CAEP | ACMU

# ROADSHOWS

Emergency Department Targeted Ultrasound

## Two Day Introductory & Scanning Program

Module 1 - Physics
Module 2 - Aorta
Module 3 - Cardiac
Module 4 - OB
Module 5 - FAST
Module 6 – CVC

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# Physics, Instrumentation and Image Generation

## Learning Objectives

- To understand how ultrasound is generated and transmitted and how it produces an image
- To recognize and understand the reasons for ultrasound artifacts
- To learn about the various types of transducers and transducer placement basics
- To define and understand common terminology

## Introduction

This reason of having the learners of EDTU to understand basic physics is because it is vital to have this knowledge in order to understand how images are generated and to enable manipulation of these images.

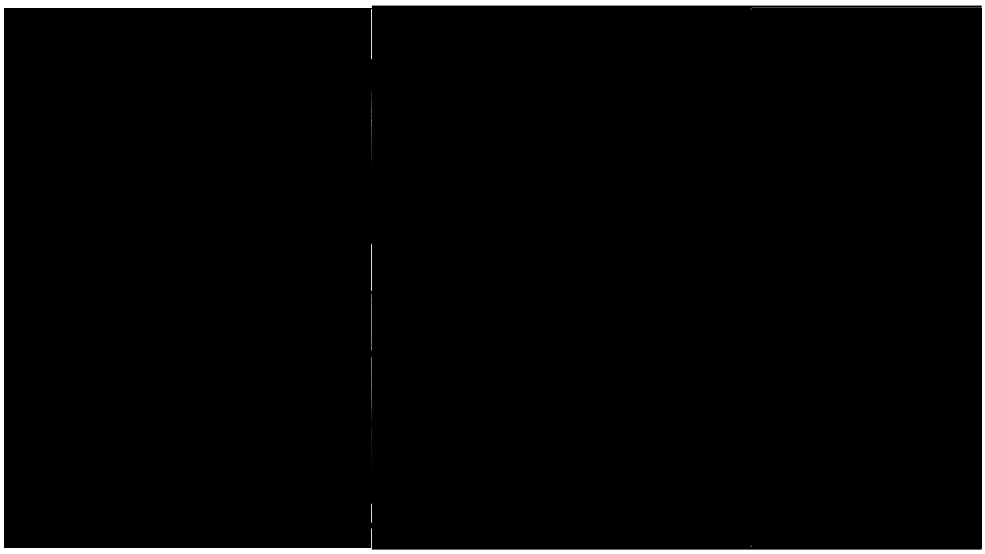
## Terminology and definitions

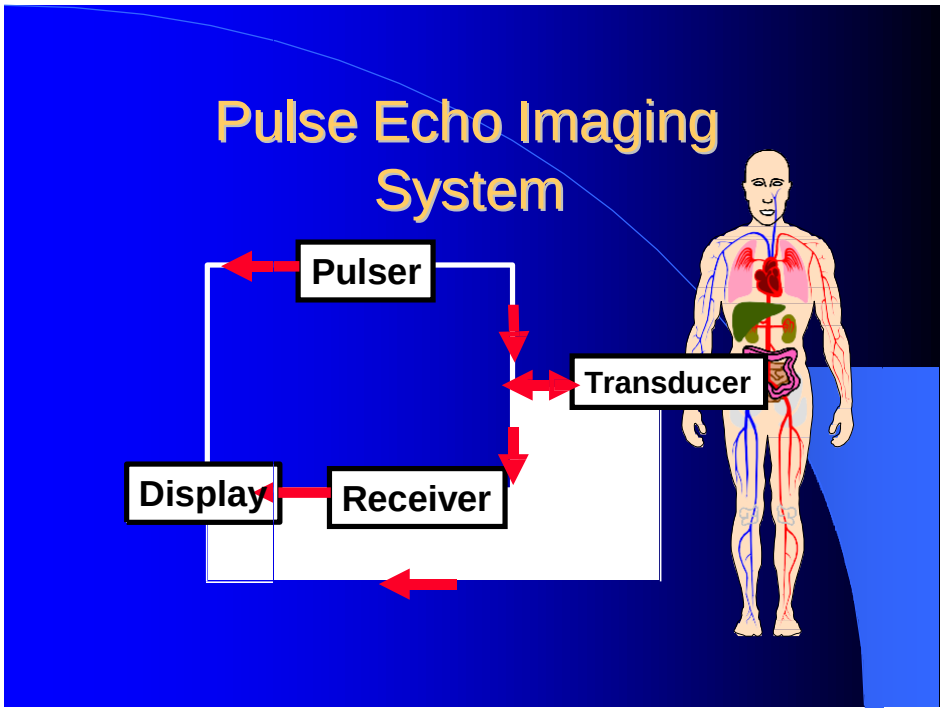
**Acoustic Power (Output)**
The ultrasonic energy emits from the ultrasound transducers is referred to as the Acoustic Power or Output. Increasing acoustic power, in general, improves image quality. Most machines have default acoustic power which is set at a level that is considered to be the safest level for tissue. Tissue heating and cavitation are the main biologic adverse effects with high acoustic output.

**Ultrasound**
As the name implies, ultrasound is simply very high pitched (frequency) sound which cannot be heard by human beings.

**Piezoelectric Effect**
Phenomenon that occurs when crystalline material vibrates at a given frequency when an alternating current is applied – crystal expands and contracts
Generates the ultrasonic wave impulse through a “pressure electric effect”
Conversely, the crystal will generate an electric current when an external ultrasonic wave hits it
- crystal acts as both speaker and microphone

**Probe ⬜Speaker and receiver**






**Frequency and Wavelength**
Sound travels in longitudinal waves. The frequency of the sound is how many of these waves (cycles) appear per second.

**Relationship of Frequency, Penetration and Resolution**
Ultrasound (US) represents those frequencies (expressed as Hertz (Hz), or cycles per second) above human hearing. Typical frequencies used for diagnostic US are between 2 – 10 MHz.

| Frequency (MHz) | Type of Imaging |
|---|---|
| 2.0 – 3.5 | Echocardiography |
| 3.0 – 5.0 | Abdominal |
| 5.0 – 10.0 | Transvaginal |

The distance traveled during one cycle is called a wavelength.

The higher the frequency, the shorter the wavelength. Picture quality or resolution improves with higher frequency and the imaging depth decreases.

$$\text{Frequency} \propto \frac{1}{\text{Wavelength}}$$

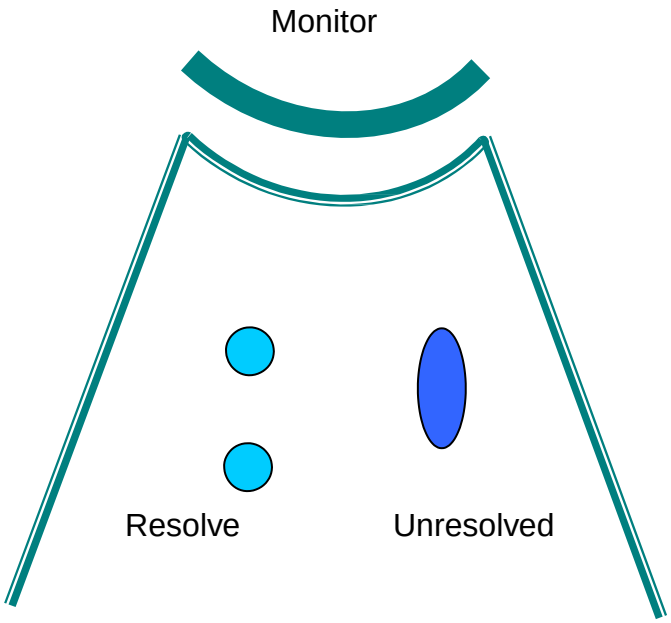
As **frequency** increases, **penetration** decreases and **resolution** increases and vice versa.

**Example:** The increased penetration (depth) necessary for abdominal organ visualization often requires the use of a lower frequency probe with some loss of resolution.

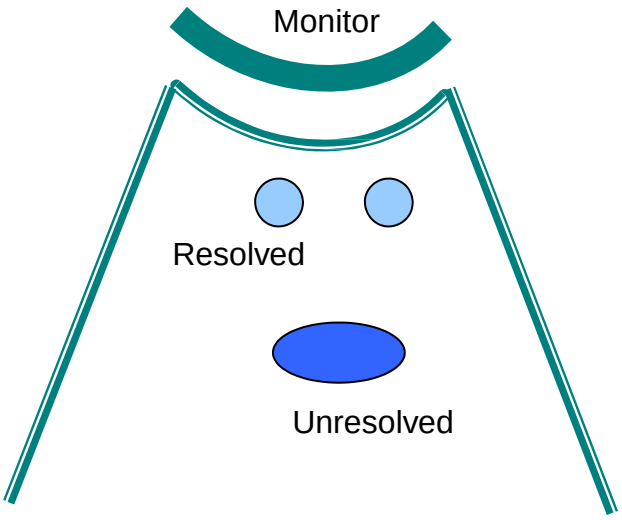
**Image Resolution**
Resolution here means quality of the image.

**Axial resolution** is the ability of US to delineate between two different objects, one on top of the other and is most dependent on frequency.

High frequency transducers have better axial resolution but lower penetration. Low frequency transducers have less axial resolution but better tissue penetration.




**Lateral resolution** is the ability to differentiate two closely spaced objects that are positioned perpendicular to the direction of the beam and therefore depends on the beam width and focal zone. The focal zone is usually in the middle of the screen, and that is where the region of interest should be adjusted to in order to improve lateral resolution.



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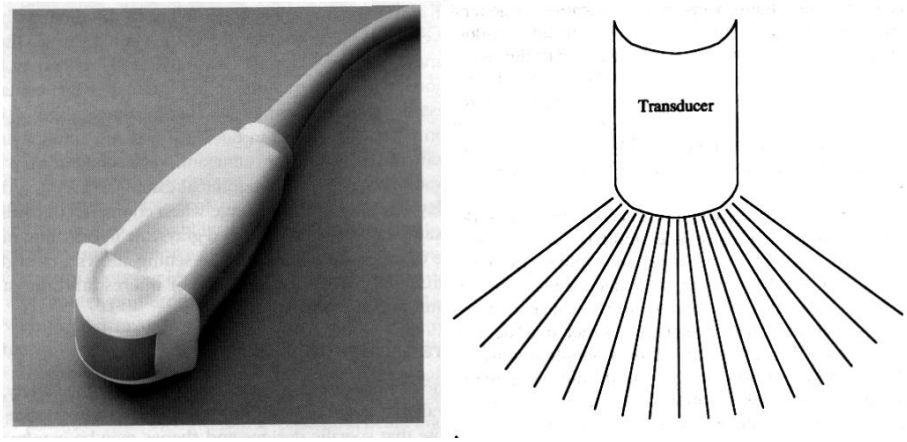
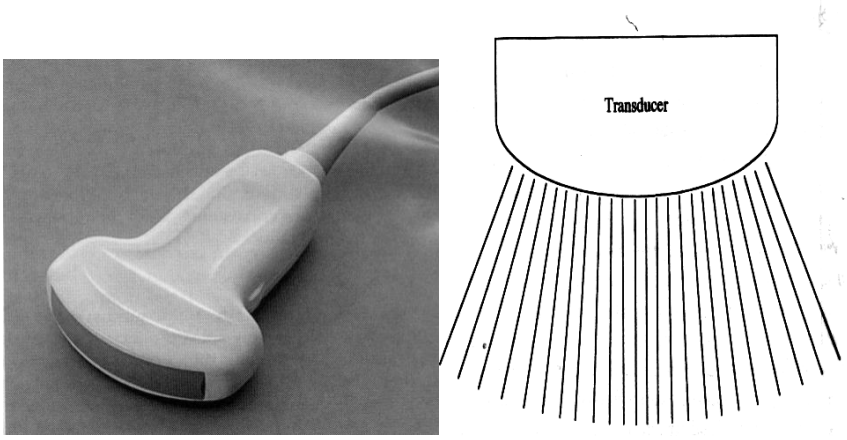



The greater distance from the probe, the less lateral resolution.




Beam distally is not as divergent ◆ better lateral resolution.

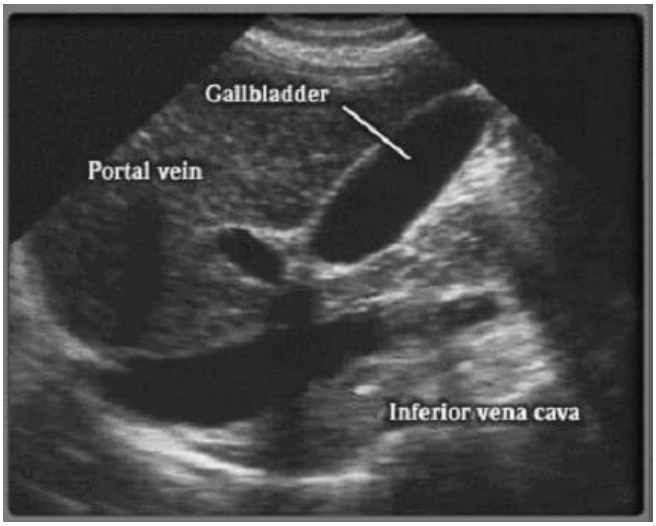
## Ultrasound Properties

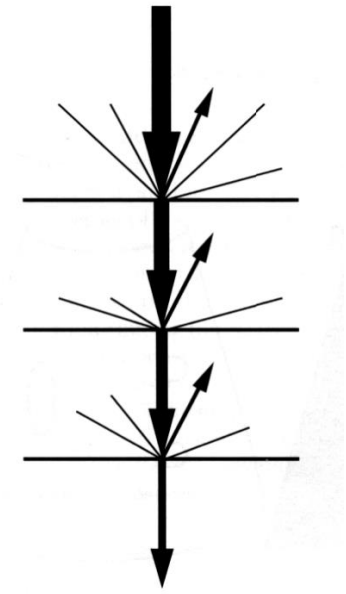
- Interfaces
- Attenuation
- Scatter
- Reflection

**Interfaces**
Different tissue types have different Acoustic Impedances which refers to the resistance of the tissue to molecular movement and is directly related to tissue density.

An Interface is said to occur when sound penetrates two adjacent tissue planes having different acoustic impedance.

How strong (intense) the ultrasound is reflected is dependent upon how great the density difference between tissues. Therefore, a small density difference (acoustic impedance) results in small echo being generated and vice versa. This is the sole reason why diagnostic ultrasound is not able to penetrate through bowel gas or bone because of too great a difference in acoustic impedance exists between these types of interfaces and the surrounding tissue.

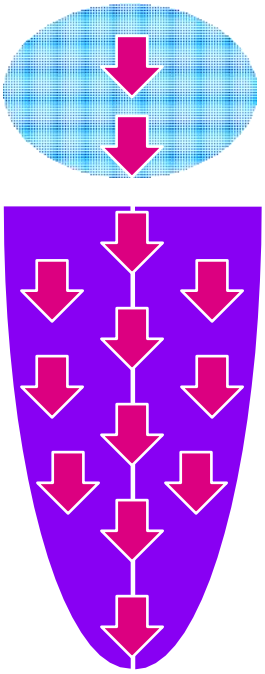


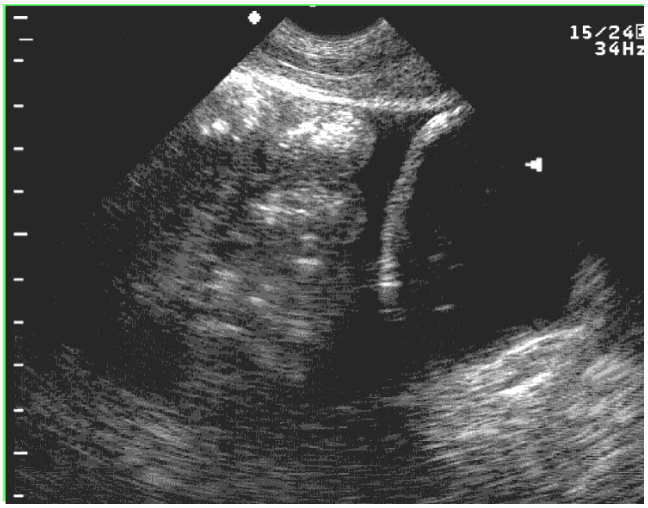



**Attenuation**
The loss of energy when ultrasound waves pass through a medium is a process named attenuation.

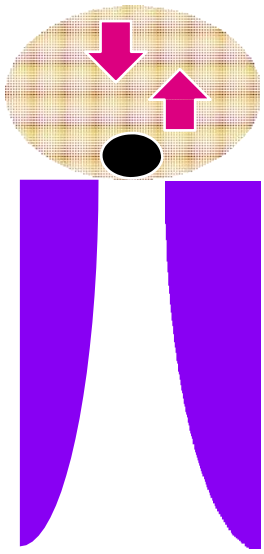
Attenuation is the process in which loss of energy takes place when US waves travels through different mediums. The rate of attenuation is determined by the type and density of tissue and the number of interfaces that the waves pass through.

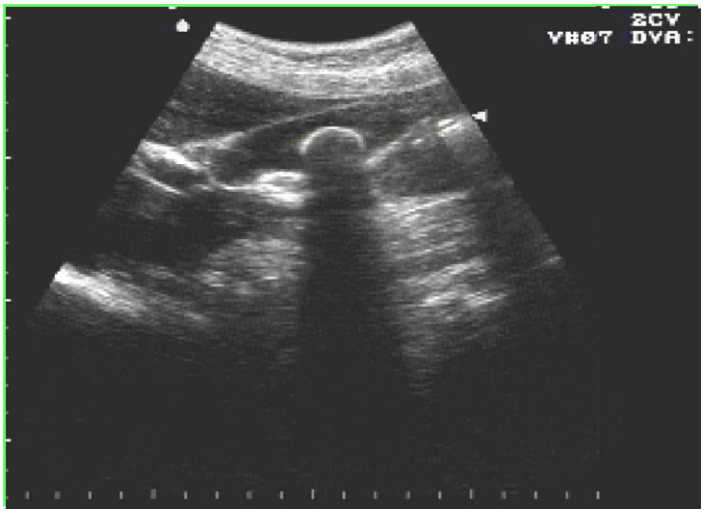
Low Attenuation:
When sound encounters low attenuating tissue, echoes are enhanced posteriorly. May be used as a “window” to visualize anatomy.





High Attenuation:
When sound encounters high attenuating tissue, echoes are diminished posteriorly and an acoustic shadow is presented.



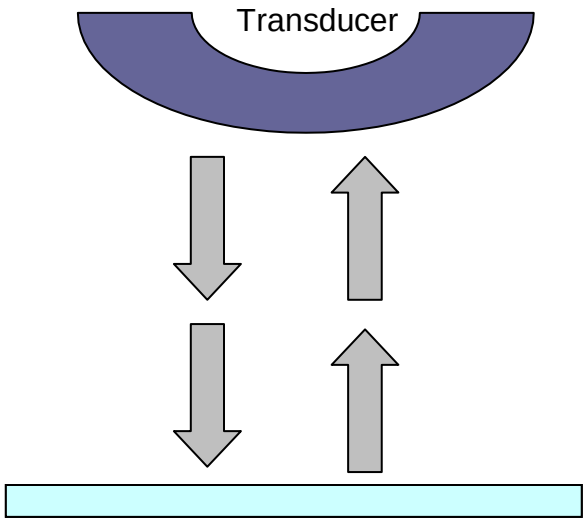



**Attenuation also occurs in the following ways:**

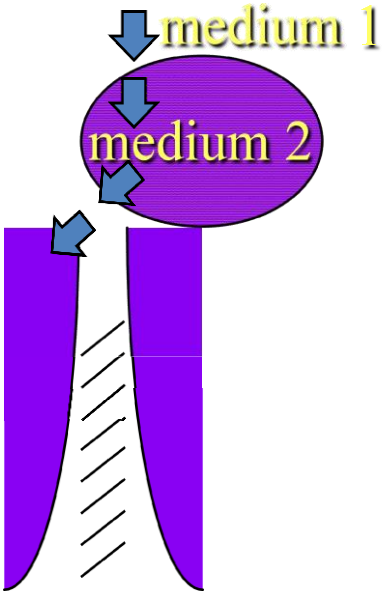
- Reflection
- Refraction
- Scattering
- Absorption

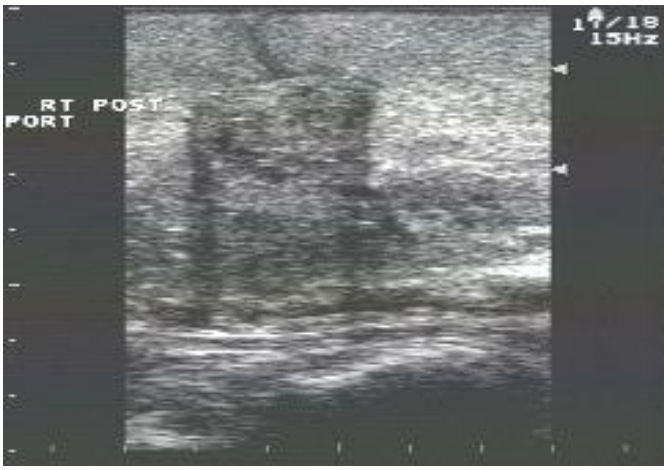
**Reflection**
Reflection is the redirection of part of the sound wave back to its source. This is the foundation on which ultrasound scanning is based. It is the sound that returns to the transducer, which produces an image on the screen.

The intensity of the reflection is determined by how much of a density difference exists between the tissues in contact. For example: It is easy to detect a blood /solid organ interface because of their high density differences.




**Refraction**
The redirection of part of the sound waves as it crosses a boundary of two different mediums describes this phenomenon. It appears as an edge artifact when sound crosses a boundary of tissue with different propagation speeds.

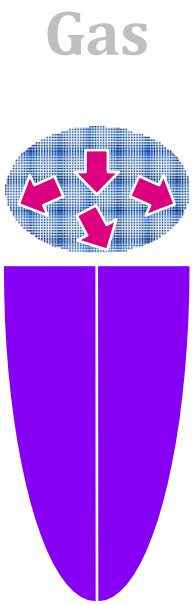


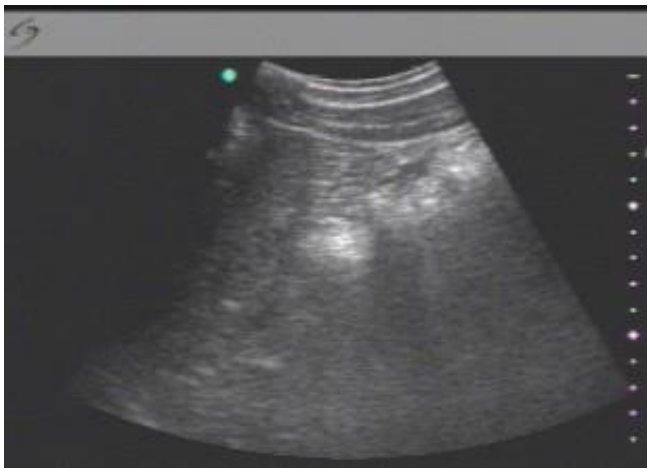



**Scattering**
This phenomenon occurs when the sound beam encounters an interface that is smaller than the sound beam in this case, the gas molecule.

Scatter is the reflection of sound off objects that are irregular or smaller than the US beam (e.g. Gas)

When Sound encounters air, much of the signal is lost to scatter and obstructs visualization of the anatomy posteriorly.

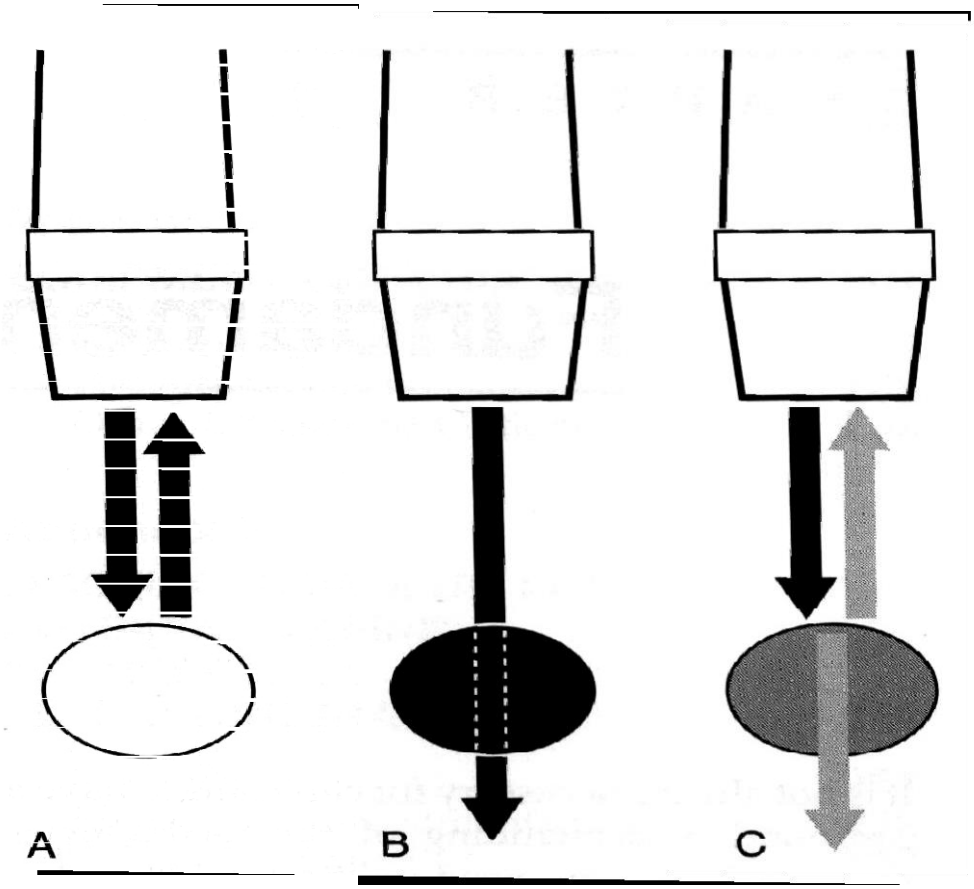


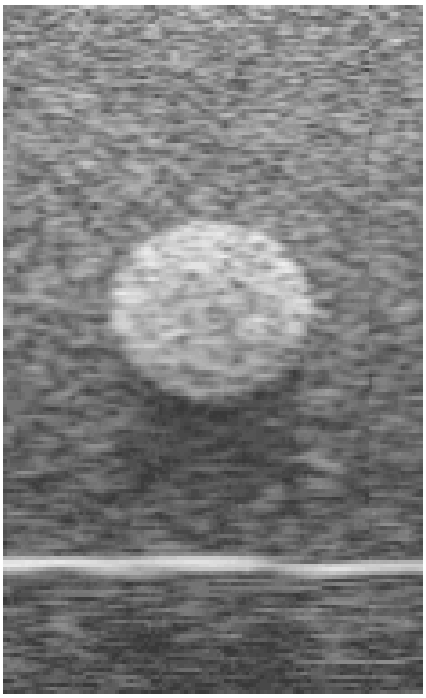
**Absorption**
This occurs when acoustic energy is converted to thermal energy and absorbed by tissue. This form of ultrasound attenuation is the foundation of therapeutic ultrasound.

Attenuation by absorption plays no role in diagnostic ultrasonography.

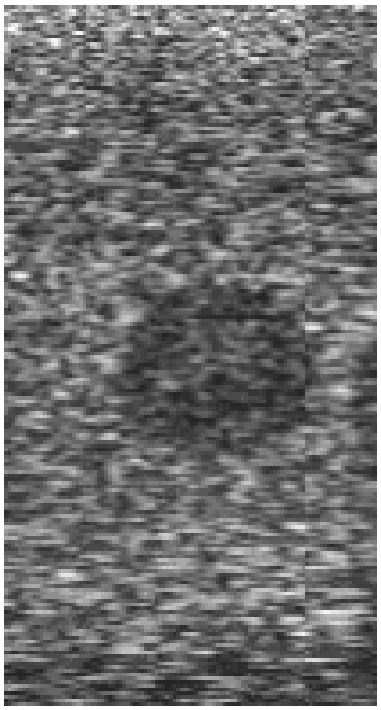
**Echogenicity**
The echogenicity of tissue refers to the amount and character of the sound waves that are reflected from it.



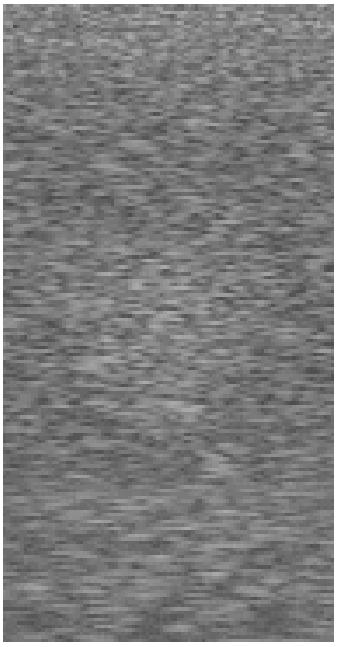

| | | |
|---|---|---|
| Hyperechoic | - | more echogenic. |
| Hypoechoic | - | less echogenic. |
| Isoechoic | - | same echogenicity as the surrounding structures. |
| Anechoic | - | the absence of echoes. |



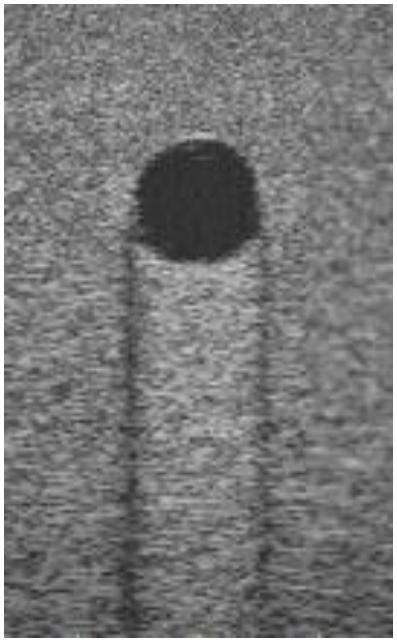
Hyperechoic



Hypoechoic



Isoechoic

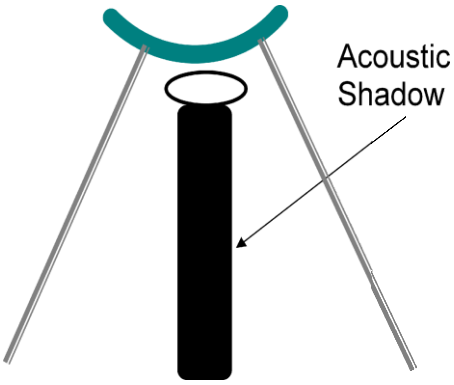


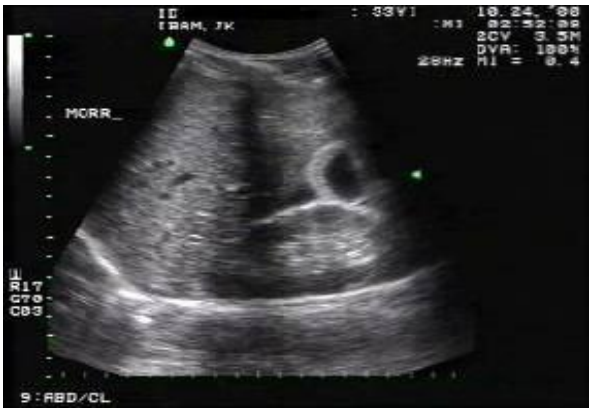
Anechoic

## Artifacts

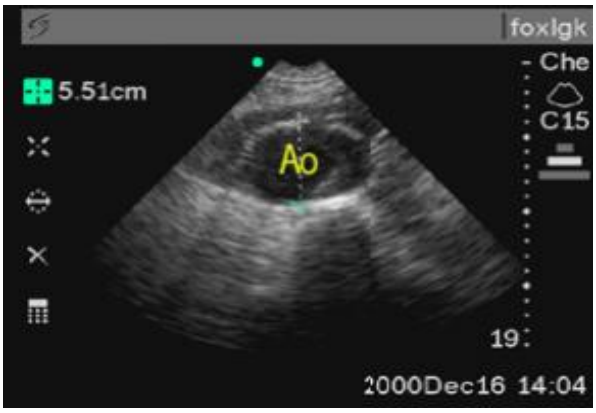
### Shadowing

When sound encounters a high attenuation object or surface, an Acoustic Shadow is generated.

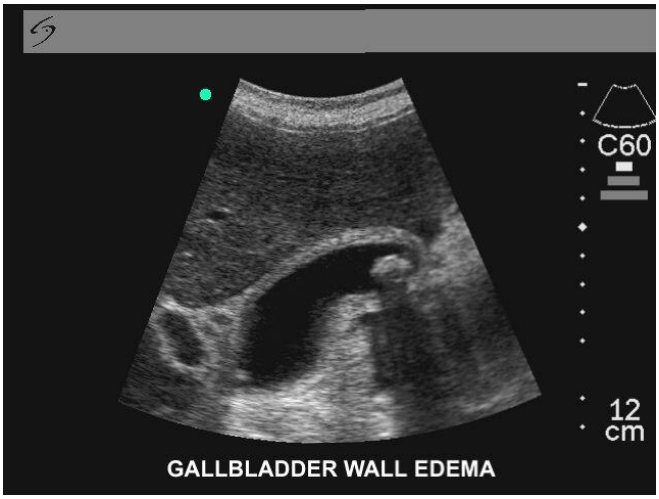



Shadow produced by a rib.



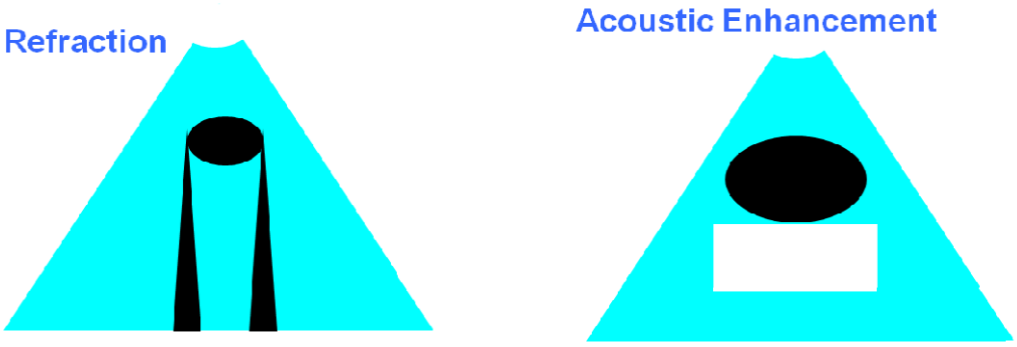

Shadow produced by the spine.

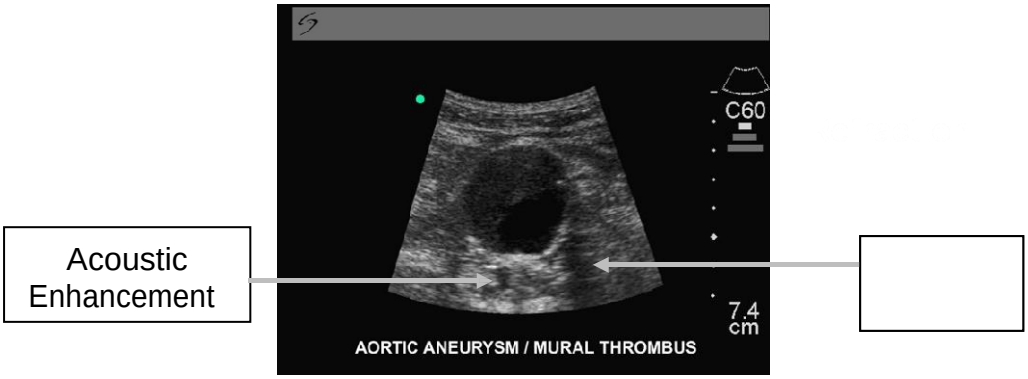



Shadow produced by a gallstone.

**Acoustic Enhancement**
When sound encounters a low attenuation object or surface, acoustic energy is enhanced or increased and continues its path

**Refraction**
As described previously in this chapter.

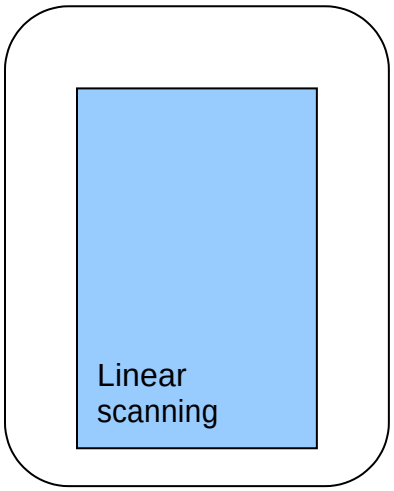


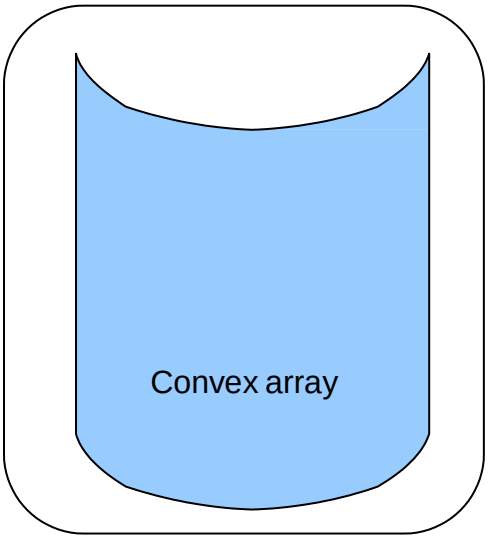
## Transducers

There are two basic real-time ultrasound scanning formats: linear and sector.

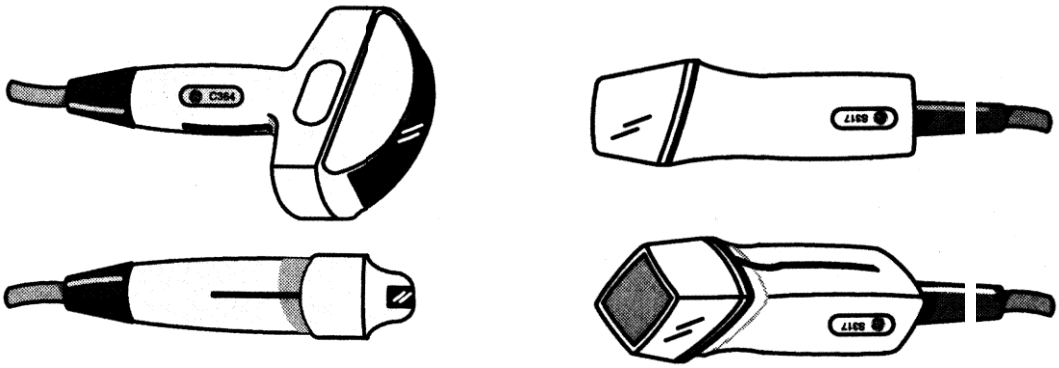
The **linear format** produces a rectangular field of view. Linear probes give better resolution for objects close to the probe. Example: Vascular probe.



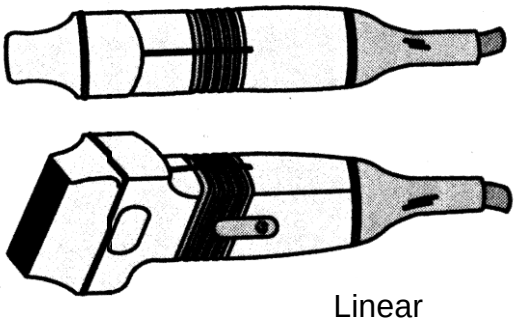

The **sector format** produces a pie-shaped image. Sector probes have a surface that conforms to body surface irregularities and gives a more consistent image. Example: Abdominal probe.



Have the piezoelectric elements linearly aligned and sequentially activated to produce an image. (this is not to be confused with linear scanning format).



Convex array



Linear

**Transducer modes**

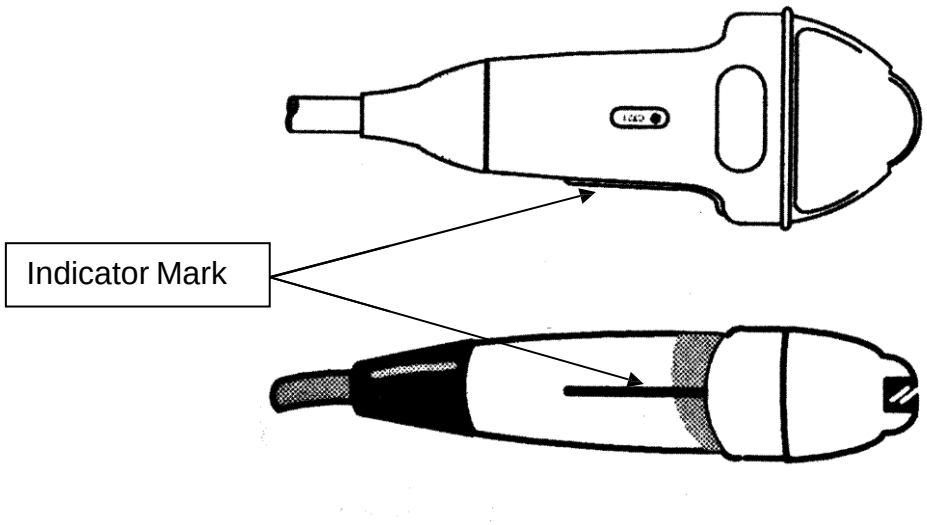
A mode = amplitude
B mode = brightness (brilliant)
C mode = motion
D mode = dopples

For emergency department ultrasound imaging, the most relevant mode is ‘B’ mode or ‘brightness’ in which reflected waveforms are converted into an anatomically recognizable image. The image generated may display up to 256 shades of gray, allowing visualization of subtle differences within tissues.

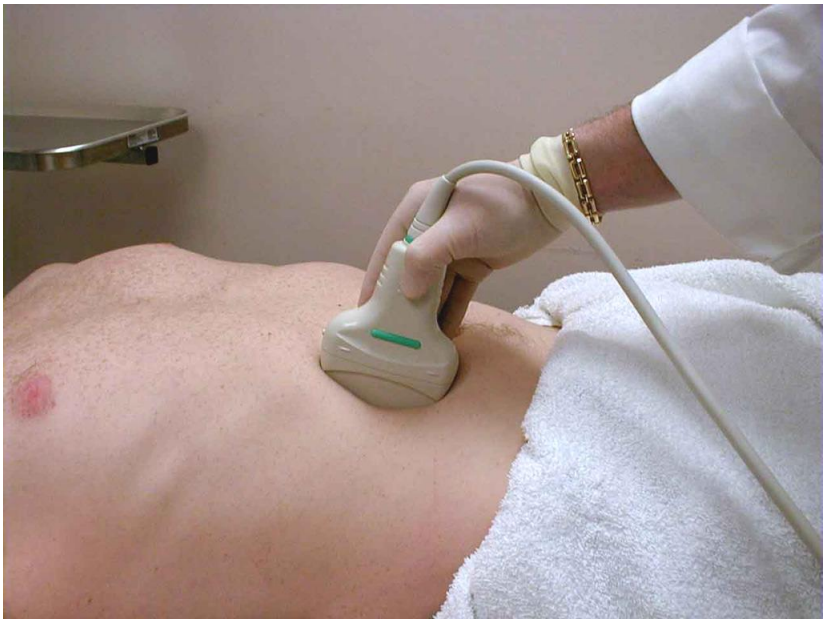
**Transducer Orientation**

Which way is up or right:

An indication mark is always placed on the probe handle surface. This identification mark is to be oriented with a corresponding identification mark located on the image display monitor.

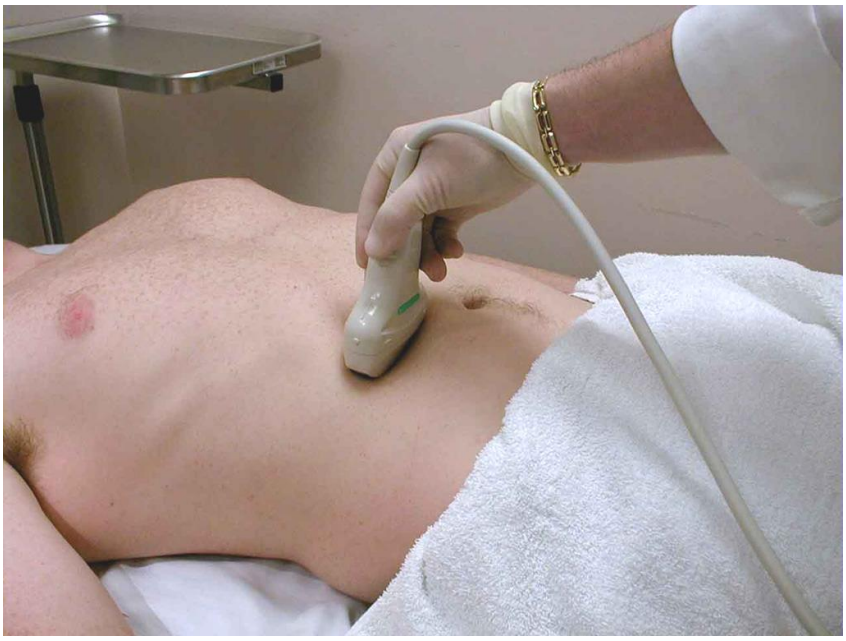



**Longitudinal (sagittal) plane**



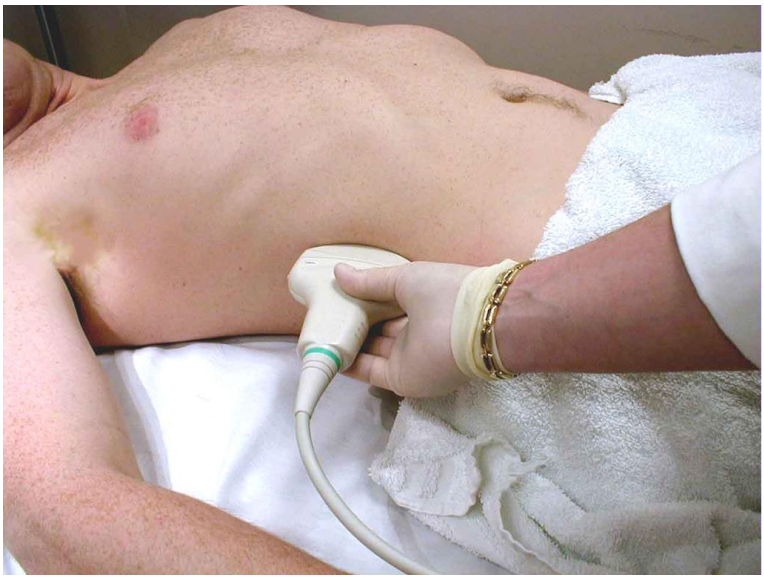
Sagittal Plane divides the body's left and right halves.

## Transverse (axial) plane



Transverse (axial) plane divides the body's superior and inferior halves.

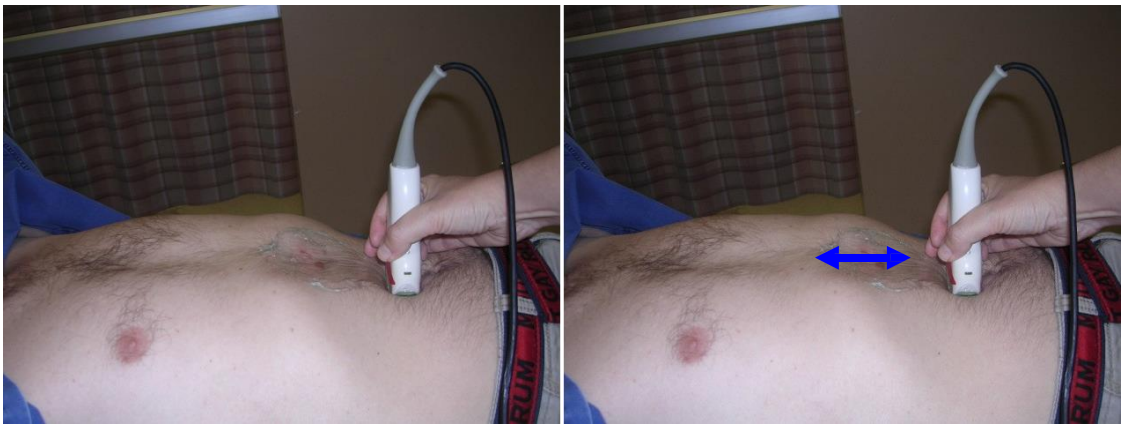
## Coronal plane



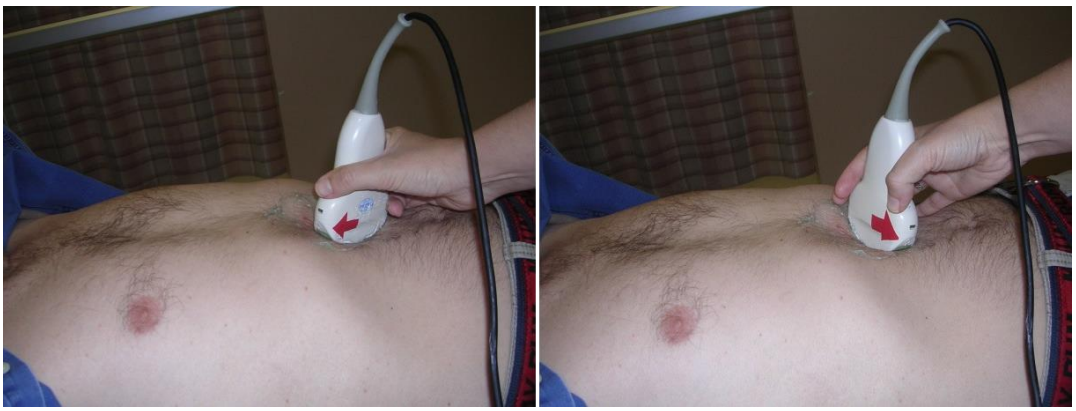
Coronal plane divides the body in anterior and posterior halves.

## Probe skills

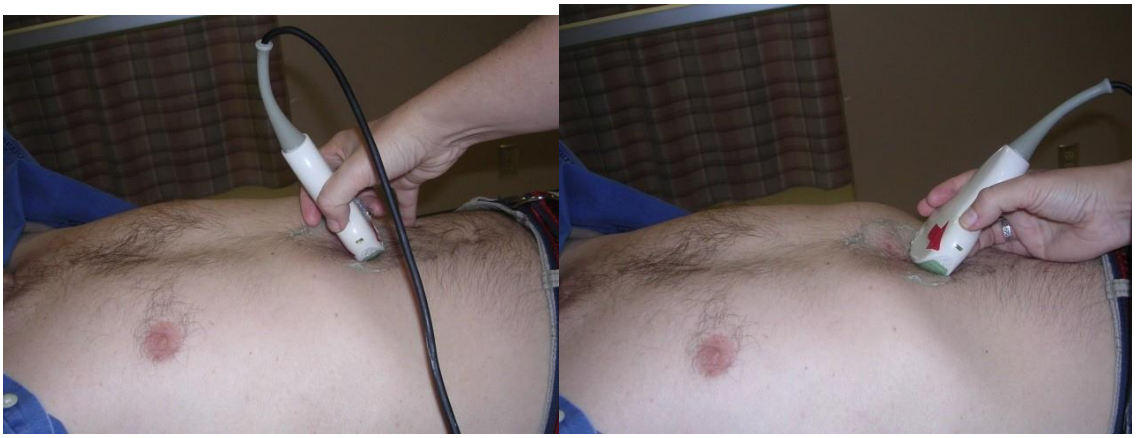
• Sliding — moving the probe on the skin while maintaining a perpendicular angle to the skin.



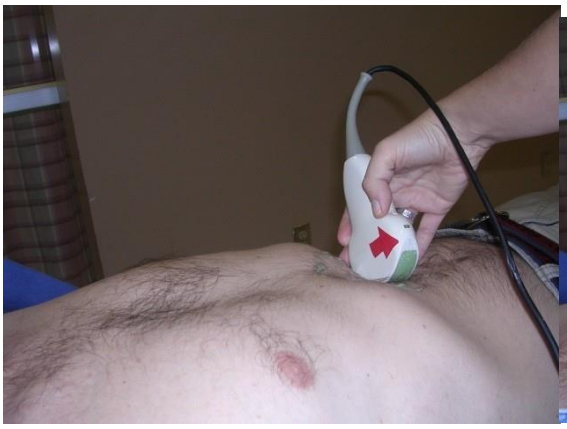
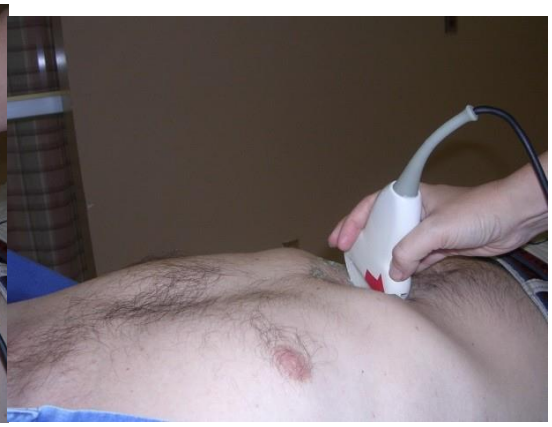
• Spinning — turning the probe on the skin, so that the indicator moves between the 9 o'clock and 12 o'clock positions or vice versa. (Provides longitudinal and transverse views of the same structure.



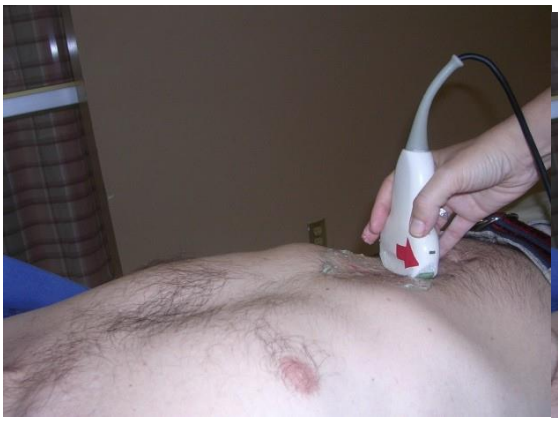
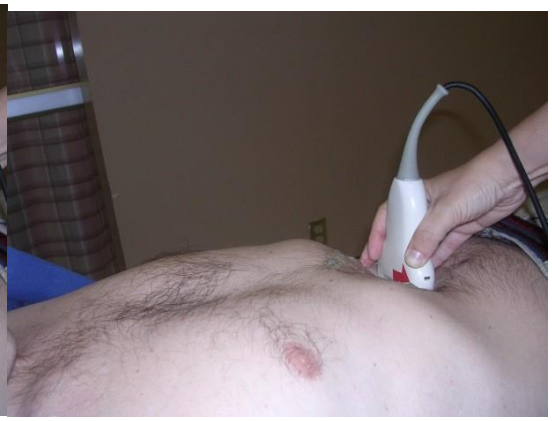
• Fanning — keeping the probe in the same location on the skin and changing its angle relative to the skin. (This is useful for visualizing the aorta bifurcating and generally giving a wider survey through a limited window. It may falsely enlarge structures (see "tangent effect" in the Aorta Chapter).



• Rocking — pronating or supinating the hand holding the probe. Also gives a wider view through a limited window.

• Compression — applying pressure to the probe to compress the structures below to displace gas or improve viewing conditions.

## Image Generation and Modification

Much of the techniques in Image Generation and Modification will be taught at the bedside practical session in the course.

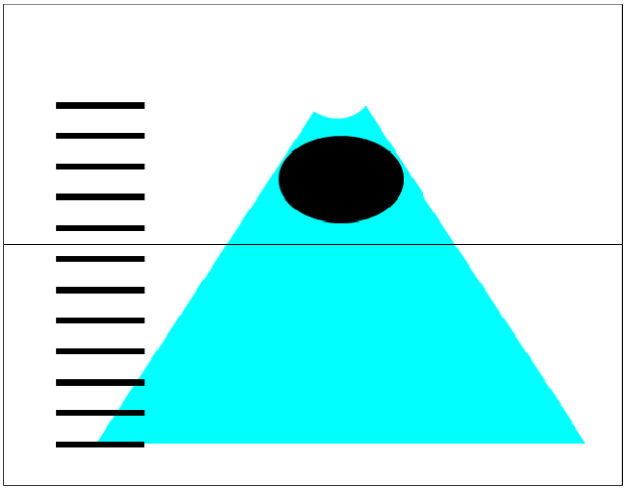
Knowledge of the basic knobs required:

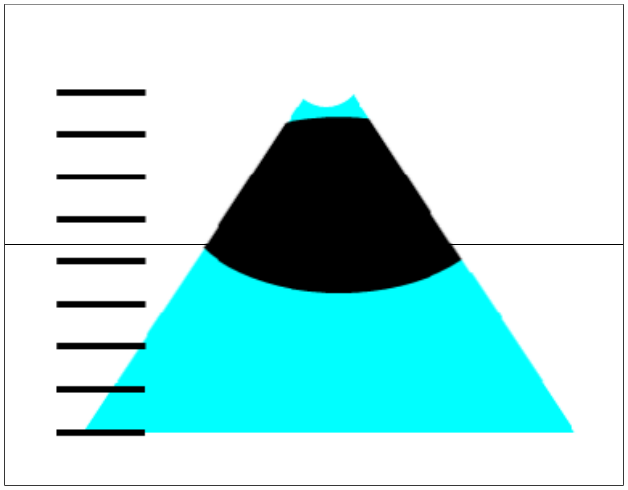
- Power
- Depth
- Gain
- Measure/Calipers
- Zoom
- Cine
- Select

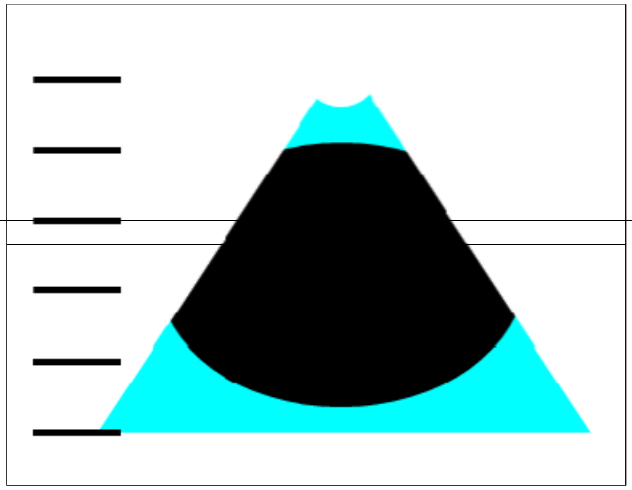
The importance of “Depth” and “Gain” will be discussed here.

**Depth**
It is recommended that a novice ultrasonographer should always start scanning with maximum depth setting. This will allow you to find your object of interest much easier.

Once the object of interest is found, you can decrease the depth to gain resolution and improve the quality of the image.

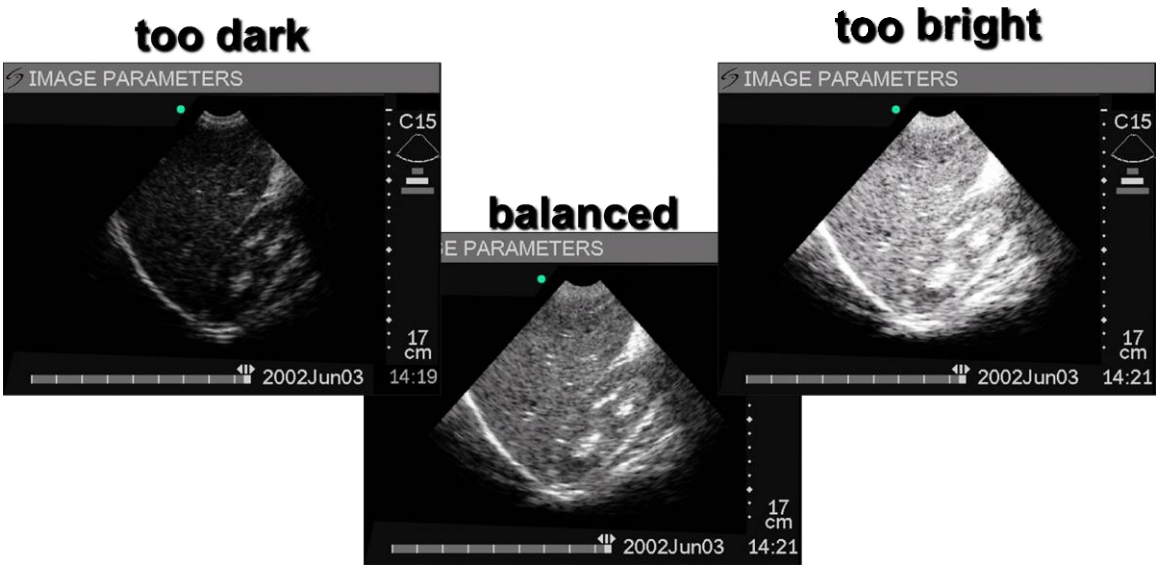






**Gain**

Gain can be adjusted to modulate the received echo signal. Increasing gain will allow more incoming echoes received and image looks brighter. Gain settings are important to obtaining adequate images.




By adjusting the overall the Gain control.

## Conclusion

This chapter provides the basic information about ultrasound physics, instrumentation and image generation. With this basic knowledge, physicians will understand how ultrasound can be an effective tool in emergency department targeted imaging.

## References and suggested reading


Ma OJ, Majeer JR (editors) *Emergency ultrasound* New York: McGraw-Hill; 2003: chapters 2 and 3.

Simon BC, Snoey E *Ultrasound in Emergency and Ambulatory Medicine* St. Louis: Mosby; 1997: chapter 2.

Brooks A, Connolly J, Chan O, *Ultrasound in Emergency Care* Blackwell Publishing Limited; 2004: Chapters 1, 2, and 3.

Heller M, Jehle D *Ultrasound in Emergency Medicine* W. B. Saunders Company; 1995: Chapter 1.

Rumack C, Wilson S, Charboneau J. *Diagnostic Ultrasound* Mosby Yearbook; 2007: Volume 1: Part 1, Chapter 1.

# The aorta

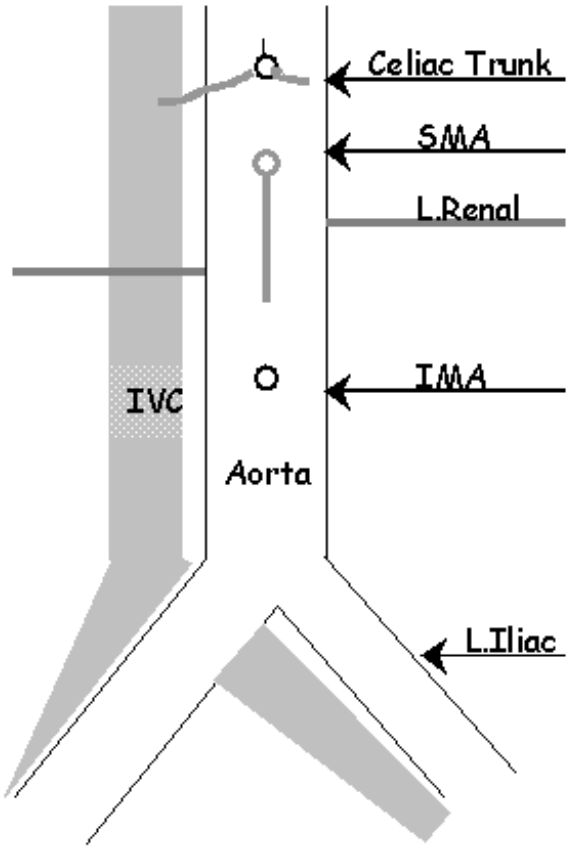
## Learning objectives

- To review the basic anatomy and pathophysiology of the aorta.
- To name the indications for ultrasound evaluation of the aorta.
- To learn the ultrasound landmarks used to reliably identify the aorta and the measurements that define abdominal aortic aneurysm.
- To know when a scan is indeterminate.
- To learn techniques to overcome difficult scanning conditions.

## Introduction

Even to the most experienced physician, the abdomen is a mystery at times. In the hypotensive patient who is unable to give any history, ruptured abdominal aortic aneurysm (AAA) has always been part of the differential diagnosis, but until the advent of bedside ultrasound, we have had no easy way to confirm or rule out this diagnosis. AAA lends itself well to bedside investigation, because these patients are semi-stable at best and, to survive, they need quick diagnosis and referral. In this chapter, we discuss the anatomy, pathophysiology, and ultrasound technique for evaluating the aorta.

## Clinical anatomy

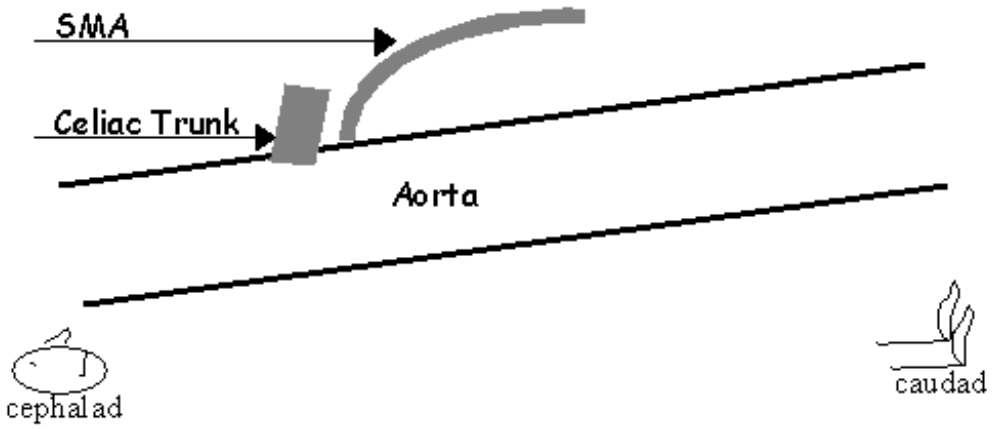



The abdominal aorta runs in the retroperitoneum from the diaphragm to the level of the umbilicus, where it bifurcates into the iliac arteries. It lies anterior to the spine and usually to the left of the inferior vena cava. As it courses distally, it tapers and becomes more superficial. The normal external diameter of the aorta is 2 cm proximally and 1.5 cm distally; in women, the maximal diameter is somewhat smaller at 1.8 and 1.4 cm, respectively.

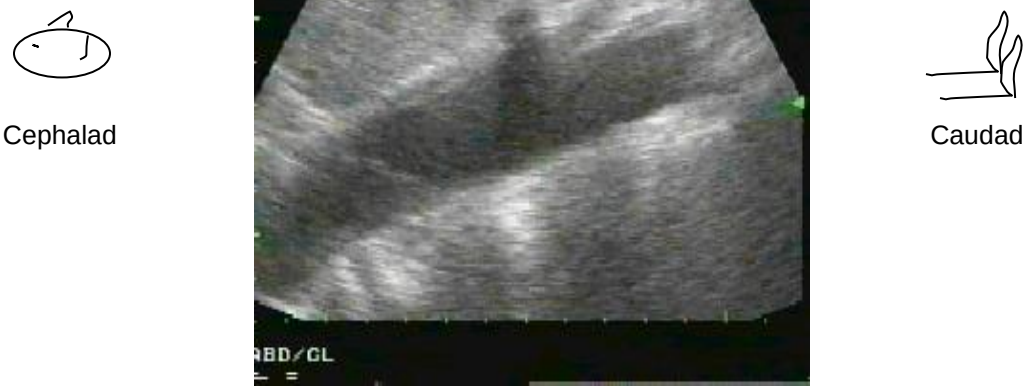
The abdominal aorta has several branches, some of which can be seen on ultrasound (Figures 1 and 2). Fortunately our only focus is the aorta itself, and it is not important or necessary to identify the branches.

**Figure 1. Anatomy of the aorta.**

**Figure 2. Longitudinal view of aorta.**




**Longitudinal view on ultrasound.**



## Abdominal aortic aneurysm

### Pathophysiology

True aneurysms occur when collagen and elastin formation is disrupted in the middle layer of the aortic wall, with subsequent dilatation and weakening of the vessel (Figure 3). By definition, an aneurysm exists when the external aortic diameter is 3 cm or more, or 1.5 times the diameter of the proximal segment. Most are fusiform or spindle-shaped, although saccular aneurysms also occur (Figure 4).

**Figure 3. True versus pseudo-aneurysm.**

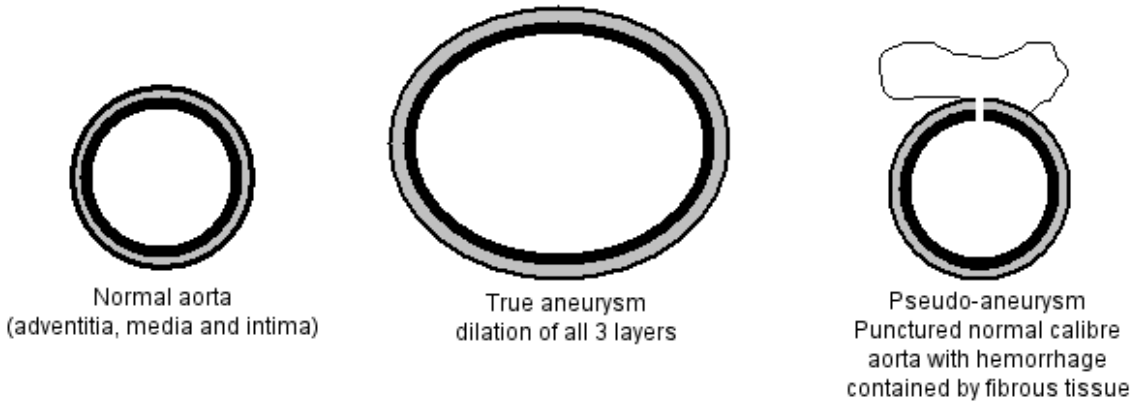
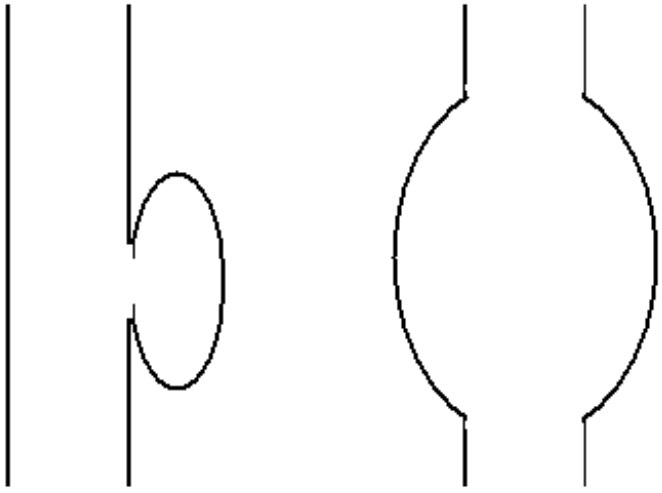



**Figure 4. Types of aneurysms: saccular (left) and fusiform (right).**



Aneurysms usually form below the origin of the renal arteries; approximately 40% will extend into the iliac vessels. The natural history is progressive enlargement, at a rate of 0.2–0.4 cm a year, followed by rupture and fatal hemorrhage. The likelihood of rupture is directly proportional to size of the aneurysm: 2% a year when the diameter is 4–5 cm, 10–20% a year at 5–7 cm, and 30% a year if the diameter is over 7 cm. The usual site of

rupture is the left retroperitoneum, which allows some containment and tamponade of hemorrhage. Free intra-abdominal rupture occurs 10% of the time, but patients rarely survive this. Once rupture occurs, mortality is 90%, with many patients dying before they reach hospital.

**Epidemiology**
Abdominal aortic aneurysms are rare before the age of 50 and become more common with increasing age; the average age of presentation is 75 years. In men over 65 there is a 5–10% incidence and, interestingly, aneurysms are approximately 7 times more common in men than women. The incidence of AAA seems to be increasing, although this may be due in part to improved diagnosis with better technology. Risk factors include smoking, occlusive peripheral vascular disease, family history of AAA, connective tissue disorders, trauma, infection and arteritis.

**Clinical picture**
*Intact aneurysms:* These are usually asymptomatic, but may be associated with a dull flank or abdominal ache. Occasionally compressive symptoms (femoral neuropathy or obstructive uropathy) or peripheral emboli may occur. Aneurysms are often incidentally discovered on ultrasounds or computed tomography (CT) scans obtained for another indication.

*Ruptured aneurysms:* The classical presentation is hypotension, back, flank or abdominal pain and a pulsatile mass, which occurs in approximately 30% of cases. Patients may also present with leg or groin pain, syncope, unexplained weakness or cardiovascular collapse. Onset is typically sudden, but may also be more gradual over many hours or days. Typically, patients are unaware of their aneurysm and, in any case, may be too unstable to give any history. Physical examination is notoriously unreliable because body habitus and patient discomfort may limit palpation of the aneurysm; hypotension and calcification diminish its pulsatility.

**Radiologic evaluation**
A calcified aneurismal aorta may be obvious on plain films, but the sensitivity is 50% or less. CT scan accurately illustrates the size and location of the aneurysm and whether it is intact or ruptured. The main drawback of CT is that it also stands for “certain termination,” and unstable patients are far from the relative safety of the emergency department. Further, CT dye may impair renal function. Magnetic resonance imaging (MRI) is very sensitive and accurate but not widely available and, again, removes the patient from the emergency department to a place where cardiovascular monitoring and resuscitation are difficult.

**Use of ultrasound**
Ultrasound is accurate for the diagnosis of AAA, with a sensitivity approaching 100%. Formal, radiology-based ultrasound holds little advantage over CT or MRI for unstable patients, because they still leave the emergency department. However, bedside ultrasound allows us to answer the question, “Does this patient have an AAA?” in a timely fashion, without the need for the patient to leave the resuscitation area. It is a quick, easy to learn test that, when positive, speeds up the patient’s definitive care and, when negative, allows us to entertain other diagnoses.

There are, of course, some limitations. Ultrasound is more affected by gas and body habitus than CT, and the aorta may not be adequately visualized. In this case, the scan

is indeterminate and aneurysm cannot be ruled in or out. Ultrasound is also poor for detecting rupture, because retroperitoneal blood is hard to see. Fortunately, we can overcome this by combining our clinical findings (i.e., symptoms and signs compatible with rupture) with an ultrasound-proven aneurysm, to reasonably assume that rupture has occurred.

**Where is the evidence for emergency department targeted ultrasound (EDTU)**

1. Do we miss AAA? In a 1992 retrospective study of 152 patients subsequently diagnosed with ruptured AAA, approximately 30% were misdiagnosed initially with the following diseases: renal colic, diverticular disease and gastrointestinal bleeds (Marston 1992). Hopefully with increased awareness of AAA this is occurring less often nowadays.

2. Can emergency physicians perform EDTU? There are many studies aimed at this question. A recent systematic review looked at 7 studies evaluating Emergency physicians' ability to diagnose AAA using EDTU, in 655 patients. The pooled sensitivity was 99% (95%CI 96-100) and specificity 98% (95%CI 97-99) (Rubano, 2013)
3. Does EDTU change outcomes? This is perhaps the most important question and yet not much researched. A small explicit chart review of 63 patients showed that when EDTU was available, the time to OR was 83 minutes (95% CI 53–113 minutes) compared with 182 minutes without EDTU (95% CI 114–250 minutes). In addition, the length of hospital stay was reduced from 27 days (95% CI 6–43 days) to 18 days (95% CI 10–26 days) with the use of ultrasound (Sierzenski et al. 2004).
4. Should we be screening patients for AAA? (either in ED or at family doctors' offices)
   This has been researched quite deeply in about 140 000 patients, prompting a Cochrane review, and a practice guideline from the Society of Vascular Surgery. The evidence seems to say that yes, one time US screening for AAA reduces AAA-related mortality and trends toward improved all cause mortality. The data is more compelling in men than women. The current guidelines are to screen all men over 65; men over 55 with a family AAA history; and women over 65 who either have a significant smoking history or family history of AAA. (MASS Study, Lancet 2002; Cosford, 2007; Chaikof, 2009)

**Treatment**
All patients with a ruptured AAA should be referred to a surgeon immediately for evaluation. Although the operative mortality is about 50%, surgery is the only chance these patients have to leave the hospital alive. Nonetheless, some patients and families may decline in favour of comfort measures.

In asymptomatic patients, elective repair is usually not carried out until the AAA diameter is 5–5.5 cm, because the 5–10% risk of surgery is higher than the risk of rupture. These patients are followed every 6 or 12 months with ultrasound.

## Clinical indications for bedside ultrasound evaluation of the aorta

Bedside ultrasound answers the question:

> "Does this patient have an AAA?"

Remember that we cannot use it to diagnose rupture — this is where the clinical picture comes in.

It is indicated in all patients over the age of 50 with:

- Back, flank, abdominal, or leg pain
- Unexplained weakness, syncope, hypotension, or cardiovascular collapse

Also consider scanning patients under the age of 50, who have significant risk factors (family history, peripheral vascular disease, connective tissue disorders) and any of the above presentations.

## Ultrasound technique

The goals of the examination are to identify the aorta, view it in its entirety, and measure its anterior–posterior diameter. All of this can be done transversely. The longitudinal view is useful to confirm findings, and it makes early, subtle dilations more obvious.

## Probe skills

- Sliding — Moving the probe on the skin while maintaining a perpendicular angle to the skin (Figure 5).
- Spinning — Turning the probe on the skin, so that the indicator moves between the 9 o'clock and 12 o'clock positions or vice versa (Figure 6). Provides longitudinal and transverse views of the same structure.
- Fanning — Keeping the probe in the same location on the skin and changing its angle relative to the skin (Figure 7). This is useful for visualizing the aorta bifurcating and generally giving a wider survey through a limited window. It may falsely enlarge structures (see "tangent effect" in the next section).
- Rocking — Pronating or supinating the hand holding the probe (Figure 8). Also gives a wider view through a limited window.
- Compression — Applying pressure to the probe to compress the structures below to displace gas or improve viewing conditions (Figure 9).

**Figure 5. Sliding. Maintain the probe perpendicular to the skin while sliding.**

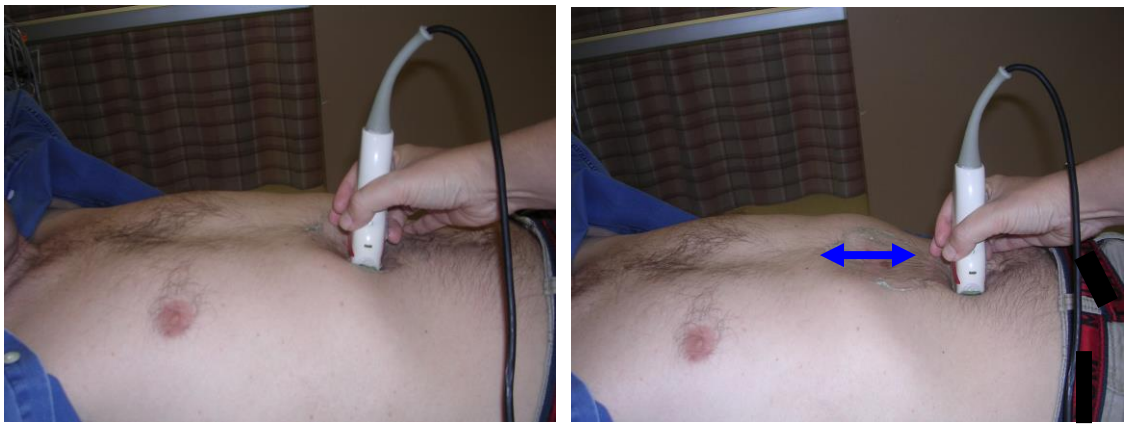


**Figure 6. Spinning. Spin the probe between the 9 and 12 o'clock positions to alternate between transverse and longitudinal views.**

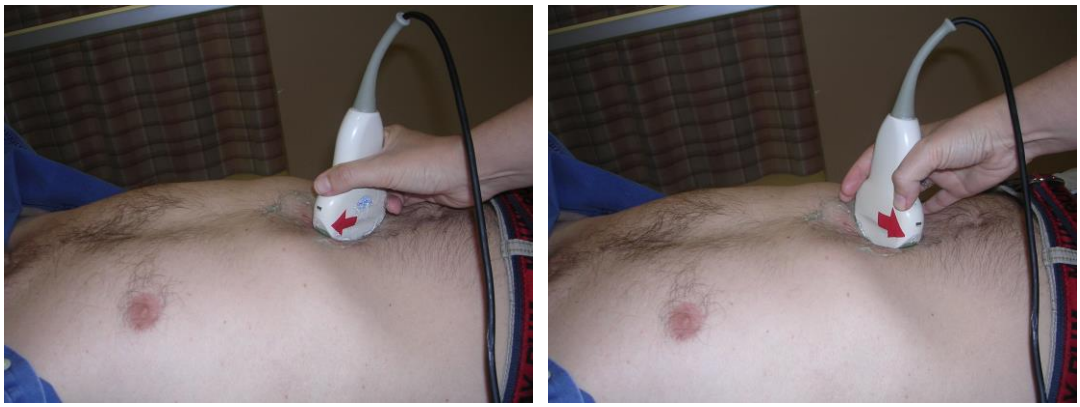


**Figure 7. Fanning. Use this motion to completely survey an area.**

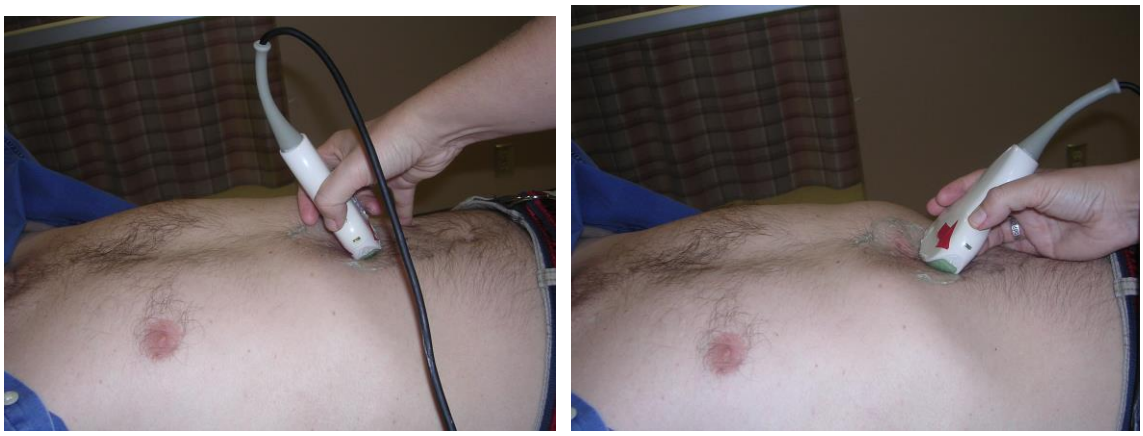


**Figure 8. Rocking.**

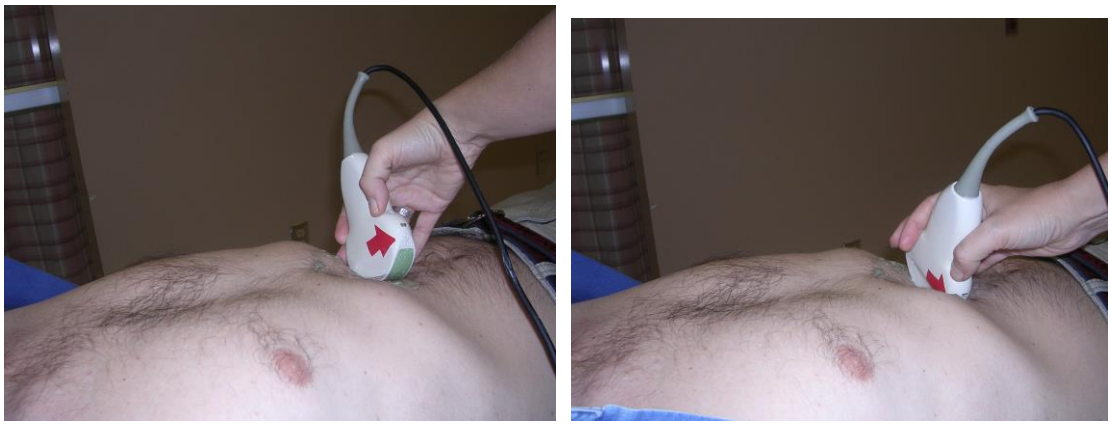
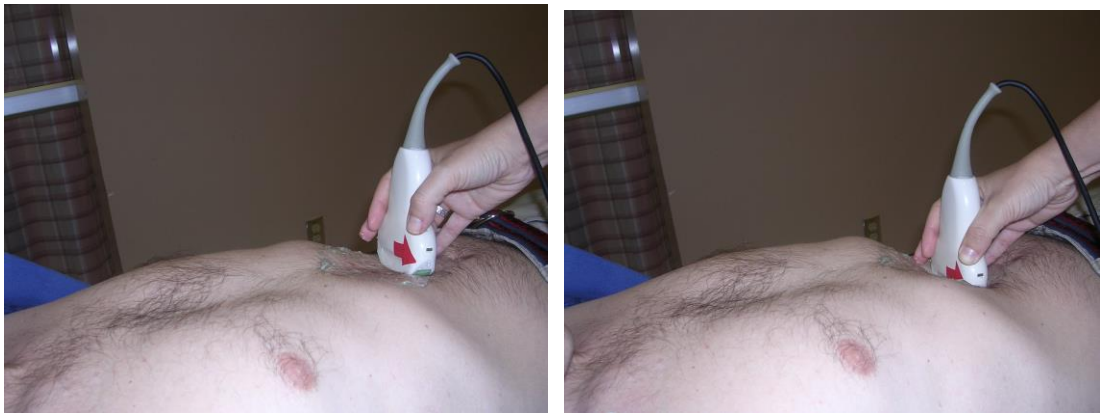


**Figure 9. Compression.**



**How do I find the aorta? What landmarks am I looking for?**
In identifying the aorta on ultrasound, the spine is the key. Transversely, the vertebral body appears as a bright white (highly echogenic) arc with a dark shadow behind it (Figure 10). The aorta and inferior vena cava (IVC) appear as two circles anterior to the spine (unhappy smiley face). The aorta is slightly left of centre and the IVC is to the patient's right. There are several ways to distinguish the aorta from the IVC (Table 1). In the longitudinal view the aorta will be on top and to the left of the IVC.

**Figure 10. Ultrasound landmarks for identifying the aorta. Look for the bright white line of the spine with the shadow behind, then the vessels just anterior to it.**

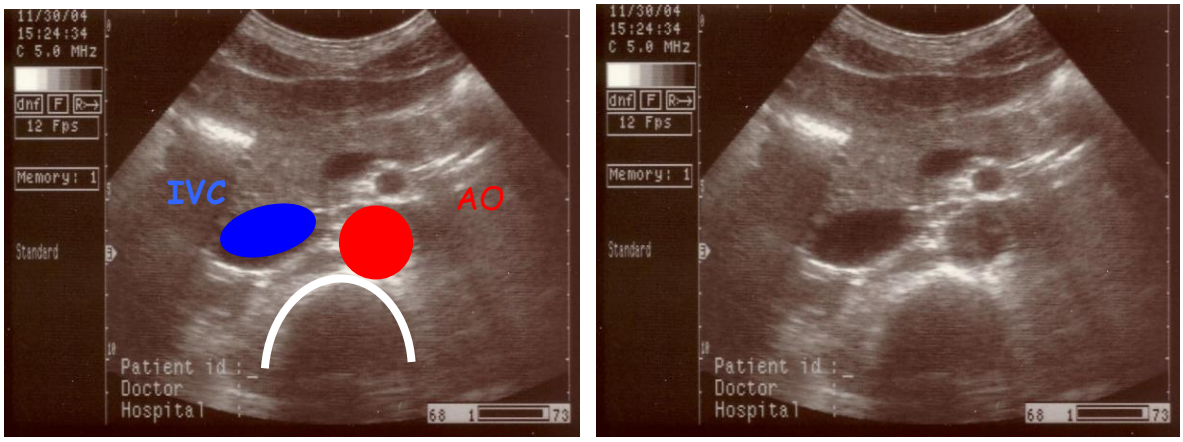



**Table 1: Differences between the aorta and inferior vena cava (IVC).**

| Aorta | IVC |
|---|---|
| • thick walled | • thin walled |
| • anterior branching | • no anterior branching |
| • midline/left | • right side |
| • round | • oval or almond shaped |
| • non-collapsible | • collapses with compression or sniff |
| • pulsatile | • may transmit aortic pulsations |

**What's normal? What's not?**

The aorta normally tapers slightly throughout its course, and has no bulges or dilatations. It should measure less than 3 cm in diameter everywhere (Figure 11). An aortic diameter between 2.5 and 3 cm is considered ectatic and with sufficient time, it may dilate further into an aneurysm. Aneurysms appear as dilatations measuring more than 3 cm, and may have clot within the lumen (Figures 12 and 13).

**Figure 11. Normal aorta, 1.94-cm diameter (transverse view).**

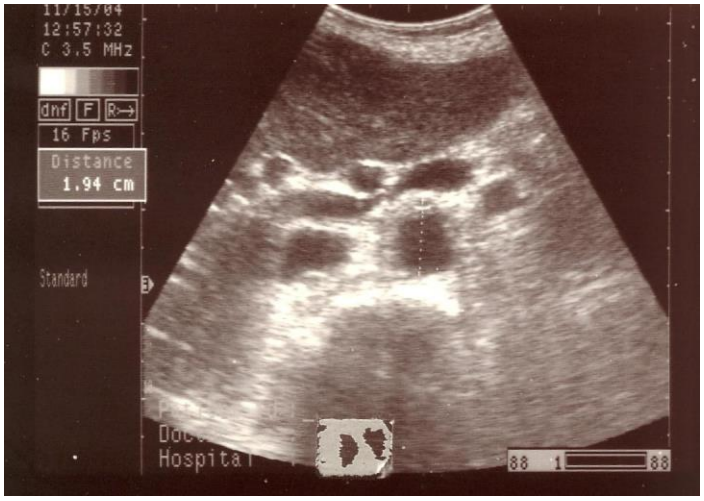



**Figure 12. A 3.7-cm aneurysm.**

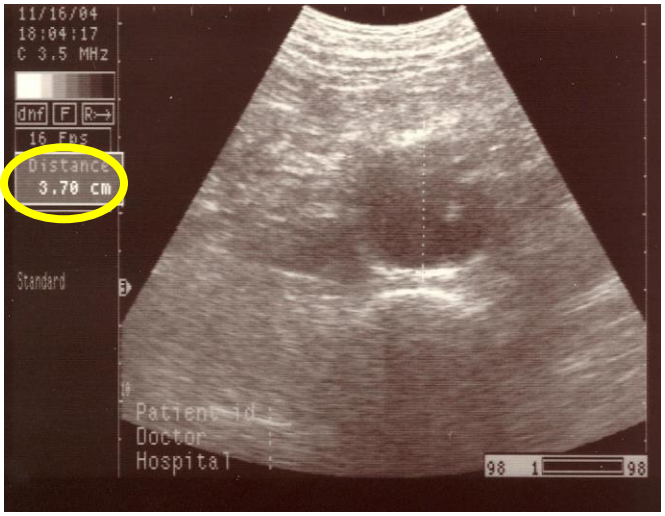
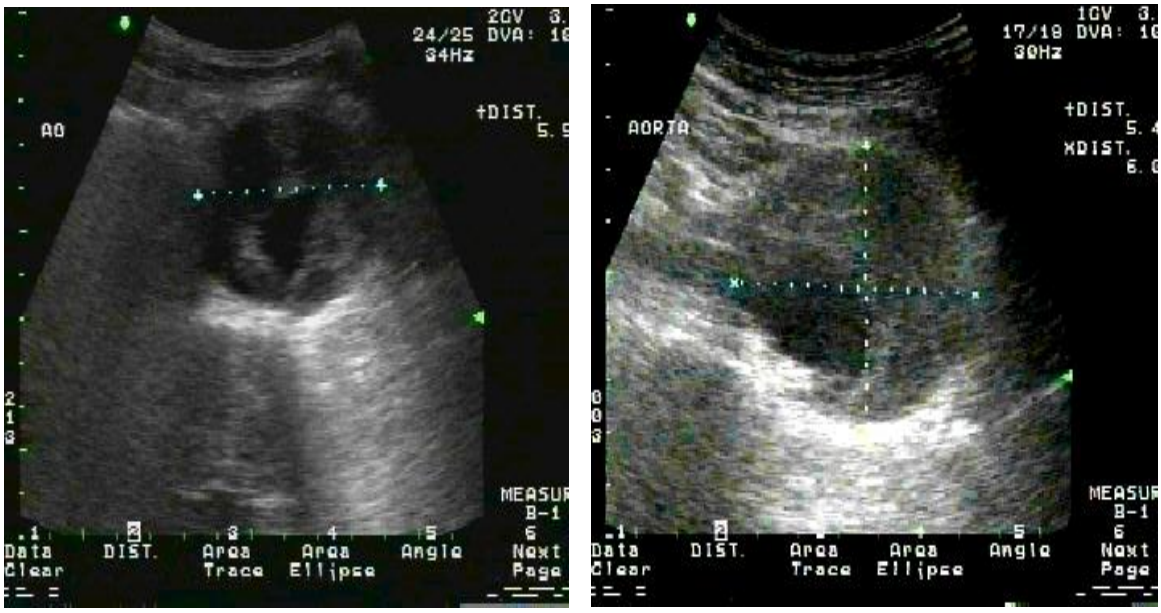


**Figure 13. Aneurysms with intraluminal clot present. Note that the presence or absence of clot does not contribute to the diagnosis of rupture; rupture is purely a clinical diagnosis from the ultrasound standpoint.**




**Step-by-step technique**

1. Set up the machine
    - Choose a low frequency probe (2.5–3.5 MHz) to give the deepest view possible
    - Maximize the depth on the machine (zoom out) to take full advantage of the probe's range.
    - Apply lots of gel to the skin.

2. Identify the aorta
    - Place the probe transversely (with the indicator to the patient's right) as high in the epigastrium as possible (Figure 14).
    - Look for the landmarks: the bright white line of the spine and the two anterior circles: the aorta in the midline-left and IVC to the right.
    - Confirm that it is the aorta; you should see a round thick-walled structure just anterior to the spine. It shouldn't compress as you push down on the abdomen (Figure 15).
    - If you can't immediately see them, try fanning the probe up or down, then moving the probe on the skin toward the head or feet, or left or right, and then applying more pressure with your hand. If this doesn't work, there are more tips in the next section.
    - Once you have identified the landmarks, zoom in so that the spine is the most distal image on the screen, and keep the aorta centered in the middle of the screen.

**Figure 14. Start with the probe as high in the epigastrium as possible.**

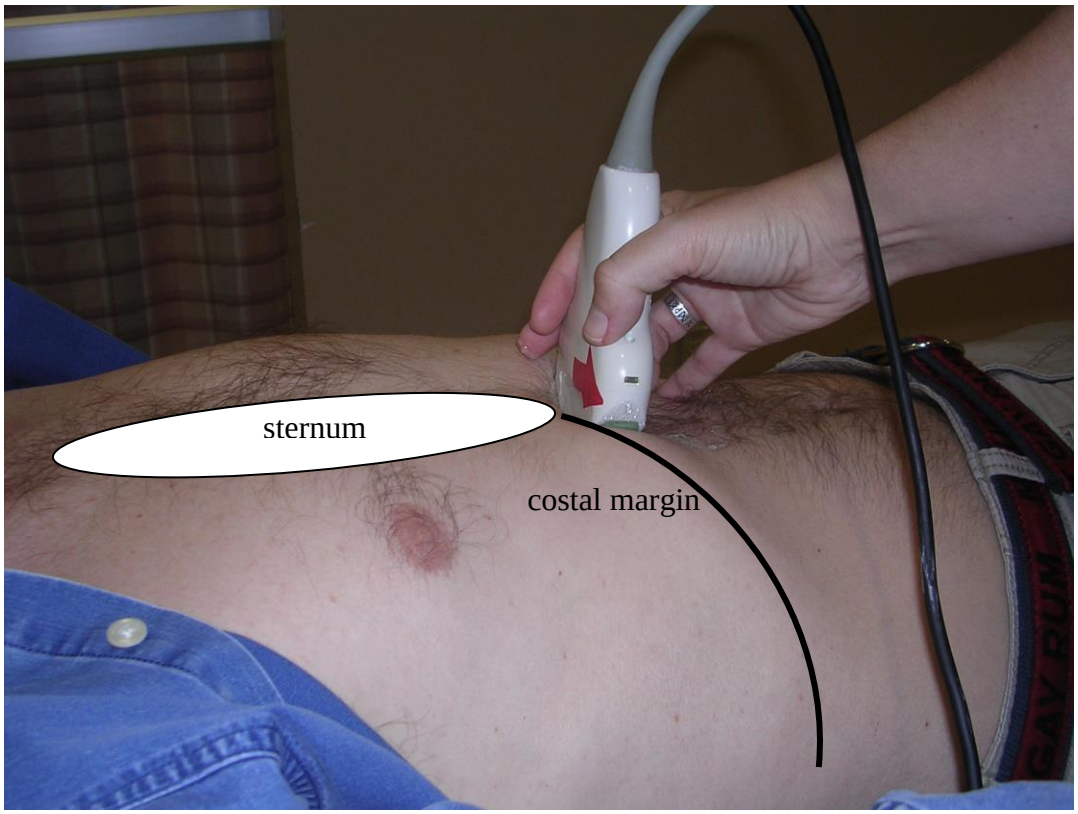
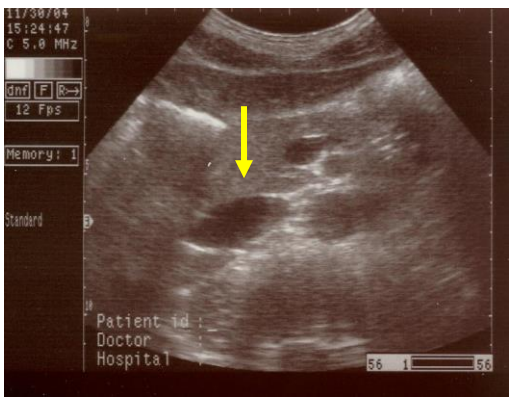
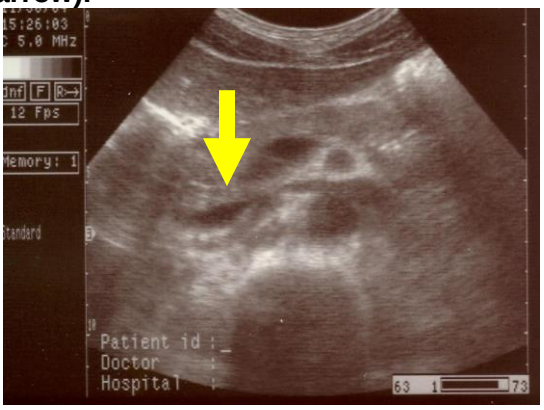



**Figure 15. Note the thick walls of the aorta, and that it does not compress with abdominal pressure (unlike the IVC--arrow).**




Minimal pressure




Increased abdominal pressure

3. Survey the whole aorta transversely
   - Slide the probe down the midline to look at the aorta from the diaphragm to the bifurcation at the umbilicus. Keep the probe perpendicular to the skin as you do this, and learn to watch the screen rather than your hand while you do this.

- About two-thirds of the way to the umbilicus, measure the anterior–posterior diameter from outer wall to outer wall using the machine's calipers. (The centimetre markings at the side of the screen also give a sense of scale, but the calipers are more accurate.)
- If an aneurysm is present, measure its maximum diameter.

4. Look longitudinally
   - With the probe still transverse, return to the epigastrium. Find the aorta again and centre it on the screen.
   - Turn the probe 90° clockwise (indicator toward the head) while watching the screen: the circle of the aorta will widen out to an oval and then to the typical longitudinal view (Figures 16 and 17).
   - Remember that the IVC, also a tubular hypoechoic structure, will be lying in this area; to distinguish the aorta, slide the probe to the patient's left and right to check for its thick walls and anterior branches.
   - Slide the probe toward the feet to follow it to the bifurcation; this may be difficult if the aorta is very tortuous.

5. Consider checking the pelvis and right upper quadrant for free fluid
   - Because most aneurysms rupture into the retroperitoneum, free fluid isn't often seen, and its absence doesn't rule out rupture.

**Figure 16. Normal aorta, longitudinal view.**

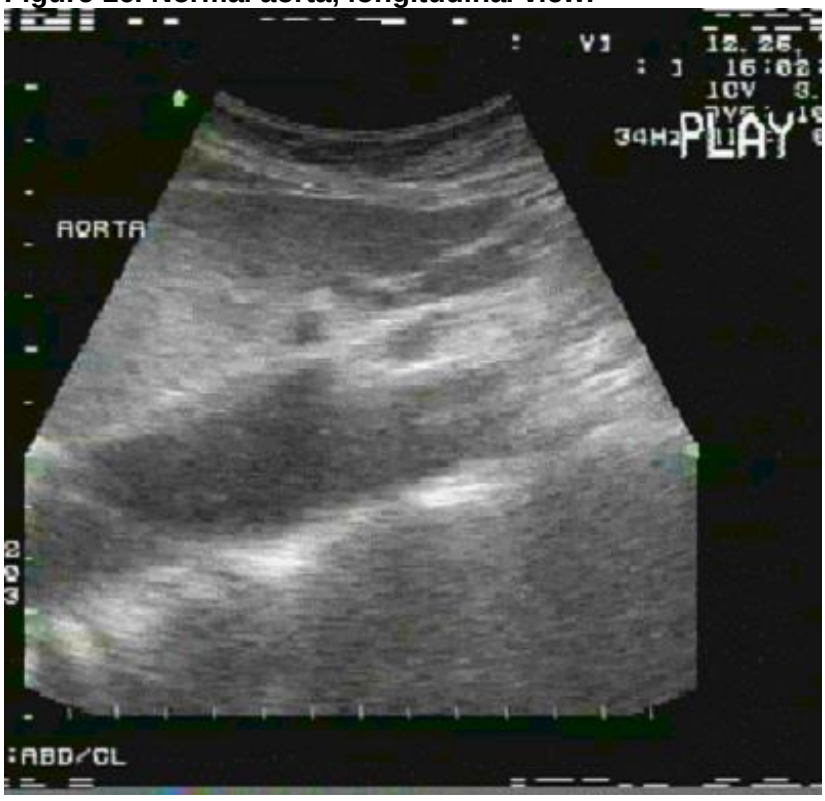
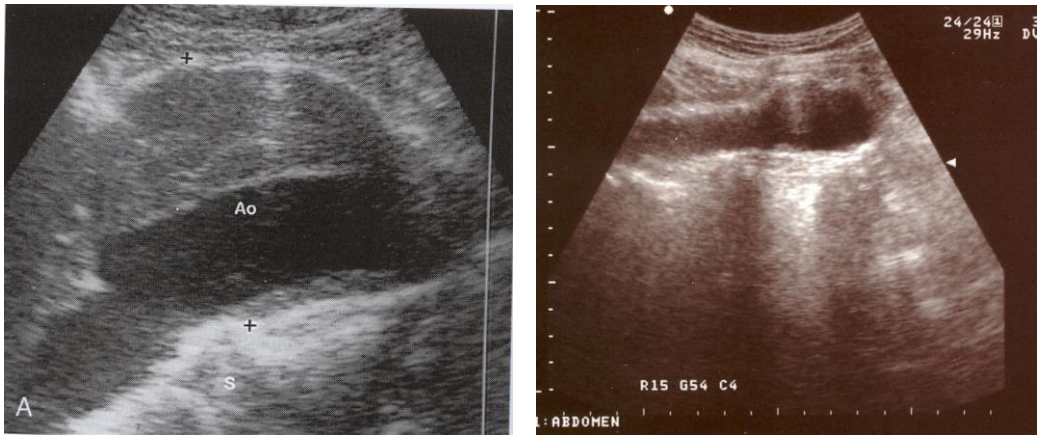


**Figure 17. The image on the left clearly shows significant dilation (don't be fooled by the intraluminal clot — look at the thick white wall of the aorta).
The aorta on the right measures just 3 cm, but in this view, the sudden bulge confirms the diagnosis of aneurysm.**




## What if I can't see it?

The aorta is not always easy to find and may take some diligent searching. If you are using the lowest probe frequency possible with maximum depth and have searched high and low, but still can't find it, try some of these tricks.

**1. Move the gas (the ultrasound beam's enemy)**
Unfortunately our patients are not usually NPO for 6 hours before their emergency ultrasound and are often full of gas. The best place to start looking is as high in the epigastrium as possible, as there is less gas there. As you slide inferiorly, gas becomes more of a problem, and a common beginner's mistake is not applying enough pressure with the probe. Pressure moves the bowel and its gas out of the way. Use a gentle, gradual compression technique to avoid patient discomfort, and use analgesia if possible. In stable or semi-stable patients, rolling them into a partial or full left lateral position will move the bowel out of the way and bring the aorta into view. Obviously this may not be an option for unstable patients.

**2. Use a window (the ultrasound beam's friend)**
The liver is an ideal ultrasound window, essentially giving the beam a free ride, and it is possible to see most of the aorta through the liver. There are several ways to do this. First, try placing the probe transversely over the liver at the mid-clavicular line and rocking it to look medially toward the aorta (Figure 18). The typical spine view will be seen. A longitudinal view in this same position may allow more distal viewing of the aorta. If the liver is mostly covered by the rib cage, then there are two things to try: ask the patient to take a deep breath in and hold it, which will move the liver downward, or place the probe between the ribs (best if you have a small footprint probe). Another way of using the liver as a window is to place the probe longitudinally in the midaxillary line below the costal margin (Figure 19). Maximize the depth so that the ultrasound beam can make it to the midline. The IVC is nearfield to the aorta in this view.

**Figure 18. The liver as a window: place the probe over the liver at the mid-clavicular line and rock the probe to look medially toward the aorta.**

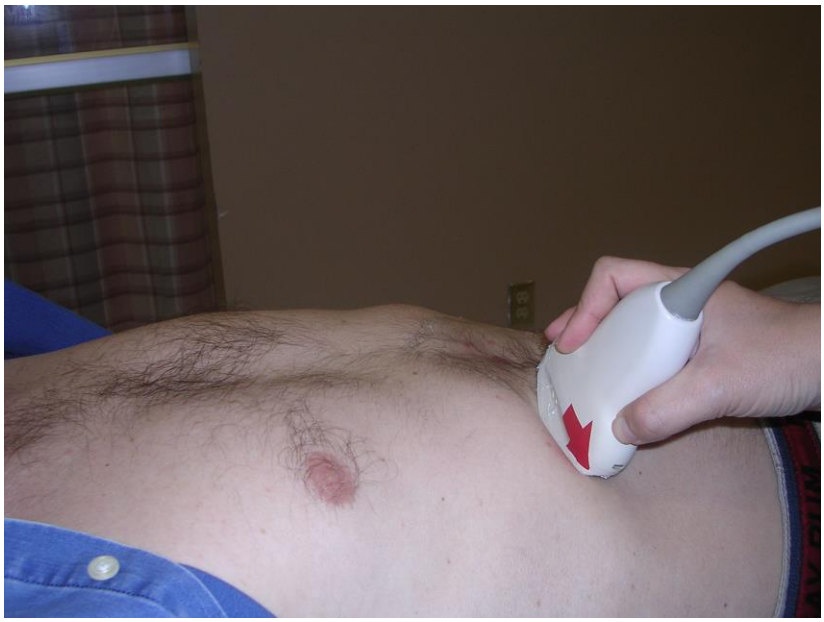
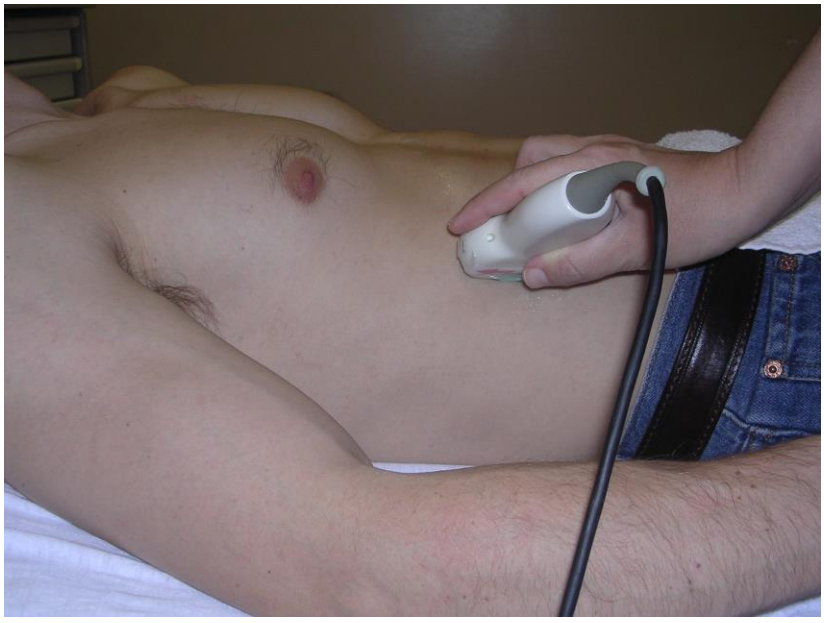


**Figure 19. The liver as a window: move the probe to the anterior axillary line and look medially toward the aorta. The IVC will be on top (in the nearfield) in this view since it is closer to the probe.**



An alternative window is the psoas muscle, but to use it the patient must be in a decubitus position and preferably prone, making it impractical in a semi-stable or unstable patient. Place the probe on the back, to the left of the spinous processes and look medially.

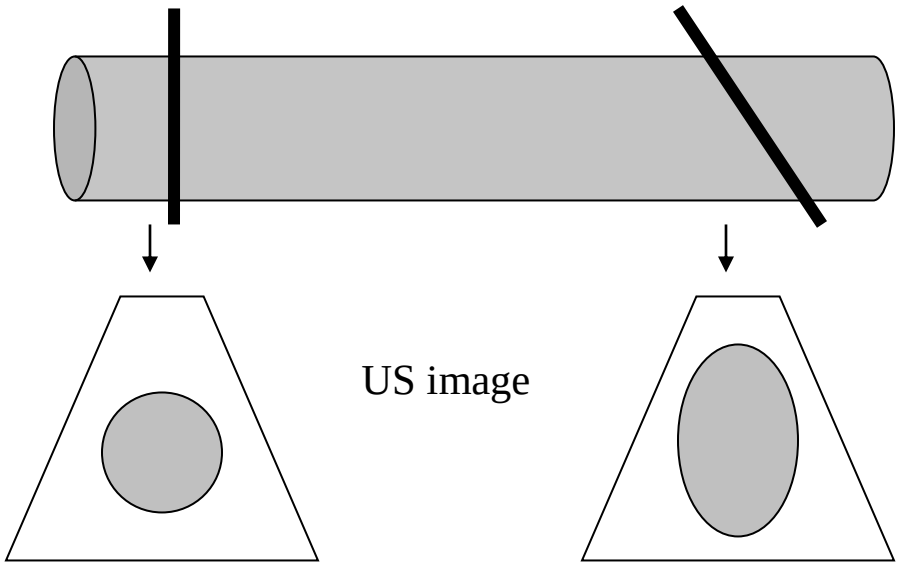
**3. Change the focus on the machine**
Many machines have adjustable focus levels. Setting the focus at the depth of the aorta will moderately improve the picture, but it will not make it magically appear out of a snowstorm (or a gas storm).

**4. Special patients**
*Obese patients* — Use the lowest frequency probe available and maximize the depth. Compression helps somewhat, but positioning is more valuable. Displace a pannus either by rolling the patient slightly or completely to a left lateral position, or ask an assistant to retract it to one side. The aorta may then be visible. If the liver is hidden under the costal margin you can still employ it as a window by elevating the patient's head or using a deep inspiration–large tidal volume.

*Previous surgery* — The bowel may be adherent to the anterior peritoneal wall and the skin anatomy may be altered (e.g., umbilicus). Moving off the midline helps, and pressure is particularly important. The liver window may be your best bet.

*Tortuous aorta* — These aortas are hard to follow. Watch the screen rather than the twisting path your hand is taking. The longitudinal view is very difficult; if you have evaluated the whole aorta transversely, that is sufficient. Fan the probe slightly to ensure that you are not over- or underestimating its size due to a tangent effect (Figure 20).

**Figure 20. Tangent effect. Avoid overestimating the size of the vessel by maintaining the probe (and thus the beam) perpendicular to the skin/vessel.**



## What if I can see part of it and it looks normal?

The main tenet of emergency ultrasound is to avoid false negatives at all costs; thus, a partial view of a normal looking aorta is not enough to rule out an aneurysm. The most common aneurysm location (infrarenal,) is also the most frequently gassed out. If you miss more than 1–2 cm of aorta, then you must consider the scan indeterminate, and are back to the pre-ultrasound days. Another test (e.g., vascular consult, formal ultrasound, CT or MRI) is necessary if the clinical picture is consistent with AAA. Somewhat reassuring, however, is the fact that most aneurysms are visible; in a recent study, although 17% of the scans were indeterminate, all the aneurysms were identified (Blaivas and Theodoro 2004).

## What if I see a small aneurysm?

It is unusual for aneurysms less than 4.5 cm to rupture, so it may not be the cause of the patient's symptoms. However, if the clinical scenario fits, then a surgical consult or CT is necessary to diagnose rupture. If you find an aneurysm as you are scanning for practice or for some other indication, then you should inform the patient and ensure that he or she has good follow-up to monitor its growth. In fact, there is good evidence that men over the age of 65 should be screened for AAA (OR for mortality from AAA in screened group 0..60 95%CI 0.47-.78). The evidence is not so clear for women. An emergency department visit may represent an opportunity to screen (and at the same time practice your ultrasound skills. (Cochrane review, Moore et al.)

## Pitfalls

*Misidentification of the aorta* — The most common structure confused with the aorta is the IVC. As you are scanning, it is important to ask yourself, "How do I know that this is the aorta?" If it is a round, thick-walled, incompressible structure just anterior to the spine, then it is the aorta (see Table 1).

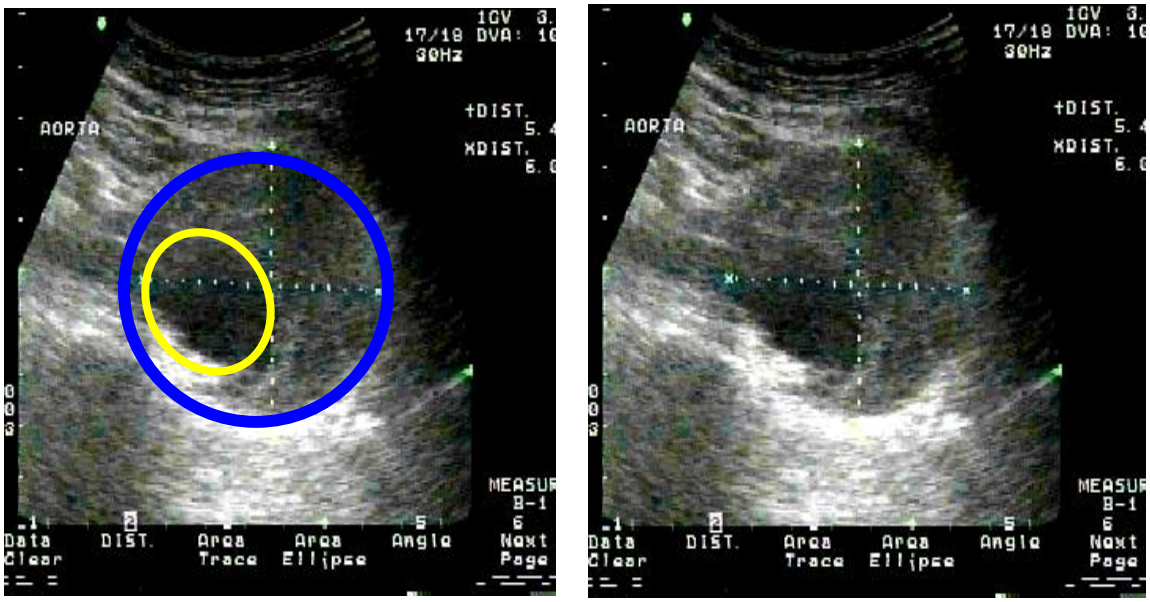
*Tangential section* — The aorta is overmeasured due to a tangent effect. Maintaining the probe at 90° to the skin helps prevent this. Twist and fan the probe to be sure that you are truly looking at a cross section (Figure 20).

*Measuring the lumen only* — Some AAAs have a large intraluminal clot that will appear hyperechoic relative to the lumen. Look for the very hyperechoic walls of the aorta and you will not miss an aneurysm (Figure 21).

*Incomplete survey/overreliance on ultrasound* — The whole aorta must be visualized to rule out AAA. Go from the diaphragm to the bifurcation. If you cannot see the whole aorta, then the scan is indeterminate and cannot be used for clinical decisions. Conversely, remember that not every aneurysm you see is ruptured — the clinical scenario is very important. Consider a surgical consult or emergency CT when in doubt.

*Failure to consider the diagnosis* — A ruptured AAA should be in the differential diagnosis for everyone over 50 with back pain or cardiovascular instability.

**Figure 21. Make sure you measure the whole outer diameter (blue ring) — don't be fooled by the small lumen (yellow ring).**




## Summary

AAA is a catastrophic disease of the older population and must be considered in those presenting with back or abdominal pain and cardiovascular instability. Bedside ultrasound is an easy, accurate and rapid test to identify aneurysms, and can be coupled with the clinical picture to assume rupture and rapidly direct patient care. Thorough scanning of the whole aorta is necessary to prevent false negatives.

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# Cardiac ultrasound

## Learning objectives

- To review the basic anatomy and pathophysiology of the pericardium and heart
- To name the indications for bedside ultrasound evaluation of the pericardium and heart
- To learn the ultrasound appearance of a pericardial effusion and asystole vs. vigorous ventricular contraction
- To define an indeterminate scan
- To develop some techniques to overcome difficult scanning conditions
- To understand the use of IVC diameter for evaluating volume status
- To describe the role of ultrasound in pericardiocentesis

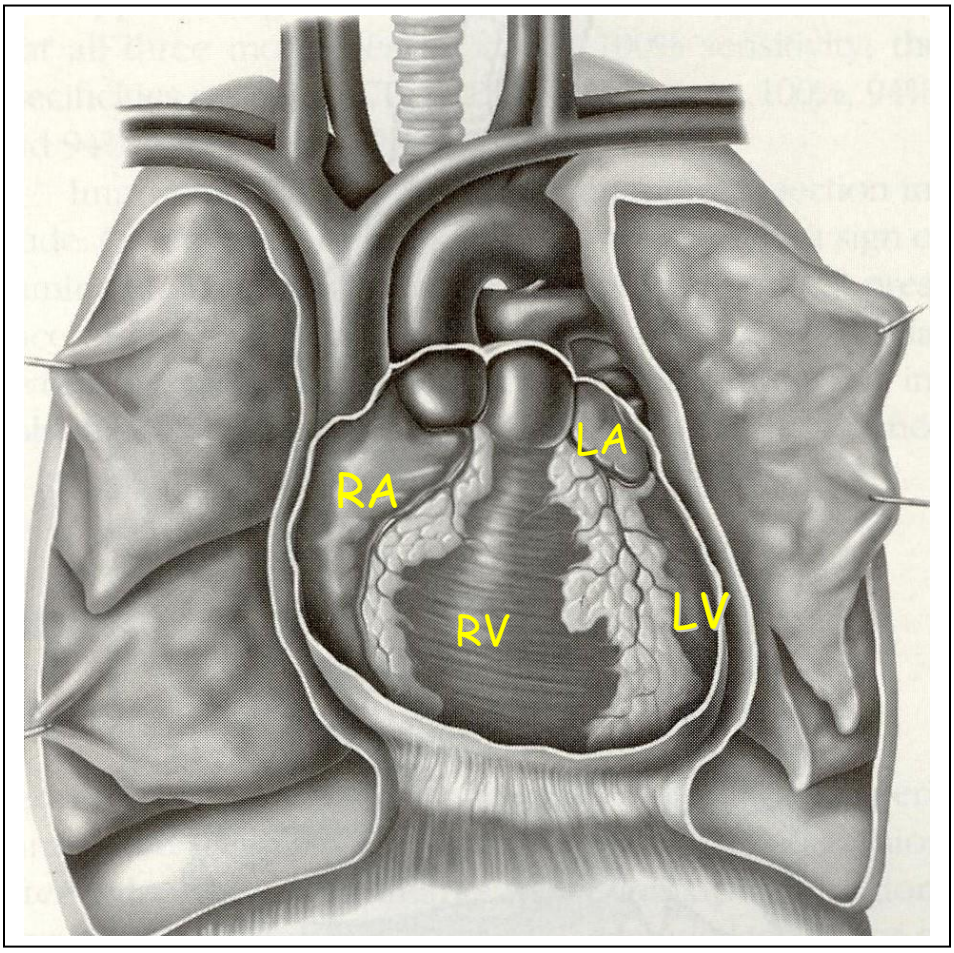
## Introduction

Laennec created an audio revolution with his invention of the stethoscope in the early 1800s. Since then, technology has come a long way and we are now into the visual revolution provided by echocardiography. Cardiologists and echocardiographers have turned this process into a fine art, assessing everything from wall motion to valvular function. Fortunately, a limited examination to evaluate patients for life-threatening conditions is easy to learn and has great utility within the emergency department. We will discuss its use in cardiac arrest and pericardial effusion or tamponade.

## Clinical anatomy

The heart is enclosed by the pericardium and lies in the left central aspect of the chest cavity. Its long axis runs diagonally between the right shoulder and left hip, and the short axis lies perpendicular to this, i.e., between the left shoulder and right hip. In young and thin patients it tends to be more vertical. The membranous visceral and fibrous parietal layers of the pericardial sac enclose the heart and are usually closely apposed, with a small amount of fluid (<50 mL) normally present. Most anterior and inferior is the right ventricle, with the left ventricle lying posterior and to the left (Figure 1).

**Figure 1. Heart and pericardium, anterior view.**




Source: Tayal et al. 2003, p. 98.

## Cardiac arrest

### Pathophysiology

Pulseless patients fall into one of three groups: ventricular fibrillation/pulseless ventricular tachycardia, pulseless electrical activity and asystole, which are usually easily distinguished on the monitor. Of note is that pulseless electrical activity (PEA) encompasses two patient groups: the profoundly hypotensive, with coordinated mechanical contractions that are simply too weak to generate a palpable pulse; and those with electrical but not mechanical capture. Asystole (cardiac standstill) is defined as the absence of any ventricular contraction, but atrial or valvular contractions may still occur.

### Epidemiology

The most common initial rhythm in out-of-hospital cardiac arrests is ventricular fibrillation. The survival-to-discharge rate is 3–5%. PEA is the second most common

rhythm, with a survival rate of 2%. Asystole is the least common initial rhythm and is associated with a 0% survival rate.

### Clinical considerations

The management of these patients is governed by the advanced cardiac life support (ACLS) protocols, which emphasize the diagnosis and treatment of reversible causes. The protocols are entered with two clearcut data points: the presence or absence of a pulse and the rhythm. The most commonly cited potential error is the misinterpretation of fine ventricular fibrillation as asystole, which is avoided by checking a perpendicular lead. The algorithmic approach makes initial treatment easy, but what is less clear is when to stop.

### Use of ultrasound

Because a formal echocardiogram is not often available in cardiac arrest, this application of ultrasound has been developed largely by emergency physicians. There are multiple uses for ultrasound in pulseless patients: distinguishing between fine ventricular fibrillation and asystole, diagnosing a pericardial effusion, monitoring the heart's contractile response to therapy, aiding in the decision to cease resuscitation, and simplifying difficult venous access.

In terms of evidence, there are some studies looking at outcomes when cardiac standstill is seen on EDTU. The largest looked at 169 patients with absent vital signs (Blaivas and Fox 2001). One hundred and thirty six of them had cardiac standstill on EDTU, and none of these patients survived. Interestingly, 71 of the patients with cardiac standstill had an identifiable rhythm on the monitor. There is also a case report of a patient with asystole on the monitor who was subsequently found to have ventricular fibrillation on EDTU (Amaya and Langsam 1999).

## Pericardial effusion

### Pathophysiology

Pericardial effusions occur in many diseases (Table 1). Although up to 50 mL of fluid in the sac is normal, larger quantities interfere with cardiac hemodynamics. The excess fluid causes a pressure rise within the sac, and right-sided filling is impaired. Eventually compensatory mechanisms are overwhelmed and cardiac output falls (i.e., cardiac tamponade). Tamponade is a clinical diagnosis and cannot necessarily be inferred from the size of the effusion, because the accumulation rate is also a key factor. A slow buildup will stretch the pericardium and patients may be asymptomatic even with several litres of fluid. In contrast, a rapid accumulation of 150 mL of fluid or blood may cause cardiovascular instability.

**Table 1. Causes of pericardial effusion**

| | |
|---|---|
| Infectious | Bacterial, viral (Coxsackie B), fungal, TB, HIV-related |
| Neoplastic | Lymphoma, bone, breast, melanoma |
| Autoimmune | SLE, RA, vasculitides |
| Trauma | Blunt, penetrating, post-pericardiotomy |
| Metabolic | Uremia or myxedema |
| Drugs | Anticoagulants, phenytoin, doxorubicin, hydralazine |
| Post-MI | |
| Mediastinal radiation | |
| Idiopathic | |

## Epidemiology

Pericardial effusions are found in 3.4% of patients at autopsy. About 21% of cancer patients will develop an effusion, and fortunately only 10% of these patients have severe effusions, with an even smaller number progressing to tamponade. In the case of penetrating trauma, stab wounds to the heart have a high incidence of tamponade (80–90%) in contrast to gunshot wounds (20%). Blunt chest trauma causes tamponade in only 4% of patients.

## Clinical considerations

Pericardial effusions are associated with dyspnea, poor exercise tolerance, chest pain, and any degree of cardiovascular instability from presyncope–syncope to cardiovascular collapse. It is a difficult diagnosis in the absence of historical clues, because the physical findings are often subtle and nonspecific. Patients may have tachycardia, pulsus paradoxus, narrowed pulse pressure, orthostatic instability, or frank hypotension. Distant heart sounds and rubs are not always present or may stem from another disease process. The intermittent nature of rubs makes them unreliable, as are dilated neck veins, which often occur late and then disappear with hypotension. Beck's classic triad of acute tamponade, distant heart sounds, dilated neck veins and hypotension, occurs late and often in an intermittent fashion.

Unfortunately, readily available tests are not reliable for identifying effusions. Cardiomegaly is present on chest films only after 200–300 mL has accumulated and is not specific for effusion. Commonly described electrocardiogram (ECG) findings include generalized low voltage (somewhat sensitive but not specific) and electrical alternans (specific but insensitive.) Effusions are seen on computed tomography (CT) scans, but this necessitates transporting an unstable patient out of the emergency department.

## Use of ultrasound

A formal echocardiogram is the gold standard test for pericardial effusion. Often it is not available on a 24/7 basis, so bedside ultrasound performed by emergency physicians offers a quick and efficient alternative when pericardial effusion or tamponade is a concern. As in the case of ultrasound for AAA, ultrasound and clinical findings must be used together for diagnosis. If there is a pericardial effusion on ultrasound and the patient has signs of vascular instability, then the diagnosis is tamponade. Without

vascular instability, the diagnosis is simply pericardial effusion. If there is no effusion, tamponade cannot be responsible for the patient's symptoms.

**Where is the evidence for EDTU?**
A large prospective study compared emergency physicians' EDTU results with those of a cardiologist in 1500 patients and found that EDTU had a sensitivity of 96% and specificity of 98% for the diagnosis of pericardial effusion (Mandavia et al. 2001).

In terms of outcomes, two small studies examined the impact of EDTU. The first examined the time to diagnosis in 39 medical patients with effusion, with and without EDTU (Sierzenski et al. 2003). When EDTU was used, pericardial effusion was diagnosed in 114 minutes (95% CI 72–156 minutes) compared with 1029 minutes (95% CI 629–1429 minutes) when it was not available. In addition, length of hospital stay was shorter at 5.1 days (95% CI 3.3–6.9 days) versus 10.9 days (95% CI 8.1–13.7 days).

In the setting of penetrating chest trauma, the impact of EDTU is impressive: in 49 patients, when EDTU was available, the time to OR was 15 minutes (95% CI 4–26 minutes), which correlated with 100% survival (Plummer et al. 1992). When EDTU was not used, the time was 42 minutes (95% CI 21–63 minutes) and only 57% of the patients survived.

**Treatment**
Treatment depends on the stability of the patient and the cause of the effusion. Patients in extremis require pericardiocentesis or a trip to the operating room for a pericardial window. Stable patients may be followed clinically and with serial echocardiograms.

## Indications for bedside ultrasound cardiac evaluation

Bedside evaluation of the heart is a brief, limited examination aimed at answering only two questions: Is the heart beating normally? Is there a pericardial effusion?

It is indicated in patients presenting with any of the following:

- Penetrating or significant blunt trauma to the chest, neck, upper abdomen, or back
- Concern for pericardial effusion (dyspnea, chest pain, post-myocardial infarction or coronary artery bypass grafting [CABG], cancer or hemodialysis patient)
- Undifferentiated hypotension or syncope
- Cardiac arrest

## Ultrasound technique

The goal of the examination is to evaluate gross contractile function and to check the anterior and posterior aspects of the pericardial sac for fluid. Most of this is done using the subxiphoid view, but alternative views are sometimes necessary.
**How do I find the heart? What landmarks am I looking for?**
The ultrasound beam must be directed behind the sternum to find the heart. In all patients except asystolic patients, the movement of the heart makes it easy to identify.

To identify the chambers, we must remember that the probe is located inferior to the heart and that we are directing it upwards toward the head (Figure 2). This means that in the near field, closest to the probe is the right ventricle, and far field to this is the more muscular left ventricle (Figure 3). The atria are not as important to identify, but will lie as follows: right atrium is superior to the left ventricle, and the left atrium is posterior to this. The atria are thin walled and normally smaller than the ventricles. The pericardium appears as a hyperechoic, bright white line closely surrounding the heart (Figure 3).

**Figure 2. Anatomy from the subxiphoid view.**

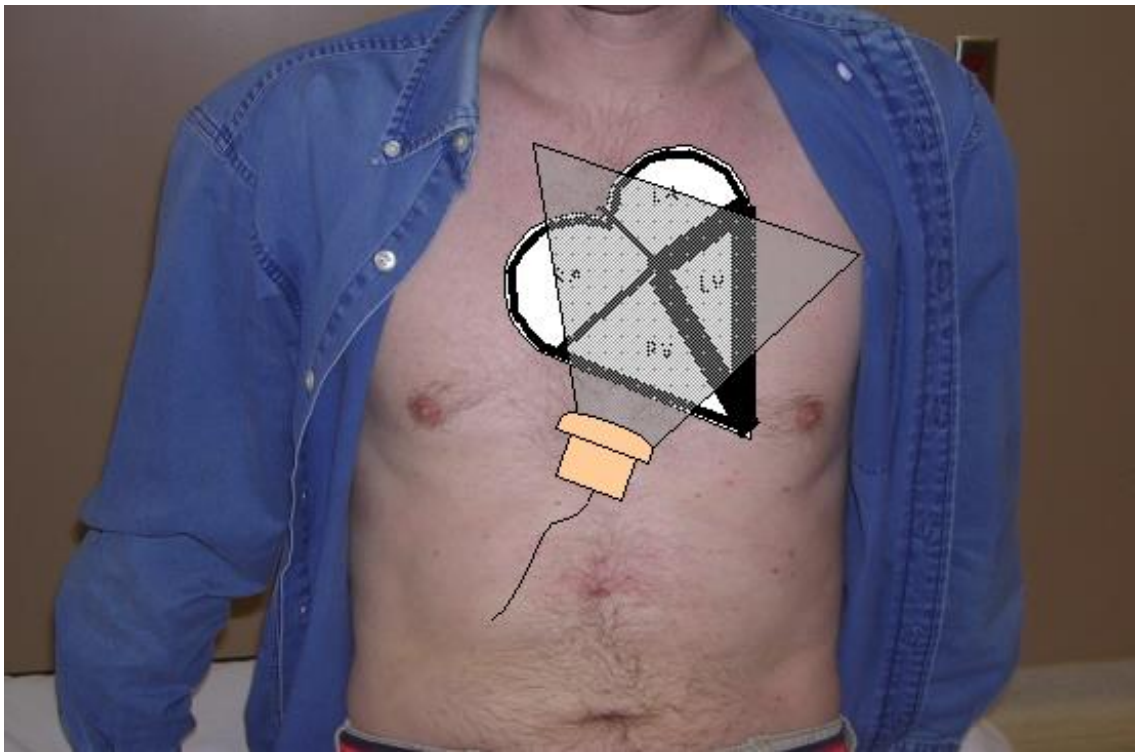
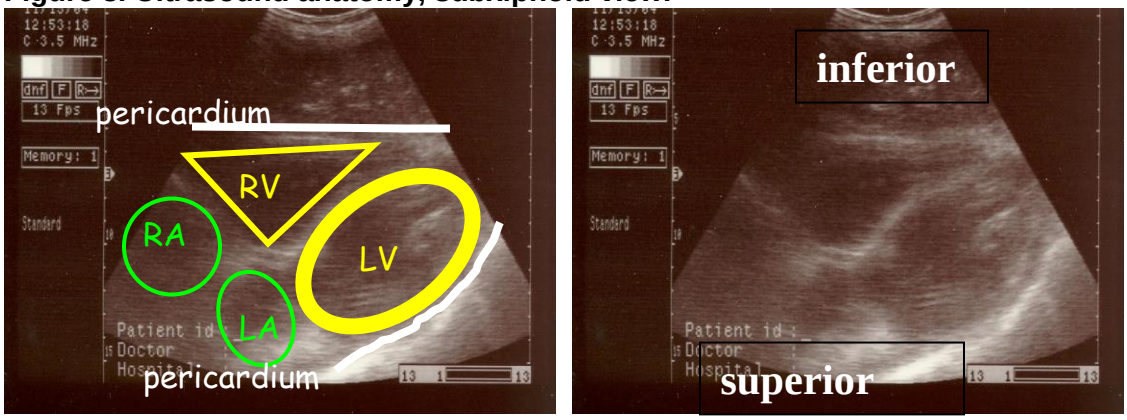



**Figure 3. Ultrasound anatomy, subxiphoid view.**




**What's normal? What's not?**

The heart should beat vigourously. Observe the left ventricular walls: do they come nearly together in systole? If they do, continue with aggressive resuscitation. If the walls

move only a few millimeters then the heart is failing and if the cause is not reversed, it will stop. Hypovolemia, hypoxia and hyperkalemia should be addressed as appropriate. If the ventricular walls do not move at all, then the patient is asystolic. The LV dilates, and blood pools and clots, causing visible fluid levels and soft internal echoes. You may still see intermittent atrial or valvular contractions but remember it is the ventricle that counts.

The pericardial sac is visible as a hyperechoic (bright white) line closely apposed to the outer ventricular walls. Normally the small amount of pericardial fluid present for lubrication is not visible. An effusion appears as an anechoic (black) line between the outer ventricular wall and the bright white pericardium (Figure 4). In supine patients, small effusions are seen posteriorly during systole only. As it accumulates to more than 100 mL, it is obvious posteriorly throughout the cardiac cycle. Fluid surrounds the entire heart when the effusion is 150–200 mL or more. As the effusion increases the heart will swing within the sac (which creates electrical alternans on ECG.) Generally an effusion less than 1 cm is considered small, while more than 1 cm is large.

**Figure 4. Pericardial effusions.**

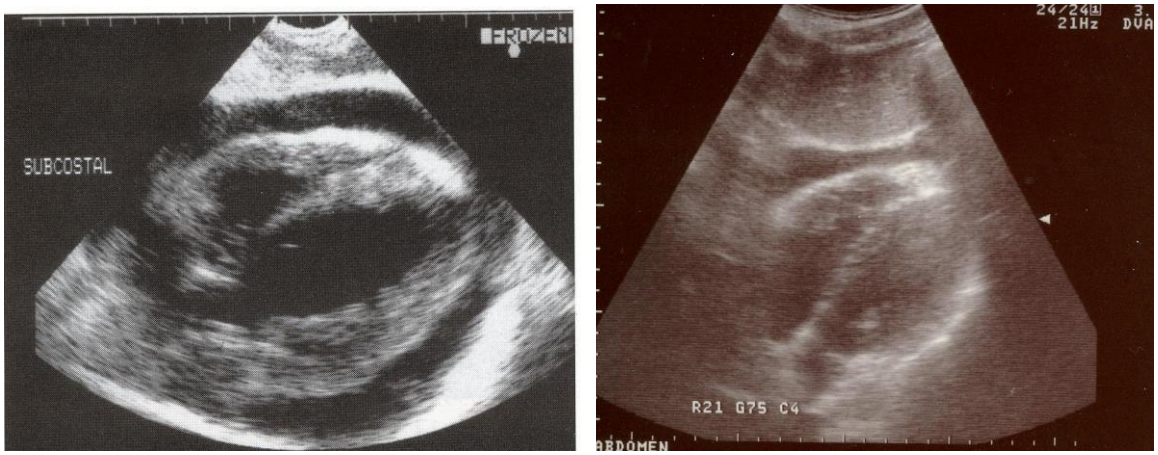
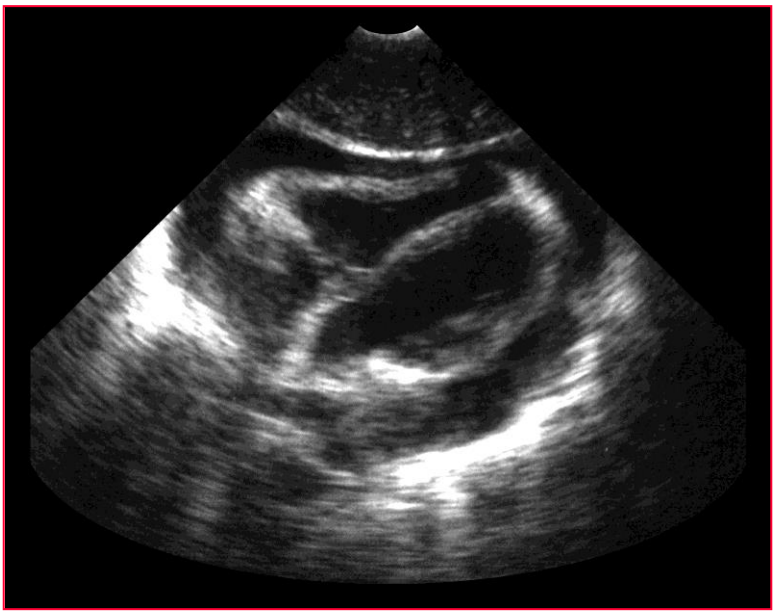


Figure on the left is from the Trauma chapter in Ma and Mateer (2003: 78)

Tamponade is a clinical diagnosis, but there are echocardiographic signs to look for as you become more experienced. These signs often precede clinical tamponade. Check the right side of the heart: tamponade causes right ventricular collapse, seen as an inbowing of the outer wall during diastole (Figure 5). Also, the inferior vena cava (IVC) dilates to more than 1.5 cm and does not vary with respiration.

**Figure 5. As the pressure rises within the pericardial sac the right ventricle begins to collapse.**



**Step-by-step technique**

1. Set up machine
    - Choose the cardiac probe if possible, otherwise use the lowest frequency probe available (2.5–3.5 MHz).
    - Choose the machine's cardiac setting if available.
    - Maximize the depth (zoom out) so that you can see deep into the chest cavity.
    - Apply lots of gel to the skin.

2. Place probe
    - Use an overhand grip on the probe so that the angle with the skin will be very shallow (Figure 6).
    - Place the probe on the skin in the subxiphoid area, slightly to the *right* of the midline, with the indicator to the patient's right (Figure 7). This position makes use of the liver window.
    - Angle the probe about 15 degrees to the skin and push "up and under," in a scooping motion so that you are aiming the beam at the left shoulder (Figure 8).

**Figure 6. Start with an overhand grip on the probe.**

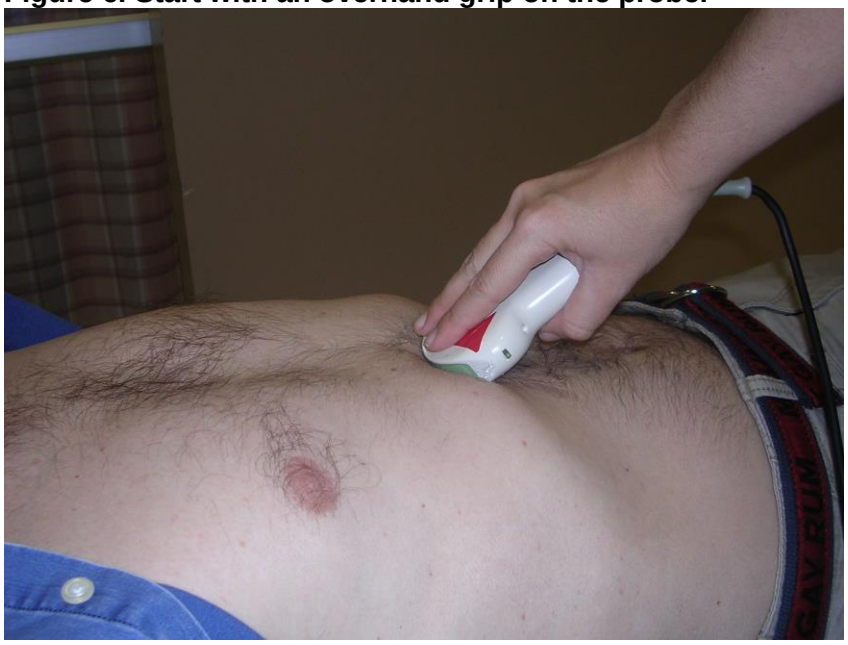


**Figure 7. Position probe to make use of the liver window.**

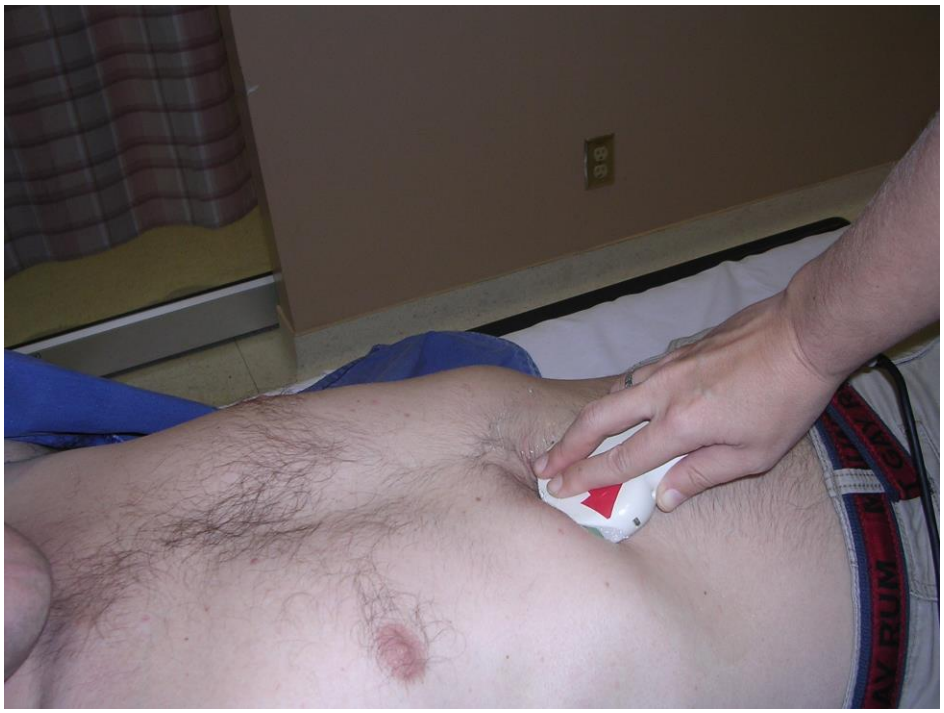
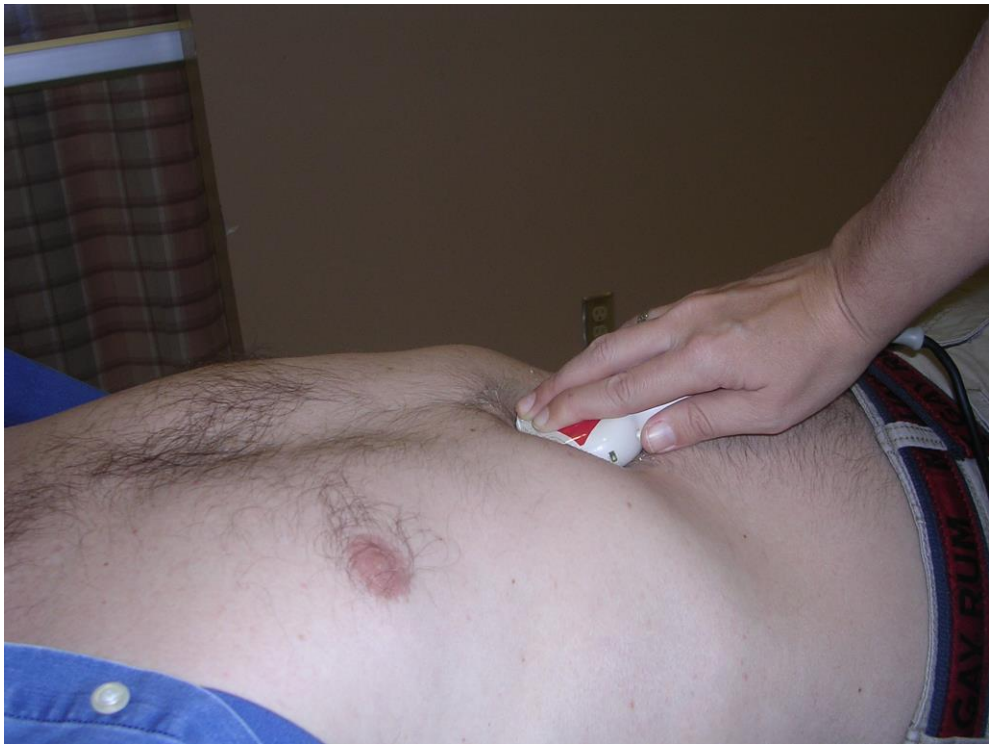


**Figure 8. Scoop up and under the sternum.**



3. Identify the heart and pericardium
   - Once you have a partial view, centre it on the screen.
   - Zoom in so that the heart and posterior pericardium fill ¾ of the screen.
   - Fan the probe to survey the inferior portion of the pericardium from anterior (shallow skin angle) to posterior (deeper skin angle) (Figure 9).
   - If you can't find the heart and pericardium, there are three ways to troubleshoot:
     - try a shallower or deeper angle to the skin
     - move the probe on the skin to the patient's right or left
     - rock the probe through an arc to aim the beam toward the left elbow, then left shoulder, then neck, then right shoulder (this catches both the vertical and lateral hearts) (Figure 10).
     - if you still are unable to find it, see the tips below.

4. Evaluate the heart and pericardial space
   - Assess the way the heart is pumping; if it is not moving, watch for 20–30 s to be sure there are no ventricular contractions.
   - View the anterior and posterior aspects of the pericardial space to check for an effusion.
   - If there is one, estimate the size of the space using the scale marks on the side of the screen or the machine's calipers if you wish. A pericardial space <1 cm is small; >1 cm is large.

**Figure 9. Fan through the whole heart from anterior to posterior. The line illustrates the path of the beam.**

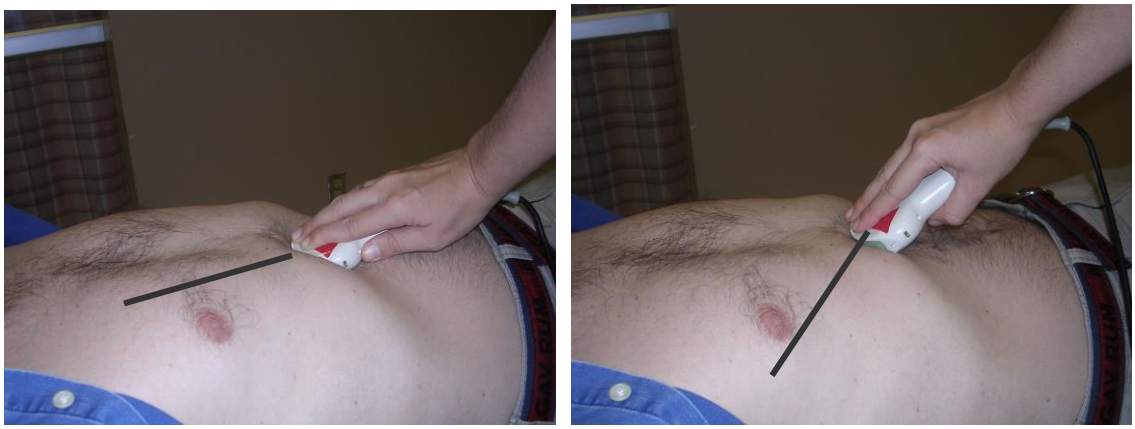
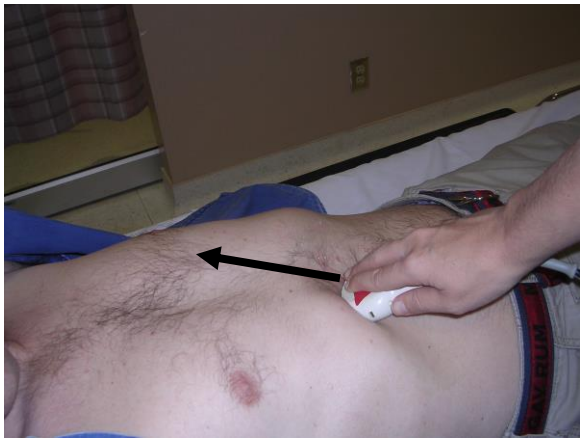
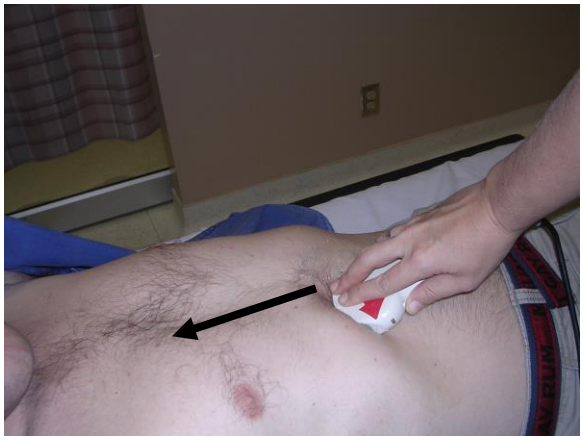
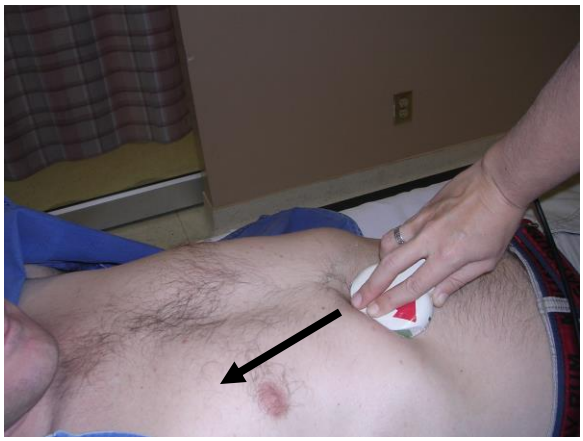


**Figure 10. Use the liver window to do a survey through the chest — first aim the beam at the left shoulder, then the neck, then the right shoulder.**







## What if I can't see it?

If you are using a low-frequency probe at maximum depth and are aiming behind the sternum, but still can't find the heart, then try some of these tricks.

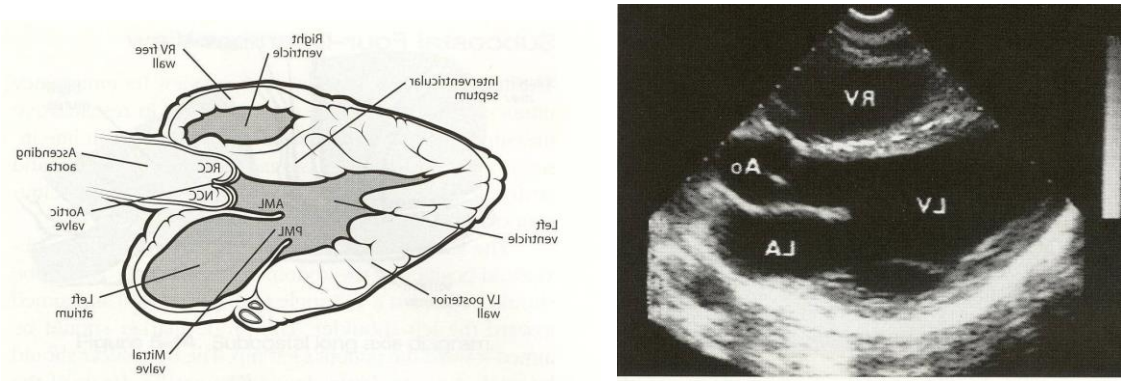
**1. Use a window (the ultrasound beam's friend)**
Again, the liver is our handiest window. Move the probe just medial to the midclavicular line, inferior to the ribs and aim toward the left shoulder or nipple, again pushing on the abdomen somewhat to maintain probe contact while looking upward. Fan the probe to look up and down within the chest cavity. In some patients a deep inspiration helps, but in others, it makes the abdominal muscles too tense to scoop under the rib cage.

**2. Move the patient**
Tense abdominal muscles interfere with our ability to indent the abdomen enough to look upward. Try the following: administer analgesia where indicated, use two hands on the probe to increase your strength, or bend the patient's knees to reduce abdominal wall tension. In stable or semi-stable patients, there are a few more options: roll the patient to the left side with or without elevating the head (this should move the heart closer to the chest wall and probe). Respirations may also be useful. Ask the patient to take a big breath in and hold it or, alternatively, hold end expiration.

**3. Move the probe**
Although we traditionally use only the subxiphoid view in emergency ultrasound, there is no reason not to use an alternative view when necessary. The parasternal long-axis view is a classic echo view that also demonstrates the pericardial sac and the contractility of the left ventricle (Figure 11). Many cardiologists prefer the parasternal long (PSL) view over the subxiphoid view to evaluate the pericardial space. The PSL view is obtained by placing the probe to the left of the sternum, at about the fifth or sixth interspace, with the indicator pointing to the patient's right shoulder (Figure 12). Note that in this view, that near field is the anterior pericardium, and the far field is the posterior pericardium. It is critical to see the posterior pericardium (far field) to accurately comment on the absence of an effusion. This may be difficult with a curvilinear probe if the patient is small, but fanning the probe back and forth should give a complete view of the anterior and posterior pericardium.

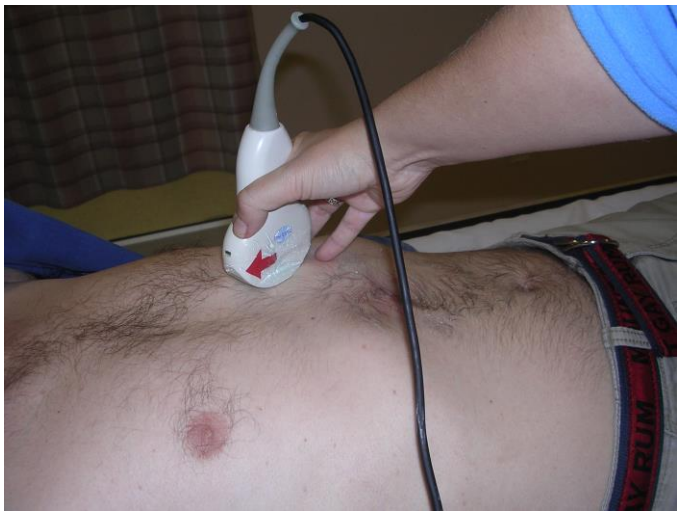
If you are wondering why the text is backward on this diagram, it is because cardiologists and echocardiographers have evolved a different standard convention for images — it is actually flipped 180 degrees. We think it is important to maintain consistency in EDTU, so we recommend that the probe indicator remains between 9 o'clock and 12 o'clock at all times. Subsequently, this will generate an image flipped to the standard echocardiography conventions. Since all we are looking for is the heart's gross contractile function and the pericardium, this difference is inconsequential.

**Figure 11. Parasternal long axis view.**




Drawing and ultrasound are from Ma and Mateer (2003, p. 102, figures 5.16 and 5.17).

**Figure 12. Find the parasternal long axis view by placing the probe in the fifth or sixth interspace just to the left of the sternal border. The indicator should be pointing to the right shoulder.**



**4. Special patients**
*Chronic obstructive pulmonary disorder (COPD)* — The hearts of patients with COPD are hidden by their large lung volume. Be sure to use the liver window and try forward and lateral positioning. A deep inspiration may help push the heart downward.

*Obesity* — The subxiphoid window may be difficult to use, but try leg flexion and gentle compression to overcome the abdominal wall. Be sure to maximize the depth. The parasternal view is a good alternative.

*Thin or young patient* — The heart tends to be much more vertical and is hidden behind the sternum. In the subxiphoid view, aim toward the neck rather than the left shoulder. Try asking the patient to hold a deep inspiration.

## What if I can see only the anterior sac and there is no effusion?

As emphasized in the aorta portion of this chapter, the goal of bedside ultrasound is to avoid false negatives at all costs. Using the subxiphoid view, we are looking at the inferior part of the heart and we must fan through this whole area from anterior to posterior. Strictly speaking, if you cannot see the posterior part of the sac, then the scan is indeterminate. If you have a moderate or high index of suspicion, a formal echo is necessary to further evaluate the patient. Realistically, a normal looking anterior sac is reassuring since an effusion large enough to cause hemodynamic compromise should be visible here too (in the absence of suspicion of loculations.)

## Pitfalls

**Heart motion:** In asystolic patients, the generalized heart motion caused by mechanical ventilation can be misinterpreted as contractile activity. True ventricular contraction changes the shape of the lumen, and is not simply a movement of the whole heart on the screen. Hold ventilation for a few seconds if you are unsure.

**Epicardial fat pads:** These are very common in the obese and elderly and can be mistaken for an effusion. A fat pad appears as a black stripe anterior to the left ventricle. Unlike effusions, they are only present anteriorly (which is why it is so important to see the posterior pericardium), they move to-and-fro with the heart and they have soft internal echoes representing fat septations. If you are unsure whether you are seeing an effusion or a fat pad, there are several things to consider:

- Unless an effusion is loculated, it will not defy gravity and will only accumulate anteriorly in the supine patient. If you are confident that the posterior pericardium looks normal then you have ruled out pericardial effusion and thus tamponade.
- If you can’t see the posterior pericardium and you are not sure whether the black stripe is an effusion or a fat pad, try the parasternal long axis view, which shows the posterior pericardium. If this looks normal then the anterior anechoic area is a fat pad. If this still does not clarify things. then the scan is indeterminate and you must get a formal echo to distinguish fat pad from pericardial effusion.

**Inadequate visualization:** Poor windows cannot always be overcome. In these cases, the scan is indeterminate, and we are back to the clinical picture alone. Consider a formal echo, CT or cardiology consult as needed.

**Clot or fibrin:** Sometimes an effusion is not black, as in the case of early clots which look similar to the ventricular wall. Suspect a clot if the ventricular wall looks very thick (>3 cm). As you watch it over several cardiac cycles, you may notice it is distinct from the ventricle. Fan the probe to check for a small hypoechoic rim that may surround a clot.

**Fluid elsewhere:** Occasionally pleural or, less frequently, abdominal fluid may be confused with pericardial fluid. In the subxiphoid view, since there is no pleural reflection, pleural fluid should not be seen (or confused) in this view. Avoid mistaking abdominal fluid for pericardial fluid by ensuring that the bright white pericardium completely surrounds it.

**Loculations:** These occur in infection or post-instrumentation. They defy the laws of gravity, but may still cause hemodynamic compromise. A complete survey of the heart and pericardium using a fanning technique will allow you to avoid missing these accumulations. Occasionally they may be mistaken for a cardiac chamber, so count the chambers to be sure.

## Expanded applications

Some claim that “knowledge creep” is dangerous and that emergency physicians should use ultrasound only for life-threatening applications. However, as you become more experienced you may wish to try some of these expanded applications. The obvious caveat is to realize your limits and use other clinical data to confirm your findings.

### Assessment of volume status

Both IVC diameter and its collapsibility with normal respiration provide some information about a patient’s volume status: a non-collapsible, dilated inferior vena cava indicates volume overload (or massive/submassive pulmonary embolism) while a collapsed, small diameter vessel occurs in hypovolemia. The chart below indicates the widely accepted correlations with right atrial pressure. Perhaps even more useful than relying on a single number is to use serial IVC ultrasounds to evaluate the response to therapy—eg in goal directed therapy for sepsis.

It is important to note that the numbers below relate to the non-ventilated patient. In a ventilated patient, an absolute diameter more than 1.2 cm correlates with a right atrial pressure >10 mm Hg, but further delineations are difficult. (Jue et al 1992)

A small study looked at children and used the ratio of the IVC to the aorta—dehydrated children had an IVC:aorta ratio in the range of 0.75 and euvolemic children in the range of 1.0. (Chen et al 2007)

| IVC diameter | Collapse with respiration | RA pressure (cmH20) |
|---|---|---|
| <1.5 cm | total | 0–5 |
| 1.5–2.5 cm | >50% | 5–10 |

| | | |
|---|---|---|
| 1.5–2.5 cm | <50% | 11–15 |
| >2.5 cm | <50% | 16–20 |
| >2.5cm | No change | >20 |

How do I Do it?

A longitudinal subxiphoid view is best—so start with the transverse subxiphoid and turn the probe 90 degrees clockwise so that the probe marker is pointing to the patient's head. (figure 13) If you are unsure if you are looking at the IVC or aorta, remember the anatomical relationship between them that you saw on the transverse view, (usually IVC is on the patient's right) and slide the probe further to the patient's right until you no longer see any tubular structures. Then slide back to the midline and the first tubular structure you see will be the IVC. It should be thin walled and without any anterior branches, unlike the aorta. The vein should be measured within 3-4cm of the junction with the right atrium, and superior to the confluence of the hepatic veins. (Figure 14) You may need to rock the probe to look upward to see the IVC at this point. Once you have observed it through some quiet respirations, try using Mmode to more easily quantify the effect of respiration. You can either eyeball it or formally measure it (figure 15).

Figure 13

Longitudinal subxiphoid view for evaluating IVC diameter. The probe marker should be pointing toward the patient's head, and notice that the probe is "rocked" upward to look at the IVC where it meets the right atrium.

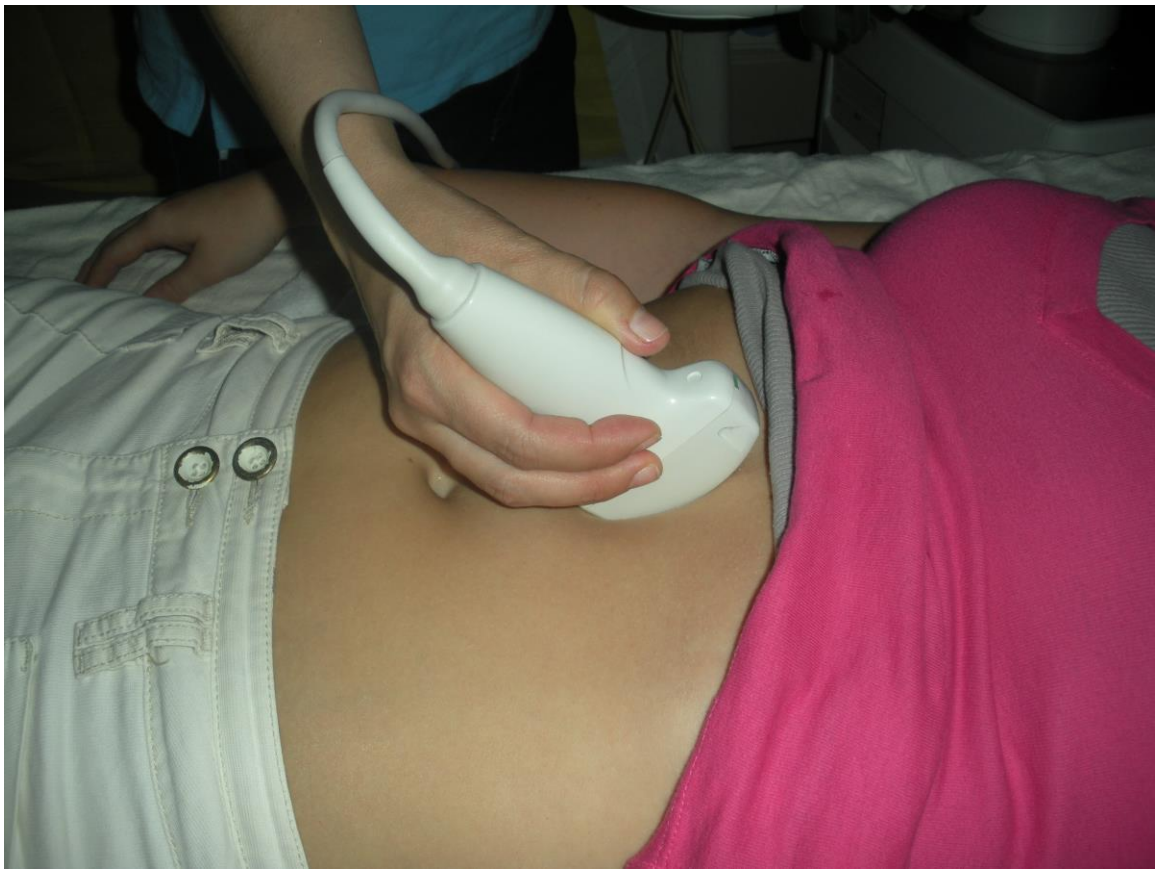


**Figure 14- longitudinal view of IVC**

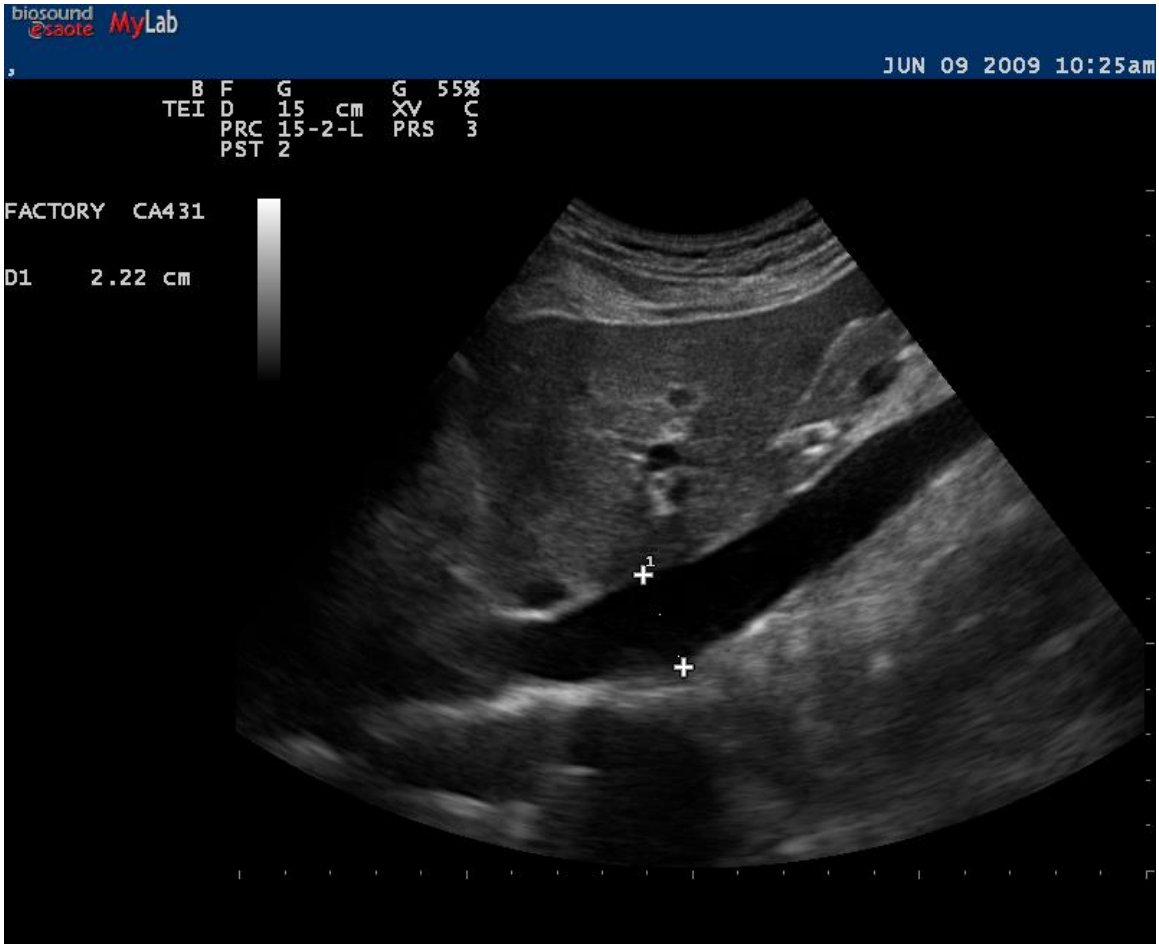
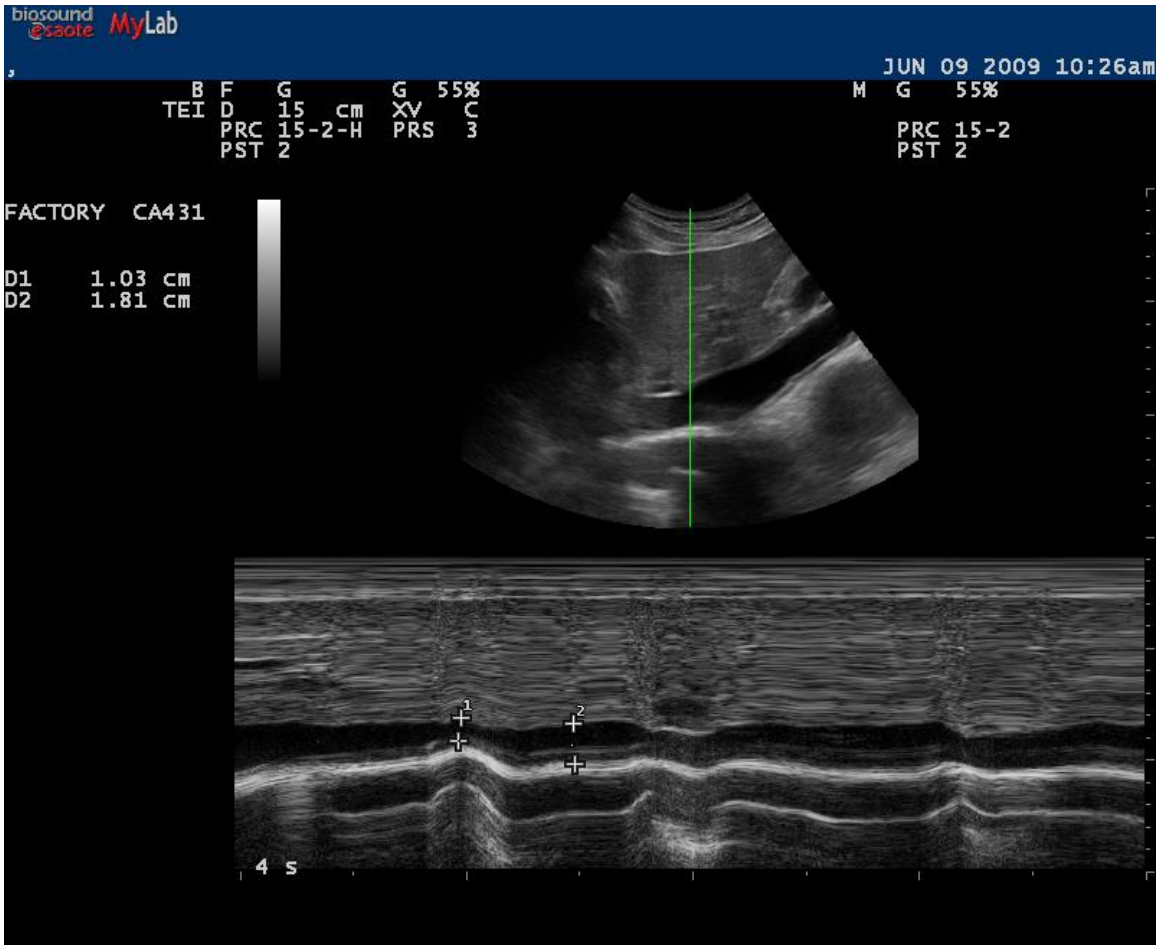


Figure 15- IVC with MMode—the green line represents the sample point which is then displayed in MMode on the bottom of the screen. You can then more accurately quantify the effects of respiration. Caliper 1 represents the collapse with inspiration and caliper 2 is the expiratory diameter. This patient likely has a right atrial pressure 11-15cmH2O (1.5- 2.5cm diameter with <50% collapse.)




**Guidance for pericardiocentesis**

Ideally this should be left to the cardiology service, but when the patient is near arrest with a large effusion, consider pericardiocentesis with ultrasound guidance instead of blind technique. The best entry site is over the biggest accumulation of fluid, with allowances made for the internal mammary artery, which lies about 3–5 cm to the left of the sternal border. A subxiphoid or an apical approach may be used, depending on the location of the largest pocket of fluid.When using an apical approach you may wish to turn the patient to a left lateral decubitus position. There are two ultrasound approaches as well: static (“x marks the spot”) or dynamic technique using a sterile probe sheath.; either one is an improvement upon blind technique.

**Pacer insertion/assessment of mechanical capture**

Ultrasound is useful both for guiding transvenous pacer insertion and for assessing mechanical capture of any pacer. Like many of the expanded applications, it is a nice

tool to have in your toolbox, but is only necessary when clinical signs are difficult to interpret.

**Wall motion assessment**
With time, you may begin to appreciate more the subtle regional wall motion abnormalities that accompany cardiac ischemia. Bedside ultrasound may become a valuable adjunct to our current clinical assessment of chest pain.

## Summary

Limited cardiac ultrasound is easy to learn and a useful tool in the emergency physician’s armamentarium. It is quick and accurate and it provides information not readily available from other tests, for patients with life-threatening conditions.

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# Obstetric emergency department targeted ultrasound

## Learning objectives

- Determine whether there is an *intrauterine* pregnancy versus a pregnancy of unknown location (PUL), and the appropriate management and disposition of the patient
- Determine when obstetric emergency department targeted ultrasound (OEDTU) is indeterminate and when to order a formal ultrasound from diagnostic imaging
- Know when to obtain surgical or obstetric/gynecologic consultation
- Know when to use the curvilinear and endocavitary probes to perform transabdominal and transvaginal assessments, respectively, of the uterus and its contents to determine the presence or absence of intrauterine pregnancy (IUP)
- Determine fetal viability via fetal movement or cardiac flicker presence when intrauterine contents are identified (versus a pregnancy of uncertain viability) which can be reassuring to both physician and patient
- Be familiar with possible different diagnoses outside of a normal pregnancy
- Consider medico-legal implications in the management of the symptomatic pregnant patient in Canada

## Introduction

Before the advent of ultrasound in the emergency department, the rate of patients discharged with an ectopic pregnancy was 40%. The mortality rate for ectopic pregnancy was 1 in 1,000 Ref Dart. Eight percent to 15% of symptomatic pregnant patients presenting to the emergency department have an ectopic presentation. This represents the rationale for vigilance in dealing with this patient population. The advantages of early diagnosis in this population include: Prevention of life threatening hemorrhage, consideration for for tubal-conserving surgery, or consideration for medical management with methotrexate.

Published evidence indicates that EDTU can reduce the frequency of missed ectopic pregnancies, decrease time to surgery for ectopic pregnancy, shorten the length of stay for patients with normal pregnancies and may be more cost-effective than diagnostic strategies requiring formal ultrasonography[1]. We will discuss what information is required to manage the pregnant patient in the safest, most efficient manner in the emergency department. We will show you how to identify a pregnancy in the uterus. If an intrauterine pregnancy is not detected, then one must assume that there is an ectopic pregnancy. Some conditions, such as a missed abortion, retained products of conception (RPOC), and hydatidiform mole, are included in the differential diagnosis and must be considered. However, if there is no definitive intrauterine pregnancy (NDIUP), the safest conclusion is that this patient has an ectopic pregnancy until proven otherwise. Having stated that, Transabdominal (TA) and Transvaginal (TV) ultrasound and BHCG testing have indisputable benefits however their misuse and misinterpretation can lead to interventions that inadvertently damage pregnancies that might have had normal outcomes. There are well-documented instances of women with intrauterine pregnancies treated with intramuscular methotrexate for suspected ectopic pregnancy, leading to failure of the pregnancy (“miscarriage”) or the birth of a malformed baby. (ref Doubilet)

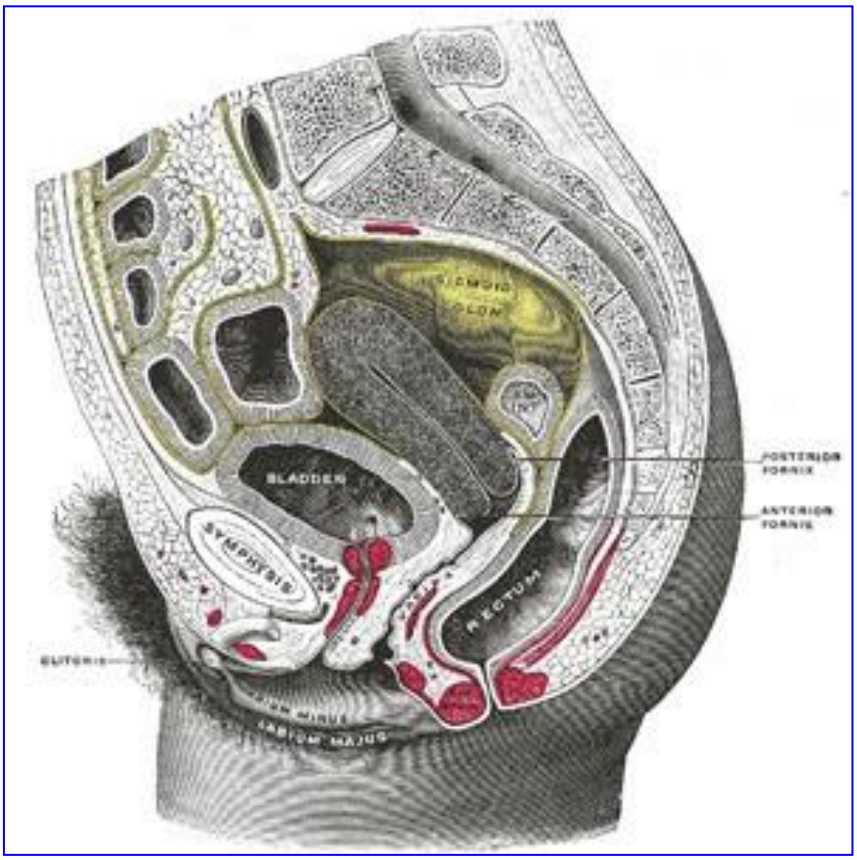
More recently there has been recognition that in some cases a pregnancy can be

present though not initially identified as a normal intrauterine gestation due to variable presentations on bedside or formal ultrasound. This may result in the inadvertent termination of a normal pregnancy. Thus new guidelines have emerged for the determination of fetal demise (ref Doubilet). For example the ED physician may be asked to interpret results relating to CRL ≥ 7 mm with no FHR and/or mean gestational sac diameter ≥ 25 mm with no embryo when a patient is sent to the ED from Diagnostic Imaging for ultrasound results. In the stable pregnant patient population with negative free fluid in the abdomen and pelvis and an ultrasound showing an intrauterine pregnancy of uncertain viability these patients require follow up ultrasound and BHCG in 2-7 days. Avoid the clinical pathway leading to MTX management without a second confirmatory US days later.

In the presence of an intrauterine pregnancy, there is also a chance of a heterotopic pregnancy (one fetus in the uterus and one outside the uterus). The incidence of heterotopic pregnancy varies, but in the general population it may be as high as 1 in 2,600 to 1 in 30,000 pregnancies. The incidence of heterotopic pregnancy in women undergoing fertility treatment can be as high as 1 in 100. Therefore if there is an IUP and the patient is NOT on fertility medications, she can be safely discharged from the emergency department with close follow up and in some cases outpatient formal ultrasound.

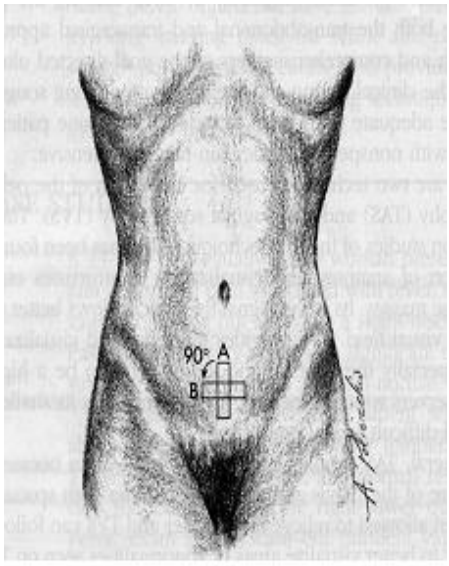
Clinical Anatomy

**Figure 1. Anatomy of the female pelvis.**




The sagittal section (above) shows the structures that will be seen on the screen from top to bottom during a transabdominal ultrasound. Imagine a probe placed just cephalad to the symphysis. The sound waves pass through the bladder first, then uterus, cul-de-sac and rectum/sigmoid.

**Figure 2 Probe Positions TAUS**




Orienting the probe marker to the 12 o'clock position yields the sagittal view (A, Figure 2 at left) and the 9 o'clock position yields a coronal view (B, Figure 2 at left) of the pelvic structures. You may need to slide from side to side to get the uterus to come into view. From the 12 o'clock position, angling the probe from 45$^{o}$ toward the patient's right to 45$^{o}$ toward the patient's left at a caudal tilt angle of up to 30$^{o}$ will allow you to scan through the uterus in the longitudinal view. We suggest beginning in the longitudinal position then moving to the transverse position. Figure 3 shows the probe position on the patient first in longitudinal view with the probe marker pointing cephalad then tilting the probe to the patients left and right 45$^{o}$.

If you now turn the probe 90$^{o}$ counter clockwise to the transverse view (probe marker at the 9 o'clock position) with the same caudal tilt as in the

longitudinal view, the sound waves will pass through the uterus from fundus to cervix visualizing the endometrial stripe as you increase the caudal tilt further (Figure 4). Because of increased transmission of sound, enhancement (increased white appearance = echogenic) may occur posterior to the bladder. Decreasing the gain will assist in visualizing the cervix and vaginal stripe.

**Figure 3. A and B (Below ) show the 45$^{o}$ tilt as the uterus is scanned from the midline position out to the patients' right (A) and left (B) side of her uterus.**

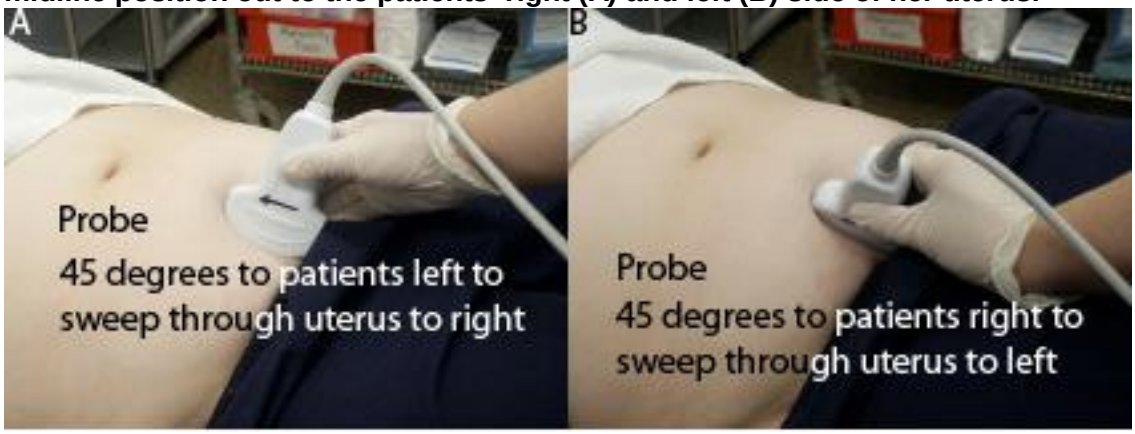
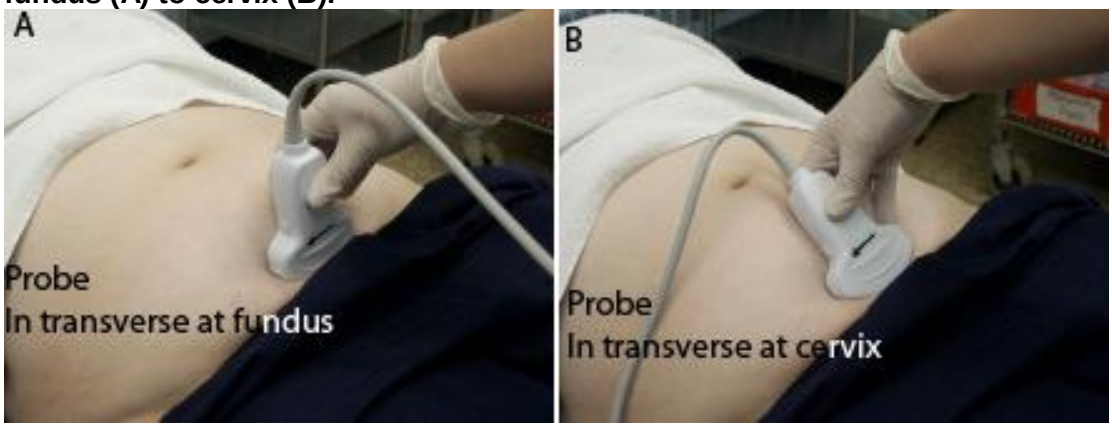



**Figure 4. Now in transverse position the Uterus is scanned from the patients' fundus (A) to cervix (B).**




When the patient is first assessed in the emergency department, while the bladder is somewhat full, a transabdominal ultrasound (TAUS) can be done to determine whether there is an intrauterine pregnancy. The TAUS can also determine if there is any free fluid in the pelvis and assess for abnormalities beyond the field of view of the high frequency endocavitary probe. You may be able to stop here if you have found a definitive intrauterine pregnancy (DIUP). Otherwise, the patient should empty her bladder (provide a urine sample if required) and a transvaginal ultrasound (TVUS) can be carried out after or in conjunction with the pelvic exam. The transvaginal ultrasound is thought to be the study of choice to evaluate first trimester bleeding.(ref ACR 2013) When the bladder is full, it acts as an acoustic window through which to examine the uterus and it's contents, which is required for TAUS; an EMPTY BLADDER is preferred for a TV ultrasound.

TAUS has the advantage of greater penetration because of the lower frequency of the probe (~3.5 vs 7 MHZ). The field of view is wider and it is easier to orient than TVUS. TAUS is helpful for looking for free fluid in a field of view not easily visualized on TV

assessment. On the other hand, TVUS is associated with greater patient comfort (because the bladder is empty) and it provides more detail, although at times it is more difficult to generate the images. TVUS is the modality of choice for early pregnancy assessment. You should advocate for this probe if your ED does not currently have one. Once training is complete please TVUS for early pregnancy assessment appropriately and often.

**Transabdominal ultrasound scan**

Placing the probe just superior to the symphysis pubis will enhance the view of the uterus in cross section. Note: For early pregnancies (up to about 12 weeks gestation), it may be necessary to tilt the probe up to 30$^{o}$ caudally (into the pelvis) to view the uterus properly. Identify the bladder and uterus. Tilting the probe from cephalad to caudad will assist in scanning the uterus from fundus to cervix and visualize the entire endometrial stripe. Likewise, for the sagittal view, tilting the probe at about 45$^{o}$ to the patient's right and left scanning through the uterus will include the region of interest, the endometrial stripe. If an IUP is noted slowly scan through it in both longitudinal and transverse planes noting the cardiac flicker if visualized. If the bladder is empty and you are unable to identify the criteria for determining an IUP then proceed to the TV ultrasound.

**Transvaginal ultrasound scan**

The objectives for the TVUS are essentially the same — to scan through the endometrial stripe in two different planes. Prepare the probe by applying ultrasound gel, then covering the probe with a condom or probe sheath; you may have to secure the condom with an elastic. A layer of water soluble gel (e.g., Muko) is then applied to facilitate probe insertion. Ultrasound gel can be irritating to the patient, so a water soluble gel is used outside the condom or sheath. Usually the gloved operator will be inserting the probe; however, some patients prefer to insert it themselves when you provide the option.

The probe should be inserted only as far as the cervix to obtain the desired view. Observe the screen as the probe is being inserted so that it is not inserted too far. With the probe marker oriented anteriorly (Figure 5), the initial view will be in the sagittal plane and scanning of the uterus will be from the endometrial stripe to the left and right borders. Once this scan is complete, turn the probe 90$^{o}$ to the patient's right (or counterclockwise) to generate the coronal view. Then, beginning at the endometrial stripe, scan anteriorly and posteriorly through the uterus.

The uterus should be completely scanned in each orientation. Then return to areas of interest to locate the gestational sac, decidual reaction, yolk sac, fetal pole and fetal heart. Measurements can be taken to date the pregnancy and determine viability. Do NOT use the doppler (or power doppler) mode of the ultrasound unit as this may result in fetal anomalies at a later date secondary to heat production (see section Education in obstetric bedside ultrasound below).

**Figure 5. A transvaginal (endocavitary) probe (7.5 MHz).**

**Figure 5a. Insert the endocavitary probe with the marker anterior (toward the ceiling) to yield a sagittal view. The white arrow is indicating the probe marker; the yellow arrow is pointing at the grey tip of the probe indicating the orientation of the ultrasound waves. Once the probe tip reaches the cervix, sweep through the**

**uterus left and right (i.e., move the handle of the probe to the left and right in the coronal plane) SLOWLY. Rotating the probe to the patient's right to a 90° angle will give you the coronal plane. Now moving the handle in the sagittal plane anterior and posterior SLOWLY will allow you to scan the uterus in the coronal plane.**

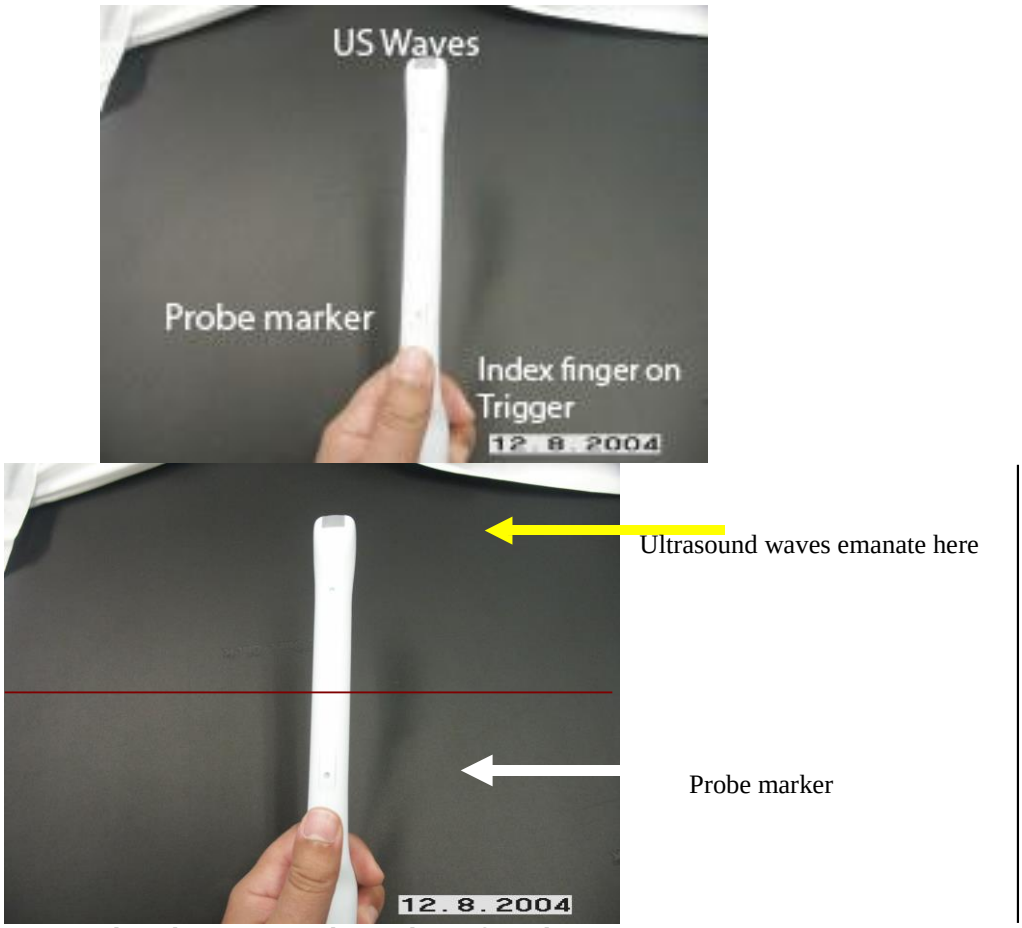
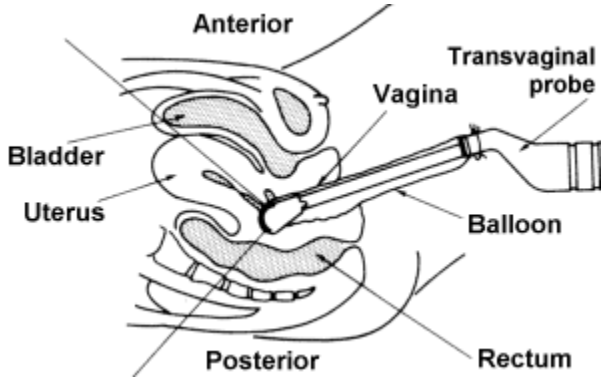



**Figure 6. Diagram showing correct insertion of probe.**



**Troubleshooting:** If you are disoriented with the first insertion withdraw to about 3 cm within the introitus and move the HANDLE slowly posteriorly (toward the floor) to locate the bladder then slowly anteriorly (toward the ceiling) to locate the area of interest. You may need to advance the probe closer to the cervix to identify the area of interest. Careful to not raise the handle too far anteriorly which can put pressure on the urethra eliciting pain (an issue when the uterus is retroverted) .

## Heat Production in obstetric bedside ultrasound

Educators in bedside obstetric ultrasound should give consideration to heat production by sustained exposure of fetal tissue to ultrasound.

The American institute of Ultrasound in Medicine (AIUM) has three statements of interest applicable to bedside ultrasound practitioners.

## Safety in Training and Research

Approved March 19 2007

Diagnostic ultrasound has been in use since the late 1950s. There are no confirmed adverse biological effects on patients resulting from this usage. Although no hazard has been identified that would preclude the prudent and conservative use of diagnostic ultrasound in education and research, experience from normal diagnostic practice may or may not be relevant to extended exposure times and altered exposure conditions. It is therefore considered appropriate to make the following recommendation:

When examinations are carried out for purposes of training or research, the subject should be informed of the anticipated exposure conditions and how these compare with normal diagnostic practice.

**From the new Statement on Heat** Approved April 6 2009:

Acoustic output from diagnostic ultrasound devices is sufficient to cause temperature elevations in fetal tissue. In general, temperature elevations become progressively greater from B-mode to color Doppler to spectral Doppler applications. For identical exposure conditions, the potential for thermal bioeffects increases with the dwell time during examination. Although, in general, an adverse fetal outcome is possible at any time during gestation, most severe and detectable effects of thermal exposure in animals have been observed during the period of organogenesis. For this reason, exposures during the first trimester should be restricted to the lowest outputs consistent with obtaining the necessary diagnostic information.

**Conclusions Regarding Epidemiology for Obstetric Ultrasound** Approved June 22 2005

Based on the epidemiologic data available and on current knowledge of interactive mechanisms, there is insufficient justification to warrant conclusion of a causal relationship between diagnostic ultrasound and recognized adverse effects in humans. Some studies have reported effects of exposure to diagnostic ultrasound during pregnancy, such as low birth weight, delayed speech, dyslexia and non-right- handedness. Other studies have not demonstrated such effects. The epidemiologic evidence is based on exposure conditions prior to 1992, the year in

which acoustic limits of ultrasound machines were substantially increased for fetal/obstetric applications.

## Medico-Legal issues

The presentation of an Ectopic pregnancy can be difficult and involve some degree of risk. Patients often present with vague symptoms and classic risk factors cannot be relied upon to exclude the diagnosis. OEDTU can improve your diagnostic accuracy and improve patient safety when used appropriately. The following statement provides support for the appropriate use of TVUS in the assessment of the symptomatic pregnant patient. The CMPA recently (June 2009) released a statement regarding the life threatening nature of ectopic pregnancy. "In the 17 closed cases, a delay in the diagnosis of ectopic pregnancy was the leading reason for the medico-legal problems encountered" The failure to perform appropriate diagnostic investigations in women of reproductive age who presented with abdominal pain and vaginal bleeding was considered a factor in the diagnostic delay.

Risk management considerations based on the college decisions are:

Have you considered the diagnosis of ectopic pregnancy when a women of reproductive age presents with abdominal pain and vaginal bleeding?

Are you familiar with the current clinical practice guidelines for the investigation and management of suspected ectopic pregnancy?

Have you performed the appropriate physical examination and arranged for any appropriate diagnostic investigations?

Is there a system in place to facilitate timely follow up of investigations and/or patients?

Does the documentation reflect your clinical impressions at the time of assessment, discussions with consultants and patient instructions?

In Ontario, the CPSO reiterated some of these issues (especially carrying out the physical exam) in the July 2009 issue of MD Dialogue.

## Criteria for determining an intrauterine pregnancy

The criteria for determining a definitive intrauterine pregnancy (DIUP) are threefold after ensuring bladder-uterine juxtaposition. In the absence of one of these criteria, there is no definitive intrauterine pregnancy (NDIUP).

1. Decidual reaction — thick white echogenic layer surrounding the gestational sac
2. Gestational sac (GS) — anechoic (black) area within the uterus
3. Yolk sac (YS) in the uterus — white ring (2D) about 5 mm in diameter within the GS

If you see an INTRAUTERINE (initially noting bladder-uterine juxtaposition) pregnancy with these components then you can call this a DIUP. Additional features which will assist in confirming that the identified structure represents a viable pregnancy are:

- Fetal pole — AKA fetus. If identified in the uterus = DIUP
- Cardiac flicker — AKA fetal heart = sign of viability if >90 bpm

Normal heart rate for crown rump length 5–15 mm is 100–120 bpm.

## BHCG

The evaluation and management of a pregnancy of unknown location have received considerable attention, with various flow charts and mathematical models proposed for use in this context. Our intent here is not to review the broad topic of pregnancy of unknown location, but instead to focus on one important element: the role of an hCG level at a single point in time in diagnosing or ruling out a viable intrauterine pregnancy and in guiding patient-care decisions. The hCG levels in viable intrauterine pregnancies, nonviable intrauterine pregnancies, and ectopic pregnancies have considerable overlap, so a single hCG measurement does not distinguish reliably among them. Considerable research during the past 30 years has sought to determine the discriminatory hCG level: the value above which an intrauterine gestational sac is consistently seen on ultrasonography in normal pregnancies. An early study, based on transabdominal ultrasonography, put the level at 6500 mIU per milliliter. With improvements in ultrasonographic technology, including the introduction of transvaginal ultrasonography, gestational sacs became detectable earlier in pregnancy, and the reported discriminatory hCG level was brought down to 1000 to 2000 mIU per milliliter. As with the crown–rump length and mean sac diameter, however, more recent research has shown that previously accepted values for the discriminatory hCG level are not as reliable for ruling out a viable pregnancy as originally thought. One reason for the lower reliability of the discriminatory hCG level today than was reported in the past may be the fact that multiple gestations, which are associated with higher hCG levels at a given stage of pregnancy than are singleton gestations, are more common now than they were 20 to 30 years ago. Failure of the discriminatory hCG level to rule out a viable intrauterine pregnancy, however, has been seen in singleton as well as multiple gestations. Several studies have documented cases in which an embryo with cardiac activity was seen on follow-up ultrasonography after initial ultrasonography showed no gestational sac with an hCG level above 2000 mIU per milliliter and even above 3000 mIU per milliliter. In a woman with a pregnancy of unknown location whose hCG level is more than 2000 mIU per milliliter, the most likely diagnosis is a nonviable intrauterine pregnancy, occurring approximately twice as often as ectopic pregnancy.[50] Ectopic pregnancy, in turn, occurs approximately 19 times as often as a viable intrauterine pregnancy when the hCG level is 2000 to 3000 mIU per milliliter and the uterus is empty, and 70 times as often as a viable intrauterine pregnancy when the hCG level is more than 3000 mIU per milliliter with an empty uterus. (These latter estimates are based on data from one institution assessing ectopic pregnancies and viable intrauterine pregnancies in relation to hCG levels in women with an empty uterus.) On the basis of these values, among women with a pregnancy of unknown location and hCG levels of 2000 to 3000 mIU per milliliter, there will be 19 ectopic pregnancies and 38 nonviable intrauterine pregnancies for each viable intrauterine pregnancy. Thus, the likelihood of a viable intrauterine pregnancy for such women is $[1 \div (1 + 19 + 38)]$, or approximately 2%. If we use the same reasoning for women with a pregnancy of unknown location and hCG levels of more than 3000 mIU per milliliter, the likelihood of a viable intrauterine pregnancy is $[1 \div (1 + 70 + 140)]$, or approximately 0.5%. We recognize that these estimates of the likelihood of a viable intrauterine pregnancy in a woman with a pregnancy of unknown location whose hCG level is 2000 mIU per milliliter or higher are not highly precise, given the limitations of the available data, but there are a number of reasons why presumptive treatment for ectopic pregnancy with the use of methotrexate or other pharmacologic or surgical means is inappropriate if the woman is hemodynamically stable. First, as noted above, there is a chance of harming a viable intrauterine pregnancy, especially if the hCG level is 2000 to 3000 mIU per milliliter. Second, the most likely diagnosis is nonviable intrauterine pregnancy (i.e., failed pregnancy), and methotrexate is not an appropriate treatment for a woman with this diagnosis. Third, there is limited risk in taking a few extra days to make a definitive diagnosis in a woman with a pregnancy of unknown location who has no signs of symptoms of rupture and no ultrasonographic evidence of ectopic pregnancy. Fourth, the progression of hCG values over a period of 48 hours provides valuable information for diagnostic and therapeutic decision making. Thus, it is generally appropriate to do additional testing before undertaking treatment for ectopic pregnancy in a hemodynamically stable patient (Table 3). Women with ectopic pregnancies have highly variable hCG levels, often less than 1000 mIU per milliliter and the hCG level does not predict the likelihood of ectopic pregnancy rupture. That is, a single hCG value, even if low, does not rule out a potentially life-threatening ruptured ectopic pregnancy. Hence, ultrasonography is indicated in any woman with a positive pregnancy test who is clinically suspected of having an ectopic pregnancy.Ref Doubilet

**Table 3. Diagnostic and Management Guidelines Related to the Possibility of a Viable Intrauterine Pregnancy in a Woman with a Pregnancy of Unknown Location.***

| Finding | Key Points |
|---|---|
| No intrauterine fluid collection and normal (or near-normal) adnexa on ultrasonography† | A single measurement of hCG, regardless of its value, does not reliably distinguish between ectopic and intrauterine pregnancy (viable or nonviable).<br>If a single hCG measurement is <3000 mIU/ml, presumptive treatment for ectopic pregnancy with the use of methotrexate or other pharmacologic or surgical means should not be undertaken, in order to avoid the risk of interrupting a viable intrauterine pregnancy.<br>If a single hCG measurement is ≥3000 mIU/ml, a viable intrauterine pregnancy is possible but unlikely. However, the most likely diagnosis is a nonviable intrauterine pregnancy, so it is generally appropriate to obtain at least one follow-up hCG measurement and follow-up ultrasonogram before undertaking treatment for ectopic pregnancy. |
| Ultrasonography not yet performed | The hCG levels in women with ectopic pregnancies are highly variable, often <1000 mIU/ml, and the hCG level does not predict the likelihood of ectopic pregnancy rupture. Thus, when the clinical findings are suspicious for ectopic pregnancy, transvaginal ultrasonography is indicated even when the hCG level is low. |

* Criteria are from the Society of Radiologists in Ultrasound Multispecialty Consensus Conference on Early First Trimester Diagnosis of Miscarriage and Exclusion of a Viable Intrauterine Pregnancy, October 2012.
† Near-normal (i.e., inconsequential) adnexal findings include corpus luteum, a small amount of free pelvic fluid, and paratubal cyst.

By using a high-frequency probe, such as the 7.5 MHz endocavitary (transvaginal) probe, we increase resolution but decrease penetration. This is desirable, as the probe tip will be placed at the level of the cervix and we are only interested in the uterus and its contents. Presence of a yolk sac is the most critical criterion in confirming an intrauterine pregnancy. If we are able to view a fetal pole with or without fetal cardiac activity in the uterus this would also be confirmation of a definitive IUP (with flicker) or IUP of uncertain viability (without flicker). In terms of viability a new threshold for determination of failed pregnancy has been published. Findings diagnostic of pregnancy failure are a crown-rump length (CRL) of ≥ 7 mm and no FHR, or mean gestational sac diameter of ≥ 25 mm and no embryo on transvaginal ultrasound. These values will be helpful in assisting you interpret formal US results from diagnostic imaging though we are not advocating you measure these as yet until you have an appropriate number of compared measurements to formal US (at least 100 for CRL as an example). Other features diagnostic of pregnancy failure are: 1) a finding of absence of an embryo with a heartbeat ≥ 2 weeks after a scan that showed a gestational sac without a yolk sac or 2) absence of an embryo with a heartbeat ≥ 11 days after a scan that showed a gestational sac with a yolk sac. (Ref Doubilet 2013)

Remember that doing a TV ultrasound in a symptomatic first trimester patient has the highest likelihood ratio for detecting ectopic pregnancy by the presence of two findings 1) Absence of an IUP 2) presence of an adnexal mass LR+ = 111 (ref Crochet 2013). Though you may not be looking for the adnexal mass yourself you may be asking a more detailed question of those performing the formal TV ultrasound => “Is there an adnexal mass?” on your US requisition. In the stable patient if you see an adnexal mass you may want to confirm this with formal US and consult your surgical colleague.

**Figure 7. Transvaginal image after having viewed the bladder-uterine juxtaposition revealing the thick white decidual reaction surrounding the gestational sac (anechoic & black) with a yolk sac (smaller white echogenic circle) within the GS. Note the strand of amnion emanating from the yolk sac in this view.**

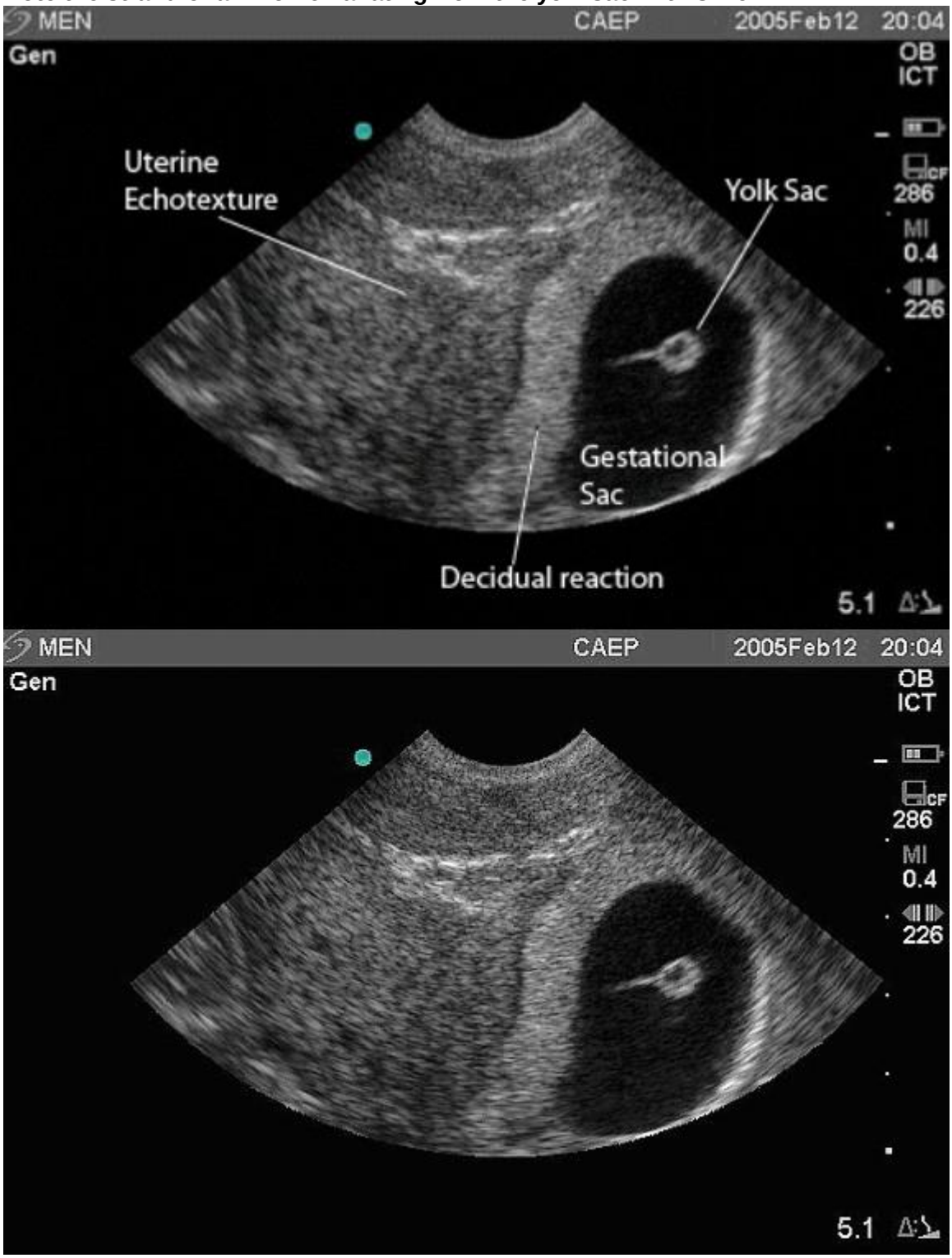
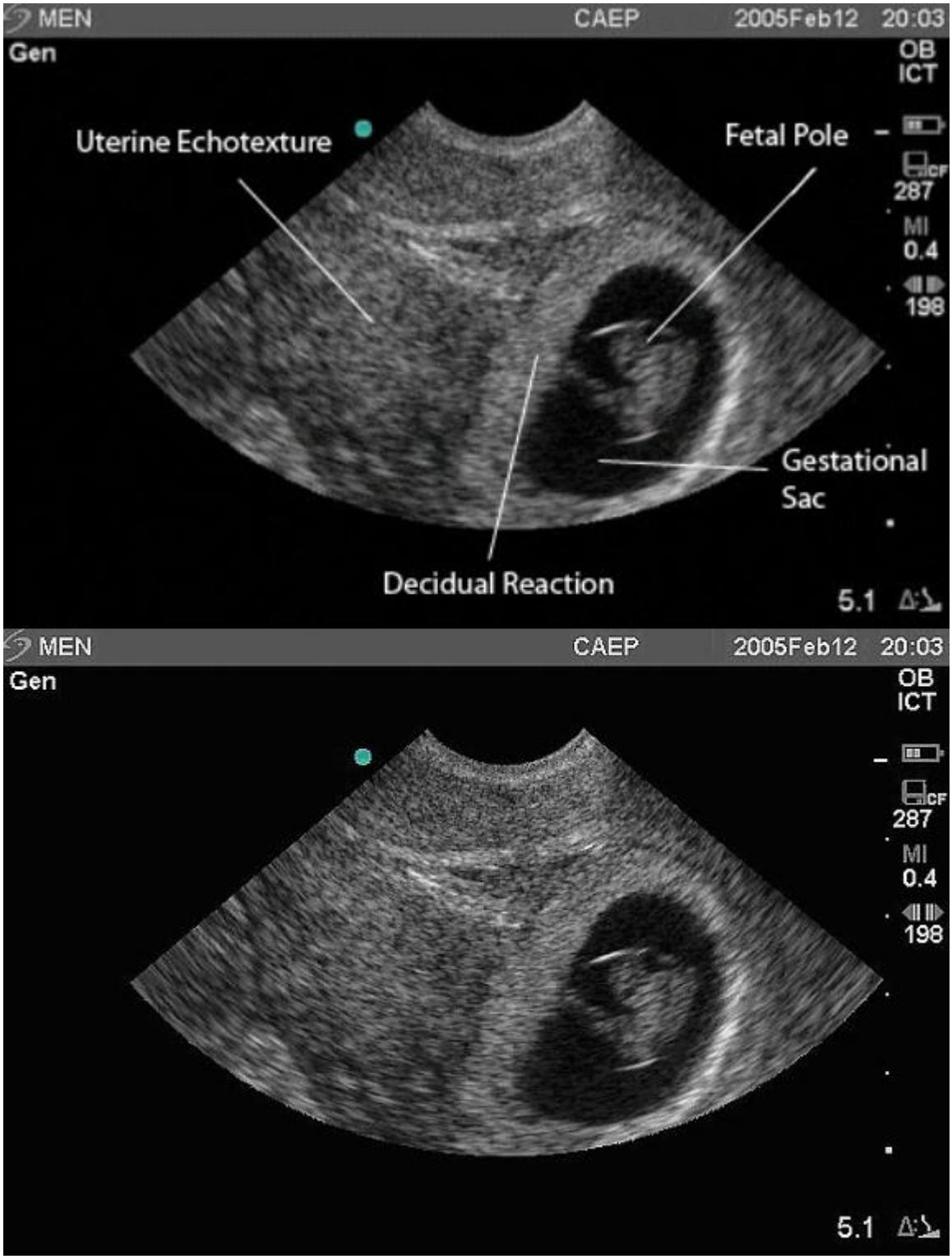


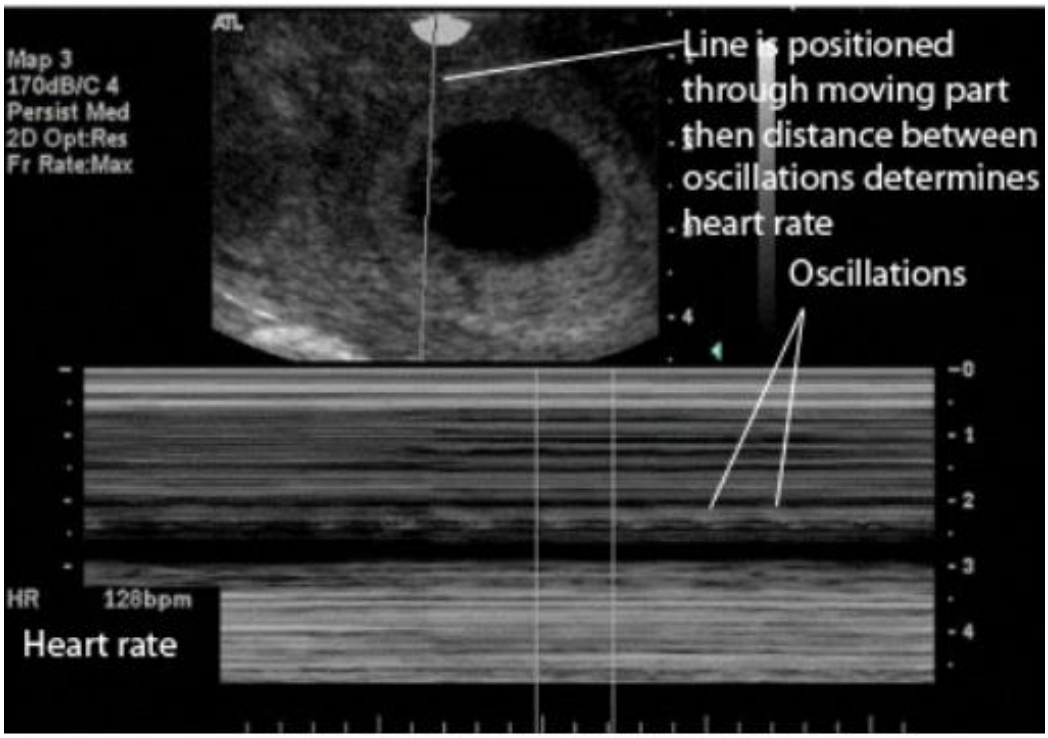

**Figure 8. One criterion to determine intrauterine pregnancy is presence of an intrauterine fetal pole.**

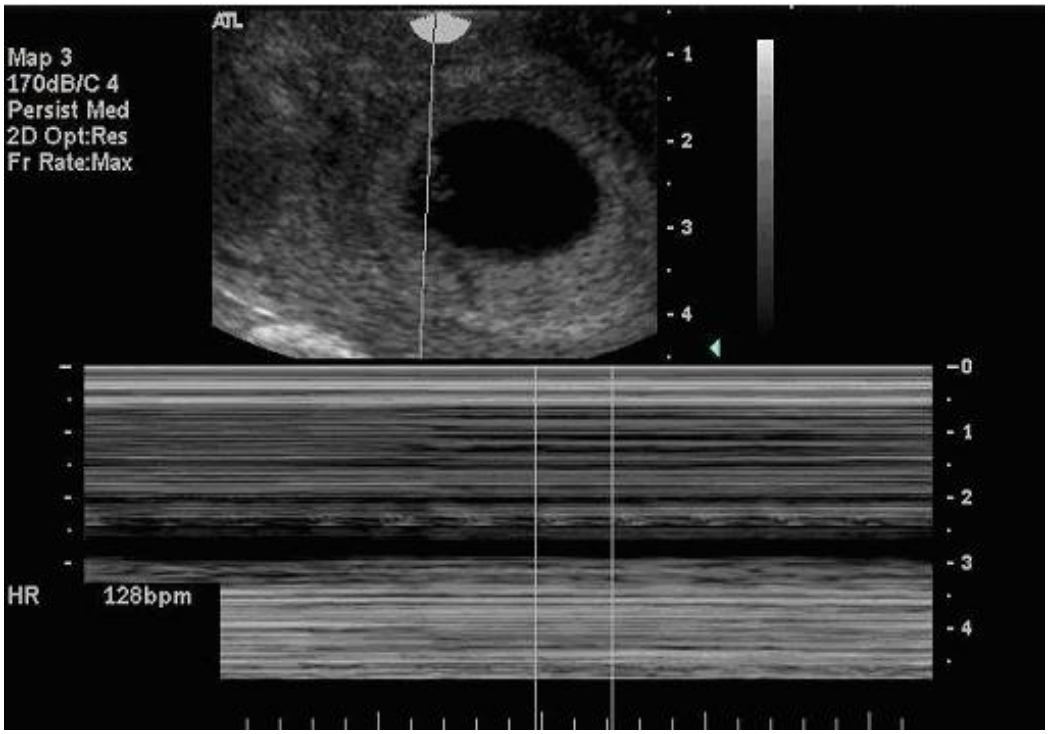



If fetal activity is detected, this will decrease the possibility of miscarriage. Cardiac activity (normal heart rate: 112–136 beats per minute) is measured using the M mode (M for motion or movement). Make sure you also measure the mother's heart rate (via the ECG/$SatO_2$ monitor) to make sure that it is not the same. A fetal heart rate of less than 90–100 beats per minute is an indicator of poor fetal outcome. If a live IUP is identified

a term pregnancy will result in about 85% of cases. A failed pregnancy can be diagnosed when the crown rump length is 15 mm and no fetal heart is detected on transabdominal scanning.

Figure 9.



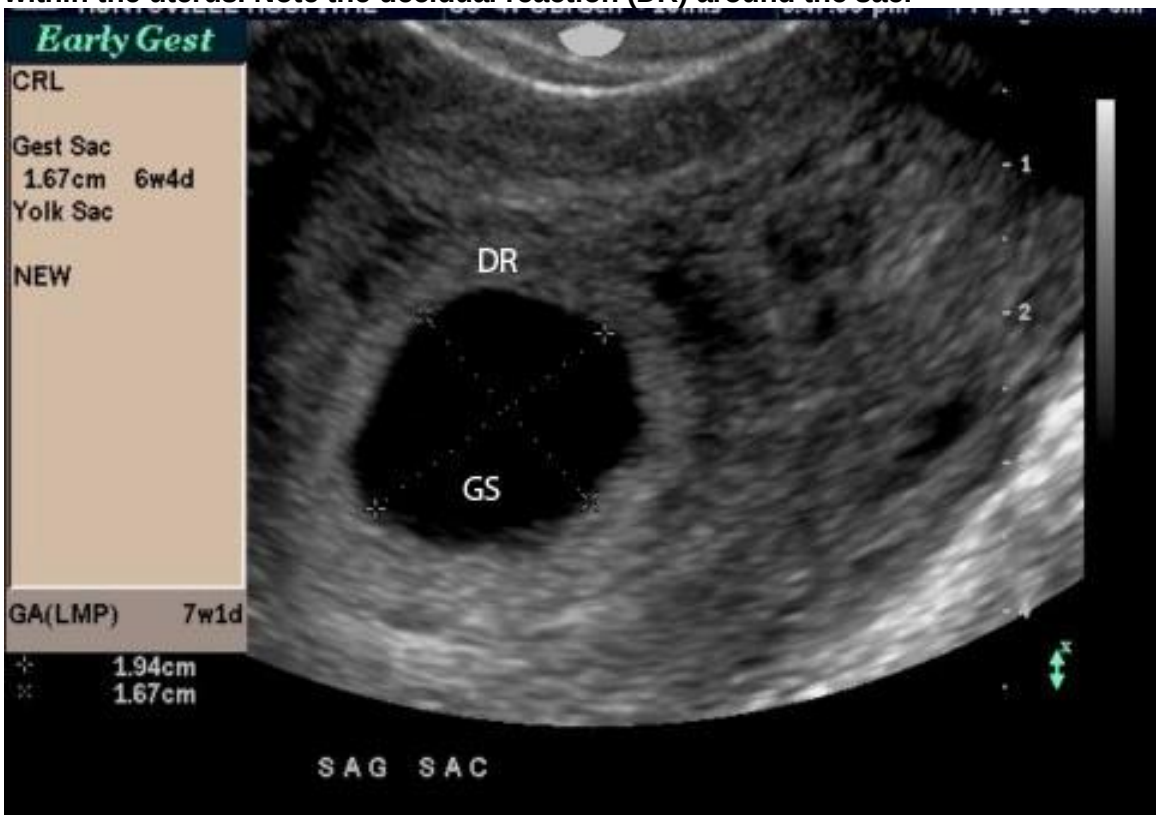



**NOTE: DO NOT USE THE DOPPLER MODE AS THIS CAN LEAD TO FETAL ANOMALIES.**

**If you have any concern about how to use your department's machine, do not attempt to measure the heart rate until you are adequately trained.**

Decidual reaction appears as an echogenic (white) stripe within the uterus. The deciduas form thick layers that appear as a white line transecting the gestational sac (Figure 10).

**Figure 10. Gestational sac (GS) appears as an anechoic black circular structure within the uterus. Note the decidual reaction (DR) around the sac.**



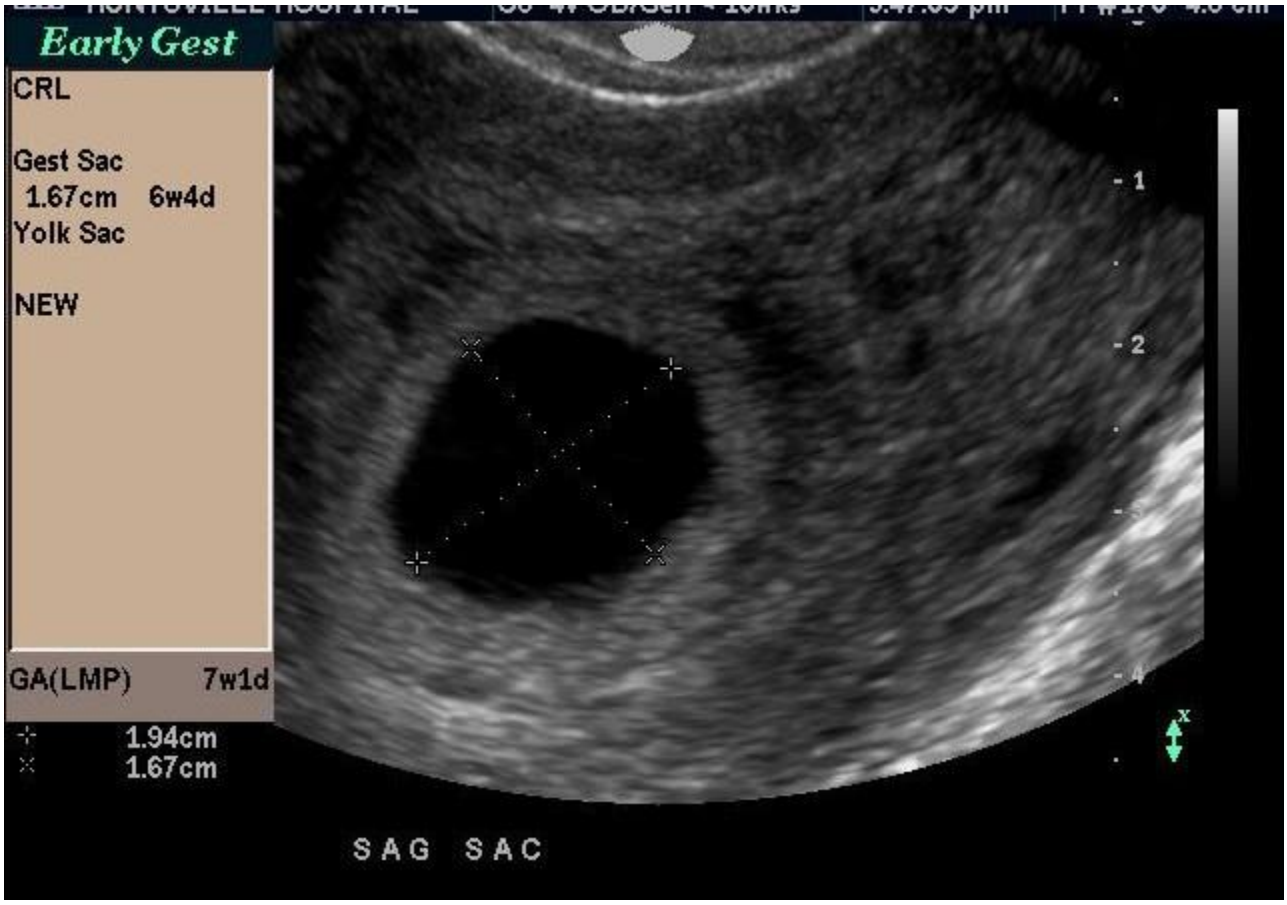
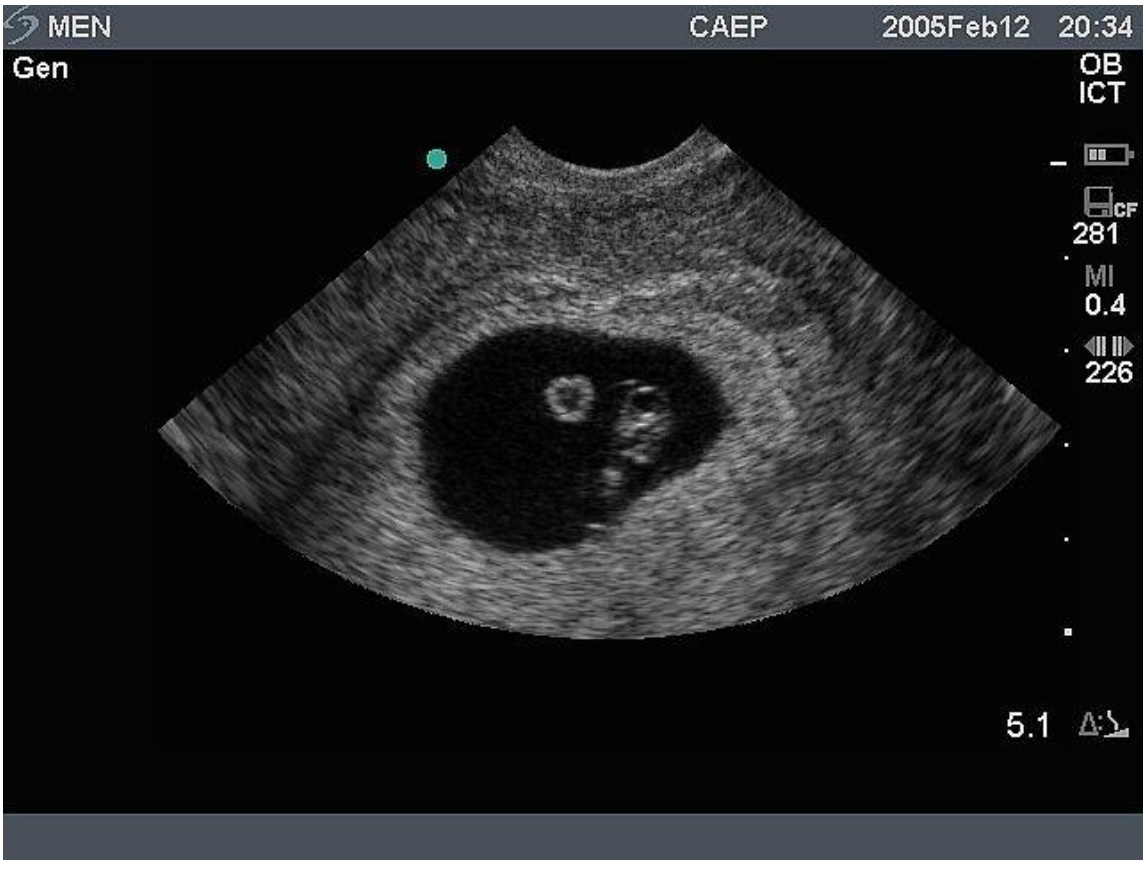



**Figure 12. The yolk sac appears as an echogenic area within the gestational sac. It can be identified beginning around 5–6 weeks by TVUS and by 7 weeks by TAUS. Note the subjacent fetal pole.**



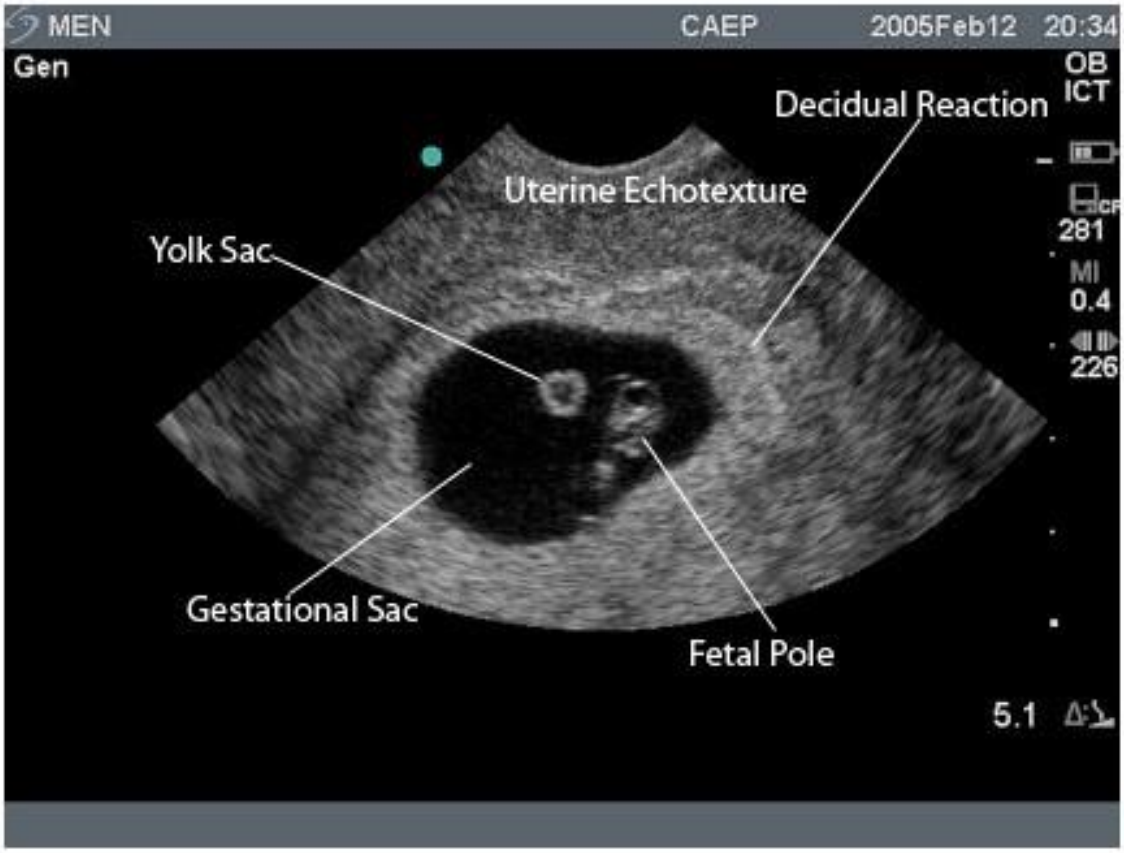
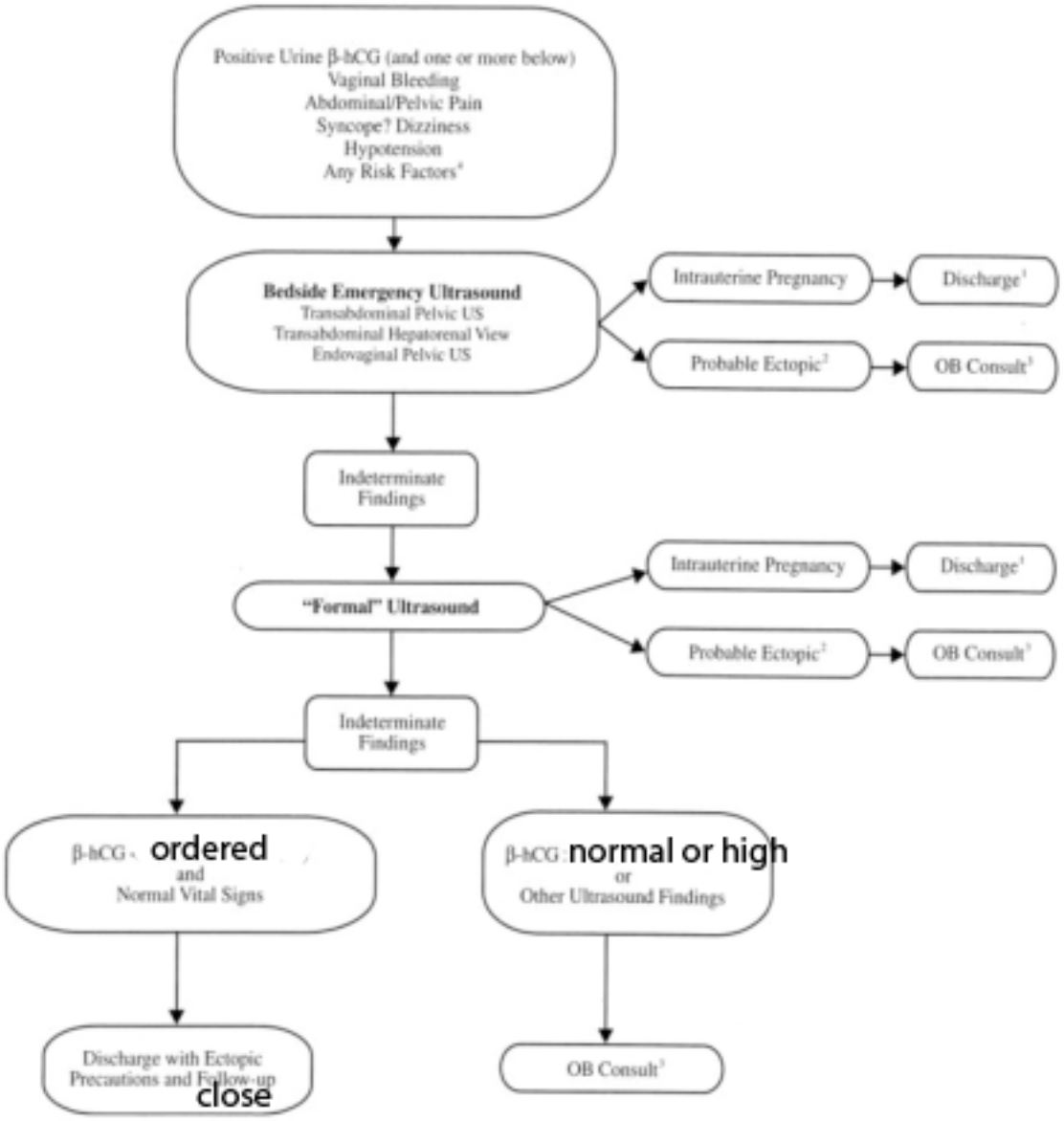

MEN
CAEP
2005Feb12 20:34
Gen
OB
ICT
Decidual Reaction
Uterine Echotexture
Yolk Sac
281
MI
0.4
226
Gestational Sac
Fetal Pole
5.1

**Figure 13. Algorithm for identification of intrauterine pregnancy in the emergency department.**




1. Unless patient is on fertility medications or undergoing IVF.
2. Ultrasound criteria for probable ectopic pregnancy: extrauterine yolk sac or embryo, tubal ring, complex mass, or free fluid.
3. Surgery may be required if the patient has hypotension, a large ectopic sac (>4 cm), a large amount of pelvic free fluid, or hepatorenal free fluid.
4. Risk factors include: PID, tubal surgery or ligation, IUDs, prior ectopic, infertility, advanced age.

## Pitfalls

# Common Pitfalls with Ultrasound in Early Pregnancy

**Exercise extreme caution with regard to last menstrual period (LMP) on history taking.** Up to 50% of women are uncertain of their dates, or have an irregular cycle, or have just stopped the oral contraceptive pill (OCP), or are lactating or did not have a normal last period. Enquire when the women had her first positive pregnancy test (which may be positive 3 days before the missed period).

**Visualise all of the uterus.** Pan through the uterus in saggital, and then rotate the probe 90 degrees to visualise from cervix to fundus. Failure to visualise all of the uterus will result in missing gestational sacs in single and multiple pregnancies.

**When ordering a formal US - Neglecting to scan the adnexae** will result in missing heterotopic pregnancies and ovarian masses which may require surgery.

**Avoid labelling subchorionic bleeds as additional gestational sacs.** Do not tell a woman that she has a twin pregnancy with one empty sac unless you are very experienced in ultrasound.

**Pseudosacs.** Exercise caution in labelling intrauterine sac–like structures as gestational sacs unless they have contents i.e. yolk sac or fetus. Pseudosacs will follow the uterine cavity and are more ellipitical, while gestational sacs are fundal and eccentrically placed.

**Fibroid Uterus**. The fundus of a fibroid uterus may not be included in the scan field at TVUS. Both TVUS and abdominal scans are needed in these women to avoid missing gestational sacs.

## Other Pitfalls

- Diagnosing a collection of intrauterine fluid as an “early” intrauterine pregnancy
- A low level of beta human chorionic gonadotropin (βhCG) does not mean low risk for ectopic pregnancy
- Failure to determine the exact location of a gestational sac
- Cul-de-sac fluid may be the only sonographic finding of ectopic pregnancy

## Troubleshooting

**Problem:** On initial insertion of the probe for TVUS, nothing recognizable appears on the screen.

**Solution:** Pull back on the probe and reinsert slowly to a depth of approximately 3 cm and attempt to orient yourself at this point. Dropping the handle toward the floor may assist. Once the bladder is identified follow it to the uterus and then on to identify the contents of the uterus.

**Problem:** On initial viewing of TAUS no images can be generated.

**Solution:** Air in the bowel may be interfering with imaging. Try orienting the probe as close to the symphysis as possible and tilting it caudally. The application of gentle TAUS probe pressure may move some of the bowel gas to optimize the view of the uterus. The bladder can also be used as a sonographic window: In the transverse orientation slide the probe as close as possible to the symphysis and angling the probe caudad. This allows the US beams to traverse the bladder to better visualize the fundus. Alternatively, move on to a TVUS.

## Case presentation

**Patient 1:** A 24-year-old G1P0 presents to the emergency department with complaints of vaginal bleeding. Urine test is positive for pregnancy and dates indicate she is 7 weeks pregnant. OEDTU produces the following images.

**Figure 14. Transvaginal image showing the yolk sac (YS), gestational sac (GS), and decidual reaction surrounding the GS.**

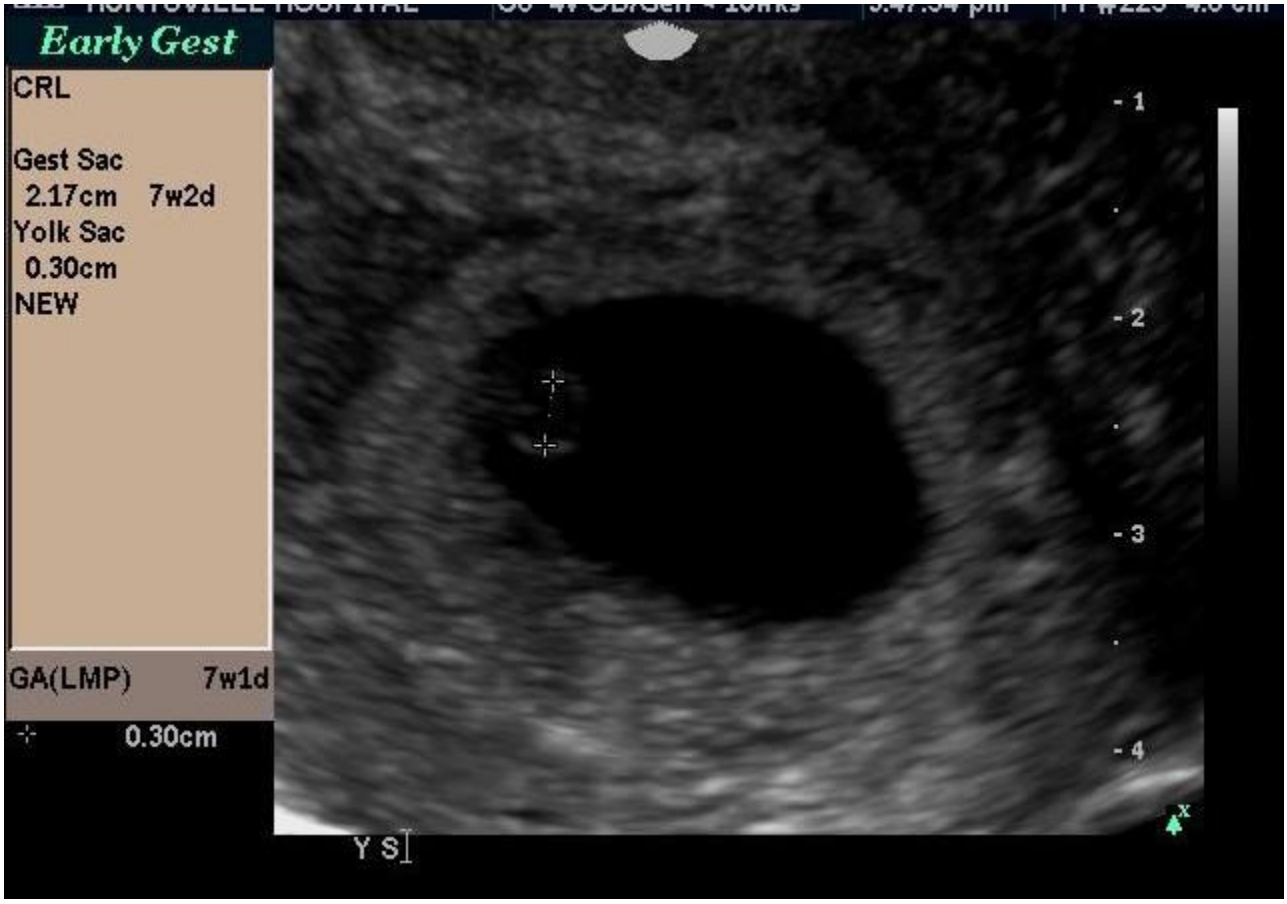
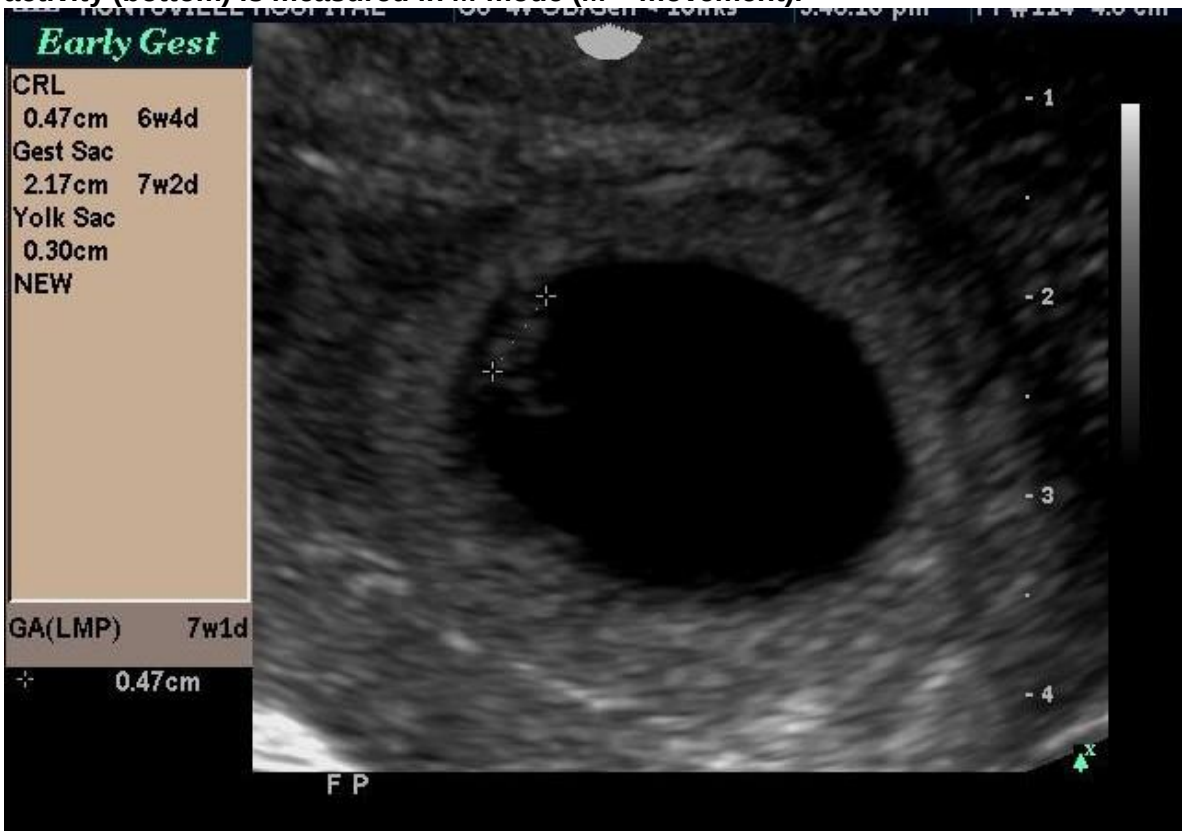
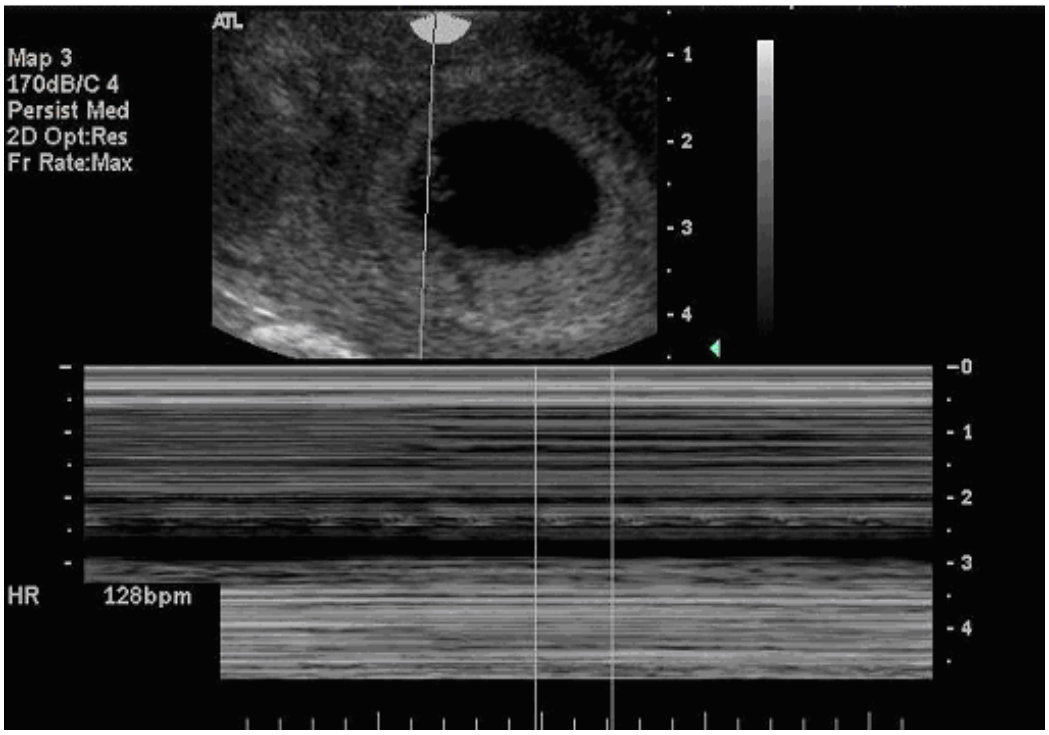


**Figure 15. The fetal pole (top). Note the measurement is from crown to rump not including the yolk sac, which is just to the right of the fetal pole. Fetal cardiac activity (bottom) is measured in M-mode (M = movement).**



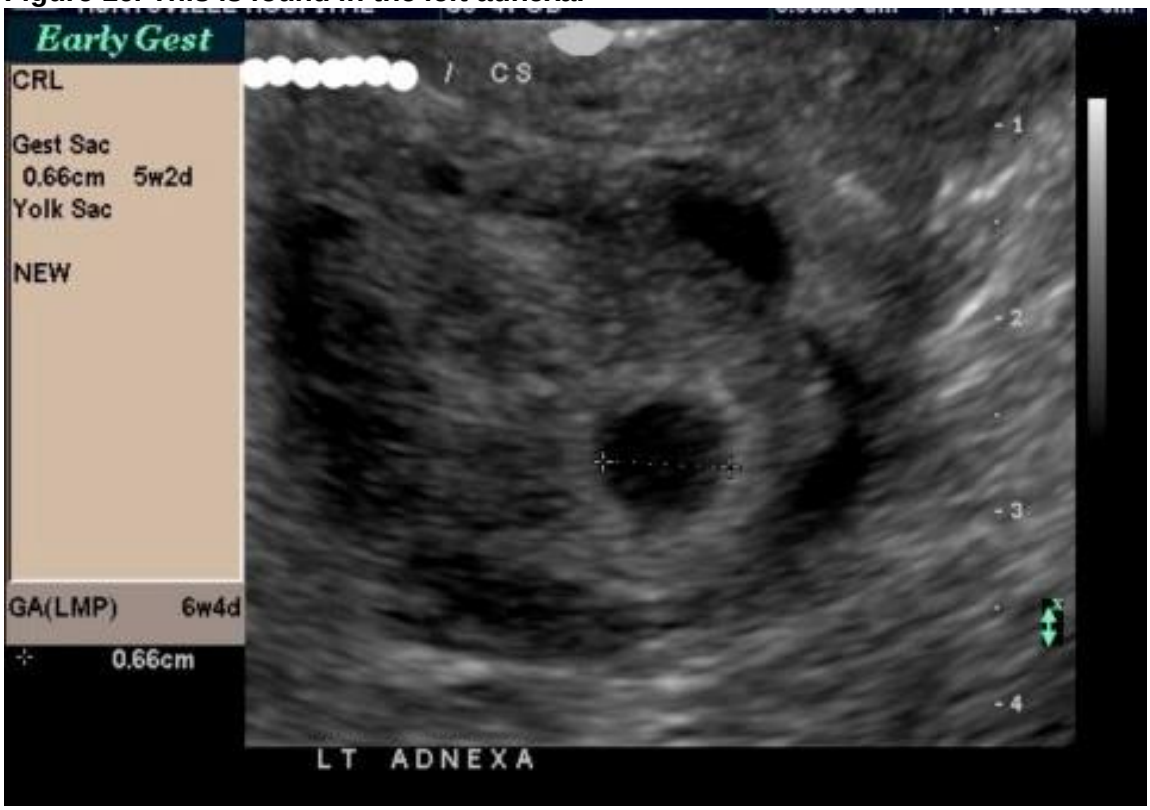



Definitive intrauterine pregnancy is demonstrated. The patient is sent home with instructions to return if she experiences increased bleeding PV, cramps, fever/chills, abdominal pain and the usual threatened abortion precautions.

## Case presentation

**Patient 2:** A 40-year-old woman presents with abdominal pain in the left lower quadrant. She is a mother of three and grandmother of two. When she was in her 20s she had a tubal ligation and a subsequent reversal which she was told was not successful. When she was offered repeat surgery, she declined and accepted that she would have no further children. Today she has no vaginal bleeding or discharge, but the urine pregnancy test is positive. Her vital signs are stable. She is told the results and is offered OEDTU, which shows an empty uterus. Bimanual examination reveals left adnexal tenderness and a cervix that is closed. (Note: When the cervix is open, an ectopic pregnancy is unlikely). Surgery is consulted and a formal ultrasound is completed, which shows the following.

**Figure 16. This is found in the left adnexa.**



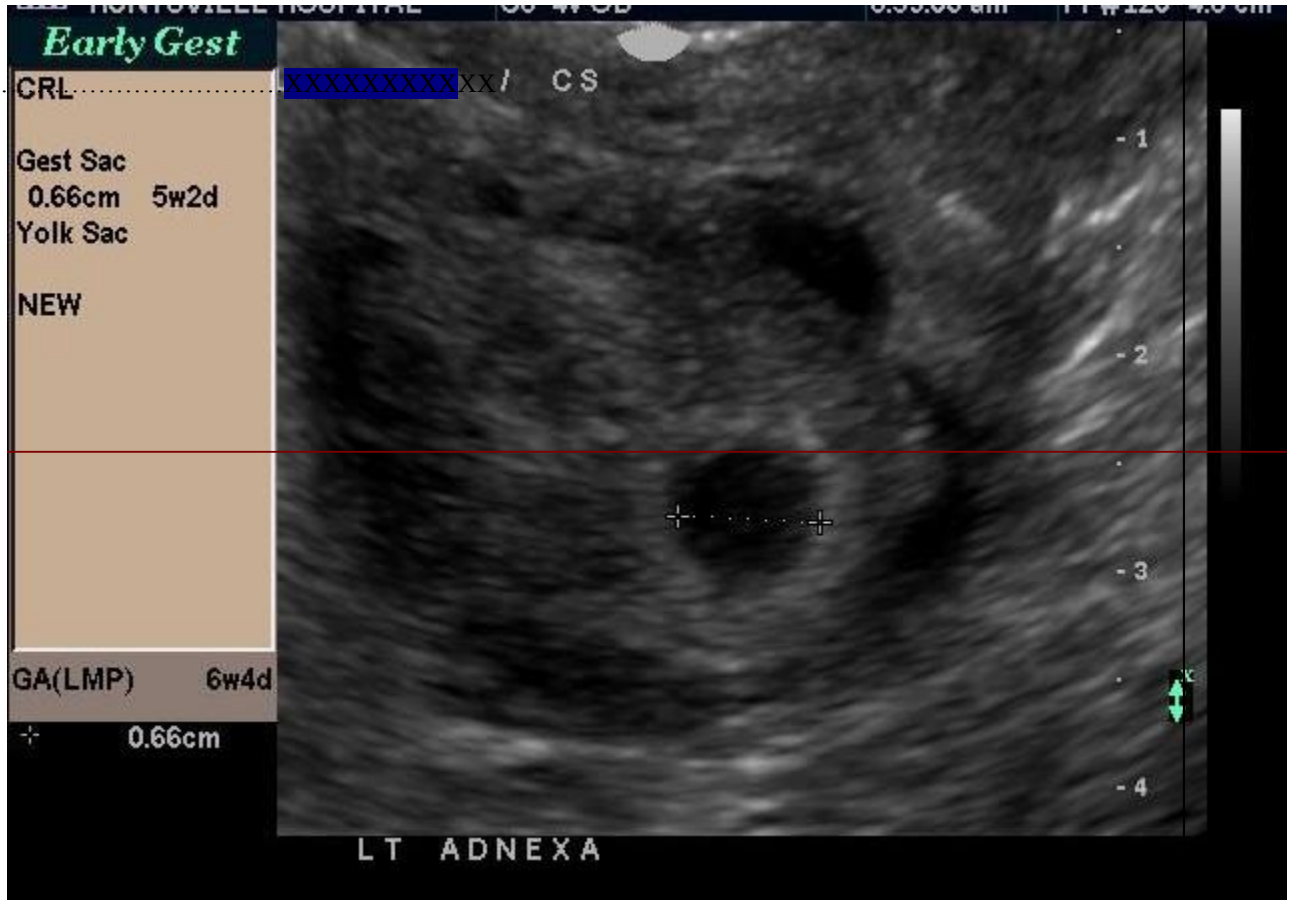
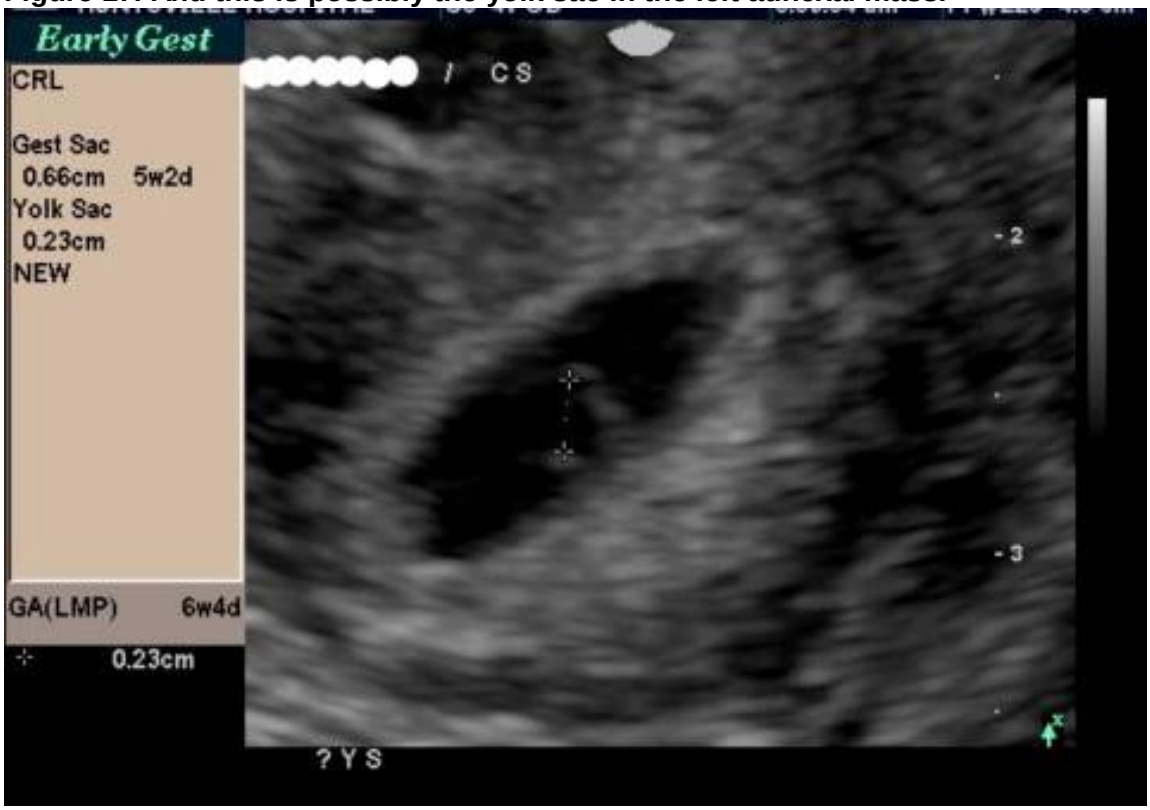

Early Gest
CRL
XXXXXXXXXXX/ CS
Gest Sac
0.66cm 5w2d
Yolk Sac
NEW
GA(LMP) 6w4d
0.66cm
- 1
- 2
- 3
- 4
LT ADNEXA

**Figure 17. And this is possibly the yolk sac in the left adnexal mass.**



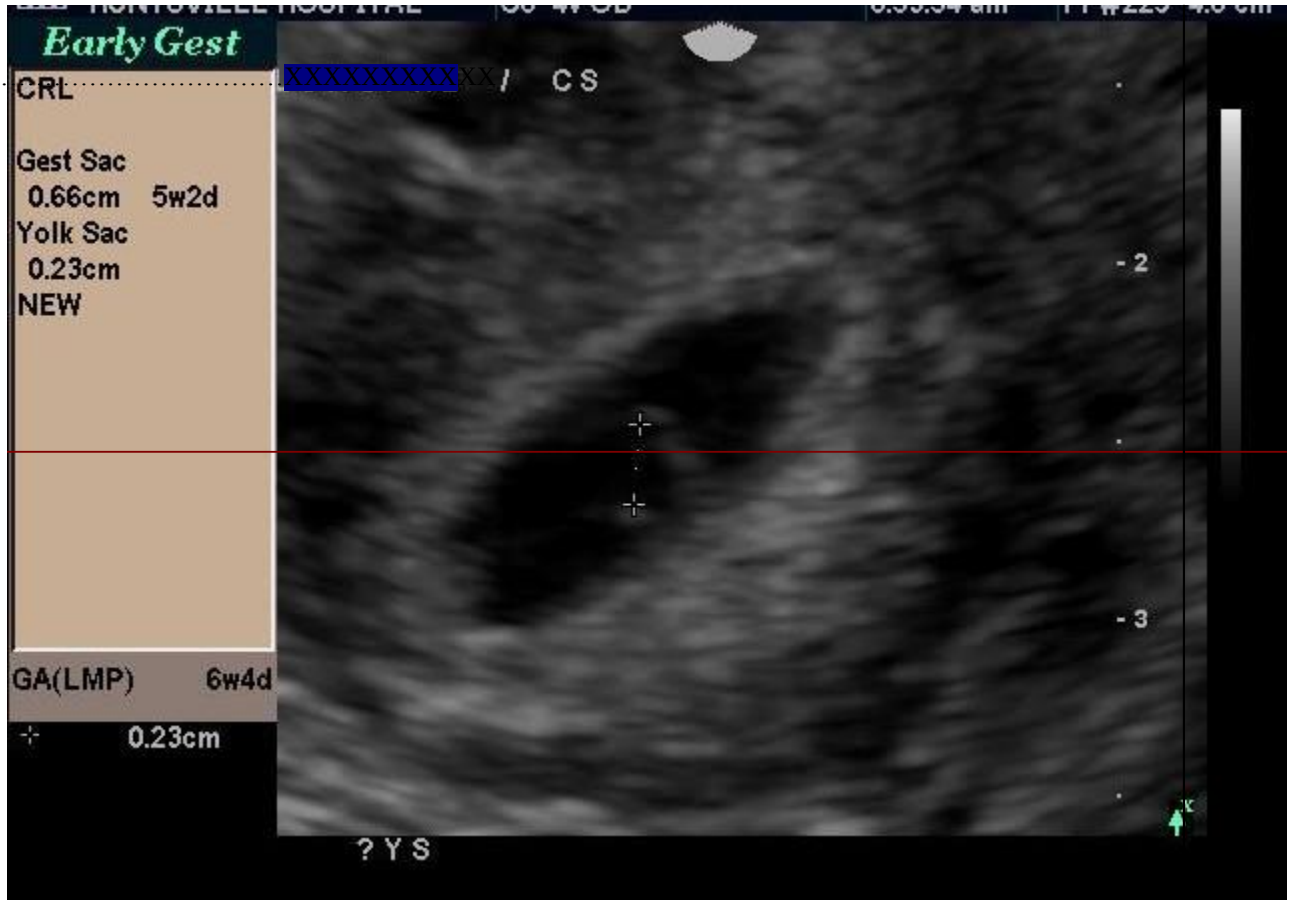
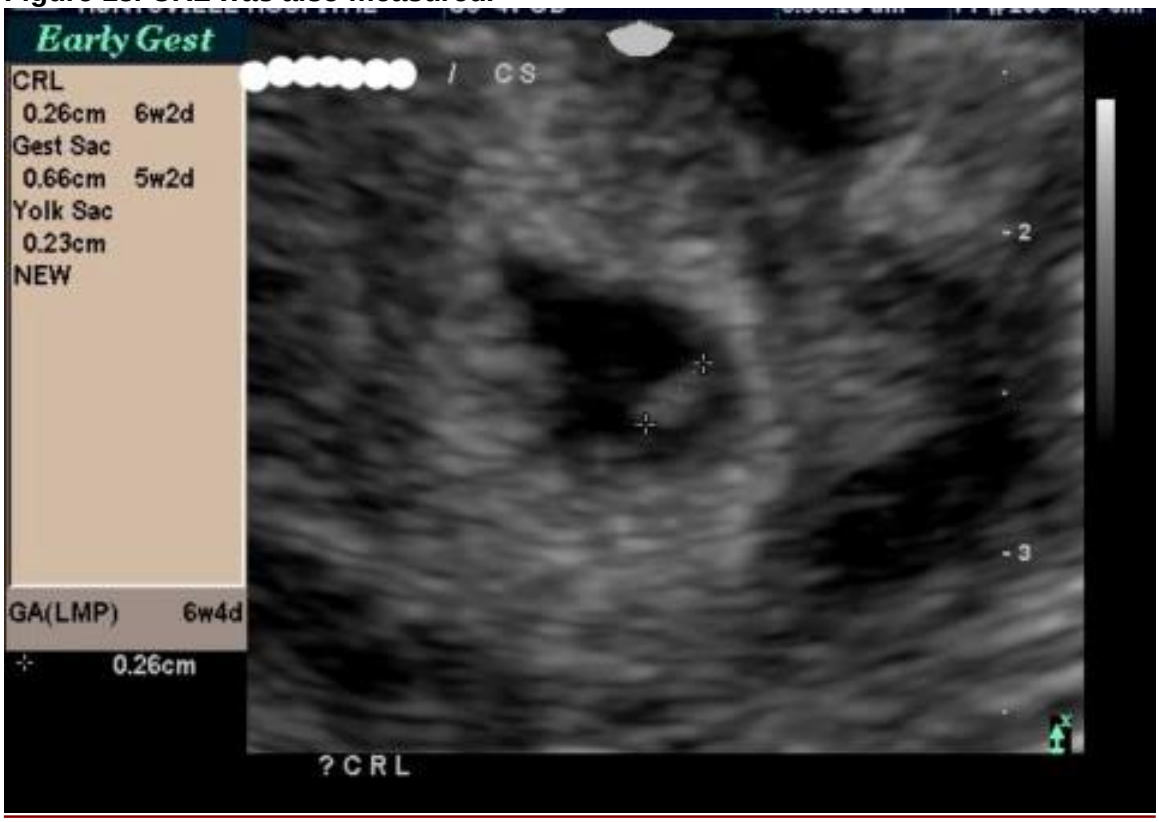

Early Gest
CRL
Gest Sac
0.66cm 5w2d
Yolk Sac
0.23cm
NEW
GA(LMP) 6w4d
0.23cm
XXXXXXXXXX
CS
- 2
- 3
? Y S

**Figure 18. CRL was also measured.**



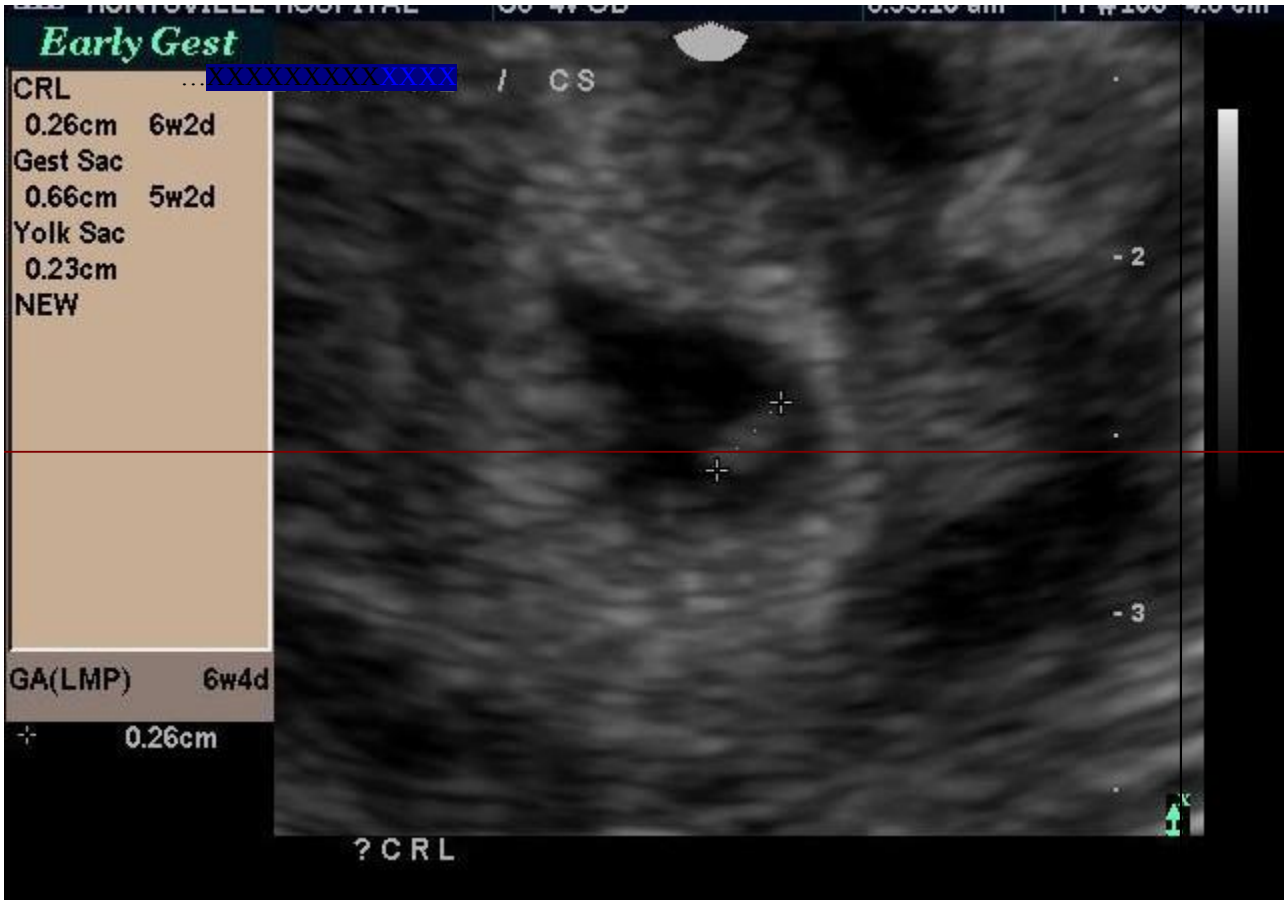
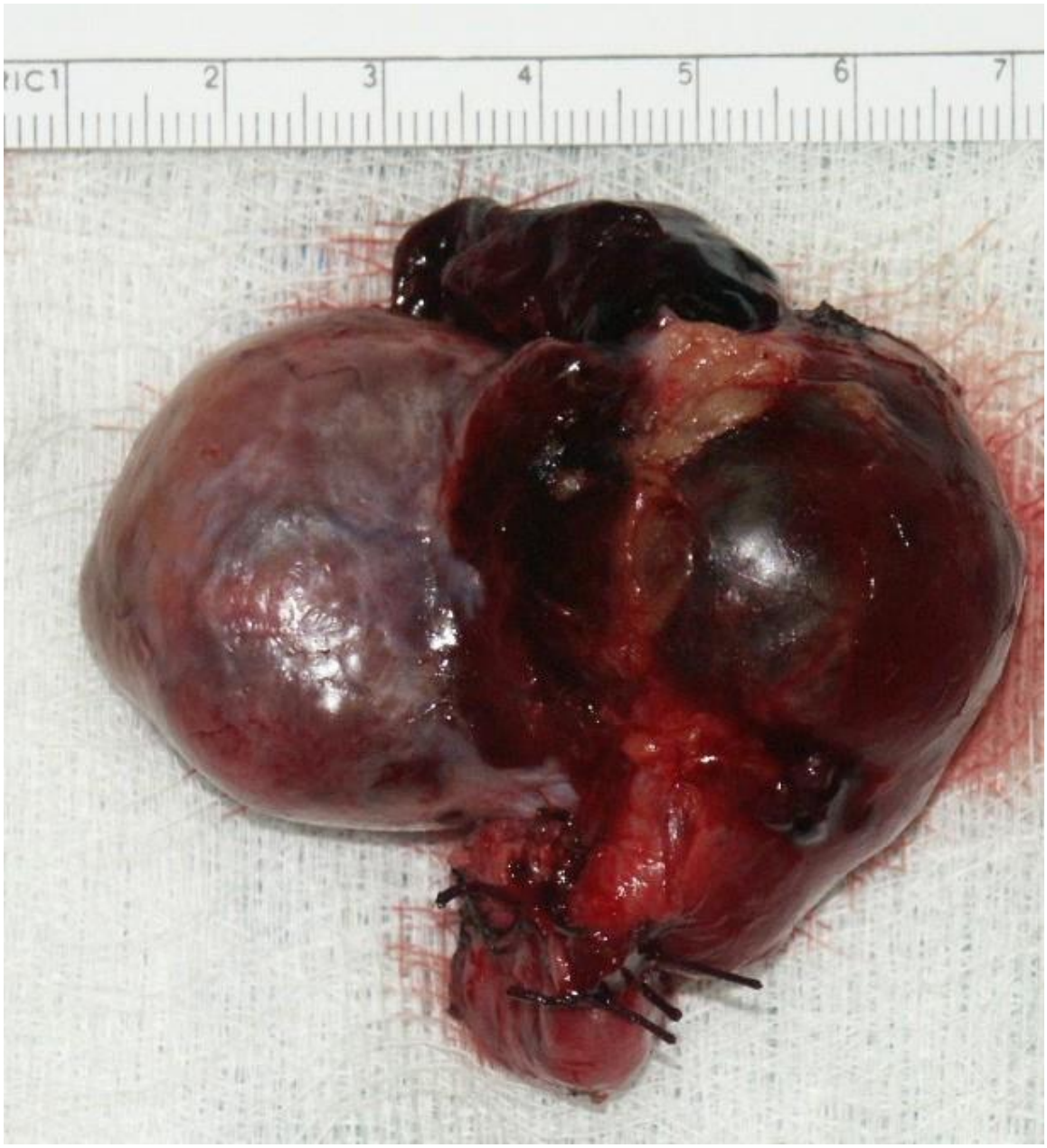

Early Gest
CRL
0.26cm 6w2d
Gest Sac
0.66cm 5w2d
Yolk Sac
0.23cm
NEW
GA(LMP) 6w4d
0.26cm
? C R L
- 2
- 3

**Figure 19. The patient is sent to surgery and the mass is excised from her adnexa along with the fallopian tube.**



## Appendix A: Sample consent form that can be used to facilitate informed consent at your hospital

**Trans-Vaginal Ultrasonic Exam Patient Consent Form**

The ultrasonic examination you are about to undergo allows for more adequate assessment of the pelvic organs.

It involves introduction of a cylindrical ultrasonic probe into the vagina; it has an approximate diameter of 2.5 cm (1 inch) and an approximate length of 15 cm (6 inches).

The probe may be self-introduced or may be introduced by the operator at your discretion. Efforts will be made to minimize the discomfort caused by this procedure. Nevertheless, the exam has various degrees of discomfort associated with it, mostly as a result of your anatomy and/or pelvic disease. In most cases more significant discomfort or even temporary pain may be experienced during the scanning. There are no known lasting ill effects from this exam.

Your signature below indicates that the procedure has been adequately explained and your informed consent has been obtained.

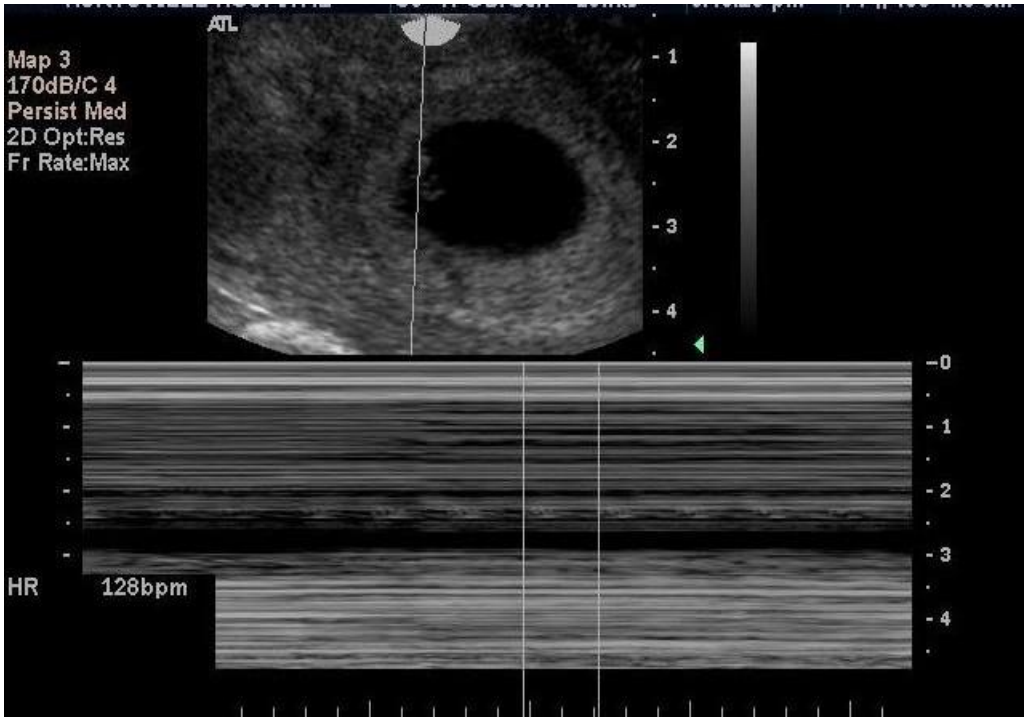
Signature:_____

Witness:_____

Date:_____

## Appendix B: M mode

Some ultrasound machines that you will have in your department can produce images similar to this one (below) and can measure movement. This is usually carried out using the M mode (M = movement). The top image has a line that you can place over an area that is moving, such as the heart of a fetus in this case. Pressing the M mode button again will produce the image at the bottom; measuring from one oscillation to the next will tell you the heart rate.



## Appendix C: Facts and figures on pregnancy loss and ectopic pregnancy

- Approximately 22% of all pregnancies detected on the basis of urinary BhCG assays are lost, usually before clinical recognition.
- The clinical loss rate is 10–12%. Most of these pregnancies are lost before 8 weeks' gestation. Only 3% of pregnancies are lost after ultrasonographic confirmation of a viable pregnancy at 8–9 weeks, and only 1% are lost after 16 weeks' gestation.
- Pregnancy losses may be recurrent, 4% of women in the United States experience two losses and 3% experience three or more losses. Although increasing after one loss, the recurrence risk generally reaches no more than 25% after three or four losses. The loss rate for 40-year-old women is approximately twice that for 20-year-old women.
- By far the most common causes of pregnancy loss are chromosomal abnormalities. At least 50% of clinically recognized pregnancy losses show a chromosomal abnormality. The types of chromosomal abnormalities differ from those found in live borns, but autosomal trisomy still accounts for 50% of abnormalities. A balanced translocation is present in about 5% of couples having repeated spontaneous abortions.
- Many other causes of repetitive abortions have been proposed, but few are proved. These include luteal phase defects and infectious processes (e.g., ureaplasma). It is reasonable to evaluate couples for these conditions, but efficacy of treatment remains uncertain.
- Uterine anomalies are accepted causes of second trimester losses. Couples experiencing such losses may benefit from metroplasty or hysteroscopic resection of a uterine septum. Uterine anomalies are less common causes of first trimester losses.
- Drugs, toxins and physical agents are associated with spontaneous abortion, but usually not with repetitive losses. Avoiding potential toxins is obviously desirable, but one should not assume that such exposures explain repetitive losses.
- The incidence of ectopic pregnancy is rising, partly through earlier detection by ultrasound and sensitive BhCG assays. Treatment may be surgical (linear salpingostomy performed through the laparoscope) or medical (methotrexate).
- Management of ectopic pregnancy has undergone significant modification over recent years. The condition is less commonly an acute emergency and more easily diagnosed early in gestation on the basis of maternal serum progesterone, maternal BhCG, transvaginal ultrasound and uterine curettage. The earlier detection of an unruptured ectopic pregnancy has greatly modified treatment. Laparotomy is now rarely necessary. Laparoscopic procedures are commonly employed, with an increase in subsequent pregnancy rates and a decrease in repeat ectopic gestations. About one third of women with ectopic pregnancies prove eligible for medical treatment (methotrexate). Patients at high risk for ectopic pregnancy may benefit from a screening serum progesterone determination at the time of the initial pregnancy test.

## Appendix D Measuring Gestational Age

Though there are no specific criteria for the training requirements for measuring crown rump length (CRL) the College of physicians and surgeons of Ontario (CPSO) does recommend the following for MD’s in independent health facilities. Educational training in ultrasound procedures for the purpose of assessing gestational age consists of a one month training program to demonstrate proficiency in a facility or its equivalent providing abortion care. It is recommended that to demonstrate proficiency a minimum of 100 such cases in total be scanned. (REF CPSO 2006)

## Appendix E American College of Radiology Appropriateness Criteria Summary

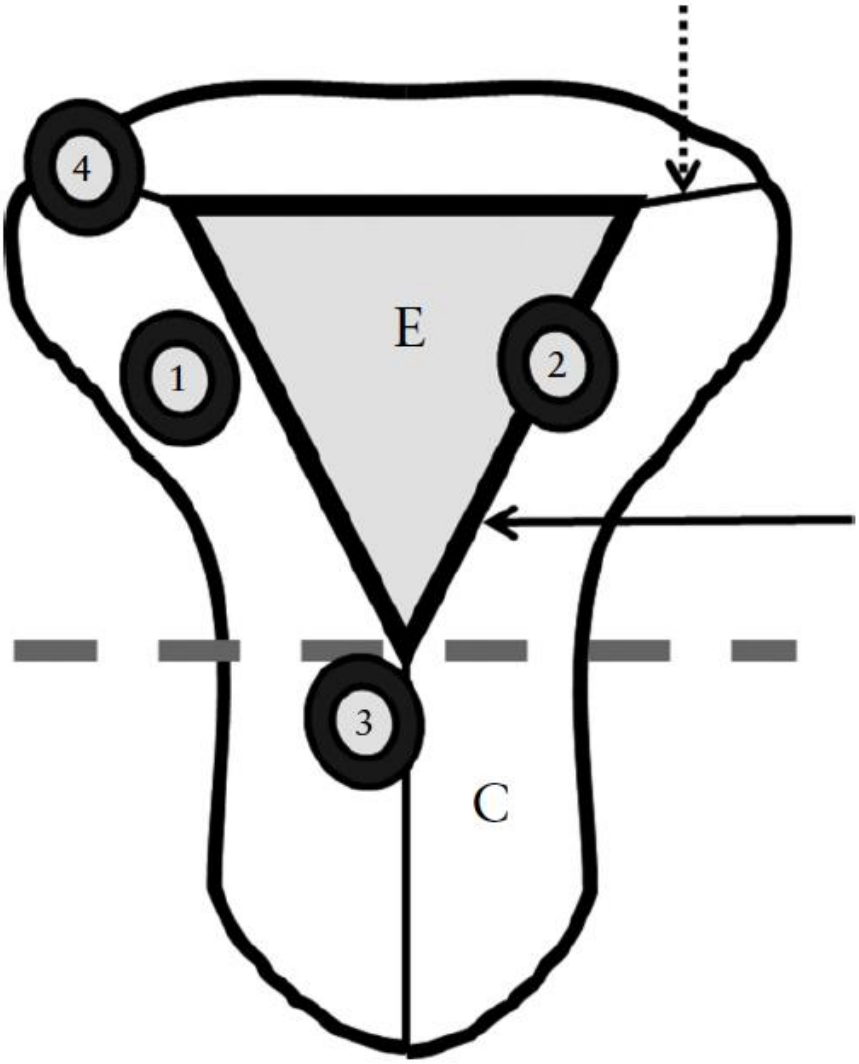
1. Although transabdominal or transvaginal US may be used for patients with first-trimester bleeding, transvaginal US is the study of choice for early pregnancies.
2. Transabdominal imaging is particularly useful to assess the amount of free fluid and for abnormalities beyond the field of view of a high-frequency vaginal probe.
3. The results of imaging should be correlated with the quantitative BHCG level and with the clinical presentation. The lack of an intrauterine gestational sac above the discriminatory BHCG level does not necessarily indicate ectopic pregnancy. If the patient is stable with no signs of ectopic pregnancy, conservative management is advised.
4. A failed pregnancy may be diagnosed when a gestational sac ≥ 25 mm in mean diameter does not contain a yolk sac or embryo or when an embryo measuring ≥ 7 mm does not have cardiac activity.
5. M-mode imaging should be used to document embryonic viability and measure heart rate.
6. Doppler US should not be used to evaluate a normal early embryo.
7. MRI of the pelvis may be used in clinically stable patients if US is insufficient for diagnosing unusual ectopic pregnancies, gestational trophoblastic disease, or vascular abnormalities, but should not delay urgent or emergent care in an unstable patient.
8. CT may be useful in pregnant patients with trauma or acute non-gynecologic pain, for staging of malignancy, or if MRI is not possible. (REF LANE ACR)

## Appendix F Terminology Legend

**Pregnancy of Unknown Location (PUL)** – Patients with no definite evidence of an ectopic pregnancy or an intrauterine pregnancy but with a positive BHCG. Commonly these patients have had a spontaneous abortion and about 8% will have an ectopic pregnancy in experienced hands (ref Lane ACR)

**Ectopic pregnancy (EP)** – Patients without an intrauterine pregnancy and positive BHCG and extrauterine or intrauterine eccentrically located mass.

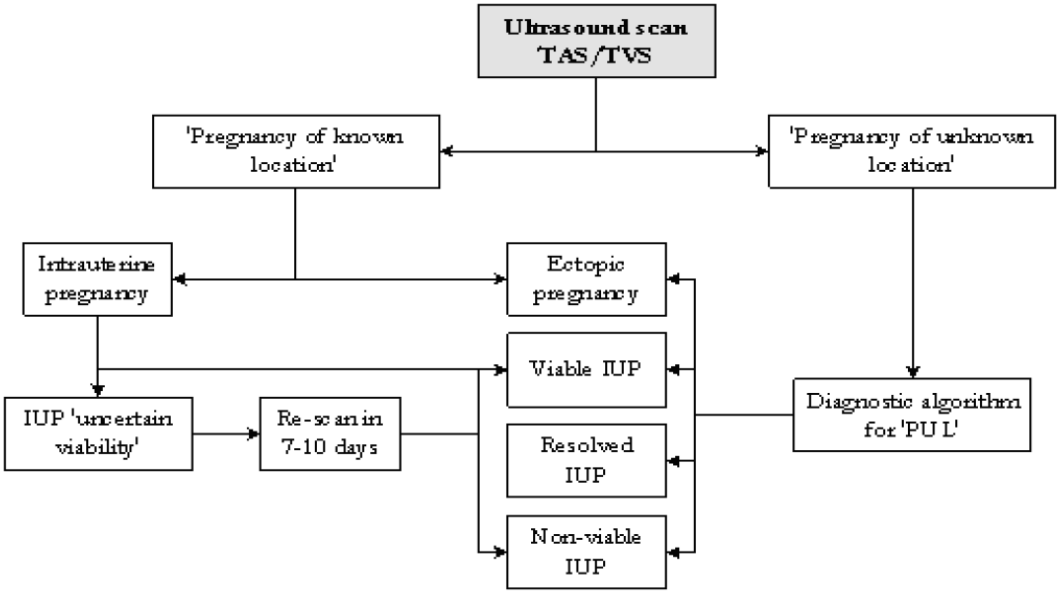
**Intramural pregnancy –** An ectopic pregnancy eccentrically located in the uterus.




Schematic illustration of differential diagnosis of various types of intrauterine ectopic pregnancy. 1, complete intramural pregnancy; 2, partial intramural pregnancy; 3, cervical/Cesarean scar pregnancy; 4, interstitial pregnancy. E, Endometrial cavity; C, cervix; solid arrow, endometrial–myometrial junction; dotted arrow, interstitial tube; dashed line, level of internal os. From Diagnosis and management of intramural ectopic pregnancy Diagnosis and management of intramural ectopic pregnancy M. MEMTSA 2013 – used with permission from D. JURKOVIC

**Insert Algorithm for Early pregnancy symptomatic presentation here . . . . . .**

## Basic Diagnostic Algorithm for Early Pregnancy Loss




IUP: Intrauterine pregnancy
PUL: Pregnancy of unknown location
TAS: Transabdominal scan
(Ref McParland)

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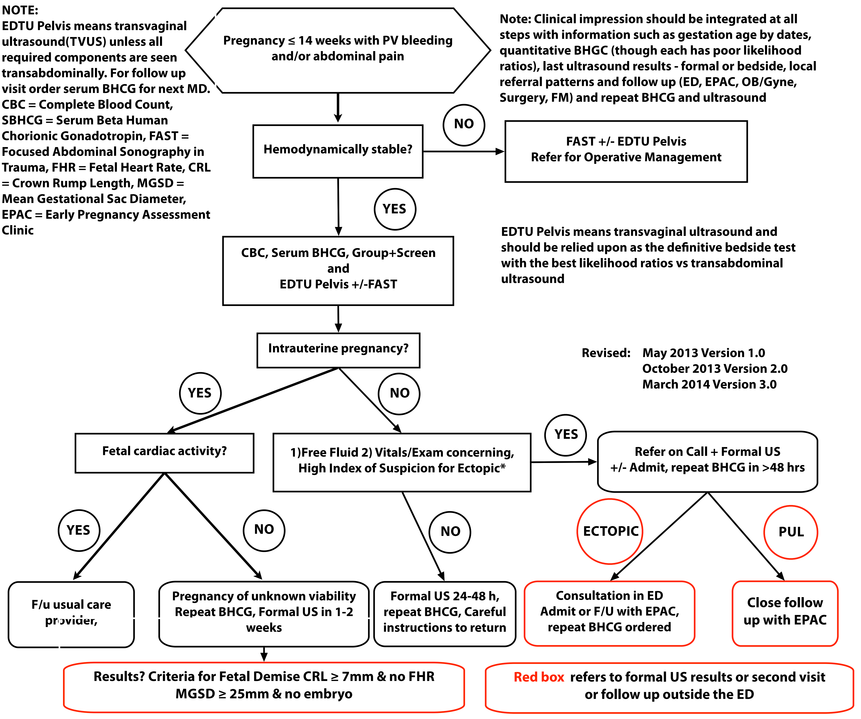
**NOTE:**
**EDTU Pelvis means transvaginal ultrasound(TVUS) unless all required components are seen transabdominally. For follow up visit order serum BHCG for next MD. CBC = Complete Blood Count, SBHCG = Serum Beta Human Chorionic Gonadotropin, FAST = Focused Abdominal Sonography in Trauma, FHR = Fetal Heart Rate, CRL = Crown Rump Length, MGSD = Mean Gestational Sac Diameter, EPAC = Early Pregnancy Assessment Clinic**




**Note: Clinical impression should be integrated at all steps with information such as gestation age by dates, quantitative BHGC (though each has poor likelihood ratios), last ultrasound results - formal or bedside, local referral patterns and follow up (ED, EPAC, OB/Gyne, Surgery, FM) and repeat BHCG and ultrasound**

**EDTU Pelvis means transvaginal ultrasound and should be relied upon as the definitive bedside test with the best likelihood ratios vs transabdominal ultrasound**

**Revised: May 2013 Version 1.0**
**October 2013 Version 2.0**
**March 2014 Version 3.0**

Notes: EDTU = Emergency Department Targeted Ultrasound, PUL = Pregnancy of unknown location, G+S= Group and screen.
If the patient is unstable, the staff gynaecologist or surgeon on call should be paged directly.
If on EDTU, an IUP is confirmed but fetal cardiac activity cannot be confirmed, we recommend that physicians use judgement with respect to follow up. The CRL will need to be ≥ 7 mm with no FHR or the MGSD > 25 mm without an embryo in order for a definitive diagnosis to be made. At least a 48 hour delay is recommended in the event of uncertainty. EPAC = Early Pregnancy Assessment Clinic (if available). *See Ectopic risk factors in text pg 18. Formal = Comprehensive for AIUM American Institute of Ultrasound in Medicine

# EDTU

## Extended Focused Assessment with Sonography
## E-FAST algorithm

### Learning objectives

**Advantages and disadvantages**
**Indications**
**Four binary questions of eFAST**
**Techniques for e-FAST**
**Evidence**
**Pearls and pitfalls in the FAST scan**

### Introduction

Bedside ultrasound is the imaging of choice supported by ATLS in the primary survey of resussitation in the trauma patient. It has replaced DPL in this role. It is foremost an excellent screening tool

The physical examination alone for predicting significant abdominal injuries in patients with multi-system trauma is unreliable. Blaivas et al reported a case series of blunt abdominal trauma patients who had a normal exam and normal vital signs before being discharged who underwent a screening bedside ultrasound, only to find significant amounts of hemoperitoneum.

The 'FAST' protocol examines the abdomen and pericardium. Extended-FAST, or 'e-FAST' extends the exam to view the lung bases and lung apices for hemothorax and pneumothorax, respectively. The technique is rapid (2–3 minutes), non-invasive and repeatable and it is carried out at the bedside in the emergency department. It has proven to be very reliable in predicting the need for immediate laparotomy and it enhances overall decision-making, priority-setting and management of complex trauma patients.

In the trauma patient, free fluid is blood until proven otherwise. The purpose of eFAST is to identify free fluid in the abdomen or thoracic cavity, to detect pneumothorax and to guide early management of resuscitation. This algorithm is not effective for specific organ damage (Kendall, et al, 2009)

### Advantages of e-FAST

**Easy to learn**
**Can be done in 2-3 minutes with high sensitivity and specificity**
**Immediate & repeatable**
**No radiation**
**No interference with ongoing resuscitation or other procedures**

**No direct complications.**

**Disadvantages**

**Operator dependent**
**Will not identify organ injury**
**Imaging interference caused by obesity,**
**Subcutaneous air, skin wounds, bandages, tubes, etc. May obstruct access**
**Will not differentiate between fluids (blood, ascites, urine, etc.).**

**Indications**

**Note:** Once mastered, the eFAST algorithm will become integrated into a **more comprehensive** use of bedside ultrasound, and extend to more broad indications.

**Blunt & penetrating cardio-thoracic trauma**
**Blunt & penetrating abdominal trauma**
**Ectopic pregnancy**
**Undifferentiated hypotension**

**Review of evidence of eFAST**

**Can be used in both adult and pediatric populations.**

**Trained physicians able to complete exam in less than 5 minutes.**

**Sensitivities of 70-90%; specificities of 90-100%, as compared to CT, observation, or laparotomy.**

**Morison's pouch has highest yield for free fluid.**

**Excellent for identification of patients in need of laparotomy when ultrasound finding links to other physical findings (specificity 96%, sensitivity 100%)**

**Negative predicitve value nearing 100% for laparotomy**

**Outperforms chest x-ray, comparable to CT in the detection of pleural effusion and pneumothorax.**

**The Four Binary Questions of eFAST:**

One attempts to answer the following yes-no questions with eFAST:

**Free Fluid in the Abdomen?**

**Hemopericardium?**

**Free fluid in the chest?**

**Pneumothorax?**

**Question 1:**

**Free Fluid in the Abdomen? Yes or no?**

## The technique

Free fluid will accumulate intraperitoneally, primarily in three locations:

1. The right upper quadrant (RUQ), also known as Morison's pouch, a potential peritoneal space between the liver and the kidney (hepato-renal). The view is also extended to visualize the base of the right lung.

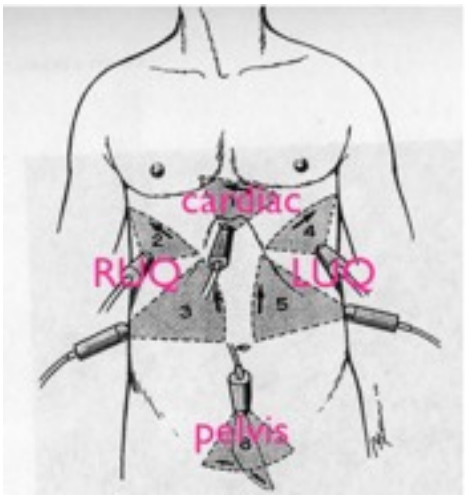
2. The left upper quadrant (LUQ), i.e., the peri-splenic space. The view is also extended upwards to view the base of the left lung.

3. The supra-pubic space, above and behind the bladder.

4. The cardiac element of the scan, the sub-xyphoid view, consists of scanning the pericardium for blood. The echocardiography section of this course will explain the technical aspects of this scan.

**Probe selection:** The probe selected is a LOW FREQUENCY curvilinear probe, commonly referred to as an abdominal probe. The frequency usually ranges between 2.5 – 5 Mhz depending on the machine manufacturer. The depth should be set to a sufficiently deep level at the start, depending on how big your patient. About 15-20 cm should suffice. The probe is applied to the abdomen as in Figure 1.

**Figure 1: Zones scanned for free fluid in trauma patients**

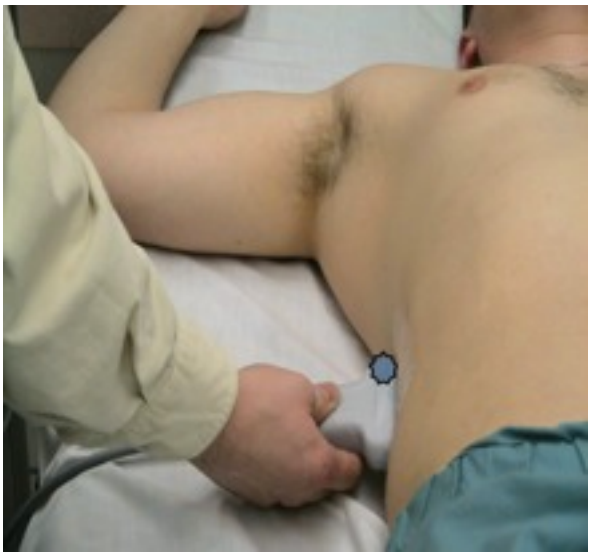


**Right upper quadrant**

The first area to scan is the RUQ. This is the most important and recognizable view in e-FAST. It is the easiest view to obtain, because of anatomy (little or no overlying bowel), and the most sensitive for detecting fluid, as several peritoneal folds converge into Morison's pouch. This view alone can detect blood in the abdomen with a 50–80% sensitivity. When combined with the other three views, the sensitivity and specificity are significantly higher, as described below.

The probe is placed on the **longitudinal axis, coronal plane** on the patient's right abdomen, between the mid-clavicular line and the posterior mid-axillary line, at the level of the lowest ribs (Figure 2). The liver is the landmark that allows one to recognize other structures.

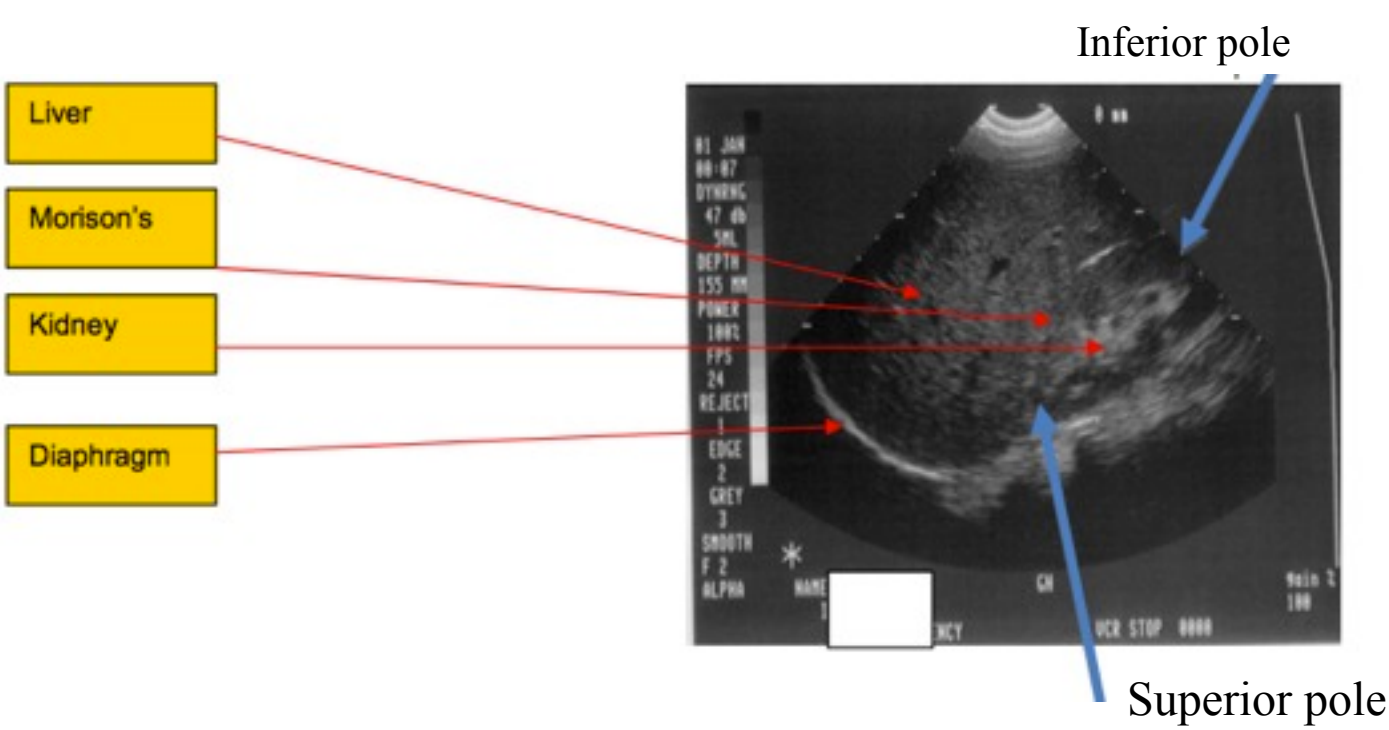
**Figure 2: Photos showing a physician at the bedside positioning the probe to scan the RUQ.**



Once the liver is identified, the probe is then adjusted to find the view incorporating the best possible view of the hepato-renal interface. At this point, it is fanned anterior and posterior in order to visualize as much of this interface as possible. The interface should be seen to the superior and inferior poles of the kidney.

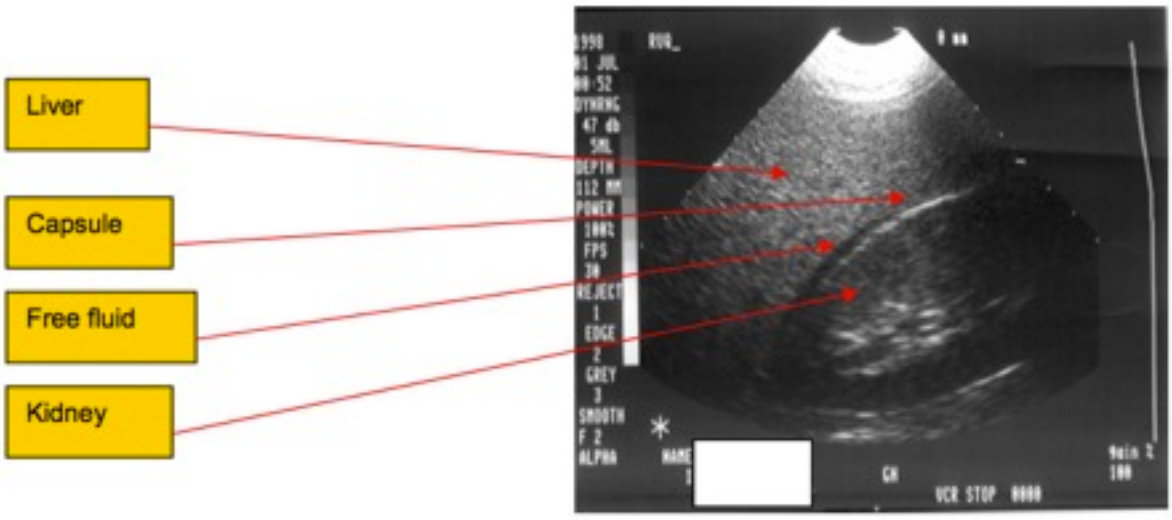
This will provide the most recognizable images in the FAST series (figures 3).

**Figure 3 View of Normal RUQ**




Free fluid will appear in Morison's pouch as an **anechoic** band (black) between the liver and the kidney. This band will be located outside and superior to the **hyper-echoic** (bright) capsule surrounding the kidney (Figure 4). The thickness of this anechoic stripe can be correlated with the amount of free fluid in the peritoneal space: **stripes wider than 0.5 cm are correlated with approximately 500 mL of fluid; stripes wider than 1 cm are correlated with over 1 L of blood in the abdomen** (Figure 5).

**Figure 4: Free fluid in the RUQ**



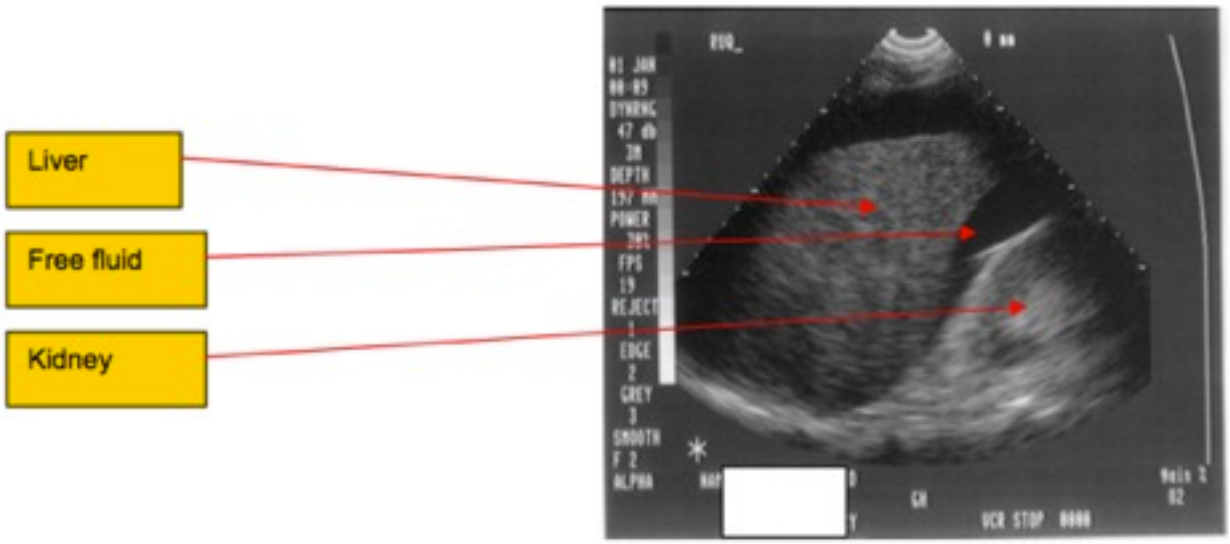



**Figure 5: Large amount of free fluid near the liver.**

**Left upper quadrant**

The LUQ is somewhat more difficult to scan, primarily because the spleen is located in a very posterior position and the acoustic window offered by the spleen is smaller than the liver. There is also more potential for the splenic flexure of the colon (gas) to interfere and to overly the splenic window. The probe must be placed in the posterior axillary line at the level of the 9th or 10th rib space. One begins by identifying the spleen, which has the appearance of the liver, only smaller and higher in the abdominal cavity.

**Figure 6. LUQ probe positioning.**

The probe is placed in a posterior mid axillary line, yielding a coronal cut of the area where the spleen will be found. A challenge in this scan is to rotate the probe a few degrees clockwise to direct the beam between ribs and avoid rib shadows. Once the spleen is found, its interface with the kidney is next step. This interface needs to be swept completely by fanning the probe anterior and posterior. In order to perform a complete scan, the full interface needs to be seen, along with the splenic tip and hemidiaphragm above the spleen, all areas where free fluid may lie.

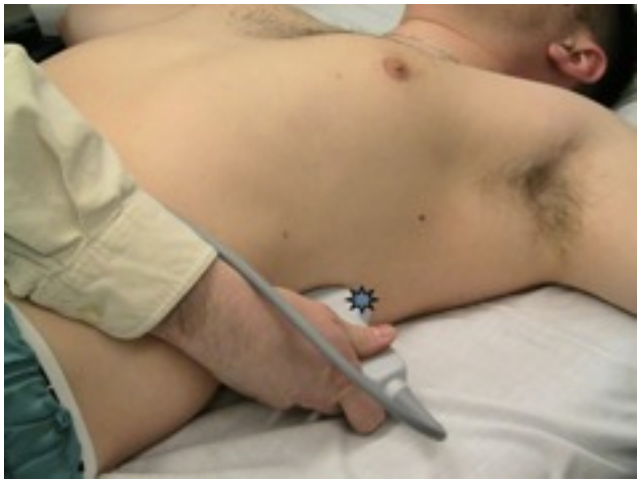


**Figure 8: View of normal LUQ**

Free fluid in the LUQ shows as an **anechoic** or black area above and anterior to the spleen, between spleen and diaphragm (Figure 9). Blood may appear in the splenic-renal interface (Figure 10).

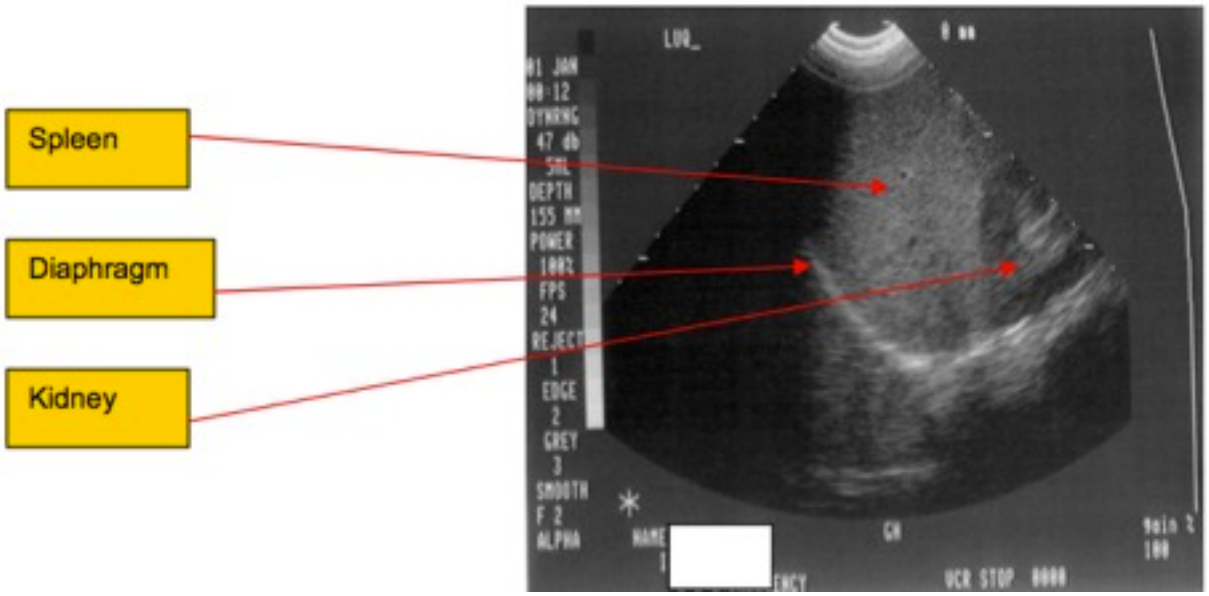


**Figure 9: Free fluid in the LUQ**

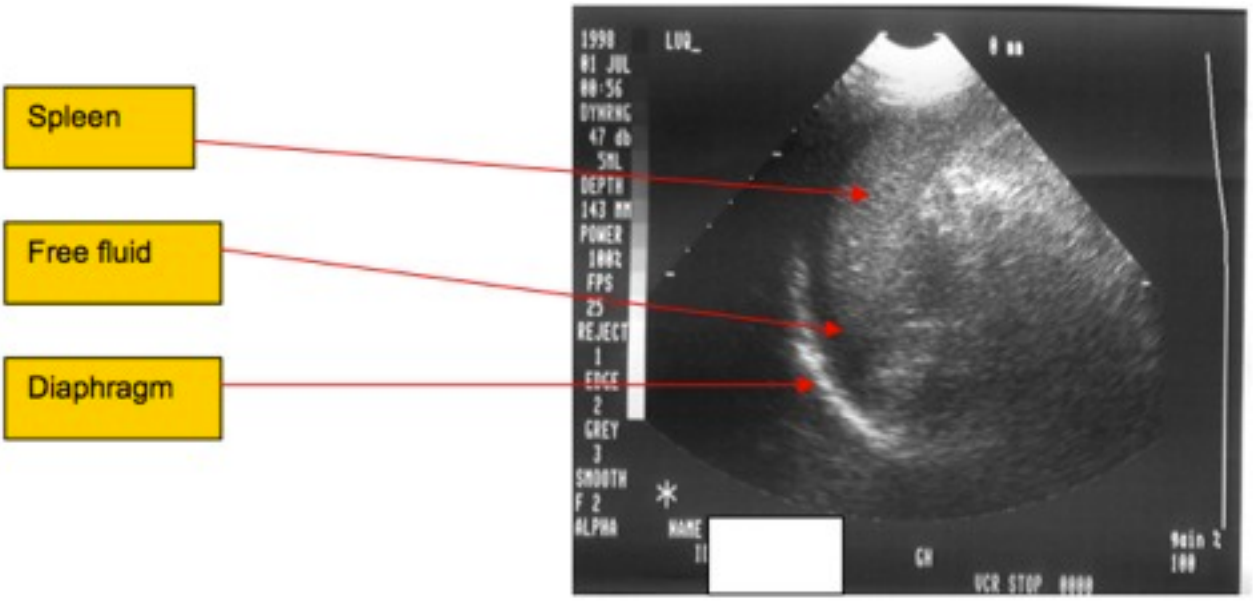
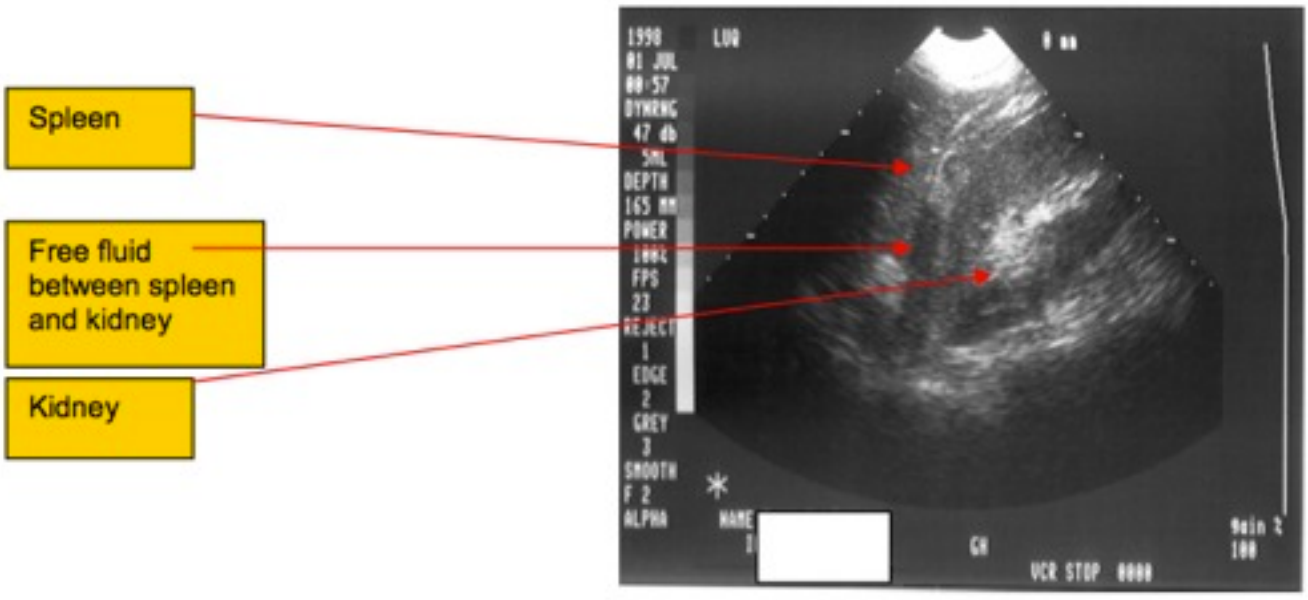



**Figure 10: Free fluid in the splenic-renal interface**




**Pelvis (suprapubic view)**
This part of the FAST series attempts to detect free fluid in the inferior aspect of the peritoneum, inferior and anterior the bladder in males (retrovesicular) and surrounding the

uterus in females (recto-uterine or Pouch of Douglas). The obstetrics section of this course addresses this topic in greater detail.

The approach is to place the probe a just above the symphysis pubis to obtain both longitudinal and transverse views.

**Figure 11. Physician placing the probe for a tranverse view.**

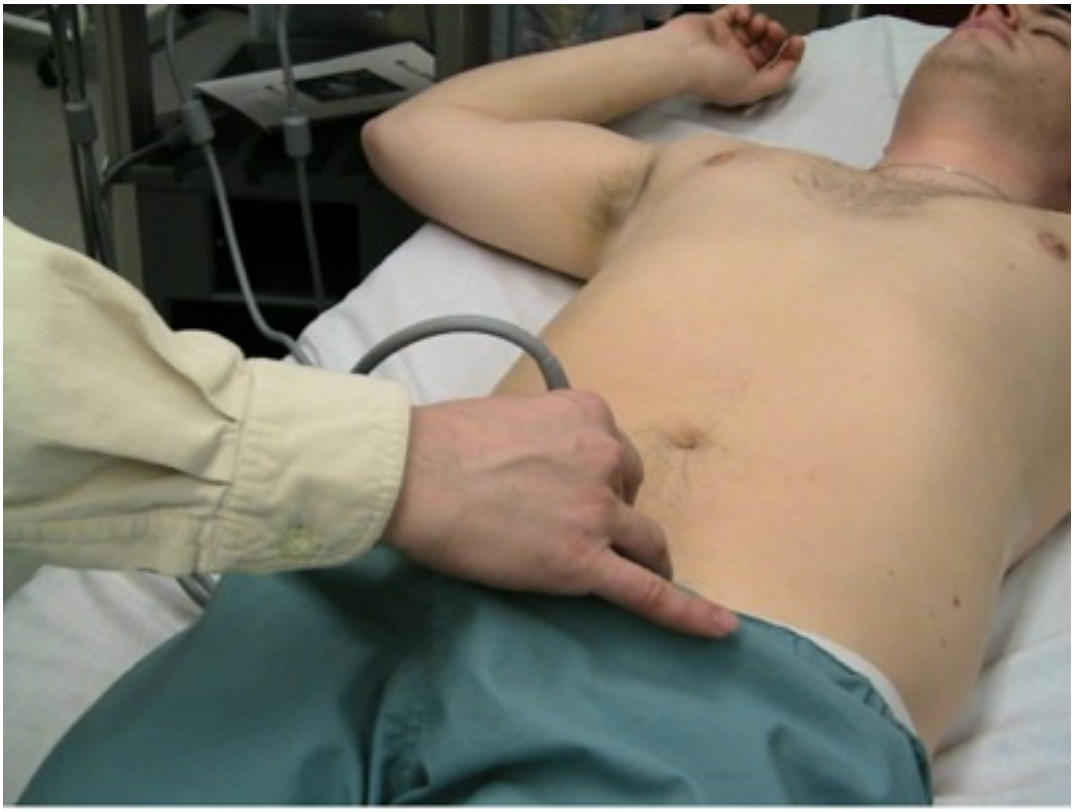
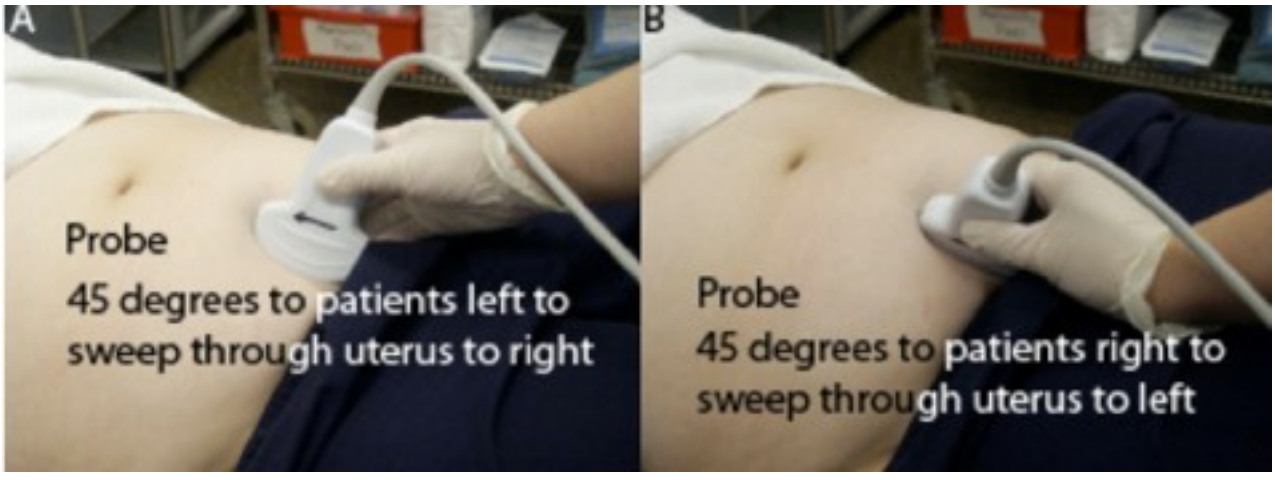


**Figure 12. Physician placing probe for longitudnal ((sagittal) view.**



The bladder is the landmark, identifiable as an anechoic sphere variable in size, depending how full it is. If it is full, it is used as an acoustic window that will permit ultrasound waves to penetrate deeply behind the bladder, allowing to identify any hypo-echoic collection of fluid. A phenomenon called “increased through-transmission” may occur through the bladder, enhancing posterior structures as excess sound reaches them. This is **enhancement artifact**. Care needs to be taken in this instance as this may obscure areas of free fluid. If this artifact is seen, the gain can be reduced to overcome it.

**Figure 13a. Transverse view of normal male pelvis.**

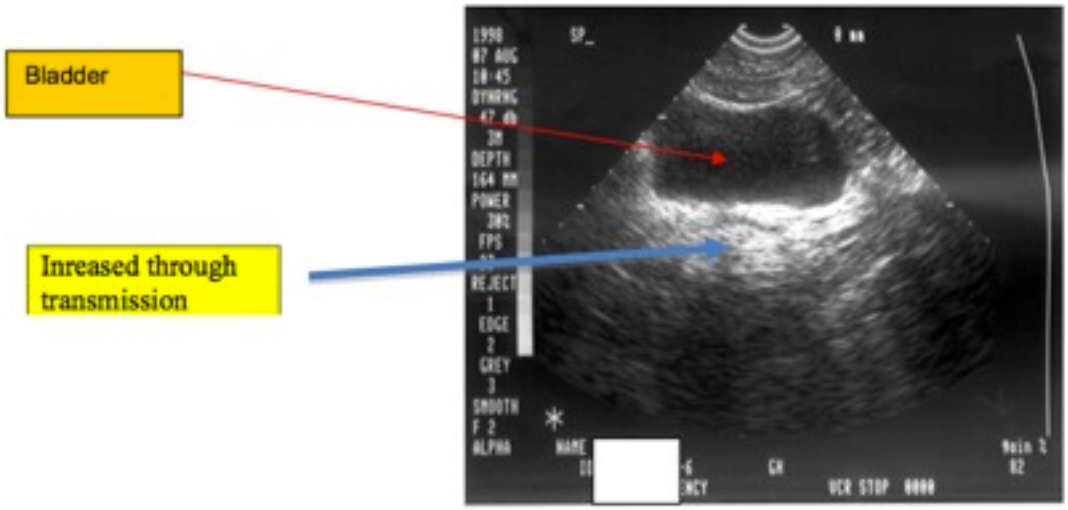
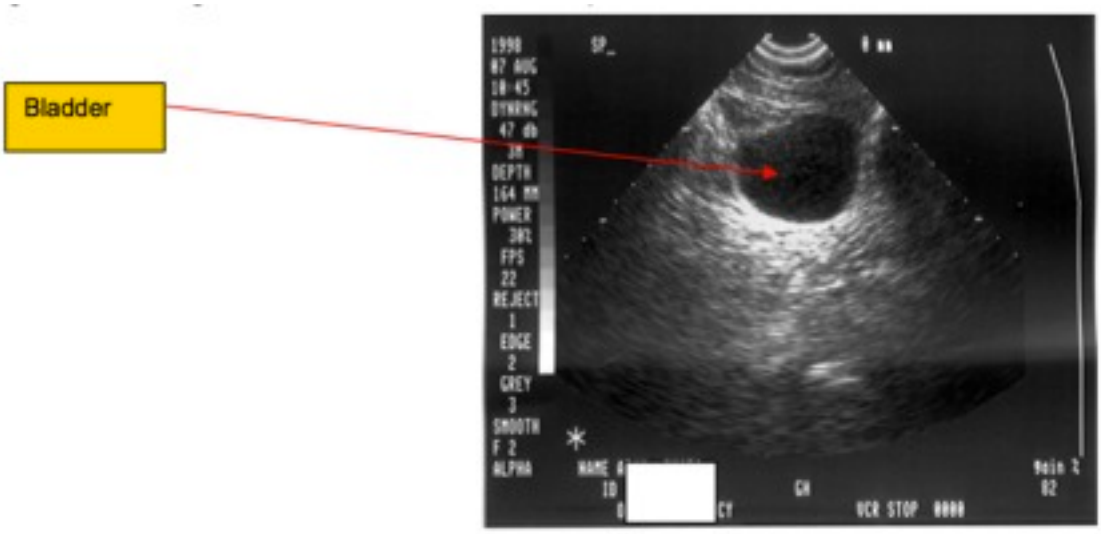
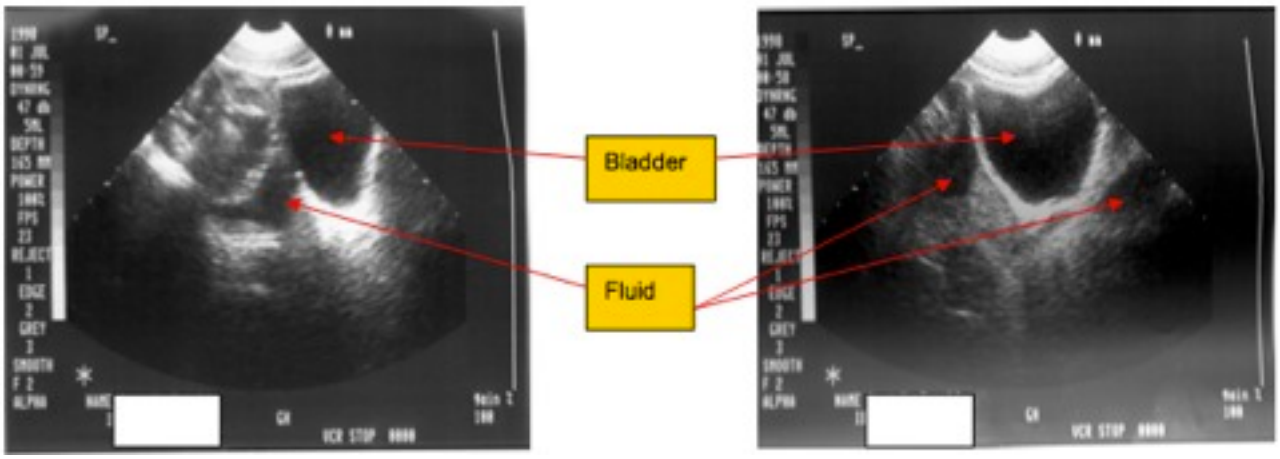



**Figure 13b. Longitudinal view of normal male pelvis.**



Fluid in the pelvis appears as a hypo-echoic area above the bladder on longitudinal views or on either side of the bladder in transverse views (Figure 14).

**Figure 14. Longitudinal (left) and transverse (right) views of fluid in the pelvis.**




## Question 2: Hemopericardium? Yes or no?

### Cardiac Views

The objective of the cardiac scan in eFAST is to **verify cardiac activity** and **to rule out pericardial effusion (hemopericardium)**. More useful in penetrating trauma, this also applies to blunt injuries. The cardiac views are covered more extensively in the cardiac chapter. Ideally, both the subxiphoid and parasternal long views will be performed. This will increase your sensitivity for detecting free fluid. See figure 15 and 16.

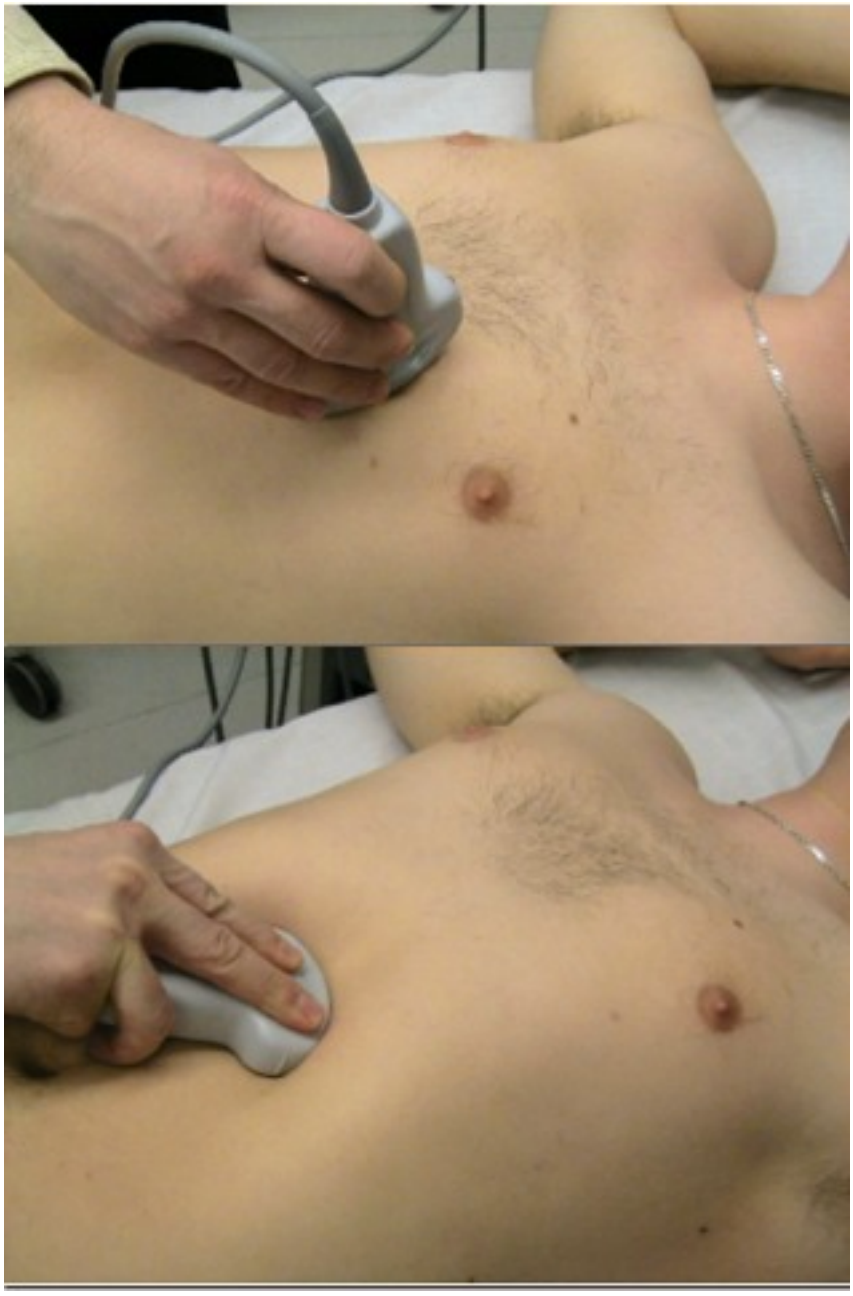
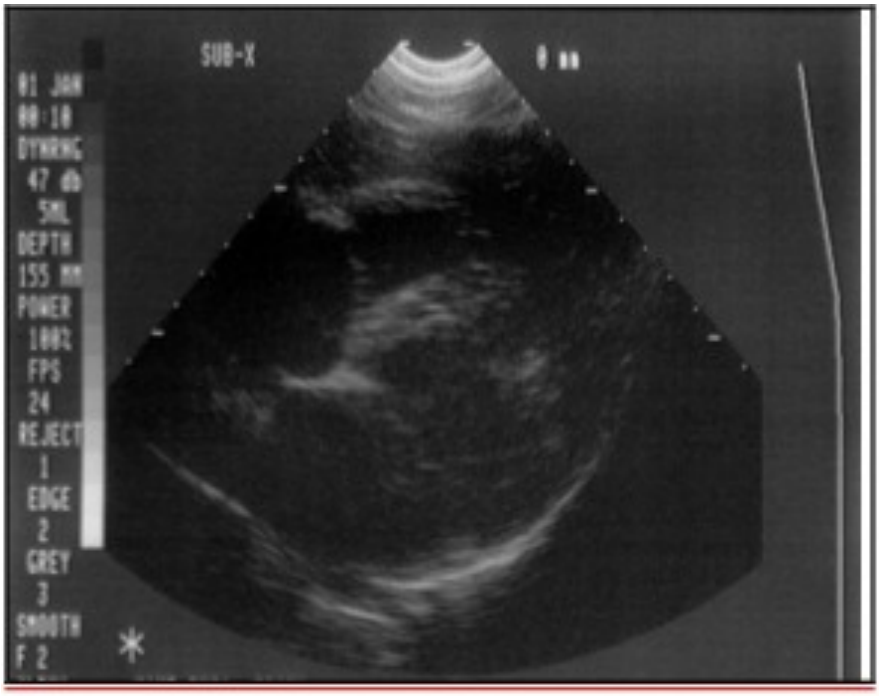
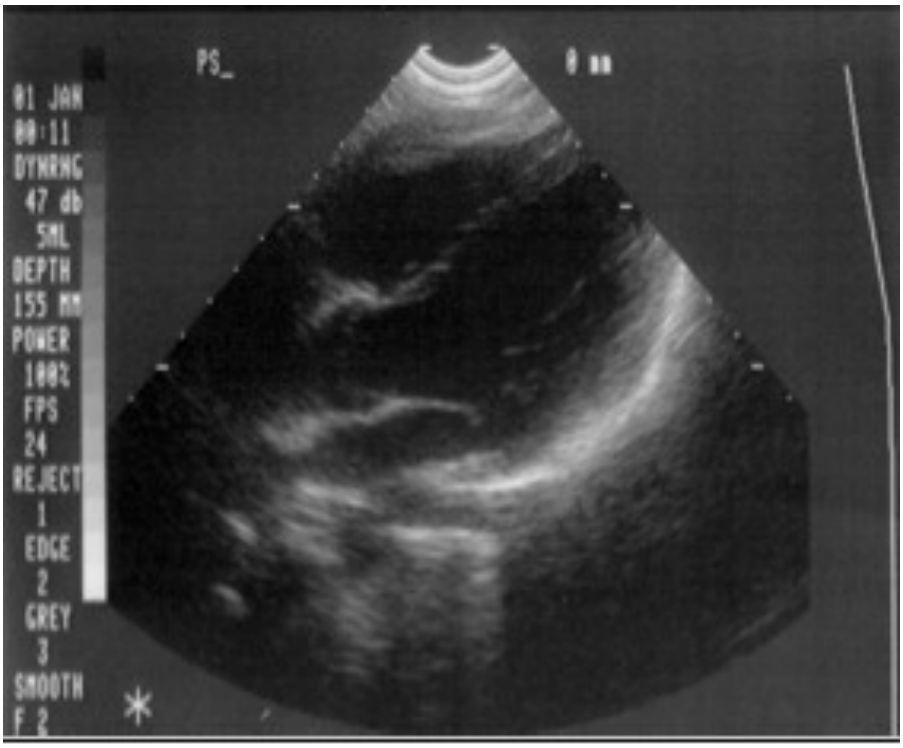


**Figure15**

**Subxiphoid view**



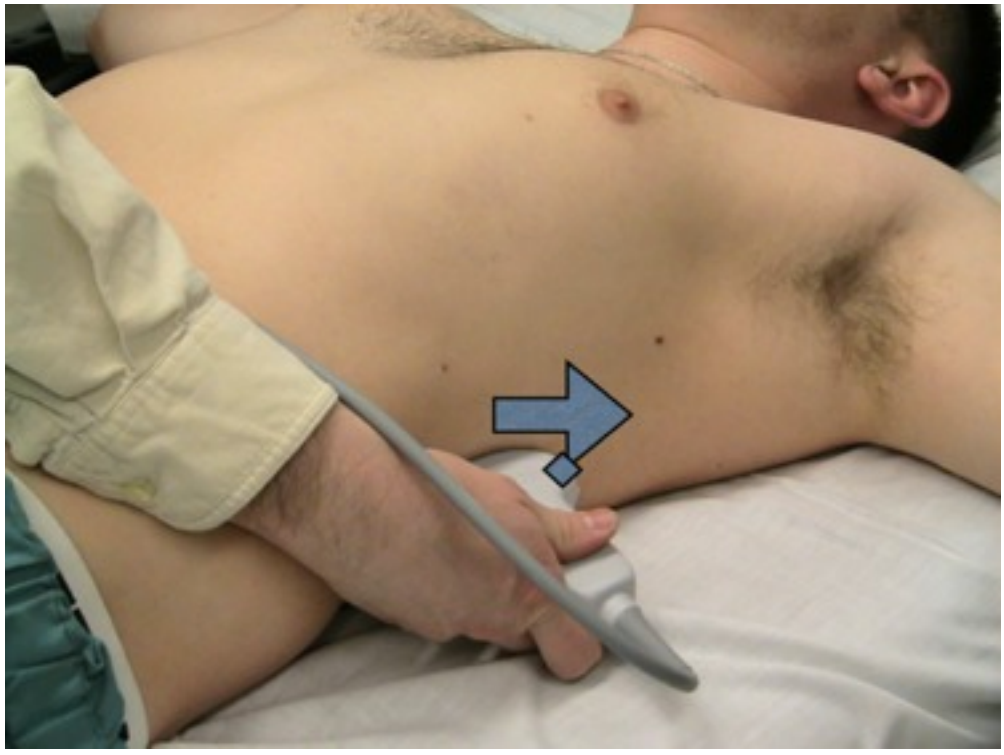

**Parasternal long**



**Question 3: Free fluid in the chest? Yes or no?**

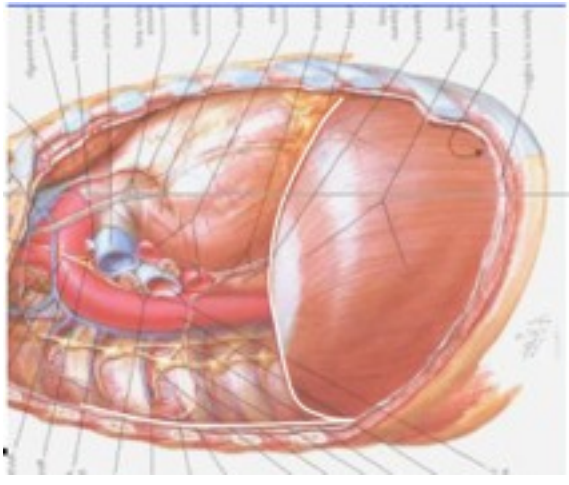
**In the trauma patient, a pleural effusion is a hemothorax till proven otherwise.** Fluid will accumulate posteriorly in the supine trauma patient. Lung bases are normally scanned at the same time as the RUQ and the LUQ, respectively. Once each upper quadrant is scanned, the probe is simply advanced cephalad in the coronal plane till the hyper-resonant linear diaphragm is seen.

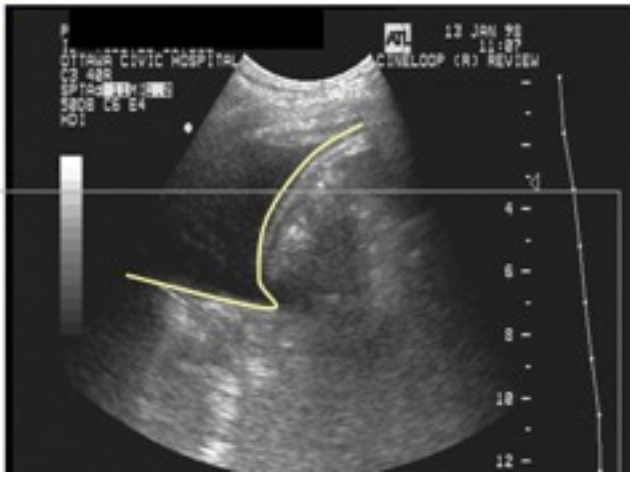
**Advancing the probe to find the diaphragm in the LUQ.**



Ultrasound waves penetrate either the spleen or the liver, depending and reveal the diaphragm, a **hyper-echoic (white), linear structure**. This structure will move with breathing. Once this structure is found, the probe can be held stationary while the patient breathes or is ventilated.

In the normal scan, air-filled lung will come from the left side of the

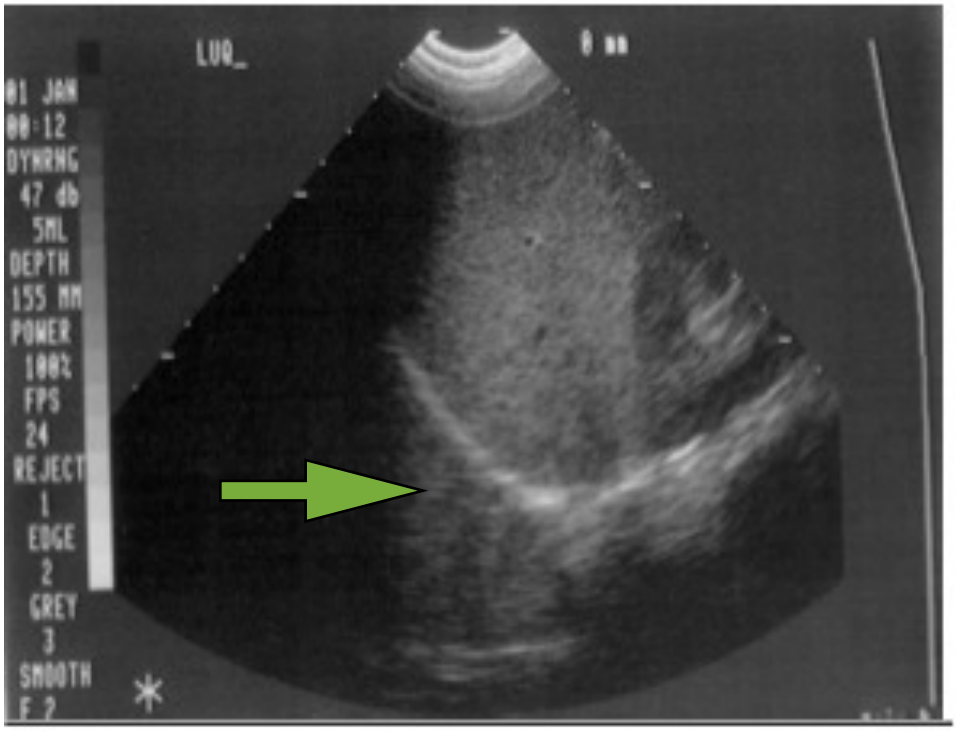




screen to obscure what is below, resulting in a sign called the **curtain sign.**

One may also note **mirror image artifact** above the diaphragm (see figure 17), where there is reflection above the diaphragm of either liver or spleen. This finding is not always present but it does suggest absence of fluid. Also, as one observes the hemidiaprphragm during inspiration, one will observe the **curtain sign**, as normal air filled lung descends into the costophrenic angle (Figure 17a). One will have the impression a curtain is being drawn across the field of vision from the cephalad (lung) side of the screen. This is highly suggestive of a normal (no effusion) scan. If the area above the diaphragm looks black (hypo-echoic), then a pleural effusion (hemothorax) is confirmed. (see figure 18). If one can easily visualize the spine above the diaphragm, this is called a **spine sign**, further suggestive of fluid above the diaphragm. The presence of fluid allows the spine to be seen, normally obscured by air-filled lungs.

**Figure 17– Normal air above the diaphragm, with mirror image artifact well demonstrated by arrow.**




Mirror image = air above the diaphragm

**Figure 17a: Curtain sign (see arrow)**

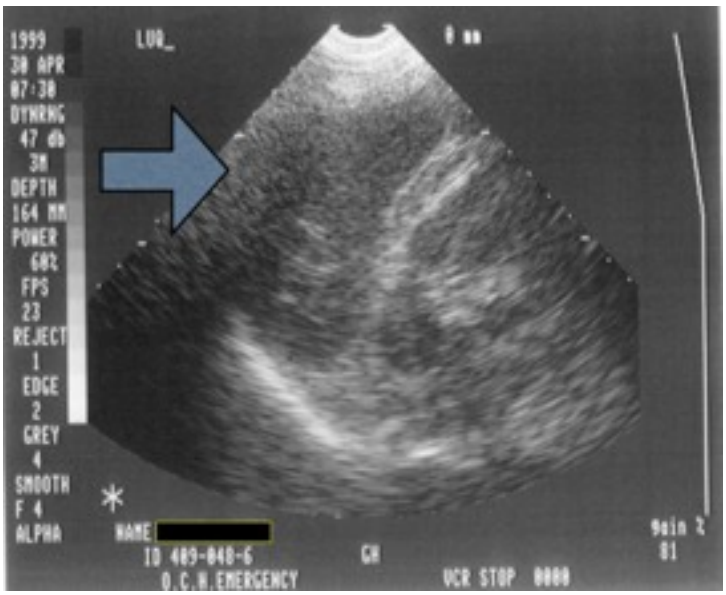



**Figure 18 – Positive free fluid (hypo-echoic area) above the diaphragm = hemo-peritoneum**

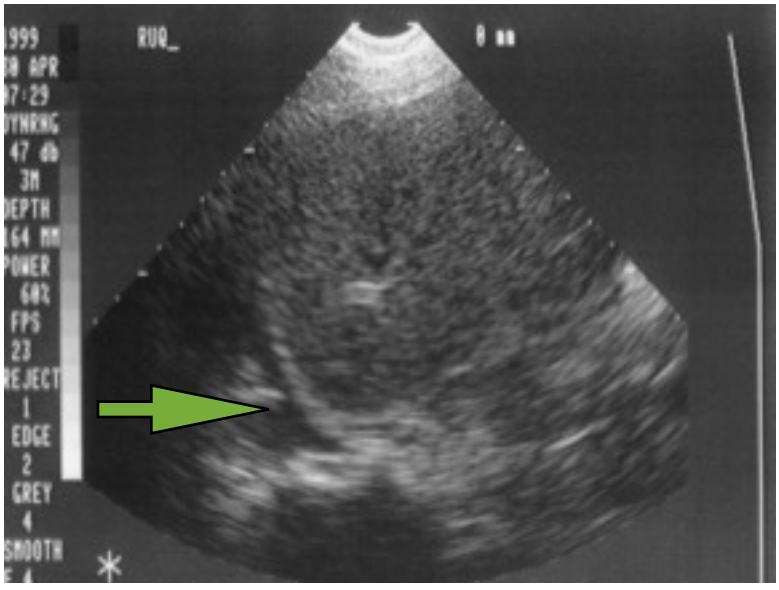
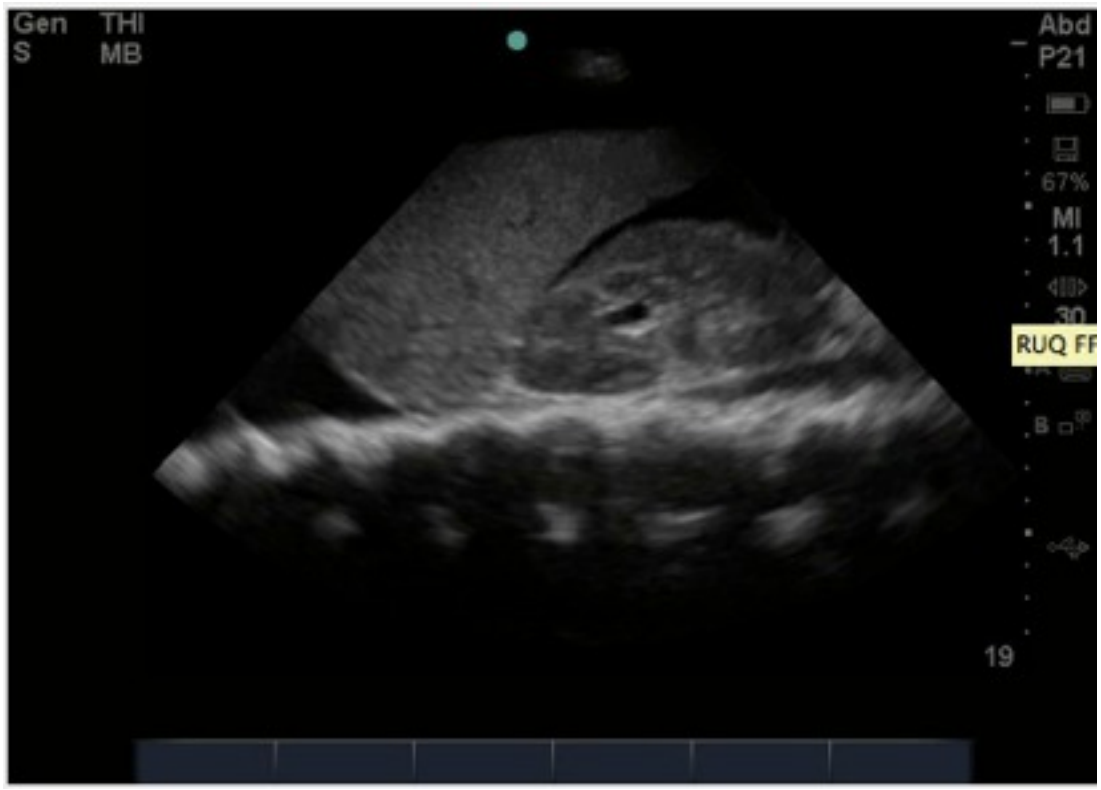


**Figure 18b - A positive Spine Sign: the spine made visible by fluid within the thorax (note: there is also abdominal free fluid)**



# Question 4:
# Pneumothorax? Yes or no

Ultrasound outperforms chest x-ray and rivals CT in the detection of pneumothorax (Lichtenstein, 2005; Blaivas, et al, 2005).

**Probe selection:** Both high frequency linear array and lower frequency abdominal probe can be used.

## Normal scan:

The patient will be supine or semi-seated. The probe is placed on the anterior chest wall, sagittal plane, at the level of the 2nd or third intercostal space and parasternally. It is set at a depth of 5-10 cm. One identifies ribs, obvious by their shape, hyper-echoic surface and acoustic shadowing. The **pleura is the area of interest**. It is a hyper-echoic, thin, linear structure that crosses both ribs just inferior to the inner surface of both ribs. (Figure 19). In the normal lung, the ***'sliding lung'*** sign is present, the artifact created by the movement of pleural surfaces against each other with respiration. If seen, there is no pneumothorax. Small '***comet tails' may also be present. Note: These are not always seen, even in normal subjects.*** But if observed, in conjunction with the sliding lung sign, there is no pneumothorax.

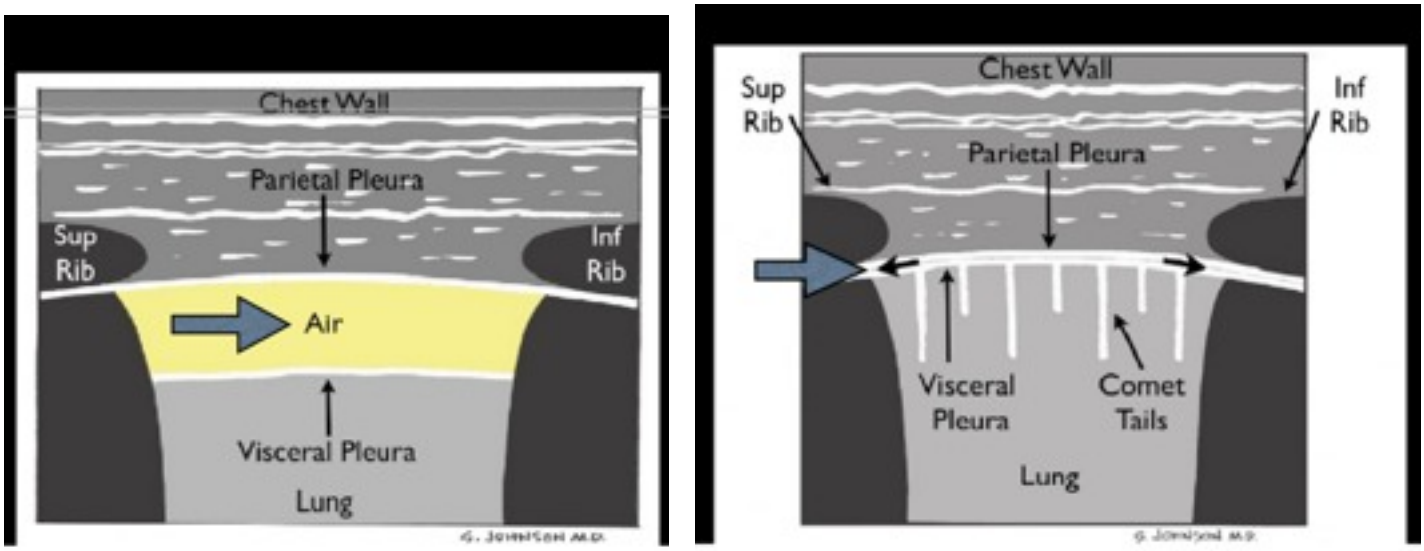
**The positive scan:** A pneumothorax is present when air is present between pleural surfaces. In this case, ultrasound artifacts explained above will be obliterated. One will see that at the pleura there is neither movement (lung slide) nor comets. This learning point will be most obvious when the video lectures is reviewed.

The absence of **both** of these signs, is highly suggestive of pneumothorax in the trauma setting (sensitivity and specificity both greater than 95%). This is not 100% diagnostic, however. Other important causes of absent lung slide, include the following:

**Previous pleurodesis**
**Apneic patient**
**Interstitial lung disease**
**ARDS**
**Right mainstem intubation**

If a pneumothorax is suspected, then the probe can be slid down laterally along the chest wall until you see the appearance of the sliding lung again. The leading edge of the sliding lung is called the ***'lung point'*** and **this sign is 100% specific for pneumothorax** (Lichtenstein, 2005). One can then estimate the size of the pneumothorax, depending on how far lateral lung point is found. If the lung point is detected only 5-10 centimeters away from the midline laterally, then a small pneumothorax is estimated. If the lung point is detected all the way down to the anterior axillary or mid- axillary line, then moderate to large pneumothorax is suspected.

Figure 19. Illustration of pneumothorax versus normal scan. In the positive scan (right), there will be no movement at the pleural surface, whereas, in the normal scan (left), lung slide will be seen.



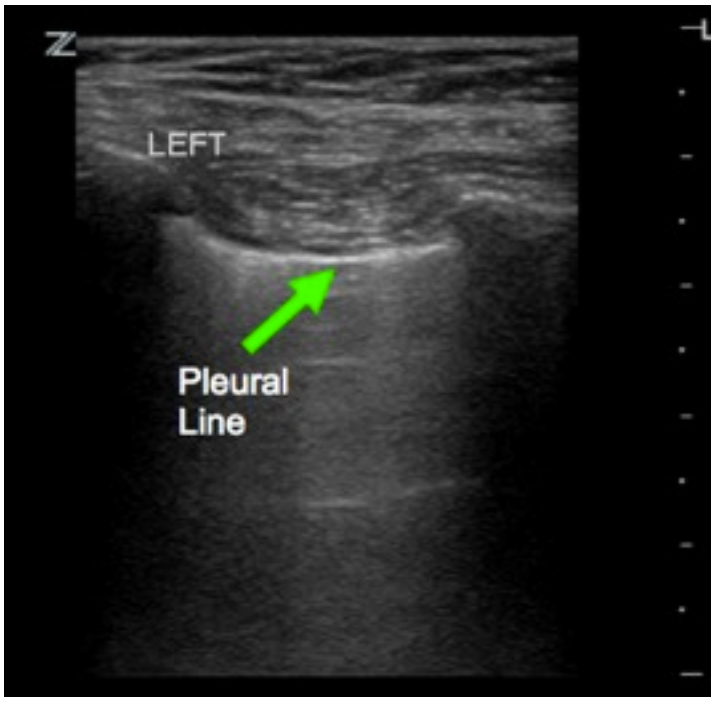




*Figure 20. Still image of anterior chest demonstrating the lung point in a patient with a pneumothorax.*

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# Ultrasound-Guided Central Venous Access

## Learning objectives

- To describe the evidence for ultrasound guided central venous access
- To understand the techniques for ultrasound guided insertion of central lines
- To distinguish between an artery and a vein sonographically
- To be able to predict patients with difficult central venous access
- To understand how to minimize central line associated blood stream infections

## Introduction

Central venous access is a common procedure and an essential skill for emergency physicians. The ability to gain central venous access is necessary for volume resuscitation, administering vasoactive medications, hemodynamic monitoring, resuscitation monitoring (via O2 saturation of central venous blood) and cardiac pacing. In the era of goal directed therapies (e.g. Sepsis) central venous access is a timely and essential procedure to be done by the emergency physician. Traditionally, the anatomical landmark method of locating and catheterizing central veins has been used in the ICU, operating room, and emergency settings. However, central venous access can be difficult and hazardous to the patient when using this landmark technique. Major and minor complication rates can be as high as 18% depending on the experience of the physician, access site chosen, number of needle passes, and the body habitus of the patient (1-4). These complications include hematoma, artery puncture and dissection, pneumothorax, hemothorax, nerve injury, CVA, death and incorrect placement of the catheter. Failure rates have been reported as high as 19% (5). Complication and failure rates associated with the anatomical landmark technique suggest the need for improved techniques for central venous access.

Ultrasound-guided central venous access has been successfully used since 1984 by several specialties. Legler et al reported the use of Doppler ultrasound to locate the internal jugular vein prior to catheterization (6). Yonei et al were the first to us 2-D real- time ultrasound-guided central venous access of the internal jugular in 1986 (7). In a case series, Hudson et al were the first to report the use of 2-D real-time US in the emergency department (8). In 1990 Mallory et al, published the first controlled study comparing the anatomical landmark technique and ultrasound-guided central access of the internal jugular vein (9). They reported decreased failure and complication rates as well as a decrease in mean number of passes compared to the conventional method. Troianos et al demonstrated similar results of decreased first pass attempts, mean time to cannulation, and lower percentage of carotid artery puncture when compared to the traditional method of internal jugular catheterization (10). In 1993 Denys et al conducted the largest controlled study comparing the landmark approach to ultrasound guidance of internal jugular cannulation (11). Complication rates were significantly lower and success rate significantly higher in this study. Furthermore, high success rates and low complication rates can be demonstrated in complicated patients. In 2006 Leung et al conducted a prospective trial in the emergency department which found a significant increase in the success rate and a significant decrease in the complication rate when using ultrasound guided central venous catheter placement compared to the anatomical landmark method (15). Mey et al evaluated ultrasound-guided internal jugular access in 493 complicated patients (e.g. obesity, thrombocytopenia, dyspnea) (12). They reported low complication and high success rates in these patients. Hatfield et al, in a prospective study, demonstrated successfully central venous access in patients that were identified as potentially difficult catheterizations (13). Criteria for potentially difficult central venous access are listed below (where ultrasound guidance may assist):

1. Surface landmarks difficult to identify (e.g. obesity, local swelling)
2. Limited sites for access attempts (e.g. other catheters, pacemakers)
3. Previous difficulties during catheterization
4. Previous or current complications (e.g. pneumothorax, arterial puncture)
5. Known vascular abnormalities
6. Coagulopathy, thrombolytics
7. Patient unable to tolerate supine position (e.g. respiratory failure, increase ICP)

The authors suggest that ultrasound-guided central venous access should be the primary choice in this patient population because of the lower complication rate associated with this technique. Finally, Randolph et al in 1996 conducted a large meta- analysis of the existing literature examining ultrasound guidance for central venous access (14). They report that ultrasound guidance significantly decreases internal jugular and subclavian catheter placement failure rates, decreases complication rates, and decreases multiple catheter placement attempts when compared to the landmark technique.
In the pediatric population, Froelich reported significant decrease in complication and decrease in placement attempts when comparing the ultrasound guided CVC technique to the anatomical landmark method in a pediatric ICU group (16). Hosokawa and others showed a significant decrease in complication rate, time to catheterization and fewer needle passes compared with the anatomical landmark method in a pre-surgical infants group (17). The National Institute for Clinical Excellence (NICE) now recommends the use of ultrasound guidance for central venous catheterization in children (18).
In the adult population, after an evidenced based literature review NICE concluded that compared to the landmark method ultrasound guidance had a relative risk reduction of 86% for failed attempts, 41% for first failed attempts and 73% for complications(19). Finally, a number of studies suggest that an increase in the number of insertion attempts is associated with a higher complication rate. McGee and Gould showed that the incidence of complications after 3 or more insertion attempts was 6 times the rate compared to 1 attempt (20)
The literature clearly supports the use of ultrasound guidance when attempting central venous catheterization. Compared to the traditional landmark technique success rates are higher and complication rates are significantly lower. Ultrasound guided CVC should be considered as a first line approach when trying to avoid complications in critically ill patients. With ultrasound widely available to emergency physicians, its use for central venous access is currently considered the safest and best care for our patients.

## Ultrasound-Guided Central Venous Access Technique

### Anatomical Considerations

It is important to be able to distinguish between veins and arteries on an ultrasound image when locating a vein for catheterization. In aorta chapter the differences between the abdominal aorta and the inferior vena cava were explained. Much of the same differences are applicable to distinguishing other arteries and central veins: Arteries have thicker, more echogenic walls, are pulsatile, non-compressible, with no variation during respirations and have a more round and regular shape. Veins have a more irregular shape, easily compressible, less echogenic wall, vary with respiration, and distend with Valsalva maneuver, humming and head-down tilt (Figure 1). Being able to distinguish the artery from the vein by using the anatomical differences seen on the ultrasound image is an essential skill. However, there are adjunctive tools than can help distinguish between artery and vein. Colour doppler and pulsed-wave Doppler are two imaging tools to be used. Colour Doppler distinguishes flow direction of vessels: blue away from the probe and red towards the probe. Pulsed-wave has distinct wave forms to distinguish between artery and vein: artery shows a

peaked pulsatile wave form and vein shows a low amplitude continuous wave form (Figure 2). Veins will change anatomical location with change in patient position. The internal jugular (IJ) will become more medial and anterior with neck rotation to the contralateral side (Figure 2). External rotation and abduction of the leg may cause the femoral artery to be position over the femoral vein.

Sonographic comparison between arteries and veins

| **Vein**<br>*Compressible* | **Artery**<br>*Non-compressible* |
|---|---|
| Thin walled | Thick walled |
| Oval Shape | Round |
| May transmit pulsations | Pulsatile |
| Enlarges with valsalva or humming | No change with valsalva |

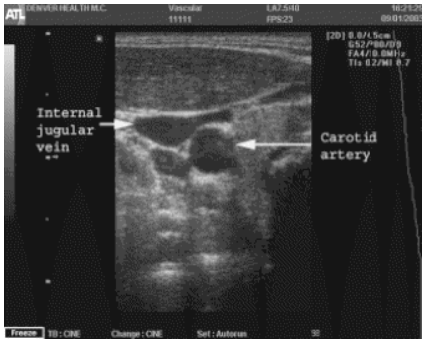


**Figure 1. This shows the anatomical differences of a vein and artery in cross-sectional image**

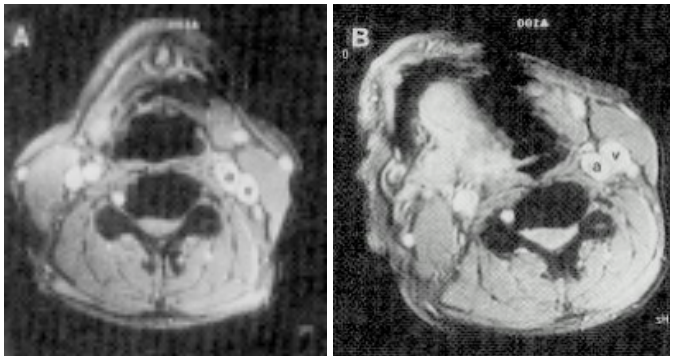


**Figure 2: MRI of neck anatomy. In (A) the IJ vein is posterior and lateral to the CA. With rotation of the neck (B) the IJ position moves medial and superior in relation to the CA.**

Anatomical variation of vein position is common. The internal jugular commonly deviates from its normal anatomical relationship to the carotid artery (Figure 3). Troianos et al found that the internal jugular was overlying the carotid artery in 54% of ultrasound-imaged patients and not in the typical anterior-lateral position (21). Also, there may be variation in diameter between the right and left internal jugular, one side may be larger, smaller, or absent. Change in vessel location with position change and anatomical variations of vein position are significant reasons to consider ultrasound-guidance instead of the landmark method for central venous access.

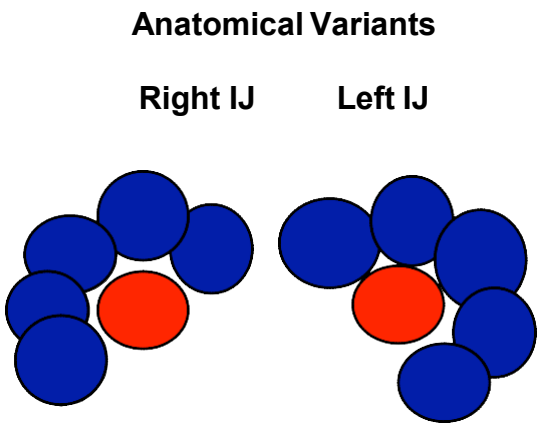


**Figure 3: Anatomical variants of IJ in relation to the CA**

## Sterile Technique

Sterile technique should and can be maintained while doing the ultrasound-guide central venous access procedure. Recent recommendations suggest that several strategies should be implemented to prevent central line-associated bloodstream infection (CLABSI) (22).

1. The development and implementation of a pre-procedural checklist along with nursing and physician education regarding the use of the checklist.

2. Establishing catheter insertion kits/carts containing all necessary items for insertion.
3. Before catheter insertion, apply a chlorhexidine solution greater than 0.5% (eg. 2%) for skin preparation. The use of a single use chlorhexidine scrub is now recommended instead of povidone-iodine solution applied with gauze.
4. A post-procedural central line maintenance protocol and infection surveillance protocol.

This sterile technique begins with standard sterile procedures typically done with any central venous access attempt. The skin is sterilized with cleanser (e.g. chlorhexidine) and the area is covered with sterile surgical drapes. Full body draping is now recommended to ensure a sterile barrier. Next, while maintaining a sterile perimeter, sterile gel is placed in either the thumb of a sterile glove or a commercially made sterile probe sheath. The probe is then placed in the glove or sheath by an assistant and pushed tightly to the end removing any air bubbles between the probe and sheath (Figure 6). Sterile gel is then applied to the skin over the vein to be catheterized. The probe with sterile sheath or glove can now be passed over the skin to locate the important anatomical structures and the vein in preparation for catheterization (Figure 7). It is important to note that the ultrasound cord covered with the sheath may be laid in the sterile field however, when using a sterile glove the cord is exposed and must not contact the sterile surface during the procedure.

## Central Line Bundle to minimize the risk of CLABSI

- Hand hygiene
- Maximal barrier precautions
- Chlorhexidine skin antisepsis
- Optimal catheter site selection
- Daily review of line necessity

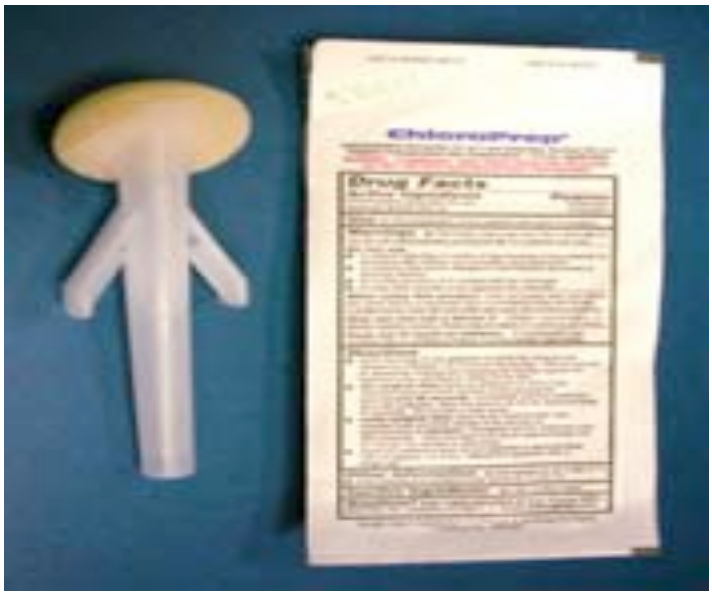


**Figure 4.Single use skin preparation scrub.**

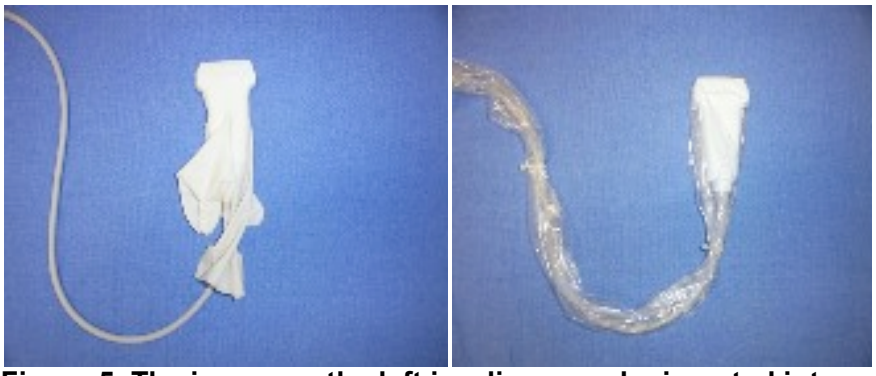

**Figure 5. The image on the left is a linear probe inserted into a sterile glove and the image on the right is a linear probe inserted into a commercially made sterile sheath.**

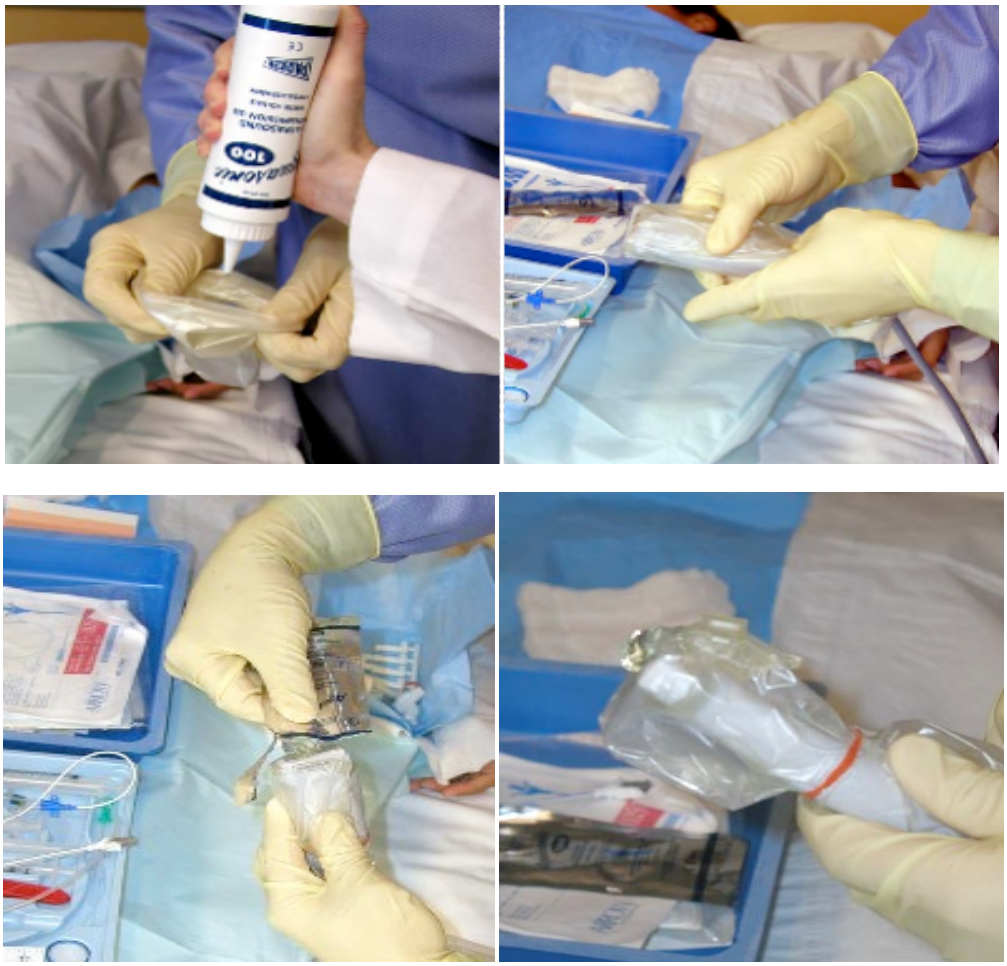

**Figure 6. Sterile sheath application**

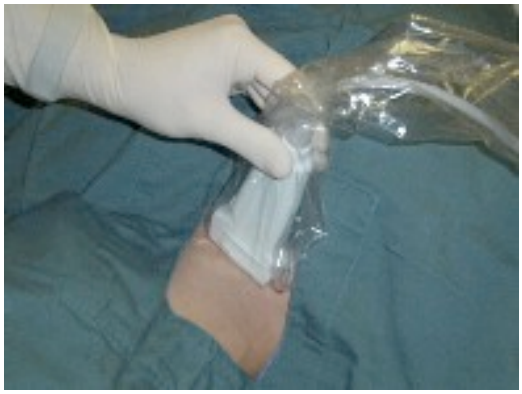

**Figure 7. The linear probe on skin using sterile technique to locate artery and vein.**

## Ultrasound-guided Central Venous Access Approaches

Ultrasound-guided central venous access technique uses a 7.5-MHz (or higher) linear probe in the B-mode on the ultrasound machine (Figure 8). As described previously in the physics chapter, the higher the frequency the lower the penetration but with increased resolution. This allows visualization of more superficial structures up to a depth of approximately 10 cm with a high frequency probe. The orientation of anatomical structures on the ultrasound screen is the same as the curvilinear probe when the probe indicator is directed to the right of the patient. Anatomical structures should be imaged and located prior to procedure. This may be done in the transverse and longitudinal views to allow the physician to identify the location and course of the vein. In the transverse view, the ultrasound image represents a cross-sectional view, and the artery and vein will appear round or oval shaped. In the longitudinal orientation, the ultrasound image represents the long axis of the artery or vein and will appear as a tube-like structure (Figure 9). The description of ultrasound-guided central venous access will include the internal jugular, and femoral vein approaches. The literature has shown a more significant reduction in complication rates and increased success rates when using the internal jugular approach. This is the approach that is the most frequently studied. However there is evidence for successful use of ultrasound guidance with the subclavian and femoral approaches. See Table 1 comparing the three most common CVC sites.

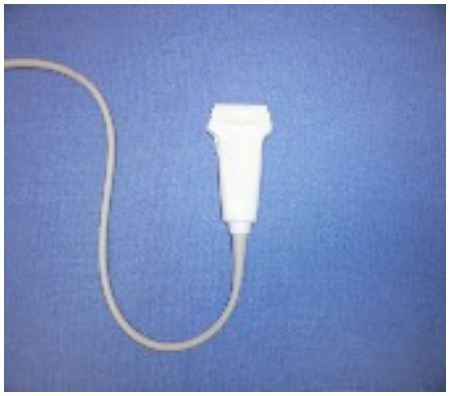

**Figure 8. Linear Probe (7.5-MHz)**

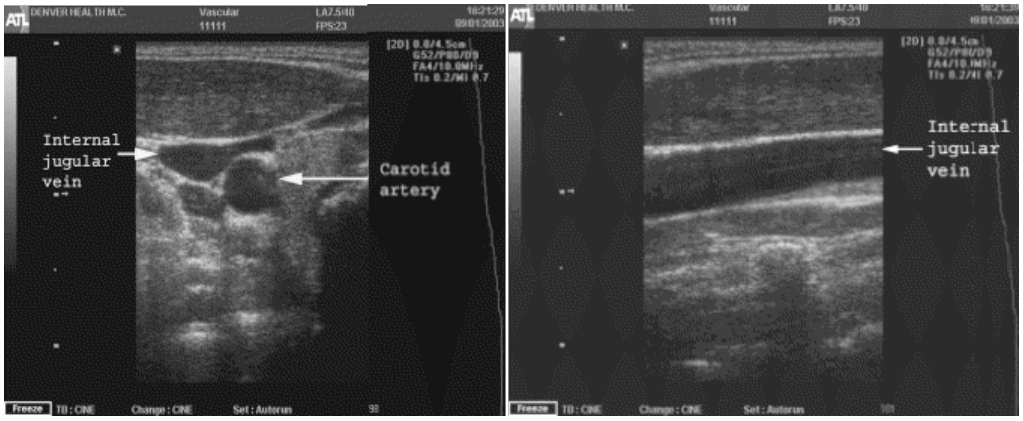


**Figure 9. The transverse and longitudinal views of artery and vein. The image on the left is a transverse view of the CA and IJ. The image on the right is a longitudinal view of the IJ**

| | Internal Jugular | Subclavian | Femoral |
|---|---|---|---|
| **Pneumothorax** | **+** | **++** | **N/A** |
| **Thrombosis** | **++** | **+** | **+++** |
| **Infection** | **++** | **+** | **+++** |
| **Catheter malposition** | **+** | **++** | **N/A** |
| **Compressibility** | **+++** | **+** | **+++** |
| **Use in resuscitation** | **+** | **++** | **+++** |
| **Ease of use with US** | **+++** | **+** | **+++** |
| **Patient comfort** | **++** | **+++** | **+** |

**Table 1. Characteristics of the three most common sites of central venous catheterization. McGee NEJM (2003). (+++ Most often, + Least often)**

**Internal Jugular Vein Catheterization Approach**

The internal jugular (IJ) in relation to the sternocleidomastoid runs medially at its superior aspect then descends between the sternal and clavicular heads. Generally, the IJ will run laterally and anteriorly to the carotid artery. Traditionally, the internal jugular is accessed at the bifurcation of the sternocleidomastoid heads. Sterile technique should be maintained according to the above description. In preparation for catheterization, the patient is placed in a head-down tilt to distend the IJ. During the assessment of any of the great vessels for central line placement the sonographer should specifically assess: the presence, size, and patency of the vein; the distensibility and compressibility of the vein; the presence of a thrombus in the vein; the position of the vein relative to the artery.

The probe is placed at or inferior to the bifurcation of the heads of the sternocleidomastoid muscle in the transverse position to locate and image the IJ and CA. The indirect or direct method of access the IJ can be attempted (See table 1 for advantages and disadvantages). In the indirect method, the IJ is located and identified on the ultrasound screen. It is then centered on the ultrasound screen and thus its anatomical position will correspond to the center of the probe (Figure 10). A mark is placed on the skin at the center on the probe. The probe is then removed and access is attempted using the mark on the skin as a guide. The preferred method of catheterization for success and patient safety is the direct method of real time ultrasound guidance. With

the direct method the IJ is located and centered on the ultrasound screen. The needle is then inserted at the center of the probe that is overlying the IJ (Figure 11). The needle is advanced at a 45-degree angle until the needle is visualized on the screen. The needle will be seen as bright echogenic spot above the vessel with the ring-down acoustic image below the needle (Figure 12). Direct visualization of the advancing needle puncturing the vessel can be achieved. This is facilitated by sliding the linear probe along the skin in the direction of the advancing needle keeping the needle tip in the plain of the ultrasound beam following the tip into the vessel. However, the position of the needle may not be directly visualized but identified by compression of the tissue overlaying the IJ with needle movement or posterior displacement of the vessel wall. Wiggling the needle slightly back and forth as the needle is advanced will move the tissue surrounding the needle and may help to identify its location above the vessel. Once the position of the needle has been located above the IJ, the needle may be advanced having an assistant or nurse watching for blood flashback to confirm

| | Direct | Indirect |
|---|---|---|
| Advantages | -Safest procedure as needle tip is visualized entering central vein | -Less equipment to handle at one time. More likely to see flashback |
| Disadvantages | -More challenging for novice ultrasonographer | -Patient movement effects landmarks |

Table 2. Advantages and Disadvantages of the Direct and Indirect CVC insertion

| | Short axis approach | Long axis approach |
|---|---|---|
| Advantages | -Artery and Vein are visualized on same screen | -Better visualization of entire needle |
| Disavantages | -Needle tip can easily be lost or not captured on screen | -More difficult for novice sonographer<br>-More difficult for pts with shorter necks |

Table 3. Advantages and Disavantages of the short and long axis approach for Direct CVC insertion

puncture of the vein. However, it is recommended that the operator directly visualize the needle advancing into the vessel for optimal patient safety.

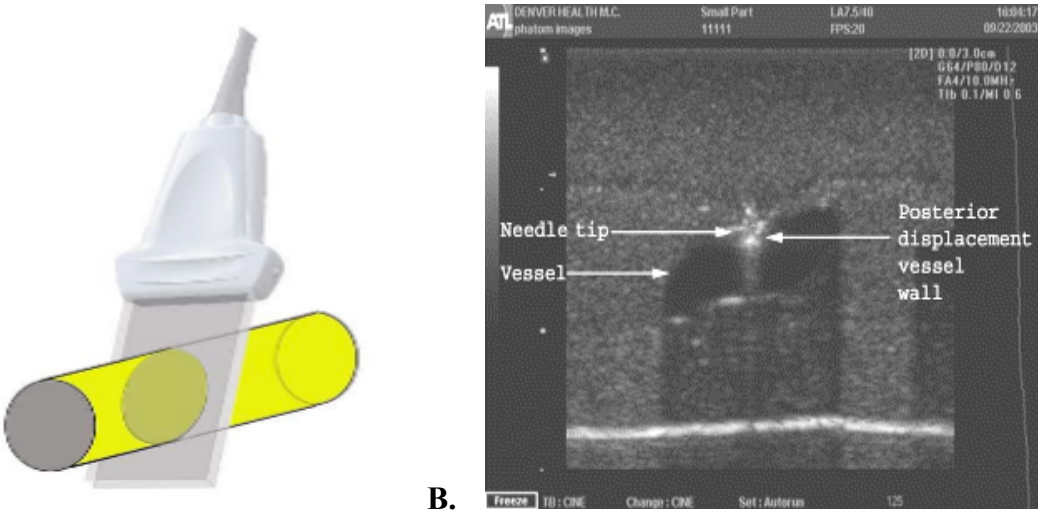


**Figure 10. When the vessel is centered on the ultrasound screen (Image B) its anatomical position will run under the center of the probe (Image A).**

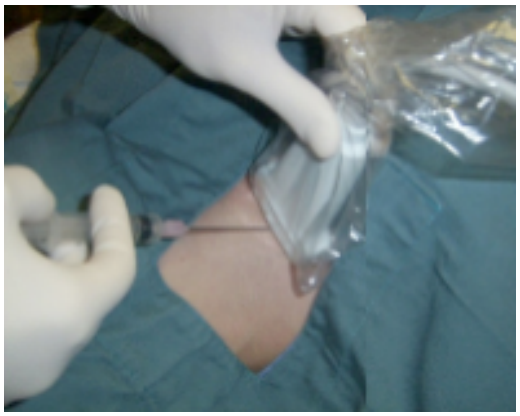

**Figure 11. The needle inserted at center of probe in the transverse orientation over the vein.**

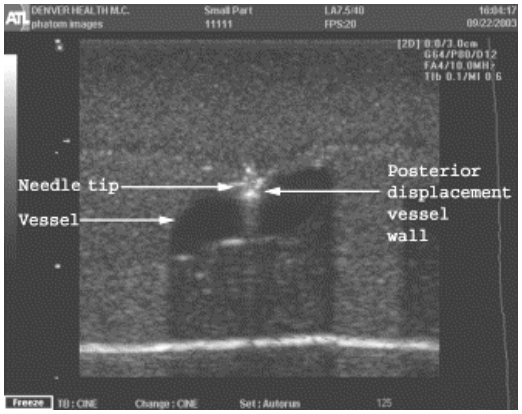


**Figure 12. This image is a transverse view of needle above the vessel, displacing the vessel wall with ring-down sign below the needle in a simulation model.**

Alternatively, after identifying the IJ in the transverse view the probe position may be changed to the longitudinal axis. With the probe over the vein, the needle is then advance at the center of the probe at a 30-degree angle (Figure 13). In the longitudinal view, direct visualization of the needle advancing through the tissue and penetrating the vein can be achieved (Figure 14). In addition to this watching for blood flash back in the syringe is used to confirm puncture of the vessel. At this point, the central venous catheter can be inserted following the traditional placement method. Successful cannulation of the IJ with the catheter can be confirmed by using the linear probe to visualize its placement in the vein.

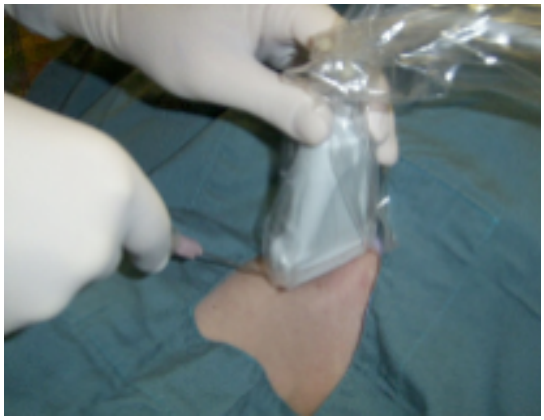

**Figure 13. The needle is inserted in the skin at the center of the probe in the longitudinal orientation over the vein.**

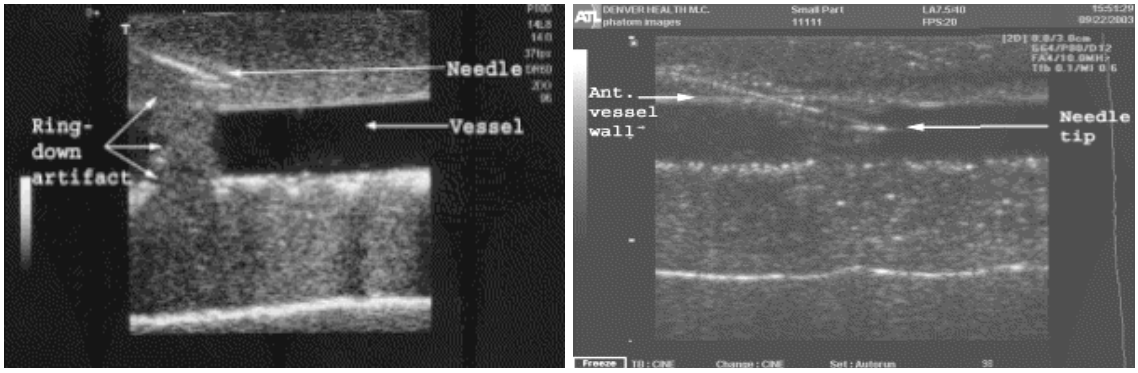


**Figure 14. The image on the left is a longitudinal view of a needle above the vessel and ring-down sign in a simulation model. The image on the right is a longitudinal view of a needle penetrating the vessel in a simulation model.**

## Femoral Vein Catheterization Approach

Catheterization of the femoral vein is a useful technique in the ED for administering fluids, blood products, medications, and for central venous monitoring. Success rates are as high as 95%. Complications of femoral vein catheterization include deep vein thrombosis, arterial puncture, hematomas, infection, and arteriovenous fistula. In the patient undergoing active resuscitation an Intra osseous (IO) needle gives rapid vascular access. However, IO may not always feasible (eg. multisystem trauma) and not entirely equivalent to central venous access (eg. central venous monitoring) . Femoral venous catheterization is commonly chosen during cardiopulmonary resuscitation (CPR) due to the limited access to the IJ and subclavian veins by concurrent treatment to the patient at the head and chest. Success rates during CPR can

be as low as 69% (14) due to low cardiac output or no palpable pulse. The traditional landmark approach to femoral venous access uses the pulsation of the femoral artery as an anatomical guide to locate the femoral vein. However, it has been demonstrated that pulsations in the femoral artery region during CPR are actually venous and not arterial (23)(24)(25). This has lead to decreased success rates and increased complication rates when attempting femoral vein catheterization during CPR. Hilty et al in 1997 conducted a prospective, randomized study comparing the success and complication rate of the traditional landmark technique to real-time ultrasound guided femoral venous catheterization during CPR (26). They showed that ultrasound-guided catheterization had a higher success rate, lower number of needle passes, and a zero incidence of arterial catheterization compared to the standard landmark approach. This evidence supports the use of real- time ultrasound-guided venous access when catheterizing the femoral vein during CPR.

The procedure to catheterize the femoral vein using ultrasound-guidance is similar to the IJ approach. Standard sterile preparation of the patient is used along with the sterile sheath or glove covering the probe as described previously. Anatomical location of the femoral vein is inferior to the inguinal ligament and medial to the femoral artery pulsation. (Figure 15)

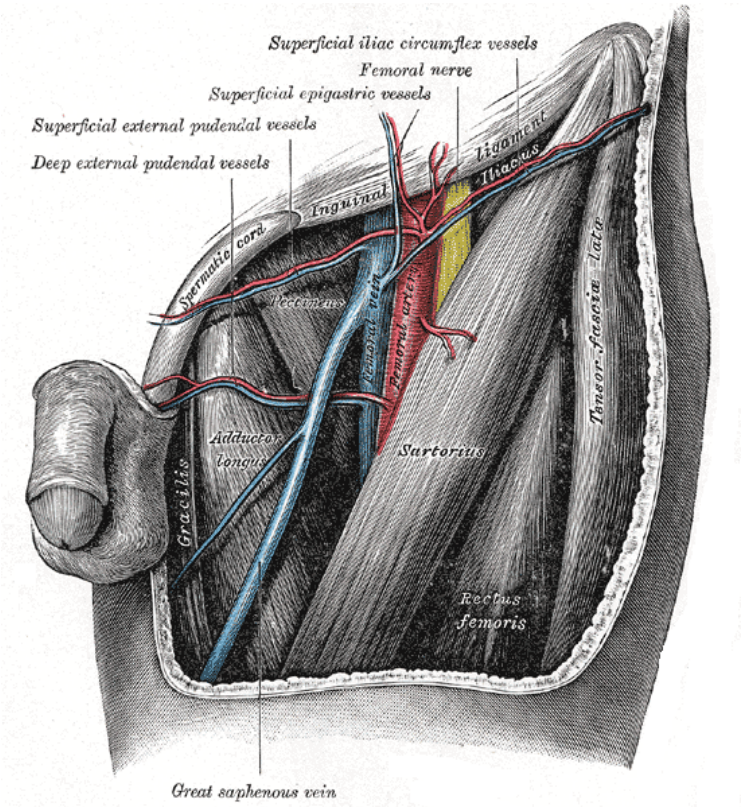


Figure 15. Femoral triangle (wikimedia.org/wikipedia/en/3/34/Femoral_triangle.gif)

The probe is first place on the skin in the transverse orientation to locate the femoral vein. In the transverse view the femoral vein will appear as round or oval shaped object medial to the femoral artery (Figure 16).

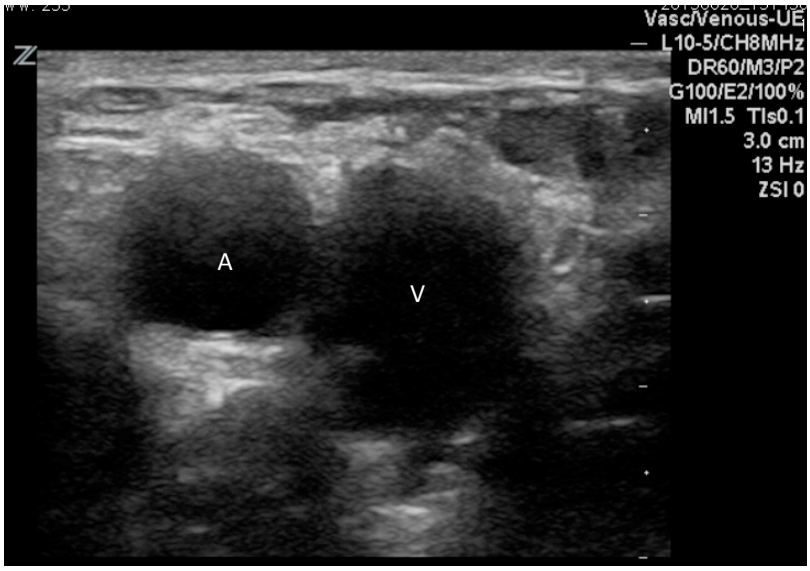


**Figure 16. Right Femoral Artery (A) and Vein (B)**

Identification of the femoral vein is confirmed by easy compressibility (Figure17), having a less echogenic wall, and diameter variability during respirations. Noncompressability of the femoral vein suggests a DVT and another site for CVC should be identified. If you are having difficulty identifying anatomic landmarks, Colour Doppler may be helpful in locating the femoral artery and vein. However in the patient receiving CPR this may give variable results.

A) B)

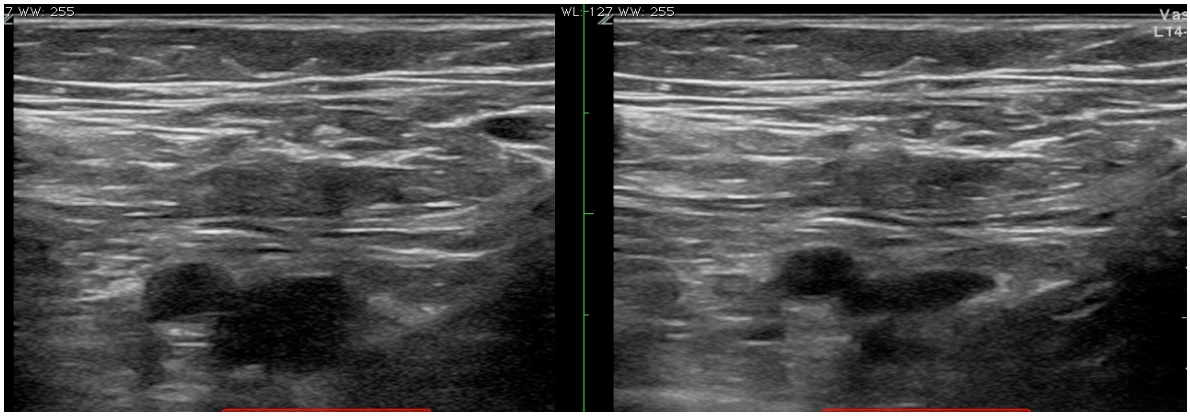

Figure 17 Femoral Vein and artery illustrating A) noncompression and B) compression.

Again, the femoral vein is then centered on the ultrasound screen so that its anatomical position will correspond to the center of the probe. Take note of the depth of the femoral vein as you plan your approach to CVC. At this point the indirect or direct method of catheterizing the femoral vein may be used. Compared with the indirect method the direct method has a higher success rate and lower complication rate. Using the direct method in the transverse orientation, the needle is inserted at the center of the probe at a 45-degree angle to the skin. The needle will appear as a bright, highly echogenic object in the soft tissue. Once the needle is positioned over the vein, the needle can be

advanced while sliding the probe along the vein towards the patient's head keeping the needle in the plain of the ultrasound beam allowing for direct visualization of venous puncture. Also, the sonographer should watch for blood flashback in the needle to confirm puncture. Alternatively you may ask and assistant to watch for blood flash back as well. The longitudinal approach may be used to see more of the needle and to visualize direct puncture of the vein as a real-time ultrasound image. Once puncture of the vein has been achieved, catheterization proceeds according to the standard Seldinger technique.

## Common Pitfalls

1. Failure to properly identify the vein: Not distinguishing the vein from the artery can lead to inadvertent puncture of the artery. The vein should be identified by easy compressibility, variation with respiration, distensible with Valsalva, humming or head down tilt (trendelenburg position) , and a less echogenic wall.
2. Failure to locate the needle tip in the tissue: This will decrease success rates and increase complication. The needle should be located by its bright, echogenic image and ring-down sign along with depression of the overlying tissue or posterior displacement of the vessel wall.
3. Failure to recognize vessel location changes with patient position: If using the indirect method, marking the skin before changing the position of the patient will lead to inaccurate localizing of the vessel.
4. Failure to center the vein on the ultrasound screen: If the center of the probe is used as guide, puncture of the skin will not be over the desired vessel to be catheterized.
5. Failure to recognize that excessive probe pressure on the skin may completely collapse the vein and thus the vein will be difficult to identify.
6. Be aware that more than 3 failed attempts to cannulate the vein can result in a 6 fold increase in mechanical complication. (McGee)

## Training and Certification

Currently, there are no established guidelines for training and certification in the use of ultrasound-guided central venous access. This skill is recognized as an adjunct to the already established skills for central venous access that emergency physicians currently posses. Extensive knowledge of vascular anatomy and the traditional landmark technique are essential for successful use of ultrasound-guided venous access. The use of ultrasound to landmark the vessels alone improves success and patient safety. Pitfalls and complication of this technique should be fully recognized and anticipated. Currently, there are several courses available that teach the ultrasound-guided central venous access technique to prepare the physician for its use. Also, there are commercially made models and teaching aids that can provide basic skills for ultrasound-guided venous catheterization. In the interest of patient safety it is helpful to have a quality assurance program established at every emergency department to monitor quality of patient care, complication rates and physician skill level for central venous access.

## Conclusion

Since 1984, various specialties including intensive care, anesthesiology, nephrology and surgery have successfully used ultrasound-guided central venous access. The literature has demonstrated higher first attempt success rates and lower complication rate when the ultrasound-guidance approach is compared to the standard landmark approach for

central venous access. Recently, its use in the emergency department has demonstrated similar success rates especially when used for central venous access during CPR. With increasing access to this technology in the emergency department, ultrasound-guided central venous access should be considered a primary choice to minimize complications, and maximize success rates especially in critically ill patients.

The American College of Emergency Physician (ACEP), in their 2001 emergency ultrasound guidelines, supports the use of ultrasound-guidance for central venous catheterization (27). They concluded that this technique is a helpful adjunct to central venous access especially in difficult or critically ill patients and classify it as a primary application for emergency ultrasound. In the United States, the Agency for Healthcare Research and Quality published an evidence-based report in 2001 supporting the widespread implementation of ultrasound-guided central venous access (28). In Canada, the Canadian Association of Emergency Physicians support ultrasound-guided central venous access use in Canadian emergency departments as an adjunctive tool for central venous access. It is evident that the use of ultrasound-guided central venous access has strong support from the literature because of it high success and low complication rates. This technique is especially useful in the emergency department and should be an essential skill for an emergency physician.

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