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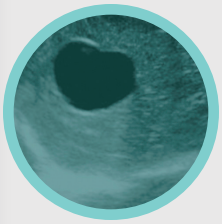

Small Animal Abdominal Ultrasonography

PART 2: PHYSICAL PRINCIPLES OF ARTIFACTS & FALSE ASSUMPTIONS

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Welcome to our new series of articles on small animal abdominal ultrasonography. The first few articles in the series are providing an overview on the basic principles of:

- Image acquisition, artifact creation, and interpretation
- Optimizing the ultrasound image for interpretation (how to *drive* the ultrasound machine).

Further articles in this series will review basic approaches to ultrasound of the abdomen as well as scanning principles for each organ/system in the abdomen. These articles will also review the normal sonographic appearance of the abdomen, including its organs and systems, and identification of common abnormalities seen during ultrasound examination.

Abdominal ultrasonography is a noninvasive technique that provides cross sectional anatomy of the organs of the abdomen based on differences in acoustic impedance.

A basic understanding of an ultrasound (US) image includes:[1,2]

- Image formation
- Artifacts present in the image
- Assumptions in image formation made by the US machine.

To ensure proper interpretation and, consequently, follow-up, each of these areas needs to be understood prior to interpreting an ultrasound study. To better understand US image formation, read **Part 1: Basics of Ultrasound Transducers & Image Formation** (January/February 2015 issue), available at **tvpjournal.com**.

This article will review common artifacts encountered during abdominal ultrasonography, which occur in most studies, and also discuss "false" assumptions made by US machines.

ULTRASOUND ARTIFACTS

Ultrasound artifacts can be divided into **useful** and **nonuseful** artifacts (**Table**).

- *Useful artifacts* provide information regarding the physical properties of the tissue being imaged.
- *Nonuseful artifacts* complicate image interpretation and do not generally result in clinically relevant information.

Useful Artifacts

The 2 most common useful artifacts include:

- Through transmission
- Distal acoustic shadowing (soft tissue–gas or soft tissue–mineral interactions).

Through transmission—also known as *distal acoustic enhancement*—occurs when US waves traverse a cystic structure filled with fluid, such as

TABLE
Useful & Nonuseful Artifacts

USEFUL ARTIFACTS	NONUSEFUL ARTIFACTS
• Through transmission (distal acoustic enhancement) • Distal acoustic shadowing » Soft tissue–gas interactions (reverberation artifact); also called *dirty shadowing* » Soft tissue–mineral (bone) interactions; also called *clean shadowing*	• Side or grating (secondary) lobe artifact • Refraction artifact • Transmission speed errors or speed propagation errors • Mirror image artifact • Contact artifact

Every sonographer should have a background in the physical principles of ultrasound image formation and how these principles can result in errors of interpretation of the ultrasound image. An excellent overview is provided by Dr. Fredrick Kremkau in *Sonography Principles and Instruments*, 8th ed.[1]

the urinary bladder or gallbladder, rather than a soft tissue dense organ, such as the liver. Attenuation occurs as sound waves travel through soft tissue. When US waves travel through the gallbladder, there is less attenuation, and more US waves are available to interact with the tissue deep to the cystic structure. Therefore, when imaging the liver, there will be a focal area of increased echogenicity deep to the gallbladder (**Figure 1**). The sonographer should be aware of this artifact and *not* mistake an area of increased echogenicity as abnormal tissue.

As the US beam travels through tissue layers, the signal becomes attenuated (loses acoustic energy, resulting in a decreased number of US waves) as the depth of penetration increases.

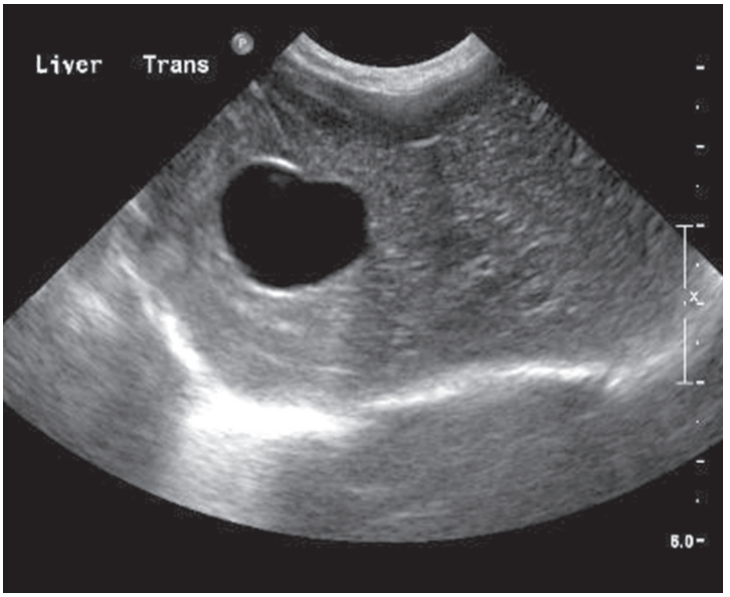

FIGURE 1. A transverse (short axis) image of the right cranial abdomen, including the liver and gallbladder (anechoic structure in left of image). Increased brightness of the hepatic parenchyma deep to the gallbladder is present when compared to the same level of the liver where US waves did not penetrate the gallbladder.

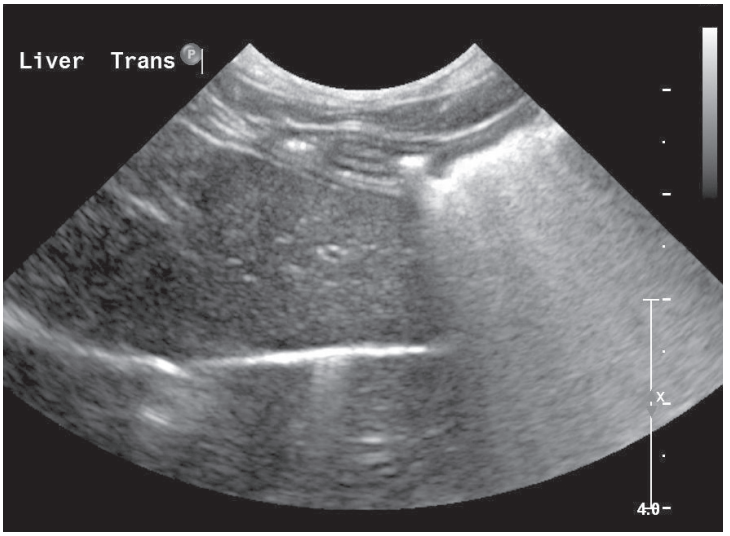

FIGURE 2. Transverse image of a small intestinal segment in which gas bubbles are noted within the lumen. The gas bubbles on the right of the luminal content create a reverberation artifact due to the US waves *bouncing* back and forth in the bubble, with the release of US waves at different times resulting in an echogenic line deep to the original gas–soft tissue US interaction.

Through transmission artifacts can also be used to help interpret US images by distinguishing between solid anechoic nodules and cystic structures. For example, anechoic lesions caused by lymphoma do not demonstrate through transmission (ie, there is no area of increased echogenicity distal to the tissue) because these mass lesions, although they are anechoic, are not fluid filled.

Distal acoustic shadowing can take one of 2 forms:

- *Dirty shadowing* is characterized by reverberation artifacts due to gas trapped in air bubbles, resulting in multiple reflections and a straight echogenic line that originates at the gas–soft tissue interface and extends deep into the tissue (**Figure 2**); also called a *comet tail artifact*.
- *Clean shadowing* is characterized by a mineral–soft tissue interface in which all US waves are reflected at the interface, which results in a bright echogenic line or curve (based on physical shape of the mineral, stone, or bone) and no US interactions (black) deep to the echogenic line (**Figure 3**).

Nonuseful Artifacts

Common nonuseful artifacts are listed in the **Table** (page 83), and are outlined in the following descriptions.

Side lobe or **grating lobe artifacts** are caused by

secondary US beams known as *lobes* that are created—by mechanical compression of the piezoelectric crystals at the transducer surface—in addition to the main US beam. Secondary lobes, however, come out at different angles (typically 45°) from the transducer surface rather than 90°, which is typical for the primary US beam. They have the same acoustic properties and frequency (MHz) as the primary US beam.

When side lobes are generated, they leave the transducer, interact with tissues, and then return and (erroneously) register tissue as if it is within the primary US beam (**Figure 4**). The most common place this effect is seen is inside the urinary bladder. In this case, focal echoes appear inside the urinary bladder that can be mistaken for pathology, such as debris or other echogenic material. In order to remove the side lobe artifact, reposition the probe so that the side lobe no longer interacts with a reflector of US waves. You can also bounce the probe on the patient and see if the echoes swirl as in the case of echogenic material in the urinary bladder. Side lobes will not create this swirling pattern.

It is important to note that side lobe artifacts are, in fact, part of every image. Unlike the urinary bladder, however, clinically relevant artifacts are not produced in other tissues because the echoes generated by the side lobes are relatively weak compared to the information returned by the primary beam.

Refraction occurs as the US beam impacts on a curved surface, resulting in US waves that are not reflected directly back to the transducer, instead

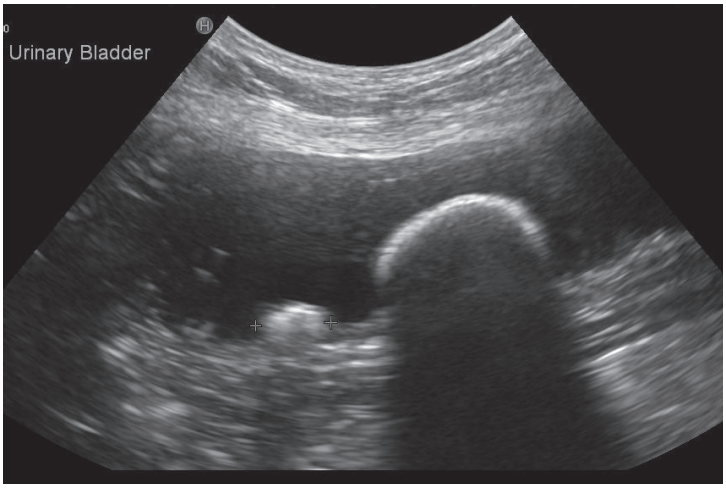

FIGURE 3. Sagittal (long axis in a dog) image of the urinary bladder containing multiple calculi. The mineral–fluid interaction results in a strong reflective boundary due to the large differences in acoustic impedance, which then results in a bright echogenic line and blackness deep to this initial interaction.

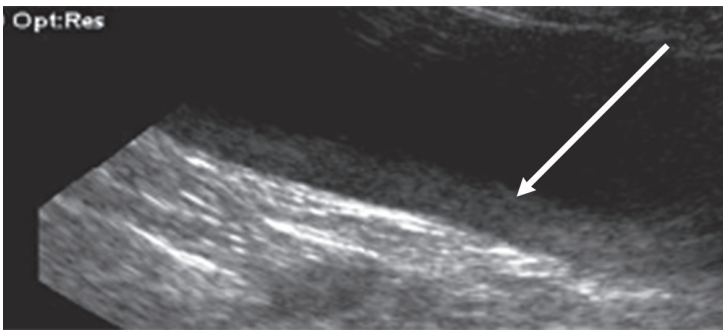

FIGURE 4. Long axis (sagittal plane image) of the urinary bladder, with a bar of echogenic returning US waves (**white arrow**) along the deep portion of the urinary bladder. These waves are from side, grating, or secondary lobes of the US beam and most likely represent interactions and reflection from the colon.

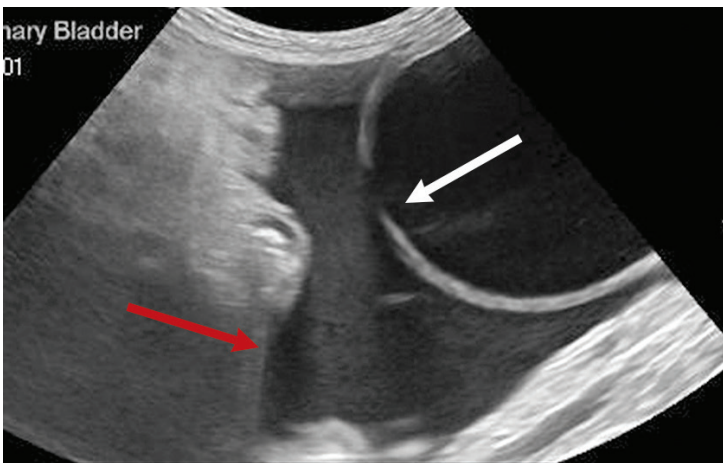

FIGURE 5. Refraction artifact from a small intestinal segment along the curve of its margin (**red arrow**). There is also a "hole" in the cranial border (**white arrow**) of the urinary bladder created by a refraction artifact. Abdominal effusion is present.

bending away from the curved surface. These US waves are not interpreted as a returning echo by the machine, which results in a zone that lacks US waves deep to the curve and, therefore, no information is provided about that area (**Figure 5**, page 85). Creation of a *hole* in the cranial border of the urinary bladder is a unique refraction artifact seen in the urinary bladder of a cat or dog with an abdominal effusion.

Speed propagation errors are calculation errors for placement of images (**Figure 6**) that occur because the average speed of sound (1540 m/sec) is used by the machine to calculate the depth from which the reflected US wave originated. US waves travel more slowly through fat (1480 m/sec) compared with the transmission speed through soft tissue structures (1540 m/sec).

If US waves are traveling the same distance toward a deeper object through fat or through soft tissue, this object is registered by the machine at 2 different distances. The object is registered disproportionately deeper if it is below fat. Theoretically, this artifact can be clinically relevant in obese animals because it can complicate performing fine-needle aspirates or biopsies in deep segments of the abdomen.

FIGURE 6. Speed propagation error in which the lung–diaphragmatic margin in the far field appears to be misaligned due to an error in propagation speed calculation (made by the machine in calculating the depth of the structure). On the left side of the image, fat in the near field results in placement of the lung–diaphragmatic line farther away from the transducer because US waves travel more slowly through fat than through soft tissues.

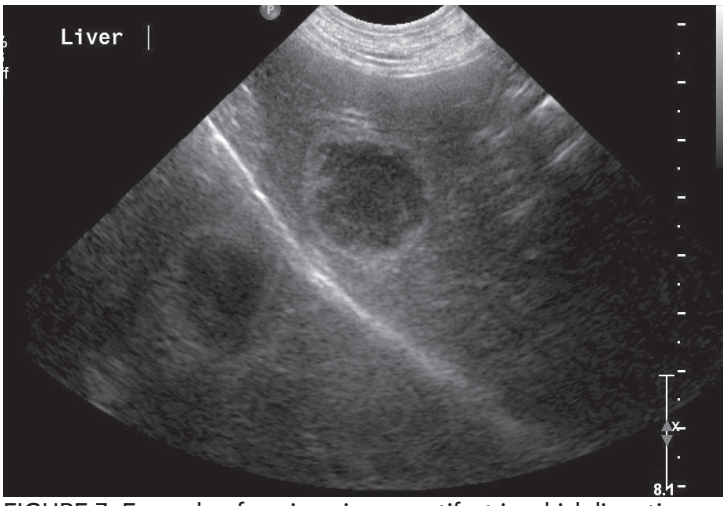

FIGURE 7. Example of a mirror image artifact in which liver tissue appears to be present cranial and caudal to the diaphragm–lung interface. In this image, a complex lesion is seen in the hepatic parenchyma; it is also seen as an artifact deep to the diaphragm-lung interface.

Mirror image artifacts result from US waves interacting with highly reflective boundaries at depth (**Figure 7**). The waves are *bounced* back and forth between the highly reflective interface and tissues; then return to the surface for registration with the US transducer. Because the bouncing increases the length of time the US waves are in the tissues, the image generated appears to be deeper in the tissues, beyond the highly reflective boundary.

The diaphragm–lung interface is the most common place for US waves to travel to the highly reflective interface, begin a return trip to the transducer, but then interact with tissue again, reflecting back toward the diaphragm. There, the US wave is reflected again, but this time travels all the way to the transducer. Due to the longer travel time, the US reflection point is interpreted by the US machine as deep to the diaphragm–lung reflective boundary.

Contact artifacts occur when the transducer surface does *not* contact the skin adequately, resulting in a dark band originating at the near field surface between the skin and probe (**Figure 8**). Moving the transducer, or applying more gel for better contact between the surface of the skin and transducer, can easily resolve this artifact. In many cases, contact artifacts are reduced and the image quality of the study improves during the course of an US examination as the US gel "soaks in" to the skin, thereby, improving probe contact with the skin. Alcohol may be applied to the skin prior to the gel to help this absorption take place.

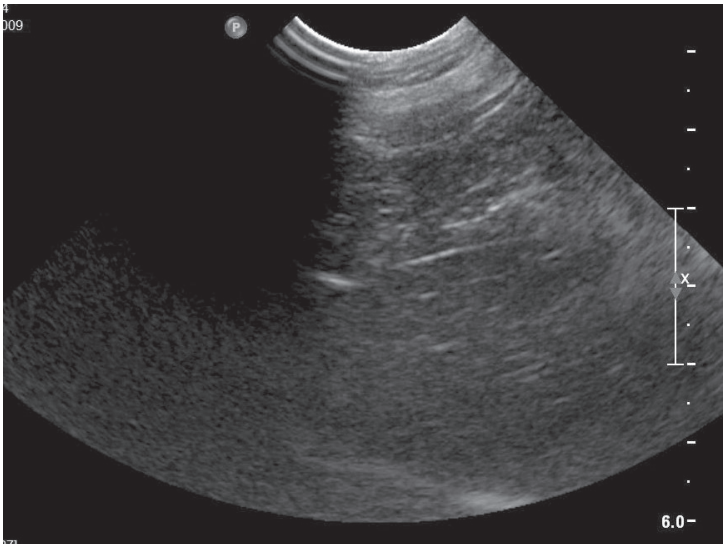

FIGURE 8. Contact artifact caused by inadequate contact of the transducer with skin. Reapplication of contact gel or movement of the transducer resolves this issue.

FALSE ASSUMPTIONS

False assumptions are errors made by the US machine when placing information about the scan area on the screen. These errors can result in misinterpretation of US images, misdiagnosis, or a missed diagnosis. Always be aware of these false assumptions:

1. The US machine assumes an average speed of 1540 m/sec in its calculation for distance of a returning US wave.
2. The US machine assumes a straight *out and back* path of US waves and leaves no room for multipath artifacts.
3. The US machine assumes that all returning echoes are from the primary beam (ie, in the direct *out and back* path). In other words, it assumes there are no secondary lobes, and that a side lobe artifact is *not* possible.
4. Remember that we are imaging differences in acoustic impedance, not anatomy, histology, or even pathology. It so happens that most pathologic conditions in the abdomen correspond with differences in acoustic impedance, but there will be US misses. Therefore, a negative scan does *not* always rule out disease.

IN SUMMARY

Artifacts occur in all US images. It is incumbent upon the sonographer to recognize the artifacts, know their causes, and correctly interpret the image without misdiagnosing changes in the image as being abnormal. For the most part, moving the transducer or ensuring adequate skin contact will avoid most artifacts. Useful artifacts should be recognized for their potential to provide additional physical information about the tissues being imaged.

US = ultrasound

References

1. Kremkau F. *Sonography Principles and Instruments*, 8th ed. Philadelphia: Saunders-Elsevier, 2010.
2. Mattoon J, Nyland TG. *Small Animal Diagnostic Ultrasound*, 3rd ed. Philadelphia: Saunders-Elsevier, 2014.

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