PEARLS-MD: *A Pocket Guide to Basic Bedside Ultrasound and Procedures*

East Alabama Medical Center (EAMC) Internal Medicine Residency Program

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East Alabama Health

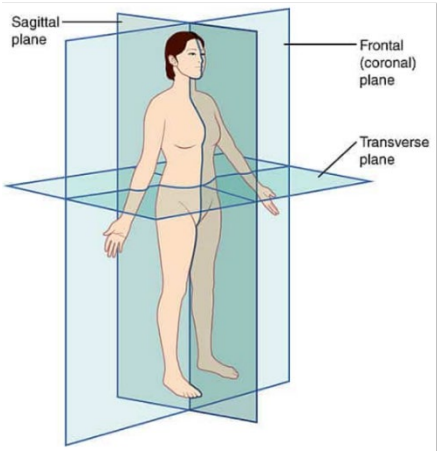
Based on the **PEARLS** method taught on the ACP POCUS website and the article *"PEARLS for an Ultrasound Physical and Its Routine Use as Part of the Clinical Examination."* Michael Wagner, MD and Janice Boughton, MD.

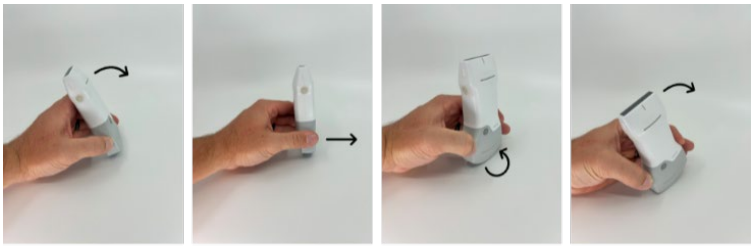
PEARLS-MD incorporates the original PEARLS pneumonic (Parasternal, Epigastric, Anterior lung/ Apical, Right upper quadrant, Left upper quadrant, Suprapubic) plus Musckuloskeletal and Deep venous thrombosis.

Table of Contents

Basics

Orientation





Imaging planes to the left of page, cardinal movements of the probe depicted below.

Imaging planes adapted from Wikimedia

(https://commons.wikimedia.org/w/index.php?title=File:Planes_of_Body.jpg&oldid=692147168)

Echogenicity

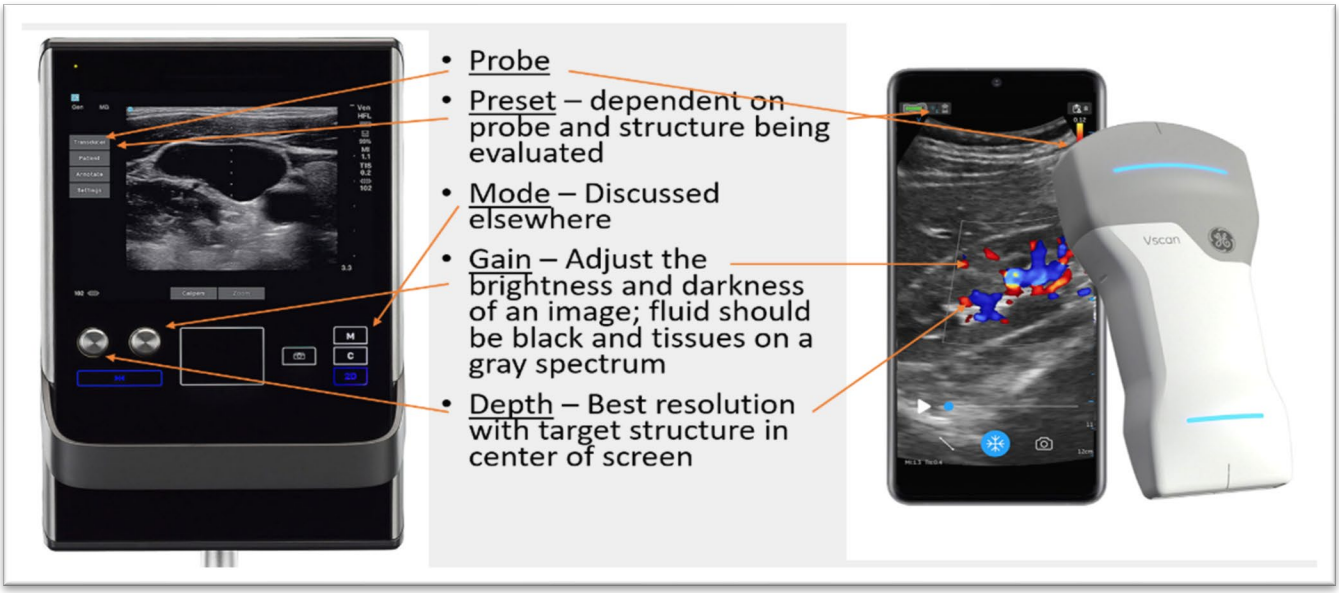
- Anechoic – Transmit all sound waves without reflection. Appears black.
- Hypoechoic – Reflect fewer sound waves than surrounding structures. Darker than surrounding structures.
- Isoechoic – Reflect sound waves similar to surrounding structures.
- Hyperechoic – Reflect most sound waves. Appears lighter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

Fluid (blood, bile, urine)

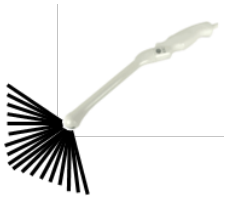
Solid organs, soft tissue, muscle

Bone, metal, air, dense/ fibrous structures

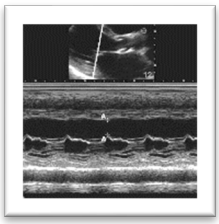
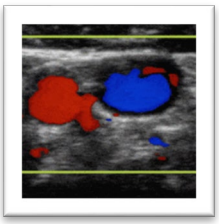
Knobology



Probes

	LINEAR	CURVILINEAR	PHASED ARRAY/ SECTOR PROBE	INTRACAVITARY
FREQUENCY	5 – 15 MHx (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, MSK, eyes, thyroid, nerves	Intrabdominal organs, Abdominal aorta, LP, bladder	Heart, IVC, lungs, pleura, intraabdominal organs, transcranial doppler	Uterus/ ovaries, pharynx

Modes

	B-MODE	M-MODE	COLOR DOPPLER	POWER DOPPLER
IMAGE				
DESCRIPTION	"Brightness" mode; The echogenicity of observed structures depends on reflected signals.	Motion mode; Movements of all tissues in a given plane or 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 US.	Size of cardiac chambers, movements of valves, measurement of respiratory variation of the IVC, eval for pneumothorax	Eval of vasculature. Affected by angle of insonation.	Advantages over color doppler include less reliance on angle of insonation and higher sensitivity in low flow states or tissues (e.g. testicles).

PARASTERNAL (all cardiac covered in this section including apical)

Probe: Phased Array, can use curvilinear but not the best choice as phased array can better peer between rib spaces and tight windows.

Preset: Cardiac

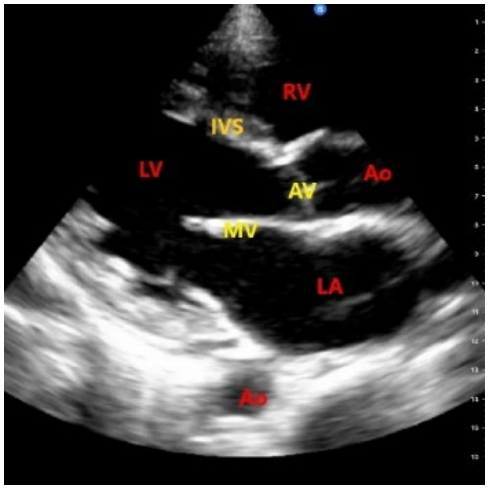
Patient position: Supine, left lateral decubitus to aid with difficult windows, especially apical view.

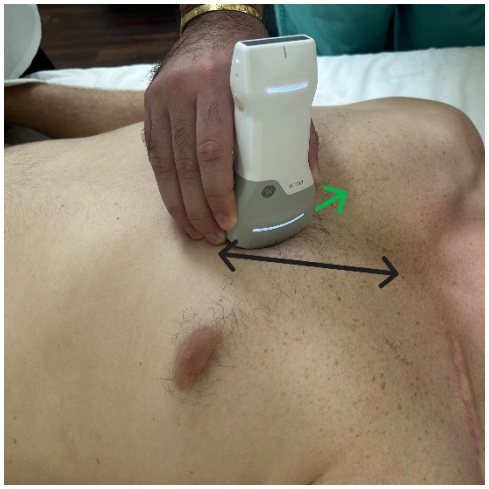
Long Axis (PLAX)

Probe marker: Towards patient's right shoulder

Probe location: Approximately left 4th intercostal space.

Window shopping: Navigate each individual rib space, starting just under the clavicle on the left parasternal border, until you find an adequate window. Always look one space above and below "best" window to ensure you are in the actual best position. Pictured below.

A. 

B. 

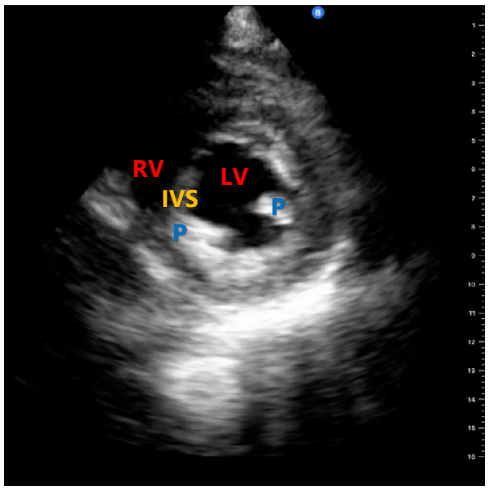
A: Should visualize right ventricle (RV), Aorta (Ao), Left atrium (LA), Left ventricle (LV), Aortic valve (AV), Mitral valve (MV), and the Interventricular septum (IVS). Deepest visualized structure should be the descending aorta (Ao). B: green arrow indicates probe marker towards right shoulder, black arrow indicates area for "window shopping."

Evaluate **endpoint septal separation (EPSS)** which is how close the MV leaflet gets to the IVS. Should be < 1 cm typically and if greater can indicate LV dysfunction. Also evaluate **"rule of thirds."** The RV, Ao, and LA should all approach approximately the same size and be 1/3 of the whole.

Short Axis (PSAX)

Probe marker: Rotate probe marker clockwise approximately 90 degrees toward patient's left shoulder from a good PLAX window. Helps if you center MV on PLAX view first.

Probe location: Approximately left 4th intercostal space (where best PLAX view is obtained). Oftentimes, you will see **"fish mouth"** sign initially, which is the MV leading into the LV. Simply fan toward the apex of the heart to get the PSAX view picture below.

A. 

B. 

A: Should visualize right ventricle (RV), Left ventricle (LV), the papillary muscles (P) and the Interventricular septum (IVS). B: green arrow indicates probe marker towards left shoulder.

Evaluate LV squeeze and for any evidence of RV strain (**RV dilation**; **D sign** – see example in image gallery in back of book).

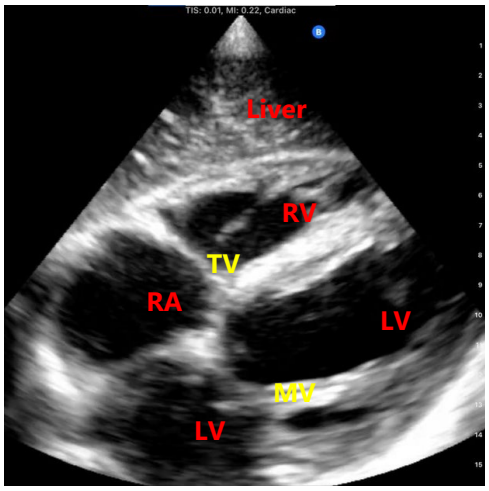
Subxiphoid (SubX)

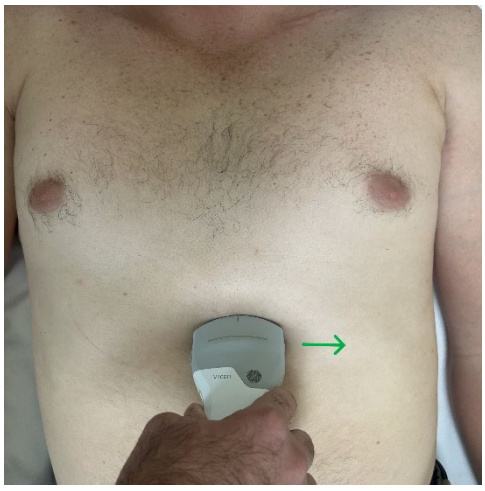
Probe marker: Pointing towards the patient's left.

Probe location: Position the probe beneath the xiphoid process. Liver is your window so will need to get a good look through the liver in order to get a good cardiac view.

Note: Since the plane of the heart is superficial, you need to use an **overhand grip** on the probe to navigate under intercostal space and fan anteriorly until adequate view is obtained.

Additionally, if liver and heart are too cephalad, can have patient **hold an inspiratory breath** to lower diaphragm and subsequently lower the liver and heart.

A. 

B. 

A: Should visualize right ventricle (RV), Left ventricle (LV), Left atrium (LA), Right atrium (RA), Aortic valve (AV), Mitral valve (MV), the interatrial septum (IAS), and the liver through which your window lies. B: Green arow represents probe marker pointing towards patient's left.

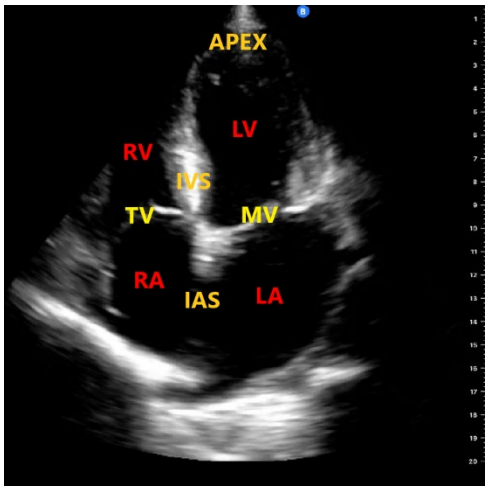
The liver is your window for this view and is therefore visualized at the top of the screen. **You MUST visulize liver prior to getting an adequate subX cardiac view.** Maneuvers such as having patient take in a deep breath can aid in achieving this goal.

Great view for evaluating for pericardial effusions and similar to PLAX/PSAX. Is very helpful when PLAX/ PSAX are difficult to obtain secondary to COPD, mechanical ventilation, etc.

Apical

Probe marker: Toward patient's left/ towards the bed. Can often follow LV from PSAX by sliding down towards the heart or find the point of maximal impulse and start there.

Probe location: Between fourth or fifth ICS, midclavicular line (have patient lie on left side to obtain better view).

A. 

B. 

A: Should visualize right ventricle (RV), Left ventricle (LV), Left atrium (LA), Right atrium (RA), Aortic valve (AV), Mitral valve (MV), the interatrial septum (IAS), and the Interventricular septum (IVS). B: Green arrow represents probe marker pointing towards the bed/ patient's left.

Can visualize many abnormalities from this view but very helpful in assessing R sided heart dysfunction and valvular abnormalities using doppler US. **McConnell's sign and RV dilation/ hypertrophy can indicate RV dysfunction.**

Epigastric

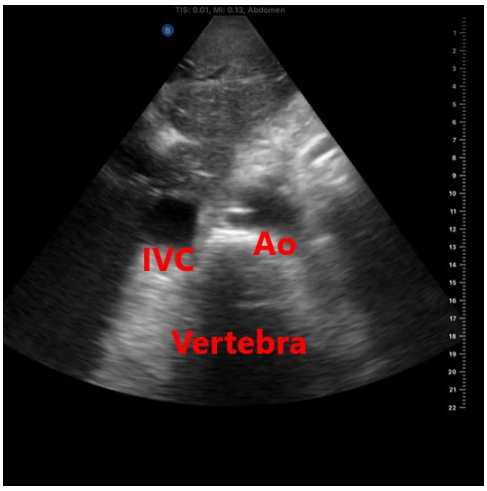
Probe: Phased-Array or Curvilinear

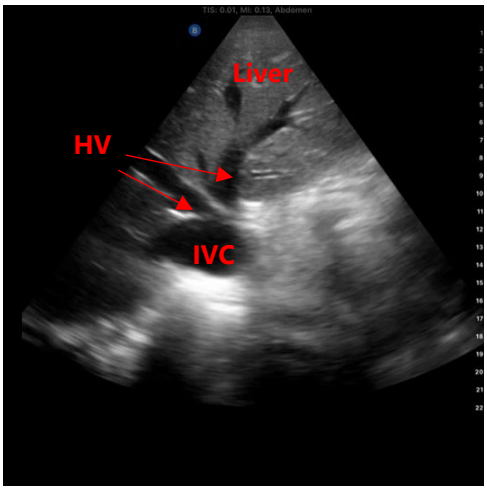
Preset: Cardiac or Abdominal (abdominal view is general convention, though some prefer cardiac convention. Know that the probe screen indicators change and therefore the probe marker side changes. When using bedside POCUS devices, it is often beneficial to use the cardiac preset because the frame rate and ability to capture the heart is less distorted when it enters the screen.

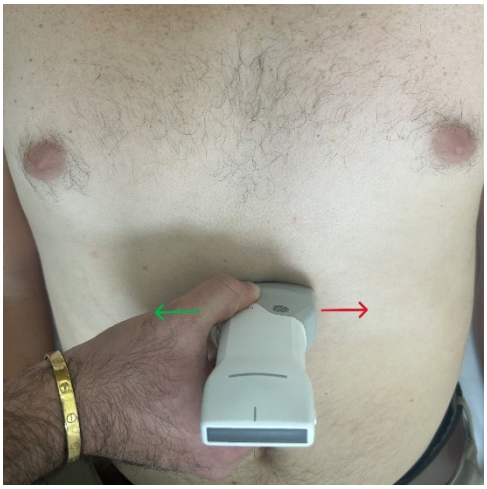
IVC/ Aorta Transverse View

Probe marker: Towards the patient's right if in abdominal preset, may need to reverse if using cardiac preset.

Probe location: Position the probe in the mid-epigastric region. Must visualize the liver well to best visualize the vasculature.

A. 

B. 

C. 

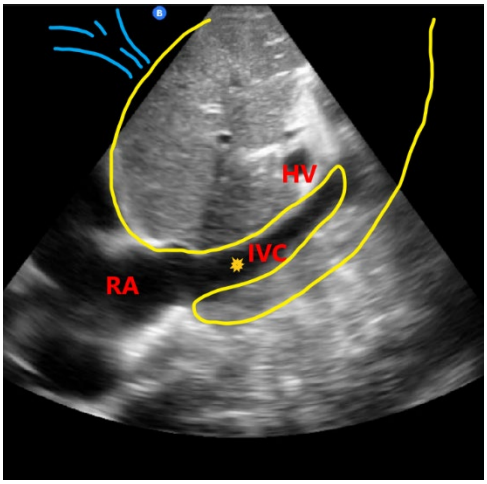
A: Should visualize inferior vena cava (IVC), aorta (Ao), and vertebrae. The Vertebrae should be the deepest structure on your screen and is oftentimes the easiest to visualize initially. B: Demonstrates following the IVC towards the heart and watching hepatic veins (HV) communicate into the IVC. C: Green arrow represent probe marker in traditional abdominal preset. Red arrow represents probe marker if in cardiac preset.

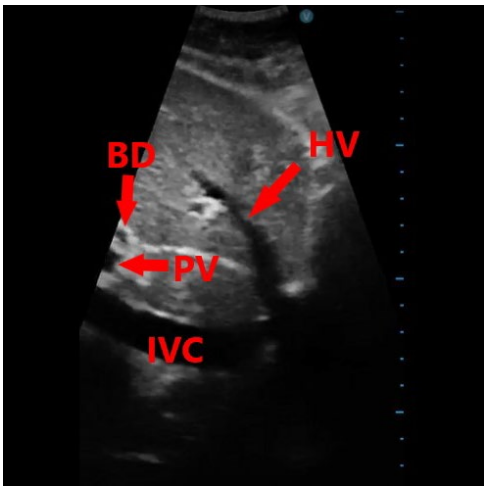
Window is the liver, a good image cannot be obtained without first getting a good window through patient's liver. Oftentimes, may be competing with bowel gas or gastric bubble. Can reposition probe or have patient hold on inspiration to improve window.

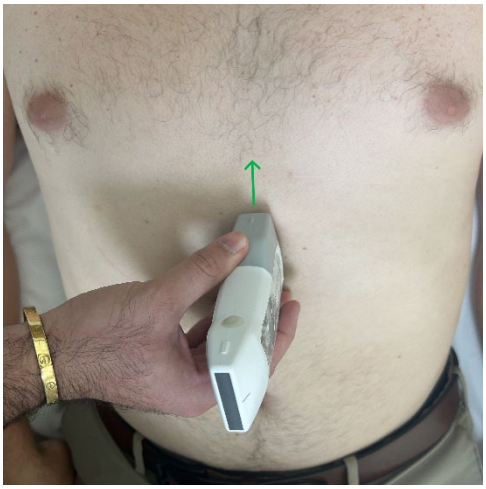
IVC Longitudinal View

Probe marker: Towards the patient's head. Keeping the right atrium in view, fan the probe to the right to locate the largest diameter of the IVC. Measurement of the IVC should be 2-3cm from the RA-IVC junction.

Probe location: Position the probe beneath the xiphoid process.

A. 

B. 

C. 

A: Happy whale sign. A/ B: Should visualize the right atrium (RA), inferior vena cava (IVC), hepatic veins/ portal veins (HV/ PV), bile duct (BD). Measurement (burst) of IVC should be performed approximately 2 cm from cavoatrial junction. C: Green arrow represents probe marker pointing cephalad in longitudinal view.

Identify the IVC (vs. aorta) by watching it drain into the right atrium, visualizing hepatic veins drain into the IVC, and fanning to patient's left to visualize the aorta separately. This epigastric view is often referred to as the "Happy Whale Sign." See depiction above. Sometimes, IVC can appear to be pulsatile secondary to referred pulsations from heart and/ or Ao so do not rely on pulsations alone to delineate from aorta.

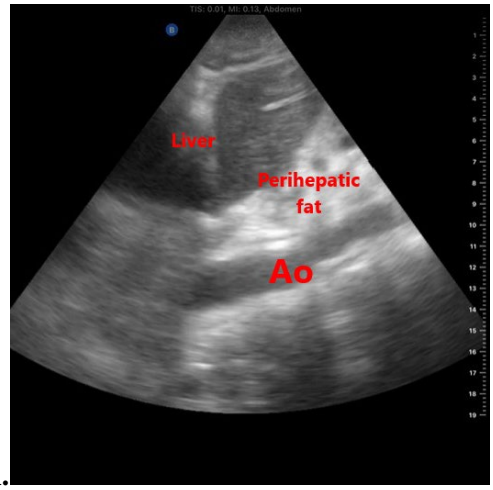
IVC diameter	IVC collapse (%)	CVP (mmHg)
<2.1	**>50**	**0-5**
<2.1	<50	5-10
>2.1	>50	5-10
>2.1	**<50**	**10-20**

Chart above is basic generalization of IVC findings correlated with CVP, though this is helpful, know that it is not a hard rule and there can be significant variation between findings and true CVP. Must use in clinical context.

Aorta Longitudinal View

Probe marker: Obtain your transverse view, rotate your probe 90˚ clockwise, with the indicator towards the patient's head.

Probe location: Place your probe below the xiphoid process, slightly left of midline to the patient. Fan to the patient's left side from looking at longitudinal IVC. See image C above.

A. 

A: Should visualize liver, perihepatic fat (oftentimes, though sometimes absent in smaller patients), and aorta (Ao).

Anterior Lung

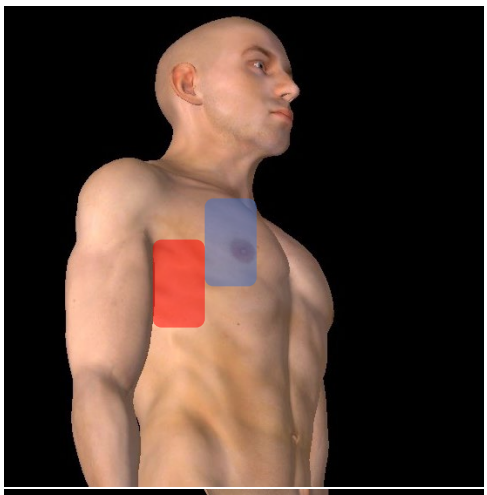
Probe: Phased array, linear for lung sliding

Preset: Lung

Probe marker: Cephalad

Probe location: Assess each of 6 zones pictured below (3 per hemithorax). Can increase from 6- point lung US to 12- point lung US by visualizing two intercostal spaces in each zone. General convention is to have probe longitudinal and span two separate rib spaces.

A.



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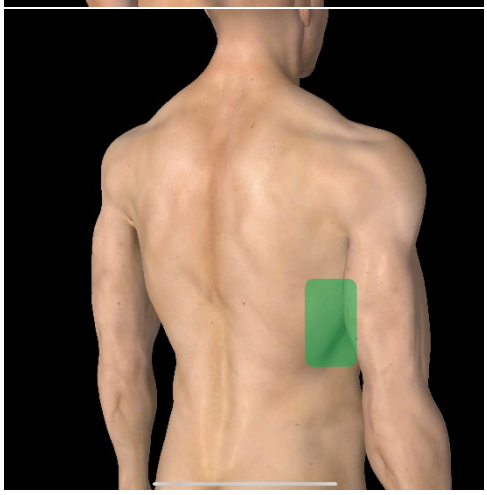

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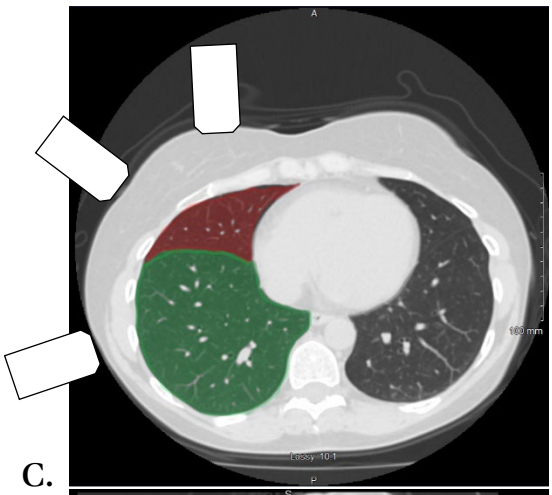

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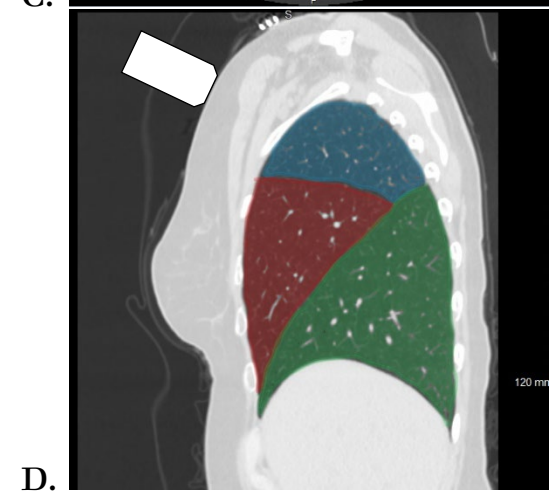

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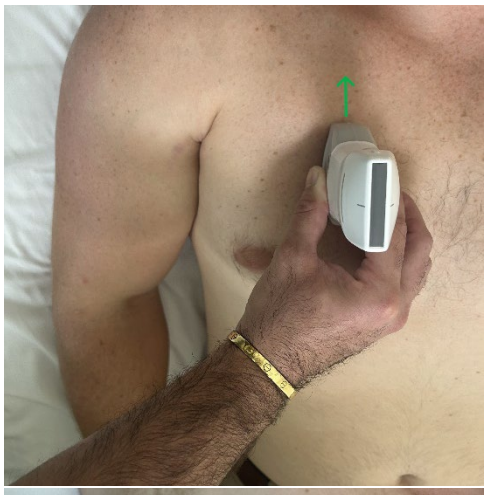

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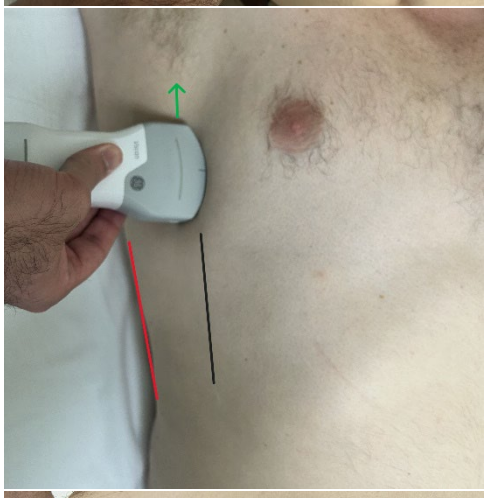
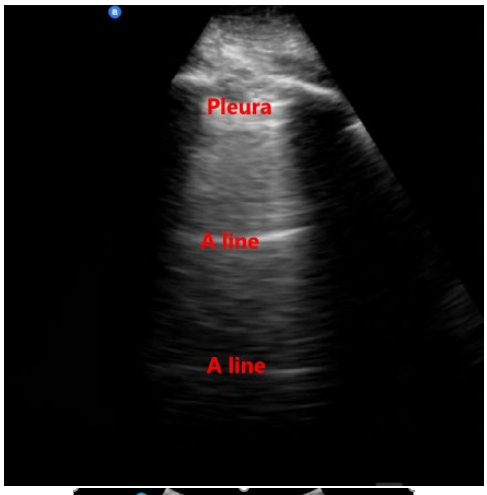
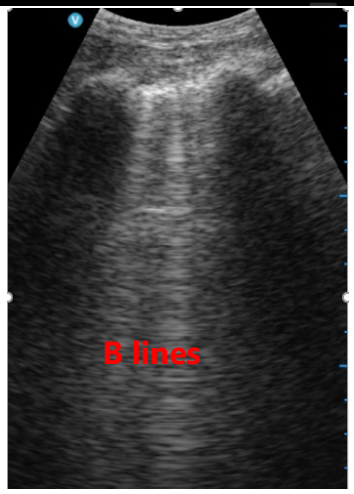


G.

H.



I.



A/B/C/D: 3 lung zones on hemithorax that, if performed bilaterally, create a 6 zone lung US exam. Each zone should be scan at multiple points. The zones will cover all three lung lobes as indicated by the accompanying CT scans. E. Anterior lung ultrasound, green arrow represents probe marker pointing cephalad. F. Zone 2 of lung US over anterior axillary line

(black line). Green arrow represents probe marker pointing cephalad. Red line is posterior axillary line. G. PLAPS point, green arrow represents probe marker pointing cephalad. H. Should visualize pleural lining and A lines. Keep in mind, must be perpendicular to lung tissue and this is often not the same as being perpendicular to chest wall. I. B lines if present (requires three or more B lines for positive result).

Evaluate for lung sliding, AKA "ants on a log." Presence of lung sliding can approach **100% sensitivity** for absence of pneumothorax and presence of **lung point** is **100% specific** for presence of pneumothorax.

6 zone approach is validated in literature and used in simplified BLUE protocol.

PLAPS (posterolateral alveolar and/or pleural syndrome) point is often your highest yield view. Demonstrated below and for our purposes, more often visualized in RUQ/LUQ views:

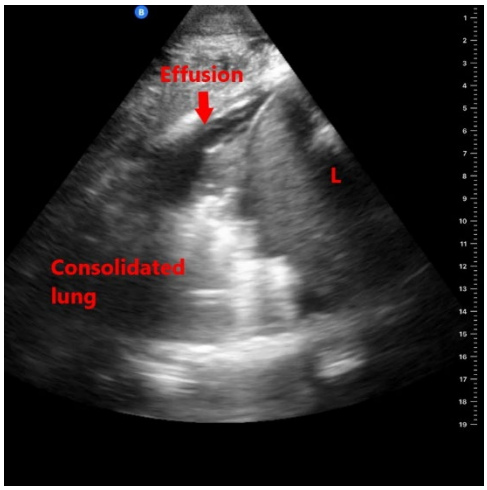


Image above is PLAPS point with consolidated lung and air bronchograms. Liver (L) noted on right side of screen.

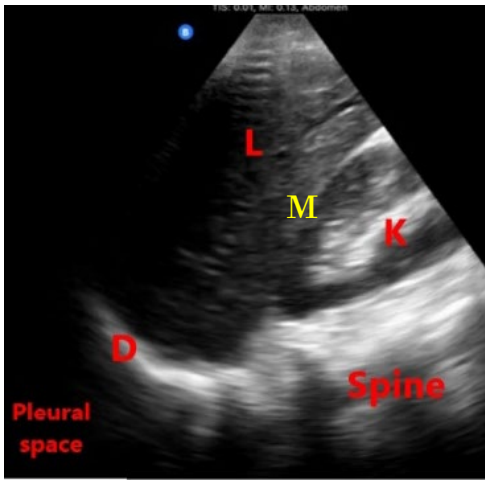
RUQ

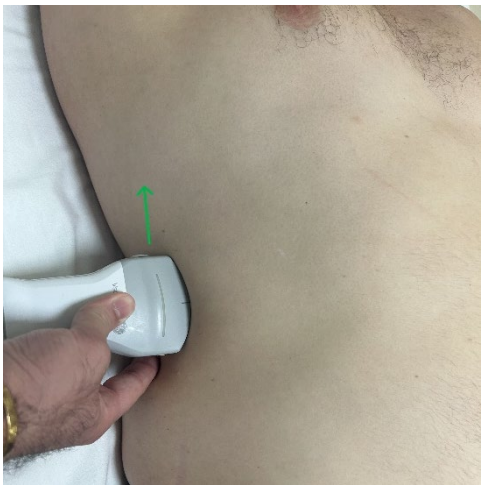
Probe: Curvilinear (preferred), Phased-Array

Preset: Abdomen

Probe marker: Cephalad for longitudinal view, posteriorly for transverse view (to better assess the right kidney cross section)

Probe location: On the patient's right in the mid-axillary line at the 10th and 11th intercostal space.

A. 

B. 

A: Should visualize liver (L), kidney (K), diaphragm (D), pleural space, and spine in RUQ "home screen." B: Probe location with green arrow representing probe marker pointing cephalad.

Potential space between liver and kidney is **Morrison's pouch (M)** and is the location that fluid is most likely to accumulate in this view.

Gallbladder

Probe: Curvilinear, Phased-Array

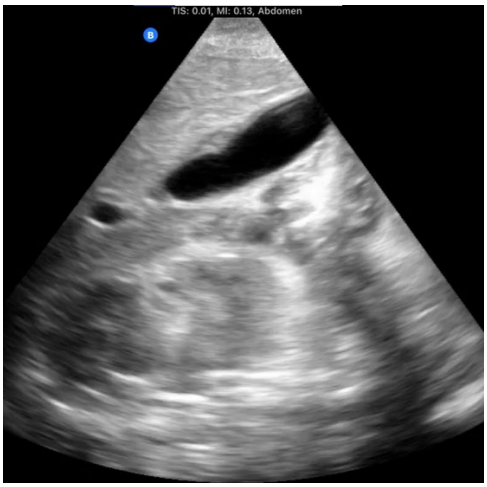
Preset: Abdomen

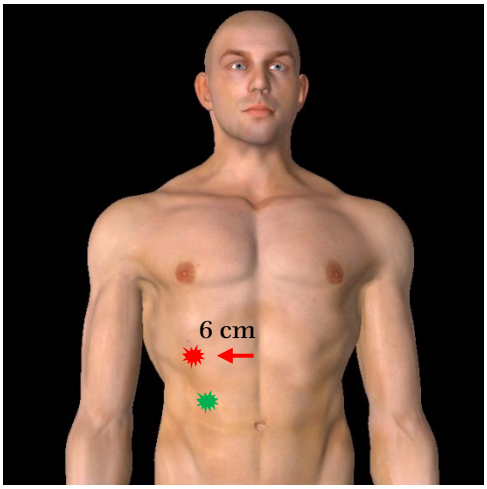
Probe marker: Start with probe marker towards patient' right side

Probe location: Can vary. Estimate approximately 6 cm left of subX and place probe in this area in intercostal space. Alternatives include the subcostal sweep, placing probe

midclavicularly underneth costal margin and fanning/sliding acros RUQ until GB comes into view. OR viewing the GB by finding your RUQ home screen and fanning anteriorly.

Find hypoechoic structure and slowly rotate and adjust image to achieve exclamation point sign pictured below.

A. 

B. 

A: "Exclamation point sign." Gallbladder is line and the point is the portal vein. Often, you can see a "Mickey Mouse" sign at the point. The two additional, smaller, circles that can arise around the portal vein include the common bile duct and hepatic artery (these three vessels make up the portal triad). B: Two options for initiating view (not including RUQ home screen alternative). Start by placing probe approximately 6 cm to patients right xiphoid in the intercostal space (red burst). My preferred location is subcostal, mid axillary line as a starting point (green burst). From here, using you 4 cardinal probe maneuvers to image and elongate the GB (subcostal sweep).

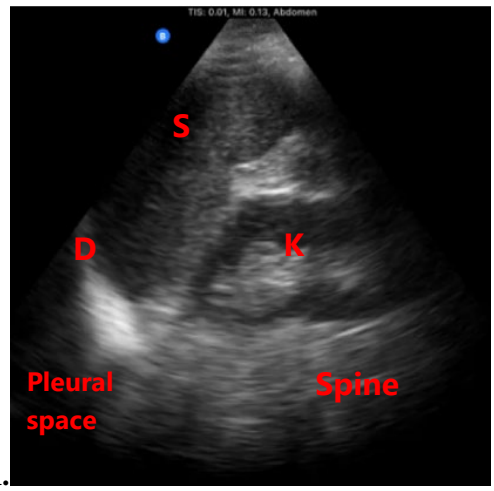
LUQ

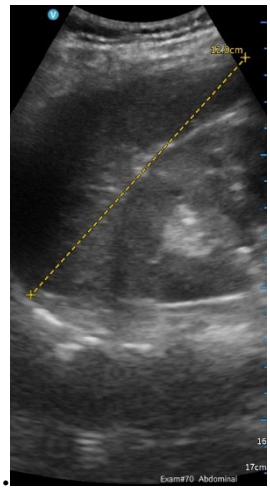
Probe: Curvilinear, Phased-Array

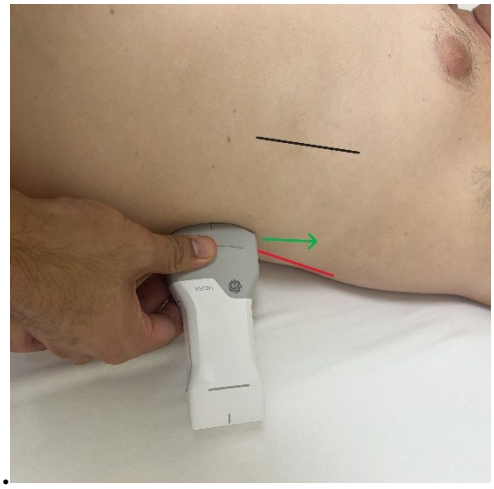
Preset: Abdomen

Probe marker: Cephalad for longitudinal view, anteriorly for transverse view (to better assess the left kidney)

Probe location: Anchor your probe in the posterior axillary line around the 8th – 10th intercostal space

A. 

B. 

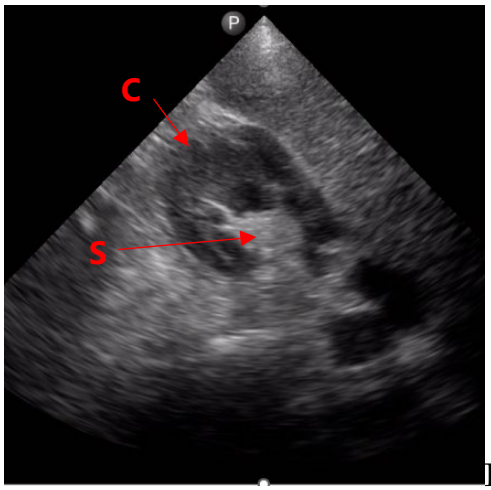
C. 

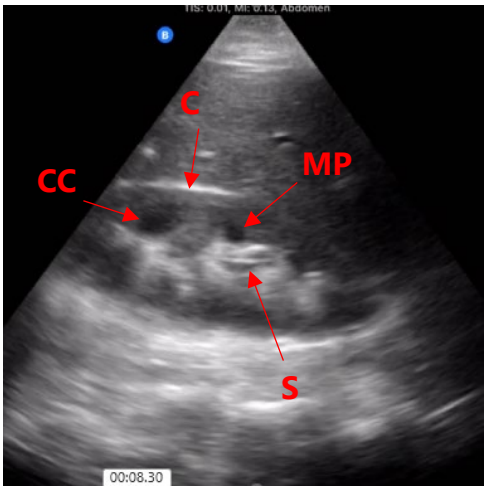
A: Visualize the spleen (S), kidney (K), diaphragm (D), pleural space, and spine. B: Measurement of the spleen craniocaudally. Should be < 12 -14 cm. C: Probe placement with green arrow representing probe marker pointing cephalad.

Fluid is most likely to accumulate in the potential space between the spleen and the diaphragm.

Kidneys

Preset, probe marker and probe location similar to the RUQ and LUQ windows.

A. 

B. 

A/B: Should visualize the cortex (C), sinus (S), medullary pyramids (MP), and note cortical cyst (CC) when present as well.

Renal sinus is hyperechoic secondary to fatty content.

Suprapubic

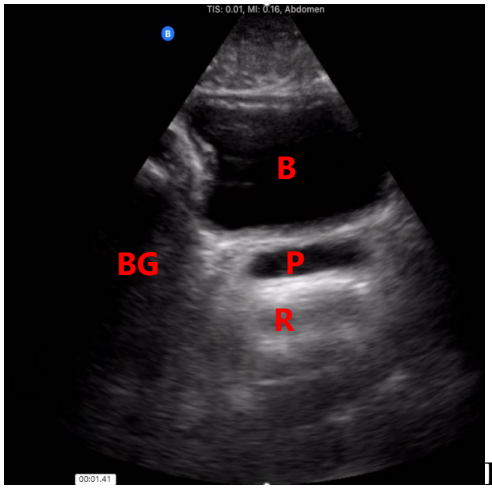
Probe: Curvilinear (Phased-Array)

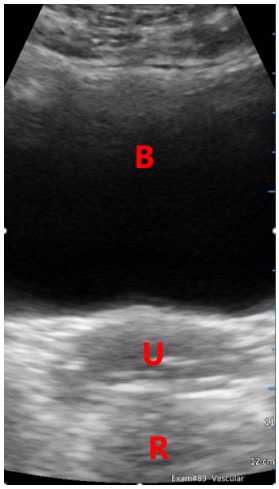
Preset: Abdomen

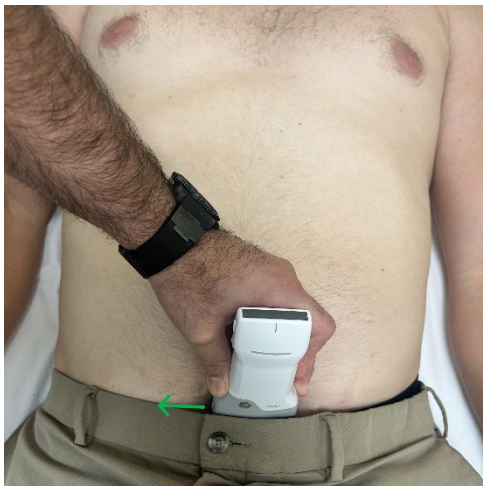
Probe marker: Cephalad for long-axis (longitudinal plane); patient's right for short-axis (transverse plane)

Probe location: Above pubic symphysis

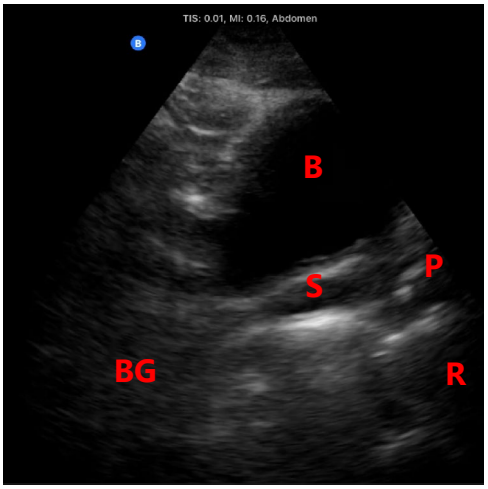
Transverse

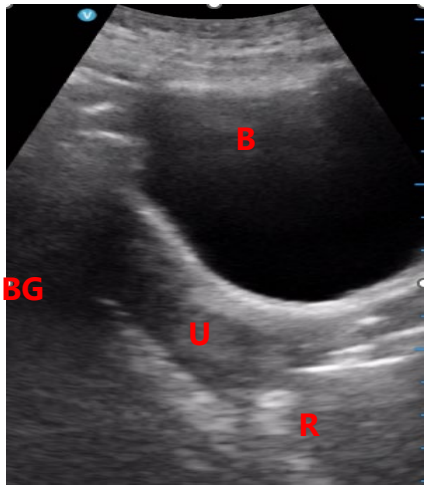
A. 

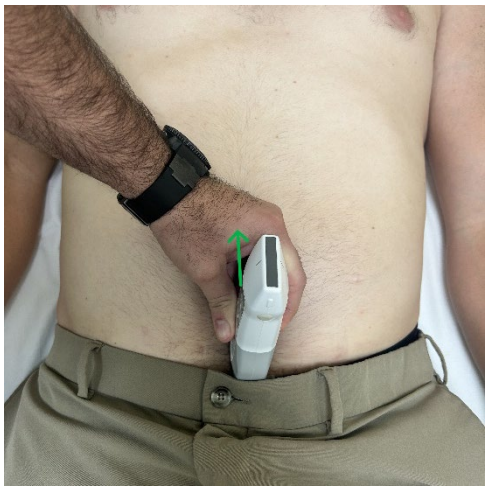
B. 

C. 

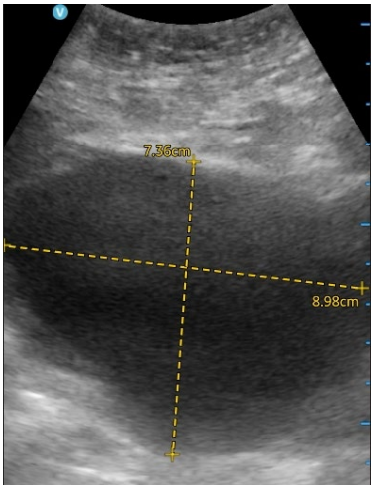
Longitudinal

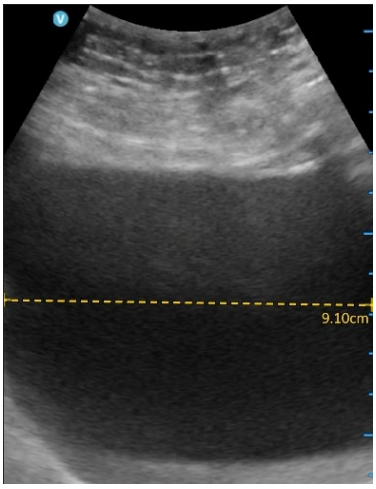
D. 

E. 

F. 

A/B/D/E: Visualize the hypoechoic bladder (B), uterus (U)/ prostate (P), rectum (R), bowel gas (BG), and sometimes the seminal vesicles in males (S). C: Demonstrates probe orientation with green arrow representing probe marker pointing towards patient's right. F: Demonstrates probe orientation with green arrow representing probe marker pointing cephalad.



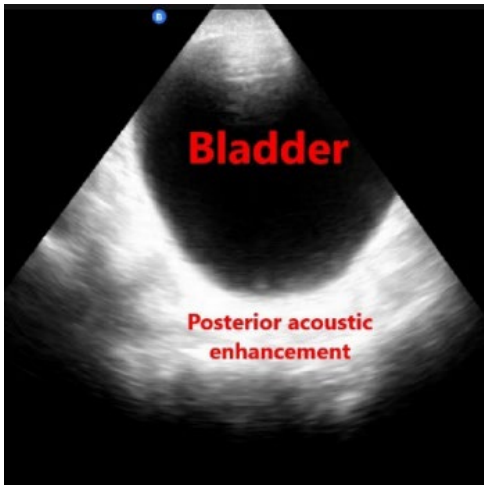


Bladder volume: (L x W x H) x 0.72 (mult. factor is variable; 0.5 – 0.8)

Fluid is most likely to accumulate posterior to the bladder in males and posterior to the uterus in females

Artifact to be considered below is posterior acoustic enhancement. It may affect any pathology behind the bladder and can be improved on some machines by adjusting "far field"

gain Aids in differentiating fluid filled structures such as cysts or abscesses from other similar appearing massess that will have no posterior acoustic enhancement.:



Musckuloskeletal

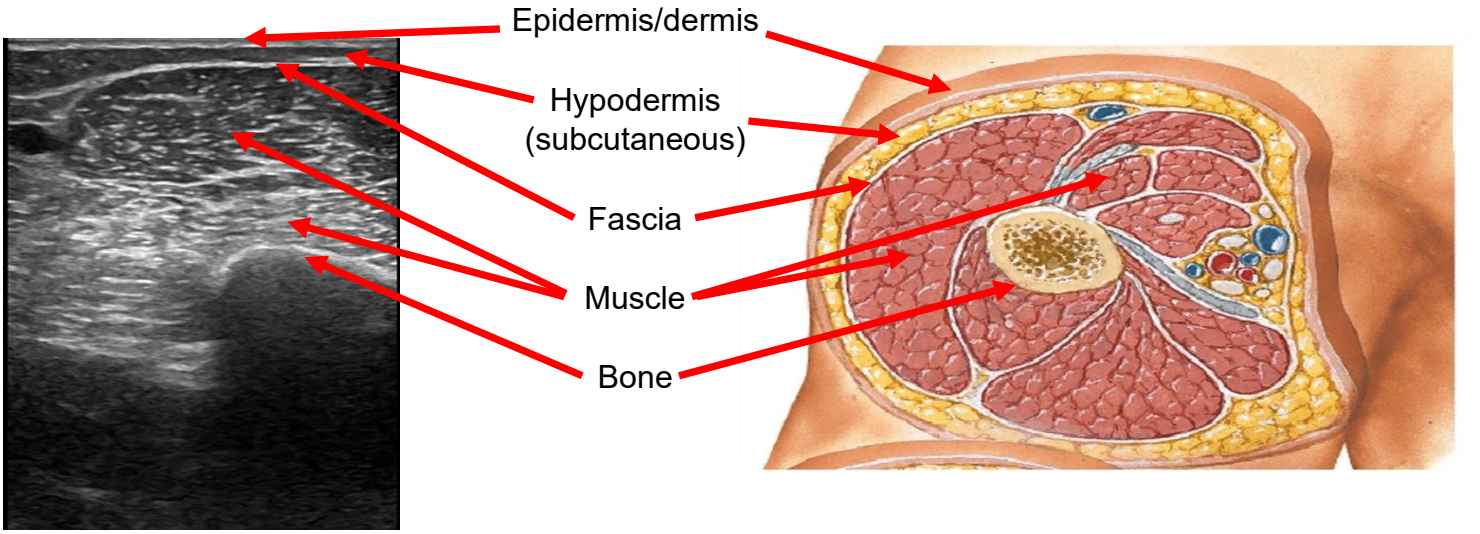
Probe: Linear

Preset: MSK/ soft tissue

Probe marker: Follows orientation of screen. Can vary depending on positioning of patient, physician, and US unit. Do what makes sense.

Probe location: Dependent on anatomy being scanned

Anisotropy: Tendons and ligaments witll appear hyperechoic when viewed perpendicularly, Obliquely they appear hypoechoic or anechoic.



Shoulder

Using the ASAP protocol (https://www.pocus101.com/shoulder-ultrasound-made-easy-step-by-step-guide/)

Anterior:

Technique: Probe placed transversely over biceps groove

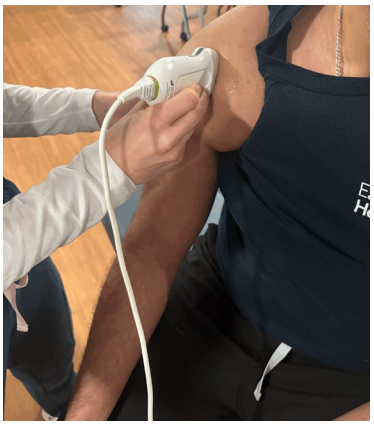
Key Structures: Biceps tendon, humeral head, deltoid

Purpose: Assess biceps tendon for tendonitis, rupture, or dislocation

Position: Seated with arm in external rotation

Short axis

Long axis



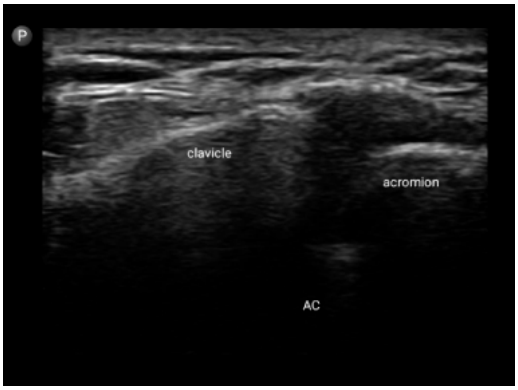
<u>Superior:</u>

Technique: Probe placed directly over AC joint

Key Structures: Acromion, Clavicle, AC joint

Purpose: Assess AC joint for arthritis/ dislocation

Position: Seated with arm relaxed at the side



Anterolateral:

Technique: Elbow flexed at 90 degress, palm up resting on ipsilateral thigh

Key Structures: Supraspinatus tendon, greater tuberosity

Purpose: Detect rotator cuff teear, tendinosis, tendonitis

Position: Seated with arm behind back or resting in lap

Posterior:

Technique: Probe positioned posteriorly

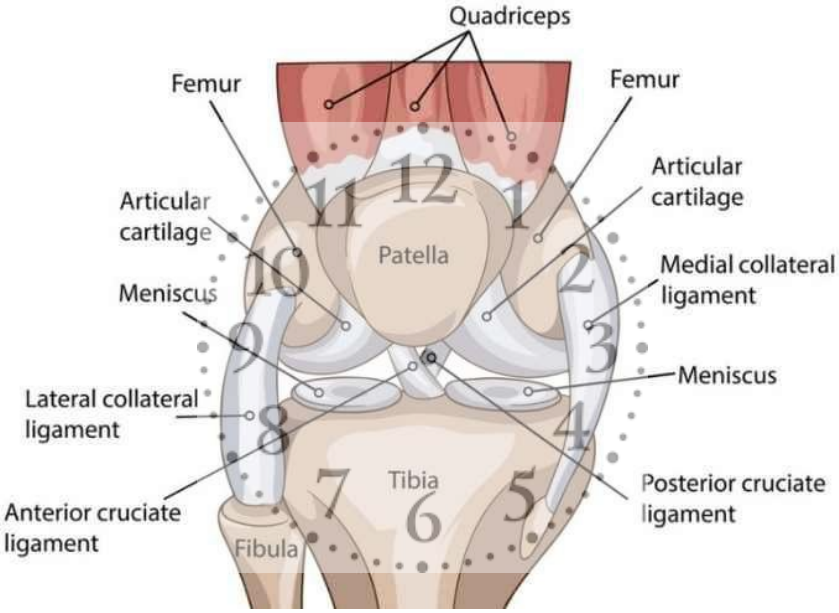
Key Structures: Glenohumeral joint and posterior labrum

Purpose: Evaluate for joint effusion, procedrual intervention such as injection/ aspiration

Position: Seated with arm crossed over chest or slightly flexed

Knee

Anatomy



Suprapatellar (12 o'clock)

Technique: Probe placed with caudal end placed over patella and probe marker cephalad

Key Structures: Patella, suprapatellar tendon, femur

Purpose: Evaluate the distal quad tendon and suprapatellar recess for effusion

Position: Supine or seated with knee slightly bent

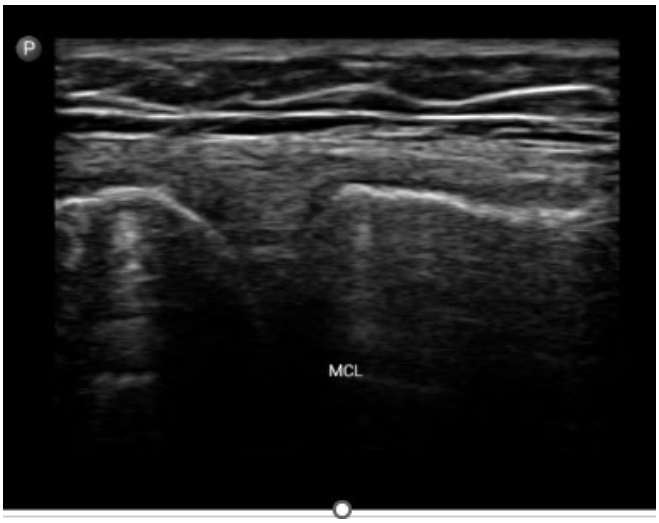
<u>Medial (3 o'clock)</u>

Technique: Probe placed on medial aspect of knee with probe marker cephalad

Key Structures: MCL, medial meniscus

Purpose: Evaluate medial collateral ligament and menisci

Position: Supine or seated with knee slightly bent



<u>Infrapatellar (6 o'clock)</u>

Technique: Probe placed with cranial end placed over patella and probe marker cephalad

Key Structures: Patellar ligament, infrapatellar bursa

Purpose: Evaluate for infrapatellar bursitis and enthesitis of the patellar ligament

Position: Supine or seated with knee slightly bent

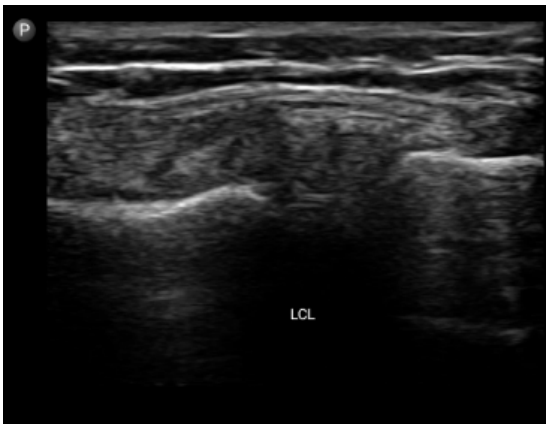
Lateral (9 o'clock)

Technique: Probe placed on lateral aspect of knee with probe marker cephalad

Key Structures: LCL, lateral meniscus

Purpose: Evaluate lateral collateral ligament and menisci

Position: Supine or seated with knee slightly bent



Deep venous thrombosis

Probe: Linear/ Curivlinear or phased array may be necessary if obese

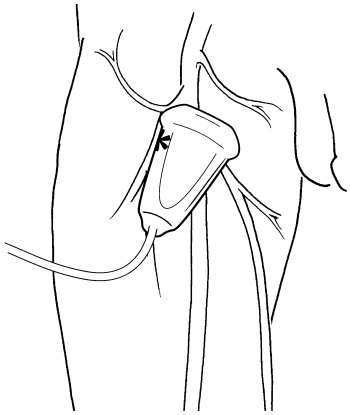
Preset: Vascular/ MSK/ soft tissue

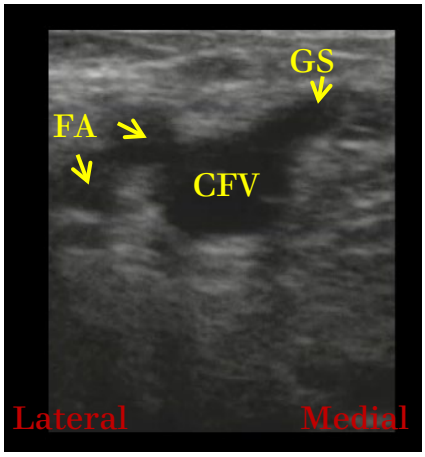
Probe marker: Probe marker to patients right or cephalad

Probe location: Dependent on anatomy being scanned, discussed further below.

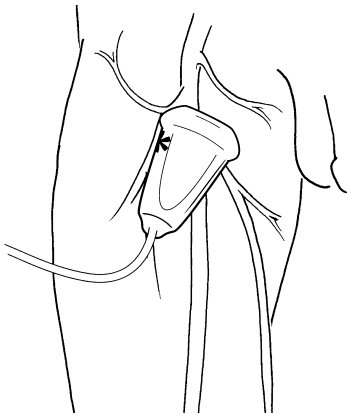
3 point DVT examination:

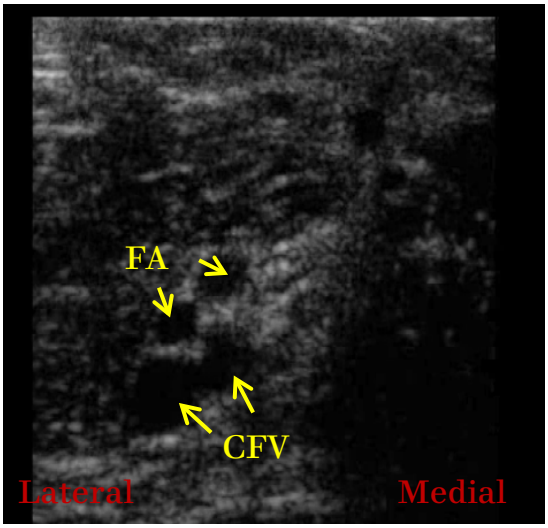
Common femoral vein (CFV) (visualizing greater sphenous vein projecting medially; GS); Other pictured, femoral artery (FA):



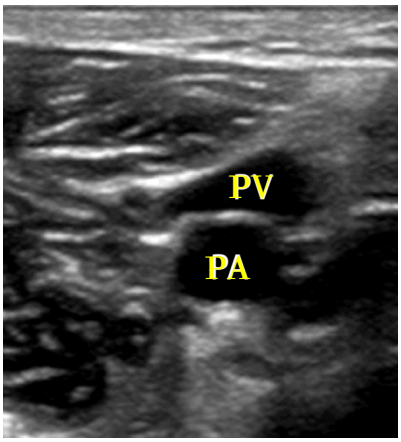


Femoral vein (FV) (visualizing bifurcation); other picture, femoral artery (FA):





Popliteal Vein (PV): other pictured, popliteal artery (PA):



Selected Protocolsa and Algorithms

Blue Protocol

Bedside Lung Ultrasound in Emergency is used used to quickly diagnose causes of acute respiratory failure in emergency settings.

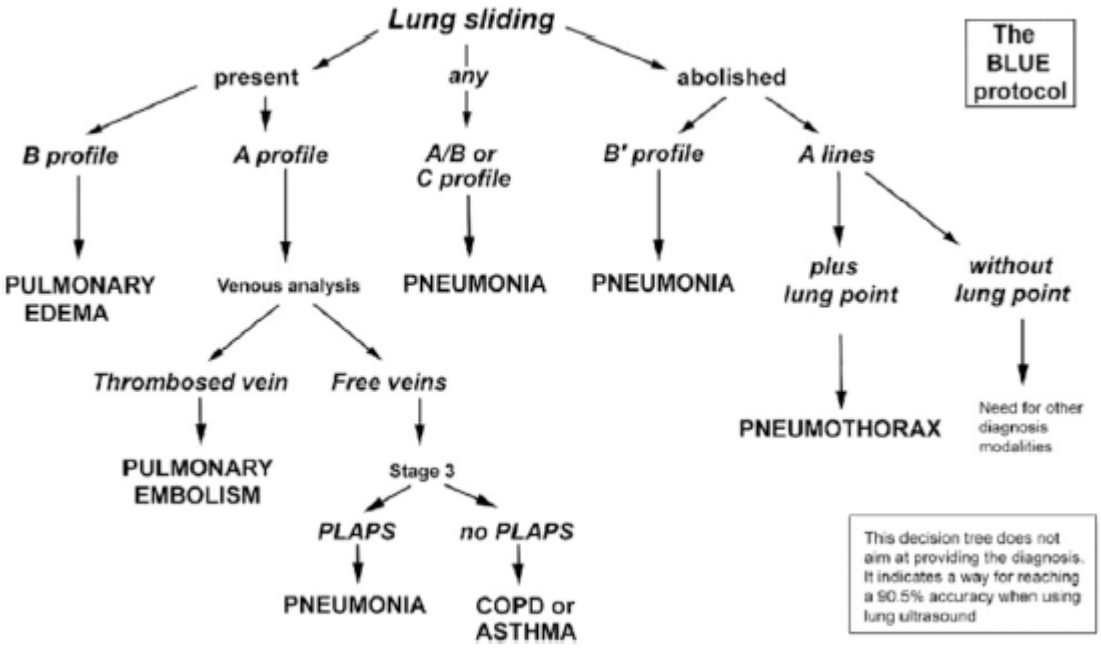
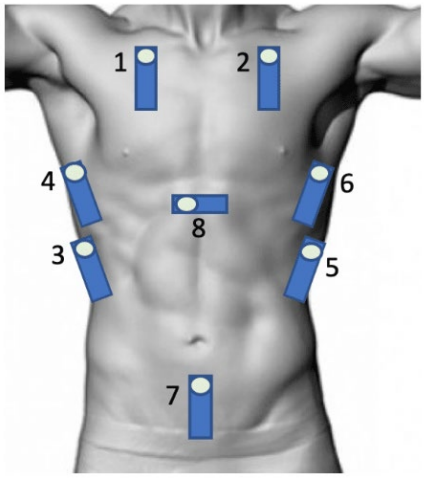


FIGURE 7. A decision tree utilizing lung ultrasonography to guide diagnosis of severe dyspnea.

Lichtenstein, D.A. and Meziere, G.A. (2008) **Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure: The BLUE Protocol**. Chest, 134, 117-125

eFAST

The Extended Focused Assessment with Sonography in Trauma is used to identify sequelae of injury in trauma patients, particularly those with penetrating or blunt injuries to chest or abdomen. The eFAST adds anterior lung views to traditional FAST exam.



https://litfl.com/pocus-made-easy-efast/

RUSH(ed)

The Rapid Ultrasound for Shock and Hypotension protocol (including the addition of ectopic and DVT evaluation) is a rapid assessment of indivduals with shock or hypotension to evaluate the cause of their presentation. Used in emergency and critical care settings.

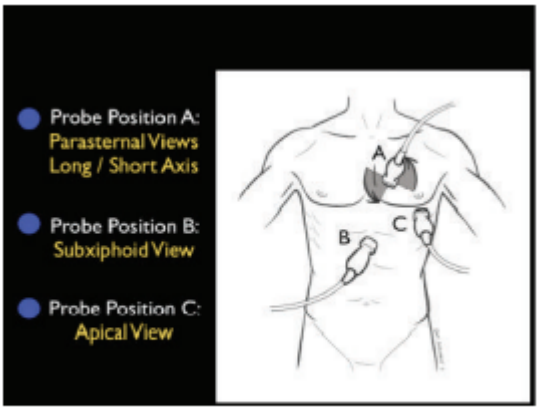


FIGURE 1: The RUSH exam. Step 1: Evaluation of "the pump".

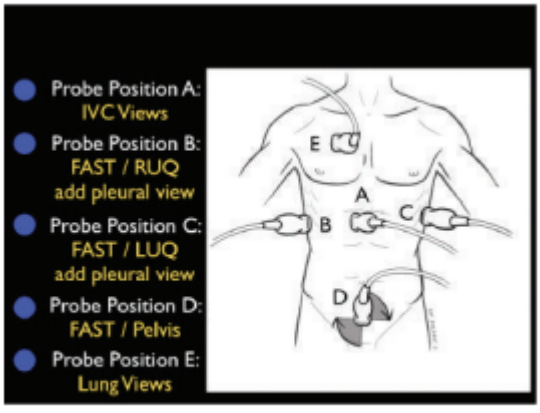


FIGURE 12: The RUSH exam. Step 2: Evaluation of "the tank".

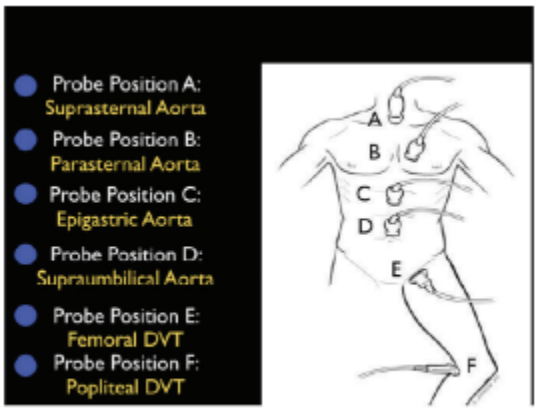


FIGURE 23: The RUSH exam. Step 3: Evaluation of "the pipes".

TABLE 1: RUSH protocol summary.

RUSH exam	Hypovolemic shock	Cardiogenic shock	Obstructive shock	Distributive shock
Pump	Hypercontractile heart Small heart size	Hypocontractile heart Dilated heart size	Pericardial effusion, RV strain Hypercontractile heart	Hypercontractile heart (early sepsis) Hypocontractile heart (late sepsis)
Tank	Flat IVC Flat IJV Peritoneal fluid Pleural fluid	Distended IVC Distended IJV Lung rockets Pleural effusions, ascites	Distended IVC Distended IJV Absent lung sliding (PTX)	Normal/small IVC Normal/small IJV Pleural fluid (empyema) Peritoneal fluid (peritonitis)
Pipes	AAA Aortic dissection	Normal	DVT	Normal

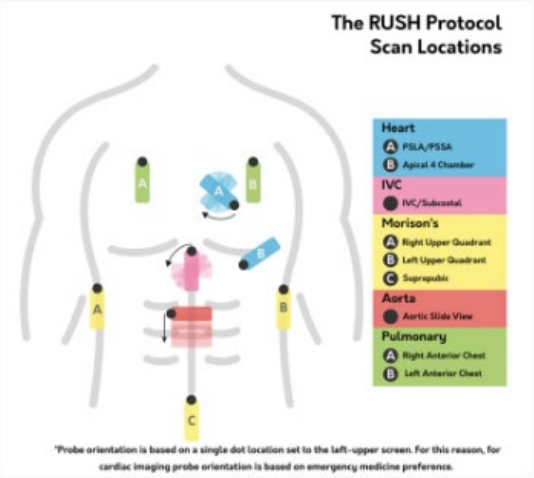
TABLE 2: Using the RUSH protocol to diagnose the type of shock.

	Step no. 1	Step no. 2	Step no. 3
Pump	Pericardial effusion: (a) Effusion present? (b) Signs of tamponade? Diastolic collapse of R Vent +/− R Atrium?	Left ventricular contractility: (a) Hyperdynamic? (b) Normal? (c) Decreased?	Right ventricular strain: (a) Increased size of RV? (b) Septal displacement from right to left?
Tank	Tank volume: (1) Inferior vena cava: (a) Large size/small Insp collapse? —CVP high— (b) Small size/large Insp collapse? —CVP Low— (2) Internal jugular veins: (a) Small or large?	Tank leakiness: (1) E-FAST exam: (a) Free fluid Abd/Pelvis? (b) Free fluid thoracic cavity? (2) Pulm edema: Lung rockets?	Tank compromise: Tension pneumothorax? (a) Absent lung sliding? (b) Absent comet tails?
Pipes	Abdominal aorta aneurysm: Abd aorta > 3 cm?	Thoracic aorta aneurysm/dissection: (a) Aortic root > 3.8 cm? (b) Intimal flap? (c) Thor aorta > 5 cm?	(1) Femoral vein DVT? Noncompressible vessel? (2) Popliteal vein DVT? Noncompressible vessel?

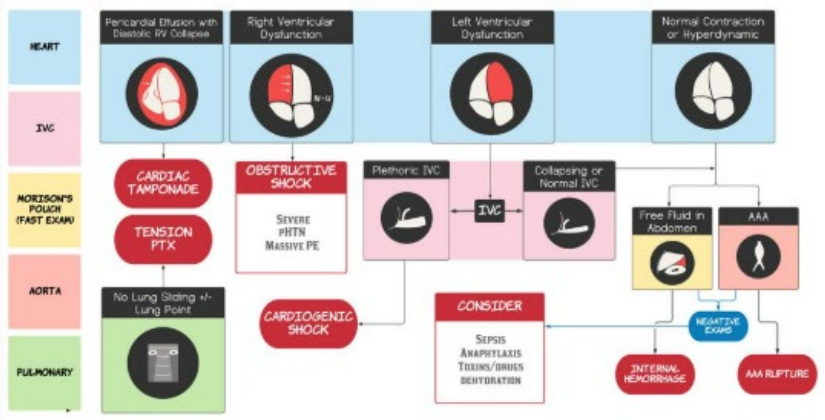
Seif D, Perera P, Mailhot T, Riley D, Mandavia D. Bedside ultrasound in resuscitation and the rapid ultrasound in shock protocol. Crit Care Res Pract. 2012;2012:503254. doi: 10.1155/2012/503254.

Original RUSH article: https://emcrit.org/rush-exam/original-rush-article/

Can be remebered with the mnemonic HIMAP(ed). The (ed) not included in many resources but has been incorporated as ectopic pregnancy and DVT evaluation.



Scanning Locations and Probe Orientation for the RUSH Exam



Algorithmic Approach to Utilizing the RUSH Exam

https://www.thepocusatlas.com/shock

Procedural Survivial Guide

Review of primary internal medicine procedures

EAMC procedural requirements:

CVL	10
Arterial line	5
Thoracentesis	5
Paracentesis	5
Lumbar puncture	3
Pelvic exam (two with pap smear)	5

CVL

Comparison of CVLS by insertion site			
	Anatomic location	Advantages	Disadvantages
IJ	Located at triangle formed by sternocleidomastoid heads and clavicle. Carotid artery is medial to vein.	Good insertion landmarks, redeuced learniing curved comparatively. Lower risk of pneumo than SC and lower risk of infection than femoral Easy to compress bleeding vessels.	Uncomfortable for the patient Higher risk of infection than subclavian line
Subclavian/ axillary	Subclavian: Begins as axillary vein travels under clavicle. Subclavian artery is above and behind the vein. Axillary: from approximately the deltopectoral groove to where it becomes SC vein under clavicle.	Lowest infection rate. Highest patient satisfaction Axillary: can be accessed with US. Lower rates of complications than SC. Can compress bleeding vessels	Subclavian: difficult to access with US. Higher rates of pneuothorax. Difficult to compress bleeding vessels Axillary: Steeper learning curve.

Femoral line	Inferior to inguinal ligament. Remember NAVEL as inguinal vascular antomy from lateral to midline.	Easy access during ACLS. Good insertion landmarks. Easy to compress bleeding vessels	Highest infection rate Highest risk of thrombosis

Procedure

This is assuming you have evaluated both the patient and situation for need of access and the ideal access site and line.

Internal Jugular vein

1. Obtain informed consent
2. Place patient in trendelenburg and have patient turn head app 45 degrees to contralateral side of vessel being accessed.
3. Don PPE
4. Cleanse the site and drape with sterile field
5. Flush catheter and apply one way caps to ports that are not the distal port. Once flushed, simply clamp distal port (will nee to be opened for guidewire later in procedure.
6. ID apex of triangle formed by the two SCM heads and the clavicle. Use US to eval and determine best site for venipuncture considereing surrounding structures, primarily location of carotid artery.
7. Using introducer needle and syringe, bevel up and at an angle of 30-45 degrees to the plane of the patient, direct your approach toward the ipsilateral nipple and ID your vein with the US probe.
8. Carefully insert your needle and through the needling technique, follow your tip all the way into the vein. BE sure to apply negative pressure on your syringe continuously as you insert.
9. If concerned for arterial puncture, remove needle and apply pressure to the site for 10-15 minutes. NEVER dilate if concerned for arterial puncture. Can consider ABG or vessel transduction if unsure.
10. Once venous blood obtained, lower the angle of your needle, can follow needle tip for 4-5 mm further. Remove syringe or use the Raulerson syringe for following steps. If syringe removed, be sure to cover needle with finger so as not to introduce air.

11. Gently pass guidewire through needle or syringe approximately 20 cm or 30 cm respectively. NEVER let go of the wire. Additional 10 cm to account for distance of syringe. No resistance should be met, if meeting resistance can reassess with US probe. Can remove wire and reassess needle location. If meeting resistance while attempting to withdraw wire. DO NOT pull on wire further as this could result in fracturing of the wire. Instead, remove needle and wire and restart the procedure.
12. Remove the introducer needle over the guidewire being sure to never let go of the guidewire.
13. Nick the skin with scalpel.
14. Thread dilator onto the guidewire WITH ONE HAND ALWAYS ON THE GUIDEWIRE. Push dilator into tissue, may needle slight rotating motion. Rember this a TISSUE dilator, **not** a VESSEL dilator. You DO NOT need to access the vessel with the dilator.
15. Remove dilator and thread catheter over wire, once again DO NOT let go of wire. May require removing guidewire at distal end until tip is protruding from the catheter access port.
16. Generally, distance of catheter insertion is **16 cm for RIJ and 20 cm for LIJ**.
17. Once catheter inserted, remove guidewire.
18. Withdraw venous blood from all ports and flush.
19. Apply occlusive dressing.
20. Obtain stat CXR to confirm placement and rule out complications (pneumothorax) prior to usage.
21. Write a procedure note and record performed procedfdure in new innovations, whether or not you were successful.

Axillary vein (this will be a modified SC vein access because we will use US and SC not likely to be the visualized access point under US guidance)

1. Obtain informed consent
2. Place patient in trendellenburg position. Can place a towel roll between the scapulae and allow ipsilateral shoulder to fall backwards. Turn patients head to contralateral side.
3. Follow steps 3,4, and 5 from above instruction.
4. Visualize the axillary vein with US in either the in-plane or out-of-plane approach/ Will discuss as the the out-of-plane approach is being used.
5. Once site of access has been determined anesthetize the skin under US visualization.
6. Follow steps 8-21 from IJ instruction. **Catheter depth of insertion approximately 20 cm for most axillary lines.**

7. If resistance is met with wire insertion, consider that the wire has traversed upward into the IJ. Remove wire, reconfrim needle placement, turn the patient's head slightly toward you and attempt once more.

Femoral vein

1. Obtain informed consent
2. Patient should be positioned in supine position with the ipsilateral thigh slightly adbucted and externally rotated.
3. Follow steps 3,4, and 5 from IJ instruction.
4. Remember the NAVEL mnemonic (from lateral to medial: Nerve, Artery, Vein, Empty space, Lymphatics) and find the location of the common femoral vein utlizing US guidance. Start just inferior to inguinal ligament.
5. Once site of access has been determined anesthetize the skin under US visualization.
6. Follow steps 8-21 from IJ instruction. **Catheter depth of insertion approximately 20 - 25 cm for most femoral venous catheters.**

Arterial Line

Procedure

Arterial

1. Obtain informed consent
2. BE sure transducer and monitor are prepared by your nursing staff before beginning.
3. Procedure will vary based upon kit used, will discuss from here as though standard seldinger technique is being performed. With addition of introducer cather as most of our seldinger kits are equipped with an introducer catheter. **Catheter length 2-7.5 cm.**
4. Perform the Allen's test or Barbeua test on the preferred site of access.
5. Dorsiflex the patient's wrist, most often done using a rolled towel while securing with cloth tape to arm board, bed, or bedside table.
6. Don appropriate PPE.
7. Clean site and apply drape or sterile surgical towels around site to provide sterile field.
8. Use US to determine appropriate access point and under US guidance, anesthetize the site.
9. Puncture the skin at approximately a 45 degree angle, using needling technique to follow needle into artery. There should be a flash of blood in the hub once accessed. I would advise trusting the US in most cases, as you can have a successful cannulation

in absence of this "flash" of blood through a variety of mechanisms (e.g. low flow state, vasospasm, clotted blood). Once access, advance 2-3 mm further to ensure catheter is in vessel.

10. Advance introducer catheter over the needle and, once hubbed, remove needle. Prepare to occlude the artery proximally, or place your finger over the catheter to reduce blood loss.
11. Insert guidewire through introducer catheter, or needle if introducer catheter not included, and remove catheter over guidewire.
12. Thread arterial catheter over guidewire and, once hubbed, connect to transducer to ensure arterial waveform.
13. Suture catheter in place
14. Apply occlusive dressing
15. Write a procedure note and record performed procedfdure in new innovations, whether or not you were successful.

Femoral

1. Obtain informed consent
2. Repear steps 2-3 from arterial line insertion. **Catheter length 12 – 15 cm.**
3. Place patient in supine position, with the ipsilateral leg slightly abducted and externally rotated.
4. Repeat steps 6-15 from arterial line placement procedure.

Thoracentesis

Procedure

1. Obtain informed consent
2. Two possible patient positions. Have patient sit upright on edge of bed, leaning forward slightly on a bedside table with a pillow for comfort. Alternatively, in those with debility or on a mechanical ventilator, this procedure can be performed with patient supine with their ipsilateral arm flexed with hand behind head and a towel rolled underneath ipsilateral side if necessary.
3. Don PPE.
4. Cleanse area and drape the patient.
5. Anesthetize the skin with a small gauge needle. Continue to anesthetize deeper tissue, being sure to traverse needle over the **superior aspect** of the inferior rib and advance slowly until pleural fluid is aspirated. Be sure to apply negative pressure prior to lidocaine administration to ensure you have not cannulated a vessel.

6. Once pleural fluid is aspirate, take note of needle trajectory and depth and remove the needle.
7. Nick entry site with scalpel.
8. Follow identical path with catheter/ needle assembly, **traversing superior aspect of inferior rib,** aspirating with a syringe all the way until pleural fluid is obtained.
9. Insert catheter/ needle assembly 3-4 mm further to ensure that catheter has been completely inserted into pleural space prior to advancing catheter over needle. Hold needl in place and do not advance further. Once catheter in pleural place, okay to withdraw needle.
10. Advance catheter until approximately a centimeter of tubing remains.
11. Attach a 50 cc syringe to catheter to obtain fluid for specimen collection.
12. Remove syringe and attach one way valve tubing to catheter and collection bag. Short end to catheter and long end to collection bag. Attach 50cc syringe to tubing and remove up to 1.5 L of fluid. Avoid vaccum containers or wall suction.
13. Once procedure complete, have patient hum or perform valsalva to remove catheter (increases intrathoracic pressure).
14. Apply occlusive bandage
15. Write a procedure note, whether or not you were successful.
16. Obtain CXR to rule out pneumothorax.
17. Send fluids for studies.

Paracentesis

Procedure

1. Obtain informed consent
2. Have patient lie supine with head of bed slightly elevated. Can place towel on contralateral side to faciliate fluid movement into procedural space.
3. Use ultrasound to confirm adequate site for drainage (3 cm clearance in all directions) and evaluate for presence of vasculature at insertion site.
4. Don PPE.
5. Cleanse area and drape the patient.
6. Anesthetize the skin with a small gauge needle. Continue to anesthetize deeper tissue until peritoneal fluid withdrawn. Apply 0.5-1 cc of lidocaine just outside of peritoneal space. Be sure to apply negative pressure prior to lidocaine administration to ensure you have not cannulated a vessel.
7. Once peritoneal fluid is aspirated, take note of needle trajectory and depth and remove the needle.

8. Nick entry site with scalpel.
9. Follow identical path with catheter/ needle assembly, using a z-track, aspirating with a syringe all the way until peritoneal fluid is obtained.
10. Insert catheter/ needle assembly 3-4 mm further to ensure that catheter has been completely inserted into peritoneal space prior to advancing catheter over needle. Hold needle in place and do not advance further. Once catheter in peritoneal space, okay to withdraw needle.
11. Advance catheter until approximately a centimeter of tubing remains.
12. Attach a 50 cc syringe to catheter to obtain fluid for specimen collection.
13. Remove syringe and attach tubing to catheter and vaccuum containers or wall suction.
14. If flow stops, possible obstructed against bowel, can attempt to discontinue suction and/ or manipulating catheter before restarting suction again.
15. Can collect up to 10L or more, 6-8 g/kg albumin if >5 L obtained.
16. Once procedure complete, remove catheter
17. Apply occlusive bandage
18. Write a procedure note, whether or not you were successful.
19. Obtain CXR to rule out pneumothorax.
20. Send fluids for studies.

Lumbar Puncture

Procedure

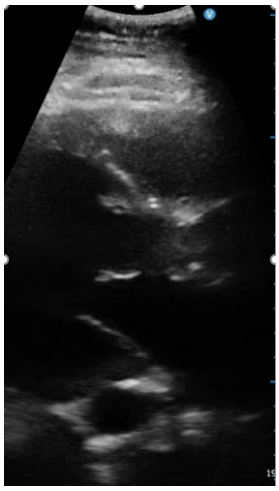
1. Obtain informed consent
2. Two possible positions. Place patient in lateral decubitus position with his of her back close to the edge of the bed or table. This position is preferred if opening pressure is needed or if patient cannot sit upright due to debility or other reasons. If opening pressure is not necessray and patient can sit upright, can have patient sit, with back near edge of bed, leaning forwar over table and pillow. This method tends to have higher first pass success rates.
3. Palpate the area of the L4/L5 space using the intercristal line. Alternatively, and preferred in obese patients or anatomy that is difficult to palpate, can locate sites with US assistance.
4. Done sterile PPE.
5. Cleanse the site and drape the patient.
6. Annesthetize the area with a small gauge needle.

7. Puncture the skin with a spinal needle (stylet in place), bevel towards the patient's head.
8. Carefully advance the needle between the patients vertebrae, aiming the tip of the needle cephalad at approximatel 15-30 degrees (towards the navel). A "pop" will often, but not always, be felt when the subarachnoid space is entered.
9. Remove the stylet and observe for CSF flow. If no flow advance further and attempt again. If bone is encountered, pull back to subcutaneous tissue and redirect.
10. When CSF flow is established, attach extension tubing, manometer, if opening pressure being obtained, and stopcock. Measure the opening pressure, then collect 3-4 cc of fluid in each tube. More may need to be collected if cytology or other studies are being performed.
11. Replace the stylet and withdraw the needle.
12. Place a bandage over the site
13. Write a procedure note, whether or not you were successful.
14. Send CSF studies.

Image gallery

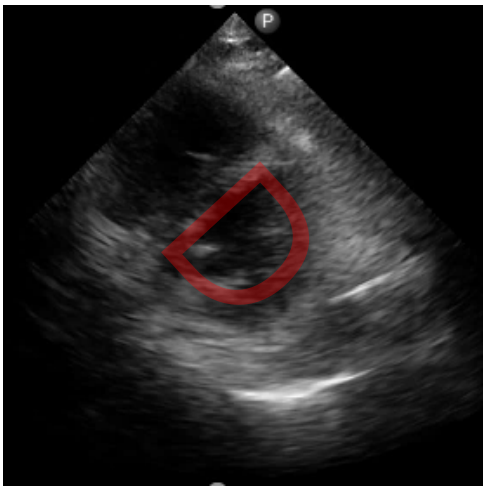
Keep in mind not all pathology can be adequately represented in a single snapshot of a complete scan and this gallery is certainly not complete.

Parasternal



PLAX with reduced EPSS, severe LV dilation, and severe RA dilation.

LV thrombus. Image is reversed so the LV is on the left side of the screen.

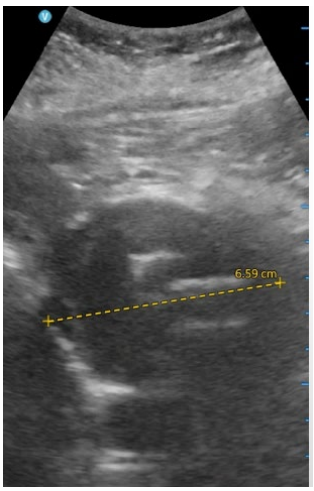


"D" sign – IVS encroaches on LV due to increase RV pressures

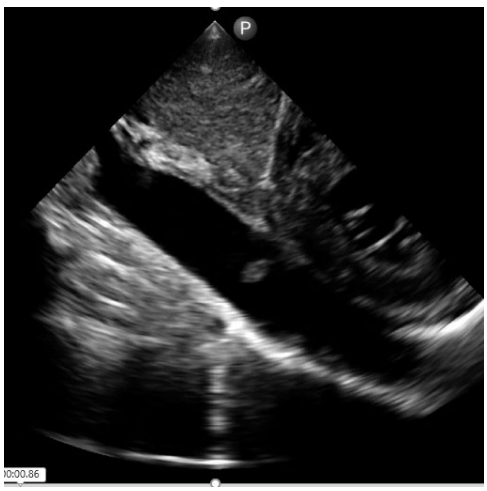
Severe LV hypertrophy

Pericardial effusion visualized in subX view

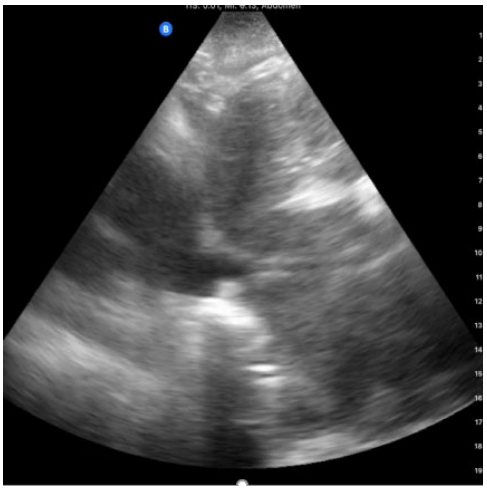
Epigastric



AAA



Abdominal aortic thrombus

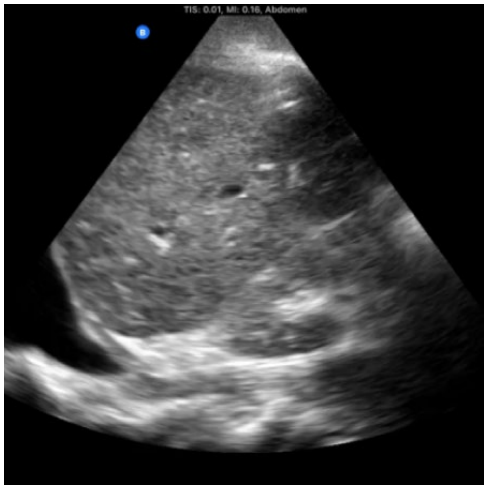


"Sliver in the liver"

Plethoric IVC

Lung

Shred Sign

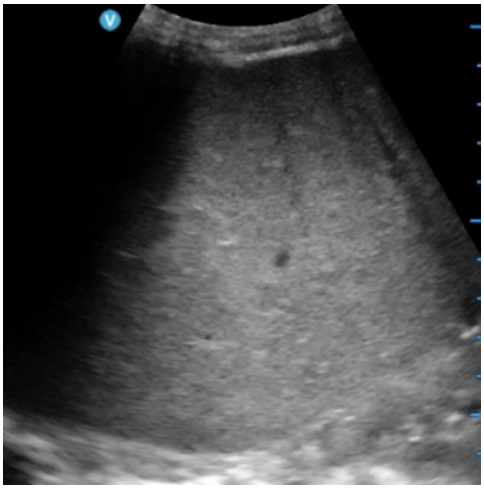


Spine sign with pleural effusion

Jelly fish sign

Fatty hernia above diaphragm

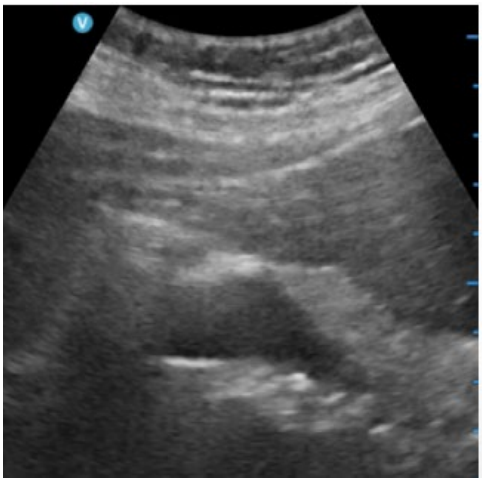
RUQ



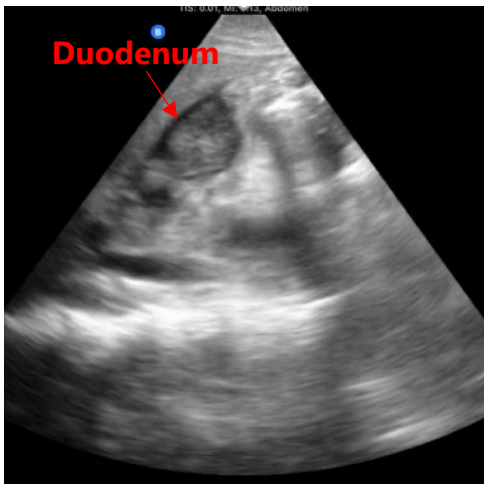
Hepatic steatosis. Note hyperechoic liver echogenicity.

Liver cirrhosis (nodular border) with ascites fluid

Gallbladder

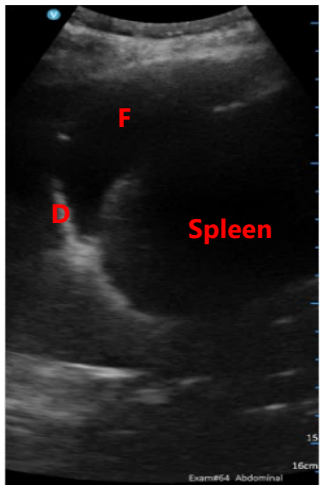


Layering of gallstones in gallbladder.



Portion of duodenum adjacent to liver that can often be mistaken for gallbladder. Note hypoechoic walls, filled isoechoic space, and you can often delineate the two by simply searching for the true gallbladder.

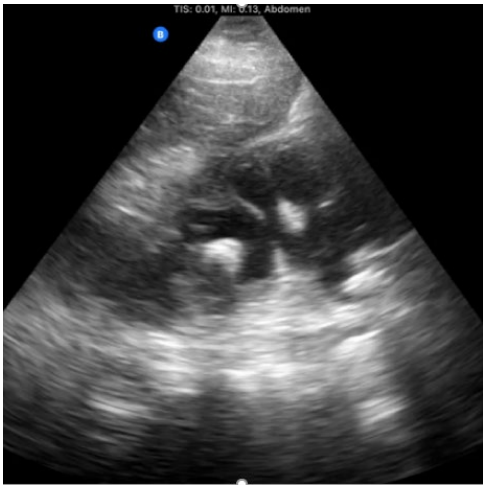
LUQ



Fluid (F) accumulation between spleen (S) and diaphragm (D)

Splenomegaly with fluid accumulation, abnormal contour and echotexture.

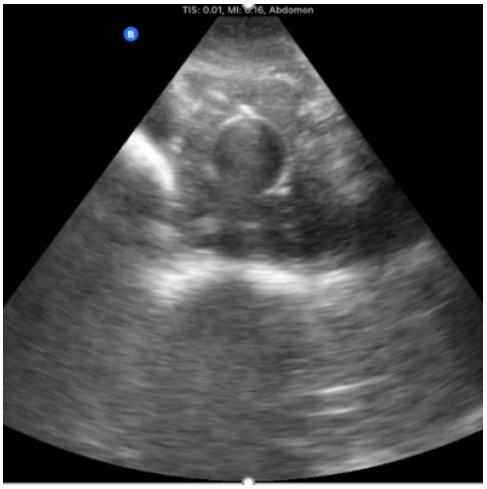
Kidneys



Hydronephrosis with kidney stones

PCKD

Suprapubic



Foley with decompressed bladder

Notes

Logbook

No.	Case ID	Date	Total time	Systems Viewed	Interpretation
1					
2					
3					
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POCUS Log

Device Check Out