2nd Edition, 2013-2014

IMBUS

pocketguide

Abbott Northwestern Hospital
Internal **M**edicine **B**edside **U**ltra**S**ound Program

Table of Content:

Introduction

The Abbott Northwestern Hospital Internal Medicine Residency's IMBUS (Internal Medicine Bedside UltraSound) program is an extensive 3-year curriculum focused on maximizing the internist's diagnostic, problem solving, and interventional abilities at the bedside. Thoughtful integration of point-of-care ultrasound into the traditional physical exam can maximize sensitivity and specificity of the internist's diagnostic ability, improve time to diagnosis and intervention in time-sensitive scenarios, improve physician understanding of physiology and anatomy, returns a sense of discovery and excitement to physical diagnosis in medical education and practice, reduces resource utilization and cost, improves patient understanding and engagement, and ultimately improves patient care.

These benefits are only realized in providers who are rigorously trained and their competency rigorously assessed in the areas of: clinical ultrasound physics, ultrasound indications, limitations & pitfalls, image acquisition, image interpretation, and clinically appropriate integration of their findings. Therefore, the IMBUS program is simultaneously evaluating the educational methods and learner metrics involved in the addition of point-of-care ultrasound into the internal medicine physician's armamentarium.

The IMBUS Pocketguide is one of many tools that help our residents, faculty, and patients understand ultrasound's integration into what they will know as the IMBUS physical exam.

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Abbott Northwestern Hospital IM Residency Program - Minneapolis, MN
IMBUS Pocketguide – 2nd Edition – 2013-2014

IMBUS Patient Explanation

Key points for patient to understand prior to and during a focused bedside ultrasound exam:

- This ultrasound machine allows us to see things with more accuracy than a physician's hands and stethoscope alone and thus make better decisions about patient care
- This ultrasound does not have the harmful radiation effects of an Xray or CT scan
- I am a resident/physician learning ultrasound and this exam is part of my education as well as your care
- This exam does not replace a formal ultrasound study, as it is asking focused questions and looking for yes/no answers only to the things I am trained to look at
- You are not being charged anything additional for the use of ultrasound in my exam
- If we find something that needs a full ultrasound study or additional testing we will discuss it with you

Example:

Hi (patients name Mr./Ms. X),

My name is _____. We are going to do a quick ultrasound here at the bedside to _____. Have you had an ultrasound before? This is a portable ultrasound machine that we use as a tool when we examine patients - similar to how we use our stethoscopes, however it allows us to visualize what we are feeling and hearing with much more accuracy. It is the same technology used to look at a baby in the womb and is not painful or harmful. We are not doing a full ultrasound exam, and therefore are only attempting to answer a few specific questions. You are welcome to see the images of your heart, kidneys, liver, etc as we go if you want. Lastly, there is no charge for this exam, it is just part of my learning and taking the best care of you that we can. You can ask to stop at any time.

Other points: Consider modesty and comfort; uncover only the areas needed for the exam. This should not cause discomfort to the patient. Stop and adjust scanning if this occurs. Bring towels with you and thoroughly remove all gel from the patient's skin. After completing the scan, make sure the patient is covered, the side rails are up, bed back down to ground level, and the call light is within reach. Thank the patient again. Be sensitive to nursing and other providers' needs when deciding when to perform an educational ultrasound exam.

"IMBUS FULL" Exam Sequence

- Prior to entering room: turn on ultrasound, open new patient, enter IMBUS ID, patient MR#, and then press **DONE** to enter scanning mode
- Explain IMBUS physical to patient, gather towels and turn down the lights.
- Traditional physical exam components come first with decisions on what IMBUS components will need to be added or substituted as you move through your initial traditional exam components.

IMBUS EXAM COMPONENTS:

Position=semi-recumbent

- **PHASED ARRAY** PROBE:
    - IMBUS **pulmonary-basic** (zone 1-4 bilaterally: lung sliding, B-lines, A-lines, effusion, alveolar syndrome?)
        ** If concern for infiltrate or effusion remains, examine zones 5-6 sitting later and consider zones 1-4 with a transverse probe orientation as well as longitudinal
    - IMBUS **heart** (PLAX, PSAX, AP4, SubX & IVC/volume assessment)
    - IMBUS **abdomen** (*RUQ*: liver size, Morrison's pouch, right kidney. *LUQ*: spleen size, splenorenal recess, left kidney, bowel)
    - IMBUS **urinary** (bladder)

Position=sitting-examiner posterior

- IMBUS **pulmonary-adv** (zone 5-6 bilaterally: B-lines, alveolar syndrome, effusion?)**

Press the "A" button on the EDGE machine or go through the machine's sequence to close the patient exam.

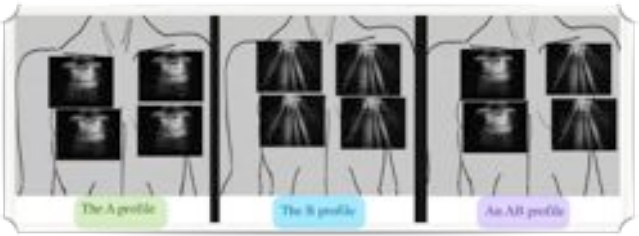
“IMBUS SHOCK” Exam Sequence

- The IMBUS shock ultrasound sequence findings are yes/no questions that should be integrated into the clinical scenario and other findings. They should never be used in isolation to guide your clinical decision-making.

RA=right atrium, RV=right ventricle, IVC=inferior vena cava, LV=left ventricule

Crit Ultrasound J (2011) 3:123–129

"IMBUS SOB" Exam Sequence



Eval Heart/IVC

Eval Heart

"PLAPS" postero-lateral alveolar and pleural syndrome

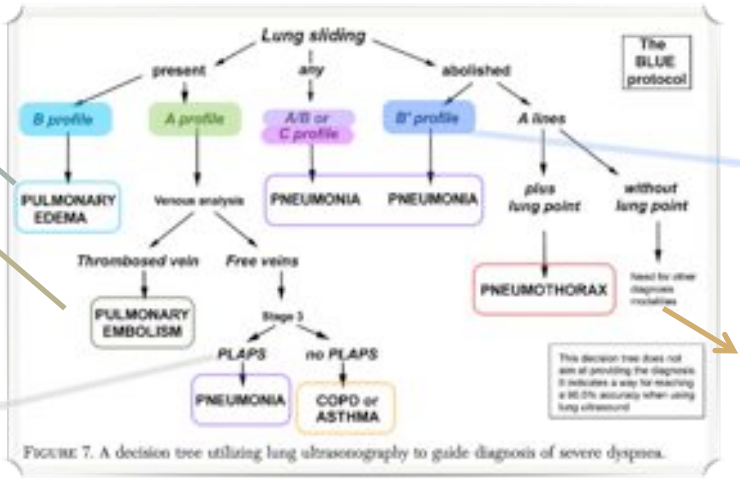


FIGURE 7. A decision tree utilizing lung ultrasonography to guide diagnosis of severe dyspnea.

B' means B profile without lung sliding present

Ptx likely in correct clinical setting but remember other causes of absent lung sliding: ARDS, pneumonia, bullae, adhesions, mainstem obstr/intubation

Adapted from: Lichtenstein. Chest 2008; 134:117-125. "The BLUE Protocol"

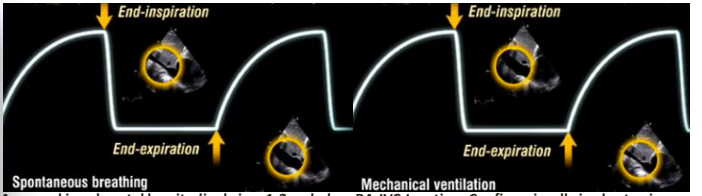
“IMBUS AKI” Exam Sequence

Pre-Renal	Intrinsic	Post-Renal
• IVC volume status • Cardiac output	• Size, cysts, perinephric space	• Hydro, bladder volume, bladder jets, prostate

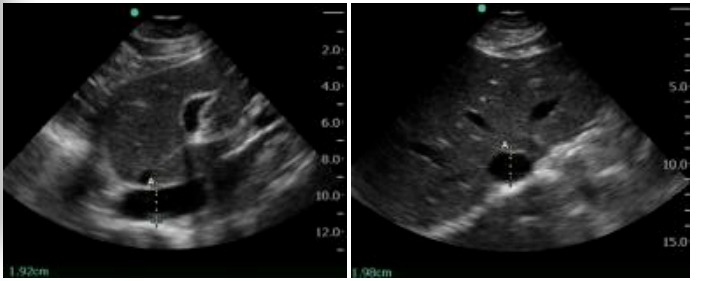
"IVC VOLUME STATUS" Exam Rationale

IVC Diameter (end expiration)	% Collapse on sniff	CVP (mmHg)
<1.7cm	>50%	0-5
>1.7cm	>50%	5-10
>1.7cm	<50%	10-15
>1.7cm	minimal	15-20
>2cm w/ dilated hepatic veins	none	>20

*Validated for spontaneously breathing recumbent patients
**Respiratory variation tested by asking pt. to take brief inspiration or "gentle sniff"



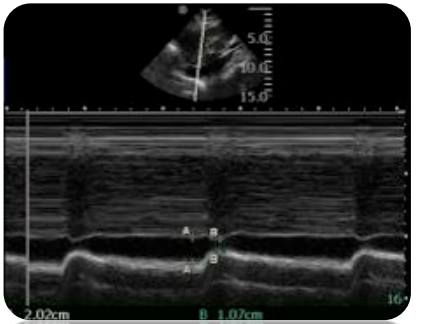
Measured in subcostal longitudinal view 1-2cm below RA-IVC Junction. Confirm visually in short axis.



Normal IVC diameters vary, but an IVC >20mm that lacks the usual normal (~50%) collapse likely indicates elevate RA pressure.

In patients on the vent, the measure is less specific, however a small collapsible IVC in these patients excludes elevated RA pressure on the vent.

In a **hypotensive pt. with IVC having >20-30% collapse** on normal inspiration will likely respond to fluid bolus.



Volume Assessment – Mechanically Ventilated Patient

Using Respiratory Variation Of The IVC Diameter

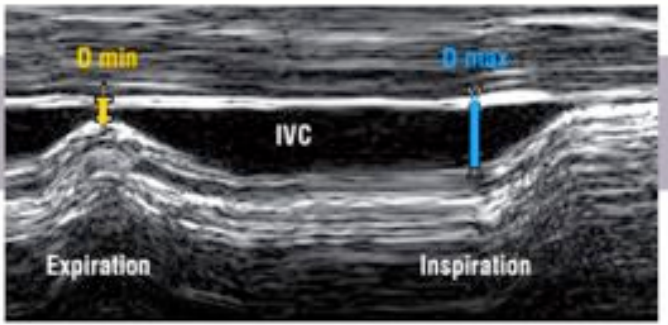
Variation of the diameter of the inferior vena cava with respiration has recently been demonstrated to be a reliable guide to fluid therapy ***in mechanically ventilated patients***. [1,2]

A **cut-off value of 12% or greater** in the percentage of variation of the IVC diameter (the "distensibility index" of the IVC*) **before** volume loading identified those patients who would respond to a fluid challenge (increase in cardiac output by ≥ 15% in patients with a distensibility index ≥ 12%) [1]

Distensibility index of the IVC*

$$\frac{\text{Dmax (insp)} - \text{Dmin (exp)}}{\text{Dmean}} = \%$$

* =see p.8 for limitations of this method



M-Mode tracing of IVC respiratory variation on mechanical ventilation

References:

1. Feissel M, et al. The respiratory variation in inferior vena cava diameter as a guide to fluid therapy. Intensive Care Med 2004;30:1834-1837.

2. Barbier C, et al. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med 2004;30:1834-1837

If you use Dmin as the denominator instead of Dmean, the cutoff value used is 18% instead of 12%. The rationale for using the >12% cutoff with Dmean as the denominator is that the sens/spec for fluid responsiveness is slightly better (PPV 93%, NPV 92%) than when using the Dmin and cutoff of >18% which has a sens 90%, spec 90%.

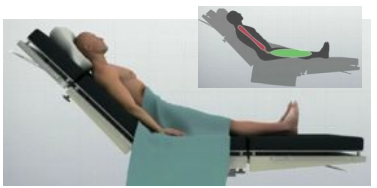
Adapted from the FOCUS Pocket Guide

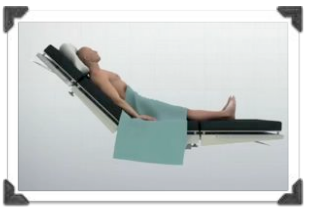
Fluid Responsiveness – Passive Leg Raise

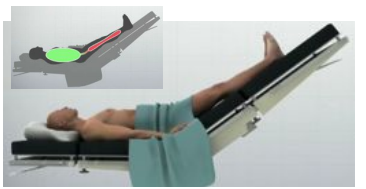
CO = SV x HR

SV = (LVOT area) x (LVOT VTI)

LVOT area = $\pi(\text{LVOTdiam}/2)^2$







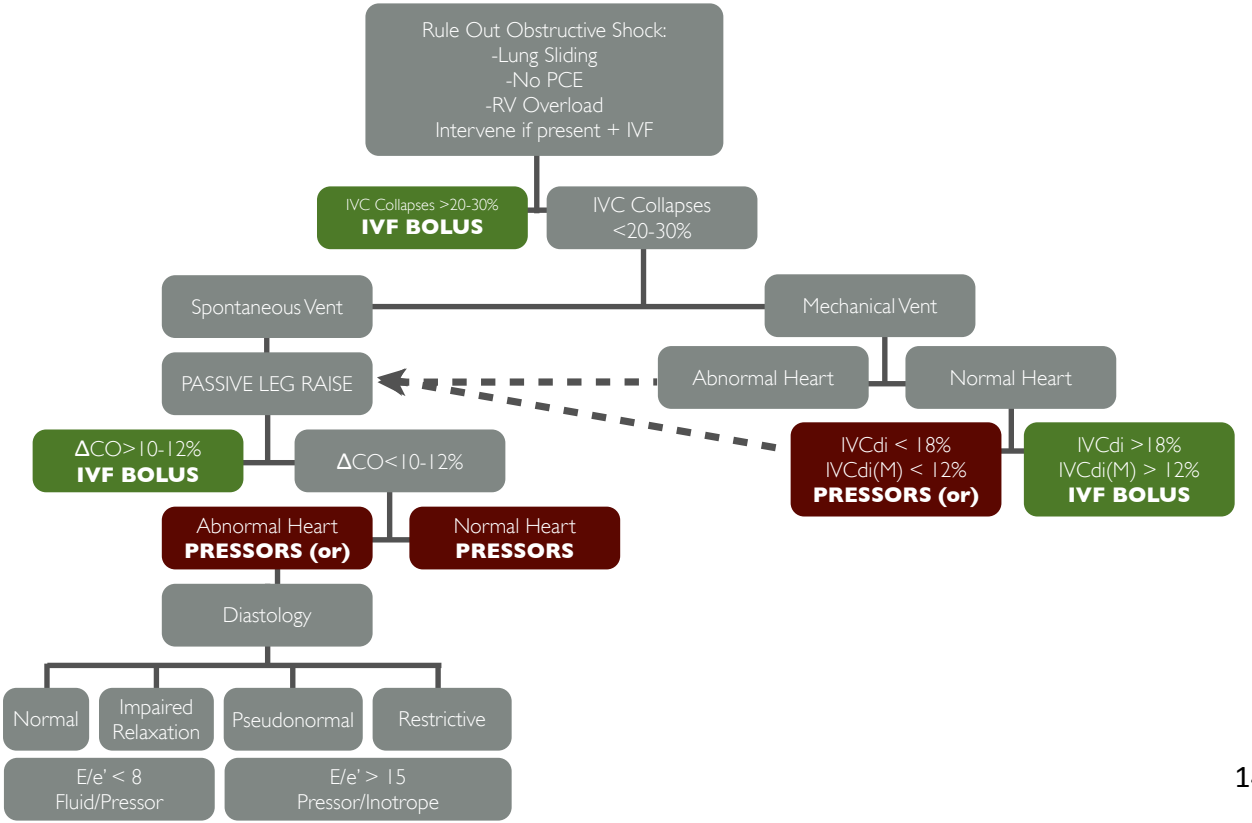
- Intubated and Non-Intubated Patients
- Measure CO in position #1
- Put pt in position #2
- Wait 1-2 minute
- Repeat LVOTvti (everything else stays the same)

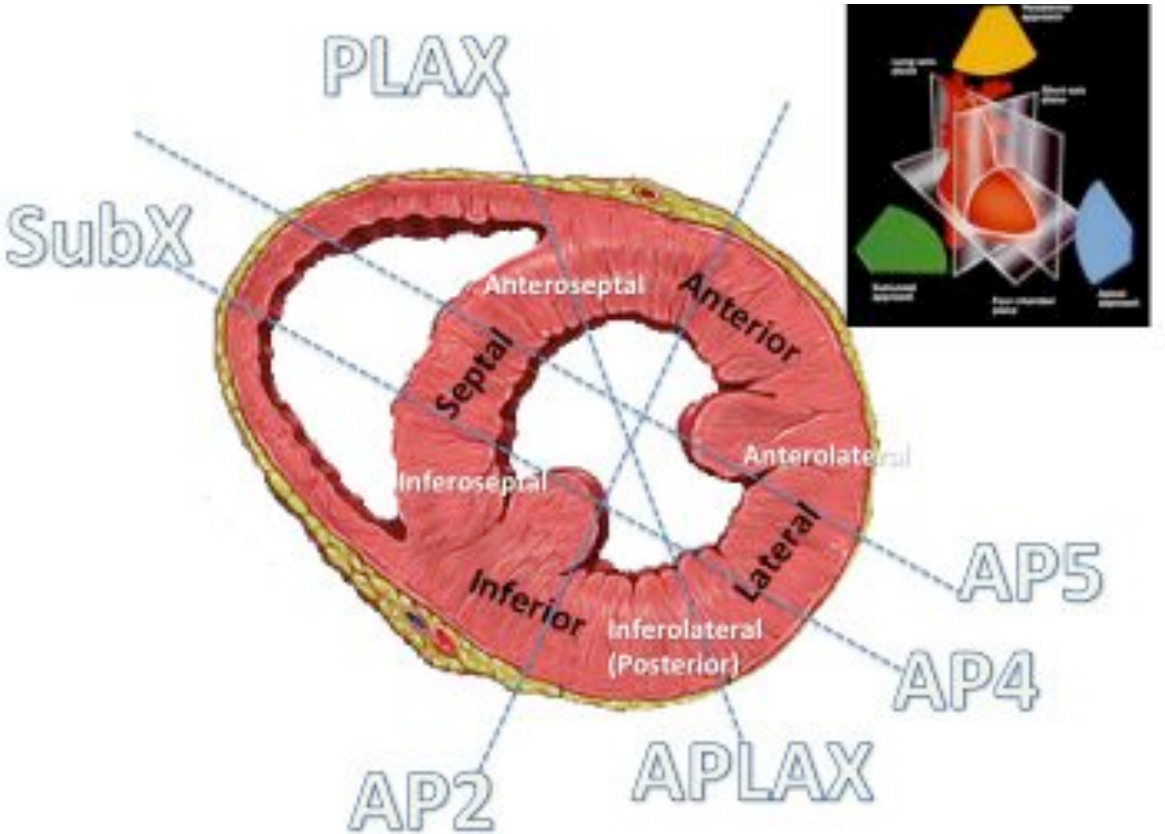
>**5%** change in CO = Fluid Responder
Sens **94**%, Spec 83%

>**10%** change in CO = Fluid Responder
Sens 97%, Spec 94%

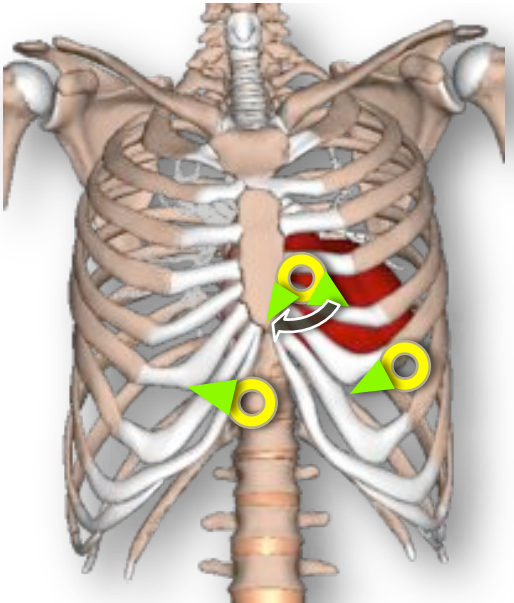
>**12.5%** change in CO = Fluid Responder
Sens 77%, Spec **100**%

Fluid Responsiveness – Integrated approach to hypotensive patient



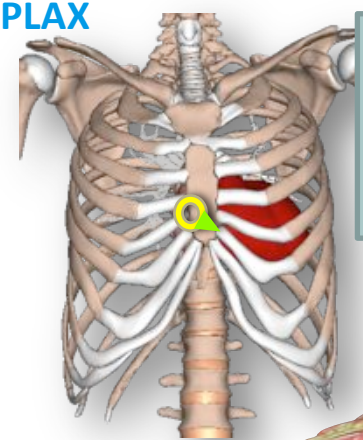

PLAX
SubX
Anteroseptal
Anterior
Septal
Anterolateral
Inferoseptal
Lateral
Inferior
Inferolateral
(Posterior)
AP5
AP4
APLAX
AP2

3 Cardiac Windows

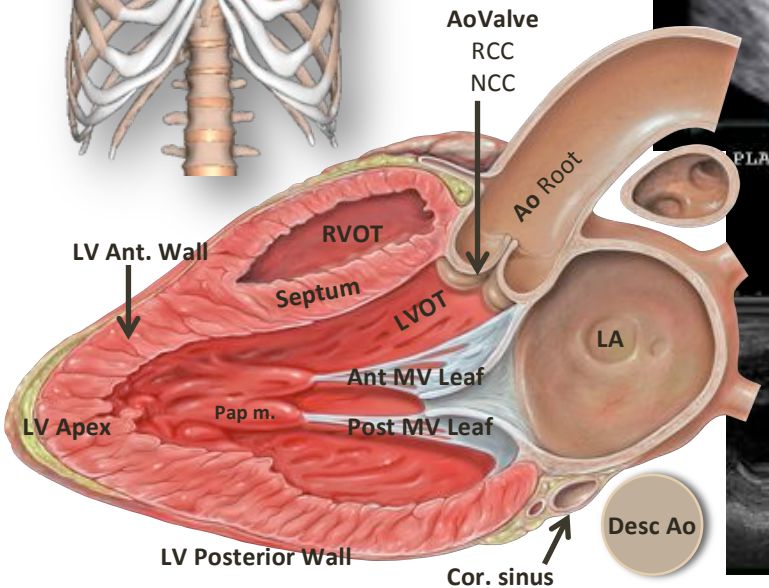


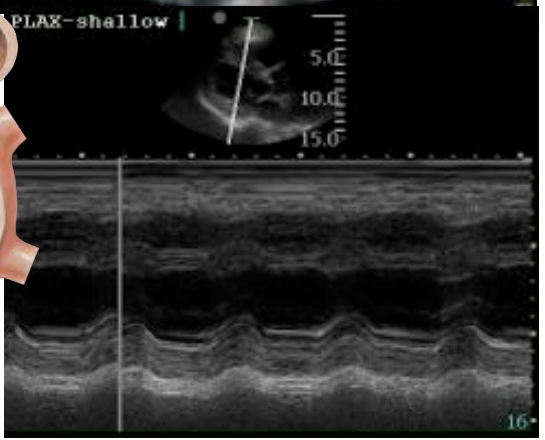
Green arrow indicates indicator direction on phased array probe when using the radiology convention (dot on left of screen). If using cardiology convention (dot on right of screen) rotate probe 180 degrees.

PLAX

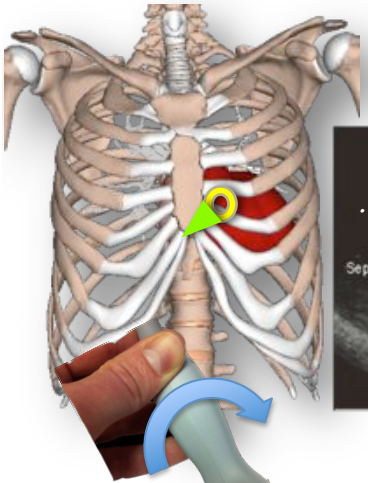


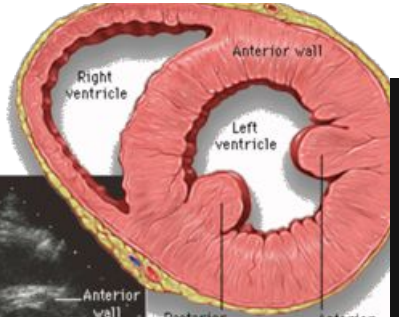
M-mode cursor for LV Systolic function should be placed perpendicular to septum and across the tip of the mitral leaflets.

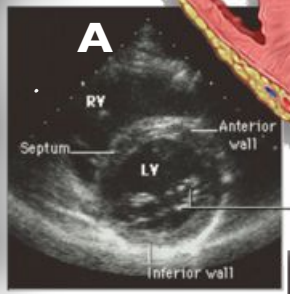


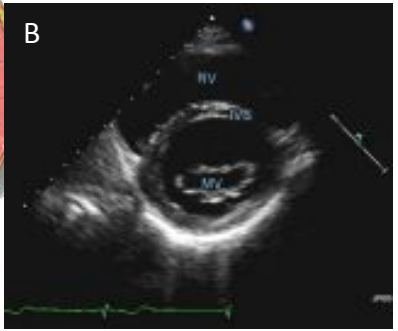


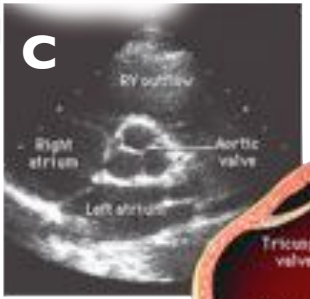
PSAX

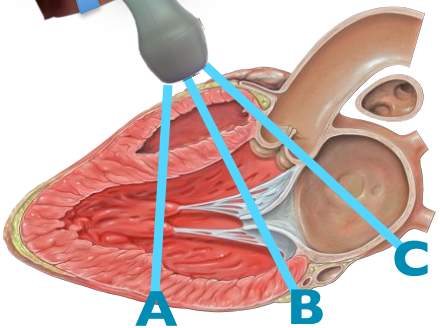


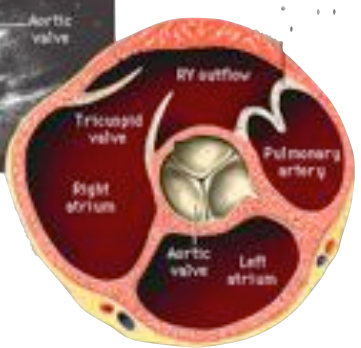

Right ventricle
Anterior wall
Left ventricle
Posterior papillary muscle
Anterior papillary muscle
Chordae tendineae and papillary muscles


A
RV
Septum
Anterior wall
LV
Inferior wall

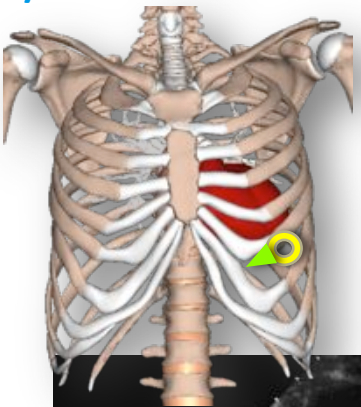

B
RV
TVS
MV

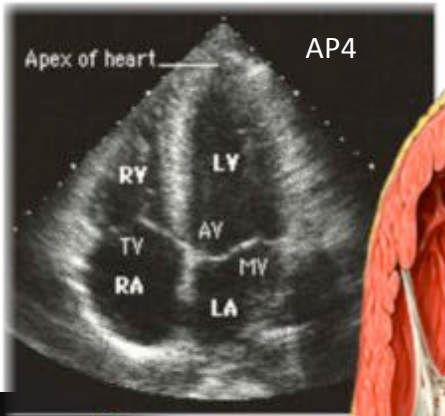

C
RV outflow
Right atrium
Aortic valve
Left atrium


A
B
C


RV outflow
Tricuspid valve
Pulmonary artery
Right atrium
Aortic valve
Left atrium

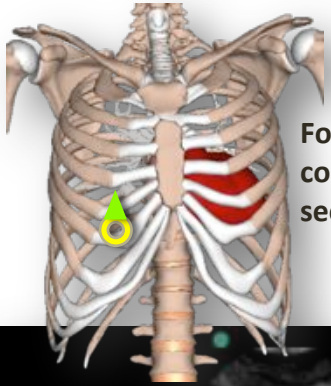
AP4/AP5



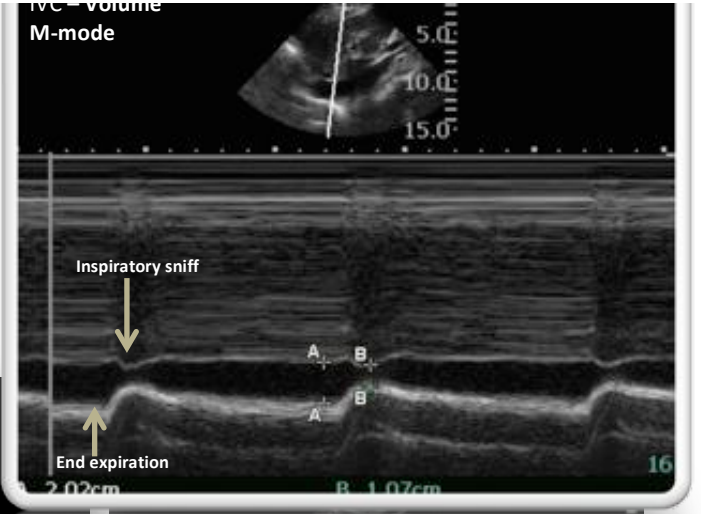


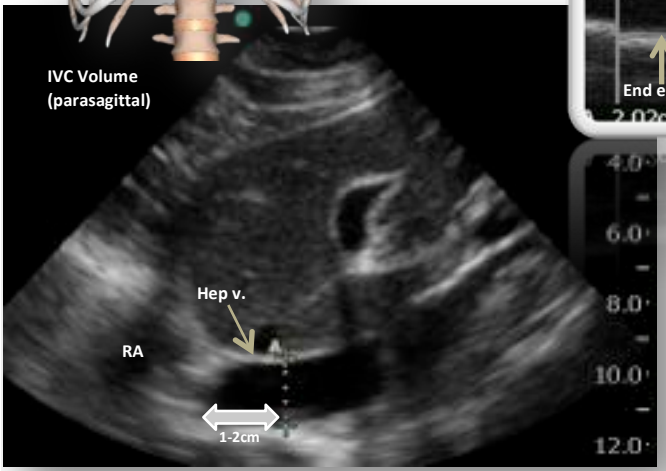
If ventricles are visible but not atria, **FAN** ANTERIOR. If left OR right chambers are present, but not both, **ROTATE** probe.

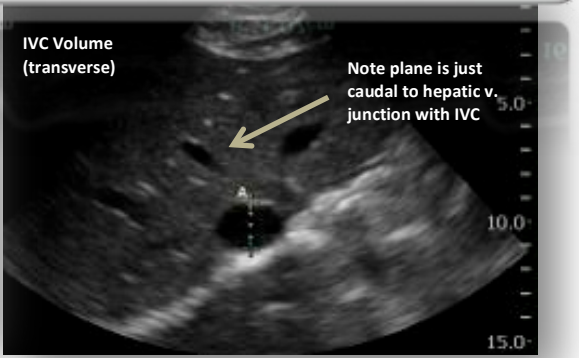
SUBX – IVC Volume



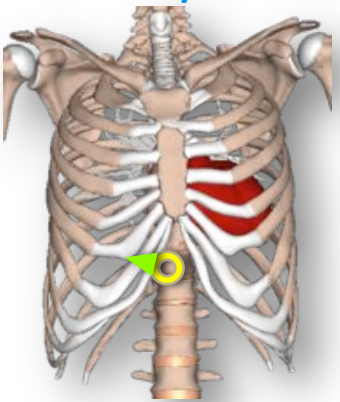
For CVP correlation table see page #12

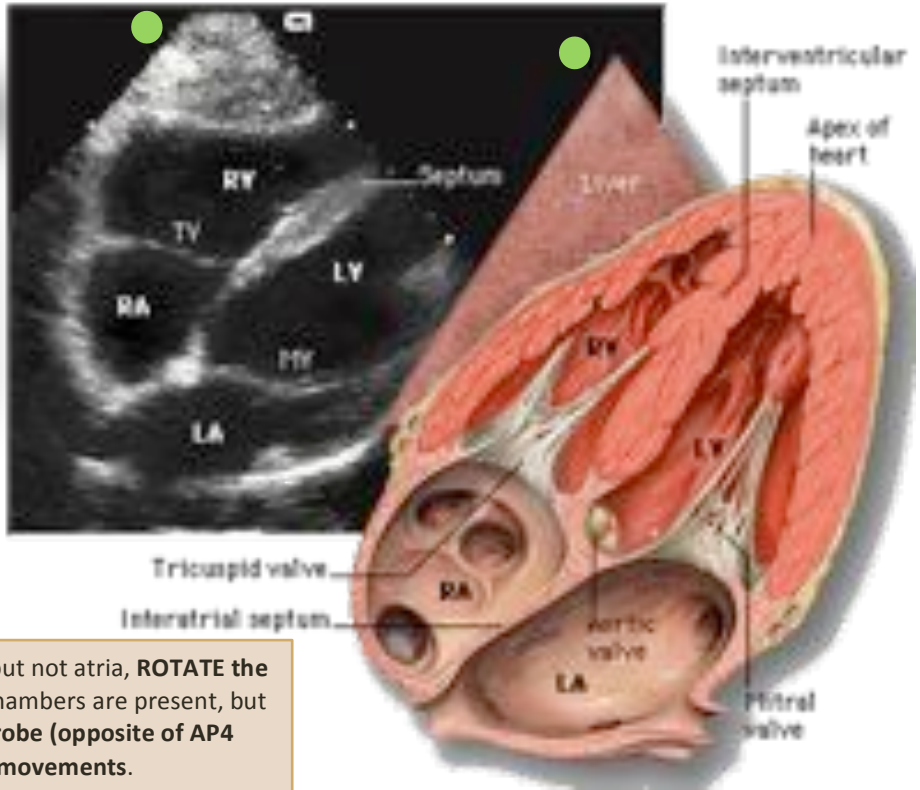






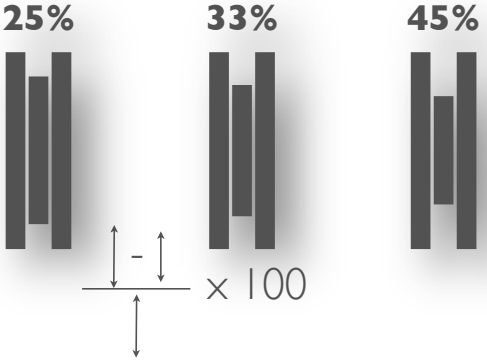
SUBX – 4ch/5ch



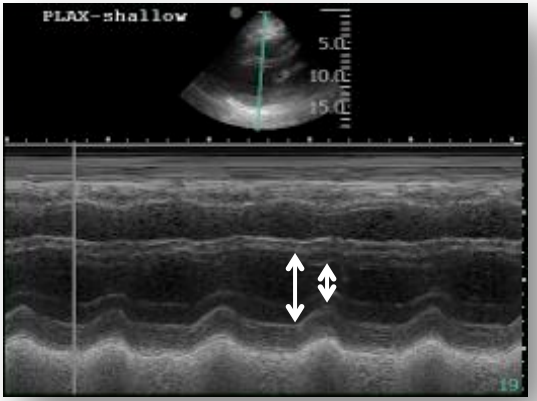


If ventricles are visible but not atria, **ROTATE the probe**. If left OR right chambers are present, but not both, **FAN the probe (opposite of AP4 correction movements**.

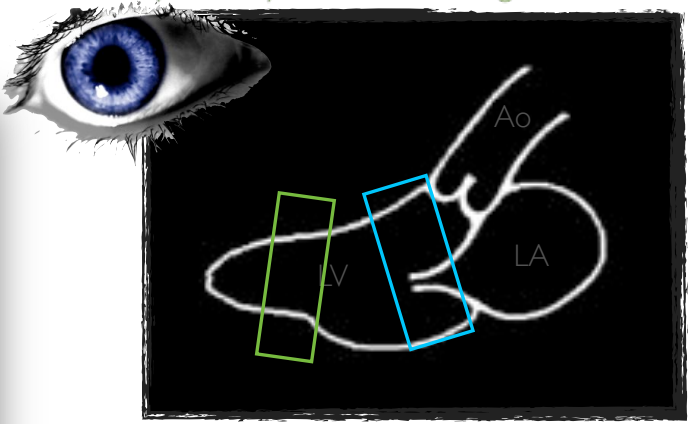
LV Systolic Function Assessment



Normal FS=30-45%

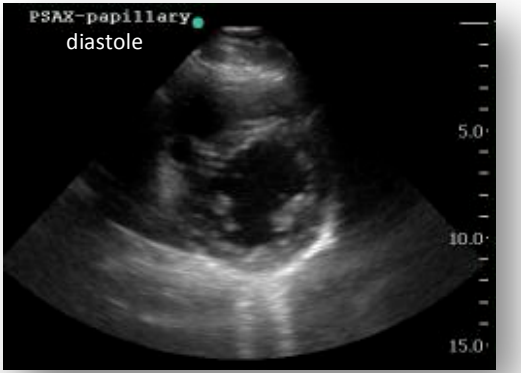


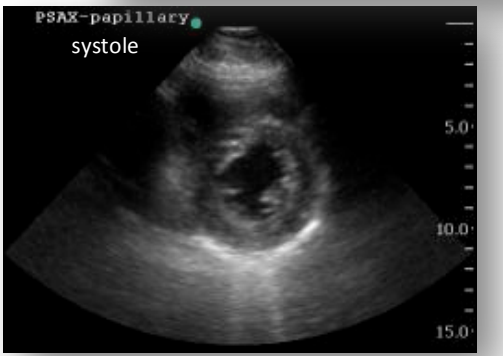
- Eyeball Method
  - Early **Diastolic** Anterior Mitral Leaflet Mvmt
  - LV Endocardial Excursion
    - FS in mind
    - Mid ventricle should be smaller than base @ end systole
  - LV Systolic Myocardial Thickening



LV Systolic Function Assessment Cont'd

• **Hyperdynamic**	**EF**>70%	**FS**>45%
• **Normal**	**EF** 55-70%	**FS** 30-45%
• **Mild/Mod Reduced**	**EF** 30-55%	**FS** 15-30%
• **Severely Reduced**	**EF**<30%	**FS**<15%



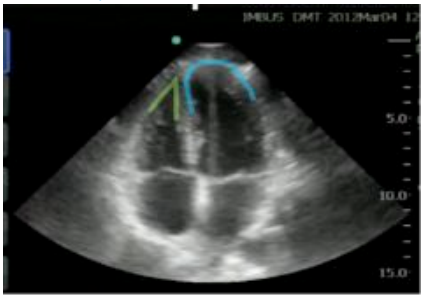


Differential of **Hyperdynamic LV Function**
(best assessed in PSAX-papillary level)

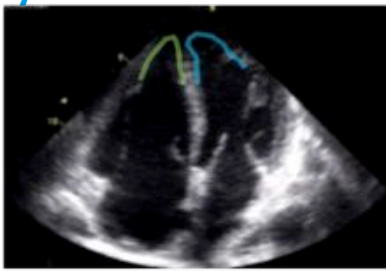
1. **LV under-filling**
   a. Hypovolemia
   b. Acute RV failure (PE, MI, ARDS)
   c. Tamponade
   d. Tension pneumothorax
2. **Increased Contractility**
   a. Endo/Exogenous catacholamines
3. **Decreased Afterload**
   a. Sepsis/anaphylaxis/vasodilatory therapy
   b. Mitral regurgitation/VSD

LV Systolic function should be evaluated in the PLAX and PSAX at the papillary muscle level. An M-mode image should be saved in PLAX. An end-diastole and end-systole 2-D image should be saved in PSAX to document systolic function.

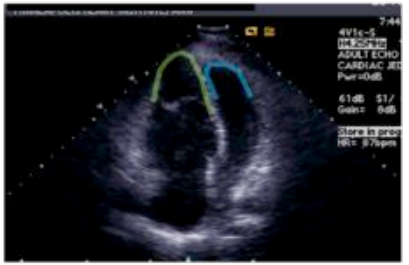
Semi-Quantitative RV Cavity Size Assessment



- **Normal**:
  - RV:LV < 2/3
  - LV dominates apex
  - RV apex triangular

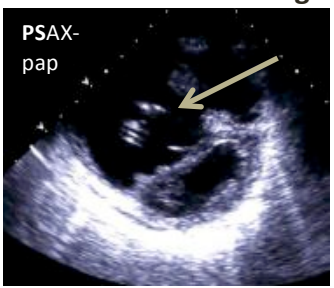


- **Mod RV enlg:**
  - RV:LV 2/3-1
  - RV/LV share the apex



- **Severe RV enlg:**
  - RV:LV >1
  - RV dominates apex
  - RV apex becomes more round in shape

Additional views of Severe RV Enlargement



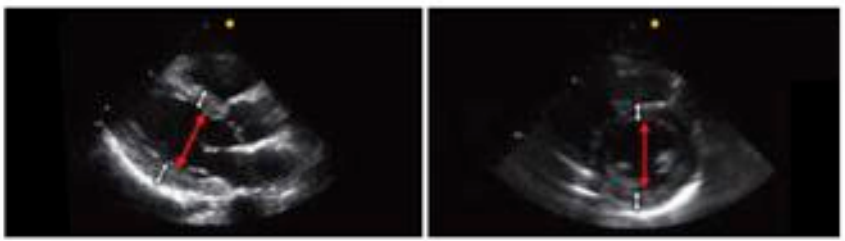
LV Chamber Size Reference Numbers

PARASTERNAL LONG-AXIS

PARASTERNAL SHORT-AXIS
(papillary muscle level)

Where?: At tip of Mitral Valve Leaflets

Where?: Between the Papillary Muscles



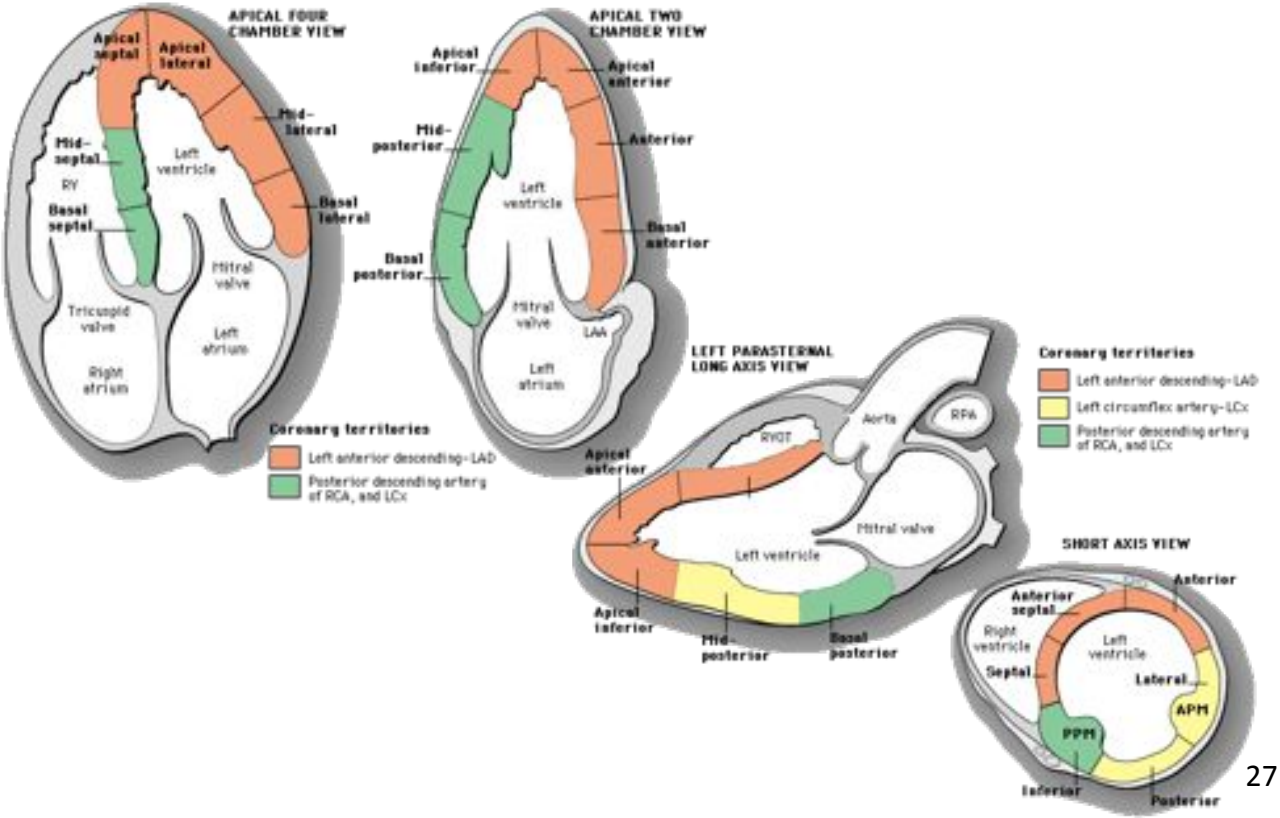
LV CAVITY DIMENSION*	END-DIASTOLE [1]	END-SYSTOLE [2]
Normal	< 55 mm	< 35 mm
Mild dilatation	55-65 mm	35-45 mm
Moderate dilatation	65-75 mm	45-55 mm
Severe dilatation	> 75 mm	> 55 mm
Normal LV wall thickness:	6-12 mm	

* Endocardial borders must be adequately visualized and the ventricular walls must be perfectly perpendicular to the ultrasound beam for precise measurements.

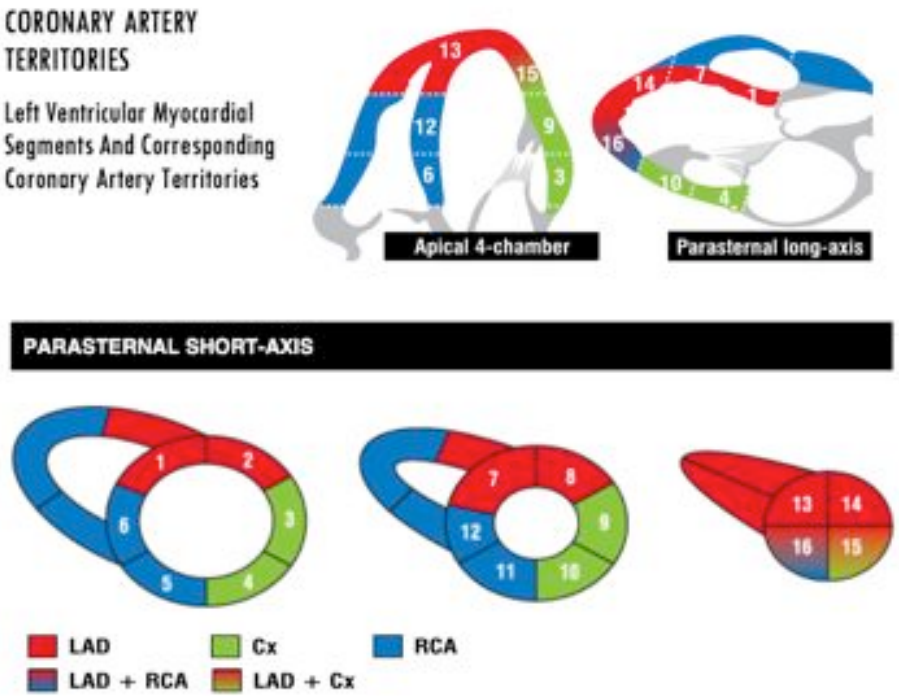
1. End-Diastole: Frame after MV closure
2. End-Systole: Frame before MV opening

FOCUS Pocket Guide

Cardiac Segments & Coronary Distribution



Coronary Artery Territories

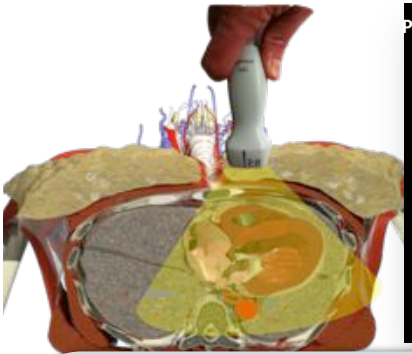


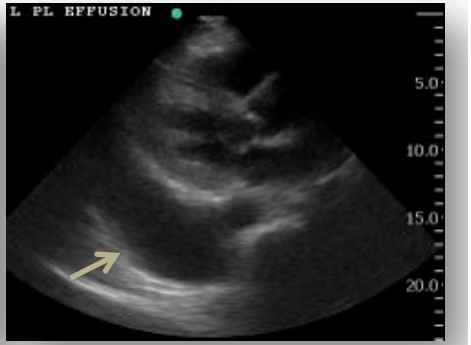
REFERENCE:

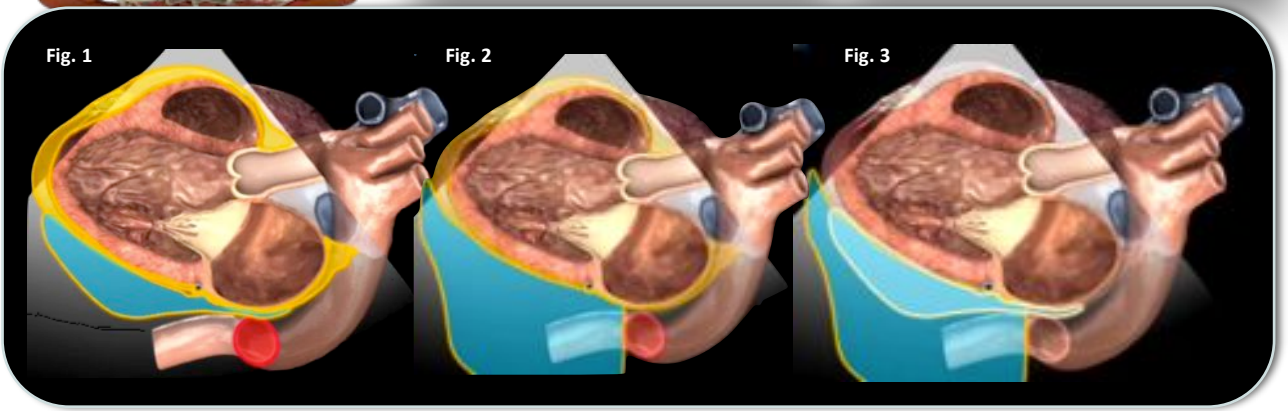
1. American Society of Echocardiography Committee Recommendations. Lang et al, J Am Soc Echocardiogr 2005; 18:1440-1463

From the
FOCUS Pocket Guide

Pericardial vs. Pleural Fluid: PLAX





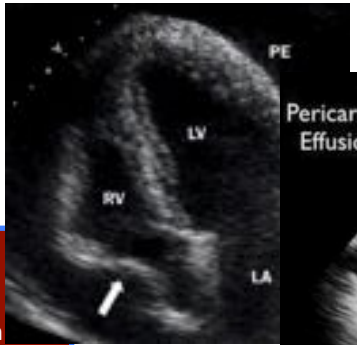


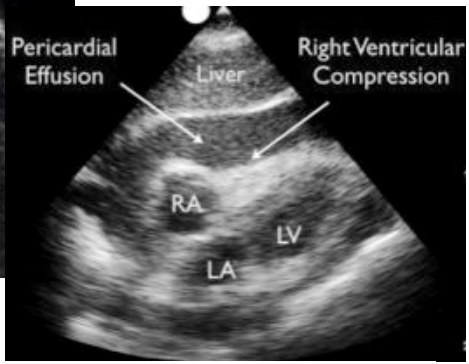
Pericardial (Fig. 1) tracks anterior to descending aorta, whereas left pleural (Fig. 2) tracks left and posterior to descending aorta. Shape tapers appropriately based on that anatomy. Figure 3 demonstrates both pericardial and left pleural fluid.

Tamponade Findings

PCE Size: measured at maximal dimension

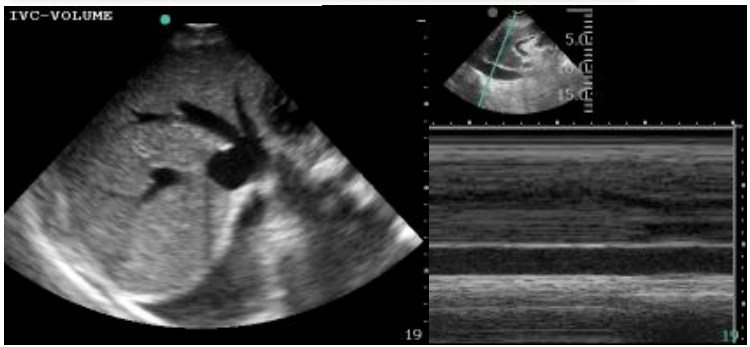
- **Small** <1cm
- **Moderate** = 1-2cm
- **Large** >2cm



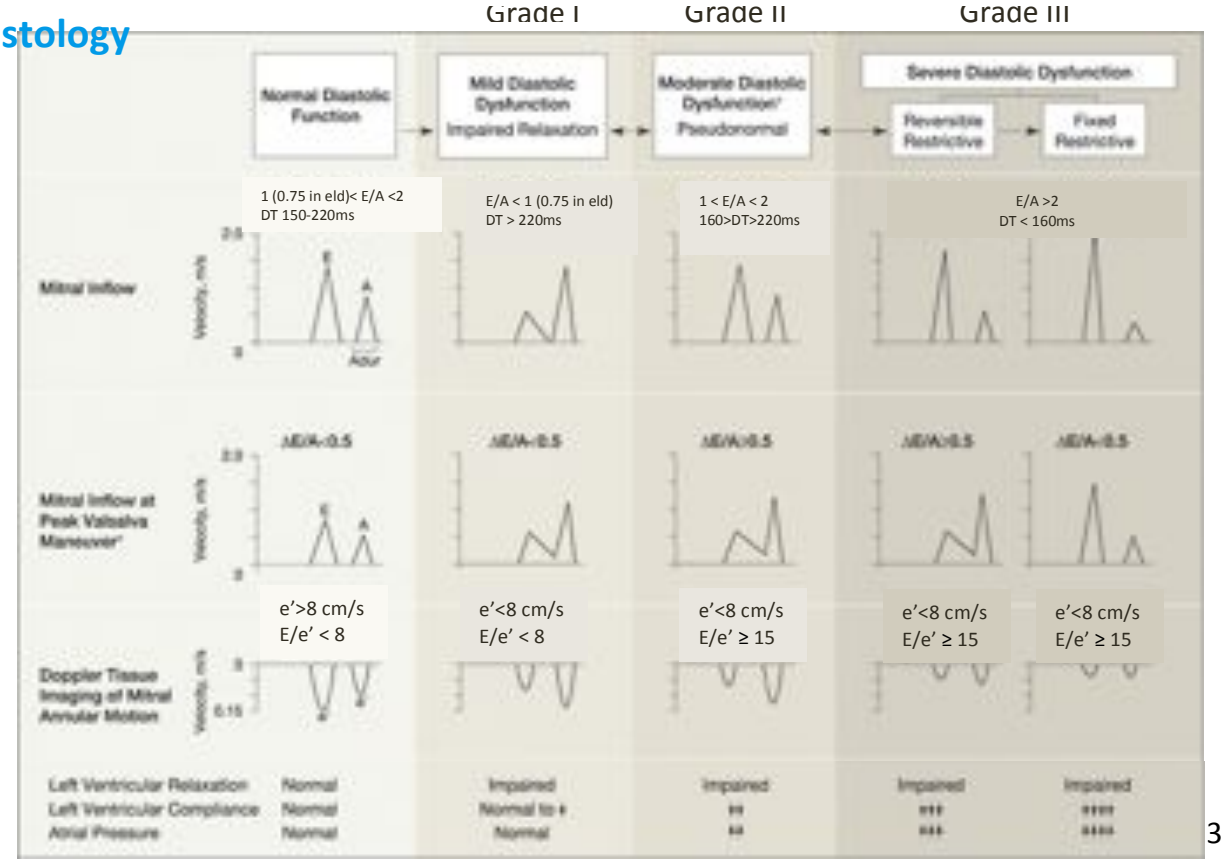


Findings pointing towards tamponade:

- Diastolic collapse of RA and/or RV
- Dilated IVC without respiratory variation
- Clinical scenario consistent with tamponade
- Swinging Heart/Electrical Alternans
- Large PCE
  - However can have tamponade with small effusion if rate of accumulation is quick

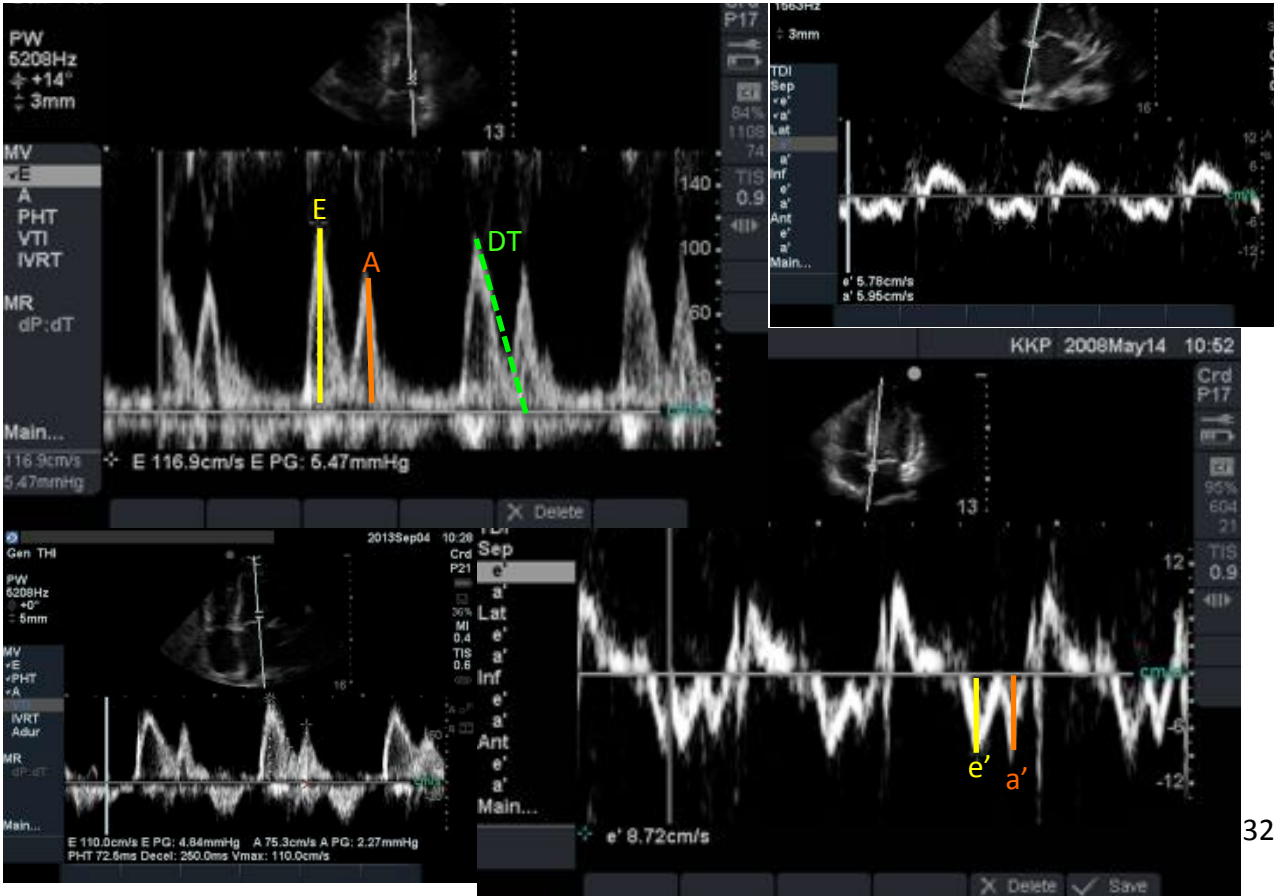


Diastology

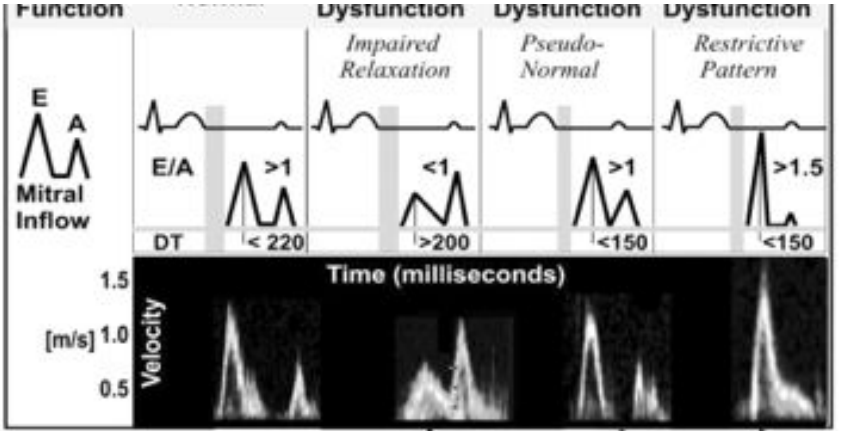


Interactive Tutorial at http://www.ecocardiografia.info/didat_diast_en_II.htm

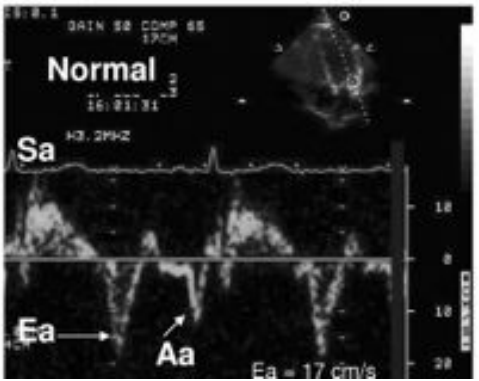
Adapted from: JAMA, January 8, 2003—Vol 289, No. 2

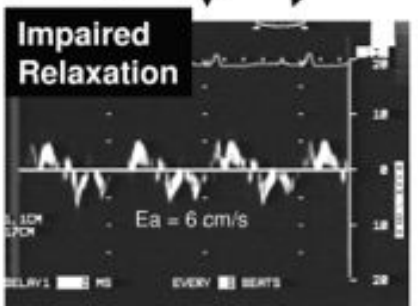

PW
5208Hz
+14°
3mm
MV
E
A
PHT
VTI
IVRT
MR
dP:dT
Main...
E
A
DT
E 116.9cm/s E PG: 5.47mmHg
Delete
TDI
Sep
Lat
Inf
Ant
Main...
e' 5.78cm/s
a' 5.95cm/s
KKP 2008May14 10:52
Crd
P17
e'
a'
e' 8.72cm/s
Delete
Save
Gen THI
PW
6208Hz
5mm
IVRT
Adur
2013Sep04
E 110.0cm/s E PG: 4.84mmHg A 75.3cm/s A PG: 2.27mmHg
PHT 72.6ms Decel: 260.0ms Vmax: 110.0cm/s

Conventional Doppler



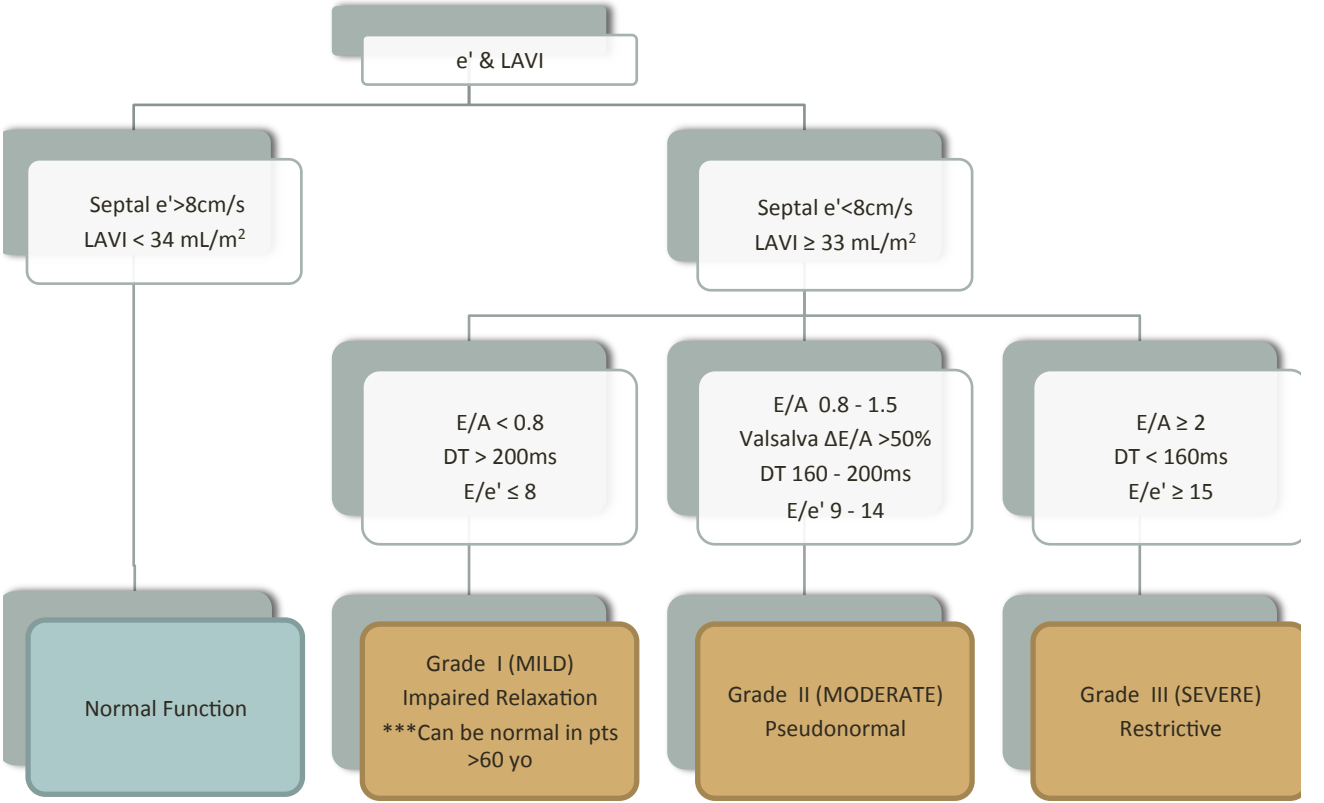
Mitral Annular Velocity Tissue Doppler

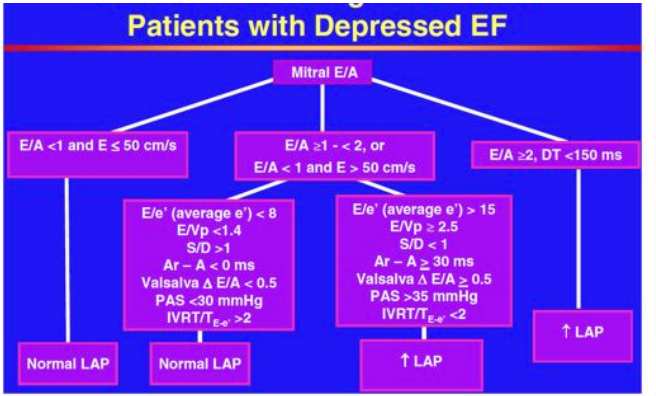


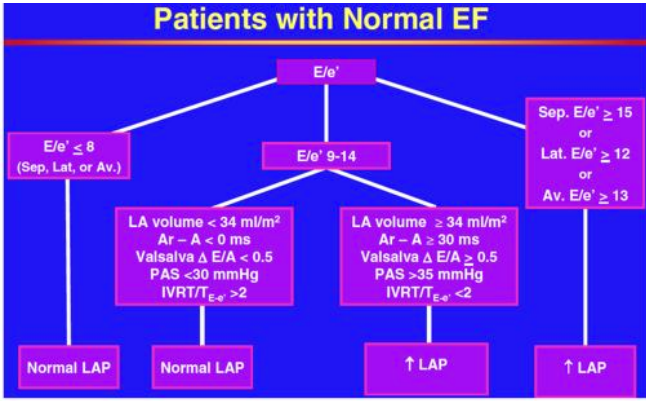


Circulation
March 14, 2006 vol. 113

Diastology: Grading diastolic dysfunction







Formulae to calculate LA pressure

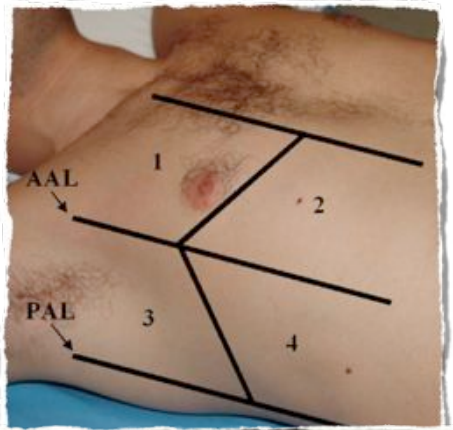
Sinus rhythm 2+1.2(E/e')

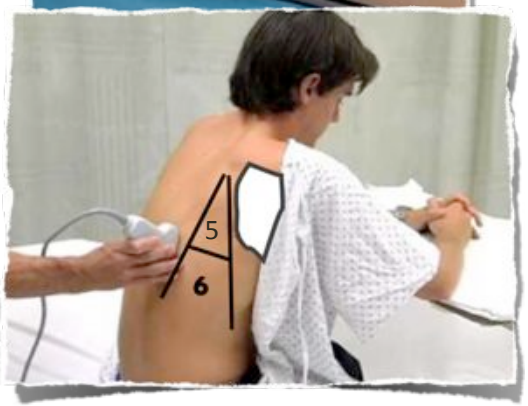
Sinus tachycardia 1.5+1.5(E/e')

Atrial fibrillation 6.5+0.8(E/e')

The E/e' included in the above calculations indicates that obtained from the medial mitral annulus.

Pulmonary Ultrasound Zones & Utility

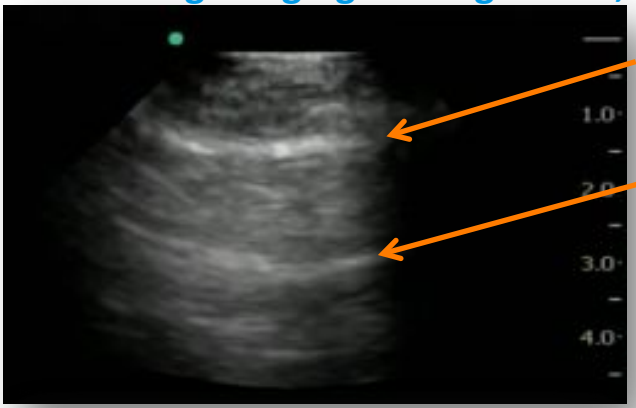




Pneumothorax: Zone 1 & 2 most sensitive in supine/semi-upright pt
Interstitial Syndrome: Zone 1-6, but cardiogenic source most likely bilateral and anterior
Pleural Effusion: Zone 4 and zone 6 most sensitive
Alveolar Syndromes: maximum sensistivity gained from full examination of all zones for pneumonia. Atelectasis most likely in zones 2, 4, 6.

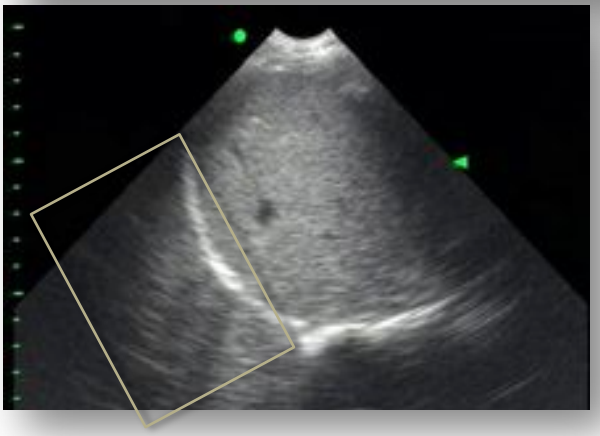
Do not need to routinely examine zones 5-6 unless you are trying to find a trace pleural effusion that was not visualized in zone 4, trying to find an occult pneumonia, or trying to quantitate the size of a pleural effusion more accurately.

Normal Lung Imaging Findings: VPPI, A-Line, Mirror Image



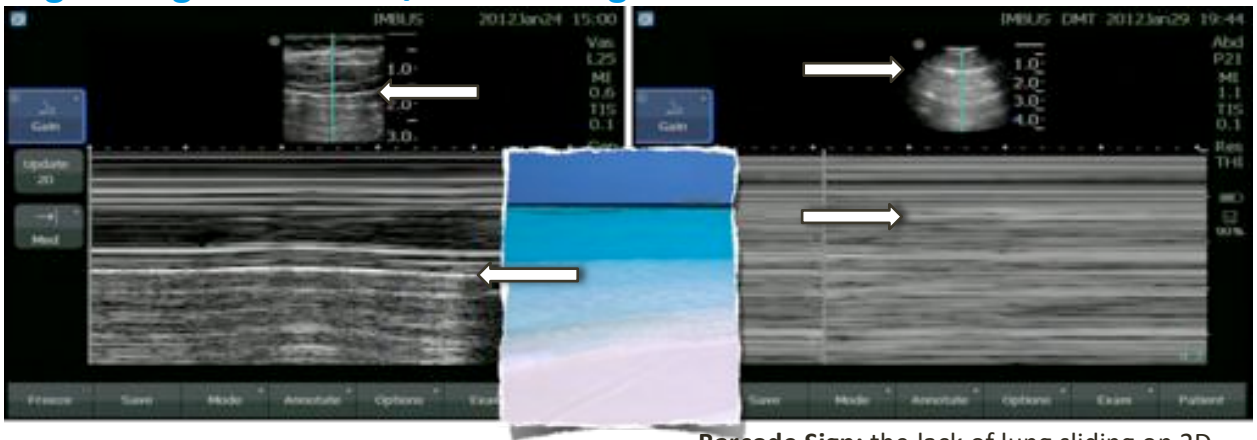
VPPI = visceral-parietal pleural interface

A-Line = represents air adjacent to the parietal pleura and is a reverberation artifact that is present both in aerated lung and pneumothorax. When absent, something that transmits US has replaced air (e.g. effusion)



Mirror Image = artifact produced as ultrasound waves moving through the liver reflect along the interface between the diaphragm and air filled lung on the cephalad aspect of the diaphragm. This occurs with the spleen and diaphragm on the left, as well as the pericardium and adjacent air-filled lung. It appears as though the solid organ is replicated on the other side of the diaphragm/pericardium.

Lung Sliding & Seashore/Barcode Signs

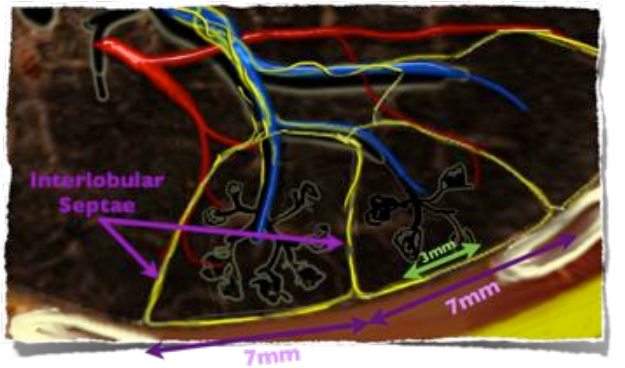


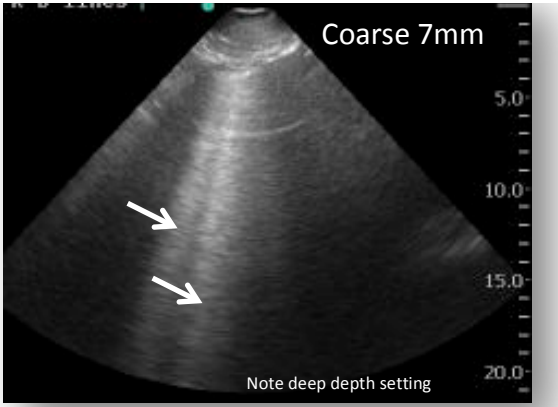
Lung Sliding: normal movement seen on ultrasound at the VPPI when pleural surfaces slide on each other. Sometimes described as “ants marching”. Structures superficial to VPPI should appear stationary and field that is deep to VPPI should show movement. This is analyzed in 2D ultrasound, but recorded with an M-mode image as above. The image on the left shows grainy motion deep to the VPPI and linear recording superficial to VPPI. This is normal and referred to as the **seashore sign**.

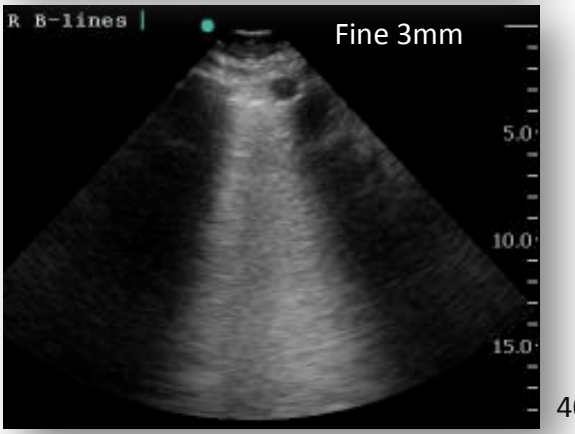
Barcode Sign: the lack of lung sliding on 2D live imaging shown as the so-called barcode sign on M-mode above represents the lack of movement at the VPPI and a stationary ultrasound field distal to the VPPI resulting in linear recordings throughout. The lack of lung sliding may represent:

- Pnemothorax
- Pneumonia, ARDS, Bullae
- Mainstem intubation
- Chest tube in place

Interstitial Syndromes & B-Lines



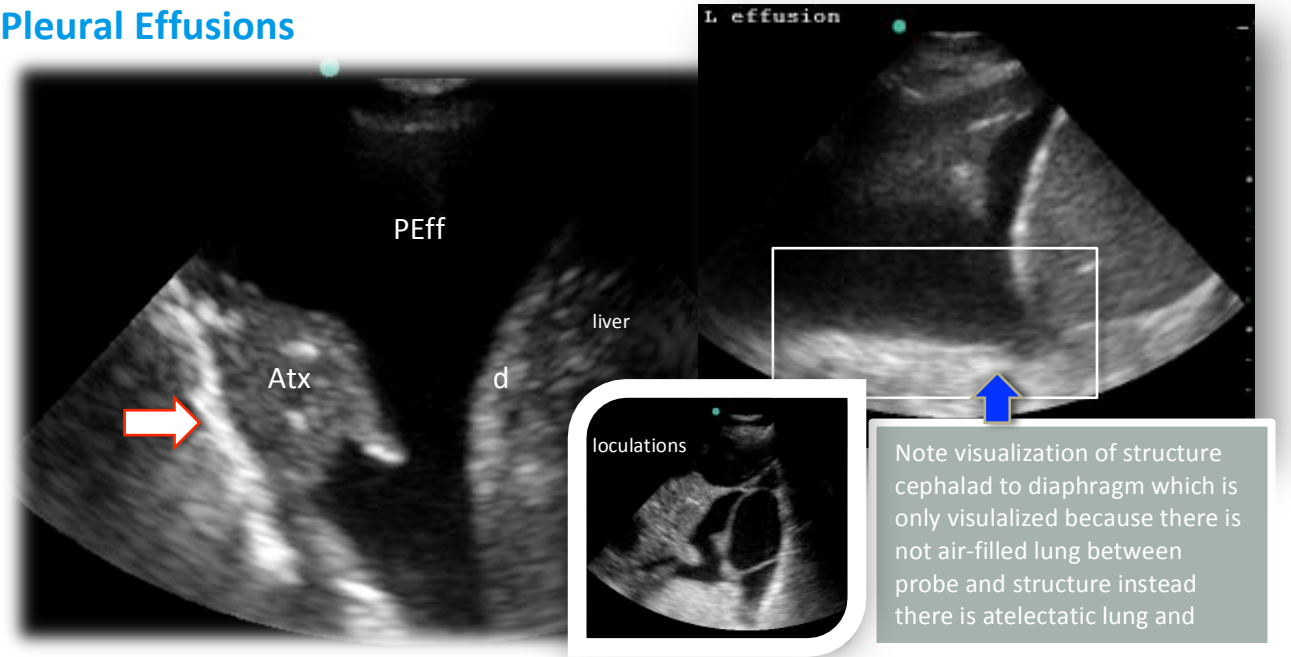




B-Lines: represent fluid or thickening of the interlobular and interalveolar septae. They can be normal if isolated to a dependent region and there are <3/interspace. They can be coarse (7mm) or fine (3mm) in nature. The latter appearing more "floodlight" in nature. Fine/floodlight B-line patterns generally represent more severe interstitial process such as severe cardiogenic pulmonary edema. B-lines are differentiated from normal "**comet-tail**" artifact that arises from the VPPI as well, in that B-lines:

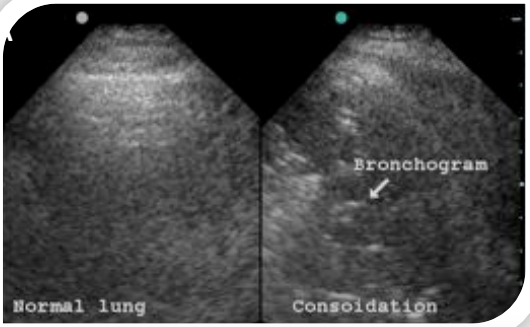
- **Extend to bottom of screen at 15-20cm screen depth**
- **Get wider as they move deep from VPPI**
- **Erase A-lines**
- **BOTH comet & b-lines move with the pleura**

Pleural Effusions



Note hypo/anechoic region (PEff) cephalad to diaphragm (d) representing fluid. The most dependent portion of the lung is atelectatic (Atx) and thus you can see the deep wall of the lung in that region. Additionally, there is a well-defined line where aerated lung meets atelectatic lung (arrow). Mirror image artifact is not present as air is not adjacent to diaphragm. Most sensitive regions are zone 4 with a fan posteriorly, and the even more sensitive zone 6 while sitting.

Alveolar Syndromes



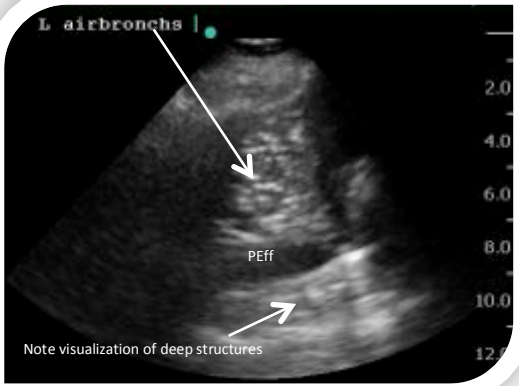
Alveolar syndromes include replacement of the air in alveoli with a fluid such as in pneumonia, atelectasis (Atx), pulmonary hemorrhage, ARDS, bronchus obstruction, etc. Thus allowing ultrasound to pass through the lung tissue, removing normal A-lines in the image. Characteristics of pneumonia include:

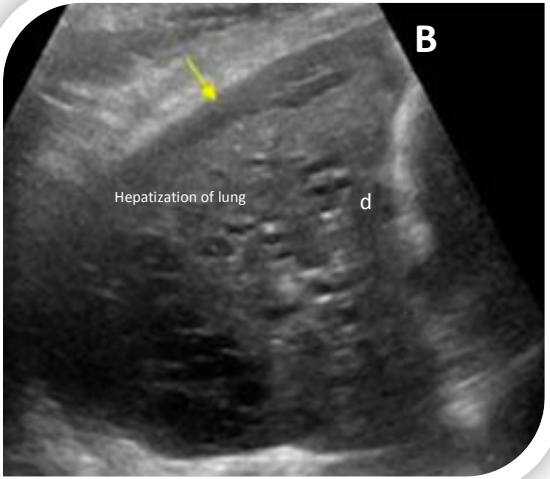
- hepatization of lung tissue (image **B**)
- dynamic air bronchograms (image **A**)

} Most specific pneumonia findings

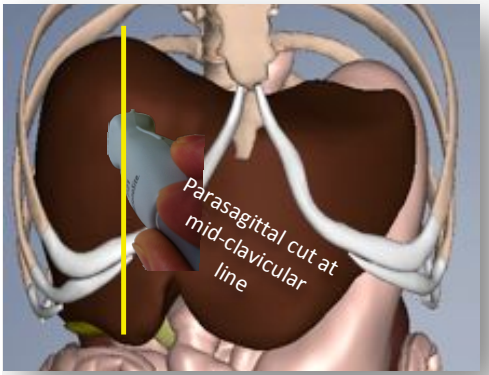
- increased vascular flow on CPD in involved lung
- irregular/serrated margins

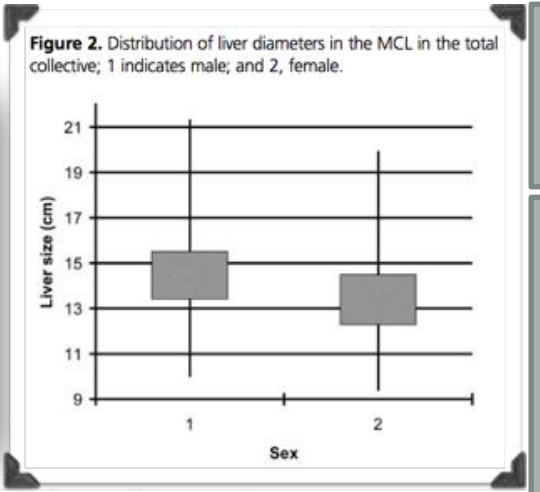
Pneumonia can be difficult to differentiate from Atx. However, Atx usually doesn't have vascular flow, usually lacks dynamic air bronchograms and has fluid bronchograms, is found dependently and frequently accompanied by a compressive cause such as pleural effusion, elevated diaphragm, etc.





Liver Measurements

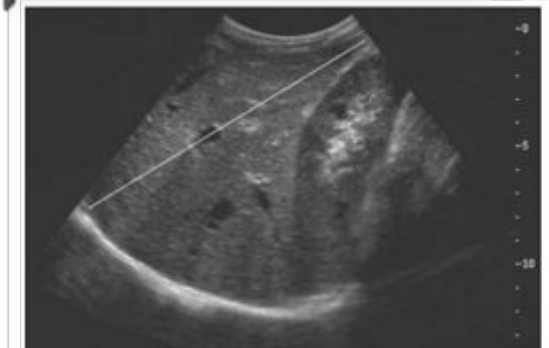


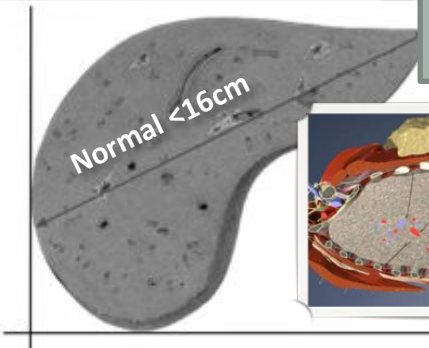


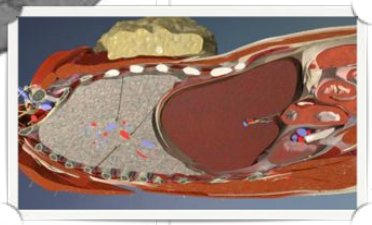
Span of **>16cm** is 87% accurate for diagnosis of hepatomegaly

Other clues to hepatomegaly:

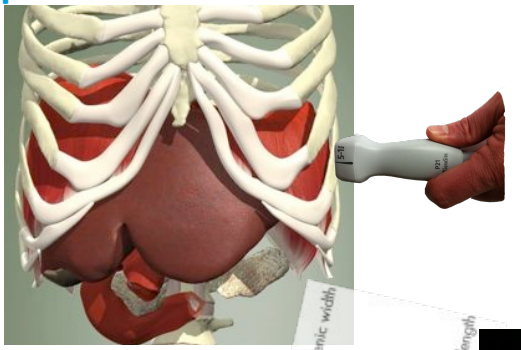
- Rounded caudal tip
- Extends caudal to inferior pole of right kidney







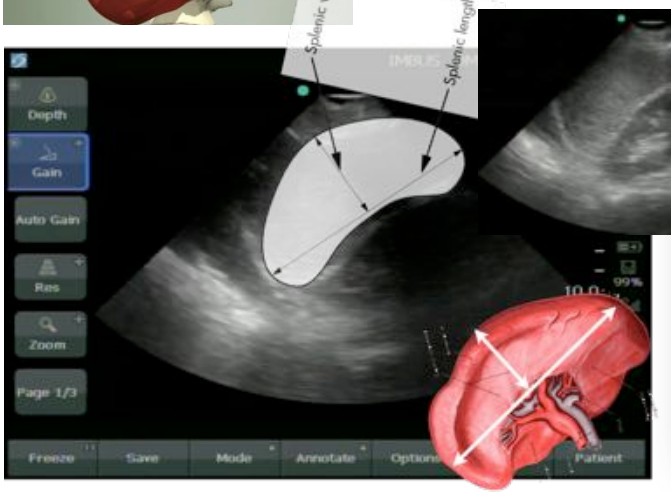
Spleen Measurements

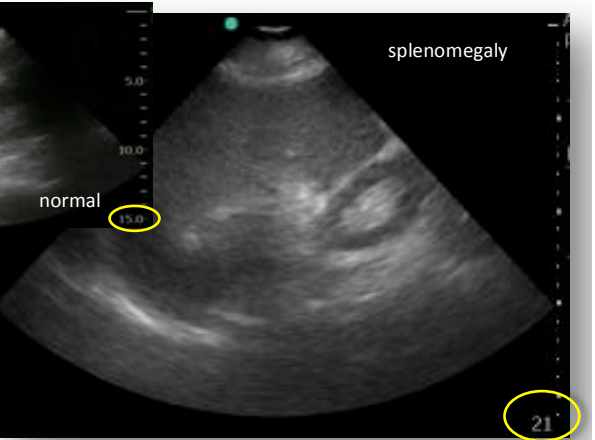


Splenomegaly is defined as length **>14cm** or width **>7cm**, however these measurements have a large range of error. Splenomegaly tends to just stand out as abnormal on ultrasound.

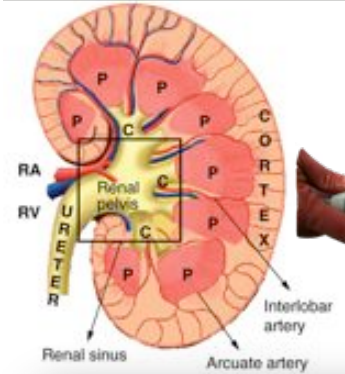
Other clues to splenomegaly:

- Medial aspect of the spleen loses its concave shape
- Extends caudal beyond inferior pole of left kidney



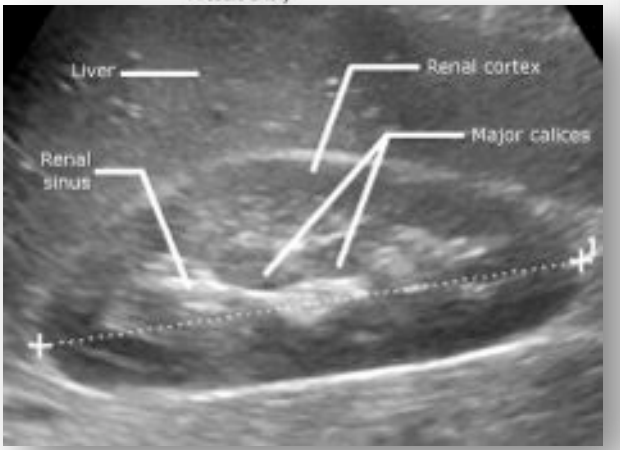


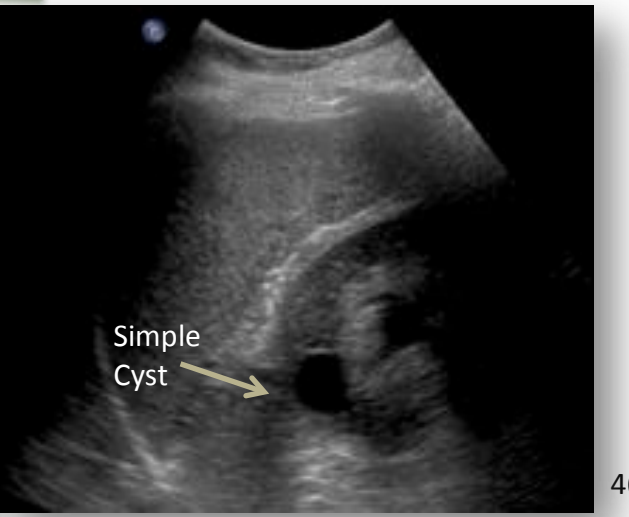
Kidney Assessment



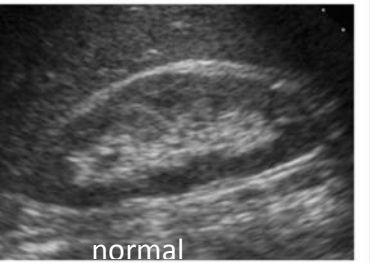
Simple Renal Cysts:

- Present in 50% of people >50yo
- Round in all projections, anechoic with posterior acoustic enhancement, arise from kidney periphery, usually single



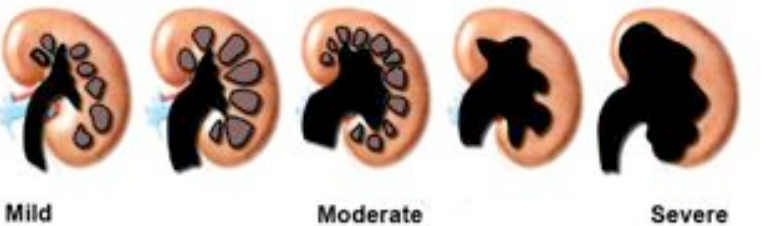


Hydronephrosis



Hydronephrosis is graded based on degree of collecting system dilation from very mild pelvis dilation (A) to dilation of the pyramids and subsequent loss of distinct cortex in severe hydro (E)

Degrees of Hydronephrosis

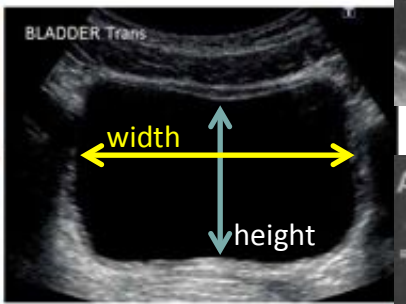


Bladder Volume Assessment

Longitudinal Bladder View

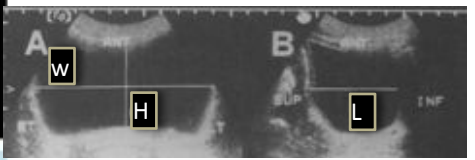
Longitudinal Bladder Image

Transverse Scan Plane

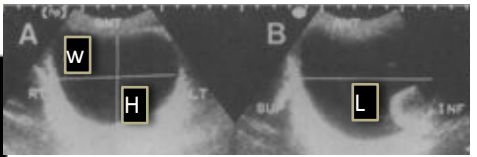


Transverse Bladder Image

Quick method is LxWxH = volume (cc). This always overestimates so if it is normal, you are done.



Cuboid = LxWxH x 0.**89**



Elipsoid = LxWxH x 0.**81**

Prism = LxWxH x 0.**66**

Peritoneal Free Fluid

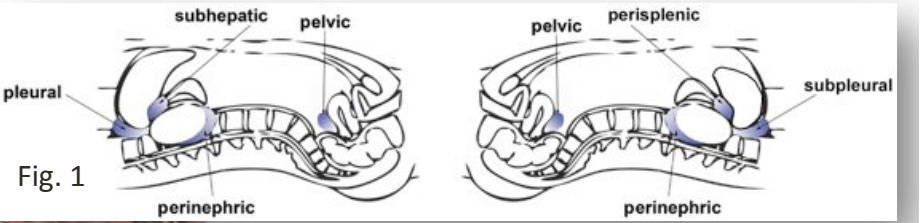


Fig. 1

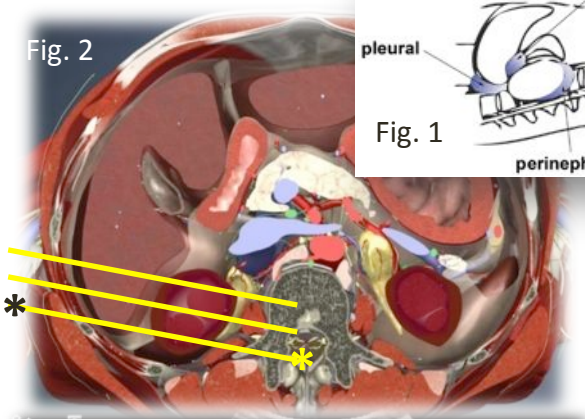


Fig. 2

Fluid in Morrison's pouch

There are several "high sensitivity" locations for picking up free peritoneal fluid (Fig. 1). The sensitivity in any of these locations is improved by positioning the patient such that the location is dependent. Morrison's pouch view and the spleno-renal location must include evaluation for fluid at the lower pole of the kidney as well. In addition, the ultrasound plane of cut should be through the most dependent part of the potential space as marked by * in Fig. 2. This is best achieved by placing the probe in a coronal orientation at the posterior axillary line and fanning posterior until the kidney passes out of plane.

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