MAYO CLINIC

Introduction to Point-of-Care Ultrasound

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Disclosures

- No relevant commercial relationships to disclose

LEARNING OBJECTIVE

- Explain the basics of ultrasound physics.
- Summarize scope and indications for Point-of-Care Ultrasound (POCUS) of the heart, lungs, peripheral vasculature, and soft tissues.
- Interpret POCUS images of the heart, lungs, peripheral vasculature, and soft tissues.
- Contrast evidence for standard of care with POCUS.
- Discuss the effect POCUS has on diagnostic evaluation, prognostication, and treatment of common diseases.

POCUS Basics

DEFINITION

- A goal directed; bedside ultrasound exam performed by a clinician used to answer a specific diagnostic question.

USES

ORGAN SYSTEMS	CLINICAL CONDITIONS	PROCEDURES
Heart	Trauma	Vascular access
Lungs	Hypotension / Shock	Paracentesis
Kidneys	Respiratory failure	Thoracentesis
Aorta	Sepsis	Lumbar Puncture
Skin and Soft Tissue	Cardiac arrest	Nerve blocks
MSK	Pregnancy	
Gallbladder		

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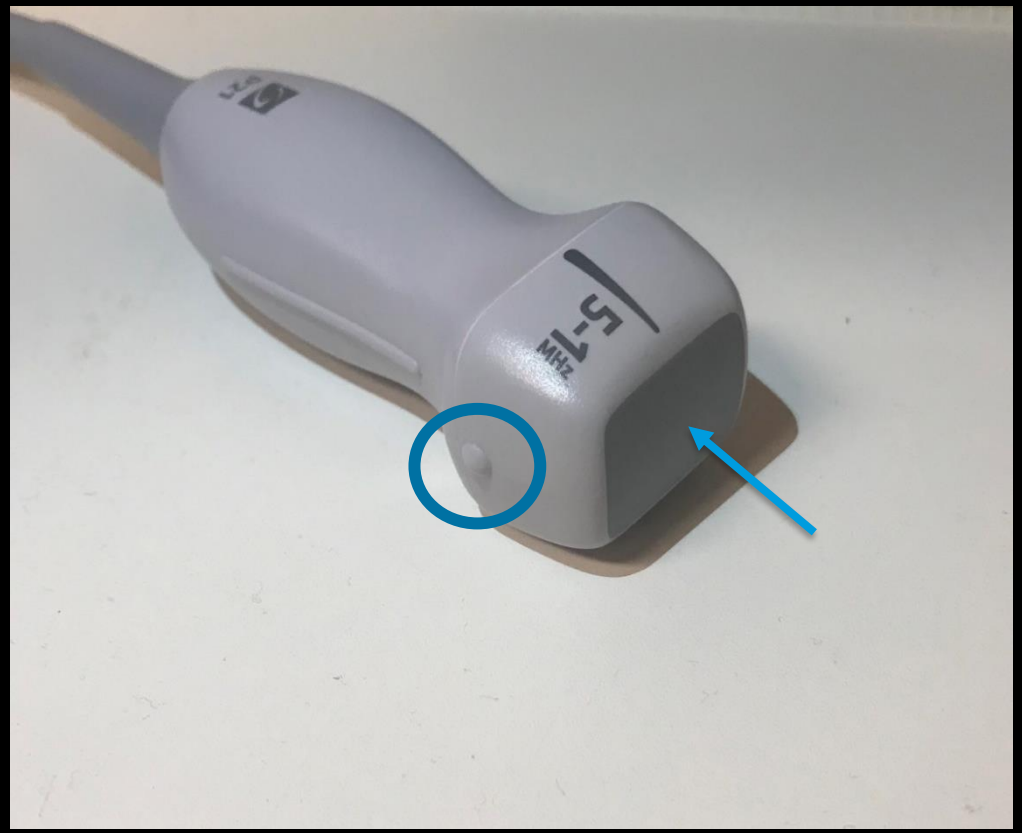
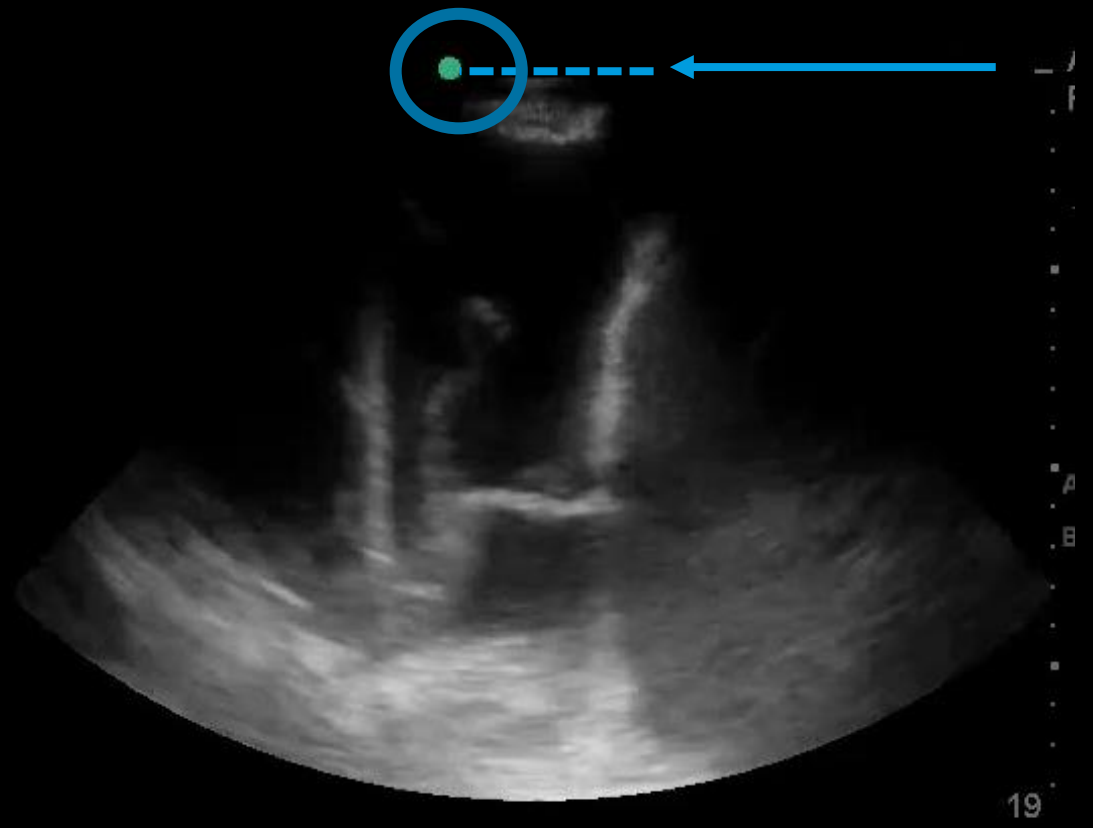
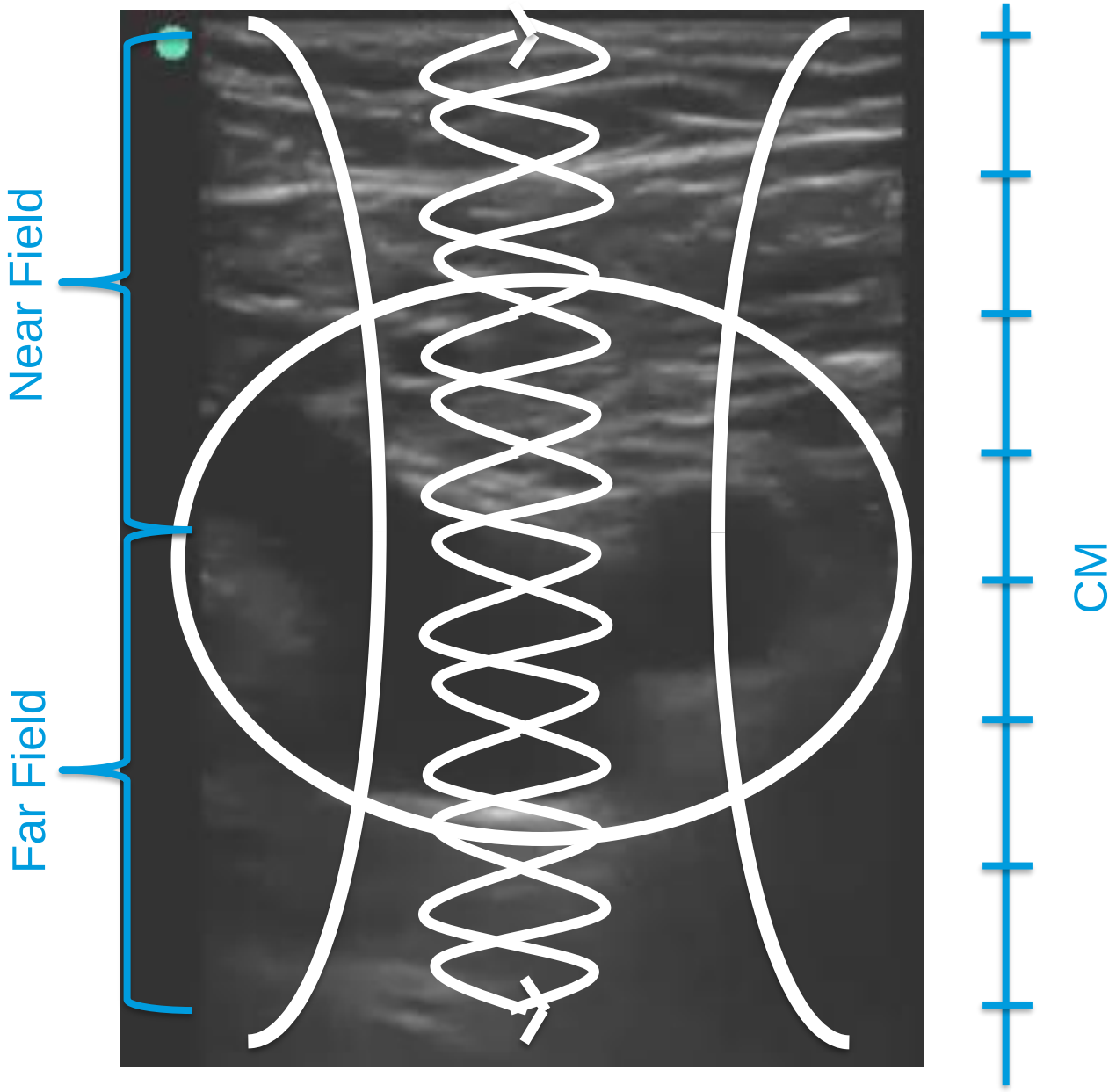
ORIENTATION





POCUS PHYSICS

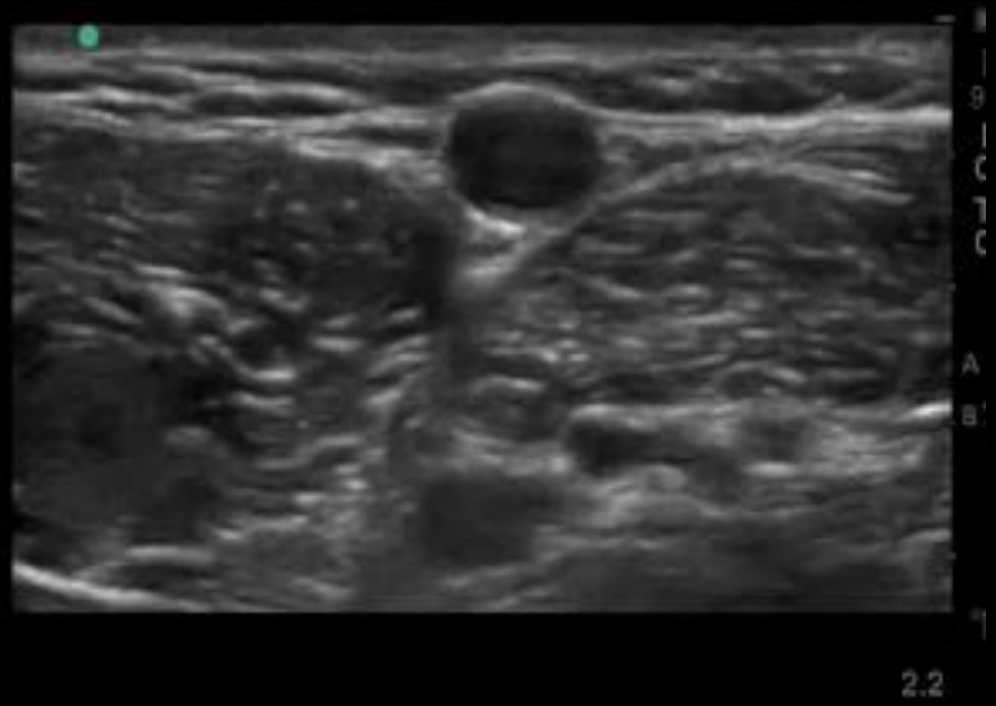
- Depth
- Focal Zone
- Gray Scale
  - Black (anechoic) = Fluid
  - White (hyperechoic) = Strong reflectors (pleura, bone, fascia, etc).
  - Gray (isoechoic) = organs, tissues.

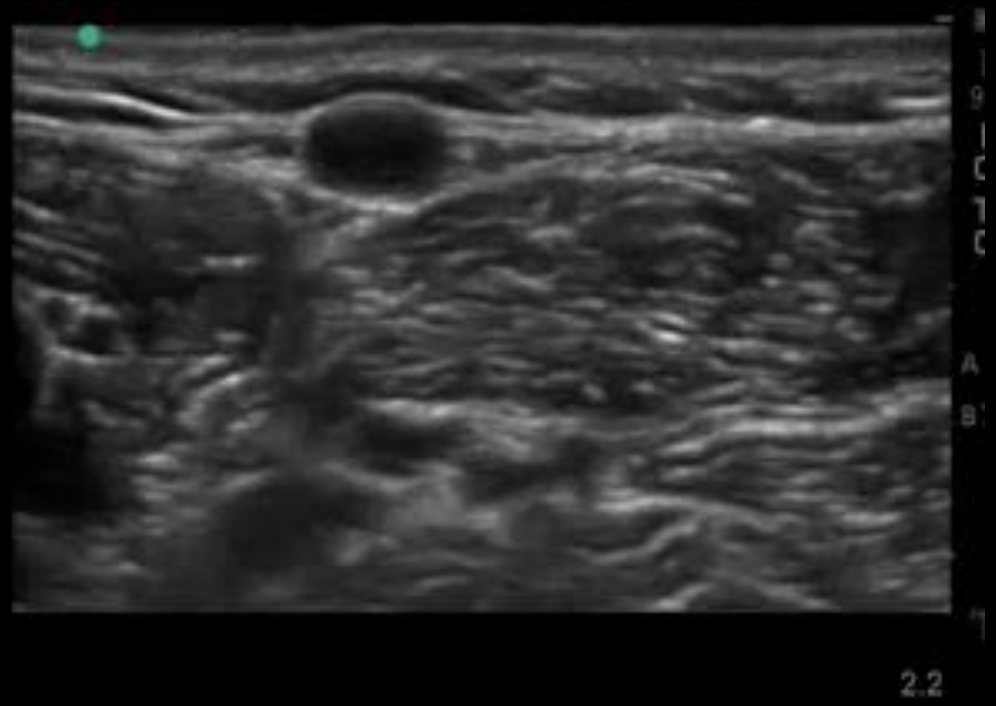


GAIN

- Amplitude of the ultrasound waves.

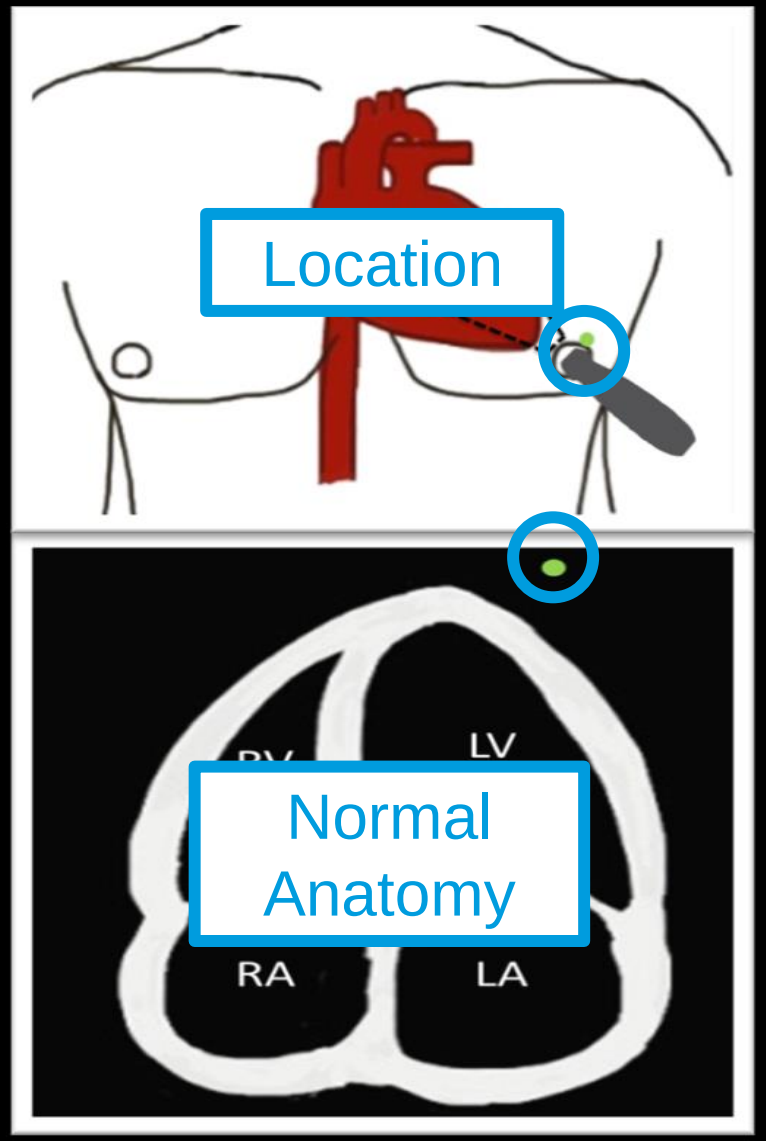
Down Gain

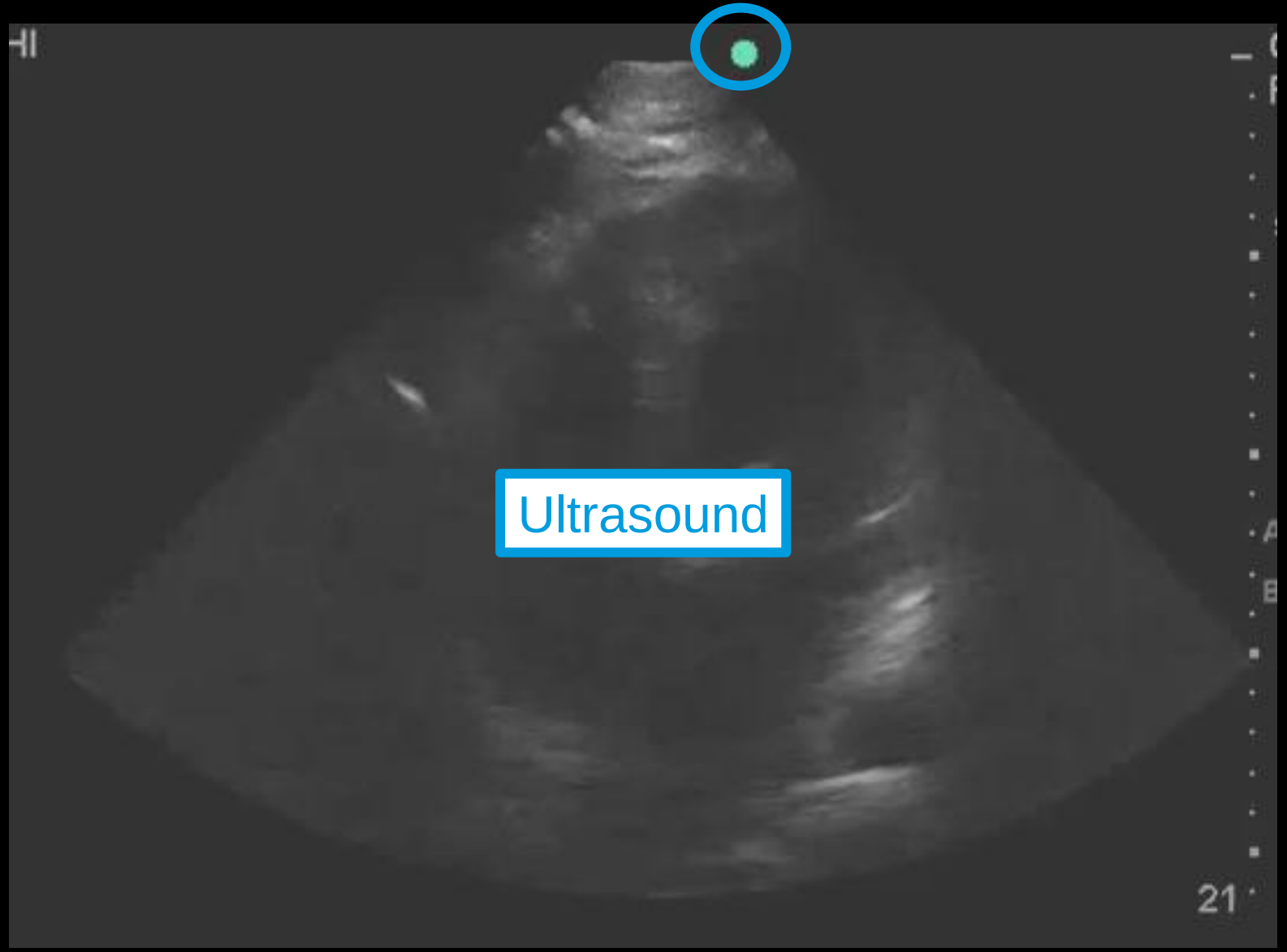




Up Gain

SLIDE CONVENTION





Case 1

HPI

- A 78 year-old gentleman presents to the emergency department for evaluation shortness of breath, progressing over 3 – 4 days.
- He endorses cough, but denies sputum production. Denies fever or rigors. Denies hemoptysis.

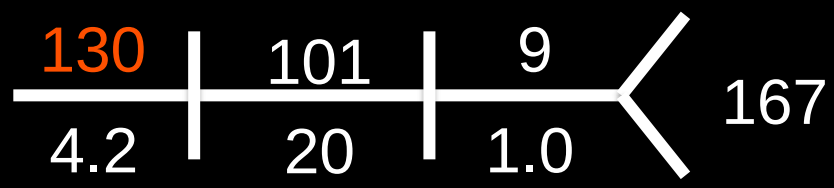
HISTORY

- Past Medical / Surgical History:
  - COPD
  - Hypertension
  - Obesity
- Social History:
  - 60 pack year history of smoking
- Family History:
  - Father – Lung cancer

OBJECTIVE

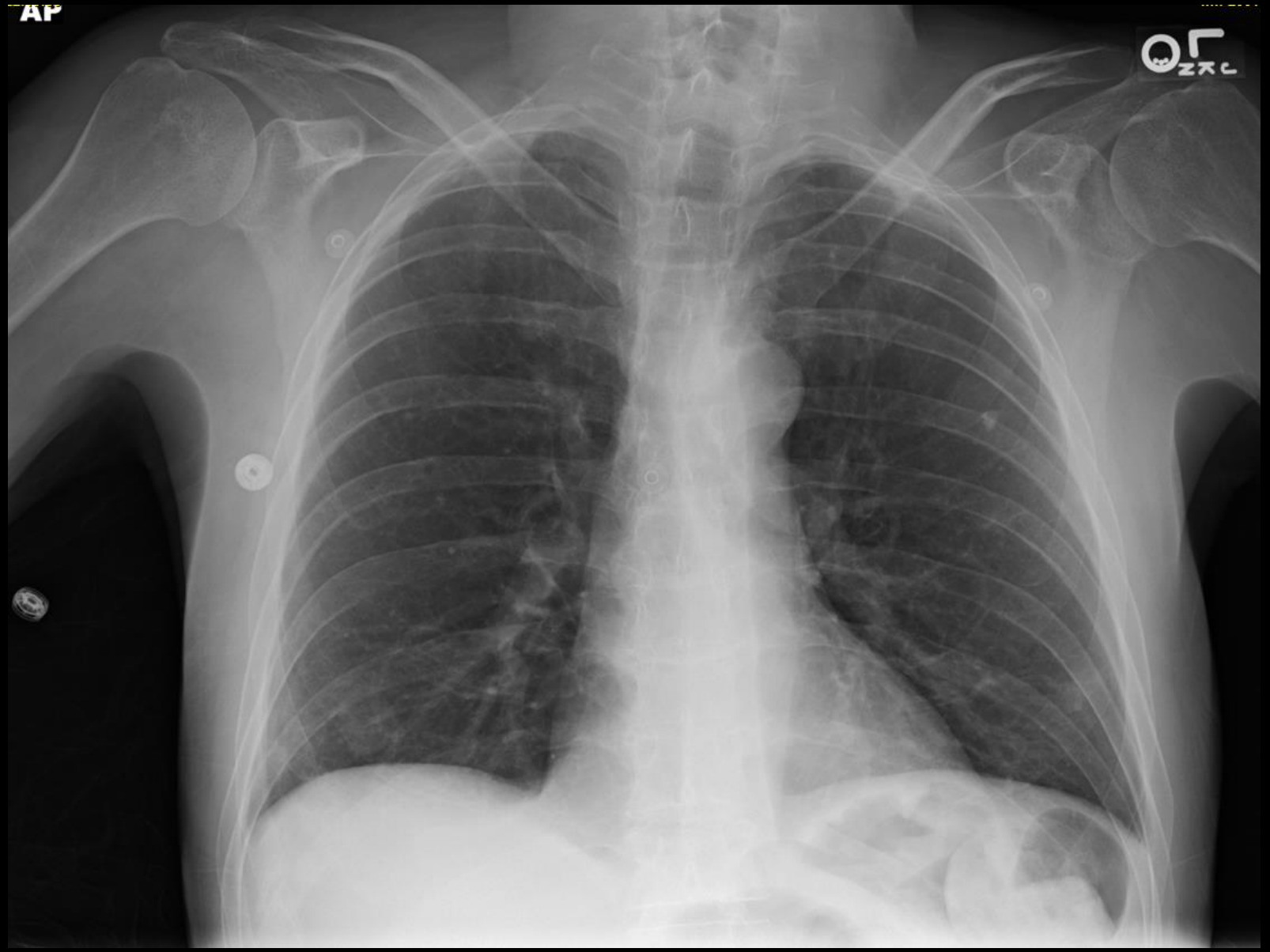
- Vital Signs:
  - HR 92, BP 156/52, SpO2 84% on room air, RR 28, Tmax 37.0 Celsius.
- Physical Exam:
  - Mild distress. Diffuse wheezing throughout all lung fields.
  - Body habitus impairs JVD assessment. 2+ pitting edema of the legs, which he states is “chronic”.

LABS



Lactate 1.7

CHEST X-RAY



REFLECTION QUESTIONS

- What is this patient's differential diagnosis? What is his leading differential?
- What evaluation or treatment would you recommend?

ED COURSE

- Presumptive Diagnosis: Acute COPD Exacerbation.
- Treatment:
  - Ipratropium/albuterol nebulizers
  - Prednisone
  - Levofloxacin
- Admitted to the hospital.

FoCUS

- Scope:
  - LV size / systolic function
  - RV size / systolic function
  - IVC size and respiratory variation
  - Pericardial effusions / Cardiac Tamponade

Hyperdynamic
Normal
Reduced Qualitatively / Severely Reduced
(not Quantitative)

- Indications:
  - Hypotension
  - Respiratory Failure
  - Intravascular volume assessment

IVC ≈ RAP / CVP

IVC Findings	CVP
IVC < 2.1 cm, with > 50% collapse	3 (range 0 – 5)
IVC < 2.1 cm, with < 50% collapse IVC > 2.1 cm, with > 50% collapse	8 (range 5 – 10)
IVC > 2.1 cm, with < 50% collapse	15 (range 10 – 20)

Focused Cardiac Ultrasound (FoCUS)

- Cardinal Views
  - Parasternal Long Axis (PLAX)
  - Parasternal Short Axis (PSAX)
  - Apical 4 Chamber (A4C)
  - Subcostal 4 Chamber (S4C)
  - Inferior Vena Cava (IVC)

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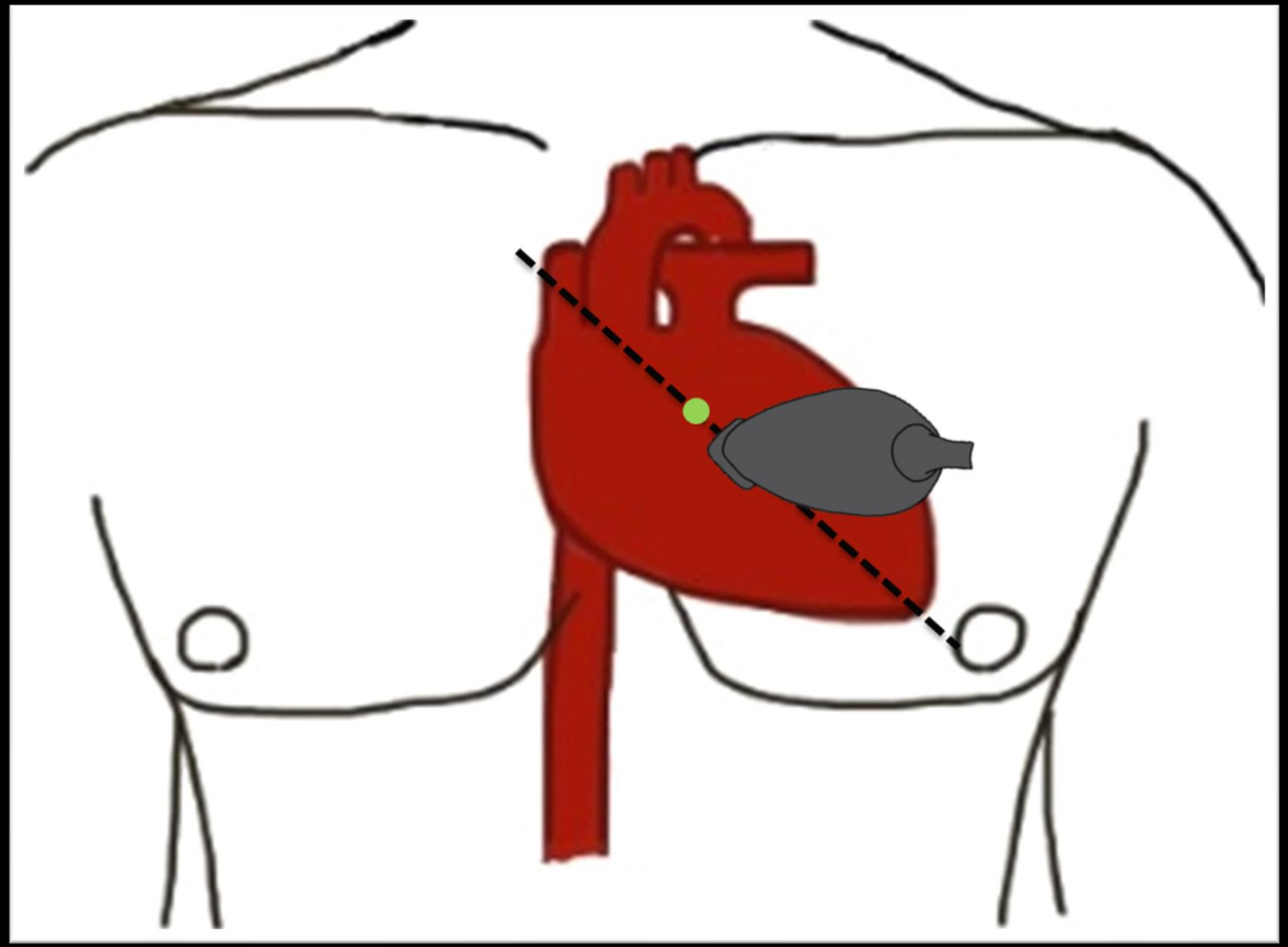
Parasternal Long Axis (PLAX)



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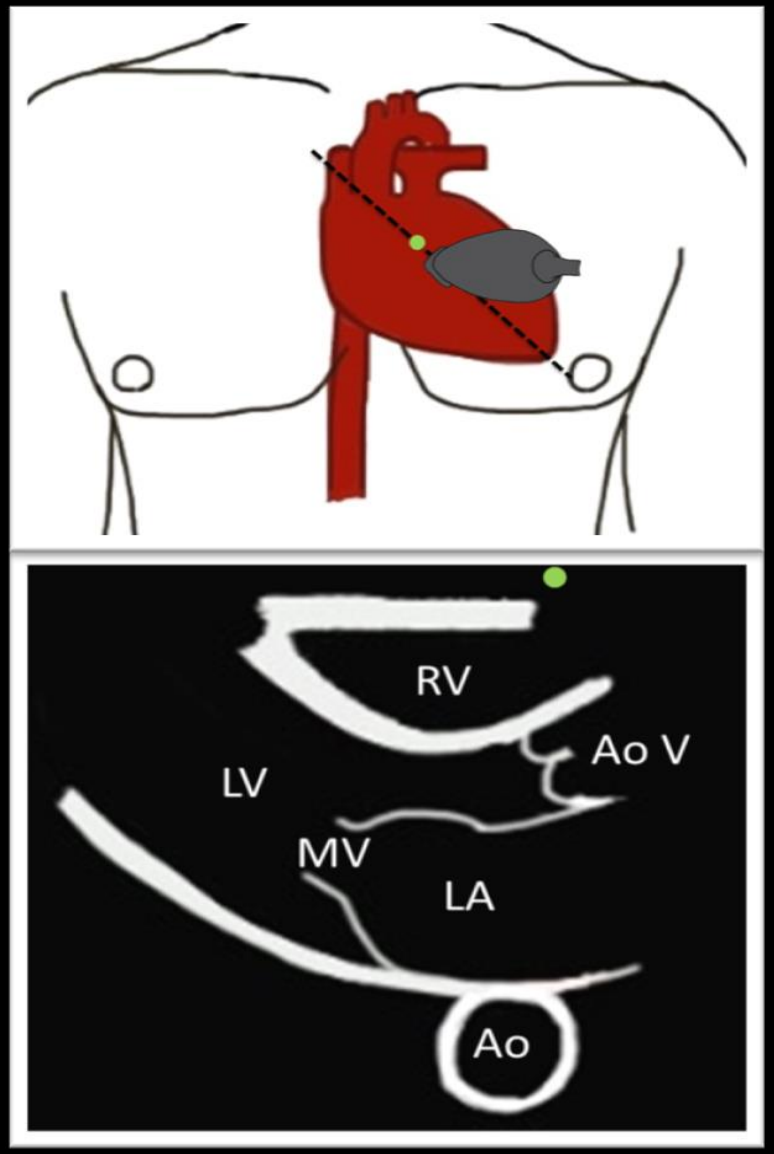
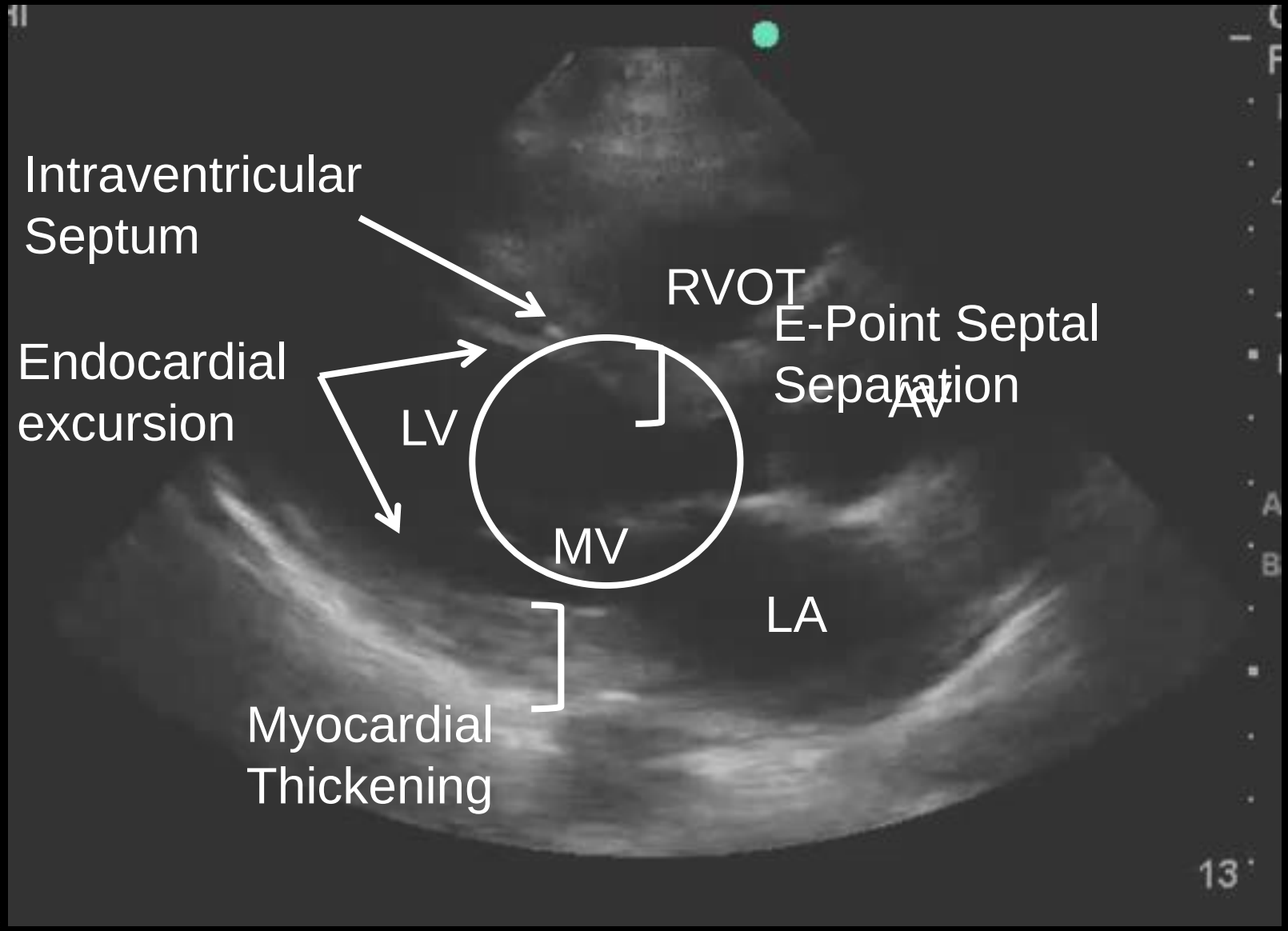
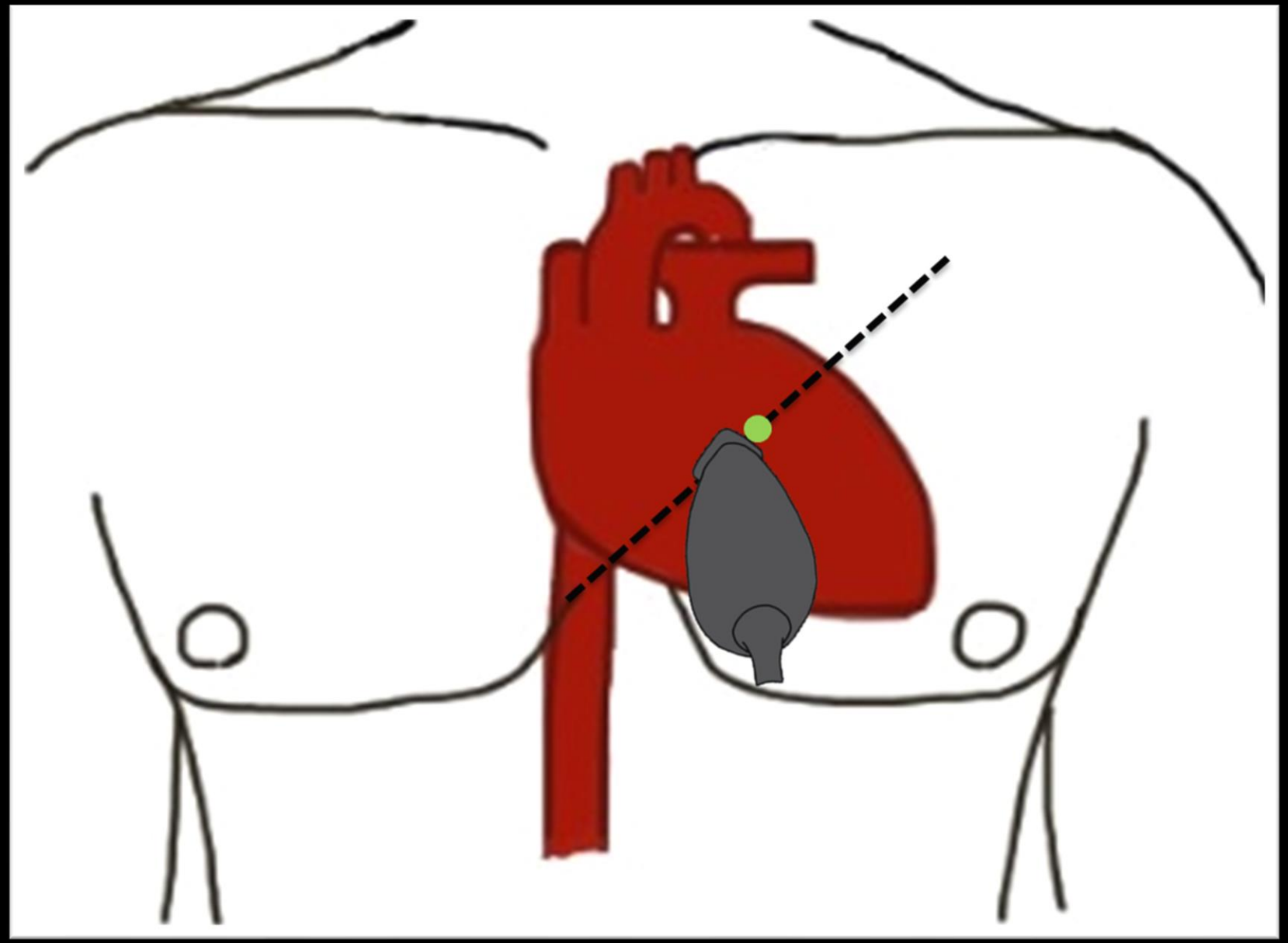




Parasternal Short Axis (PSAX)



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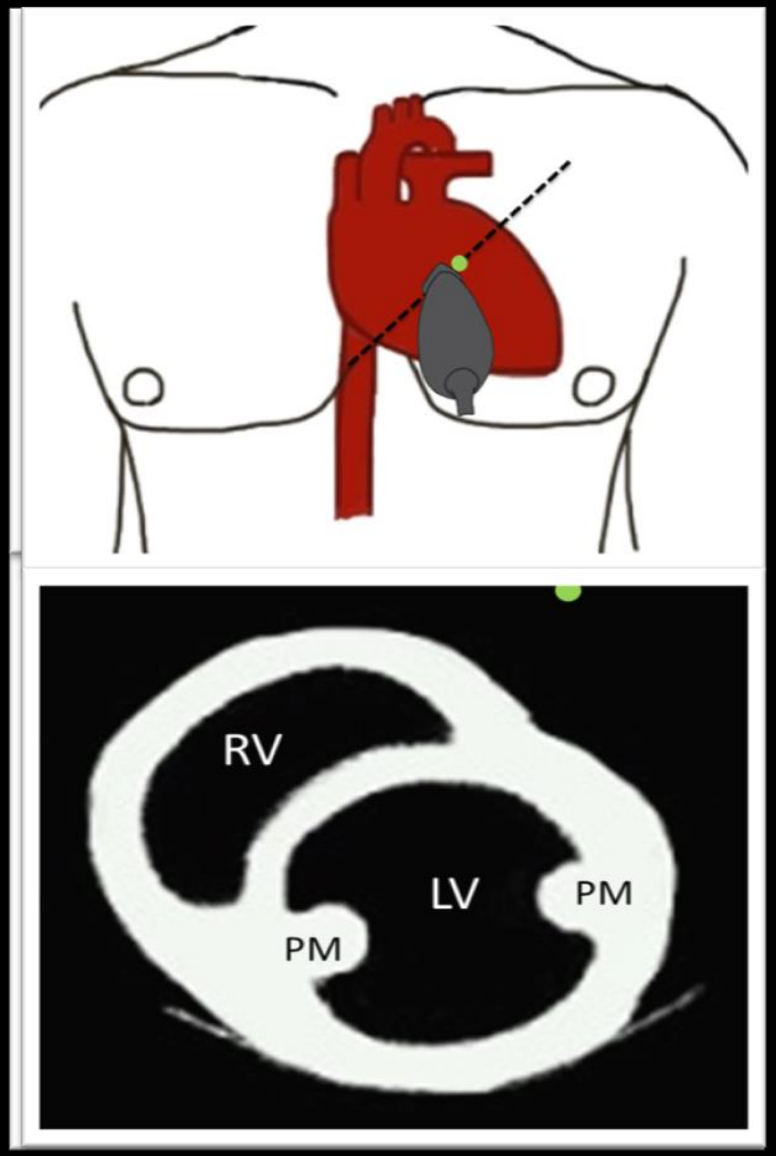
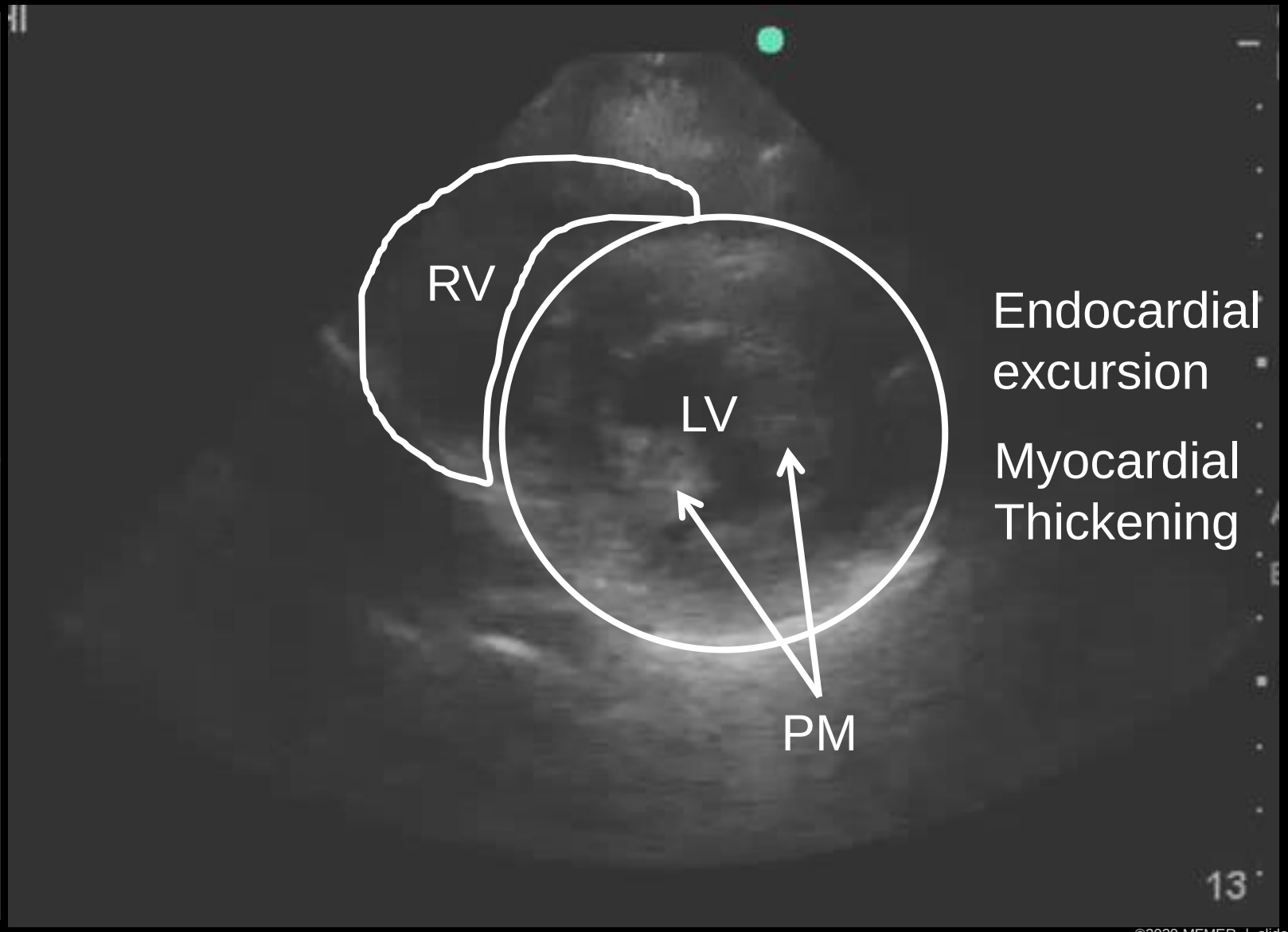
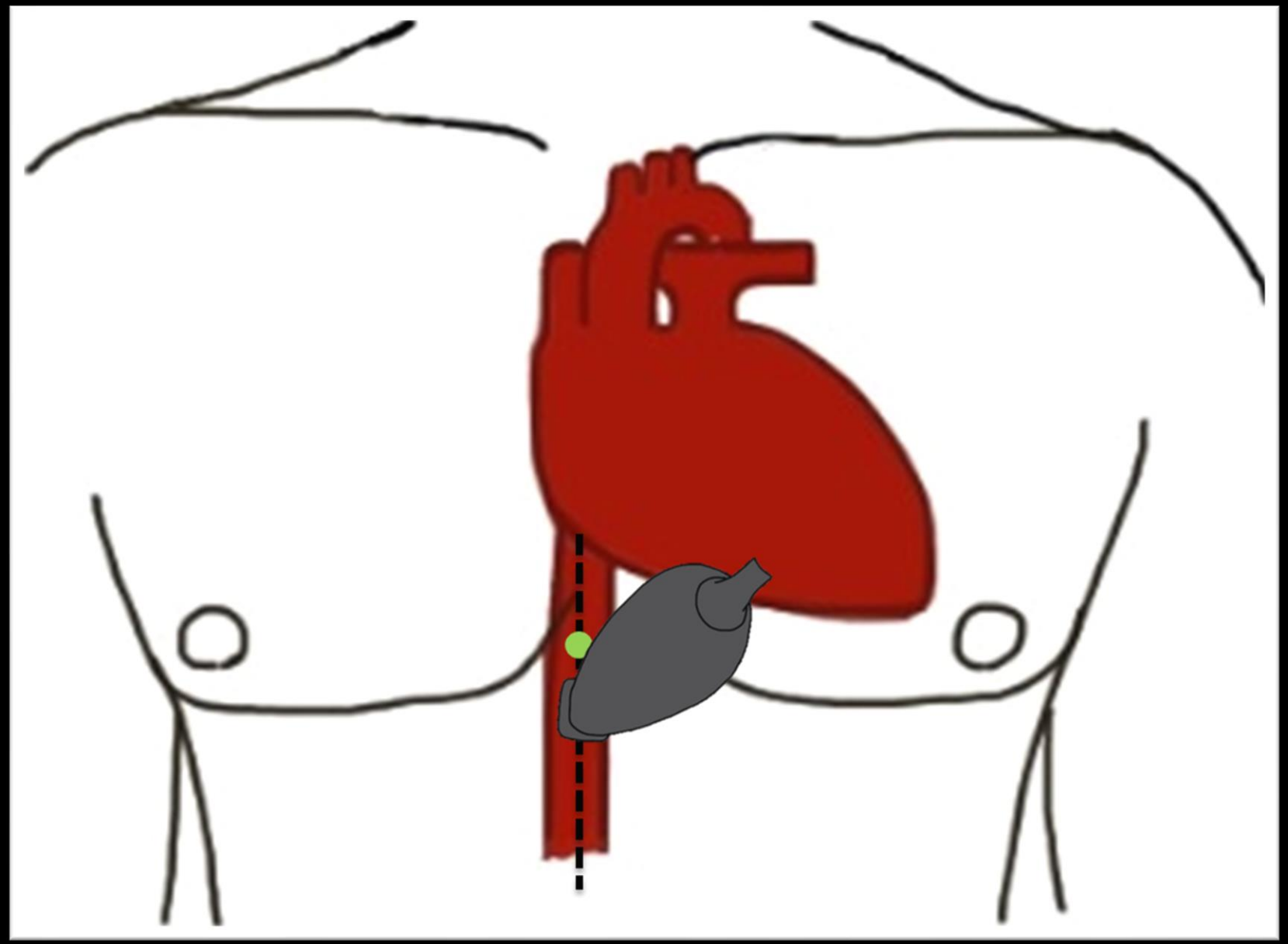




Inferior Vena Cava (IVC)



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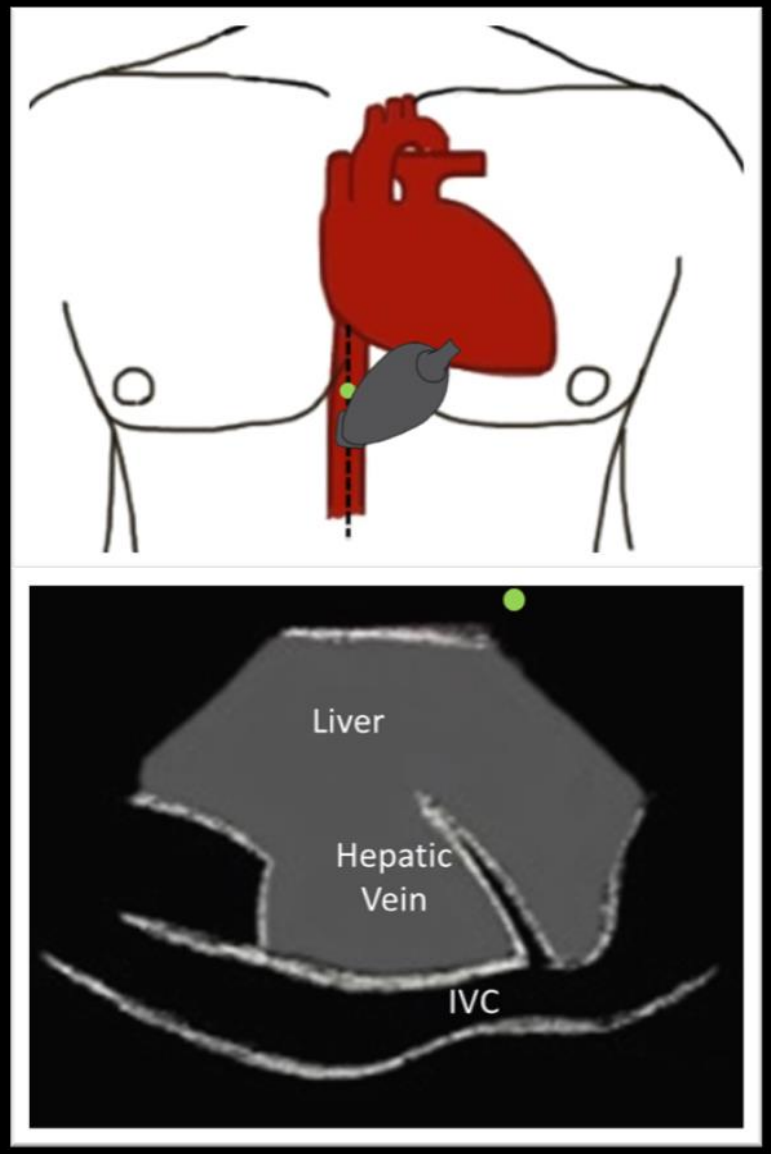
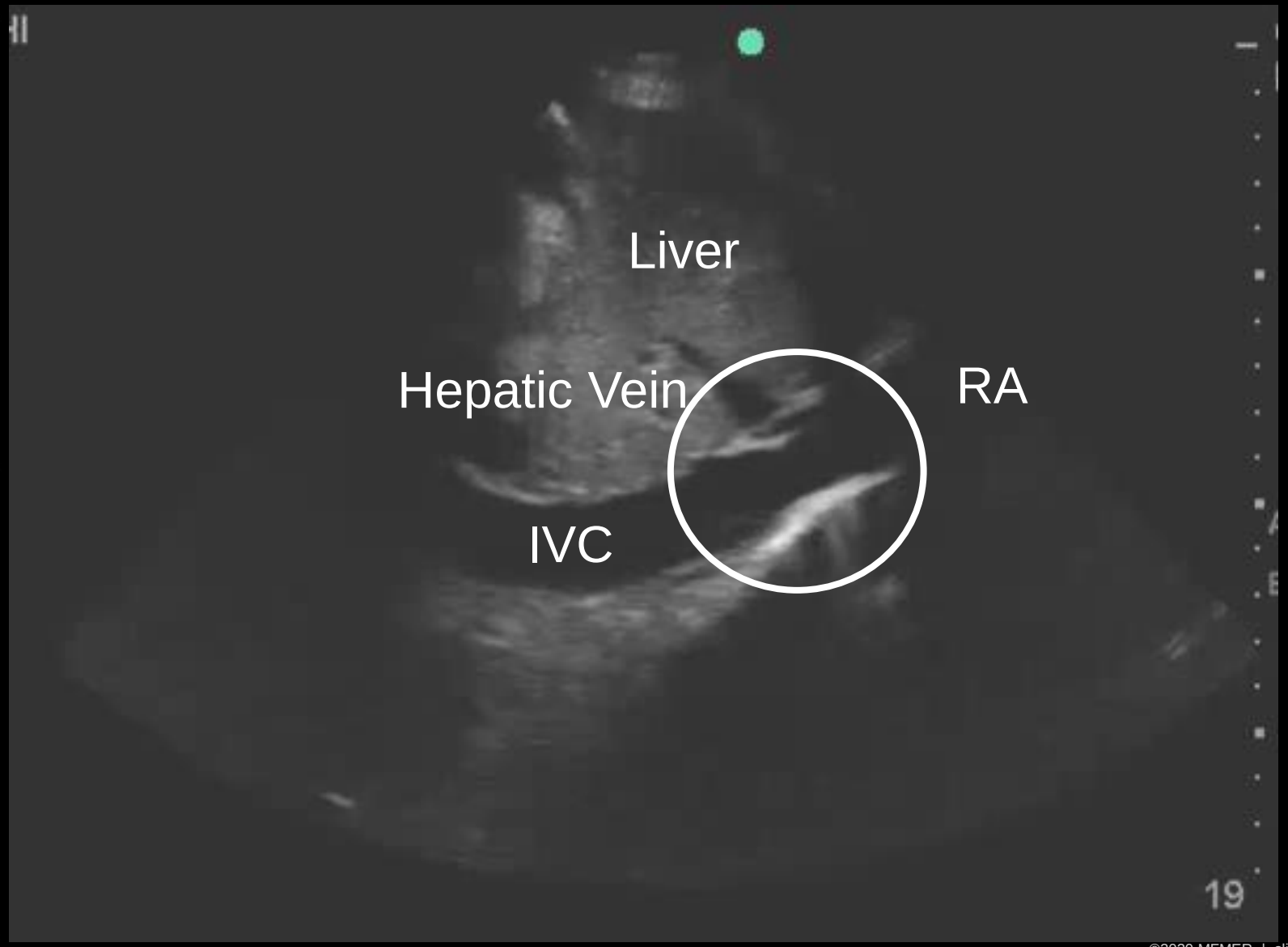
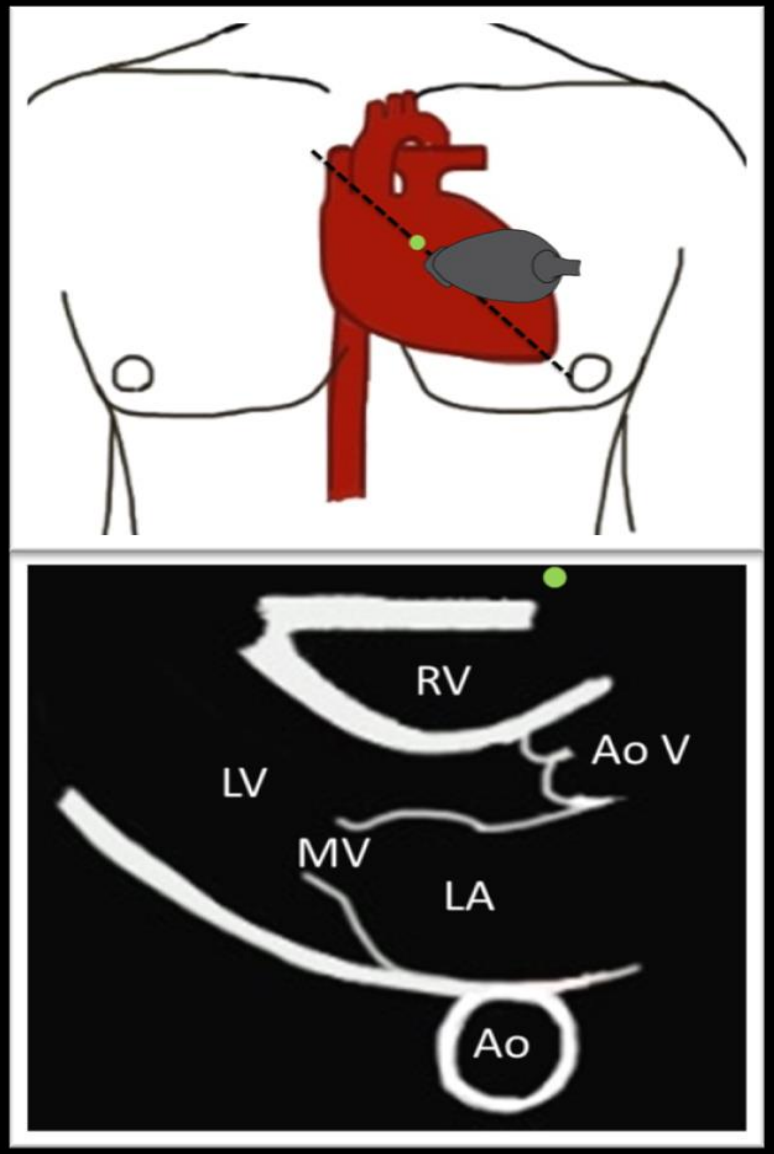




Parasternal Long Axis (PLAX) – Case 1



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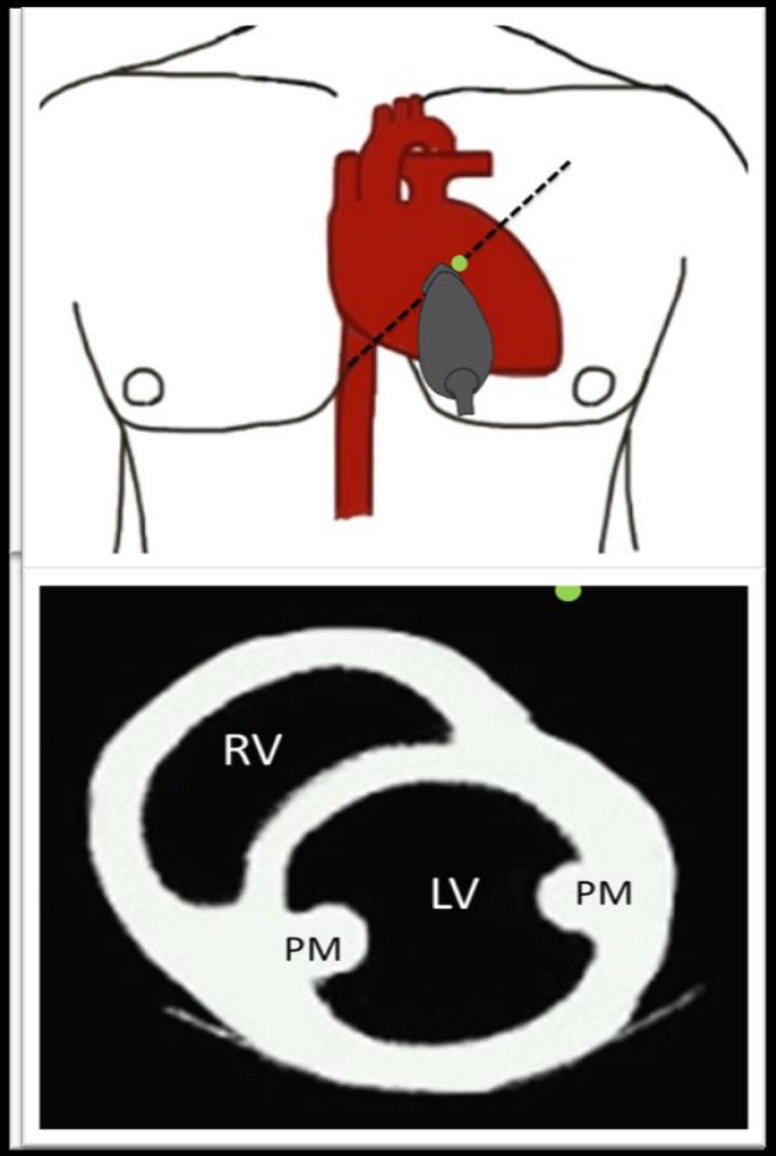

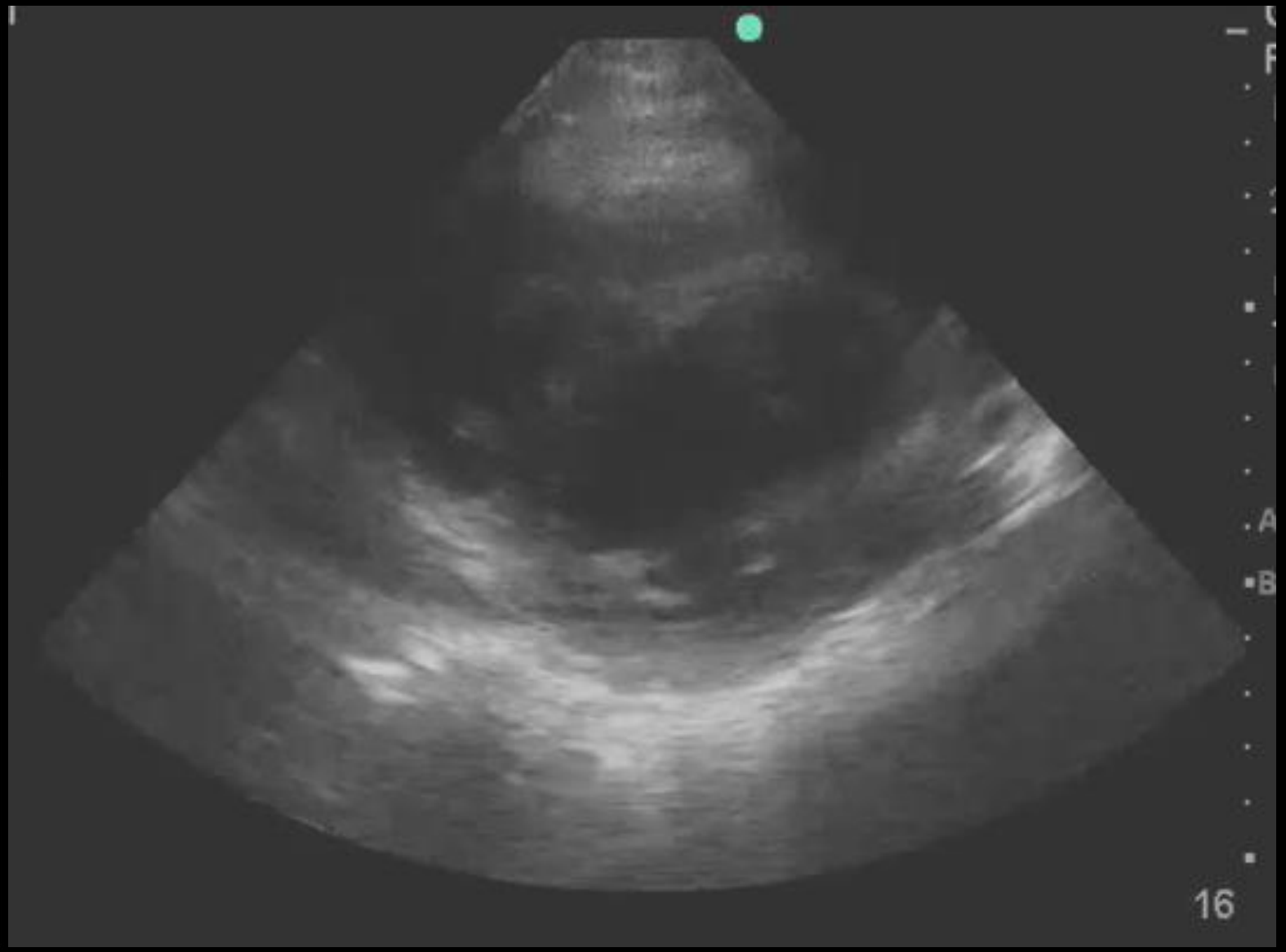

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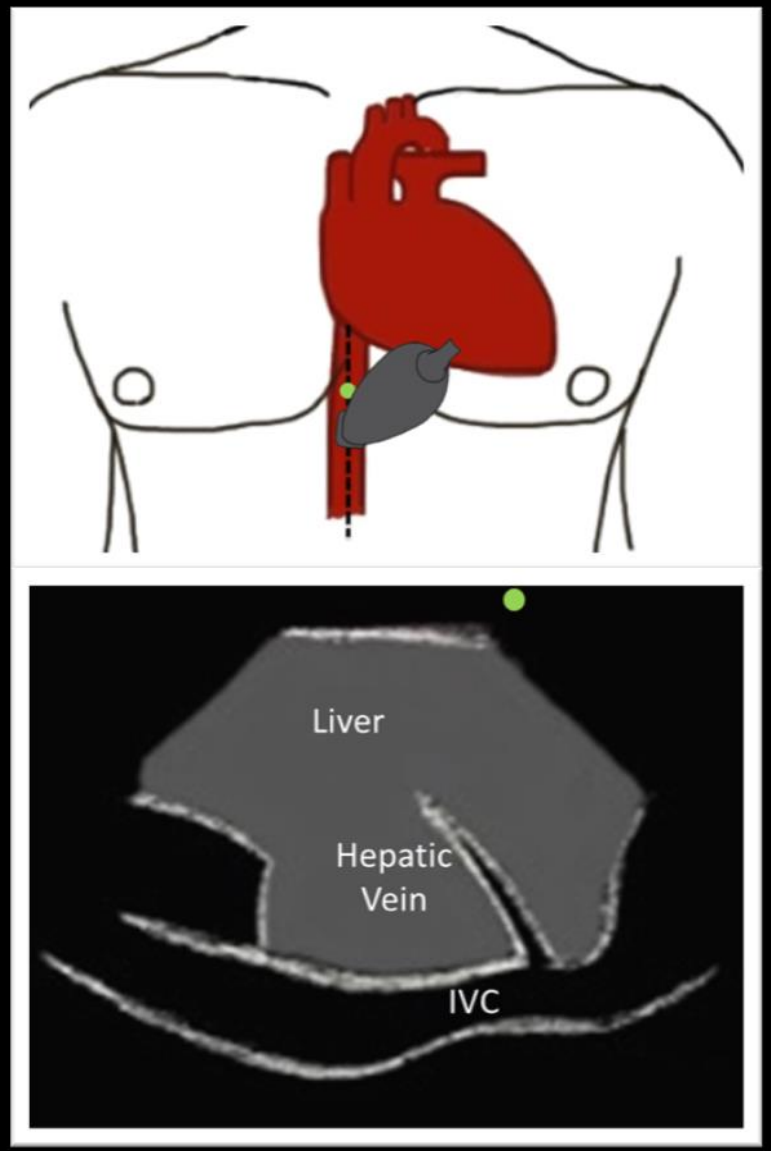


REFLECTION QUESTIONS

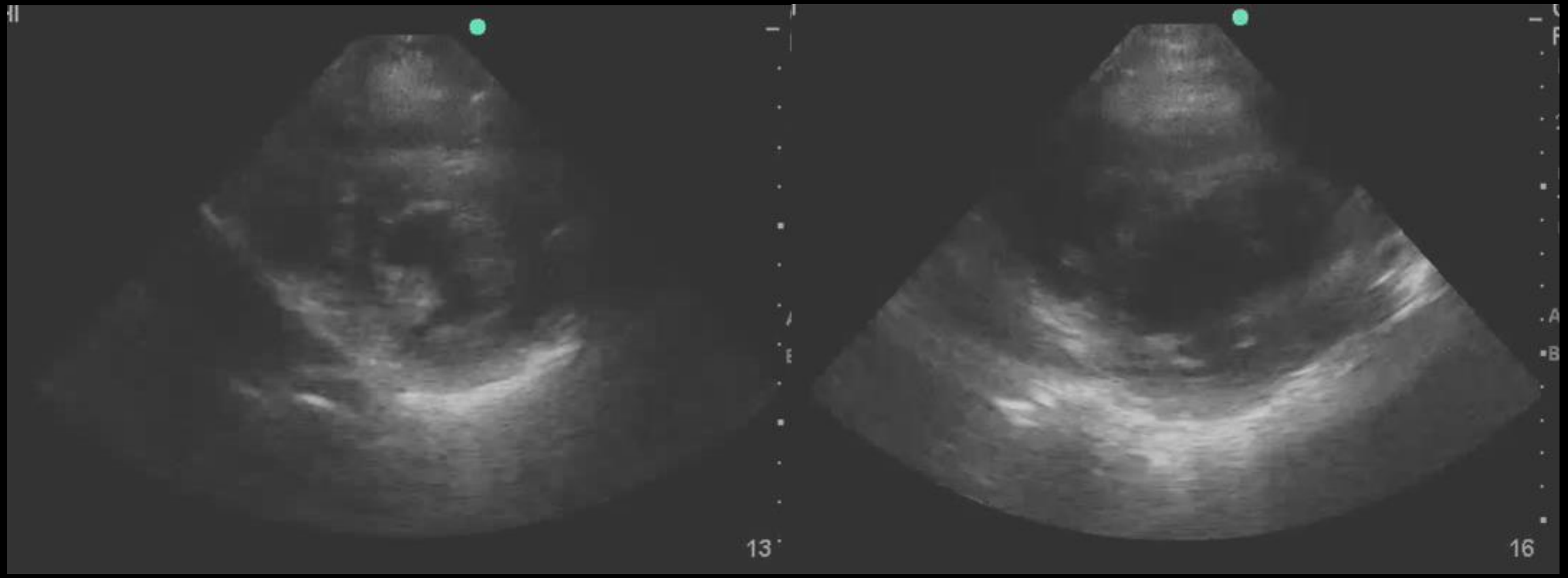
- What is this patient's qualitative LV systolic function?
- What is the patient's RA pressure / volume status?

Parasternal Long Axis (PLAX)

Normal

Patient’s

Parasternal Short Axis (PSAX)



Normal

Patient’s

Inferior Vena Cava (IVC)

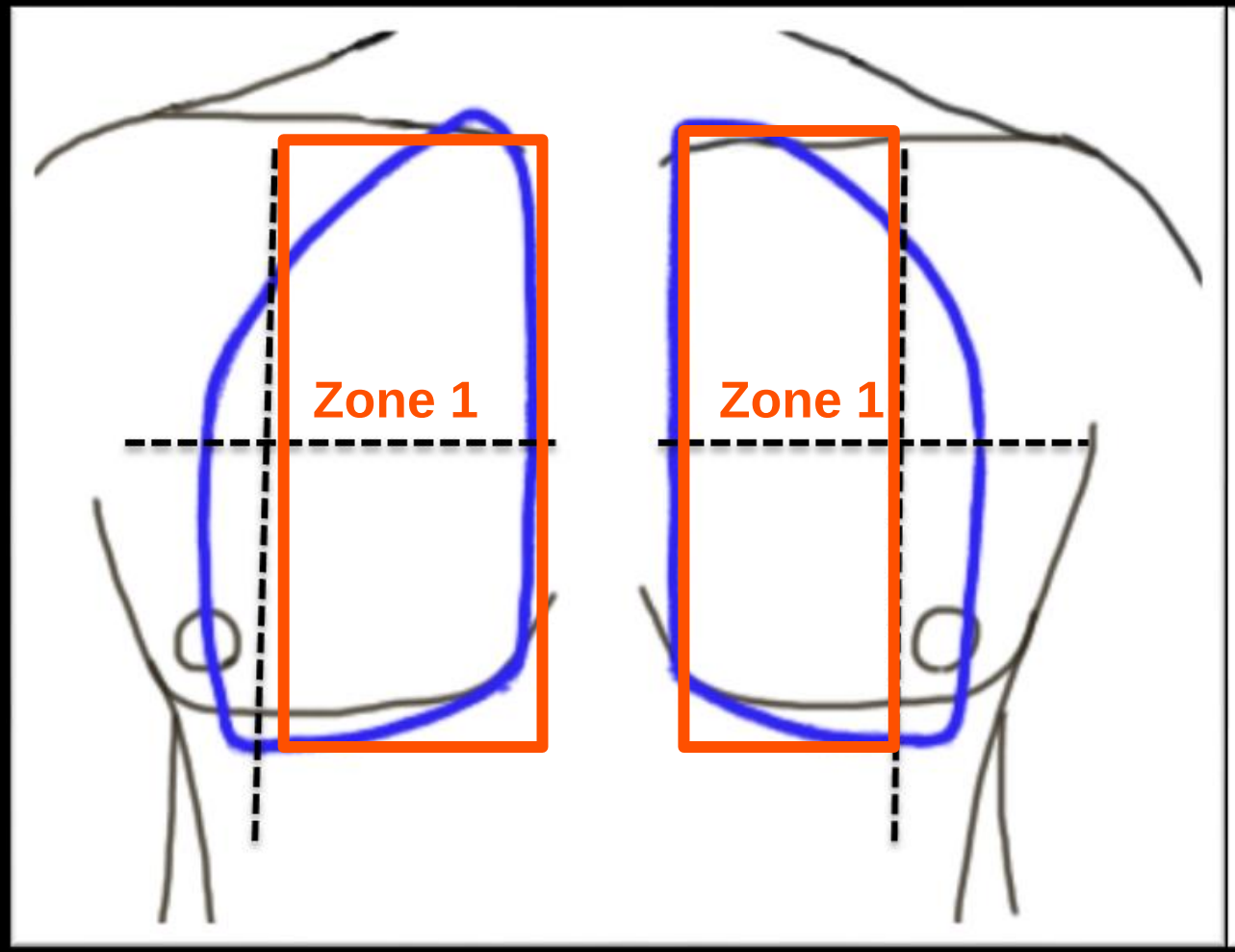
Normal

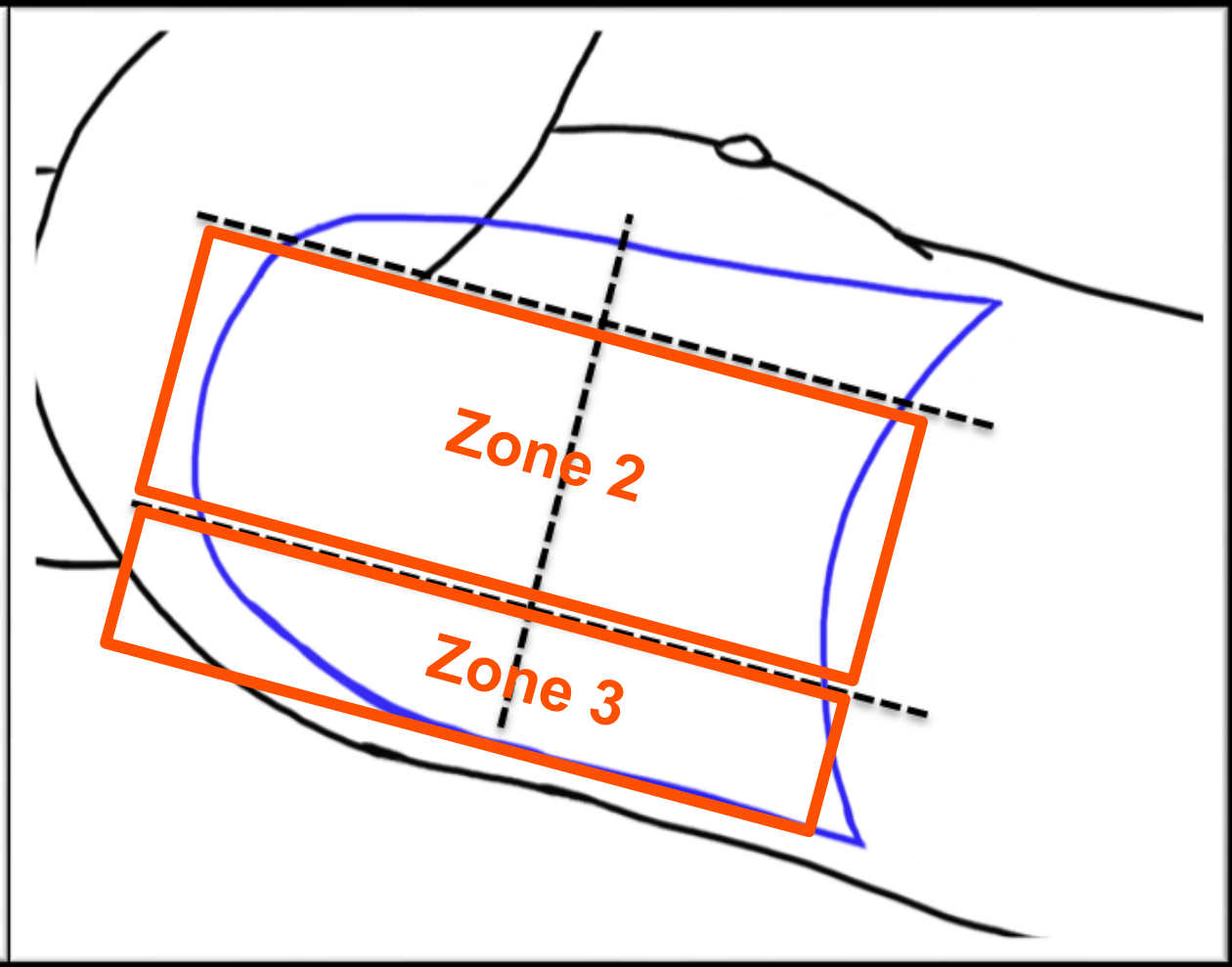
Patient’s

LUNG ULTRASOUND

- Scope:
  - Pulmonary edema
  - Consolidation/Pneumonia
  - Pleural effusions
  - Pneumothorax
  - PE, Asthma, COPD (in the absence of other findings)
- Indications:
  - Hypoxia / Dyspnea.
  - Cough
  - Assessing volume status / Fluid resuscitation.

LUNG ULTRASOUND





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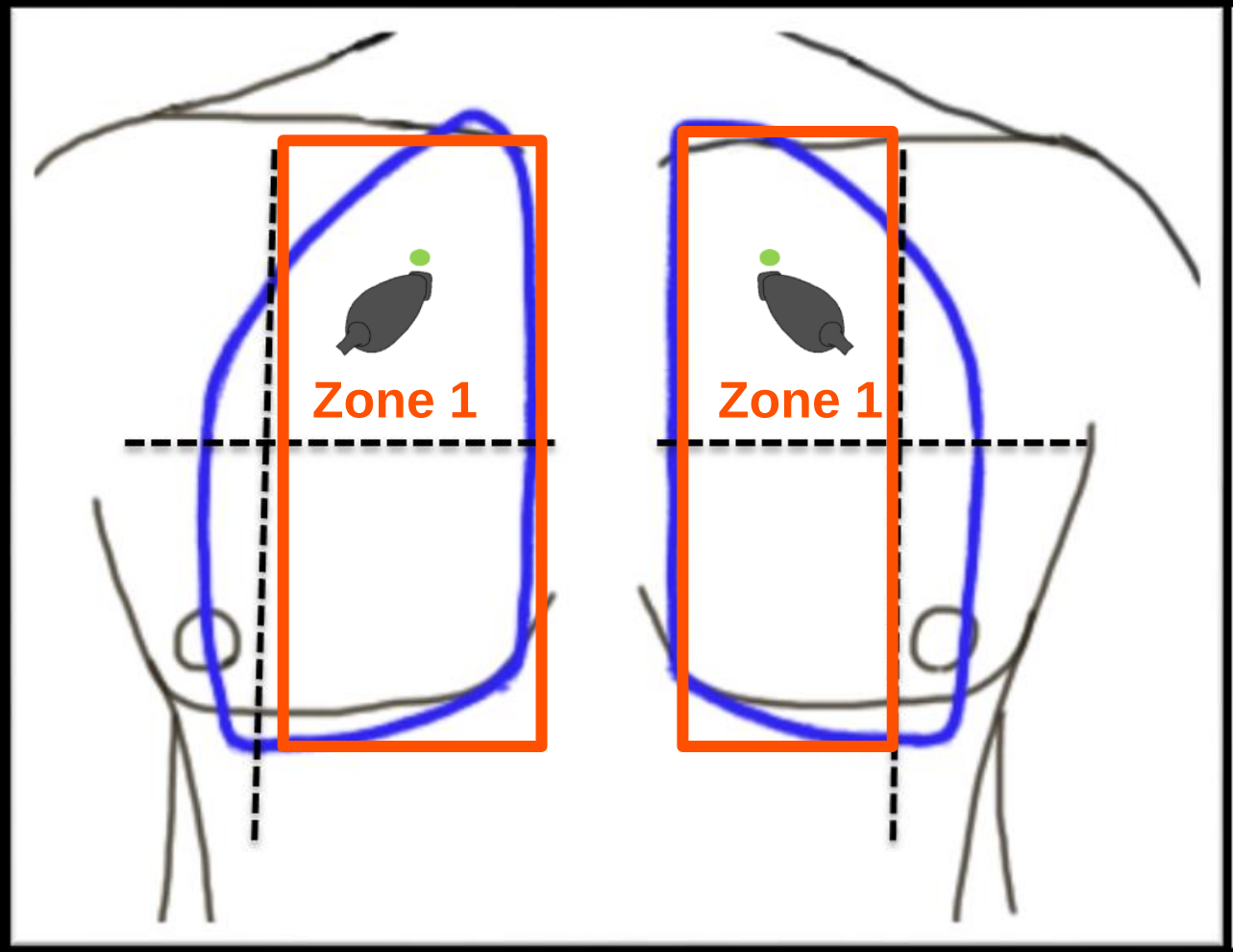

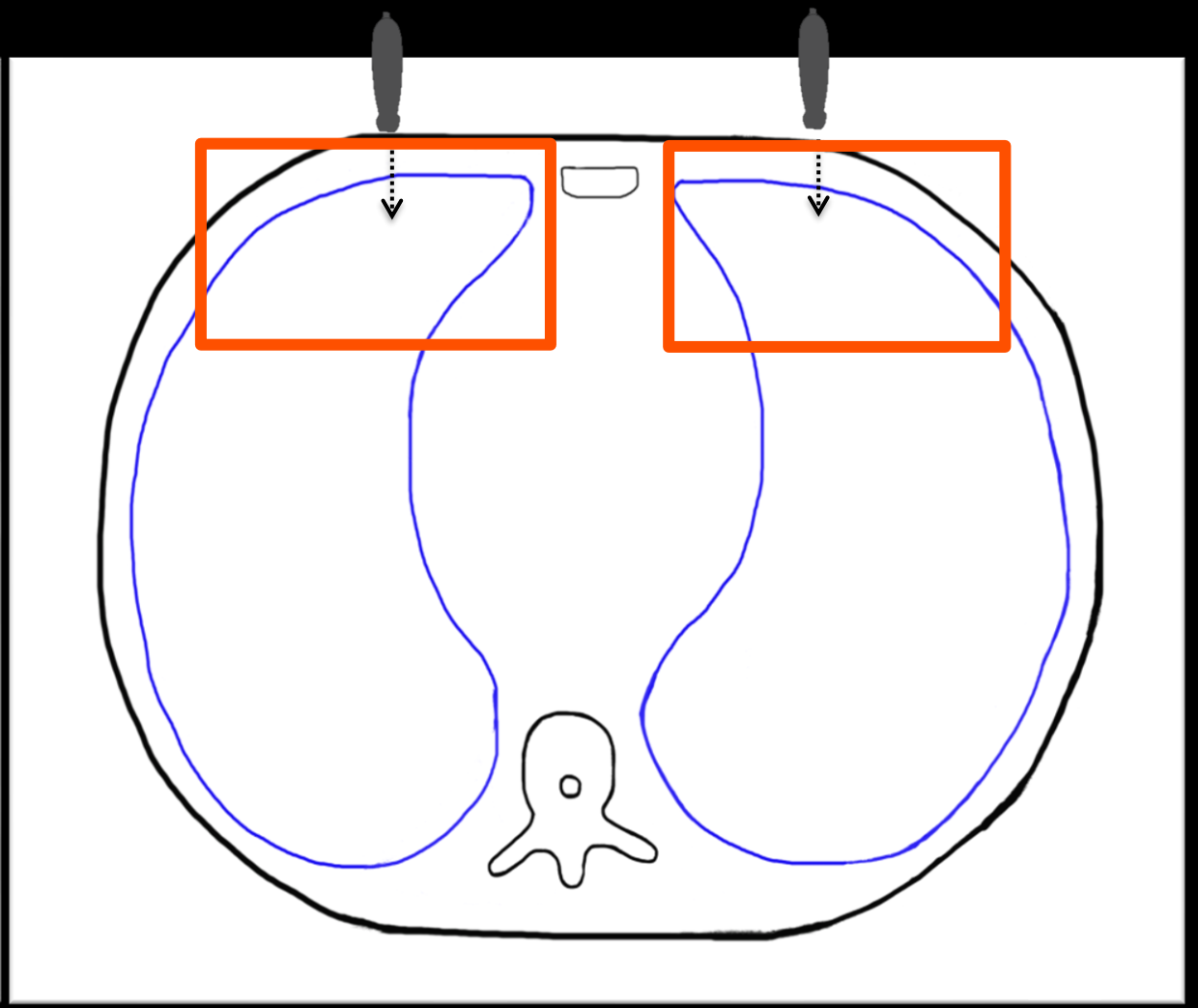

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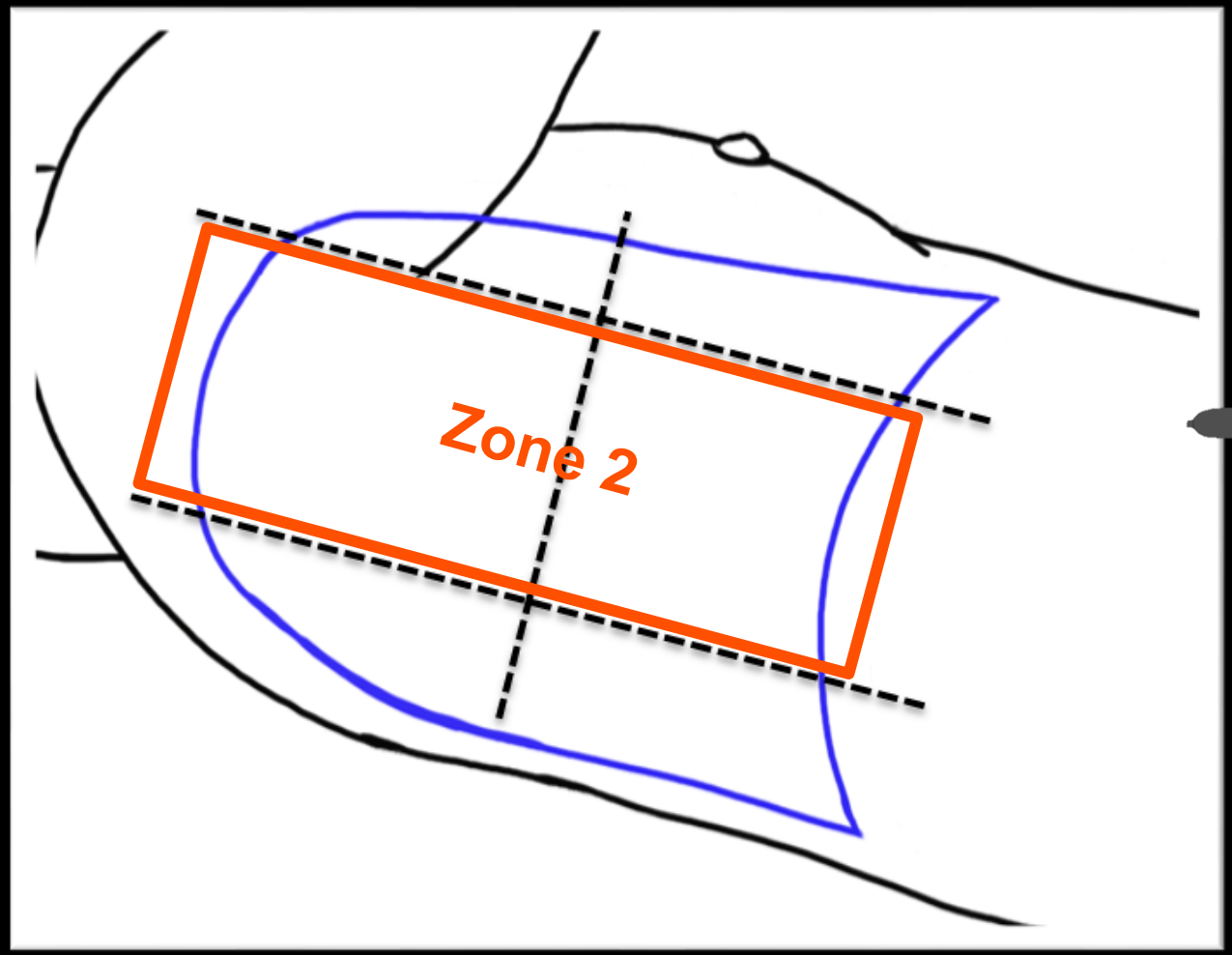

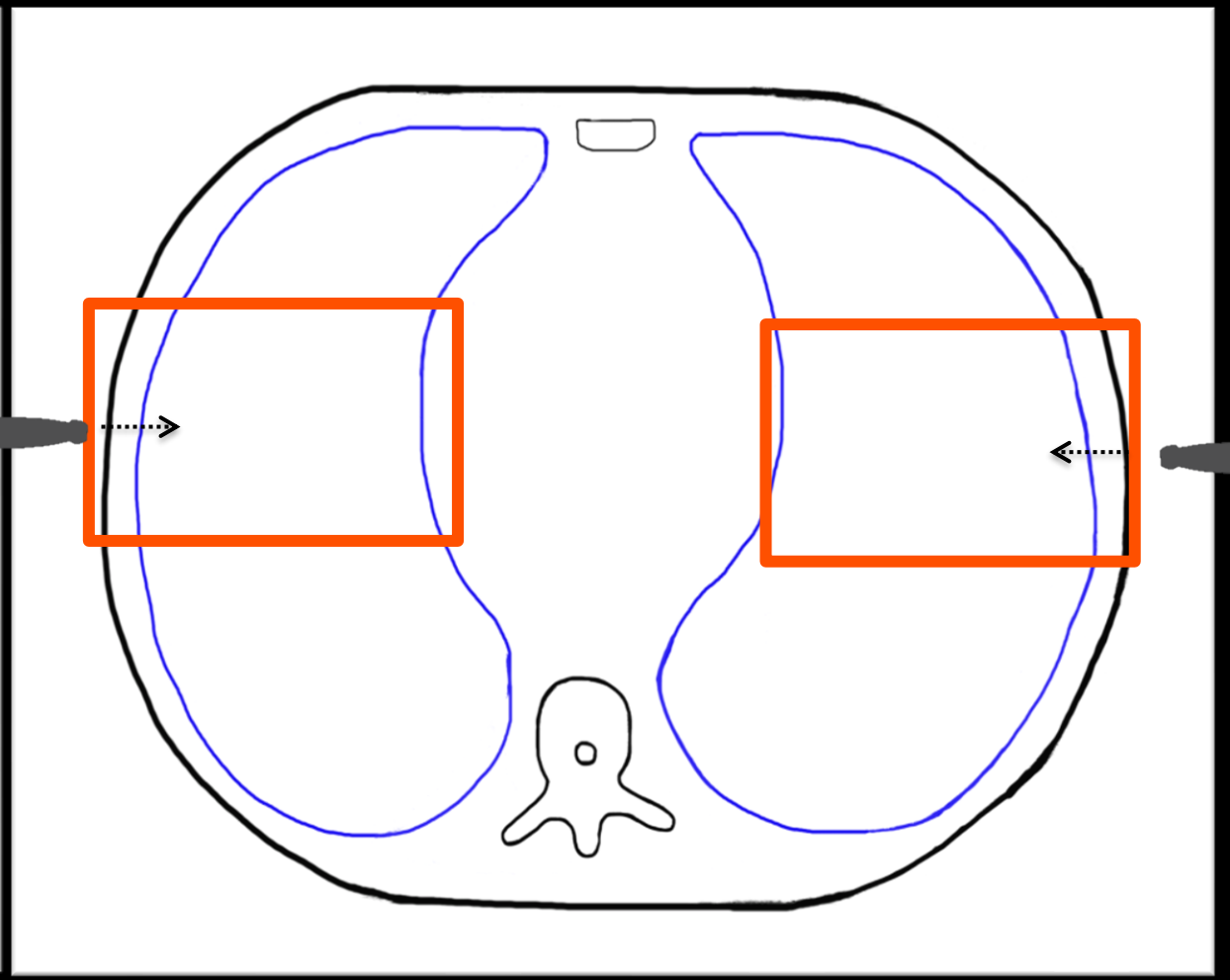

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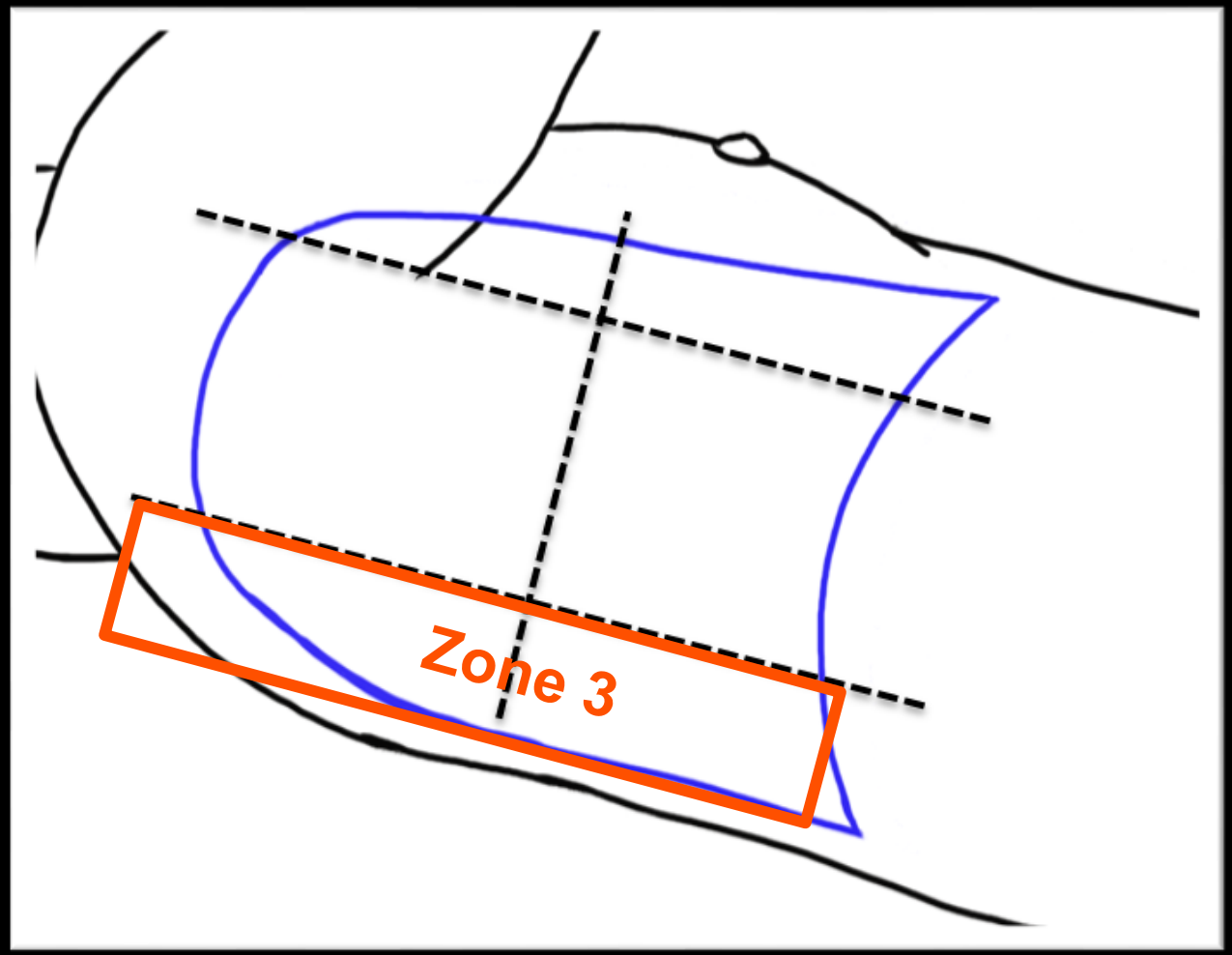
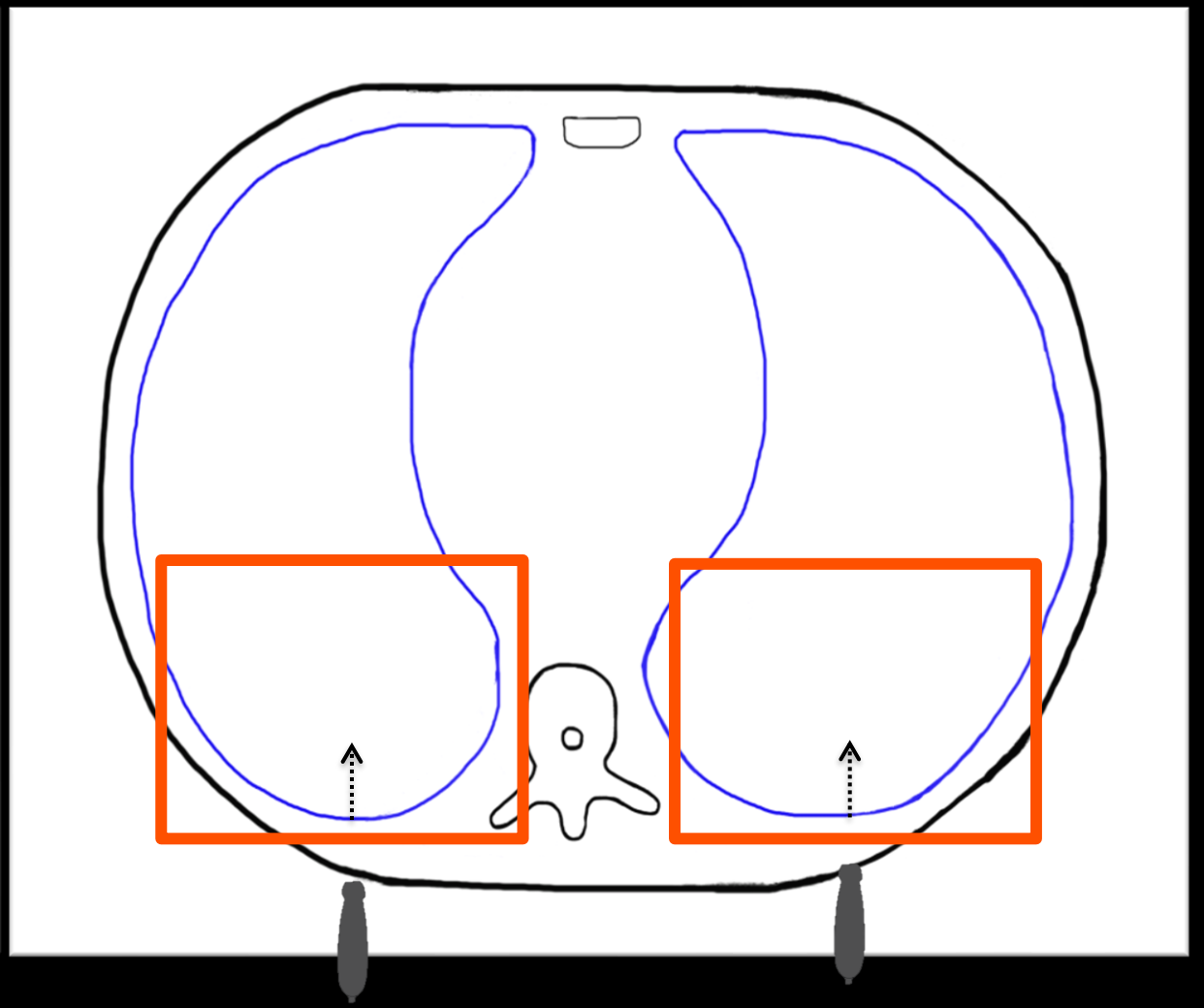
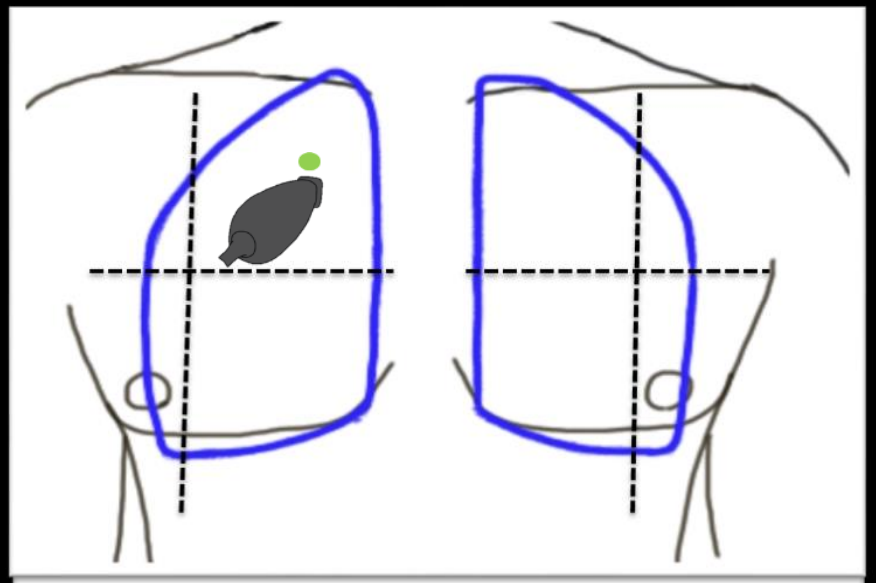
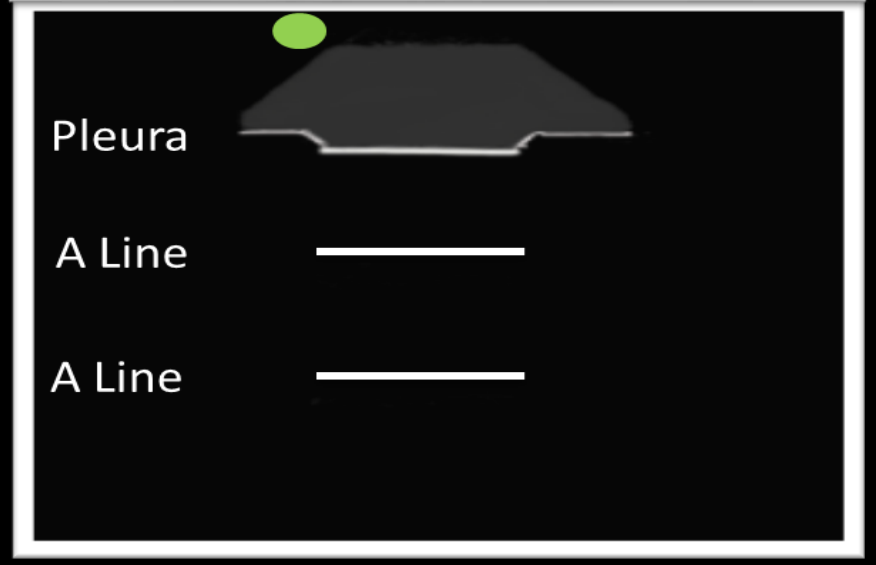


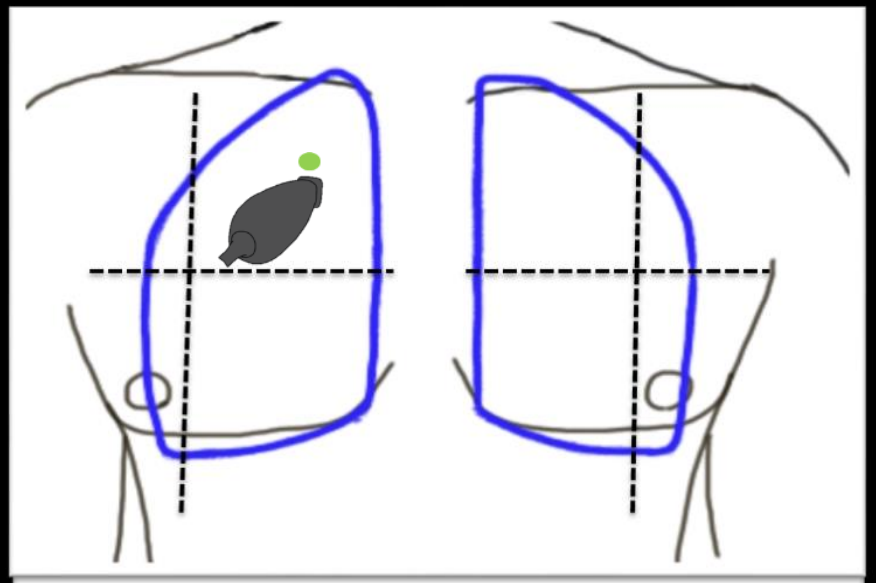


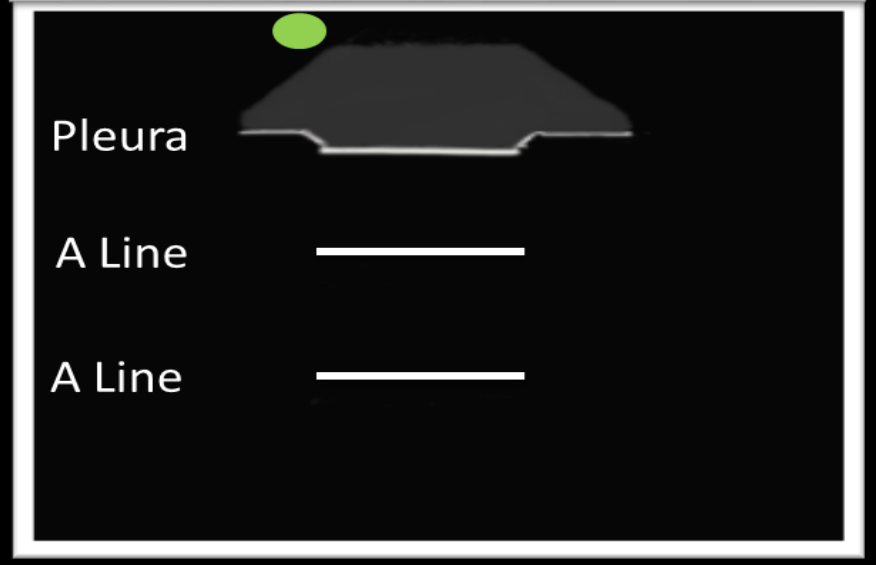
LUNG ULTRASOUND – A LINES

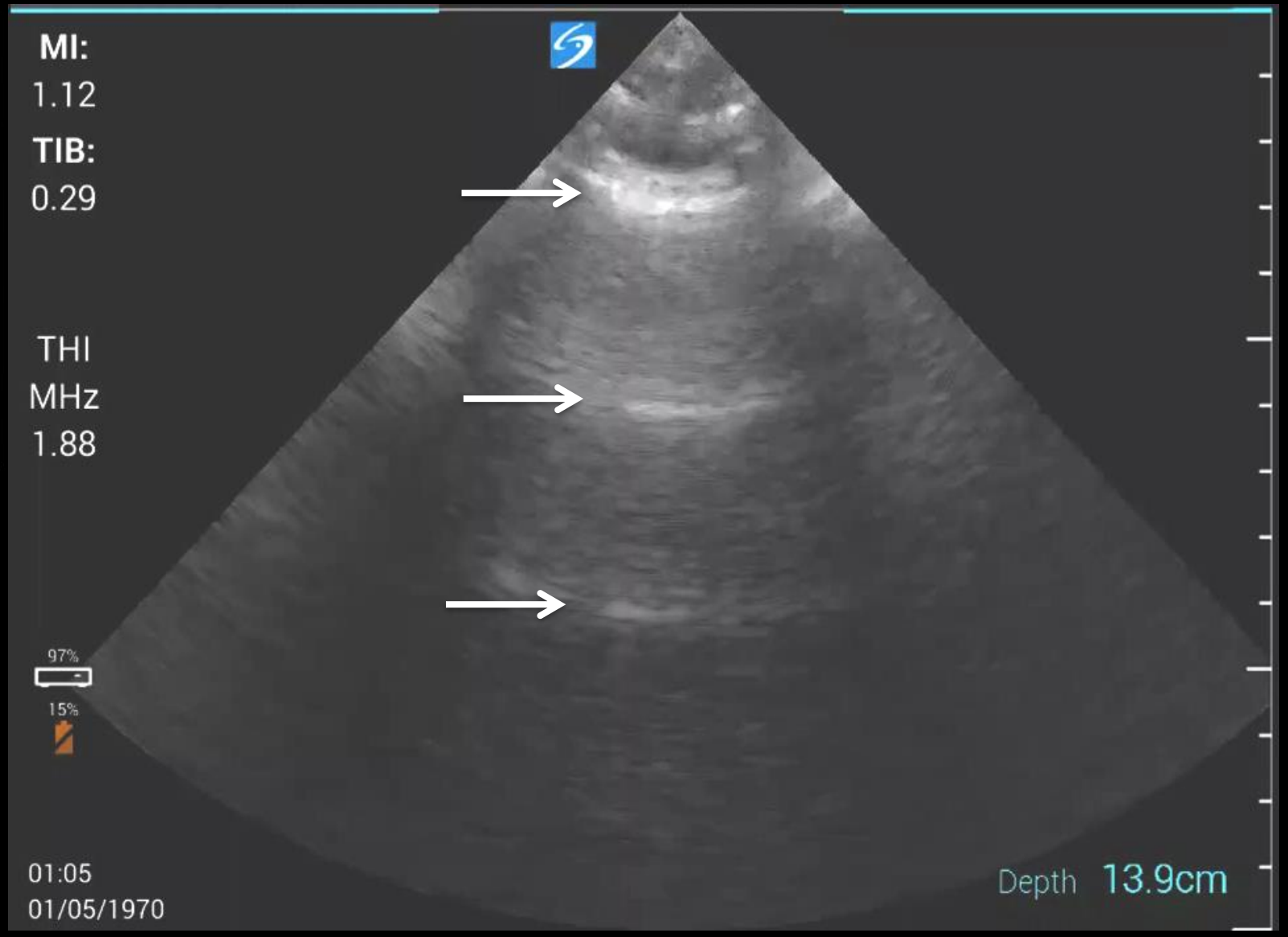




LUNG ULTRASOUND – ABSENT LUNG SLIDING







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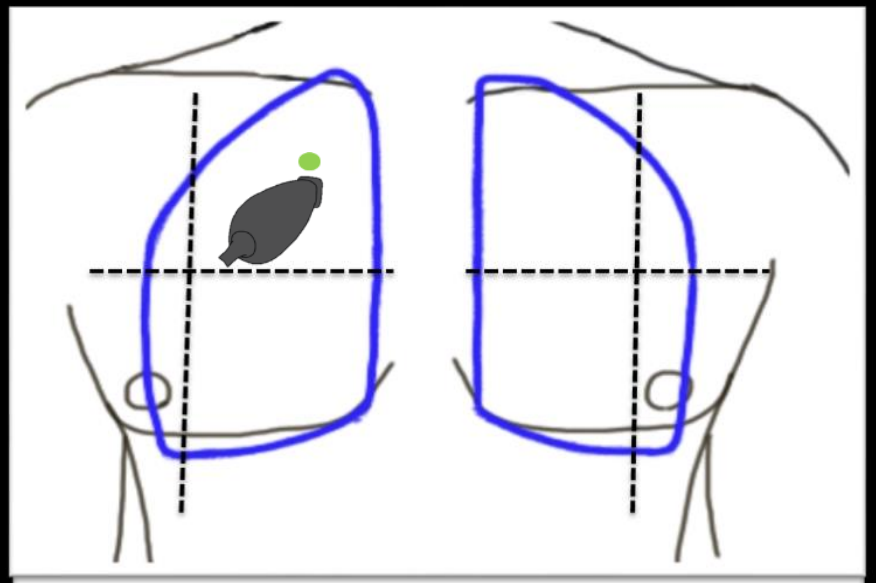
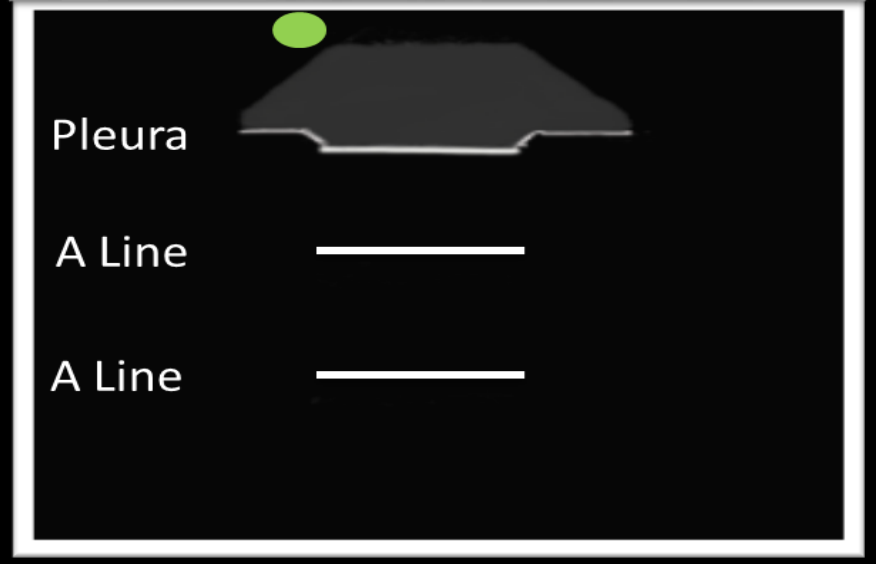
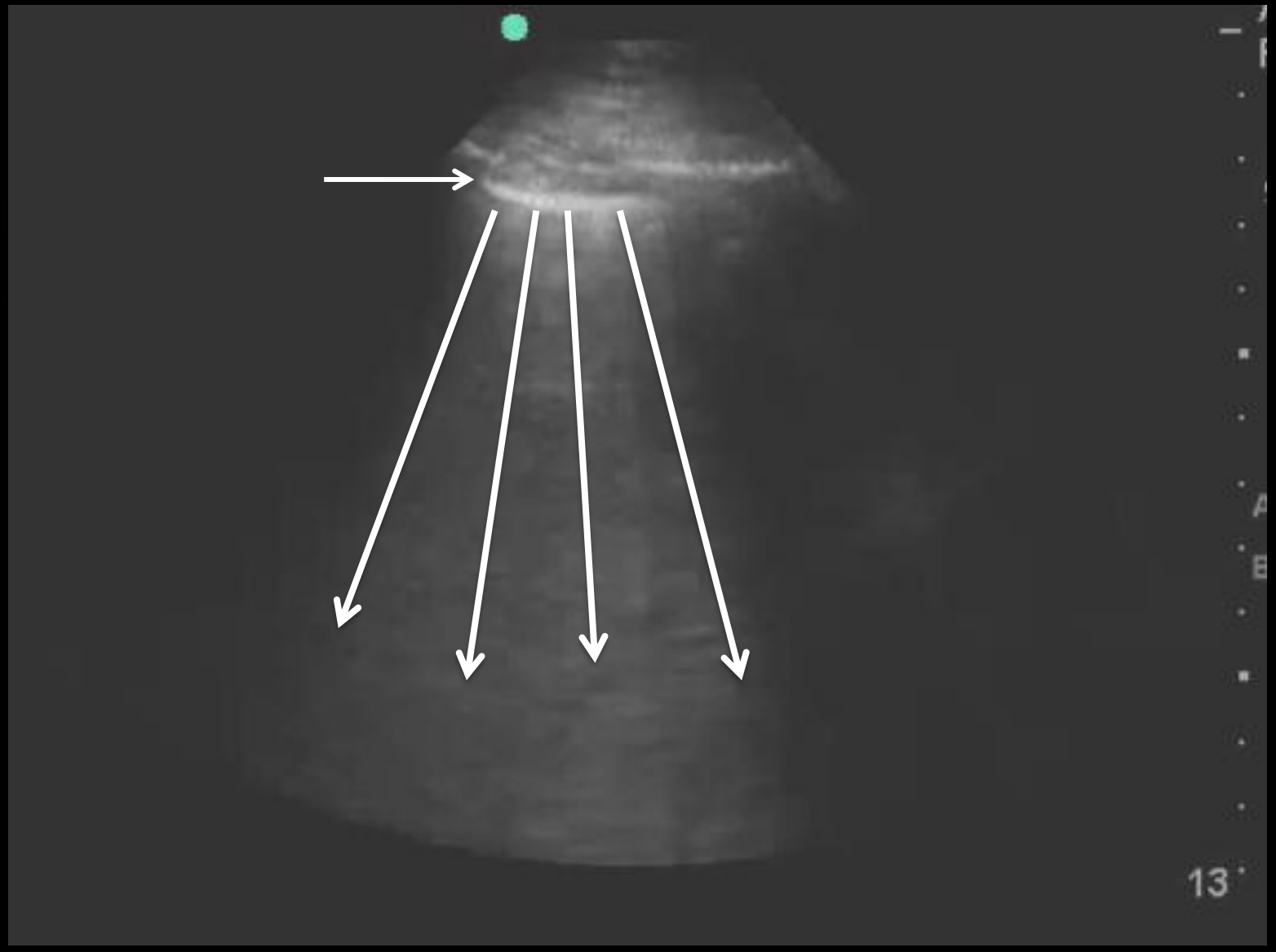
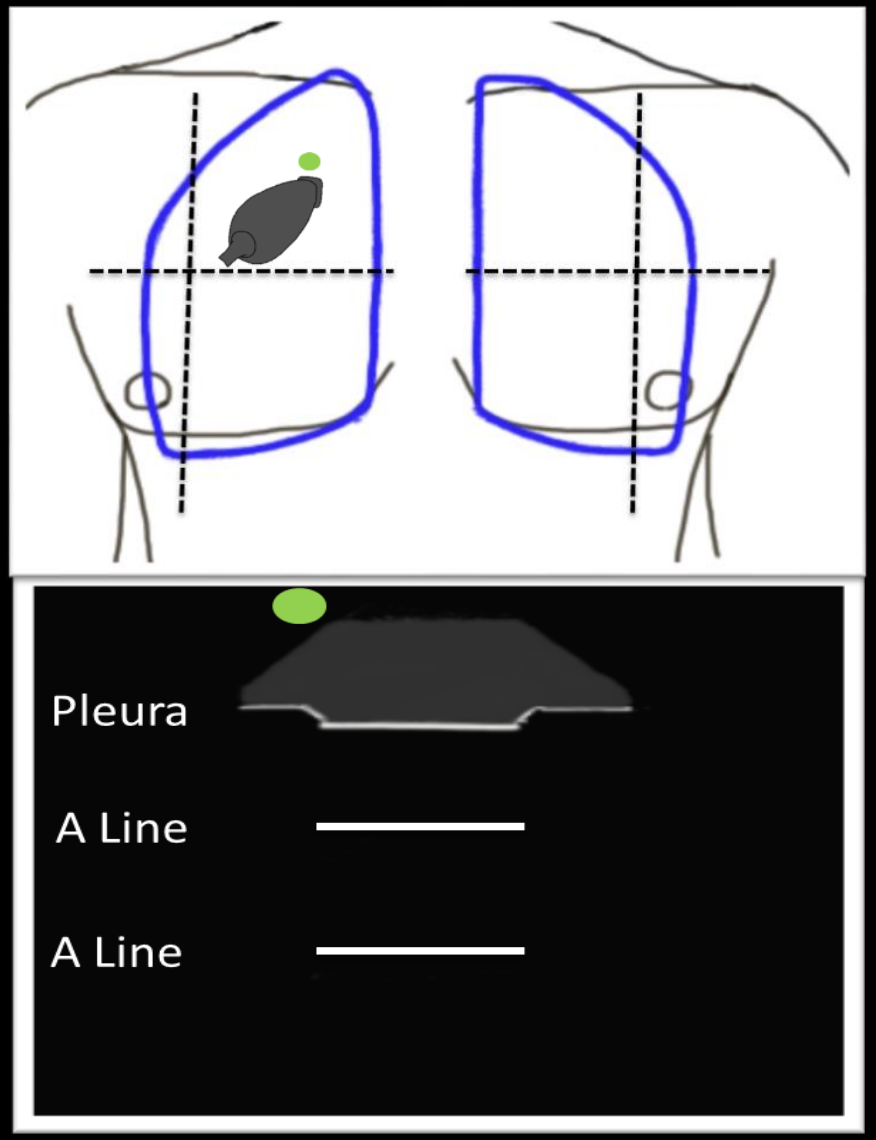
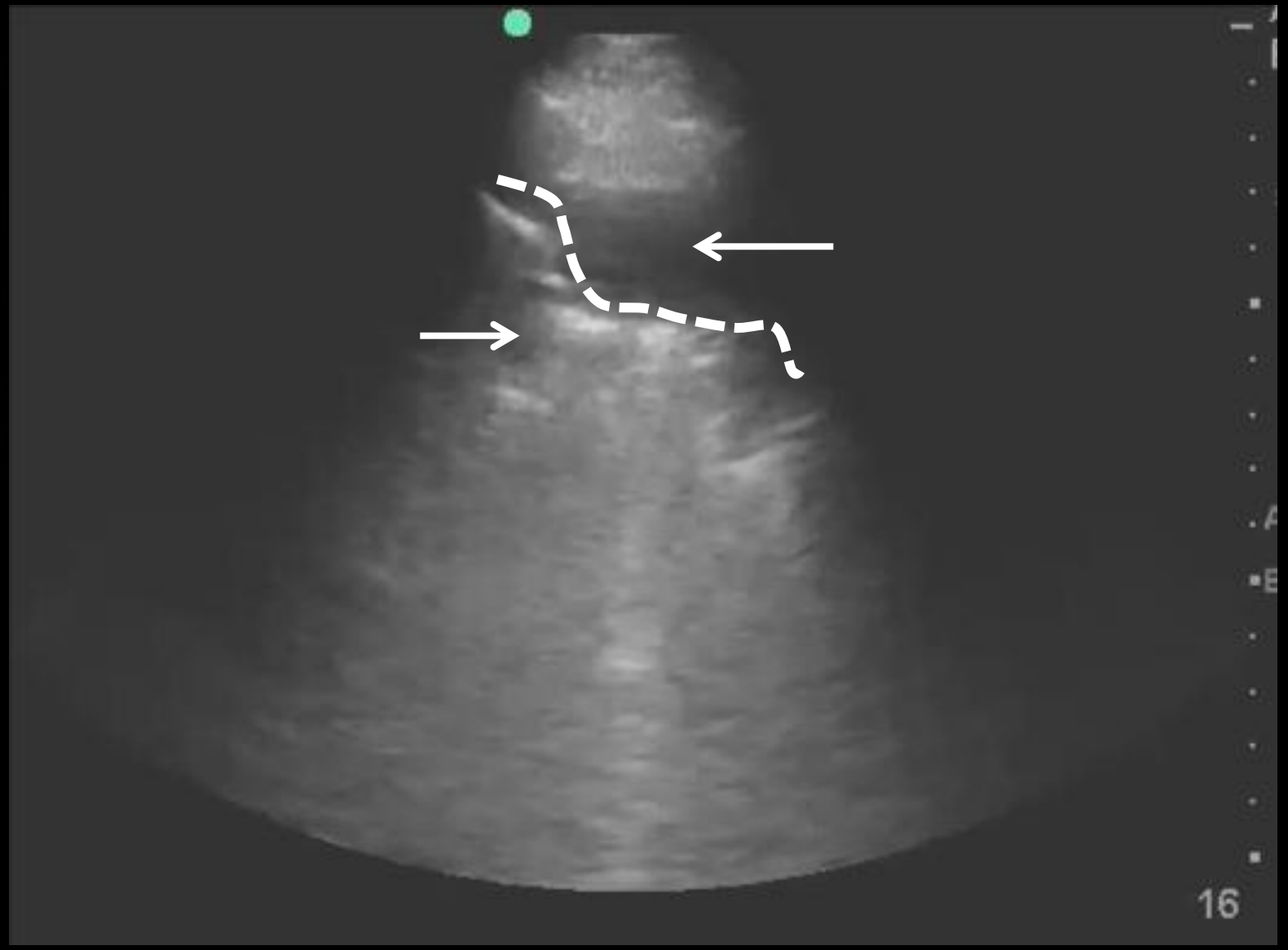






LUNG ULTRASOUND – CONSOLIDATION





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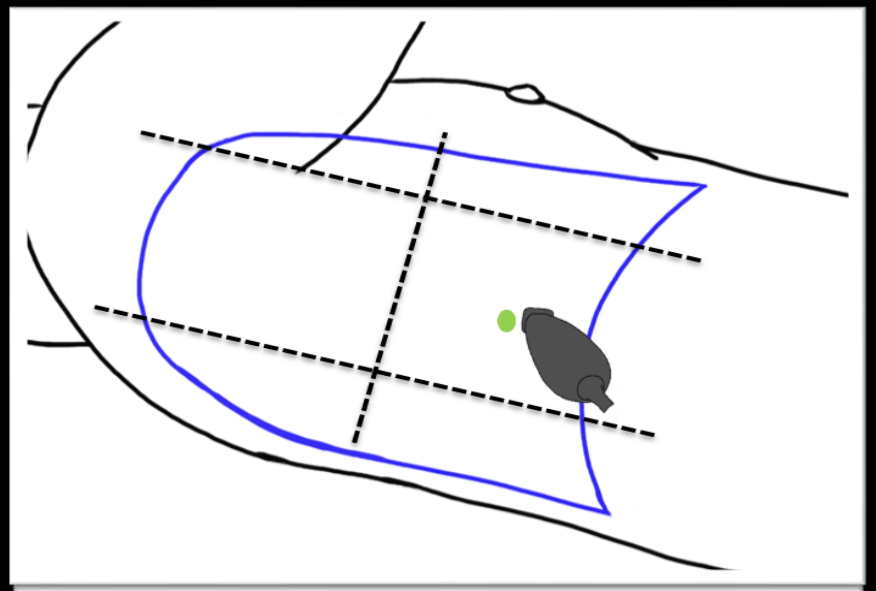
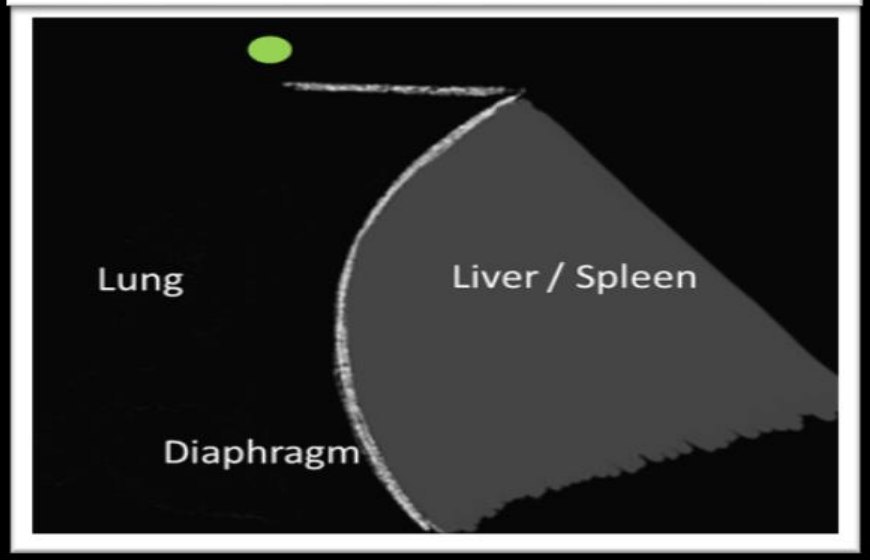
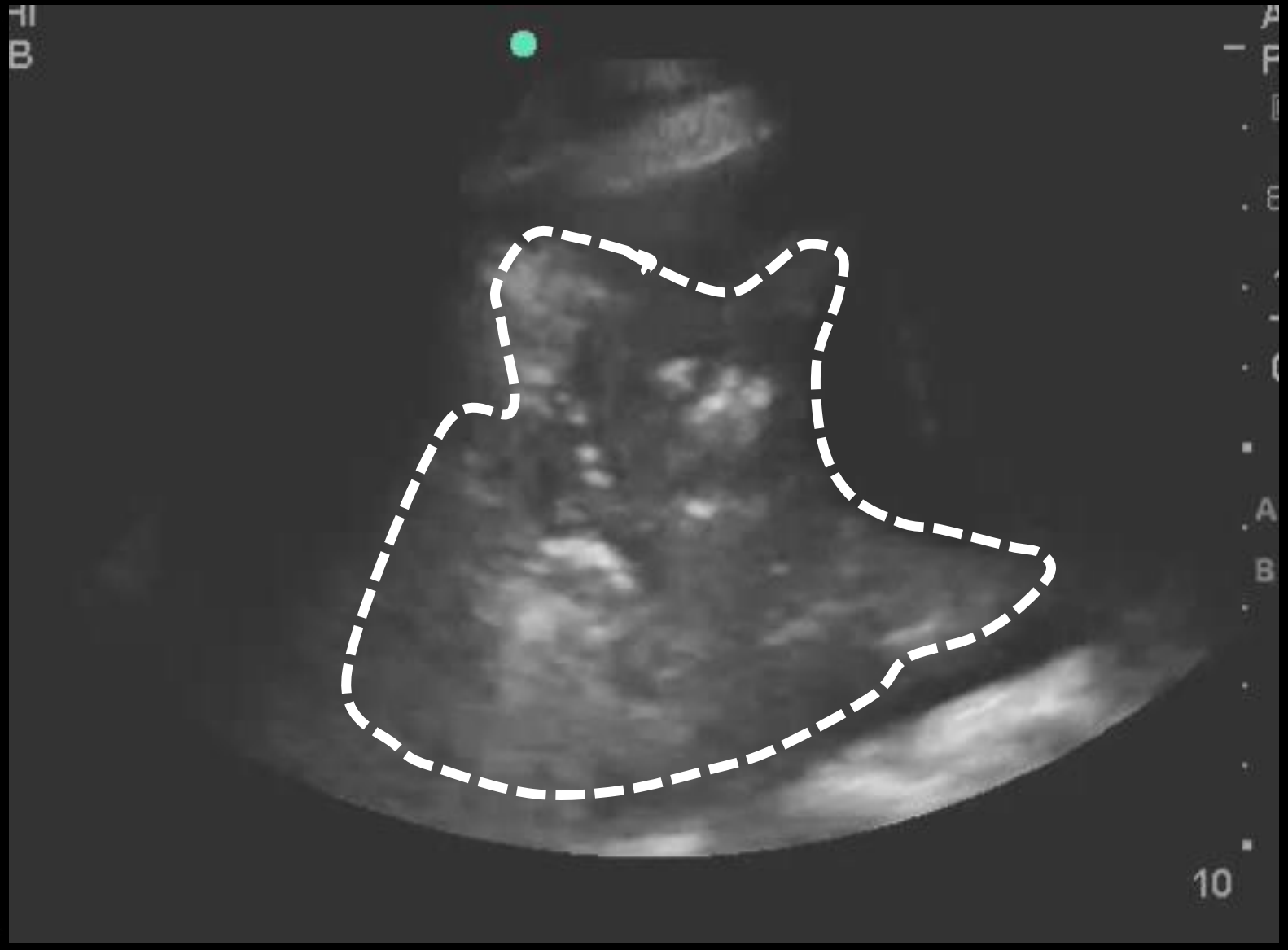
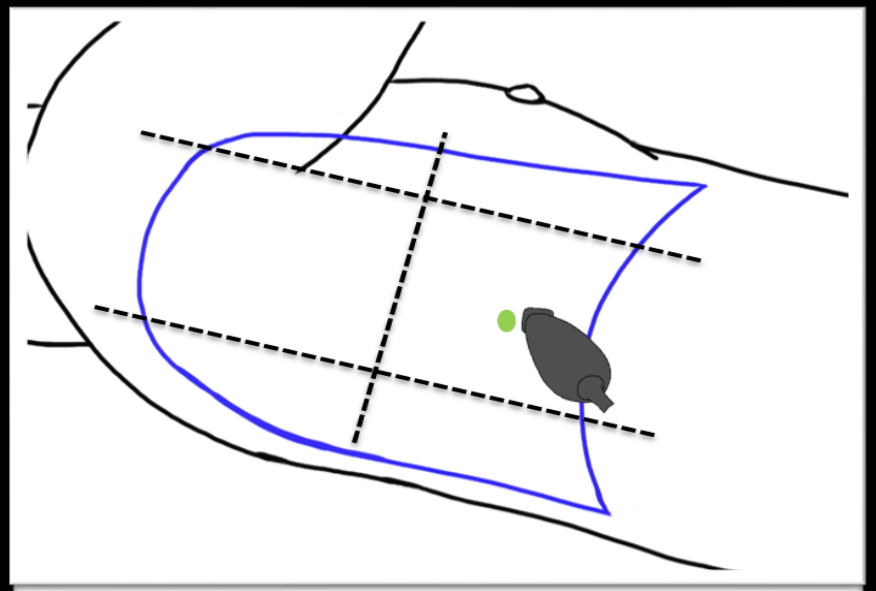
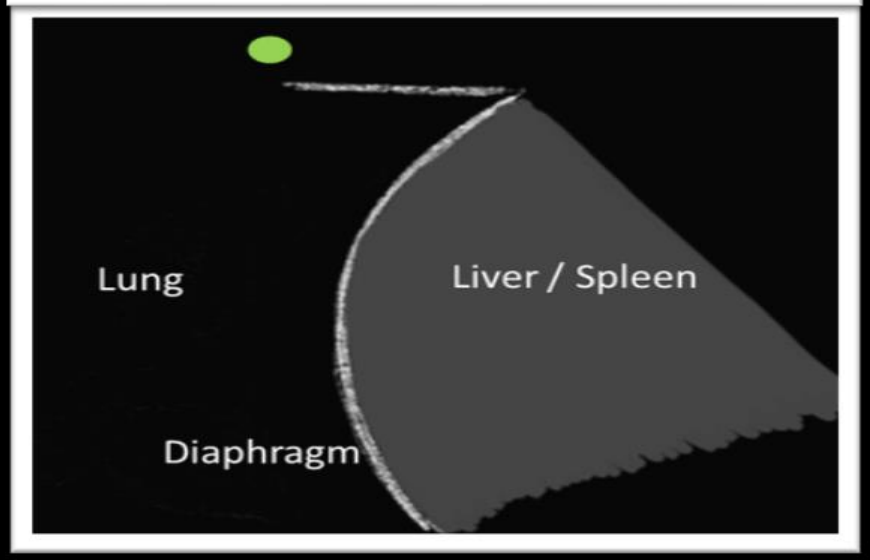


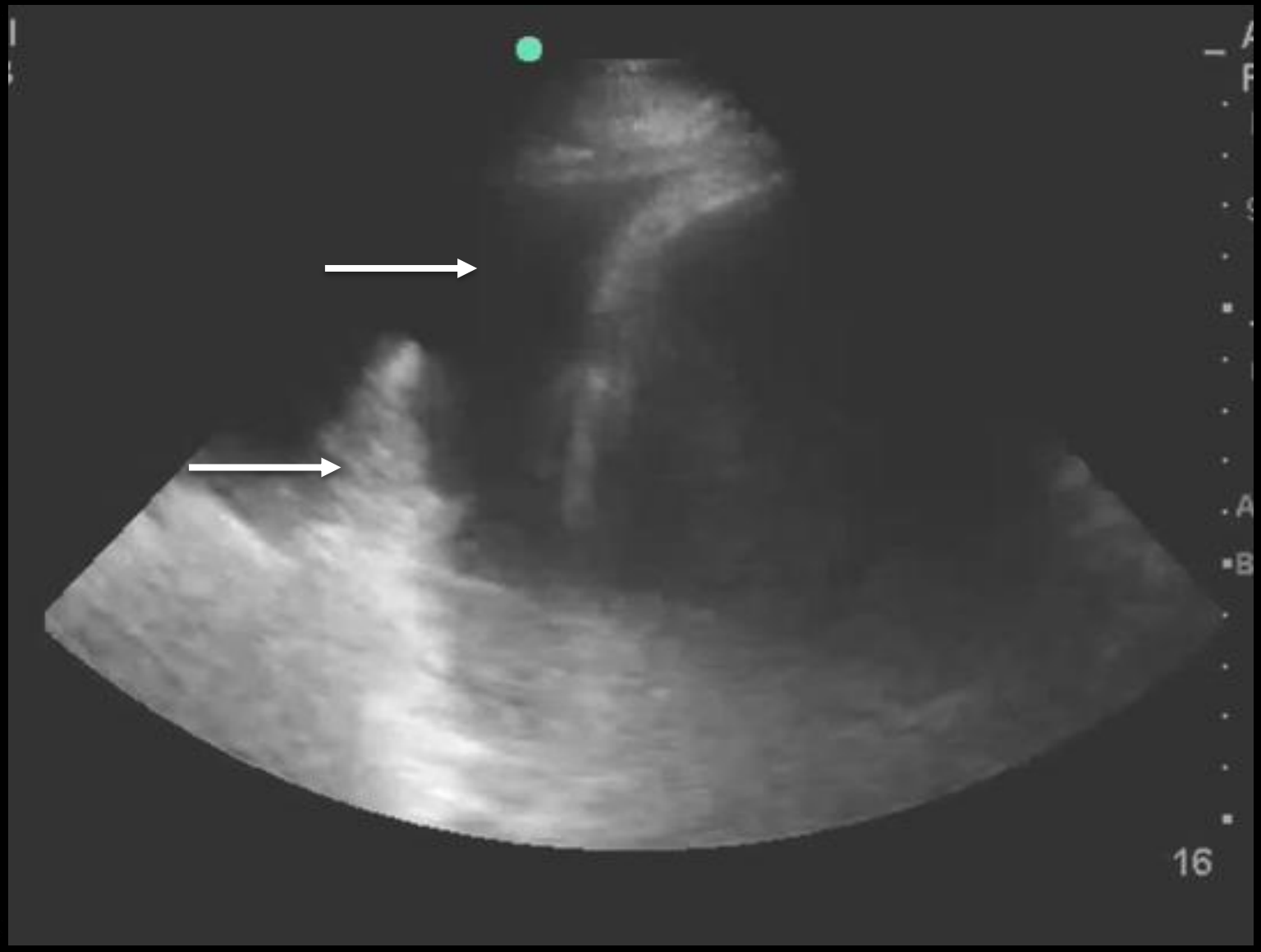




LUNG ULTRASOUND – PLEURAL EFFUSION







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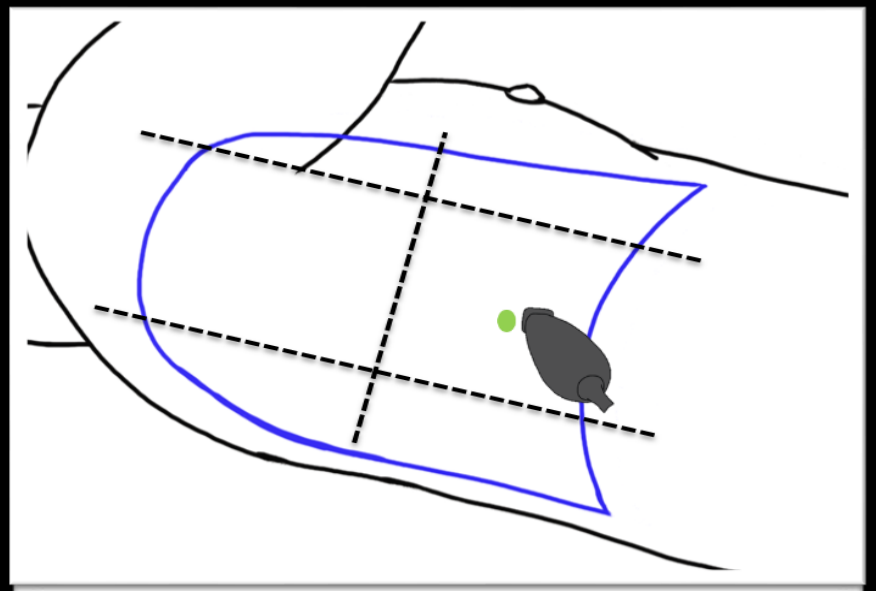
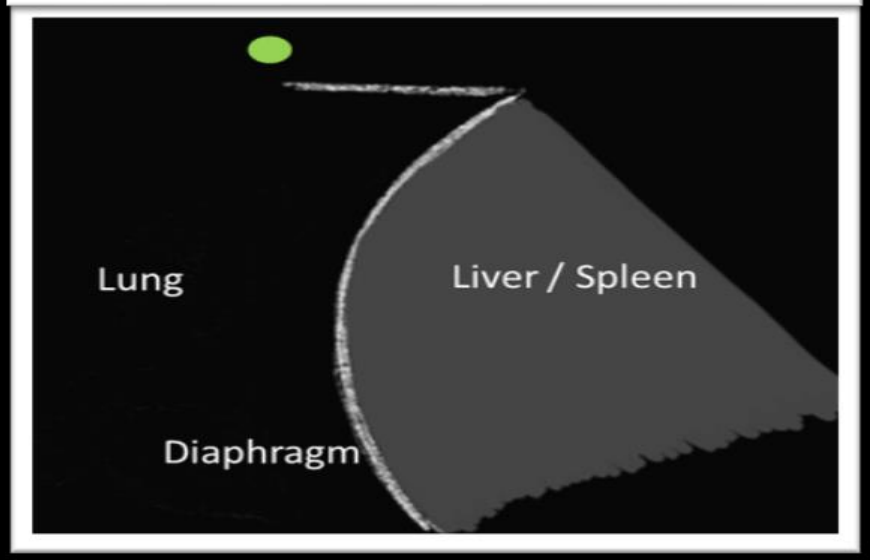
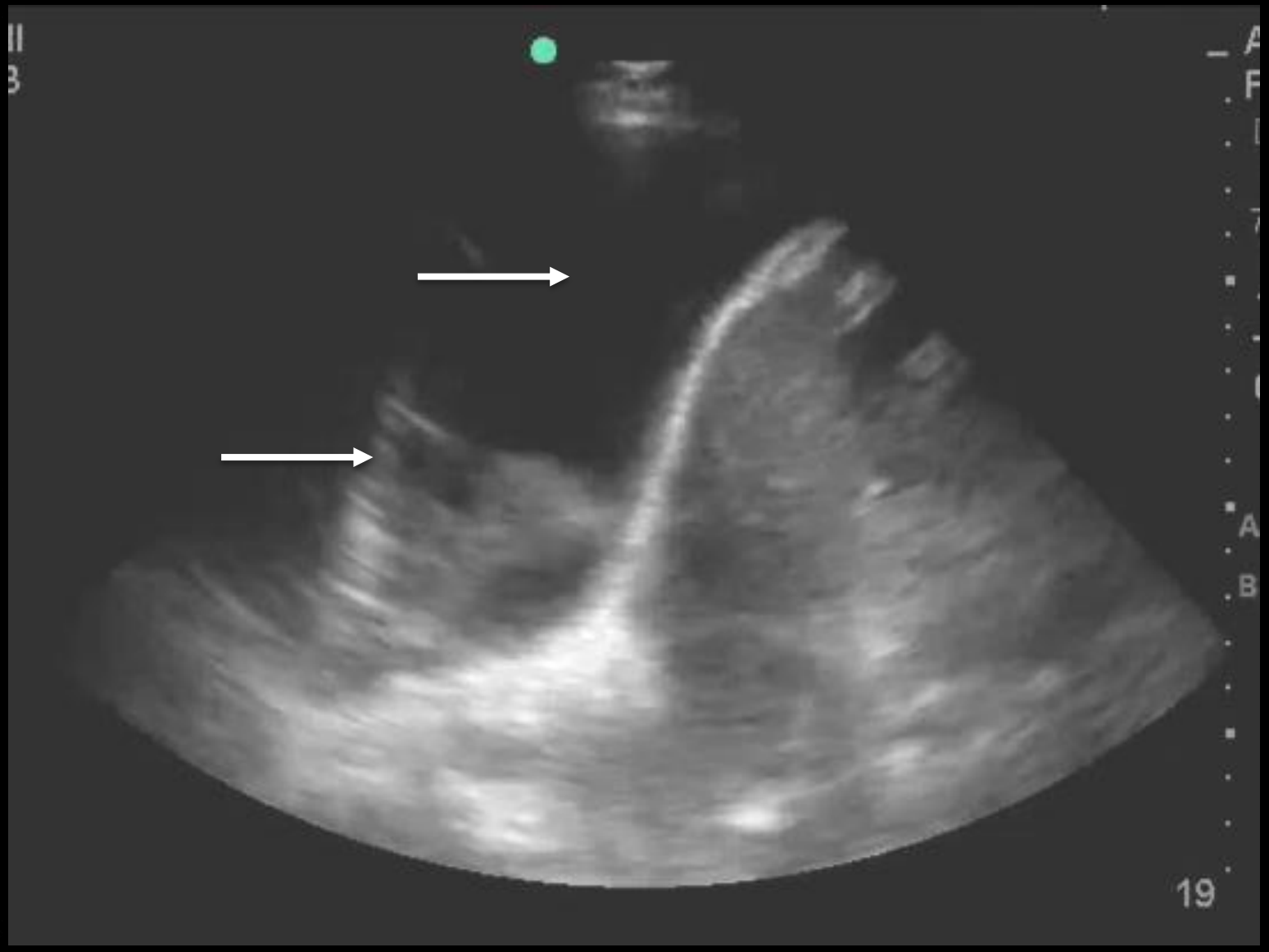
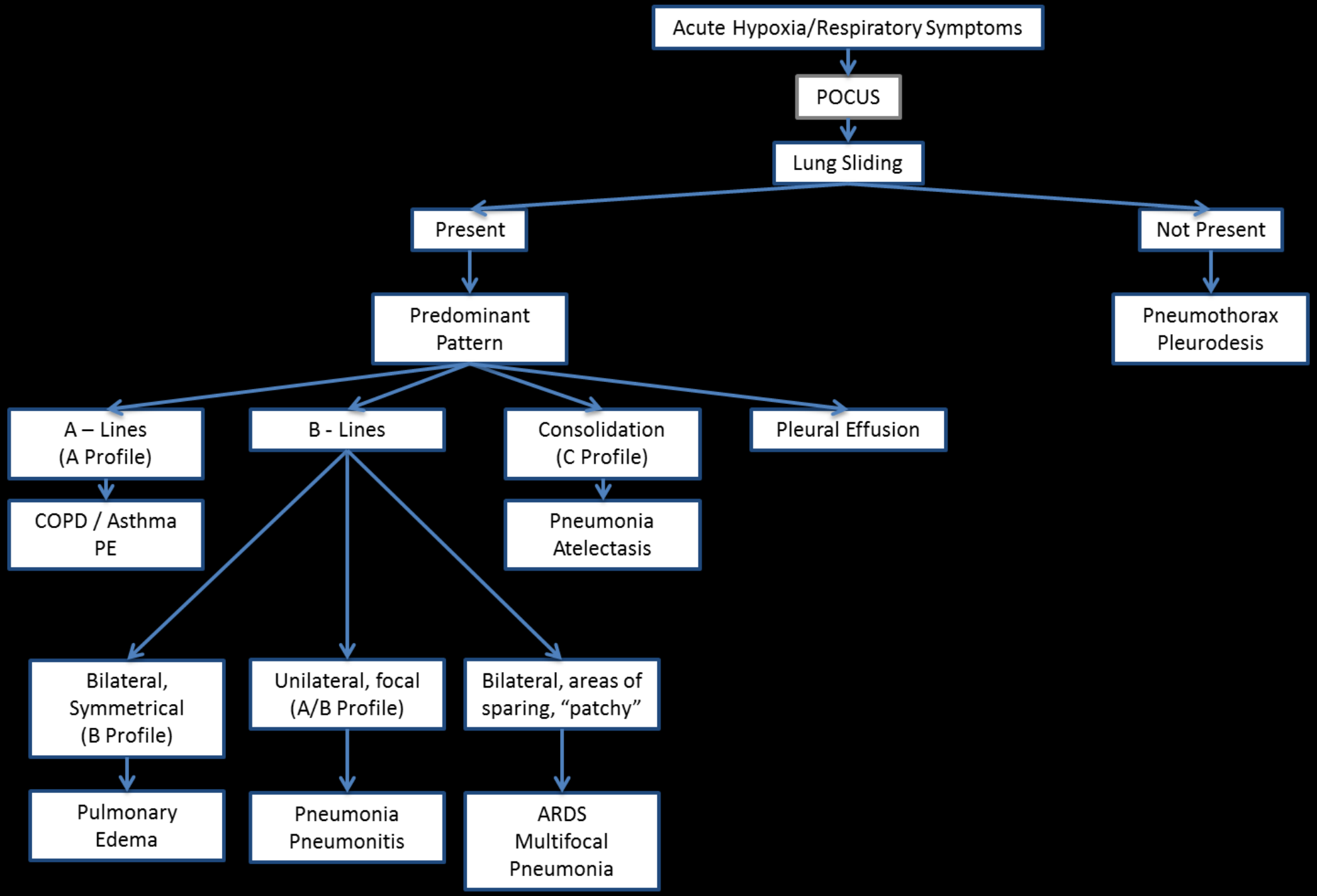
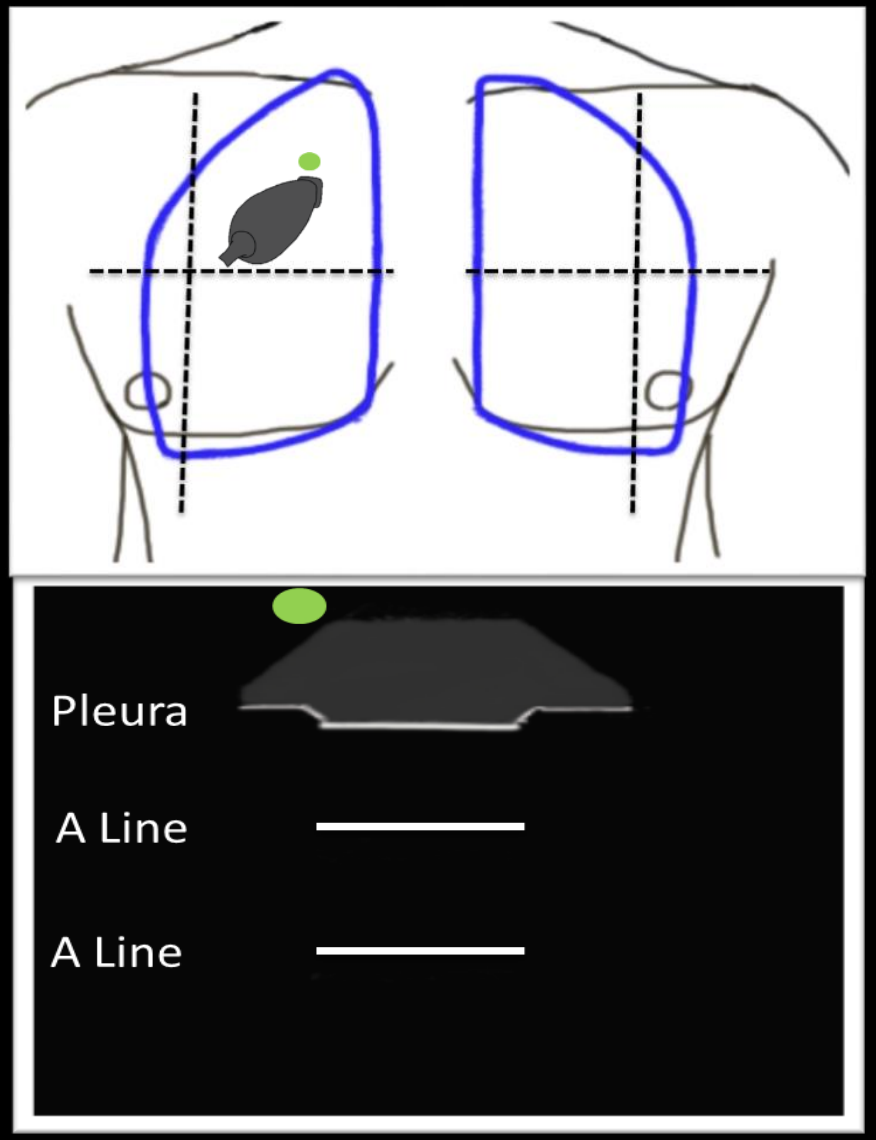




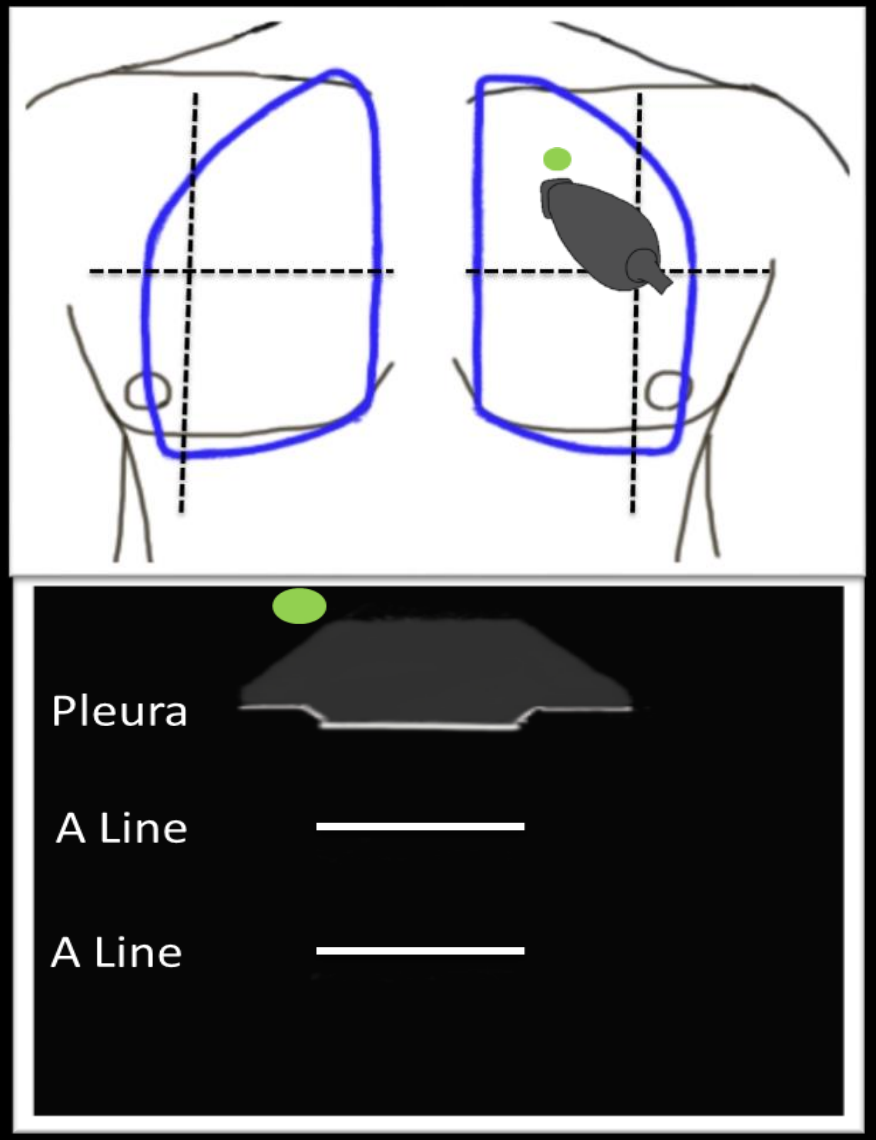



Acute Hypoxia/Respiratory Symptoms
POCUS
Lung Sliding
Present
Not Present
Predominant Pattern
Pneumothorax Pleurodesis
A – Lines (A Profile)
B - Lines
Consolidation (C Profile)
Pleural Effusion
COPD / Asthma PE
Pneumonia Atelectasis
Bilateral, Symmetrical (B Profile)
Unilateral, focal (A/B Profile)
Bilateral, areas of sparing, "patchy"
Pulmonary Edema
Pneumonia Pneumonitis
ARDS Multifocal Pneumonia

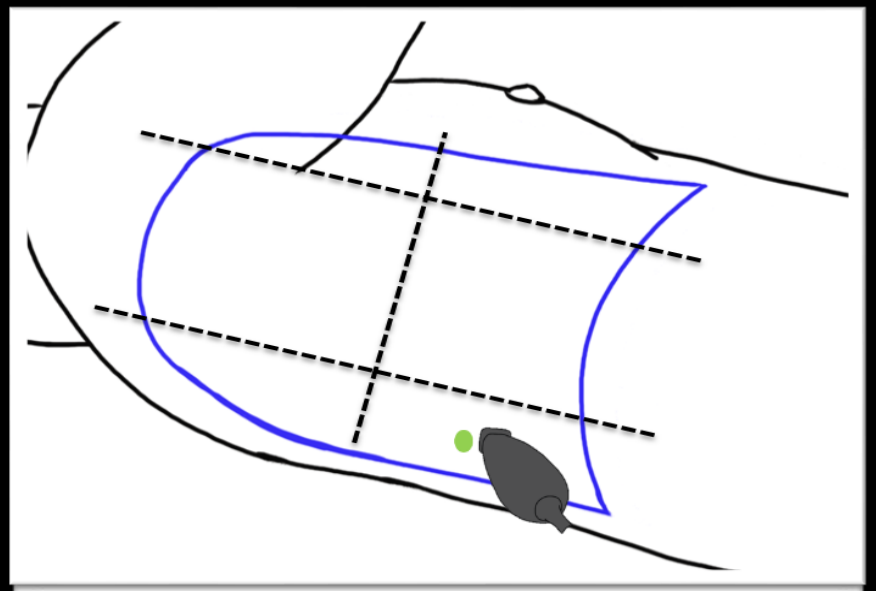
CASE 1

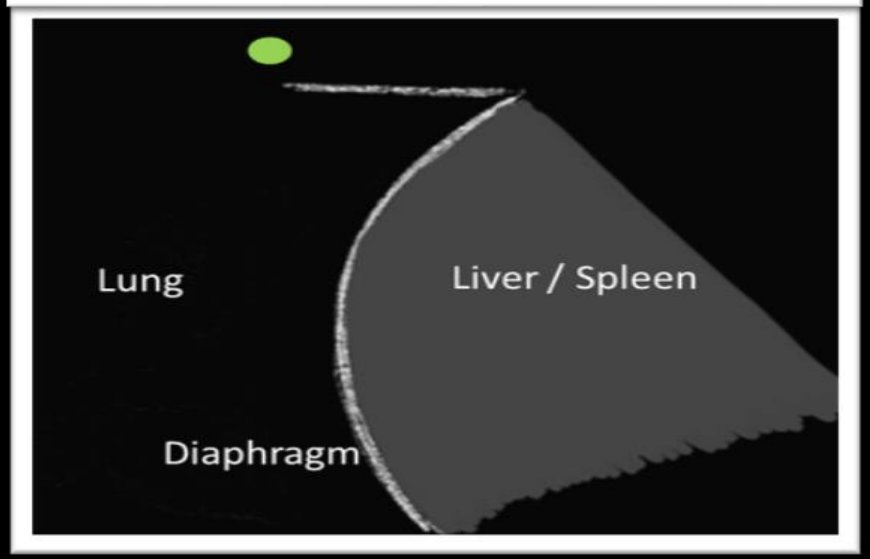


CASE 1

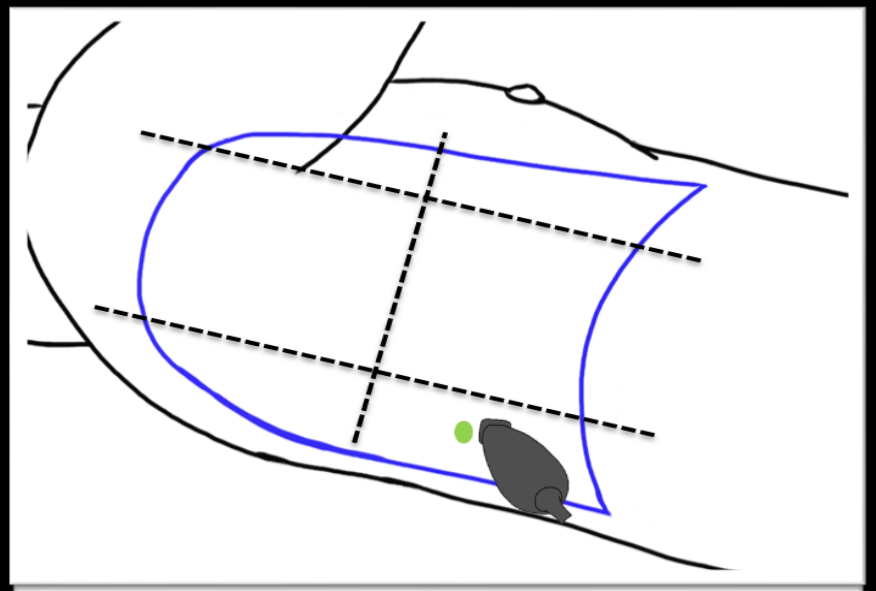


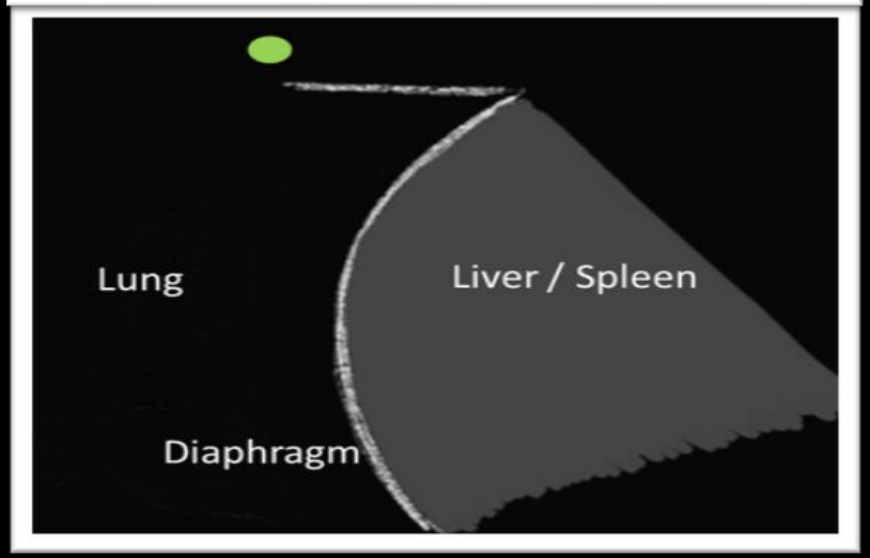
CASE 1





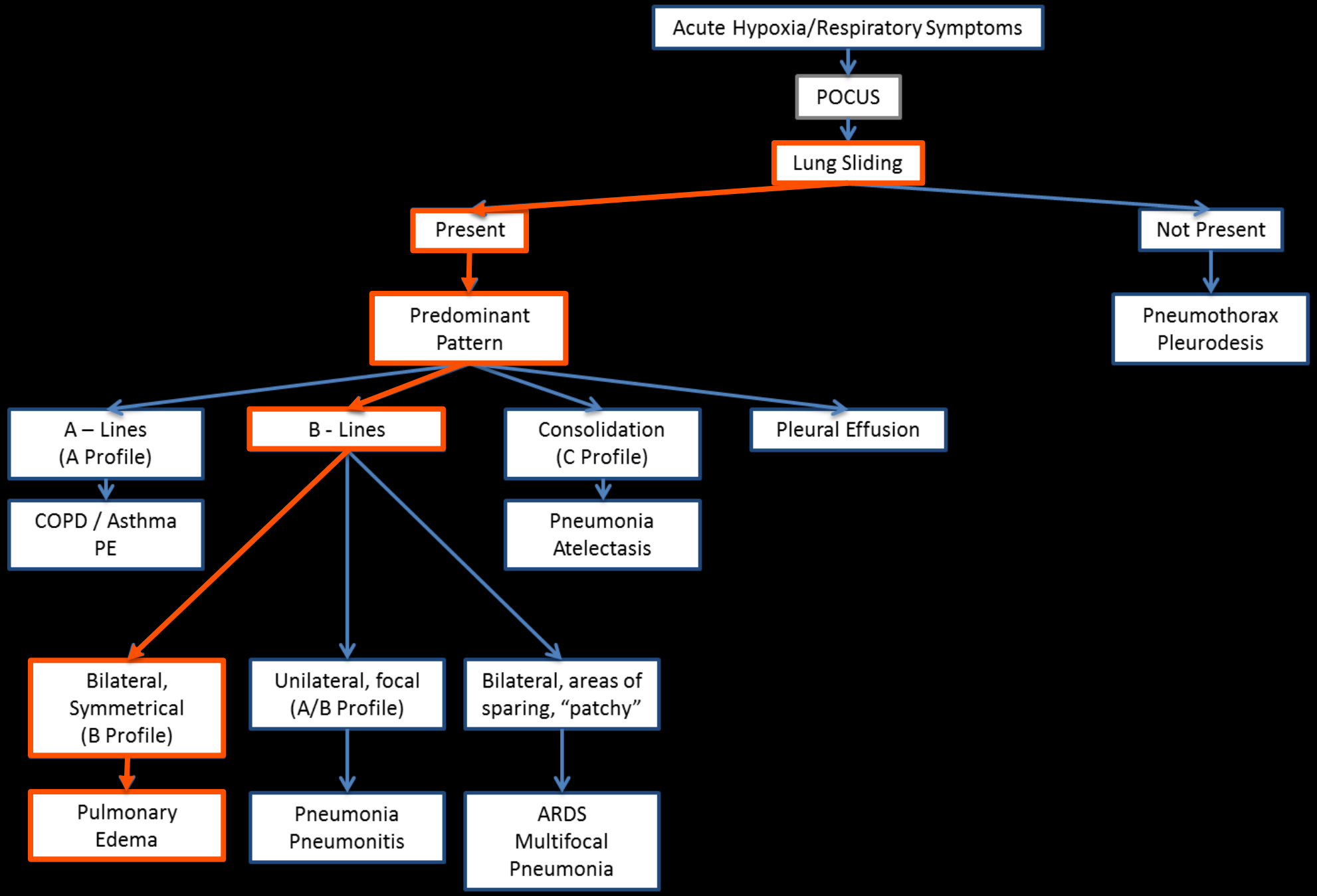
CASE 1





REFLECTION QUESTIONS

- Based on the lung ultrasound, what is the likely cause of the patient's hypoxia


Acute Hypoxia/Respiratory Symptoms
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Unilateral, focal
(A/B Profile)
Bilateral, areas of
sparing, “patchy”
Pulmonary
Edema
Pneumonia
Pneumonitis
ARDS
Multifocal
Pneumonia

REFLECTION QUESTIONS

- Putting the patient’s FoCUS and Lung ultrasound together, what is the likely diagnosis?
- What further evaluation and treatment would you recommend?

Literature Review – Case 1

- Diagnosing CHF
  - In patients admitted for dyspnea, where the final diagnosis was CHF exacerbation, CHF was missed on initial presentation in 33.5% of cases.
  - In patients presenting for dyspnea and a history of CHF and COPD, correct diagnosis (CHF exacerbation vs COPD exacerbation) was made in 52% of cases.

- Collins SP, Lindsell CJ, Peacock WF,Eckert DC, Askew J, Storrow AB. Clinical Characteristics of emergency depatrement heart failure patients initially diagnosed as non-heart failure. BMC Emergency Medicine. 2006;6:11. doi:10.1186/1471-227X-6-11.
- Russell FM, Ehrman RR, Cosby K, Ansari A, Tseeng S, Christain E, Bailitz J. Diagnosing acute heart failure in patients with undifferentiated dyspnea: a lung and cardiac ultrasound (LuCUS) protocol. Academic Emergency Medicint. 2015;22:182-191.

Literature Review – Case 1

- Diagnosing Acute Heart Failure in the Emergency Department: A Systematic Review and Meta-analysis
  - Chest X-ray: Sensitivity **56.9%**, Specificity 89.2%.
  - Lung Ultrasound: Sensitivity 85.3%, Specificity 92.7%.

"Bedside lung US and echocardiography appear to the **most useful test** for affirming the presence of AHF."

- Martindale JL, Wakai A, Collins SP, Levy PD, Diercks D, Heistand BC, Fermann GJ, deSouza I, Sinert R. Diagnosing Acute heart Failure in the Emergency Department: A Systematic Review and Meta-analysis. Acad Emerg Med. 2016;23(3):223-242.

Literature Review - Case 1

- Pulmonary Edema

	Chest X-Ray	Lung Ultrasound
Sensitivity	56.9%	85.3 – 92.1%
Specificity	89.2%	92%
+ LR	5.2	12.38
- LR	0.48	0.06

- Alrajab S, Yousef AM, Akkus N, Caldito G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of theliterature and meta-analysis. Critical Care 2013, 17:R208.
- Martindale JL, Wakai A, Collins SP, et al. Diagnosing Acute Heart Failure in the Emergency Department: A Systematic Review and Meta-analysis. Acad Emerg Med. 2016 Mar;23(3):223-42. doi: 10.1111/acem.12878. Epub 2016 Feb 13.
- Al Deeb M, Barbic S, Featherstone R, Dankoff J, Barbic D. Point-of-Care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: a systematic review and meta-analysis. Acad Emerg Med . 2014 Aug;21(8):843-52. doi: 10.1111/acem.12435

Literature Review - Case 1

- Pneumothorax

	Chest X-Ray	Lung Ultrasound
Sensitivity	50.2%	90.9%
Specificity	99%	99%
+ LR	50	50.5
- LR	0.51	0.09

- Alrajhi K, Yoo MY, Vaillancourt C. Test Characteristics of Ultrasonography for the Detection of Pneumothorax: a Systematic Review and Meta-analysis. CHEST 2012; 141(3):703–708.
- Alrajab S, Yousef AM, Akkus N, Caldito G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of theliterature and meta-analysis. Critical Care 2013, 17:R208.

Literature Review - Case 1

- Pneumonia

	Chest X-Ray	Lung Ultrasound
Sensitivity	38 - 64%	85 – 96%
Specificity	93%	93 – 96%
+ LR	9.14	12.14
- LR	0.39	0.16

- N. Xirouchaki, E, Magkanas, K, Vaporidi, et al.: Lung ultrasound in critically ill patients: comparison with bedside chest radiography. Intensive Care Med. 37:1488-1493 2011
- Alzahrani SA, Al-Salamah MA, Al-Madani WH, et al. Systematic review and meta-analysis for the use of ultrasound versus radiology in diagnosing of pneumonia. Crit Ultrasound J (2017) 9:6.
- Pereda MA, Chavez MA, Hooper-Miele CC, et al. Lung Ultrasound for the Diagnosis of Pneumonia in Children: A Meta-analysis. Pediatrics. 135: 714-722

Literature Review - Case 1

- Pleural Effusions

	Chest X-Ray	Lung Ultrasound
Sensitivity	51%	94%
Specificity	91%	98%
+ LR	5.6	47
- LR	0.54	0.06

- Yousefifard M, Baikpour M, Ghelichkhani P, Asady H, Shahsavari NK, Moghadas JA, Hosseini M, Safari S. Screening Performance Characteristics of Ultrasonography and Radiography in Detection of Pleural Effusion: a Meta-Analysis. Emerg (Tehran). 2016;4(1):1-10.

Literature Review - Case 1

- Pleural Effusions
  - Chest X-ray misses up to 10% of parapneumonic effusions warranting thoracentesis.
  - Chest X-Ray only identifies only 70% loculated effusions, while POCUS identifies 94% (compared to CT)
  - The American Association for Thoracic Surgery consensus guidelines for the management of empyema recommends routine use of ultrasound for evaluation of pleural space infections.

- Himelman R, Callen P. The Prognostic Value of Loculations in Parapneumonic Pleural Effusions. Chest. 1986; 90: 852–56.
- Svigals P, Chopra A, Rvenel J, Nietert P, Huggins J. The accuracy of pleural ultrasonography in diagnosing complicated parapneumonic pleural effusions. Thorax. 2017;72(1): 94-95.
- Shen K, Bribriesco A, Crabtree T, Denlinger C, Eby J, Eiken P, Jones D, Keshavjee S, Maldonado F, Paul S, Kozower B. The American Association for Thoracic Surgery consensus guidelines for the management of empyema. The Journal of Thoracic and Cardiovascular Surgery. 2017;153(6):129-146.

Case 2

HPI

- A 72 year old female presents to the emergency department for evaluation of right lower extremity redness and swelling.
- She endorses:
  - Generalized malaise
  - Flushing
  - Dyspnea and dyspnea on exertion
  - Bilateral lower extremity swelling, right greater than left.

HISTORY

- Past Medical History:
  - CAD
  - Hypertension
  - Hyperlipidemia
  - Diabetes mellitus type II.
  - Diastolic heart failure
- Past Social History:
  - Smoker (50 pack years).
  - Daily alcohol use.

OBJECTIVE DATA

- Vital Signs:
  - HR 110, BP 101/51, SpO2 89% on room air, RR 24, Tmax 37.7 Celcius.
- Physical Exam:
  - Mental – Alert, oriented. Moderate acute distress, appears uncomfortable.
  - Heart – Regular rhythm and rate.
  - Lungs – Faint crackles in the bilateral bases; left slightly greater than right.
  - Lower extremities – 2+ pitting edema noted on the left, 3+ pitting edema noted on the right. Erythema and tenderness from the right thigh distally to just below the knee.

REFLECTION QUESTIONS

- What is the differential diagnosis for the patient's presentation, noting her symptoms (lower extremity edema, RLE redness, SOB / DOE) and her abnormal vital signs?

Cellulitis
Abscess
Necrotizing fasciitis
DVT / PE

VASCULAR ULTRASOUND

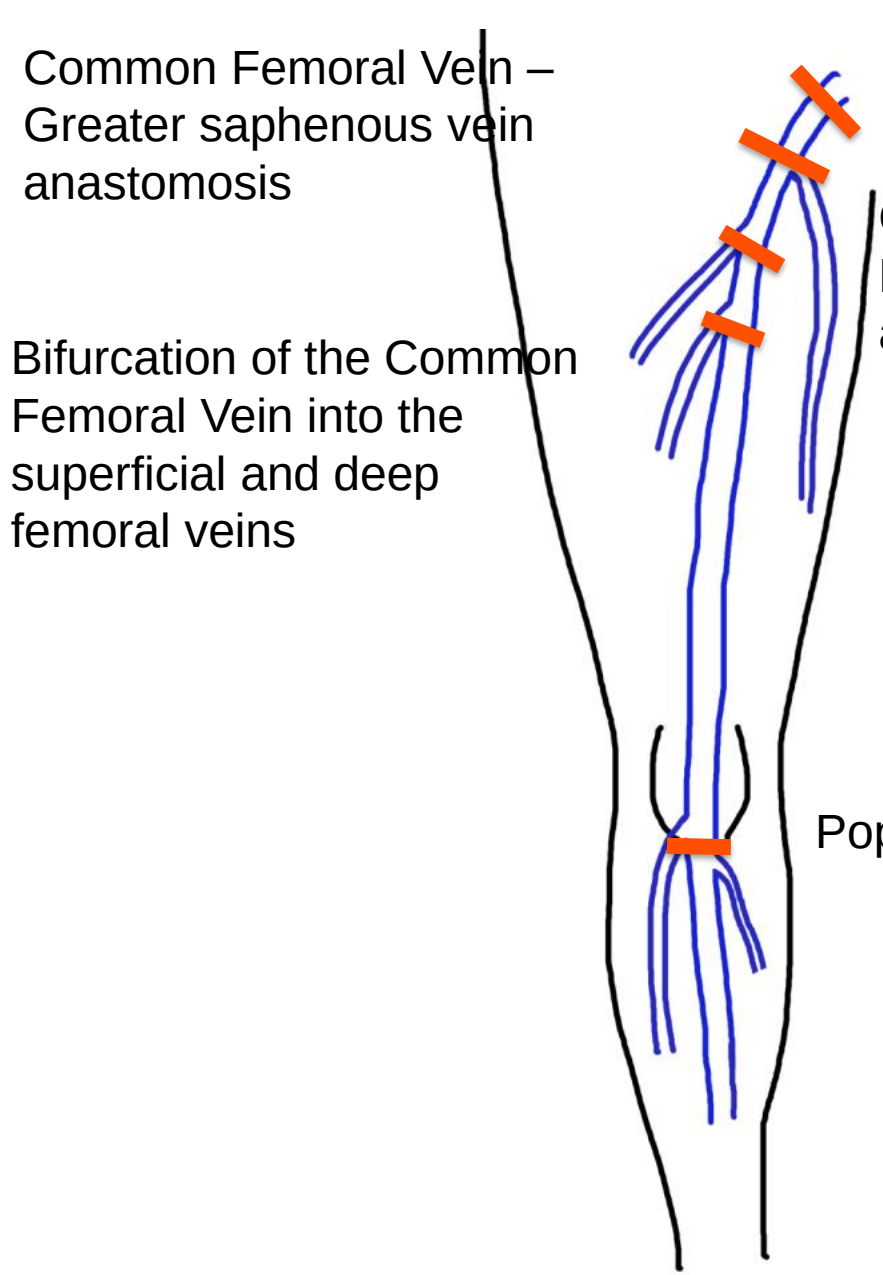
- Scope
  - Rule out DVT via compressive ultrasonography
  - Rule out PE?

VASCULAR ULTRASOUND

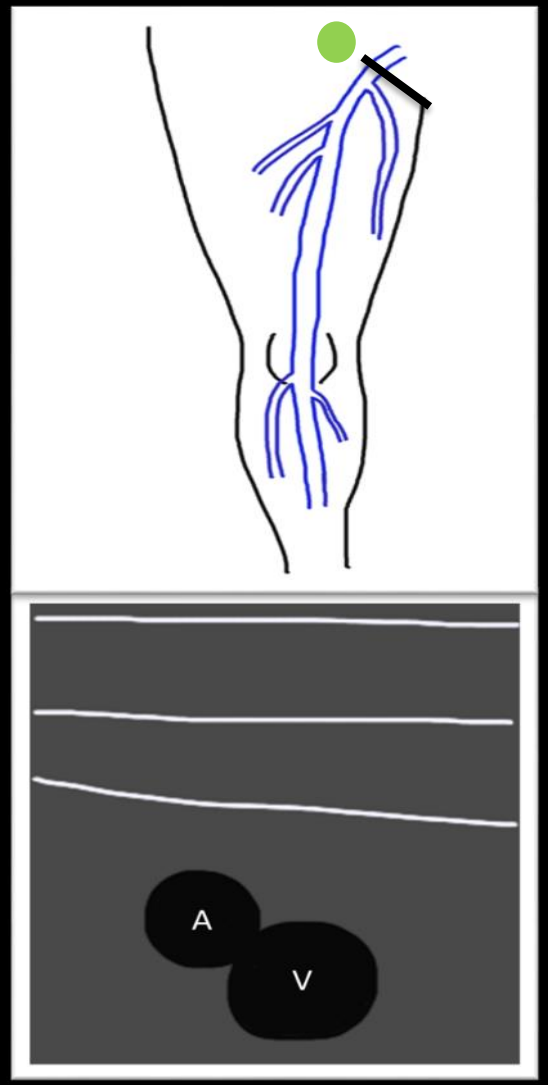
- Compressive ultrasonography
  - Compressible veins = Normal
  - Non-compressible veins = abnormal (probable DVT)
- 2 point vs 3 point vs 5 point exam vs compression every 1-2 cm.

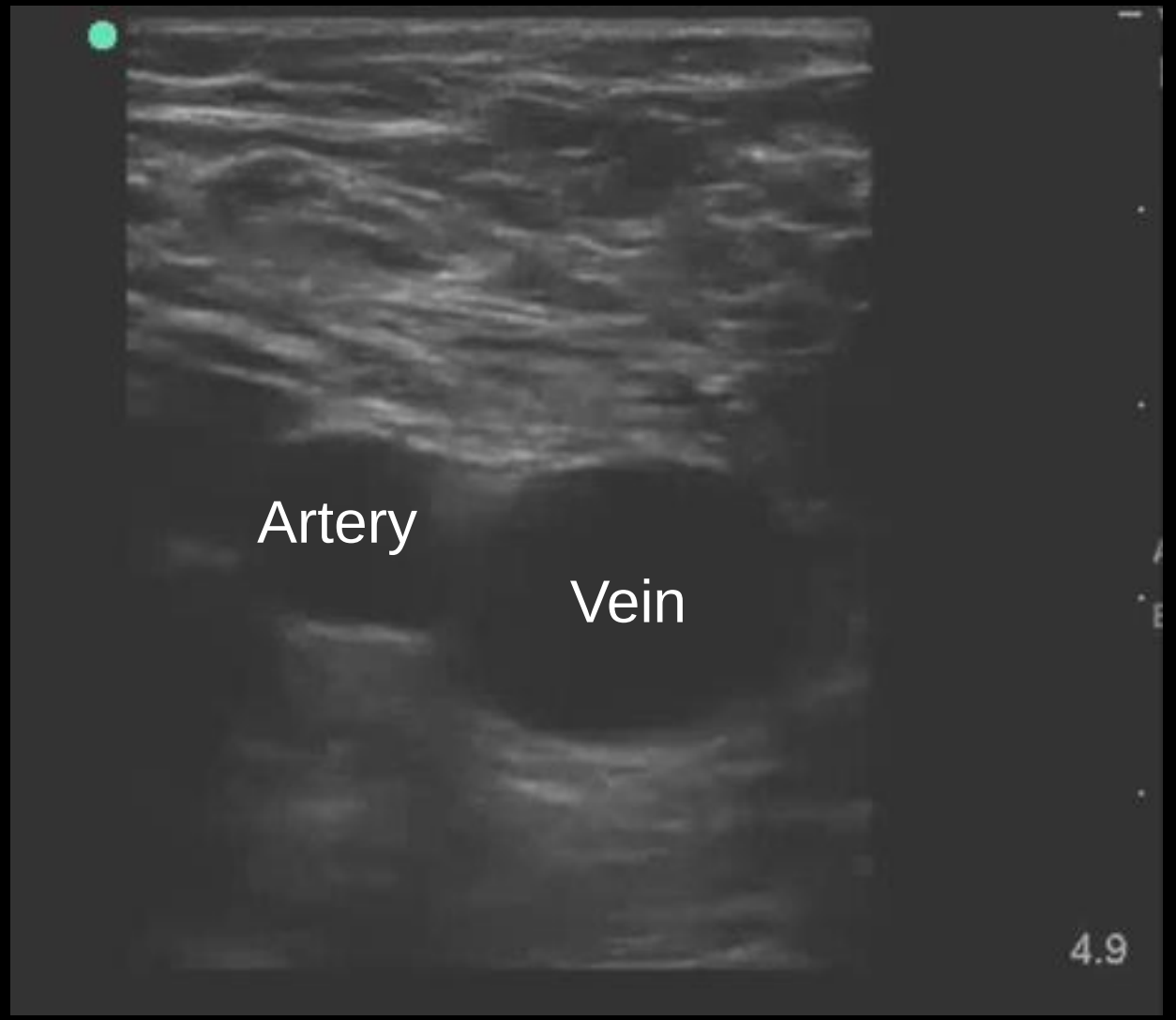
VASCULAR ULTRASOUND

- 5 Point Exam

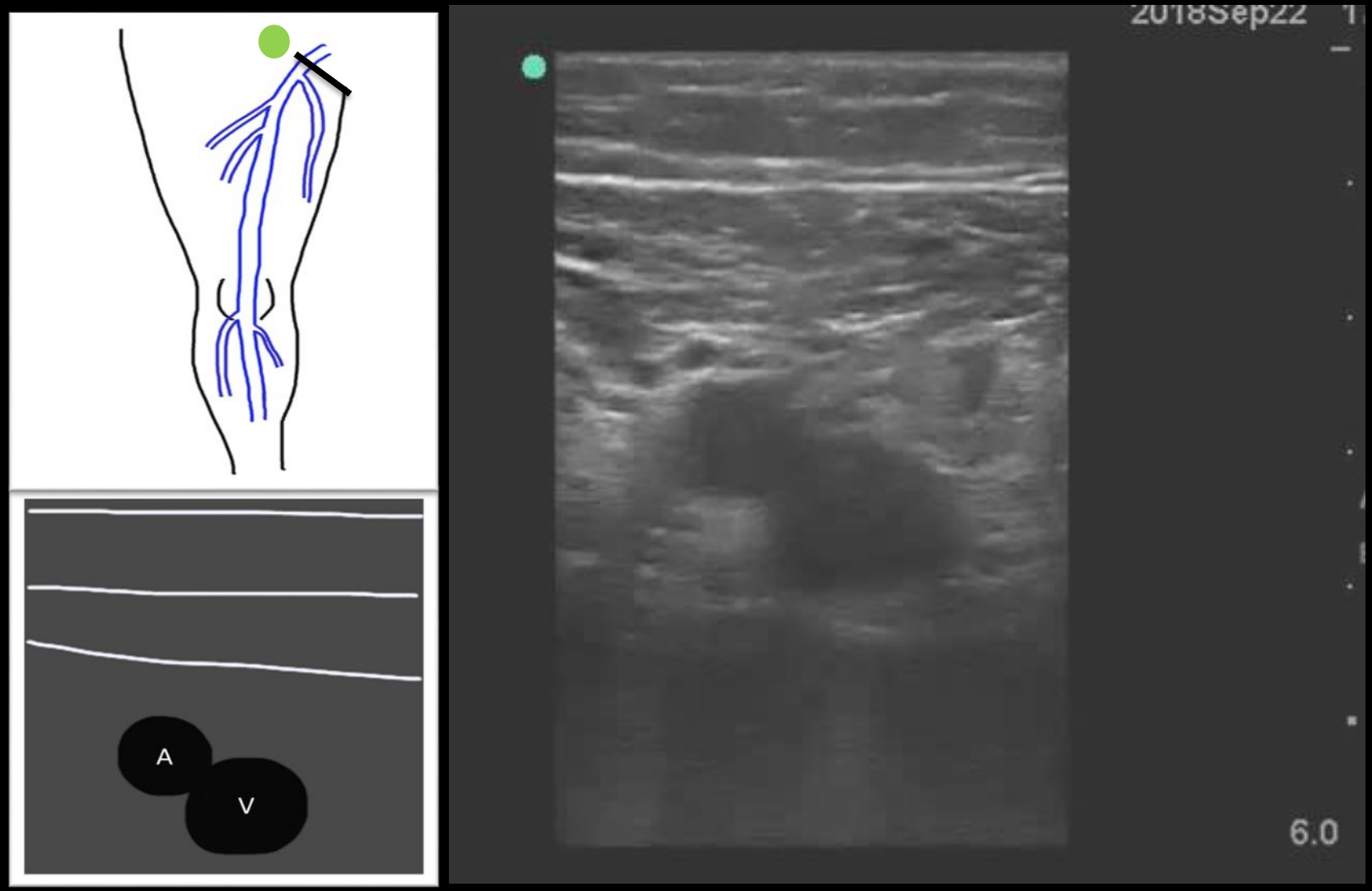


VASCULAR ULTRASOUND

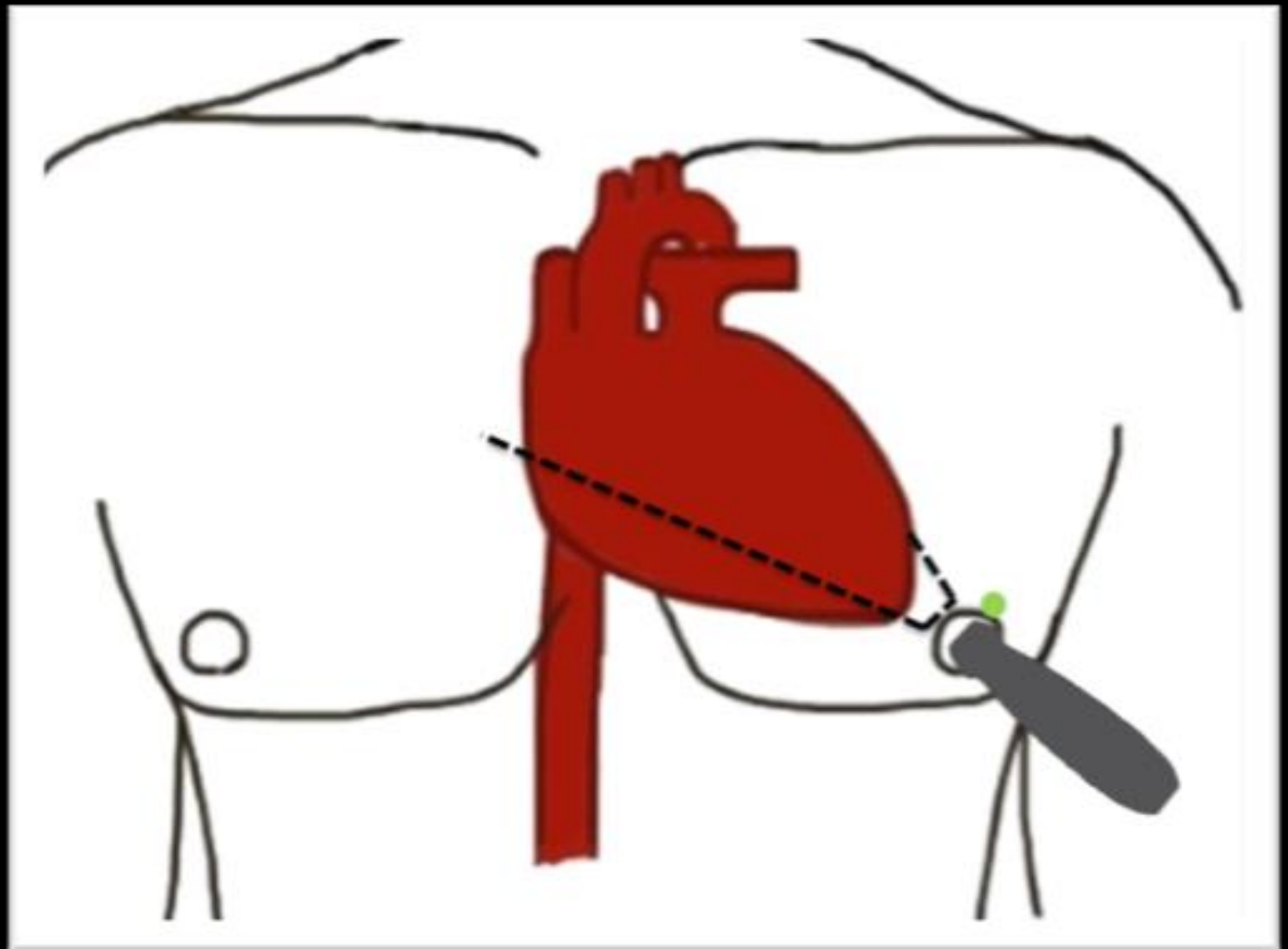




VASCULAR ULTRASOUND – DVT



Apical 4 Chamber (A4C)



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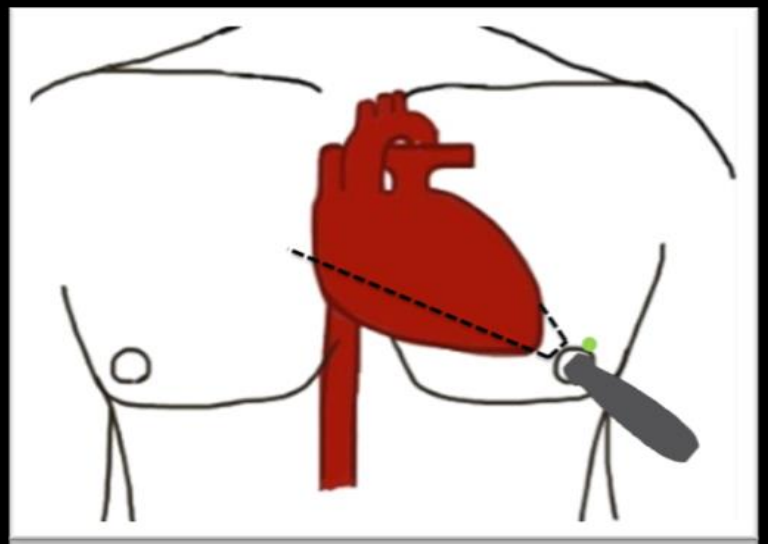
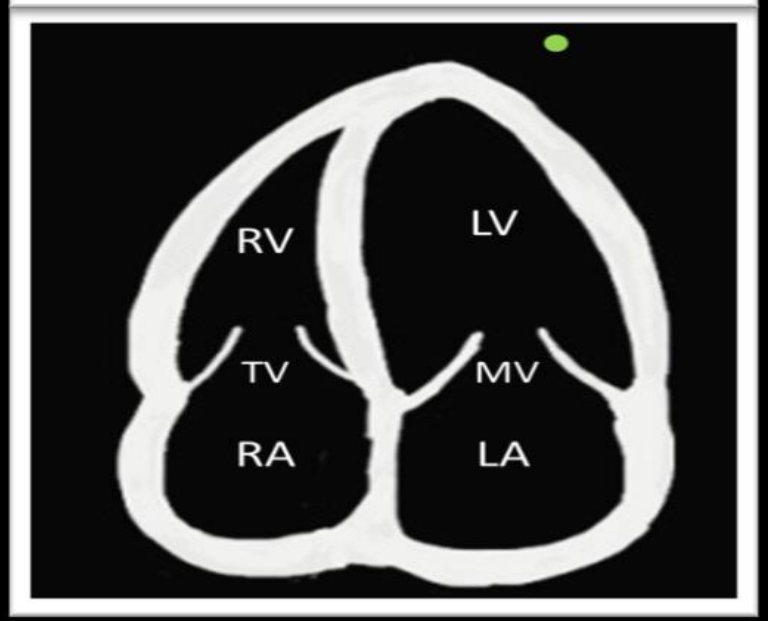
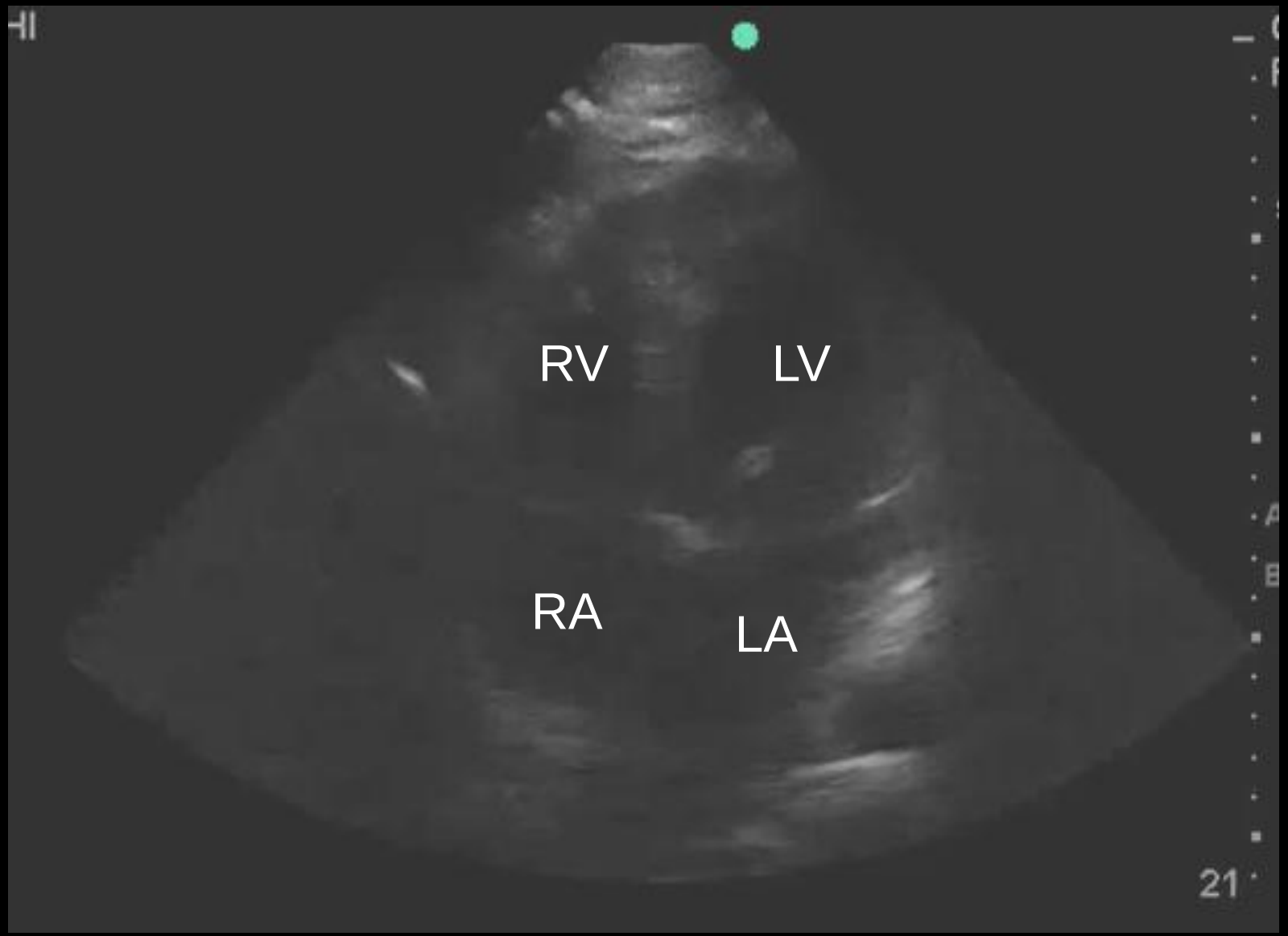
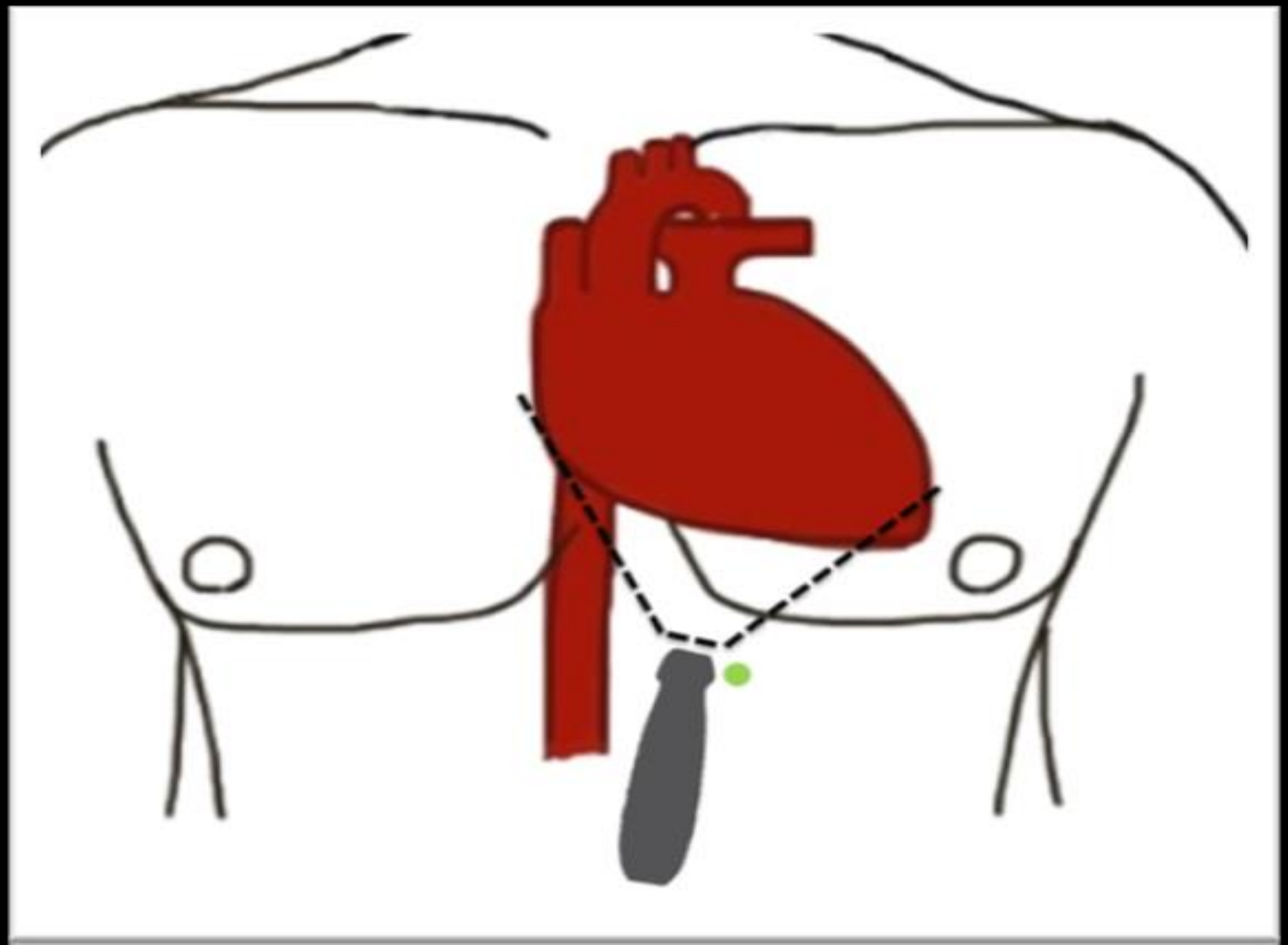


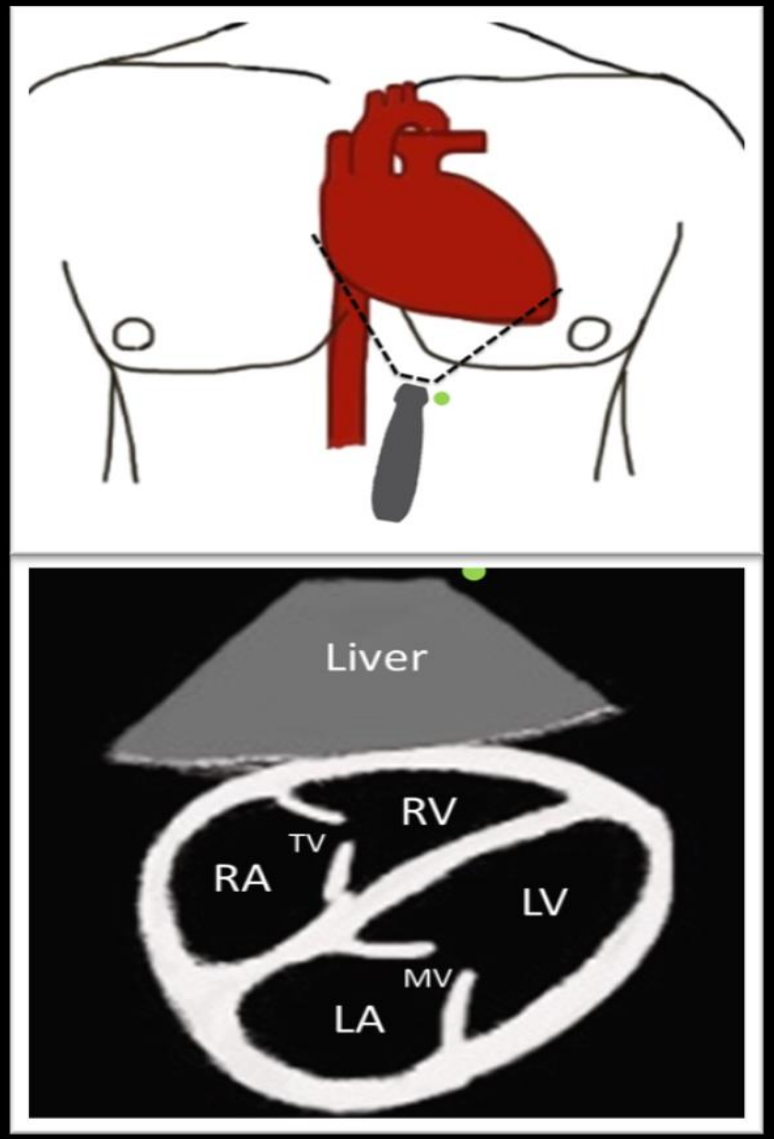


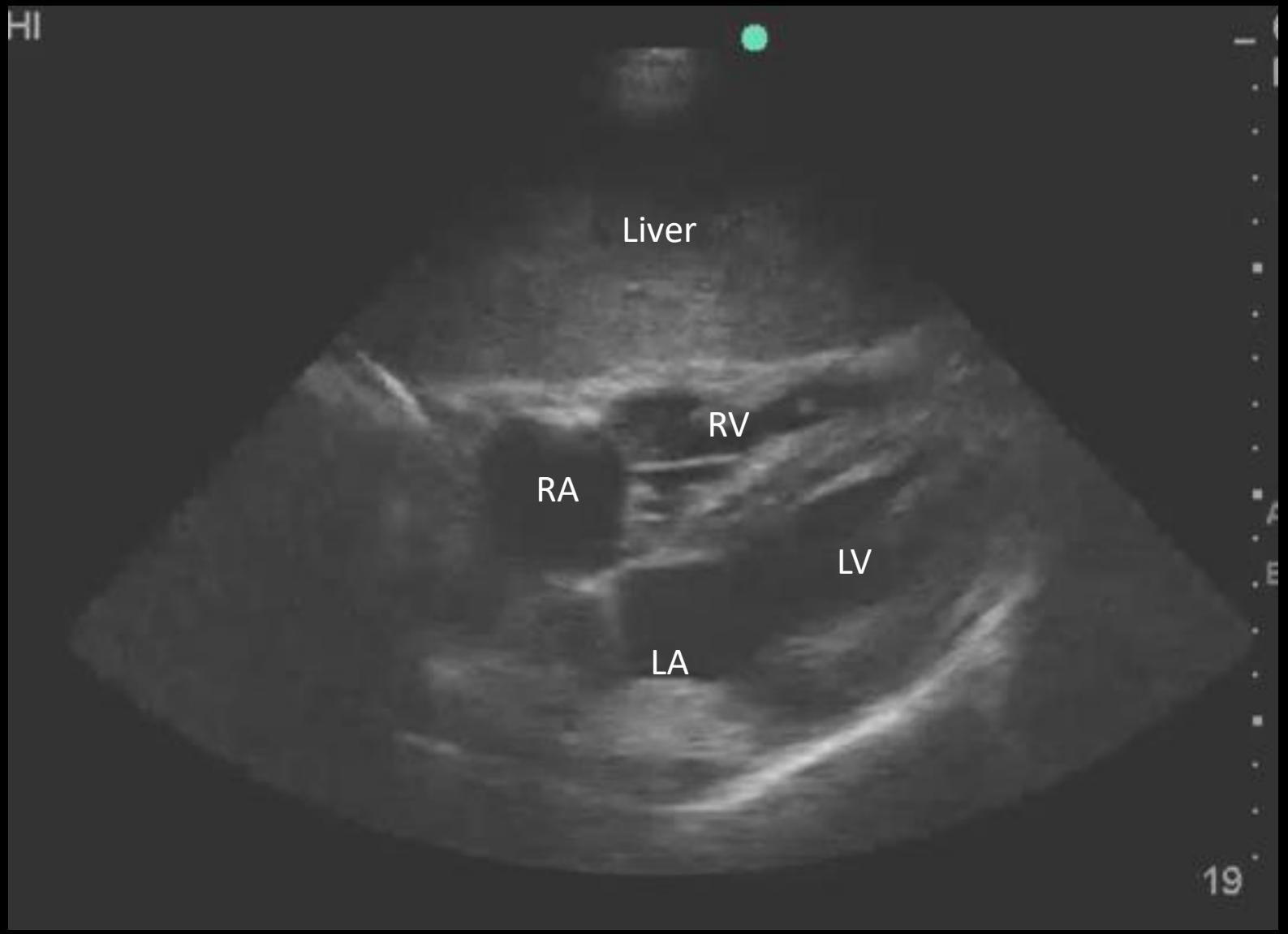


Subcostal 4 Chamber (S4C)

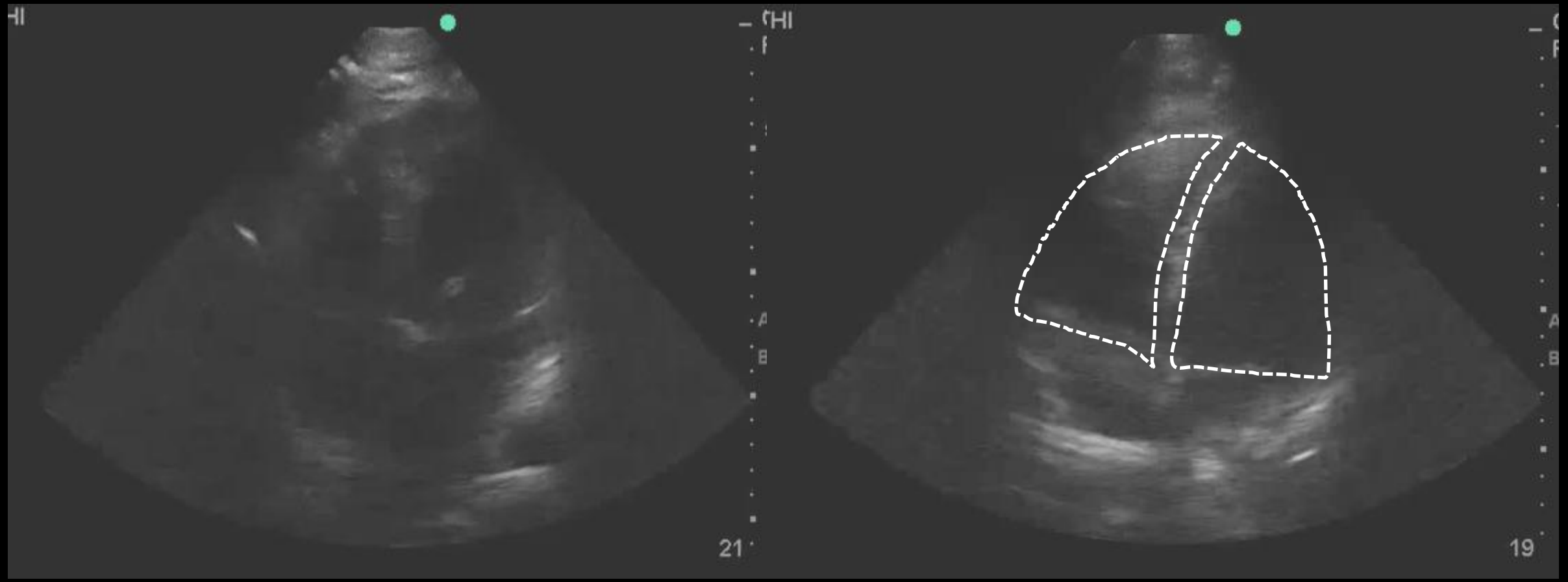


Subcostal 4 Chamber (S4C)





RV Enlargement – A4C



LITERATURE REVIEW – CASE 2

- DVT
  - Sensitivity: 96.1%
  - Specificity: 96.8%

- Pomero F. Dentali F, Borretta V, Bonzini M, Melchio, Douketis, JD, Fenoglio. Accuracy of emergency physician-performed ultrasonography in the diagnosis of deep-vein thrombosis: a systematic review, meta-analysis. Thromb Haemost 2013; 109(01): 137-145.

LITERATURE REVIEW – CASE 2

- Multi-organ (Heart, Lung, DVT) POCUS for PE
  - Sensitivity: 90 - 92%
  - Specificity: 64 - 86.2%
- Multi-organ (Heart, Lung, DVT) POCUS for PE + Tachycardia
  - Sensitivity: 100% (from 92%)
  - Specificity: 63% (from 64%)

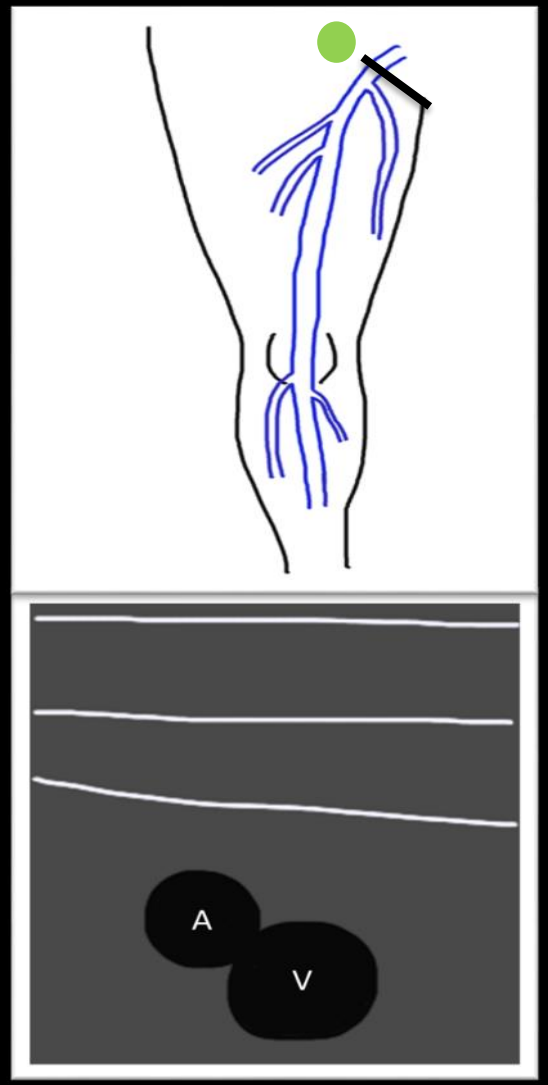
Not a replacement for CT

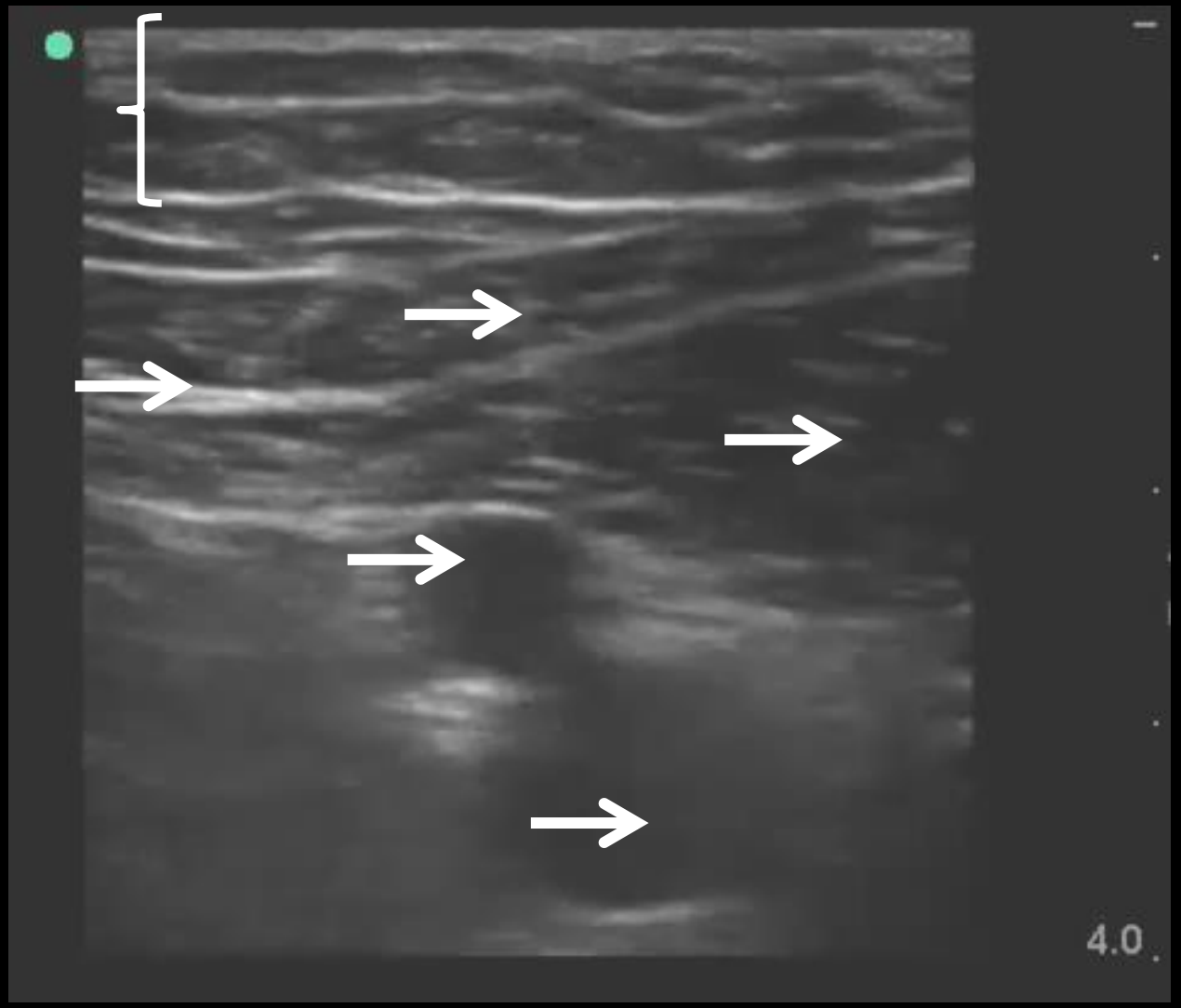
- Pomero F. Dentali F, Borretta V, Bonzini M, Melchio, Douketis, JD, Fenoglio. Accuracy of emergency physician-performed ultrasonography in the diagnosis of deep-vein thrombosis: a systematic review, meta-analysis. Thromb Haemost 2013; 109(01): 137-145.
- Nazerian P, Vanni S, Volpicelli G, et al. Accuracy of point-ofcare multiorgan ultrasonography for the diagnosis of pulmonary embolism. *Chest.* 2014;145(5):950-957.
- Dwyer DJ, Grunwal Z. Increased sensitivity of Focused Cardiac Ultrasound for Pulmonary Emobolism in Emergency Departrment Patients with Abnormal Vital Signs. Academic Emergency Medicine. 2019; 26(11):1211-1220

SOFT TISSUE ULTRASOUND

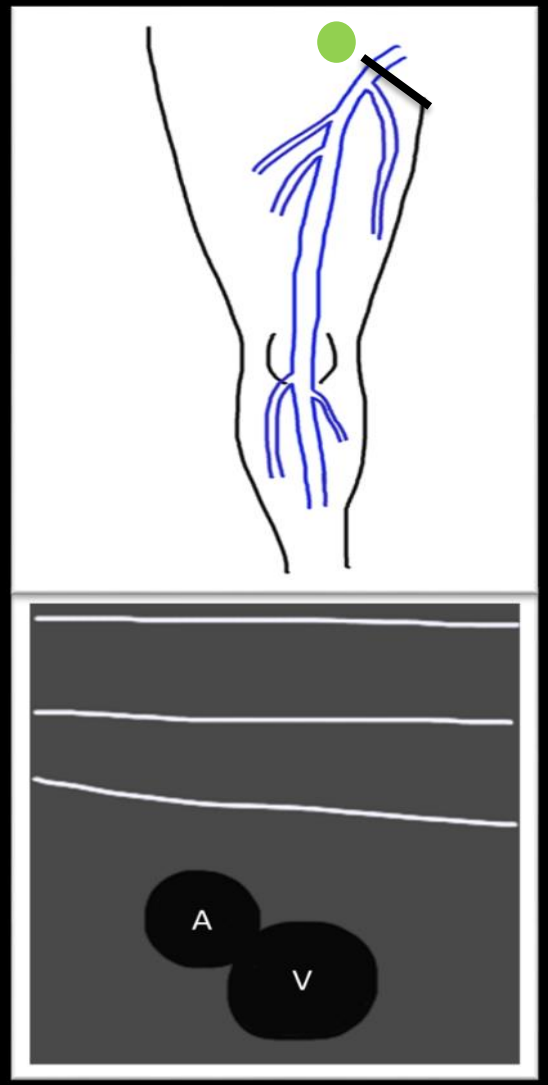
- Scope
  - Skin and Soft Tissue Infection (SSTI) → Cellulitis vs Abscess
  - Foreign body identification

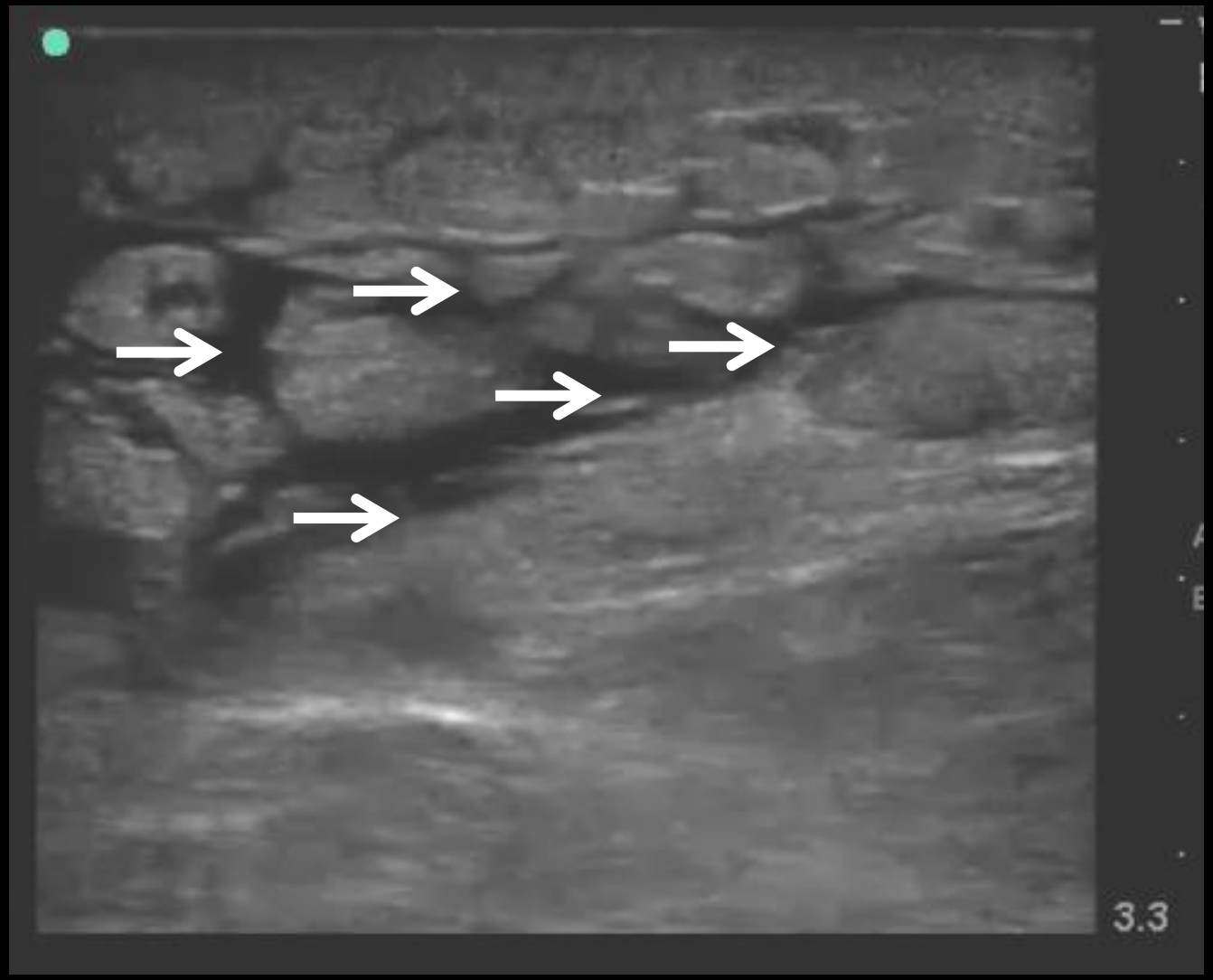
SOFT TISSUE ULTRASOUND - Normal



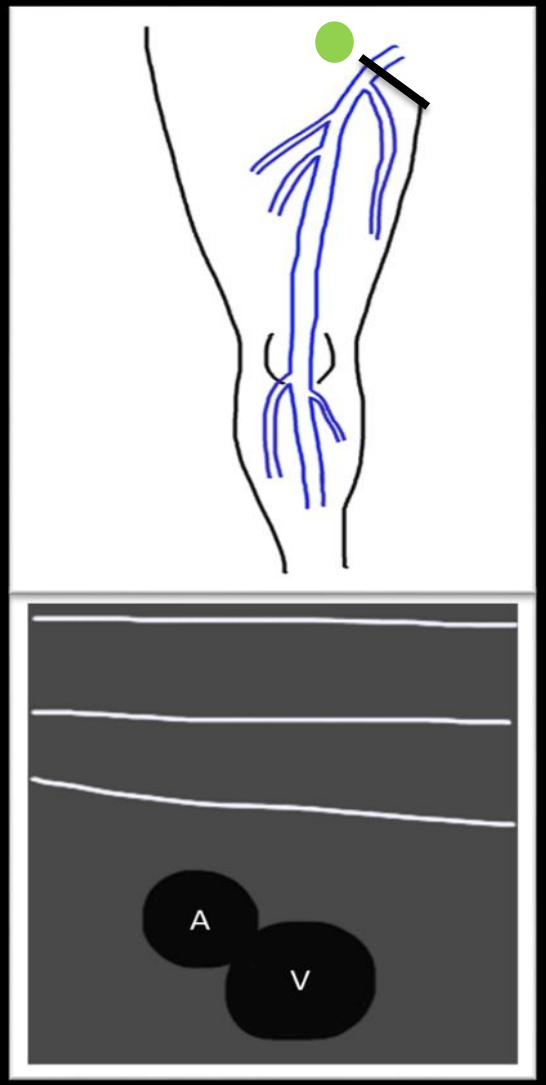


SOFT TISSUE ULTRASOUND – Cobblestoning





SOFT TISSUE ULTRASOUND – Abscess



LITERATURE REVIEW – CASE 2

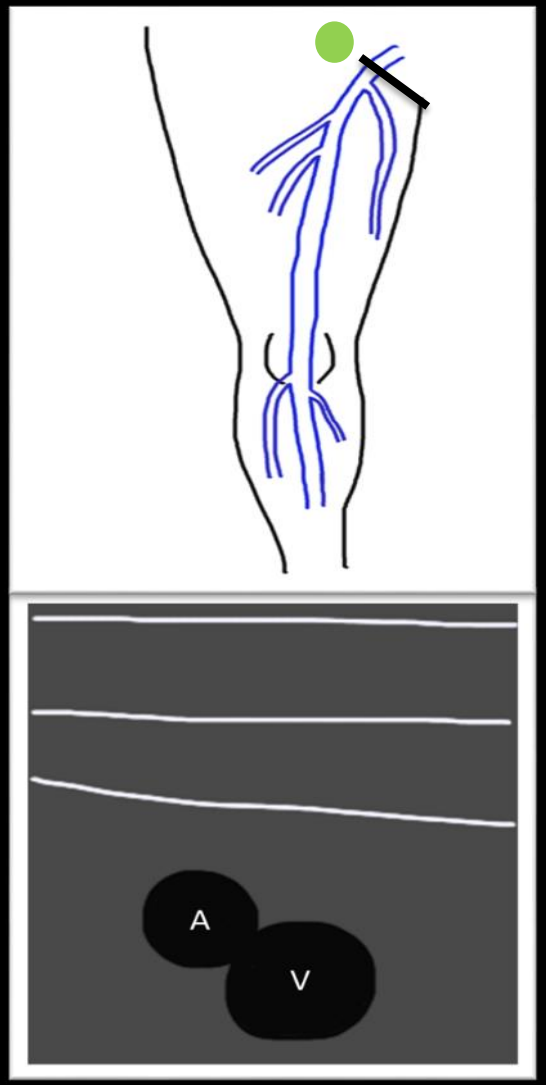
- Cellulitis vs Abscess

	Sensitivity	Specificity
Physical Exam	75 – 95%	60 – 84%
POCUS	95.5 – 97%	80.3 – 83%

  - Changes management (up to 50% of patients)
  - Reduces treatment failure rates (17% to 3.7%)
  - Shorter ED Length of stay.

- Barbic D, Chenkin J, Cho DD, et al. In patients presenting to the emergency department with skin and soft tissue infections what is the diagnostic accuracy of point-of-care ultrasonography for the diagnosis of abscess compared to the current standard of care? A systematic review and meta-analysis. *BMJ Open*. 2017;7(1):e013688.
- Subramaniam S, Bober J, Chao J, Zehtabchi S. Point-of-care ultrasound for diagnosis of abscess in skin and soft tissue infections. *Acad Emerg Med.* 2016;23(11):1298-1306.
- Tayal VS, Hasan N, Norton HJ, Tomaszewski CA. The effect of soft-tissue ultrasound on the management of cellulitis in the emergency department. *Acad Emerg Med*. 2006;13(4):384-388
- Gaspari RJ, Sanseverino A, Gleeson T. Abscess incision and drainage with or without ultrasonography: a randomized controlled trial. *Ann Emerg Med.* 2019;73(1):1-7

CASE 2



CASE 2

LITERATURE REVIEW – CASE 2

- Necrotizing Fasciitis
  - Test Characteristics:
    - Sensitivity 88.2%
    - Specificity 93.3%
    - Study: Single center (Taiwan), 62 patients, abnormally high rate of nec fasc (27.4% of patients) → limits generalizability.
  - Practical Use:
    - Does not replace standard of care
    - But… if you see air in the soft tissues, think necrotizing fasciitis

- Yen ZS, Wang HP, Ma HM, et al. Ultrasonographic screening of clinically-suspected necrotizing fasciitis. *Acad Emerg Med*. 2002;9(12):1448-1451.

Advanced POCUS

QUESTIONS?