Ultrasonography is a key part of emergency care because of its convenience and the importance of the information it provides.
Use of Ultrasonography in Veterinary Emergency Rooms

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Use of ultrasonography in veterinary emergency and critical care situations continues to grow. Over the past 15 years, FAST scans have become integral diagnostic tools in veterinary emergency rooms. FAST scans enable emergency room clinicians to obtain vital information via ultrasound quickly, without the help of a radiologist.\(^1\) FAST stands for Focused Assessment with Sonography for Trauma and can be categorized as abdominal (AFAST) or thoracic (TFAST). A newer acronym, TFAST3 (for trauma, triage, and tracking), applies to extended use of the TFAST examination beyond trauma patients to include any patient who is at risk for pleural effusion, hemothorax, or pyothorax.\(^1\)

AFAST and TFAST can be performed by persons with minimal ultrasonographic experience. With proper training, veterinary nurses can perform the scanning without a veterinarian present, but only a veterinarian can make a diagnosis based on the images. No specific licenses or education beyond the veterinary license are required for veterinarians to perform FAST. Recommended training, however, includes hands-on training by a board-certified radiologist, reviewing FAST images, and performing a series of on-the-job scans witnessed by a more experienced practitioner. Short courses with wet labs are also available. Ideally, all of the training tools listed above will be utilized. A properly trained veterinary nurse who was present for the initial examination can keep the clinician updated as to the progression of free fluid and alert the doctor to any significant changes, but the final decision as to
the patient’s status and actions to be taken are, of course, up to the veterinarian.

Although FAST scans are especially useful, they are no substitute for a full examination by a board-certified radiologist. FAST scanning is often compromised by the situation of a busy emergency room: the lighting is usually too bright for optimal imaging, patients are often scared and painful, it may not be possible to place them in the proper position, and their abdomen may be tense. These factors combined with the skill level of the sonographer may affect accuracy of the assessment.

FAST scans are noninvasive, quick (median AFAST scan time is 6 minutes\textsuperscript{2}), and repeatable. They can be performed at the time of presentation, often while the initial physical examination is being performed, IV catheters are being placed, and other diagnostic or stabilizing procedures are being initiated.

AFAST and TFAST should be used to answer the following question: is there free fluid, pericardial effusion, or free air in the abdomen and/or thorax? Any question as to tissue integrity or pathology of organ/endocrine systems should be answered by a board-certified radiologist performing a full examination.

An AFAST examination is performed to look for free fluid, indicative of injury, within the peritoneal and retroperitoneal spaces. The significance of the AFAST study cannot be overstated. The leading cause of death in human trauma patients is undiagnosed intra-abdominal injuries, which are not always easily found at the time of initial presentation.\textsuperscript{2,3} Use of AFAST can help expedite surgery for those who need it and decrease the number of exploratory laparotomies that reveal no abnormalities.

Serial AFAST scans, when possible, are beneficial because subsequent scans may show fluid accumulation not detected on the initial scan.\textsuperscript{1} Serial AFAST scans in conjunction with abdominal fluid scoring (AFS) can indicate changes in the quantity of abdominal fluid. AFS also has been shown to correlate well with the level of injury,\textsuperscript{1} thereby helping guide the clinician’s decisions as to what further diagnostics or stabilization are needed. A complete AFAST examines 4 sites (BOX 1). The AFS score reflects the number of sites with free fluid. For example, AFS 1 indicates 1 site with free fluid; AFS 4 indicates 4 sites with free fluid.

A TFAST examination is performed to look for fluid in the pericardium and fluid or free air in the pleural space.\textsuperscript{1}

Performing a FAST scan requires an understanding of the basics of ultrasonography: the image, acoustic impedance, image appearance, and artifacts. Tips for creating a good image are shown in BOX 2.

The ultrasound images shown in this article are in 2-dimensional grayscale. They are produced with the machine in B-mode (brightness). Most ultrasonography machines also have M-mode (motion), which is used in echocardiography.
The B-mode image is made up of thousands of pixels which are lined up across the screen and correlate with the head of the transducer. The ultrasonography transducer is placed against the patient’s body after coupling gel has been applied. The transducer emits ultrasonic sound waves, which travel through the body until they cease to exist due to attenuation (absorption, reflection, or scattering of waves).

Reflected waves returning to the transducer are called echoes. When they are received by the transducer, their amplitude and the time they took to enter the body and return are assessed. According to this information, a shade of gray is assigned to the correlating pixel and creates the image.

**Acoustic Impedance**

Acoustic impedance is the tendency of a tissue to absorb or reflect sound waves. It is determined by the density of the tissue and the velocity of sound waves traveling within the tissue.

The amplitude of the returning echo is determined by the difference in the acoustic impedance of 2 tissues where they touch (tissue interface). There is not much variation in the acoustic impedance of different soft tissue structures. Soft tissue next to soft tissue results in shades of gray, which produces echoes with moderate amplitudes. The acoustic impedance of bone, however, is much higher than that of soft tissue and the impedance of gas much lower. Therefore, when soft tissue is interfaced with bone or gas, we get an echo with a high amplitude, resulting in a very bright pixel.

**Image Appearance**

There is no single normal shade of gray for each body tissue; therefore, the terms used to describe the ultrasonography image are comparative. Sonographers become familiar with this range of gray shades but must compare an organ with the other organs in the same patient before it is declared normal or abnormal. Using the liver and spleen as examples, liver is typically a darker shade of gray than the spleen. Echogenicity refers to the brightness of the area/organ imaged. A normal liver is less echogenic than a normal spleen, or is hypoechoic to the spleen. The spleen would be hyperechoic to the liver (**FIGURE 1**). Typical tissue appearances are as follows.

- **Soft tissue**: varying shades of gray
- **Fluid**: hypoechoic or anechoic (black)

**Artifacts**

As with most imaging modalities, artifacts appear on ultrasonography images. Artifacts are alterations in the image that do not represent the actual image. Some artifacts are helpful and aid in the diagnosis. Others are not helpful; they can interfere with the image, making it difficult to see the desired area.

- **Fat**: hyperechoic to other soft tissue
- **Bone and gas**: very bright or echogenic and cause an acoustic shadow

**BOX 2**

**Tips for Creating a Good Image**

- Contact between the transducer and the skin is imperative. Air blocks sound waves and so cannot be allowed between the skin and probe. If the patient has short or thin hair, applying alcohol to the area may be enough to provide good contact. Long- or thick-coated patients may need to be shaved. Ultrasonography gel helps provide good coupling of skin and transducer.
- Make sure that the area of interest is in the center of the focal zone.
- Using the depth knob, go only as deep as necessary to image the area of interest.
- To find the optimal level, increase and decrease the gain often as you scan.
- Make sure you have chosen the most appropriate transducer for the size of the patient.
To properly interpret an image, the sonographer must be familiar with artifacts, which can confuse a less experienced sonographer and lead to a misdiagnosis. The types of artifact discussed here are distal (or acoustic) enhancement, distal (or acoustic) shadowing, mirror imaging, and refraction. These artifacts should be recognized early, while learning to perform FAST scans. Other artifacts that a sonographer should be aware of can be found in most texts on veterinary ultrasonography.¹

**Distal enhancement** (FIGURE 2) refers to increased echogenicity of tissue distal to a fluid-filled structure. A wave travels through fluid with little attenuation. As the wave continues into the soft tissue distal to the fluid-filled structure, echo amplitude will increase in comparison with the surrounding soft tissue. This artifact is useful because it can help confirm whether an anechoic structure is a fluid-filled cyst or a hypoechoic mass. A fluid-filled cyst will have an area of increased echogenicity deep to it; a hypoechoic mass will not.

**Distal shadowing** is absence of a signal behind structures that strongly absorb or reflect ultrasonic waves. When a sound wave meets bone or gas, most of it is reflected or absorbed. Therefore, there is not much left entering the tissue distal to the bone or gas. This area of low-amplitude echoes gives the appearance of a dark shadow deep to the bright structure. When gas is imaged, most of the wave is reflected, resulting in an inhomogeneous or “dirty” shadow. When bone is imaged, it absorbs most of the wave, resulting in a uniformly hypoechoic or “clean” shadow.

**Mirror imaging** occurs when the sound beam encounters a large, highly reflective interface, such as the diaphragm. An example of a mirror image is a false appearance of the gallbladder on the thoracic side of the liver (FIGURE 4).

**Refraction artifact** occurs when ultrasound encounters a boundary between two medium with different acoustic properties. This results in a shift in the direction of the wave, giving the appearance of a fluid-filled structure deep to a soft tissue structure. An example of this is the refraction artifact seen with the urinary bladder (FIGURE 3).

**Focal refraction artifact** occurs when ultrasound encounters a boundary between two medium with different acoustic properties. This results in a shift in the direction of the wave, giving the appearance of a fluid-filled structure deep to a soft tissue structure. An example of this is the refraction artifact seen with the urinary bladder (FIGURE 3).

**FIGURE 2.** Distal enhancement deep to fluid-filled gall bladder.

**FIGURE 3.** Refraction artifact, urinary bladder with effusion and loops of bowel.

**FIGURE 4.** Longitudinal or long-axis view of liver.

**FIGURE 5.** Transverse or short-axis view of liver.
the diaphragm, which could be misinterpreted as a diaphragmatic hernia. This artifact can be eliminated by decreasing the depth of ultrasound penetration.

**Refraction** is a change in direction (deflection) of the ultrasound beam. Typically, when the beam hits a tissue interface at a perpendicular angle as desired, some of the beam is reflected back to the transducer to create the image of that area, some of the beam is absorbed, some is scattered, and the rest continues on to create the image of deeper structures. However, when the ultrasound beam hits a tissue interface at an oblique angle and is deflected, the image is improperly displayed. An example of a refraction artifact is a urinary bladder within peritoneal effusion falsely appearing to be missing part of its wall (**FIGURE 3**).

**PERFORMING THE AFAST EXAMINATION**

Before starting the study, you must be familiar with the orientation of the ultrasonography machine and transducer. Each transducer has a marker (a notch, nub, or groove) on one side. This marker correlates with a mark on the ultrasonography screen (a dot or brand icon), which will be in the upper left- or right-hand corner of the screen. The marked side of the screen should be assigned to either the cranial or caudal end of the patient. Typically, the nose points to the left side of the screen and the tail to the right. When placing the probe on the patient, you will know if you are viewing the cranial or caudal aspect of the organ you are viewing. Placing the probe with its marker toward the patient’s head will give you a longitudinal or long axis view. Turning the probe 90 degrees will give you a transverse or short axis view, providing a cross-section of the organ you are imaging (**FIGURES 4–7**).
Selecting the Transducer

**Frequency**
Transducers (probes) operate at different frequencies, some at multiple frequencies. You need to choose the correct transducer or probe for your study. The higher the frequency, the better the resolution; but depth is sacrificed. The lower the frequency, the deeper the penetration into the patient; but resolution is sacrificed. You should choose the highest frequency that will get to the depth you need. Deeper areas on larger patients will usually require a 5-MHz probe, less deep areas and smaller patients can be imaged well at 7.5 to 12 MHz.

**Style**
Transducers also come in different styles. The most common are convex or sector, linear, and phased array.

- **Convex array probes or sector scanners** are commonly used. They give a wedged-shaped image with a curvilinear near field. They fit the body well and have good image quality.

- **Linear array probes** give a rectangular image. They typically give the best image quality in the near field but are awkward for all but the most superficial structures because they do not fit the body comfortably. They cause discomfort when pushed into the abdomen.

- **Phased array probes** give a triangular image. They have a very small footprint (the area of skin that must be contacted). They are good for placing between ribs to get a broad look deep to the ribs. They are not good for imaging the near field.

Creating the Image
The AFAST examination evaluates 4 sites (BOX 1). The patient can be in either right or left lateral recumbency, although it is sometimes easier to find the right kidney in left lateral recumbency. Each site should be imaged in both the long- and short-axis views. In each view, the probe should be fanned through an angle of 45 degrees. The probe should also be slid an inch cranially, caudally, and to the right and left of each starting point, fanning and changing from long and short axis at each placement. Be sure to image each organ from end to end and to thoroughly evaluate the area. FIGURES 8–13 show some AFAST images demonstrating pathology.

For those with little to no ultrasonography experience, a significant amount of practice is necessary. It is best to find a friendly, relaxed, healthy dog or cat on which to practice. A good place to start is the urinary bladder. Place the probe ventrally on the caudal abdomen. Point the marker on the probe cranially. Place the probe where you think the urinary bladder should be. Unless the animal has recently urinated, it should be easy to image. After you have located the bladder, practice bringing it into the center of the screen. Ideally, the organ of interest should take up to two-thirds of the screen. Adjust the depth knob accordingly. Move the probe slowly; quick movements change the image dramatically and create confusion. To change location, you can slide the probe over the patient’s body. It can also be kept in place and tilted or fanned to alter the angle of the view. Rotate the probe to experiment with the longitudinal versus transverse image. Notice how a small (not full) urinary bladder can be compressed by the probe and made more difficult to image. The amount of pressure applied to the probe is equally as important as the placement/position of the probe.

**FIGURE 10.** Spleno–renal view; long-axis or sagittal view of left kidney with effusion.

**FIGURE 11.** Spleno–renal view; spleen with effusion.
Some organs require more pressure to image than others. For instance, the left kidney imaged from the left side does not require much pressure. It takes much more pressure to image the right kidney from the right side when the patient is in right lateral recumbency. Imaging the whole liver, or the pylorus of the stomach of some deep-chested dogs, requires a significant amount of pressure ventrally, just behind the xiphoid process. Sometimes a patient with a painful abdomen may require analgesia/sedation.

Next, practice imaging the left kidney. Place the dog or cat in right lateral recumbency. Place the probe on the left lateral abdomen just caudal to the 13th rib with the probe marker pointed toward the patient’s head. Aim dorsally toward the spine. Fan up and down and from side to side. The left kidney is often quite easy to find. Other times you may need to slide the probe across the patient, altering the amount of pressure as you go to find it. After you have located the kidney, image it longitudinally to reveal a sagittal section, then transversely to reveal a cross-section.

It is also a good idea to experiment with the knobs on the machine. The parameters you will use the most often are gain, depth, focal zones, and time gain compensation (TGC). Note how manipulating these parameters affects the image. Different machines may have different names for their knobs. The names in this article are the ones most often used; if they differ, please consult the user manual for your machine.

- **Gain** increases or decreases the overall brightness of the image by amplifying the returning echoes.
- **Depth** controls the depth of the image shown on the screen. Decreasing the depth enlarges the image in the near field. The screen has centimeter markings on the right side, which become farther apart as you decrease depth (e.g., 4-cm deep will be magnified to fit the whole screen; at 15-cm deep of the same image, the area of interest will appear smaller, in the near field with a lot of wasted space deep to it). When counted, the centimeter markings will always represent the true depth and size of what is imaged despite the level of magnification on the screen.
- **Focal zone**, the area on the screen of the highest resolution, should be centered on the area of interest.
- **TGC** increases or decreases the brightness of the screen in strips, allowing for adjustment for near, mid, and far fields. This adjustment is necessary to compensate for attenuation of the beam in the far fields causing a darker image.

**PERFORMING THE TFAST EXAMINATION**

The objective of the TFAST examination is to identify air and fluid within the pleural spaces and to look for pericardial effusion. Use of TFAST increases detection of complications and emergent situations early on, improving patient outcomes.

When looking for free air or fluid in the pleural spaces, the patient can be in lateral or sternal recumbency. Either way, both sides should be imaged. The probe should be placed dorsolaterally between the seventh and ninth intercostal spaces, with the probe marker aimed toward the head.

Imaging a healthy thorax reveals a glide sign when the interface of the lungs and parietal surface is visualized and the patient’s respiratory pattern can be seen in a real-time gliding motion. Presence of air in the pleural space interrupts this motion; lack of a glide sign is indicative of pneumothorax.
PLEURAL EFFUSION

Pleural effusion is seen as anechoic areas between lung lobes or around the heart (FIGURE 14).

To look for pericardial effusion, go to the subxiphoid area, visualizing the liver, diaphragm, and thorax. Pericardial effusion appears as an anechoic area surrounding the apex of the heart, within the thin echogenic wall of the pericardium. A scant pericardial effusion may be missed. Differentiating between a pericardial and pleural effusion can be difficult with the subxiphoid view and easier with intercostal views.

OTHER TYPES OF EMERGENCY ULTRASONOGRAPHY

Two other examination techniques being used with positive results are FoCUS (focused cardiac ultrasound) and the Veterinary Bedside Lung Ultrasound Examination (Vet BLUE) Lung Scan. Another useful examination technique is evaluating the patient’s vascular volume status by comparing the sizes of the left atrium and the aortic root (LA/AO ratio). These examinations can be performed by nonradiologist veterinarians but require more extensive training than the FAST scans.

All of these modalities have become a necessary part of patient assessment because of the ease with which they are performed, the ability to do them without having to transport the patient to a different part of the hospital, and the value of the information they provide. Becoming proficient in performing these ultrasonography examinations is well worth the effort.

References