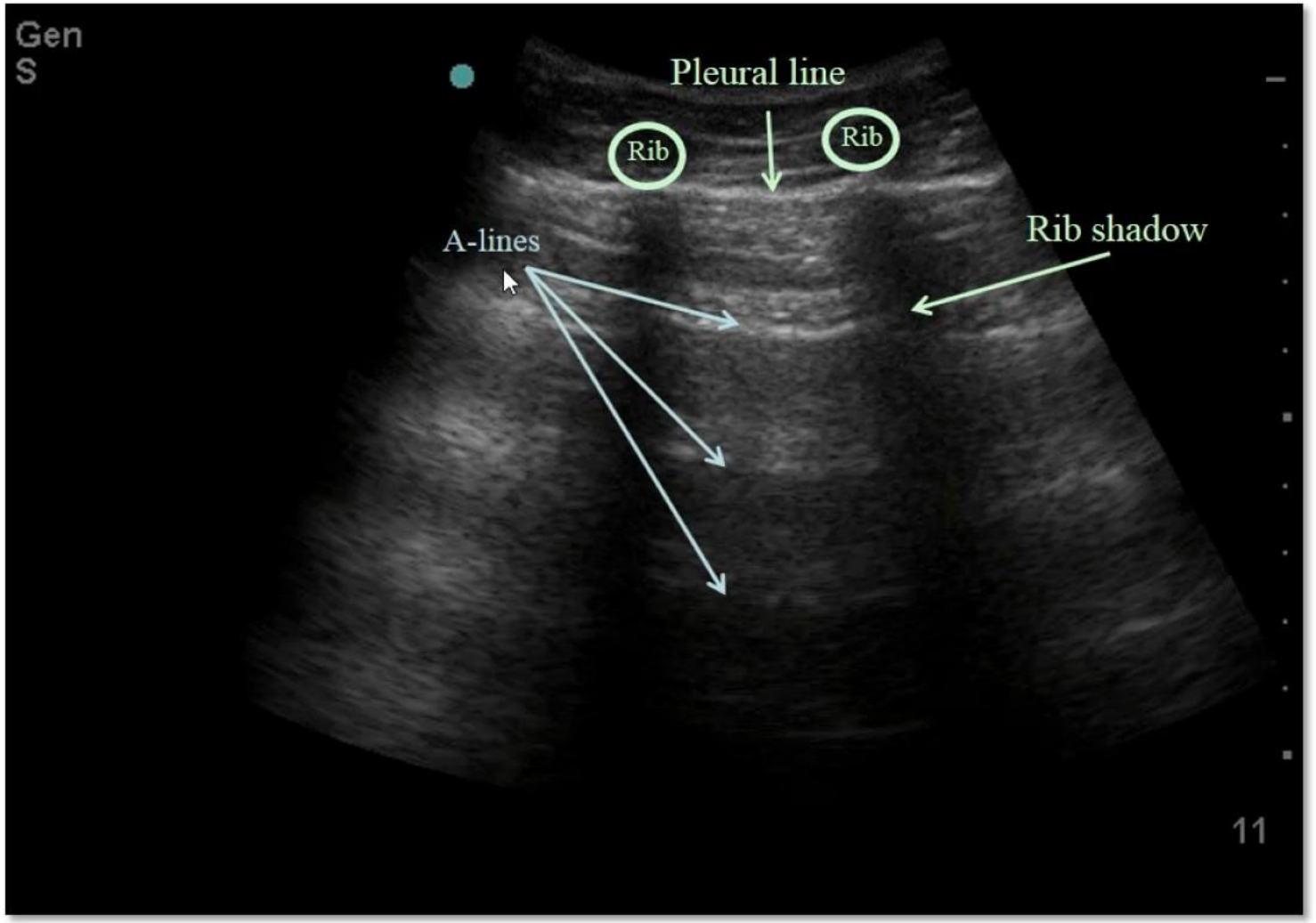
Normal lung



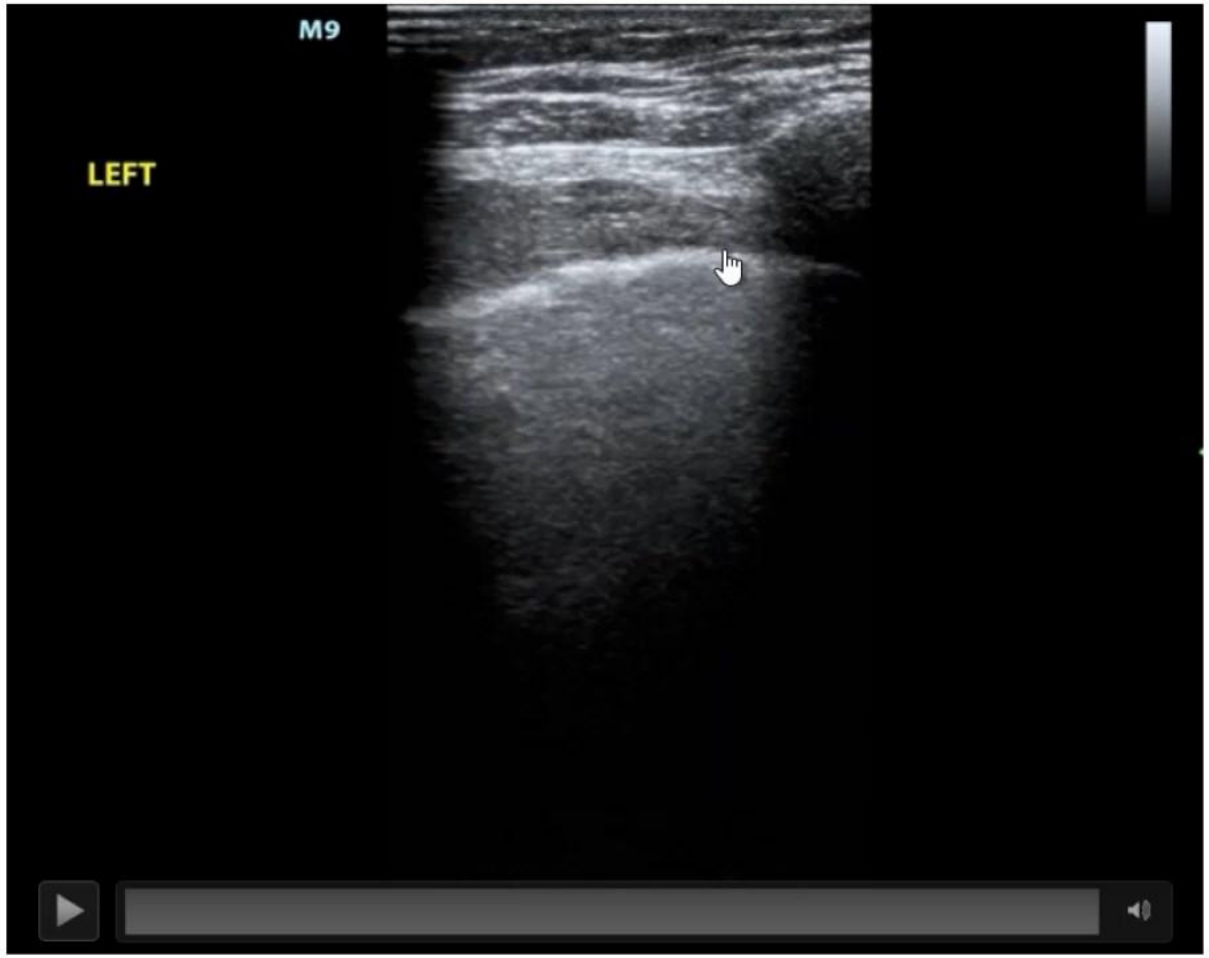
Normal lung



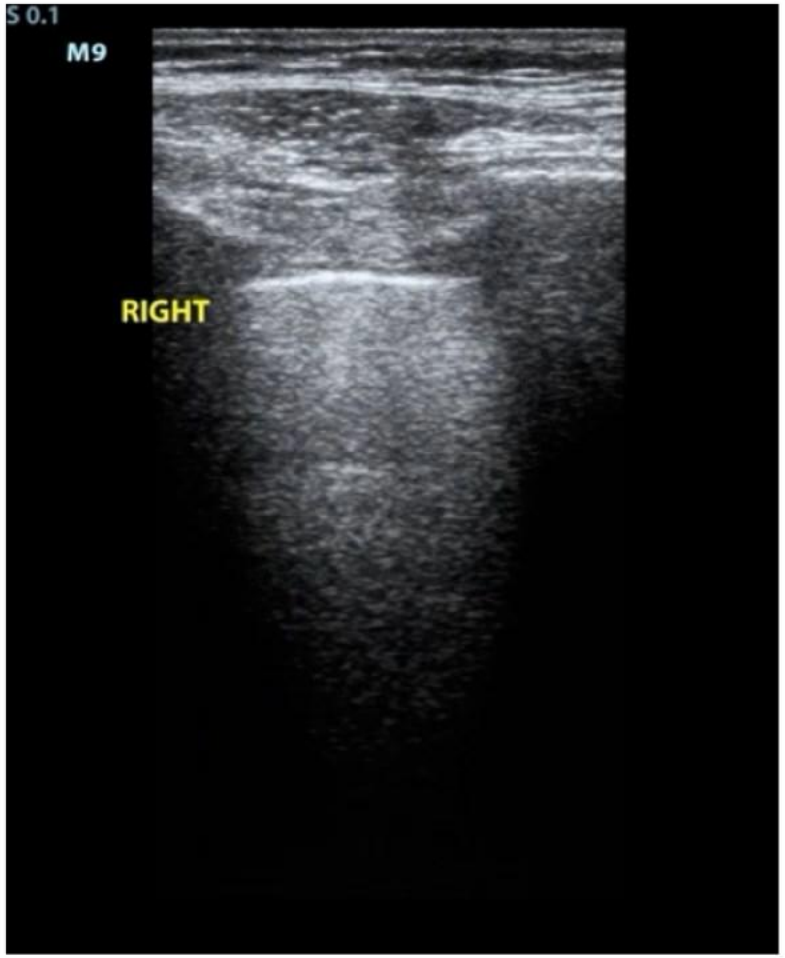
Normal lung



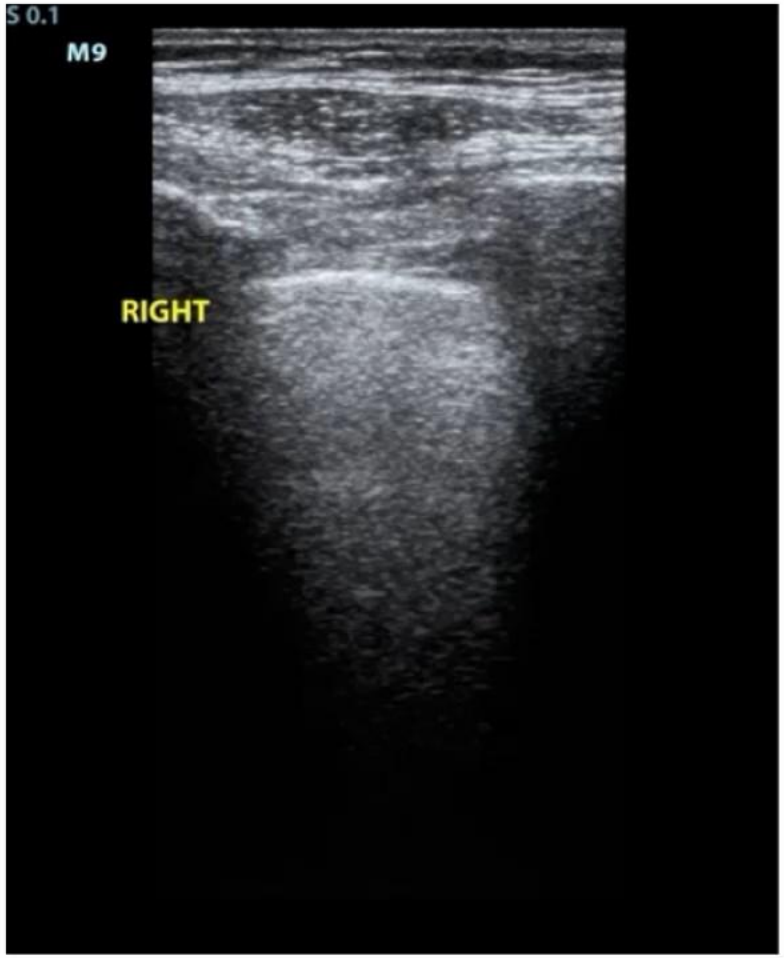
Lung sliding

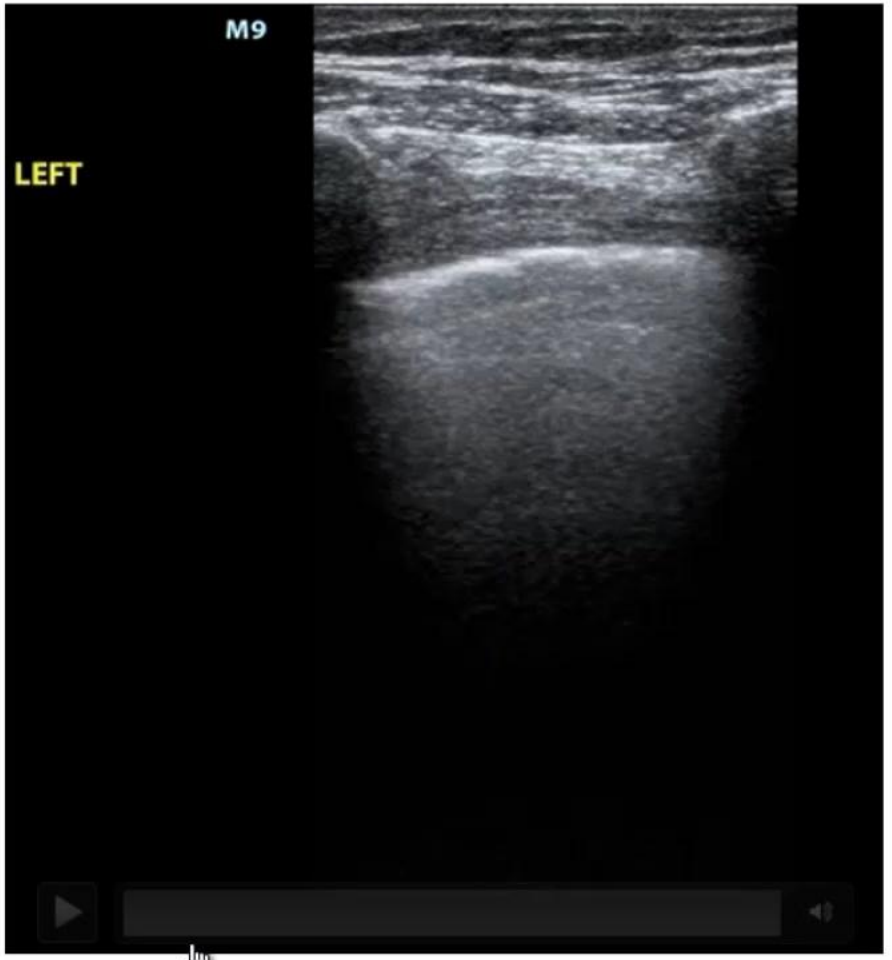


Pneumothorax

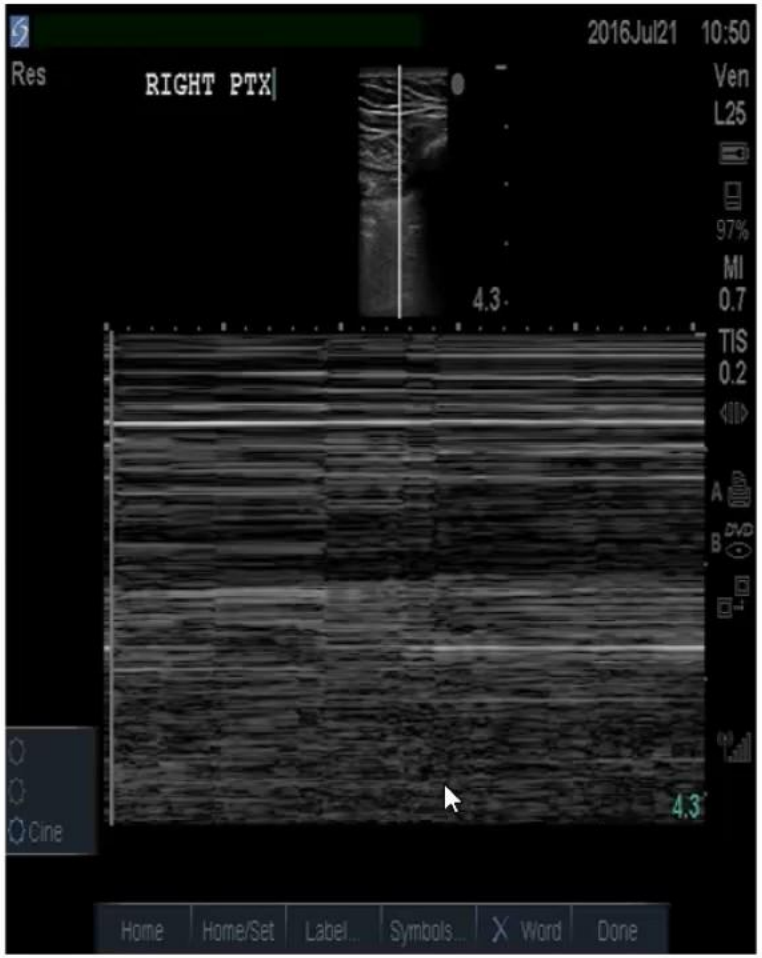


Pneumothorax

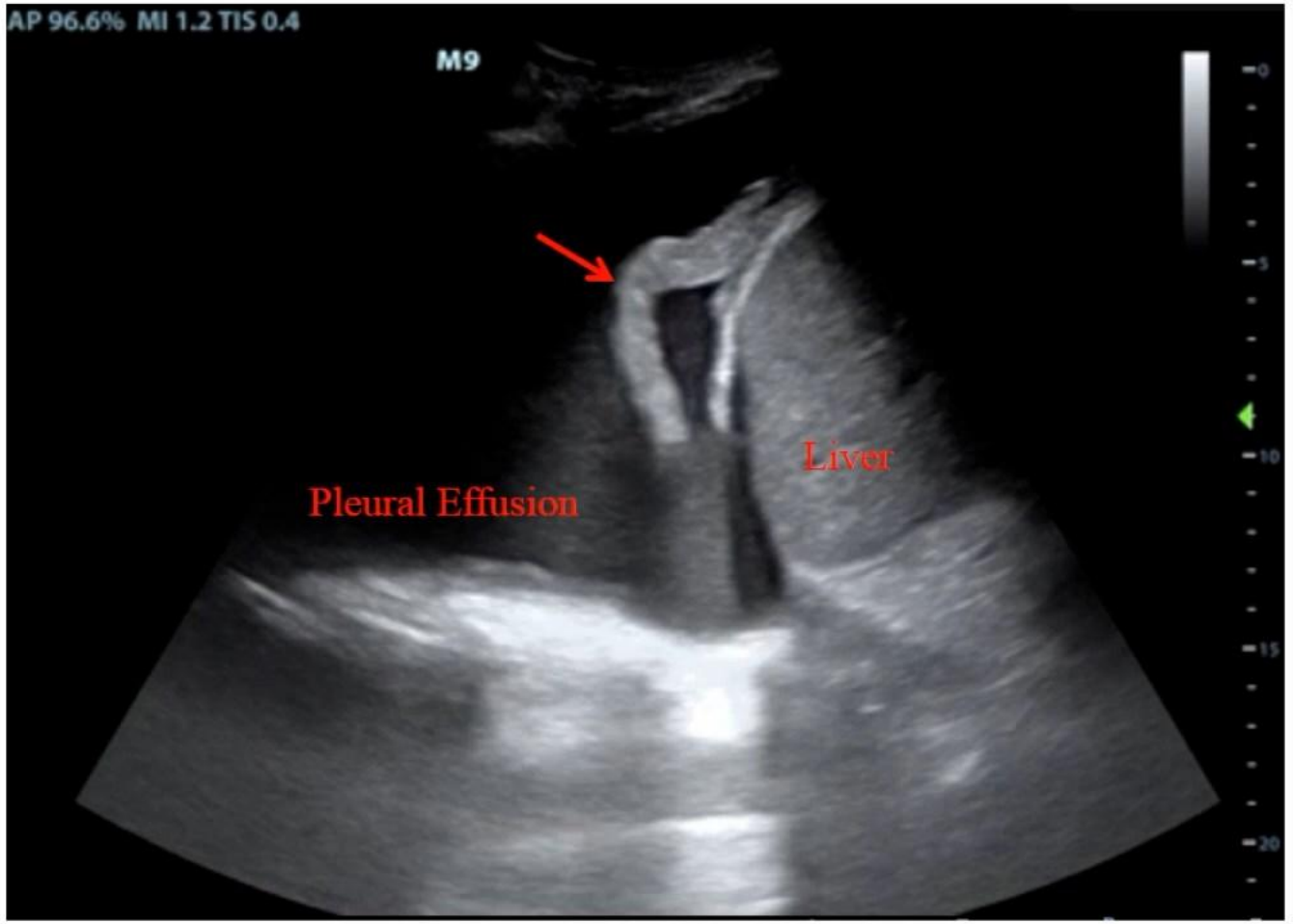




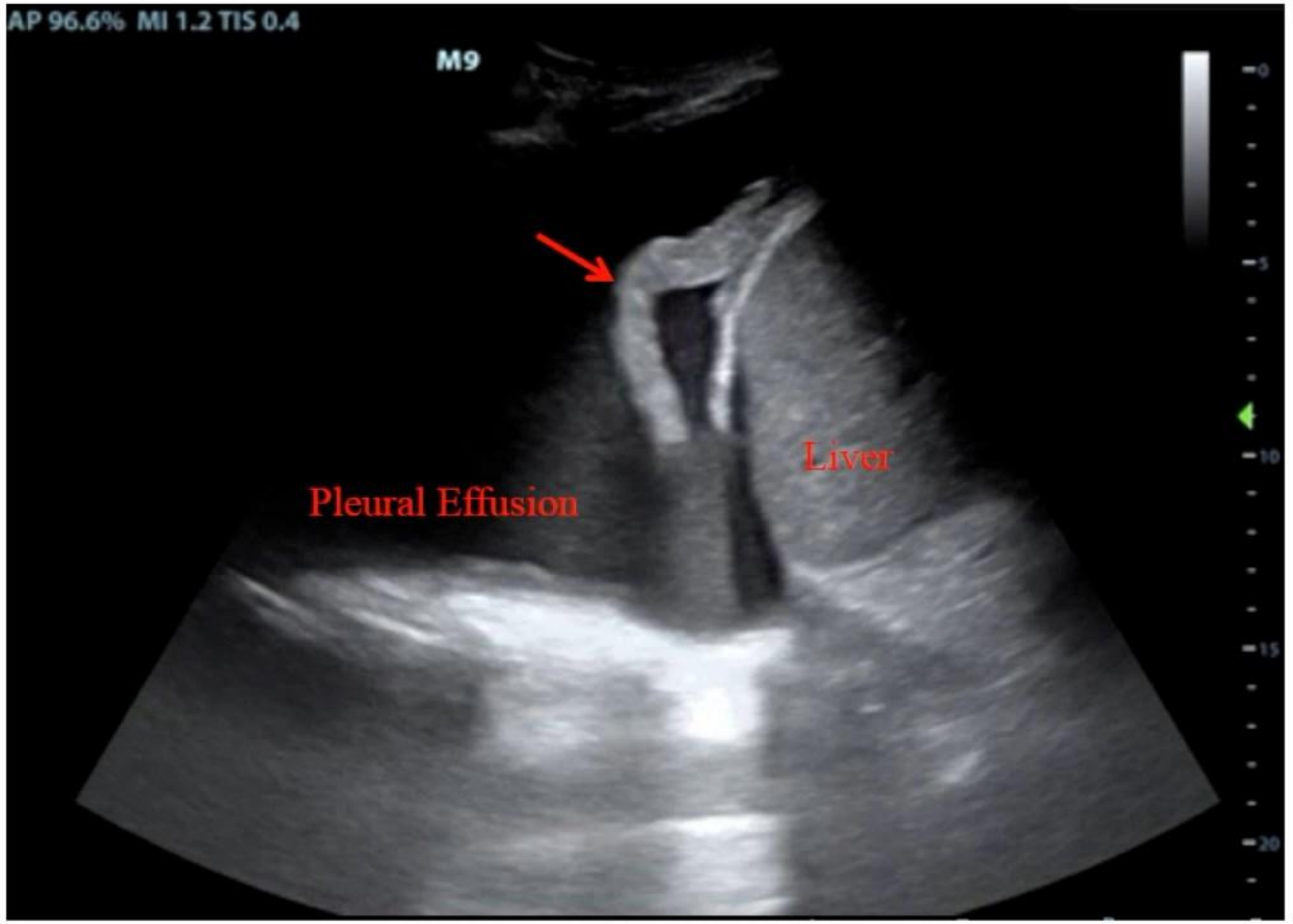
Pneumothorax



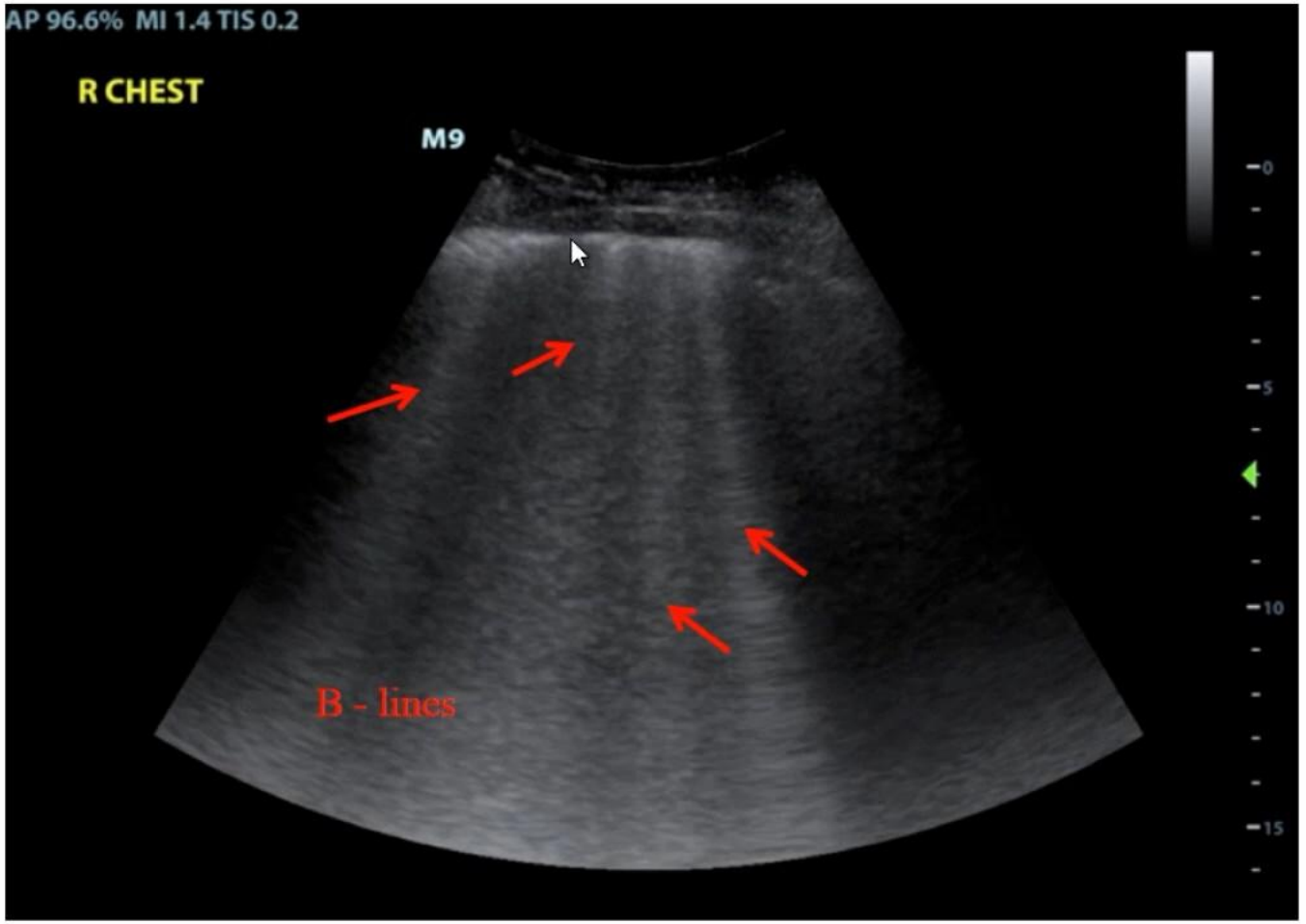
Pleural Effusion



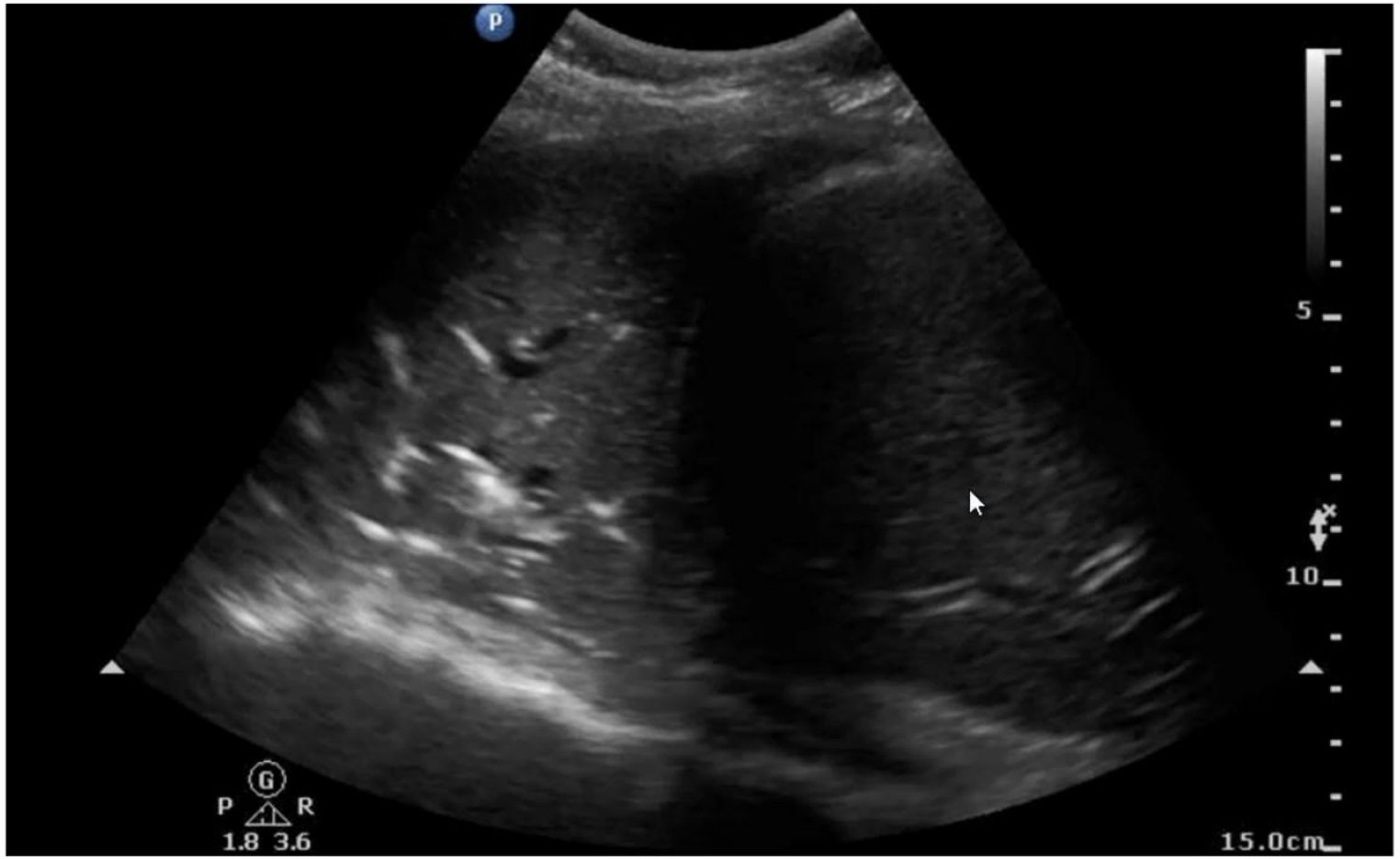
Pleural Effusion



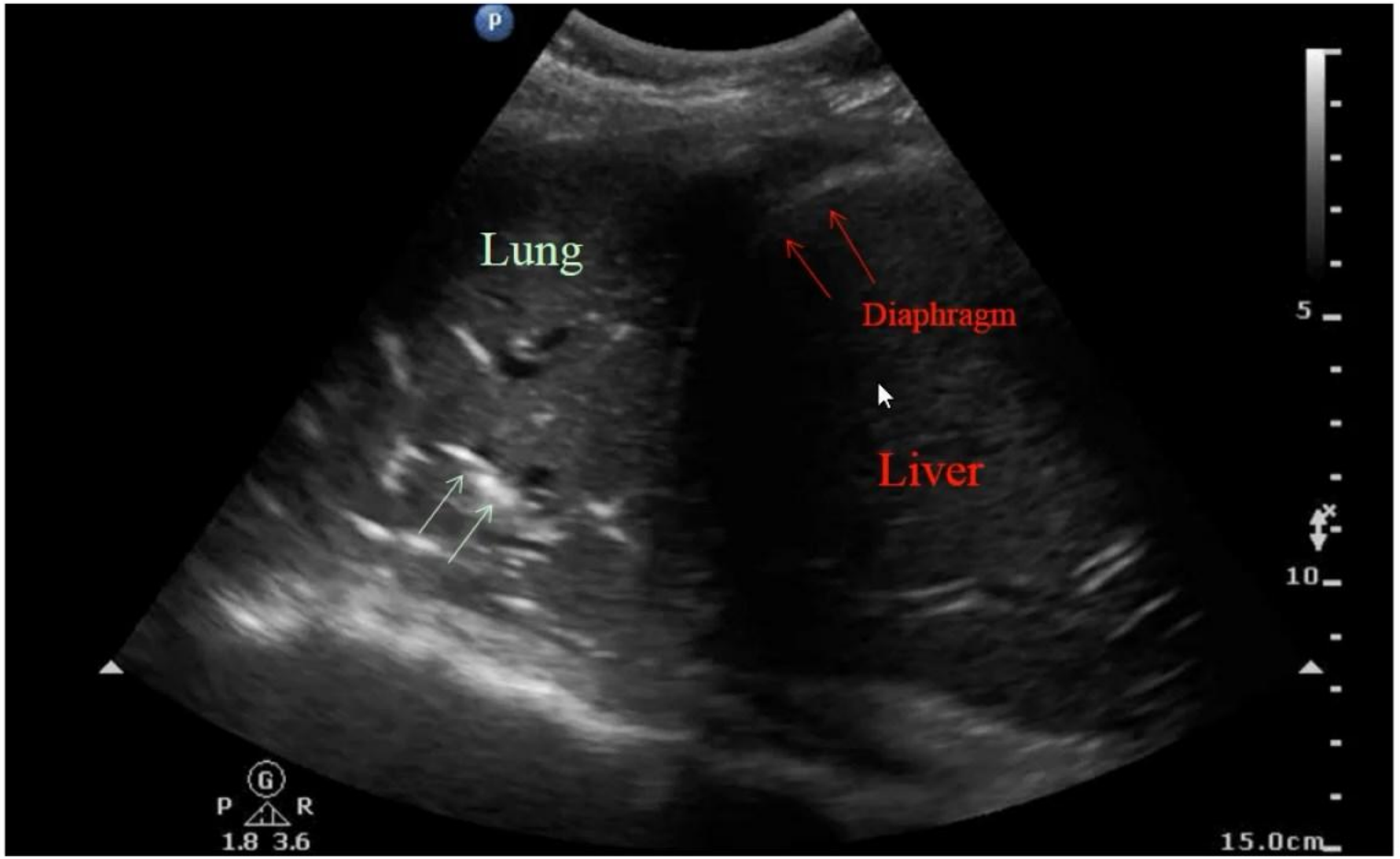
Interstitial Edema



Consolidation



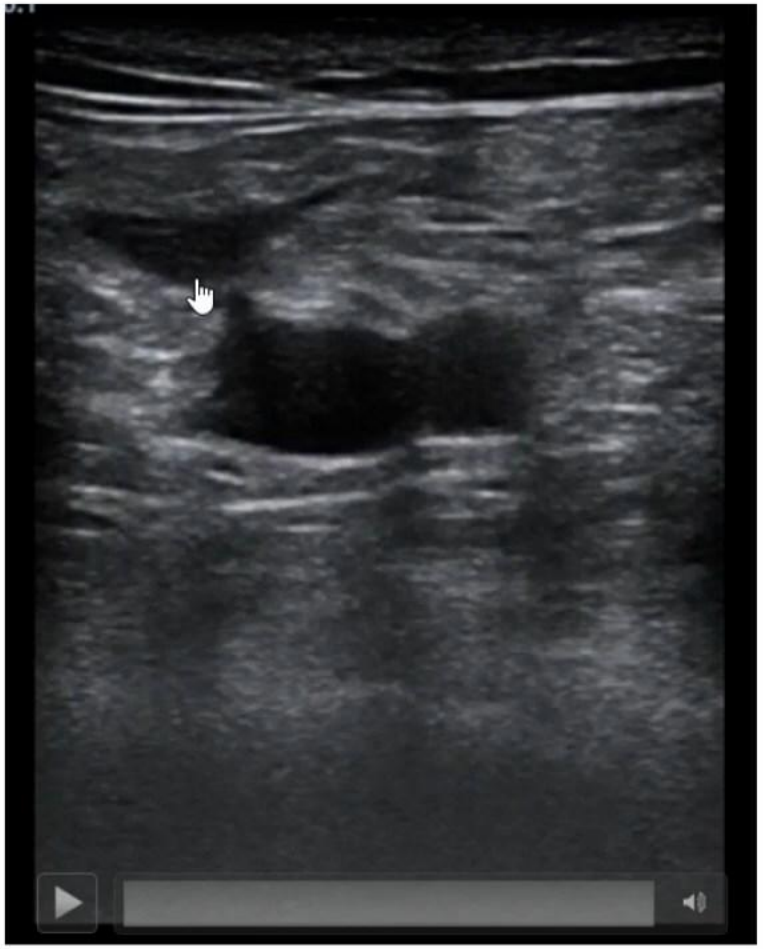
Consolidation



Vascular Ultrasound

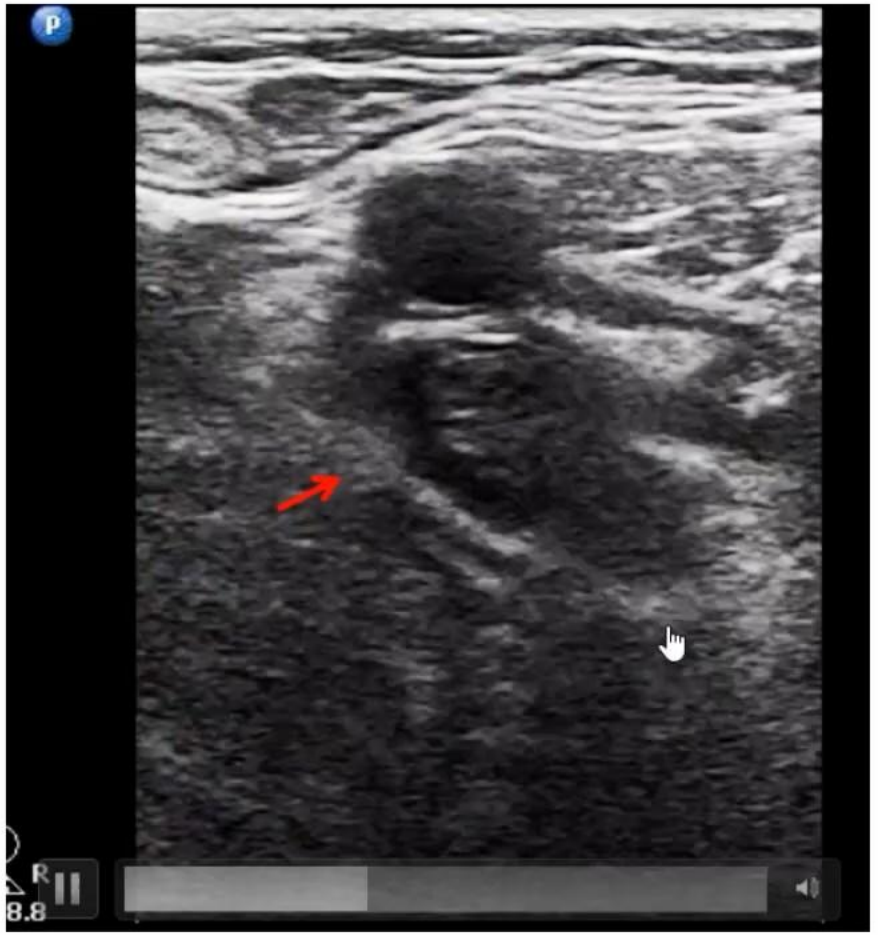
- Identify venous thrombosis
- Procedures

Normal



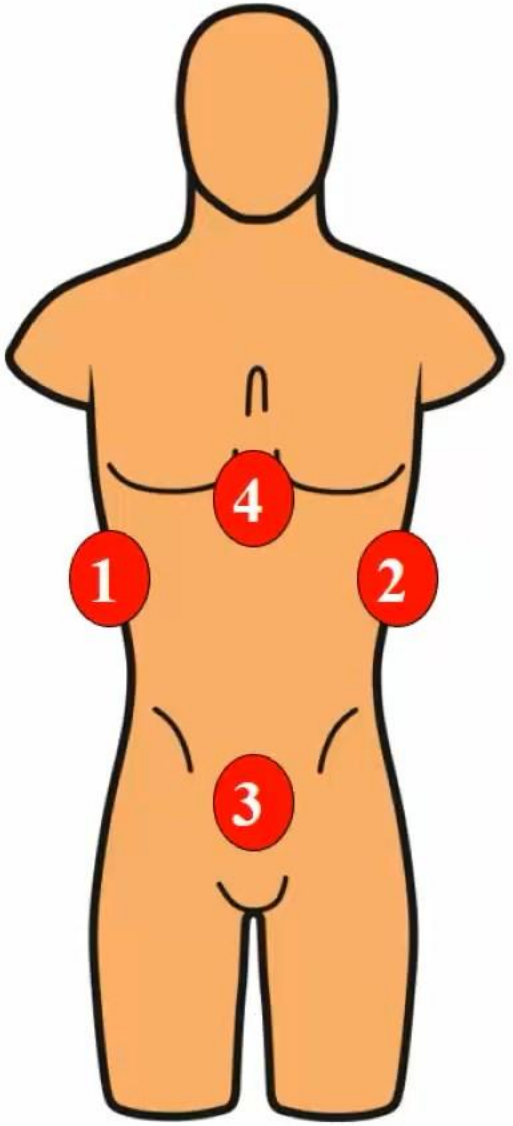
Normal

+ DVT

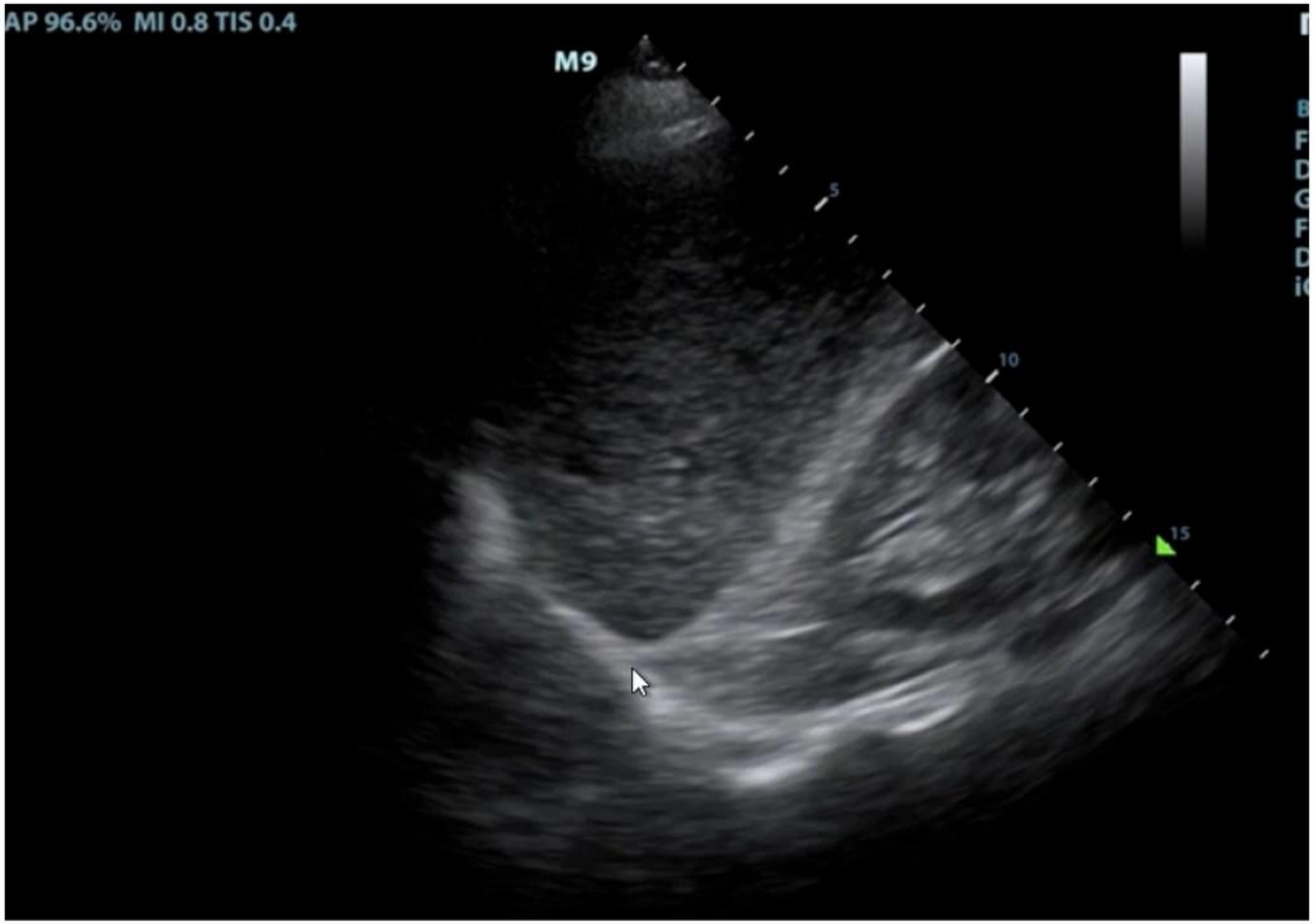


FAST

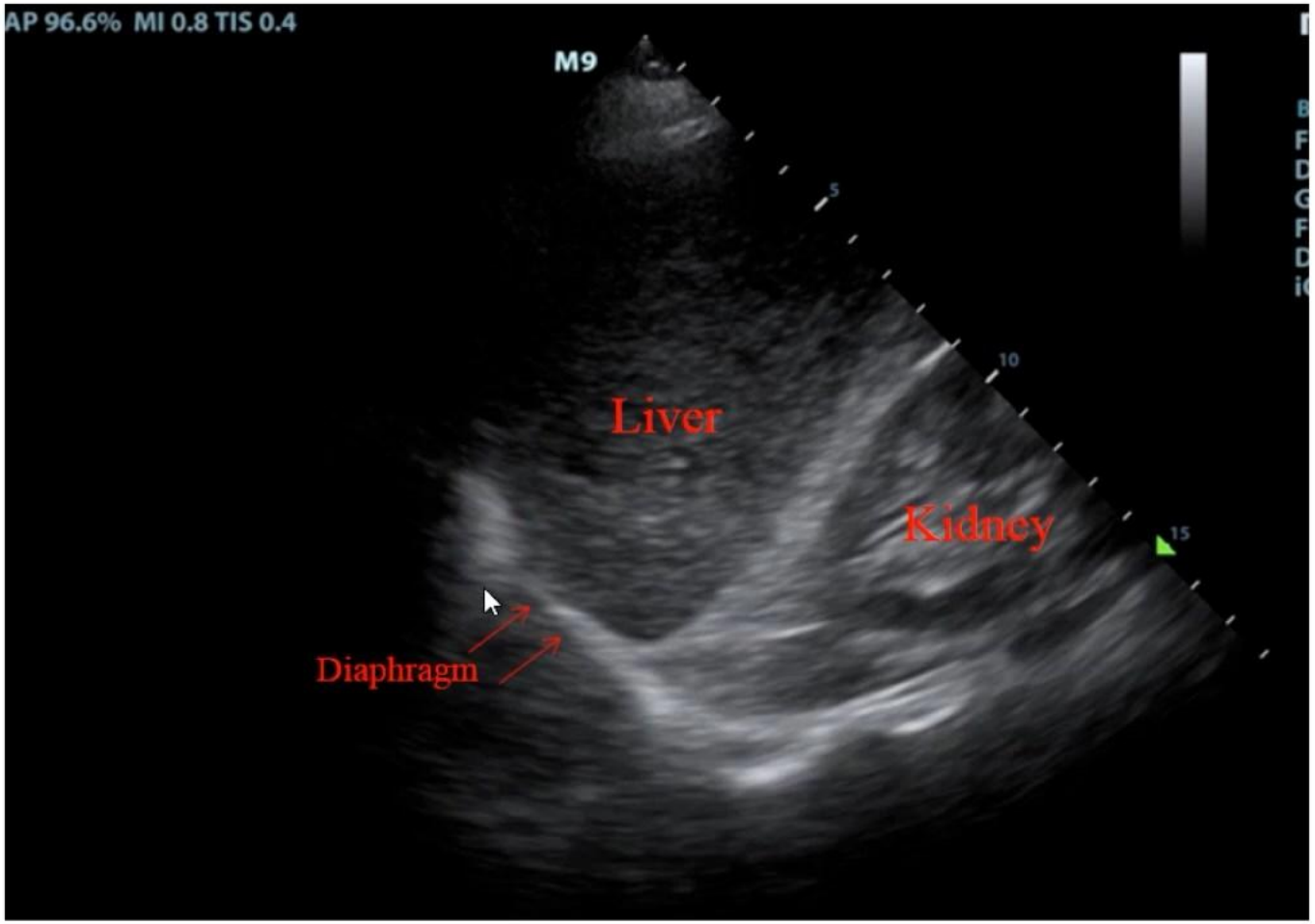
- *Focused Assessment with Sonography in Trauma* (FAST)
- 4 views
  - ① RUQ (Morrison's pouch)
  - ② LUQ (splenorenal recess)
  - ③ Suprapubic
  - ④ Subcostal long-axis
- Rapidly identify free intraperitoneal or pericardial fluid in trauma
- Sensitivity 70 – 95%, specificity 95 – 100%



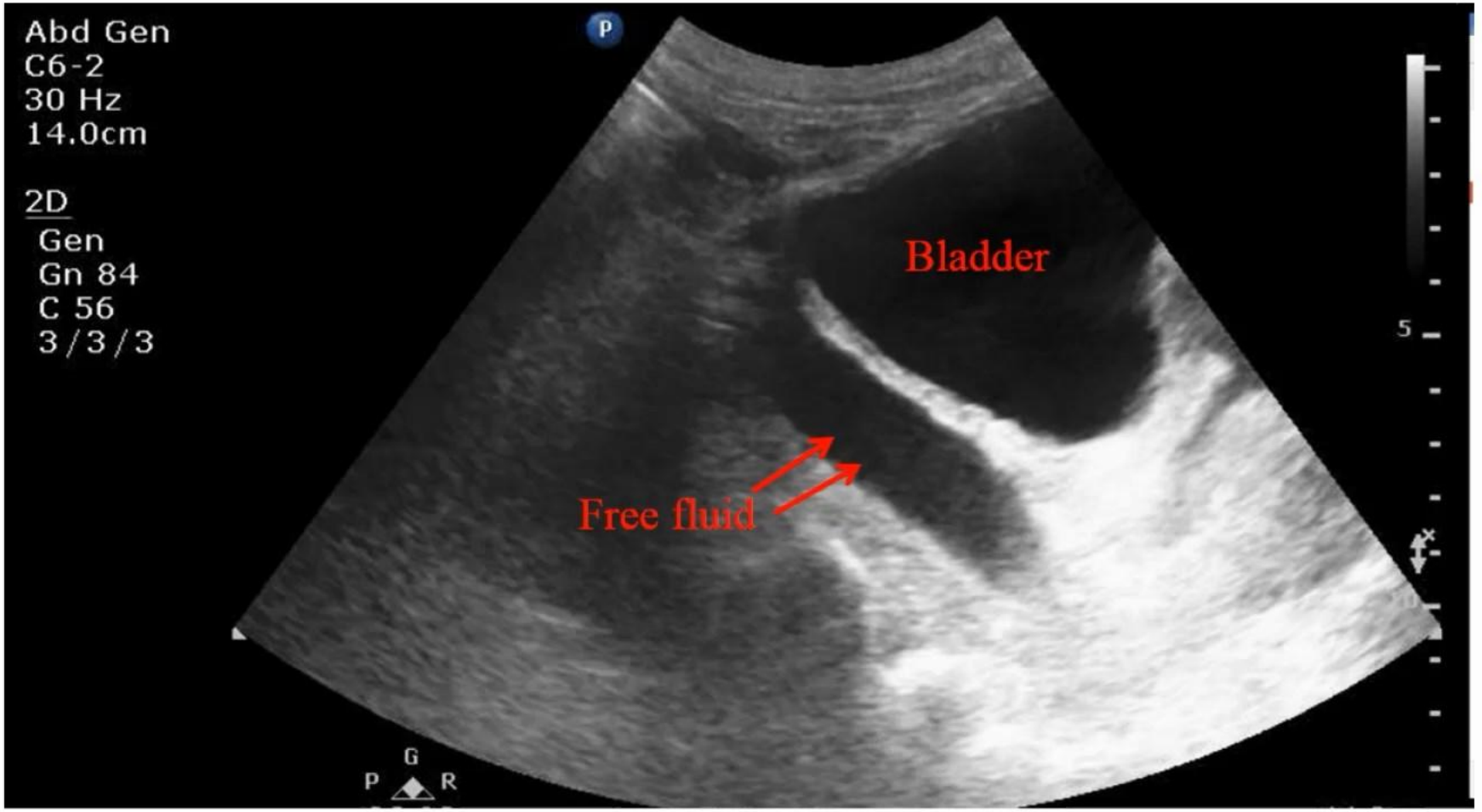
Normal RUQ



Normal RUQ



Free Fluid


Abd Gen
C6-2
30 Hz
14.0cm
2D
Gen
Gn 84
C 56
3/3/3
Bladder
Free fluid
5
G
P
R

- Lower failure rate
- Higher first attempt success rate
- Reduced time to perform procedure
- Decreased arterial punctures
- Decreased rate of hematoma

Cochrane Database Syst Rev. 2015 Jan 9;1:CD006962

[Original Research **Pulmonary Procedures**]

CHEST

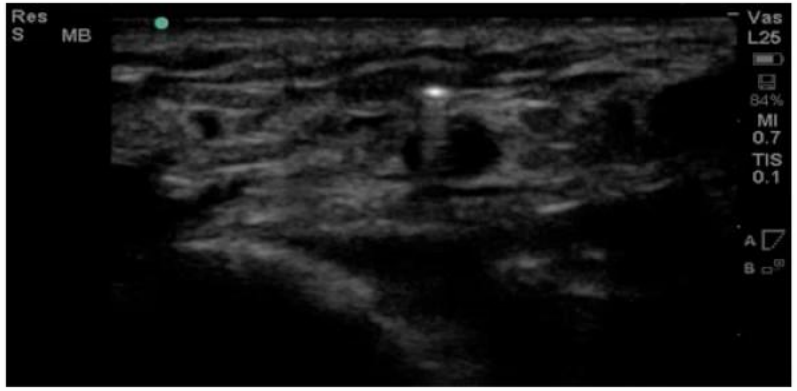
Ultrasound Guidance Facilitates Radial Artery Catheterization

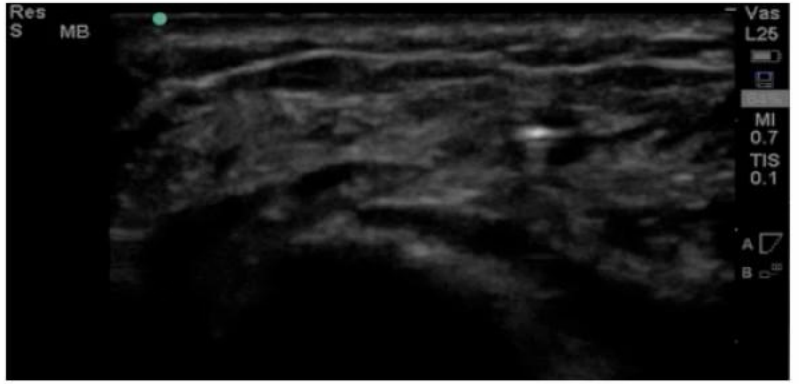
A Meta-analysis With Trial Sequential Analysis of Randomized Controlled Trials

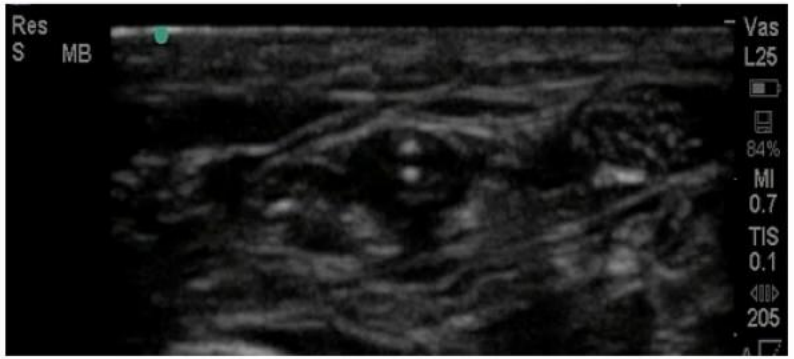
Wan-Jie Gu, MD; Xiang-Dong Wu, MSc; Fei Wang, MD, PhD; Zheng-Liang Ma, MD, PhD; and Xiao-Ping Gu, MD, PhD

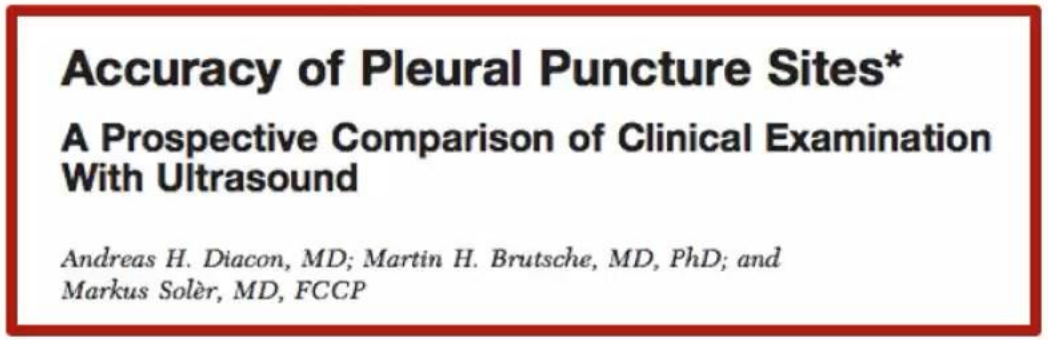
- Decreases first-attempt failure
- Decreases mean attempts to success
- Decreases mean time to success
- Decreases occurrence of hematoma complications

Arterial line









Accuracy of Pleural Puncture Sites*

A Prospective Comparison of Clinical Examination With Ultrasound

Andreas H. Diacon, MD; Martin H. Brutsche, MD, PhD; and Markus Solèr, MD, FCCP

REVIEW ARTICLE

Pneumothorax Following Thoracentesis

A Systematic Review and Meta-analysis

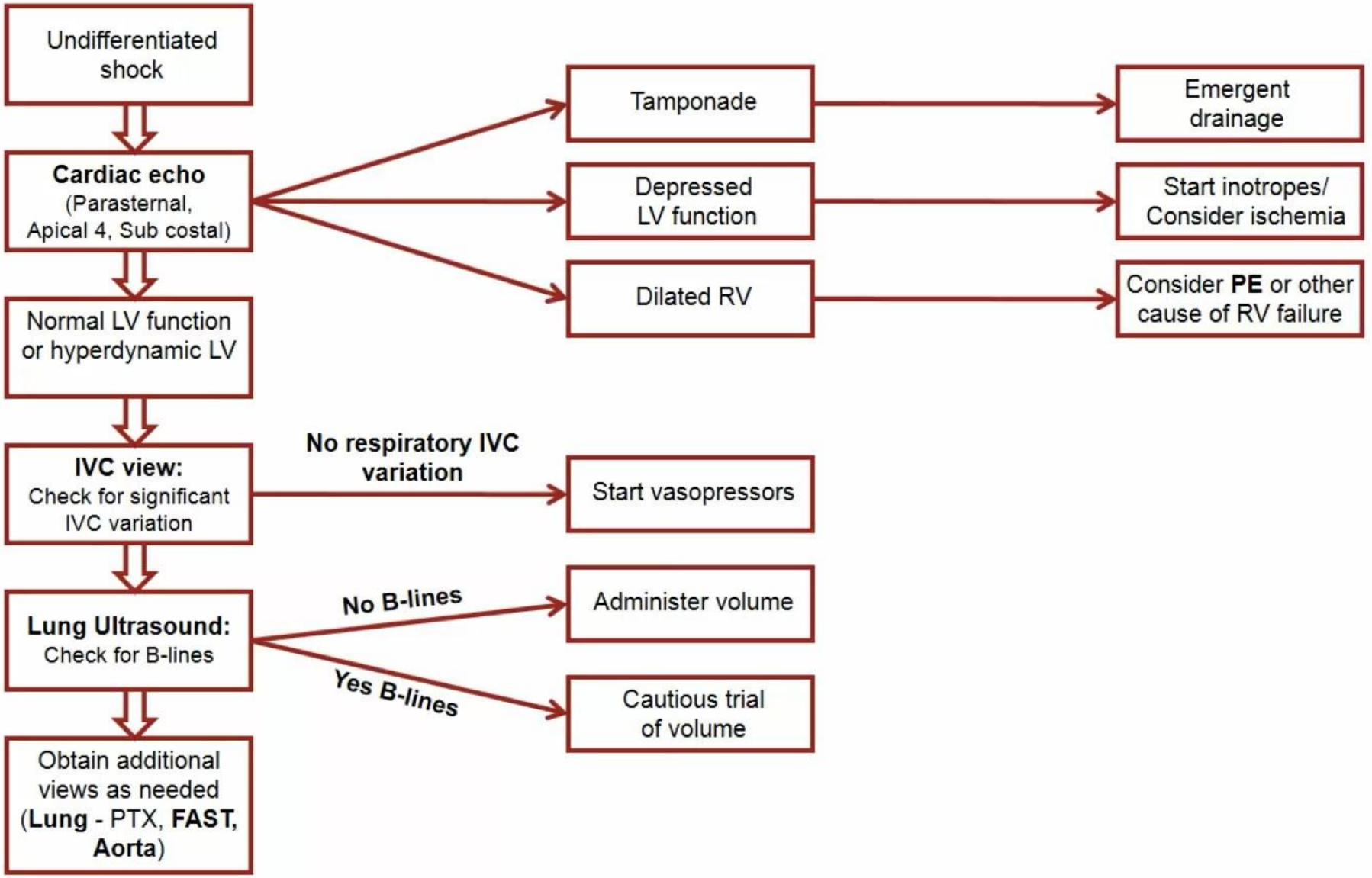
Craig E. Gordon, MD, MS; David Feller-Kopman, MD; Ethan M. Balk, MD, MPH; Gerald W. Smetana, MD

- US increases the yield of thoracentesis and potentially reduces complication rate
- US use was associated with significantly lower risk of pneumothorax (odds ratio [OR], 0.3; 95% CI, 0.2-0.7)

Chest. 2003 Feb;123(2):436-41

Arch Intern Med. 2010;170(4):332-339

Shock


Undifferentiated shock
Cardiac echo (Parasternal, Apical 4, Sub costal)
Normal LV function or hyperdynamic LV
IVC view: Check for significant IVC variation
Lung Ultrasound: Check for B-lines
Obtain additional views as needed (Lung - PTX, FAST, Aorta)
Tamponade
Emergent drainage
Depressed LV function
Start inotropes/ Consider ischemia
Dilated RV
Consider PE or other cause of RV failure
No respiratory IVC variation
Start vasopressors
No B-lines
Administer volume
Yes B-lines
Cautious trial of volume

SUMMARY

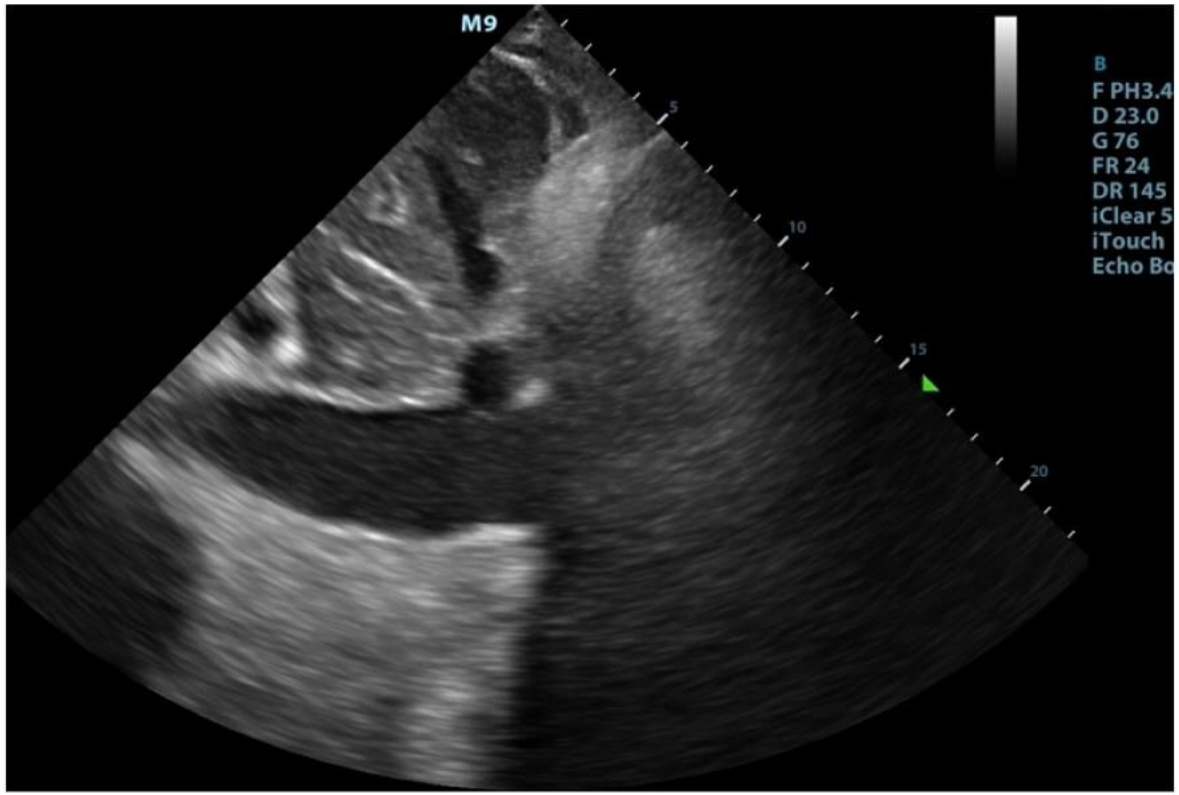
- Ultrasound can be very useful in the ICU!
- The intensivist should be familiar with the following ultrasound applications: basic cardiac, thoracic, abdominal, vascular, and procedural
- Can help answer critical questions:
  - Why is my patient in shock?
  - Is my patient likely to be fluid responsive?
  - Why is my patient's respiratory status deteriorating?
- Ultrasound has been shown to make common ICU procedures easier and safer

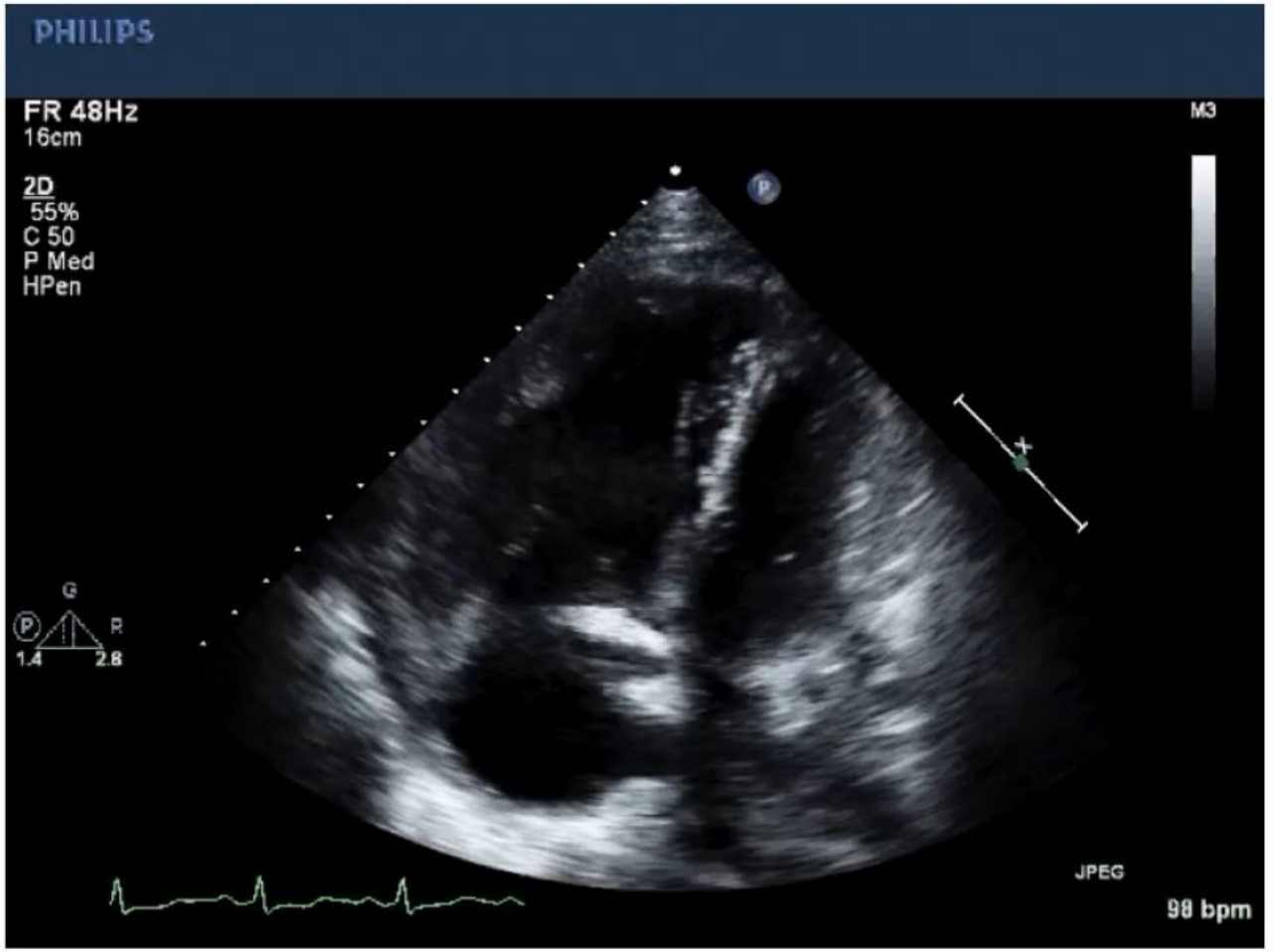
Question # 1

- 40 yo female history of lupus and recent flu like illness admitted to the ICU for fever, hypoxia, and hypotension. Portable CXR is read as right sided effusion. The ED physician administered 4L NS, broad spectrum antibiotics, placed a right subclavian central line, and started the patient on a moderate dose of norepinephrine infusion. Upon arrival to the ICU the patient becomes hypotensive.
- Vitals are as follows: HR 122, BP 81/46, T100.6, RR 28, 93% on 6L NC.
- The nurse asks you want you want to do about the low BP.

What should you do next?

- A. Administer 1 L NS bolus
- B. Administer thrombolytics
- C. Start vasopressin 0.04 U/min
- D. Administer furosemide 100 mg IV push
- E. Needle decompression, followed by chest tube placement


M9
5
10
15
20
B
F PH3.4
D 23.0
G 76
FR 24
DR 145
iClear 5
iTouch
Echo Bo


PHILIPS
FR 48Hz
16cm
2D
55%
C 50
P Med
HPen
M3
G
P
R
1.4
2.8
JPEG
98 bpm

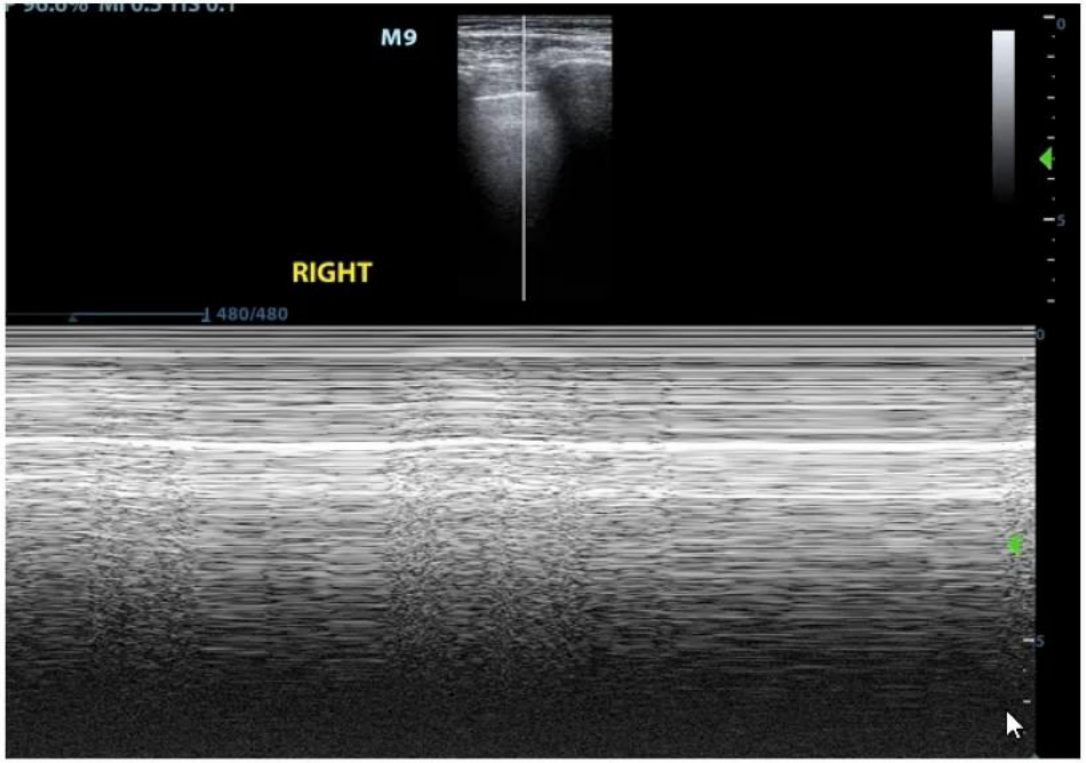

Stud

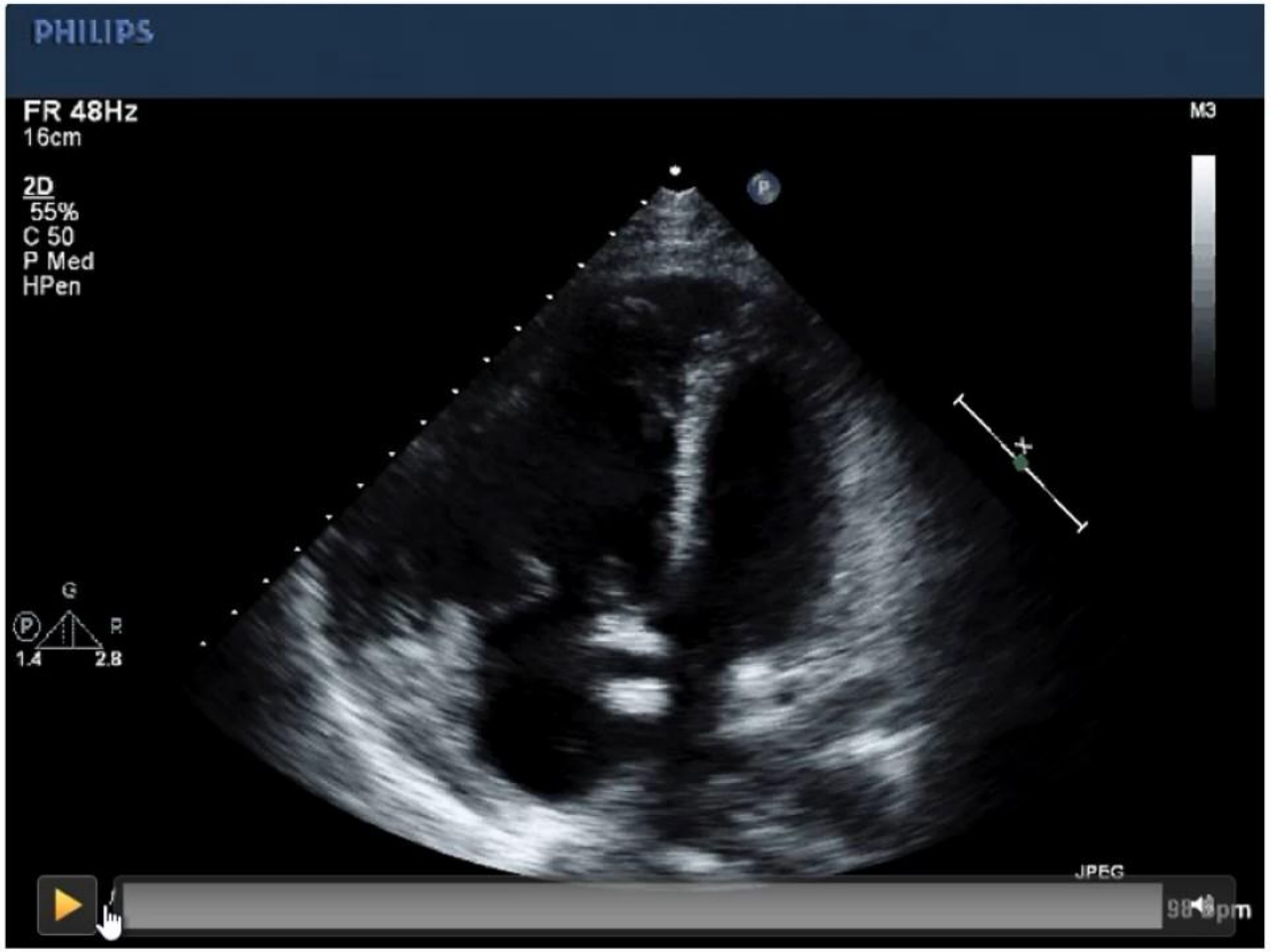
Answer, Question # 1

- A. Administer 1 L NS bolus
- B. Administer thrombolytics
- C. Start vasopressin 0.04 U/min
- D. Administer furosemide 100 mg IV push
- E. Needle decompression, followed by chest tube placement

Question # 2

- 40 yo female history of lupus and recent flu like illness admitted to the ICU for fever, hypoxia, and hypotension. Portable CXR is read as right sided effusion. The ED physician administered 4L NS, broad spectrum antibiotics, placed a right subclavian central line, and started the patient on a moderate dose of norepinephrine infusion. Upon arrival to the ICU the patient becomes hypotensive.
- Vitals are as follows: HR 122, BP 81/46, T100.6, RR 28, 93% on 6L NC.
- The nurse asks you want you want to do about the low BP.


M9
RIGHT
480/480


PHILIPS
FR 48Hz
16cm
2D
55%
C 50
P Med
HPen
M3
G
P
R
1.4
2.8
JPEG

Answer, Question # 2

- A. Administer 1 L NS bolus
- B. Administer thrombolytics
- C. Start vasopressin 0.04 U/min
- D. Administer furosemide 100 mg IV push
- E. Needle decompression, followed by chest tube placement

Question # 3

- 40 yo female history of lupus and recent flu like illness admitted to the ICU for fever, hypoxia, and hypotension. Portable CXR is read as right sided effusion. The ED physician administered 4L NS, broad spectrum antibiotics, placed a right subclavian central line, and started the patient on a moderate dose of norepinephrine infusion. Upon arrival to the ICU the patient becomes hypotensive.
- Vitals are as follows: HR 122, BP 81/46, T100.6, RR 28, 93% on 6L NC.
- The nurse asks you want you want to do about the low BP.

Answer, Question # 3

- A. Administer 1 L NS bolus
- B. Administer thrombolytics
- C. Start vasopressin 0.04 U/min
- D. Administer furosemide 100 mg IV push
- E. Needle decompression, followed by chest tube placement