Point-of-Care Ultrasound Manual

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It is an honor to present the **2nd edition** of the **MGH Department of Medicine Point-of-Care Ultrasound Manual**. In its second edition, **"The Gray Book"** is updated as a trusted resource for medical residents and other clinicians at MGH to introduced to the basics of Point-of-Care Ultrasound (POCUS).

The Gray Book is comprised of a collective of clinical experiences on the medical services as well as an annual review of the literature. This book is a product of diligent work of many resident contributors (listed on the bottom of each page) and MGH Department of Medicine faculty and leadership who are committed to the integration of POCUS into daily medical practice.

We extend our sincere gratitude to those residents who contributed significant time and energy in writing the content for the entire sections of this manual:

Knobology: Vladislav Fomin, Zachary Sporn	**Renal**: Lauren Maldonado, Esra Gumuser
Cardiac: Chris Marnell, Alli Levin	**Abdominal**: D.J. Flynn, Vladislav Fomin
Pulmonary: Krystle Leung, Krishna Pandya	**Soft Tissue**: D.J. Flynn, Zachary Sporn

We would like to thank the many faculty who assisted with this book, particularly Daniel Restrepo who in his role as the Associate Program Director for POCUS has championed the creation of this manual alongside a POCUS curriculum.

And of course, none of this would be possible without the guidance and support of so many amazing people that make up the Department of Medicine. In particular, we extend special thanks to Gabby Mills, Libby Cunningham, and Paula Prout for supporting this project. In addition, we would like to thank our Chief Residents – Ali Castle, Rashmi Jasrasaria, Arielle Medford, and Jon Salik – as well as Jay Vyas and Katrina Armstrong for their undying support and endless devotion to the housestaff and our education. We will always be grateful for their unwavering leadership during the COVID-19 pandemic.

It has been an incredible honor to create and edit The Gray Book. We look forward to the contributions of future generations of authors and editors in the years to come.

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As with any other medical reference, this manual is NOT intended to provide specific clinical care decisions in an individual case, and should NOT substitute for clinical judgment. Every clinical care decision must be made by the exercise of professional judgment by the individual responsible for the care of a patient based on the facts of that individual case, which may differ from the facts upon which entries in this manual are based. You should consult other references and your fellow residents, fellows, and attendings whenever possible. We have carefully inspected every page, but errors may exist. If you find any errors, we would appreciate it if you would inform next year's editors to make sure these errors are corrected.

Introduction to Ultrasound

Fundamentals

What is ultrasound?

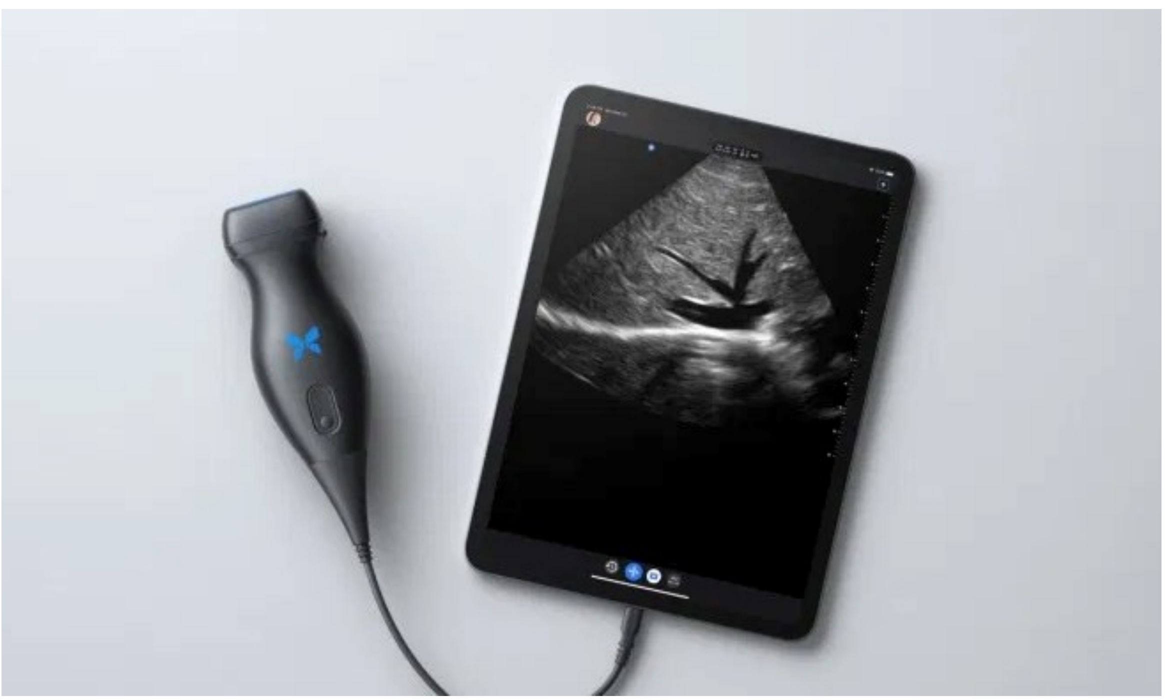
- Ultrasounds use an array of high-frequency sound waves to create a cross-sectional 2D image of underlying structures and acoustic artifact.

How does ultrasound work?

- Piezoelectric crystal in transducer transforms electrical current to sound waves
- Sound waves (usually 2-20 MHz) travel through tissue and bounce back. The sound that bounces back is captured by the probe and transformed to image on screen
- Higher frequencies provide a higher resolution but are not able to penetrate as deeply. Lower frequencies penetrate deeper into tissue but have a lower resolution.

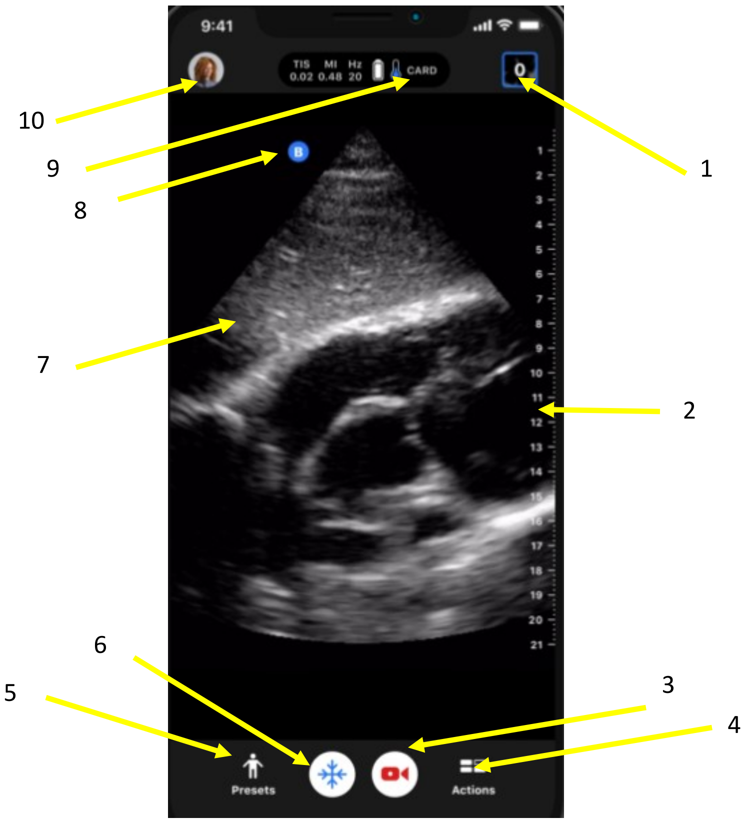
Ultrasounds in the DOM

- 6 Butterfly iQ handheld, all-in-one probes located on White 8, 9, 10, Bigelow 7 and 11, and Lunder 9.
- 1 SonoSite Edge cart-based machine: Blake 15 (through Ellison 15).
- 1 Mindray TE7 cart-based machine: Blake 15 (through Ellison 15). Please discuss with HMU prior to using.



Example of Butterfly IQ ultrasound

Ultrasound Machine Overview



There are several different ultrasound machines in use at MGH. Bellow are the guidelines for the Butterfly ultrasound available for resident use.

1 = Image gallery, Click to save image
2 = Depth measurements
3 = Record

4 = Actions: Doppler, M-mode, annotations, linear/area measurements, volume calculation
5 = Presets (Lung, cardiac, vascular etc.)

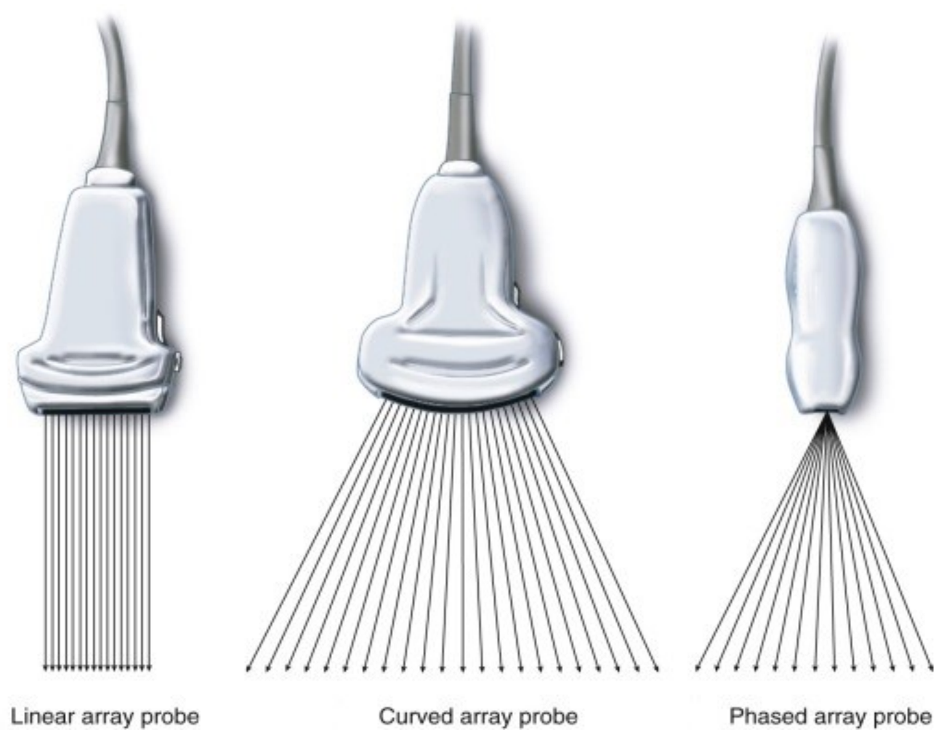
6 = Freeze
7 = Vertical swipe = change depth, Horizontal swipe= change gain
8 = Probe indicator
9 = Selected preset
10 = User data

Probe Overview

Linear Array Probe: >7.5MHz. Increased resolution with decreased depth. Primarily used for shallow imaging including musculoskeletal, soft tissue, and vascular

Curved Array Probe: 2-5 MHz. Decreased resolution with increased depth. Used for abdominal imaging, but can be also be useful for lung and thoracic ultrasound

Phased Array Probe: 1-5MHz. Useful for deeper imaging with a short footprint that allows the probe to fit between rib spaces making it ideal



Using the Transducer

Be cautious to avoid dropping ultrasound probes. They contain fragile crystals that can break AND avoid letting the cart's wheels or feet trample over the transducer cords as these can be permanently damaged costing thousands of dollars to repair.

If using a cart-based machine to perform a diagnostic scan, place the ultrasound at the head of the bed and position yourself between the machine and the patient. If doing procedures with dynamic ultrasound guidance, place the machine on the opposite side of the bed.

While different exams or situations require adjusting how you hold the probe, the best method is to mimic the way you hold a pencil to write with the base of your hand planted on the patient's skin for stability (**demonstrated below**)

Place the probe surface *lightly* on the skin provided there is an adequate coupling agent such as gel or sterile lubricant to displace air between the probe and tissue surface.

Orient the **probe marker** (a notch or dot on one end of the long axis of the probe) to the orientation marker on the screen. By convention in general ultrasound, the marker is on the left of the image on the screen, and you will want to keep the probe marker to the patient's right or towards the patient's head.


Correct Standard Position


Incorrect


Incorrect


Incorrect

Cardinal Probe Movements

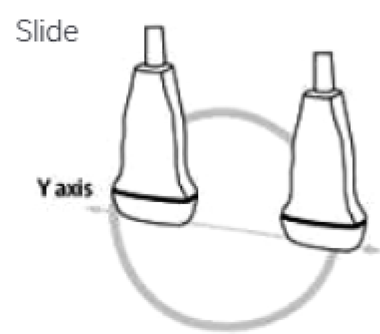
The act of deliberate scanning means moving the transducer in one direction at a time and progressing to the next movement in response to the real time image. Thus, to achieve a high quality scan, it is important to understand the language of cardinal movements.

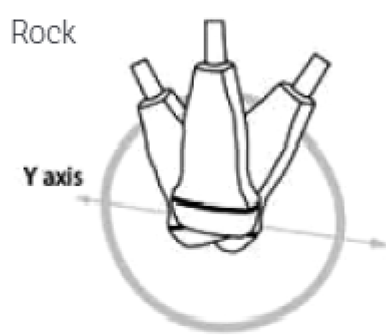
Slide: Moving the probe over the skin along Y axis without changing the orientation of the beam

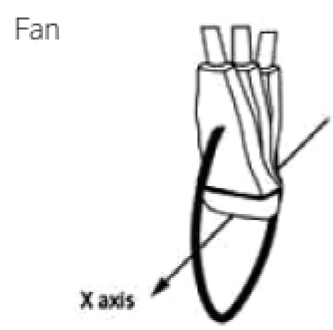
Rock: Keeping the probe on a fixed point along the skin, change the angle of orientation along the probe's long axis (Y)

Fan: Keeping the probe on a fixed point along the skin, change the orientation along probe's short axis (X).

Rotate: Keeping the probe on a fixed point, perform clockwise or counterclockwise movement within a particular angle





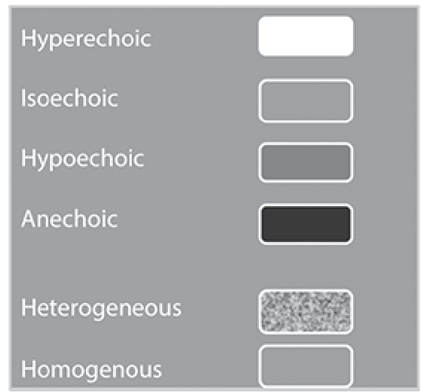


Ultrasound Terminology

Echogenicity: Ability to reflect or transmit US waves in the context of surrounding tissues.
- **Hyperechoic** (white on the screen)
- **Hypoechoic** (gray on the screen)
- **Anechoic** (black on the screen)

Gain: Amplifies signal which results in brighter image (higher gain) and dimmer image (lower gain)

Depth: Changes the field of view



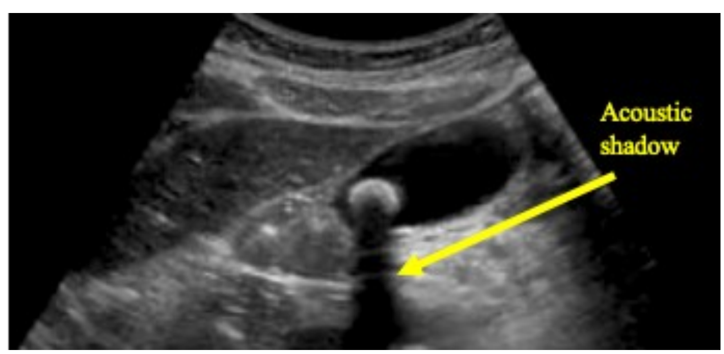
Modes:
- **B mode** (Brightness Mode): The standard 2-D used for most imaging
- **D mode** (Doppler Mode): Detects flow. Useful for imaging blood vessels, flow across valves
- **M mode** (Motion Mode): Plots waveform of a fixed B-Mode slice over time. Often used to study motion of valves.

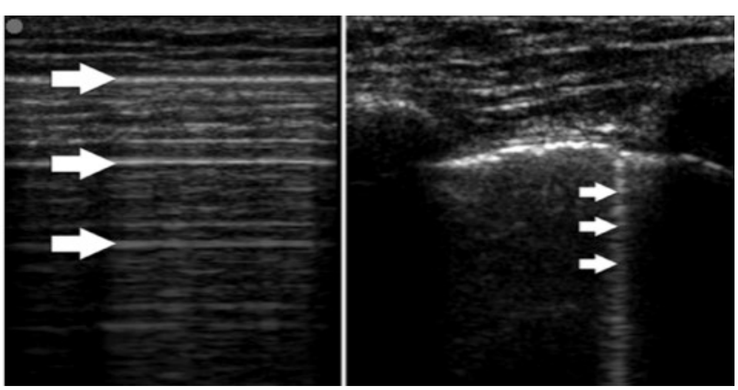
Ultrasound Effects and Artifacts

Reflection: Process by which sound waves hit tissue and redirect back to its source. The number of waves reflected is proportional to amount of acoustic impedance between two tissues

Acoustic Impedance: The resistance to propagation of ultrasound waves through tissues. Each tissue has a unique impendence by which we are able to distinguish during sonography

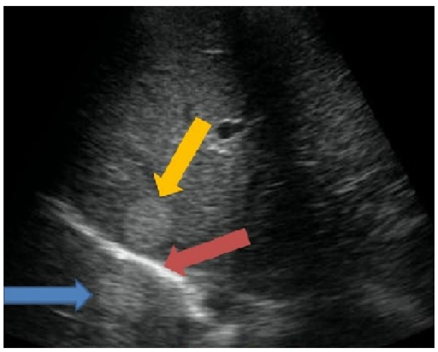
Acoustic Shadowing: Creation of a "no-image" zone deep to a structure of high density that will not allow passage of sound past it. This typically occurs in the context of solid structures, such as bones or stones.



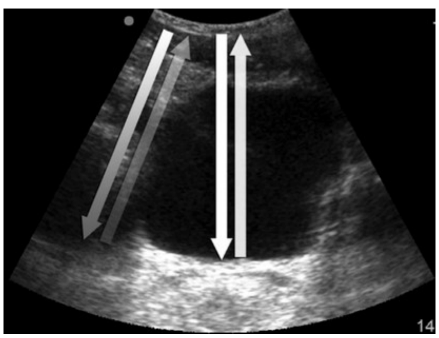


Reverberation: Sound beam bouncing between reflective structures causing arcs that display at equidistant intervals from transducer. Produces "A-lines" and "comet tails" (see Lung ultrasound).

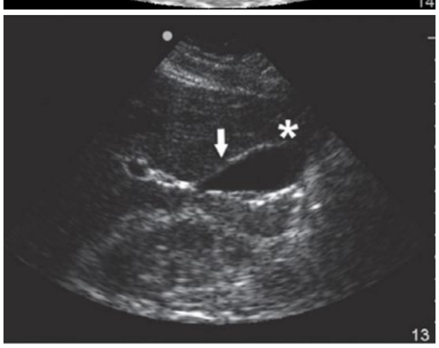
Refraction: Governed by Snell's Law $\sin\theta_1/\sin\theta_2 = c_1/c_2$. ($\theta$ = incident angle, *c* = speed). The equation describes how sound waves travel as they strike boundary of two tissues at an oblique angle. This direction of the wave changes according to Snell's and causes an acoustic shadow that can usually seen at edge of transverse structures, like blood vessels. This phenomenon is also known as **acoustic edge shadowing**.



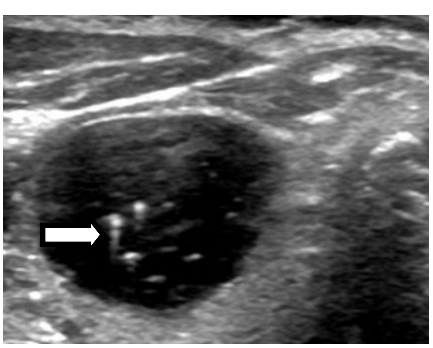
Mirror Image Artifact: Occurs when sound waves are reflected multiple times, after which it may either be reflected off the boundary and returned to the probe or reflected off boundary and bounced between and the object and the boundary again before returning to the probe. It can lead to incorrect interpretation by ultrasound machine resulting in mirror image on the other side of reflective surface.



Posterior Acoustic Enhancement: Refers to the phenomenon of increased echogenicity deep to an anechoic structure stemming from enhanced transmission of sound through the structure. This is characteristic of fluid filled structures, like blood vessels gallbladder or urinary bladder.



Beam Width Artifact: At interface between structures of different echogenicity, the echogenicity value of the reflected waves (some of which are brighter and some dimmer) are averaged by machine. In the example on the right, the gallbladder bile has a consistent density throughout, but appears more anechoic near the neck (arrow) than the fundus (asterisk).



Comet-Tail Artifact is a finding seen when small calcific / crystalline / highly reflective objects are interrogated and is believed to be a special form of reverberation artifact . In the example on the right a comet– tail is seen behind thyroid calcifications

Determinates of Image Quality

There are numerous factors discussed prior that impact overall image quality. A systemic way to think through both assessing and improving your image quality through addressing the following factors:

Probe type: phased array, curvilinear, and linear

Presets: Exam type, for example: cardiac, abdominal, vascular etc.

Depth: Affects frequency and frame rate. Is your target structure shallow or deep?

Gain: Amplification of the ultrasonic signal that affects resolution. Is your target easily visible?

Patient: Affects quality of acoustic window, depth required etc

Ultrasonographer: Positioning and adjustments of the transducer etc

Protocol for Resident Scan Feedback

As POCUS use expands within the residency program, there has been a system trialed in order for residents to get feedback on scans. This is meant for residents with prior experience (from electives, clinical experience, etc) rather than new learners.

The basic workflow is:

- Resident will **perform** and **save** their exam on the Butterfly. Please enter pertinent details, like location of exam - Volpicelli 1, bladder (saggital) - which can help guide interpretation. If you are not using a Butterfly, feel free to useHaiku to save your image.
- Save images under MGH Med—Training folder
- If you are working with POCUS trained faculty, you can ask them to then review the images and provide feedback. Additional, Dan Restrepo is a willing to help with feedback as well.
- Keep a log of your scans that you do this for!

Remember: Do **not** base clinical decisions on POCUS exams unless the exam and decisions are supported by a supervising fellow or attending.

Cardiac POCUS: Overview

Focused Assessment

1. Parasternal Long Axis (PLAX)
2. Parasternal Short Axis (PSAX)
3. Apical Four Chamber (A4)
4. Subxiphoid
5. Inferior Vena Cava (IVC)

Qualitative Assessment

1) **Equality:** Chamber/structure size comparison

2) **"Ejection":** Qualitative LV function. NOT true EF.

3) **Effusion:** Pericardial vs. pleural effusion?

4) **Entry:** IVC diameter, respirophasic variation

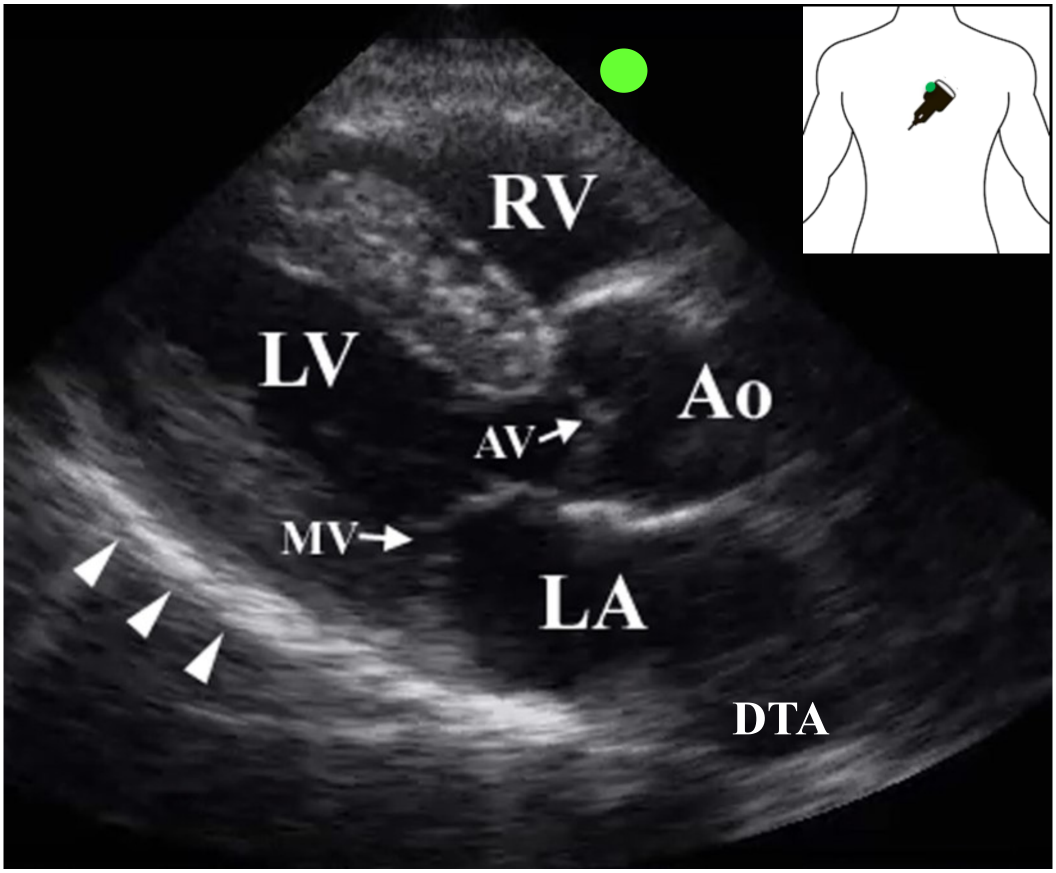
5) **Exit:** Aortic root diameter

Conventions in Probe Positioning

- There are two main conventions for cardiac ultrasound probe placement, the Emergency Medicine Convention and the Cardiology Convention
- ED —> probe marker on the right of the screen, Cards —> probe marker on LEFT of screen
- Although the probe orientation is inverted in each, the image procured is the same.
- For simplicity the Gray Book images are displayed in the Cardiology Convention, however each scanner is encouraged to attempt both conventions.

	Probe Indicator Orientation *(cardiac convention)*	
	Cardiology	**Emergency Medicine**
PLAX	Patient's Right Shoulder	Patient's Left Hip
PSAX	Patient's Left Shoulder	Patient's Right Hip
A4	Superior	Inferior
Subxiphoid	Patient's left	Patient's Right
IVC	Superior	Inferior

Cardiac POCUS: Parasternal Long Axis View (PLAX)



Assessment

1) Equality

-Qualitative EF

-RV:Ao:LA size is 1:1:1

-RV < LV

2) "Ejection"

-Anterior MV Leaflet touches the septum

3) Effusion: See Page #13

4) **Exit:**

- Aortic root diameter

<u>Probe Positioning</u>

- Perpendicular to the patient's chest wall, at left parasternal border, aim indicator at patient's <u>right</u> shoulder (cardiology convention)
- Start at 2-4th intercostal space, try different spaces to see which gives optimized view

<u>Optimize View:</u>

- Ideally see both MV and AV clearly, centered on screen
- Depth adjustments may help optimize

Question

How is the squeeze?

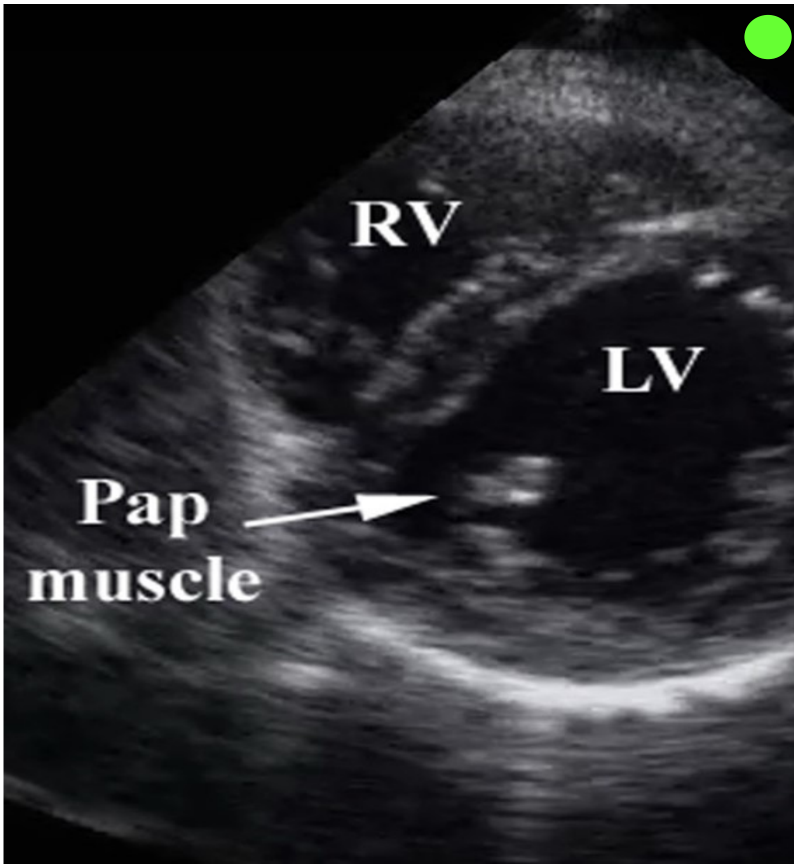
Is there an effusion?

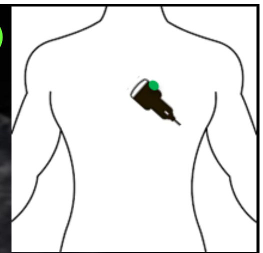
Pro Tip

In patient's with COPD, the heart may be displaced inferiorly.

Pitfall

Be sure to adjust the depth to capture the de-scending thoracic aorta (~10-16 cm)





Quality Metrics

1) Equality

-RV<LV (best seen in A4)

2) "Ejection"

-Ventricular walls collapse centrally during systole

Landmarks

-Identify the MV and the papillary muscles

Probe Positioning:

- First, obtain a clear PLAX
- Then, hold the probe steadily and rotate the indicator 90 degrees toward the *patient's left shoulder* (cardiology convention)

PSAX view has different "levels", based on which structures you visualize by fanning the probe superiorly and inferiorly, which is a more advanced skill (start by fanning to visualize the MV and papillary muscles)

Question

How is the squeeze?

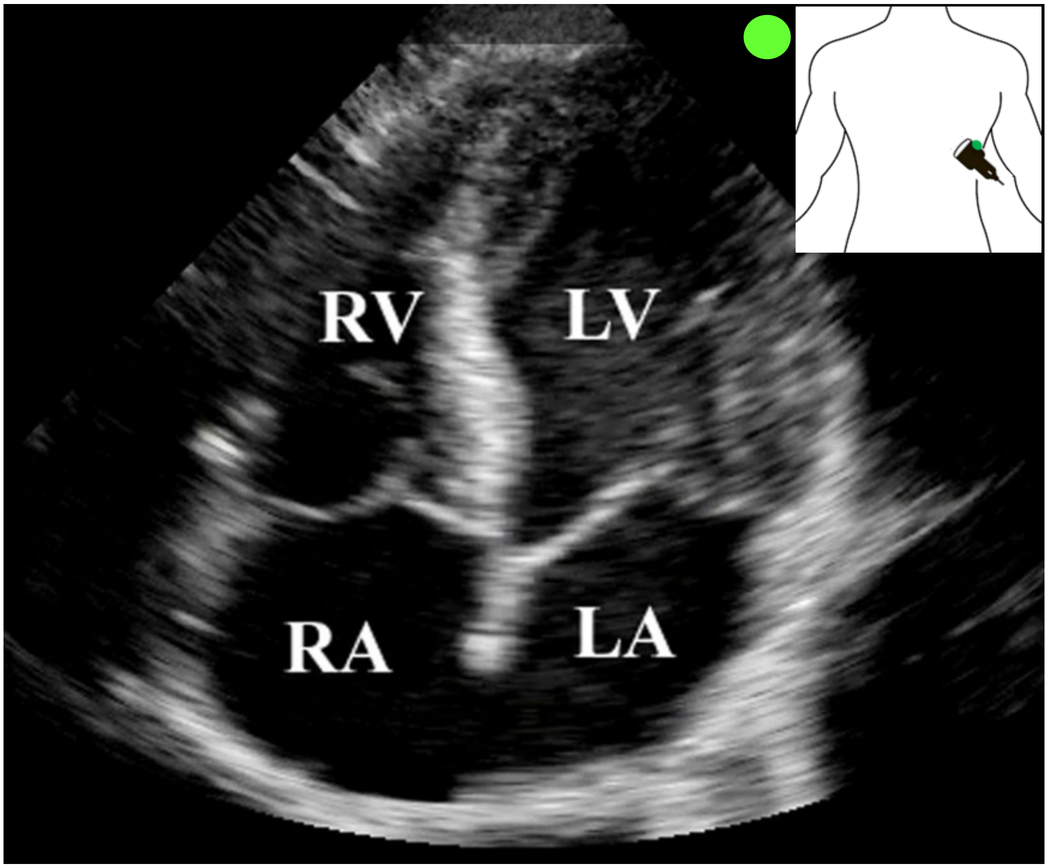
Is there septal flattening (D-sign)?

Pro Tip

Attempt using two hands as you rotate, keeping LV in view.

Pitfall

The RV can be difficult to capture, practice rocking the probe until it comes into view.



Quality Metrics

1) Equality

-RV:LV ratio <1

2) "Ejection"

-Assess for anterior excursion of the mitral and tricuspid valves

Landmarks

-Septum should be centered on the screen

Probe Positioning

- If able, have the patient roll into left lateral decubitus position to improve image quality
- Place the probe in the left 5th intercostal space at the mid-clavicular line, or at the PMI, with the indicator oriented superiorly.
- Attempt sliding up or down one rib space until the image comes into view, sliding laterally if ventricular hypertrophy is suspected.

Question

How is the squeeze?

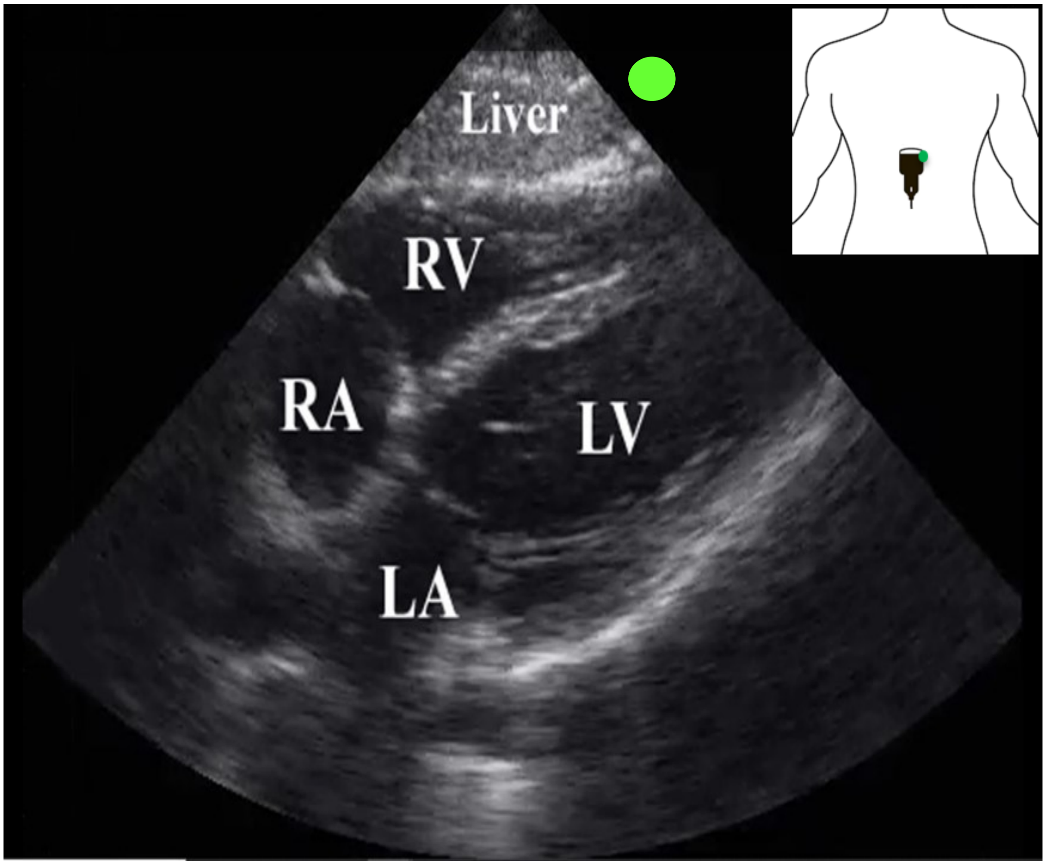
Is there septal bowing?

Pro Tip

Palpate the PMI to find optimal probe placement. Angle along the long axis of the heart

Pitfall

This can be a difficult view to obtain, especially in patients with large habitus.



Quality Metrics

1) Equality
   - RV < LV
2) "Ejection"
   - Global assessment of squeeze
3) Effusion
   - Excellent view to assess for a pericardial effusion

Make sure the patient is laying completely flat, and place the probe flat against the patient's abdomen near the xiphoid process.

Gently push the probe deep, such that the line of sight is aimed beneath the rib cage.

Slide the probe towards the patient's right in order to capture more of the liver, using it as an acoustic window.

Question

Is there an effusion?

Is the heart beating?

(example: in a code)

Pro Tip

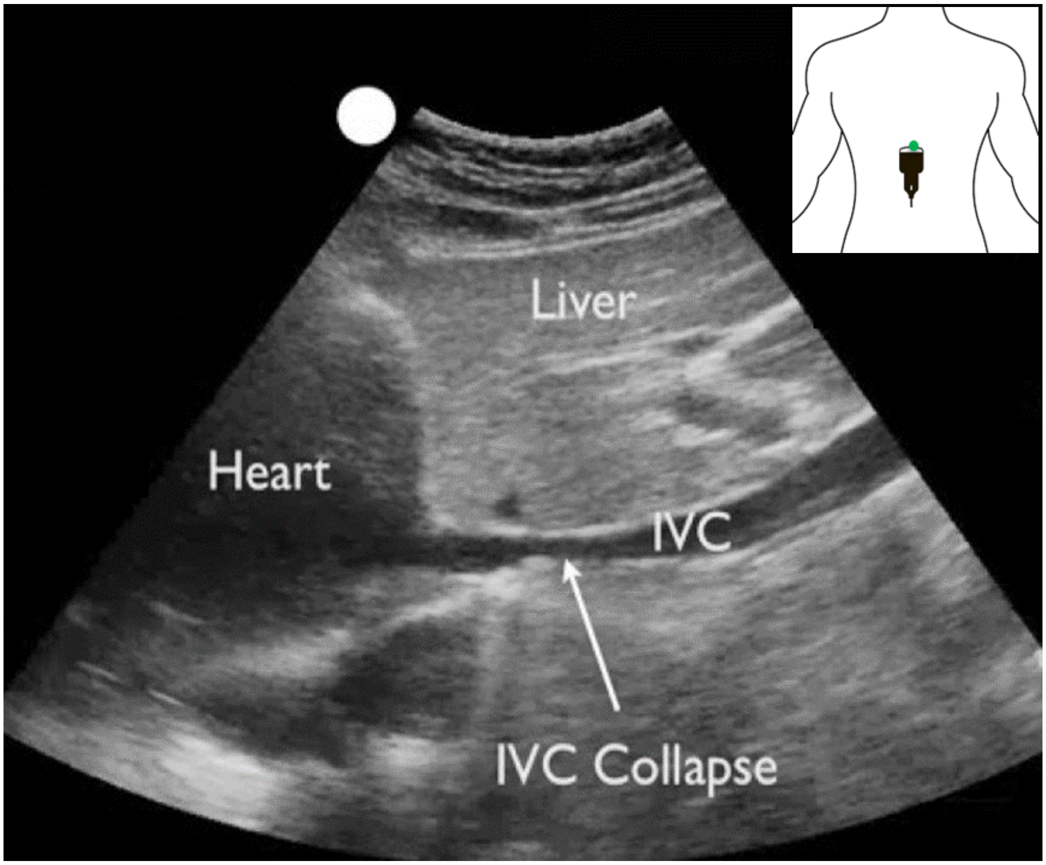
Identify the liver and use it as an acoustic window; waves are transmitted better through solid parenchyma than bowel gas.

Pitfall

Don't forget to lay the patient flat!

Flat patient, flat probe.

Cardiac POCUS: Inferior Vena Cava View (IVC)



Quality Metrics

1) Entry

-Assess for IVC size and collapse.

-Interpret using table below, and within clinical context

Caveats

-Always interpret within clinical context.

- Not applicable if positive pressure ventilation.

Obtain a clear subxiphoid view, and rotate the probe indicator superiorly.

Aim the probe deep towards the vertebral column, and fan left and right until a large blood vessel comes into view.

Slide or tilt superiorly to confirm IVC by viewing it drain into the right atrium.

IVC <1.5cm >50% collapse	Low CVP, volume likely to help
IVC 1.5-2.5cm >50% collapse	Volume may help, patient likely to tolerate
IVC 1.5-2.5cm <15% collapse	Volume unlikely to help
IVC >2.5cm <15% collapse	High CVP, volume likely to hurt

Measure IVC ~ 2 cm from entry of IVC to RA
Note: above is in setting of hypotension

Question

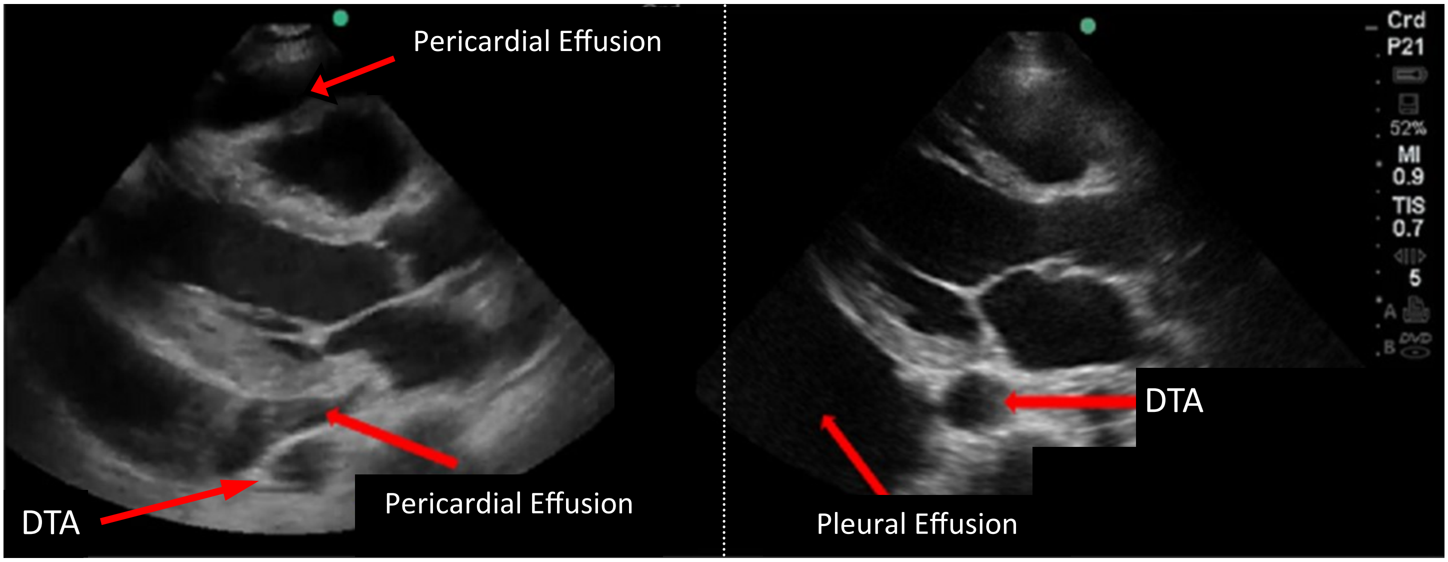
Is the IVC collapsible?

Pro Tip

Fan left and right to alternate views to capture the IVC (enters RA) versus aorta.

Pitfall

Do not interpret IVC collapsibility in isolation, synthesize it with all available clinical info.



Pericardial vs. Pleural Effusions

- Pericardial effusions are best visualized in the **PLAX** or **subxiphoid** views, and are easily visualized as anechoic collections **anteriorly** between the chest wall and pericardium.
- In the PLAX view, effusions can also be visualized **posteriorly**, however this may represent a pericardial or pleural.

The position of the descending thoracic aorta (DTA) can help to distinguish between a pericardial and pleural effusion

Pericardial: Effusions track along the heart and separate the aorta from the pericardium and cross the midline, note the relationship to the DTA above.

Pleural: Effusions will accumulate posterolateral to the DTA.

Pro Tip

A small anterior hypoechoic signal may represent the epicardial fat pad, as opposed to a pericardial effusion.

Pitfall

If a new or increasing effusion is visualized via POCUS, a formal echocardiogram should be pursued.

Probe Positioning

Probe Selection

♦ Linear:
Use: pleural surface (for lung sliding)
Limitation: does not image deeper structures well (specifically, ***cannot be used to visualize B-lines)***

♦ Phased Array:
Use: deeper visualization (including B-lines, effusions) and fits neatly between rib spaces.

♦ Curvilinear:
Allows evaluation of several lung fields within a zone

Patient Positioning

Supine or seated depending on pathology

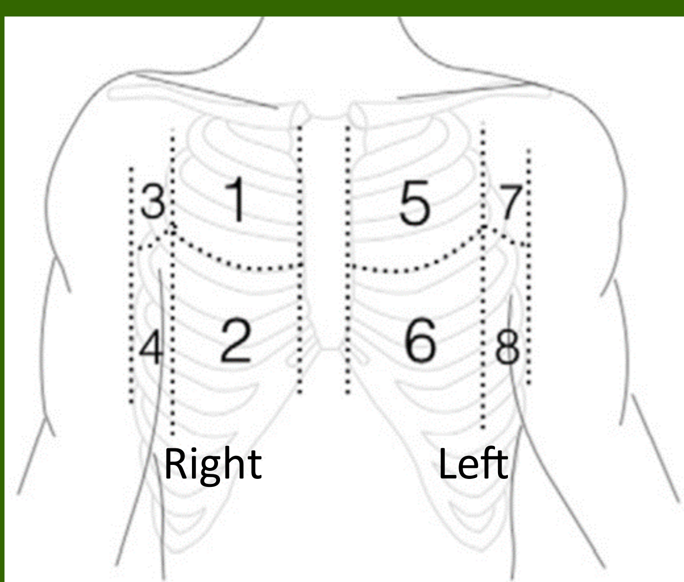
Transducer Positioning

Probe indicator should be oriented superiorly toward the patient's head.

Probe should be held perpendicular to the pleura and in between rib spaces.

Note: Best images are obtained when the probe is perpendicular to the pleura which is not necessarily the same as perpendicular to the chest.

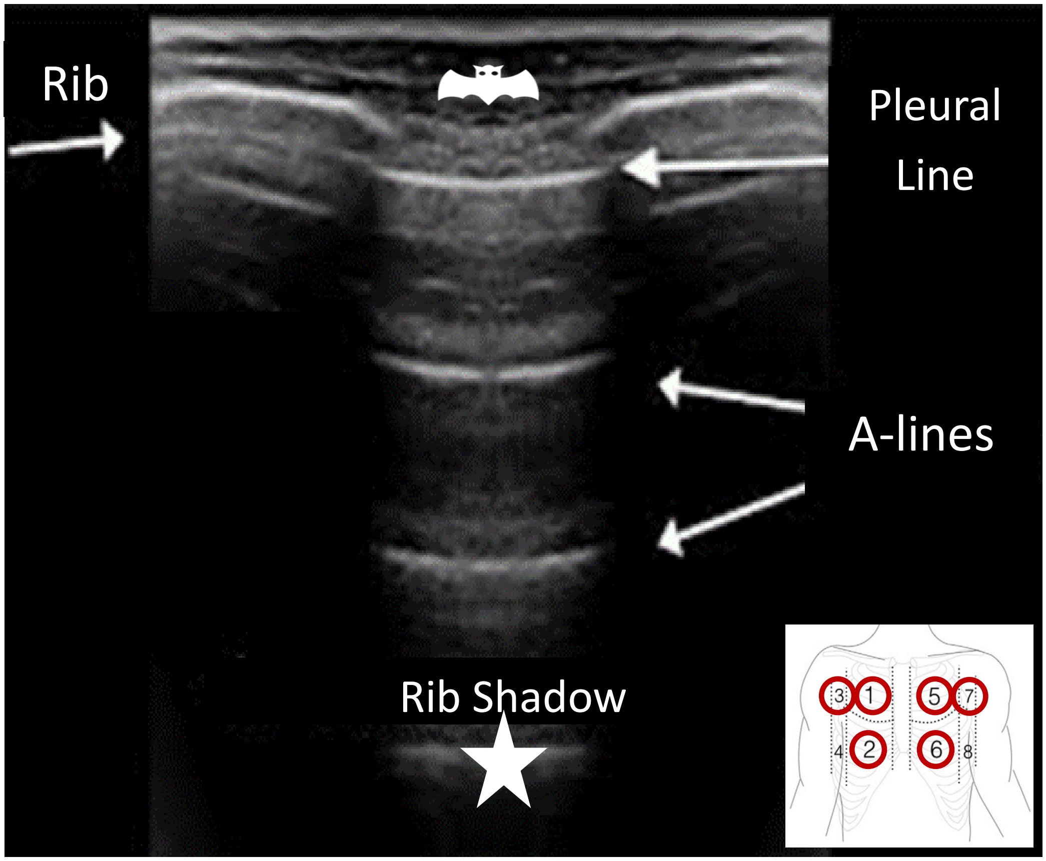
Volpicelli Lung Zones



- The third intercostal space divides upper and lower zones of the chest
- The anterior axillary line divides the anterior and lateral zones in each hemithorax.
- Naming convention is moving towards 1-4 on each side. Ex: 1R = 1. 2R = 2, 3R = 3, 4R = 4. 1L = 5, 2L = 6, 3L = 7, and 4L = 8.

Normal Anatomy: Pleura & A-lines

Seen in Zones 1L/R, 2L/R, 3L/R

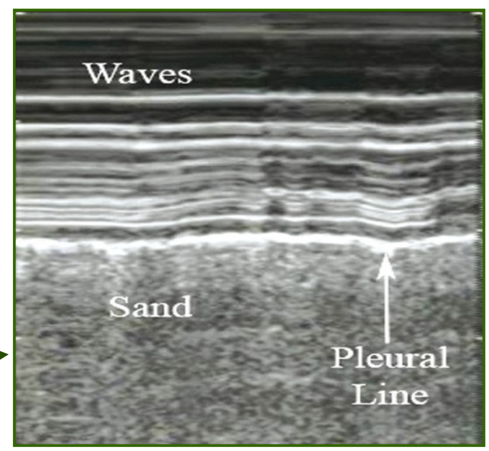


Quality Metrics

- In the intercostal space, a pleural line will be seen slightly below the surrounding rib lines (***bat wing sign***).
- A normal scan will show ribs with posterior **rib shadowing**
- A-lines are a reverberation artifact from pleural air reflections and are deep to the pleural line.

Lung Sliding

- "**Sliding**" represents the normal movement of visceral pleura against parietal pleura (occurs with respiration).
- In **B-mode**, the hyperechoic (bright) pleural line between two ribs appears to move or shimmer (described as ***"ants-marching"*** appearance)
- In **M-mode**, a normal image is described as the ***"seashore sign"***
  - **"Waves"** : motionless area superficial to pleural line
  - **"Sand"**: grainy image (artifact of lung/air) below the pleural line



Question

Is lung sliding present?

Are A-lines present?

Pro Tip

Always scan in multiple lung fields.

Pitfall

Fluid and air shift with positioning; attempt scanning in upright and supine positions.

Pathology: Loss of Lung Sliding

Seen via linear probe

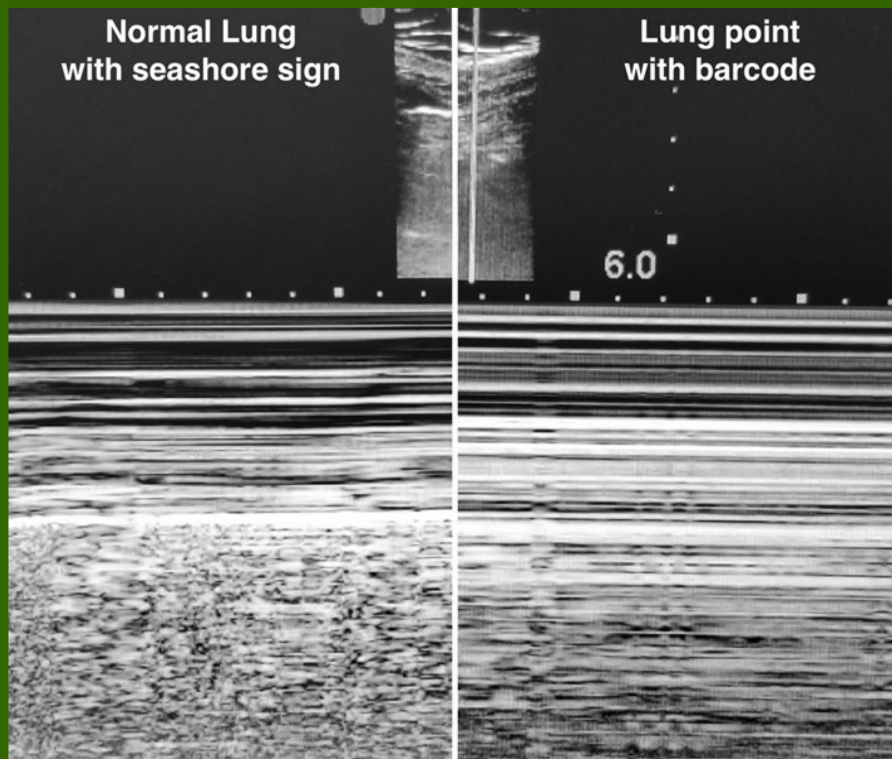
Pleural Separation

- Leads to loss of lung sliding (when parietal and visceral pleura no longer slide against each other)

In **B-mode,** pleural line appears static, with loss of shimmering / "*ants marching*"

In **M-mode,** loss of seashore sign, instead visualizing the "**barcode sign**"

- **Barcode sign:** a set of parallel, non-moving lines as the pleura are no long in contact (*image, right*).



Lung Point: the transition point between a segment where the pleura approximate and where they separate; sliding appears next to an area without lung sliding

Differential Diagnosis

- **Pneumothorax -** a large pocket of air physically separates the visceral pleura (which is still moving) from the parietal pleura
- **Pleurodesis** - chemical pleurodesis or chronic inflammation/fibrosis results in a genuine loss of movement as the visceral and parietal pleura are fused
- **Volume loss -** pneumonectomy or large volume atelectasis (for instance, from mainstem intubation)

Normal Anatomy: Diaphragm

Seen in Zones 4, 8

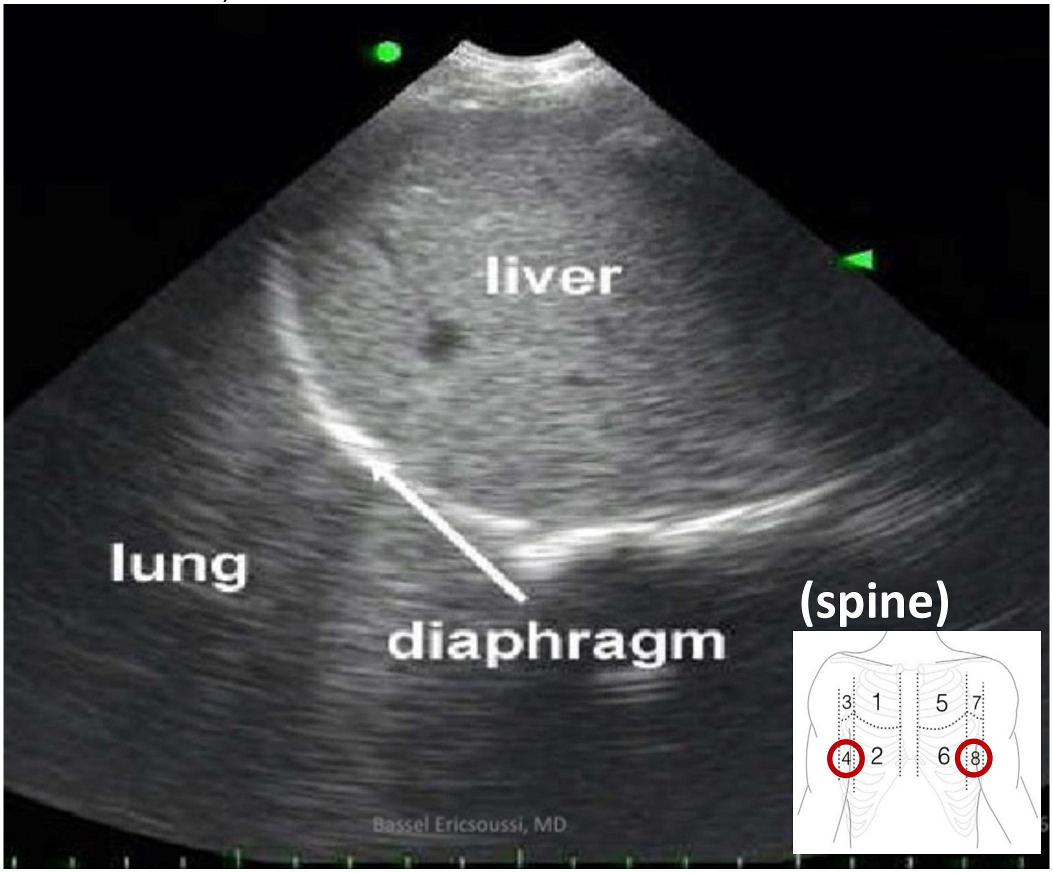


Image Acquisition

- Use B-mode.
- Place phased array probe in Zone 4R or Zone 4L, in the mid-axillary line with the indicator oriented superiorly.

Quality Metric:

- Lung, diaphragm, and liver (R) or spleen (L) should be visualized in one view.
    - Visualizing the diaphragm as a landmark allows for detection of pleural fluid *above* the diaphragm, and abdominal free fluid *below* the diaphragm (see Pleural Effusion page).
- In patients without a pleural effusion, the spine is obscured by air in the lung but may be seen in the abdomen (see ***Spine Sign****,* Page 19).
- Healthy aerated lung may fall into view during inspiration as a **"Curtain Sign"**, obstructing view of abdominal organs.

Question

Can you find the diaphragm?

Pro Tip

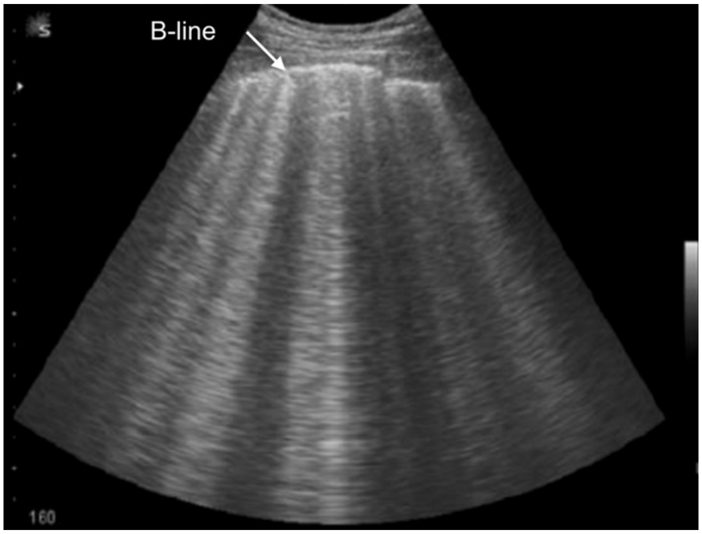
If rib shadows obstruct the view, have the patient sustain a prolonged breath to lower the diaphragm and hold in place.

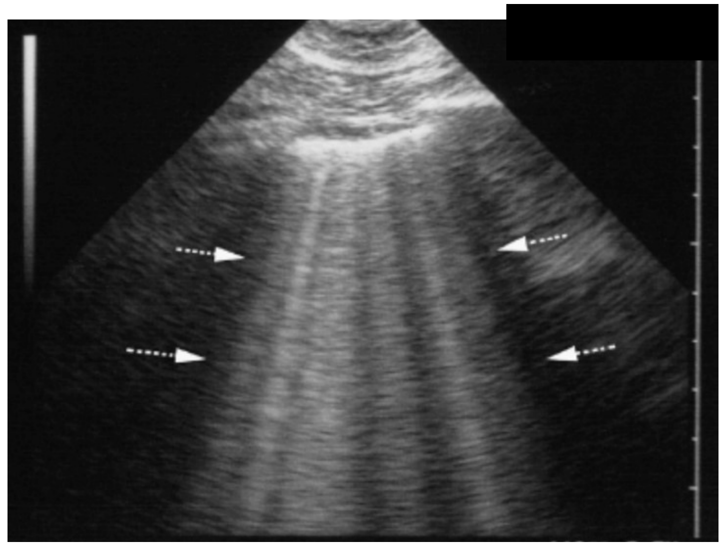
Pitfall

Avoid scanning too anteriorly. Keep your *"Knuckles to the Bed"* for the best views.

Pathology: B-lines

Seen via phased array probe





What is a B-line?

B lines are an artifact created by thickened interlobular septa in the lung which allows ultrasound waves to propagate through the tissue.

B lines have a "comet-tail"-like appearance, with lines that appear to almost originate from the probe, and move with lung sliding.

<u>Criteria for Pathologic B-line</u>

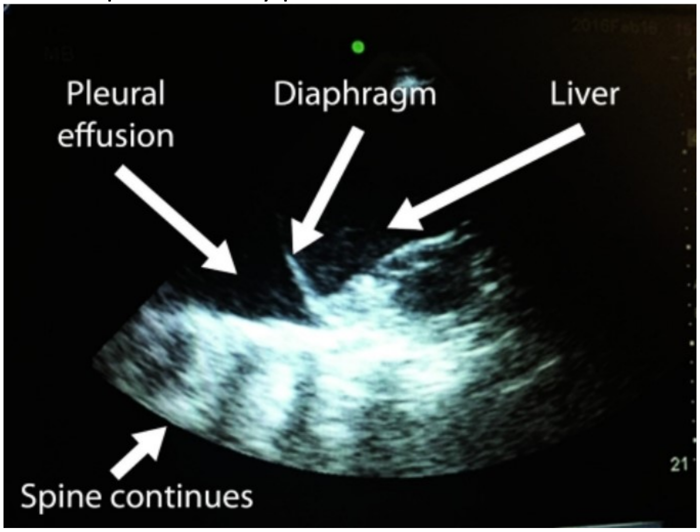
- Comet tail artifact, arising from the pleural line
- >3 B-lines in one view
- Depth of at least 15cm (i.e. cannot be visualized with the linear probe)

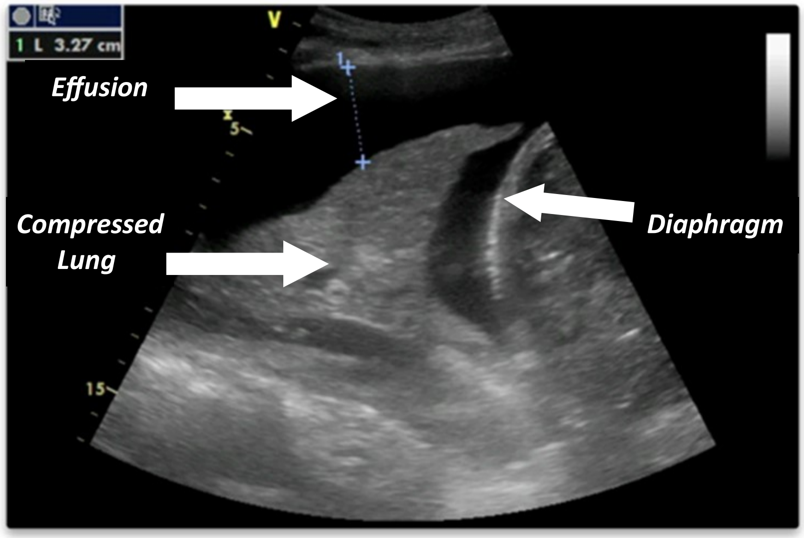
Differential Diagnosis *(always consider the clinical context)*

- **Pulmonary edema** - typically bilateral and diffuse B-lines
- **Pneumonia** - unilateral or asymmetric B-lines, sometimes with consolidation
- **Pulmonary fibrosis** - diffuse B-lines, sometimes with sub-pleural consolation and thickened pleura.
- **And many more. As above, always consider the clinical context.**

Pathology: Pleural Effusions

Seen via phased array probe





Pleural Effusions

- Seen as an **anechoic space** (black) above the diaphragm.
- Consolidated lung from compressive atelectasis may be floating in the fluid.
- Complicated effusions (typically exudative) may show septations, or lines of thin fibrous tissue that tether the visceral pleural to the parietal pleura.

Spine Sign: the spine is only visualized **in the presence of** an effusion as ultrasound waves travel through fluid. Normally, the spine is obscured by air in the lung.
Absent Curtain Sign: In the presence of an effusion, aerated lung may no longer obstruct the view of abdominal organs with inspiration.

Pro Tip #1

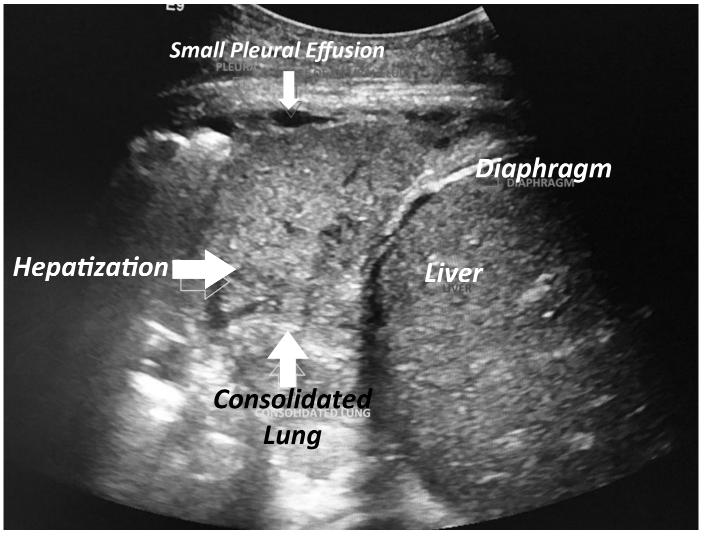
Smaller effusions may be more easily visualized if the patient is in a seated position.

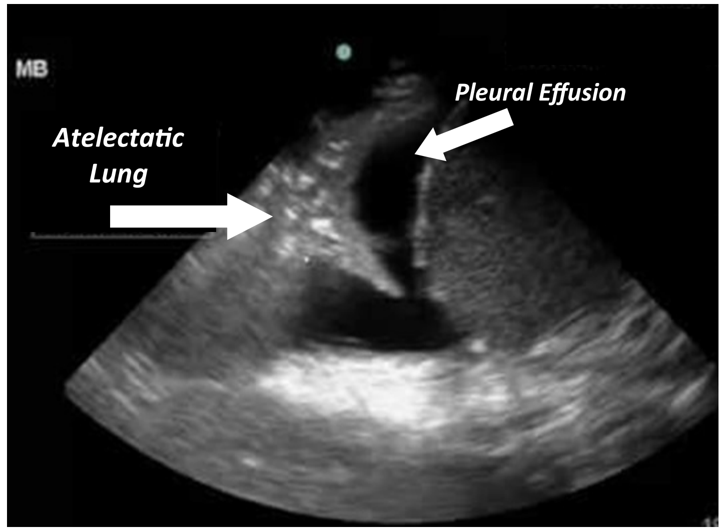
Pro Tip #2

Effusions are not always anechoic; at times, exudative effusions have "echogenic swirls" of debris in the fluid.

Pathology: Consolidation

Seen via phased array probe



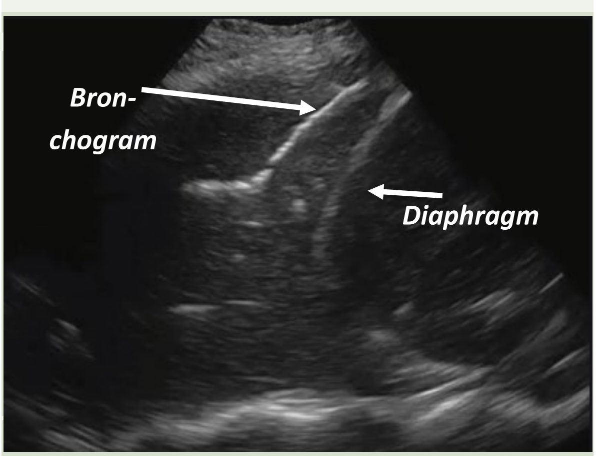


Consolidation

- Created by absence of air in parts of the lung due to any alveolar filling process or atelectasis, resulting in **hepatization** (solid-appearance of the lung that appears as dense as the liver).

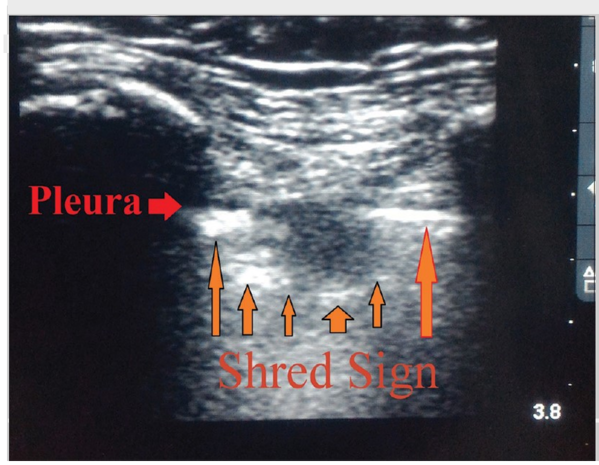
Bronchogram

Created by the visualization of air (white) in consolidated lung



Shred Sign

Aerated lung tissue adjacent to consolidated lung reflects ultrasound waves, obscuring distant structures



Introduction: Renal

Probe Selection Curvilinear Probe

Patient Positioning

- Start with the patient in the supine position.
- Bowel gas can obscure visualization of the left kidney. Troubleshoot this by repositioning the patient in the lateral decubitus or prone position.

Transducer Positioning

Step 1: Place the transducer at the R 10th rib, mid axillary line.

Step 2: Probe marker should be directed toward patient's head. **Slide/Rock** the probe superiorly and inferiorly to locate the **longitudinal** view of the kidney.

*You may need to **rotate** the probe to find the kidney in its longest axis.

Step 3: **Rotate** the transducer 90 degrees, to locate the **transverse** view of the kidney. **Fan** the transducer superiorly and inferiorly to view the kidney from top to bottom.

Step 4: Place the transducer at the L 8th rib, posterior axillary line. Repeat Steps 2-4.

Introduction: Bladder

Basics

The bladder is an easily identifiable structure on ultrasound. In the setting of retention, POCUS can be used quickly to estimate bladder volume.

Probe Selection Curvilinear Transducer

Patient Positioning Supine

Transducer Positioning

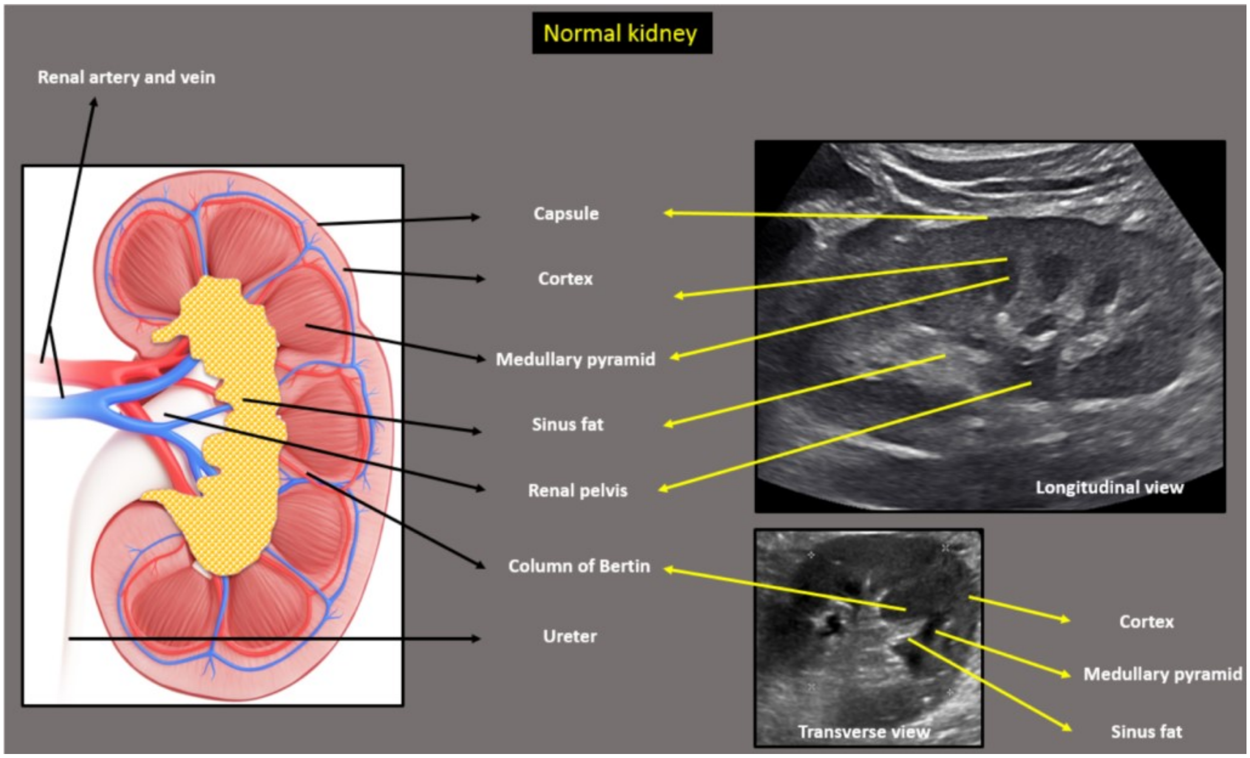
Step 1: Place transducer mid pelvis, superior to the pubic symphysis, to locate the **longitudinal** view. The probe marker should be directed towards patient's head.

Step 2: Sweep the probe left and right to view the bladder in the **longitudinal** plane.

Step 3: Rotate the probe 90 degrees to the right, to locate the **transverse** view. The probe marker should be directed towards patient's right

Step 4: Sweep the probe superiorly and inferiorly to view the bladder in the **transverse** plane.

Normal Anatomy



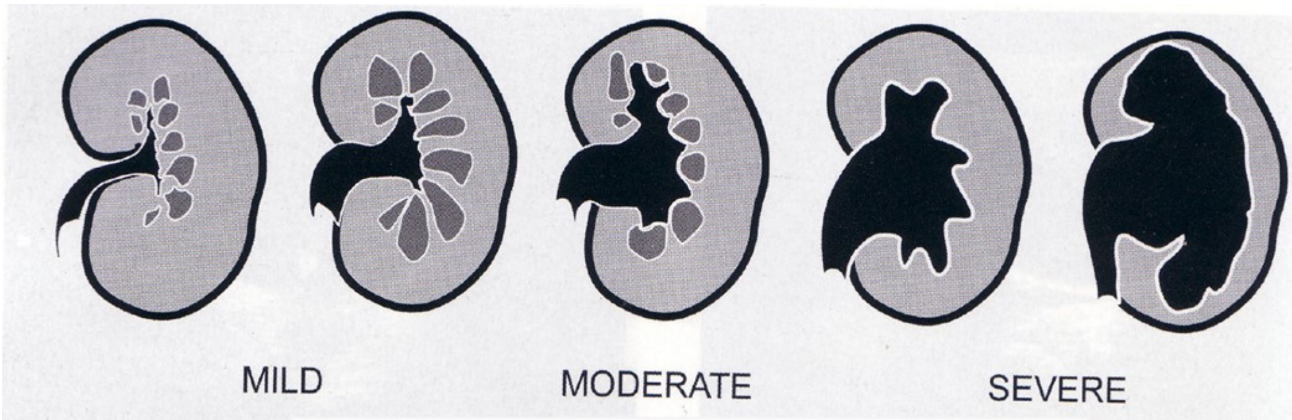
Renal Anatomy

- **Gerota's Fascia/Capsule**: fibrous surface of kidney, appears <u>hyper</u>echoic relative to peri-nephric fat. Using these margins, the kidney's pole to pole (longitudinal) length is typically about 10-12 cm.
- **Renal cortex**: Hypervascular area between the capsule and medulla, appears <u>iso</u>echoic to the liver. The cortical thickness is typically about 7-10 mm, but can be reduced in CKD.
- **Renal medulla**: Consists of medullary pyramids (<u>hypo</u>echoic to the cortex) which are "bundles" of papillae draining urine into calyces. They are discrete and separated by columns of Bertin (<u>iso</u>echoic to the cortex)
- **Sinus fat**: Fatty tissue that is <u>hyper</u>echoic to the cortex and <u>iso</u>echoic to the peri-nephric fat
- **Renal pelvis**: Area where renal calices meet the ureter that is <u>hypo</u>echoic to the cortex but typically <u>hyper</u>echoic to the medullary pyramid. They are normally collapsed, but dilated and <u>hypo</u>echoic in obstruction.

Bladder Anatomy

- **Bladder:** <u>An</u>echoic fluid filled structure (urine is <u>*black*</u> on US). Edge artifact casts shadows from the curved edges of bladder.
- **Ureteral Jets**: The passage of urine from the ureter into the bladder can be seen when viewing the bladder in the longitudinal plane in doppler mode indicating that the ureters are patent.
- **Bladder volume**: Bladder volume can be estimated with three orthogonal measurements of the bladder
  Step 1: In the longitudinal view, measure the height of the bladder
  Step 2: In the transverse view, measure the length and width of the bladder
  Step 3: Estimated volume = **L x W x H x 0.7**
- **Uterus:** Visible left and deep of the bladder in longitudinal view

Pathology: Hydronephrosis



mage from *World J Nephrol* 2019; 8(3):44

Hydronephrosis

- Obstruction can lead to dilation and decreased echogenicity of the renal collecting system including the renal pelvis and calyces. POCUS has **high sensitivity** (Gaspari and Horst 2005).
- **Mild**: Dilation and increased hypoechoity of the of the renal pelvis and calyces with retained architecture of the pelvis, calyces or medullar pyramids.
- **Moderate**: Collecting system, open and blunted, mimicing a "cauliflower appearance." There is flattening of the medullary pyramids with mild thinning of cortex.
- **Severe**: Ballooning of the pelvis and calyces with loss of cortico-medullary differentiation. The cortex is thin and the kidney looks like a fluid filled bag

Question Asked

Is hydronephrosis present?

Quality Metrics

Identify the pelvis and cortex in **both** longitudinal and transverse views, then fan through the entire kidney.

Pro Tip

If difficult to identify, aim **posteriorly** near CV angle & **rotate** probe to maximize window between ribs.

Esra Gumuser & Lauren Maldonado

Pathology: Nephrolithiasis

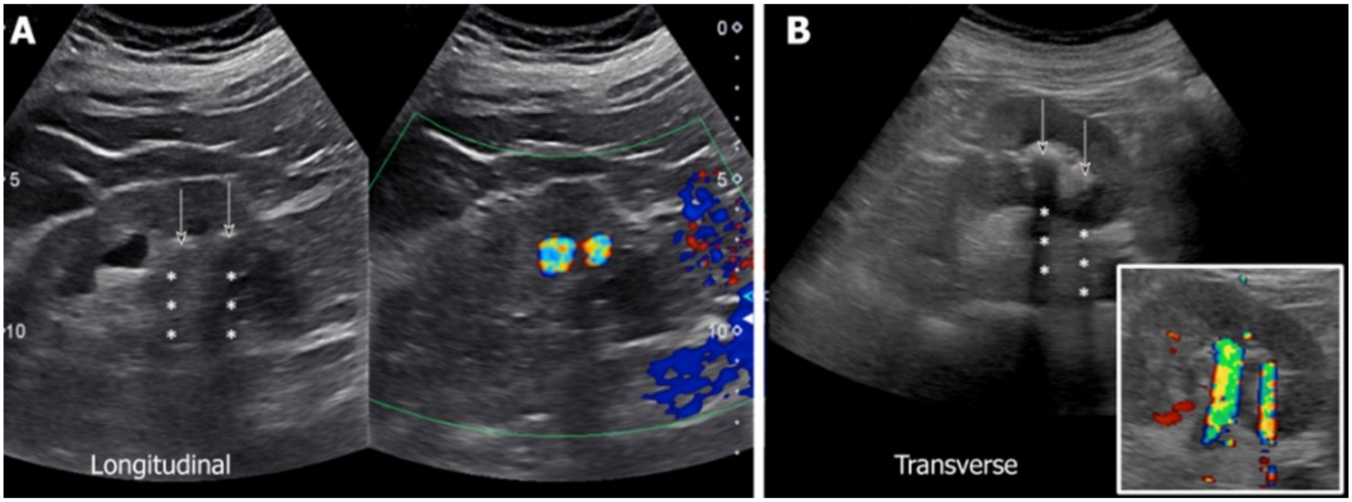
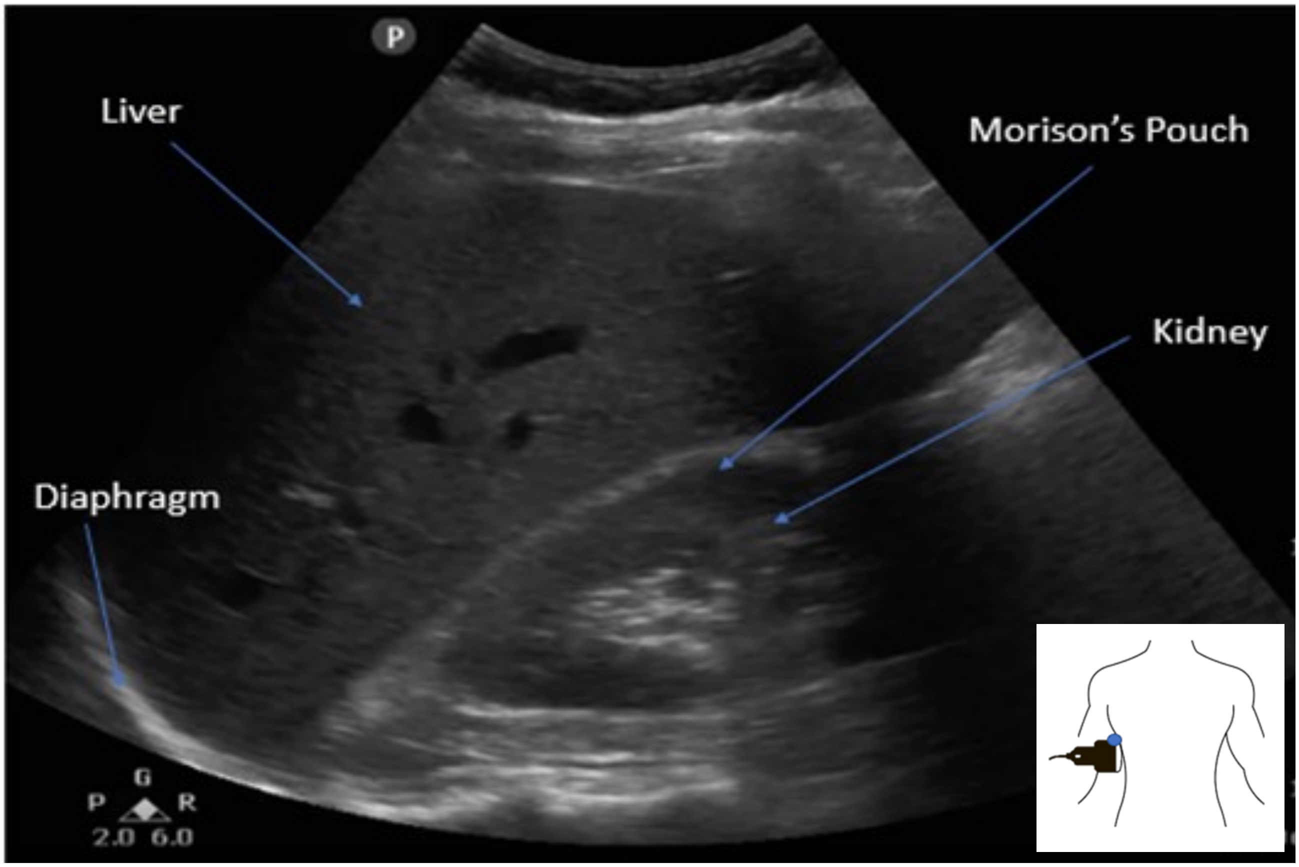


Image from *World J Nephrol* 2019; 8(3):44

Nephrolithiasis

- POCUS can visualize stones in the calyces, renal pelvis and upper ureter. However, sensitivity is decreased when size of stone < 7 mm (Fowler 2004). **CT stone protocol is the *more sensitive* modality**
- Stones appear as *hyper*echoic structures with ***acoustic shadowing*** distal to the structure from the probe (*** in Image A and B)
- Doppler mode can cause a ***twinkling artifact*** over a the area of a stone due to turbulent flow of fluid around the stone (Multicolored/Dopplers in Image A and B)

Hepatorenal "Morrison's" Pouch



- Standing on the right side of the bed place the curvilinear probe in the mid-axillary line between the 8 and 11 rib spaces.
- Place the indicator to the head and knuckles to the bed.
- Fan the probe anteriorly to see the liver tip.
- Slide the probe caudally to evaluate diaphragm.
- Slide the probe cephalad to visualize the liver tip, kidney and right paracolic gutter.

Quality Metrics

The lung, diaphragm, and liver should be present in one view.

Question

Is there abdominal free fluid?

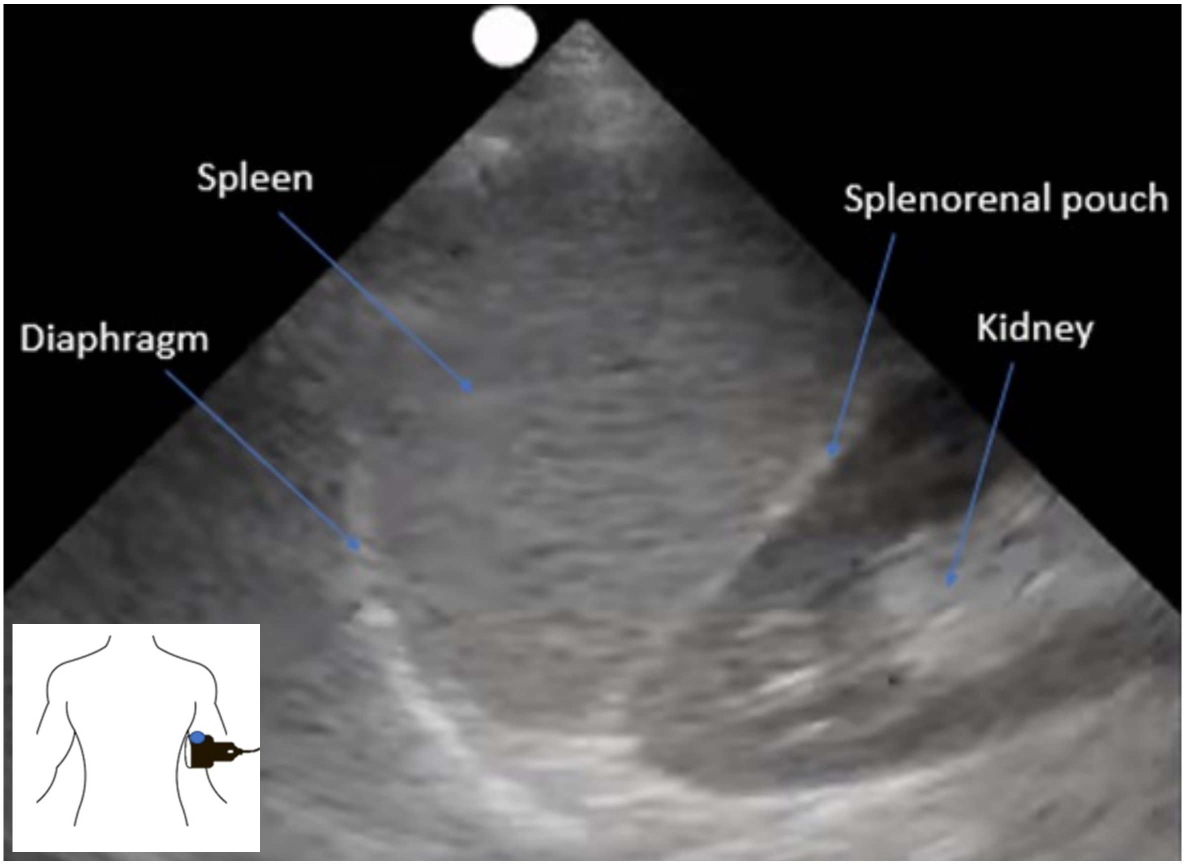
Pro Tip

If difficult to obtain image due to rib shadowing, have patient hold breath.

Pitfall

Beginners often scan too anteriorly when trying to obtain this view.

Splenorenal Pouch



- Standing on the right side of the bed place arm over the patient and with your knuckles on the edge of the bed place the ultrasound between the 6th and 9th rib spaces (more posteriorly than on the right) with probe indicator facing cephalad.
- Move the probe caudally to evaluate diaphragm. Move the probe cephalad to visualize the spleen , kidneys and left paracolic gutter.

Quality Metrics

The lung, diaphragm, and spleen should be present in one view.

Question

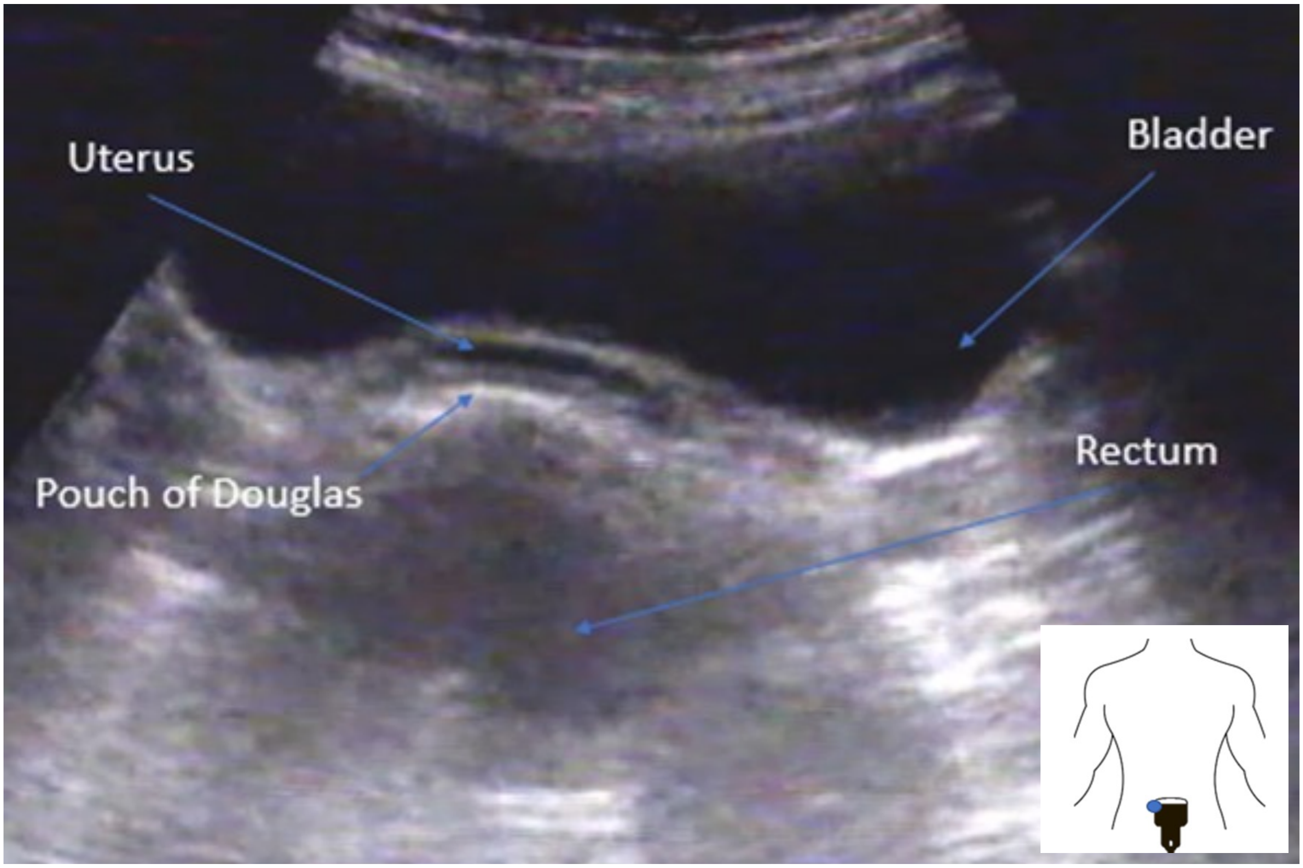
Is there abdominal free fluid?

Pro Tip

If difficult to obtain image due to rib shadowing, have patient hold breath.

Pitfall

The Splenorenal Pouch is often more difficult to visualize then the Hepatorenal Pouch



- Standing on the right locate the pubic symphysis and place the probe cephalad with the probe marker facing the right.
- Increase the depth to visual behind the bladder.
- Sweep up and down to visualize the retro vesicular space in men and the vesico-uterine pouch (pouch of Douglas) in women for the transverse view .

Quality Metrics

Visualize the bladder in the transverse and longitudinal views.

Question

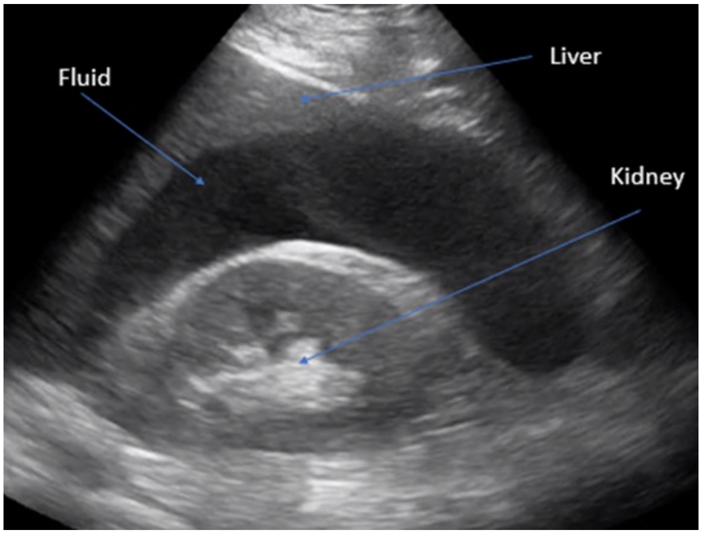
Is there free fluid behind the bladder?

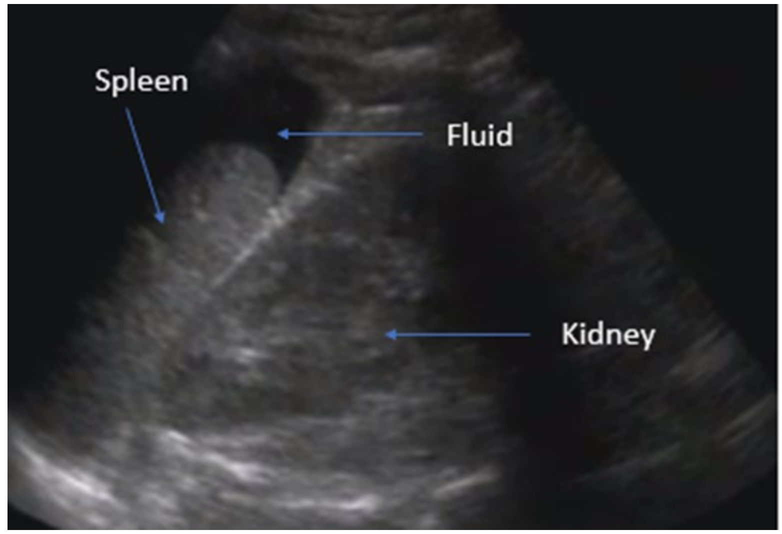
Pro Tip

Turn the probe 90 degrees with probe facing the head for the longitudinal view.

Pitfall

Visualizing the bladder may be difficult after voiding or when a foley catheter is in place.





Free Fluid

- Free abdominal fluid is hypoechoic to the surrounding structures. To reliably detect fluid, ultrasound requires at least 150cc-200cc of intraperitoneal fluid, with the pelvic view as the most sensitive.
- Ultrasound can typically identify fluid, but cannot typically differentiate the type of fluid. At best, hemorrhagic or purulent fluid can appear more echoic due to clot or septations, making it difficult to distinguish from surrounding structures.
- Presence of bowel gas can obstruct view. Point the probe posteriorly when looking in the RUQ and LUQ in order to avoid bowel.

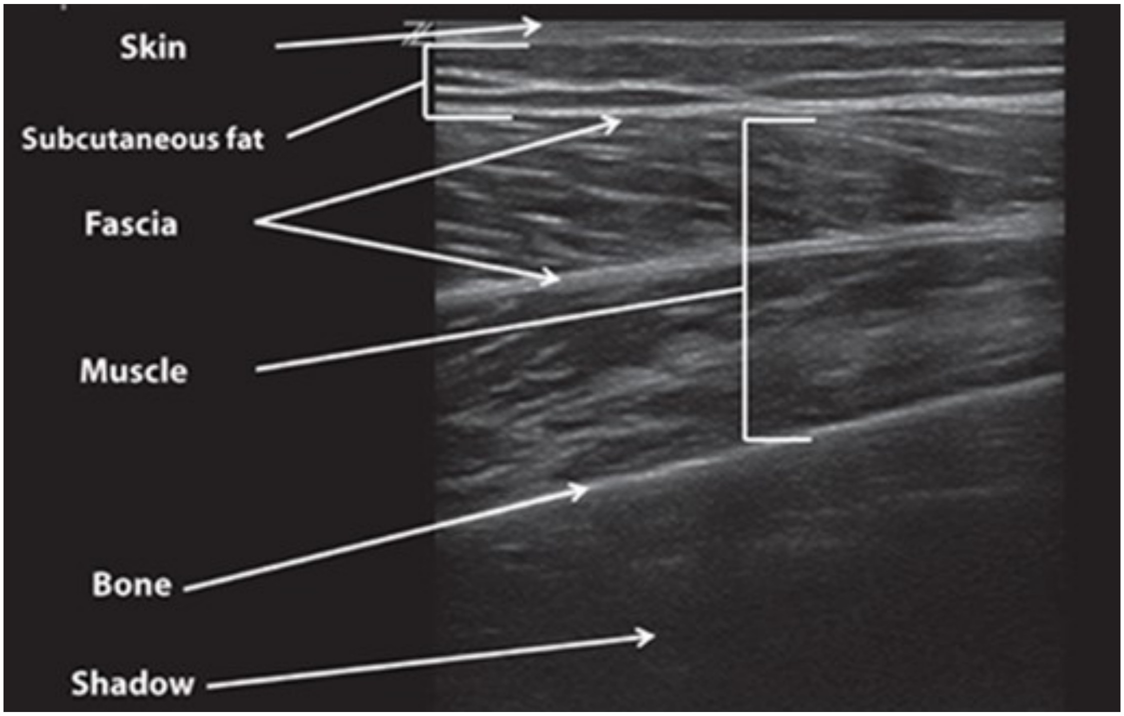
Pro Tip

Many structures look similar to fluid: hepatic vessels, the gallbladder, and hypoechoic renal parenchyma,

Pitfall

If you cannot see the uterus, increase depth, but be careful to distinguish the bladder (distinct borders) from free fluid.

Soft Tissue Basics



- Ultrasound has high sensitivity and specificity for the soft tissue examination. It can be used to evaluate for cellulitis, abscesses, and deeper fluid pockets.
- The linear probe (5-10 MHz) is used in the majority of cases.
- Subcutaneous tissue is primarily **hypoechoic** and contains **connective tissue strands**. Orthogonal planes are hyperechoic. Muscle is striated, nerves appear stippled. Lymph nodes can be identified by an echogenic center with a hypoechoic periphery. Bone is quite hypoechoic with a hyperechoic periphery (cortex) and demonstrates a shadowing phenomenon.

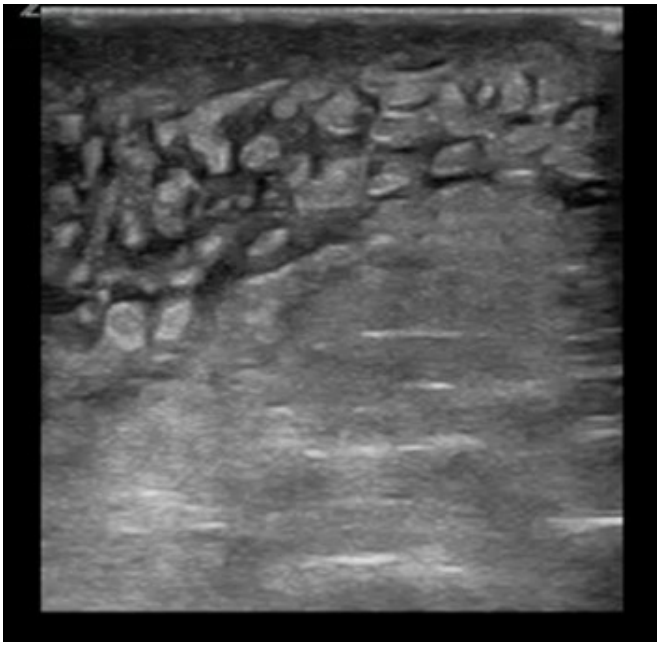
Pro Tip

Hold transducer perpendicular to the skin surface at the area of interest, and visualize in at least two orthogonal planes. Scan the entire extent of the affected area AND compared to the unaffected side.

Pitfall

To asses a deeper structure in an obese patient, a lower frequency curvilinear probe may be substituted for a linear probe for increased depth.

Pathology: Soft Tissue Infections



- Soft tissue swelling demonstrates ***cobblestoning*** and echogenicity higher than normal subcutaneous tissue. For example, in cellulitis, inflammatory fluid is visualized around tissue, creating a cobblestone appearance (***above left***; seen in any edema and not specific to cellulitis).
- Abscesses (***right***) are typically **hypoechoic** but may enhance and become more echogenic at deeper levels (known as **posterior acoustic enhancement).** They **do not demonstrate pulsatile Doppler flow** but are often **hyperemic on Doppler signal**. Other signs include **irregular walls** and **heterogeneous/anechoic material** inside.
- A "squish sign" may be observed, where compression causes fluctuance of purulent material within the abscess. Necrotizing fasciitis will have subcutaneous thickening as in cellulitis, with anechoic fluid and potentially **subcutaneous gas** (though ultrasound is not the imaging study of choice for this).

Pro Tip

Air within an abscess will cause reverberation artifact, much like A-lines in a normal lung scan.

Pitfall

Soft tissue pathology can be subtle, so make sure to compare to the contralateral side if there are subtle findings.