

# Ultrasound in the ICU: What Every Intensivist Should Know

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**Instructor of Emergency Medicine**

# 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





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



Accreditation Council for  
Graduate Medical Education

- 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 and 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





### **Assessment of Left Ventricular Function by Intensivists Using Hand-Held Echocardiography\***

*Roman Melamed, MD; Mark D. Sprenkle, MD; Valerie K. Ulstad, MD;  
Charles A. Herzog, MD; and James W. Leatherman, MD, FCCP*

- 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

**Relevance of Lung Ultrasound in the  
Diagnosis of Acute Respiratory Failure\***

**The BLUE Protocol**

*Daniel A. Lichtenstein, MD, FCCP; and Gilbert A. Mezière, MD*

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



## Deep Impact of Ultrasound in the Intensive Care Unit

### *The "ICU-sound" Protocol*

Emilpaolo Manno, M.D.,\* Mauro Navarra, M.D.,† Luciana Faccio, M.D.,† Mohsen Motevallian, M.D.,†  
Luca Bertolaccini, M.D., Ph.D.,‡ Abdou Mfochivè, M.D.,† Marco Pesce, M.D.,†  
Andrea Evangelista, M.S.§

- 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%)

# Critical Care Ultrasound

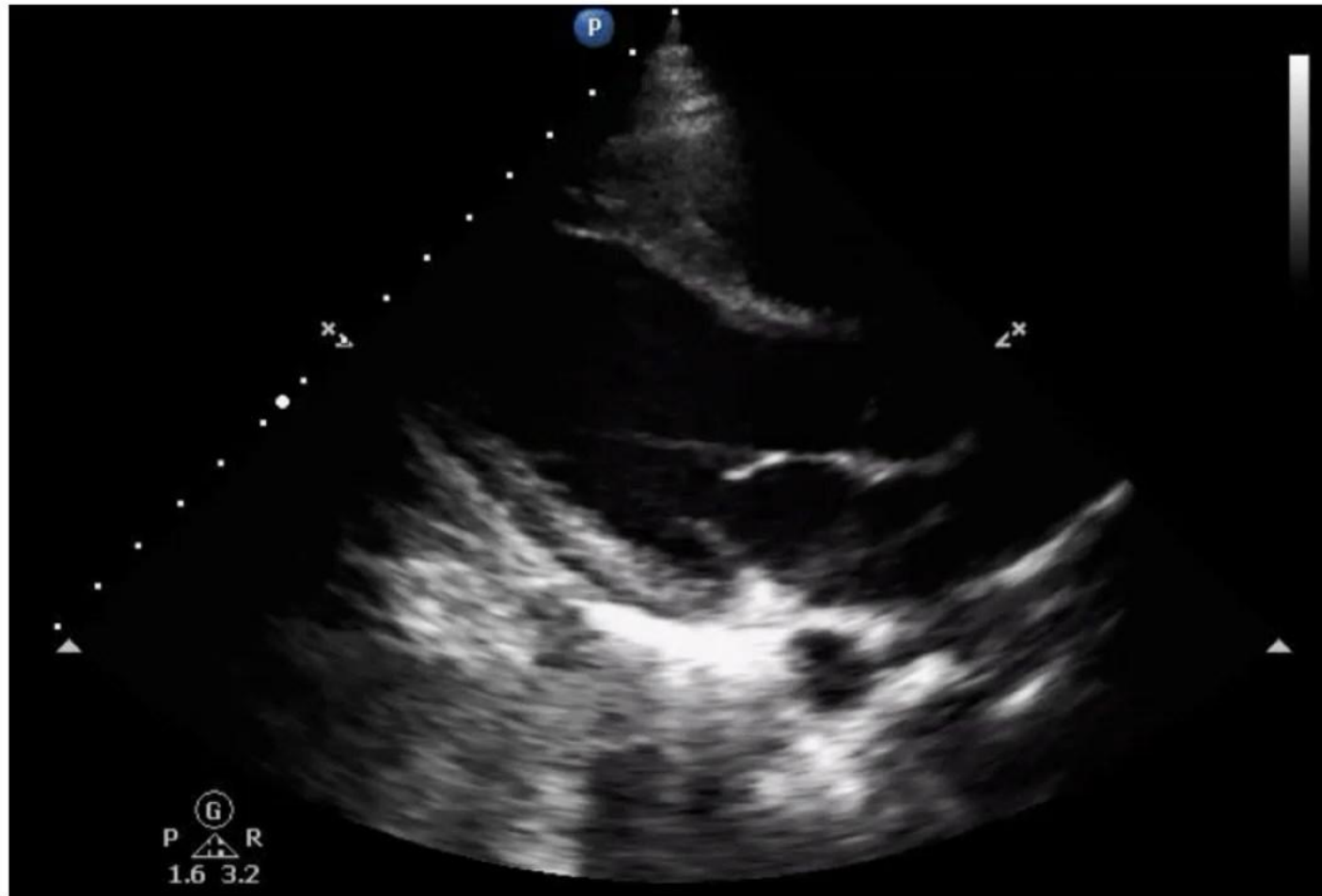
- Cardiac
  - Basic
  - Advanced
- Thoracic
  - Pleura
  - Lung
- Vascular
- Abdominal
- Procedural



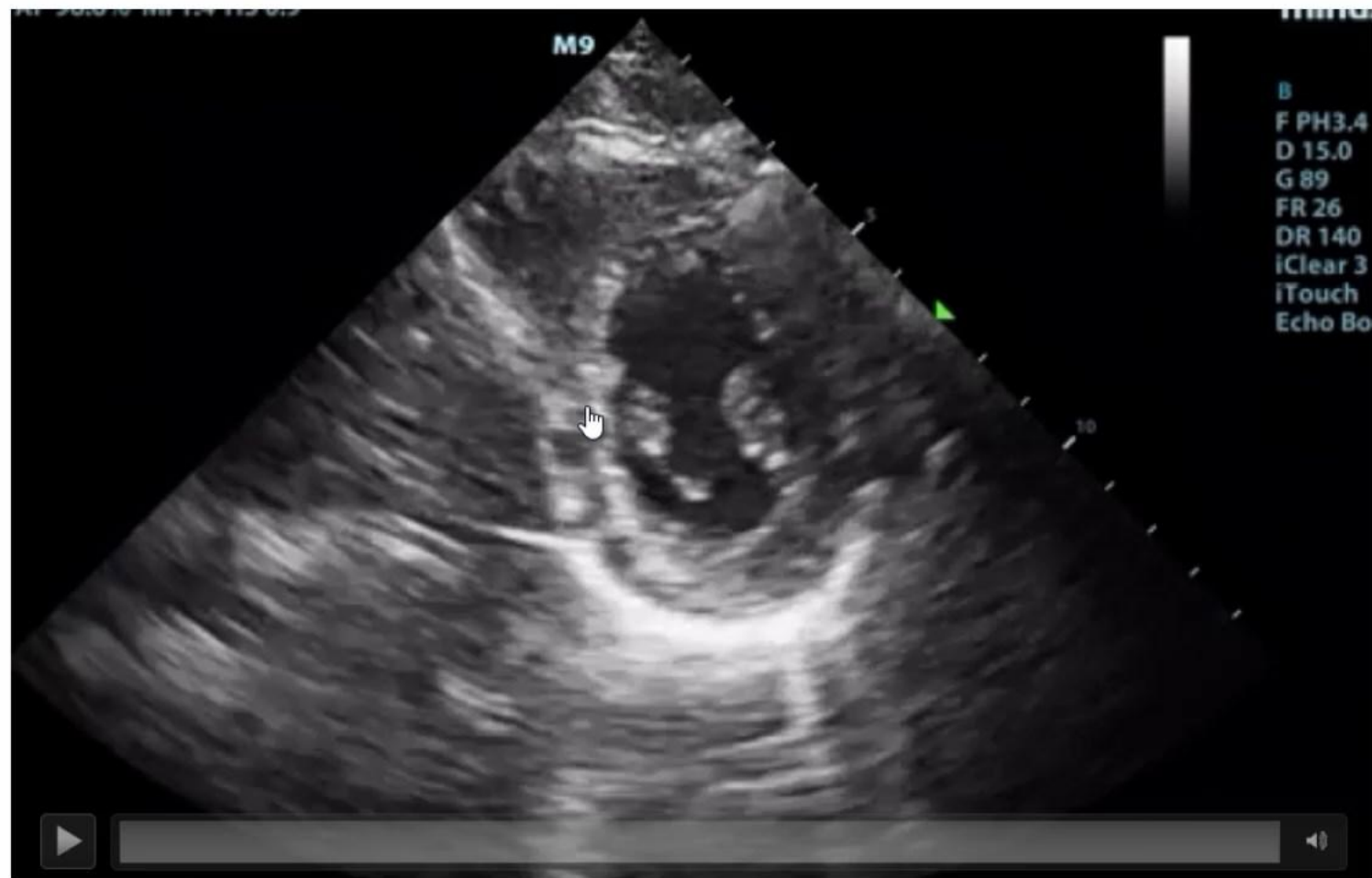
# Basic critical care echocardiography

- 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

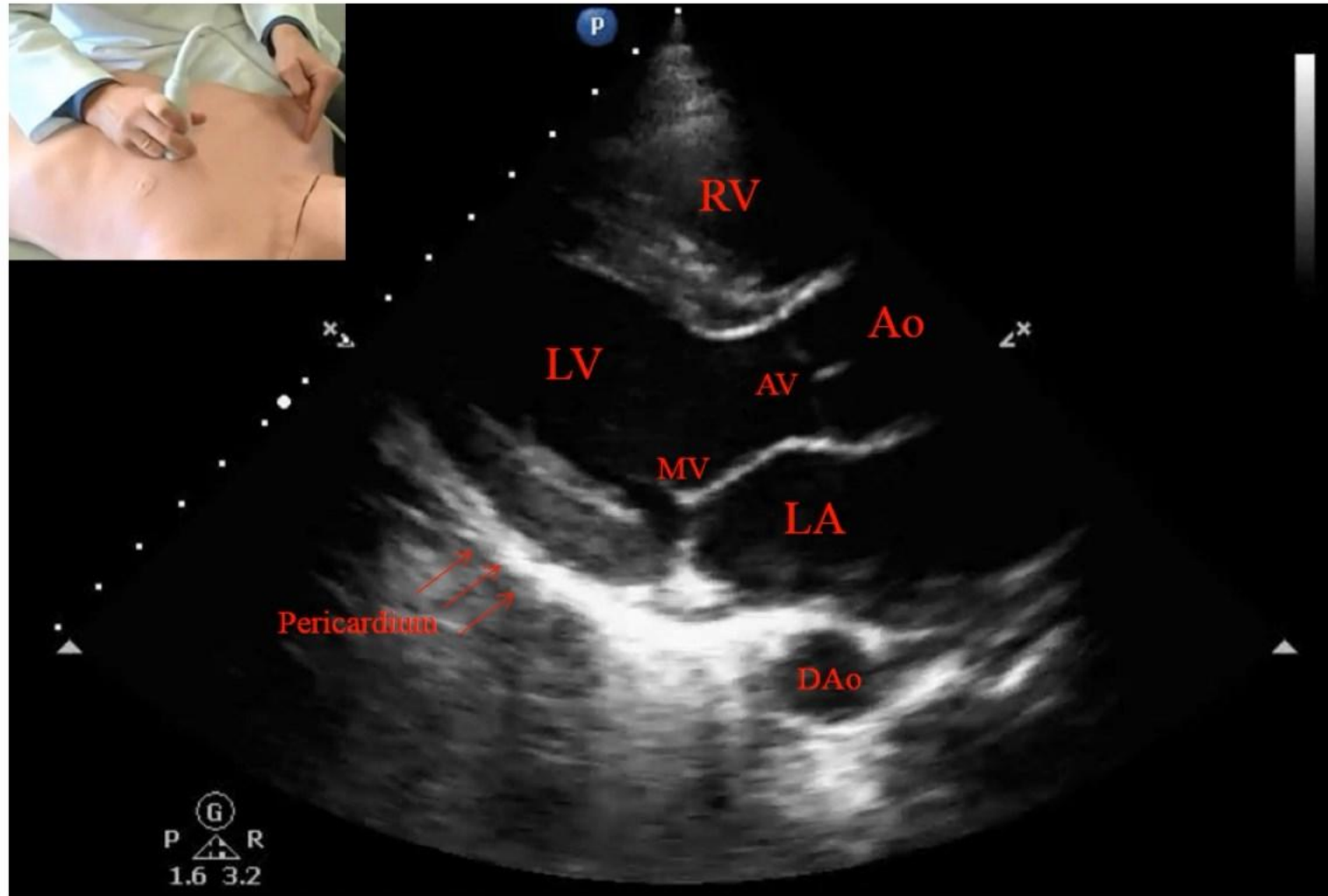
# Parasternal long-axis



# Parasternal long-axis



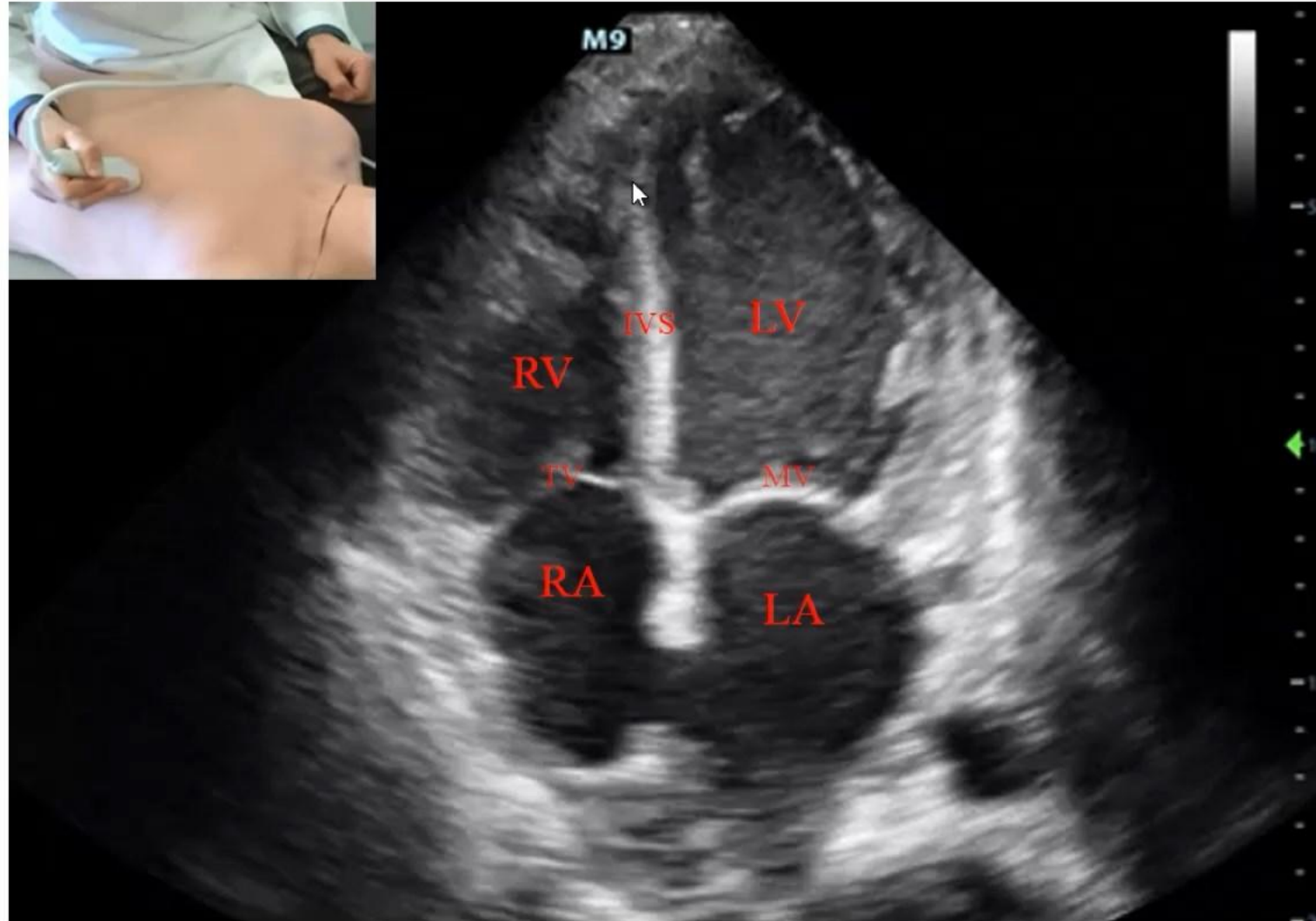
# Parasternal long-axis



# Parasternal short-axis

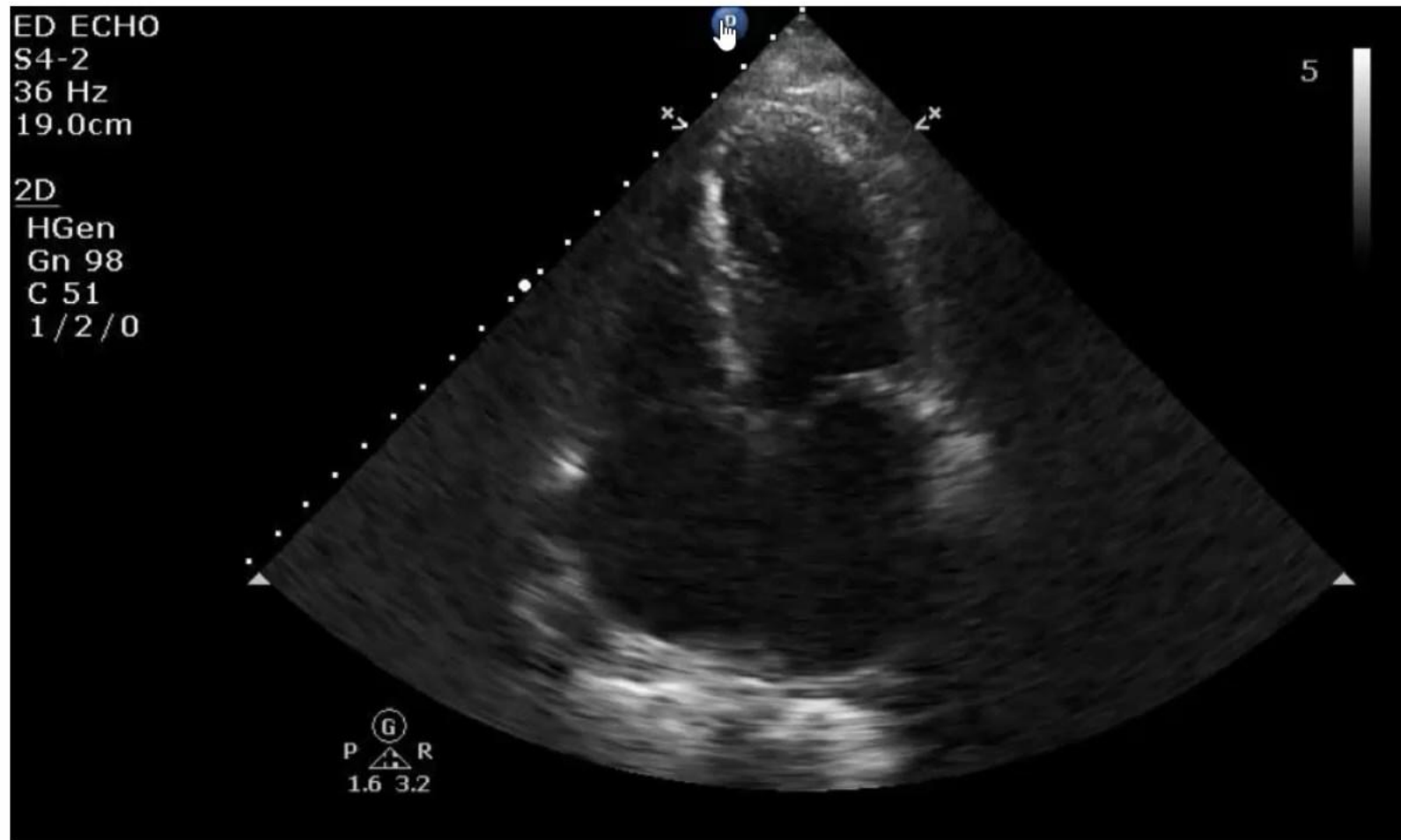


# Apical 4-chamber

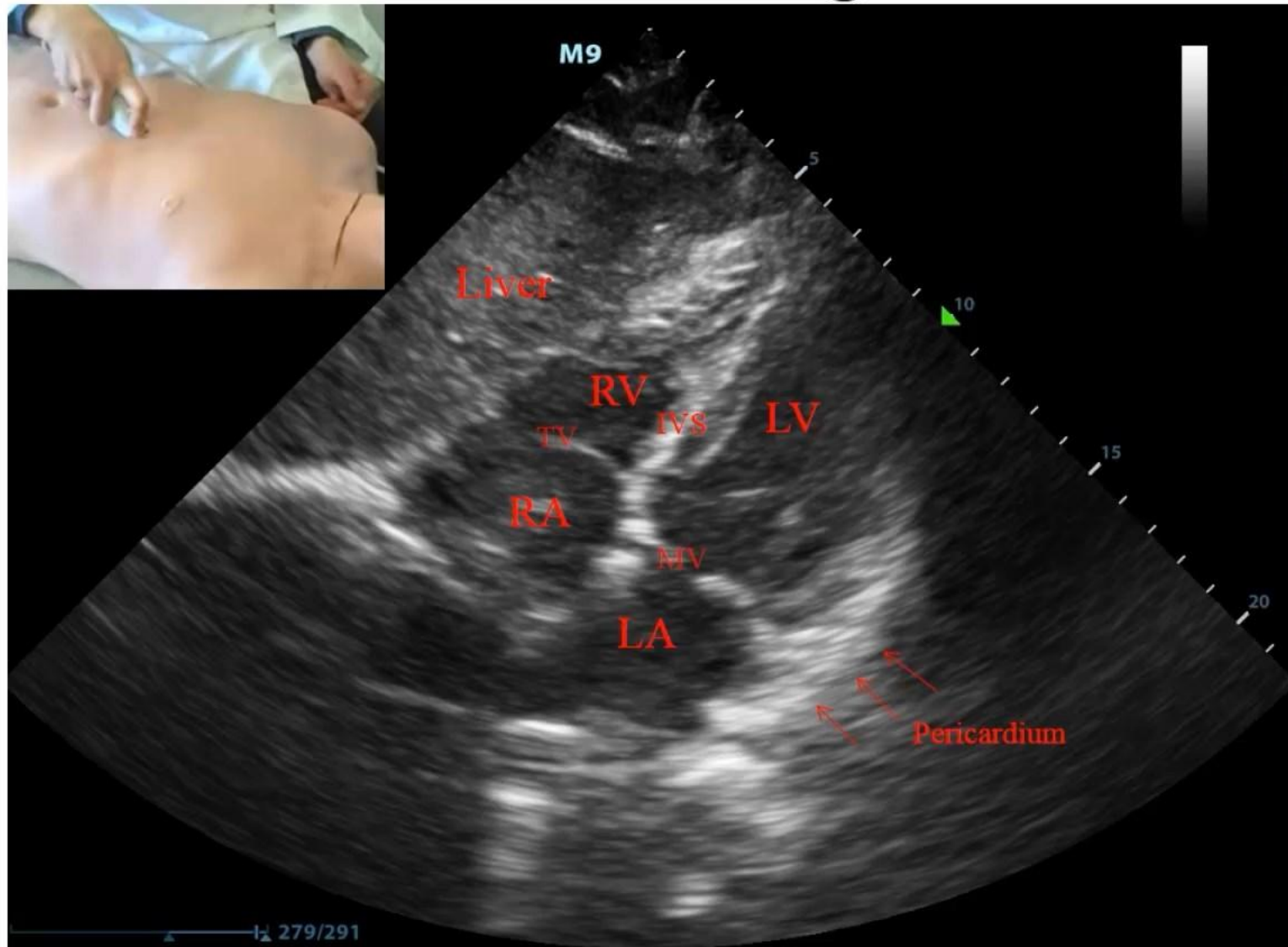




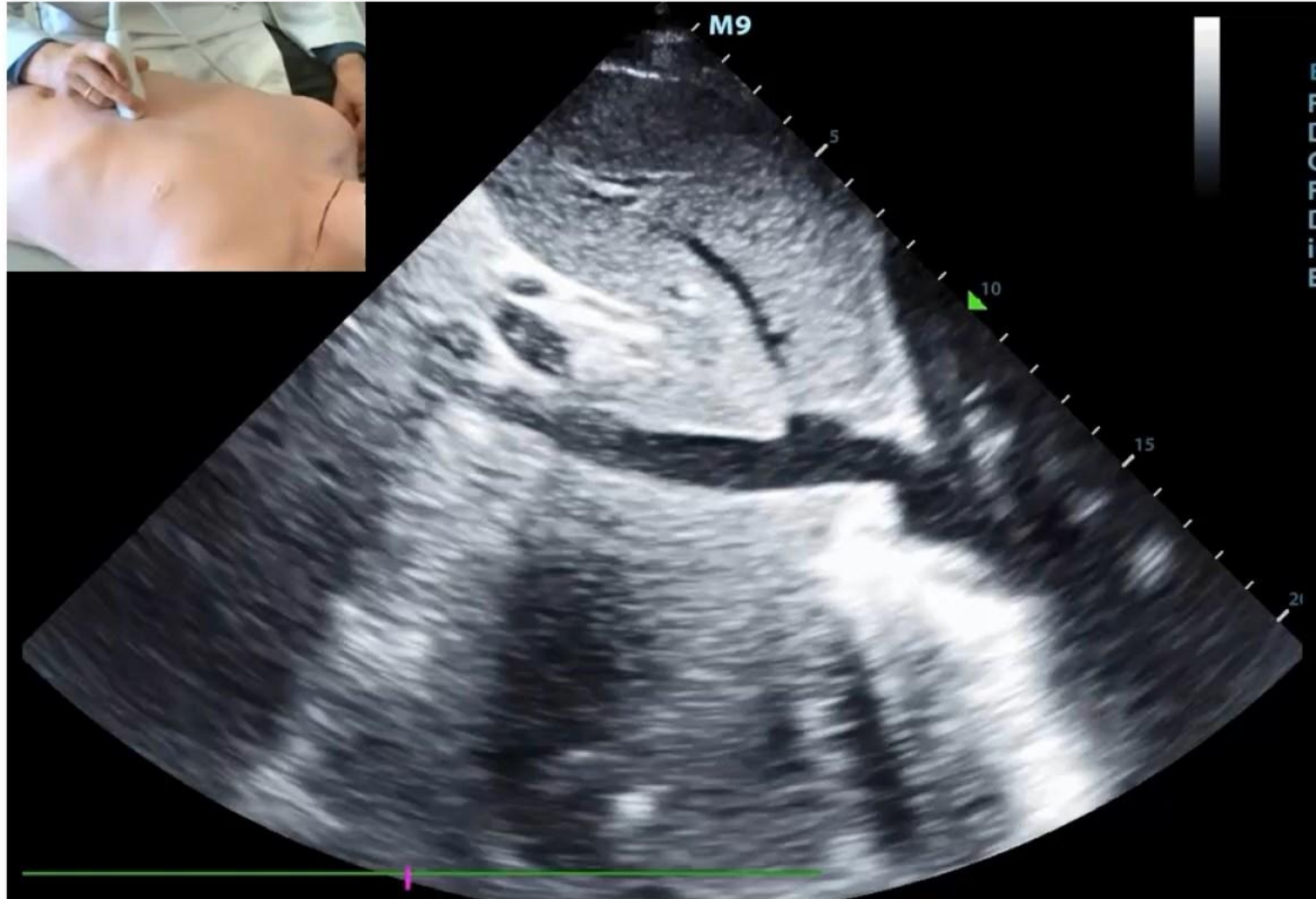
# Apical 4-chamber



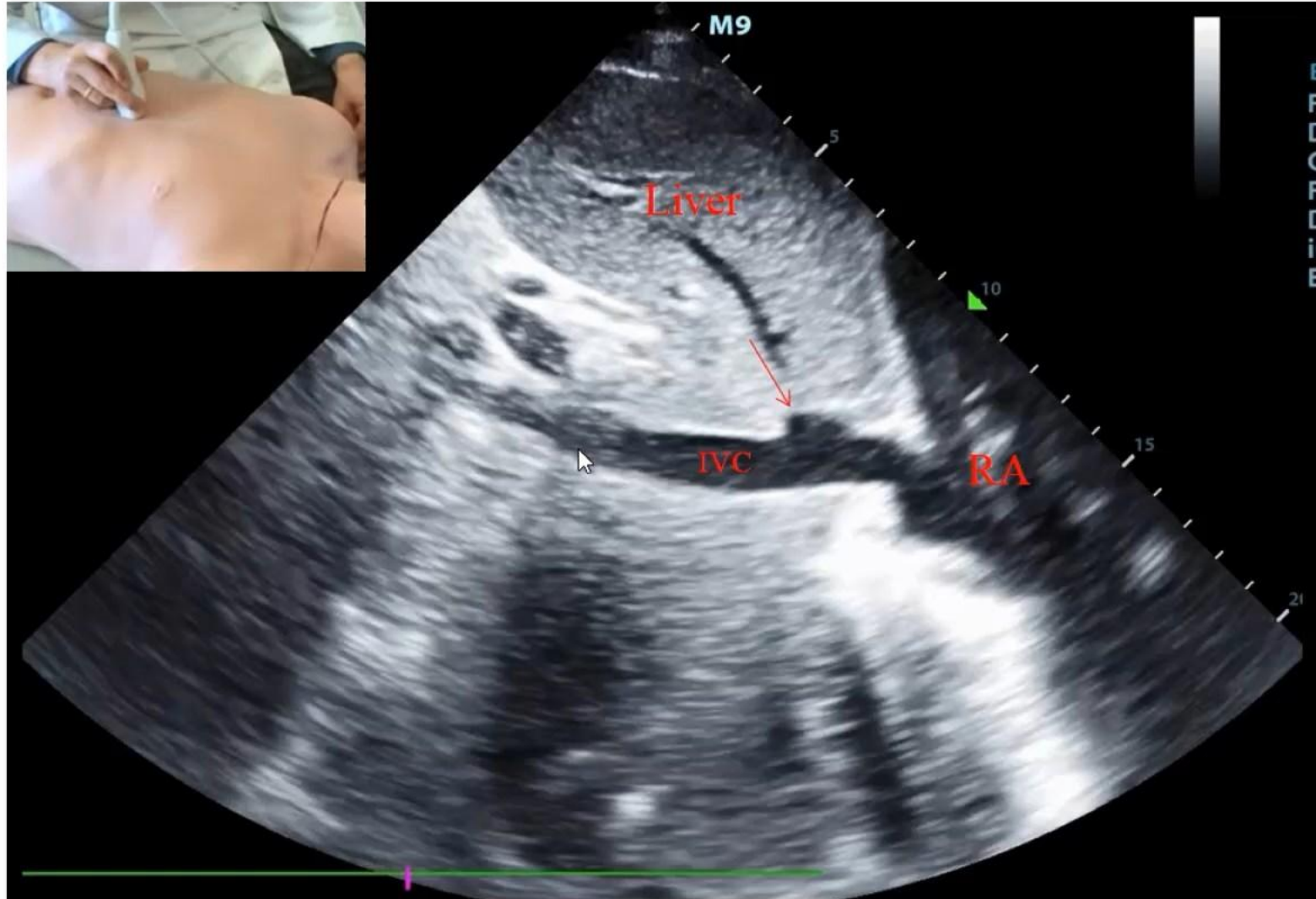
# Subcostal long-axis



# IVC



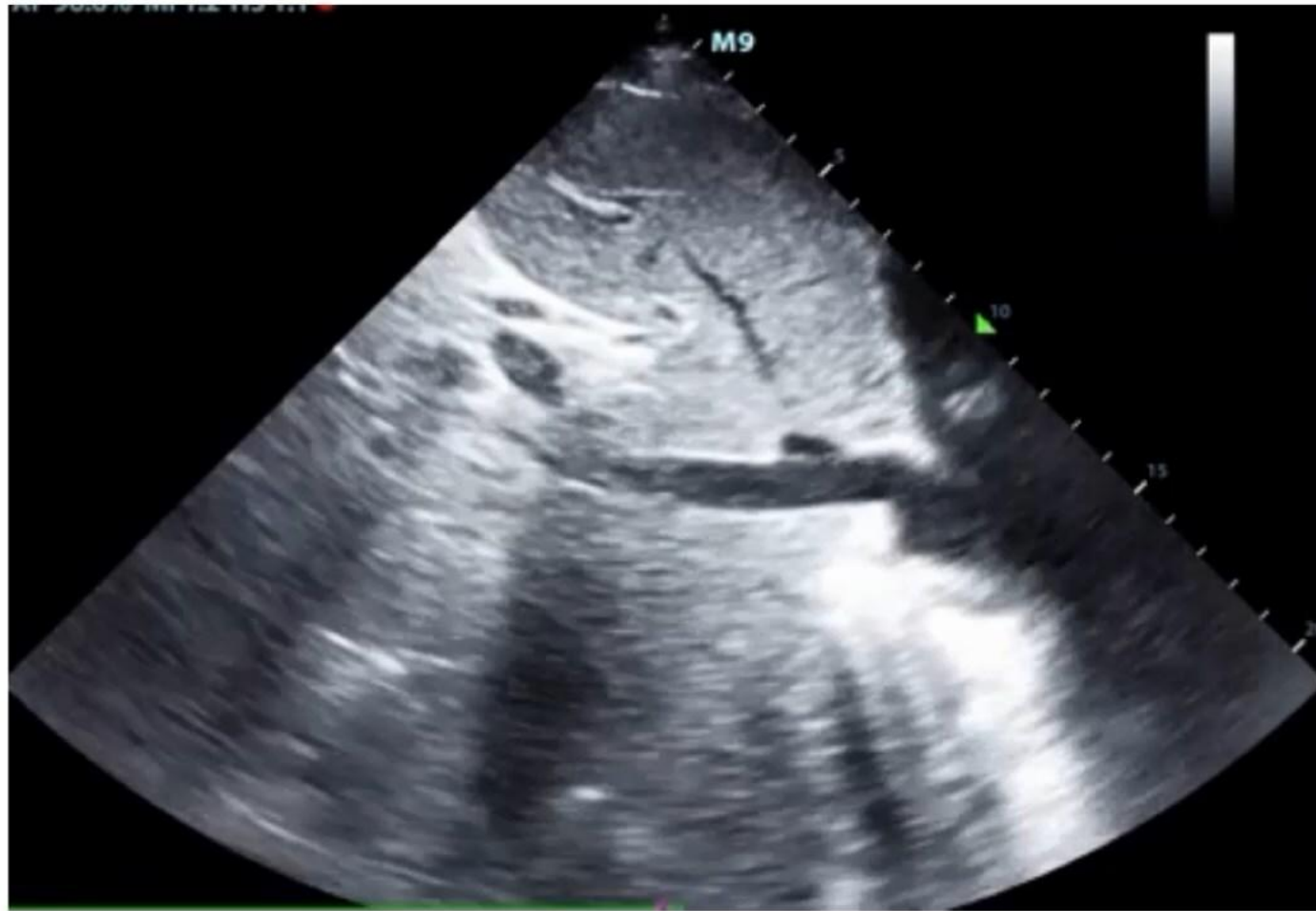
# IVC



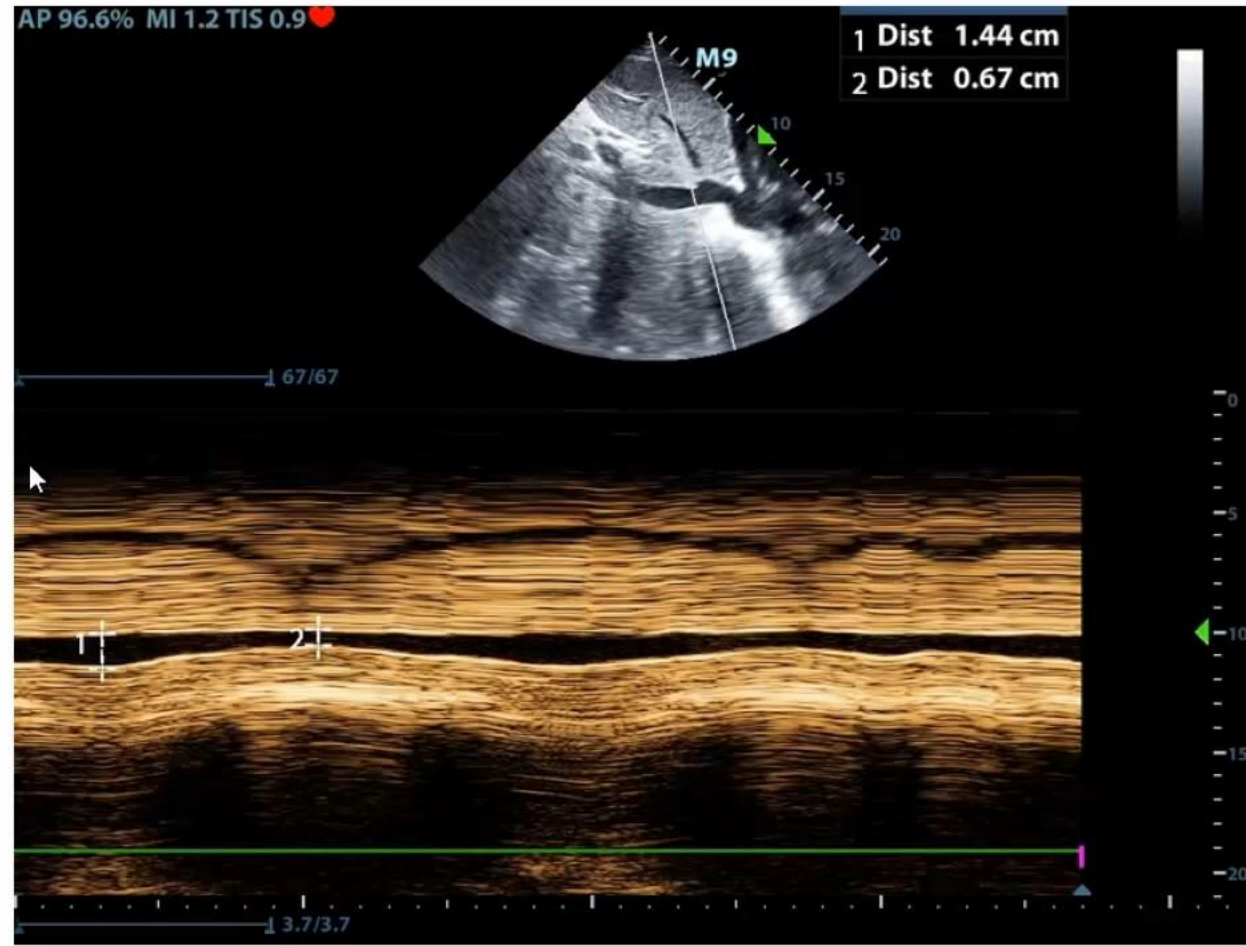
# IVC evaluation for fluid responsiveness

- Best studied in mechanically ventilated, fully sedated patients without any spontaneous respirations
  - Respiratory variation greater than **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

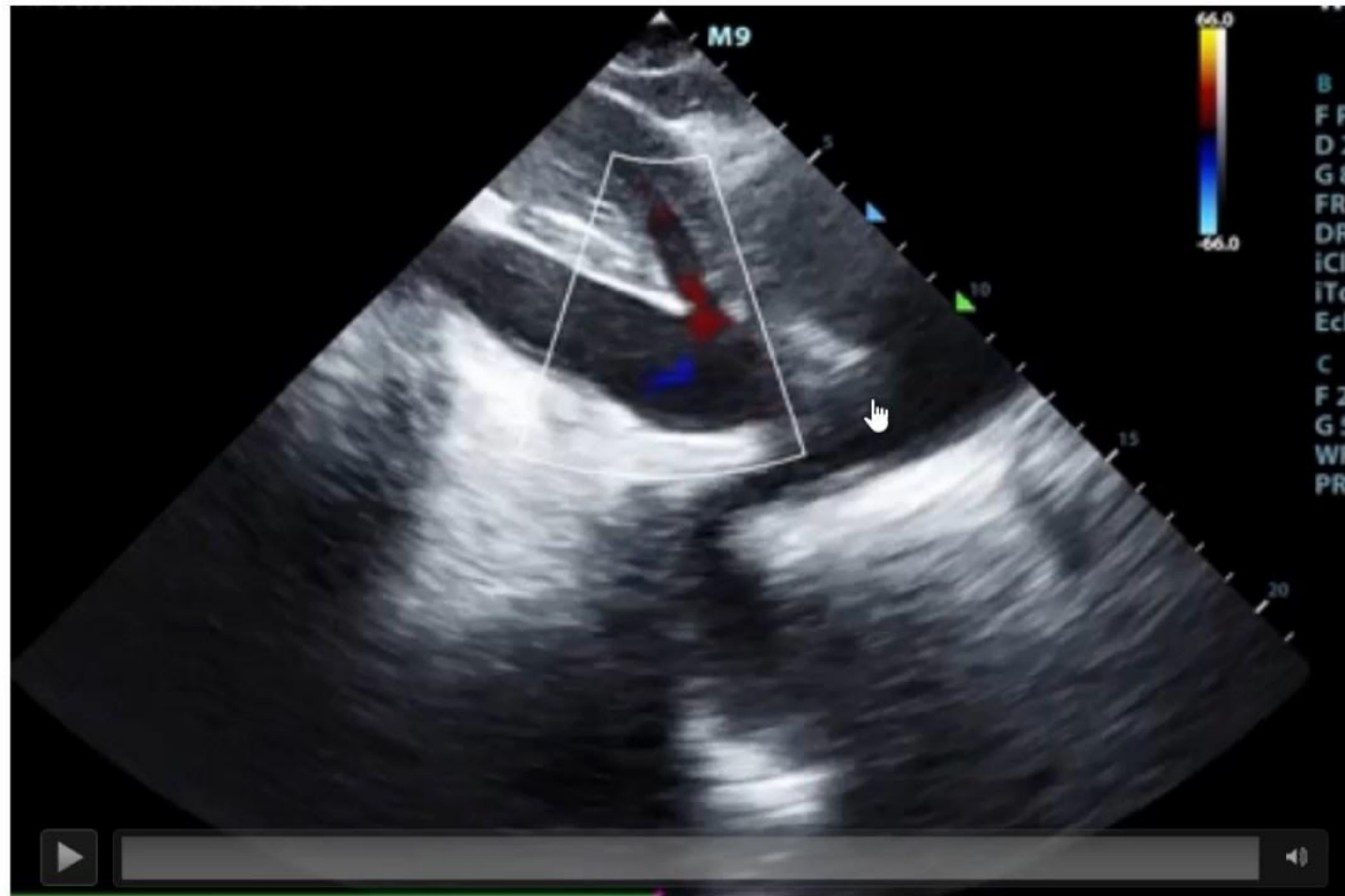
# Hypovolemia



# Hypovolemia



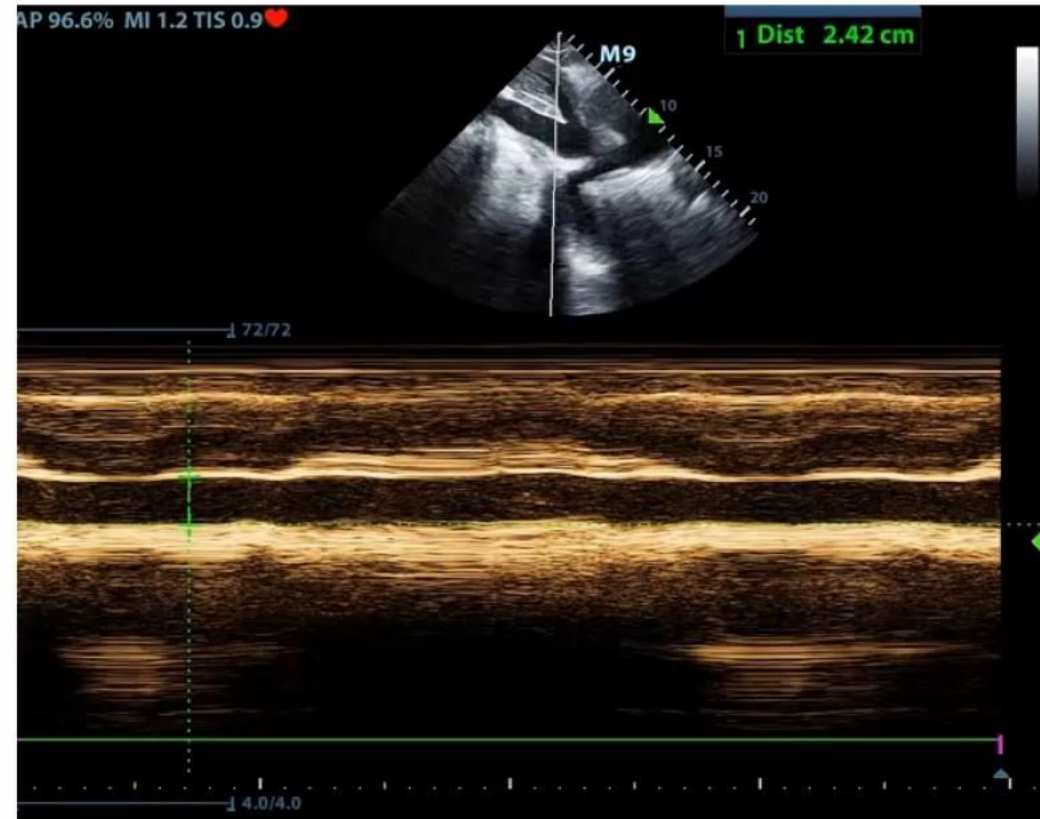
# Volume overloaded IVC



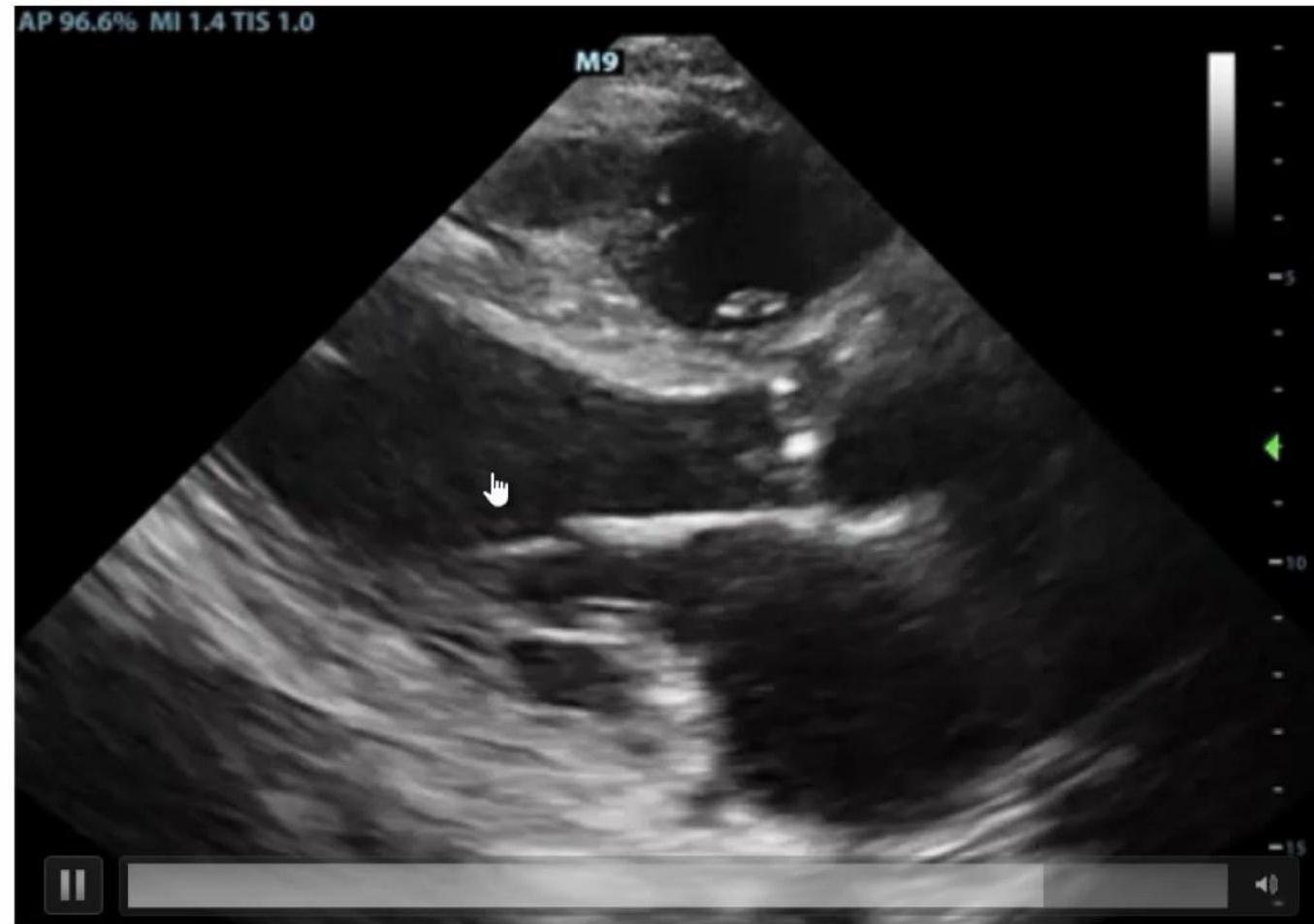


# Volume overloaded IVC

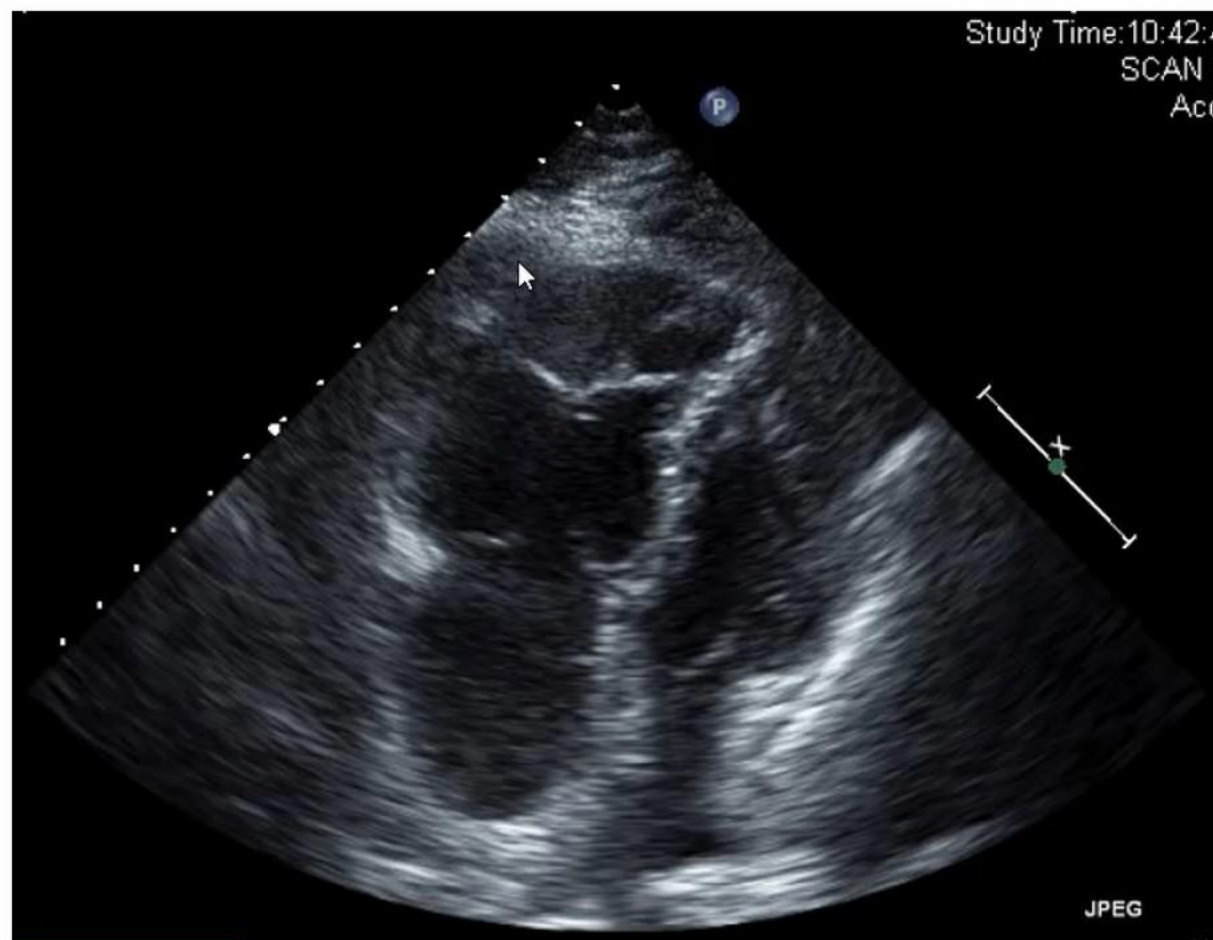
- $> 2$  cm
- No respiratory variation



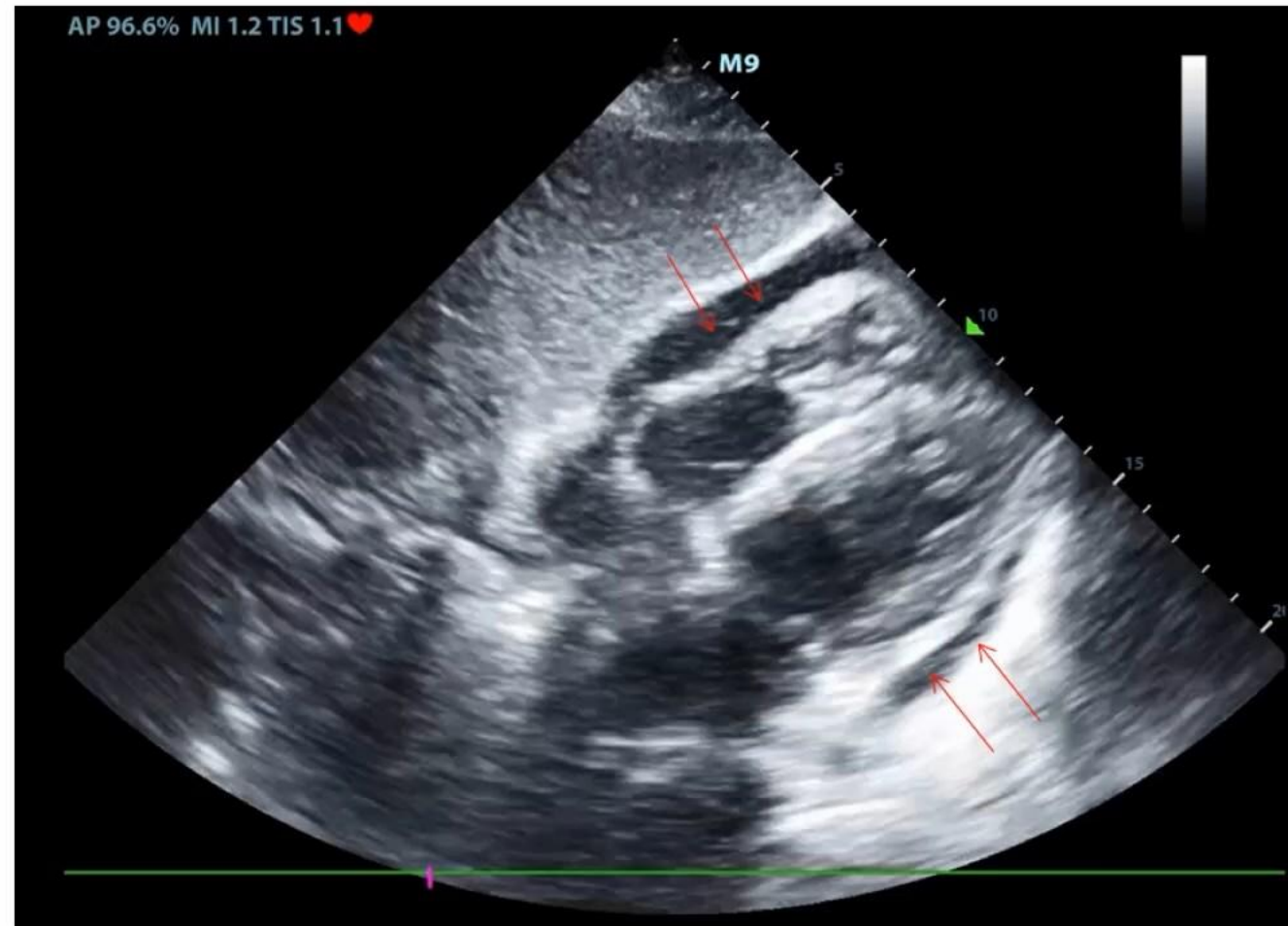
# Depressed LV function



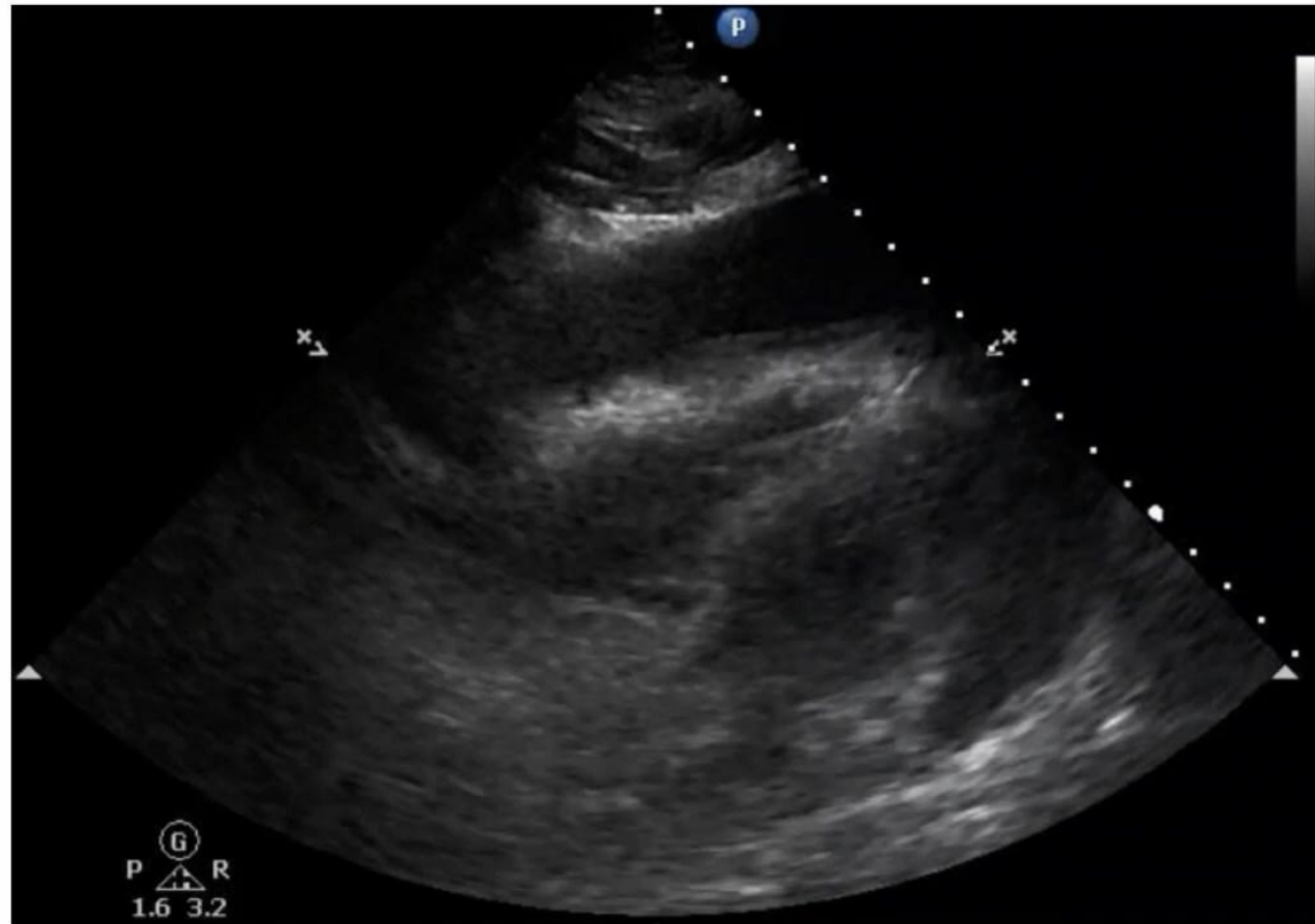
# RV Strain



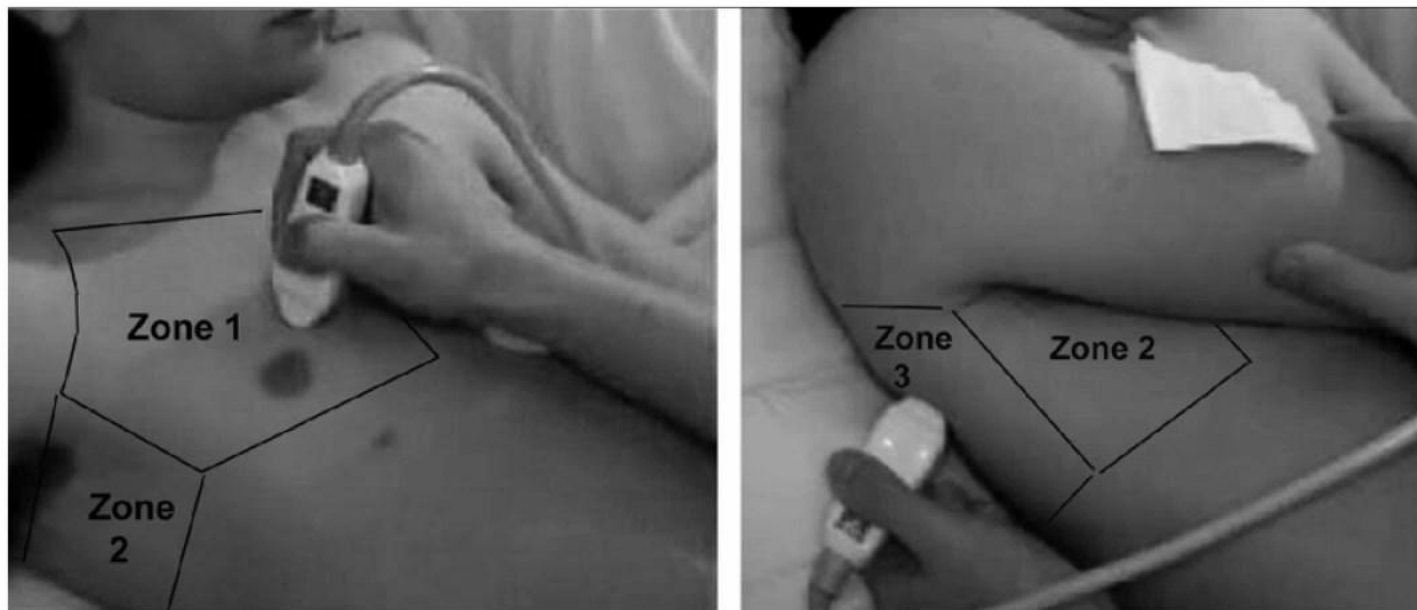
# Pericardial Effusion



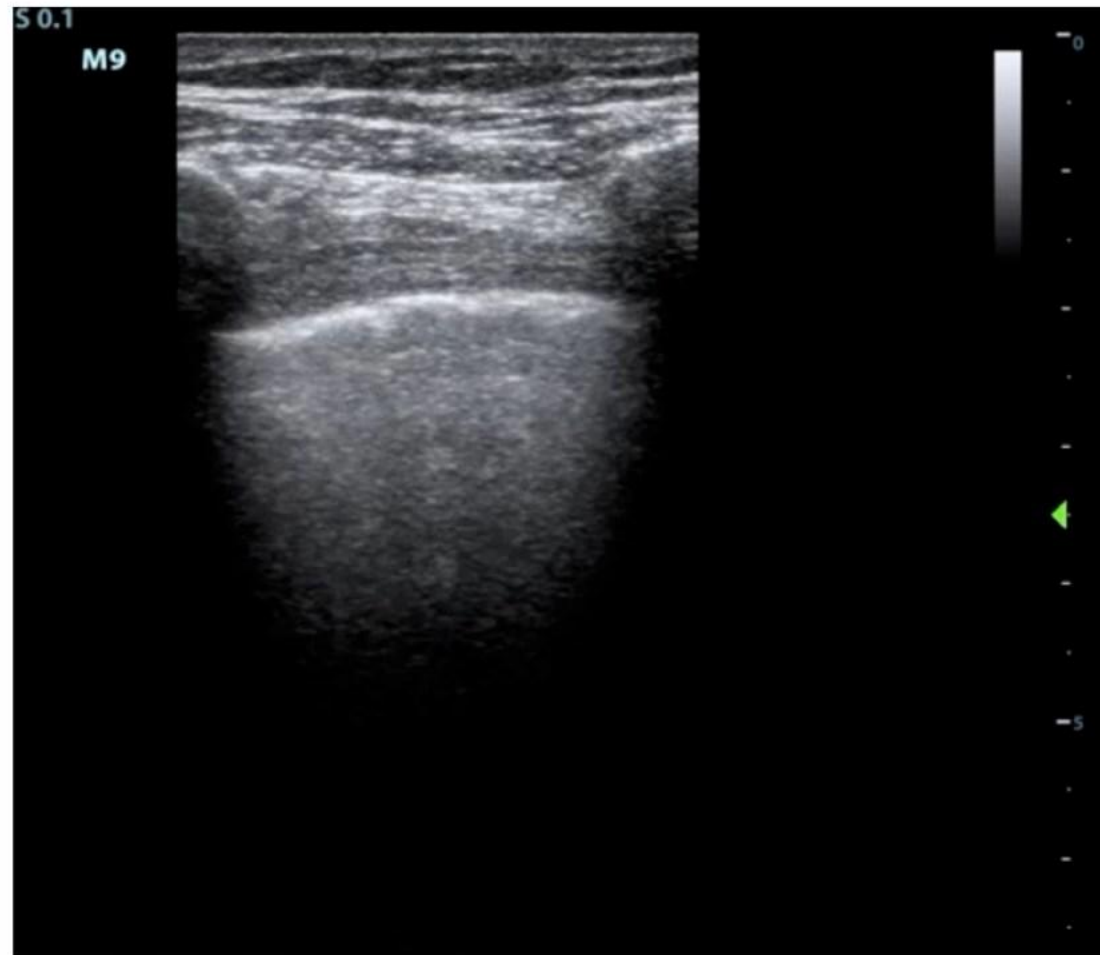
# Tamponade



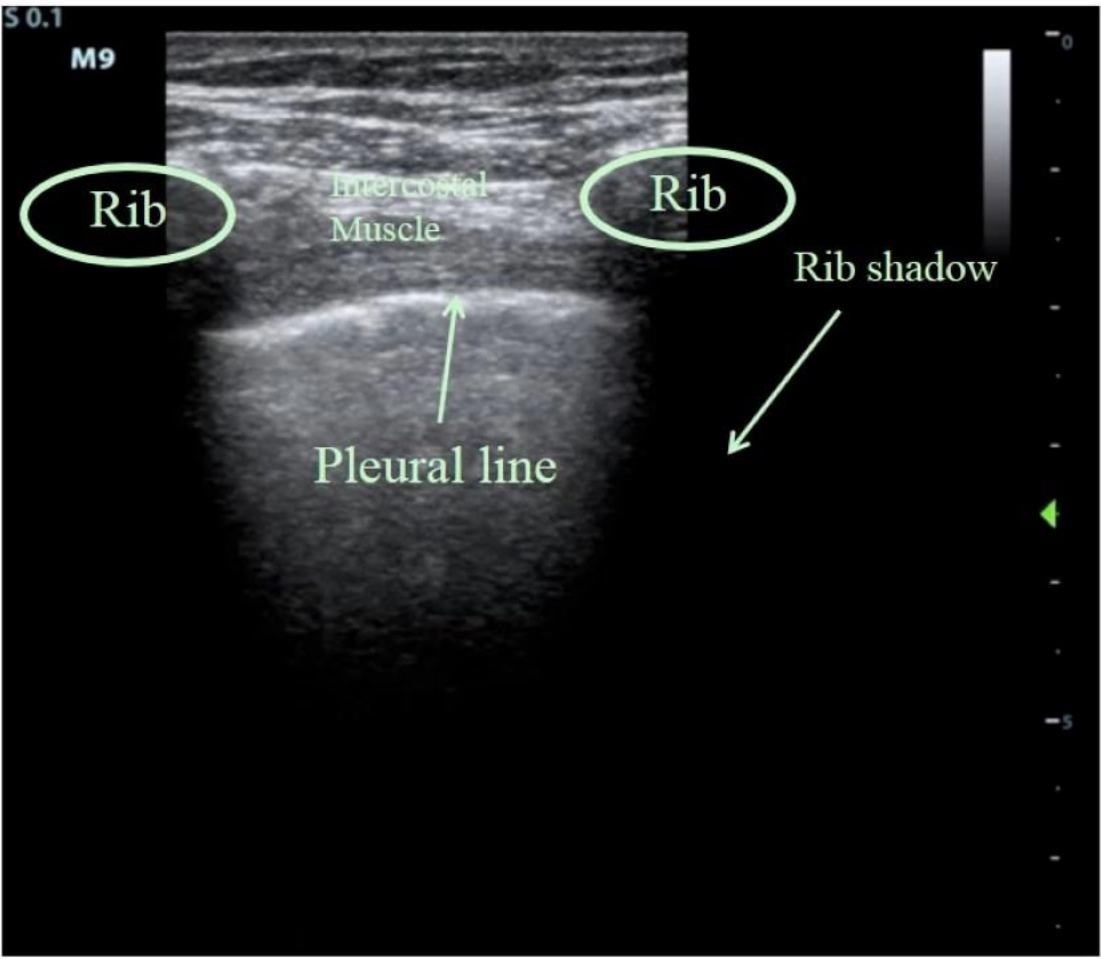
# Basic views



# Normal lung

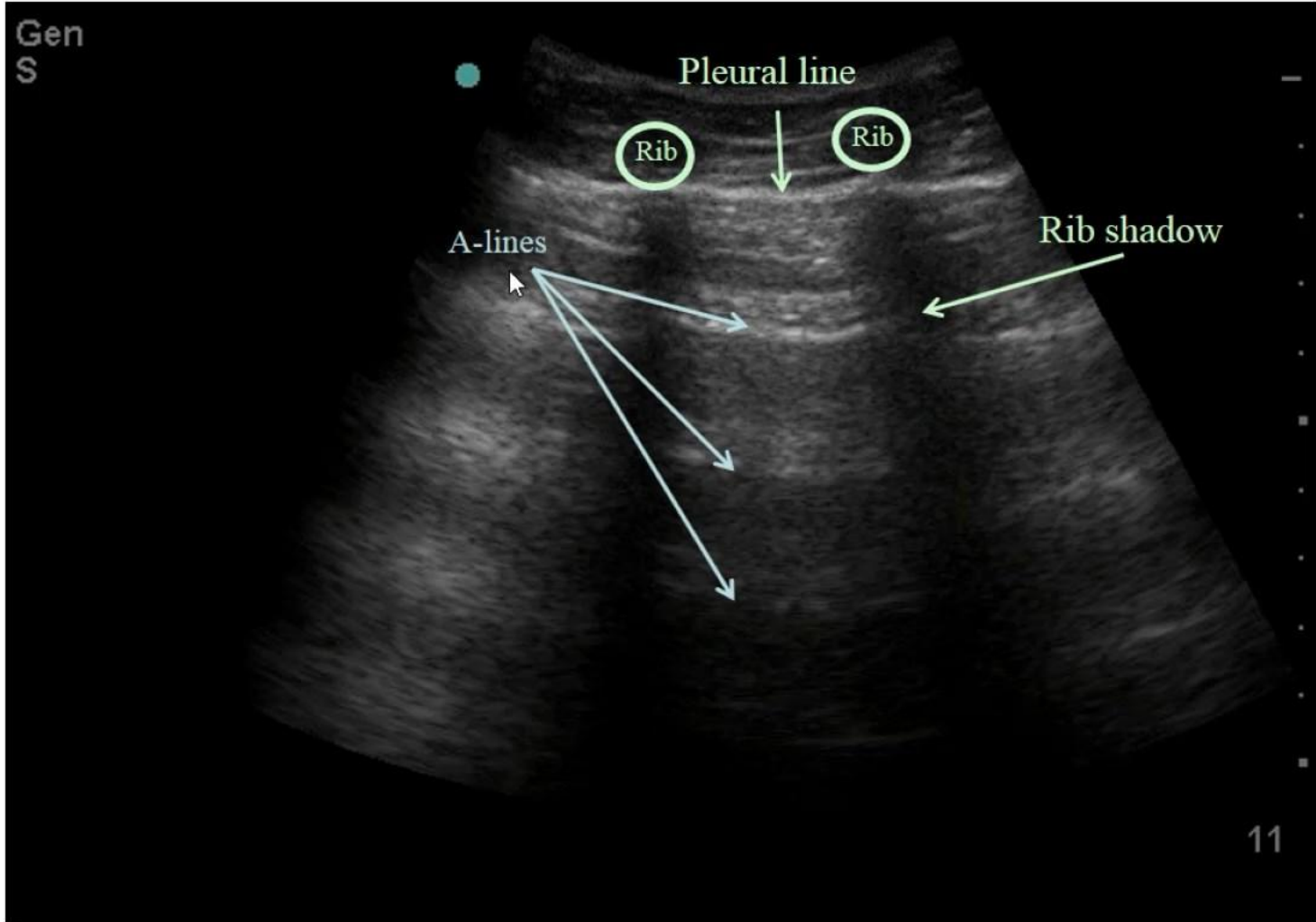


# Normal lung

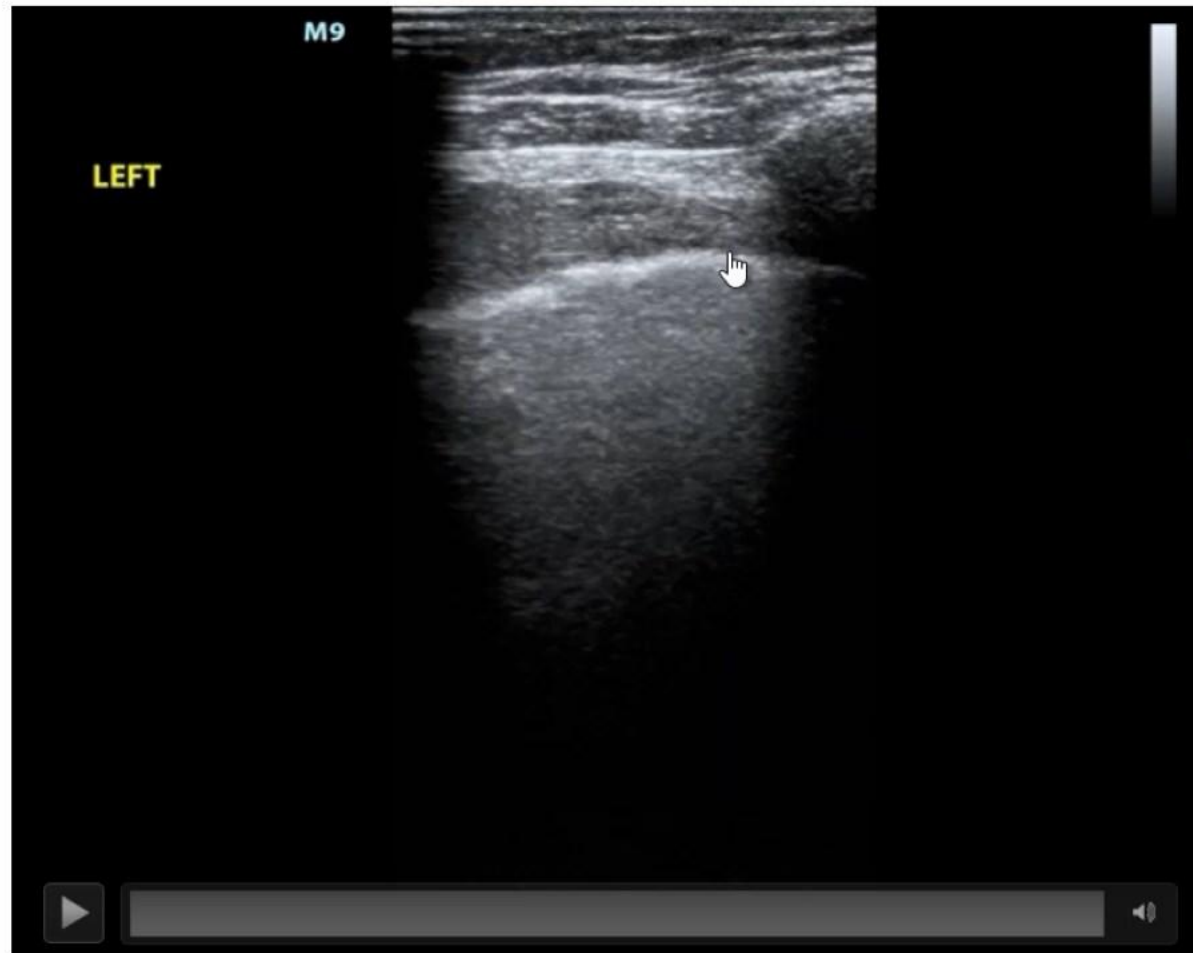




# Normal lung



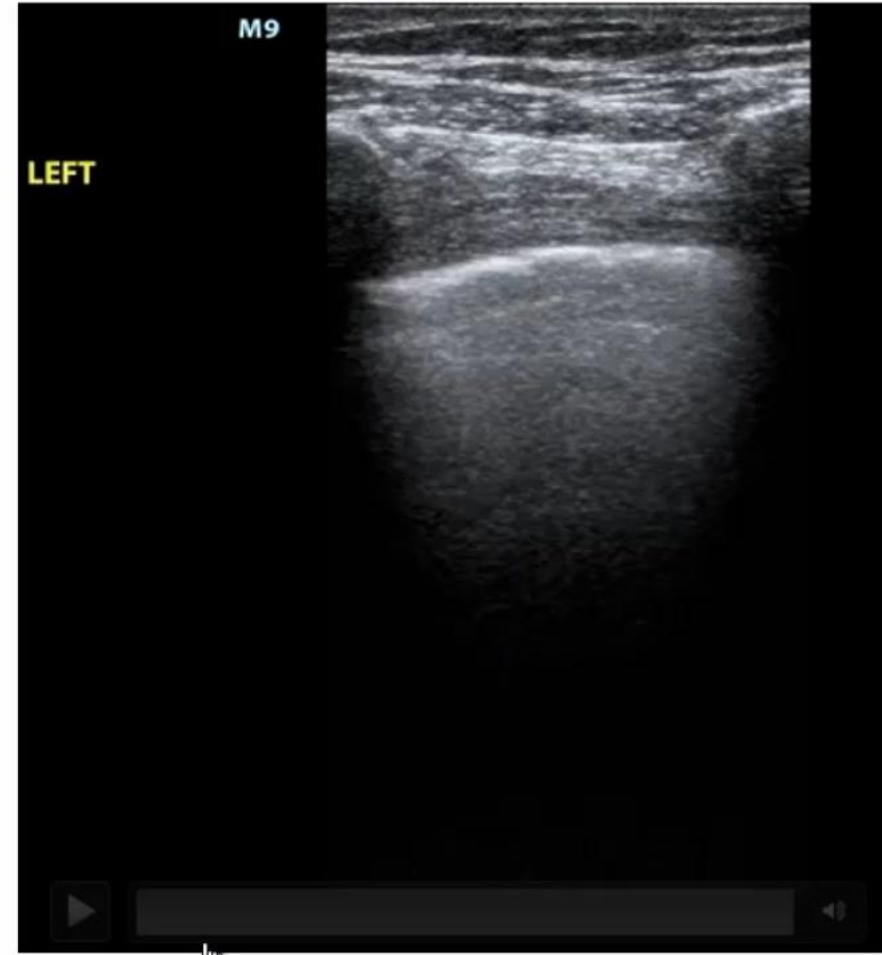
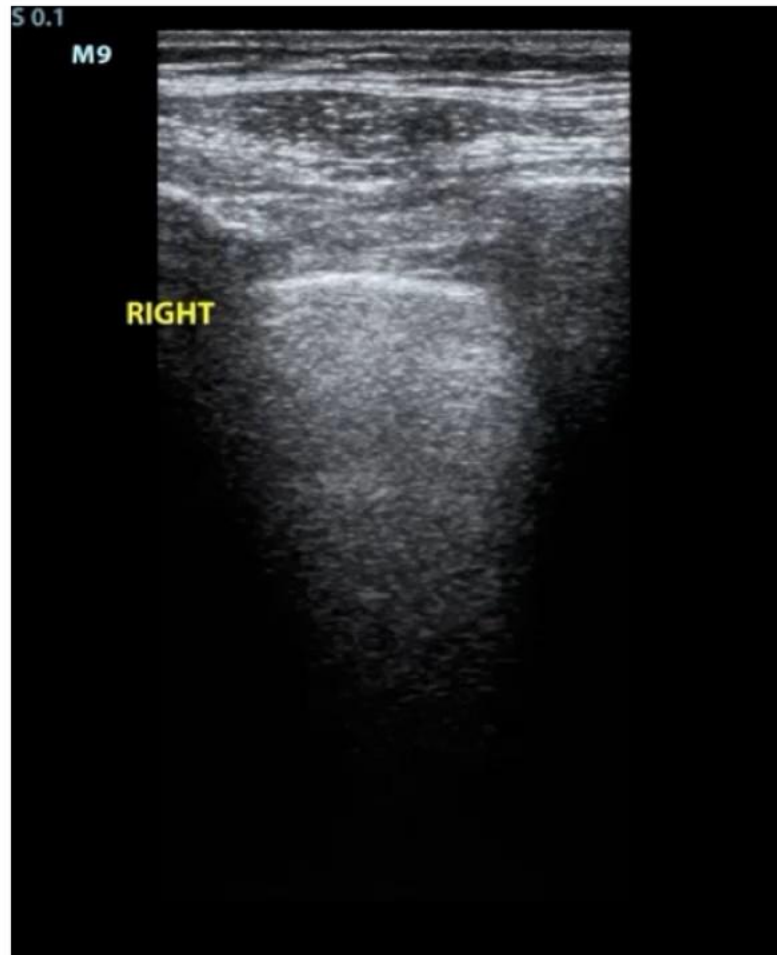
# Lung sliding



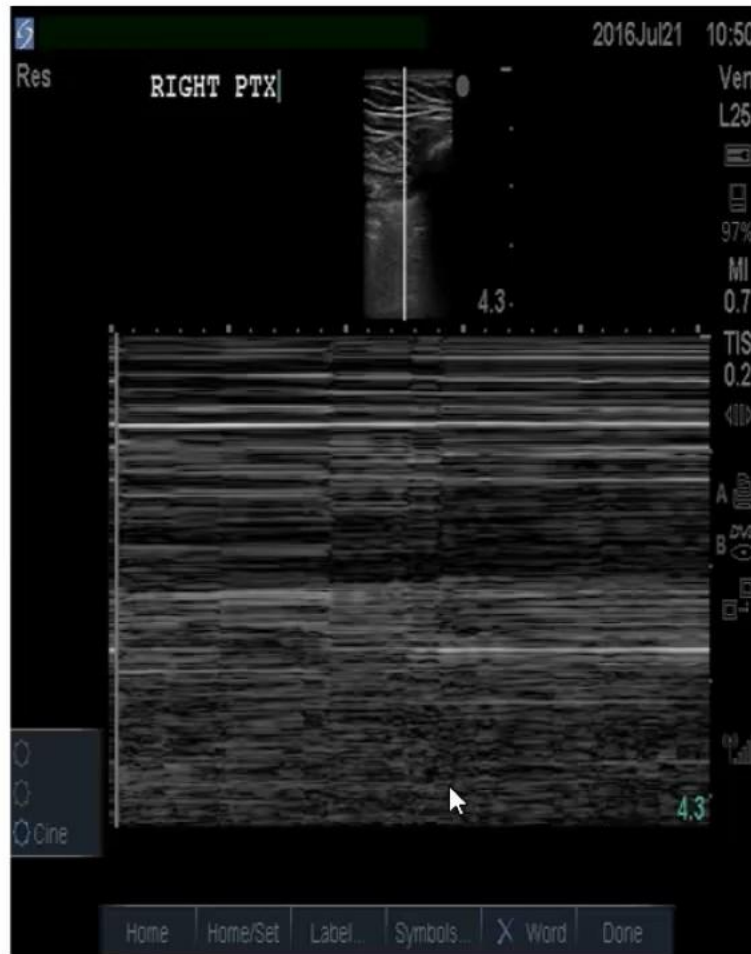
# Pneumothorax



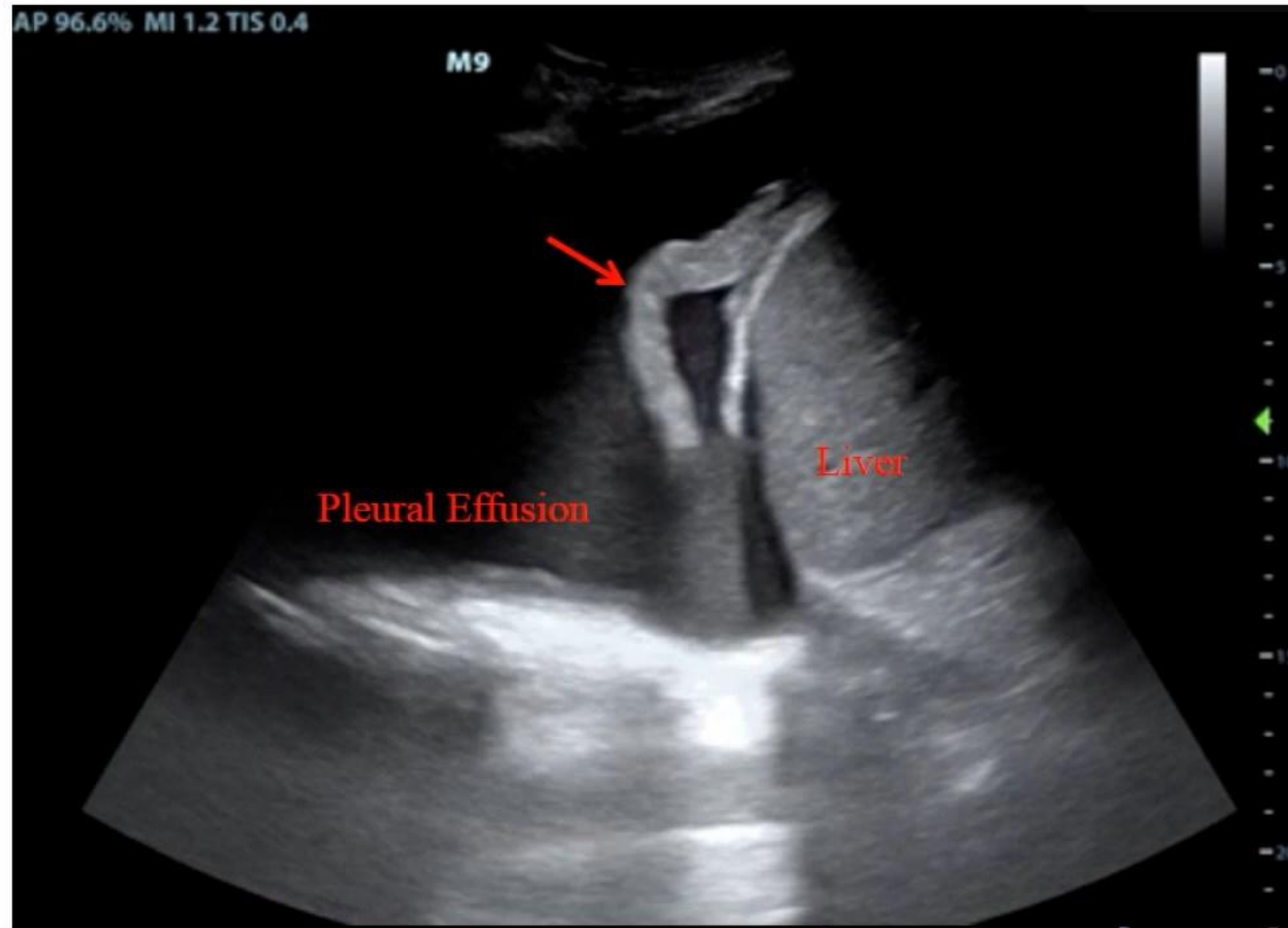
# Pneumothorax



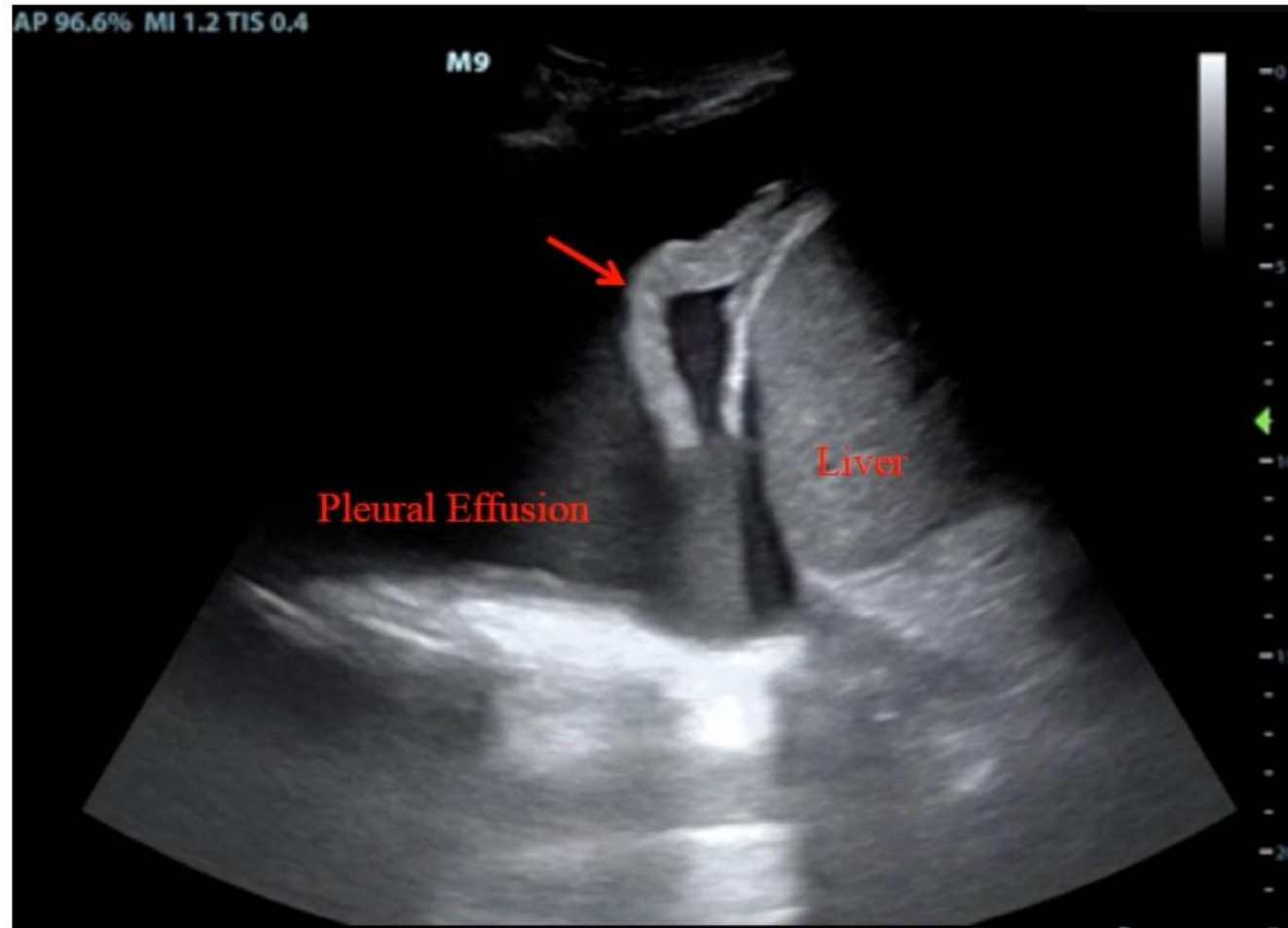
# Pneumothorax



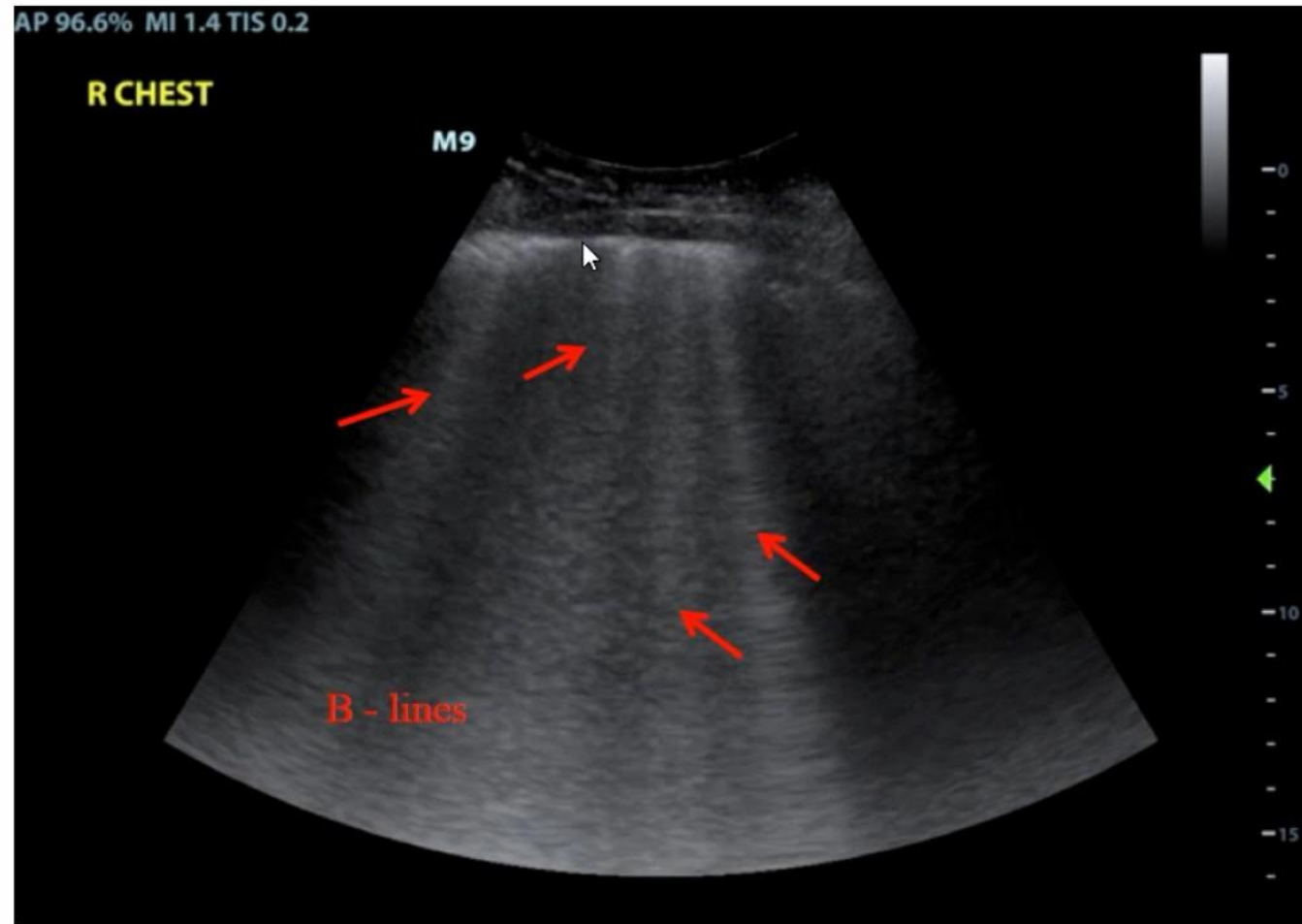
# Pleural Effusion



# Pleural Effusion



# Interstitial Edema

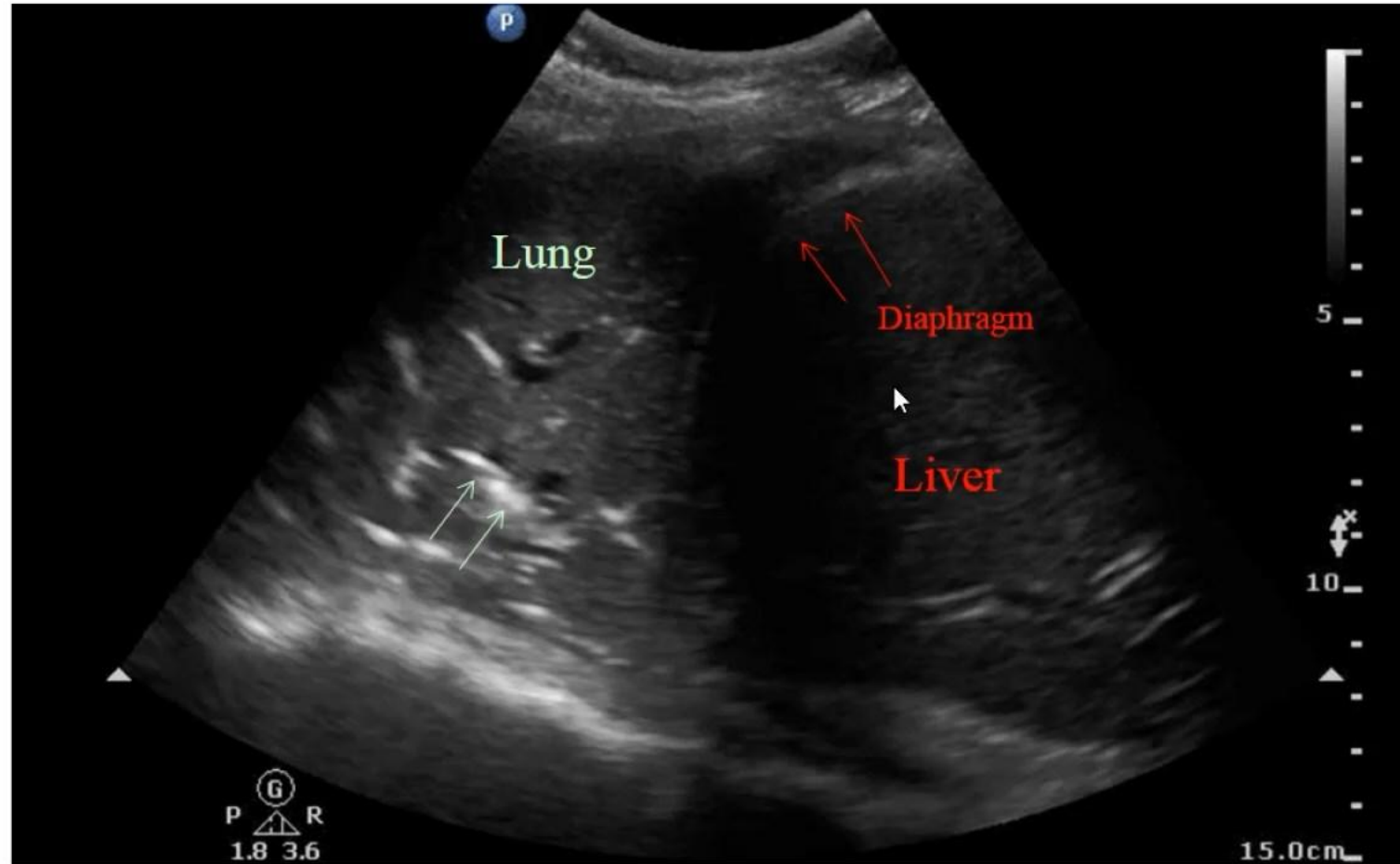




# Consolidation



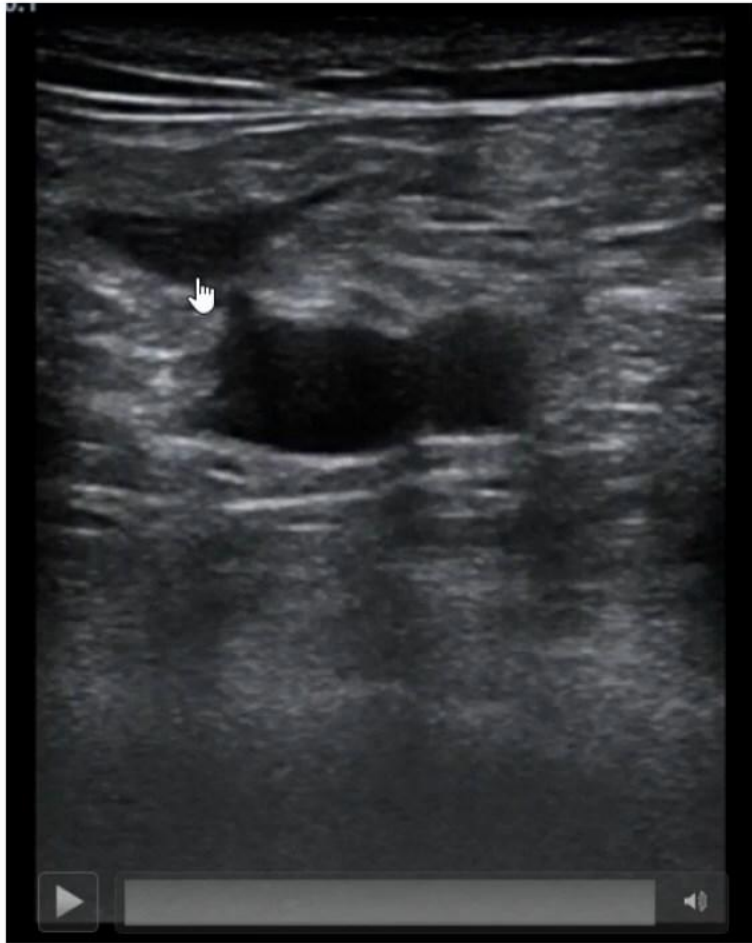
# Consolidation



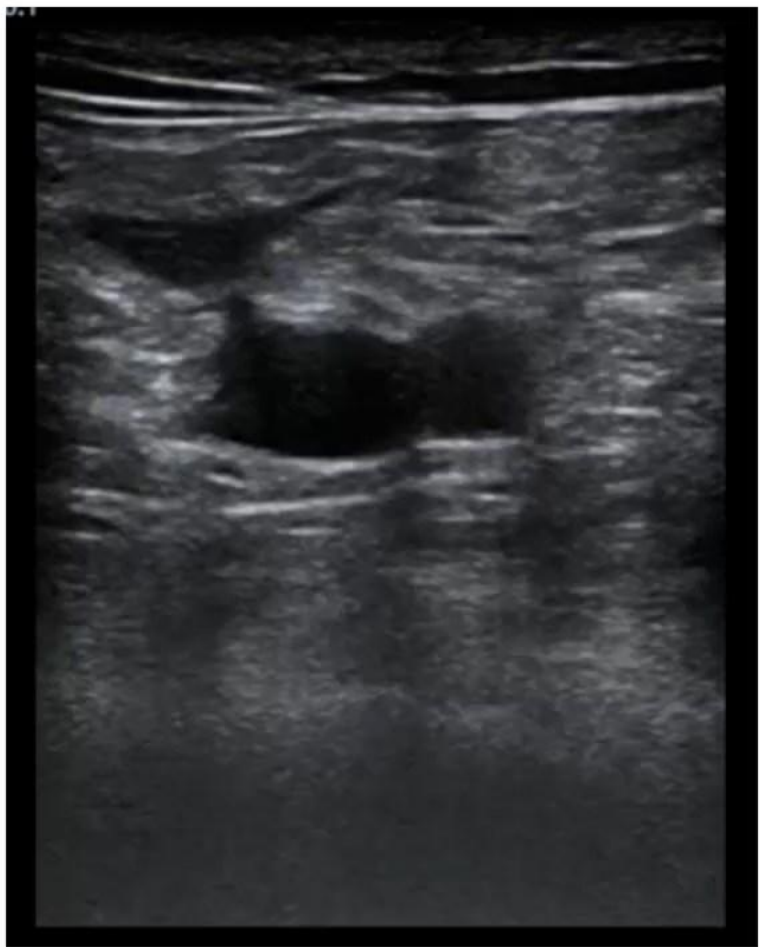
# Vascular Ultrasound

- Identify venous thrombosis
- Procedures

Normal



Normal

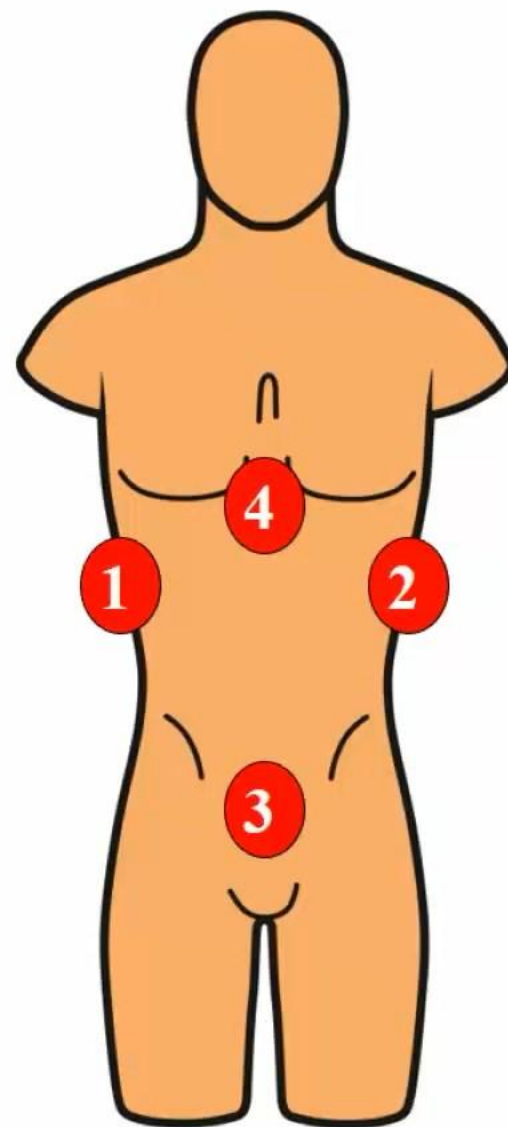


+ DVT

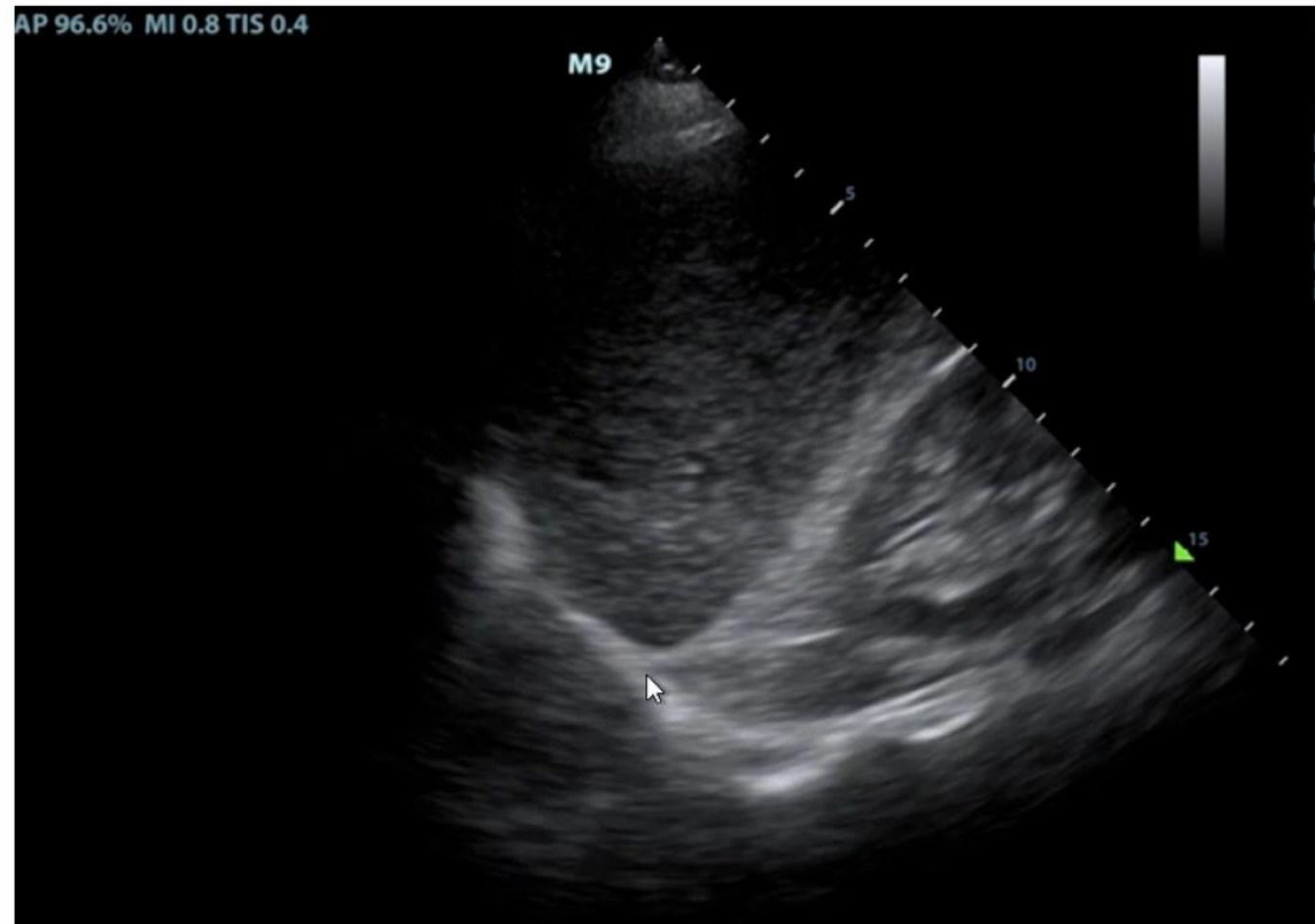


# FAST

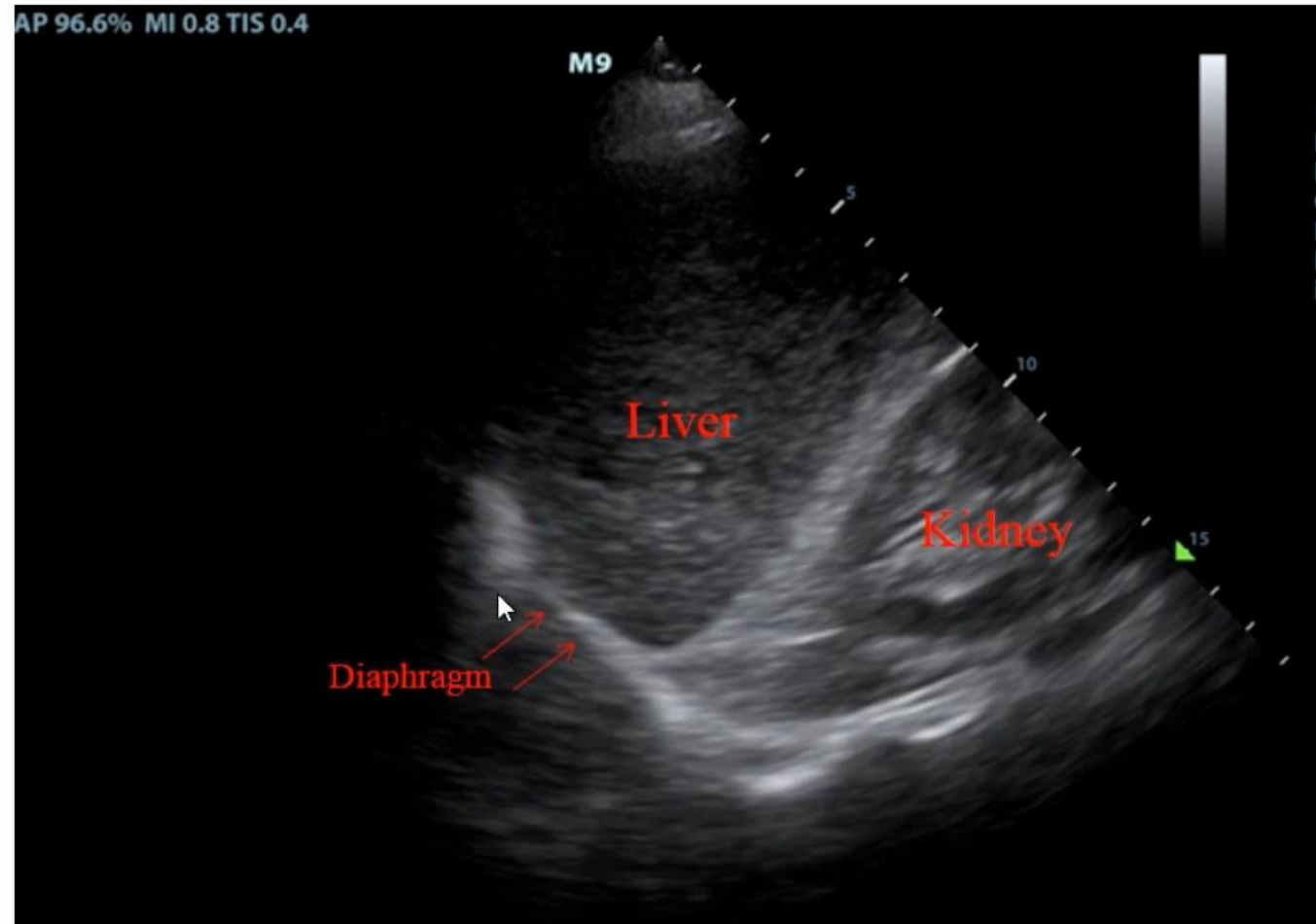
- *Focused Assessment with Sonography in Trauma (FAST)*
- 4 views
  - ① RUQ (Morrison's pouch)
  - ② LUQ (splenorenal recess)
  - ③ Suprapubic
  - ④ Subcostal long-axis
- Rapidly identify free intraperitoneal or pericardial fluid in trauma
- Sensitivity 70 – 95%, specificity 95 – 100%



# Normal RUQ



# Normal RUQ





# Free Fluid



**Ultrasound guidance versus anatomical landmarks for  
internal jugular vein catheterization (Review)**

Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF

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

## Ultrasound Guidance Facilitates Radial Artery Catheterization

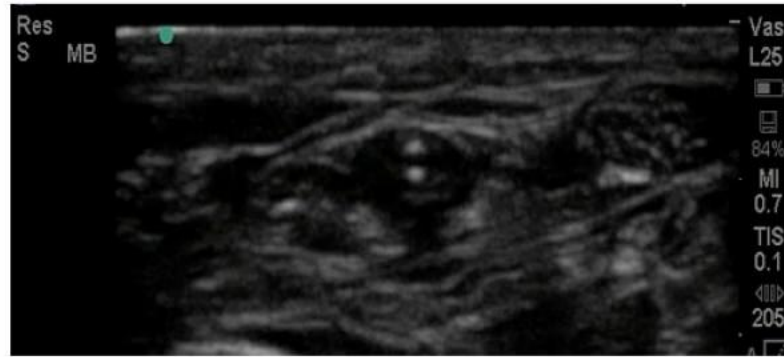
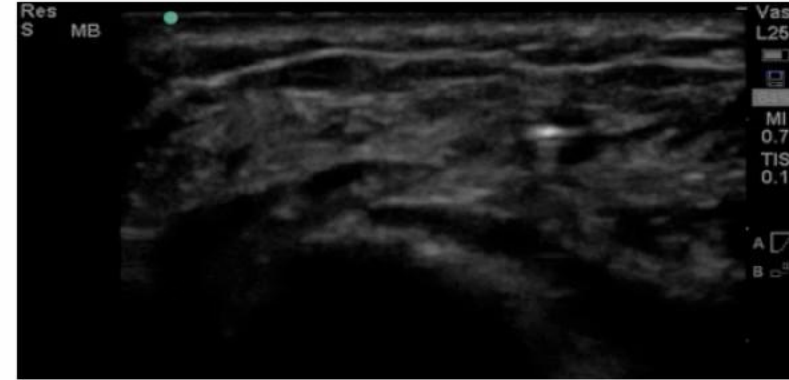
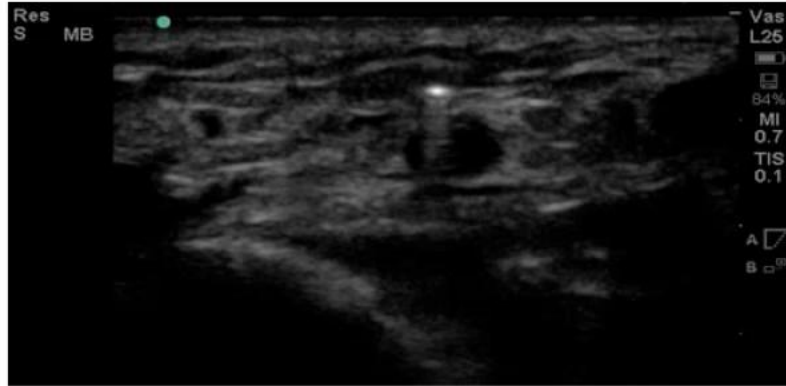
A Meta-analysis With Trial Sequential Analysis of Randomized Controlled Trials



*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*

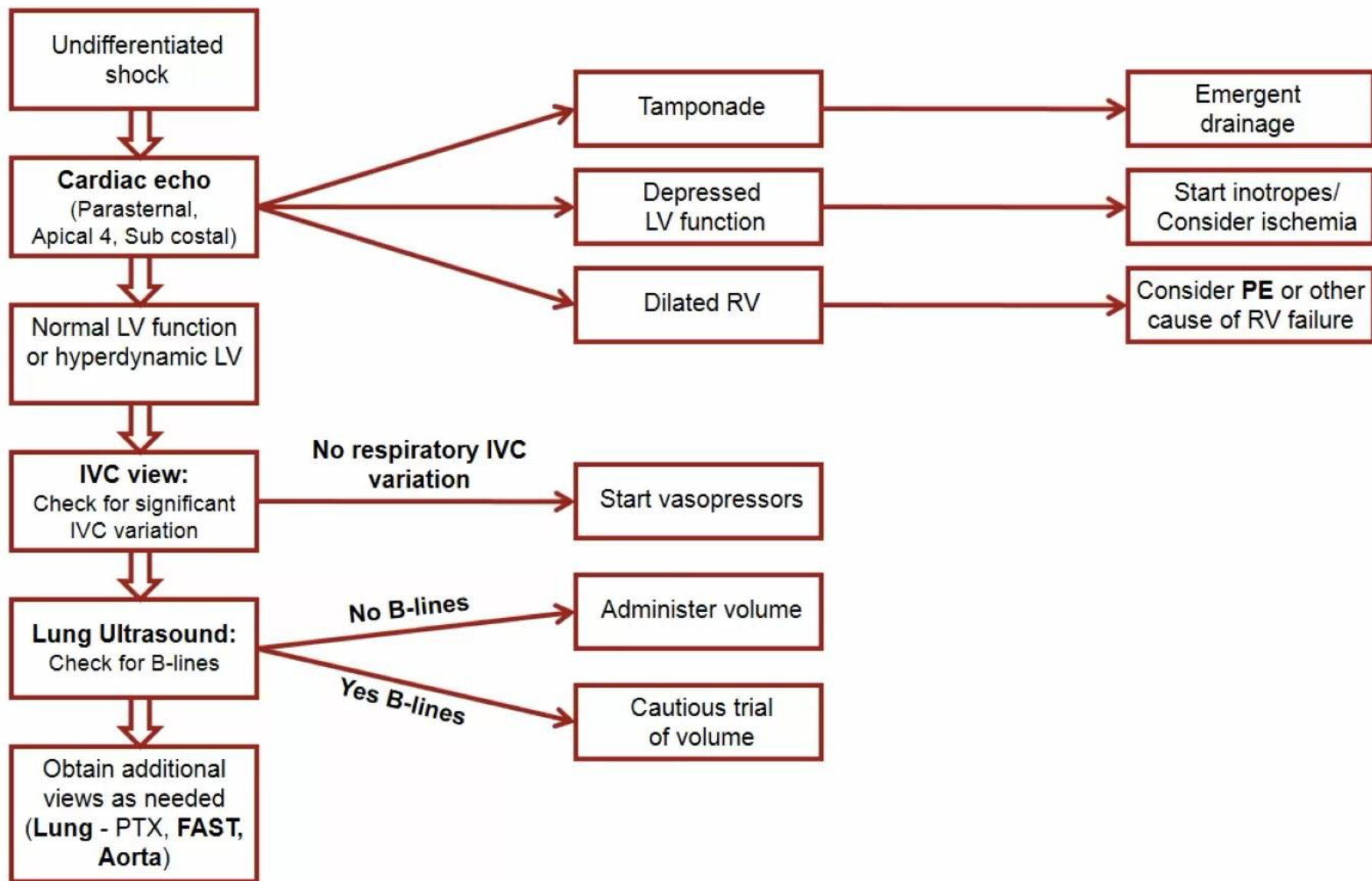
*Craig E. Gordon, MD, MS; David Feller-Kopman, MD; Ethan M. Balk, MD, MPH; Gerald W. Smetana, MD*

- 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



# 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



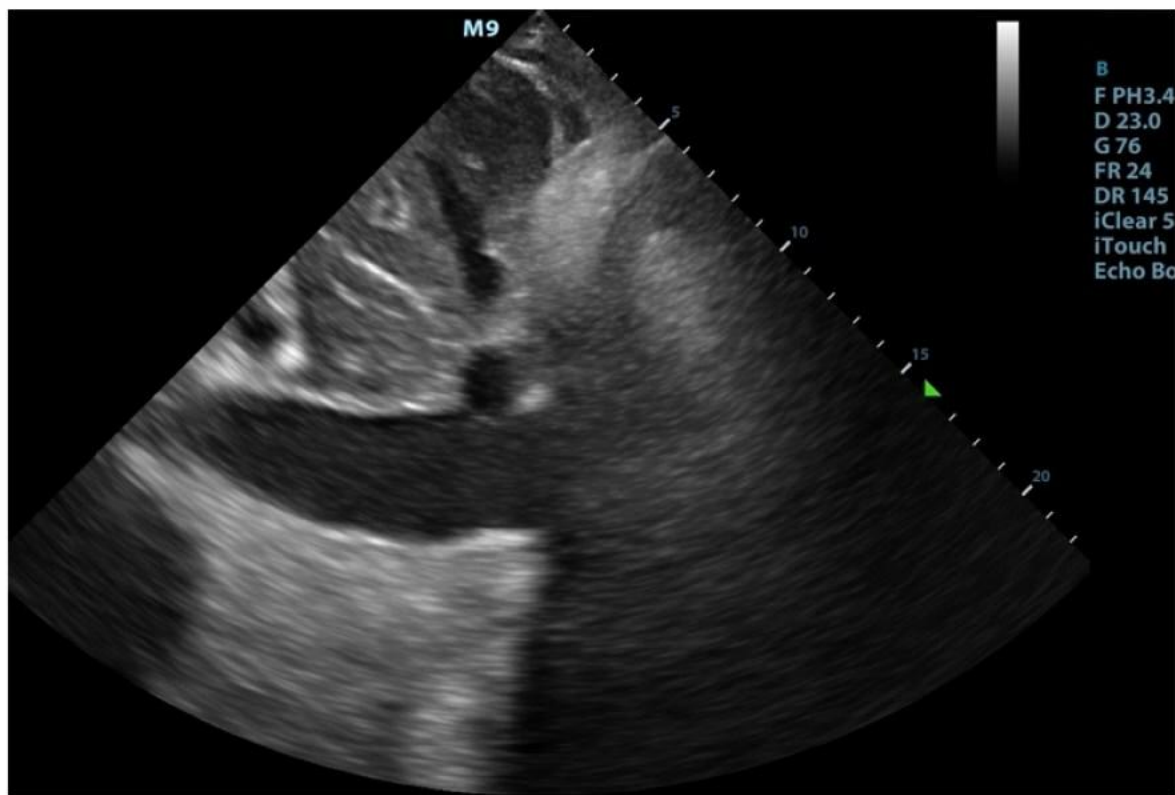
# Question # 1

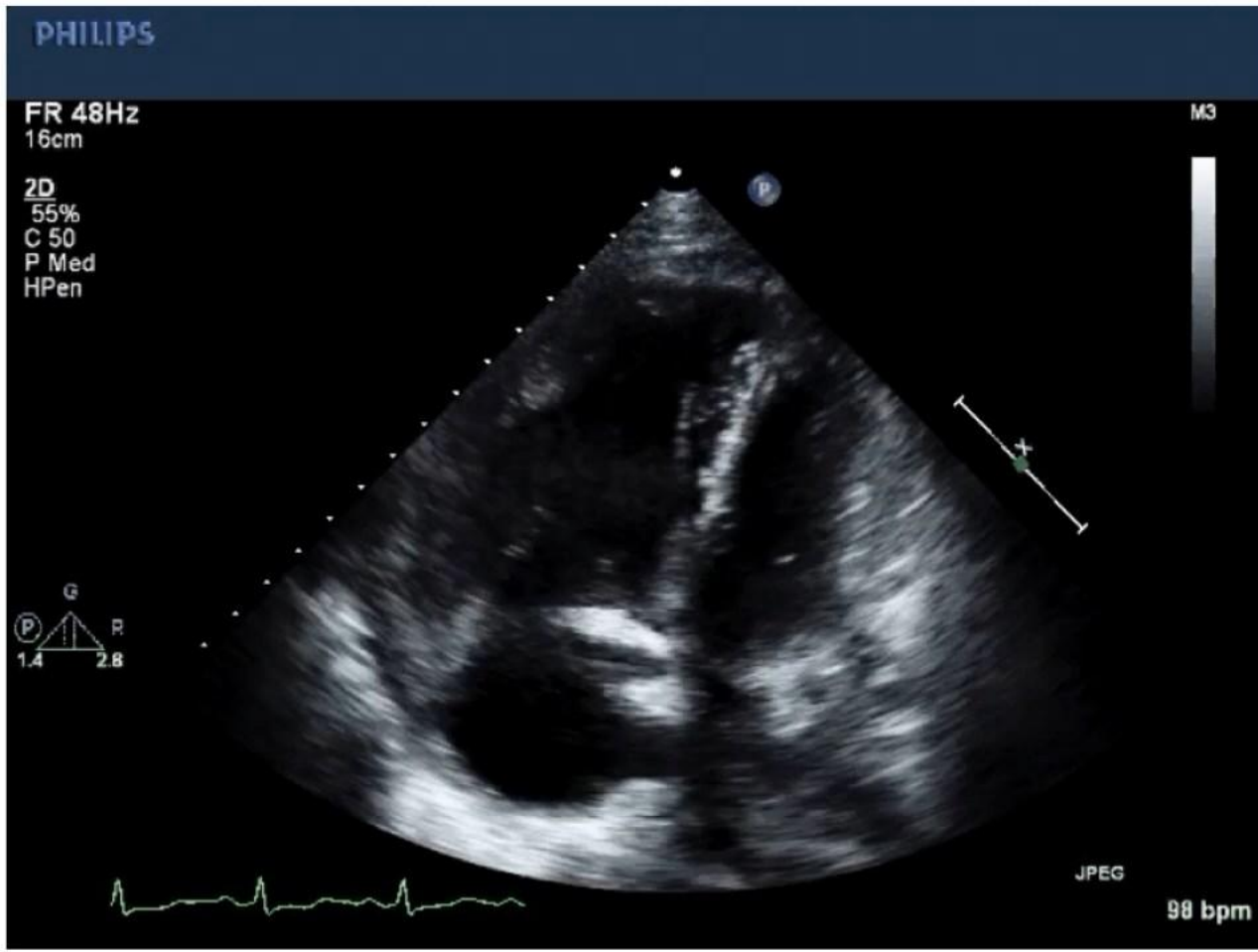
- 40 yo female history of lupus and recent flu like illness admitted to the ICU for fever, hypoxia, and hypotension. Portable CXR is read as right sided effusion. The ED physician administered 4L NS, broad spectrum antibiotics, placed a right subclavian central line, and started the patient on a moderate 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







BRIGHAM AND  
WOMEN'S HOSPITAL  
A Teaching Affiliate of Harvard Medical School



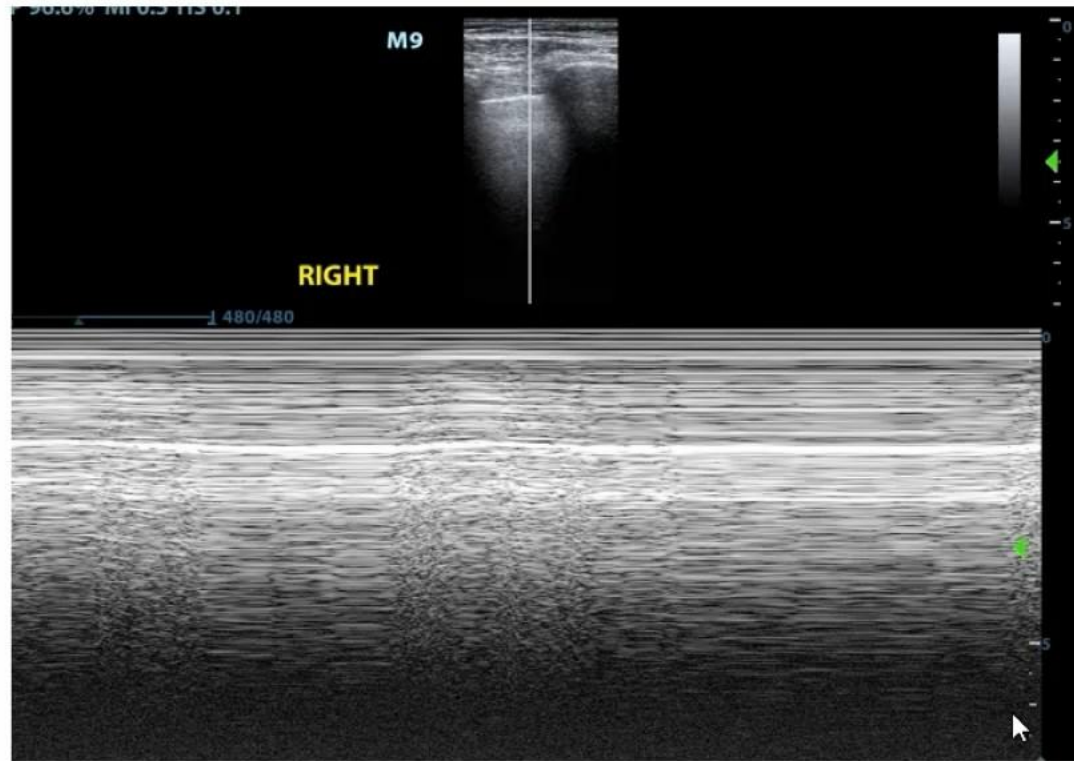
HARVARD  
MEDICAL SCHOOL

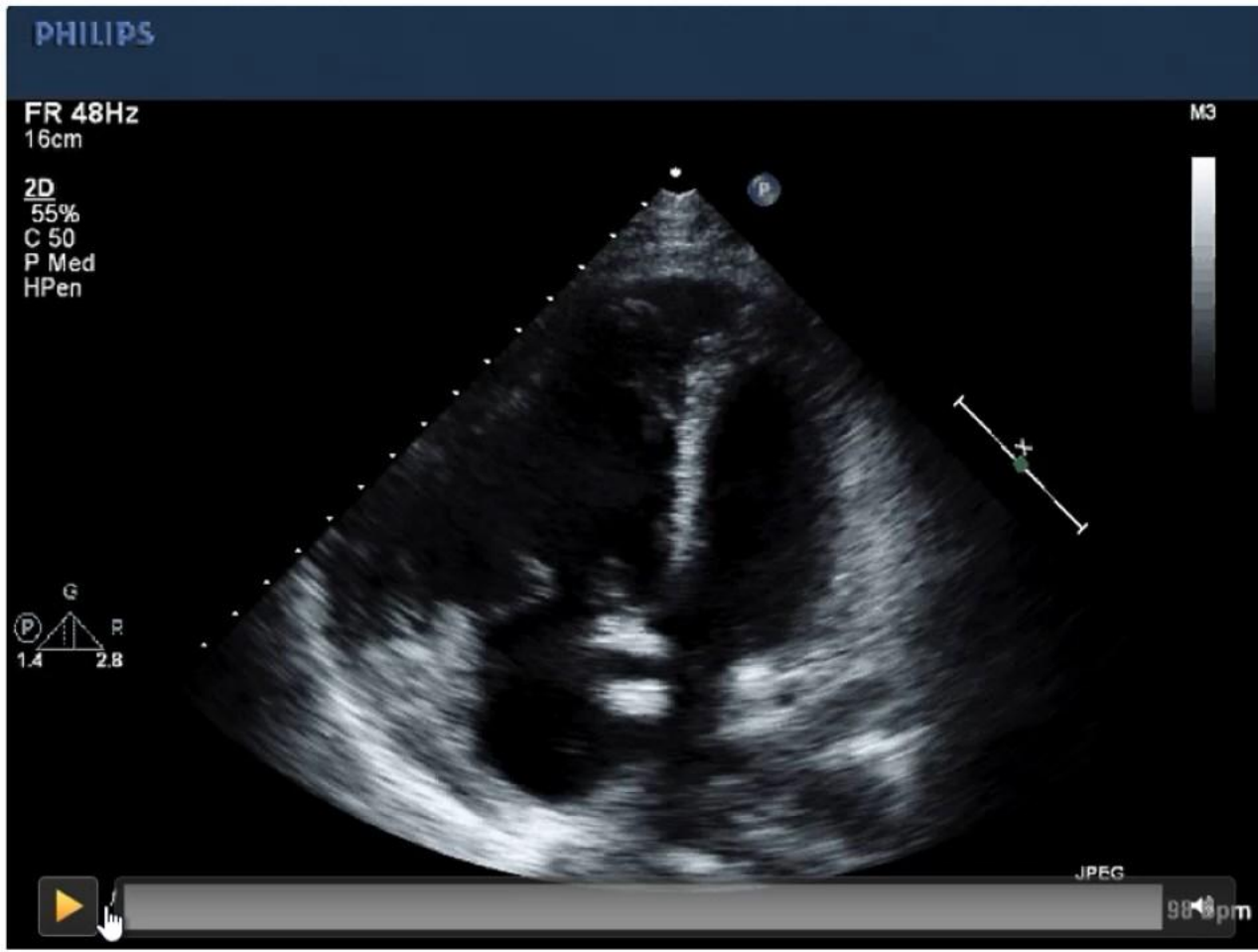
# Answer, Question # 1

- 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.







## 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