EMERGENCY ULTRASOUND FAQs

1. Describe the relationship between ultrasound frequency and depth of penetration.

A. Ultrasound frequency is the number of cycles or waves of sound per second and is measured in Megahertz (MHz) or million hertz range. *Higher frequency* ultrasound provides greater detail, but has poorer penetration of tissues. This is because the small wavelengths allow for the differentiation of very small structures. *Lower frequency* ultrasound provides less detail but does have better penetration of tissues.

Medical ultrasound frequencies range from 3.5 to 7.5 MHz. For deep structures 3.5 MHz is appropriate. This is the frequency that is used the most for ER scans including the abdominal trauma exam. For thin patients and children, 5 MHz may be used which will provide more detail than 3.5 MHz as depth of penetration is not as important. 5 MHz is useful for testicular scans and transvaginal exams where detail is more important than depth of penetration. Frequencies of 7.5 MHz have a few specific uses. The high frequency gives great detail, but the depth of penetration is poor. 7.5 MHz is used primarily for foreign bodies, testicular, transvaginal and vascular scans since these are modalities where fine detail is more important than penetration depth.

2. Briefly describe the relationship between echogenicity and the depiction of ultrasound images as white, gray and black.

A. Echogenicity refers to the ability of a substance to reflect or transmit ultrasound waves.

An echogenic image is an image that is produced by an object that reflects most ultrasound waves. It will appear white on the ultrasound screen.

An anechoic image is one that is produced by an object that transmits most ultrasound waves. It will appear dark or black on the ultrasound screen.

An image that is gray is produced by an object that both reflects and transmits ultrasound waves to varying degrees.

3. What is the difference between a mechanical sector scanner and a linear electronic transducer?

A. In general, ultrasound devices all utilize a transducer. The transducer directs a narrow ultrasound beam along its line of sight, which returns a reflected ultrasound wave. This provides a one-dimensional line of information. By rapidly sweeping this line back and forth across a sector of tissue, a two-dimensional plane of information is generated, i.e., a cross-sectional ultrasound image of the tissue in question.

Mechanical sector scanners employ this principle by utilizing a small transducer element, which by rapidly pivoting back and forth (or through the use of a pivoting mirror), swings the ultrasound beam and generates a pie-shaped two-dimensional image. Since a single, small element is employed, these transducers are useful in situations where a narrow window is available, ie, imaging the heart through the space between two ribs.

As opposed to a singles winging beam, linear electronic (array) transducers utilize a linear arrangement (or array) of many small elements. When this device is held against the skin the elements fire rapidly in succession and in this fashion, generate a rectangular shaped two-dimensional image. Since many elements are required, linear arrays are longer (and more expensive) than mechanical sector scanners. In certain situations this can be a disadvantage. The advantage of linear arrays, however, lies in the fact that by providing small alterations in the sequence of firing of the individual elements, changes in the direction and depth of focus of the beam can be instantaneously achieved.

4. Discuss the conventional position of the marker on the transducer when scanning in the cross-sectional plane and describe the orientation of the resultant image on the display.

A. The cross-sectional or transverse ultrasound image should by convention, display the patient's right side of the body on the left side of the viewing monitor. The transverse ultrasound image is displayed so that the transverse "slice" is being viewed from the perspective of the patient's feet. (This is the same convention used for displaying CT images).

To produce a transverse image following this convention, the physician performing the exam should be on the patient's right side, and the transducer should be oriented in the transverse plane. The marker on the transducer should be directed towards the patient's right side. The resulting image will show a transverse view with the patient's right-sided structures (ie liver) on the left side of the monitor.

5. Define GAIN and TGC (Time Gain Compensator).

A. GAIN refers to the amplification of the received signal. It is the artificial increase in the strength of the signal. All parts of the image on the screen are equally affected (as opposed to TGC). Adjustments of gain should be done with respect to tissues of known echogenicity.

The TGC allows for 'fine tuning' of the attenuated signal. It allows one to sharpen the images of deeper structures that are normally attenuated by their passage through more superficial tissues. TGC is used when it is perceived that the gain in one part of the field is unequal to that of another.

6. Discuss the causes for the following common ultrasound artifacts:

- **a. pseudo-sludge (beam-width artifact)**
- **b. side lobe artifact**
- **c. reverberation artifact (ring down artifact)**
- **d. mirror effect**
- **e. gain artifact**

A. a. *Pseudo-sludge (beam-width artifact):*

When the focal zone of the transducer is at the center of the gallbladder, the beam is of greater width at the posterior border of the gallbladder. The partial volume effect along the posterior wall results in the appearance of sludge (but it is really the posterior gallbladder wall). Also, gas bubbles in the duodenum can be projected adjacent to the gallbladder, simulating a gallstone.

b. *Side lobe artifact:*

This artifact is caused when weaker sound beams from the sides of the transducer are returned by a very reflective bowel-gas interface. This may appear as a line within the lumen of the gallbladder. To eliminate this artifact, try and alternate the angle of the transducer head.

c. *Reverberation artifact:*

This artifact is caused when ultrasound waves are being bounced back and forth between two or more highly reflective surfaces such as in the abdominal wall or a foreign body.

d. *Mirror Effect:*

Mirror effect is caused when the ultrasound beam is reflected back into the liver by the diaphragm and bounces back again to the transducer via the diaphragm. This results in intrahepatic structures appearing as if cephalad to the diaphragm.

e. *Gain Artifacts:*

Gain artifacts are caused by both overuse of gain in an attempt to enhance structures or under use of gain, which results in eliminating tissue character.

f. *Contact Artifact:*

When insufficient gel is used, the transducer makes only intermittent contact with the skin surface resulting in contact artifact.

7. Discuss the difference between the ultrasound appearance of a simple pericardial effusion and that of an organized pericardial hematoma.

A. The effusion seen in an organized pericardial hematoma will show some degree of echogenicity rather than being perfectly anechoic as in a simple pericardial effusion. This may provide a clue as to the underlying cause, as in the investigation of malignancy.

8. **Discuss the sensitivity of ultrasound for diagnosis of pericardial fluid and the possible confusion with pleural effusion or pericardial fat.**

A. Ultrasound is exquisitely sensitive for the detection of pericardial fluid as the effusion appears as an anechoic space that separates the echogenic pericardium from the heart. Pericardial fat would be found outside the pericardium.
Occasionally, pleural effusions may be confused with pericardial effusions. Using the subcostal view may differentiate them because there is no pleural reflection between the liver and the heart. It is necessary to visualize the hyperechoic image of the pericardium to ensure that the anechoic fluid surrounding the heart is intrapericadial.

9. **What are the sonographic features of pericardial tamponade?**

A. In the evaluation of a pericardial tamponade, one should look for an anechoic space that separates the echogenic pericardium from the heart. It is important to know that small effusions first collect around the dependent portions of the heart and around the ventricles while the larger collections surround the entirety of the heart.
To detect the presence of the fluid, the transducer is placed at the subcostal margin and aimed toward the left shoulder. If the fluid contains some amount of blood or fibrin, the effusion will show some degree of echogenicity rather than being totally anechoic. With large effusions, the heart can be seen with remarkable motion as it floats and swings within the pericardial sac.
The most important finding to be aware of is a circumferential pericardial effusion with a hyper-dynamic heart which demonstrates diastolic collapse of the right ventricle or atrium.

10. **Describe the findings seen on the standard left parasternal view which suggest aortic dissection.**

A. The left parasternal view is obtained by placing the US probe left of the sternum traversing the 2nd to 4th intercostals spaces. The probe is rotated to obtain long and short axis views.
Short axis views are obtained by tilting the probe to visualize the apex through the mitral valve to the aortic valve.
Long axis views are obtained along an imaginary line extending from the right shoulder to the left hip. They permit visualization from the aortic valve through the proximal ascending aorta and left ventricle.
Transthoracic echocardiography has a sensitivity of 77-80% (per Rosen) with a specificity of 93 to 96%. It therefore, has a high false negative rate.
Findings suggesting aortic dissection:
Hemopericardium
Abnormal aortic valve leaflet movement
Visualization of a flap
Increased aortic diameter can be visualized in Type I (ascending aorta, arch, and descending aorta) and Type II dissections (ascending only).

11. Discuss the benefit of rapid bedside sonography for the diagnosis of abdominal aneurysms. State the size of the aorta's external diameter at the level of the diaphragm and the level of the iliac bifurcation. What is the accuracy of ultrasound in diagnosing AAA?

A.

a. Discuss the benefit of rapid bedside sonography for the diagnosis of abdominal aneurysms.

   The major advantages of this modality are speed (approximately one minute in experienced hands), and the fact that a potentially unstable patient does not have to be transported out of the department for other studies, such as cat scan or aortography. The 3.5 MHz transducer is used to visualize the aorta from the xyphoid process to the umbilicus.

b. State the size of the aorta's external diameter at the level of the diaphragm and the level of the iliac bifurcation.

   At the level of the diaphragm, the normal aorta is less than or equal to 3 cm in external diameter. At the level of the bifurcation (iliac arteries), the normal external diameter is 1-1.5 cm. The overwhelming majority of AAAs begin distal to the renal arteries (infrarenal).

c. What is the accuracy of ultrasound in diagnosing AAA?

   According to Rosen, ultrasound is close to 100% sensitive in identifying AAA (both length and width). The limitations are that the test is operator dependent, may be limited by body habitus and overlying bowel gas, and cannot accurately assess whether rupture has occurred.

   The traditional cross-table lateral abdominal X-ray, in comparison, demonstrates a very low sensitivity for identifying AAA. It relies on calcification in the walls of the aorta which is not always present. CT is both very sensitive and very specific as it better identifies false lumens, rupture, and dissection than ultrasound. As previously mentioned, however, this test takes more time and requires transport of the patient who very well may be unstable.

12. What are the specific sonographic findings that lead to the diagnosis of AAA and how can we distinguish (sonographically) between a stable and unstable aneurysm?

A. Loss of the normal proximal-to-distal taper (earliest sign) or a diameter greater than 3 cm indicates the presence of an AAA. Large aneurysms, more than 6 cm and definitely more than 7cm, are at much greater risk for early rupture than smaller lesions. Bedside sonography is used in large part to identify the risk of rupture based on aneurysm size. A recent study found that 25% of abdominal aortic aneurysms measuring more than 5cm ruptured in the subsequent 5 years, whereas no rupture occurred in the 130 aneurysms measuring less that 5 cm.

13. Name some of the common errors in scanning for AAA.

A.
a. Failure to adequately compress overlying bowel with probe pressure
b. Confusion of the vena cava with the aorta due to transmitted pulsations
c. Overestimating the aneurysmal width due to lack of a true cross section
d. Misinterpreting acoustic enhancement distal to the aorta as evidence of leakage
e. Failure to move the transducer off the sagittal plane while following a tortuous aorta
f. Neglecting to note the take-off of the renal arteries
g. Not measuring external diameter (outer wall to outer wall)
h. Reluctance to move the transducer far enough laterally in an attempt to visualize an aorta that is obscured by overlying bowel gas
i. Neglecting to visualize the bifurcation of the iliacs
j. Confusing artifact for thrombus

14. Compare ultrasound for detecting hemoperitoneum to DPL with respect to sensitivity, ease and time required for performing the procedure.

A. The sensitivity and specificity of ultrasound have routinely been between 90 and 100%, with most recent reports emphasizing near-perfect specificity and somewhat lower sensitivity. The interpretation of a positive or negative ultrasound for hemoperitoneum is the same as for a positive or negative DPL, with all that implies in terms of admission, transfer, and surgery. Most observers agree that both the time required obtaining interpretable results and the incidence of procedure-related complications for DPL are significant when compared to ultrasound.
From ATLS, the following table appears.

	DPL	**Ultrasound**	**CT Scan**
Indication	Document fluid if decreased BP	Document fluid if decreased BP	Document organ injury if BP normal
Advantages	Early diagnosis and sensitive; 98% accurate	Early diagnosis, noninvasive and repeatable; 86-97% accurate	Most specific for injury; 92-98% accurate
Disadvantages	Invasive, misses injury to diaphragm or retro peritoneum	Operator dependent, bowel gas and subcutaneous air distortion; misses diaphragm, bowel and some pancreatic injuries	Cost and time; misses diaphragm, bowel tract, and some pancreatic injuries

15. What are the regions routinely examined for hemoperitoneum?

A.
a. Morison's pouch
b. Left upper quadrant in the paracolic gutter or between the spleen and left kidney.
c. Over the pelvis in the region of the cul-de-sac.

16. **Discuss the threshold for reliably diagnosing hemoperitoneum and state the qualitative fluid characteristics of blood over time. Discuss the significance of absent liver mirror image artifact above the diaphragm.**

A. The threshold for reliably diagnosing hemoperitoneum is 250 mL of fluid, although 100-200 mL can ordinarily be detected (and as little as 10 mL may be picked transandominally, 5mL transvaginally in the cul-de-sac). However, given the time, space and equipment constraints of trauma resuscitation and the variable viscosity of partially defibrinated blood one may encounter, ultrasound cannot be considered positive for hemoperitoneum unless 250 mL of fluid is present (high specificity). A very thin anechoic stripe under the liver represents 250mL of blood. The same stripe 0.5 cm in width represents 500 mL of blood. Larger amounts of blood (greater than 1L) can be seen almost anywhere in the abdomen and may even change the appearance of organs by outlining them in fluid.
Fresh blood appears anechoic and may form sharp angles when free in the peritoneum. Intravascular blood does not form such angles. Blood also tends to layer along an organ's surface. Over time, blood starts to clot and loose its anechoic appearance. It becomes more echoic, taking on variable echoes as fibrin and degenerating cells make up a greater portion of its substance. Both changes in the quantity and quality of fluid can be appreciated with serial ultrasound exams.
Absence of liver mirror image artifact above the diaphragm is a sign of pleural effusion. This fluid may be blood or from any other cause. Essentially, fluid is present and has displaced normal lung parenchyma.

17. **List the common errors in scanning for hemoperitoneum including artifacts.**

A.
a. Failure to scan the paracolic regions as well as Morison's pouch.

   Morison's pouch is usually the first region to be visualized-quantities of fluid>250 cc ought to be detectable.

   The right and left paracolic gutters and the space between the spleen and left kidney are scanned next.

b. Failure to scan the pelvis.

   The pelvis is usually left to last unless the bladder is about to be emptied. Transabdominal approach is usual in a man, whereas a transvaginal approach looking for fluid in Douglas's pouch is usual in a woman. The transvaginal approach may identify quantities of blood as small as 5-10 cc. (The rectal approach may be considered in a man.

c. Failure to scan from both the anterior intercostal approach as well as the posterolateral.
d. Failure to note echogenicity within the stripe.

   Blood is initially anechoic (ie, it looks black). However, as it begins to clot, it begins to develop echogenic areas within the anechoic stripe.

e. Failure to consider the possibility of urine, intestinal contents and prior ascites and instead assuming the presence of blood.

   The difficulty of differentiating between blood and other fluids is clear (one advantage DPL has over US). Such false positive results will occasionally lead to unnecessary laparotomy though bladder or bowel rupture may nevertheless require surgical repair.

f. Failure to perform serial scans.

When the initial scan is negative but the index of suspicion is high, one must perform serial scans.

g. Failure to appreciate the relative insensitivity of US for solid organ injury.

CT is far superior in the identification of solid organ injury. Nonetheless, the perceptive clinician may pick up a ruptured spleen, a fractured kidney or a large liver laceration with access to an US machine.

h. Confusion of hypoechoic perinephric fat with fluid in Morison's pouch.

By placing the patient in a little reverse Trendenlenburg, one may be able to make a distinction between fluid and perinephric fat. If the hypoechoic area is really perinephric fat, the echogenicity will not change with a change in position.

18. State the various sonographic characteristics of the gallbladder that make it favorable for ultrasound evaluation.

A.
a. The gallbladder is a cystic structure filled with echo-free substance (bile), which is perfectly outlined by the surrounding GB wall.
b. Gallstones themselves (the most common sign of GB disease), are highly refractile to US waves-visualization of a stone less than 1mm is routine.

19. Discuss the significance of the sonographic Murphy's sign, sludge, acoustic shadows and gallbladder size and wall thickness in evaluating a patient for gallbladder disease.

A.
a. In cases of suspected acute cholecystitis, a positive sonographic Murphy's sign has a sensitivity and specificity of approximately 90%.
b. A thickened gallbladder (>3mm) can be suggestive of acute cholecystitis. However, it is also seen in CHF, RF, as well as the post-prandial state.
c. The presence of acoustic shadows is highly suggestive of the presence of gallstones and implies that perhaps one should look in multiple planes until the stones are visualized.
d. Sludge represents echogenic bile related to stasis and is seen in approximately 50% of patients with acute cholecystitis. It is also seen in fasting conditions and nursing home patients with poor oral intake. When seen in ambulatory patients, its presence is highly suggestive and perhaps diagnostic of gallbladder disease.
e. In general, focal tenderness with other signs such as sludge, gallstones, pericholecystic fluid, or abnormal wall size makes the diagnosis of acute cholecysitis with >90% certainty.

20. **Name the common errors in gallbladder scanning.**

A.
  a. Failure to position the patient properly- Supine with patient in left posterior oblique position works well, as does standing the patient upright.
  b. Failure to use the intercostal approach which avoids bowel gas.
  c. Mistaking hyperechoic spiral valves for stones.
  d. Impacted stones at the gallbladder neck may be missed. Contracted, scarred down gallbladders may reduce visualization of the chronic calculi or the entire gallbladder itself due to reduced bile and overall hyperechogenicity.
  e. Postprandial patients and those with edematous states often have thickened gallbladder walls which can be misdiagnosed as intrinsically pathologic (ie cholecystitis).
  f. Missing small stones which don't cause shadows.
  g. Missing the entire lumen because it is folded over.
  h. Mistaking artifact at the gallbladder edges for the acoustic shadow of stones.

21. **State the conditions in which ultrasound may be preferable to IVP in the evaluation of renal colic. State the specific focus of the ultrasound exam for renal colic.**

A. Pregnancy
Contrast allergy
Diabetes Mellitus
Proteinuria
Renal Failure
Dehydration
Poor venous access
Differential dx includes gallbladder, appendicitis, PID
Time constraints
State the specific focus of the ultrasound exam for renal colic: Confirmation or refutation of significant obstructive uropathy based on the presence or absence of proximal dilatation of the collecting system.

22. **Why is the right kidney generally easier to visualize than the left? Describe some techniques that help us visualize the left kidney more easily?**

A. Anatomic differences make the right kidney more accessible to ultrasound than the left. The visualization of the right kidney is facilitated by the overlying liver which acts as an acoustic window. Conversely, visualization of the left kidney is hampered by the overlying air-filled stomach which prevents optimal scanning anteriorly. Dilated loops of bowel can also hamper visualization especially on the left and must be circumvented by a more posterior window. Most commonly scanning is done intercostally from the lateral approach using the liver as a window on the right and the spleen as a window on the left.

23. **Name some common errors in scanning the kidney.**

A.
  a. Failure to scan contralateral kidney for evidence of obstruction when hydronephrosis is noted on symptomatic side.
  b. Mistaking prominent renal pyramids for hydronephrosis.
  c. Mistaking prominent renal pyramids for multiple small cysts.
  d. Interpreting an extensive extrarenal pelvis as a sign of obstruction.
  e. Failure to look for perinephric extravasation.
  f. Confusing normal renal arteries for the not normally visible ureter.
  g. Overdiagnosing hydronephrosis in presence of a full bladder.

h. Failure to appreciate the renal origin of a large cystic structure due to the distortion of normal anatomy.
i. Failure to scan through the urinary bladder for a stone at the uretero-vesicle junction.
j. Inability to visualize left kidney completely because the transducer position is anterior to the left posterior axillary line.

24. Discuss the relative merits of transabdominal vs. transvaginal ultrasound in evaluating the pregnant uterus.

A. Both transvaginal (TV) and transabdominal (TA) US have advantages in the evaluation of the pregnant uterus in the ED. The transvaginal approach is more sensitive in detecting small amounts of cul-de-sac fluid, in defining early intrauterine pregnancies (because of the close proximity of the probe to the embryo), and in revealing some early adnexal masses. An added advantage is that transvaginal ultrasonography does not require a full bladder as does the transabdominal approach. However, the field of view with TVUS is smaller, and orientation more difficult, making this approach more cumbersome for the inexperienced examiner. Transabdominal ultrasound provides a better overview of pelvic structures, and also reveals structures beyond the shallow field of TVUS. Although the resolution is lower with the TAUS, making it harder to see the smaller structures including early IUP, orientation and general structures can more easily be identified. This method, while requiring a full bladder to be effective, is obviously more familiar and comfortable for patients over the transvaginal approach.

25. Discuss the expected sonographic findings (both transabdominal and transvaginal) of a normal IUP.

A. The first finding of a normal IUP is the *gestational sac*, otherwise known as the chorionic sac. It is a small sonolucent area surrounded by a bright echogenic ring within the uterus. There are no visible structures within the sac. This can be seen at approximately 5 weeks (Beta HCG-1800) by transabdominal and transvaginal techniques, although with possibly more detail via the transvaginal approach. When the sac grows to 5-8mm you may, depending on the operator and the equipment, see the first embryonic structure-the *yolk sac* (literally looks like a balloon within a balloon).
From the 6th week on, the gestational sac is growing by 1 mm/day and at this time, it may be possible, before a measurable embryo is seen, to visualize cardiac activity between the yolk sac and gestational sac. This cardiac activity is noted at what is now called the *fetal pole*. The embryo, being considerably smaller than the yolk sac, is located in that complex of tissue between the yolk sac and gestational sac. At 6 weeks, the yolk sac can be seen by transabdominal US when the gestational sac is >20mm but transvaginally you may see a yolk sac and a 5mm embryo at 6 weeks.
The embryo grows about 1 mm/day measured as crown-rump length and by the 7th week is 5-10mm. At 8 weeks, cardiac motion and an embryo should clearly be seen on US by both transvaginal and transabdominal techniques. At 14 weeks the amnion that surrounds the embryo fuses with the gestational sac (aka chorionic sac) obliterating the space which had filled the sac previously.

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Based on "Ultrasound in Emergency Medicine" by M. Heller & D. Jehle, W.B. Saunders, Co., 1995.