



POINT-OF-CARE ULTRASOUND IN CRITICAL ILLNESS

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AAPA 2022
Indianapolis, IN

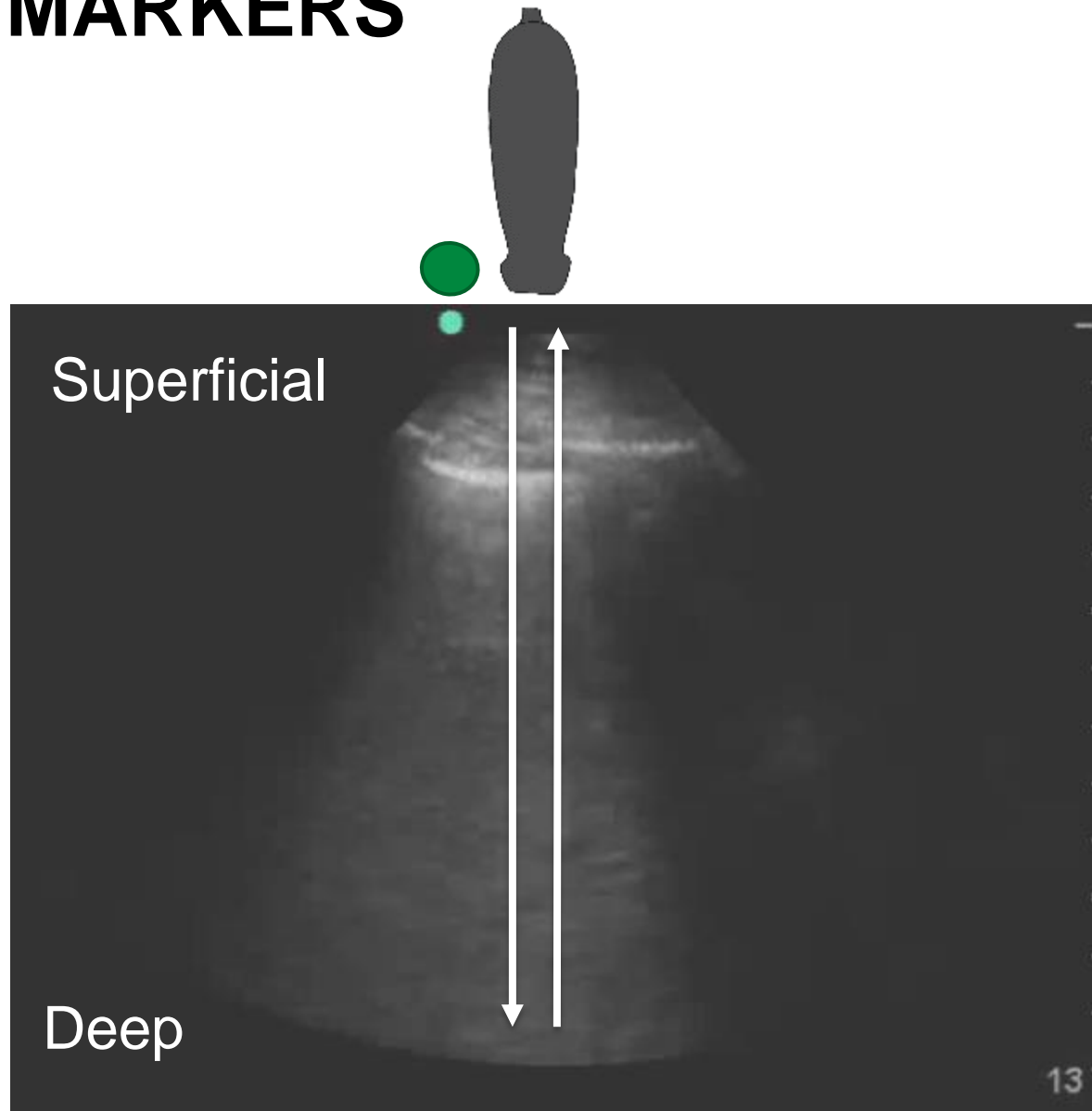
DISCLOSURES

None

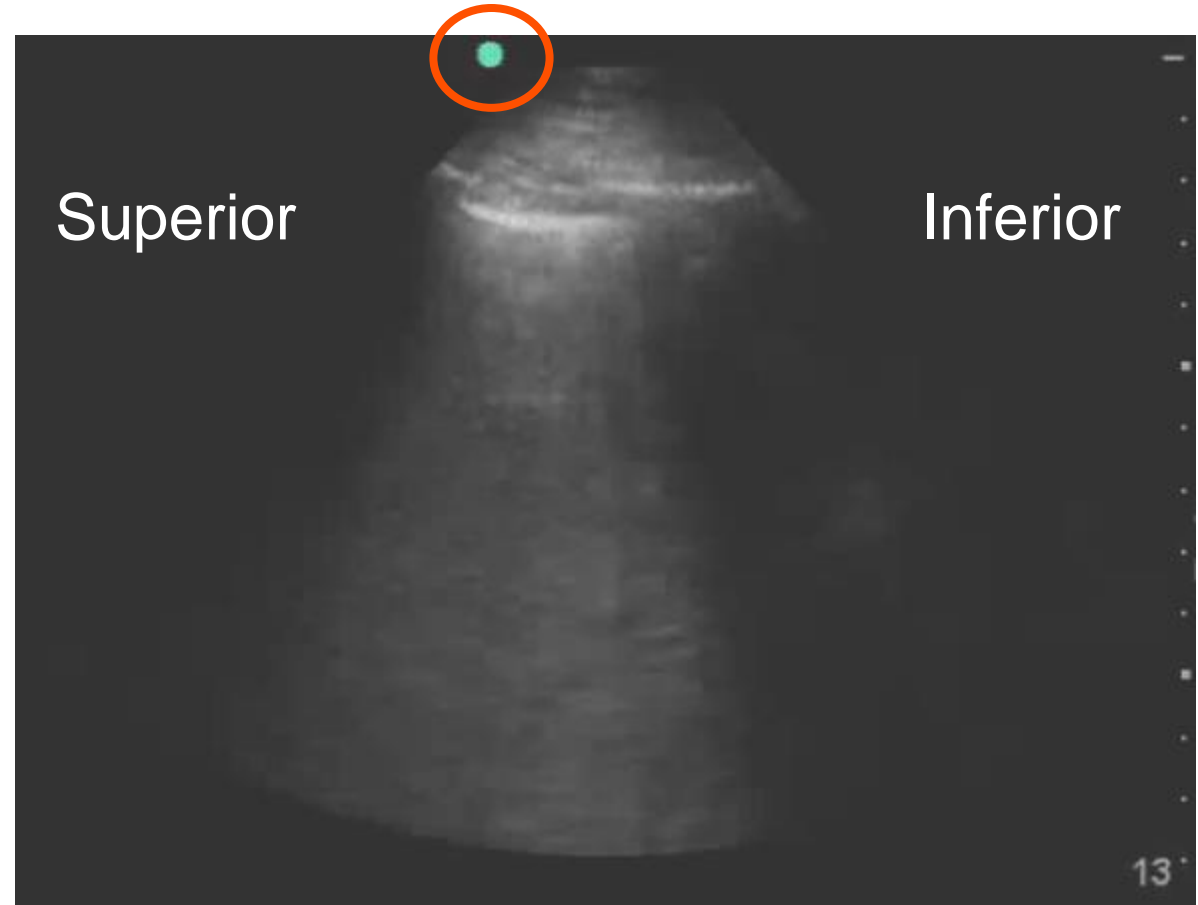
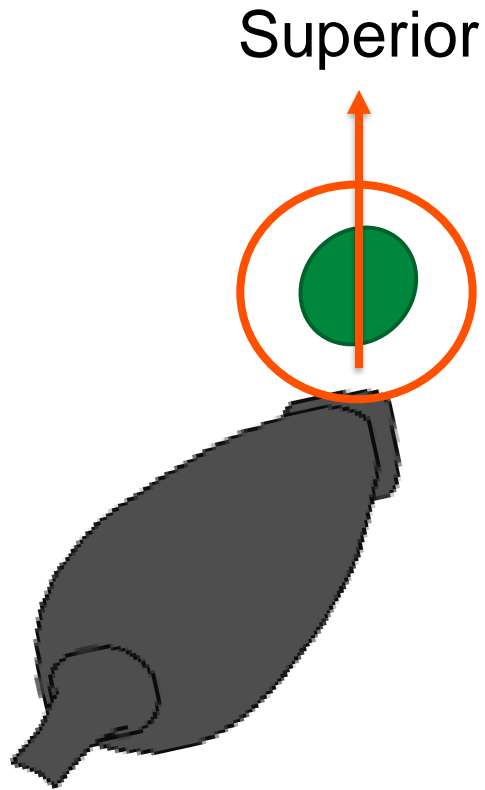
LEARNING OBJECTIVE

- Summarize scope and indications for Point-of-Care Ultrasound (POCUS) in the setting of acute, critical illness.
- Interpret POCUS images in the context of acute, critical illness.
- Contrast evidence for standard of care with POCUS.
- Discuss the effect POCUS has on diagnostic evaluation and treatment of acute, critical illness.

INDICATOR MARKERS

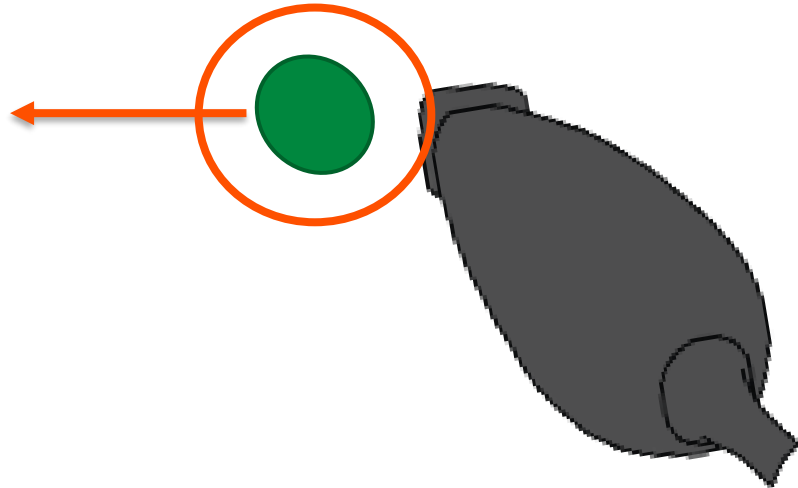


INDICATOR MARKERS



INDICATOR MARKERS

Patient's
Right

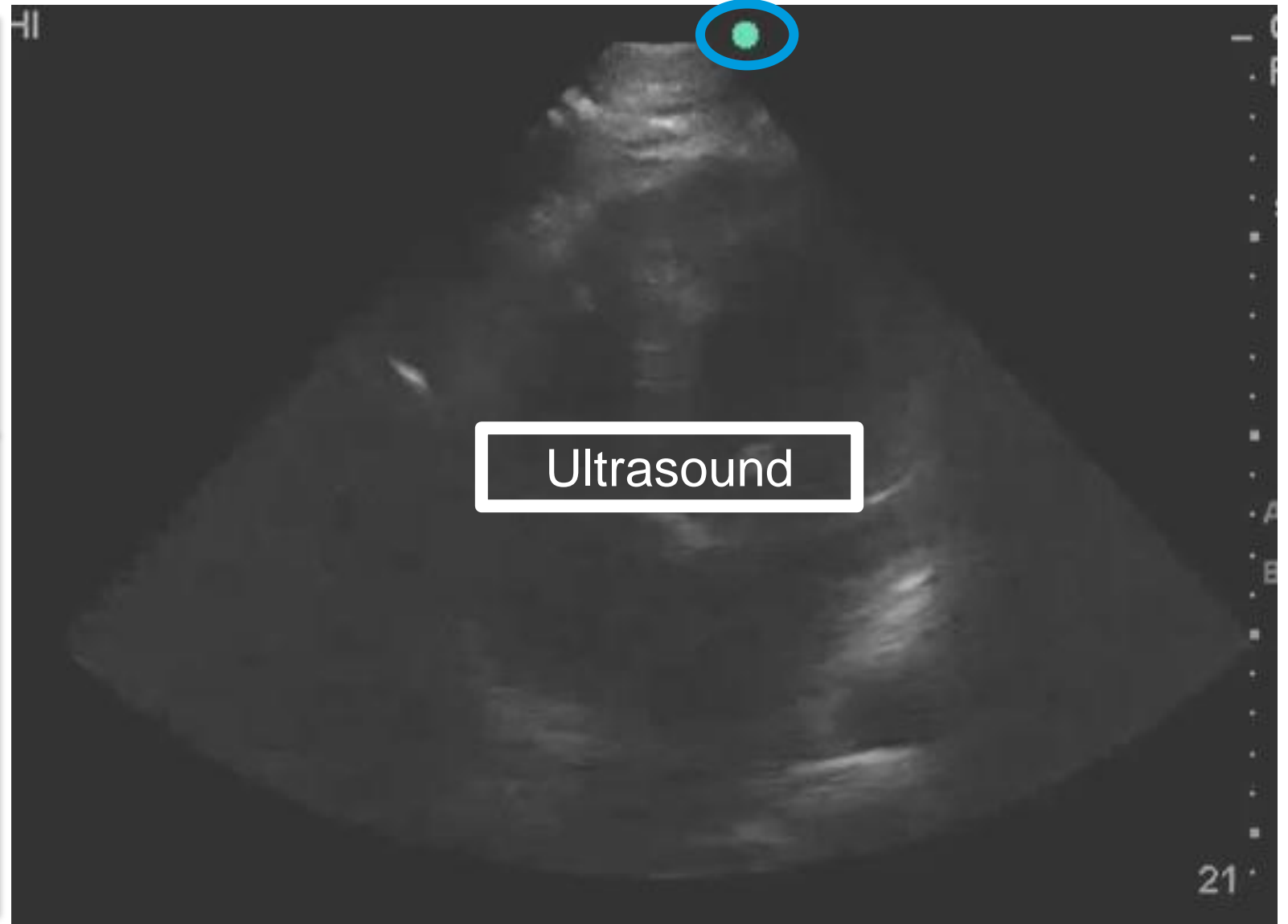
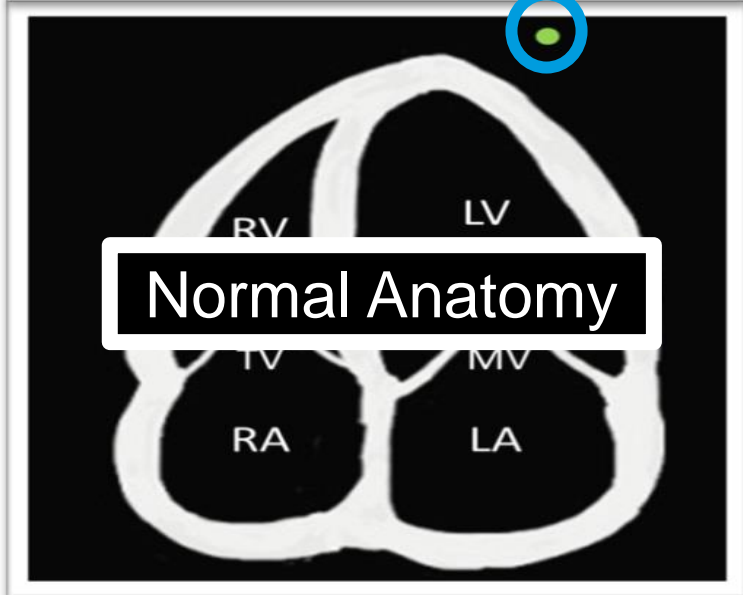
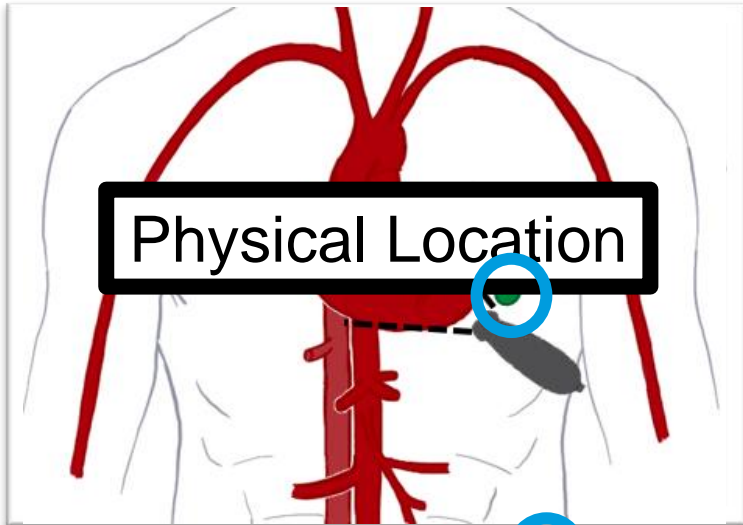


Patient's
Right



Patient's
Left

SLIDE CONVENTION

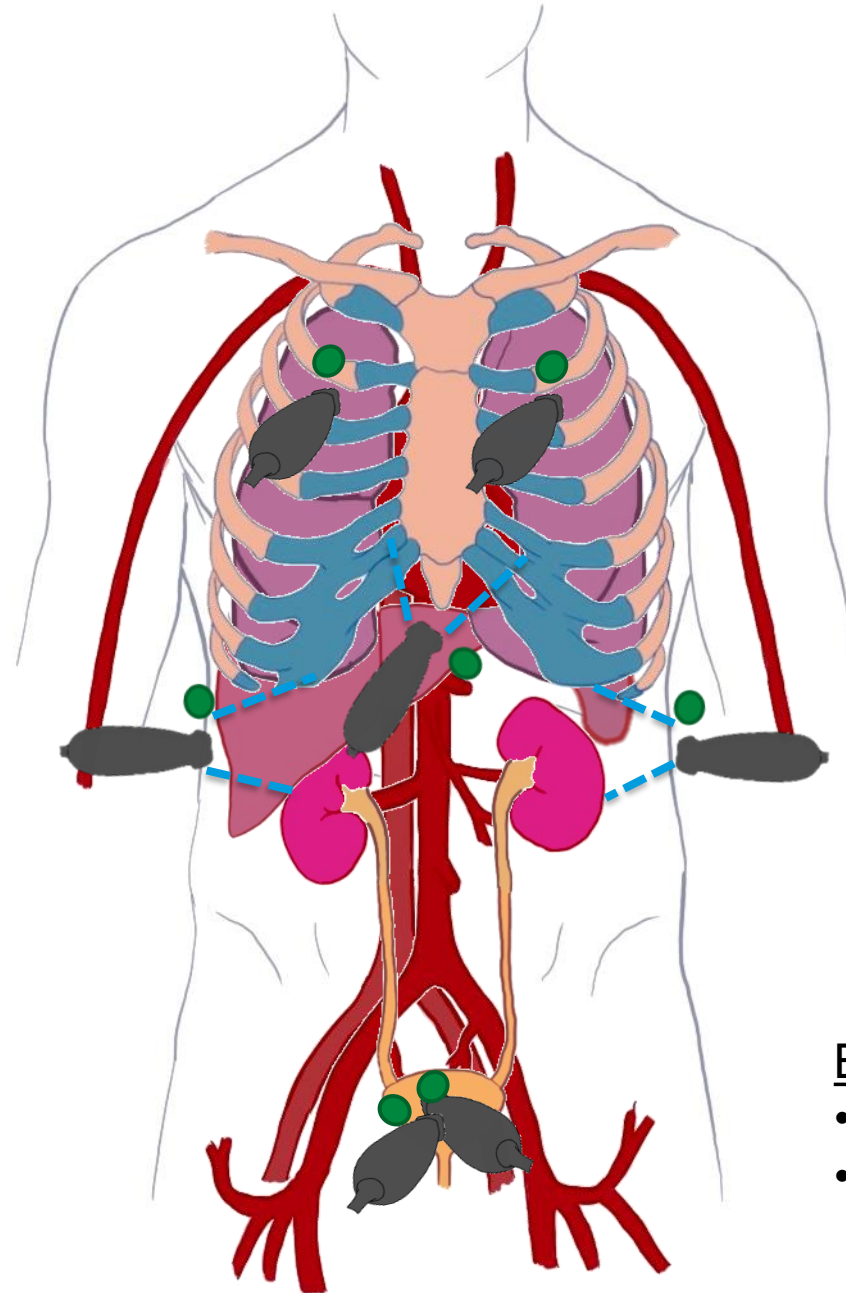


CASE (TOPIC) 1

EFAST

- Scope
 - Following a traumatic injury, rapidly assess for free fluid (presumed bleeding) or air following (presumed pathologic) suggesting injury.
 - Abdominal cavity (RUQ, LUQ, Pelvis) → intra-abdominal bleed
 - Heart → hemopericardium
 - Lung → hemothorax or pneumothorax
- Indications
 - Trauma

EFAST



Subcostal 4 Chamber:

- Hemopericardium

RUQ:

- Intra-abdominal bleed
- Subdiaphragmatic space
- Hepatorenal space
- Caudal tip of kidney

Lung Apices:

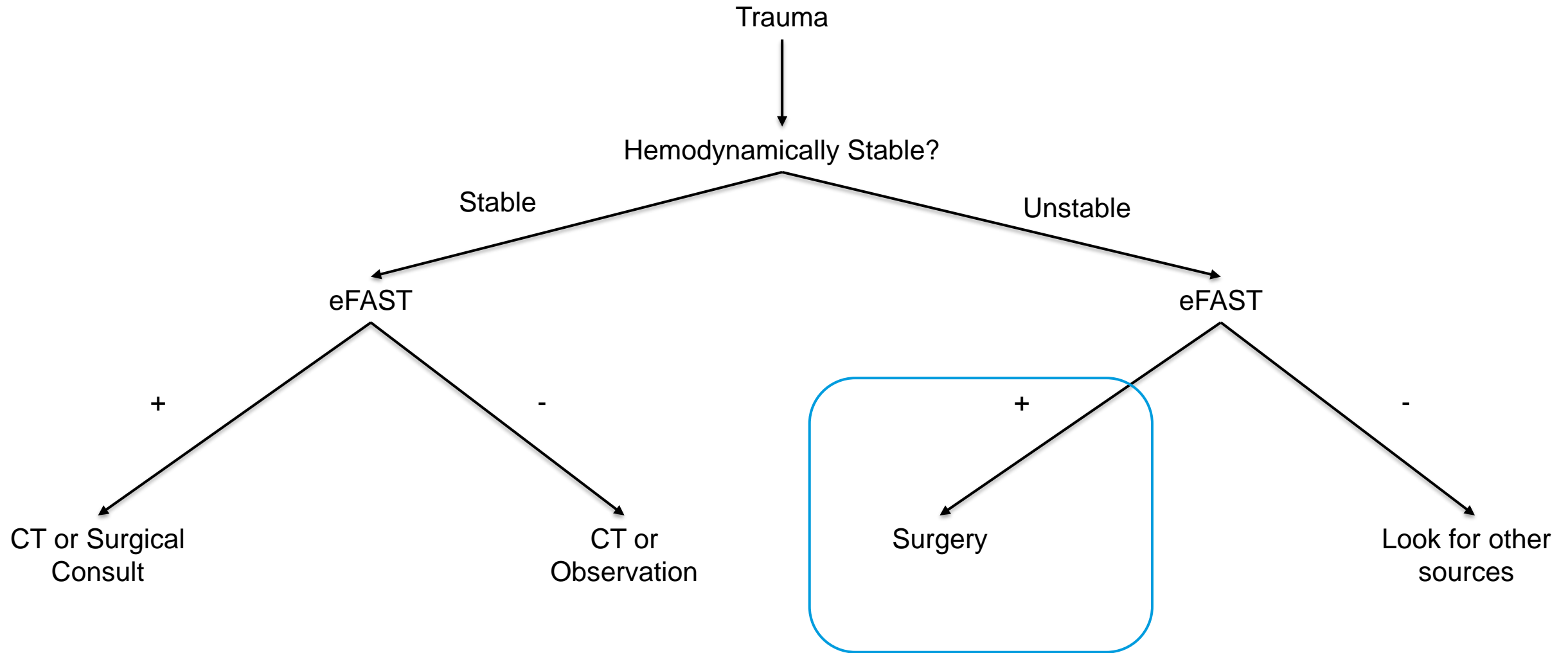
- Pneumothorax

LUQ:

- Intra-abdominal bleed
- Subdiaphragmatic space
- Splenorenal space
- Caudal tip of kidney

Bladder:

- Intra-abdominal bleed
- Rectovesicular + Ureterovesicular



EFAST

- Location of Fluid in + eFAST exams:
 - Right Upper Quadrant 67%
 - Pelvis 48%
 - Left Upper Quadrant 35%
- Location can be patient dependent:
 - Supine / brought by EMS → RUQ most common
 - Upright / Ambulatory → Pelvis is more common

Lobo, V, Hunter-Behrend M, Cullnan E, Higbee R, Phillips C, Williams S, Perera P, Gharahbaghian L. Caudal edge of the liver in the right upper quadrant view is the most sensitive area of free fluid in the FAST exam.

EFAST

- Chest:
 - Sensitivity 96%
 - Specificity 99%
- Abdomen:
 - Sensitivity 68 - 71%
 - Specificity 95%
- Repeat assessments:
 - Sensitivity 71% → 93%

EFAST

- Use of eFAST in trauma
 - Changed management in 33% of cases
 - Time to OR 64% faster
 - 27% fewer hospital days

EFAST

- Jump-started POCUS as we know it.

CASE 2

CASE 2

- Asked to urgently evaluate a 74 year-old gentleman for confusion and hypotension.
 - Unable to provide history.
- Hospital Course:
 - Admitted for osteomyelitis of the left lower extremity, status post BKA
 - Diagnosed with critical limb ischemia of the right upper extremity and started on a heparin infusion.
- Past Medical History:
 - ESRD on HD
 - Diastolic left ventricular heart failure.
 - Diabetes mellitus type II.
- Past Social History:
 - Smoker (50 pack years).
 - Daily alcohol use.

CASE 2

Vital Signs:

- HR 107
- BP 84/55 (from 148/90)
- SpO2 98%
- RR 18
- T 36.8 Celsius

Exam:

- Mental – Alert to person, not place or time. Lethargic. CAM positive.
- Heart – Regular rhythm and rate.
- Lungs – Faint crackles at the left base.
- Abdomen – Mildly tender to palpation.

POCUS IN SHOCK

EGLS

RUSH: HI-MAP

FATE

RUSH: Pump, Tank, Pipes

ACES

FREE

- Weingart SD, Duque D, Nelson B. The RUSH Exam: Rapid Ultrasound for Shock and Hypotension. <https://emcrit.org/rush-exam/original-rush-article/>
- Perera P, Mailhot, T, Riley D, Mandavia D. The RUSH Exam: Rapid Ultrasound in Shock in the Evaluation of the Critically Ill. Emerg Med Clin N Am 2010;28:29–56.
- Lanctot JF, Valois M, Beaulieu Y. EGLS: Echo-Guided Life Support – An algorithmic approach to undifferentiated shock. Crit Ultrasound J 2001;3:123-129.
- Ferrada P, Murthi S, Anand RJ, Bochicchio GV, Scalea T. Transthoracic Focused Rapid Echocardiographic Examination: Real-Time Evaluation of Fluid Status in Critically Ill Trauma Patients. J Trauma. 2011;70:56-64.

POCUS IN SHOCK

- Systematic POCUS evaluation to determine the cause / type of shock.
 - FoCUS
 - Lung
 - Aorta
 - Abdominal free fluid
 - DVT
 - Soft tissue

POCUS IN SHOCK

Goal:

1. Quickly rule in / rule out specific pathology.
2. Narrow differential diagnosis.
3. Characterize type of shock / hypotension.

POCUS IN SHOCK

	Hypovolemic	Vasodilatory	Cardiogenic	Obstructive
Heart	Hyperdynamic LV function		Reduced / Severely Reduced LV fxn RV Dilation (MI)	+/- Dilated RV (PE) +/- Pericardial Effusion (Cardiac Tamponade)
IVC	Small IVC		Dilated IVC	Dilated IVC
Morrison's Pouch	+/- Abdominal free fluid (hemorrhage)	Normal	+/- Abdominal free fluid (ascites)	Normal
Aorta	+/- Aortic aneurysm / dissection	Normal	Normal	Normal
Pulmonary	Normal	+/- Consolidation (pneumonia)	B-Lines	+/- Absent lung sliding (pneumothorax)
Peripheral Veins	Normal	Normal	Normal	+/- DVT

POCUS IN SHOCK

5 Cardinal Views of the Heart

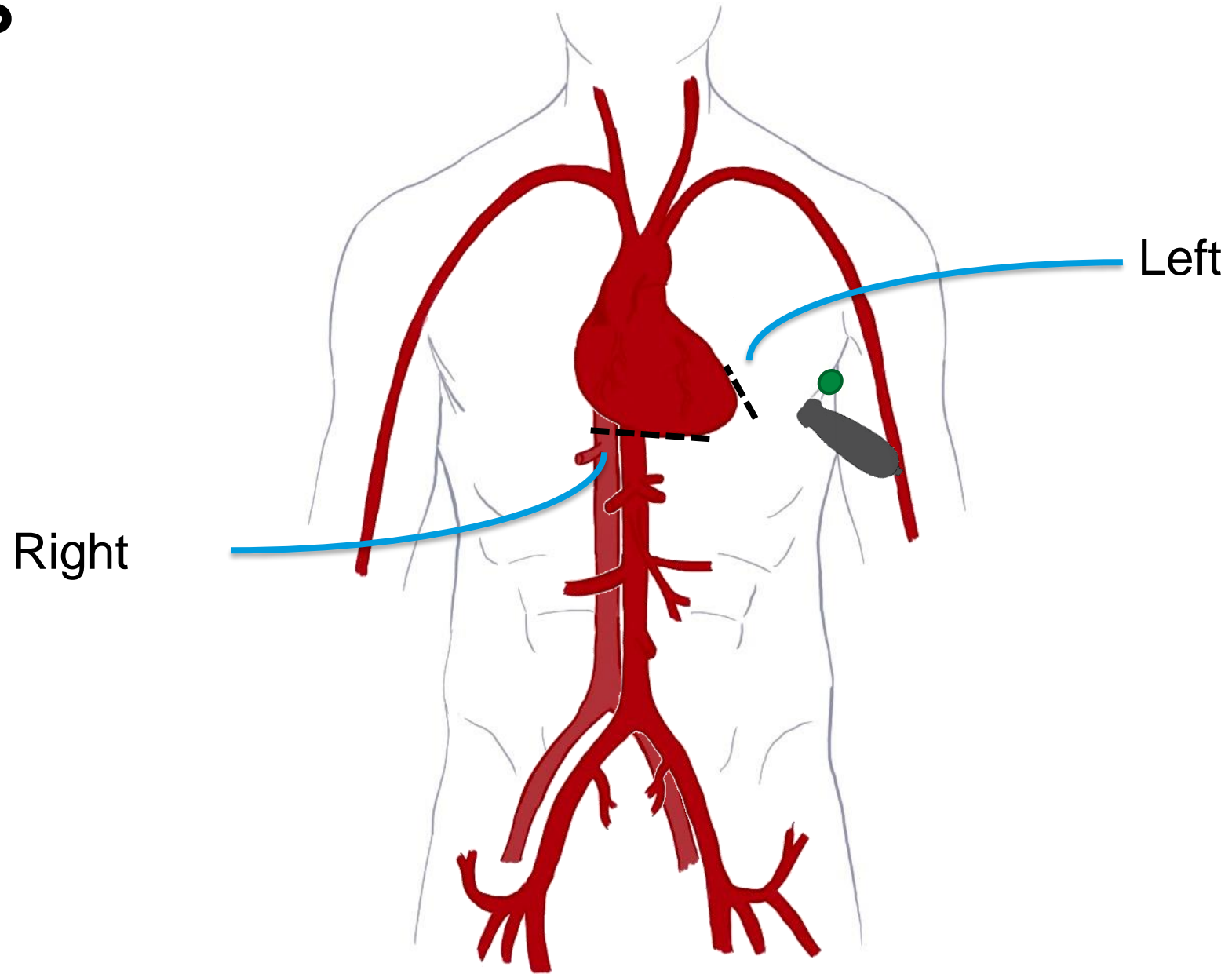
- Parasternal Long Axis (PLAX)
- Parasternal Short Axis (PSAX)
- Apical 4 Chamber (A4C)
- Subcostal 4 Chamber (S4C)
- Inferior Vena Cava (IVC)

POCUS IN SHOCK

5 Cardinal Views of the Heart

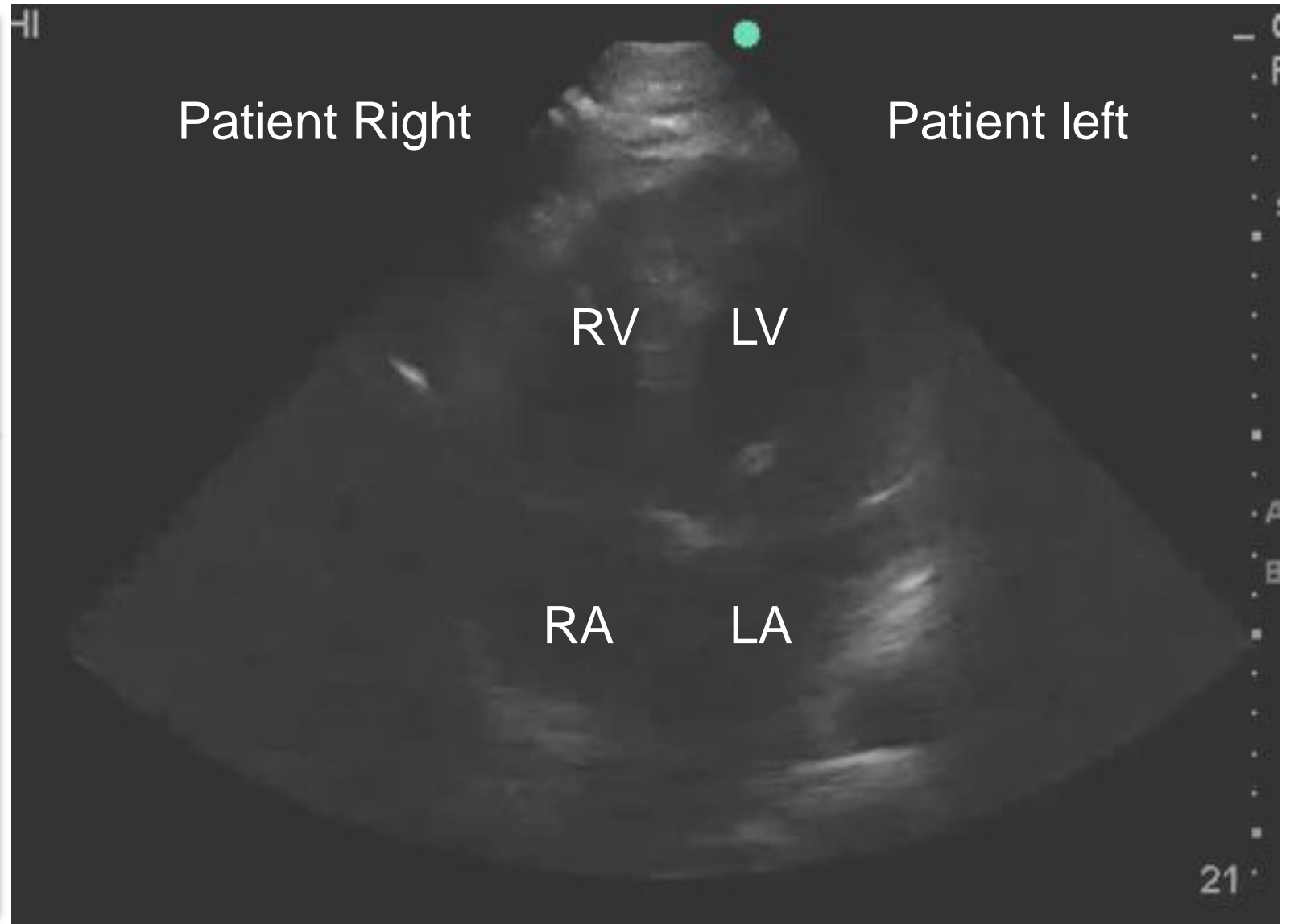
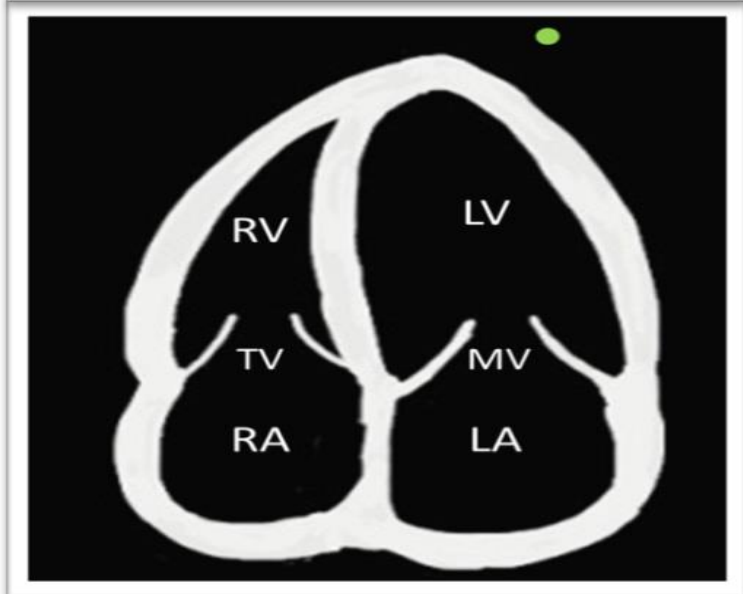
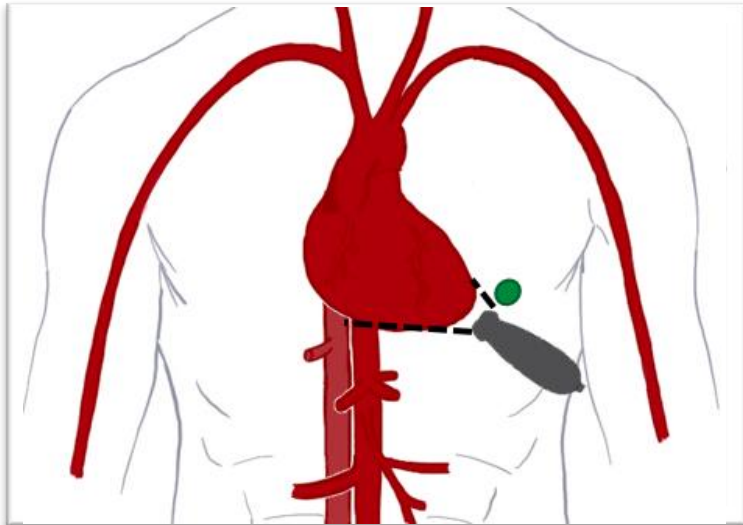
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- Inferior Vena Cava (IVC)

FoCUS A4C

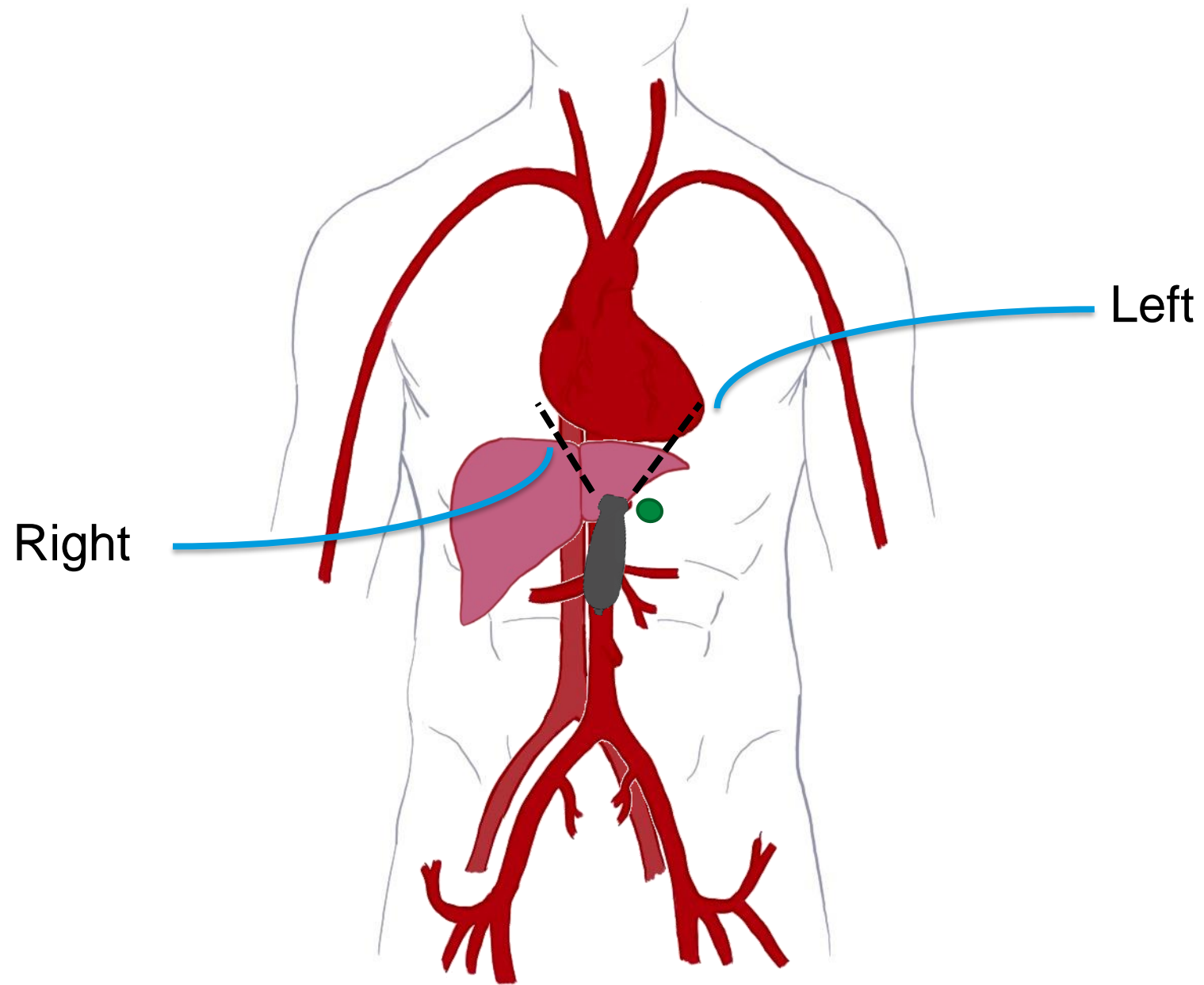


FoCUS

A4C

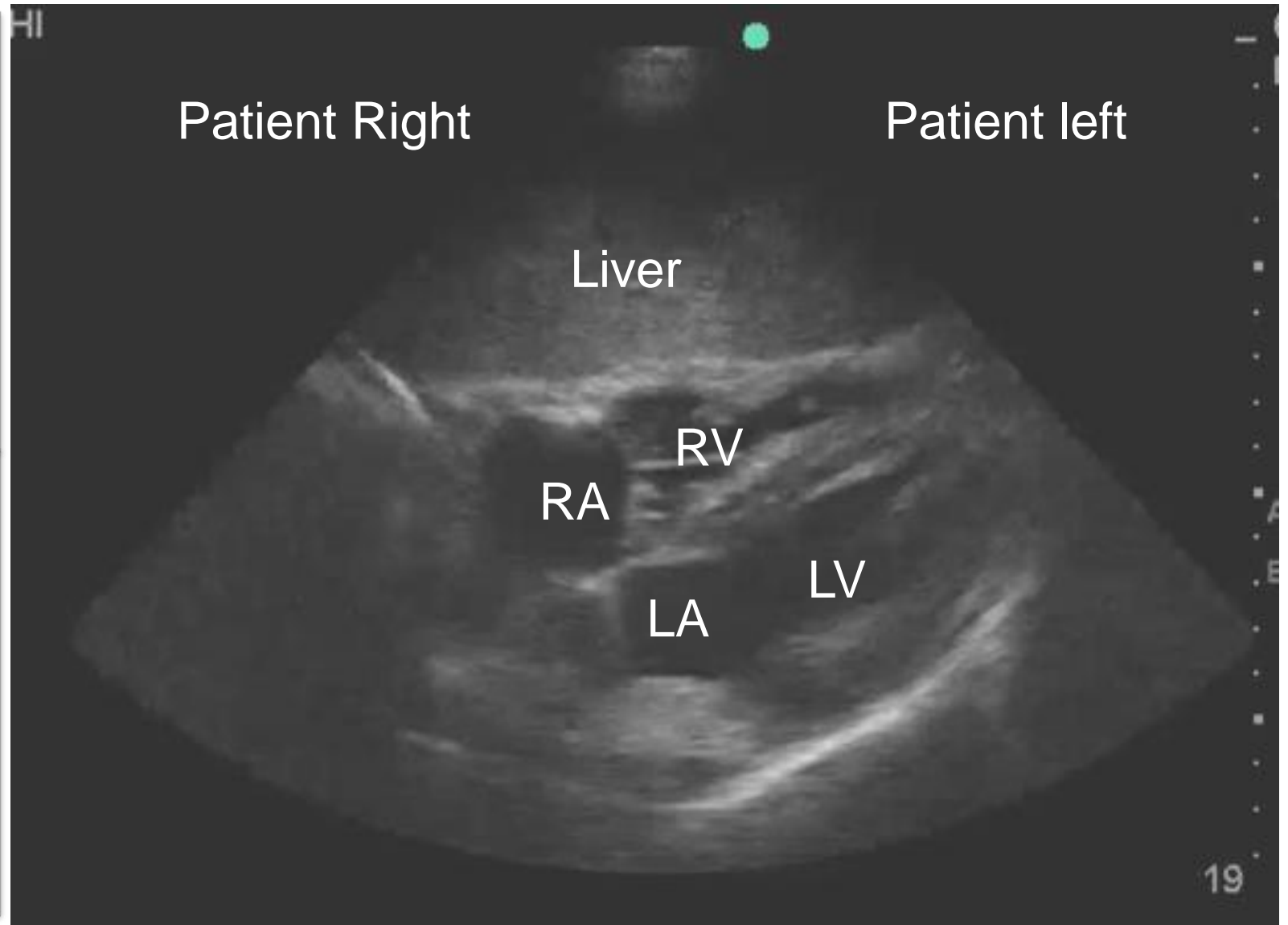
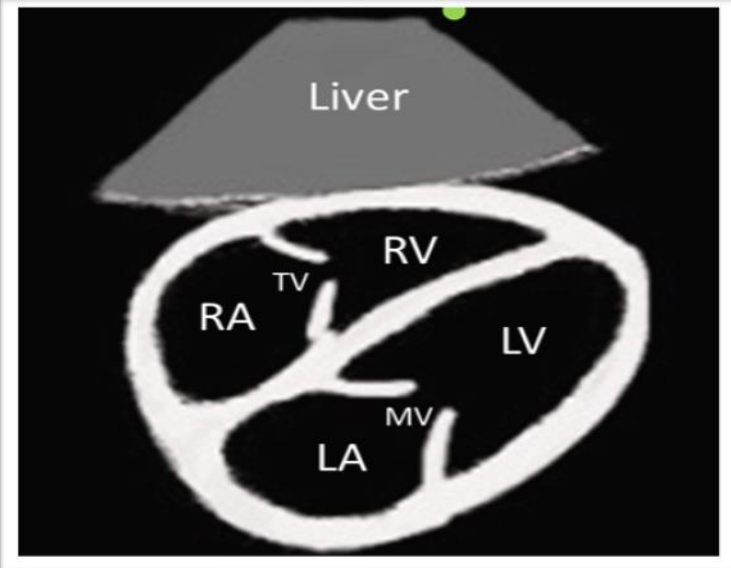
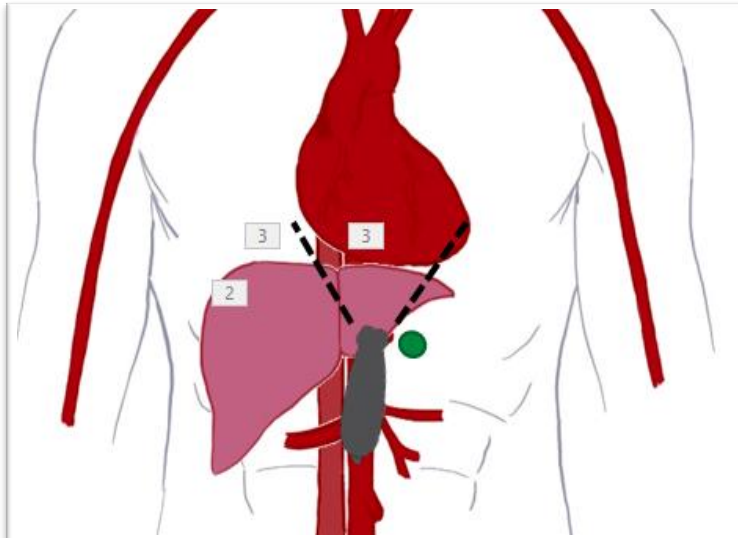


FoCUS S4C

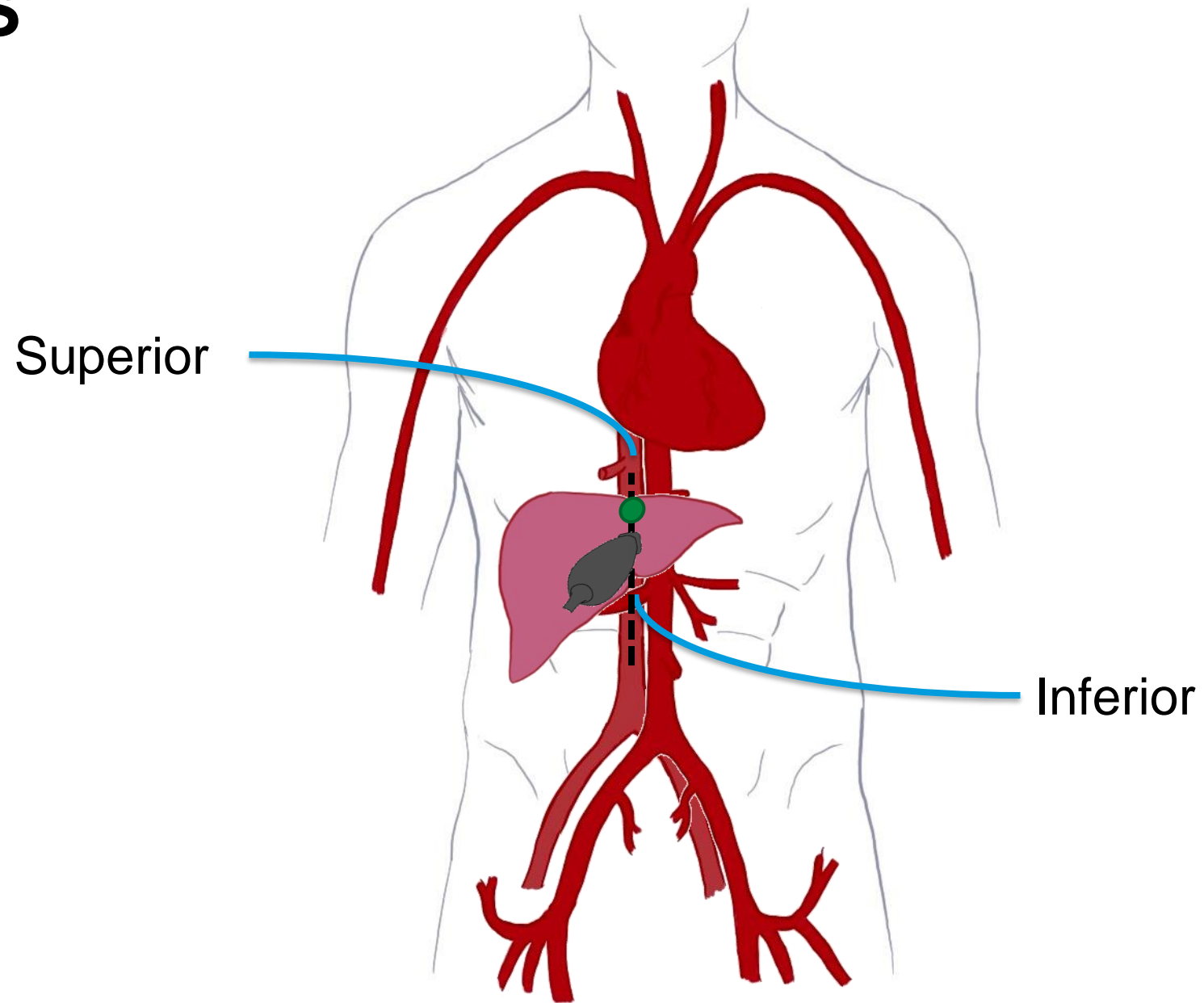


FoCUS

S4C

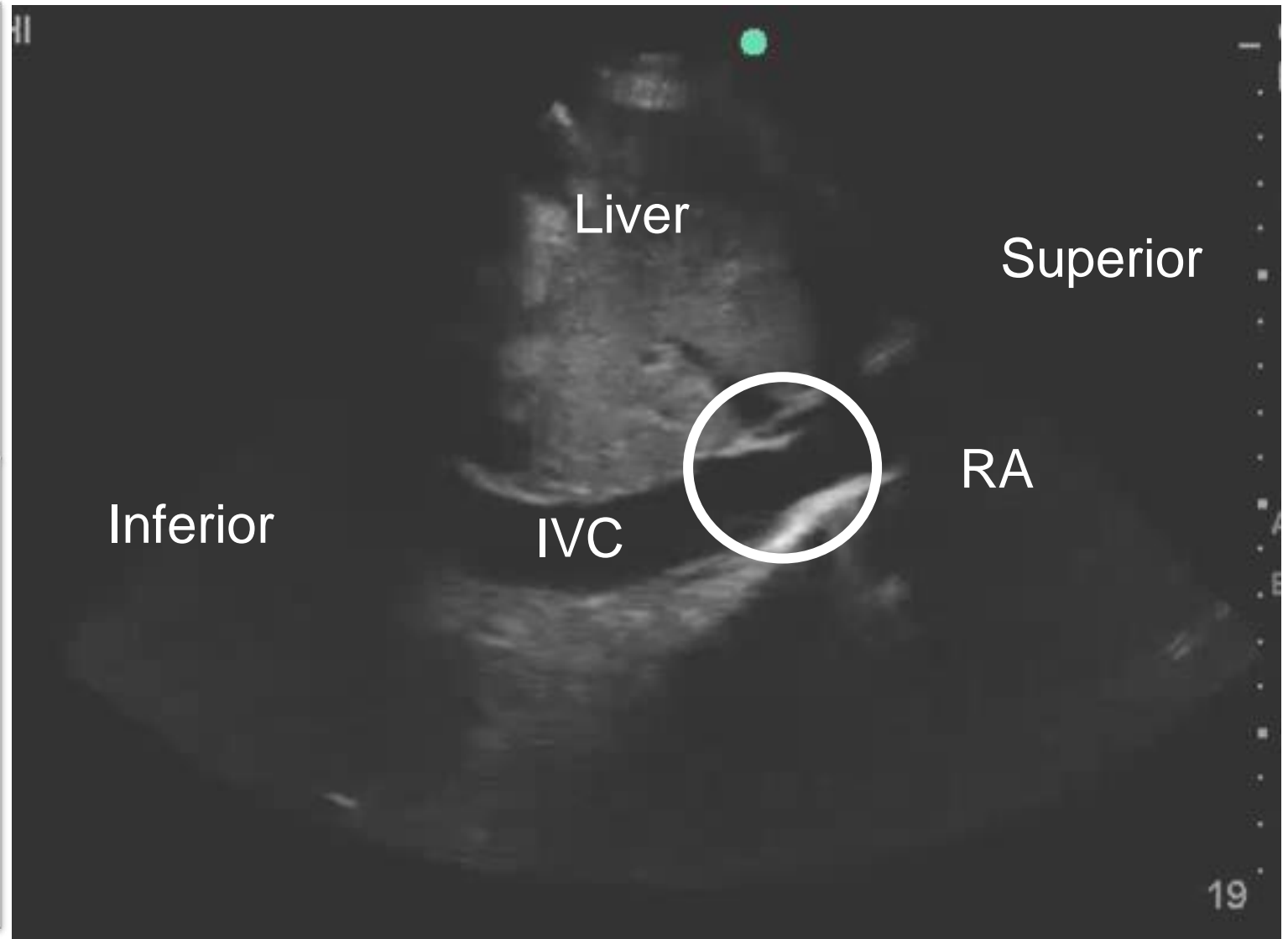
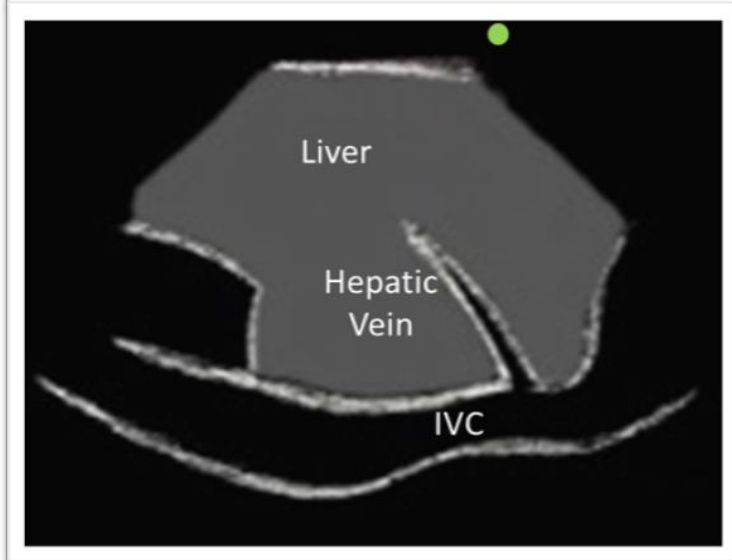
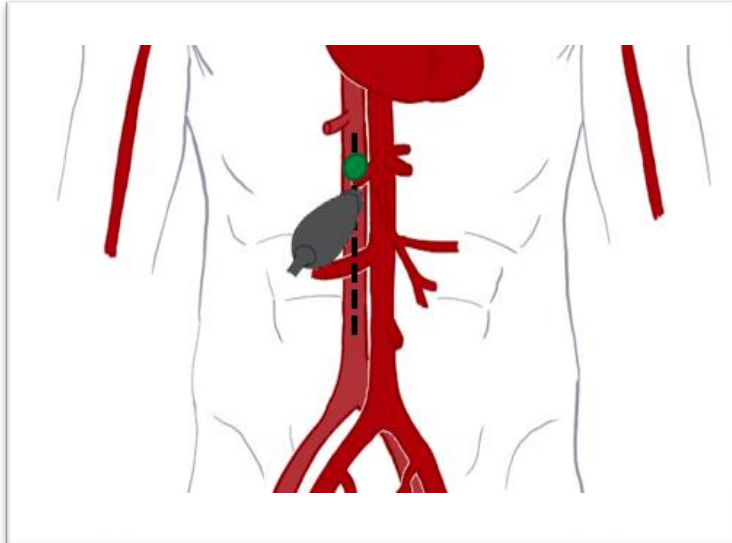


FoCUS IVC



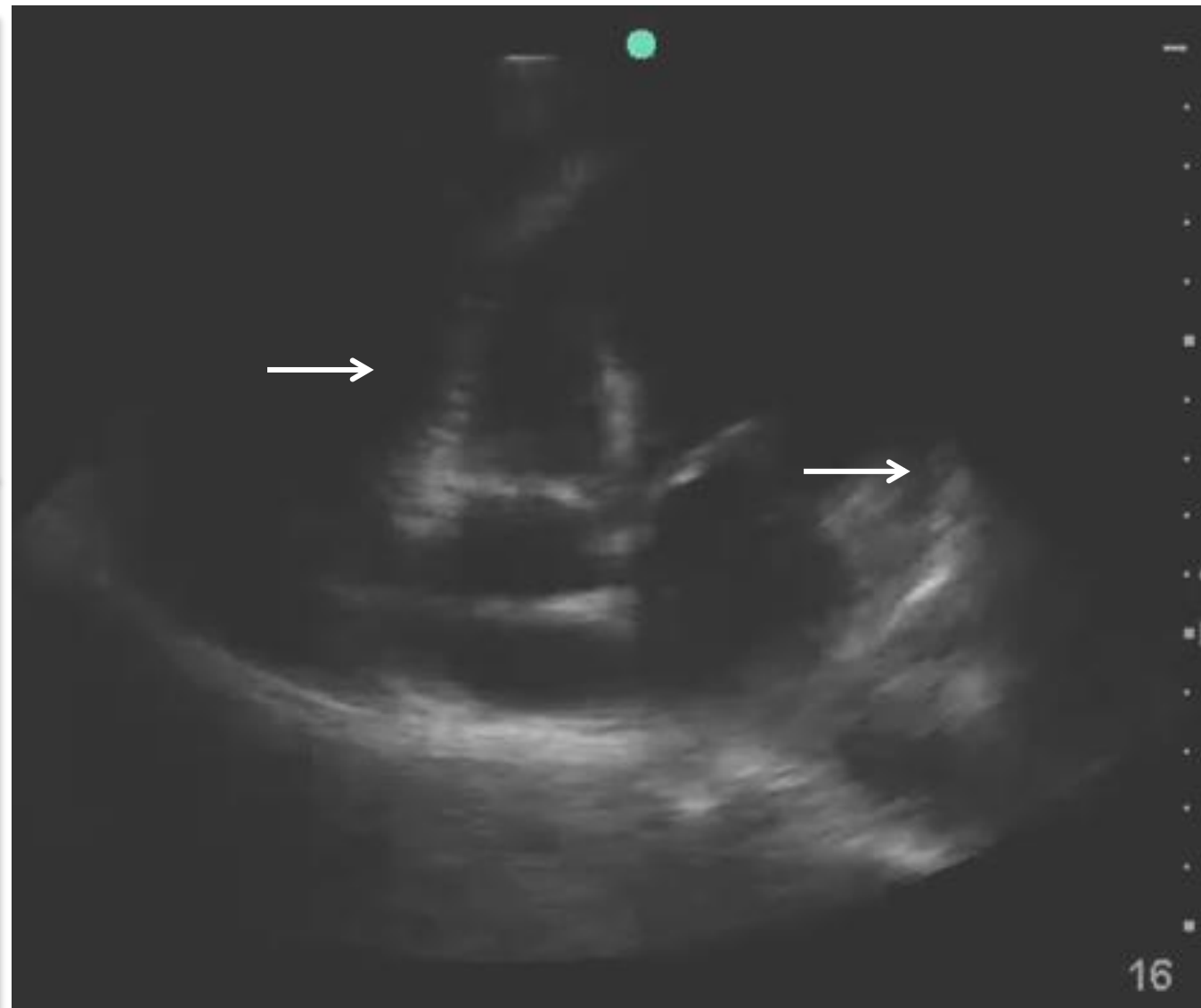
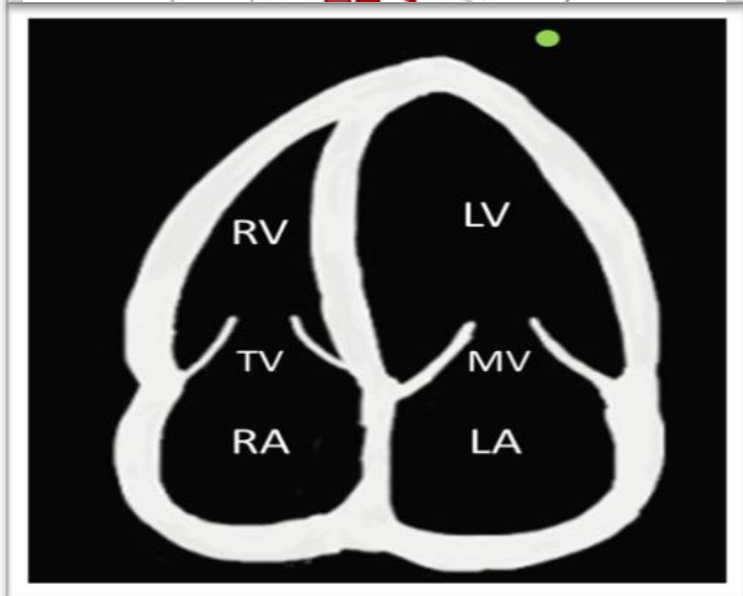
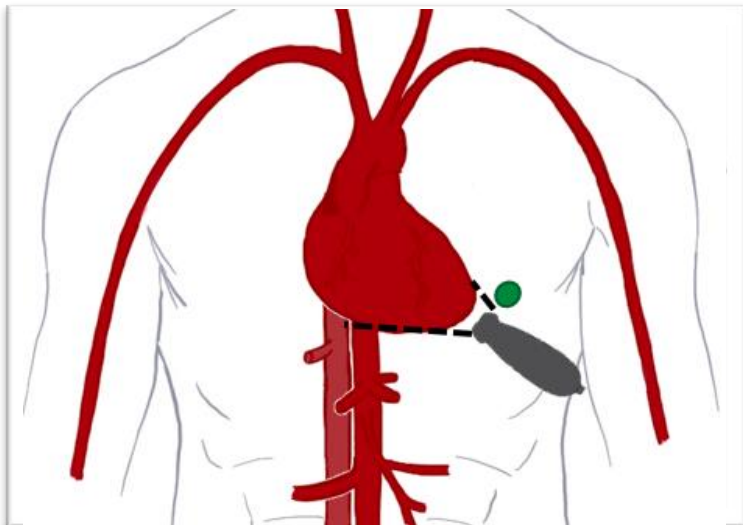
FoCUS

IVC



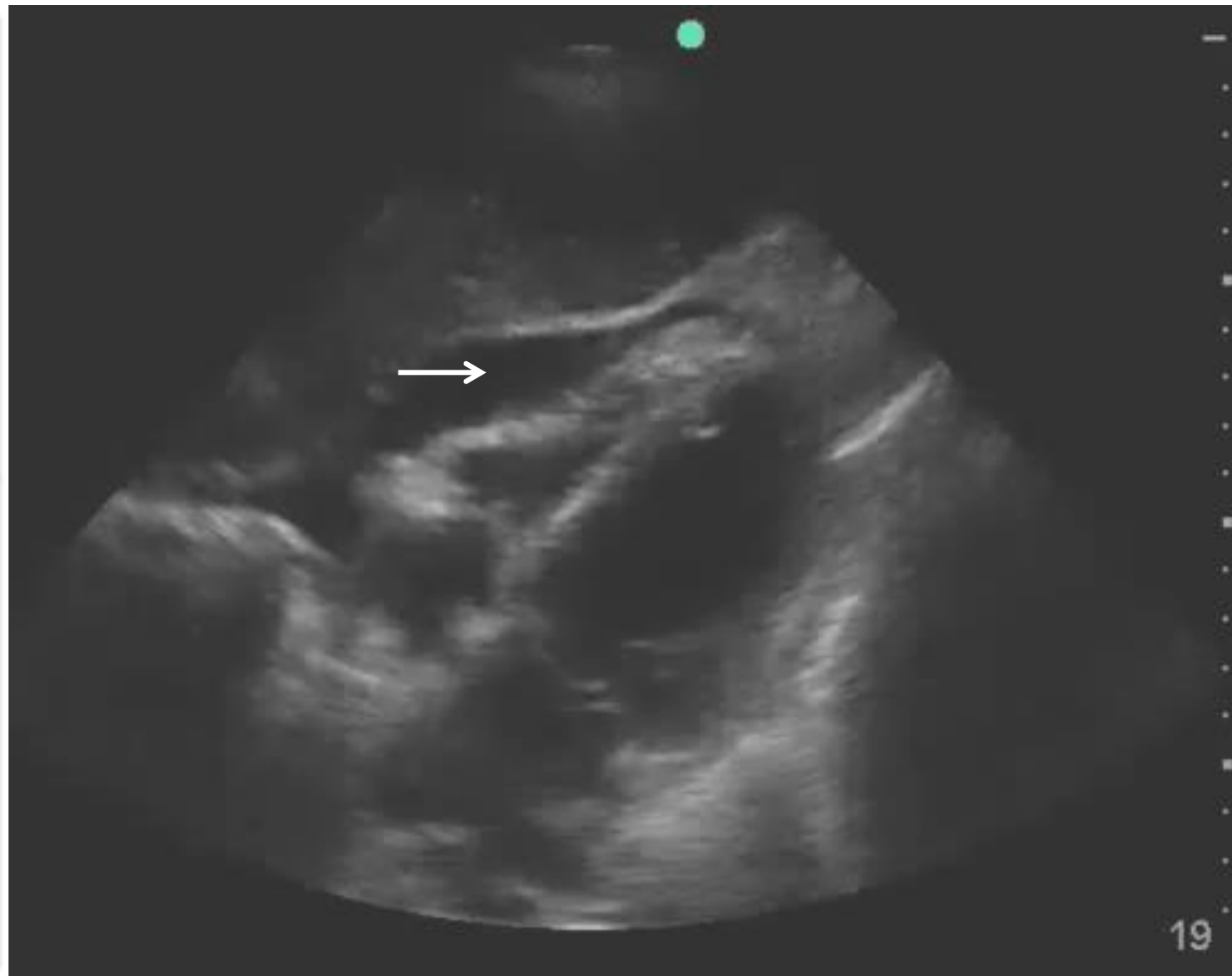
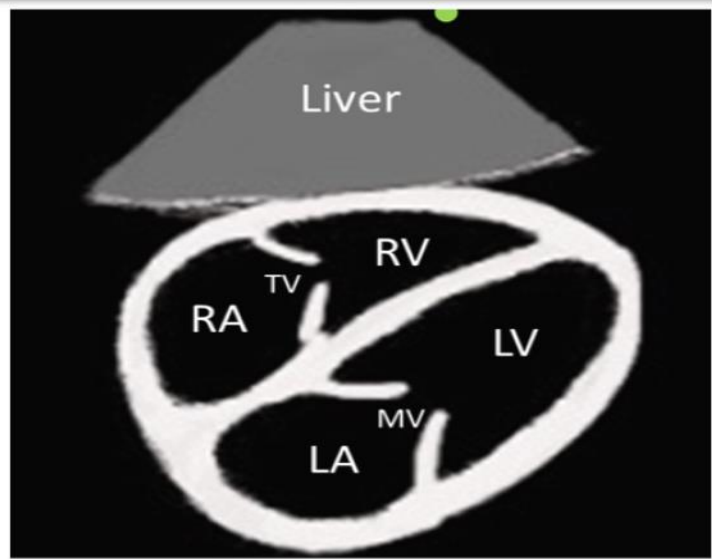
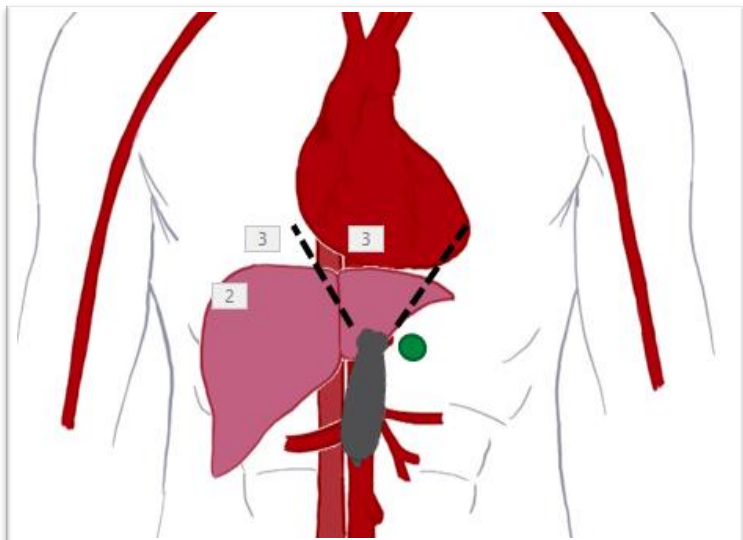
CASE 2

A4C



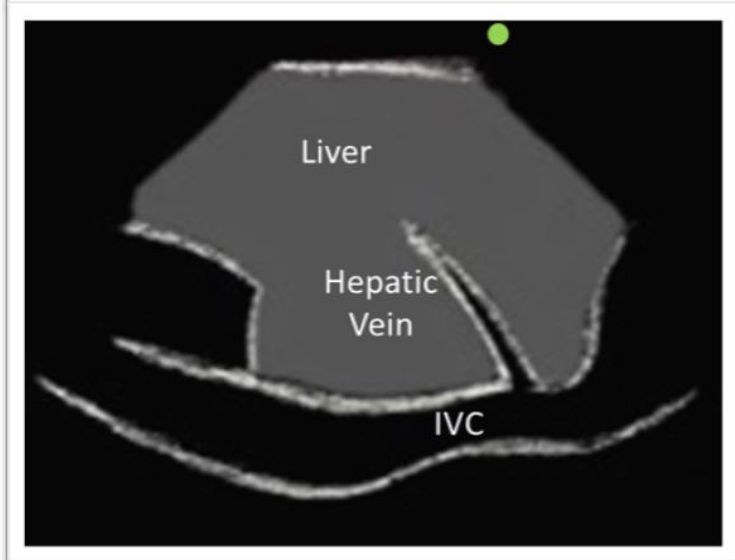
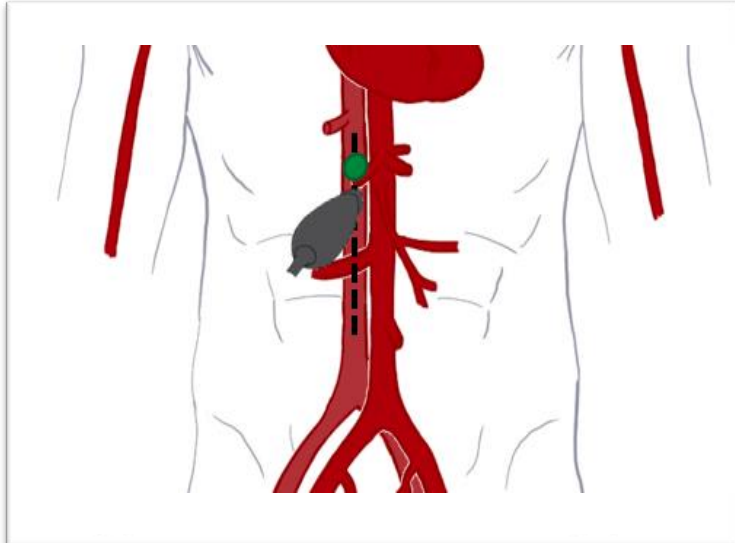
CASE 2

S4C

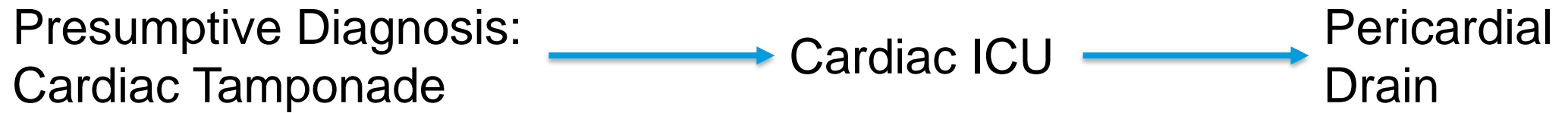


CASE 2

IVC



CASE 1



POCUS IN SHOCK

Pericardial Effusion

- Sensitivity 96%
- Specificity 98%

Cardiac Tamponade

- RA Systolic Collapse
 - Sensitivity 64-100%
 - Specificity 82%
- RV Diastolic Collapse
 - Sensitivity 60-92%
 - Specificity 85-100%
- IVC with collapse
 - Sensitivity 97%

- Mandavia DP, Hoffner RJ, Mahaney K, Henderson SO. Bedside echocardiography by emergency physicians. *Ann Emerg Med*. 2001;38:377-382.
- Gillam LD, Guyer DE, Gibson TC, et al. Hydrodynamic compression of the right atrium: a new echocardiographic sign of cardiac tamponade. *Circulation*. 1983;68(2):294-301.
- Singh S, Wann LS, Schuchard GH, et al. Right ventricular and right atrial collapse in patients with cardiac tamponade – a combined echocardiographic and hemodynamic study. *Circulation*. 1984;70(6):966-971.

POCUS IN SHOCK

- Cardiac Tamponade

Finding	Sensitivity	Specificity	
Hypotension	26% (16-36%)	N/A	
Elevated JVP	76% (62-90%)	N/A	
Muffled Heart Sounds	28% (21-35%)	N/A	
Pulsus Paradoxus	82-98%	83%	2 Studies; 1981; 56 patients
RA Systolic Collapse	64-100%	82%	
RV Diastolic Collapse	60-92%	85-100%	
Normal IVC	97%	-	



POCUS IN SHOCK



Aids in Diagnosis

- Decreased uncertainty
- Narrower DDx
- More definitive diagnoses

No effect on Patient Centered Outcomes

- Mortality
- ICU / Hospital LOS



So far...

- Shokoohi H, Boniface KS, Pouramand A, Liu YT, et al. Bedside Ultrasound Reduces Diagnostic Uncertainty and Guides Resuscitation in Patients With Undifferentiated Hypotension. *Critical Care Medicine Journal* 2015;43(12):2562-2569.
- Jones AE, Tayal VS, Sullivan DM, et al: Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med* 2004; 32:1703–1708
- Atkinson PR, Milne J, Diegelman L, Lamprecht H, Stander M, Lussier D, et al. Does Point-of-Care Ultrasonography Improve Clinical Outcomes in Emergency Department Patients With Undifferentiated Hypotension? An International Randomized Controlled Trial From the SHoC-ED. *Annals of Emergency Medicine* 2018.

POCUS IN SHOCK

- Diagnostic Evaluation

Measurement	Standard of Care	Standard of Care + POCUS
Viable Diagnoses on initial evaluation	9	4
Provider confidence in diagnosis	50%	80%
Definitive diagnosis on initial evaluation	0.8%	12.7%

- Diagnosis by POCUS has excellent concordance with final consensus diagnosis ($k=0.80$).

- Shokoohi H, Boniface KS, Pouramand A, Liu YT, et al. Bedside Ultrasound Reduces Diagnostic Uncertainty and Guides Resuscitation in Patients With Undifferentiated Hypotension. *Critical Care Medicine Journal* 2015;43(12):2562-2569.
- Jones AE, Tayal VS, Sullivan DM, et al: Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med* 2004; 32:1703–1708
- Atkinson PR, Milne J, Diegelman L, Lamprecht H, Stander M, Lussier D, et al. Does Point-of-Care Ultrasonography Improve Clinical Outcomes in Emergency Department Patients With Undifferentiated Hypotension? An International Randomized Controlled Trial From the SHoC-ED. *Annals of Emergency Medicine* 2018.

POCUS IN SHOCK

- The diagnostic accuracy of a point-of-care ultrasound protocol for shock etiology: A systematic review and meta-analysis (2019)
 - Hypovolemic shock: LR+ 8.25, LR- 0.19
 - Cardiogenic shock: LR+ 24.14, LR- 0.24
 - Obstructive shock: LR+ 40.54, LR-0.13
 - Distributive shock: LR+ 17.56, LR- 0.30
 - Mixed shock: LR+ 12.91, LR- 0.32

- Stickles SP, Carpenter CR, Gekle R, Kraus CK, Scoville C, Theodoro D, Tran VH, Ubiñas G, Raio C. The diagnostic accuracy of a point-of-care ultrasound protocol for shock etiology: A systematic review and meta-analysis. CJEM. 2019 May;21(3):406-417. doi: 10.1017/cem.2018.498. Epub 2019 Jan 30. PMID: 30696496.

POCUS IN SHOCK

Does Point-of-Care Ultrasonography Improve Clinical Outcomes in Emergency Department Patients With Undifferentiated Hypotension? An International Randomized Controlled Trial From the SHoC-ED Investigators

- Primary Outcomes:
 - 30 day mortality or discharge survival
- Results:
 - No difference between standard of care vs standard of care + POCUS

POCUS IN SHOCK

Does Point-of-Care Ultrasonography Improve Clinical Outcomes in Emergency Department Patients With Undifferentiated Hypotension? An International Randomized Controlled Trial From the SHoC-ED Investigators

	POCUS (138)	Control (135)
Sepsis	74 (53.6%)	68 (50.4%)
Dehydration	17 (12.3%)	20 (14.8%)
LV failure	10 (7.2%)	12 (8.9%)
Other (medications, hemorrhage, autonomic dysfunction, arrhythmia, etc)	34 (24%)	34 (25%)
Aortic Dissection	2 (1.4%)	0
Tension Pneumothorax	1 (0.7%)	0 (0%)
Cardiac Tamponade	1 (0.7%)	1 (0.7%)

CASE 3

CASE 3

- A 62 year-old female was admitted to your service overnight from the ED for complaints of fevers and rigors over the last 2 days.
- She endorses:
 - Dysuria
 - Urinary frequency
 - Urinary urgency
- Past Medical / Surgical History:
 - Pseudomonas aeruginosa UTI (~3 months prior).
 - Hypertension
 - Left ventricular diastolic heart failure

CASE 3

16.7 15.2 389

141 101 52 98
4.2 20 2.6

Lactate 3.7

- U/A –
 - Many gram negative bacilli
 - RBC normal
 - WBC > 100 / hpf

CASE 3

Presumptive Diagnosis:
Sepsis due to UTI



LR 30 ml/kg
Cefepime



Admitted
Continued
Cefepime
Gentle IVF

CASE 3

- HR 112
- BP 98/55
- RR 24
- SpO2 91%
- Tmax 39.0 C

14.1 15.2 389

141 101 52 98
4.2 20 2.2

Lactate 2.4

I/O's +2.6L

POCUS-GUIDED FLUID RESUSCITATION

- DO NOT IGNORE THE GUIDELINES

POCUS-GUIDED FLUID RESUSCITATION

- Fluid Responsiveness – An increase of stroke volume of 10-15% after the patient receives 500 ml of crystalloid over 10-15 minutes
 - IVC size / Respiratory variation

- Accuracy of Ultrasonographic Measurements of Inferior Vena Cava to Determine Fluid Responsiveness: A Systematic Review and Meta-Analysis (2020)
 - Pooled sensitivity 71%, specificity 75%; LR +2.8 LR -0.39.

POCUS-GUIDED FLUID RESUSCITATION

- Intravascular Volume Status
- Fluid Tolerance – The ability to receive IV fluids without developing adverse affects; such as, pulmonary edema/hypoxia.

POCUS-GUIDED FLUID RESUSCITATION

Cardiac Auscultation

JVP

Lung Auscultation

Lower extremity edema



FoCUS

IVC

Lung Ultrasound



LV Function

Size

+/- Pulmonary Edema



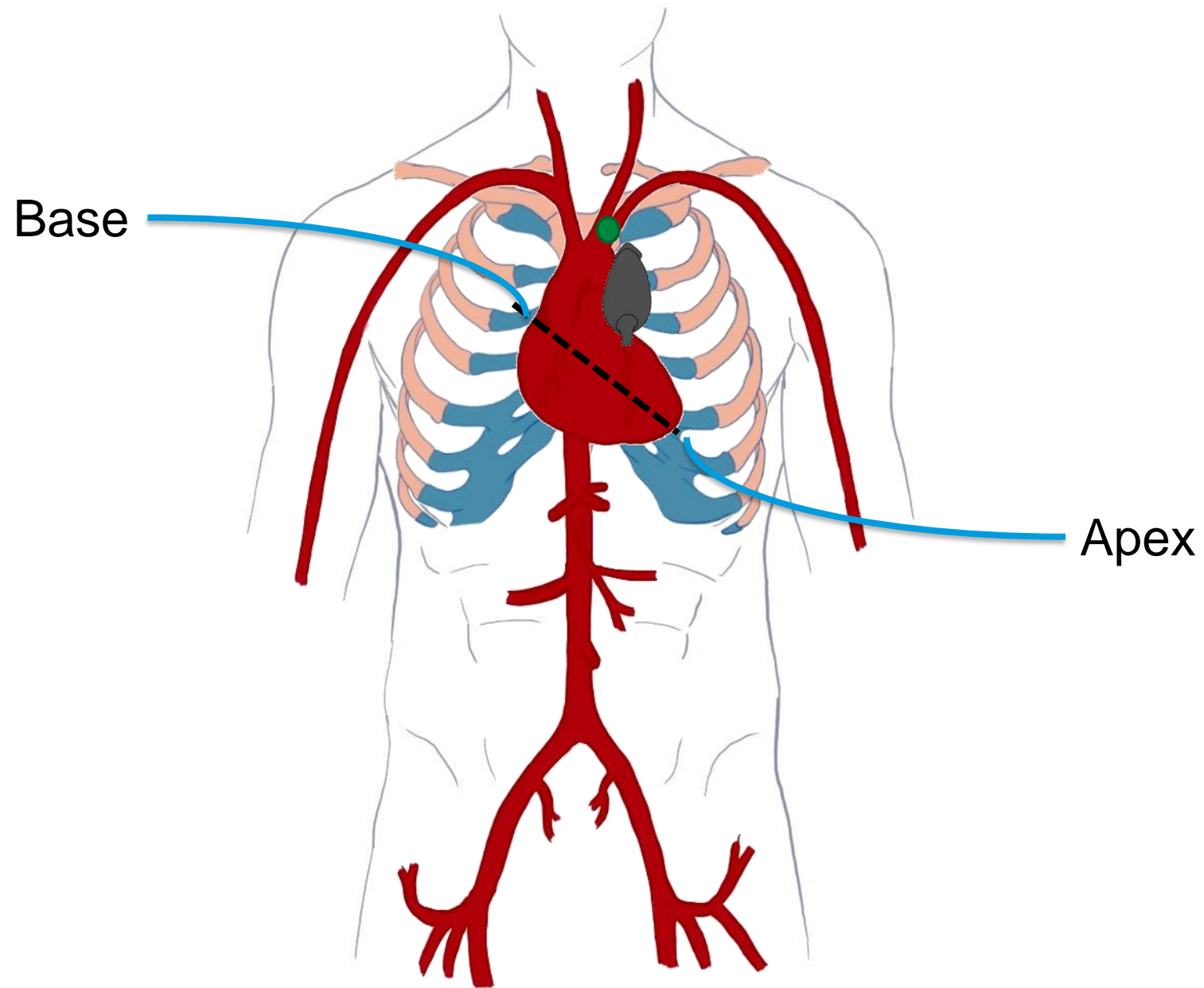
- Theerawit P, Tomuan N, Sutherasan Y, Kiatboonsri S. Critical Care 2012,16(Suppl 1): P248. doi: 10.1186/cc10855.
- Lichtenstein D, Karakitsos D. Integrating lung ultrasound in the hemodynamic evaluation of acute circulatory failure (the fluid administration limited by lung sonography protocol). Journal of Critical Care (2012)27, 533.e11–533.e19.

POCUS-GUIDED FLUID RESUSCITATION

	Fluid Tolerance	Fluid Intolerance
Heart	Hyperdynamic LV Function Small RV / Normal RV Function	Reduced LV Function Dilated RV / reduced RV Function
IVC	Small Collapsing	Large Reduced collapse
Lung	A-Lines	B-Lines

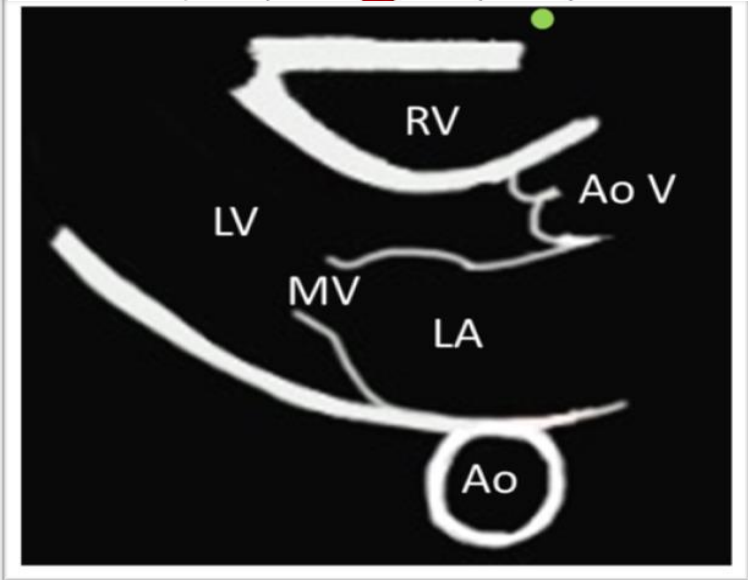
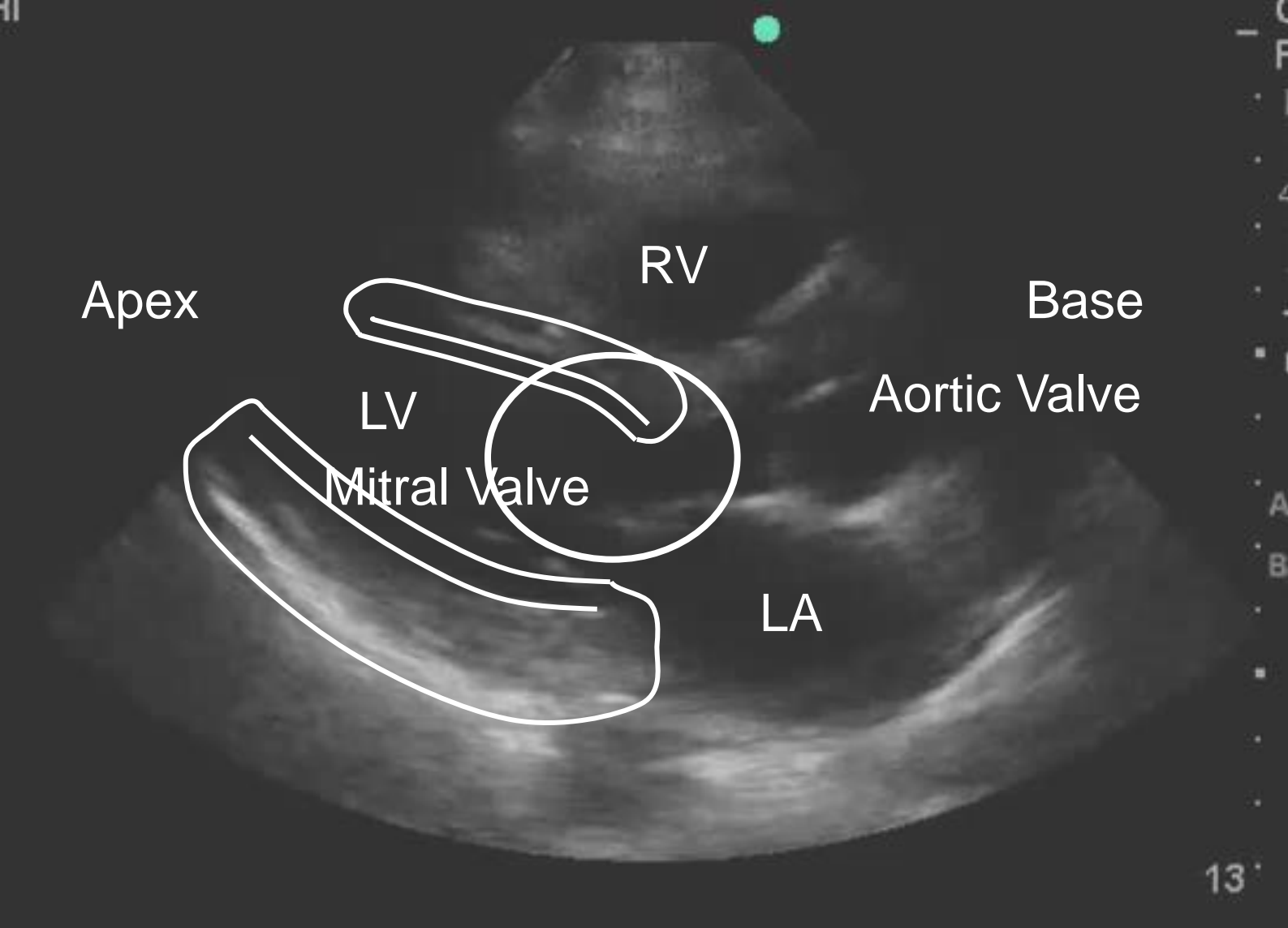
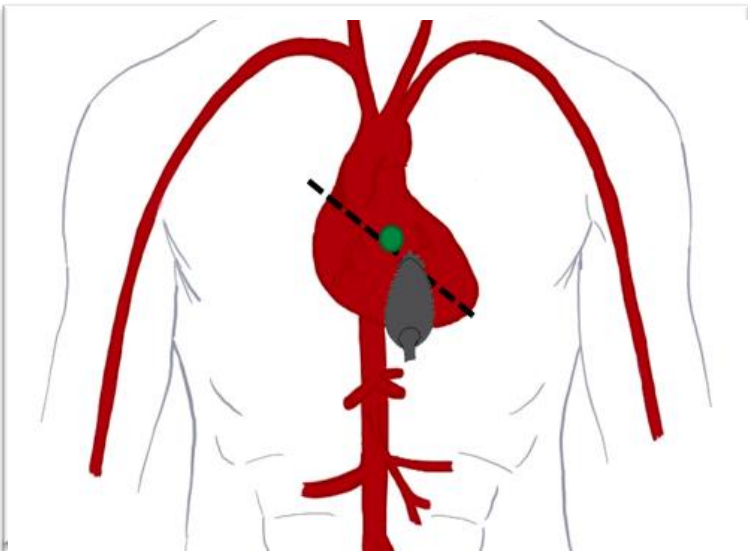
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FoCUS PLAX



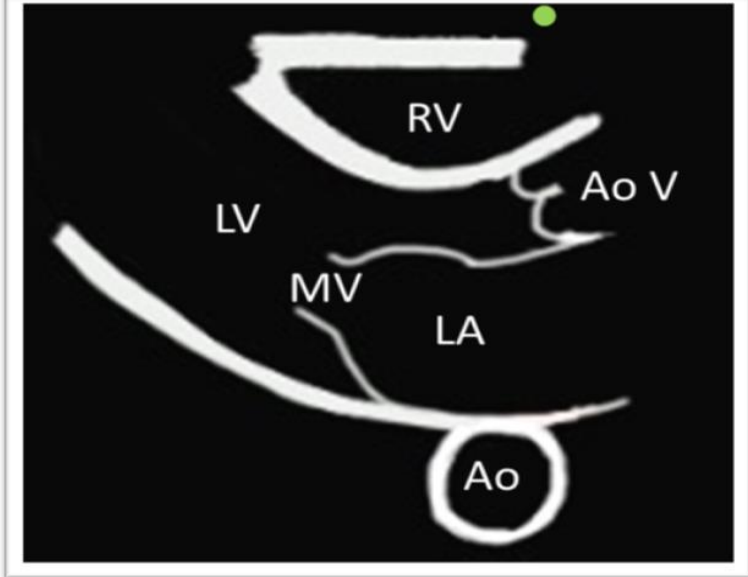
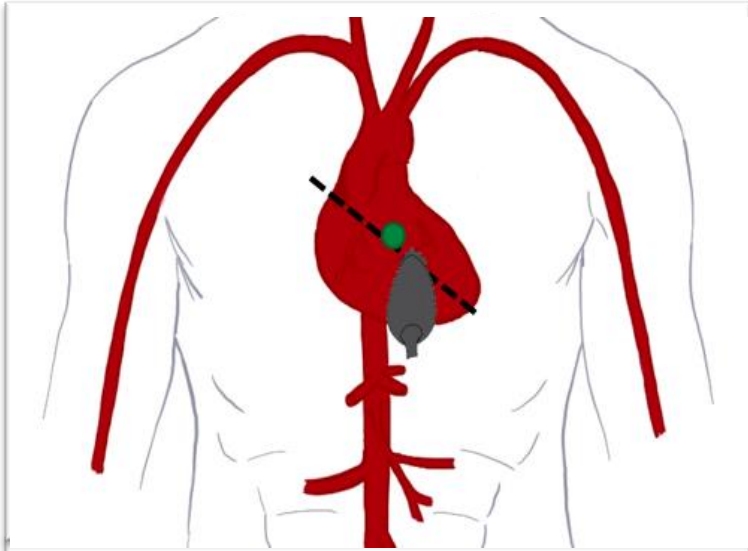
FoCUS PLAX

- 1. Endocardial Excursion
- 2. Myocardial Thickening
- 3. E Point Septal Separation



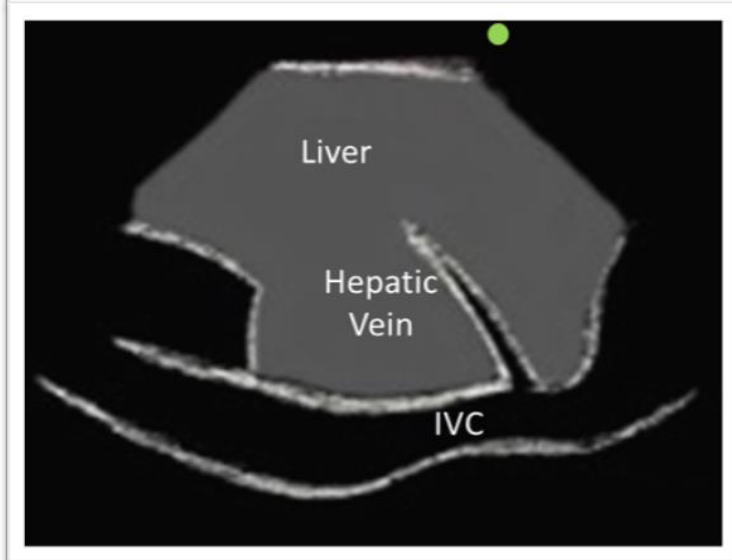
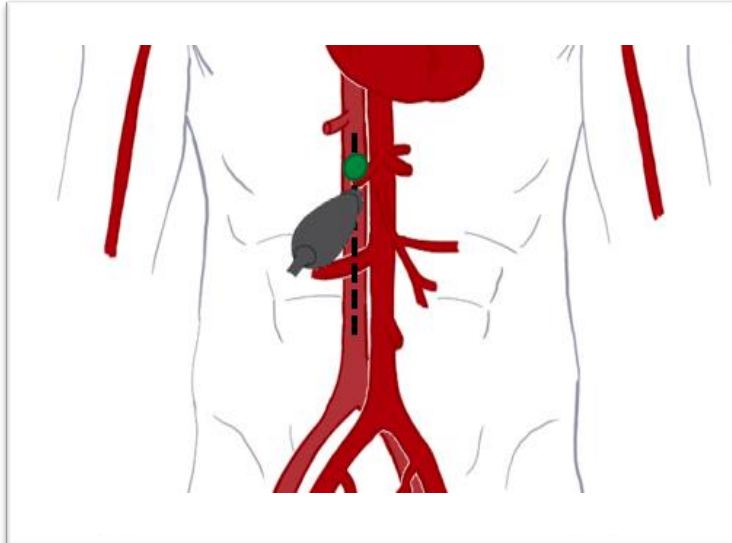
CASE 3

PLAX



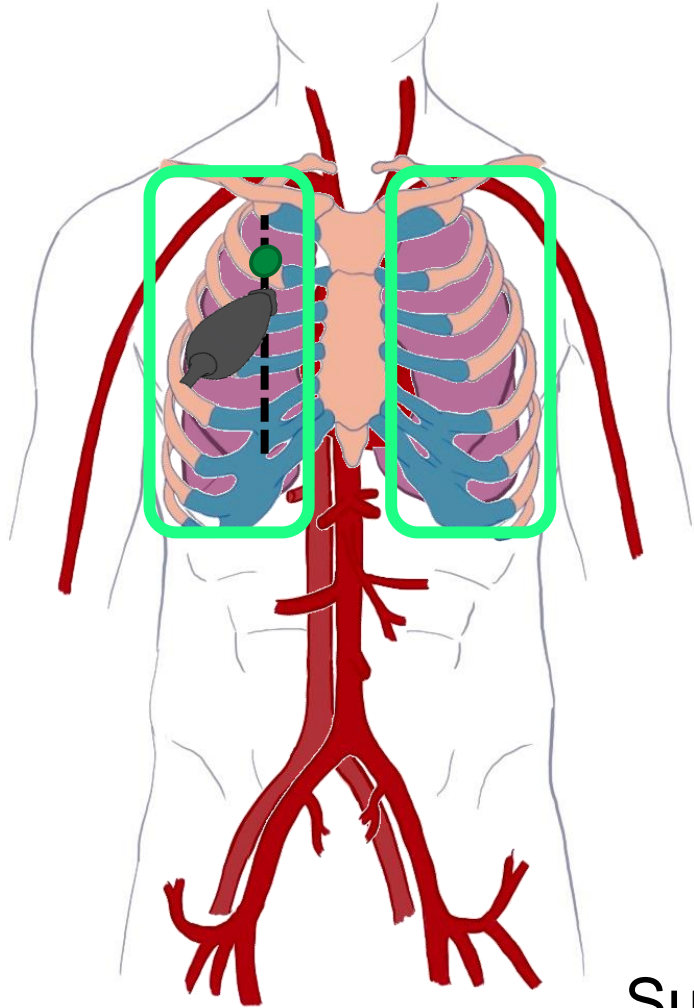
CASE 3

IVC



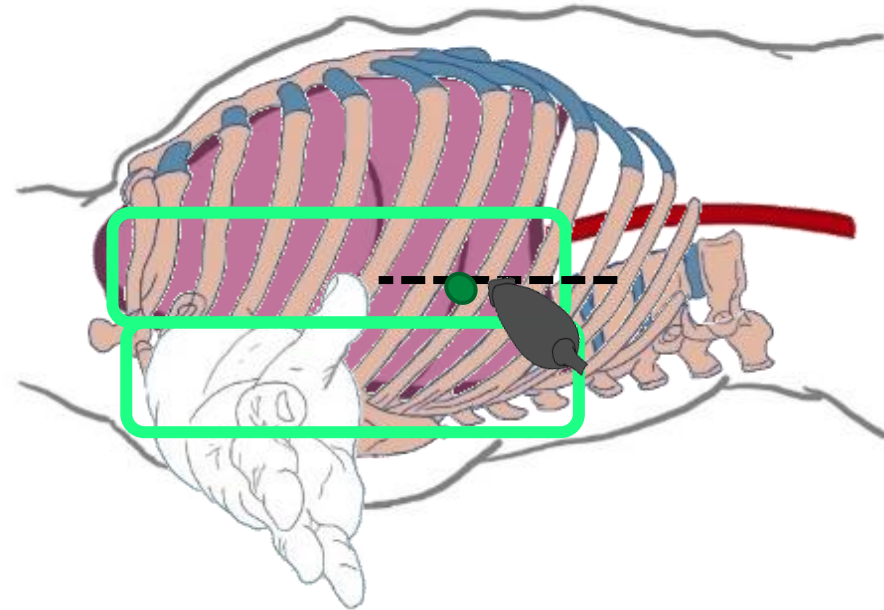
LUNG ULTRASOUND

Zone 1



Zone 2

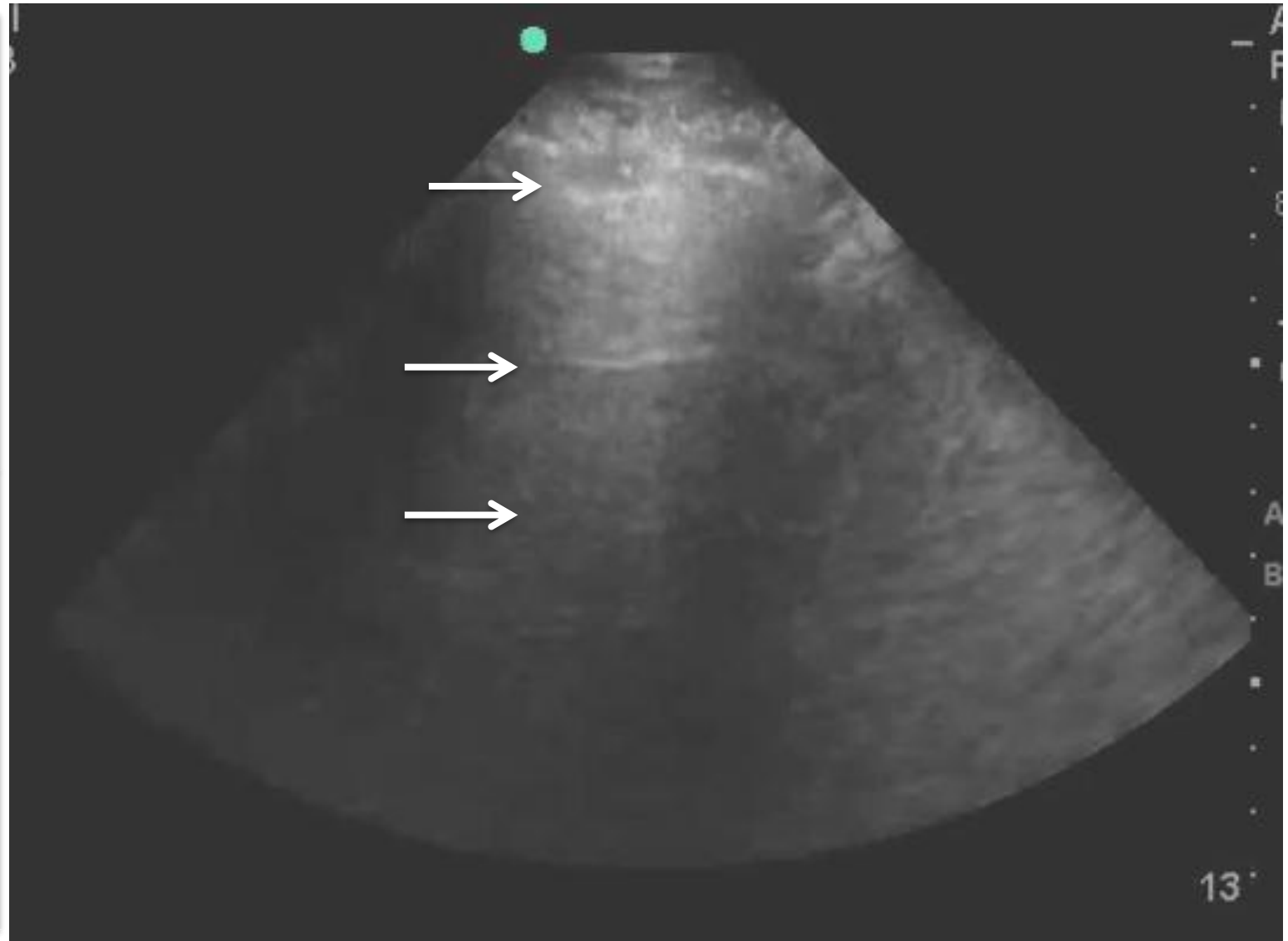
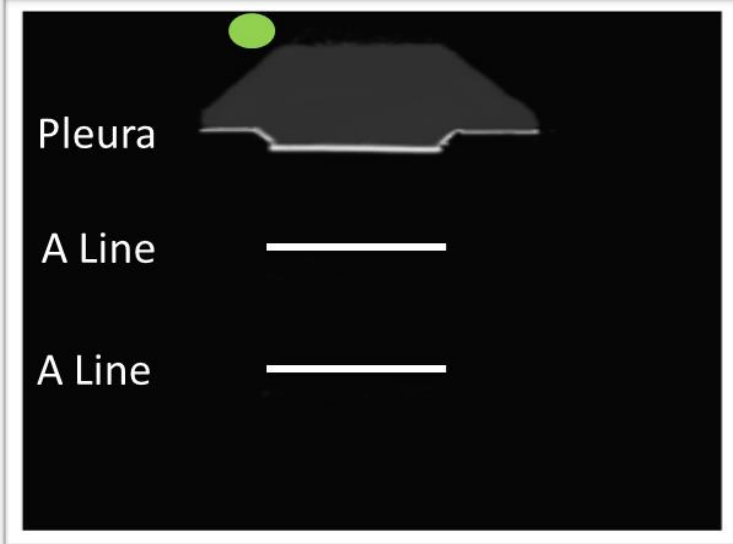
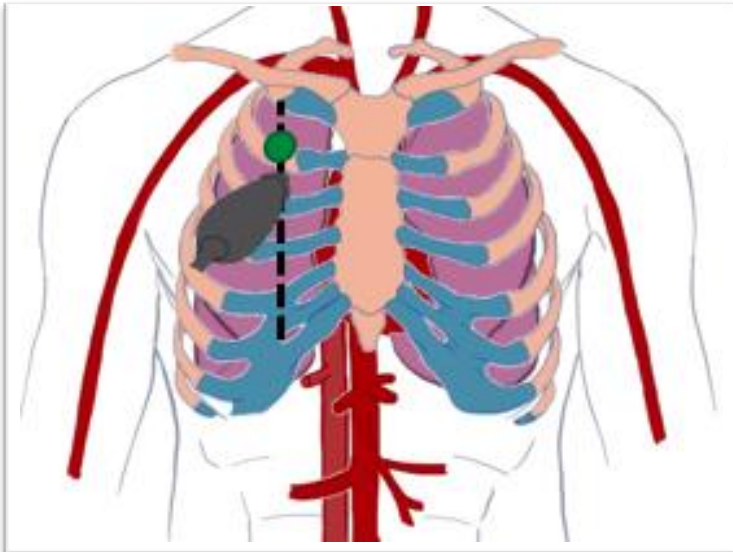
Zone 3



Superior + Inferior Points

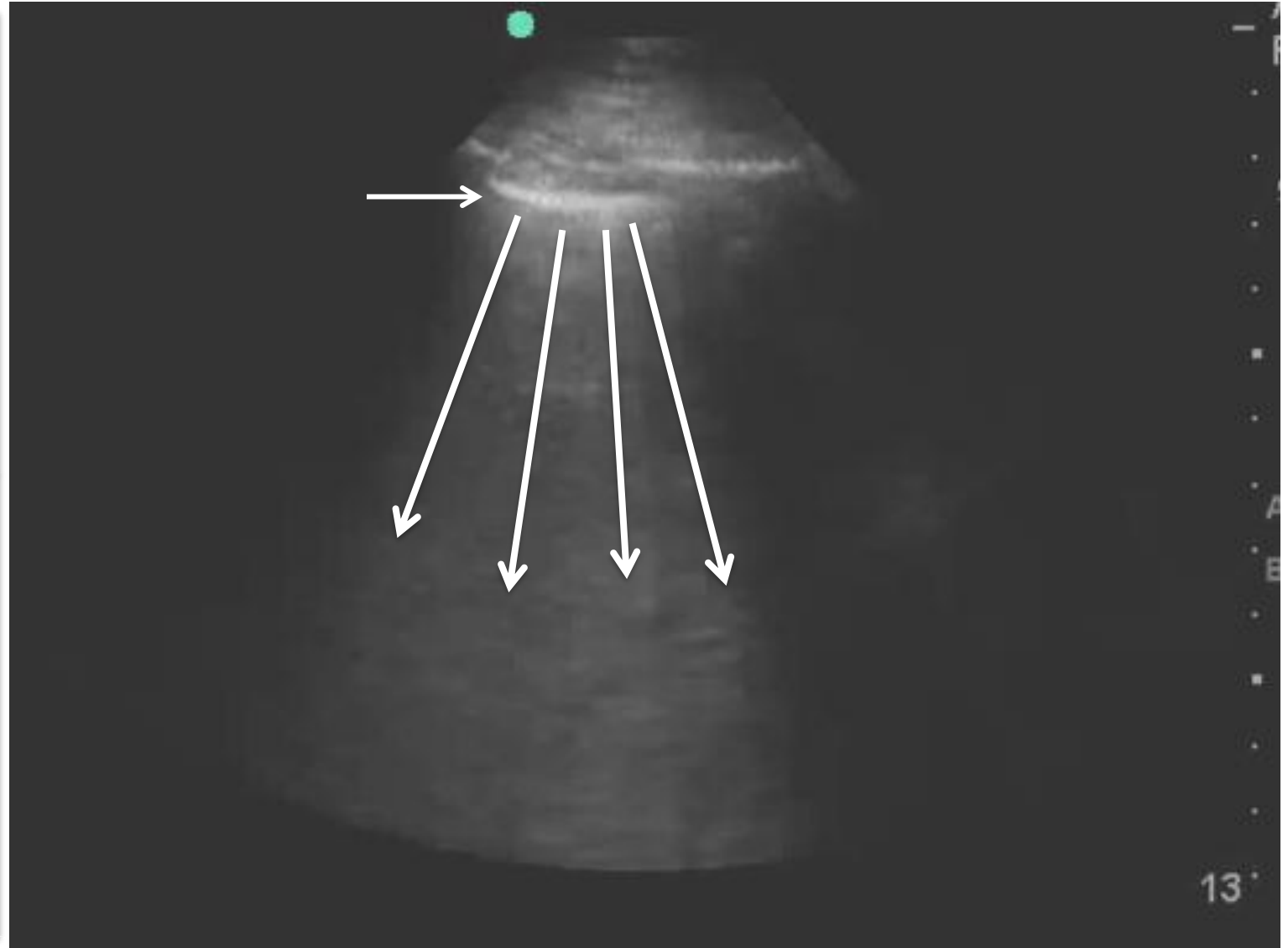
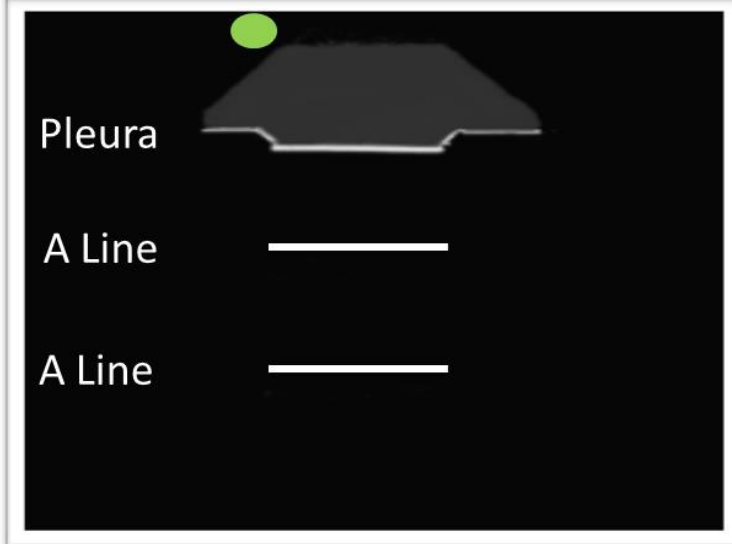
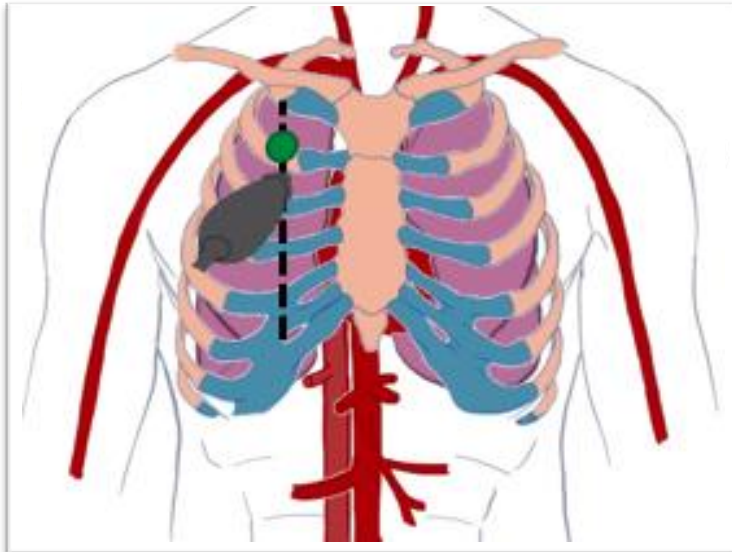
CASE 3

LUNGS



LUNG ULTRASOUND

B LINES



POCUS-GUIDED FLUID RESUSCITATION

	Fluid Tolerance	Fluid Intolerance
Heart	Hyperdynamic LV Function Small RV / Normal RV Function	Reduced LV Function Dilated RV / reduced RV Function
IVC	Small Collapsing	Large Reduced collapse
Lung	A-Lines	B-Lines

- Theerawit P, Tomuan N, Sutherasan Y, Kiatboonsri S. Critical Care 2012,16(Suppl 1): P248. doi: 10.1186/cc10855.
- Lichtenstein D, Karakitsos D. Integrating lung ultrasound in the hemodynamic evaluation of acute circulatory failure (the fluid administration limited by lung sonography protocol). Journal of Critical Care (2012)27, 533.e11–533.e19.

POCUS IN SEPSIS

- Accuracy of point of care ultrasound to identify the source of infection in septic patients: a prospective study

Standard of Care (History / Physical / Basic labs)

vs

Standard of Care + Targeted POCUS (Kidneys, soft tissues, lungs, gallbladder, etc.)

POCUS IN SEPSIS

- Accuracy of point of care ultrasound to identify the source of infection in septic patients: a prospective study

	Standard of Care	Standard of Care + POCUS
Sensitivity	48%	73%
Specificity	86%	95%
LR+	3.54	16.1
LR-	0.59	0.28
Diagnostic Accuracy	53%	75%

POCUS IN SEPSIS

- Accuracy of point of care ultrasound to identify the source of infection in septic patients: a prospective study
 - Antibiotic Regimen altered in 24% of cases
 - Diagnosis made substantially quicker

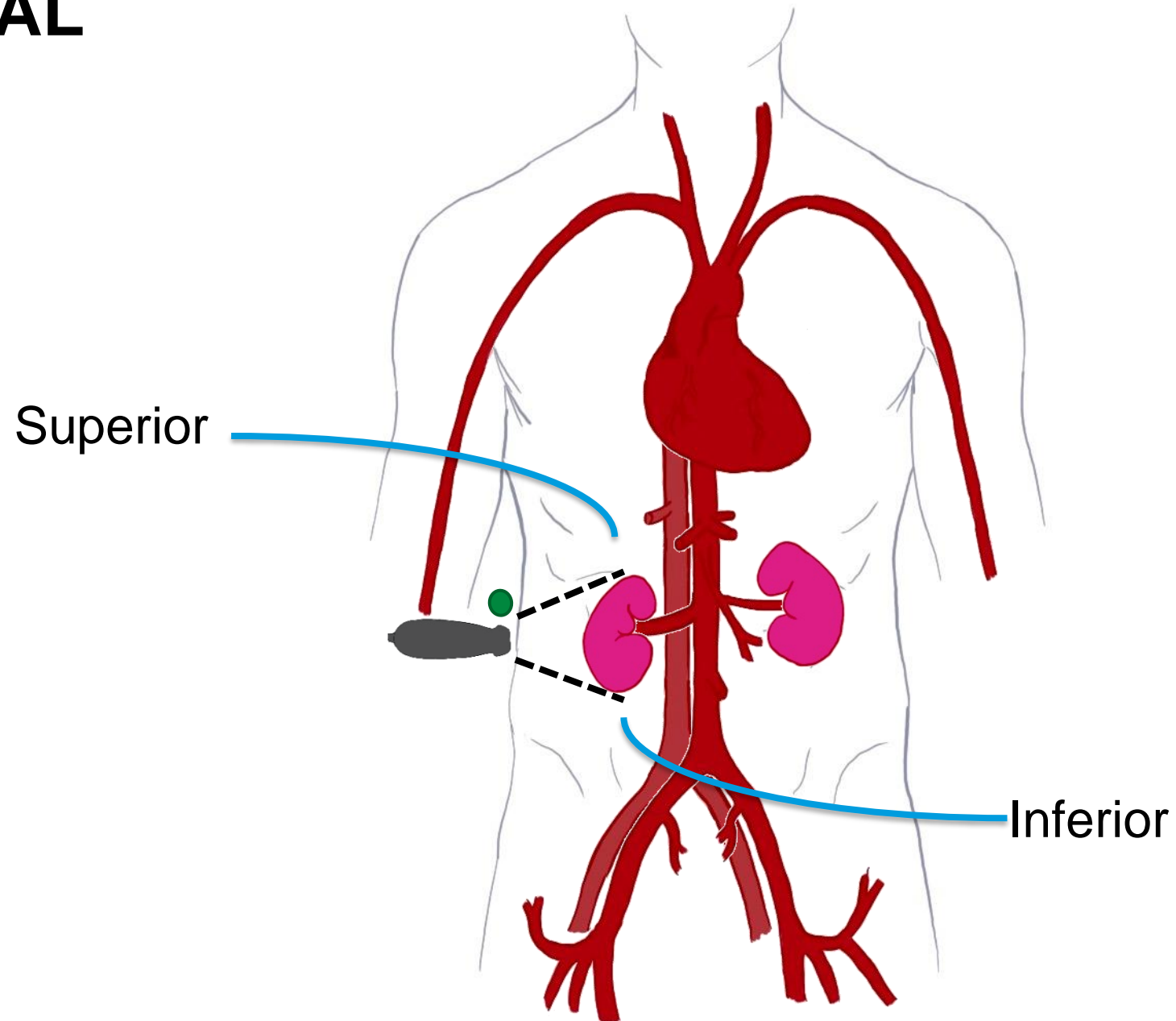
POCUS OF THE KIDNEYS

- Scope:
 - Nephrolithiasis
 - Hydronephrosis
- Indications:
 - AKI
 - UTI with Sepsis
 - Renal colic

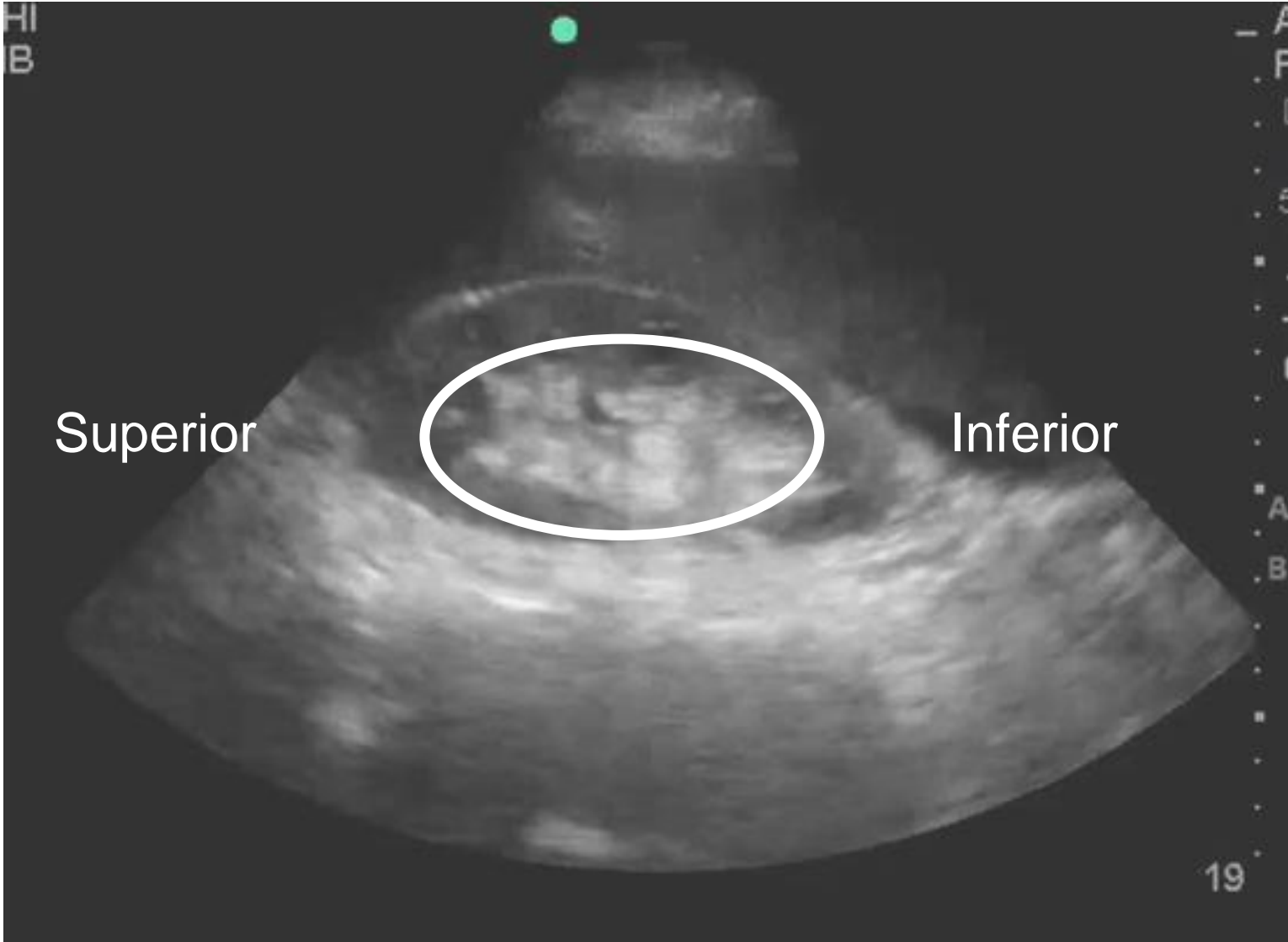
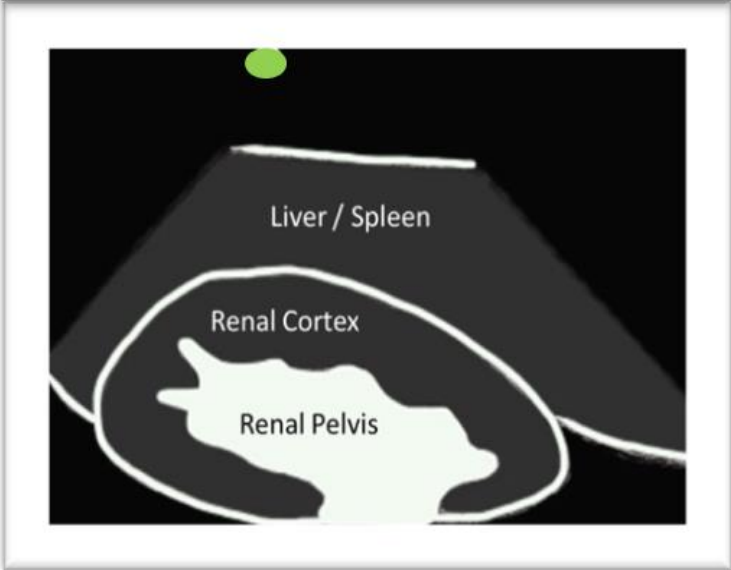
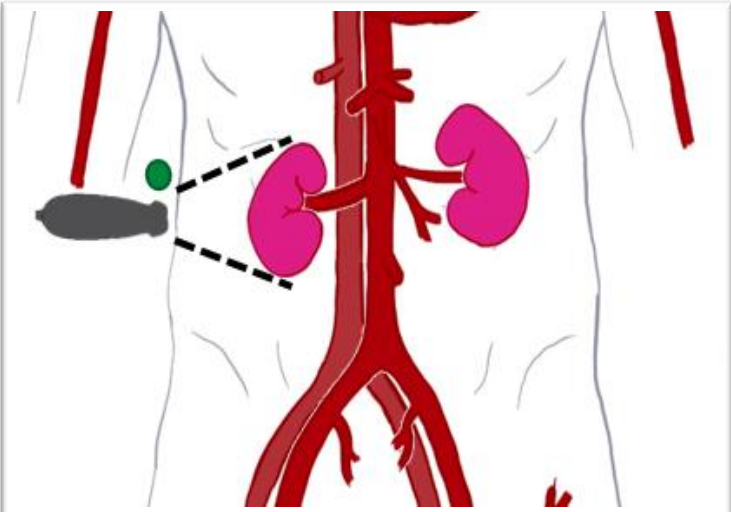
	Sensitivity	Specificity
Nephrolithiasis	19 – 62%	90 – 98%
Hydronephrosis	72 – 97%	73 – 93%

- Yilmaz S, Sindel T, Arslan G, Ozkaynak C, Karaali K, et al. Renal colic: Comparison of spiral CT, US, and IVU in detection of ureteral calculi. *Eur Radiol.* 1998;8:212-217.
- Sheafor DH, Hertzber BS, Freed KS, Carroll BA, Keogan MT, Paulson EK, DeLong DM, Nelson RC. Nonenhanced Helical CT and US in the Emergency Evaluation of Patients with Renal Colic: Prospective Comparison. *Radiology.* 2000;217:792–797.
- Fowler KA, Locken JA, Duchesne JH, Williamson MR. US for Detecting Renal Calculi with Nonenhanced CT as a Reference Standard. *Radiology.* 2002; 222:109–113.
- Kanno T, Kubota M, Sakamoto H, Nishiyama R, Okada T, Higashi Y, Yamada H. Determining the Efficacy of Ultrasonography for the Detection of Ureteral Stone. *Urology.* 2014;84:533-537.

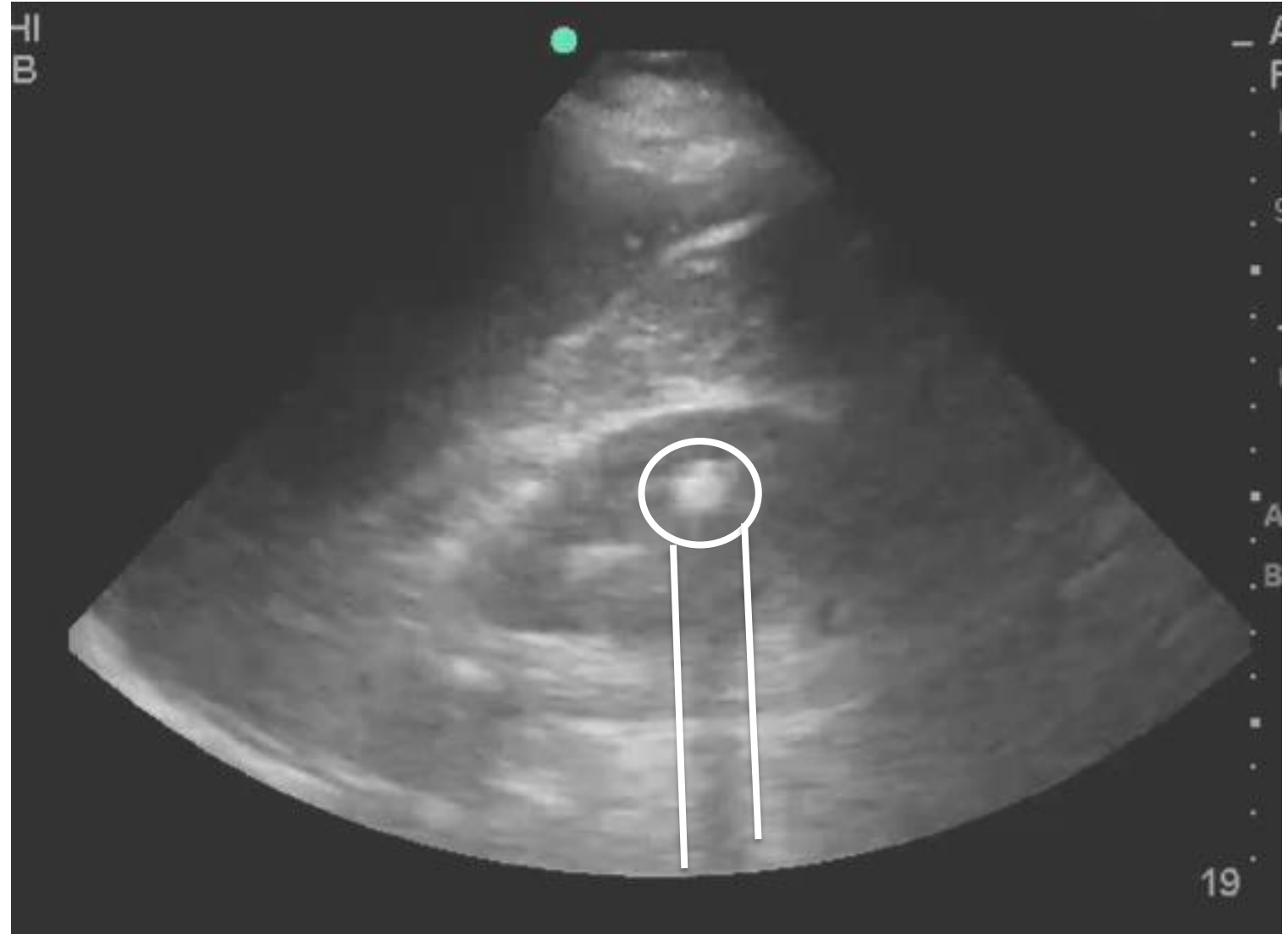
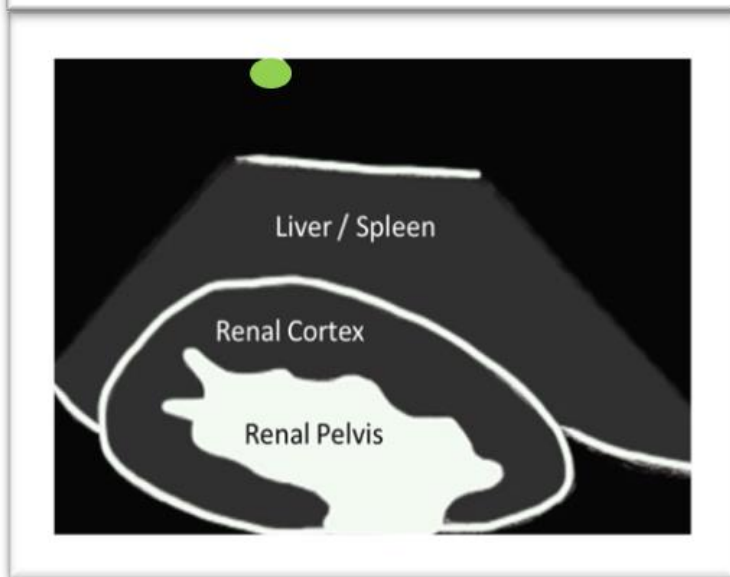
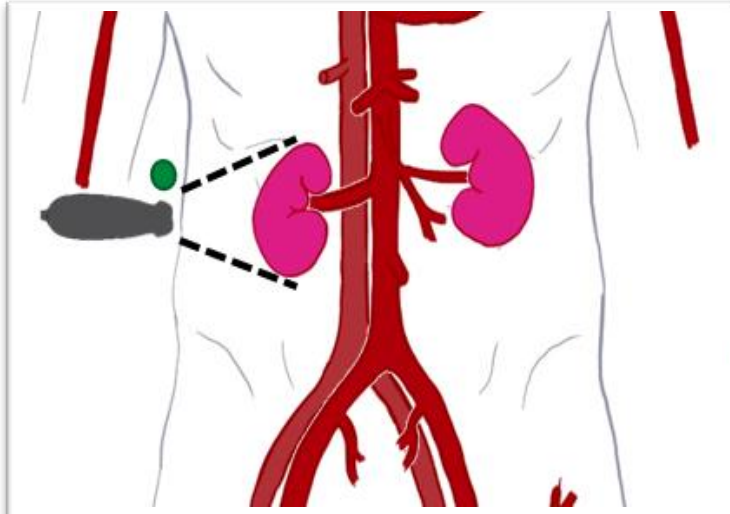
RENAL



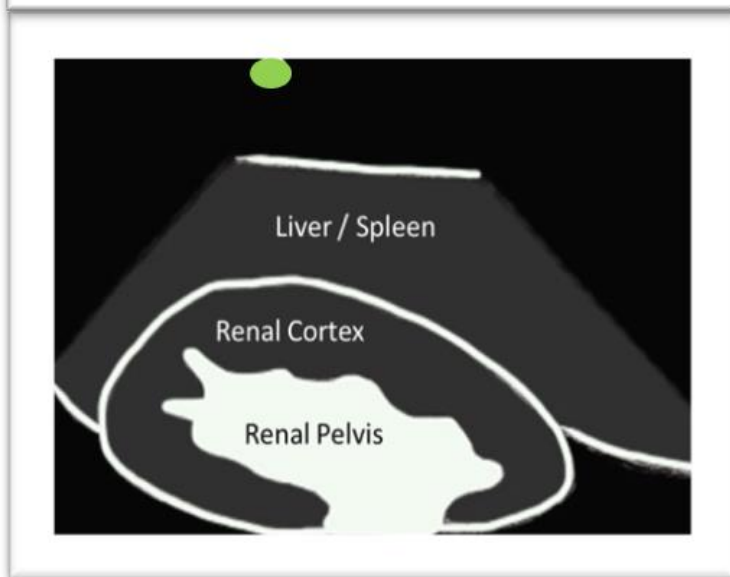
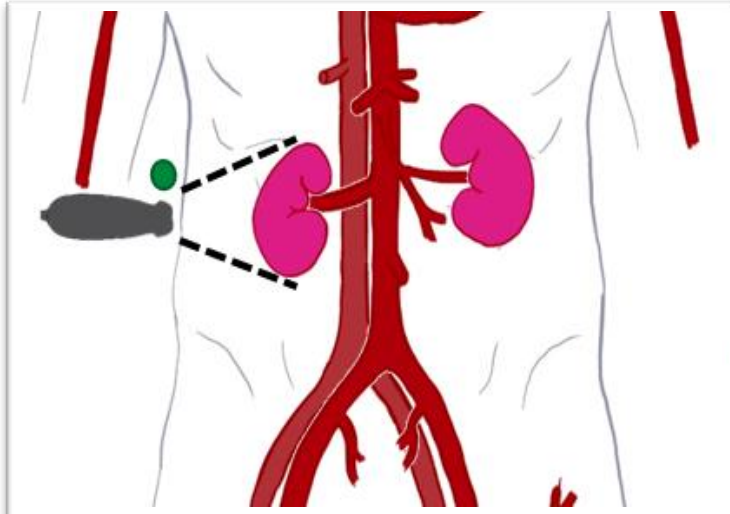
RENAL POCUS



RENAL POCUS

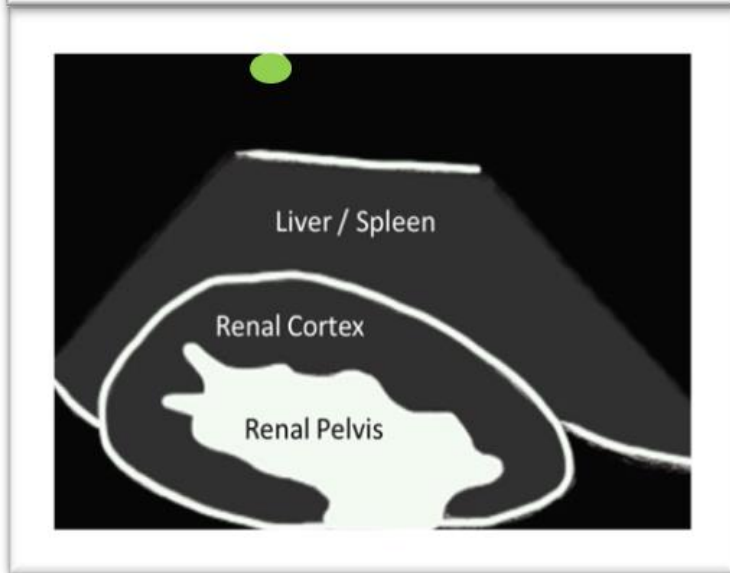
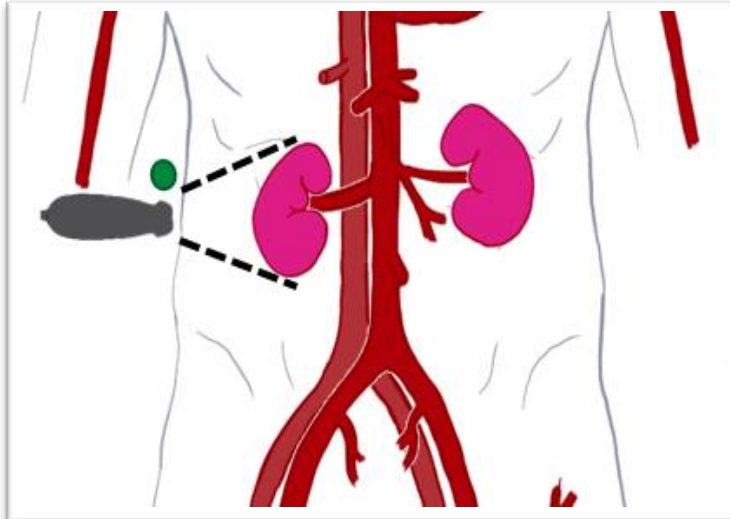


RENAL POCUS



CASE 3

RENAL POCUS



CASE 3

Hypovolemic / Fluid
Tolerant



Obstructive
Uropathy



IVF
Emergent CT
Nephrostomy Tube

SUMMARY

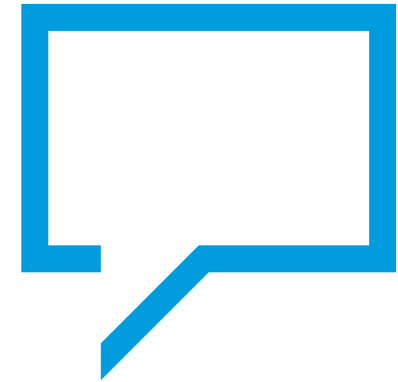
POCUS USES				
Trauma	Shock	Sepsis	Fluid status	Renal

SUMMARY

POCUS USES				
Trauma	Shock	Sepsis	Fluid status	Renal
FoCUS	Lung	Aorta	Bladder	Ocular
OB	SSTI	Bones	Joints	Testicular
SBO	Gallbladder	Appendicitis	Vascular Access	AKI
Foreign body	Cardiac arrest	Procedural guidance	Nerve block	DVT

QUESTIONS AND DISCUSSION

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Heart



Lungs



Shock



Kidneys

