# Internal Medicine Point-of-care Ultrasound: Introduction

Dr. Jordan Nickols, M.D

EAMC Internal Medicine Residency Core faculty

Internal Medicine Point-of-care Ultrasound medical director

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# Objectives

- Discussion evolution of POCUS and pertinence for IM physicians
- Define POCUS
- Ultrasound physics
- Getting comfortable with the probe and orientation
- Knobology and ultrasound modes
- Discuss various artifacts associated with ultrasound
- PEARLS
- Next steps…

# Evolution of POCUS

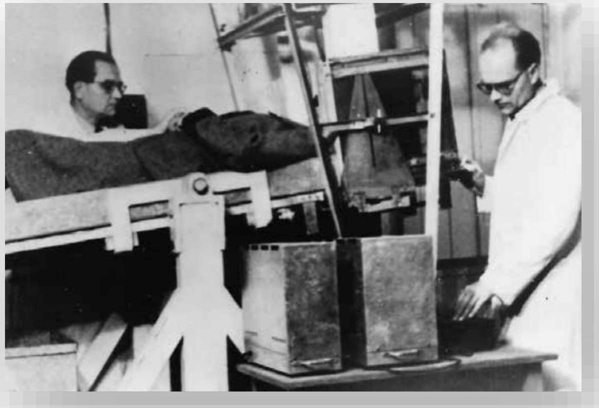
That it will ever come into general use, notwithstanding its value, is extremely doubtful; because its beneficial application requires much time and gives a good bit of trouble both to the patient and the practitioner; because its hue and character are foreign and opposed to all our habits and associations.

# Evolution of POCUS

"… I have no doubt whatever, from my own experience of its value, that it will be acknowledged to be one of the greatest discoveries in medicine by all those who are of a temper, and in circumstances, that will enable them to give it a fair trial. That it will ever come into general use, notwithstanding its value, I am extremely doubtful; because its beneficial application requires much time, and gives a good deal of trouble both to the patient and the practitioner; and because its whole hue and character is foreign, and opposed to all our habits and associations. It must be confessed that there is something even ludicrous in the picture of a grave physician formally listening through a long tube applied to the patient's thorax, as if the disease within were a living being that could communicate its condition to the sense without."

# Brief history…

Served as the catalyst for the development of sonar technology (1912)



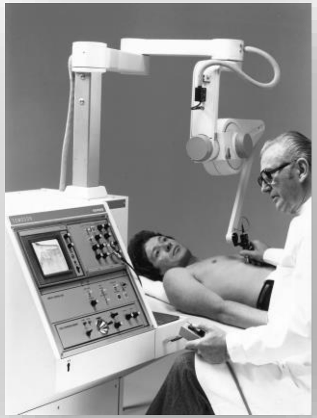
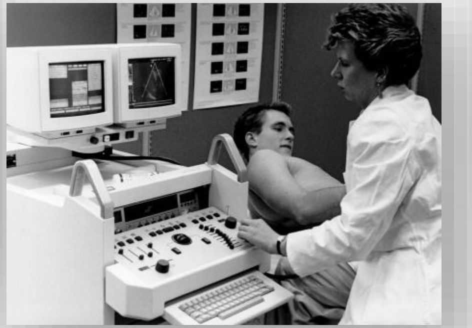
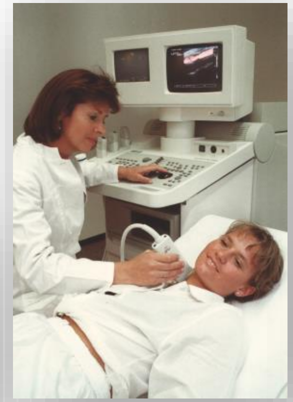
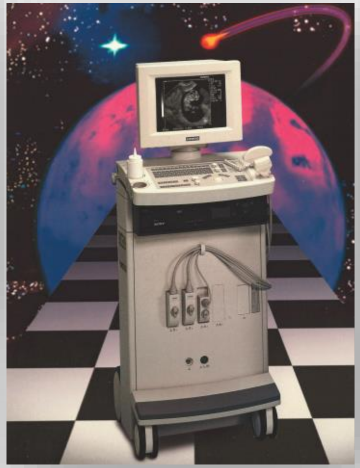
Karl Theodore Dussik , Austrian physiatrist and neurologist, using a primitive ultrasound device to aid in diagnosis of neurological disease (1942)

Immersion tank ultrasound ("somascope") introduced by Douglass Howry and Joseph Holmes resulted in publication of the first 2D ultrasound images (1954)

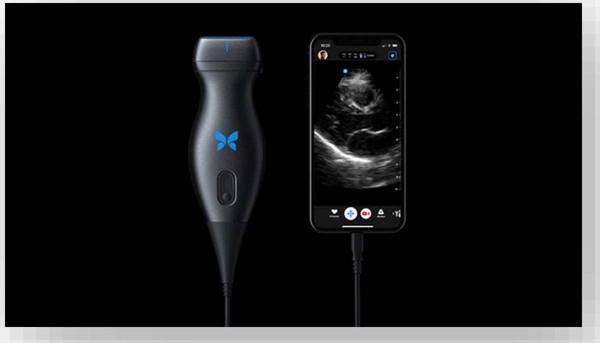
The Vidoson. First real time ultrasound scanner that could display 15 images per second (1965)

# Brief history...

Then came sector scanning and steady advancement of technology and probes...


# AND THEN...




The Accuson P10 ultrasound system was the first pocket ultrasound device (2007)

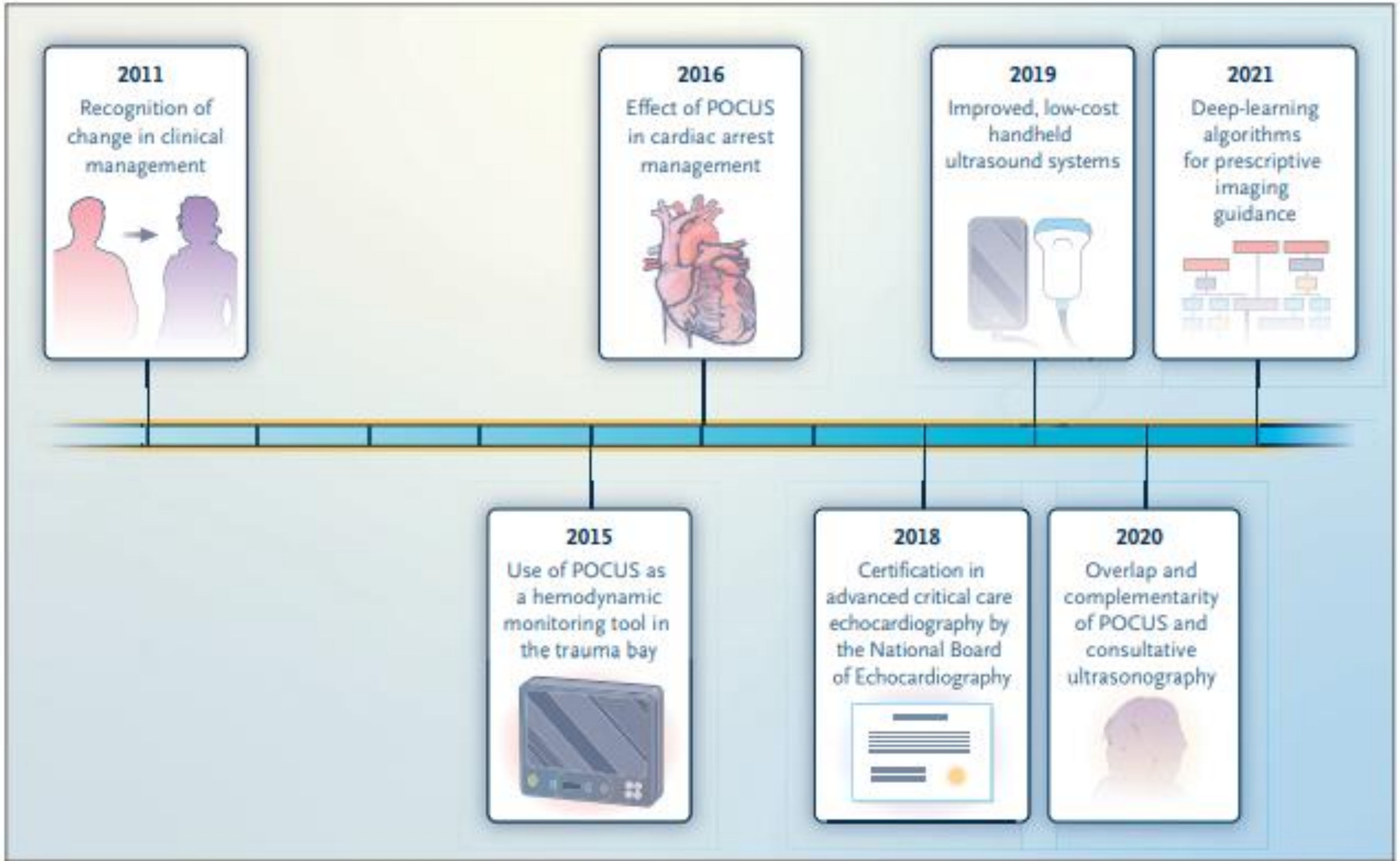



**Figure 1. Evolution of Point-of-Care Ultrasonography (POCUS) during the Past Decade.**
The leading areas of research on POCUS have been cardiothoracic ultrasonography and ultrasound-guided procedures. Most of the studies have been published in critical care medicine and emergency medicine journals.

(Diaz-Gomez, *Point-of-care Ultrasonography* 2021)

# Incorporation by specialty

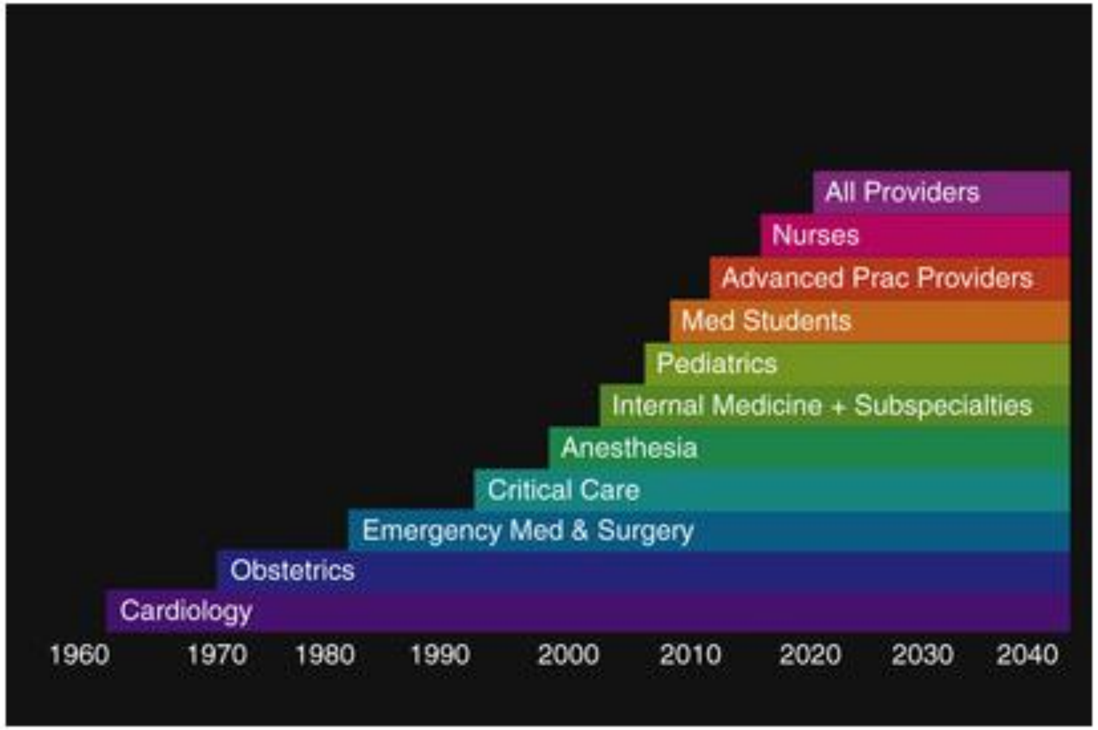



**FIGURE 1.4** Integration of Point-of-Care Ultrasound in Medical Specialties.

"We anticipate nearly all health care providers, including nurses, advanced practice providers, and physicians, will be using point-of-care ultrasound in their clinical practice over the next ten years." (Copyright 2015)

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Soni NJ, Arntfield R, Kory P. *Point-of-Care Ultrasound*. Elsevier; 2020.

# What is POCUS?

| What POCUS is | Comprehensive US examination |
|---|---|
| Answer focused questions (Abdomen: is there intrabdominal free fluid? Are gallstones present?) | Evaluate all organs in an anatomical region (abdomen: will evaluate the liver, gallbladder, and biliary ducts) |
| Generally performed by the same clinician who generates the clinical question and will subsequently act on the findings. | Performed by a sonographer, interpreted by a specialist, who will then report the findings back to the Primary clinician. |
| POCUS is often evaluating multiple body systems. | Localized to a specific anatomic region |
| Can be performed serially to evaluate for change over time (response to fluid resuscitation) | |

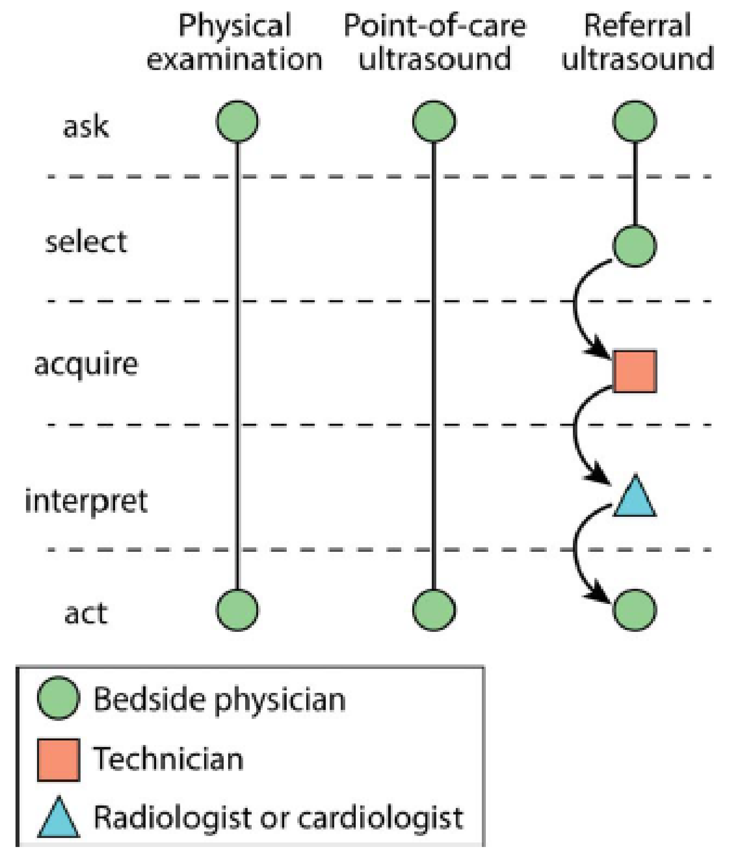



**FIG. 1.** Comparison of physical examination and point-of-care and referral ultrasound examinations. The circles, squares, and triangles represent different healthcare providers. The dotted lines separate 5 stages of bedside providers' clinical decision making. The curved arrows represent transfer of information—most commonly through written reports—from 1 provider to another.

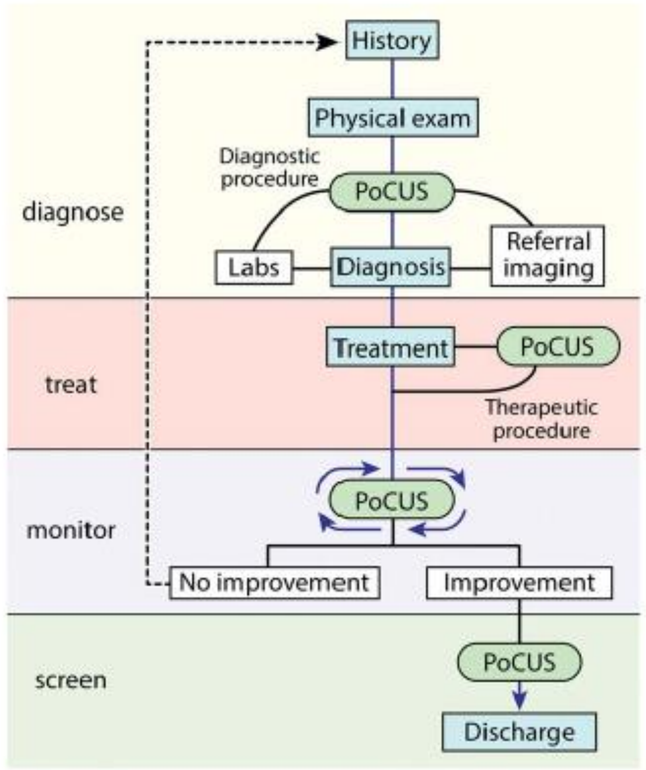
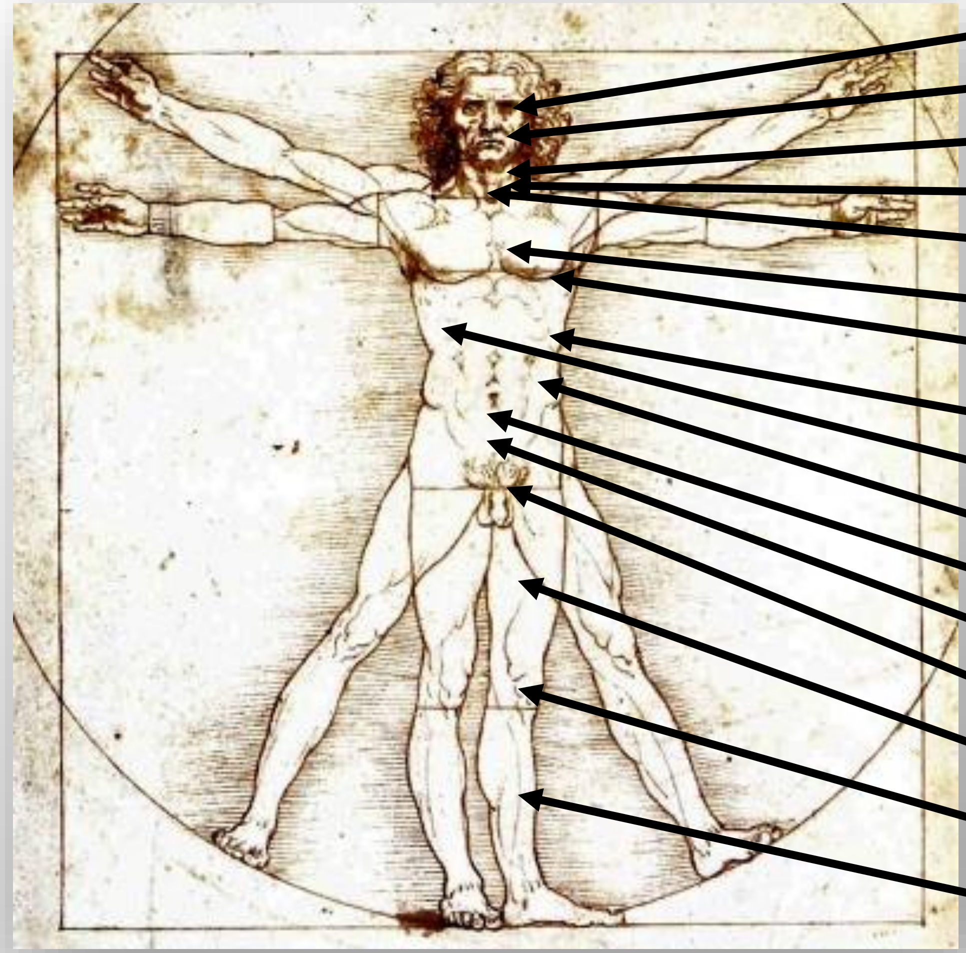



**FIG. 2.** Point-of-care ultrasound in hospitalized patients. After gathering a medical history and performing a physical examination, a focused bedside ultrasound exam can facilitate making a diagnosis or guiding further workup. Diagnostic or therapeutic bedside procedures are performed with ultrasound guidance to reduce complications. Serial point-of-care ultrasound exams are performed to monitor disease processes and treatment effects. Screening to detect asymptomatic, potentially treatable conditions can be undertaken with point-of-care ultrasound. Abbreviations: PoCUS, point-of-care ultrasound.

(Soni & Lucas, *Diagnostic point-of-care ultrasound for Hospitalists* 2014)

# SOME of the applications for Diagnostic POCUS



- **Ocular** – retinal detachment, intracranial pressure
- **ENT** – sinusitis, peritonsillar abscess
- **Carotid** – plaque/stenosis, dissection, volume responsiveness
- **Thyroid** – nodules, Graves
- **Trachea/ Esophagus** – endotracheal tube placement
- **Heart/ IVC** – pericardial effusion, EF, valves, chamber size, CVP
- **Lung** – pneumothorax, pleural effusion, pulmonary edema, pneumonia
- **Spleen** – splenomegaly
- **Liver/ GB** – hepatomegaly, gallstones, cholecystitis
- **KUB** – hydronephrosis, urinary retention
- **Intestines** – SBO, appendicitis
- **Peritoneum** – hemoperitoneum/ ascites, paracentesis
- **Genitals/ pelvic** – mass, torsion, pregnancy
- **Vascular** – DVT, central and peripheral line placement
- **MSK** – fractures, tendon injury, joint injections
- **Skin/soft tissues** – Cellulitis, abscess

# Common applications for hospitalists…

TABLE 1. **Common POCUS applications for hospitalists**

| Cardiac | Pulmonary | Abdominal | Vascular | MSK | Procedural |
|---|---|---|---|---|---|
| LV assessment | Pleural effusion | Free fluid | DVT | Cellulitis | Paracentesis |
| RV assessment | Interstitial syndromes | Kidney size | AAA | Abscess | Thoracentesis |
| Atrial size | Alveolar syndromes | Hydronephrosis | | Joint effusions | CVC placement<br>PIV placement |
| Central venous pressure (IVC/IJ) | Pneumothorax | Bladder volume | | Fractures | Arterial line placement |
| Pericardial effusion | | Gallbladder | | | Arthrocentesis |
| Chamber hypertrophy | | Spleen size | | | Abscess drainage |
| Gross valvular abnormalities | | Liver size | | | Lumbar puncture |

**Multisystem**

Hypotension and shock: cardiac, central venous pressure, pulmonary, DVT, abdominal free fluid

Resuscitation: cardiac, central venous pressure, pulmonary

Dyspnea: pulmonary, cardiac, central venous pressure, DVT

Acute renal failure: renal, bladder, central venous pressure, pulmonary

Abbreviations: AAA, abdominal aortic aneurysm; CVC, central venous catheter; DVT, deep venous thrombosis; IJ, internal jugular vein; IVC, inferior vena cava; LV, left ventricle; MSK, musculo-skeletal ; PIV, peripheral intravenous catheter; RV, right ventricle..

Soni, N.J., et al. Point-of-Care Ultrasound for Hospitalists: A Position Statement of the Society of Hospital Medicine 2019

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# Ultrasound physics (Basics)

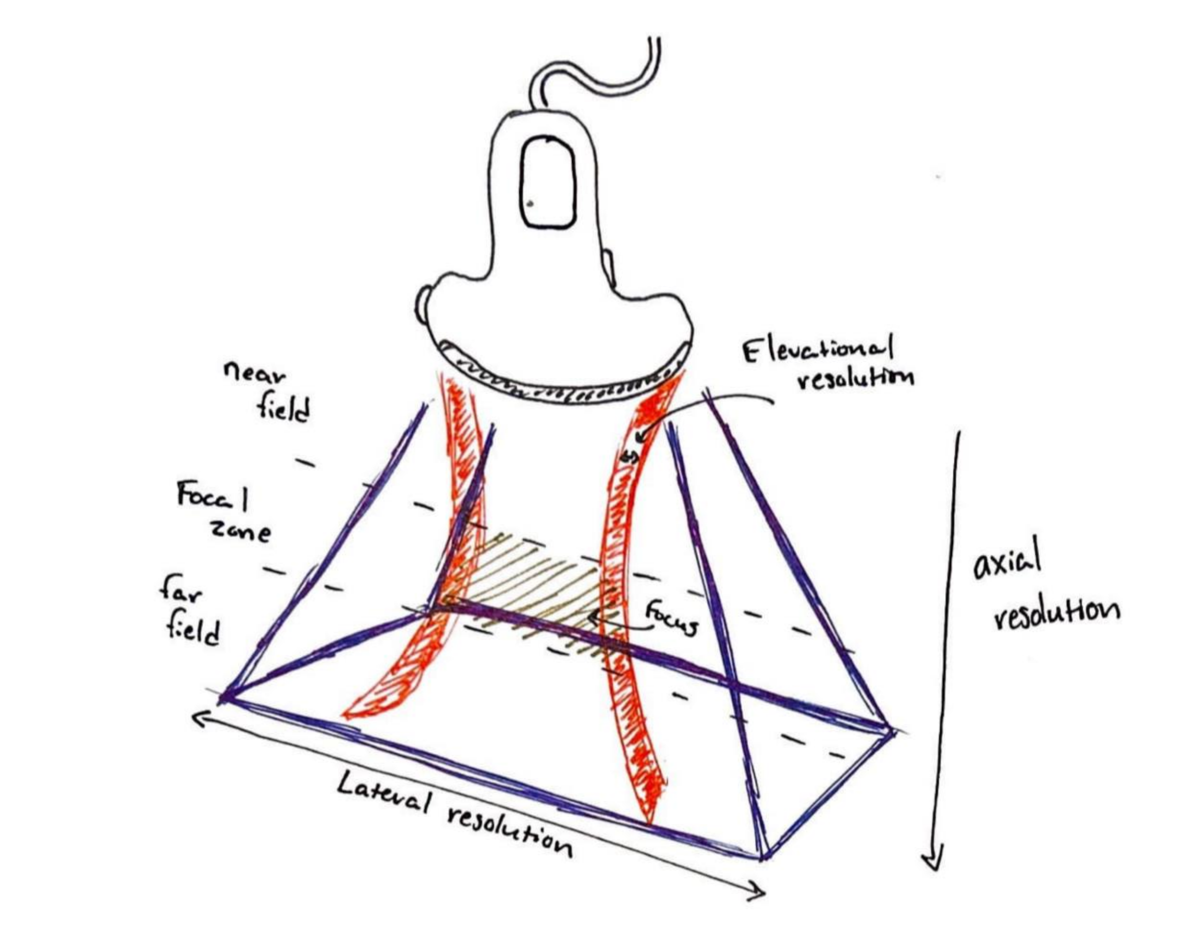
- At its core ultrasound uses sound waves to visualize internal organs.
- Core considerations: frequency, wavelength, velocity, power, and intensity.

# Ultrasound physics (Basics)

- **Frequency and wavelength**
  - Inversely related using the equation $f=c/\lambda$. Where, $f$ – frequency, $c$ – speed of sound in a given tissue, λ – wavelength.
  - Lower frequencies penetrate deeper and have somewhat lower resolution. Utilize for deep structures in the thorax, abdomen, and pelvis.
  - Higher frequencies have shorter lengths of penetration and higher resolution. Usually limit to < 6cm deep and utilized for vasculature, joints, soft tissues.
- **Power and intensity**
  - Power (*W*)*:* The total energy on a tissue in a specified time.
  - Intensity: Power per unit area ($W/cm^2$)
  - These will become more important later.

# Resolution

- **Axial:** Differentiate between two object as your beam travels from near field to far field. Dependent upon frequency of transducer.
- **Lateral:** Horizontal resolution. Dependent on width of beam at a given depth.
- **Elevational:** resolution within the thickness of the beam.
- **Temporal:** Resolution of moving structures.



# Variations in Echogenicity

- Anechoic – Transmit all sound waves without reflection. Appears black.
- Hypoechoic – Reflect fewer sound waves than surrounding structures. Darker than surrounding structures.
- Isoechoic – Reflect sound waves similar to surrounding structures.
- Hyperechoic – Reflect most sound waves. Appears lighter than surrounding structures.

Fluid (blood, bile, urine)

Solid organs, soft tissue, muscle

Bone, metal, and air

Dense, fibrous structures (e.g. diaphragm)

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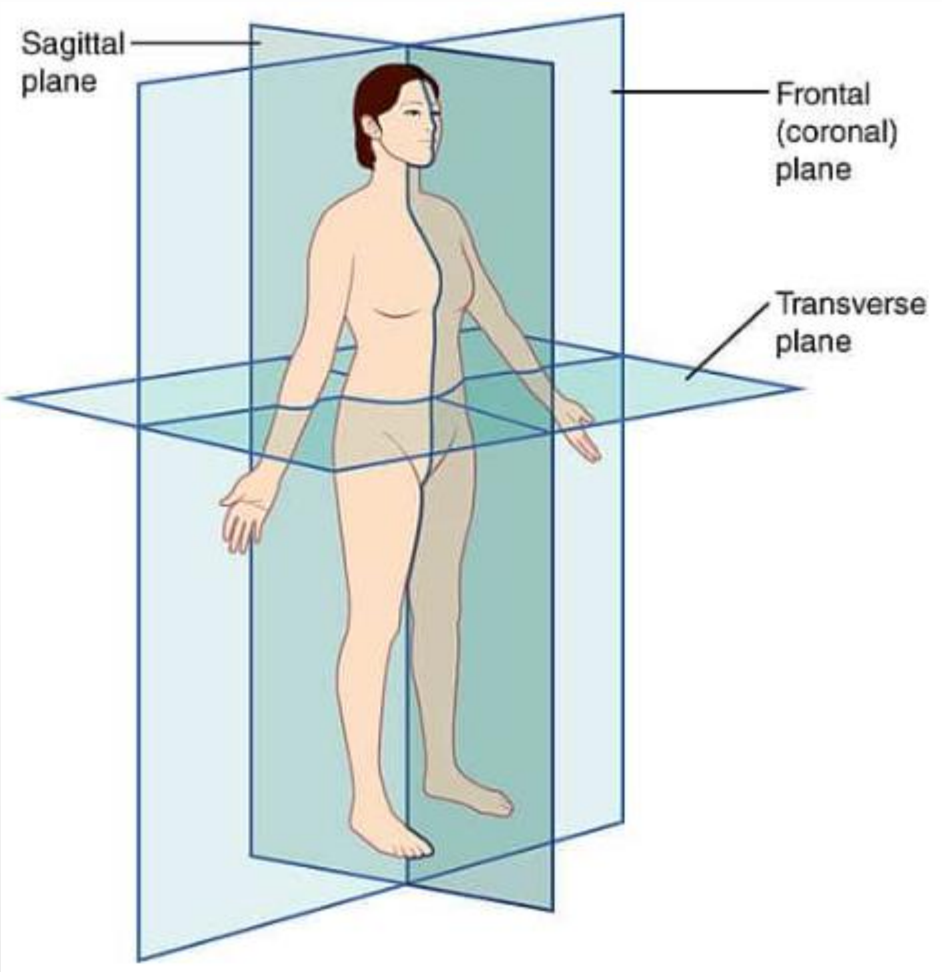
# Getting oriented




Imaging planes adapted from Wikimedia

Planes of cut depicted on left of screen. 4 cardinal movements of ultrasound imaging pictured at bottom right of screen.

A critical skill in ultrasound imaging is learning to visualize 3 dimensional structures in 2 dimensional images.

Sliding

Fanning

Rocking

Rotating

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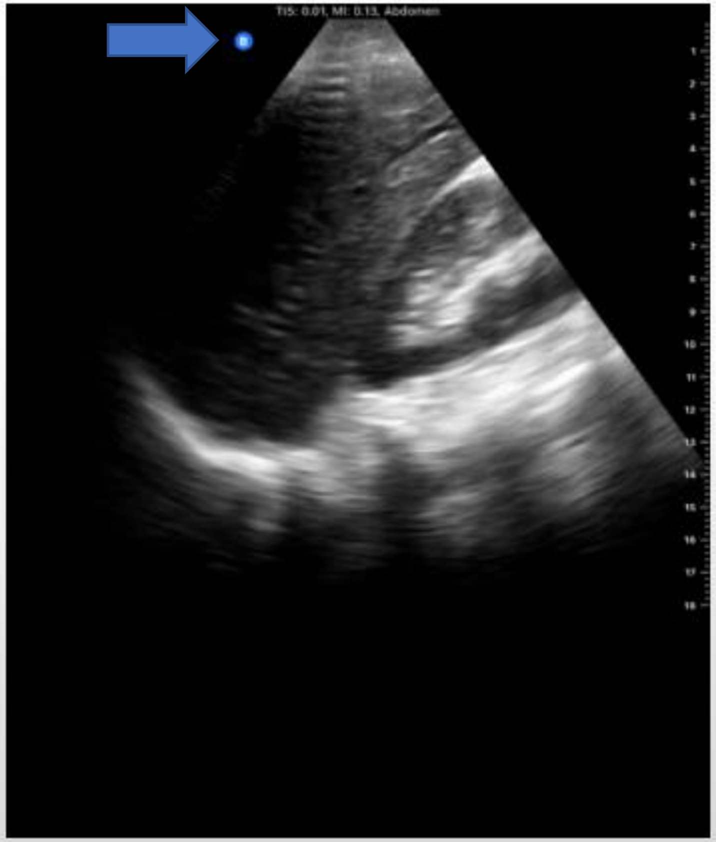
# Probe marker, screen marker, and ultrasonographer orientation



**2 Major conventions for screen marker orientation:**

Standard medical convention -> Screen marker in upper left corner

Cardiac convention -> Probe marker in upper right corner (Will review more when reviewing cardiac imaging specifically)

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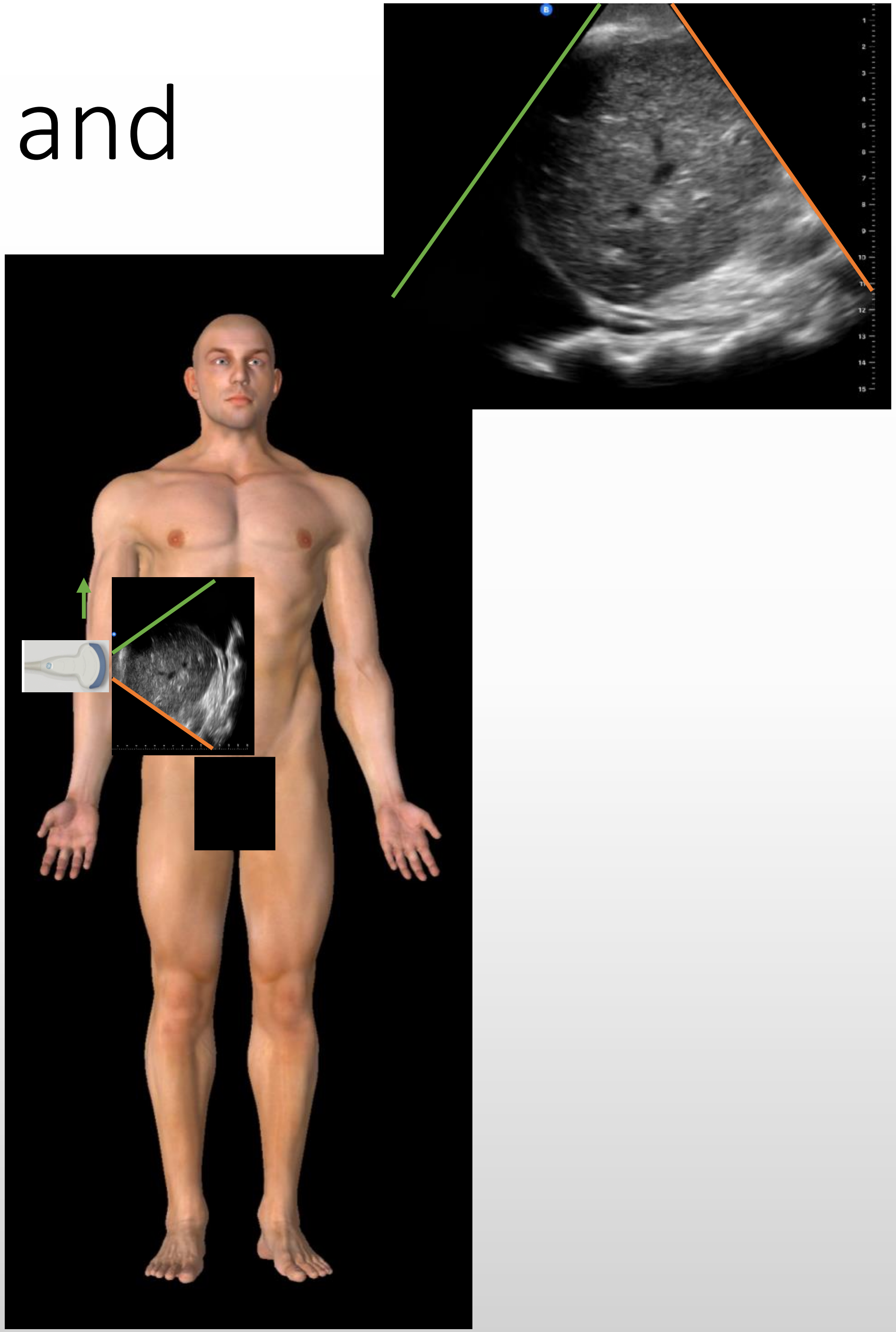
# Probe marker, screen marker, and ultrasonographer orientation

Standard convention is to stand on patient's right side, left side of bed.

When using standard medical imaging convention, probe marker should always be pointed toward the patient's right, or the ultrasonagrapher's left hand side when obtaining axial images.

In sagittal/ coronal views, the probe marker should point toward the patient's head.



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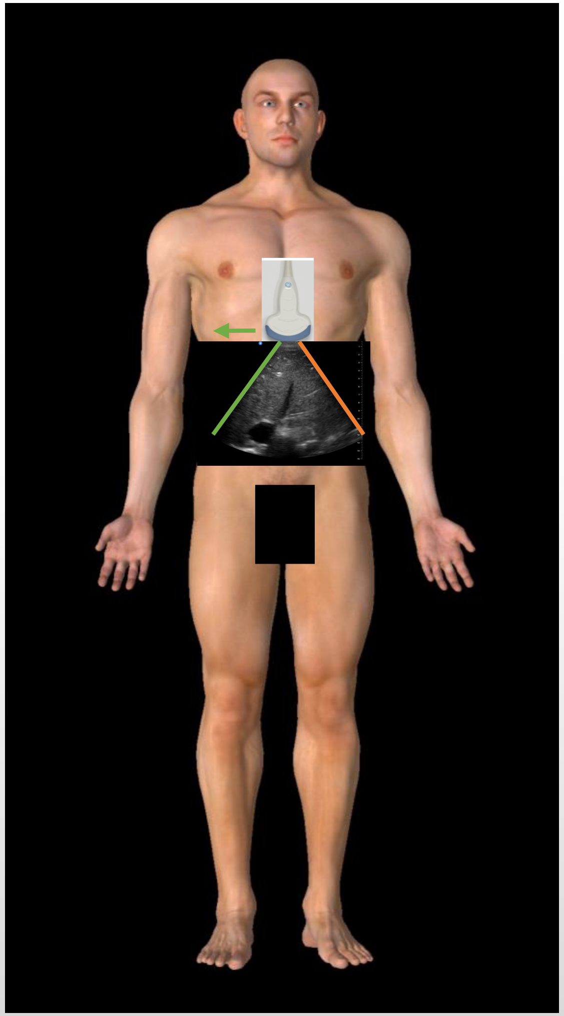
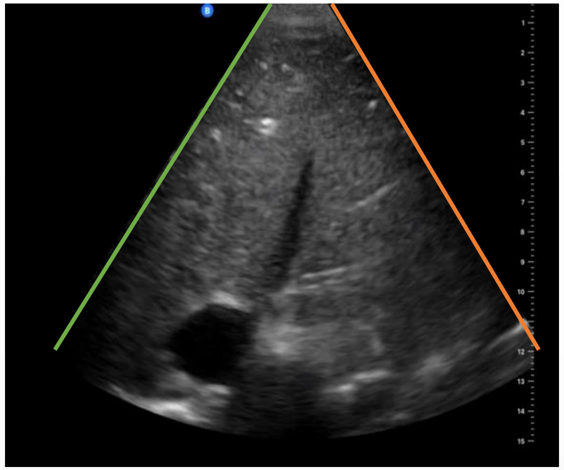
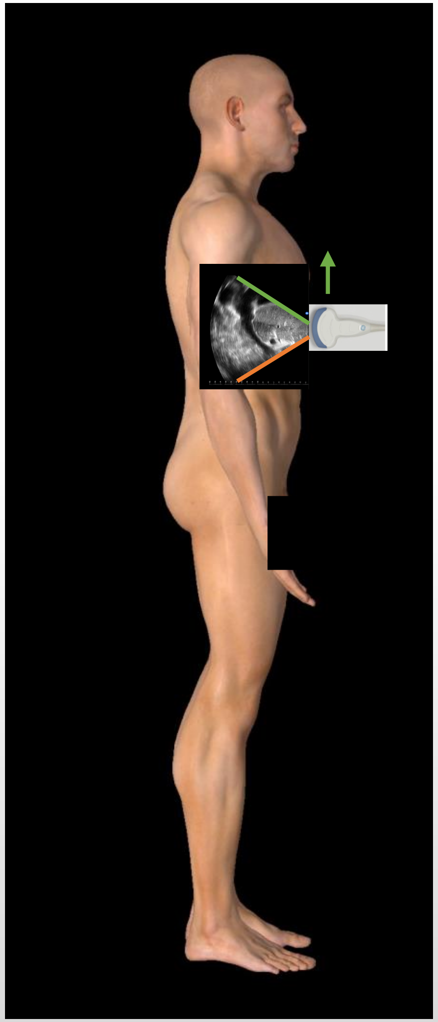
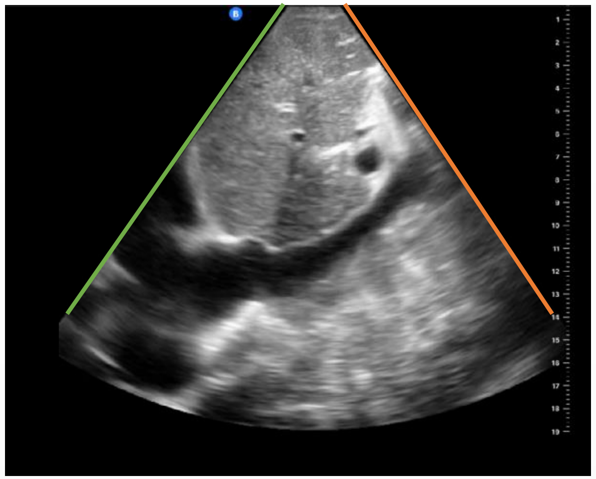
# IVC in transverse and longitudinal axis









# Knobology

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# Knobology


- <u>Probe</u>
- <u>Preset</u> – dependent on probe and structure being evaluated
- <u>Mode</u> – Discussed elsewhere
- <u>Gain</u> – Adjust the brightness and darkness of an image; fluid should be black and tissues on a gray spectrum
- <u>Depth</u> – Best resolution with target structure in center of screen


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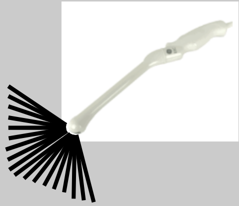
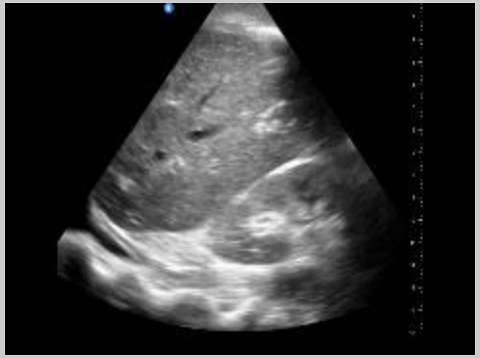
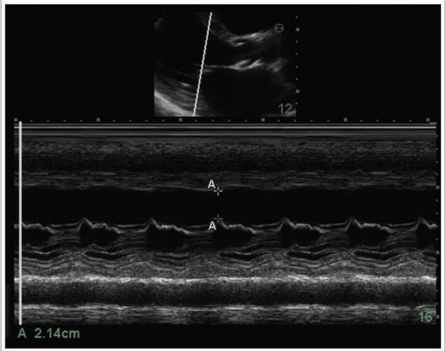
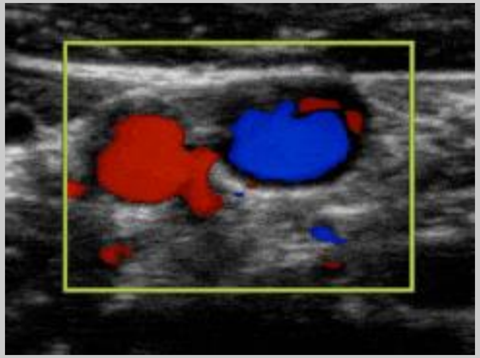
# Transducers

| Probes | Linear | Curvilinear | Phased array (AKA cardiac probe, sector probe) | Intracavitary |
|---|---|---|---|---|
| Frequency | 5-15 MHz (high) | 2-5 MHz (low) | 1-5 MHz (low) | 5-8 MHz (low) |
| Depth (Max) | 6 - 9 cm | 30 cm | 35 cm | 13 cm |
| Probe/ footprint |  |  |  |  |
| Applications | Superficial structures, procedures, arteries/ veins, skim/ soft tissues, eyes, thyroid, nerves, MSK | Intrabdominal organs, Abdominal aorta, LP, bladder | Heart, IVC, lungs, pleura, intraabdominal organs, transcranial doppler | Uterus/ ovaries, pharynx. |

# Modes

- B-mode, M-Mode, Doppler, Power doppler, among others.

| | B-mode | M-Mode | Color Flow Doppler | Power Doppler |
|---|---|---|---|---|
| Image |  |  |  |  |
| Description | “Brightness” mode; The echogenicity of observed structures depends on reflected signals. | Motion mode; Movements of all tissues in an axis are plotted over time. | Measures directional blood flow. | Measure magnitude of non directional flow. 3-5 times more sensitive than Doppler imaging. |
| Uses | Standard mode for bedside ultrasound. | Size of cardiac chambers, movements of valves, measurement of respirator variation of the IVC, eval for pneumothorax | Evaluation of vasculature. Affected by angle of insonation. | Advantages over color Doppler include less reliance on angle off insonation and higher sensitivity in low flow states or tissues (e.g testicles) |

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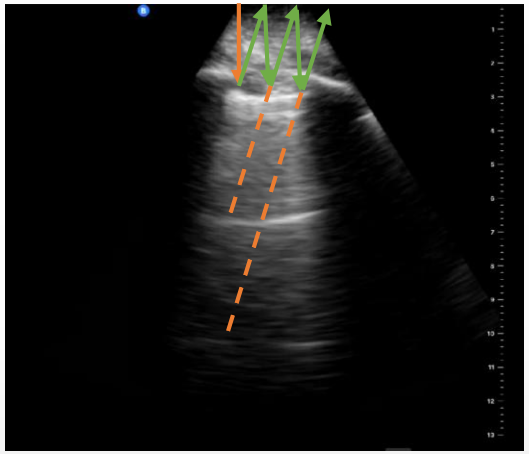
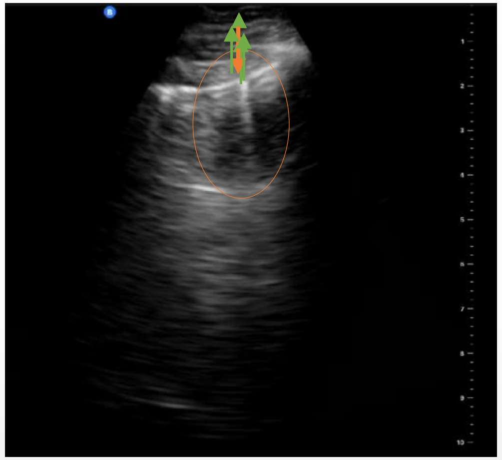
# Imaging artifacts

- Artifacts due to wave propagation
- Artifacts due to beam characteristics
- Artifacts due to velocity errors
- Artifacts due to attenuation

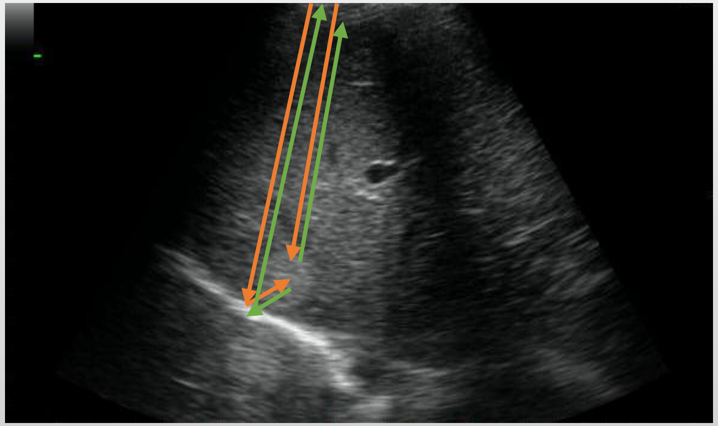
# Artifacts due to wave propagation

- Reverberation – occurs at an interface where there is a large difference in the speed of sound in two tissues (acoustic impedance = measure of resistance of sound through a tissue) (e.g. A-lines, comet tail, ring down)





- Mirroring – refection of sound waves between a transducer, strong reflector, and target structure

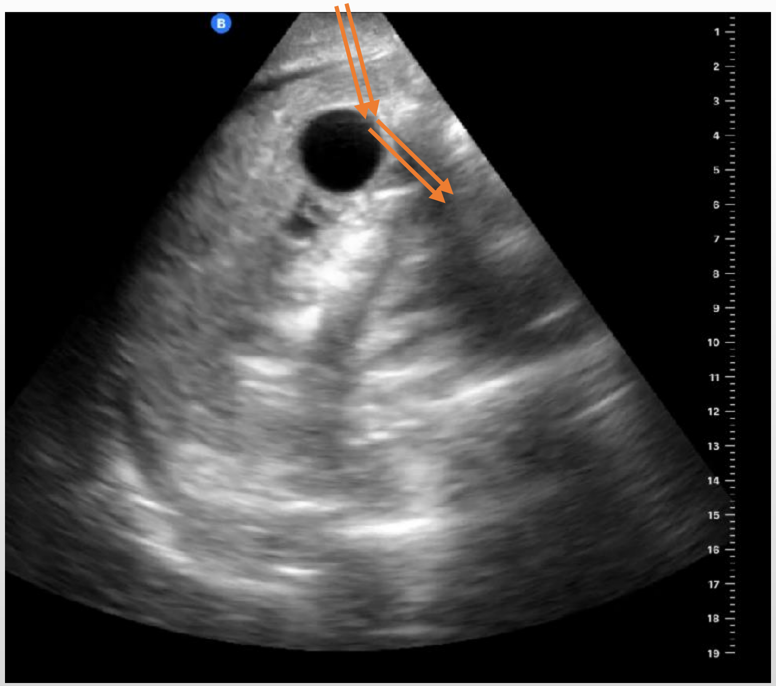


# Artifacts due to beam characteristics

- Side lobe artifact, grating lobe artifact, beam width artifact, and slice thickness artifact
- Included these for completeness sake. Can look these up later, thus far, these rarely affect my own scanning.

# Artifacts due to velocity errors

- Refraction – change of direction of sound waves as they travel from one tissue to the next. Affected by significant differences in tissue velocities. Can manifest as edge shadowing, displacement of structures, or duplicate structures.



**Edge shadowing** – sound waves are refracted and do not return to probe, creating a shadow

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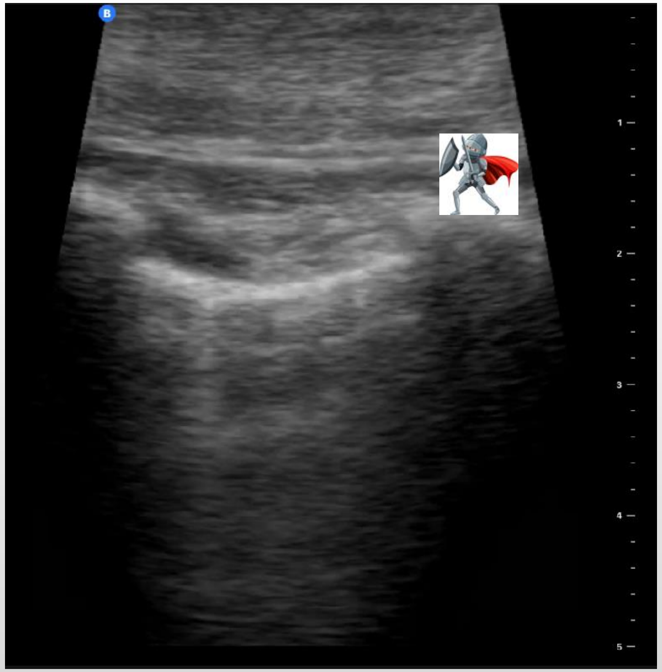
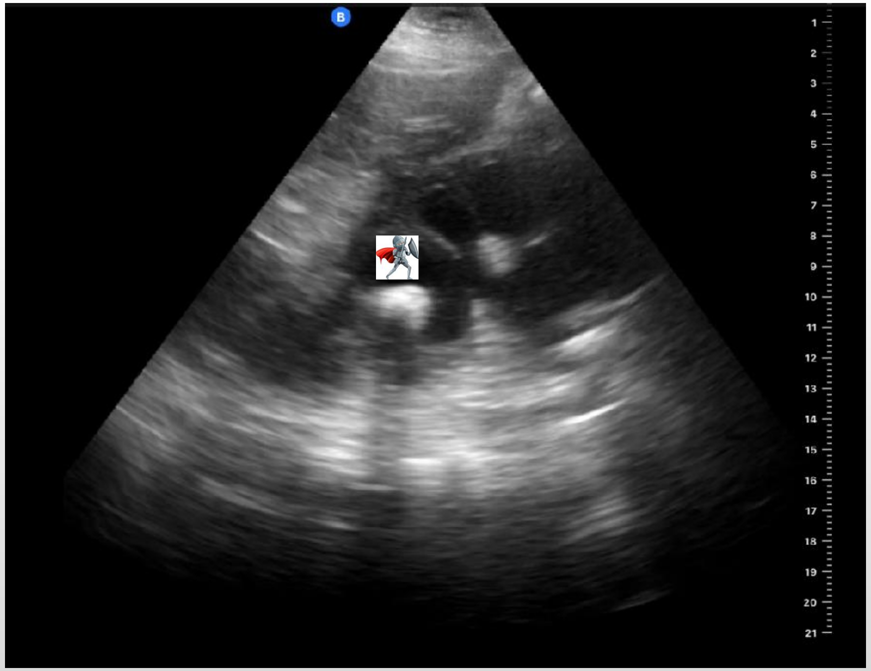
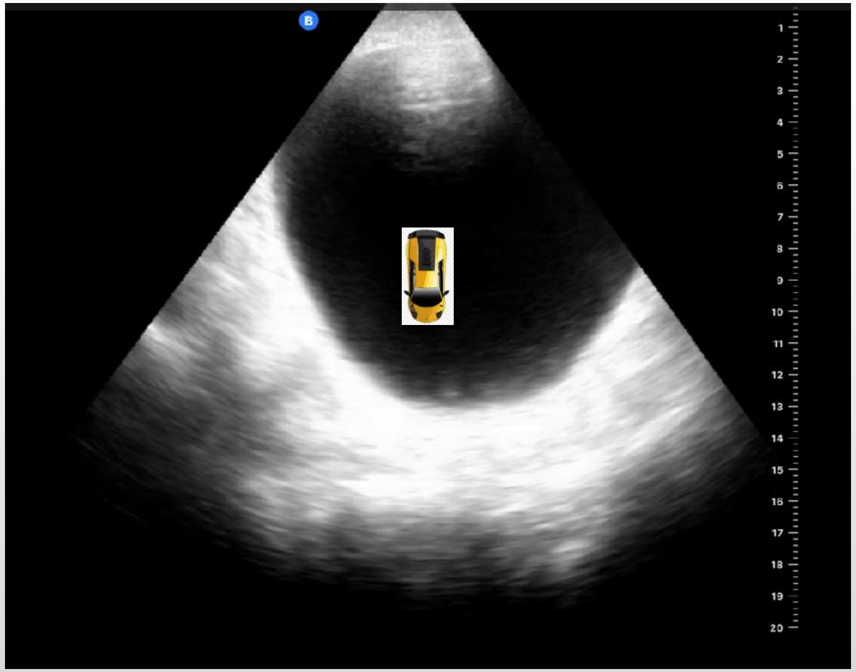
# Artifacts due to wave attenuation

**Acoustic shadowing –** very few waves return to transducer due to scattering, reflecting or absorbing the US waves

**Acoustic enhancement (Posterior acoustic enhancement) –** high energy is perpetuated through fluid filled structures







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# Time to scan

- Patient position
- Power
- Patient data
- Probe
- Preset
- Position
- Preserve

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# PEARLS

P - Parasternal

E - Epigastric

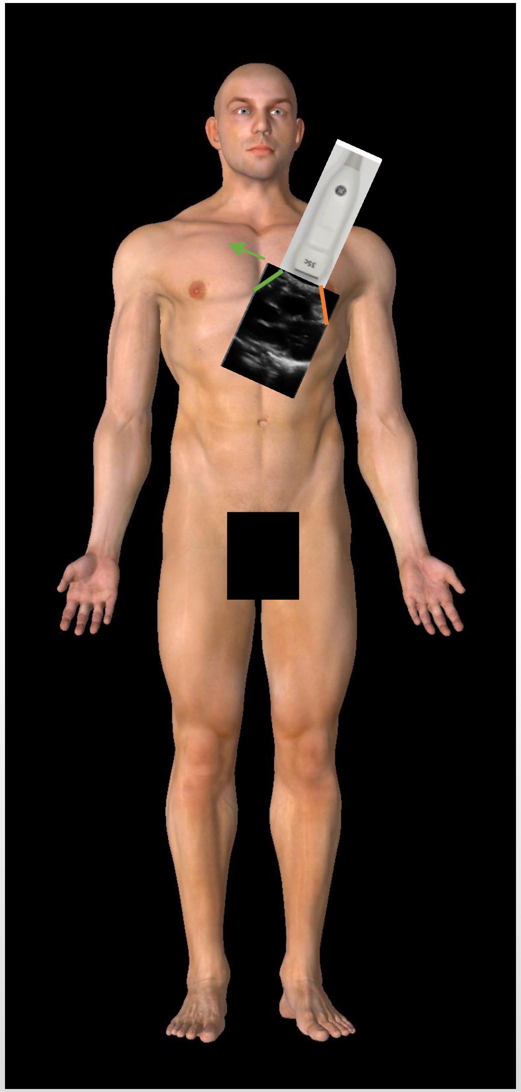
A - Anterior lung; apical (cardiac)

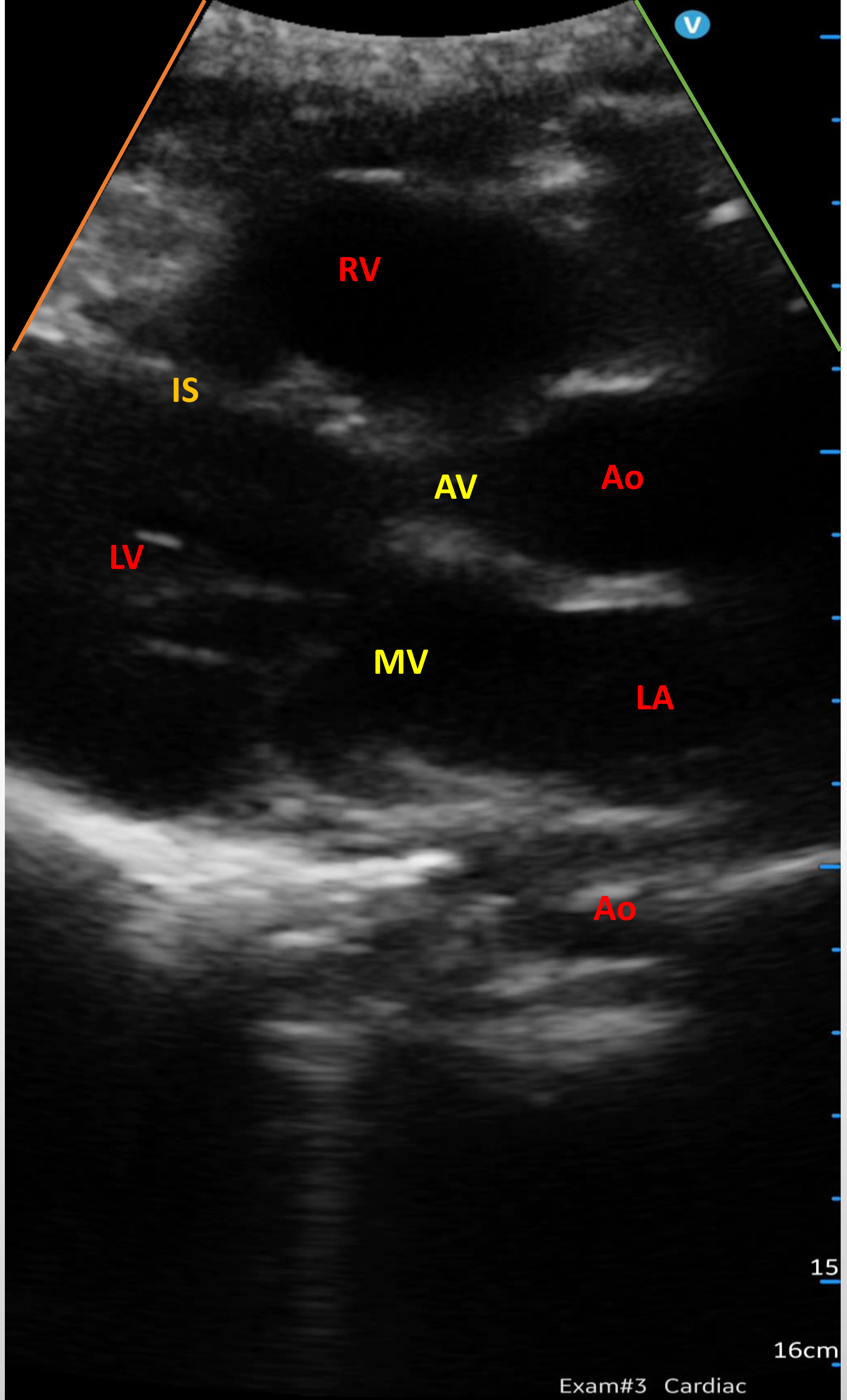
R - RUQ

L - LUQ

S - Suprapubic

# Parasternal
(Long axis)



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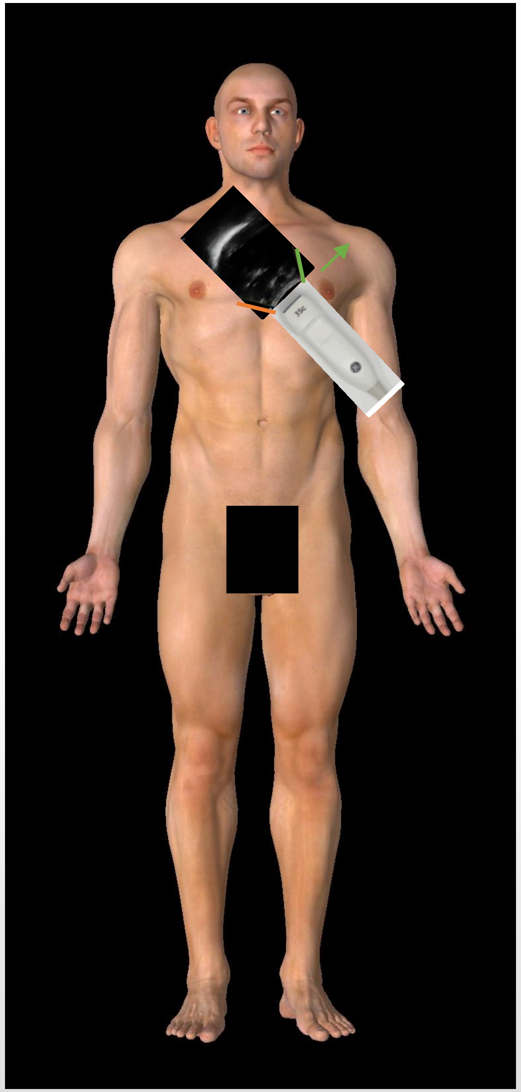
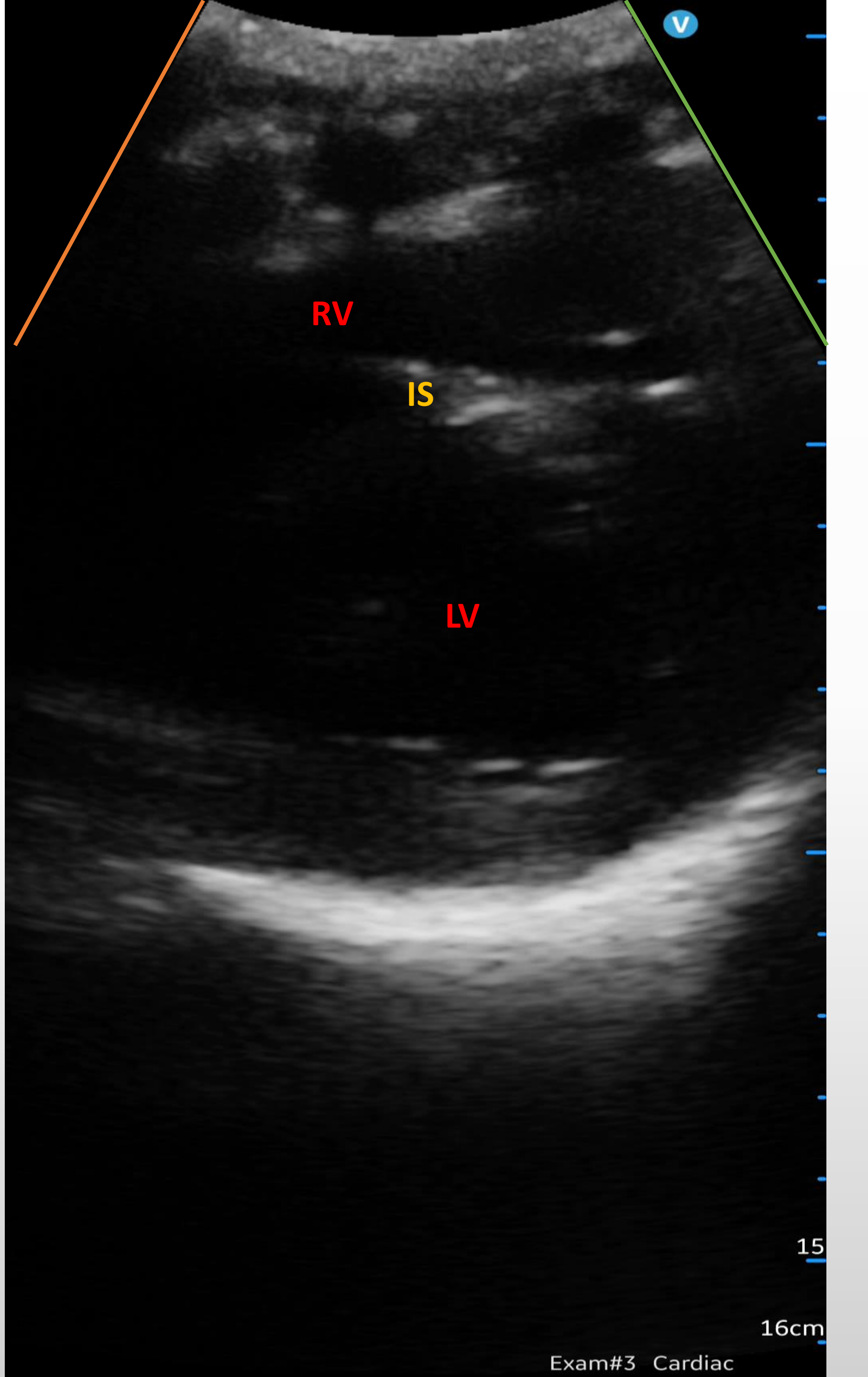
# Parasternal
(short axis)



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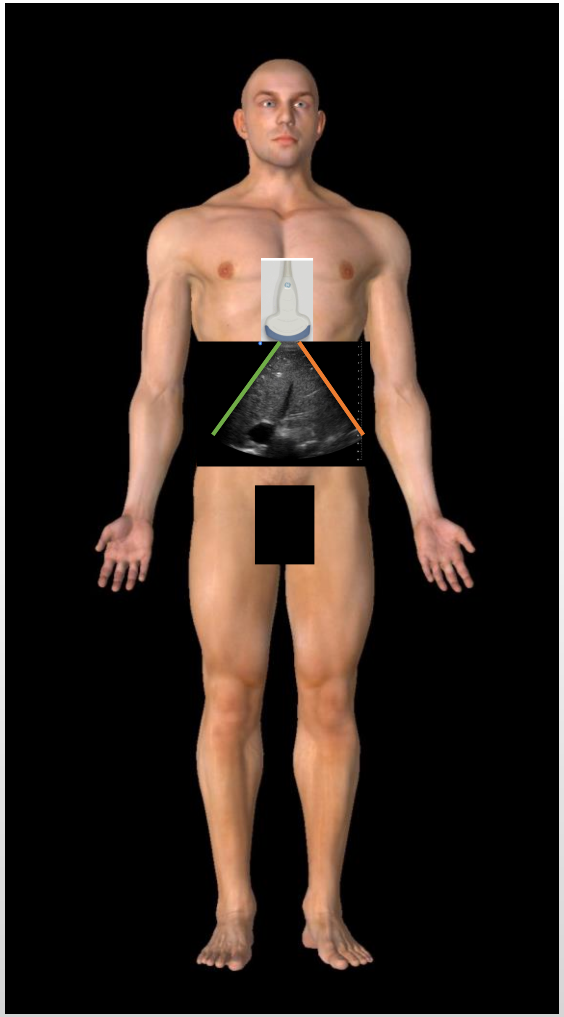
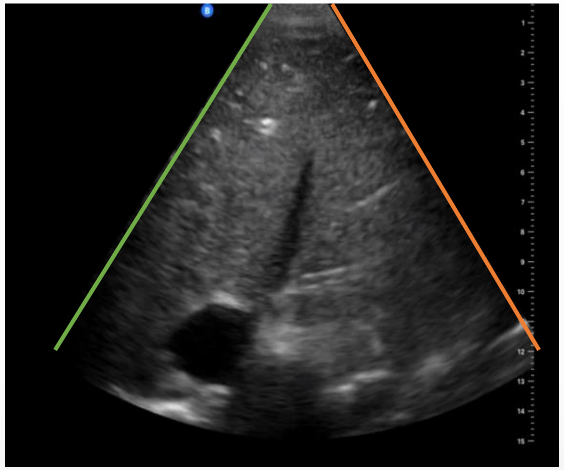
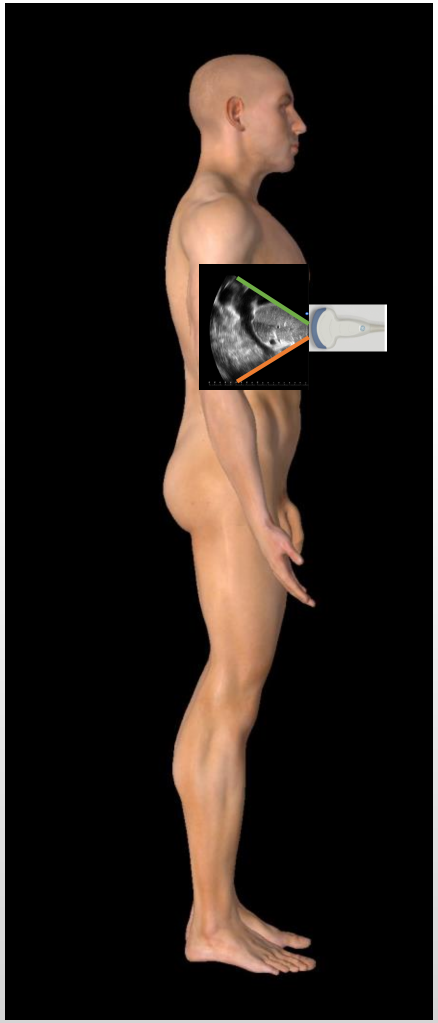
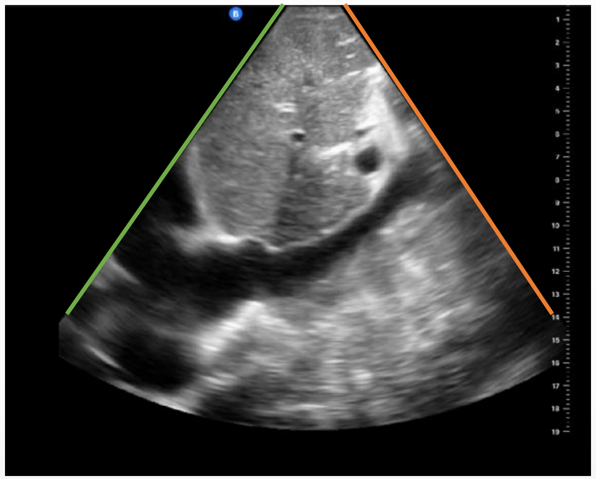
# Epigastric









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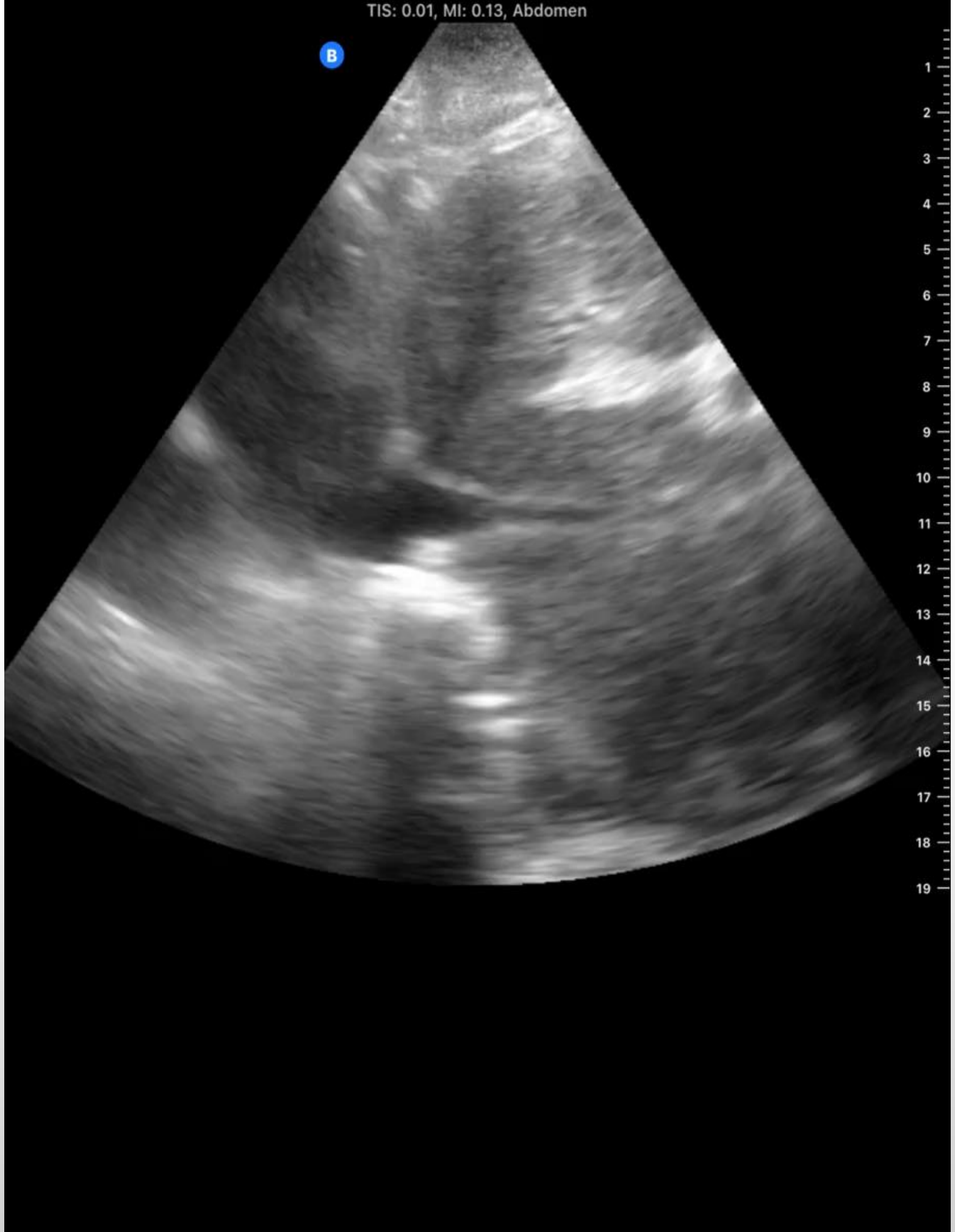
# Epigastric


V
23
24cm
Exam#10 Cardiac


TIS: 0.01, MI: 0.13, Abdomen
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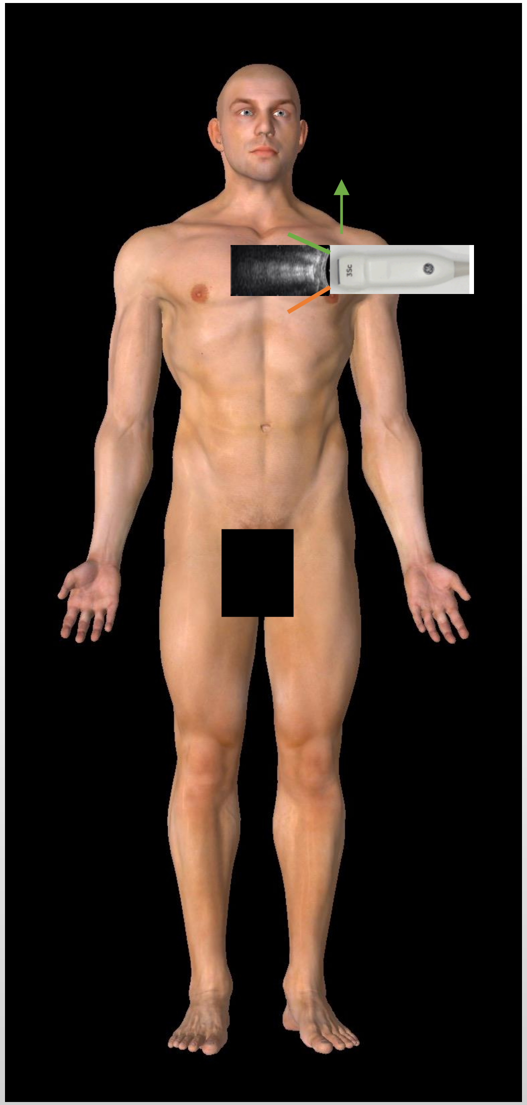
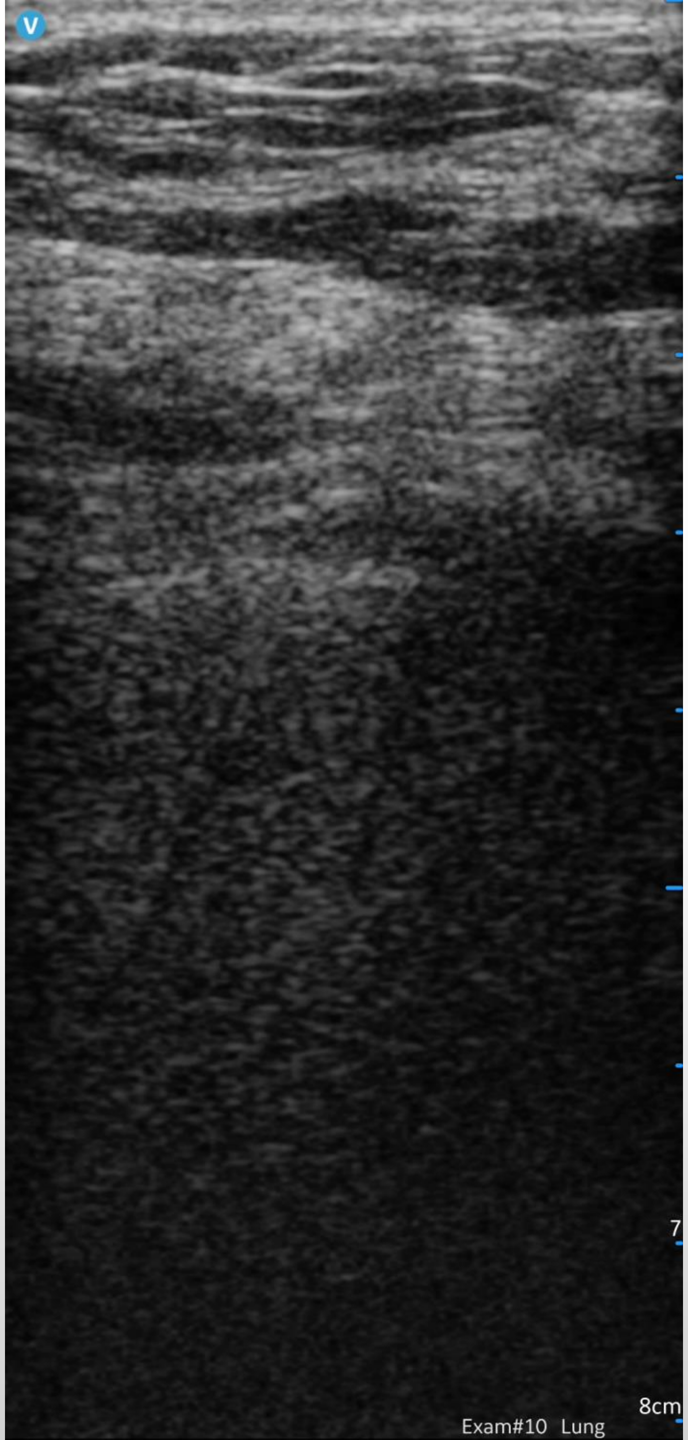
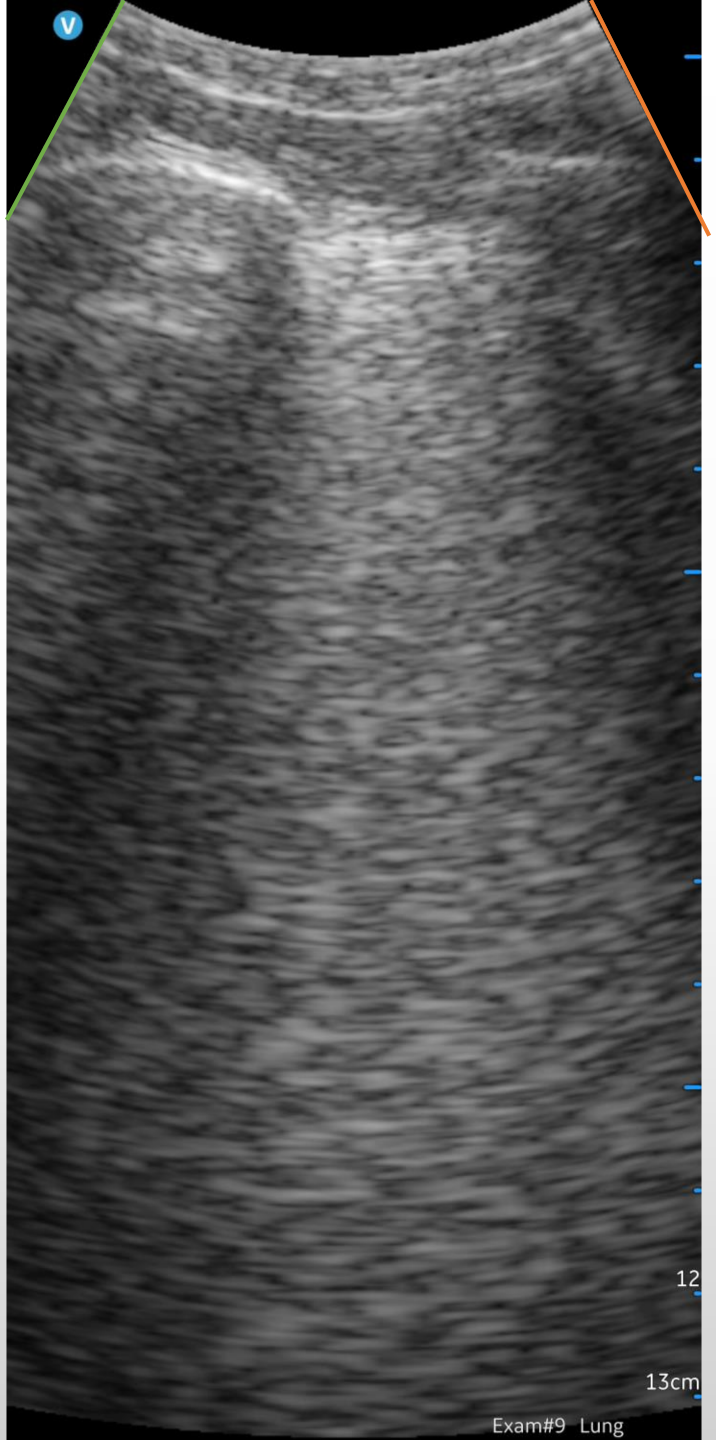
V
17
18cm
Exam#3 Abdominal

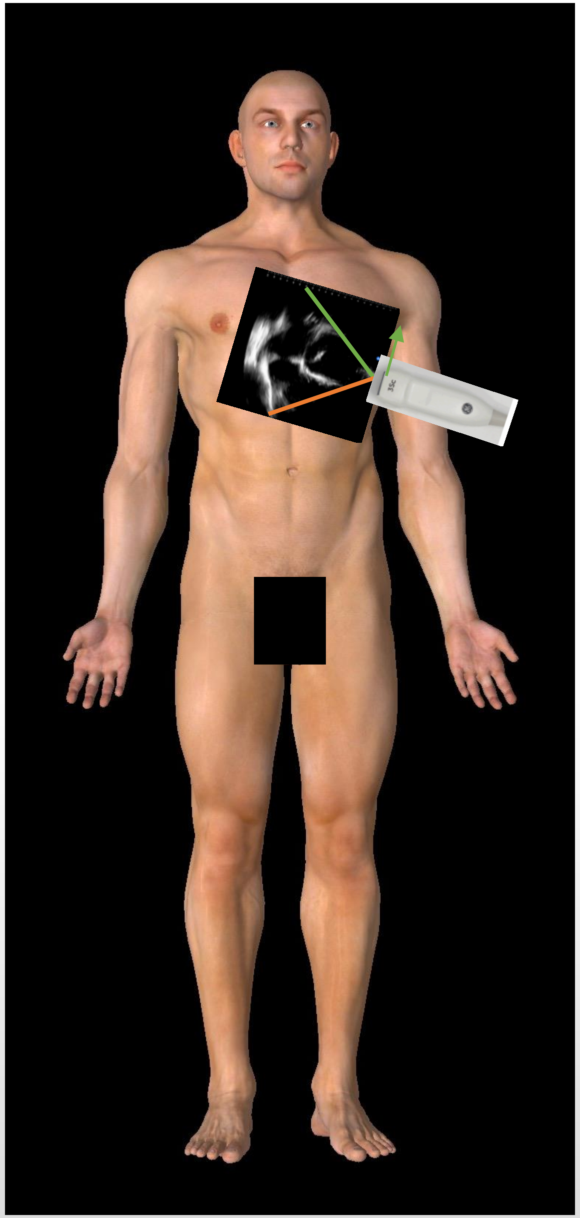
# Anterior lung

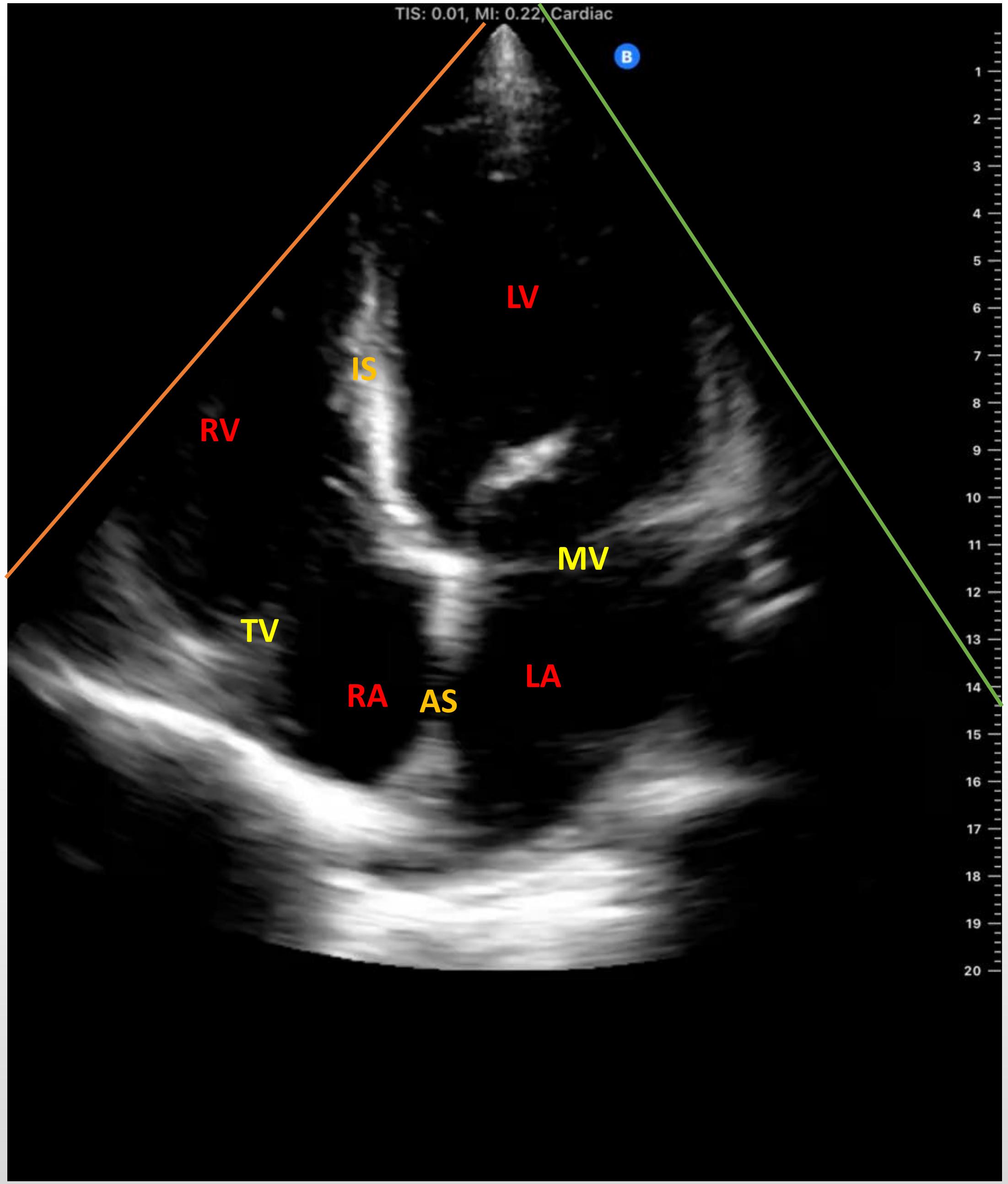




# Apical



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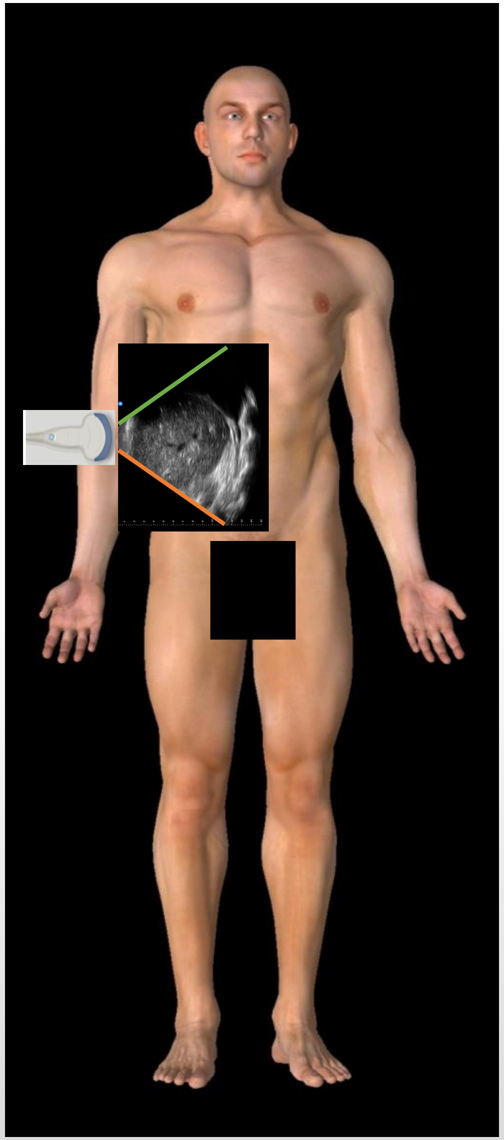
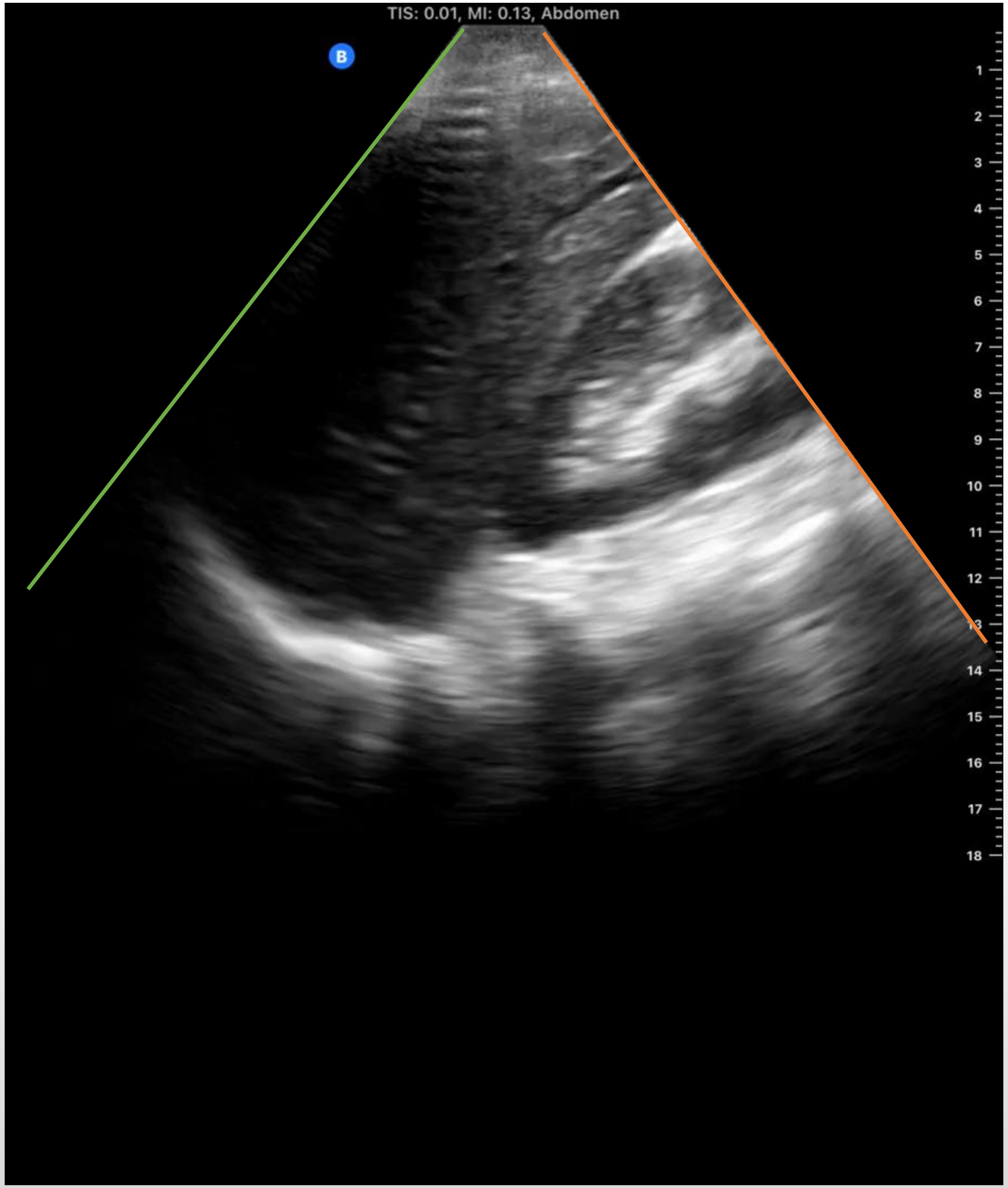
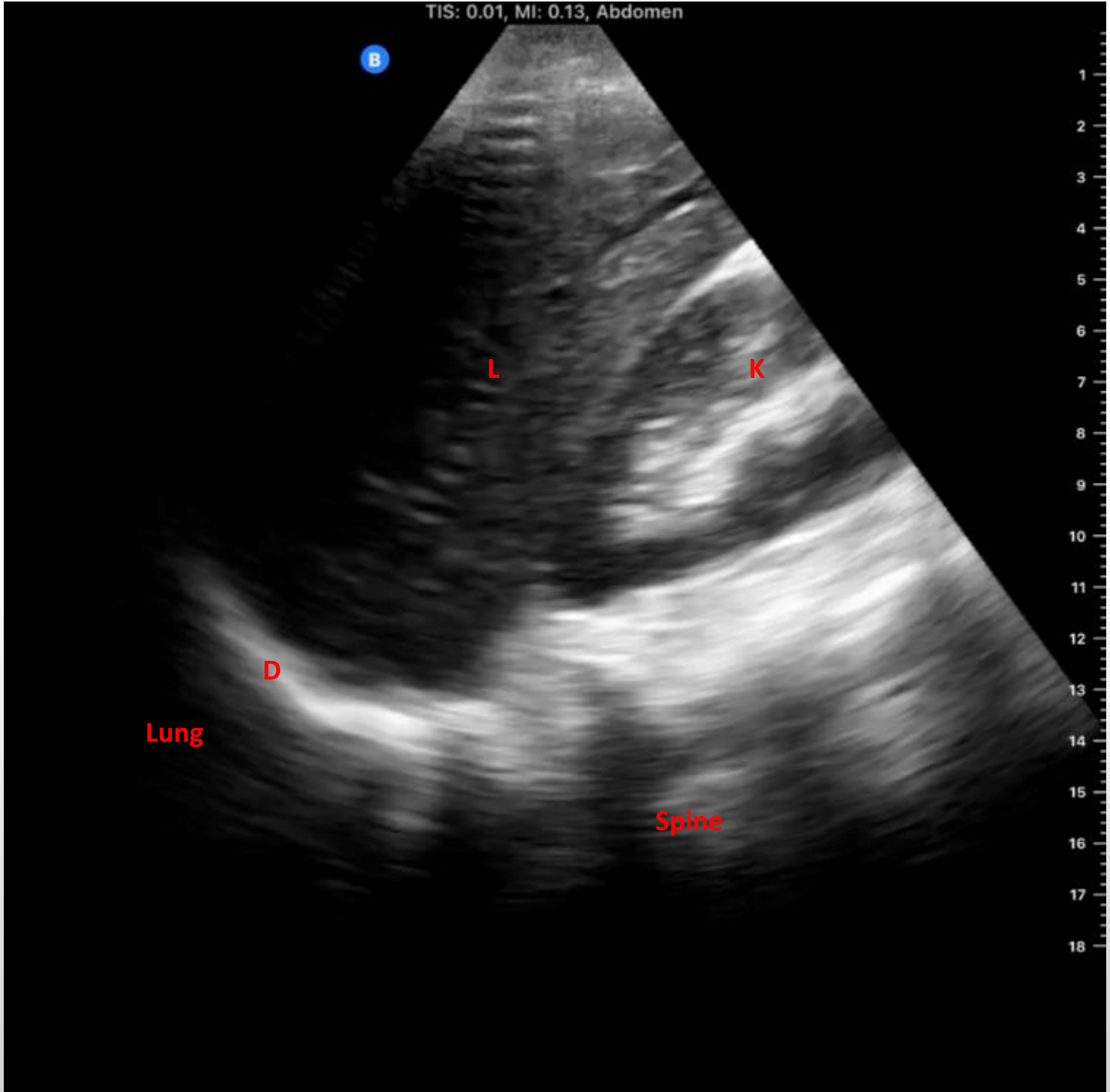
# RUQ





RUQ


TIS: 0.01, MI: 0.13, Abdomen
B
L
K
D
Lung
Spine
1
2
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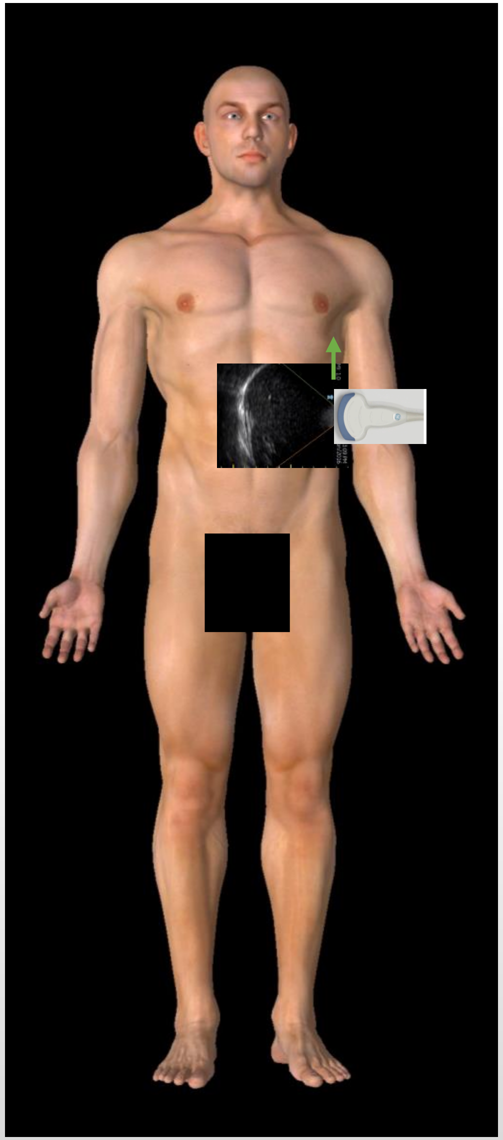
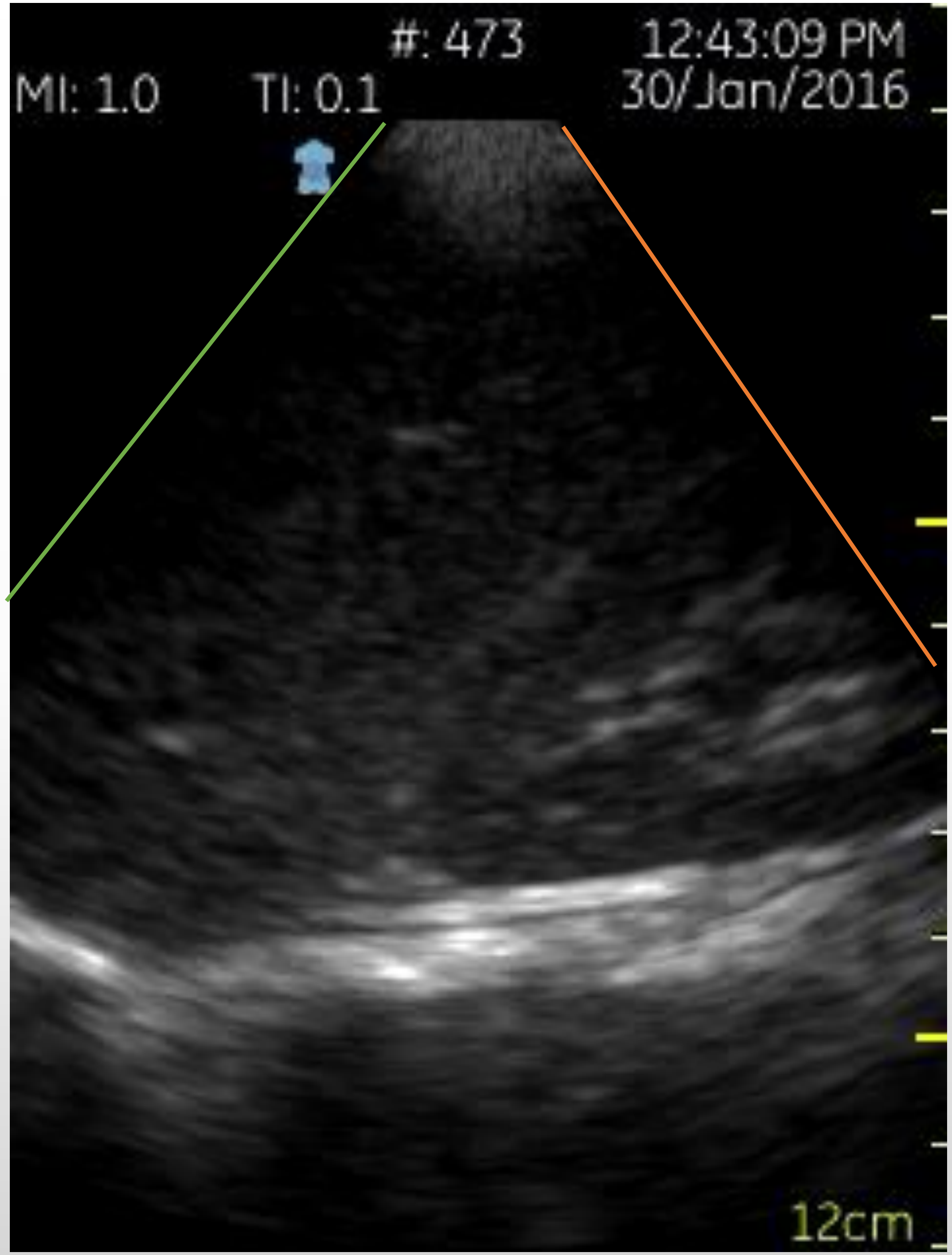
# LUQ



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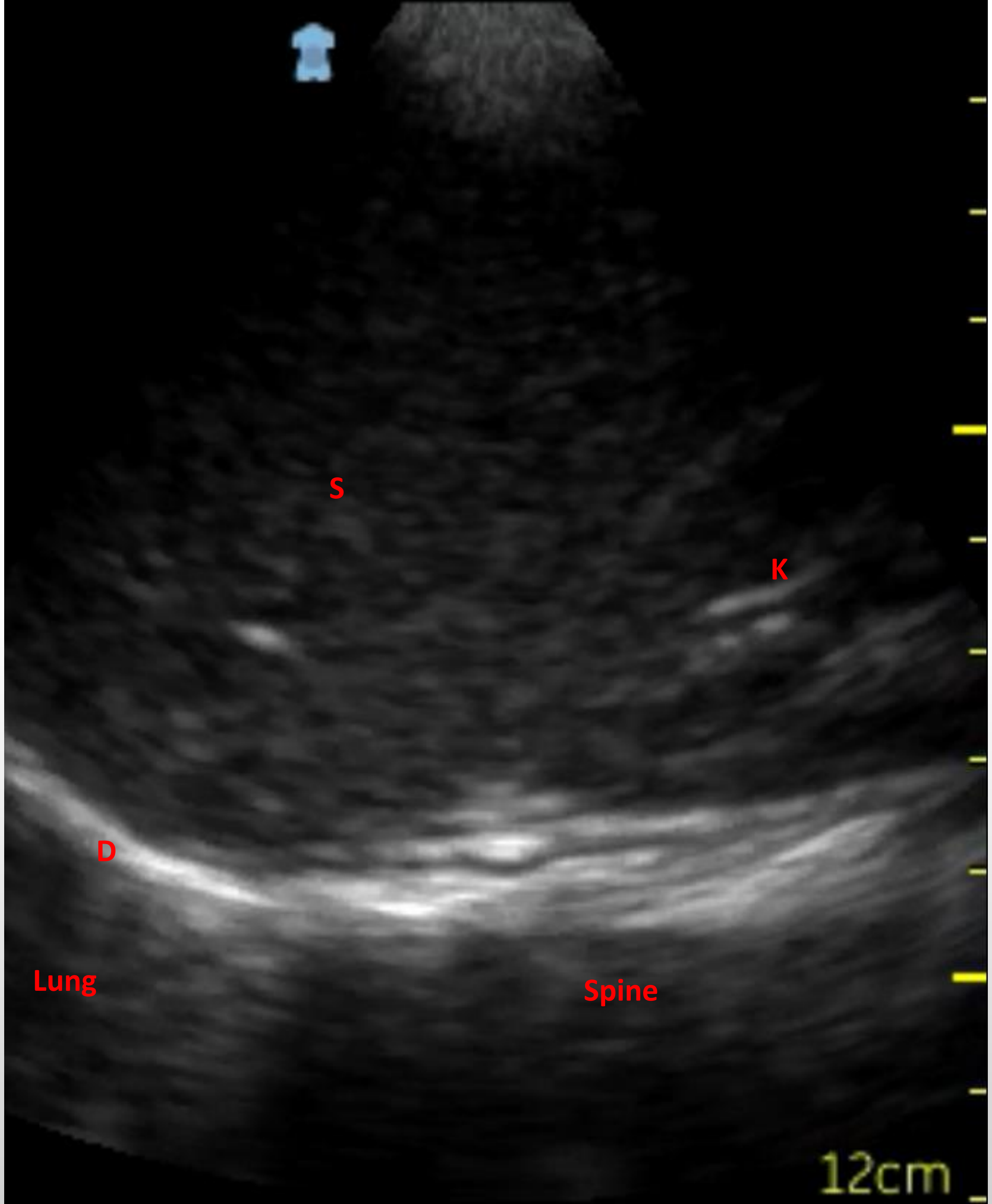
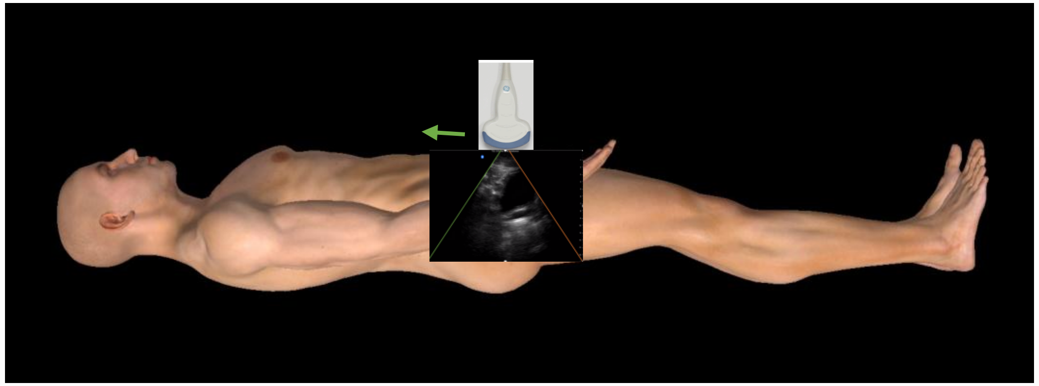
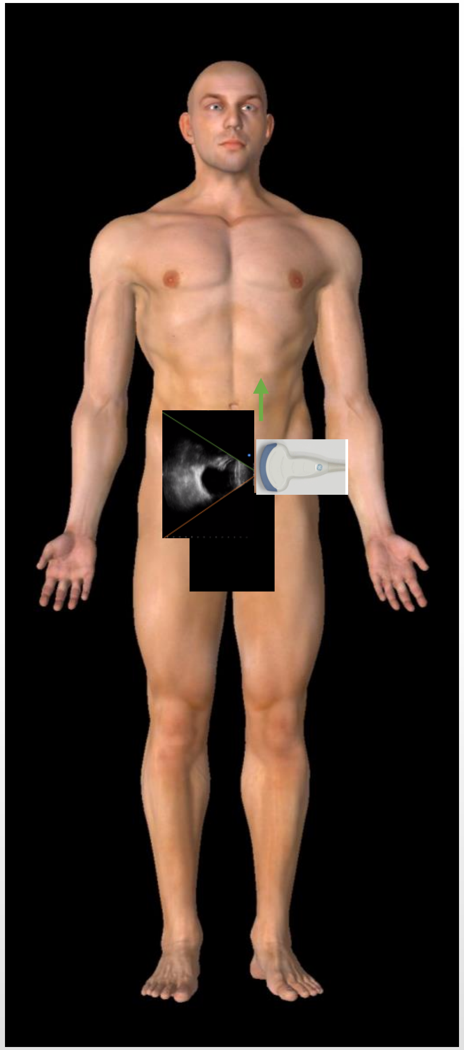
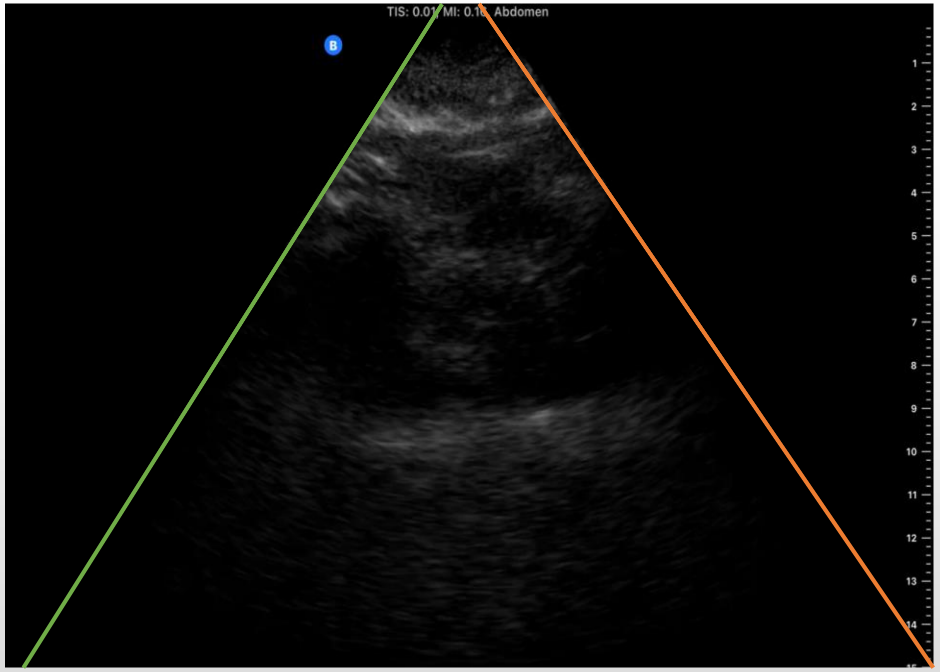
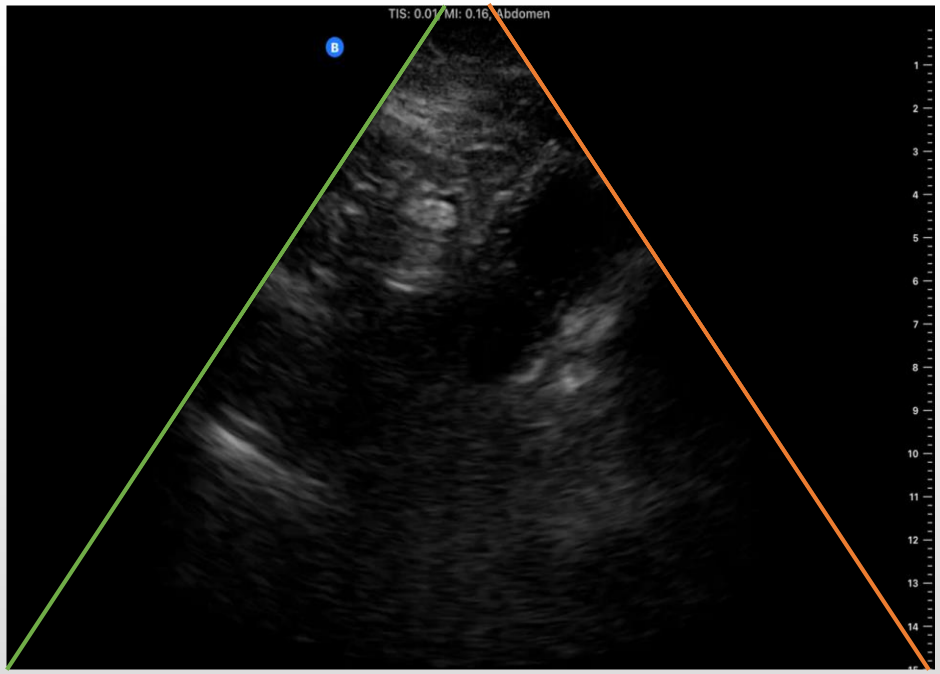


# Suprapubic





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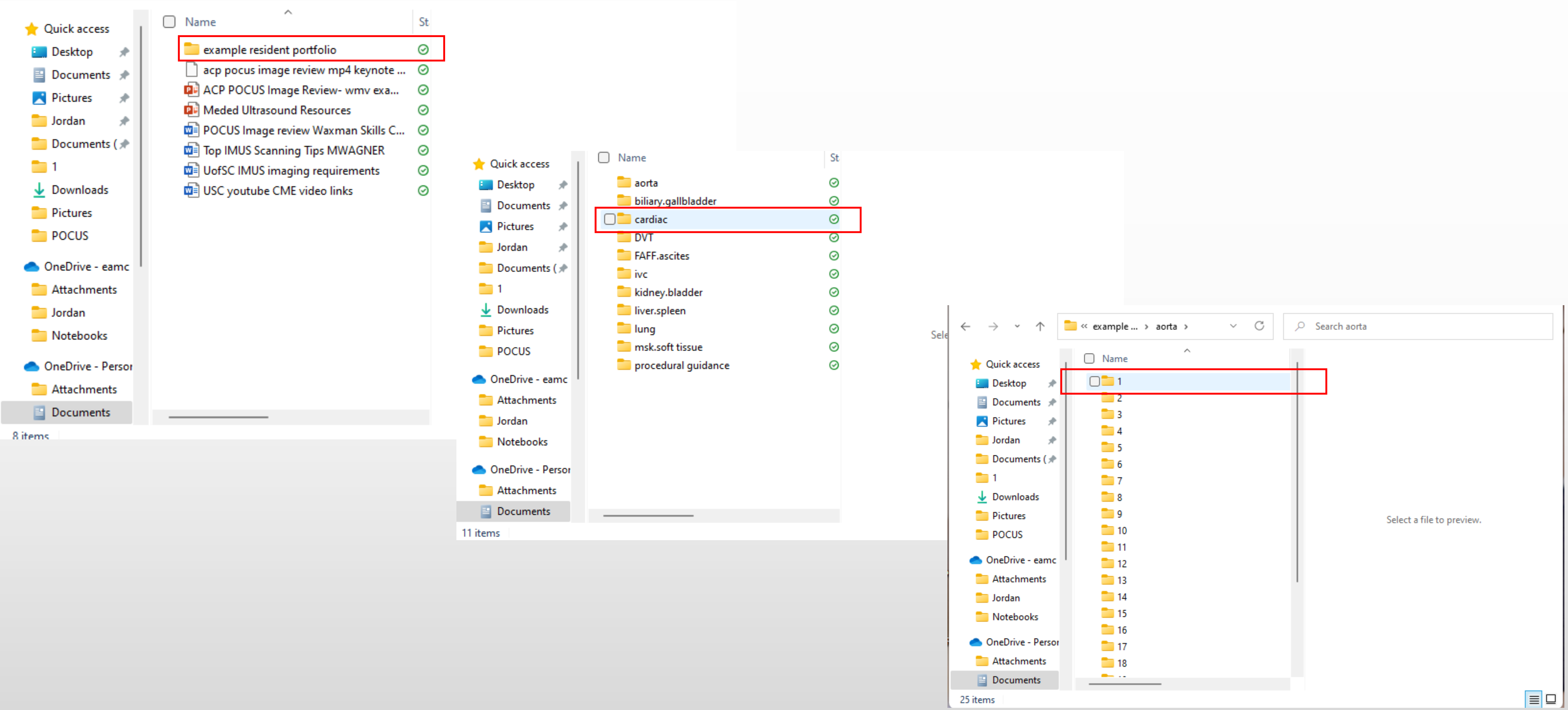
# Creating a portfolio



# References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