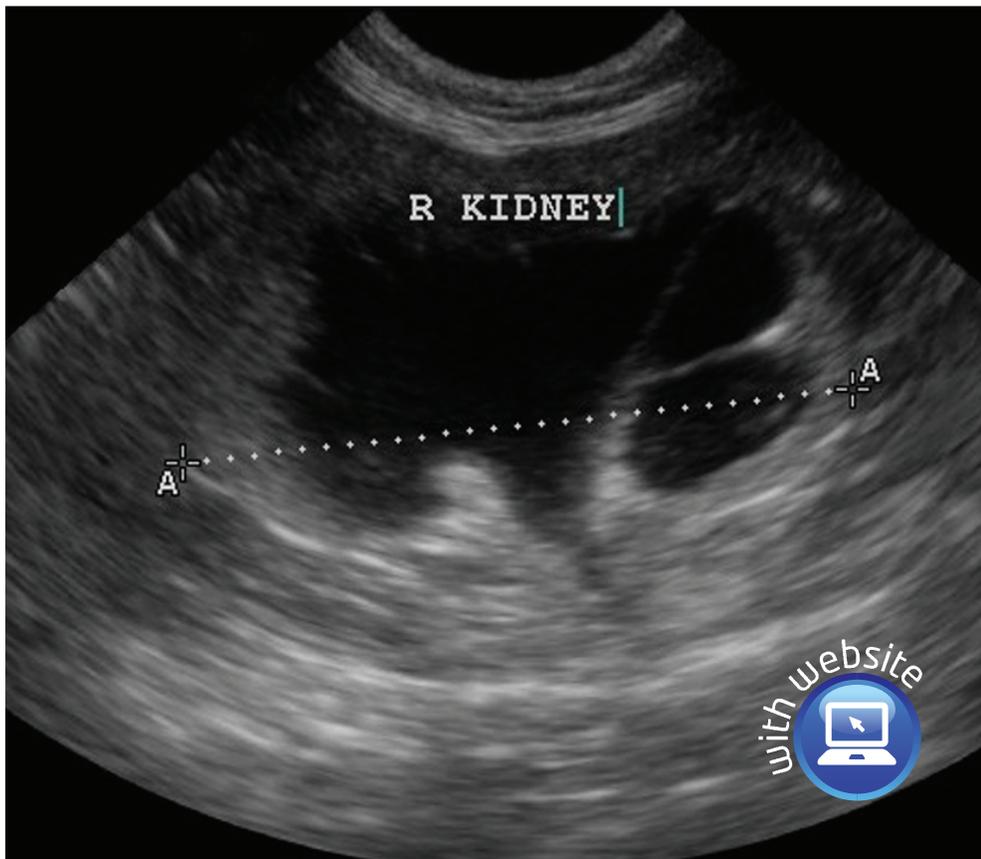
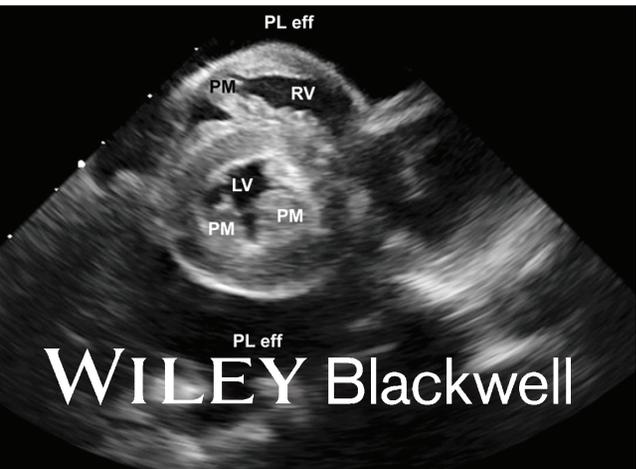
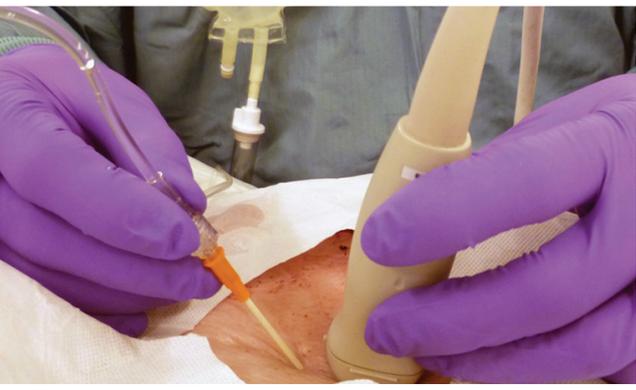


Focused Ultrasound Techniques for the Small Animal Practitioner

Edited by **Gregory R. Lisciandro**



FOCUSED ULTRASOUND
TECHNIQUES FOR THE
SMALL ANIMAL
PRACTITIONER

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ANIMAL
PRACTITIONER

Edited by

Gregory R. Lisciandro

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DEDICATION

To my grandparents Sam and Bernice Long and John and Mary Lisciandro; my parents Richard and Judy and siblings Denise, Kim, Kelly, and John; and most especially my lovely wife Stephanie and our children Noah, Hannah, Sarah, and Joshua for their patience, encouragement, and inspiration; and lastly the good Lord for making the textbook and all its many variables miraculously fall in place to its completion.

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INTRODUCTION TO FOCUSED ULTRASOUND FOR THE SMALL ANIMAL PRACTITIONER

Gregory R. Lisciandro

The translational study from the human to the veterinary patient regarding the focused assessment with sonography for trauma (FAST) exam by Dr. Søren Boysen in 2004 has opened the veterinary imaging world's eyes to legitimate non-radiologist use of abbreviated ultrasound exams. Such exams are of utmost importance because they are safe (no radiation) and non-invasive, allowing point-of-care evaluation of short-duration with limited patient restraint. These ultrasound interrogations also carry the potential to answer clinically important questions that remain enigmatic by using traditional means of physical examination, laboratory findings, and radiographic imaging. Moreover, by using abbreviated ultrasound exams, patients have the potential to survive because traditionally occult life-threatening disease was historically missed without using ultrasound. By using abbreviated ultrasound exams, disease may be detected on our terms rather than the disease's in the midst of traditionally less sensitive means, and the delay of scheduling formal or complete ultrasound exams or other advanced imaging studies is avoided. In human medicine, the so-called turf wars between who should and should not be conducting ultrasound studies has been somewhat mitigated by the realistic impression that abbreviated exams not only detect disease in a more timely manner, but also keep patients alive by better directing care. As more patients survive, the need for formal or complete ultrasound studies or other advanced imaging techniques increases. In other words, the human and veterinary radiologist to the contrary may become even busier.

The readers of this text should review the following sections to optimize the didactic potential of our textbook. We welcome feedback (woodydvm91@yahoo.com; www.fastvet.com) from your experiences as general practitioners and emergency and critical care veterinarians on the front lines of veterinary medicine.

Terminology

For a grasp of some of the concepts described below and throughout the subsequent chapters, let's define a few things.

The Abbreviated Ultrasound Exam

With the sudden eruption of bedside ultrasound exams by non-radiologists in human medicine, terminology has become convoluted, but generally the term "bedside" seems to be winning out. For example, a bedside gallbladder exam will be called just that, with its objectives being to answer simple clinical questions to help expediently guide the clinical course and to trigger the possible need for more formal (or complete) ultrasound examinations or other advanced imaging. On the other hand, the veterinary bedside lung ultrasound exam (called Vet BLUE) is similarly performed, however, it has been given an acronym. For clarity and to prevent an onslaught of terminology in veterinary medicine, we will use a limited number of terms.

Abbreviated ultrasound exams may be termed either "focused X" or "focused Y" exams, as suggested by the General Practitioner's Ultrasound Group (GPUS Group, www.gpultrasound.org) (see Appendix V for Internet access to the document). Such exams also may be referred to analogously as in the human literature, replacing "bedside" with "cageside." Thus, a "cageside organ assessments for trauma, triage, and tracking" may be turned into the acronym "COAST³" and similarly used as a "COAST³ X" or "COAST³ Y" exam with the "T³" standing for trauma, triage, and tracking (monitoring) subsets of veterinary patients. The "T³" has been previously proposed in the veterinary literature regarding the use abdominal FAST (AFAST) and thoracic FAST (TFAST) exams (Lisciandro 2011). Thus, the terms AFAST³ and TFAST³ seem best suited for use in many non-trauma subsets of veterinary patients for triage and tracking.

Importantly, the standardization of veterinary terminology gives absolute clarity among colleagues as to the exact exam format being performed. The accepted use of these veterinary terms has been previously proposed for preventing an onslaught of terms in veterinary medicine (avoiding what has occurred in human medicine) (Lisciandro 2011).

The terminology for radiologist-performed exams in human medicine has generally taken on the term “formal” abdominal ultrasound or “formal” echocardiography. The use of “diagnostic” is not adequate and should be discouraged in veterinary medicine because any abbreviated ultrasound exam format may be “diagnostic.” Rather than use the term “formal,” consistent with human terminology, we use the term “complete,” as suggested by the GPUS Group. Thus, the terminology for veterinarians is as follows for the abdominal cavity and thorax, respectively: “complete abdominal ultrasound” and “complete echocardiography.”

Recording Findings of the Focused, COAST³ and FAST³ Exams

The authors of this textbook acknowledge that each of these abbreviated ultrasound exams will evolve over time as to the diagnostic abilities in terms of their sensitivity, specificity, and accuracy. At this time, the best way to study results seems to be through template, goal-driven, formatted entries for medical records. In a bold attempt, by using both our experiences and those of the GPUS Group, such examples have been listed in the Appendices (Appendix II) and should be reviewed (and we encourage their use) by our readers.

Echogenicity: The Whites, Grays, and Blacks of Ultrasound

The jargon of ultrasound can be intimidating to the novice non-radiologist ultrasonographer. Clarity may be accomplished through acknowledging that ultrasound is the opposite of what tissues appear as on radiographic studies (our brain needs to reformat itself). For example, and very simplistically, air is white on ultrasound and black on radiographs. Bone is black (shadows) on ultrasound and white on radiographs. The ultrasound terms describing whites, grays, and blacks are referred to as hyperechoic, hypoechoic, and anechoic, with the terms “relative to X” and “relative to Y” used to further describe ultrasound imaging when detail is somewhere in between (Figure 1). For example, the spleen is hyperechoic

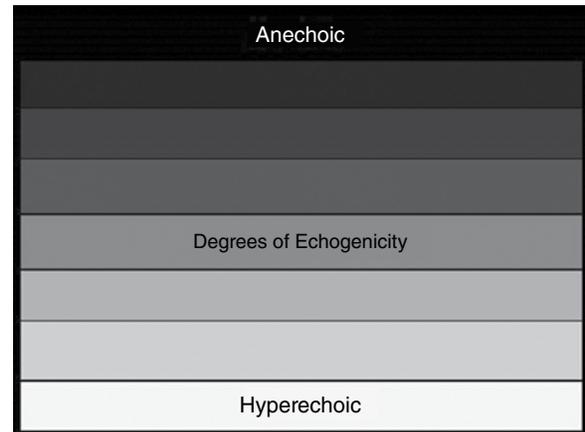


Figure 1. Illustration of degrees of echogenicity, ranging from anechoic (darkest [black]) to hyperechoic (lightest [white]).

(brighter) when compared to the left kidney. A few definitions:

Anechoic (pure black): Occurs when no ultrasound waves are reflected back to the receiver. Thus, normal urine, normal bile, transudates, and blood all are purely anechoic (black).

Hypoechoic (shades of gray): Occurs when variable degrees of the ultrasound waves are reflected back to the receiver. Thus, all soft tissues that are not fully aerated are described relative to other distinct tissues; for example, the liver is hypoechoic (darker than) relative to the spleen.

Hyperechoic (whites, bright whites): Occurs when all or nearly 100% of ultrasound waves are reflected back to the receiver. Thus, bone, stone (metals), and air are strong reflectors, resulting in hyperechoic interfaces with either shadowing, comet-tail artifacts, ultrasound lung rockets, or reverberation artifact projected distally.

Isoechoic (same echogenicity): Occurs when tissues are the same shades of gray. For example, if the liver is isoechoic to the spleen, then they are the same echogenicity (same shades of gray).

Directional Terms for Orientation

Longitudinal and sagittal: The term longitudinal refers to orientation parallel to the spine or long-axis of the patient’s body. The term sagittal refers to the longitudinal axis of the respective deeper structure being evaluated. For example, the superficial jugular vein is imaged in longitudinal, whereas the deeply located right kidney (angled and not parallel to the body’s long-axis) is imaged in sagittal planes (parallel to the right kidney’s long-axis). The terms are often

used interchangeably (or arguably misused); however, by appreciating that both terms are in their own right long-axis views, directional communication between veterinarians seems to be clear by use of either term. The probe marker is directed toward the patient's head.

Transverse: The term transverse refers to orientation 90 degrees to the long-axis of the structure being evaluated. The probe marker is turned to the left (or counterclockwise) to the patient's right side (if in dorsal recumbency or right lateral recumbency).

With that said, let's get on with Chapter 1. And remember, focused and FAST³ saves lives.

Reference

Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–122.

ABOUT THE COMPANION WEBSITE

This book is accompanied by a companion website:

www.wiley.com/go/lisciandro/ultrasound

The website includes a video bank containing more than 80 videos.

FOCUSED—BASIC ULTRASOUND PRINCIPLES AND ARTIFACTS

Robert M. Fulton

Introduction

Turn on the machine. Apply coupling gel. Start scanning. In the realm of the busy veterinary general practice, emergency clinic, or intensive care unit, that statement really sums up the basic use of ultrasound. Just as natural as it is for us to take the stethoscope from around our neck and place it on a patient's thorax, so should be picking up the ultrasound probe and placing it on the patient. No wonder that ultrasonography has been appropriately dubbed both "an extension of the physical exam" and the "modern stethoscope" (Rozycki 2001; Filly 1988). Really, one doesn't need a whole lot of instruction to start scanning; however, as for a lot of things in life, the devil is in the details. Proper imaging technique and understanding its limitations are the keys to accurate image interpretation of diagnostic ultrasound.

The focus of this chapter is a fairly brief review of the basic physics and principles of ultrasound including the more common problematic artifacts. For interested readers, there are more comprehensive textbooks dedicated to the physics and interpretation of ultrasound imaging (Nyland 2002; Penninck 2002).

What Focused Basic Ultrasound Principles and Artifacts Can Do

- Provide a basic review of ultrasound physics, image formation, common artifacts, and ultrasound systematics
- Provide a basic understanding of how artifacts are formed to allow better interpretation of the ultrasound image

What Focused Basic Ultrasound Principles and Artifacts Cannot Do

- Cannot provide an in-depth discussion of ultrasound physics, principles, and artifacts

Indications

- Provide a basic understanding of ultrasound physics, principles, and artifacts for the non-radiologist veterinarian

Objectives

- Provide an understanding of the basic fundamentals of ultrasound physics and how they relate to image formation
- Provide an understanding of how basic ultrasound artifacts are formed to avoid misinterpretation
- Provide a review of basic ultrasound systematics including image orientation and storage and machine and probe care

Basic Ultrasound Principles

The ultrasound (US) machine consists of two main parts, the probe and the processor. The probe is the "brawn" and the processor the "brains" of the operation. The probe has two main functions: first, to generate a sound wave (acts as a transmitter); second, to receive a reflected sound wave (acts as a receiver). The processor, located within the mainframe, takes these incoming signals and turns them into a useful image.

The transmitter and receiver functions of the transducer do not occur simultaneously, but rather sequentially. When placed under mechanical stress the ceramic crystals in the transducer generate a voltage. This process, known as the piezoelectric effect, occurs during the receiving phase, which is when returning sound waves strike the transducer. When an external voltage is applied to the crystals they exhibit the reverse phenomenon and undergo a small mechanical deformation. The subsequent release of this energy generates the ultrasound wave. This is known as the reverse piezoelectric effect. World War I saw the first practical use of the piezoelectric effect in the development of sonar using a separate sound generator and detectors (Coltera 2010).

The sound waves generated by diagnostic US machines are typically in the 3- to 14-megahertz (MHz) range and are thus too high pitched to be perceived by the human ear. We can hear sounds in the range of 20 Hz (cycles/second) to 20,000 Hz. In contrast, our average canine patient hears sounds in the range of 40 Hz–60,000 Hz. The high frequencies are in the realm of what is termed the “ultrasonic” range—basically any sound above our ability to hear—and hence the name for this clinical tool (Nyland 2002).

The sound waves produced by the transducer penetrate the body tissues and are subject to all the rules surrounding any sound wave including reflection, refraction, reverberation, attenuation, and impedance. The processor analyzes the transmitted signals and the returning waves, including their quantity, strength, and the time they took to return. By applying pre-programmed algorithms, the processor translates this information into a pixel, gives it an appropriate intensity (its echogenicity), and places it on the monitor screen to give us the image (sometimes being “fooled” into creating artifacts).

Between the transducer and the processor, it is easy to see why the equipment for this modality can be rather pricey. However, by using the variety of focused or COAST³ ultrasound exams outlined in this textbook, we hope that your US machine will become an asset not only with improved patient care, but also with a return on investment.

Velocity

Sound travels at specific known velocities through various materials. Remember from physics that sound travels faster through solids than it does through liquid or gas, and its velocity through various body tissues is known (Figure 1.1). Notice that velocity is similar through most of the soft tissues; however, current US machines cannot determine what tissues are being penetrated. Therefore, all US machines use an average velocity of 1540 m/sec for their imaging algorithms averaging the speed of sound through fat, liver, kidney, blood, and muscle (Coltera 2010).

The first and last columns in the table illustrate that sound passes relatively slowly through air and relatively quickly through bone. Anyone who has picked up an US probe knows that bone (solid) or lung (air) cannot be adequately imaged using US. To address the issue, the sonographer must understand the principle of acoustic impedance.

Remember the saying: Ultrasound hates bone or stone and is not too fair with air.

Acoustic Impedance

Acoustic impedance refers to the reflection and transmission characteristics of a substance. It is a measure of absorption of sound and the ratio of sound pressure at a boundary surface to the sound flux. Sound flux is

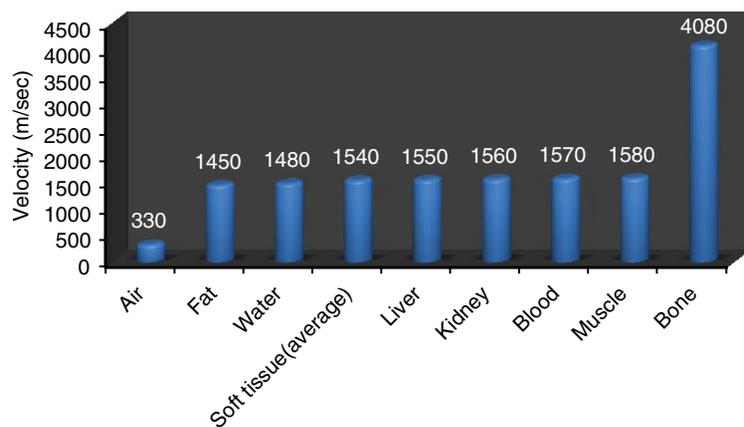


Figure 1.1. Velocity (m/sec) of sound through common body tissues or substances. Note the similar velocity through most soft tissues. This is the basis for using 1,540 m/sec as the number in depth calculations by the ultrasound processor. (Coltera 2010)

flow velocity multiplied by area. If we draw an analogy to electronic circuits, acoustic impedance is like electrical resistance through a wire, sound pressure is like voltage, and flow velocity is like current. The equation that brings it all together is:

$$Z = p/v$$

where Z =acoustic impedance, p =sound pressure (or tissue density), and v =velocity (Nyland 2002). The amplitude of a reflected sound wave is proportional to the difference in acoustic impedance between two different tissues. Air has a low impedance and bone has a high impedance when compared to soft tissue (Reef 1998) (Figure 1.2). Therefore, when a sound wave comes across a soft tissue-bone or a soft tissue-air interface (large difference in acoustic impedance), nearly all of the sound waves are strongly reflected (and a bright white echogenic line is formed at either interface). Reflection is why the sonographer cannot image through bone (solid) or lung (air), and strikes up one of the most common misnomers used in clinical ultrasonography: When imaging through the liver into the thorax, we believe the bright, curved cranial border is the diaphragm. In reality, the diaphragm is rarely imaged except in bicavitary effusions. The bright white (hyperechoic), curved line is actually the strongly reflective surface of the lung (air) at the soft tissue-air boundary or interface serving as a strong reflector.

In conclusion, by comparing the acoustic impedance of most tissues in the body—other than bone (solid) and lung (air)—we see that they are very similar (there is little difference in acoustic impedance among them). This similarity makes US a great imaging tool for examining into and through soft tissues (their parenchyma). On the other hand, due to the large difference in acoustic impedance between soft tissue-air and soft tissue-bone interfaces, US is not an effective

tool for examination beyond the surfaces of either aerated lung or bone (Reef 1998).

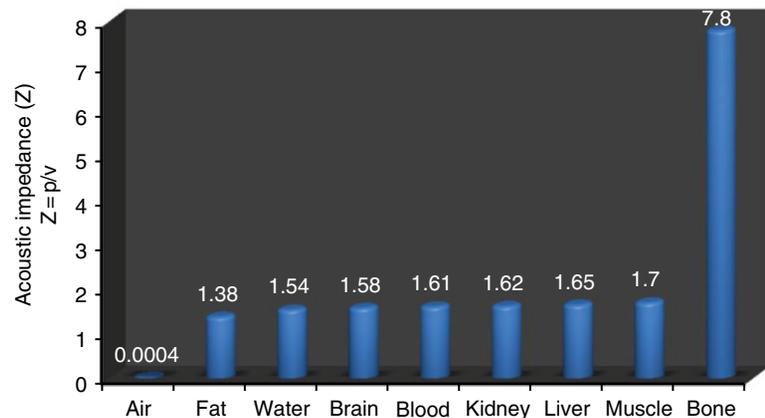
Absorption, Scatter, and Reflection

Other US principles that affect our image include absorption, scatter, and angle of reflection. As the sound waves enter the body, some of them are absorbed by the tissues and are never reflected back to the probe. These waves are lost and do not contribute to the image. Furthermore, many of the waves are scattered by the tissues and their surface irregularities and either return to the probe (receiver) in a distorted path or do not return at all. As a result, the US waves are “misinterpreted” by the processor and the image and its resolution are affected. The ideal angle of US reflection for generating the best image is 90 degrees; this is why linear probes (not used by most small animal practitioners) provide superior detail when compared to curvilinear probes (more commonly used among small animal practitioners). Interestingly, a deviation of as little as 3 degrees from this ideal causes US waves to be lost and not returned to the receiver, thus decreasing the detail of the US image.

Attenuation

All sound beams become attenuated, or lose energy, during transmission through tissues; therefore, the returning sound wave is weaker than when it started. Different frequencies (MHz) are attenuated to different degrees. Low frequency is attenuated less than high frequencies and therefore allows deeper tissue penetration. Conversely, high frequency gives better resolution but undergoes more attenuation. Strategies that include lowering the MHz for better penetration (depth) come at the expense of detail. Conversely, using higher frequency for more detail comes at the

Figure 1.2. Acoustic impedance ($10^6 \text{ kg/m}^2\text{sec}$) of common body tissues or substances. This figure illustrates the degree of difference in acoustic impedance between substances that helps determine sound wave transmission. The greater the difference, the greater reflection or loss of transmission. You can see how ultrasound is ideally suited for most soft tissue and why it is not suited for imaging bone or air-filled structures. (Reef 1998)



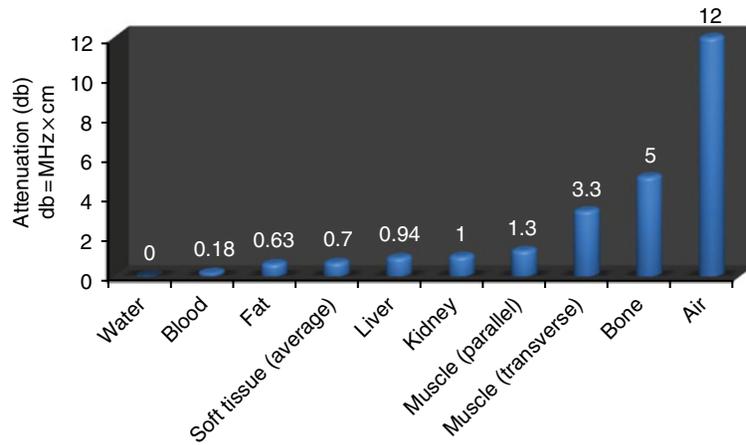


Figure 1.3. Attenuation (db/cm/MHz) in common tissues. Attenuation of sound energy within tissues varies with the frequency of the sound and is affected by reflection, scattering, and absorbance. Note how bone and air have the greatest attenuation values. (Reef 1998)

cost of less penetration (depth). Furthermore, high-density tissues attenuate the sound waves more than low-density tissues (Figure 1.3). These principles will be further discussed in Basic Artifacts.

The analogy of hearing a boom box from a distance can help you remember which MHz penetrates more. The bass dominates (low MHz) over higher frequencies (high MHz); thus, low MHz penetrates deeply at the expense of detail, and high MHz gives better detail at the expense of penetration.

Basic Artifacts

Now we'll take the fundamental laws governing wave dynamics and see how artifacts are created. Artifacts may be grouped by the most important principles leading to their formation including attenuation, velocity, or propagation, and artifacts associated with multiple echoes.

Artifacts of Attenuation, Strong Reflectors (Bone, Stone, Air)

Shadowing, "Clean" and "Dirty"

Clean shadows and dirty shadows result from strong reflectors (bone, stone, and air). We know from differences in acoustic impedance at soft tissue-air and soft tissue-bone (stone) interfaces that most of the sound waves will be reflected, albeit in different degrees (Figures 1.4 and 1.5A).

Bone (or Stone) Interface

When the US wave strikes bone (and stone), most of the waves are reflected back thus there will be an area of intense hyperechogenicity (whiteness) at the soft

tissue-bone (stone) interface. Because the surface of bone is often smooth, there is little scattering or reverberation of the US wave and a nice, clear-cut, anechoic (blackness) "clean shadow" is produced beyond the reflector (bone or stone) (Figure 1.4B, also see Figures 15.1, 15.2, 15.6, and 15.7).

Air Interface

On the other hand, soft tissue-air interfaces are more variable in their degree of reflection with some of the US waves incompletely moving through the air-filled structure unlike the complete reflection at bone (or stone); thus reverberations occur distal to the air interface creating a "dirty shadow." (Penninck 2002) (Figure 1.4A, 1.5A).

Artifacts of Attenuation (Fluid-Filled Structures)

Edge Shadowing (Fluid-Filled Structures)

When the US waves strike the edge of a fluid-filled structure with a curved surface (its wall), such as the stomach wall, urinary bladder, gallbladder, or cyst, US waves change velocity and bend, resulting in the physical process of refraction. As a result, a thin hypoechoic (darker) to anechoic (black) area lateral and distal to the edge of the curved structure is formed. The novice may mistake this artifact as a "rent" in the urinary bladder wall when in fact it is an artifact created by the US machine (Nyland 2002) (Figure 1.5).

Acoustic Enhancement (Fluid-Filled Structures)

When the sound beam passes through a fluid-filled structure, such as the gallbladder, urinary bladder, fluid-filled stomach, or a cyst, US waves do not become

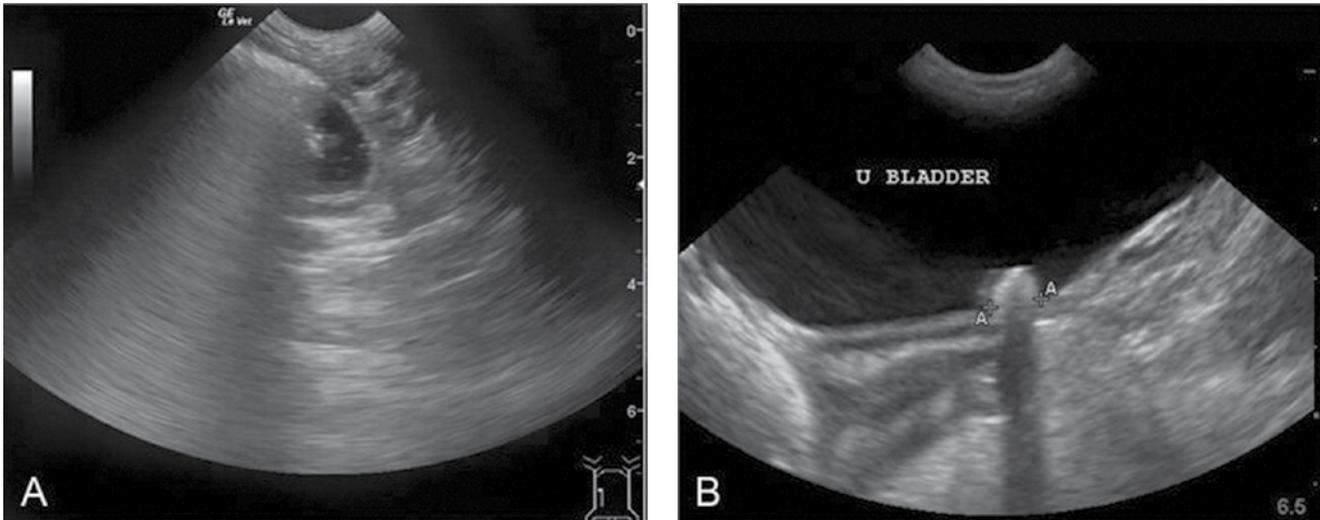


Figure 1.4. Clean versus dirty shadowing. (A) “Dirty” shadow. A gas bubble within a fluid-filled distended loop of small bowel generates a dirty gas shadow (image on the left) because some US waves pass through the structure. Contrast the dirty shadow with the “clean” shadow of the cystourolith (urinary bladder stone) in (B). Note how a body icon was used to show the approximate location of the probe because there are no anatomical landmarks within the image itself. (B) “Clean” shadow. The smooth surface of the cystourolith (urinary bladder stone) generates the clean shadow typical of bone or stone with a hyperechoic (bright white) reflective surface in the near field, completely blocking all echoes and thus resulting in an anechoic (dark or black) shadow extending from it. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

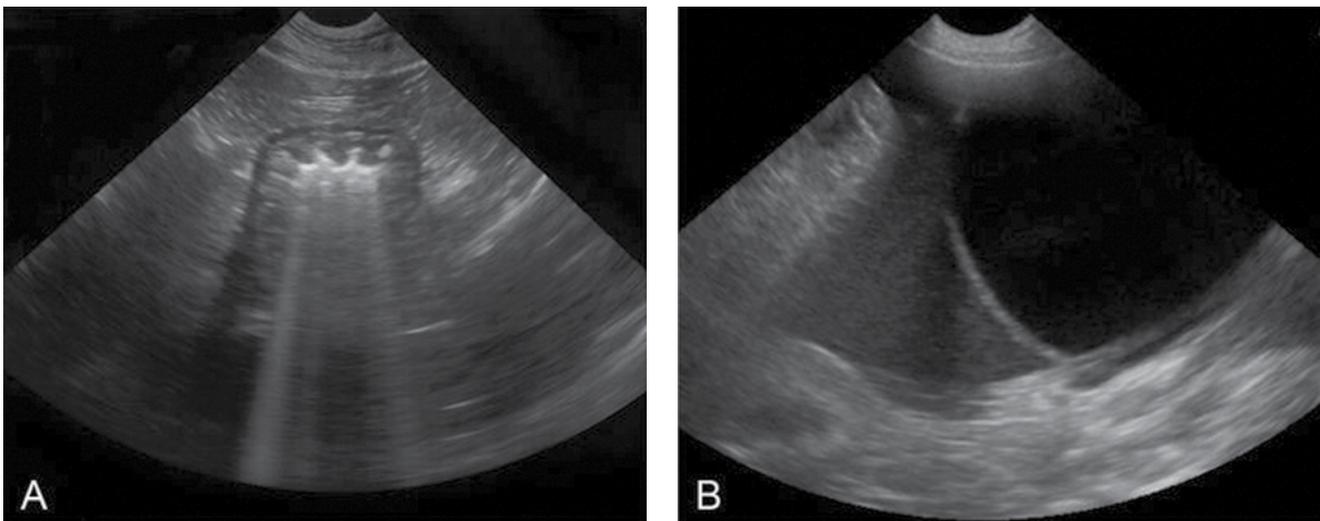


Figure 1.5. Edge shadow artifact. (A) An edge shadow artifact is seen arising from the curved edge on the left side of the stomach wall in this image, making its wall appear to extend distally as an anechoic (dark or black) line. A dirty gas shadow is also produced from gas within the stomach lumen. (B) An edge shadow artifact at the apex of the urinary bladder makes it falsely appear to have a rent which can fool the novice into thinking the free fluid is from a ruptured bladder. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

as attenuated as the neighboring waves passing through more solid tissues to either side of the structure. Therefore, the tissues on the far side of the fluid-filled structure appear much brighter than the neighboring tissues at the same depth. Acoustic enhancement is

obvious, looking past the fluid-filled gallbladder and urinary bladder (Figure 1.6). On the other hand, by realizing how the artifact is formed, the acoustic enhancement artifact can be advantageously useful to the savvy sonographer in determining if a structure of interest is

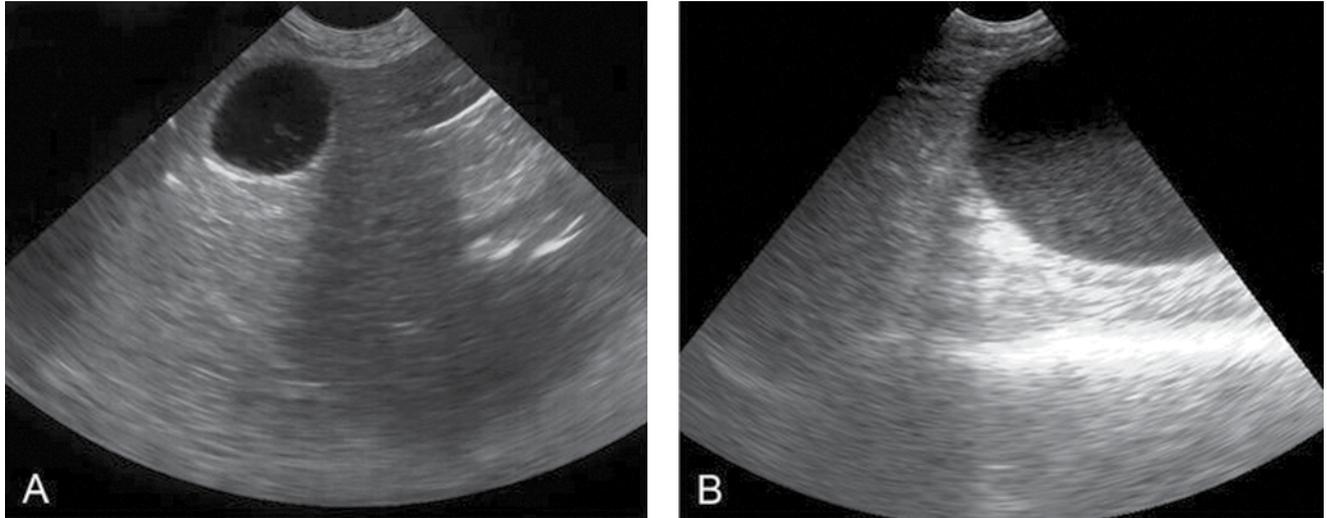


Figure 1.6. Acoustic enhancement artifact. Because there is less attenuation when sound moves through liquid, the area distal to a fluid-filled structure will appear hyperechoic (brighter or whiter) to the surrounding tissue. Note the hyperechoic region distal to the gallbladder (A) and distal to the urinary bladder (B).

fluid-filled (brighter through the far field having acoustic enhancement) or soft tissue (lacking acoustic enhancement) (Penninck 2002) (Figure 1.6).

Artifacts of Velocity or Propagation

Mirror Artifacts (Strong Reflector [Air])

When we image a structure that is close to a curved, strong reflector such as the diaphragm (actually the lung-air interface following the curve of the diaphragm), a sound beam can reflect off the curved surface, strike adjacent tissues, reflect back to the curved surface, and then reflect back to the transducer. Because the processor only uses the time it takes for the beam to return home and cannot "see" the ongoing reflections, it will be fooled into placing (mirroring) the image on the far side of the curved surface. The classic place for a mirror artifact is at the diaphragm, and the classic mistake is interpreting the artifact as a diaphragmatic hernia (Penninck 2002) (Figure 1.7).

Reverberation or A-Lines (Strong Reflector [Air])

Reverberation occurs when sound encounters two highly reflective layers. The sound is bounced back and forth between the two layers before traveling back. The probe will detect a prolonged traveling time and assume a longer traveling distance and display additional reverberated images in a deeper tissue layer. The reverberations can get caught in an endless loop and extend all the way to the bottom of the screen as parallel equidistant

lines, referred to as A-lines (also see chapters 9 and 10). This artifact most commonly extends beyond air-filled structures within the thorax, (e.g., lung) and within the abdomen (e.g., gastrointestinal tract), with varying width (Penninck 2002) (Figures 1.8A, Figure 1.5A).

Comet-Tail or Ring-Down Artifact (Strong Reflector [Usually Metal or Bone but Can Be Air])

A comet-tail artifact, also called a ring-down artifact, is similar to reverberation. It is produced by the front and back of very strong reflectors with high acoustic impedance, such as metallic foreign bodies or implants, needles, and stylets during US-guided procedures (chapters 12 and 17), or strong reflectors with very low acoustic impedance, relative to their adjacent soft tissues, such as gas in the lung, gas bubbles, or gas in the bowel. The reverberations are spaced very narrowly and blend into a small band. The greater the difference between the acoustic impedance of the reflecting structure and the surrounding tissues, the greater the number of reverberation echoes (Reef 1998) (Figure 1.8B).

Ultrasound Lung Rockets or B-Lines (Air Immediately Next to Water)

Ultrasound lung rockets (ULRs), more recently termed B-lines (Volpicelli 2012), are vertical, narrow-based lines arising from the near field's pulmonary-pleural line, extending to the far edge of the ultrasound screen, always obliterating A-lines, and moving "to and fro" in concert with inspiration and expiration. Although ULRs

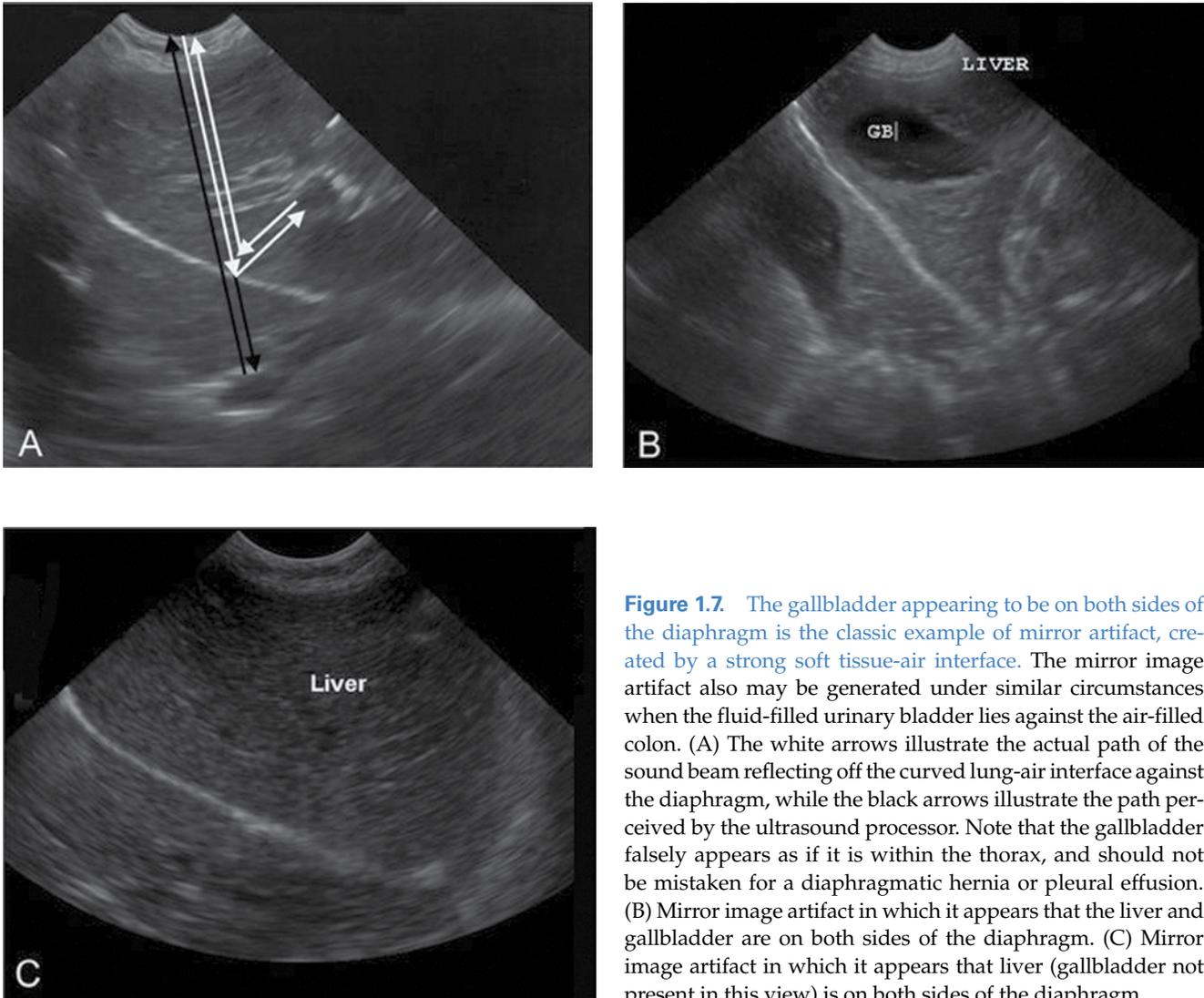


Figure 1.7. The gallbladder appearing to be on both sides of the diaphragm is the classic example of mirror artifact, created by a strong soft tissue-air interface. The mirror image artifact also may be generated under similar circumstances when the fluid-filled urinary bladder lies against the air-filled colon. (A) The white arrows illustrate the actual path of the sound beam reflecting off the curved lung-air interface against the diaphragm, while the black arrows illustrate the path perceived by the ultrasound processor. Note that the gallbladder falsely appears as if it is within the thorax, and should not be mistaken for a diaphragmatic hernia or pleural effusion. (B) Mirror image artifact in which it appears that the liver and gallbladder are on both sides of the diaphragm. (C) Mirror image artifact in which it appears that liver (gallbladder not present in this view) is on both sides of the diaphragm.

are similar to comet-tail artifacts, they are specifically created by the strong impedance of air adjacent to a small amount of water, and are the ultrasound near equivalent of radiographic Kerley B lines (representing interlobar edema). Their clinical relevance is very important and explained later (chapters 9 and 10) (Lichtenstein 2008, 2009, Lisciandro 2011, Volpicelli 2012) (Figure 1.9).

Artifacts of Multiple Echoes

Side-Lobe Artifact

We like to think of the ultrasound beam as extending from the probe in a very thin fan or rectangle, and this is exactly what the processor thinks it sees. In reality, there are smaller beams that travel laterally to the main beam. When one of these smaller side beams is of sufficient strength and bounces off a highly reflective

surface, such as the wall of the urinary bladder, it will be interpreted as coming from the main beam and the processor will place the resulting image within the bladder, mimicking sediment. The resulting image is usually weaker in intensity than the main image. It is possible that the artifact can be altered by changing probes or dropping the focal point, or that it will disappear with lower gain settings—all things that will not happen with true pathology (i.e., bladder sediment, bladder stones, etc.) (Penninck 2002) (Figure 1.10).

Slice-Thickness Artifact

Slice-thickness artifact is somewhat similar to the side-lobe artifact. Particularly in the gallbladder and urinary bladder, this artifact mimics sludge or sediment. It occurs when part of the beam's thickness lies just outside of a fluid-filled structure. These artifacts

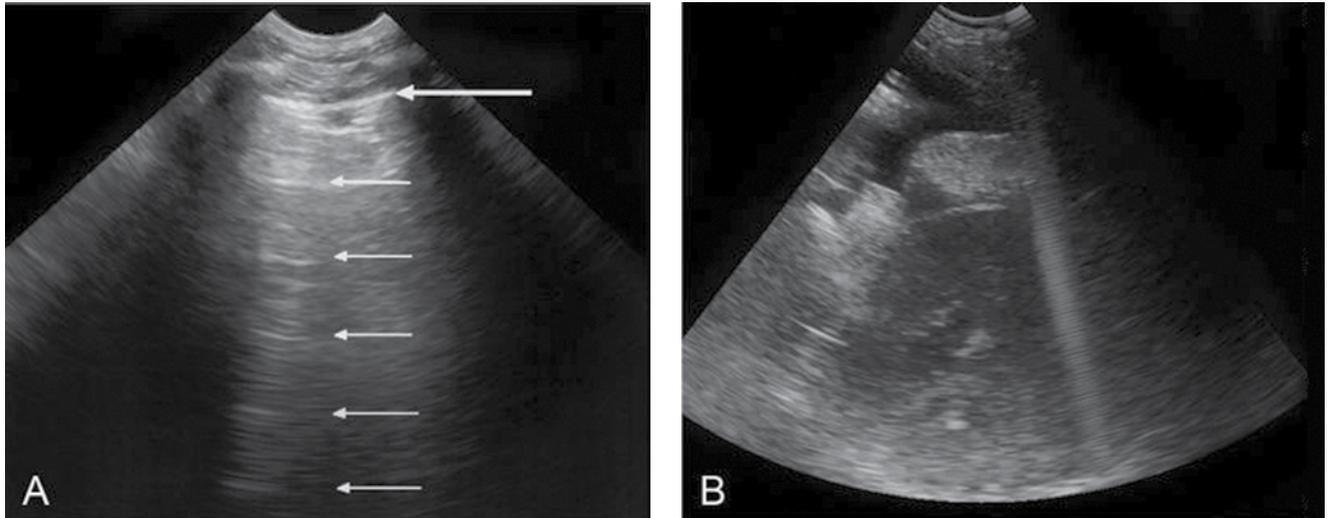


Figure 1.8. Reverberation artifacts of strong reflectors, A-lines, comet-tail, and ring-down artifacts. (A) A reverberation artifact, also known as A-lines (think of it as “A” for air), is seen as regularly spaced parallel lines illustrated by the small white arrows. The larger arrow in the near field denotes the lung’s pleural surface, evident in the intercostal space between two ribs [bone] creating the clean shadowing through the far field. (B) The very tight and distinct reverberation artifact, referred to as a comet-tail or ring-down artifact, is caused by sound waves reflecting off a metal needle used during abdominocentesis. Any strong reflector of US waves produces this artifact; this typically involves bone, stone, or metal, such as implants, needles, and foreign bodies.

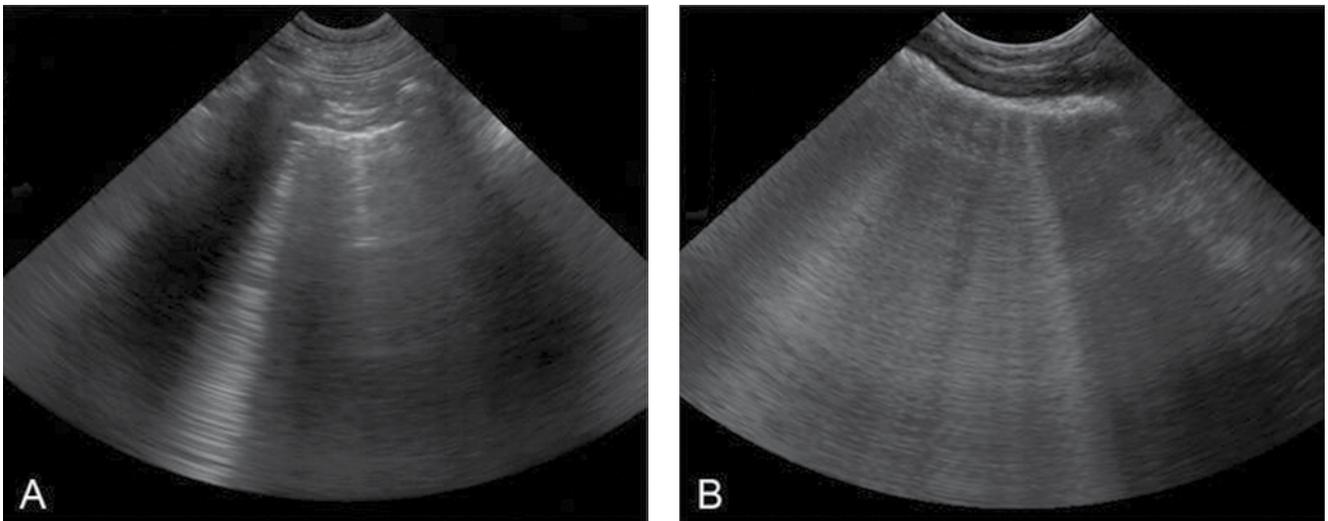


Figure 1.9. Recently the nomenclature for this lung ultrasound artifact has been changed from comet-tail artifact to ultrasound lung rockets (URLs), also called B-lines. URLRs are generated from the lung’s most outer (1- to 3-mm) pleural surface when a small amount of interstitial fluid (e.g., water) is immediately next to air. The ULR artifact begins at the lung’s pleural surface and continues without loss of intensity through the far field of the image as a hyperechoic (bright white) streak that obliterates A-lines. In real-time, ULRs must oscillate with the to-and-fro motion of inspiration and expiration. (A) Single ULR. (B) Multiple ULRs. Courtesy of Dr. Greg Lisciandro, Hill Country Veterinary Specialists, San Antonio, Texas.

typically appear within the lumen of these structures and are somewhat hyperechoic (bright) and curved. They can be differentiated from real sediment by several methods or clues. First, gravity dependent sediments have a flat surface, whereas the artifact will be rounded. Second, by changing the position of the

patient, the relative position of true sediment will change as gravity pulls it to the new lower point. Third, the sonographer can use the US probe to ballot the bladder and stir the sediment up a bit; the artifact will not yield a “snow globe” effect (sediment will) (Penninck 2002) (Figure 1.10).

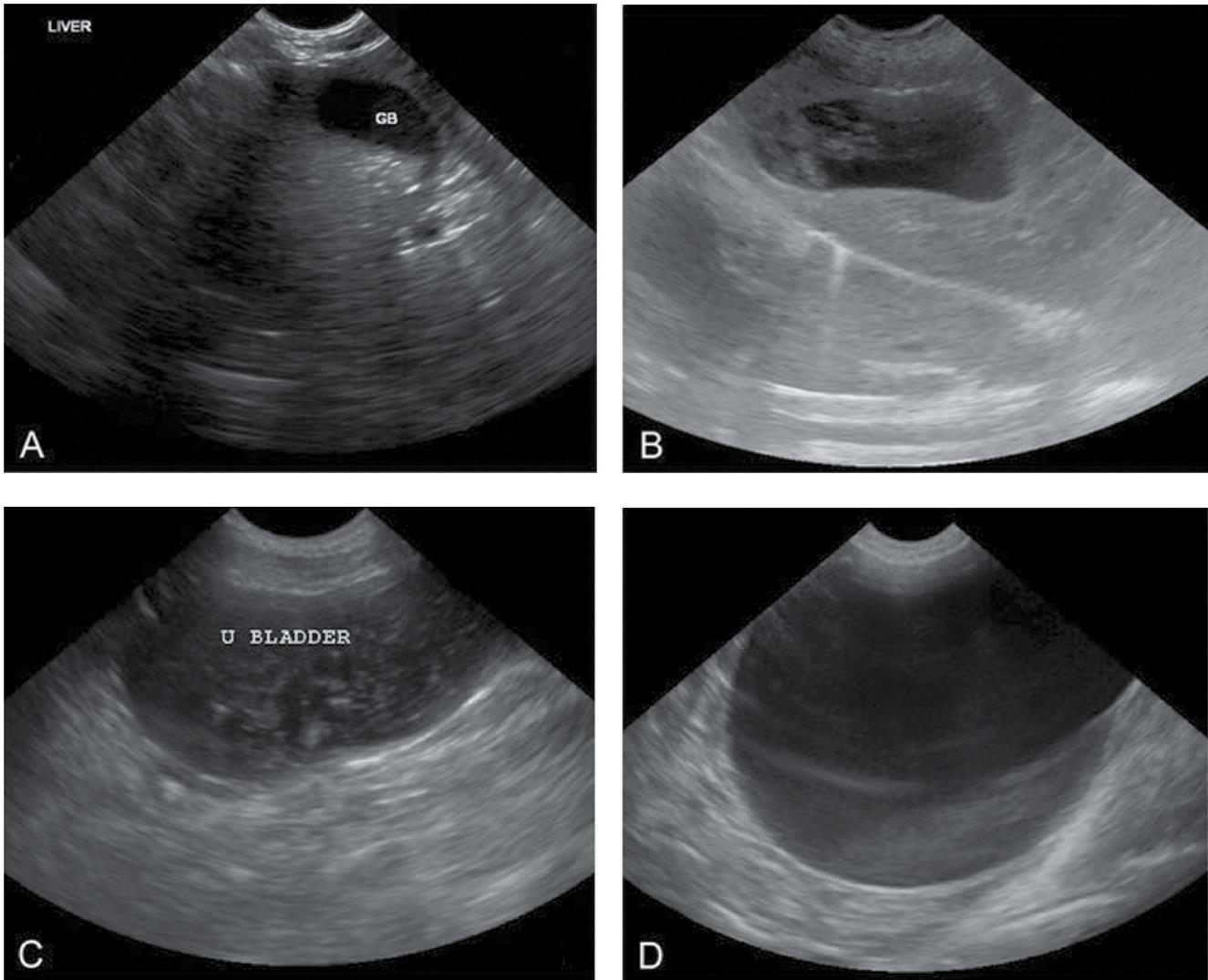


Figure 1.10. Sediment vs. side-lobe and slice-thickness artifact. (A) Sediment is affected by gravity and leads to a flat surface, as seen with the sludge within this gallbladder's lumen. True sediment can be stirred up by repositioning the patient or through ballottement with the ultrasound probe, whereas artifacts mimicking sediment cannot. (B) Slice-thickness and side-lobe artifacts mimic sediment in the gallbladder shown here; however, the artifact will not be altered by moving the patient's position or by ballottement. (C) True sediment in a urinary bladder with ballottement gives a snow globe appearance. (D) In contrast, the slice-thickness and side-lobe artifacts mimicking sediment shown here will fail to ballot (will not give the snow globe effect) or change position to the gravity dependent side of the urinary bladder when the patient is moved. Other helpful tricks that discriminate true sediment from artifact include lowering the gain and/or moving the focus cursor. Generally speaking, artifacts can be eliminated by these maneuvers, but true sediment cannot.

Basic Scanning

Image Orientation

Any part of a medical record must contain the essentials of basic medical communication to have value. As veterinarians, we are taught how to communicate with each other in such a way that regardless of our individual personality and training, one veterinarian can describe a lesion to another half a world

away and pass along vital information. Ultrasound exams likewise need to have standard image orientation and recording of findings to give the study meaning.

For standard plain radiography, the lateral film is oriented with the patient's head to the left, and the spine is dorsum and at the top of the viewer. This is the same for either a right or left lateral image. For the

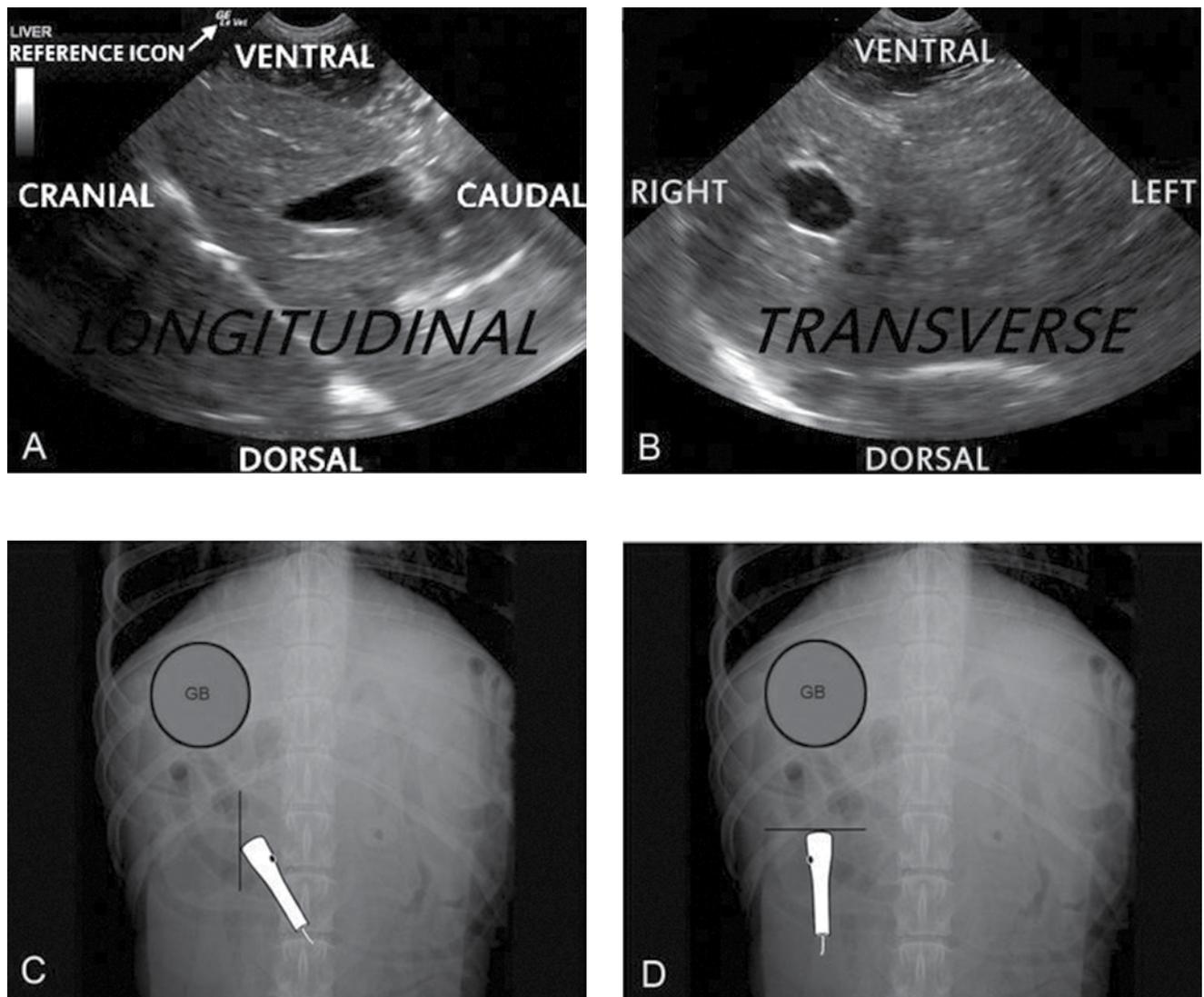


Figure 1.11. Standard ultrasound screen orientation, longitudinal (sagittal) and transverse. The radiograph for each orientation is located below the respective ultrasound image. Figures (A) and (C) illustrate longitudinal (or sagittal) and (B) and (D) transverse orientation with the corresponding probe position during interrogation of the liver and gallbladder via the subxiphoid region of a dog. Note that the reference icon (GE_{Le}) corresponds with the probe reference marker (dot on the probe) with the GE_{Le} reference icon (labeled with arrow in (A) to the left on the US image). The best way to make standard ultrasound imaging a habit is to have the probe marker toward the head for longitudinal (or sagittal) orientation (black dot on the probe in (C) and turn (the probe head) left or counterclockwise for transverse orientation (black dot on the probe in (D) with the reference icon (in this case the GE_{Le}) to the screen's left (shown at the top of the US image in (A) and (B)). If your reference icon is to the right of the US image, most US machines have a "reverse" button feature on their keyboard to flip the reference icon back to the standard left side (with the exception of echocardiography orientation; see Chapter 11).

ventrodorsal or the dorsoventral view, the radiograph is positioned with the head pointed up, and the patient's right side toward the left-hand side of the view box.

Ultrasound follows similar convention. When we scan from the ventral aspect (as when the patient is in dorsal recumbency), the following orientations applies:

Longitudinal image: The ventrum is on the top of the screen, dorsum on the bottom. Cranial is to the left, and caudal is to the right (Figure 1.11A).

Transverse image: Ventral and dorsal remain top and bottom, respectively, and the patient's right side is represented on the left side of the screen, and the patient's left side is represented on the right side of the screen (Figure 1.11B).

This US image orientation convention is the most intuitive if the patient is positioned in dorsal recumbency with its head facing the same way the sonographer is facing (toward the machine). Many emergent patients are not stable enough to be placed in dorsal recumbency and all FAST³ scans actually prescribe lateral or sternal recumbency, so the sonographer may need to do a little mental gymnastics at times to orient the image on the screen with the patient.

When scanning from the lateral aspect of the patient (i.e., in a dorsal plane), the following convention applies:

Longitudinal image: Non-recumbent side is on top of the screen, recumbent side is on the bottom. Cranial is to the left side of the screen, and caudal is to the right (Figure 1.11A).

Transverse image: Non-recumbent side is still on top of the screen, recumbent side still on screen's bottom. Ventral is on the left, dorsal is on the right (Figure 1.11B).

Develop the habit of having the marker toward the patient's head (longitudinal imaging) and turning left for transverse imaging to maintain proper orientation etiquette.

All US probes have a reference mark to allow for proper orientation. The marker may be a raised dot or line molded into the plastic, or possibly a small LED light. On the image screen, there will be a symbol (often the company's logo) that corresponds with the probe's reference mark. The marker on the screen is commonly referred to as the "reference icon" (Figure 1.11). Sonographers should familiarize themselves with the various types of US probes—phase array, linear, and curvilinear—and know that by looking at the shape of the US image the probe is readily apparent—pie-shaped pointed near field (phase array or sector), rectangular (linear), and pie-shaped with curved concave near field (curvilinear) (Figure 1.12).

Most veterinarians are taught that when scanning the abdomen in long-axis, the probe's reference mark is pointed toward the patient's head. Therefore, by convention, the reference icon on the screen will also be positioned on the left side of the screen (left=cranial, right=caudal). When the probe is turned into the transverse orientation, the reference mark is pointed toward the patient's right, making a counterclockwise

motion ("turning left") if one views the probe from its tail, or cable, end (left=right side of patient, right=left side of patient).

Cardiac Orientation

See chapters 9 (TFAST³) and 11 (focused ECHO) for information on cardiac orientation.

Deciding on an Ultrasound Machine

Selecting the Machine

There are three main types of US machines: consoles, portables, and handhelds. The console machines are big and bulky, but they have stronger processors and thus give a better image. The portables, often laptop format, are easy to move to the exam table or cageside and their image quality is constantly improving. There are several small handheld machines now on the market. Some have pretty decent depth and resolution capabilities. Just make sure they don't walk out of your clinic. It's very easy to put these in a lab jacket pocket and forget about them.

You may be limited to whatever you currently have in your veterinary practice, but if you are thinking of buying a new unit, consider what your main use is going to be, and get the best US machine you can afford for that purpose. The axiom holds true—the better the machine, the better the image, and the better the diagnostic information.

Selecting the Probe

Probes, or transducers, come in two basic types, mechanical and electronic. Mechanical probes are by many accounts considered outdated but there are still some around with their working parts visibly rotating or rocking under their translucent covers. Newer ultrasounds come standard with electronic probes. Electronic probes come in various arrangements. Probes are generally described by the size and shape of their face, referred to as their "footprint," which is represented by the gray rubber probe covering (Figure 1.12A). Selecting the right probe is essential to getting good images, although there may be times when more than one probe may be appropriate for a given exam.

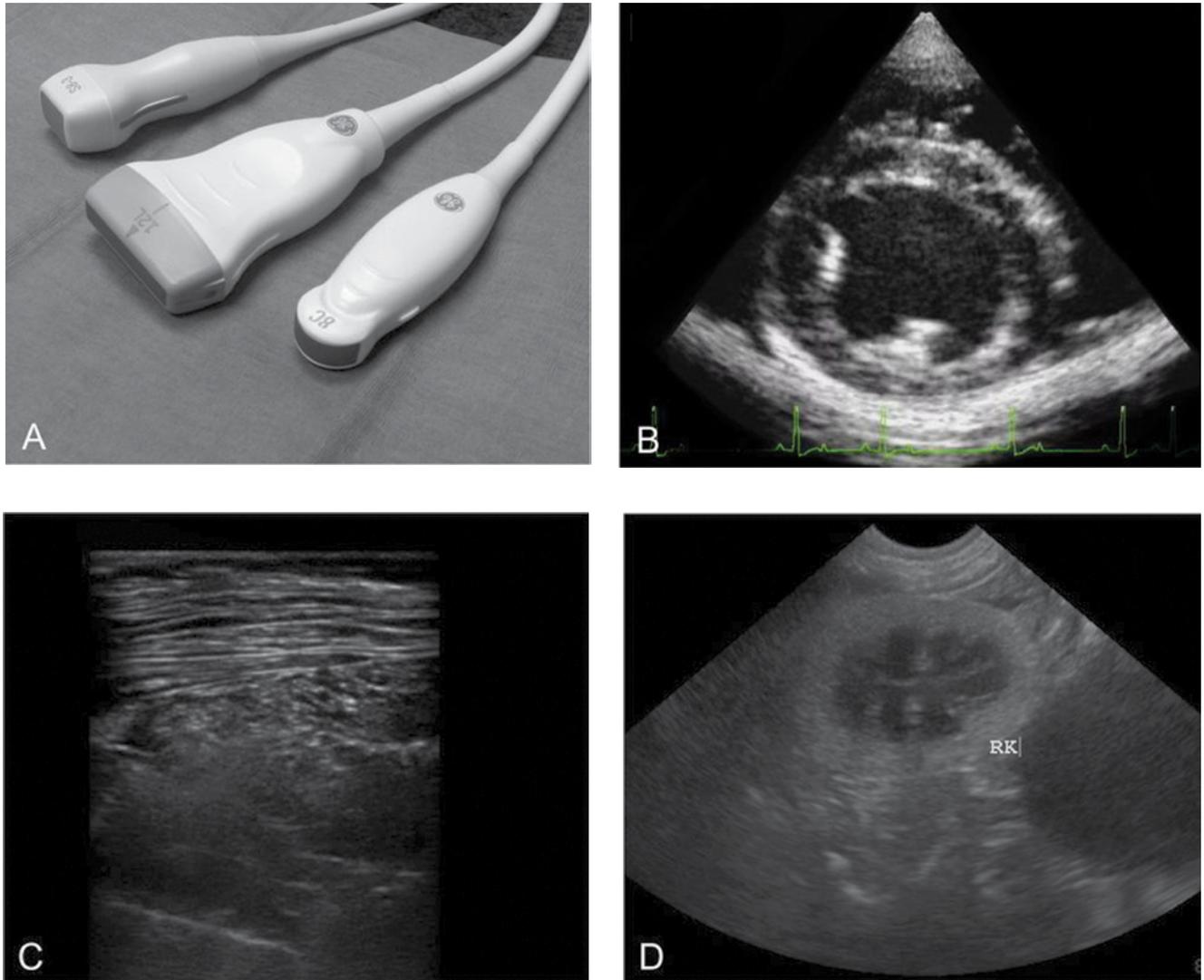


Figure 1.12. Electronic ultrasound probes and their characteristic B-mode images. The probe used for the US image is easily recognized by the US image's shape. (A) Ultrasound probes, from left to right: phased-array (also known as sector), linear, and curvilinear (also referred to as microconvex). A molded reference marker can be seen on all three of these probes. Other probes may use an LED light as the reference marker. The rubber probe heads (gray) represent the "footprint" or contact surface of each probe. (B) The phased-array probe US image is pie-shaped with a near field "point." Phased-array is ideal for echocardiography because it best avoids ribs (note no rib shadow). (C) Linear probe US image with its rectangular shape. Linear is superior in detail because it sends and receives US waves 90 degrees to structure(s) of interest. (D) Curvilinear probe US image is pie-shaped but wide and concave in the near field. Curvilinear (microconvex) is most commonly used by non-radiologist veterinarians because of its versatility.

Three basic types of probes are used in general practice, emergency, and critical care point-of-care ultrasound: linear, curvilinear, and phased-array (also known as sector) (Figure 1.12A). Linear probes are typically of higher frequency and have a rectangular footprint (Figures 1.12A and C). Curvilinear probes are arranged along a convex face and are typically of lower

frequency than the linear probes. A phased-array (sector) probe generates an image from an electronically steered beam in a close array, generating an image that comes from a point and is good for getting between ribs, such as in cardiac ultrasound (Figures 1.12A and B). Both curvilinear and phased-array probes generate sector or pie-shaped images, narrow in the near field

and wide in the far field (Figures 1.12A and D). Phased-array probes are typically lower frequency. Because of their smaller footprint, pie-shaped image, and common frequencies, the curvilinear probes are generally the most versatile and ideal for the focused, COAST³, and FAST³ studies.

Probes are generally named for the primary frequency they emit. For example, a General Electric (GE) 8C probe indicates that 8MHz is its primary frequency and the C represents the probe's curvilinear footprint. Moreover, a GE 9L probe indicates a 9MHz primary frequency in a linear (L) probe, and a GE 7S as having 7MHz as its primary frequency in a sector (S) probe. However, modern probes are capable of emitting a range of frequencies known as bandwidth. In choosing the best frequency, we need to go back to the basics. Remember that higher frequencies are attenuated more, and that means less penetration but better detail. Lower frequencies are attenuated less, and that means deeper penetration but less detail.

For the focused, COAST³, and FAST³ ultrasound scans, begin with an intermediate setting of 8MHz as a general rule of thumb. That being said, most chapters in this textbook provide probe frequency recommendations.

Image Optimization Using the Big 4 Knobs

For an US image to have meaning, it must have adequate detail. The best rule of thumb is that the image should simply look "nice." Pretty or nice may be a little different from one person to another, but they should all be fairly similar. There are numerous buttons and knobs that can be used improve, or worsen, the image. The Big 4 are depth, gain, frequency, and focus position and number.

Know the "Big 4" knobs: depth, gain, frequency, and focus position and number.

Depth

When reviewing a radiograph, the clinician can become narrow-sighted by focusing on one area and not looking at the rest of the film. With US, however, the goal is to focus on one area. Adjust the depth to the area of interest. Filling up the screen with the area of interest will result in a better diagnostic US image.

Gain

Gain is the overall brightness of the image. The ideal is not too bright and not too dark. The gain knob is the one knob that will adjust the overall setting. After first setting the overall gain, minimize dark or light bands across the screen by using the time gain compensation (TGC) knobs. These are usually sliders that adjust brightness along discrete bands across the image. The goal is to have a consistent brightness from top to bottom of the screen.

Frequency

Find a happy medium between penetration and resolution. Use the highest frequency (MHz) you can get away with and still see as deeply as needed.

Focal Position and Number

The US beam has a focus position where the beams narrow to give a more detailed image at a certain depth. The beams do not converge, as we may think of light focusing on the retina, because they will again diverge beyond the focal position. The physics of this can be found in additional references (Nyland 2002). Both the focus position and number of focal points can be set by the sonographer. However, the processor can only handle a certain amount of information and by asking it to do more, it will reduce other items, normally the frame rate, or how many times/second the image is refreshed. High frame rates make for a smooth image, but take a lot of processing power. Low frame rates give a choppy image. Ask the processor to do more and it will respond by giving you a lower frame rate.

For the focused, COAST³, and FAST³ scans, generally keep the focal point number at one, and set the focal point's position at, or just deep to, the area of interest.

Presets, Abdominal, Cardiac, Small Parts, etc.

Even with just these four settings, that's still a lot of knobs to be adjusting in the emergent situation. Modern US machines have a collection of imaging presets which the user may select based upon the area of interest (such as cardiac vs. abdomen vs. small parts and others) and patient size (adult vs. pediatric). It is prudent to remember, however, to adjust your depth.

Alternate Imaging Tools

Up until now, we have been talking about B-mode, or standard 2-dimensional, ultrasonography. A-mode has no practical bearing on the emergency scans outlined in this book and therefore will not be discussed. However, M-mode and color Doppler imaging are used in some focused, COAST³, and FAST³ protocols (see chapters 8 and 11).

M-mode

The "M" in M-mode stands for motion. This mode has also been called the "ice pick" mode because it reflects a small column of US waves but follows it over time. Cardiac US is where M-mode is best known. It can be a little challenging to understand what is being displayed on the screen, but using the B-mode view to show just where that "ice pick" is cutting through is helpful. M-Mode is used not only for certain cardiac studies, but also in certain lung studies and fetal imaging (see chapters 8, 10, and 11).

Color Flow Doppler

Color flow Doppler is used in combination with B-mode ultrasonography. It allows you to see flow of blood within a vessel and helps to determine the direction of that flow. Doppler is best when the flow is parallel with the sound beam. Color signatures are usually set up so that flow toward the probe is red and flow away from the probe is blue, although this can be set on most machines to user preference. Color flow Doppler has its limitations with low velocities.

Color signatures are usually set up so that flow toward the probe is red and flow away from the probe is blue (remember "away" and "blue" have the same number of letters). An alternate form of color flow Doppler, called power Doppler imaging (PDI), can be employed. Similar to color flow, this shows flow of fluid but at much lower velocities. The trade-off is a lack of directionality. Blood flowing 0.5 cm/s away from the probe will have the same color signature as blood flowing at 0.5 cm/s toward the probe.

On The Horizon

Single Crystal Probes

Single crystal probes emit a large bandwidth of sound beams instead of just one, thereby combining the benefits of high-frequency resolution and low-frequency

penetration. The learning curve for imaging is generally much different than that of traditional multicrystal US probes.

Smartphone Applications

At the time of this writing, there is at least one smartphone-powered US device approved by the U.S. Food and Drug Administration (FDA). Technology is advancing quickly and one must wonder what the future holds for US imaging.

Recording Ultrasonographic Findings, Labeling Still Images

Documentation of the Focused, COAST³ and FAST³ Ultrasound Exam

Save the images. A medical record is not complete with just a written description of an image, whether that is a radiograph, an ultrasound image, a computerized tomography (CT), or magnetic resonance imaging (MRI). The image must be there to back it up. Furthermore, the other modalities have information to know exactly where an image was obtained. For the radiograph there are anatomic landmarks; for both CT and MRI, there is a pilot image that records where all the remaining images are obtained. For US images there may not be any definitive markers.

An US image that makes sense to the sonographer when it was recorded may make no sense when under review two days or even two hours later. One of the most common mistakes veterinarians make is not labeling their images. Label the organ or structure of interest and label your orientation (longitudinal vs. transverse) if it is not evident from the image. There will be times when there are no anatomic landmarks evident on the image.

Most US machines have some sort of body pattern that can be placed on the image with an icon to show the approximate location of the probe (Figure 1.4A). Put all labels outside the image, too. Placing words across the image can potentially hide diagnostic information. If you must write across the US image, first save a picture of the unadulterated image and then save a second picture of the annotated image. Short video clips can also be saved on most US machines.

For recording US findings in medical records, see Appendix II with suggested goal-driven templates.



Figure 1.13. The damage to the surface of this probe was attributed to repeated or prolonged contact with isopropyl alcohol. The contact layer is clearly lost over a portion of this probe, negating its ability to serve as an electrical insulator between the probe and patient. It is possible for potentially serious electric shock to occur through the damaged area to the contact area.

Ultrasound Machine and Probe Care

Not all US machines were designed for the battlefield with parts that can sustain a six-foot drop. Most were designed for the relative quiet and safety of a hospital. The US machines and their components can be broken by rough handling and improper use, and replacement can be costly, especially if you drop an US probe and damage its crystals.

The most common misuse of the US machine is probe abuse resulting in probe head damage (Figure 1.13). In the haste of the moment, the attending sonographer will often grab a bottle of isopropyl alcohol, wet down the fur with only the alcohol, and apply the probe. Nearly all US manufacturers list alcohol as an inappropriate liquid to place in direct contact with the probe head because alcohol, over time, can cause probe head damage (Figure 1.13).

Always use acoustic coupling gel on the probe head and be familiar with the US machine's manufacturer guidelines. Importantly, it should be noted that the rubber probe head accomplishes two things. First, it acts as coupling media to transmit the sound wave out of the probe. Second, it is part of an electrical insulator serving as an electrical ground between the patient and the electricity being sent from the US machine to the transducer's crystals. There are no documented electrocutions via a damaged US probe, but theoretically, it's possible.

Avoid probe head damage by using an acoustic coupling media on the probe head as a barrier to alcohol.

Setting up an Ultrasound Program

See Appendix I for information on setting up an ultrasound program.

Pearls and Pitfalls, the Final Say

In summary, this chapter has briefly covered some of the basics. Other textbooks are available that go into more detail regarding US principles and artifacts, and many US courses sponsored by ultrasound companies are available throughout the year to enhance learning (see Appendix V). Also see the editor's website: www.fastvet.com. It is important to be familiar with some of the basic principles, artifacts, and nuances associated with US as an imaging modality for your busy general practice, emergency room, or critical care unit to minimize misinterpretations. It truly is an "extension of the physical examination" and "the modern stethoscope" (Rozycki 2001, Filly 1988).

So there you have it. Turn on your ultrasound machine, apply your coupling medium, and start scanning. Get focused and save lives.

References

- Coltera M. 2010. Ultrasound physics in a nutshell. *Otolaryngol Clin North Am* 43(6):1149–59.
- Filly RA. 1988. Ultrasound: the stethoscope of the future, *alas. Radiology* 167:400.
- Lichtenstein DA, Meziere GA. 2008. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 134(1):117–125.
- Lichtenstein DA, Meziere GA, Lagoueyte J, et al. 2009. A-lines and B-lines. Lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. *Chest* 136(4):1014–1020.
- Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–122.
- Nyland TG, Mattoon JS, Herrgesell EJ, Wisner ER. 2002. Physical principles, instrumentation, and safety of diagnostic

- ultrasound. In: *Small Animal Diagnostic Ultrasound, 2nd edition*, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 1–18.
- Penninck DG. 2002. Artifacts. In: *Small Animal Diagnostic Ultrasound, 2nd edition*, edited by Nyland TG, Mattoon JS. Philadelphia: WB Saunders, pp 19–29
- Reef V. 1998. Thoracic ultrasonography: Noncardiac imaging. In *Equine Diagnostic Ultrasound*, edited by Virginia Reef. Philadelphia: WB Saunders, pp 187–214.
- Rozycki GS, Pennington SD, Feliciano DV, et al. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50:636–642.
- Volpicelli G, Elbarbary M, Blaivas M, et al. 2012. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med* 38:577–91.

THE ABDOMINAL FAST³ (AFAST³) EXAM

Gregory R. Lisciandro

Introduction

A focused assessment with sonography for trauma (FAST) exam was prospectively validated in traumatized dogs by Boysen in 2004. The Boysen (2004) study documented that intra-abdominal injury, and more specifically, hemoabdomen, was far more frequent than previously reported prior to FAST (38%–45% with FAST vs. 12%–23%) (Boysen 2004). The abdominal FAST exam was again prospectively studied in dogs in 2009 (Lisciandro), and findings supported the conclusions of the 2004 study (Boysen) when a higher rate of intra-abdominal injury was again detected (hemoabdomen rate of 27%). The term “AFAST” (abdominal FAST) was coined to better designate the performed FAST scan because the same group was concurrently developing a novel thoracic FAST scan, which they named “TFAST” (thoracic FAST) (Lisciandro 2008). The same prospective AFAST study (Lisciandro 2009) validated an AFAST-applied abdominal fluid scoring system used initially and serially (four hours post admission) in all hospitalized dogs for semi-quantitating volume of intra-abdominal hemorrhage.

Additionally, the Lisciandro (2009) study found that the initial and serial AFAST-applied fluid scoring system reliably predicted the degree of anemia in dogs with hemoabdomen, differentiating lower-scoring “small bleeders” from higher-scoring “big bleeders.” They also found that abdominal radiographic (AXR) serosal detail was a poor predictor for the presence of free fluid. In fact, 24% of cases with normal AXR serosal detail were AFAST positive, and 32% of decreased AXR serosal detail were AFAST negative.

Moreover, AFAST and the use of the patient’s abdominal fluid score (AFS) were invaluable for detecting

developing hemoabdomen (initially negative turned AFAST positive), ongoing hemorrhage (increasing fluid score), and resolution of hemoabdomen (decreasing fluid score). Finally, higher-scoring big bleeder (AFS 3, 4) dogs not only predictably became anemic vs. lower-scoring small bleeder dogs (AFS 1, 2), but they were also more likely to need blood transfusions. The investigators, comparing their results to the 2004 study, surmised that because of the lower transfusion rates in their case population of hemoabdomen dogs, attending veterinarians were likely more judicious in administering fluid therapy during the resuscitation phase of treatment by knowing that their dog had a positive score consistent with hemoabdomen within minutes of presentation at triage. It has been clearly shown in bleeding humans that graduated fluid therapy titrated to more conservative end points minimizes exacerbation of hemorrhage, reducing the probability of the “pop the clot” or re-bleeding phenomenon.

It is noteworthy that dogs with pneumothorax, pelvic fractures, and high alanine transaminase (ALT) were more likely to concurrently have or develop hemoabdomen on either their initial or serial AFAST examinations than dogs without these findings (Lisciandro 2009). AFAST was additionally used to survey for intrathoracic trauma through the acoustic window of the liver and gallbladder via the diaphragmatico-hepatic (DH) view, as previously found (Boysen 2004). The serial use of AFAST was also helpful in determining the integrity of the urinary bladder; both FAST studies found that when the urinary bladder was imaged with a normal contour, it was unlikely to be ruptured. Using AFAST imaging of the urinary bladder, pre and post resuscitation, proved very helpful because the presence of a urinary bladder without using

ultrasound has been traditionally difficult to determine by physical examination, catheterization, and with plain radiography in trauma patients (Boysen 2004, Lisciandro 2009).

Since studying AFAST applied to trauma, the clinical utility of the AFAST scan and its applied fluid scoring system have been found to be helpful for many non-traumatic and post-interventional subsets of patients including those suffering from anaphylaxis, pericardial effusions and tamponade, pleural effusions, and non-traumatic hemoabdomen; for early detection of hemorrhage; and for all forms of peritonitis in presenting and post-interventional cases. Thus, the proposed nomenclature for the AFAST exam has morphed to AFAST³—a beyond-trauma ultrasound scan that rapidly provides important clinical information to better treat our veterinary patients. The “T³” now signifies AFAST³ use for trauma, triage, and tracking (monitoring) (Lisciandro 2011).

In conclusion, FAST is the standard of care for blunt trauma and non-traumatic uncharacterized hypotensive subsets of human patients. A local trauma surgeon a few years ago remarked that he performed 12–18 FAST exams on most busy weekend nights. Likewise, AFAST³ and its sister techniques of TFAST³ and Vet BLUE (chapters 9 and 10) need to be moved to the forefront of veterinary trauma and triage algorithms (Lisciandro 2011).

What AFAST³ and AFS Can Do

- Detect free fluid in small amounts superior to physical examination and abdominal radiography and comparable to the gold standard of computerized tomography (CT)
- Anticipate the degree of anemia in traumatized hemorrhaging dogs without pre-existing anemia by applying an abdominal fluid score (AFS). AFS of 1 and 2 = “small bleeders”; AFS 3 and 4 = “big bleeders.” (AFS acquired by using the AFAST³—applied abdominal fluid scoring system [0–4])
- Anticipate the degree of anemia in dogs with non-traumatic hemoabdomen (ruptured mass, coagulopathic) using the same principles of “small bleeder” (AFS 1 and 2) vs. “big bleeder” (AFS 3 and 4). The AFS works similar to bluntly traumatized dogs in predicting the degree of anemia in this subset of canine patients
- Predict the degree of anemia using the “small bleeder” vs. “big bleeder” concept in post-interventional (percutaneous biopsy, laparoscopy) and

post-surgical (ovariohysterectomy, splenectomy, adrenalectomy, liver lobectomy, nephrectomy, gastrointestinal surgery, bladder surgery, etc.) subsets of small animal patients. AFS helps with decision making regarding re-exploration and other supportive (blood transfusions) and corrective interventions (ligate the bleeder[s])

- Be used serially post-interventionally (percutaneous biopsy, laparoscopy) and post-surgically (ovariohysterectomy, splenectomy, adrenalectomy, liver lobectomy, nephrectomy, gastrointestinal surgery, bladder surgery, etc.) in cases at-risk for peritonitis and other effusive conditions
- Be used serially to monitor for development of previous occult hemorrhage (AFS negative turned positive), ongoing worsening hemorrhage (increasing AFS), or resolution (decreasing AFS) of hemorrhage by tracking AFS over time in all at-risk cases or clinically affected small animals
- Detect clinically significant pleural and pericardial effusions in most instances through the AFAST³ diaphragmatico-hepatic (DH) view
- Detect retroperitoneal effusion through the spleno-renal (SR) and hepato-renal (HR) views
- Be used to screen for anaphylaxis in dogs by observation of the gallbladder double rim or “halo sign”; however, the sonographer should have a working understanding of the causes of false positives
- Be used to assess volume status and right-sided cardiac function by subjectively evaluating caudal vena caval size and for the presence of hepatic venous distension via the AFAST³ diaphragmatico-hepatic (DH) view
- Increase the sensitivity of AFAST in all subsets of patients via serial examinations; a four-hour post-admission exam is minimally warranted in all at-risk hospitalized cases

What AFAST³ and AFS Cannot Do

- Cannot ultrasonographically characterize fluid; thus, sample acquisition via abdominocentesis or diagnostic peritoneal lavage or modified ultrasound-guided (MUG) peritoneal lavage (Chapter 17) is needed when appropriate
- In penetrating trauma, AFAST³ lacks sensitivity (in contrast to blunt trauma where sensitivity is high) but is probably very specific for intra-abdominal and retroperitoneal injury, similar to human studies

- AFAST³ potentially may miss peritonitis in dehydrated or hypotensive patients and thus should always be used in serial fashion post-resuscitation and rehydration out to 12–24 hours post admission
- AFAST³ cannot reliably predict the degree of anemia in bluntly traumatized cats, and large volumes of intra-abdominal fluid are more likely to be due to uroabdomen

Indications for the AFAST³ and AFS Exam

- All blunt trauma cases as standard of care for screening for intra-abdominal injury
- All collapsed (both recovered and unrecovered cases) with unexplained hypotension, tachycardia, or mentation changes
- All anemic cases
- All “ain’t doing right” (ADR) cases
- All post-interventional, post-surgical cases at-risk for bleeding
- All post-interventional, post-surgical cases at-risk for peritonitis and other effusions
- All peritonitis suspects for expedient diagnosis through the detection of free fluid (and sampling, testing as deemed appropriate)
- Add-on for abdominally-related focused or COAST³ Exams to ensure that forms of peritonitis and pleuritis, or presence of bleeding, is not missed by traditional means

Objectives of the AFAST³ and AFS Exam

- Perform the classic AFAST³ views and apply the fluid scoring system
- Apply the “small bleeder” vs. “big bleeder” concept to non-traumatic and traumatic hemoabdomen cases to better direct definitive therapy (medical vs. surgical)
- Recognize the gallbladder “halo sign” and recognize the major causes of false positives
- Recognize pleural and pericardial effusion via the diaphragmatico-hepatic (DH) view
- Recognize retroperitoneal free fluid
- Recognize caudal vena caval size and distended hepatic veins at the DH view
- Be familiar with false positives and false negatives at each AFAST³ site

How to Do an AFAST³ Exam

Ultrasound Settings and Probe Preferences

Standard abdominal settings with depth adjustment to visualize the standardized views are outlined below. A curvilinear (or linear) probe with a range of 5–10MHz is usually acceptable for most dogs and cats.

Patient Positioning

Fur is generally not shaved but rather parted for probe-to-skin contact with the use of alcohol and/or gel. Alcohol should not be used if electrical defibrillation is anticipated (poses serious fire hazard). The clinician should be aware that alcohol may physically cool and be noxious to some patients, and cause probe head damage (Figure 1.13).

By not shaving (or limiting shaving to small viewing windows), the cosmetic appearance of the patient is preserved (happier clients), the exam time is lessened, and imaging quality is sufficient with most newer ultrasound machines (median time less than three minutes) (Lisciandro 2009, 2011).

Right lateral recumbency is generally preferred for AFAST³ because it is standard positioning for electrocardiographic and echocardiographic evaluation (Figure 2.1). Moreover, the left kidney (a window into the retroperitoneal space) at the SR view, and the gallbladder at the DH view (by directing the probe slightly downward toward the table top), are readily and consistently imaged on nearly every exam. Right lateral recumbency is arguably better for abdominocentesis because the spleen lies anatomically on the left side of dogs and cats. Left lateral recumbency may be used in cases in which injury prohibits right lateral positioning, or the right retroperitoneal space warrants imaging.

Modified sternal recumbency positioning may be used for AFAST³ in stressed patients by allowing the forelegs to be in sternal position and moving the hind legs together (placed on the same side as the sonographer) laterally.

Dorsal recumbency should never be used for several important reasons including (Sigrist 2011, Lisciandro 2011):

- The lack of validation of the AFAST-applied fluid scoring system (not validated in either dorsal or sternal recumbency)

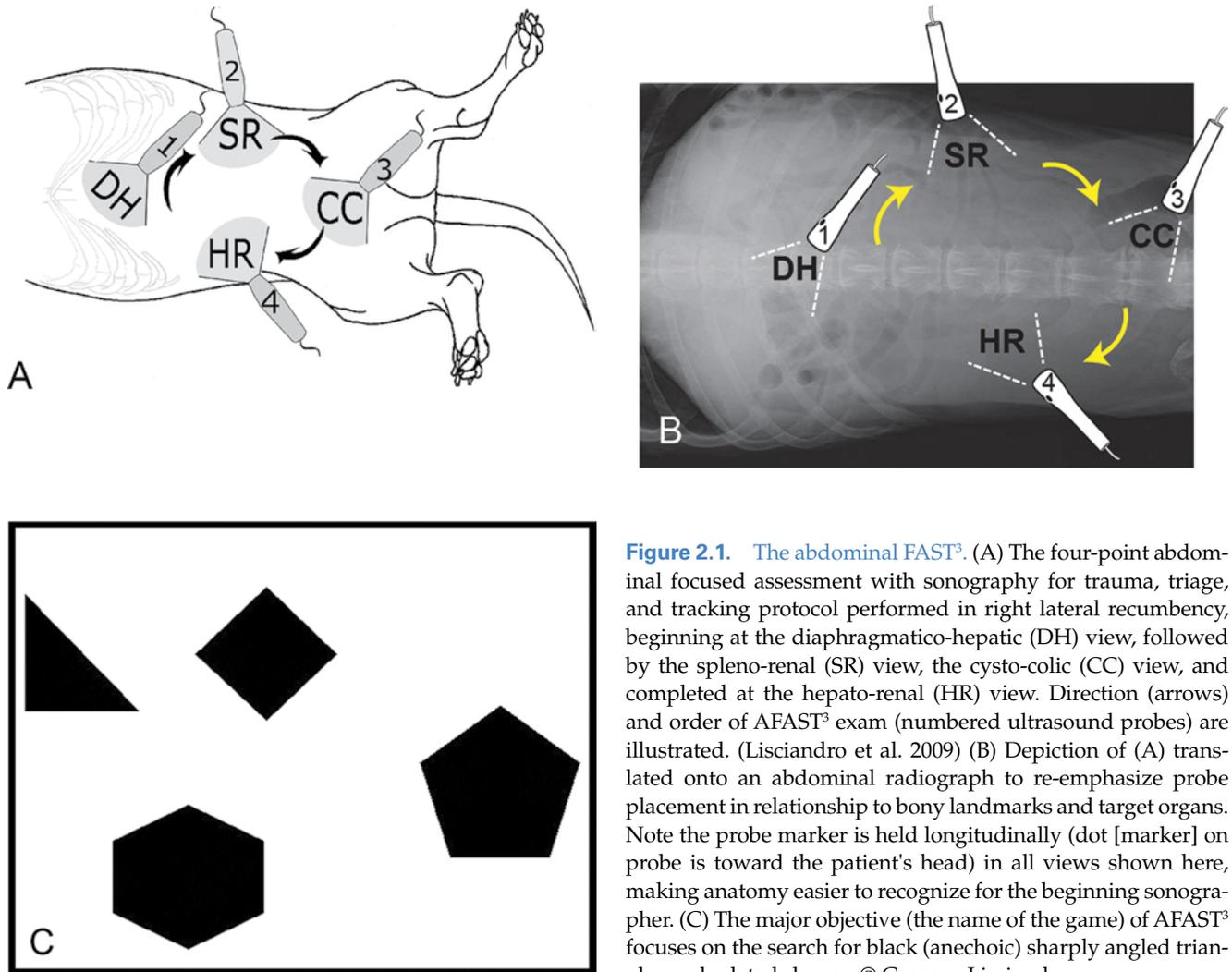


Figure 2.1. The abdominal FAST³. (A) The four-point abdominal focused assessment with sonography for trauma, triage, and tracking protocol performed in right lateral recumbency, beginning at the diaphragmatico-hepatic (DH) view, followed by the spleno-renal (SR) view, the cysto-colic (CC) view, and completed at the hepato-renal (HR) view. Direction (arrows) and order of AFAST³ exam (numbered ultrasound probes) are illustrated. (Lisciandro et al. 2009) (B) Depiction of (A) translated onto an abdominal radiograph to re-emphasize probe placement in relationship to bony landmarks and target organs. Note the probe marker is held longitudinally (dot [marker] on probe is toward the patient's head) in all views shown here, making anatomy easier to recognize for the beginning sonographer. (C) The major objective (the name of the game) of AFAST³ focuses on the search for black (anechoic) sharply angled triangles and related shapes. © Gregory Lisciandro

- The high risk to compromised trauma patients (prevalence of thoracic injury and hemoabdomen is high, approximately 50%–60% and 27%–45%, respectively, in dogs with vehicular trauma)
- The stress it causes in respiratory-compromised and hemodynamically fragile non-trauma patients

Naming and Order of the AFAST³ Views

The AFAST³ sites in preferred right lateral recumbency are named according to target organs and are pursued in a counterclockwise order as follows (Figure 2.1):

1. Diaphragmatico-hepatic (DH) view, or “designated hitter” site, because the DH view is part of both the AFAST³ and TFAST³ exams for intra-abdominal

- and intrathoracic imaging, serving as an acoustic window into the pleural and pericardial spaces
2. Spleno-renal (SR) view, also used as a window into the retroperitoneal space
3. Cysto-colic (CC) view
4. Hepato-renal (HR) view, or “home run” site because it completes the AFAST³ exam and is a favorable site for abdominocentesis

Internal ultrasonographic anatomy is better appreciated by imaging using the target-organ approach, and thus the sonographer is building focused ultrasound skills on every AFAST³ exam.

For beginners, all AFAST³ sites are imaged in longitudinal view with the marker of the probe directed toward the patient's head. In longitudinal orientation,

target organs appear in a more recognizable view (than transversely) for the novice. Furthermore, the single longitudinal view is supported by a previous FAST study in which longitudinal and transverse views matched 399 out of 400 views (Boysen 2004).

Stay in longitudinal orientation while fanning with your probe when learning AFAST³ because abdominal organs are more recognizable (than transverse orientation).

AFAST³ Diaphragmatico-Hepatic View

The classic DH view (nicknamed the “designated hitter” because the DH is part of AFAST³ and TFAST³ and is used for intra-abdominal and intrathoracic imaging) initially begins with longitudinal placement of the probe (marker toward the head) immediately caudal to the xiphoid process. The probe is directed toward the patient’s head (Figure 2.2A) and the gallbladder “kissing” the diaphragm is imaged by keeping the probe toward the head and scanning slightly downward toward the table top (Figure 2.2B).

The gallbladder wall and its shape should be noted, and the gain may be adjusted based on the echogenicity of its luminal contents for the remainder of the AFAST³ exam.

In the event the gallbladder is not visualized, its rupture or displacement (diaphragmatic herniation) should be considered in light of the patient’s history, presenting complaint, other diagnostic findings, and major rule outs (see Figures 3.2E and F, 3.14D, and 9.21).

Once this classic DH view is appreciated, fanning upward away from the table top through the liver lobes while keeping the diaphragm in view and maintaining its depth into the thorax during the scanning is optimal (Figure 2.2C). In low-scoring dogs, one of the most common positive sites is the DH view (along with the CC view).

Small volumes of fluid are typically between the liver and diaphragm and between liver lobes; this is seen by fanning upward away from the gallbladder (but you should also fan downward [toward the table top] as well) (Figure 2.2C and D).

The sonographer should now use the DH view advantageously (less lung [air] interference) as an

Keep 25%–33% of the far field as a window into the thorax as you fan through the DH view. This may not be possible in large dogs because the distance exceeds the maximal imaging (distance) window of the ultrasound machine (Figure 2.2E).

acoustic window (via the liver and gallbladder) into the thorax.

Always look into the thorax. If pleural or pericardial effusion is suspected, the TFAST³ pericardial site (PCS) views should be added (see Chapter 9) for confirmation or refutation of the AFAST³ DH view’s intrathoracic suspicion, unless, however, the DH view clearly shows the distinction between pleural and pericardial effusion (Figures 2.2E and 2.3; also see Figures 9.17 and 9.18).

Always look into the thorax for pleural and pericardial effusions. A recent retrospective review showed that 88% of clinically relevant pericardial effusions were detected by the DH view (Lisciandro 2012, unpublished data) (Figure 2.3A and B; also see Figure 9.17).

Diaphragmatico-Hepatic View and Pericardial Imaging

The canine and feline heart and pericardial sac do not normally rest on the diaphragm (as in humans). Thus, these structures may be unreliably visualized in normalcy in dogs and cats because of the air-filled gap (lung) which lies between the diaphragm and heart (ultrasound does not transmit through air). In most cases of clinically relevant pericardial effusion, however, diagnosis may be made via the AFAST³ DH view, especially in cats and small to medium-sized dogs (Figure 2.3). If an adequate discriminatory DH view is not possible, the pericardial sites of TFAST³ should be used in combination with the DH view for clarity (see Figures 9.18 and 9.19).

The axiom “One view is no view” should be taken seriously if pleural vs. pericardial fluid cannot be clearly discriminated because it is possible to mistake normal or dilated cardiac chambers for pleural and pericardial effusions, thus potentially leading to the most catastrophic of mistakes of performing centesis on a heart chamber (see Figure 9.14 as well as Chapter 11).

The reader should additionally review the section DH View for Pericardial Effusions in this chapter and the section on the TFAST³ pericardial site (PCS) and its pitfalls in Chapter 9.

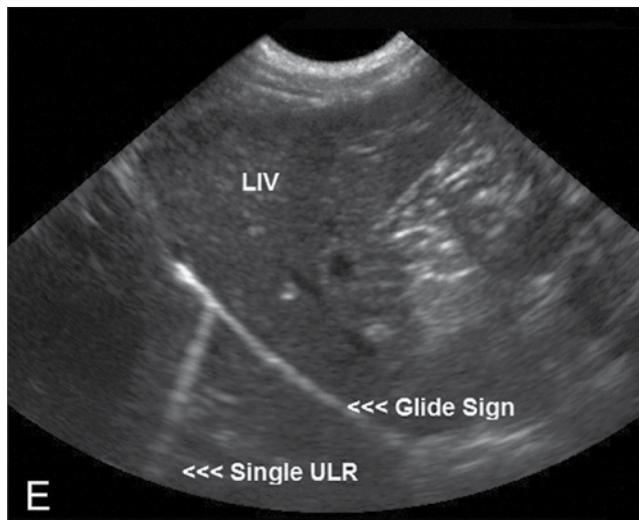
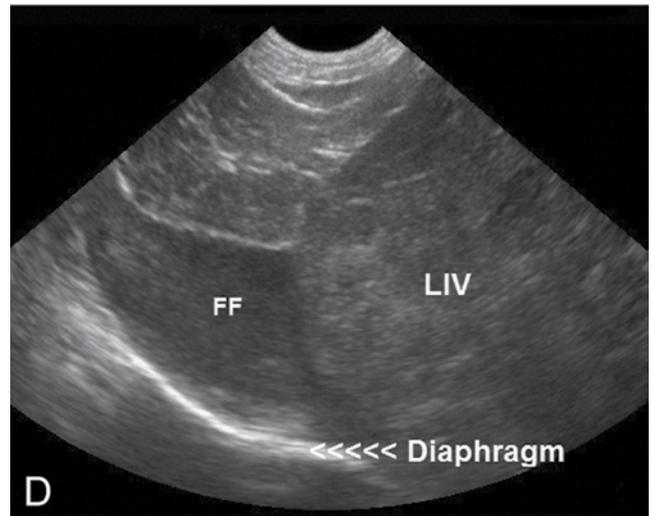
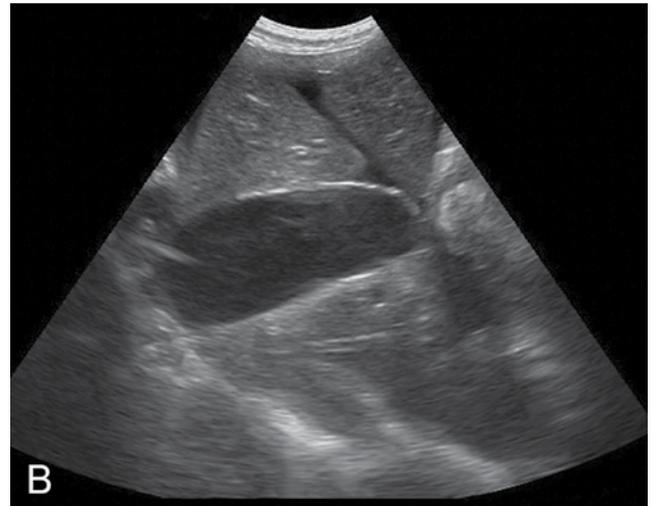
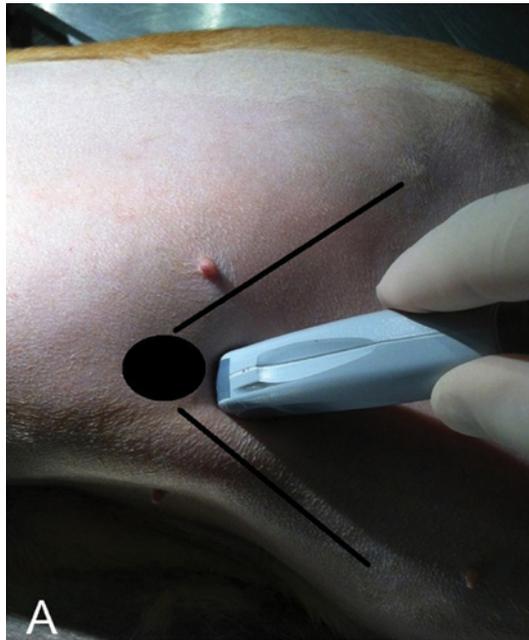


Figure 2.2. The AFAST[®] diaphragmatico-hepatic view. (A) Photo of probe placement at the DH view in right lateral recumbency on a dog. The probe is positioned longitudinally (marker toward the head) just below the xiphoid (solid black oval) with the costal arch outlined by black lines. Keeping the probe at the angle shown, directed toward the head (with probe marker also toward the head), and then fanning toward the table top, brings the gallbladder “kissing the diaphragm” into view. By fanning back through the original DH starting point and then away from the table top (to the patient’s left side), the confluence of liver lobes and their margins are surveyed for interposing free fluid, completing the DH scan. (B) The classic ultrasound image at the DH view begins with imaging the gallbladder kissing the diaphragm by directing the probe toward the table top (to the patient’s right side). Note the anechoic (black triangles) in between liver lobes,

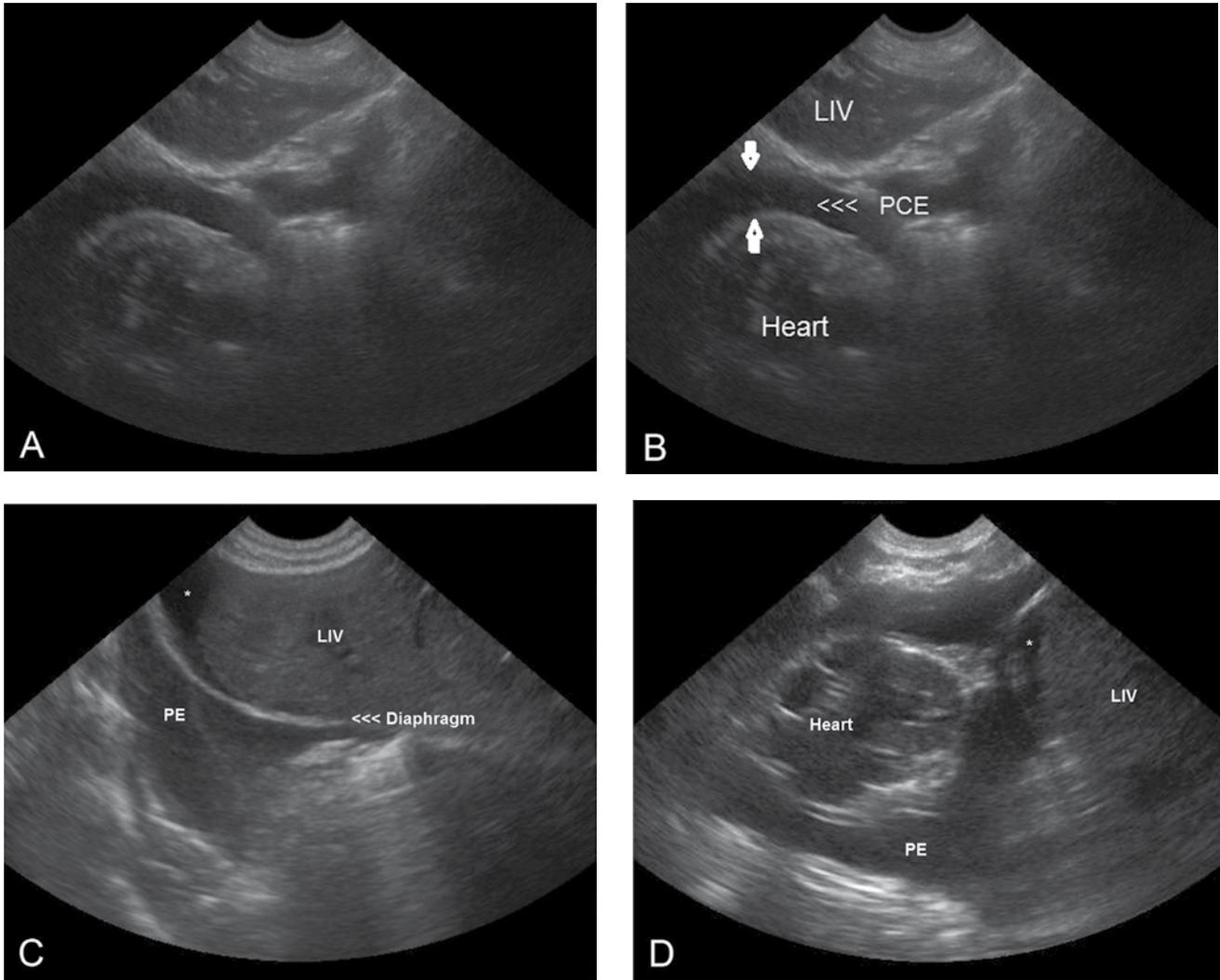


Figure 2.3. The diaphragmatico-hepatic view is part of both the AFAST³ and TFAST³ exams. (A) The image shows a DH view into the thorax of a dog revealing pericardial effusion (PCE). (B) The same image as in (A) but labeled with arrows showing the borders to the circular rim of contained pericardial fluid (PCE) within the pericardial sac (called the “race track sign” by the author). The liver (LIV) and heart are labeled. In most clinically relevant cases of PCE, the DH view will be diagnostic. In contrast, (C) and (D) show pleural effusion in a cat. (C) Pleural effusion (PE) from the DH view is suspected. Note there is also a small volume of intra-abdominal free fluid (*) in between the diaphragm and liver lobes (LIV). The fluid is not contained within a rim of anechoic fluid as compared to pericardial effusion in (B), but rather a large anechoic triangle of free fluid typical of pleural effusion is evident. (D) Pleural effusion (PE) is confirmed by adding the TFAST³ pericardial site (PCS) showing that the intrathoracic free fluid is not contained from a second confirmatory (TFAST³ PCS) view (again revealing irregular fluid borders) (pleural effusion, PE; free intra-abdominal fluid [*]; liver, LIV). Adhering to the axiom “One view is no view” by using the DH and at least a single PCS view prevents mistaking dilated (or normal) heart chambers for pericardial or pleural effusion. Keep in mind that the presence of both pericardial and pleural effusion occurs in some patients. © Gregory Lisciandro

← making this image positive. (C) Next, fan back through the DH starting point and away from the table top (to the patient's left side) through the confluence of liver lobe margins, looking for free fluid. This image is also AFAST³-positive. Note the tips of liver lobes highlighted by the free fluid. (D) Typical free fluid (FF) positive as a large anechoic (black) triangle in between the falciform fat and ligament (near cranial field) and the liver (LIV) and diaphragm. (E) A single ultrasound lung rocket extends from the lung's surface normally positioned against the diaphragm. There is a “glide sign” along the lung-diaphragm interface similar to the “glide sign” of lung along the thoracic wall (see TFAST³, Chapter 9). Each of these images shows a good depth into the thorax for detecting pleural and pericardial effusions, and each hints of mirroring the liver into the thorax (mirror artifact), especially (E). © Gregory Lisciandro

The axiom “One view is no view” should be taken seriously because it is possible to mistake normal or dilated cardiac chambers for pleural and pericardial effusions, potentially leading to the most catastrophic of mistakes of performing centesis on a heart chamber.

Diaphragmatico-Hepatic View and Ultrasound Lung Rockets

Ultrasound lung rockets (ULRs) are typically present to a small extent (none to one or two ULRs) along the diaphragm in normal dogs and cats (Figure 2.2E; also see Figures 9.15 and 10.14). Their presence and the glide sign along the diaphragm may be used to determine whether pneumothorax (PTX) is present. The sensitivity and specificity for PTX using the DH view is unknown, however, and it should be kept in mind that the DH view does not represent the highest point (where air would accumulate) on the thorax as does the preferred and documented reliability of the TFAST³ chest tube site (CTS) view (highest point) (Lisciandro 2008).

Diaphragmatico-Hepatic View and Preload Volume Status, Indirect Right-Sided Cardiac Assessment

Finally, the “advanced” DH view includes evaluating patient volume status by generally directing the probe slightly further downward (it may also be slightly upward depending on the patient’s anatomy, concurrent conditions) from the gallbladder (in right lateral recumbency) and imaging the caudal vena cava (CVC) as it passes through the diaphragm (Figure 2.4; also see Figures 11.8, 11.9, and 16.2). The CVC looks like a large “equal sign” created by the near field and far field venous walls. Furthermore, the CVC wall in the far field appears as a bright white line because of the acoustic enhancement of the ultrasound beam as it travels through its lumen, helping to rapidly identify the CVC (Figure 2.4, also see Figure 11.9). Subjectively, caudal vena caval diameter and hepatic venous distension may be assessed, the latter by tracing the hepatic veins as they branch into the CVC (Nelson 2010) (see Figures 16.8 and 11.8 and 11.9). Generally speaking, if the hepatic veins are obvious, often appearing as tree trunks (hepatic veins are not readily seen during the DH scan in normalcy), the patient’s volume status and right-sided cardiac function should be questioned and appropriately investigated (volume overload, right-sided heart

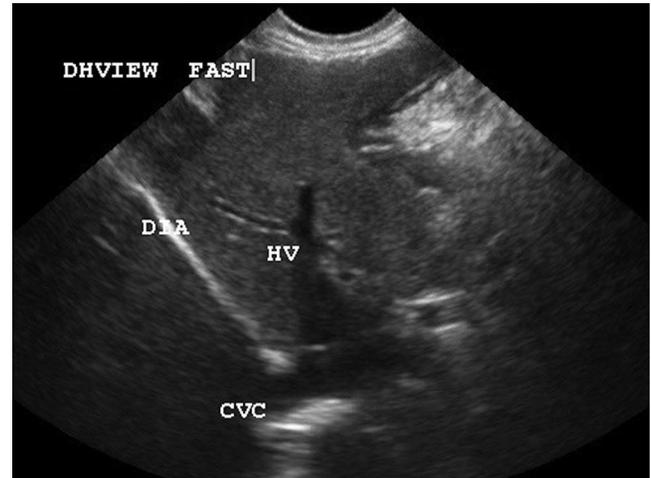


Figure 2.4. The DH view may be used for right-sided volume status (preload) during resuscitation and in at-risk patients for volume overload during fluid therapy. After imaging the classic starting point of the gallbladder kissing the diaphragm, direct the probe slightly more downward toward the table top (to the patient’s right side) searching deeper (the far field along the diaphragm) while maintaining the same original longitudinally held probe angle. You should be able to achieve the image shown with the caudal vena cava (CVC) passing through the diaphragm and its branching hepatic veins. Especially note the brightness from acoustic enhancement of the CVC’s far field wall (the two walls look like an equal sign as they traverse the diaphragm). Shown here is a dog with right-sided heart failure and its caudal vena cava as it passes through the diaphragm (CVC) and the liver with overly distended hepatic veins (HV) draining into the CVC. Normally, the hepatic veins are not obvious; thus, when hepatic veins are overtly obvious (as shown here) as they branch into the CVC (appear like tree trunks), clinical suspicion should be raised regarding right-sided heart status, volume overload, and the possibility for obstructive lesions between the right atrium and liver as applicable to the patient’s clinical picture (also see Figures 11.8 and 11.9 and 16.2 in chapters 11 and 16, respectively). © Gregory Lisciandro

failure, obstructive conditions between the right atrium and liver, i.e., caval syndrome, Budd-Chiari-like conditions, hepatic cirrhosis (also see Figures 3.3, and 3.10A, B, and E).

Additionally, volume status may be further assessed using the TFAST³ PCS view for contractility and left ventricular (LV) filling (the LV short-axis “mushroom view”) (see Figures 9.12, 9.14, 9.16, and 16.2, and Chapter 11) and its CTS view for presence of pulmonary edema (ULRs) (Figures 9.6; 10.7, 10.14, and 10.16; and 16.2).

Once the acquisition of the gallbladder kissing the diaphragm view is mastered, the sonographer should add on the right-sided cardiac volume status evaluation by generally directing the probe slightly downward (in some patients slightly upward) toward the table top (right lateral recumbency). This builds skills in evaluating for caudal vena caval diameter (as it passes through the diaphragm) and associated hepatic venous distention, using them as markers for right-sided heart status and patient volume status including use in pre- and post resuscitation.

Classic Diaphragmatico-Hepatic Positives

The classic intra-abdominal positives at the DH view are usually seen while moving upward (away from the table top) from the gallbladder, typically in between the divisions of the liver lobes, between the liver and the diaphragm, or between the liver lobes and the falciform ligament and fat. It is important to recognize that the falciform ligament and fat are typically hyperechoic (bright) in the near field and have coarser echotexture relative to the liver (Figure 2.2B through D; also see Figure 3.2).

The most common AFAST³-positive sites in low-scoring (AFS-1 and -2 dogs) are the non-gravity dependent DH and CC views, so pay special attention to the presence of anechoic triangles (free fluid) while fanning through liver lobes (Figure 2.15).

The classic pleural and pericardial positives are clearly located on the other side of the diaphragm, and should be confirmed with the TFAST³ PCS views if the sonographer is not able to confidently interrogate the effusion via the DH view (Figures 2.3 and 2.17; also see Figures 9.17 and 9.18).

Pitfalls of the Diaphragmatico-Hepatic View

The DH view has many artifacts including mirror image (Figures 1.7 and 3.9D), acoustic enhancement (Figures 1.6 and 3.6A and C), side-lobe, and edge shadowing (Figure 1.5). It is very important to be familiar with these artifacts as well as false positives (listed after artifacts) at the DH site because it is the most common positive (along with the CC site) in low-scoring AFS-1 and -2 dogs (see Chapter 1).

Artifacts

The DH view is the classic site for the creation of the mirror image artifact. The strong air-soft tissue interface between the lung-diaphragm and liver is misinterpreted, so to speak, by the ultrasound machine, which displays the liver and its structures flipped into the thoracic cavity (Figure 2.2C and E; also see Figures 1.7, 3.9D). The classic misdiagnosis of a diaphragmatic hernia has occurred by the novice; and odd-shaped mirroring of the gallbladder into the thorax may be mistaken for pleural effusion.

The gallbladder will make the soft tissues distal through its fluid-filled luminal contents appear much brighter (hyperechoic) than soft tissues adjacent to this ultrasound path. Typically this includes the liver and lung in the far field (see Figures 1.6 and 3.6A and C).

Side-lobe and edge shadowing artifacts result in loss of interpretative clarity by the ultrasound machine along any luminal borders, falsely making it appear that the lumen contains sediment or other intraluminal abnormalities, or has defects in its wall, respectively (see further explanation in Chapter 1 and Figures 1.5 and 1.10). A good way to remember that side-lobe artifact mimics sediment is that “side” may be rearranged to spell “sedi.”

False Positives

The gallbladder and its biliary system can look like free fluid and anechoic sharp angles. This false positive is easily avoided by fanning and connecting the gallbladder to its biliary tree (Figure 2.5A; also see Figures 3.2A and B).

Hepatic and portal veins (not normally obvious) can look like free fluid and anechoic sharp angles. This false positive may be easily avoided because most free fluid is not as linear as the venous system, and the venous system in most instances can be traced and seen branching (Figure 2.4; see also Figure 11.8). Color flow Doppler may be used to distinguish the venous system from free fluid but is rarely needed (Figure 2.5B).

Differentiating hepatic from portal veins may be done a couple of ways. Portal veins have more hyperechoic (brighter) walls when compared to hepatic veins (and often appear as hyperechoic [bright white] equal [=] signs, Figure 3.10A and B); hepatic veins branch into the caudal vena cava (Figure 2.4; also see Figures 11.8, 13.1D, and 16.2).

The stomach wall may look like free fluid. Typically the sonographer should stay away from this area during the DH view. The stomach has a sonolucent (dark or black) component to its wall, which typically

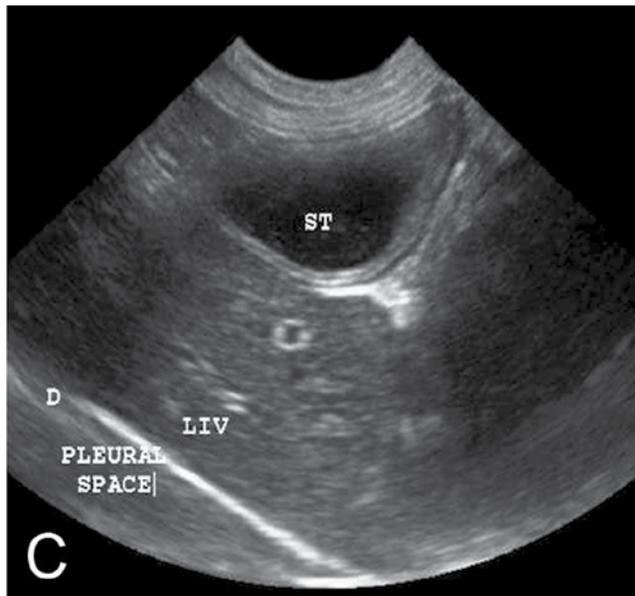
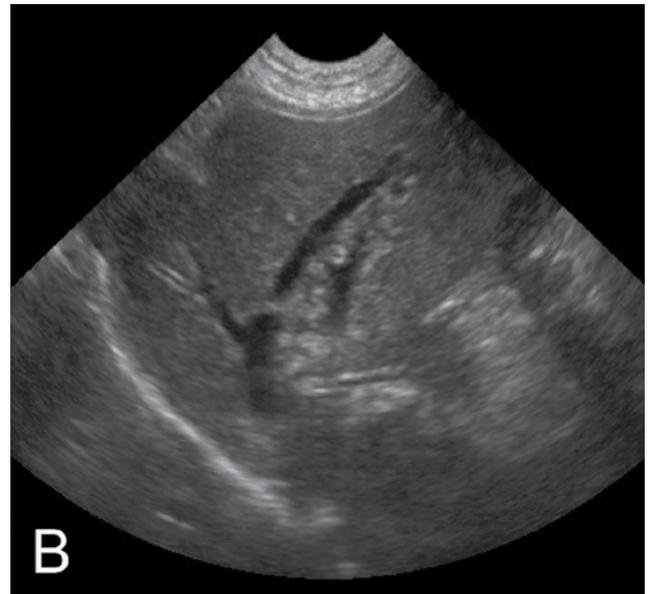
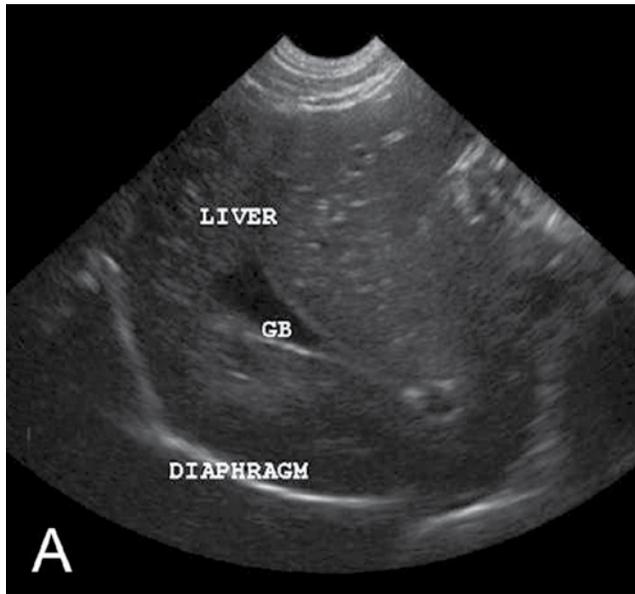


Figure 2.5. False positives at the DH view. (A) Mistaking the gallbladder and its ductal system for free fluid. Shown is an anechoic triangle (GB) that is actually part of the bile-filled gallbladder and not free fluid. Fanning through the DH view avoids this error because the gallbladder and its ductal system are more fully appreciated in real-time imaging. (B) Hepatic and portal veins can be mistaken for free fluid. Fanning through the DH view allows for tracking the venous system and prevents this error. Color flow Doppler may be used but is rarely needed. In general, portal veins have hyperechoic (bright white) walls when compared to hepatic veins; the latter can be identified as they branch from the caudal vena cava (Figures 2.4, 11.8, and 11.9). (C) Margins of the stomach wall (ST) may appear anechoic and be mistaken for free fluid. Note the stomach's lumen is fluid-filled (anechoic). In general, recognize this stomach wall error as such and avoid it by directing your attention to areas between the liver lobes and diaphragm, which are the most common DH locations for free fluid. Serial exams are key to increasing the sensitivity of all FAST³ exams, especially when small amounts of free fluid are suspected. © Gregory Lisciandro

appears linear in real-time imaging. The stomach wall is also subject to artifacts such as edge shadowing (see Figure 1.5). Both related artifact(s) and the sonolucency of the stomach wall can be mistaken for free fluid (Figure 2.5C).

Stay away from the stomach area; it is generally too far caudally for the DH view.

False Negatives

Serial AFAST³ exams increase sensitivity. Don't sweat questionable small pockets of free fluid. Serially repeat the AFAST³ exam at least a second time four hours later.

Repeat AFAST³ serially in four hours post-admission (sooner as clinical course dictates), or after resuscitation and rehydration. The four-hour post-admission rule of thumb is supported by the American College of Emergency Physicians (ACEP) guidelines (www.acep.org) as standard of care.

The AFAST³ Spleno-Renal View

The classic spleno-renal (SR) view includes the visualization of both the spleen (peritoneal cavity) and the left kidney (retroperitoneal space) (Figure 2.6A).

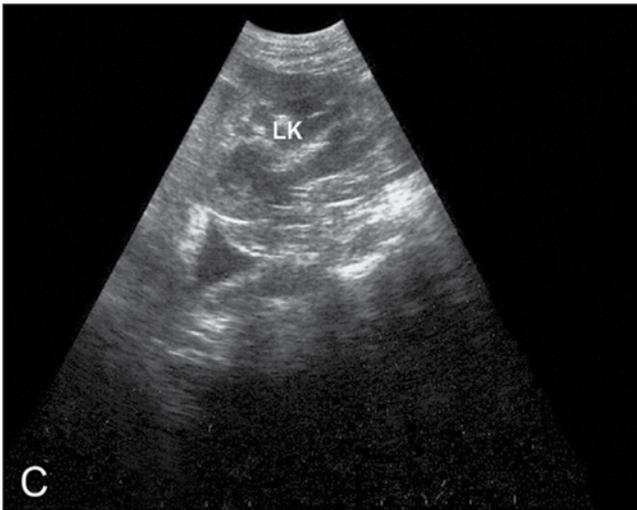
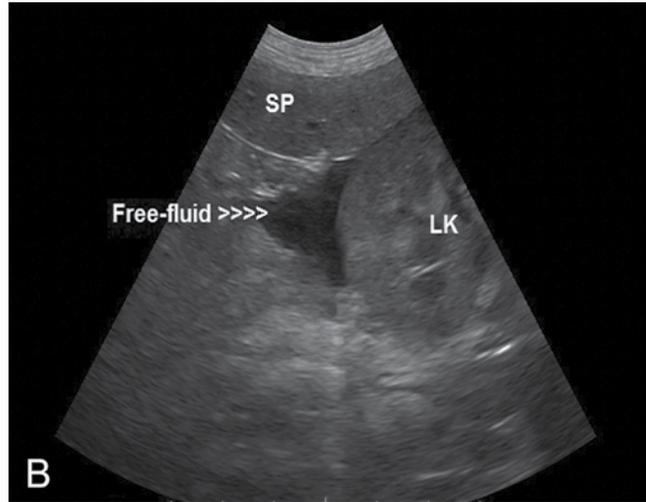


Figure 2.6. The classic AFAST[®] spleno-renal view includes the spleen and the left kidney. (A) Photo of the SR view in right lateral recumbency on a dog. The probe is positioned longitudinally (marker toward the head) more or less parallel to the spine just caudal to the costal arch because the kidney is more recognizable in longitudinal orientation. By keeping the probe at the angle shown and the probe marker directed toward the head, fanning toward the table top often brings the left kidney and spleen into almost immediate view. After doing so, fan back through the original starting point and then away from the table top to further image the retroperitoneal space and its great vessels (aorta and caudal vena cava). (B) The spleen normally runs its course with its tail just reaching the left kidney. Use this trick to help find the left kidney (follow the spleen caudolaterally to help find the left kidney). Shown is the spleen (SP) in the near field and the left kidney (LK), with a classic positive image of free fluid (anechoic triangle) in between. (C) The left kidney is obvious with an associated classic anechoic (black) triangle of free fluid (typically the triangle of free fluid is located between the left kidney and wall of the colon). (D) SR positive with an anechoic (black) triangle (or diamond) of free fluid located in an area where the spleen and left kidney are not obvious. (E) A final SR positive with free fluid as an anechoic (black) triangle shape again as in (D) without a recognizable spleen or left kidney. © Gregory Lisciandro

The SR target organs are readily imaged in the preferred positioning of right lateral recumbency by placing the probe longitudinally just caudal to the last rib and fanning cranially under the rib and then moving caudally.

The spleen may be used to locate the left kidney by following it caudally and laterally because of its anatomical association with the left kidney (Figure 2.6B).

Fanning dorsally is also recommended to screen for any pathology associated with the great vessels (aorta and caudal vena cava). The great vessels are common confounders and cause false positives, which may be easily overcome by remembering that positives are rarely anechoic (black) stripes (vessels and intestinal tract) but rather anechoic (black) triangles (free fluid) (Figure 2.8C and D, below).

The great vessels may be discriminated by the anechoic (black) linear stripe in longitudinal view as well as by observing for pulsation. Turning your probe transversely (turn left or counterclockwise) should change the linear stripe to an anechoic (black) circle representing the vessel's lumen in cross section.

Retroperitoneal fluid in this area should raise the suspicion for hemorrhage, urine, and sterile and septic effusions. Cranially, fluid sources would include the kidneys, vertebral bodies, and the great vessels and adrenal gland, and caudally, the kidneys, ureters, vertebral bodies, and pelvis (Figure 2.9A and B below; also see Figures 5.6, 5.8, and 5.14).

Retroperitoneal fluid is not part of the abdominal fluid score (AFS) but should be noted and its widest depth measured by either the eyeball method (using the centimeter scale on the far right of the US image) or using the caliper function on your machine.

Classic Positives

The majority of positives at the SR view are classically anechoic (black) triangles formed between the spleen and colon (Figure 2.6B through E).

Artifacts

Generally the SR view has few artifacts, most of which are colon related.

The colon's air-causing interference (cannot image through air) is usually not problematic because dogs and cats in right lateral recumbency have their colon (by gravity) fall away from the SR view. However, it is not uncommon for the air-filled colon to cause a "dirty" shadow in the far field (Figure 2.7; also see Chapter 7).

False mirror image in cats. Especially in cats and rarely in small dogs, both kidneys will be apparent in the SR view. It is unlikely to be a mirror image artifact (Figure 2.7).

False Positives

Linear anechoic stripes rarely represent free fluid and are more likely small intestine (intra-abdominal) or the great vessels (retroperitoneal). Color flow Doppler is rarely needed to decipher between these structures and free fluid but may be used (Figure 2.8C and D). Also, small intestine will look like small hamburgers when the bowel segment is viewed in cross section by rotating the probe (Figure 2.8B; also see Figures 7.3 and 7.4).

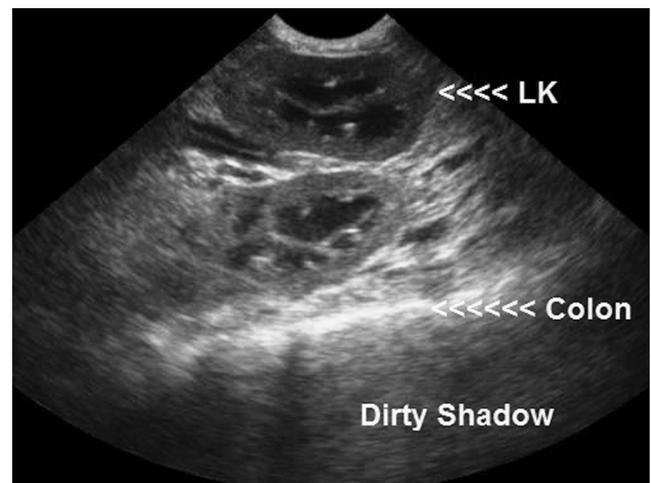


Figure 2.7. The SR view is from a cat and shows both left (LK) and right (unlabeled) kidneys in the same view. This is not a mirror artifact. In some small dogs both kidneys may also be imaged from the SR view. Commonly, the descending colon, which runs along the left side of dogs and cats, is gas-filled, which obscures distal or far-field imaging and causes a "dirty shadow" artifact. Lateral recumbency is advantageous in that the often air-filled (US does not transmit through air) small and large intestine fall away from the kidney at the non-gravity dependent site (SR in right lateral; HR in left lateral), facilitating ultrasound imaging. ©Gregory Lisciandro

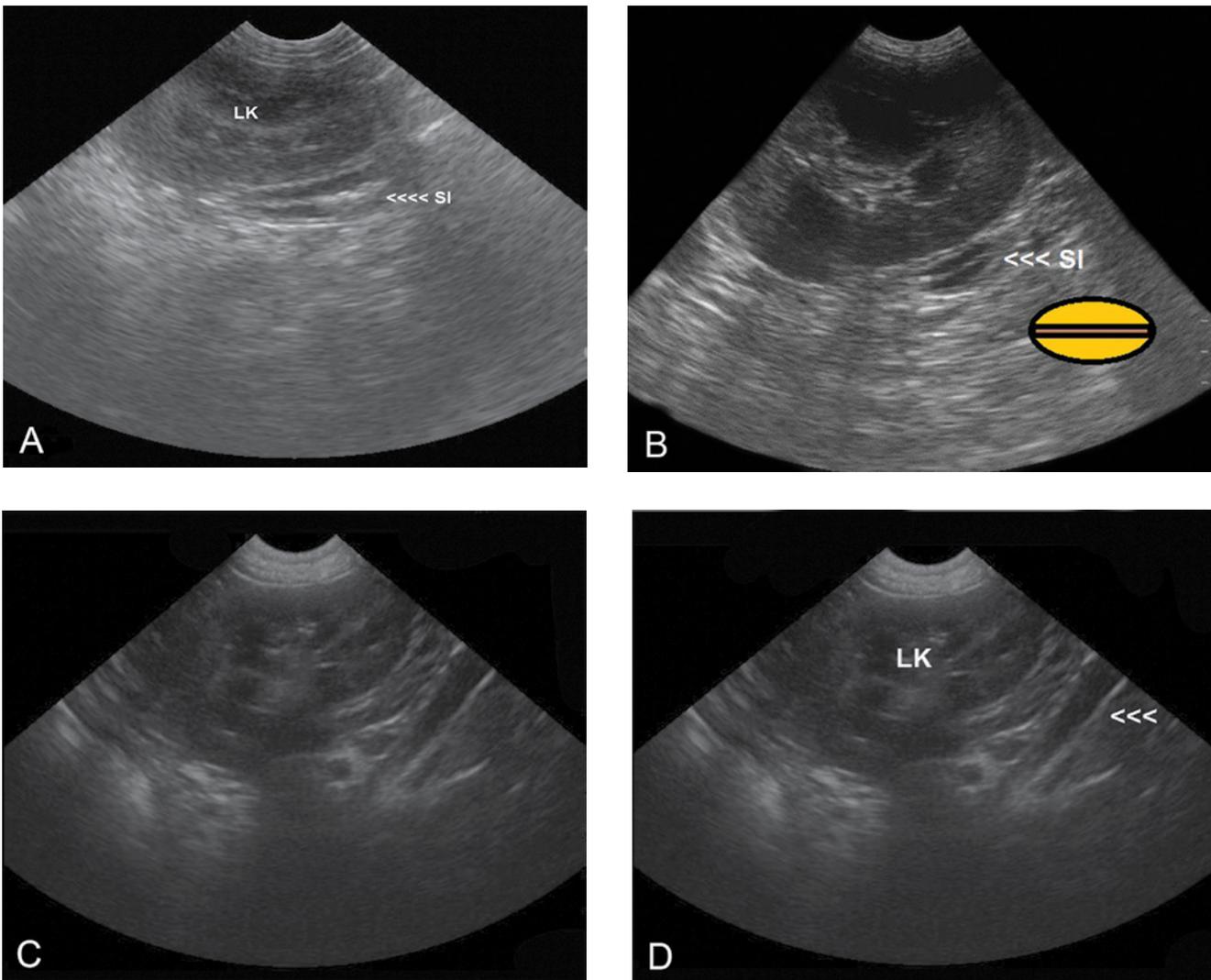


Figure 2.8. False positives at the SR view typically involve the small intestine (ventral to SR) and the great vessels (dorsal to SR, aorta and caudal vena cava). Typically they appear as anechoic stripes (linear), which is atypical of free fluid (free fluid is classically revealed as anechoic [black] triangles). (A) Shown here is a linear stripe in the immediate far field to the kidney which is not free fluid but rather a loop of small intestine (SI). (B) By turning (the probe) left (counterclockwise) the SI is imaged in standard transverse orientation and appears as a classic “hamburger” (see Chapter 7). (C) The great vessels (also linear stripes) as false positives are recognizable in the majority of instances without color flow Doppler by observing for pulsation (aorta) and considering the probe direction (dorsal to the SR starting point), and turning (the probe) left for standard transverse imaging (normal flowing vessels become anechoic [black] circles) (see Chapter 12). (D) The same image labeled as left kidney (LK) and cursors (<<<) to the anechoic (black) linear stripe coursing at a 45-degree angle as a great vessel (linear anechoic [black] stripe) and not free fluid (typically anechoic [black] triangles). © Gregory Lisciandro

Remember, classic positives at the SR view are anechoic (black) triangles, not linear stripes.

The problem of retroperitoneal fluid vs. peritoneal fluid in people differs from our veterinary patients that are generally less obese and have a

suspended (vs. attached) colon by its mesocolon. In lateral recumbency, retroperitoneal fluid will remain static and not fall away from the field of view. Zooming out, or increasing depth, also helps interrogate the two spaces (Figure 2.9A and B; also see Chapter 5).

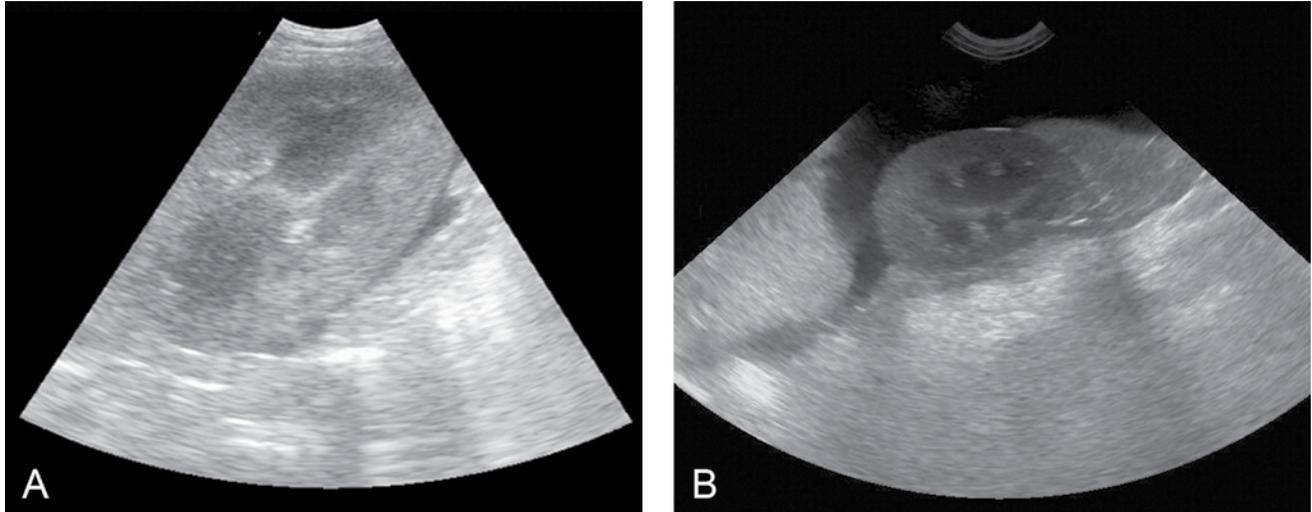


Figure 2.9. Retroperitoneal vs. peritoneal fluid at the SR view. (A) The image shows a small rim of retroperitoneal effusion that is easily discriminated from peritoneal fluid by zooming away (increasing depth). The thin rim of fluid shown is classic for acute kidney injury and is from a dog with heat stroke. The fluid resolved 24 hours later (serial exam) as its kidney failure resolved. Note that such a small rim of fluid is not safely amenable to sampling by aspiration. (B) The image shows a large peritoneal effusion that is easily discriminated from retroperitoneal fluid by zooming away (increasing depth) as well as placing the kidney of interest on the non-gravity dependent side (left kidney imaged in right lateral recumbency; right kidney imaged in left lateral recumbency) because confounding structures fall away. Retroperitoneal fluid is not scored as part of the abdominal fluid scoring system. © Gregory Lisciandro

False Negatives

Serial AFAST³ exams increase sensitivity. Don't sweat questionable small pockets of free fluid. Serially repeat the AFAST³ exam at least a second time four hours later.

Repeat AFAST³ serially in four hours post-admission (sooner as clinical course dictates), or after resuscitation and rehydration. The four-hour post-admission rule of thumb is supported by the American College of Emergency Physicians (ACEP) guidelines (www.acep.org) as standard of care.

The AFAST³ Cysto-Colic View: The Little Fib

The classic cysto-colic (CC) view includes imaging the urinary bladder (when present) “kissing” the abdominal wall by longitudinally placing the probe on top of the site and directing the probe into the gravity dependent pocket formed between the bladder and the ventral body wall (Greg’s pouch) (Figure 2.10A and B). The CC view is slightly a misnomer, or a “little fib,” because of its target organs; only the bladder is imaged, whereas the colon is not. It is important to remember,

though, that an air-filled colon will obscure imaging (ultrasound does not transmit through air), and because of its air-filled proximity may create some odd-appearing bladder images.

Classic Positives

The classic CC positive in a small volume effusion is a small anechoic (black) triangle at the base of Greg’s pouch between the urinary bladder apex and the body wall (Figure 2.10C). Large-volume positives are usually easy to see in real-time with the wafting movement of small intestines and omentum (Figure 2.10D and E).

Artifacts

Acoustic enhancement artifact: The fluid-filled urinary bladder makes the soft tissue distal through it brighter (hyperechoic). By the recommended probe positioning above, the body wall will be bright in the far field in the Greg’s pouch because of this artifact (see Figures 1.6 and 6.9). The artifact is readily seen along the ventral abdominal wall in Figure 2.10C and D.

Reverberation and shadowing artifact: An overlying air-filled colon can obscure the far field, making

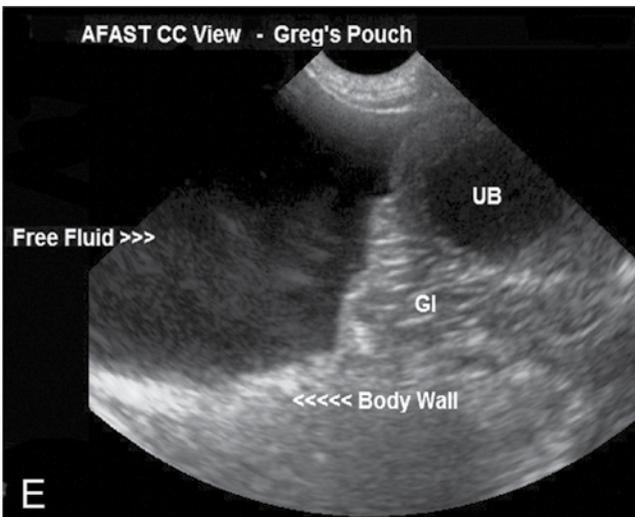
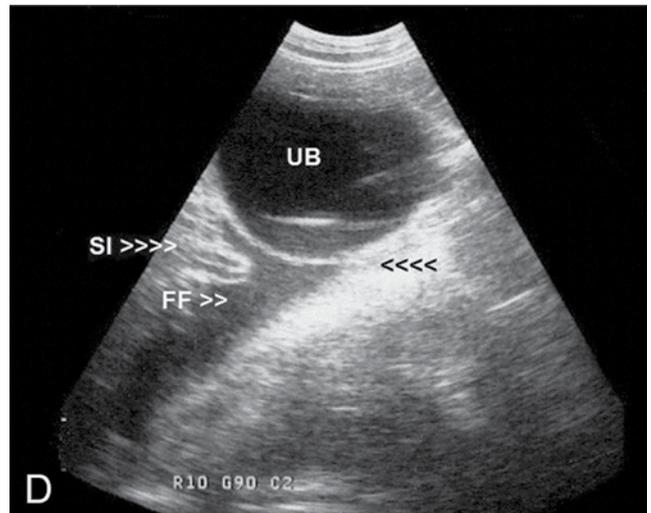
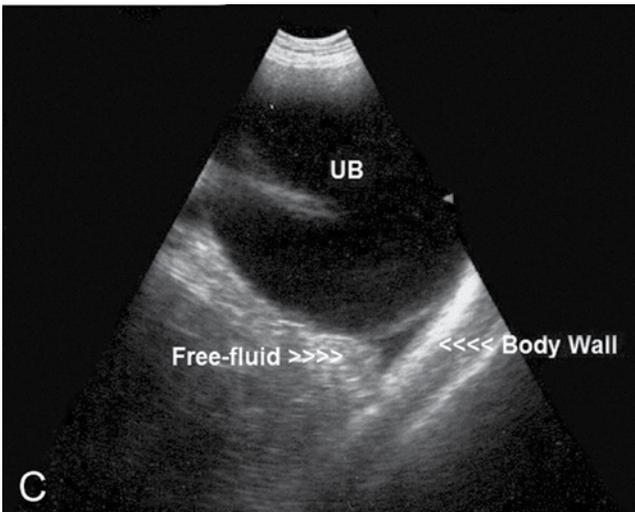
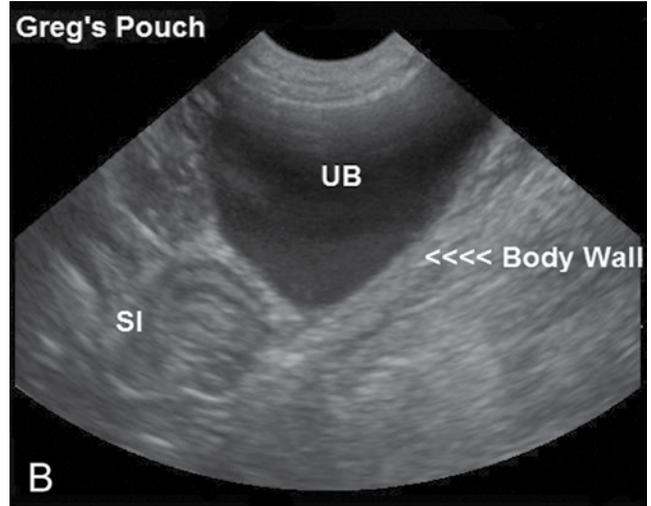
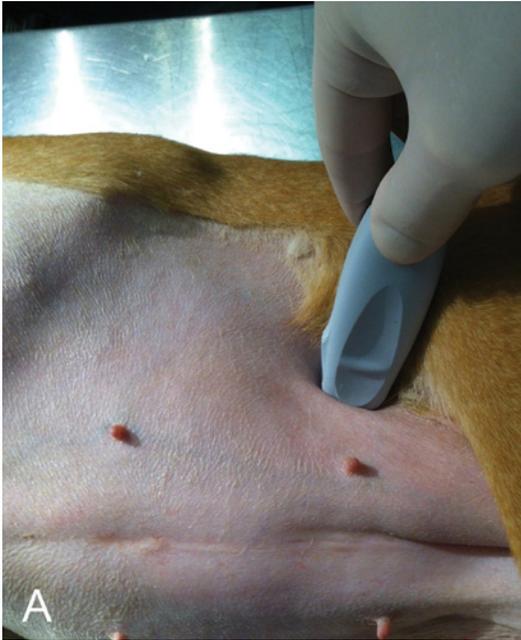


Figure 2.10. The classic cysto-colic view and its positives. (A) The probe is placed over the urinary bladder region and directed into the gravity dependent pouch (Greg's pouch) in that area. (B) The classic CC view is acquired by directing the probe downward toward the table top and thus imaging the urinary bladder (UB) against or "kissing" the ventral abdominal wall. By doing so the sonographer has a view of the most gravity dependent area where free fluid accumulates (small intestine, SI). (C) The small anechoic triangle (free fluid) between the apex of the urinary bladder and the ventral body wall (Greg's pouch) is classic for small volume effusions. (D) Zooming away and observing Greg's pouch with acoustic enhancement artifact, making the body wall brighter (dark arrows) and seeing clearly the free fluid (FF) and small intestine (SI) appearing like "hamburgers" in transverse view adjacent to a full urinary bladder (UB). (E) A final image illustrating the difference when the urinary bladder (UB) is smaller (or absent) with small bowel (GI) floating (obvious in real-time imaging) in the free fluid typically seen in larger volume positives. © Gregory Lisciandro

the bladder appear in odd shapes (see Figures 1.4, 1.5, 6.3, and 6.10).

Change the position of the probe and alter the pressure of the probe on the patient (both a little more and a little less) to coax the colon out of your way.

False Positives

False positives are generally not a problem at the CC site when directing the probe into the pocket between the urinary bladder and the body wall (called Greg's pouch).

It should be noted that puppies and kittens may have a small amount of (anechoic) ascites, which is considered normal (see Chapter 13).

If you fan dorsally into the sublumbar area (generally unnecessary), the great vessels and lymph nodes may become confounders.

Keep your probe in Greg's pouch. Figure 2.10B through D clearly shows how the urinary bladder abuts the ventral body wall, forming Greg's pouch.

False Negatives

Serial AFAST³ exams increase sensitivity. Don't sweat questionable small pockets of free fluid. Serially repeat the AFAST³ exam at least a second time four hours later.

Repeat AFAST³ serially in four hours post-admission (sooner as clinical course dictates), or after resuscitation and rehydration. The four-hour post-admission rule of thumb is supported by the American College of Emergency Physicians (ACEP) guidelines (www.acep.org) as standard of care.

The AFAST³ Hepato-Renal View: The Big Lie

Finally, the classic hepato-renal (HR) view is obtained by placing the probe just ventral to the umbilicus. Typically the HR view includes loops of small bowel and occasionally the spleen (Figure 2.11B; also see Figures 7.3 and 13.7). The probe should be directed downward toward the table top into the most gravity dependent pouch of all the AFAST³ sites by starting closer to the umbilicus and directing downward toward the table top. Alternately, you may move the probe below the umbilicus and fan upward again, keeping in mind that the area of interest is this most gravity dependent pouch. If

you are too low toward the table top you may be imaging through planes of body wall. The probe is not routinely run under the patient unless imaging of the right kidney is necessary (Lisciandro 2009, 2011).

The HR view is performed just below the umbilicus to image the most gravity dependent area of the laterally recumbent veterinary patient (and the probe not moved underneath).

"The big lie" is two-fold: first, the liver (unless it is enlarged it is not seen) and the right kidney are not aggressively searched out; thus, neither HR target organ is directly scanned. Second, transverse imaging (in addition to longitudinal) is advised because it is less confusing at this site in discriminating intestinal contents from free fluid (Lisciandro 2009).

The probe is longitudinally placed just under the umbilicus and fanned downward to the table top into the most gravity dependent pouch (Figure 2.11A). Here, turning left for transverse imaging is not as confusing for beginners as the other sites (i.e., DH, SR, and CC) which helps differentiate small intestinal loops from free fluid (see Figures 7.3, 7.4, and 13.7, as well as Chapter 7). Small intestines generally look like hamburgers when viewed in cross section (Figure 2.8B; see also Figures 7.3 and 7.4).

Stay longitudinal at all sites (DH, SR, CC) except at the HR view where it is helpful to do both longitudinal and transverse imaging to discriminate free fluid (anechoic black triangles) from small bowel (referred to as appearing like "hamburgers" on cross-section) (Figure 2.7A and B) (also see Figures 7.3, 7.4, 13.7, and Chapter 7).

In the event that the right kidney should be imaged (if there is concern about retroperitoneal injury on the right side or that hematuria may be a kidney-related injury or non-trauma-related pathology), smaller-sized dogs and cats may be moved more dorso-laterally while in right lateral recumbency and the probe slipped underneath them (works well in most cases). Otherwise, as with larger patients, it may be necessary to move the dog to left lateral recumbency.

The right kidney is generally more difficult than the left kidney to image because of its more cranial location under the rib cage within the renal fossa of the caudate liver lobe (Figure 2.12; also see Figures 3.1 and 5.1). However, lateral recumbency is advantageous when looking at kidneys at the non-gravity AFAST³ site because bowel falls away from the respective kidney.

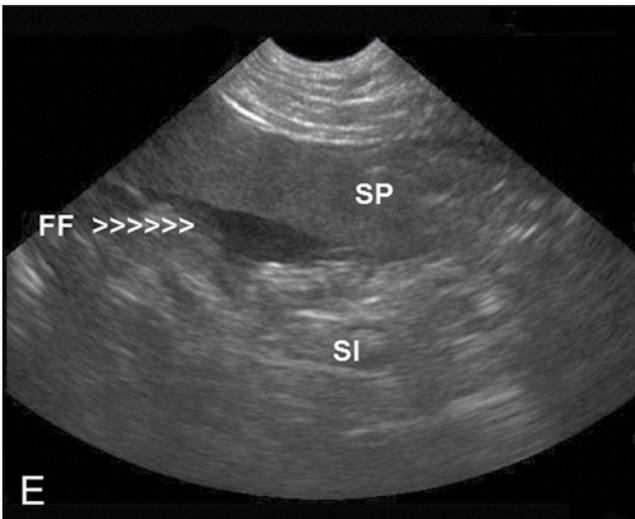
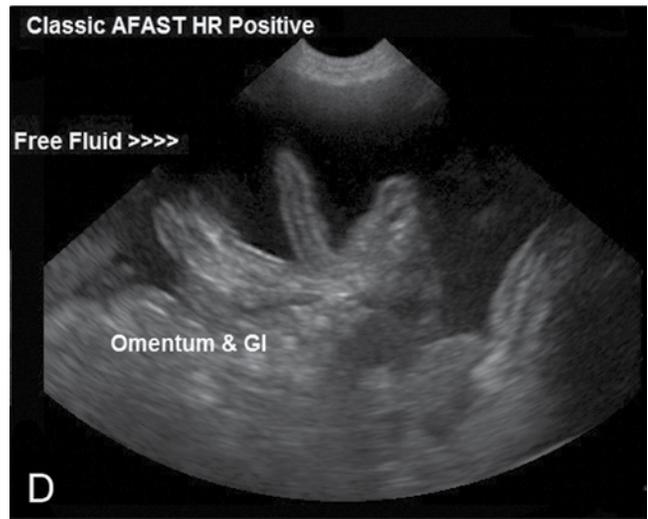


Figure 2.11. The classic AFAST³ hepato-renal (HR) view and positives. (A) The probe is not moved under the patient, but rather placed just ventral to the umbilicus mid to just cranial mid-abdomen to image the most gravity dependent pocket in a laterally recumbent patient. The target organs are generally not seen but rather loops of small intestine and occasionally the spleen are more commonly present here. (B) Typical image for the HR view with spleen (SP) and small intestine (SI). There is no free fluid in the image. Recall that the HR view is the “big lie” because neither target organ (liver and right kidney) is searched out. (C) Small-volume HR positive with an obvious anechoic (black) triangle. (D) Large-volume HR effusion with the “rabbit sign” or small intestine and omentum wafting in the free fluid, creating such an image. (E) Small-volume free fluid (FF) located between the spleen (SP) and the small intestine (SI). © Gregory Lisciandro

Classic Positives

Because the HR view is the most gravity dependent site in right lateral recumbency, the positives are usually remarkable (Figure 2.11C through E) and easily recognized. The “rabbit ear” sign is typical in large-volume effusions created by small intestine and



Figure 2.12. Image of the right kidney (RK) at the HR view. In right lateral recumbency the right kidney is not typically searched for and imaged (unless injury is suspected or pathology based on other findings). The right kidney is more difficult to reliably image than the left because it is tucked up into the liver (LIV). In left lateral recumbency, the right kidney should be routinely imaged at the HR view (in contrast to right lateral recumbency when it is often skipped over) so that a window into the retroperitoneal space during AFAST³ is appreciated. © Gregory Lisciandro

omentum wafting in the free fluid (Figure 2.11D). The most common AFAST³-positive sites in low-scoring AFS-1 and 2-dogs are not the HR view, but rather the non-gravity dependent CC and DH views (Lisciandro 2009). Thus, the site is nicknamed the “home run” site because it completes the AFAST³ exam and if positives were seen at other views, the sonographer is likely to be performing abdominocentesis here.

Fluid should be characterized if safely retrievable by abdominocentesis because ultrasound cannot characterize the type of fluid based on its echogenicity.

False Positives

- The GI tract. Bowel may be fluid-filled or have its wall infiltrated (abnormal) in diseased states and may appear mistakenly as free fluid (see Chapter 7).

Moving your probe from longitudinal to transverse typically discriminates between free fluid (anechoic black triangles) and normal and abnormal GI tract (small bowel, referred to as “hamburgers” in cross-section; see Figures 7.3, 7.4, 8.4, and 13.7).

- Mid-abdominal masses. Large centrally located necrotic fluid-filled splenic, hepatic, mesenteric or renal masses may be mistaken for free fluid (Figure 2.13A).

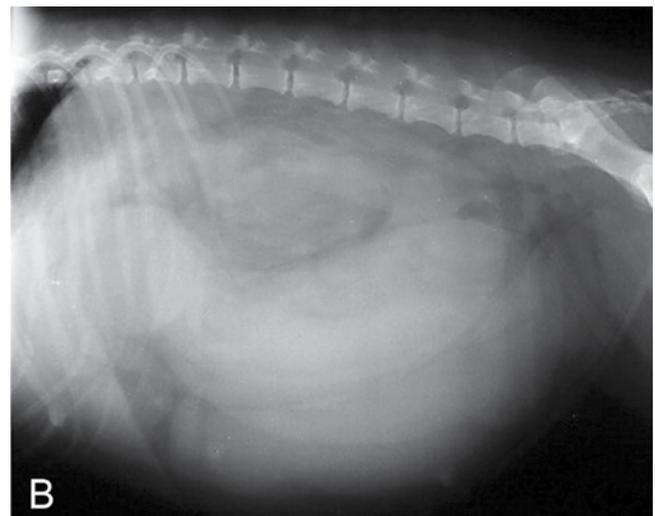
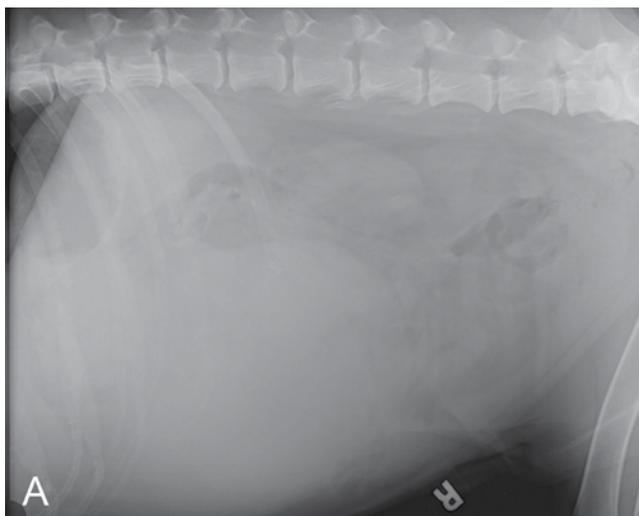


Figure 2.13. False positives at the HR view. It is possible to mistake fluid-filled structures for free abdominal fluid including large midabdominal masses (splenic mass with necrotic center, large cystic masses), pyometra, a distended fluid-filled stomach, and others. Although these possibilities are uncommon, they exist as possible mistakes. (A) A large midabdominal splenic mass with a necrotic center that falsely appeared to the sonographer as wafting free fluid. (B) A large pyometra that falsely appeared as free fluid. Pyometra is often compartmentalized into triangles and thus differentiated from free fluid (see Chapter 8). © Gregory Lisciandro

Zoom out and increase depth so margins of a centrally located mid-abdominal mass may be better recognized and not mistaken for free fluid (see Figure 4.12).

- Fluid-filled uterus. A large fluid-filled uterus in an intact female may be mistaken for free fluid (Figure 2.13B, also see Figure 8.6). The female reproductive tract is addressed in Chapter 8.

Consider your patient's signalment and don't mistake an enlarged uterus for free fluid.

False Negatives

- Serial AFAST³ exams increase sensitivity. Don't sweat questionable small pockets of free fluid. Serially repeat the AFAST³ exam at least a second time four hours later.

Repeat AFAST³ serially in four hours post-admission (sooner as clinical course dictates), or after resuscitation and rehydration. The four-hour post-admission rule of thumb is supported by the American College of Emergency Physicians (ACEP) guidelines (www.acep.org) as standard of care.

The AFAST³-applied Abdominal Fluid Scoring System

The abdominal fluid scoring system was purposely named such and not the "hemorrhage" scoring system to avoid the system being type-casted for only hemorrhage. The name, however, seems to have prevented its routine use in trauma despite its documented ability to semi-quantitate volume of hemorrhage. By predicting the anticipated degree of anemia (AFS 1 or 2, "small bleeders"; AFS 3 or 4, "big bleeders"), the scoring system may be used to anticipate the need for blood transfusions (Lisciandro 2009) and rarely exploratory laparotomy in bluntly traumatized dogs with traumatic hemoabdomen (Boysen 2004, Lisciandro 2009, Simpson 2009).

A decision-making algorithm correlating the abdominal fluid score to the anticipated degree of anemia in bluntly traumatized and post-interventional (surgery, percutaneous biopsy, laparoscopy) dogs (not reliable in cats) is shown (Figure 2.14).

The Clinical Significance of the Abdominal Fluid Score (AFS) in Dogs

The abdominal fluid score (AFS) is as follows: 0 if negative at all 4 AFAST³ views, to a maximum AFS of 4 if positive at all four views. Each of the four views receives a score of 1 that is then totaled (Figure 2.15).

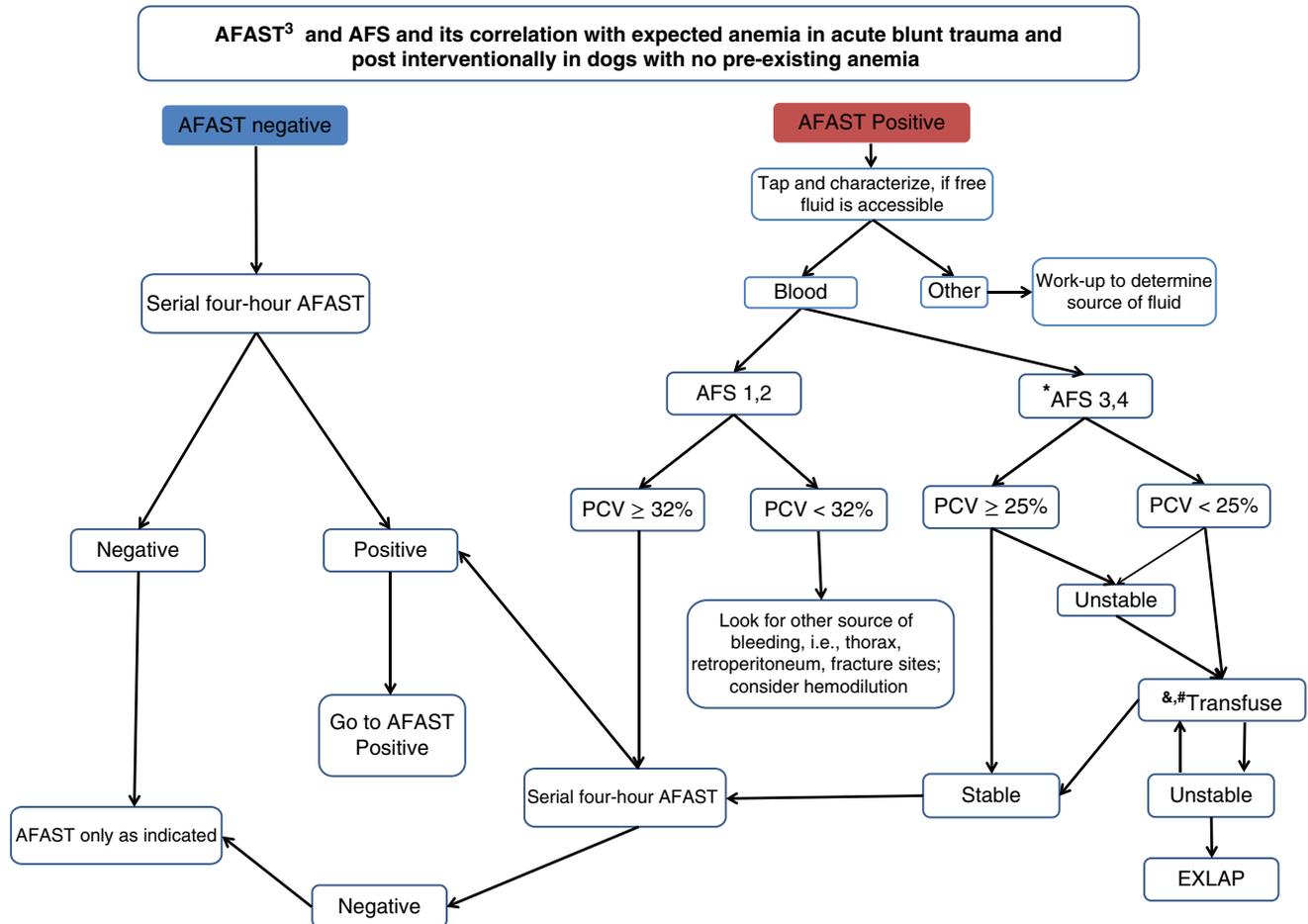
From the assigned AFS, dogs may be categorized into "small bleeders" (AFS 1 and 2) and "big bleeders" (AFS 3 and 4). AFS 1 and 2 dogs, or small bleeders, will reliably not become significantly anemic if they had no pre-existing anemia and remain AFS 1, 2 on serial examinations unless they are bleeding at another site(s) or experiencing hemodilution due to large fluid volumes.

In the event an AFS 1, 2 dog without pre-existing anemia becomes anemic (packed cell volume (PCV) less than 30%), the attending clinician should explore other sites (retroperitoneal, pericardial, pleural, lungs, fracture sites) readily accessible by AFAST³, TFAST³, and the Vet BLUE lung scan and focused musculoskeletal exams at fracture sites for hemorrhage (Chapter 15).

AFS 3 and 4 dogs, or big bleeders, will reliably become anemic, predictably 20%–25% below their admission baseline PCV if they had no pre-existing anemia. Approximately 20%–25% of these AFS 3, 4 dogs will become severely anemic (PCV less than 25%) on serial AFAST³ examinations, potentially needing a blood transfusion(s) (Lisciandro 2009) and rarely emergent exploratory laparotomy (Boysen 2004, Lisciandro 2009, Simpson 2009).

By knowing within minutes of presentation on the triage table that your dog is a bleeder (hemoabdomen), fluid therapy with more conservative endpoints may be initiated, and the anticipation for the need of blood products may be made ahead of time (directing resources) according to the small bleeder vs. big bleeder concept used on initial and serial AFAST³ examinations. A decision-making algorithm correlating the abdominal fluid score to the anticipated degree of anemia in bluntly traumatized and post-interventional (surgery, percutaneous biopsy, laparoscopy) dogs (not reliable in cats) is shown (Figure 2.14).

Humans may lose 75% and 50% of their blood volume in pelvic and femoral fracture sites, respectively, whereas dogs and cats uncommonly become anemic from these fractures. However, significant blood loss (if TFAST³ and Vet BLUE scans are unremarkable for other sources of blood loss) should be considered from fracture sites; as has been



The flow chart provides general guidelines regarding the decision-making process for acutely bleeding dogs when applying the abdominal fluid score (AFS) during AFAST. *Post-interventional cases that are bleeding, non-coagulopathic, with an AFS 3,4 are often compensating for their intra-abdominal bleed and generally should be explored rather than waiting. However, these post-interventional cases would be those with an AFS 0 post-procedure (abdominal cavity suctioned dry post-operatively [AFS 0] or AFS 0 prior to a percutaneous procedure). †In contrast, bleeding dogs with an AFS 3,4 from blunt trauma often require transfusion products but uncommonly require exploratory laparotomy to control their intra-abdominal hemorrhage. ‡In some dogs with graduated fluid therapy and hypotensive resuscitation strategies, blood transfusion may not be necessary despite marked anemia (< 25%).

Figure 2.14. Decision-making algorithm for dogs correlating the abdominal fluid score to the anticipated degree of anemia in bluntly traumatized and post-interventional (surgery, percutaneous biopsy, laparoscopy) canine cases. The AFS has not been proven to be a reliable predictor of anemia in cats; however, it is still a useful monitoring tool for serially assessing whether effusions are developing (negative to positive score), worsening (higher score), or resolving (lower score). © Gregory Lisciandro

sporadically reported in both species, more commonly from pelvic fractures.

Waiting on a compensated post-interventional big bleeder (AFS 3, 4) instead of surgically addressing the cause of bleeding often leads to increased morbidity and cost (e.g., transfusion products) because big bleeders predictably become markedly anemic and overtly clinical (decompensate) in time.

If it's a bleeding 3 or 4, (AFS 3, 4), then you should explore (surgically). The exception is hit-by-car dogs that often are successfully treated medically with transfusion products.

The Clinical Significance of the Abdominal Fluid Score in Cats

The same AFS system was studied prospectively in 49 traumatized cats and importantly found to not correlate with anemia as in dogs (Lisciandro 2012). However, the number of cats with traumatic hemoabdomen was small, concluding that cats more often do not survive automobile-induced traumatic hemoabdomen as dogs, similar to a previous report (Mandell 1995).

Cats with automobile-induced traumatic hemoabdomen often declare themselves non-survivors before making it to veterinarians. Free fluid in cats is more likely to be urine (or less commonly other non-hemorrhagic effusions) in these surviving cats.

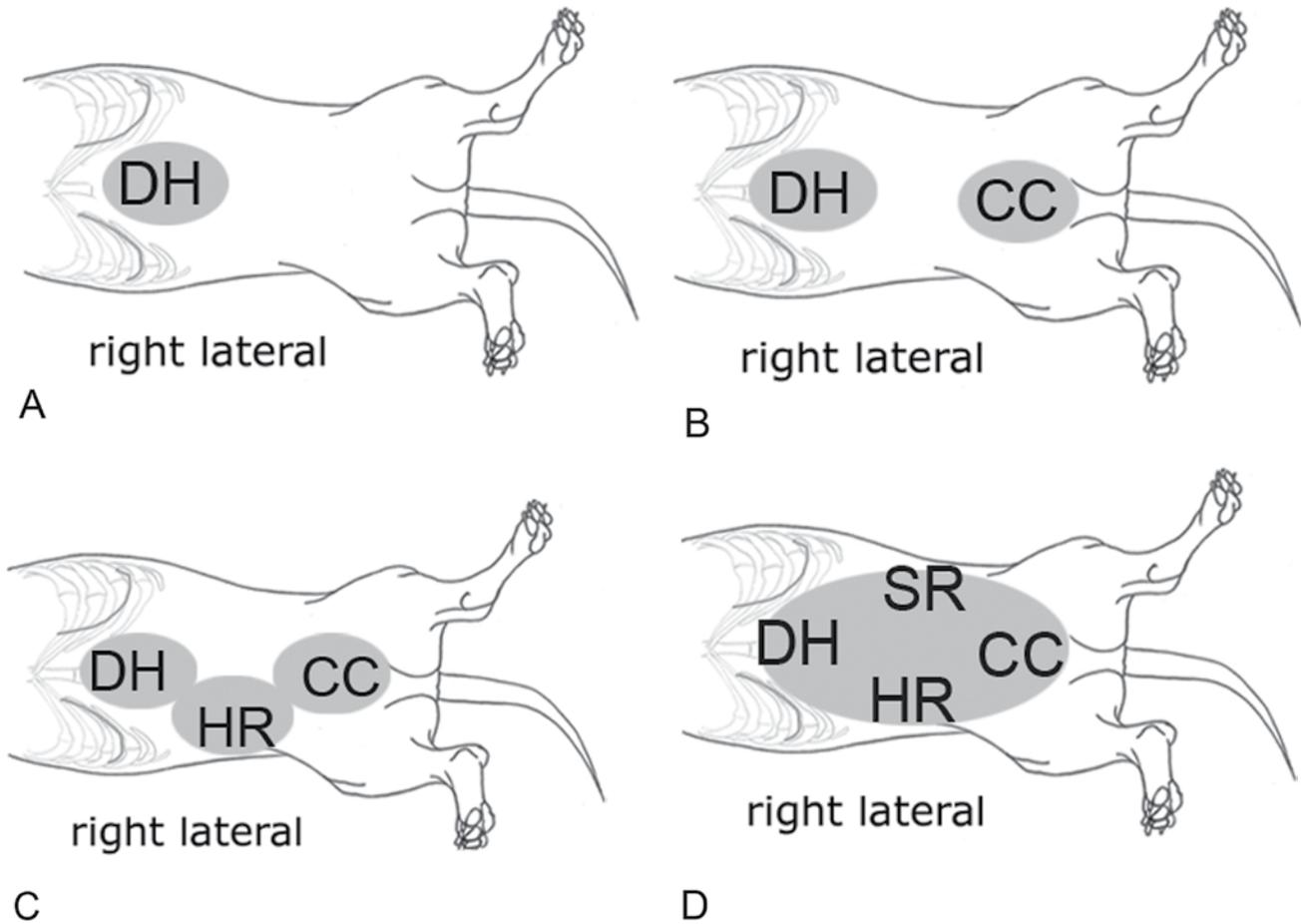


Figure 2.15. Illustration showing the relationship between abdominal fluid score (AFS) and the location(s) of the respective AFAST³-positive site(s) in right lateral recumbency. The AFS is defined as follows: (A) AFS 1, positive at any one site; pictured is the most common AFS 1 site, the DH view. (B) AFS 2, positive at any two sites; pictured are the two most common AFS 2 sites, the non-gravity dependent DH and CC views. (C) AFS 3, positive at any three sites; pictured are the most common AFS 3 sites which now generally become gravity dependent (D) AFS 4, positive at all four sites. Lateral recumbency inherently provides a depth gauge for the volume of fluid as shown in the progression from AFS 1 to AFS 4. Note that lower-scoring AFS-1 and AFS-2 hemoabdomen dogs are most commonly positive at non-gravity dependent DH and CC AFAST³ sites. (DH, diaphragmatico-hepatic; SR, spleno-renal; CC, cysto-colic; HR, hepato-renal) (Lisciandro 2011). © Gregory Lisciandro

Most Common AFAST³ Positive Sites in Low-Scoring Patients

The most common positive sites in low-scoring small bleeder dogs are those in the non-gravity dependent DH and CC views. Clinicians performing AFAST³ should become especially familiar with the proper imaging and the pitfalls of these two views as noted above (Figure 2.15A and B).

The most common low-scoring sites in AFAST³-positive dogs are in the non-gravity dependent DH and CC views (Figure 2.15A and B).

Use of AFAST³ and Abdominal Fluid Score in Non-Traumatic Bleeding Subsets of Patients

The same AFS concept may be applied to dogs with non-traumatic abdominal bleeding (ruptured mass), those that are coagulopathic (actively bleeding), or in post-interventional patients that are at risk for bleeding (surgery [spay, liver lobectomy, splenectomy, adrenalectomy, etc.] and percutaneous or laparoscopic aspirate or biopsy [liver or splenic, aspirate or biopsy, etc.]). AFAST³ is superior in detecting hemorrhage to

laboratory values (packed cell volume), physical examination findings, and radiography (Lisciandro 2009; Rozycki 1998, 2001).

For example, AFAST³ and the AFS should be used as a more effective screening test than traditional means by performing an AFAST³ four hours (or sooner as clinical course dictates) post-percutaneous interventional and post-surgical procedures. Furthermore, AFAST³ should be the preferred screening test for coagulopathic dogs and cats because AFAST³ screens the peritoneal and retroperitoneal spaces and when combined with TFAST³ and Vet BLUE also screens for occult bleeding in the pleural and pericardial spaces and within the lungs.

It is noteworthy that in contrast to dogs, cats with spontaneous non-traumatic hemoabdomen generally have a poor prognosis (Culp 2010), and the reliability of the AFS is unknown in this subset of hemoabdomen cats.

AFAST³ should become routinely administered as a post-interventional monitoring tool in all subsets of at-risk veterinary patients. AFAST³ can be used as an initial evaluation technique as an extension of the physical examination for the early detection of bleeding and other complications in both dogs and cats, in preference to less sensitive traditional means of clinical evaluation. The value of the technique for post-interventional monitoring has clearly been shown in people (see below) (Rozycki 1998, 2001). Initial and serial AFAST³ with the application of the AFS will help survey for ongoing bleeders. In addition, the technique aids in the detection of big bleeders and may allow the clinician to have a high index of suspicion in advance of the possibility of overt clinical decompensation than would be possible by waiting on less sensitive traditional indicators such as packed cell volume and vital signs. In humans, it is well known that patients can compensate and fool physicians with unremarkable vital signs, mucus membrane color, heart rate, and pulse quality with up to a loss of 30% of their blood volume (Muir 2006). Dogs may very well be able to compensate even more due to blood reservoirs provided by splenic contraction.

In post-interventional dogs, AFS may be used to anticipate the need for emergent exploratory using the small bleeder vs. big bleeder concept. Remember, “If it’s a 3 or 4 you should generally explore” and more expediently address [ligate] the source of bleeding in this subset of veterinary patients.

The Use of AFAST³ and Abdominal Fluid Score in Non-Bleeding Subsets of Patients

The use of the abdominal fluid scoring system may help with tracking (monitoring) any effusive condition of the abdomen, and additionally proves helpful in tracking post-operative patients at risk for all forms of peritonitis. These subsets of veterinary patients often do not produce ultrasonographically visible free fluid until they are resuscitated and rehydrated. In human with possible bowel injury, serial ultrasound examinations are recommended out to 12–24 hours post admission (Mohammadi 2012).

Serial AFAST³ exams increase the sensitivity in peritonitis suspects and should be performed four hours post-admission and again after resuscitation and rehydration. If the patient has not declared itself overtly surgical but remains a candidate, AFAST³ should be used serially out to as long as 12–24 hours.

Use of AFAST³ and Abdominal Fluid Score in Penetrating Trauma

The use of AFAST³ in penetrating trauma such as bite wounds, especially in cases of big dog-little dog or big dog-cat, was hypothesized as being helpful in detecting intra-abdominal injury (and intrathoracic injury, see TFAST³, Chapter 9). However, it was found that AFAST³ performed in many of the 145 dogs in the TFAST³ study often missed serious operative intra-abdominal injury.

Although abdominal radiography (AXR) is typically a low yield diagnostic test in bluntly traumatized dogs, it should always be part of the standard work-up in penetrating trauma.

The difference probably lies in the nature of each type of trauma, blunt vs. penetrating, because blood is rapidly defibrinated in blunt trauma and generally appears anechoically (black) and conspicuously as free fluid. In contrast, penetrating trauma, especially bite wounds, causes a different initiation of the coagulation cascade because the tissue is crushed and torn, resulting in clotted blood. Clotted blood has echogenic

characteristics similar to soft tissue (shades of gray) and hence, is not readily detectable by ultrasonography. However, in time, clotted blood may defibrinate, and viscous organs may leak their contents into accessible spaces as free fluid; thus serial AFAST³ exams are helpful in the decision-making process of medical vs. surgical care.

AFAST³ misses clotted blood because its echogenicity is similar to soft tissue.

Even though no studies have specifically looked at AFAST³ in penetrating trauma, its ability to detect injury probably has low sensitivity but high specificity in such cases, in the author's experience. In other words, a negative AFAST³ warrants serial examinations (or other higher yielding tests), and although AFAST³ is a first-line test in blunt trauma, it is probably better suited as an ancillary test in penetrating trauma for more seriously injured animals when deciding whether they are best managed medically vs. surgically. A positive AFAST³, however, warrants serious consideration for emergent laparotomy because of the likelihood of significant intra-abdominal injury as shown in people, and serial examinations increase the sensitivity of FAST (Udobi 2001, Kirkpatrick 2004,

Matsushima 2011). In human with possible bowel injury, serial ultrasound examinations are recommended out to 12–24 hours post admission (Mohammadi 2012).

Serial AFAST³ exams increase the sensitivity in penetrating trauma suspects with possible intra-abdominal injury, and should be performed four hours post-admission and at least once post-resuscitation and rehydration and out to 24 hours or more in questionable cases.

The Use of AFAST³ for Anaphylaxis in Dogs

In 2009, the clinical use of ultrasound in dogs for the diagnosis of anaphylaxis was documented and shown to be helpful. Because the shock organs in dogs are the liver and gastrointestinal tract, hepatic venous congestion occurs rapidly (experimentally within seconds) with massive histamine release within the portal circulation (Quantz 2009). As a result, the gallbladder wall thickens and appears striated with alternating echogenicity followed by sonolucency and then again echogenicity (Figure 2.16A and B).

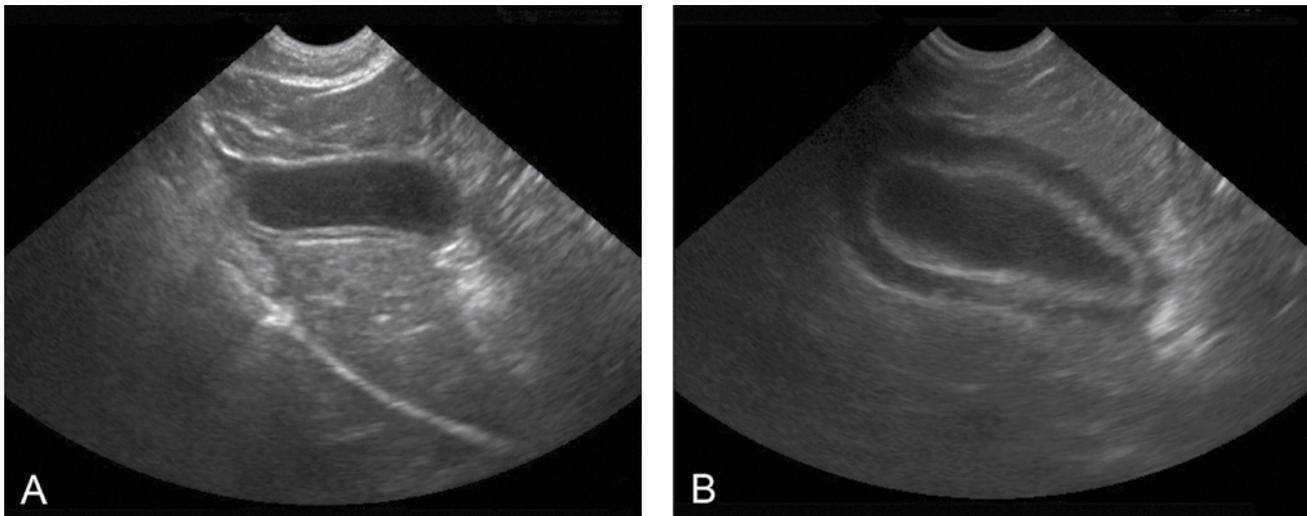


Figure 2.16. The gallbladder halo sign of anaphylaxis. (A) Anaphylaxis and the gallbladder double rim or halo sign in a dog with multiple bee stings without angioedema or urticaria. The gallbladder wall is classically thickened (greater than 3 mm) with inner and outer hyperechoic (bright white) walls sandwiching a middle layer of sonolucency (dark) causing a double rim sign, also referred to as the gallbladder halo sign. (B) Another example of an impressive gallbladder halo sign in an anaphylactic dog presenting with acute collapse and again without obvious angioedema or urticaria. It is very important to perform a complete AFAST³ exam and rule out other causes of collapse, some of which (especially pericardial effusion/cardiac tamponade) may cause a false positive gallbladder halo sign (Figure 2.17). Furthermore, canine anaphylaxis cases can develop various degrees of coagulopathic non-surgical hemoabdomen as a complication (see section on the use of AFAST³ for anaphylaxis in dogs).

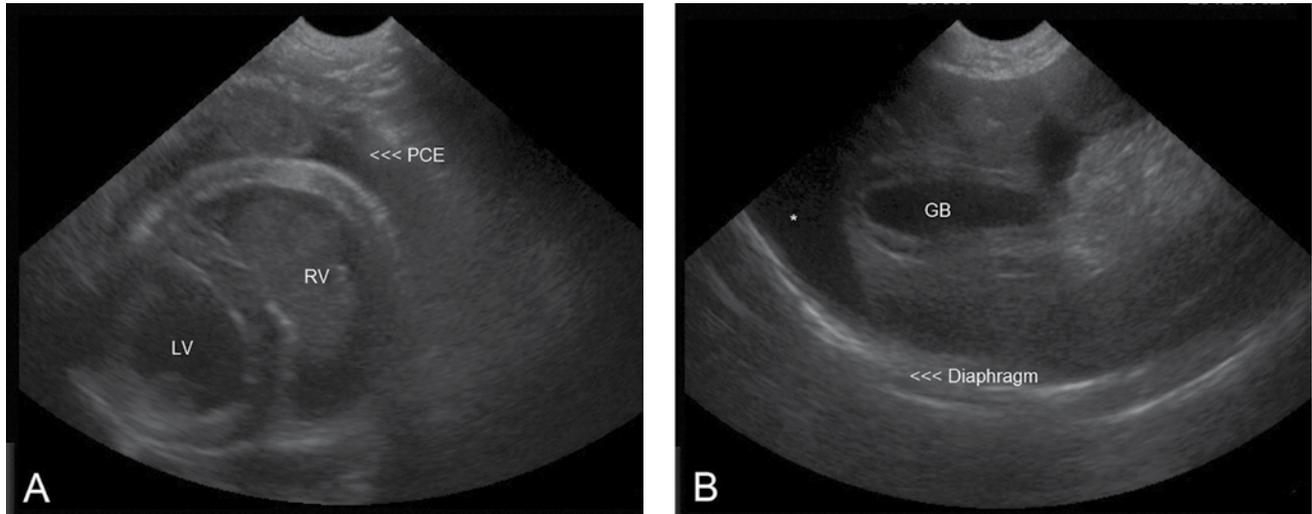


Figure 2.17. Acute tamponade and a false positive halo sign. (A) This middle-aged medium-sized dog presented in acute collapse and was rapidly assessed using combination FAST³ (AFAST³ and TFAST³). Cardiac tamponade was diagnosed and an emergent pericardiocentesis was performed (pericardial effusion, PCE; right ventricle, RV; left ventricle, LV). Note the race track sign with the rim of fluid around the heart with heart chambers clearly identified. (B) Shown here at the diaphragmatic-hepatic (DH) view is abdominal effusion and a gallbladder halo sign secondary to venous congestion from the cardiac tamponade (free intra-abdominal fluid [*]; liver, LIV; gallbladder, GB). Looking into the thorax on all AFAST³ exams will help avoid this potentially catastrophic misinterpretation of the gallbladder halo sign for anaphylaxis because a large intravenous bolus of fluids may be detrimental to this patient. © Gregory Lisciandro

These gallbladder changes are much more rapid (less than two to four minutes) than traditional markers such as the alanine transaminase (ALT) level (peak two to four hours) used in veterinary medicine. This change in the gallbladder has been termed the “halo sign” (Quantz 2009). It is critical to note that there are other causes of gallbladder wall thickening (normal thickness in dogs is less than 2–3 mm) and a double rim or halo sign, including conditions that cause obstruction to venous and lymphatic return such as cardiac tamponade and congestive heart failure; conditions that affect the regional anatomy such as pancreatitis, cholangiohepatitis, and primary gallbladder diseases (cholecystitis); and conditions that lead to third spacing such as severe hypoalbuminemia, volume overload including over-resuscitation, and others (Nelson 2010).

With that being said, regarding acute collapse, the three major rule-outs in San Antonio, Texas, are acute hemoabdomen, acute cardiac tamponade, and anaphylaxis. Importantly, acute cardiac tamponade may cause a false positive gallbladder halo sign (unpublished) (Figure 2.7). As a result, the author’s practice has goal-driven templates for AFAST³ findings that include remarks about the pleural and pericardial spaces (see Appendix II) so the gallbladder halo sign is not misinterpreted.

There are other causes of unexplained collapse in dogs so it is very important to always perform a complete AFAST³ exam so as to not miss hemorrhage in the peritoneal or retroperitoneal spaces or cardiac tamponade, the latter of which may cause a false positive gallbladder halo sign. The resuscitative treatment for anaphylaxis includes the rapid bolus of intravenous fluids and epinephrine, in contrast to cardiac tamponade, in which such an intervention could be catastrophic to the dog.

There are other causes of unexplained collapse in dogs so it is very important to always perform a complete AFAST³ exam, and even better, a TFAST³ and Vet BLUE.

It is not uncommon for anaphylactic dogs to develop a coagulopathic hemoabdomen that is typically low-scoring at the DH view (and sometimes AFS 2 at the DH and CC views). However, it is possible to have marked hemoabdomen (AFS 3, 4) in some dogs with severe anaphylaxis on presentation (unpublished). The clinical key to avoid mistakenly (and potentially catastrophically) taking the case to surgery is the finding of markedly elevated clotting times, a markedly elevated ALT, and significant hemoconcentration.

Anaphylactic dogs may have a coagulopathic hemoabdomen on admission or develop one post-resuscitation that is medically (not surgically) treated.

The Use of AFAST³ and its DH View for Pericardial Effusions

Veterinarians incorporating the FAST³ protocols into their practice should review the causes and treatment of pericardial effusion, including left atrial tears (mitral valve disease in dogs). Comparing 2005 (pre-FAST³) to 2011 (post-AFAST³ and TFAST³) at the author's practice, the incidence in detecting pericardial effusion was dramatic (two cases vs. 24, annual caseload approximately 11,000). Moreover, of the 24 cases, 21 of 24 (88%) were recognized by the diaphrag-

matico-hepatic (DH) view, either during TFAST³ or AFAST³. Approximately 50% had pericardiocentesis performed and cardiac tamponade could be diagnosed by the DH view (Lisciandro 2012, unpublished data) (Figure 2.3A, B). Generally, in real-time ultrasound imaging, this life-threatening condition may be easily recognized by the non-radiologist veterinarian using TFAST³ (see Figures 9.17, 9.18, 9.19, and 9.20 and Chapter 11).

Most cases of clinically significant pericardial effusion may be detected using the DH view during AFAST³ (and further confirmed as needed by the pericardial TFAST³ views, adhering to the sage axiom that "One view is no view"). Always attempt to look into the thorax via the DH view and include the data in your goal-directed templates.

Table 2.1.
Indications for AFAST³.

Uses of AFAST ³ Initial and Serial Exams	Objectives
Trauma	
Blunt trauma	Hemoabdomen, uroabdomen and other effusive peritoneal and retroperitoneal conditions; and pericardial and pleural space conditions Note: Standard of care as first-line screening test as in human trauma
Penetrating trauma	Hemoabdomen, uroabdomen, bilioabdomen, septic abdomen, and other effusive peritoneal and retroperitoneal conditions; and pericardial and pleural space conditions Note: First-line screening test or secondary test, depending on suspected type of injury. Serial exams are key because clotted blood will defibrinate and viscous organs will leak contents that then can be detected as free fluid Note: May be able to detect pneumoabdomen and pneumoretroperitoneum in some cases
Non-trauma	
Uncharacterized hypotension (collapsed, weakness, even if apparently recovered)	Pericardial effusion/tamponade, pleural effusion, anaphylaxis, hemoabdomen, retroperitoneal bleed, and other effusive peritoneal and retroperitoneal conditions
Coagulopathy	Quad-cavity evaluation as screens four spaces for bleeding including peritoneal, retroperitoneal, pleural, and pericardial spaces Note: Add on Vet BLUE, and lung hemorrhage may also be screened
Anemia	Quad-cavity evaluation as screens four spaces for bleeding including peritoneal, retroperitoneal, pleural, and pericardial spaces Note: Add on Vet BLUE, and lung hemorrhage may also be screened
All peritonitis suspects	Detect septic abdomen earlier than traditional means without ultrasound
Post-interventional	
Percutaneous aspirates	Bleeding, forms of peritonitis, and pleural and pericardial space problems
Percutaneous biopsies	Bleeding, forms of peritonitis, and pleural and pericardial space problems
Post-laparoscopic	Bleeding, forms of peritonitis, and pleural and pericardial space problems
Post-surgical	Bleeding, forms of peritonitis, and pleural and pericardial space problems
CPR	See Chapter 16 Rapidly assess for potentially treatable causes of cardiopulmonary arrest. Use to survey for complications and for guiding fluid resuscitation.

Incidental Findings During AFAST³

Incidental findings, including non-trauma related conditions in target-organs, are not uncommon during AFAST³ exams. The phenomenon has likewise been recognized in human medicine (Sgourakis 2012). Through the repetition in performing initial and serial exams, ultrasonographic “normals” of target organs and deviations from these normals will become easily recognized by the non-radiologist sonographer, often triggering additional imaging, including a complete abdominal ultrasound or complete echocardiography by a veterinary radiologist or internist with advanced ultrasound training. Shown here are trauma-related findings of an intraparenchymal hematoma in a spleen and a large blood clot filling the entire lumen of the urinary bladder (Figure 2.18A and B).

Documenting AFAST³ Findings in Medical Records

The use of standardized templates is imperative, not only for communication of AFAST³ findings between veterinarians but also for evaluating serial findings. The use of standardized templates that are goal-driven also accelerates the learning curve and disciplines the sonographer by making him or her look at certain aspects of the target organs (looking into the thorax for

pleural and pericardial effusion [DH view]; looking at the hepatic veins for venous congestion [DH view]). The “Comments” section allows for any findings outside of the goal-driven standard format to be listed (e.g., a urinary bladder stone or mass, a splenic mass, etc.). Finally, the AFAST³ protocol and its strengths and weaknesses may be evaluated and improved upon with recorded data. Suggested templates for medical records are in Appendix II.

Pearls and Pitfalls, the Final Say

AFAST³ is an advantageous ultrasonographic format for non-radiologist veterinarians to use for the timely detection of free fluid representing bleeding or forms of peritonitis because ultrasound is superior in sensitivity to physical examination and abdominal radiography. Of note:

- AFAST³ should be a routine add-on to all intra-abdominal focused or COAST³ exams.
- AFAST³ should be standard of care for all bluntly traumatized dogs and cats, as it is in people.
- AFAST³ should be used in penetrating trauma cases with the understanding that AFAST³ is generally thought to be very specific for detecting intra-abdominal injury (by finding free fluid), but lacks high sensitivity.

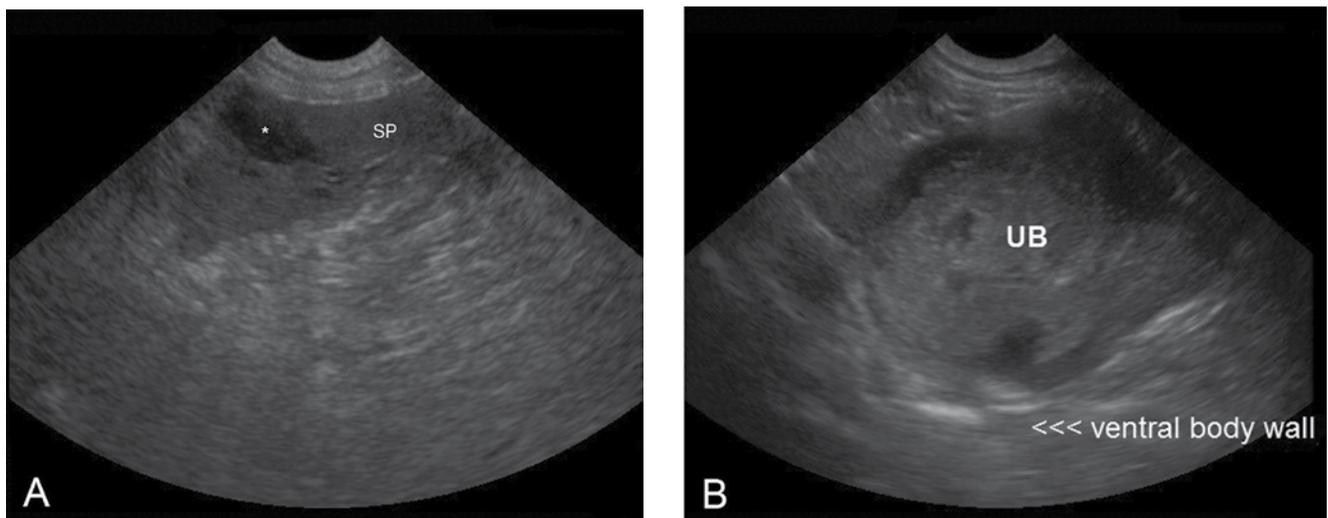


Figure 2.18. Organ injury detected during AFAST³. (A) Splenic (SP) intraparenchymal hematoma apparent by the anechoic region (*) near the head of the spleen found during the initial AFAST³ in a dog with automobile-induced trauma (also see Figure 13.8B). (B) A large blood clot nearly filling the lumen of the urinary bladder (UB) found during the initial AFAST³ in a dog with automobile-induced trauma. © Gregory Lisciandro

- Serial exams should always be performed in bluntly traumatized animals four hours post-admission; and after rehydration and resuscitation in penetrating trauma and non-trauma at-risk cases, including suspect peritonitis cases.
- The use of the AFS system may be effectively applied in bleeding traumatized and non-traumatized dogs to predict the degree of anticipated anemia in dogs (not reliable in cats). It also may be used for peritonitis or other effusive conditions as a monitoring tool.
- The diagnosis of anaphylaxis in dogs may be supported with the finding of a gallbladder halo sign; however, a complete AFAST³ including ruling out cardiac tamponade and placing the finding within the complete clinical picture is important to avoid mistakes (false positive).

References

- Boysen SR, Rozanski EA, Tidwell AS, et al. 2004. Evaluation of a focused assessment with sonography for trauma protocol to detect free abdominal fluid in dogs involved in motor vehicle accidents. *J Am Vet Med Assoc* 225(8):1198–1204.
- Culp WT, Weisse C, Kellogg ME, et al. 2010. Spontaneous hemoperitoneum in cats: 65 cases (1994–2006). *J Am Vet Med Assoc* 236(9):978–82.
- Kirkpatrick AW, Sirois M, Ball CG, et al. 2004. The hand-held ultrasound for penetrating abdominal trauma. *Am J of Surg* 187:660–665.
- Kolata RJ, Dudley EJ. 1975. Motor vehicle accidents in urban dogs: a study of 600 cases. *J Am Vet Med Assoc* 167:938–941.
- Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–122.
- Lisciandro GR, Lagutchnik MS, Mann KA, et al. 2009. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma in 101 dogs with motor vehicle trauma. *J Vet Emerg Crit Care* 19(5):426–437.
- Lisciandro GR, Lagutchnik MS, Mann KA, et al. 2008. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 18(3): 258–269.
- Lisciandro GR. 2012. Evaluation of initial and serial combination focused assessment with sonography for trauma (CFAST) examinations of the thorax (TFAST) and abdomen (AFAST) with the application of an abdominal fluid scoring system in 49 traumatized cats. Abstract. *J Vet Emerg Crit Care* 22(S2):11.
- Lisciandro GR. 2012. The clinical utility of the AFAST diaphragmatico-hepatic view for the detection of pericardial effusion. Unpublished data.
- Mandell DC, Drobatz K. 1995. Feline hemoperitoneum: 16 Cases (1986–1993). *J Vet Emerg Crit Care* 5(2):93–97.
- Matsushima K, Frankel HL. 2011. Beyond focused assessment with sonography for trauma: ultrasound creep in the trauma resuscitation area and beyond. *Curr Opin Crit Care* 17(6):606–12.
- Mongil CM, Drobatz KJ, Hendricks JC. 1995. Traumatic hemoperitoneum in 28 cases: a retrospective review. *J Am Anim Hosp Assoc* 31:217–222.
- Mohammadi A, Ghasemi-Rad M. 2012. Evaluation of gastrointestinal injury in blunt abdominal trauma FAST is not reliable: the role of repeated ultrasonography. *World J Emerg Surg* 20;7(1):2.
- Muir W. 2006. Trauma: physiology, pathophysiology, and clinical implications. *J Vet Emerg Crit Care* 16(4):253–263.
- Nelson NC, Drost WT, Lerche P, et al. 2011. Noninvasive estimation of central venous pressure in anesthetized dogs by measurement of hepatic venous blood flow velocity and abdominal venous diameter. *Vet Rad and Ultrasound* 51(3):313–323.
- Quantz JE, Miles MS, Reed AL, et al. 2009. Elevation of alanine transaminase and gallbladder wall abnormalities as biomarkers of anaphylaxis in canine hypersensitivity patients. *J Vet Emerg Crit Care* 19(6):536–544.
- Zozycki GS. 1998. Surgeon performed US: its use in clinical practice. *Ann Surg* 228:16–28.
- Zozycki GS, Pennington SD, Feliciano DV. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50(4):636–42.
- Sgourakis G, Lanitis S, Zacharioudakis C, et al. 2012. Incidental findings in trauma patients during focused assessment with sonography for trauma. *Am Surg* 78(3):366–72.
- Sigrist NE, Adamik KN, Doherr MG, et al. 2011. Evaluation of respiratory parameters at presentation as clinical indicators of the respiratory localization in dogs and cats with respiratory distress. *J Vet Emerg Crit Care* 21(1):13–23.
- Simpson SA, Syring R, Otto CM. 2009. Severe blunt trauma in dogs: 235 cases (1997–2003). *J Vet Emerg Crit Care* 19(6):588–602.
- Udobi KF, Rodriguez A, Chiu WC, et al. 2001. Role of ultrasonography in penetrating abdominal trauma: a prospective study. *J Trauma* 50:475–479.

FOCUSED OR COAST³—LIVER AND GALLBLADDER

Stephanie Lisciandro

Introduction

The goals of using focused ultrasound examination for evaluation of the liver include recognizing focal and multifocal mass lesions and evaluating diffuse parenchymal changes and changes in echogenicity. Evaluation for hepatic venous congestion may also be accomplished. The goals for focused exam of the gallbladder include recognizing abnormalities of the gallbladder wall and luminal disease processes, and identification of signs that may support biliary obstruction.

The focused liver and gallbladder exam can help guide clinical decisions by providing initial information that may not be otherwise evident by traditional means without ultrasound. With that said, this exam is not meant to replace a complete abdominal ultrasound study by a veterinarian with advanced training (the veterinary radiologist or internist). The use of the focused exam may direct the clinician to obtain a complete study because the evaluation of the liver and biliary tract is inherently more difficult for the novice sonographer than other abdominal organs. It is especially important to note that an unremarkable focused liver and gallbladder exam does not rule out the possibility of significant hepatobiliary dysfunction and disease. Liver biopsy may still be indicated depending on the patient's clinical profile because there may be ultrasonographically occult architectural changes even when there is evidence of hepatic dysfunction or inflammation on laboratory testing.

As a general rule with all abdominal focused exams, AFAST³ with the application of the abdominal fluid scoring system should be performed to avoid missing free fluid of the peritoneal and retroperitoneal spaces

as well as the pleural and pericardial spaces via the AFAST³ and TFAST³ diaphragmatico-hepatic (DH) view (see AFAST³, Chapter 2). The addition of an AFAST³ exam with focused liver and gallbladder is minimally time consuming and prevents missing the easy detection of abdominal and retroperitoneal effusions, including peritonitis and hemorrhage, that would otherwise be missed.

What the Focused Liver and Gallbladder Exam Can Do

- Screen for differences in echogenicity among liver lobes
- Search for focal or multifocal masses or nodules
- Determine if gallbladder luminal contents are abnormal
- Determine if the gallbladder wall is abnormal
- Screen for vascular congestion

What the Focused Liver and Gallbladder Exam Cannot Do

- Cannot differentiate benign vs. malignant liver masses
- Cannot be the sole diagnostic indicator used in the diagnosis of biliary obstruction
- Cannot diagnose liver conditions based on echogenicity

- Cannot reliably determine liver size or hepatomegaly vs. microhepatica (microhepatia)
- Cannot rule out severe liver disease such as hepatic neoplasia and cirrhosis based on an unremarkable focused liver exam

Indications for the Focused Liver and Gallbladder Exam

- Increased liver enzymes, total bilirubin
- Cranial organomegaly on physical examination, abdominal radiography, or both
- Abnormal serum bile acids (SBA) or resting ammonia levels
- Decreased albumin, cholesterol, blood urea nitrogen (BUN)
- Persistent hypoglycemia
- Prolonged anorexia (especially cats)
- Vomiting

Objectives of the Focused Liver and Gallbladder Exam

- Recognize liver masses (single, multifocal)
- Recognize regional changes in liver echogenicity
- Recognize venous congestion
- Recognize gallbladder wall abnormalities
- Recognize gallbladder luminal conditions such as mucoceles, choleliths, and biliary sludge
- Recognize signs supporting biliary obstruction such as severe gallbladder and bile duct distension and abnormal biliary contents (choleliths and inspissated bile), which, when found, should prompt referral for a complete abdominal ultrasound study by a veterinary radiologist or internist with advanced training

Ultrasound Settings and Positioning

When imaging the liver, a 5- to 10-MHz curvilinear probe may be used depending on the size of the animal. Generally, smaller dogs and cats are imaged using 7.5- to 10-MHz probes. Large dogs are usually imaged with a 5-MHz probe for deeper penetration. The depth of field should be adjusted initially to allow for the diaphragmatic interface with the liver to be visualized in the far field. Gain should also be adjusted to maximize image quality. Adjustments in depth, gain, and focus

position will need to be made repeatedly during the exam to optimize penetration and image quality.

The patient is most commonly imaged in dorsal recumbency. The transducer is placed on the ventral abdomen just caudal to the xiphoid process. The liver is then scanned in transverse and sagittal planes. Generally, this position allows for adequate visualization of the liver in smaller dogs and cats. However, in deep-chested dogs or larger animals, additional approaches through the right and left intercostal spaces may also be needed. In addition, the presence of an overlying gas-distended stomach or colon can interfere with adequate visualization of the liver in dorsal recumbency. In these instances, the patient is positioned in right and/or left lateral recumbency. In this positioning, these structures will fall to the gravity dependent side of the patient, optimizing ultrasound imaging by the intercostal approach on the non-gravity dependent side.

How to Do the Focused Liver and Gallbladder Exam

The patient is positioned in dorsal recumbency and the fur is clipped from the ventral abdomen and as needed over intercostal spaces. Acoustic gel is applied to the abdomen. The transducer is placed caudal to the xiphoid process with the probe marker facing toward the head of the patient using a subcostal approach (see Figures 2.2 and 13.1). Generally, this will allow for visualization of a sagittal view through the midline of the liver. The pleural margin of the diaphragm should be evident as a hyperechoic (bright white) line in the far field (Figure 3.1). If this is not visualized in the initial image, then the depth of field should be adjusted to bring it into view. Falciform fat may be seen in the near field along the ventral margin of the liver, especially in overweight animals, and should not be mistaken for hepatic parenchyma (Figure 3.2A through D).

The probe should then be fanned to the right side of the patient, where the gallbladder should come into view. The probe may need to be rotated to bring the gallbladder into a long-axis view. The probe is then fanned to the patient's left so that the entirety of sonographically accessible liver is visualized. In larger animals, it may be necessary to move the probe along the costal arch to visualize the entire liver. As the probe is fanned to the left, the stomach will come into view. After thoroughly scanning in the sagittal view, the probe is then rotated with the marker facing to the right side (turn left or counterclockwise) of the patient and the liver is

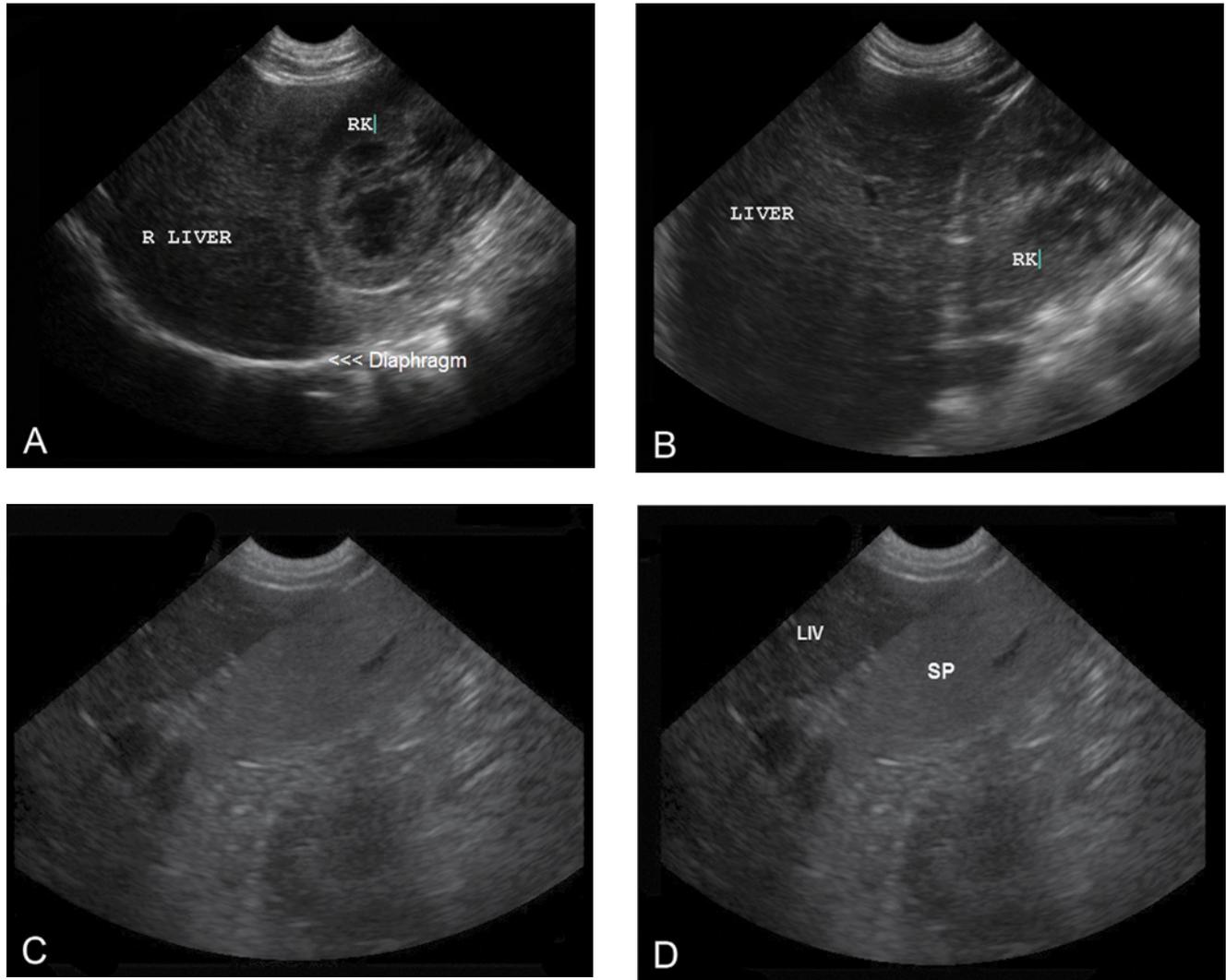


Figure 3.1. Comparative echogenicity of the liver to the cortex of the right kidney and spleen. (A) The liver (R LIVER) is normally slightly more echogenic (brighter) or the same echogenicity (isoechoic) as the cortex of the kidney (RK). (B) The right kidney (RK) is best compared to the liver because it is seated in the renal fossa of the caudate lobe. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (C) Normally, the spleen is more echogenic than the liver (unlabeled). (D) Same image as (C) with the liver and spleen labeled. The use of the split screen function of your ultrasound machine facilitates comparative echogenicities of the liver to the spleen and kidney

Figure 3.2. Liver margination and comparative echogenicity to the falciform fat. (A) Image of the falciform fat. Note the linear subcutaneous facial planes and falciform fat. Liver echogenicity can be similar to the falciform fat. This especially depends on sonographic gain settings and hence comparative echogenicity can vary. This image demonstrates the delineation between the falciform fat and normal liver by the thin echogenic line (arrow) representing the liver capsule. (B) Another example of the contrast in echogenicity between the liver and falciform fat. Note the sharp, normal liver margin. (C) Example of prominent falciform fat in a more obese patient. The falciform in the near field is juxtaposed with the normal liver (LIV) in the far field. Compare to (A) and (B) and note that the liver capsule as a hyperechoic line (<<<) is also apparent. (D) Delineation of the liver lobes can be difficult to see unless anechoic free fluid (*) (ascites) is present. Normally the caudal margins of the liver lobes are easily identified and sharply demarcated. Imaging of the liver should always be deep enough to appreciate the diaphragm. Note the sharply marginated hyperechoic curvilinear structure representing the diaphragm (<<<). (E) The majority of the diaphragm can be imaged. This is important in trauma cases and in cases for which the integrity of the diaphragm may be compromised (e.g., congenital or acquired diaphragmatic hernia). Shown here is a peritoneal pericardial hernia in a cat. Note the embryologic persistence of the septum transversum. In this patient, the liver would dynamically slip into the pericardial sac depending on how the patient was positioned. In many cases, other abdominal organs (such as the spleen, liver, or bowel) can be seen within the pericardial sac. These can be an incidental finding or seen in patients with exercise intolerance or respiratory distress. (F) Shown here is another peritoneal pericardial diaphragmatic hernia in a cat with concurrent pleural effusion. Note how contained within the pericardial sac there is no recognizable heart but rather homogeneous echotexture more supportive of a solid organ, which in this case was liver. The small bowel is also commonly herniated and easily recognized by the layering of its walls (also see Figure 9.23). Figures (A), (B), (E), and (F) Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

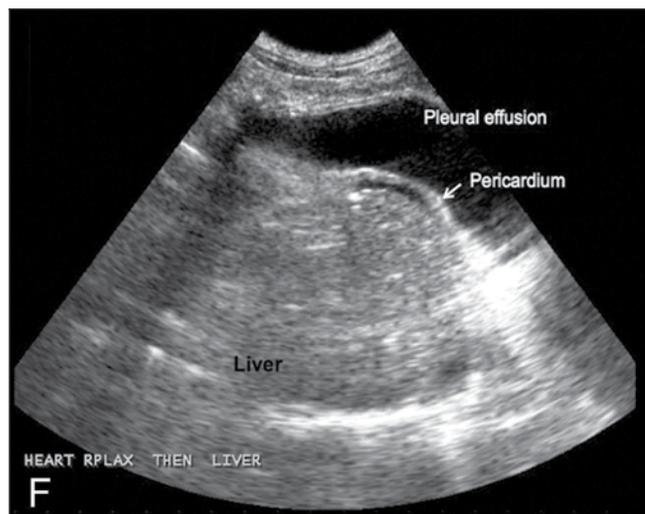
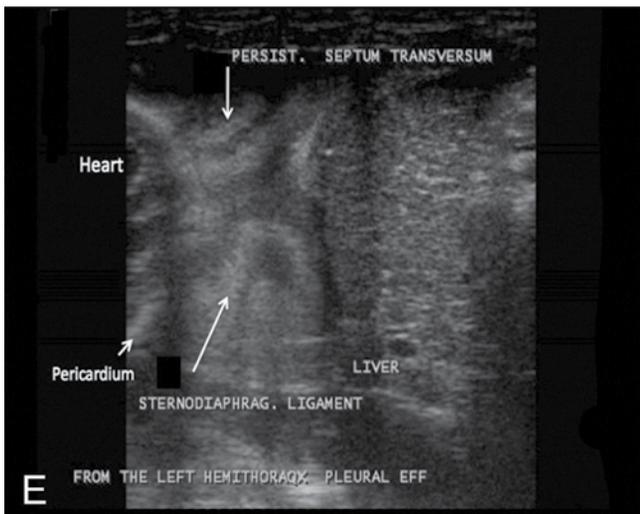
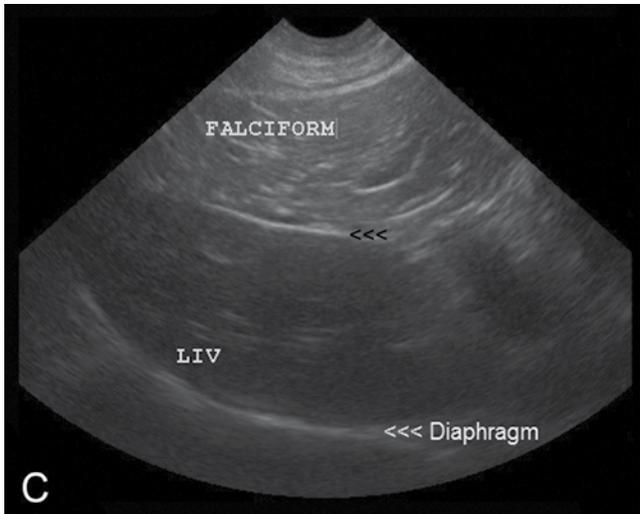
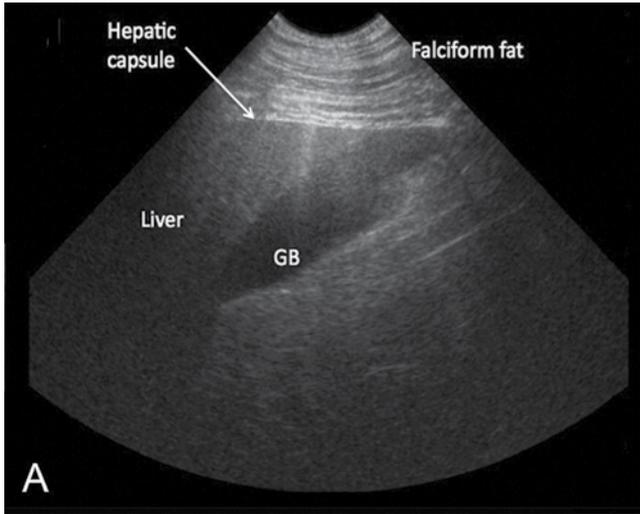


Figure 3.2.

scanned from right to left again in the transverse view. The hepatic veins and portal vein can be identified using these planes of imaging and discriminated by the portal venous walls, which are more hyperechoic (brighter) and often appear as bright “equal signs” (see Figure 3.10A and B; also see Figure 13.1).

If the stomach contains a large amount of gas or ingesta this may prevent complete visualization of the left side of the liver. The descending colon may also interfere with imaging of the left side of the liver if it contains a large amount of stool or gas. If the stomach or colon interferes with imaging, the patient should be repositioned in right lateral recumbency and a left intercostal approach used (so the fluid- or gas-filled structures fall away). Alternatively, the patient can be re-imaged following fasting and/or colonic evacuation if necessary and if the patient is stable enough.

In deep-chested dogs, the liver may be difficult to image using a subcostal approach because the entire liver may lie up under the rib cage. In these instances, right and left intercostal approaches are often needed to evaluate the liver. The sonographer should be aware that complete ultrasonographic interrogation of the liver is often not possible.

Ultrasonographic Findings in a Normal Focused Liver and Gallbladder Exam

The liver is comprised of six lobes including the left medial and lateral lobes, quadrate lobe, right medial and lateral lobes, and caudate lobe. Sonographically, the right and left medial and lateral lobes are poorly defined. The left liver is largest and may comprise up to one-half of the liver mass. The gallbladder contacts the quadrate and right medial lobe. The left liver can be seen lateral and left to the gallbladder and medial to the gastric fundus. The caudate process of the caudate lobe comes in contact with the right kidney on the right side (Figure 3.1A and B). In general, it is difficult to visualize the divisions between liver lobes unless peritoneal fluid (ascites) is present (Figure 3.2D; also see Figure 2.2B and C). Falciform fat can be imaged in the near field at the ventral margin of the liver (near field) along with the variability of its size depending on body condition and probe position (Figure 3.2A through D; also see Figure 3.10D and 2.2D). The diaphragm is imaged cranially as a hyperechoic (bright white) line, which is actually the interface of the diaphragm and the bright reflector of air in lung in the far field (Figure 3.2B through D). When this expected interface is not present

or if there is interruption of the normal curvilinear continuity of the structure, congenital or acquired diaphragmatic herniation and/or traumatic rents should be ruled out (Figure 3.2E and F; also see Figure 9.21).

Normal hepatic parenchyma is homogeneous and uniform in echogenicity with medium echotexture (coarser echotexture than spleen) (Figure 3.1C and D). Echogenicity is generally evaluated in comparison with falciform fat, the right renal cortex, and spleen (Figures 3.1A and B, 3.2A through D). Falciform fat must be distinguished from hepatic parenchyma and is generally isoechoic (same as) or hyperechoic (brighter than) when compared to normal hepatic parenchyma (Figure 3.2A through D and compare to 3.10D). The echotexture of falciform fat is coarser than hepatic parenchyma. The liver is generally hypoechoic when compared to normal spleen and should be compared to the head of the spleen where depth is similar and allows for better comparison (Figure 3.1C and D). The liver may be isoechoic (same as) or mildly hypoechoic (darker than) when compared to the renal cortex (Figure 3.1A and B). Subtle changes in echogenicity of the hepatic parenchyma can be difficult to evaluate for the novice sonographer. Using the split screen function on your ultrasound can be helpful when the spleen, liver, and kidney cannot be evaluated on a single screen for assessing comparative echogenicities.

Remember the “SLiCK” mnemonic regarding echogenicity as follows: the spleen (S) is hyperechoic or brighter than the liver (Li), which is slightly more hyperechoic (brighter) or isoechoic (same echogenicity) as the cortex of the kidney (CK), or in order of most (brightest) to least (darkest) echogenic spells “SLiCK.”

Evaluation of the size of the liver is subjective and generally not adequately assessed using ultrasound due to patient variability in conformation. Normal liver margins are sharp and not rounded (Figure 3.2A, B, and D).

Evaluation of hepatic vasculature should generally be reserved for the more experienced sonographer. However, distention of the hepatic veins is fairly easy to identify and can be learned by the novice. Hepatic veins are distinguished from portal veins by the presence of echogenic walls (bright) in the portal veins, which are lacking in hepatic veins (Figure 3.10A and B; also see Figure 13.1D). The hepatic veins can be traced to the caudal vena cava near the diaphragm on the right side of the abdomen to confirm their identity (Figure 3.3; also see Figures 2.4 and 11.8). When hepatic

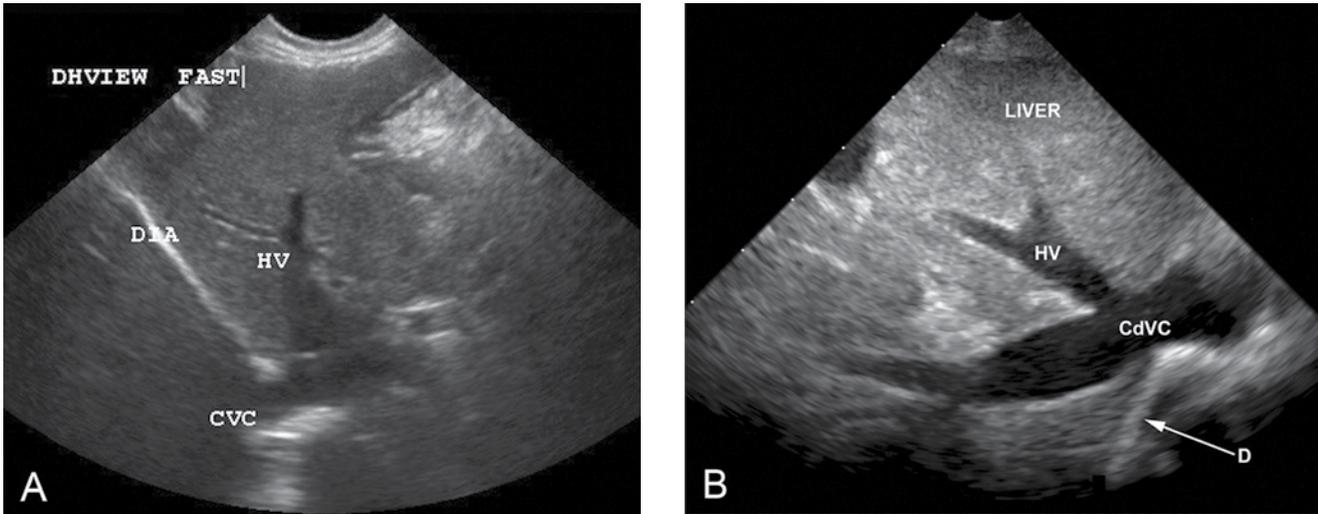


Figure 3.3. Hepatic venous congestion. The differentiation between hepatic veins and portal veins can be challenging for the novice. However, imaging the caudal vena cava as it passes through the diaphragm is easy to learn and helps accurately identify distended hepatic veins by their associated branching into the caudal vena cava. Normally, hepatic veins are rather inconspicuous. (A) Example of moderate to severe hepatic venous (HV) congestion. Note how the hepatic veins can be seen emptying into the caudal vena cava (CVC) prior to it passing through the diaphragm (DIA). This image was taken via the thoracic FAST (TFAST³) diaphragmatico-hepatic (DH) view (labeled as DHVIEW FAST). (B) Another example of hepatic venous (HV) congestion being traced to the caudal vena cava (CdVC) near the diaphragm (D with arrow). Detecting hepatic venous distension is clinically helpful and can aid in the detection of volume overload, right-sided heart failure, or an obstructive lesion between the liver and right atrium, which would then prompt further investigation and may guide management. Figure (B) Courtesy of Dr. Terri DeFrancesco, North Carolina State University.

veins are overly distended they appear like large tree trunks (Figure 3.10B).

The gallbladder is visualized on the right side of the liver. The size is variable depending on when gallbladder contraction last occurred. The gallbladder should appear as an anechoic structure with a thin echogenic uniform wall (normal gallbladder wall thickness in cats is less than 1 mm and in dogs is less than 2–3 mm) (Hittmair 2001, Spaulding 1993) (Figure 3.4, and compare to thickened examples in Figure 3.11; also see Figures 2.16 and 2.17). Echogenic gravity dependent material within the lumen is common in dogs and generally a benign finding in the absence of other significant ultrasonographic and clinical findings (Tsukagoshi 2012) (Figure 3.12; also see Figure 1.10). The intrahepatic bile ducts are generally not visualized unless there is extrahepatic biliary obstruction. The common bile duct may be visualized normally but evaluation is generally difficult for the novice sonographer, and dilation of the biliary system may appear like hepatic or portal veins or other pathology (Figure 3.15A and B; also see Figure 2.5A and B). If available, color flow Doppler is useful for differentiating the dilated biliary tract from hepatic and portal vessels; however, tracing structures in real-time is often adequate (see Figure 2.5A and B).

It may be difficult to tell the difference between a dilated biliary tract and hepatic or portal veins, in which case color flow Doppler may be helpful.

Artifacts are commonly encountered when performing the focused liver and gallbladder exam and include mirror image, acoustic enhancement, side-lobe, slice-thickness, and edge shadowing (see Figures 1.5, 1.6, 1.7, and 1.10). These are discussed below and in more detail in Chapter 1.

The most common of these artifacts results in a mirror image of the liver and gallbladder being seen on the far side of the lung-diaphragm interface. This should not be mistaken for a diaphragmatic hernia; in some cases the gallbladder's contents are mirrored into the thorax and are mistaken for pleural effusion (Figure 3.9D; also see Figure 1.7A through C).

Acoustic enhancement is associated with a fluid-filled gallbladder that causes an increase in echogenicity of the hepatic parenchyma in the far field to the gallbladder (see Figure 1.6). Acoustic enhancement should not be mistaken for increased liver echogenicity.

Side-lobe and slice-thickness artifacts involve the fluid-filled organs like the gallbladder and make it falsely appear that luminal sediment is present

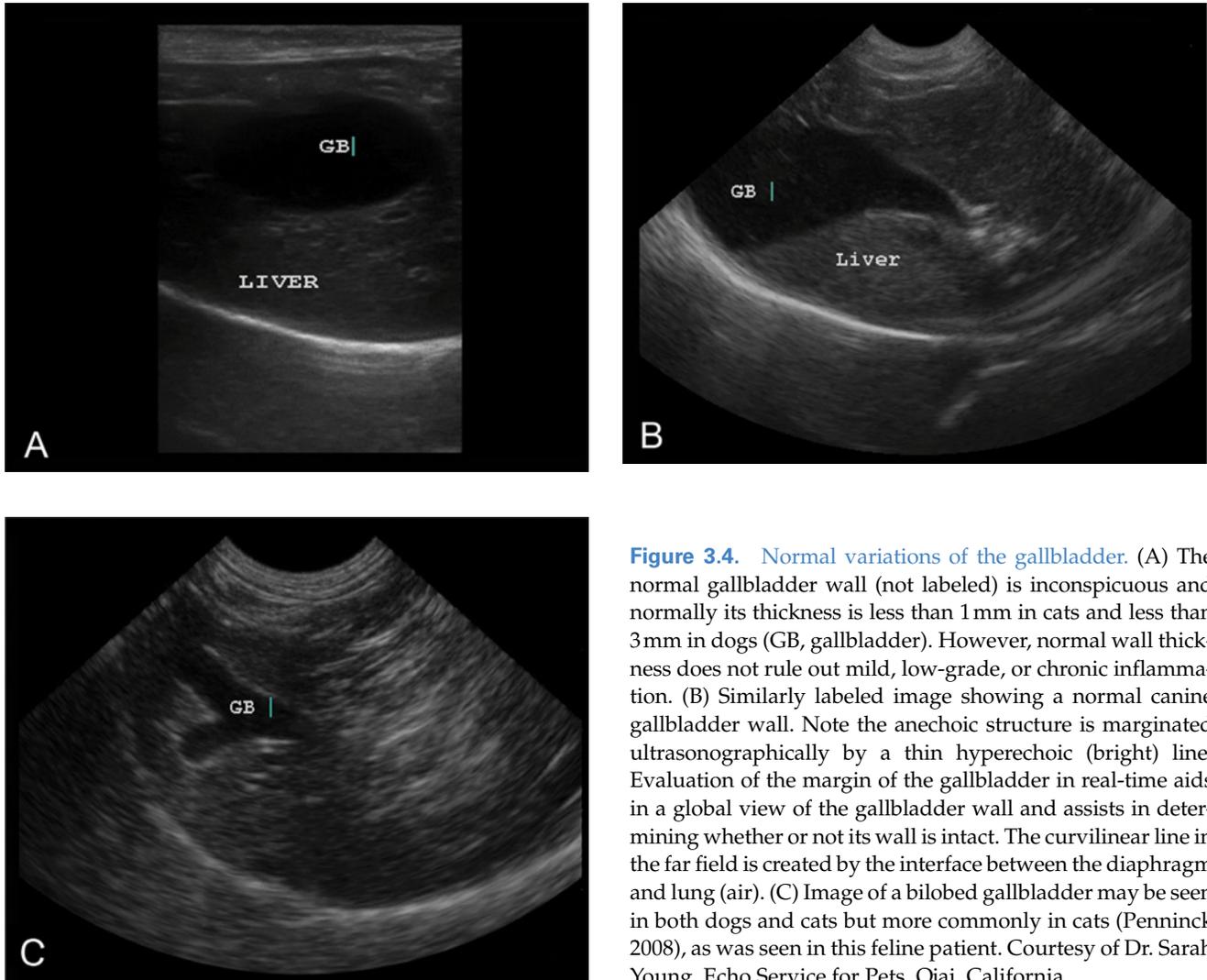


Figure 3.4. Normal variations of the gallbladder. (A) The normal gallbladder wall (not labeled) is inconspicuous and normally its thickness is less than 1 mm in cats and less than 3 mm in dogs (GB, gallbladder). However, normal wall thickness does not rule out mild, low-grade, or chronic inflammation. (B) Similarly labeled image showing a normal canine gallbladder wall. Note the anechoic structure is margined ultrasonographically by a thin hyperechoic (bright) line. Evaluation of the margin of the gallbladder in real-time aids in a global view of the gallbladder wall and assists in determining whether or not its wall is intact. The curvilinear line in the far field is created by the interface between the diaphragm and lung (air). (C) Image of a bilobed gallbladder may be seen in both dogs and cats but more commonly in cats (Penninck 2008), as was seen in this feline patient. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

(see Figure 1.10). It is easy to remember that side-lobe mimics sediment because “side” may be rearranged to spell “sedi” for sediment.

Edge shadowing also involves the fluid-filled organs like the gallbladder and may make its wall appear to have a rent and be mistaken for gallbladder rupture (see Figure 1.5B).

Clinical Significance and Implications of Abnormal Focused Liver and Gallbladder Findings

The goals of the focused liver and gallbladder exam include recognition of liver masses (single, multifocal), changes in liver echogenicity, hepatic venous

Common artifacts in the liver include mirror image, acoustic enhancement, side-lobe and slice-thickness, and edge shadowing.

congestion, identification of gallbladder wall abnormalities and gallbladder luminal conditions, and recognition of signs of biliary obstruction. Such findings should prompt referral for a complete ultrasound or possibly other interventions.

Liver Masses

Identification of focal liver masses is the easiest task to learn with the focused exam. It is important to remember that it is not possible to differentiate between benign and malignant processes on the basis of ultrasound alone. Focal lesions may be produced by regenerative nodules or nodular hyperplasia, neoplasia,

focal inflammatory disease, cysts, abscesses, granulomas and hematomas.

Nodules associated with nodular hyperplasia may be variable in echogenicity when compared to normal hepatic parenchyma (hyperechoic, hypoechoic, isoechoic, or mixed echogenicity). Generally, well-defined hyperechoic homogeneous nodules are more likely to be benign but cytology or histopathology is

necessary for definitive evaluation. Nodular hyperplasia is commonly seen in older dogs (Nyland 2002) (Figure 3.5).

Hepatic cysts consist of round to oval anechoic (fluid-filled) structures with well-defined walls. These are generally benign unless a significant amount of hepatic architecture is disrupted and there is evidence of hepatic dysfunction (polycystic

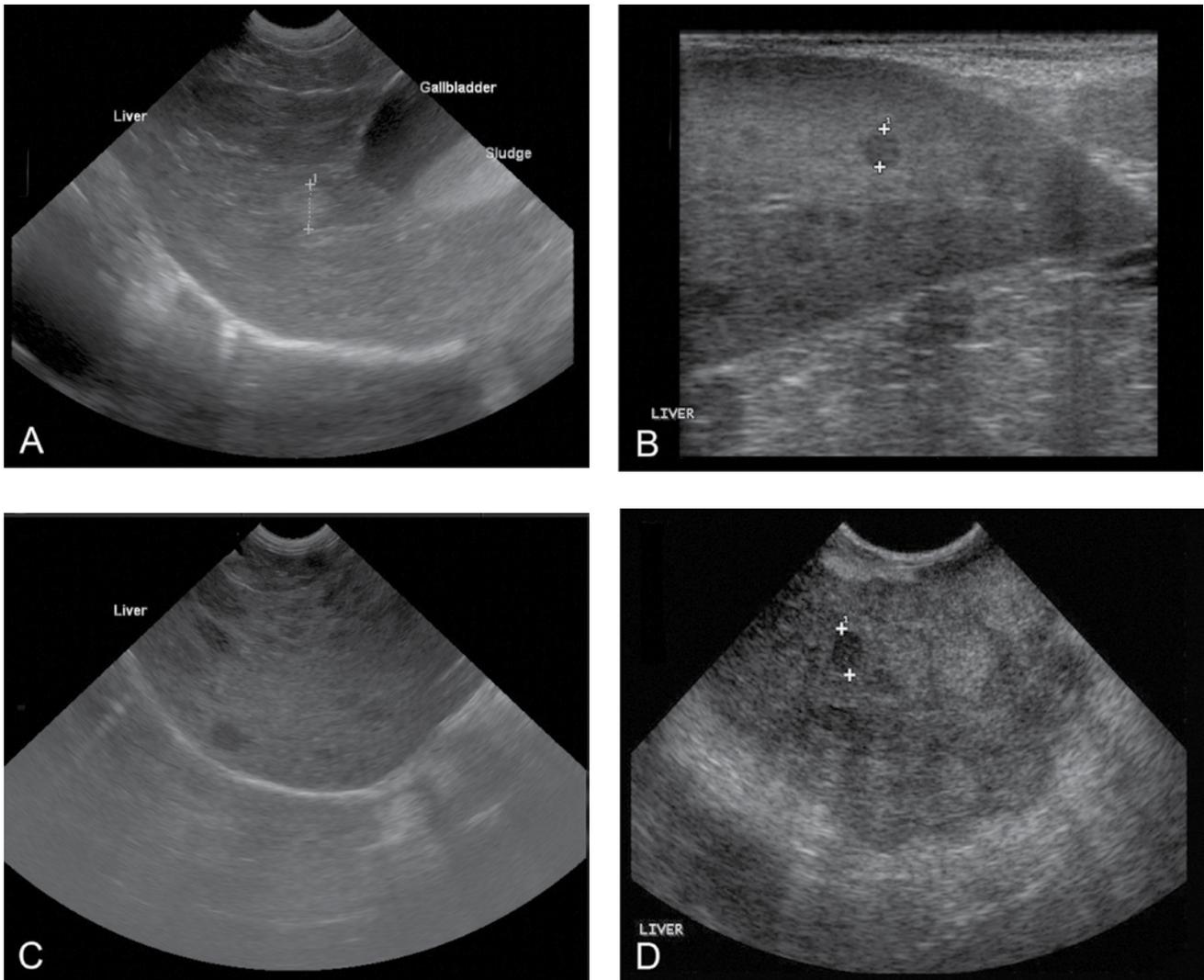


Figure 3.5. Benign hepatic nodules. (A) Small hyperplastic nodule as demarcated by the caliper marks made by the sonographer, consistent histopathologically with benign nodular hyperplasia. This is a common finding in older dogs. Generally, nodules are seen as discreet well demarcated hyper- or hypoechoic homogeneous nodule(s) and can be singular or multiple. Nodules can be any size. Hence, findings are non-specific and fine needle aspiration or biopsy is needed to differentiate these nodules from malignant processes. (B) Nodular hyperplasia with multiple various-sized homogeneous hypoechoic nodules with the largest marked with calipers (+). (C) Example of an older dog with multiple hypoechoic nodules representing benign nodular hyperplasia. (D) In contrast to (B), example of a severely nodular liver in a 10-year-old male castrated Chihuahua with poorly controlled diabetes and pancreatitis. The process is diffuse and the liver margins are severely rounded. Calipers, as marked by the sonographer, demonstrate a hypoechoic cyst with distal enhancement. Note that there are multiple nodules throughout the parenchyma that are hyperechoic. Fine needle aspiration results were consistent with a vacuolar degeneration and lipidosis. Benign hyperplasia and neoplasia would also be considered as a differential. A biopsy would be more definitive in this case. Figures (B) and (D) Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

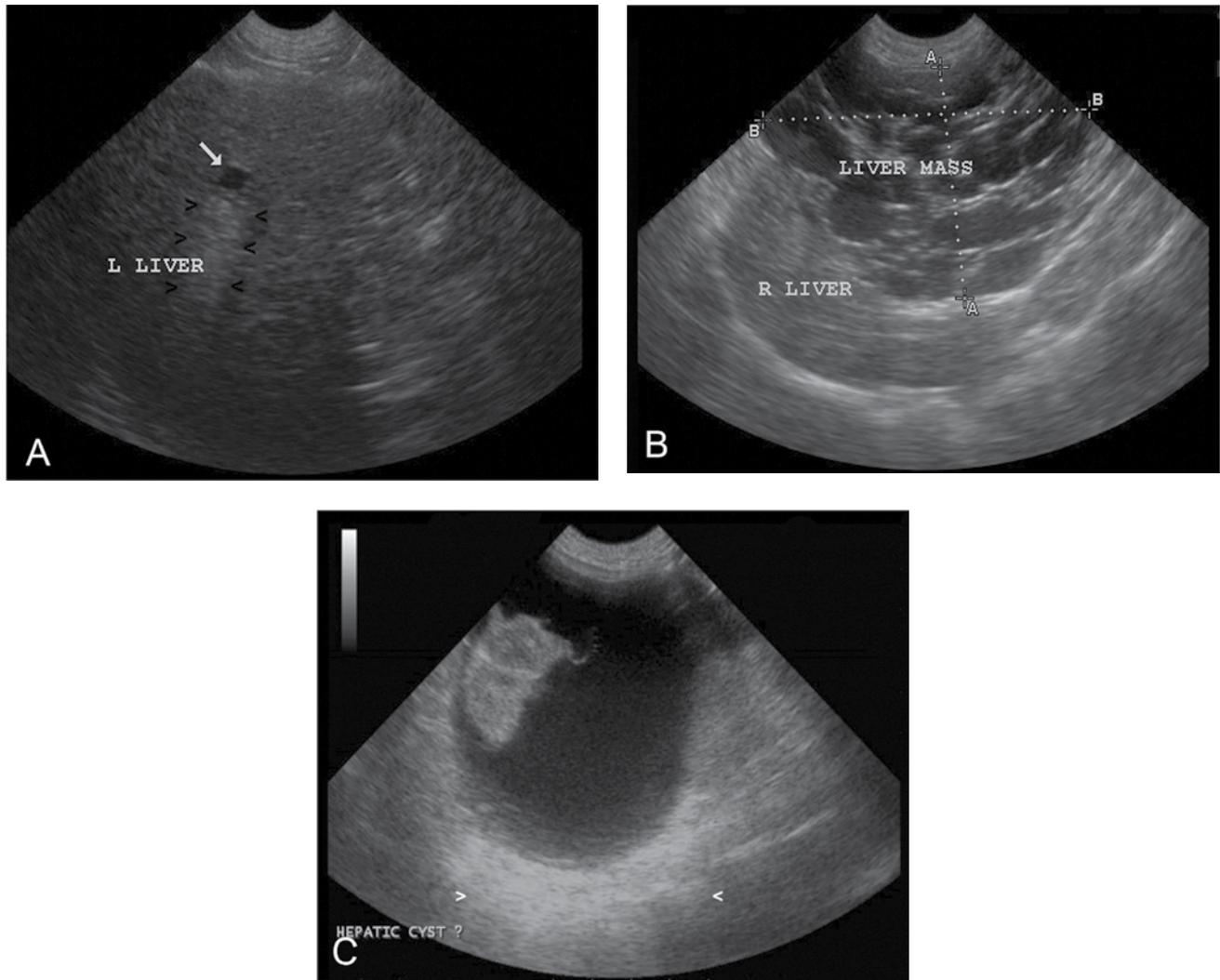


Figure 3.6. Hepatic cyst and biliary Cysts. (A) Hepatic cyst (arrow). Note the distal acoustic enhancement as a hyperechoic (bright white) shadow extending from the far margin of the hepatic cyst (marked with subtle black cursors [$>$ <]) on both sides of the hyperechoic track). Hepatic cysts are typically thin-walled and filled with anechoic fluid. A fluid-filled structure can be differentiated from a solid nodule by looking in the far field for acoustic enhancement artifact (the bright track extending from the far field of the cyst to the text "L LIVER"). A solid structure will conversely have acoustic shadowing artifact in the far field. (B) Multiple biliary cystadenomas in a cat (labeled liver mass by the sonographer). This can be difficult to differentiate from malignant masses. However, acoustic shadowing artifact helps discriminate fluid-filled cysts from nodules in real-time. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (C) Large hepatic cyst in a dog. Note the large anechoic structure with distal acoustic enhancement (labeled $>$ <). Within the cyst is a large, echogenic, ovoid to amorphous structure. Irregularly marginated cysts or those containing echogenic material are less likely to be benign. An additional differential for the structure within the cyst includes fibrinous material or hemorrhage and may represent abscessation, inflammation, or neoplastic change. Fine needle aspiration may allude to the diagnosis. Alternatively, excisional biopsy may be needed. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

disease). Cysts may be parenchymal or biliary in nature. They may be congenital or acquired. Cysts which have irregular margins or contain echogenic material are less likely to be benign and may represent abscesses, inflammation, or neoplastic changes. (Figure 3.6).

Other parenchymal masses may have variable appearances and include abscess, hematoma, nodular hyperplasia, or neoplasia.

Hepatic abscesses are uncommon and usually cannot be distinguished from other processes that produce nodular or mass lesions (Figure 3.7A). Their

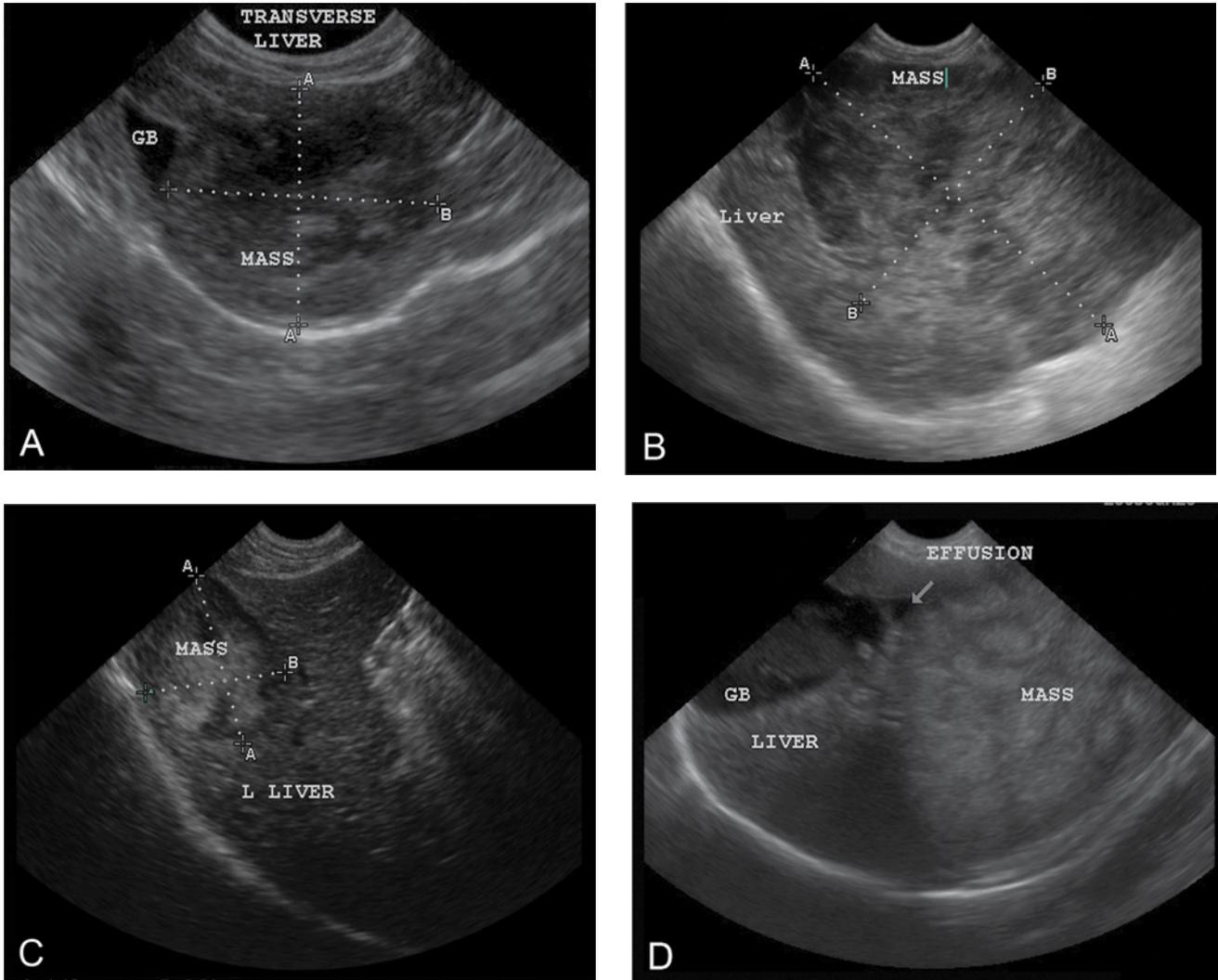


Figure 3.7. The ultrasonographic appearance of liver masses cannot differentiate between benign and malignant conditions. (A) Hepatic abscess in a cat that appears like a solid tumor. The gallbladder (GB) appears like free fluid but typically can be distinguished from free fluid during real-time imaging (also see Figure 2.3). The hallmark of an abscess regardless of location is the presence of air within the mass effect as evidenced by comet tails and other air-related artifacts caused by gas-producing bacteria (such artifacts are not evident here). Diagnosis was made by liver biopsy. (B) A large, mixed echogenicity mass (labeled mass by the sonographer). It can be difficult to determine the origin of large masses. The liver, spleen, kidney, or other adjacent structures should be considered if a region of organ confluence cannot be identified. The histopathological diagnosis in this case was hemangiosarcoma of the liver. (C) Another example of a hepatic mass with mixed echogenicity adjacent to the diaphragm. Note the abrupt change of echogenicity between the mass and normal hepatic parenchyma. Percutaneous biopsy result was hepatocellular carcinoma. (D) Large hyperechoic, lobulated mass. The diagnosis was hepatocellular carcinoma. Note the differences between sonographic appearances of (C) and (D) for the same histopathologic diagnosis, demonstrating the poor specificity of ultrasonographic findings with regard to histopathologic diagnosis. Additional differentials might have included a hepatoma (benign liver mass) or other solid parenchymal tumor. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

appearance may be variable with well-defined or indistinct margins and variable echogenicity. Most commonly, abscesses appear as relatively hypoechoic, thick-walled lesions which may have cystic or cavitory components or mixed echogenicity. A more definitive finding is the presence of gas (due to gas-forming bacteria) within the lesion, which appears as focal

areas of hyperechogenicity with distal edge shadowing and possibly comet-tail artifacts. Fine needle aspiration with cytology and bacterial culture and sensitivity is helpful in confirming the diagnosis. However, neoplastic lesions can have necrotic centers that can be mistaken for abscesses and therefore, diagnosis should always be in conjunction with additional

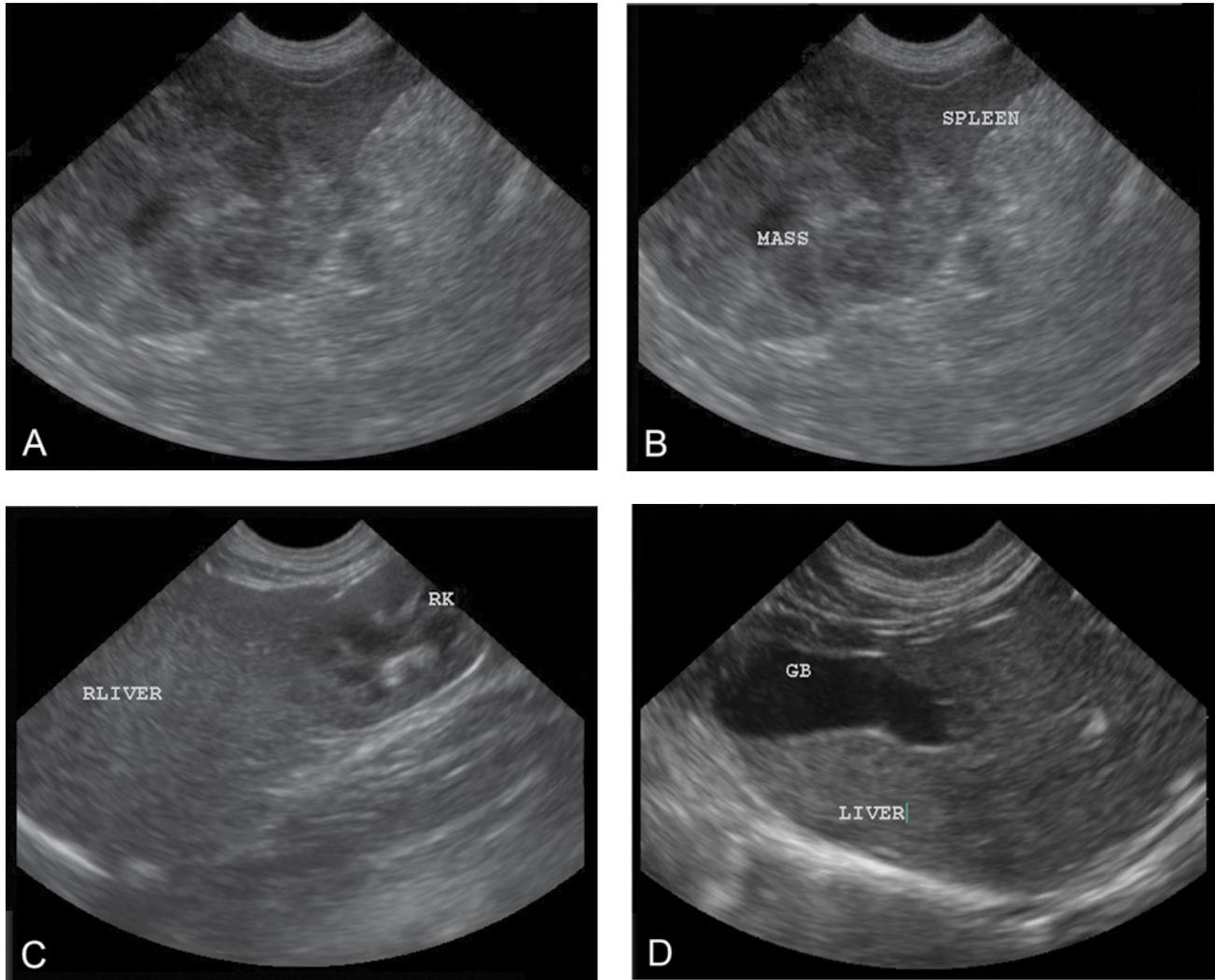


Figure 3.8. Liver and splenic masses. The origin of a mass can be challenging to determine ultrasonographically, and is sometimes not possible. (A and B) show the same large mass in a dog with mixed echogenicity (unlabeled and labeled). Careful evaluation showed confluence of the tumor with the splenic parenchyma. (C and D) are images of a cat (same patient) with a hepatic mast cell tumor. Note that a well-defined mass is not seen. Rather, the parenchymal changes are subtle and the liver is coarse in echotexture. In this case, a fine needle aspirate and/or liver biopsy are needed to determine the patient's diagnosis. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

clinical findings that support the diagnosis, which may include even further tissue sampling.

Hematomas may be variable in appearance but are generally anechoic or hypoechoic (darker) when compared to normal hepatic parenchyma initially. As the blood within the hematoma forms a clot, the lesion may become more isoechoic (same as) or hyperechoic (brighter than). As the clot retracts, the lesion may become more hypoechoic again. Anechoic fluid may form around the clot and appear as a cyst-like lesion. Hematomas may be difficult to distinguish from other mass lesions including neoplasia (hemangiosarcoma) (Figures 3.7B and Figures 3.8A and B). Fine needle biopsy of hematomas generally

yields non-specific cytological results and therefore, the absence of neoplastic cells on cytology does not rule out neoplasia.

Neoplastic lesions can have a wide range of morphological changes when associated with the liver. As emphasized above, it is not possible to distinguish between benign and malignant lesions based on ultrasonographic appearance alone. There are a variety of primary liver tumors including hepatocellular adenoma and adenocarcinoma as well as mesenchymal tumors (Figure 3.7B through D). Metastatic neoplasia, often appearing as target lesion(s), is common in the liver (Figure 3.9A and B). Lymphosarcoma can appear as either focal or multifocal mass lesions or as diffuse

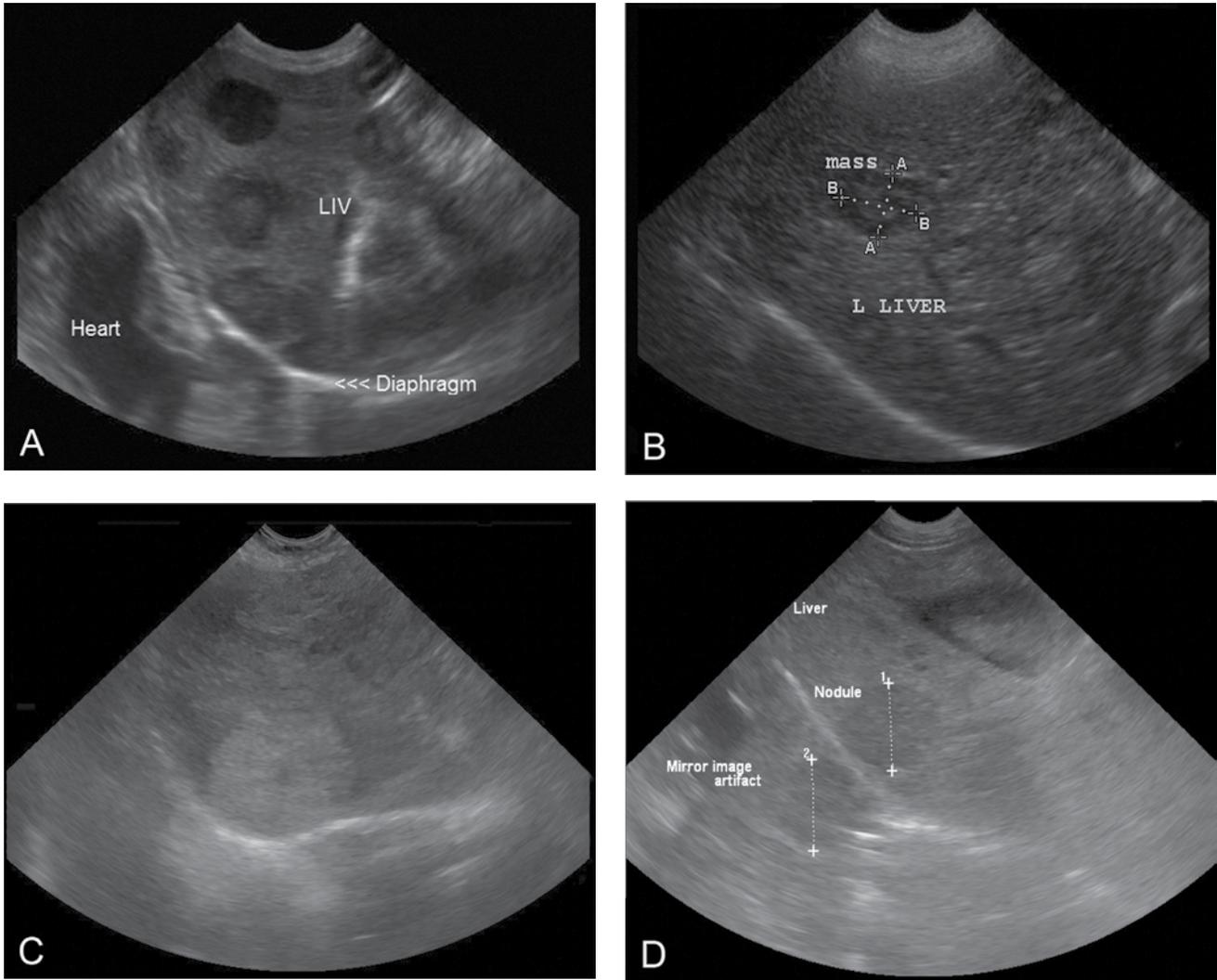


Figure 3.9. Liver masses. (A) Image of a dog with target lesions of the hepatic parenchyma. These lesions are generally considered malignant and may be consistent with metastatic disease; however, they are less commonly seen as primary hepatic neoplasia, granulomatous disease, chronic active hepatitis, or even benign hyperplasia. This patient also had a large cavitary splenic mass supportive of metastatic disease. (B) An example of a small target lesion in a dog with splenic hemangiosarcoma identified by the caliper-measured lesion (A-A, B-B) labeled "mass." Keep in mind that the visualization of a target lesion sonographically is non-specific and a biopsy is required. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (C) A large hyperechoic, well-margined mass in a dog that was percutaneously biopsied as hepatocellular carcinoma. (D) Another example of hepatocellular carcinoma. Note the commonly encountered mirror image artifact because of the strong, reflective soft tissue-air interface of the liver, diaphragm, and lung.

parenchymal disease. Hemangiosarcoma generally appears as complex mass lesions with mixed echogenicity and cavitations that distort the splenic capsule (Figures 3.7B and 3.8A and B). However, hematomas can have a similar appearance. As with other mass lesions in the liver, it is necessary to obtain cytology or histopathology samples to formulate a definitive diagnosis. Ultrasound-guided fine needle or Tru-Cut biopsy of mass lesions is generally relatively easy depending on the location of the mass.

Single target lesions have a high predictive value for malignancy. When multiple target lesions are seen, the positive predictive value of malignancy increases from 74% to 81% (Cuccovillo 2002) (Figure 3.9A and B). However, one must keep in mind that the visualization of a target lesion(s) ultrasonographically is non-specific and a biopsy is required. On the other hand, another diagnostic strategy when finding a hepatic target lesion is to look for other intra-abdominal masses using ultrasound or performing thoracic radiography (screening

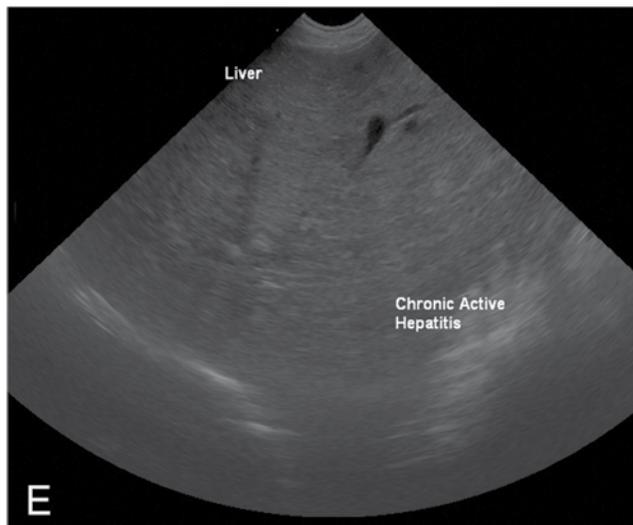
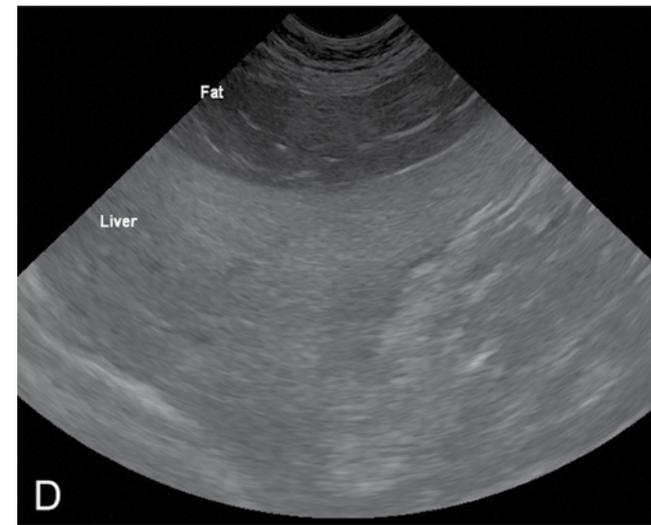
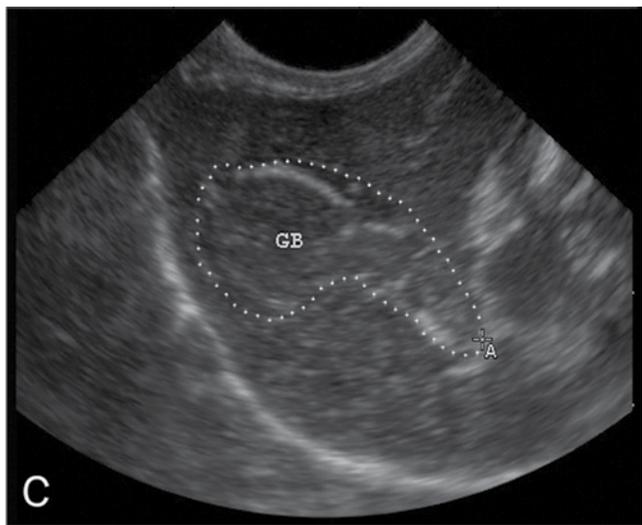
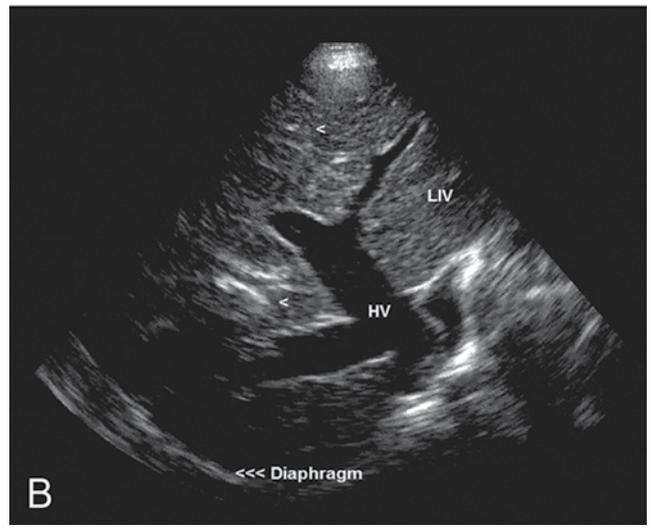
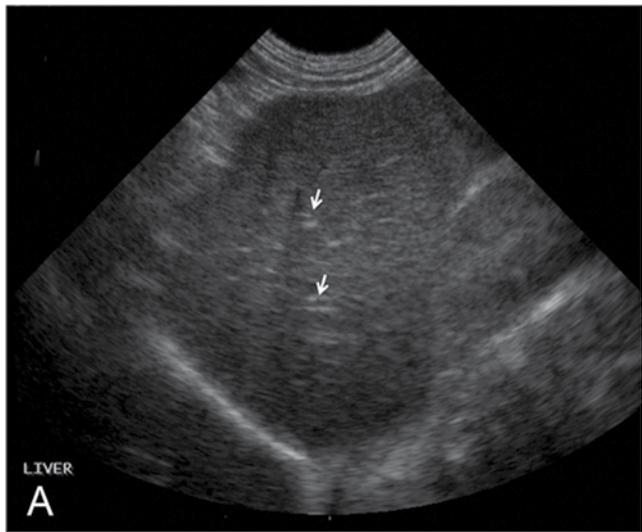


Figure 3.10.

for lung nodules), or both. By doing so, further evidence may be found that supports clinical suspicion or provides a more readily accessible mass or lesion for diagnosis via aspiration or biopsy.

Liver Parenchymal Disease

Evaluation of diffuse parenchymal disease is inherently more difficult than evaluation of focal lesions using the focused ultrasound exam. Ultrasound is not always sensitive to detection of diffuse parenchymal disease, and therefore, liver biopsy is generally needed for evaluation and diagnosis. However, some generalizations may be made regarding changes in echogenicity.

Diffuse hepatic hypoechogenicity (parenchyma is relatively darker than normal) is generally noted when the hepatic parenchyma is significantly hypoechoic (darker than) when compared to the renal cortex (Figure 3.10A and B). In addition, the portal veins appear more prominent due to the contrast between the hyperechoic walls of the veins and the hypoechoic parenchyma (Figure 3.10A and B). The portal veins appear as linear equal signs (=) when evaluating them in real-time. As a general rule, if they are prominent and very many in number against a hypoechoic background, the liver can be said to be diffusely hypoechoic. Again, this finding can be readily seen, especially in real-time, and can occur with diffuse inflammatory diseases such as cholangiohepatitis and diffuse infiltrative diseases such as lymphosarcoma (lymphosarcoma can also be seen with diffuse hyperechoic changes or normal echogenicity) and mast cell disease (Figures 3.8C and D and 3.10C). Passive congestion can also result in mild to moderate hypoechogenicity (Figure 3.10A and B).

Diffuse hepatic hyperechogenicity (liver is brighter than normal) can be seen with fatty infiltration (hepatic lipidosis in cats), steroid hepatopathy,

other metabolic and endocrine hepatopathies (diabetes mellitus), chronic hepatitis, and cirrhosis (Figure 3.10E). Infiltrative neoplastic disease such as lymphosarcoma and mast cell tumor can also produce diffuse (homogeneous) hyperechoic changes (Figure 3.8C and D). Neoplasia can alternatively be hypoechoic and/or inhomogeneous. This needs to be kept in mind and a tissue sample is most definitive in cases in which fine needle aspiration is non-diagnostic. In cats with hepatic lipidosis, the liver is usually hyperechoic to falciform fat, although this change can also occur in obese cats as an incidental finding (Nicoll 1998) (Figure 3.10D). In cats with lipidosis, steroid hepatopathy, and infiltrative diseases, the liver is usually larger than normal. In animals with chronic hepatopathies, the liver is generally expected to be smaller than normal.

Mixed hepatic echogenicity can be due to diffuse infiltrative disease (neoplasia, fungal infection) or inflammatory disease.

Often animals with toxic hepatopathies have normal echogenicity (Nyland 2002). Other conditions may also have normal echogenicity and fine needle aspiration and/or biopsy should be considered in the face of a normal ultrasonographic appearance if clinical and biochemical parameters support primary liver disease.

It is important to remember that animals may have severe hepatic dysfunction or diseases and normal ultrasound findings (Nyland 2002). Therefore, additional assessment is always indicated when liver disease is suspected and the ultrasound findings are unremarkable for liver changes. This includes fasting ammonia (NH₃) levels, pre- and post-prandial serum bile acid levels, and ultimately liver biopsy.

Liver disease cannot be ruled out on the basis of an unremarkable ultrasound examination. If liver disease is strongly suspected, additional evaluation is indicated.

Figure 3.10. Diffuse homogeneous hypoechoic and hyperechoic livers. (A) Hepatic venous congestion (veins not shown) with a homogeneously hypoechoic liver. Note the increase in portal markings seen, analogous to a "starry night" (arrows). The portal vein reflections look like stars against the night sky, and if you look closely at the arrow heads the portal vein walls appear as hyperechoic (white) equal (=) signs. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine. (B) Hepatic venous congestion with obvious distended hepatic veins (HV) with a homogeneously hypoechoic liver (LIV). The background is another example of the starry night caused by increase in portal markings, noted with cursor (<). If you look closely at the cursors the portal vein walls appear as hyperechoic (white) equal (=) signs. Compare to (A). (C) A dog with cholangiohepatitis is an additional example of a disease process that can have homogeneously hypoechoic liver changes. Also note the inspissated contents of the gallbladder. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (D) Diffusely hyperechoic (bright) liver in a cat diagnosed with hepatic lipidosis. Note that the liver is diffusely hyperechoic (bright) to the falciform fat of the near field; however, this can be a normal variant in obese cats (Nicoll 1998). The patient's clinical picture and cytological and histopathological sampling must be considered for an accurate diagnosis. (E) Image of a patient with chronic active hepatitis. Note the homogeneously hyperechoic liver, demonstrating the variability of ultrasonographic findings in livers with changes in echogenicity.

Liver Vasculature

Moderate to marked dilation of the hepatic veins is usually secondary to right-sided cardiac insufficiency or pericardial effusion. Obstruction of the caudal vena cava due to thrombosis, stricture (kinking), or neoplasia can also cause marked distention of the hepatic veins (Kolata 1982, Crowe 1984, Lisciandro 1995, Fine 1998). These are best visualized on the right side of the liver at the level where the hepatic veins join the caudal vena cava (Figure 3.3A and B). The significance of hepatic venous distention should be evaluated in conjunction with other clinical signs. Hepatic venous congestion in conjunction with ascites (modified transudate) further supports the presence of forms of right-sided heart failure or obstruction of the caudal vena cava (also see Chapter 11).

Gallbladder

The gallbladder is easy to image using ultrasound because it is fluid-filled. The gallbladder is generally round to oval; however, it may be bilobed, which is more commonly seen in cats than dogs, and of no clinical consequence (Figure 3.4C). Because the gallbladder is fluid-filled, it is also subject to several artifacts as previously mentioned. The novice sonographer should become familiar with these artifactual confounders to minimize misinterpretations (see Figures 1.5, 1.6, 1.7, and 1.10; also see Chapter 1).

Gallbladder Wall

Evaluation of the gallbladder wall is generally easily accomplished because the gallbladder is fluid-filled and ultrasound penetrates best through fluid. The normal gallbladder wall is not obviously visible or may appear as a faintly echogenic line (Figure 3.4A through C). Diffuse thickening of the wall may occur with a wide range of conditions and therefore, must be interpreted in conjunction with additional ultrasound findings as well as clinical signs and biochemical alterations (Figure 3.11A through D). Diffuse wall thickening may be seen with cholecystitis (acute or chronic), hepatitis (acute or chronic), anaphylaxis (Quantz 2009) (see Chapter 2), right-sided congestive heart failure, pericardial effusion, or volume overload (also see Figure 16.8A) (Nelson 2010), and hypoalbuminemia (Nyland 2002).

The appearance may be similar in all of these conditions because the change generally involves edema of the gallbladder wall (Figure 3.11A through D). Most commonly, in these situations the wall appears diffusely hypoechoic with parallel hyperechoic lines on either side, referred to as a double rim or halo appear-

ance (Quantz 2009, Nyland 2002). This change needs to be distinguished from small volume fluid on the outside of the gallbladder. Focal and/or irregular thickening of the gallbladder wall is less common but generally represents a neoplastic change.

Gallbladder Lumen

Evaluation of the luminal contents of the gallbladder is easy because luminal fluid serves as an acoustic window and ultrasound penetrates best through fluid.

Biliary sediment or sludge is common in dogs and can easily be recognized with the focused exam (Figure 3.12A through C, also see Figure 1.10A and B). In general, the finding of gravity dependent material is an incidental finding unless accompanied by clinical signs, changes in the gallbladder wall, and/or clinicopathological changes. Sediment is usually hyperechoic (bright) and does not result in an acoustic shadow unless contents are mineralized (Figure 3.12D; also see Figure 1.4). The material is classified as gravity dependent or non-gravity dependent. Non-gravity dependent material is additionally classified as adherent or non-adherent in relation to the gallbladder wall.

Calcified material or calculi can occasionally be observed within the lumen of the gallbladder and may also be an incidental finding. Calcified material or calculi (gallbladder stones) will result in a distal acoustic shadow (Figures 3.12D and 3.13A through D; also see Figure 1.4).

Gallbladder mucoceles always have significant implications and their presence should be confirmed by an experienced sonographer because therapy often requires surgery. Gallbladder mucoceles have a distinct appearance and in the mature form, have a stellate ("kiwi fruit") appearance caused by fracture lines between mucous collections (Figure 3.14A and B). When immature, there are variable degrees of non-mobile sludge seen between the focal collections of mucous. In addition, the gallbladder wall may be thickened, irregular, and hypoechoic or hyperechoic. These findings may precede gallbladder rupture. (Figure 3.14C and D).

Biliary System

Biliary obstruction can be difficult to assess by the novice sonographer and it should be noted that biliary tree distension can mimic other pathology, and tortuosity is a normal variation, especially in cats (Figure 3.15). In cases in which biliary obstruction is

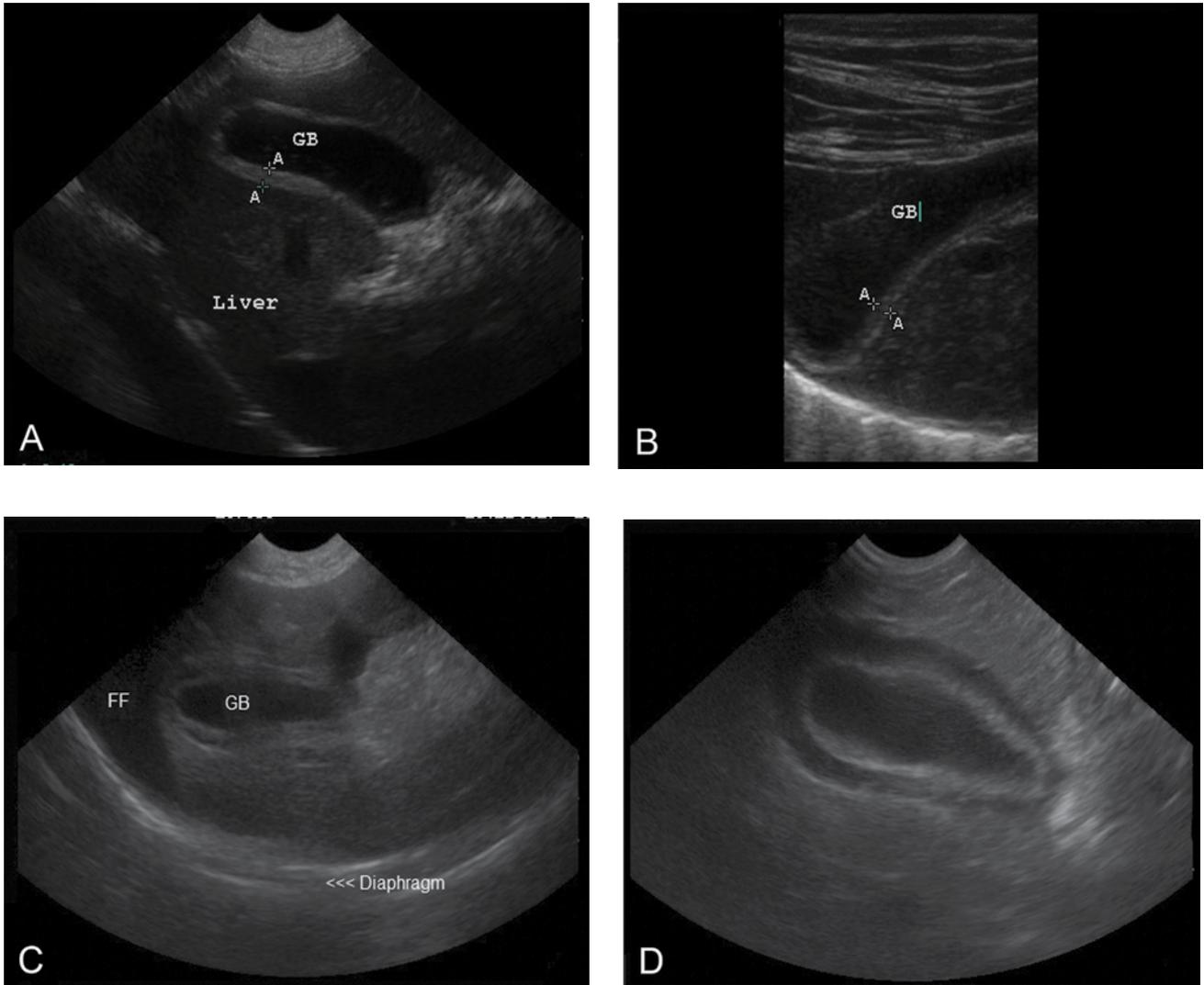


Figure 3.11. Gallbladder wall abnormalities. (A) Thickened gallbladder wall seen as a hyperechoic rim outlining the hypoechoic gallbladder (GB) luminal contents. This has been referred to as a double rim sign or halo sign caused by several conditions. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (B) A mildly thickened gallbladder (GB) wall in a cat similarly outlined with a hyperechoic line. The caliper measurement is 1.9 mm in thickness, which is considered thickened in cats (normal is less than 1 mm). Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (C) This image is of a dog seen for acute collapse. Note the halo sign hallmarked by the outer and inner hyperechoic borders of the gallbladder (GB) wall with central hypoechogenicity. The thickening of the gallbladder wall is consistent with edema. This case illustrates the value of concurrent evaluation of the pleural and pericardial spaces because the cause of collapse (not always known at triage) was due to obstructive shock secondary to pericardial effusion and cardiac tamponade and emergent pericardiocentesis is indicated as a lifesaving procedure. Note the small volume of effusion within the gallbladder fossa and ascites (FF, free fluid). (D) The gallbladder double rim or halo sign, which can range in its degree of gallbladder wall thickness, has been reported to be a marker supportive of anaphylaxis in dogs (also see Figure 2.16A and B). This image depicts an acutely collapsed dog diagnosed with anaphylaxis caused by insect envenomation. The gallbladder double rim or halo sign and wall thickening is severe. In contrast to 3.11C, the emergent treatment is a rapid intravenous fluid bolus and epinephrine administration, emphasizing the importance of surveying the pleural and pericardial spaces in acutely collapsed dogs for optimizing appropriate therapy (also see Chapter 2). Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, CA.

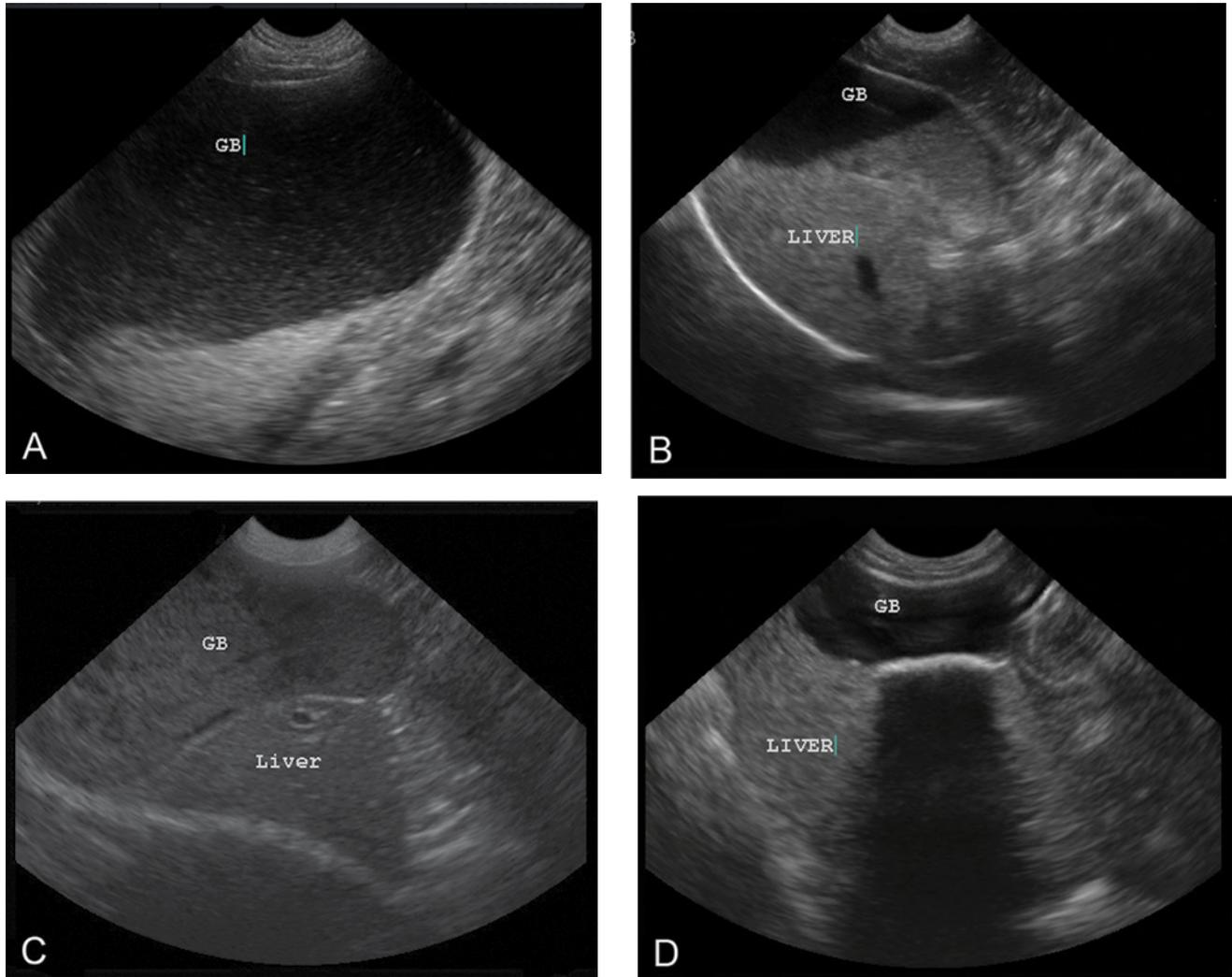


Figure 3.12. Degrees of gallbladder sedimentation (sludge). (A) A mild amount of echogenic debris in suspension within the gallbladder lumen with a faint sedimentation line along the dependant portion in an asymptomatic dog. (B) Moderate echogenic debris settled within the dependent portion of the gallbladder lumen in an asymptomatic dog. (C) Moderate to severe echogenic debris in suspension, some of which is adherent to the gallbladder wall (this is best appreciated in real-time). (D) Shadowing debris settled within the dependent portion of the gallbladder in a dog diagnosed with mineralized biliary sediment, which can be distinguished from a large cholelith by ballottement (agitation) or changes in patient positioning. Images such as these should prompt full and complete evaluation of the hepatobiliary tract and liver when there is biochemical or clinical evidence of hepatobiliary disease. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

suspected it is best to refer for a complete abdominal ultrasound as soon as possible to minimize morbidity and potentially life-threatening peritonitis in the event of or propensity toward gallbladder rupture (Figure 3.14C and D). In cats, a bile duct greater than 4 mm is considered to be consistent with extrahepatic biliary obstruction (Penninck 2007). In cases in which peritonitis is clinically suspected or needs to be ruled out, an AFAST³ should be performed and can facilitate fine needle aspiration of peritoneal effusions and determination of the fluid character (see Chapter 2).

The Routine Add-on of AFAST³ and its Abdominal Fluid Scoring System

In the author's experience, it is extremely valuable to perform an AFAST³ exam in right lateral recumbency as part of a complete diagnostic exam. There are several reasons why the addition of AFAST³ improves the diagnostic potential of the ultrasound exam. Positioning small animals in dorsal recumbency for focused abdominal organ exams potentially misses

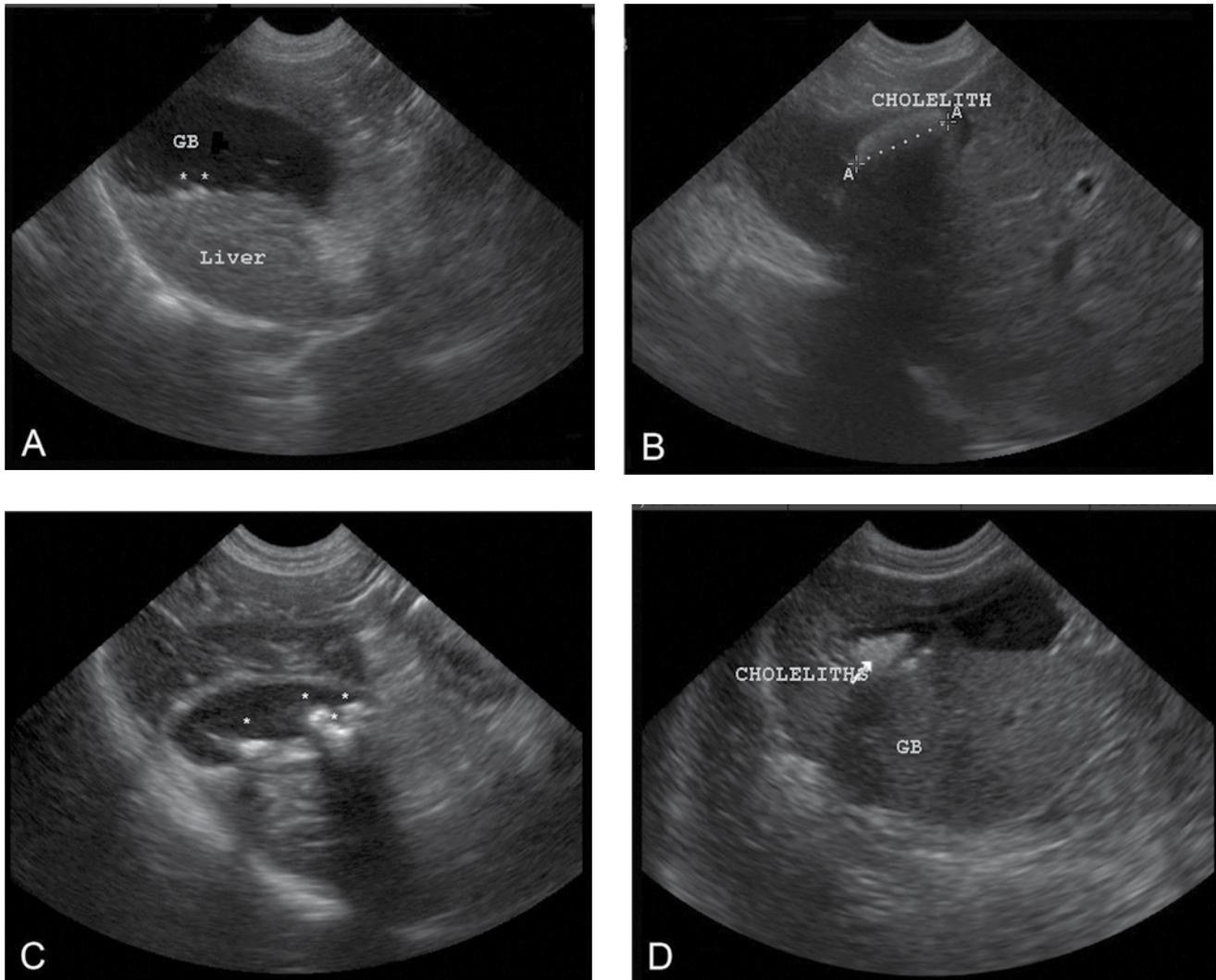


Figure 3.13. Gallbladder stones or choleliths. (A) Two small choleliths in a dog (identified by a small asterisk [*] over each cholelith). The finding was incidental. Note the two linear distal clean shadows cast by the small solid structures. These hypoechoic low-amplitude echo regions are caused by the highly attenuating structures. (B) Large, 2-cm cholelith in a dog with biochemical and clinical evidence of biliary obstruction. Note the strong (anechoic) distal shadow. A complete ultrasonographic evaluation of the biliary tract is indicated by a veterinary radiologist or specialist with advanced ultrasound training. (C) Multiple, shadowing choleliths demonstrating the variability of size and number (identified by a small asterisk [*] over each cholelith). Such findings can be seen incidentally or in patients with clinical evidence of advanced hepatobiliary obstruction. In cases with signs of severe hepatobiliary disease, the entire biliary tract should be evaluated by an experienced sonographer given the potential need for surgical intervention. (D) Example of a shadowing cholelith in a cat. Note the strong, clean acoustic shadowing in the far field. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

the presence of small volume abdominal effusions and more importantly, probably underestimates the volume of effusion present. As a result, moving the patient to lateral recumbency and performing AFAST³ along with its applied abdominal fluid score (AFS) to all complete abdominal ultrasound exams has become standard protocol by the author and is recommended for each of the focused abdominal organ exams. Of note, the addition AFAST³ and the application of

the AFS adds little time (less than two minutes) to the focused organ exam and improves diagnostic evaluation.

The early detection of abdominal effusion is clinically important and helps direct additional diagnostic recommendations as well as potentially avoiding serious morbidity, complications, and patient mortality in the event the effusion is missed. Although no veterinary studies have been performed comparing the detection and

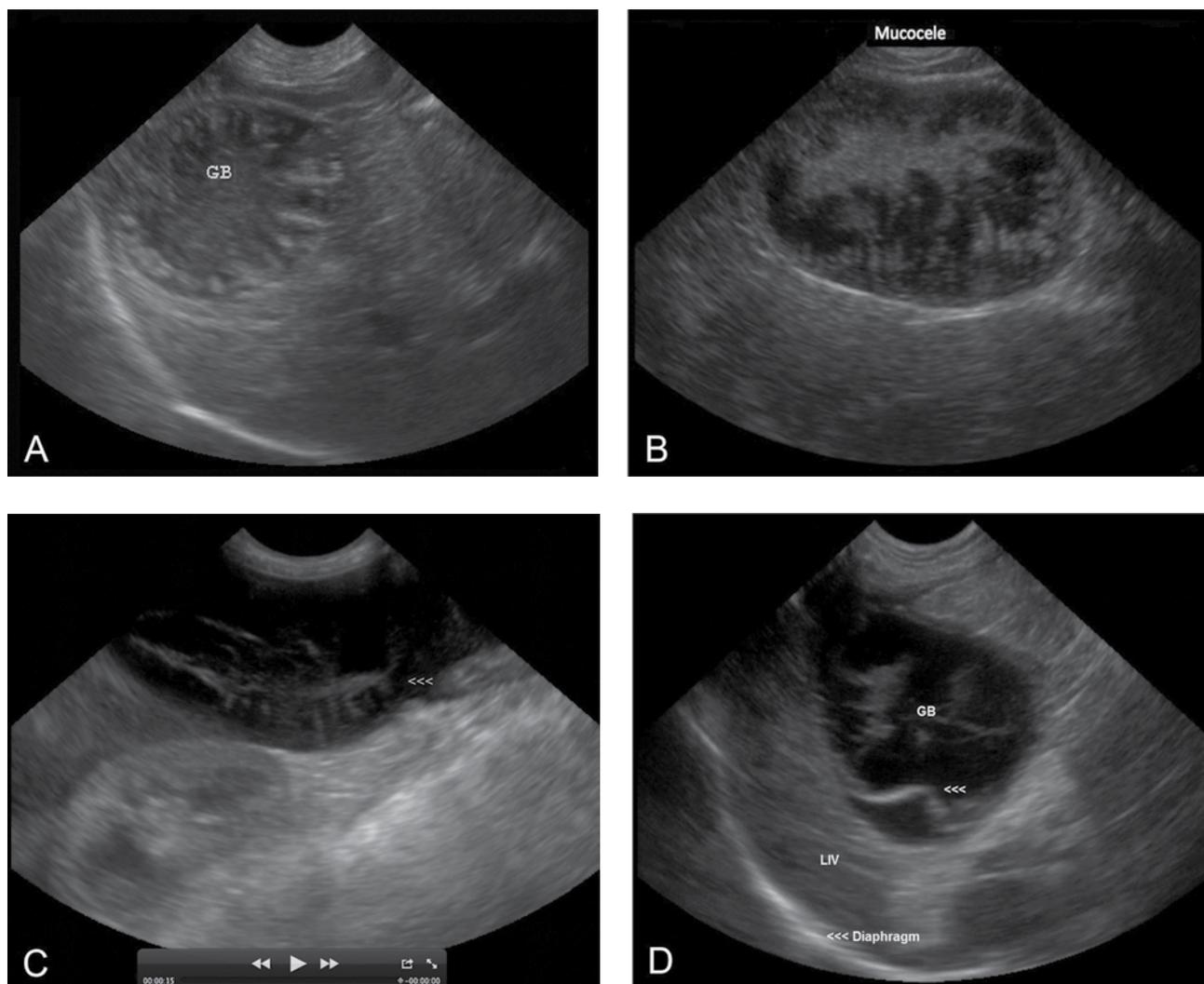


Figure 3.14. Gallbladder mucocele without and with the complication of gallbladder rupture. (A) Gallbladder mucocele in a dog. Note the echostructural appearance of the gallbladder lumen. In real-time, mucoceles are typically seen as immobile biliary patterns that have a stellate or fine striated character. Also note the typical concurrent distention of the gallbladder that is enlarged because of the mucocele. These findings should also prompt complete evaluation of the peritoneal cavity by AFAST³ to search for any evidence of bile peritonitis (free fluid) secondary to gallbladder rupture, and a thorough ultrasonographic interrogation of the entire biliary tract by an experienced sonographer. (B) Additional example of a gallbladder mucocele demonstrating the variability of their ultrasonographic appearance. (C) Ruptured gallbladder secondary to mucocele. When a structure like this is not seen associated with the gallbladder in any quadrant of the peritoneal cavity, a mucocele (marked with cursors [<<<]) may be eviscerated from the gallbladder and freely floating within the abdomen as shown in this image. Characterization of the abdominal effusion (anechoic in near field) as bile peritonitis further supported this clinical suspicion. (D) Ruptured gallbladder. If the gallbladder (GB) is not visualized, or lacks its normal expected curvilinear contour, gallbladder rupture should be suspected. In this image, the dorsal gallbladder wall is deviated from its expected course. Signs of rupture of the gallbladder can also include loculated echogenic fluid within the gallbladder fossa with adjacent hyperechoic reactive mesentery and/or free-floating shadowing choleliths. Degrees of bile peritonitis (either loculated within the gallbladder fossa or throughout the abdominal cavity) should be present and an AFAST³ should be performed. Accessible fluid should be aspirated to characterize its nature and direct surgical intervention. Discontinuity of the dorsal aspect of the gallbladder is marked with cursors [<<<]. In cases of gallbladder rupture, emergent exploratory surgery is indicated. Additional, less common rule-outs for the lack of visualization of the gallbladder include gallbladder agenesis (which is rare but has been reported), and obstruction of the cystic duct (such as with a mass lesion) which is impairing normal gallbladder and bile duct filling. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

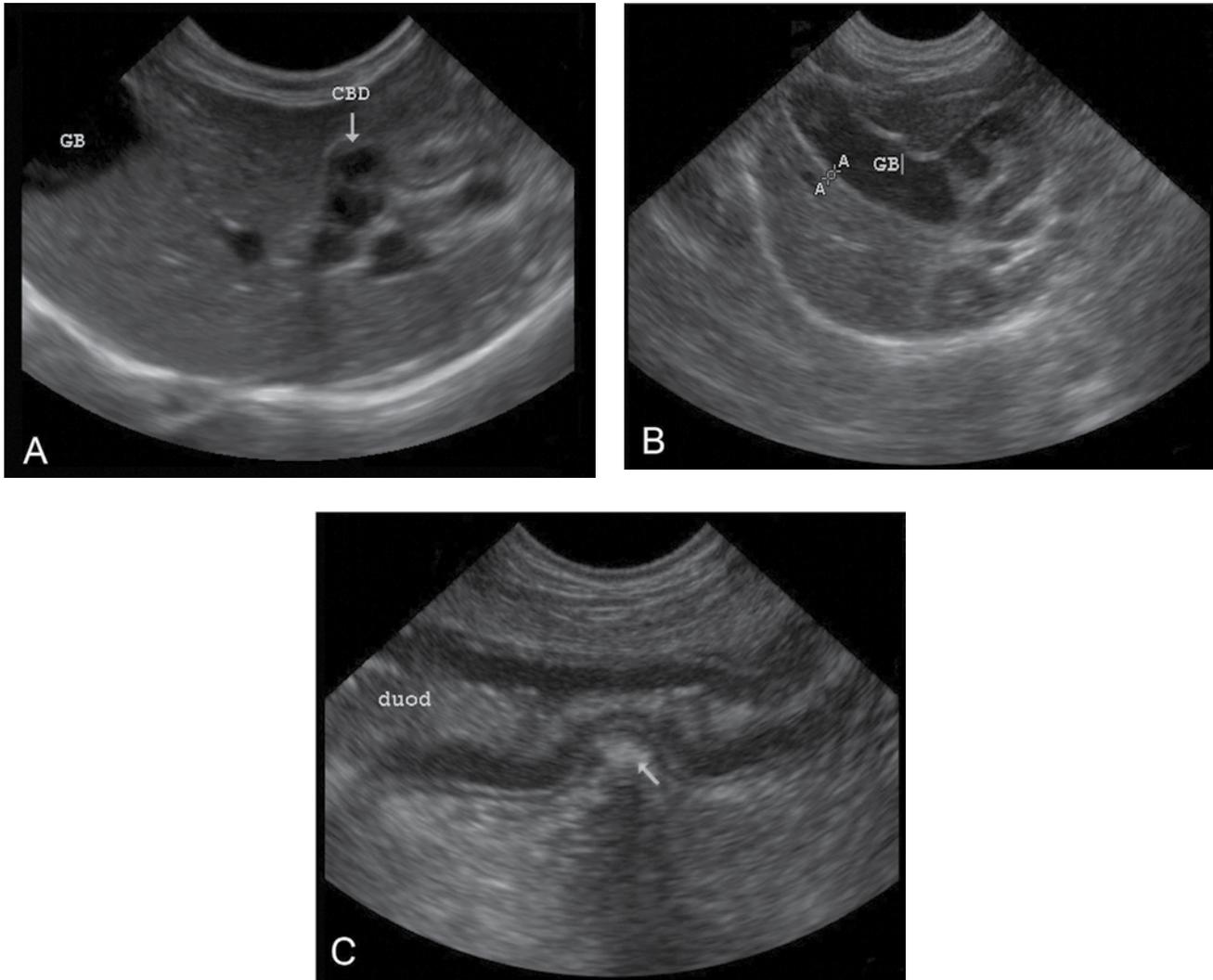


Figure 3.15. Biliary tract distension. (A) Shown here is a cat with bile duct tortuosity which can be a normal variant and common finding. This variant can be easily mistaken for a variety of pathologies (nodules, cysts, masses) by the novice or hasty sonographer. Careful correlation with other clinical findings is imperative for an accurate assessment. (B) A cat with suppurative cholangitis with concurrent pathologic tortuosity and dilation of the bile duct. The bile duct is seen ventral to the portal vein and can be distinguished from vessels with color flow Doppler evaluation. In cats, a bile duct greater than 4mm is considered to be consistent with extrahepatic biliary obstruction. When the biliary duct wall is irregular or unevenly thickened, neoplasia should be a differential. (C) Cholelithiasis can be seen anywhere along the biliary tract and presents challenges for the novice sonographer. This image demonstrates a hyperechoic cholelith at the level of the duodenal papilla in a dog. Note the strong distal acoustic shadow and lack of normal architecture of the duodenal papilla. This example emphasizes the need for a complete abdominal ultrasound evaluation by a veterinary radiologist or specialist with advanced ultrasound training. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

volume of abdominal effusions between dorsal recumbency and AFAST³ positioning, the author's experience has shown the comparison to often be remarkably different. AFAST³ is more sensitive for the detection of free fluid, especially if small volumes are present, and allows for better and less subjective assessment of the volume of fluid by also using the AFS score.

Pearls and Pitfalls, the Final Say

- Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK), which

is remembered as the S>Li ≥ CK or the mnemonic “SLiCK.”

- Benign conditions can ultrasonographically appear malignant and hepatic echogenicity can be difficult to interpret. Conversely, even with an unremarkable focused liver and gallbladder exam, significant liver disease can still be present.
- Be familiar with the range of associated artifacts related to the liver and gallbladder. The fluid-filled gallbladder is subject to several artifacts including side-lobe, edge shadowing, and acoustic enhancement in the far field, and the liver and gallbladder being adjacent to the strong soft tissue-air interface between the diaphragm and the aerated lung, subject to mirror image artifact on the thoracic side of the diaphragm.
- If it is difficult to determine the origin of a large midabdominal mass, move the patient from dorsal to lateral recumbency because by doing so the liver and spleen will often separate from one another, helping to better determine the origin of the mass.
- Always look into the thorax to investigate the pleural and pericardial spaces.
- An AFAST³ should be considered as routine in all focused liver and gallbladder exams to best ensure that intra-abdominal bleeding, other effusions, and peritonitis are not missed.
- Post-interventional procedures, including liver and gallbladder surgeries, percutaneous aspirates and biopsies, or laparoscopically related procedures, should be monitored for complications such as hemorrhage and peritonitis (free fluid) using the AFAST³ protocol and its fluid scoring system (see Chapter 2).

References

Crowe DT, Lorenz MD, Hardie EM, et al. 1984. Chronic peritoneal effusion due to partial obstruction caudal vena caval obstruction following blunt abdominal trauma: diagnosis and successful surgical management. *J Am Anim Hosp Assoc* 20:231–238.

- Cuccovillo A, Lamb CR. 2002. Cellular features of sonographic target lesions of the liver and spleen in 21 dogs and a cat. *Vet Rad and Ultrasound* 43(3):275–278.
- D’Anjou MA. 2008. Liver. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D’Anjou. Ames, Iowa: Blackwell Publishing, pp243–247.
- Fine DM, Olivier NB, Walshaw R, et al. 1998. Surgical correction of late onset Budd-Chiari-like syndrome in a dog. *J Am Vet Med Assoc* 212(6):835–837.
- Hittmair KM, Vielgrader HD, Loupal G. 2001. Ultrasonographic gallbladder wall thickness in cats. *Vet Radiol and Ultrasound* 42:149–155.
- Kolata RJ, Cornelius LM, Bjorling DE, et al. 1982. Correction of an obstructive lesion of the caudal vena cava in a dog using a temporary intraluminal shunt. *Vet Surg* 11:100–104.
- Lisciandro GL, Harvey HJ, Beck KA. 1995. Automobile-induced obstruction of the caudal vena cava in a dog. *J Small Anim Pract* 36(8):368–372.
- Nelson NC, Drost WT, Lerche P, et al. 2010. Noninvasive estimation of central venous pressure in anesthetized dogs by measurement of hepatic venous blood flow velocity and abdominal venous diameter. *Vet Radiol and Ultrasound* 51(3):313–323.
- Nicoll RG, O’Brien RT, Jackson MW. 1998. Qualitative ultrasonography of the liver in obese cats. *Vet Rad and Ultrasound* 39(1):47–50.
- Nyland TG, Mattoon JS, Herrgesell EJ, et al. 2002. Liver. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by Nyland TG and Mattoon JS. Philadelphia: WB Saunders, pp 93–127.
- Quantz JE, Miles MS, Reed AL, et al. 2009. Elevation of alanine transaminase and gallbladder wall abnormalities as biomarkers of anaphylaxis in canine hypersensitivity patients. *J Vet Emerg Crit Care* 19(6):536–544.
- Spaulding KA. 1993. Ultrasound corner: Gallbladder wall thickness. *Vet Radiol and Ultrasound* 34:270–272.
- Tsukagoshi T, Ohno K, Tsukamoto A, et al. 2012. Decreased gallbladder emptying in dogs with biliary sludge or gallbladder mucocele. *Vet Rad and Ultrasound* 53(1): 84–91.

FOCUSED OR COAST³—SPLEEN

Stephanie Lisciandro

Introduction

The focused use of ultrasound to evaluate the spleen may answer clinically relevant questions for the non-radiologist veterinarian and thus help more expediently guide clinical course in a positive manner than without using ultrasound. Many findings involving the spleen are non-specific and may be subjective. Subjective findings may include assessment of the size of the spleen as well as evaluating for diffuse changes in its echogenicity. In addition, because the spleen overlies the liver anatomically, it can be difficult at times for the less experienced sonographer to differentiate between splenic and hepatic masses. Therefore, assessment of splenic changes may be inherently more difficult than those in other organs.

The focused spleen exam is not meant to replace a complete abdominal ultrasound study by a veterinarian with advanced training (the veterinary radiologist or internist). As stated earlier, when using any of the focused abdomen-related organ exams, the attending clinician should routinely perform an abdominal focused assessment with sonography for trauma (AFAST³) to look for effusions, and particularly rule in or out the presence of concurrent splenic hemorrhage. Not only can an AFAST³ exam help detect free peritoneal fluid, but also semi-quantitate its volume (using the abdominal fluid score, see Chapter 2) and help predict the degree of anticipated anemia in cases of hemoabdomen (see Chapter 2). Conversely, if splenic hemorrhage is missed by not performing an AFAST³, the consequences could result in a negative clinical outcome for the patient.

What the Focused Spleen Exam Can Do

- Help the clinician to recognize splenic masses which may be either focal or multifocal
- Help the clinician to recognize parenchymal changes associated with diffuse splenic diseases
- Help the clinician to recognize splenic infarction and thrombosis
- Help the clinician to recognize splenic torsion

These last three goals are inherently more difficult for the novice sonographer, and abnormalities should prompt referral for a complete abdominal ultrasound examination by an experienced sonographer.

What the Focused Spleen Exam Cannot Do

- Cannot differentiate benign vs. malignant splenic masses
- Cannot definitively diagnose diffuse and localized splenic conditions based on echogenicity
- Cannot reliably determine splenic size (splenomegaly) except in cases of marked splenomegaly

Indications for the Focused Spleen Exam

- Cranial organomegaly or pendulous abdomen
- Abdominal pain

- Abdominal trauma
- Hematological disorders such as anemia or thrombocytopenia
- Generalized lymphadenopathy

Objectives of the Focused Spleen Exam

- Recognize splenic masses (single, multifocal)
- Recognize regional and diffuse changes in splenic echogenicity
- Recognize splenic venous congestion, thrombosis, and infarction
- Recognize splenic torsion

Patient Positioning and Probe Selection

When imaging the spleen, a curvilinear probe is generally used and the MHz adjusted depending on the size of the animal. Generally, smaller dogs and cats are imaged using the higher frequencies of 7.5–10MHz (less penetration, better detail) and large dogs are usually imaged with lower frequencies such as 5MHz (deeper penetration, less detail). However, in small dogs and cats a linear probe may be used.

The patient is most commonly imaged in dorsal recumbency. However, in large dogs, the cranial aspect of the spleen is often located under the rib cage

on the left side. Repositioning these patients into right lateral recumbency allows visualization of the cranial aspect or head of the spleen using a left intercostal approach (Penninck 2008). The abdomen is shaved for the exam and acoustic coupling gel is applied for best visualization.

How to Do the Focused Spleen Exam

The patient is placed in dorsal recumbency. The spleen is located caudal to the stomach on the patient's left side and generally provides an acoustic window for the left kidney. The spleen may vary in position between patients and varies with the degree of gastric filling. The entire length of the spleen is generally not visualized in one acoustic window, so its entirety must be traced cranially to the head of the spleen and caudally to its tail.

The head or cranial aspect of the spleen is generally located on the left side caudal to the last rib. In large dogs, it may be located under the rib cage and therefore, repositioning into right lateral recumbency with a left intercostal approach may be necessary. The spleen is then traced caudally toward its hilus, where the splenic vein is imaged and seen branching in a "Y" configuration (Figure 4.1). Splenic arteries are usually not visualized (Penninck 2008). Evaluation of the spleen continues as the sonographer follows the spleen distally along the left side of the abdomen to examine the caudal aspect of the spleen to its

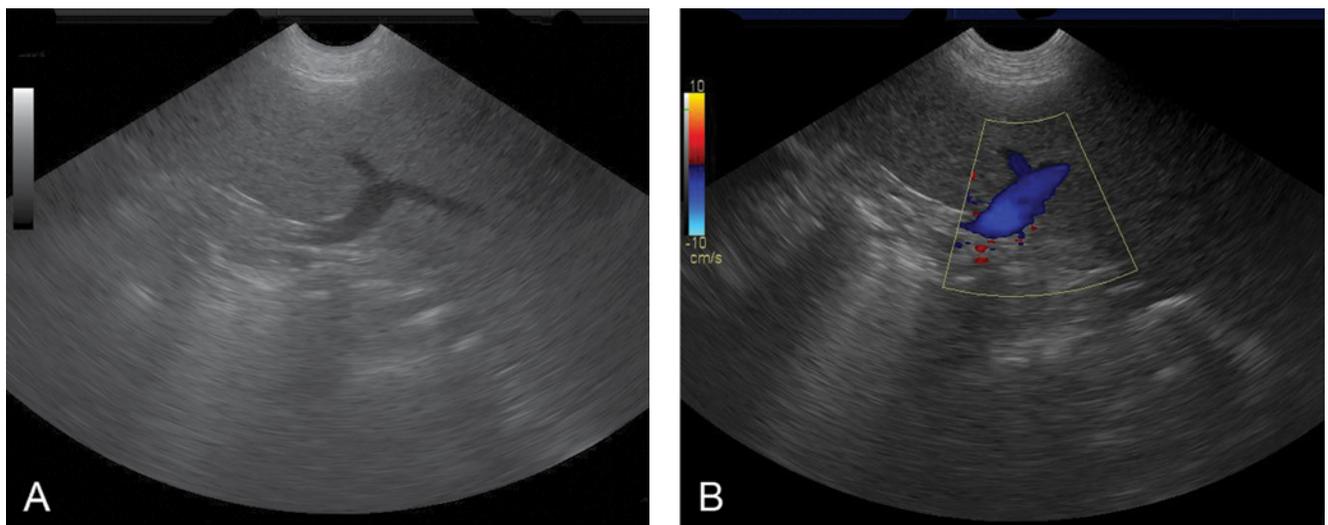


Figure 4.1. Normal splenic hilus. (A) The "Y" shape of the splenic vein as it branches at the hilus is helpful for identifying the spleen and discriminating it from the liver. (B) Color flow Doppler may be used to assess blood flow and rule out splenic venous thrombosis and splenic torsion when suspected.

tail so that the entire spleen has been examined. In some patients, the tail of the spleen may be located medially and to the right instead of on the left lateral abdomen. Several sweeps, fanning through its long-axis (sagittally) and transversely, along the length and width of the spleen, may be necessary for thorough interrogation, especially in animals with splenomegaly.

Ultrasonographic Findings in a Normal Spleen

When assessing the spleen, systematic evaluation should include the following four features: estimation of size (subjective), changes in echogenicity of the parenchyma, presence of mass lesions and nodules, and assessment of splenic vasculature.

The general contour of the spleen is tongue-shaped, and when viewed adjacent to the left kidney it appears more triangular than flat in cross-sectional views. Because the size of the spleen can vary in normal animals, estimation is generally subjective in dogs except in cases of marked splenomegaly. In cats, splenomegaly is almost always due to pathology and should prompt further evaluation. The finding of a cat's spleen thicker than 10 mm or a folded spleen invariably indicates splenomegaly in this species (Reese 2012, Penninck 2008) (Figure 4.2).

Moderate splenomegaly occurs in dogs with many forms of sedation or anesthesia (Reese 2012, Penninck 2008); thus, the effects of sedation and anesthesia must be considered.

The echogenicity of the splenic parenchyma should be evaluated for diffuse and focal changes. Normal splenic parenchyma is homogeneous in appearance with fine echotexture, and its thin hyperechoic (bright white) capsule may be apparent on long-axis (sagittal) views. The spleen is generally mildly to moderately more hyperechoic (brighter) than normal liver tissue (Figure 4.3A and B) and more significantly hyperechoic (brighter) than the normal renal cortex (Penninck 2008) (Figure 4.3C and D).

Remember the mnemonic “SLiCK” regarding relative normal echogenicity in that spleen (S) is hyperechoic (brighter) than the liver (Li), which is generally slightly more hyperechoic (brighter) or isoechoic (same shades of gray) as the cortex of the kidney (CK).

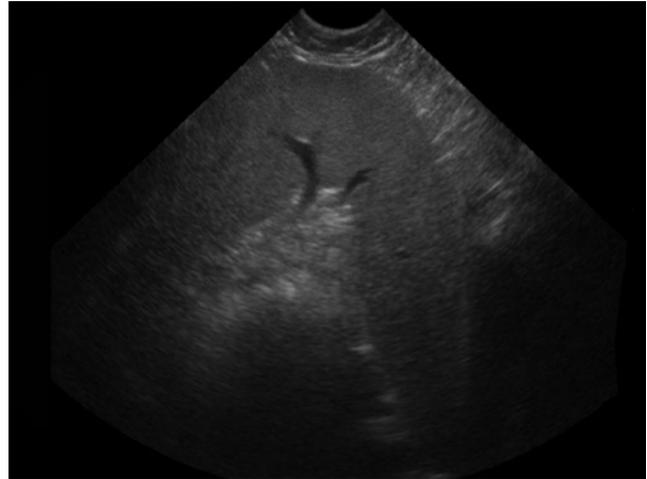


Figure 4.2. Subjective size evaluation of the spleen. Splenic enlargement as evidenced by its folding. The Y-shaped splenic veins departing from its hilus are helpful for its identification and for discriminating it from the liver. The spleen here has a homogeneous normal echotexture.

The splenic parenchyma is normally homogeneous with fine echotexture and free of focal lesions (Figure 4.4).

The splenic vein can be seen branching into a “Y” within the splenic parenchyma at its hilus, which is located centrally. The splenic vein can be traced as it exits the spleen toward the portal vein to the patient's right side. If color flow Doppler evaluation is available, this will allow for additional evaluation of the splenic vein and its branches (Figure 4.1A and B and 4.2, also see Figure 13.2A).

The branching of the splenic veins as they depart the splenic hilus as a “Y” may be used to identify the spleen as well as its hilus.

Clinical Significance and Implications of Abnormal Findings

Abnormal findings that may be appreciated during the focused ultrasound exam of the spleen include the four features mentioned above: subjective evaluation of size (splenomegaly), changes in echogenicity (evaluation for diffuse parenchyma disorders), presence of mass lesions (solitary and multifocal mass lesions), and the assessment of its vasculature (thrombosis and torsion).

The four features of focused spleen are its size, echogenicity, presence of nodules, and vasculature.

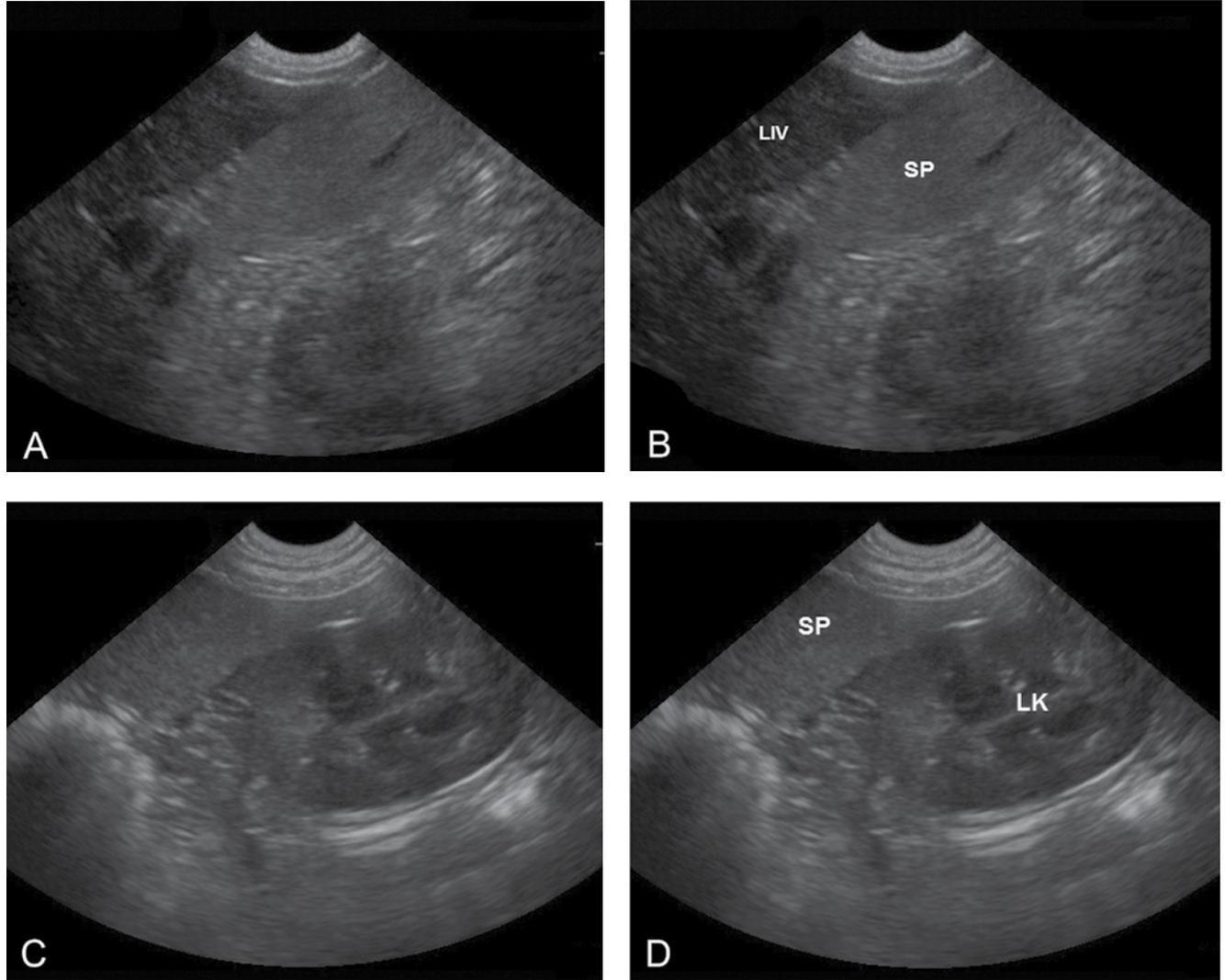


Figure 4.3. Relative splenic echogenicity compared to the liver and the cortex of the kidney. (A) Comparison of the echogenicity of spleen to the liver, unlabeled. (B) Same as (A) but labeled as liver (LIV) and spleen (SP). (C) Comparison of echogenicity of the spleen to the cortex of the left kidney, unlabeled. (D) Same as (C) but labeled as spleen (SP) and left kidney (LK).

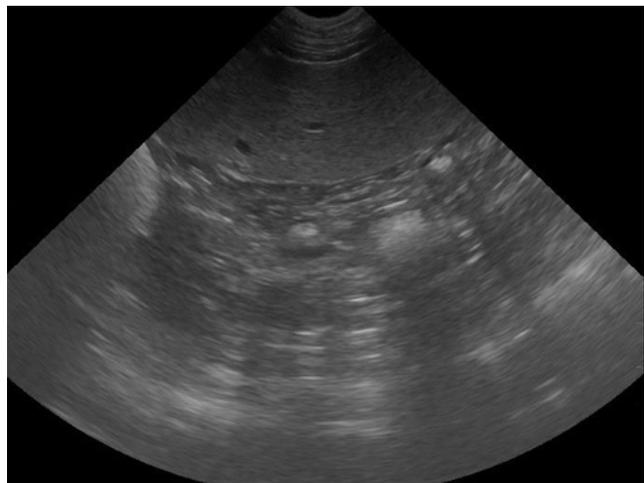


Figure 4.4. Spleen by itself, showing its homogeneous nature with normal echogenicity. The anechoic areas (circular) are normal vasculature and readily appreciated in real-time evidenced by their branching.

Splenic Size

Splenomegaly is usually a subjective assessment except in cases of severe enlargement of the spleen. The following ultrasonographic clues help in discriminating between normal size and splenomegaly.

Marked enlargement may result in the distal tip of the spleen folding back on itself (Figure 4.5A and B) and therefore, the distal tip or tail is visualized medial to the left kidney (Figure 4.5C and D). In addition, the markedly enlarged spleen may extend caudally and

come in contact with the urinary bladder (Figure 4.6). In cats a folded spleen (Penninck 2008) and a spleen thicker than 10 mm (Reese 2012) supports splenomegaly (Figure 4.9B).

In cats, a folded spleen invariably indicates splenomegaly, which is always abnormal in felines. The splenic thickness is normally less than 10 mm in cats (Reese 2012).

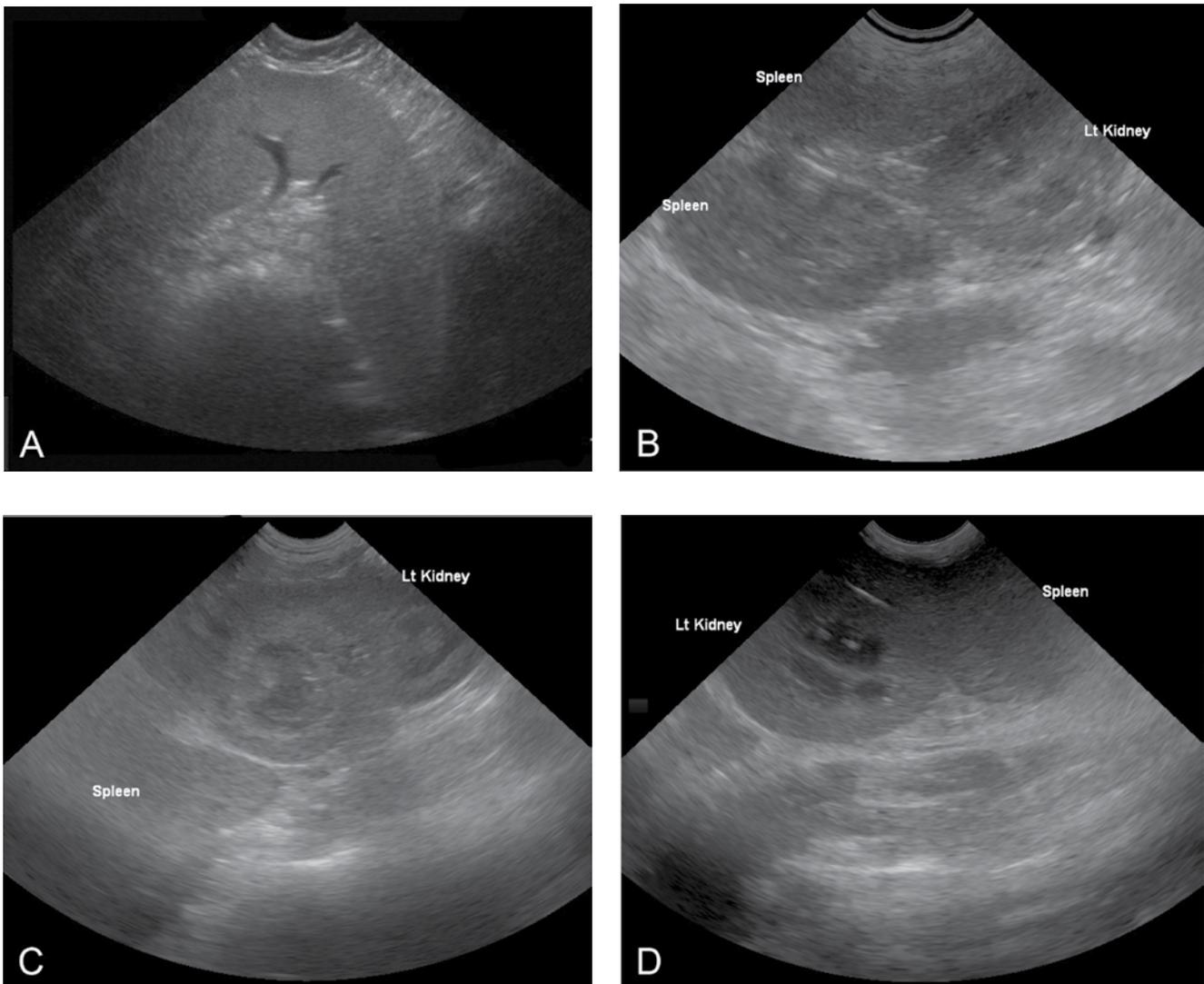


Figure 4.5. Signs of splenomegaly. (A) Splenomegaly or splenic enlargement as evidenced by its folding. The Y-shaped splenic veins departing from its hilus are helpful for its identification and for discriminating it from the liver. The spleen here has a homogeneous normal echotexture. (B) Another example of an enlarged folded spleen enveloping the left (Lt Kidney) kidney. (C) Splenic enlargement similar to (B). It is folded and medial to the left kidney with comparative normal echogenicity. The spleen is hyperechoic (brighter) when compared to the cortex of the left kidney (Lt Kidney). (D) Similar to (C), the spleen extends caudal to the left kidney (Lt Kidney).

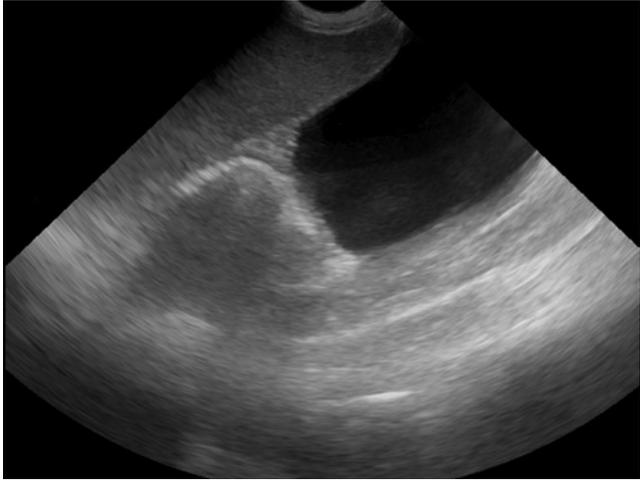


Figure 4.6. This severely enlarged spleen extends caudally to the fluid-filled (anechoic) urinary bladder. Although it appears relatively normal regarding its echotexture and echogenicity, this dog had splenic lymphosarcoma diagnosed by percutaneous needle biopsy. Compare to Figure 4.13, showing the ultrasonographic variability of splenic lymphosarcoma (LSA).

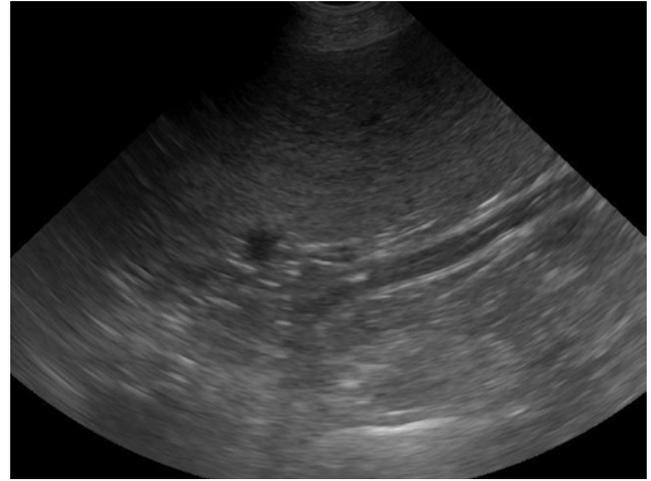


Figure 4.7. Splenomegaly with normal echogenicity. Infectious diseases can cause splenomegaly with variable changes in echogenicity. Shown here is an image from a dog with ehrlichiosis.

Marked splenomegaly most commonly occurs with neoplasia (lymphosarcoma), other infiltrative processes (fungal infection), acute inflammation, or in some cases of immune-mediated hemolytic anemia. Marked splenomegaly also occurs in animals with splenic torsion (see additional description below, as well as Figure 4.15). However, when splenomegaly is confidently ascertained, its correlation with echogenicity can be clinically helpful as follows:

- Mild to moderate splenomegaly with normal echogenicity and architecture is most commonly associated with sedation, extramedullary hematopoiesis, antigenic stimulation (acute inflammatory and infectious diseases), and passive congestion (Figures 4.7 and 4.8A and B).
- Splenomegaly with mild to moderate hypoechogenicity may be associated with nodular hyperplasia or extramedullary hematopoiesis, passive congestion, inflammation, infection (fungal, bacterial, rickettsial), immune-mediated diseases, and lymphosarcoma. Marked splenomegaly also occurs in animals with splenic torsion (variable echogenicity) (see additional description below). Comparison with the adjacent liver and the renal cortex can help when assessing echogenicity (Figures 4.8A and 4.9A; also see normal relative echogenicity in Figure 4.3A through D).

In general, unless splenic torsion is identified (often urgent surgical disease), fine needle biopsy with cytological evaluation is indicated in cases of moderate to marked splenomegaly.

Splenic Mass Lesions

The identification of solitary or multifocal nodules or mass lesions within the splenic parenchyma is generally the most easily learned ultrasound skill of the four features of the focused spleen exam: size, echogenicity, nodules, and vasculature. It is important, however, to recognize that despite the recognition of a mass lesion, ultrasound does not allow differentiation between benign and malignant processes unless advanced contrast-enhanced ultrasound studies are performed (not readily available) (Fife 2004, Rossi 2006). The sonographer should keep in mind that according to one study, benign splenic masses are more common than malignant splenic masses in dogs (Fife 2004).

Nodules associated with nodular hyperplasia or extramedullary hematopoiesis may be variable in echogenicity when compared to normal splenic parenchyma (hyperechoic, hypoechoic, isoechoic, or mixed echogenicity) (Figure 4.10A and B). In

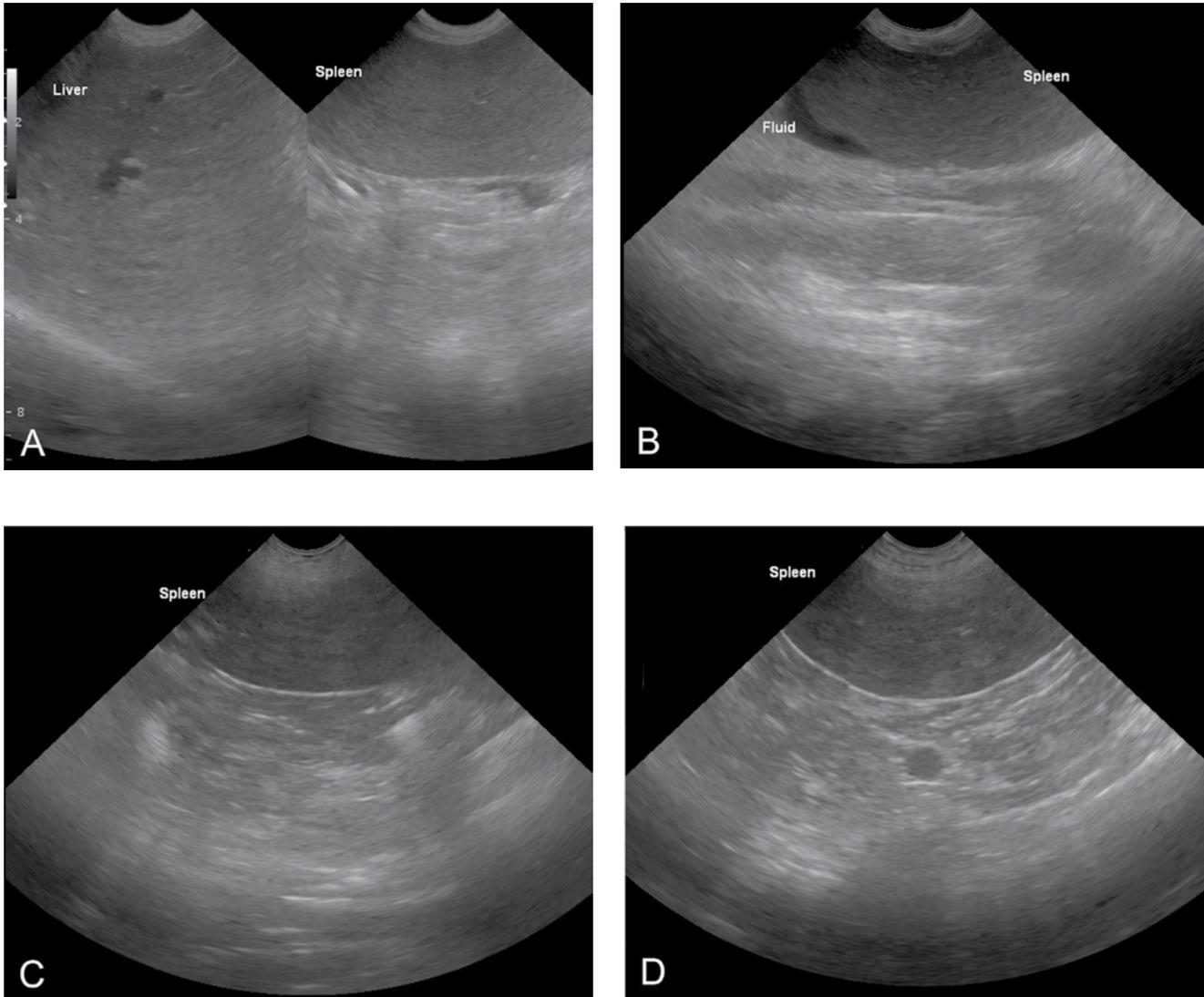


Figure 4.8. Splenomegaly with splenic hyperechogenicity (brighter than normal) and hypoechogenicity (darker than normal). (A) Relatively normal homogeneous echotexture in a hyperechoic (brighter than the liver) spleen. The diagnosis by percutaneous needle biopsy was lymphosarcoma (LSA). (B) Another relatively unremarkable hyperechoic spleen in a cat diagnosed with splenic LSA by percutaneous needle biopsy. Note an anechoic triangle of free fluid (Fluid). (C and D) Mottled echotexture with hypoechogenicity (darker) in spleens representing nodular hyperplasia diagnosed by percutaneous needle biopsy.

addition, nodular hyperplasia may be associated with a mildly irregular splenic capsule without associated nodular lesions. This change is commonly seen in older dogs.

In cases with nodular lesions, it may be difficult to differentiate changes associated with nodular hyperplasia from other processes without further testing (cytology or histopathology).

Myelolipomas are incidental findings in older dogs and are identified as discrete strongly hyperechoic (bright) nodules which are most commonly located near the hilus or associated with the parenchymal vessels. Myelolipomas are generally small in size but may occasionally be relatively large. They are typically of no clinical consequence (incidental finding) (Figure 4.10C and D).

Hematomas and splenic parenchymal injury may be associated with abdominal trauma (Figure 4.11; also see Figures 2.18A and 13.8B). Hematomas (benign masses) may be variable in appearance but initially are generally

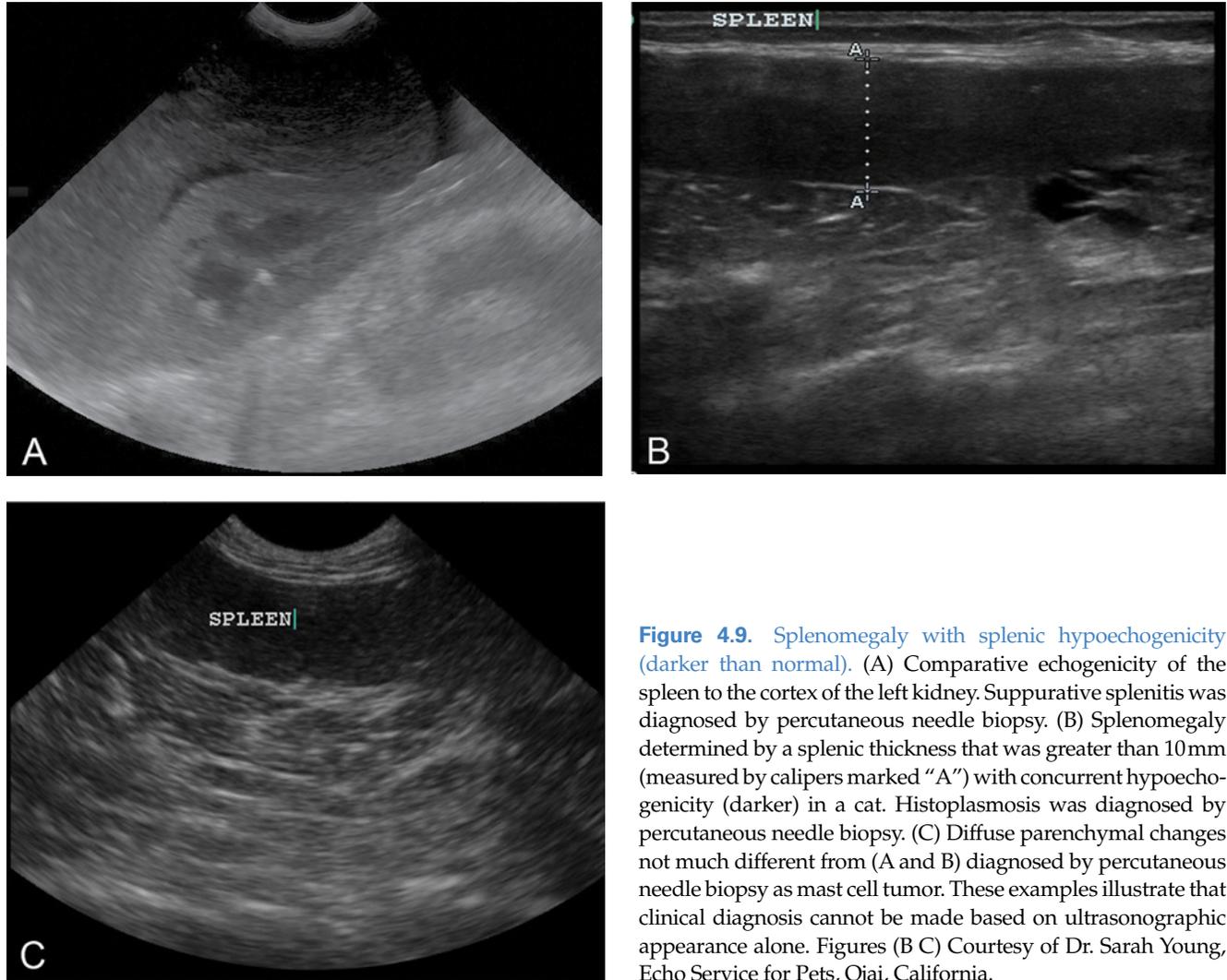


Figure 4.9. Splenomegaly with splenic hypoechoogenicity (darker than normal). (A) Comparative echogenicity of the spleen to the cortex of the left kidney. Suppurative splenitis was diagnosed by percutaneous needle biopsy. (B) Splenomegaly determined by a splenic thickness that was greater than 10mm (measured by calipers marked “A”) with concurrent hypoechoogenicity (darker) in a cat. Histoplasmosis was diagnosed by percutaneous needle biopsy. (C) Diffuse parenchymal changes not much different from (A and B) diagnosed by percutaneous needle biopsy as mast cell tumor. These examples illustrate that clinical diagnosis cannot be made based on ultrasonographic appearance alone. Figures (B C) Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

anechoic to hypoechoic (darker than) compared to normal splenic parenchyma. As the blood within the hematoma forms a clot, the lesion may become more isoechoic or hyperechoic. As the clot retracts, the lesion may become more hypoechoic again. Anechoic fluid may form around the clot and appear as a cyst-like lesion. Hematomas may be difficult to distinguish from other mass lesions, including neoplasia.

Fine needle biopsy of hematomas generally yields non-specific cytological results and therefore, the absence of neoplastic cells on cytology does not rule out neoplasia. Definitive diagnosis of hematoma is obtained by splenectomy and histopathological evaluation.

Splenic abscesses are uncommon and usually cannot be distinguished from other processes that produce nodular or mass lesions. The appearance may be variable

with well-defined or indistinct margins and variable echogenicity. Most commonly, abscesses appear as relatively hypoechoic lesions which may have cystic components or mixed echogenicity. A more definitive finding for an abscess (in contrast to neoplastic processes) is the presence of gas (due to gas-forming bacteria) within the lesion which appears as focal areas of hyperechogenicity with distal edge shadowing and possibly comet-tail artifacts (see Figures 1.4A, 1.5A and 1.8B).

Regarding splenic abscesses, fine needle aspiration/needle biopsy with cytology and bacterial culture and sensitivity is helpful in confirming the diagnosis. However, neoplastic lesions can have necrotic centers that can be mistaken for abscesses. Therefore, diagnosis should always be in conjunction with additional clinical findings that support the diagnosis. Furthermore, definitive diagnosis may only be gained by splenectomy and histopathological evaluation.

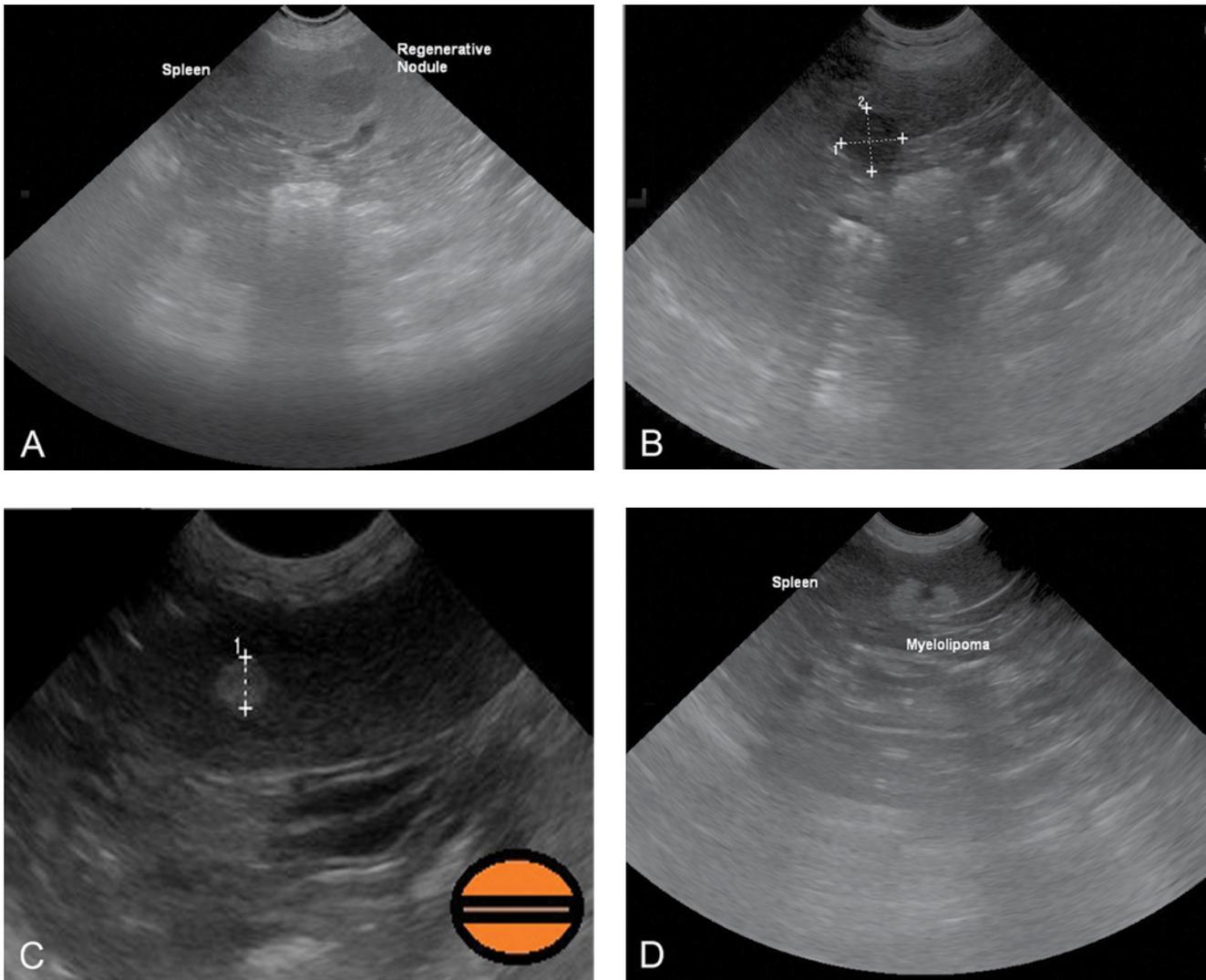


Figure 4.10. Splenic nodular hyperplasia and myelolipomas. (A–C) are examples of nodular hyperplasia characterized by homogeneous echogenicity of the mass which may be hyper- or hypoechoic relative to the adjacent splenic parenchyma. Importantly, note that in contrast to fluid-filled structures that have acoustic shadowing artifact extending through their far field, each of these solid nodules do not. Also, in the distal field is a transverse image of normal small bowel that appears like a “hamburger” (colored illustration to the lower right of the small bowel). (D) An example of a myelolipoma, a common incidental finding in older dogs, often characterized by hyperechoic (bright) discrete nodules located near the splenic hilus but may also be located parenchymally.

Neoplastic lesions can have a wide range of ultrasonographic changes when associated with the spleen. As emphasized above, it is not possible to distinguish between benign and malignant lesions based on ultrasonographic appearance alone. The most common types of splenic neoplasia found in dogs are hemangiosarcoma and lymphosarcoma (Penninck 2008); however, several other types of primary and metastatic tumors are possible.

Hemangiosarcoma (HSA) generally appears as complex mass lesions with mixed echogenicity and cavita-

tions that distort the splenic capsule (Figure 4.12). HSA of the spleen is often associated with acute or chronic hemorrhage. A recent study shows that animals with ruptured splenic masses causing hemoabdomen have a higher likelihood of malignancy (hemangiosarcoma) rather than a benign tumor (Hammond 2008). However, because rupture of splenic masses with resultant hemoabdomen can occur with both benign and malignant processes, and benign hematomas can have a similar ultrasonographic appearance as HSA, definitive diagnosis in the absence of metastasis

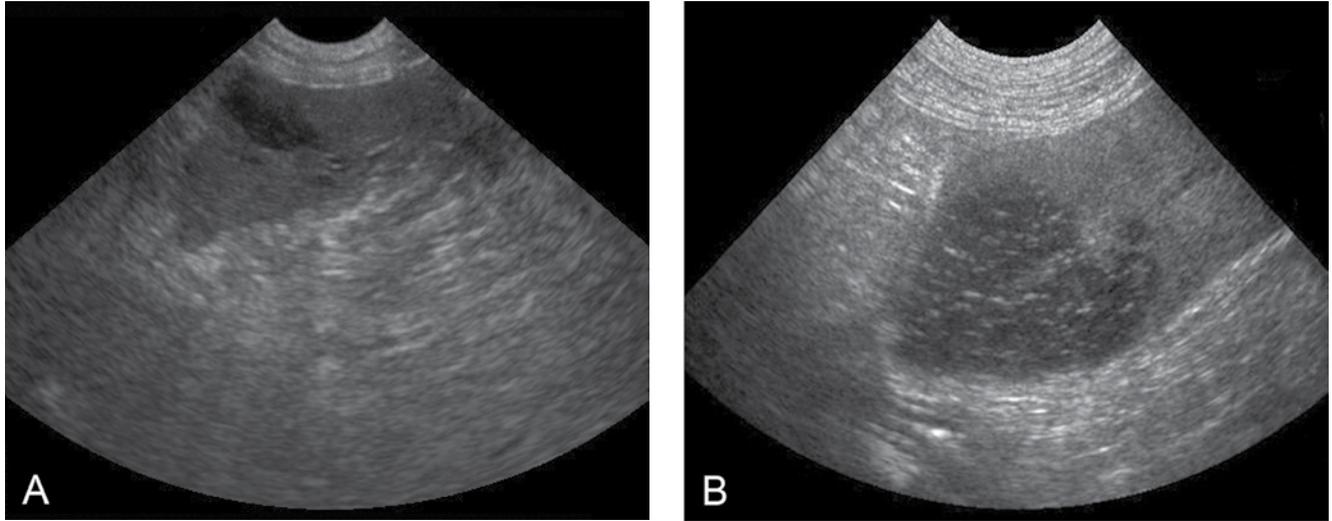


Figure 4.11. Splenic hematomas and infarcts. (A) The spleen has a hypoechoic (dark) area within its parenchyma that represents an acute hematoma in a young dog that had just incurred blunt automobile trauma. The splenic finding was observed during an AFAST³ exam. (B) The spleen has a hypoechoic area within its parenchyma that represents an infarcted region seen in a bluntly traumatized puppy. Figure (B) Courtesy of Dr. Autumn Davidson and Tomas Baker, University of California, Davis.

through pre-operative staging often requires splenectomy and histopathological evaluation.

Staging of HSA may be performed (depending on the primary presentation) using advantageous AFAST³ to investigate the presence of hemoabdomen, TFAST³ (or Focused ECHO) for pericardial effusion (and right atrial mass), and Vet BLUE for evidence of lung metastasis.

Lymphosarcoma (LSA) has a variable appearance when associated with the spleen. LSA may appear as either a focal mass lesion or multifocal mass lesions, or as diffuse parenchymal disease described as having a honeycomb, moth-eaten, or Swiss cheese appearance (Figure 4.14) (Nyland 2002). Generally, mass lesions due to LSA are hypoechoic with indistinct margins and may be singular or multifocal in nature. However, they can also be isoechoic or slightly hyperechoic to normal splenic parenchyma which may or may not distort the splenic contour (Figures 4.6 and 4.8A and B).

Diagnosis of LSA may be made via percutaneous needle biopsy (Crabtree 2010).

Metastatic lesions may be hypoechoic or hyperechoic in nature. Metastatic lesions are more likely to

have a “target” appearance consisting of hypoechoic margins with a relatively hyperechoic center (Figure 4.13). It has been reported that single target lesions have a high predictive value for malignancy. When multiple target lesions are seen, the positive predictive value of malignancy increases from 74% to 81% (Cuccovillo 2002) (also see Figure 3.9A and B). However, keep in mind that the visualization of a target lesion(s) ultrasonographically is non-specific and a biopsy is required. On the other hand, another diagnostic strategy when finding a splenic target lesion is to look for other intra-abdominal masses using ultrasound or performing thoracic radiography (screening for lung nodules) or both. By doing so, further evidence may be found that supports clinical suspicion or provides a more readily accessible mass or lesion for diagnosis via aspiration or biopsy.

Other tumors may have similar variable size, echogenicity, and an ability to distort the splenic contour. Therefore, it is always important to base a diagnosis on other clinical findings as well as cytological and histopathological evaluation.

Echogenicity

Evaluation of diffuse parenchymal disease is subjective and can be difficult for the novice sonographer. Echogenicity of the spleen is assessed by comparing splenic parenchyma to the adjacent liver and the left renal (kidney) cortex as described above.

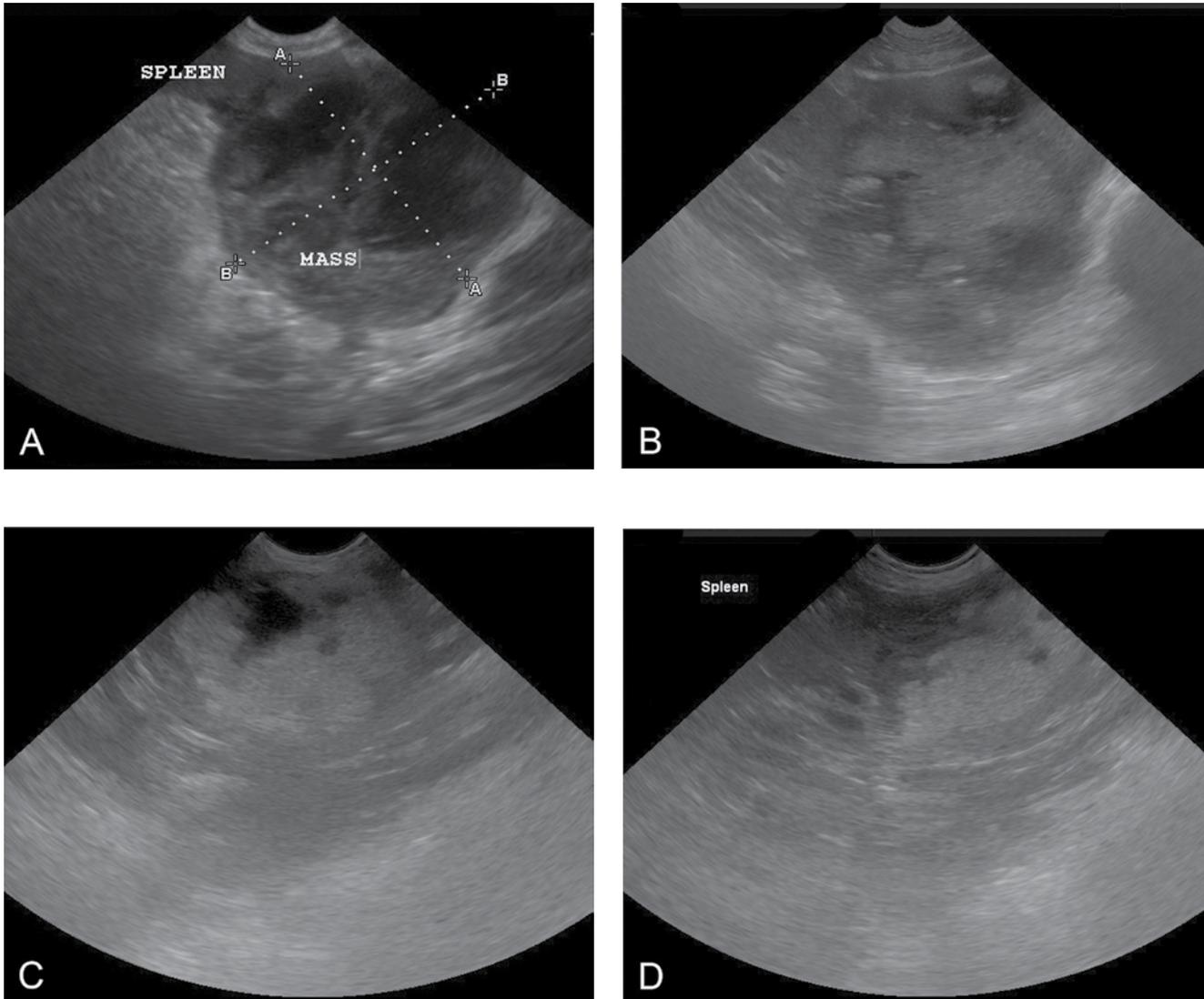


Figure 4.12. Splenic hemangiosarcoma (HSA) and its variability. (A) A splenic mass that was diagnosed as HSA by splenectomy and histopathological evaluation. Note that normal spleen in the upper left image is confluent with the mass of mixed echogenicity determining its splenic origin. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, CA. (B and C) represent typical mass appearances of splenic HSA. For positive splenic identification, the mass should be traced into obvious splenic parenchyma. Surprisingly, in some cases, HSA and other splenic masses can mimic the less common benign diagnosis of splenic abscess. A large splenic mass of mixed echogenicity or with a necrotic center may also mimic free fluid when depth is inadequate (too zoomed in or the depth set too shallow) or the mass is excessively large (exceeding the depth limits of your US machine). (D) An example of HSA that is more infiltrative and less mass-like. Note that despite the mixed echogenicity, the spleen has little to no deformation of its normal contour.

Changes in echogenicity can be seen with extramedullary hematopoiesis, passive congestion, nodular hyperplasia, inflammation, infection, neoplasia, and splenic torsion.

Extramedullary hematopoiesis is generally associated with mildly reduced echogenicity (hypoechoic).

Passive splenic congestion is generally associated with hypoechoic changes in acute phases but may be

associated with hyperechoic changes in more chronic processes. Generally, architecture is not disrupted.

Nodular hyperplasia may be associated with either hypoechoic (darker) or hyperechoic (brighter) changes that are relatively mild. The splenic capsule may be mildly irregular as described above. Nodular hyperplasia is a benign condition commonly seen in older dogs (Figure 4.8C and D).

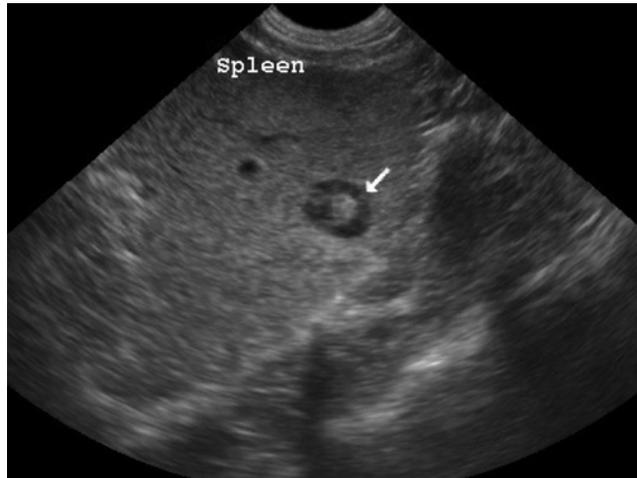


Figure 4.13. “Target” lesions suggest metastatic neoplasia and should trigger a search for a primary tumor as well as other sites of metastasis. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.



Figure 4.14. The “Swiss cheese” or “moth-eaten” appearance of the spleen is often caused by LSA. However, LSA has variable presentations including a diffuse homogeneous echogenicity change that is hyper- or hypoechoic. Moreover, splenic LSA may appear ultrasonographically unremarkable. Compare to Figure 4.6, showing the variability of splenic LSA, and Figure 4.15, showing the lacy appearance of splenic torsion. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Inflammatory or infectious diseases (fungal, bacterial, rickettsial) generally cause mild to moderate splenomegaly with diffuse hypoechoic. With acute inflammation or infection, the changes are more pronounced with a more prominently hypoechoic and finely mottled appearance (Figures 4.7 and 4.9A and B).

Neoplastic conditions such as lymphosarcoma, mast cell tumor, and other myeloproliferative diseases generally produce a diffusely, coarsely mottled appearance, described as honeycomb, moth-eaten, or Swiss cheese (Nyland 2002) (Figure 4.14; compare to Figures 4.6 and 4.8A and B). It is important to remember that both lymphosarcoma and mast cell tumor can also be present with very mild diffuse changes and occasionally can even have a fairly normal appearance. Therefore, if lymphosarcoma, other myeloproliferative disease processes, or mast cell disease are suspected, fine needle biopsies may be indicated, even if the spleen appears ultrasonographically normal, because these diseases may have only subtle changes in echogenicity.

Marked splenomegaly with a diffusely hypoechoic to anechoic lacy appearance (compared to a generally hyperechoic [brighter] lacy appearance with LSA in Figure 4.14) of the parenchyma is typical of splenic torsion (Figure 4.15A and B). If color flow Doppler evaluation is available, evaluation of the splenic vein and parenchymal vessels may help support the diagnosis. The finding of the absence of blood flow in the splenic vein is consistent with torsion. Thrombus formation may also be identified within the splenic vein in some dogs. A perivenous hyperechoic triangle at the level of the splenic hilus has been described as a common feature in dogs with splenic torsions (Mai 2006, Penninck 2008).

Vasculature

Finally, evaluation of the splenic vasculature may help identify splenic torsion (as discussed above) and thrombus formation and its sequela, splenic infarction.

Marked splenomegaly with a diffusely hypoechoic to anechoic lacy appearance of the parenchyma is the hallmark of splenic torsion (compared to a generally hyperechoic [brighter] lacy appearance with LSA in Figure 4.14). If color flow Doppler evaluation is available, evaluation of the splenic vein and parenchymal vessels may help support or refute the diagnosis (Figure 4.1A and B). The finding of absence of blood flow in the splenic vein and the observation of the perivenous hyperechoic (bright) triangle at the splenic hilus is also consistent with torsion (Mai 2006) (see and compare Figure 4.1A and B to Figure 4.16).

Thrombi are recognized as echogenic structures within the splenic vein or parenchymal splenic vessels. They may or may not have clinical consequences depending on the degree of occlusion of the vessel

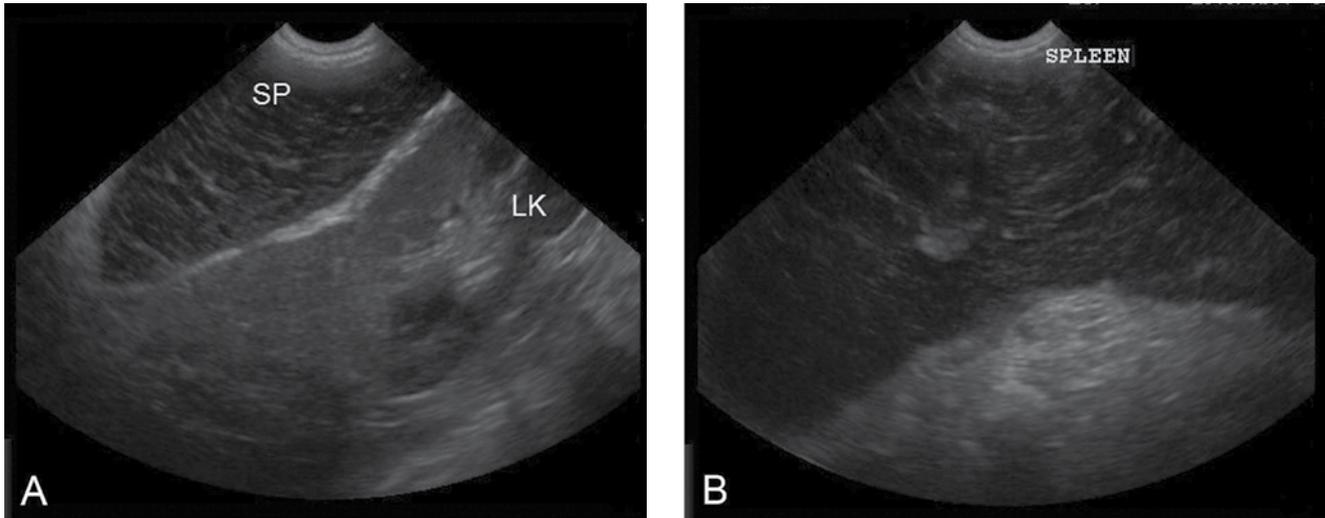


Figure 4.15. Splenic torsion parenchymal lesion. (A) Note the hypoechoic (dark) lacy appearance to the spleen (SP) shown adjacent to the left kidney (LK). (B) Another view of the same spleen in (A), showing its thickness and its hypoechoic (dark) lacy parenchymal appearance. Compare to the hyperechoic (bright) lacy appearance of splenic lymphosarcoma in Figure 4.14. The perihilar region is hyperechoic (bright) without clear imaging of the hyperechoic triangle shown in Figure 4.16. Color flow Doppler was helpful in this case (not shown), documenting the lack of perihilar blood flow. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

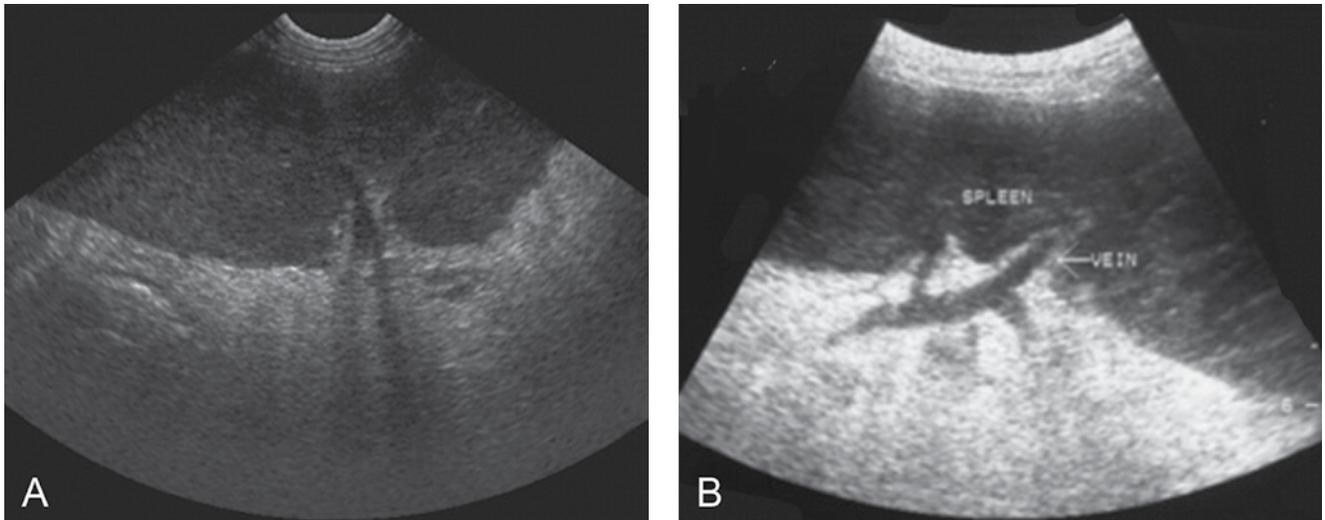


Figure 4.16. Splenic torsion vascular lesion. (A) Image of the splenic hilus in a dog with splenic torsion. Note the hyperechoic triangular region around the vessel, continuous with the hyperechoic and hyperattenuating mesenteric fat. (B) Image of the splenic hilus in another dog with splenic torsion. There is a hyperechoic triangular region around the splenic veins, continuous with the mesenteric fat which is markedly hyperechoic and hyperattenuating. There are also intraluminal echoes in the splenic veins consistent with thrombosis. Both (A and B) show the perivenous hyperechoic triangle supportive of splenic torsion. Courtesy of (Mai 2006), page 489.

(Figure 4.17, and compare to Figure 4.1A and B). However, splenic thrombi should raise clinical suspicion for the presence of lymphosarcoma (Laurenson 2010).

Splenic thrombi are most commonly associated with lymphosarcoma (Laurenson 2010).

Splenic infarction is a possible sequela to splenic thrombi occurring when blood flow is occluded to an area of splenic parenchyma or as a result of trauma. Infarcted areas tend to be hypoechoic with poorly defined or sharp delineated margins in acute phases which generally become more hyperechoic and smaller in chronic phases (Figure 4.11A and B).

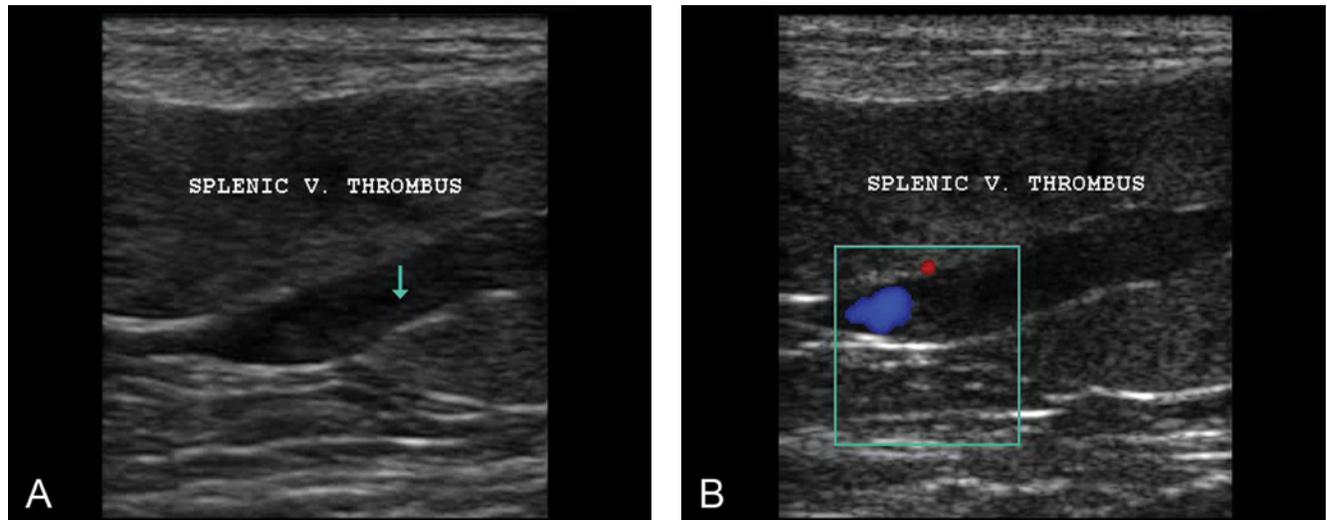


Figure 4.17. Splenic thrombus. (A) The splenic vein near the hilus, which appears distended by its relative size to the body of the spleen. Within the lumen there appear to be isoechoic material/intraluminal echoes. (B) Same image as (A), confirming the presence of the suspected splenic thrombus using color flow Doppler. Splenic thrombi are most commonly associated with lymphosarcoma but are also associated with other prothrombotic conditions. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

The Routine Add-on of AFAST³ and its Abdominal Fluid Scoring System

In the author's experience, it is extremely valuable to perform an AFAST³ exam in right lateral recumbency as part of a complete diagnostic exam. There are several reasons that the addition of AFAST³ improves the diagnostic potential of the ultrasound exam. Positioning small animals in dorsal recumbency for focused abdominal organ exams potentially misses the presence of small volume abdominal effusions and more importantly, probably underestimates the volume of effusion present. As a result, moving the patient to lateral recumbency and performing AFAST³ along with its applied abdominal fluid score (AFS) to all complete abdominal ultrasound exams has become standard protocol by the author and is recommended for each of the focused abdominal organ exams. Of note, the addition AFAST³ and the application of the AFS adds little time (less than two minutes) to the focused organ exam and improves diagnostic evaluation.

The early detection of abdominal effusion is clinically important and helps direct additional diagnostic recommendations and potentially avoids serious morbidity, complications, and patient mortality in the event the effusion is missed. Although no veterinary

studies have been performed comparing the detection and volume of abdominal effusions between dorsal recumbency and AFAST³ positioning, the author's experience has shown the comparison to often be remarkably different. AFAST³ is more sensitive for the detection of free fluid, especially if small volumes are present, and allows for better and less subjective assessment of the volume of fluid by also using the AFS score.

Pearls and Pitfalls, the Final Say

It is important for the non-radiologist veterinarian to respect the limitations of the focused spleen exam because of the variability of ultrasonographic features of many diffuse and mass lesion and nodular conditions. However, when pathology is recognized by ultrasound, the spleen is amenable to relatively non-invasive cytological evaluation by percutaneous needle biopsy or aspirates.

With hemorrhage being a common complication of these procedures, the AFAST³ format with its applied fluid scoring system (see Chapter 2) is an excellent way to screen (four hours post procedure and as needed thereafter) for bleeding that may be occult based on less sensitive traditional means of laboratory testing such as packed cell volume (hematocrit). Finally, the

spleen may be sacrificed with few long-term consequences in both dogs and cats, and a definitive diagnosis and treatment plan may lie in performing a splenectomy with appropriate culture and histopathological testing.

Other points to consider:

- Evaluation of splenomegaly is usually a subjective assessment in dogs unless splenic enlargement is severe.
- The finding of splenomegaly in cats is almost always due to pathology, and warrants additional evaluation.
- Nodular and mass lesions within the splenic parenchyma are common and usually easy to identify. However, it is not possible to distinguish benign and malignant processes without additional cytology or histopathology.
- Splenic hematoma and hemangiosarcoma cannot be differentiated on the basis of ultrasound alone.
- If it is difficult to determine the origin of a large midabdominal mass, move the patient from dorsal to lateral recumbency because by doing so the liver and spleen will often separate from one another, helping better determine the origin of the mass.
- Ultrasound facilitates fine needle percutaneous biopsy of nodular or mass lesions in the spleen. The finding of non-specific cytology results after fine needle biopsy does not rule out the possibility of a malignant lesion.
- Mild diffuse changes in echogenicity can be subjective for the novice sonographer.
- Remember the mnemonic “SLiCK” regarding the degrees of echogenicity between the spleen (S), liver (Li), and cortex of the kidney (CK). In other words, the echogenicity of the spleen is greater (brighter) than the liver, which is slightly greater (brighter) or isoechoic (same as) as compared to the cortex of the kidney.
- There are several benign processes that cause mild to moderate diffuse changes in echogenicity including extramedullary hematopoiesis, passive congestion, and antigenic stimulation.

- Diffuse changes associated with lymphosarcoma or other myeloproliferative disorders can be variable in appearance and occasionally can be associated with a normal or unremarkable splenic appearance.
- Fine needle percutaneous biopsies are indicated in cases of moderate to severe splenomegaly or in animals with diffuse changes in echogenicity.

References

- Crabtree AC, Spangler E, Beard D, Smith A. et al. 2010. Diagnostic accuracy of gray-scale ultrasonography for the detection of hepatic and splenic lymphoma in dogs. *Vet Radiol Ultrasound* 51(6):661–614.
- Cuccovillo A, Lamb CR. 2002. Cellular features of sonographic target lesions of the liver and spleen in 21 dogs and a cat. *Vet Rad and Ultrasound* 43(3):275–278.
- Fife WD, Samii VF, Drost JS, et al. 2004. Comparison between malignant and nonmalignant splenic masses in dogs using contrast enhanced computed tomography. *Vet Radiol Ultrasound* 45:289–297.
- Hammond TN, Pesillo-Crosby SA. 2008. Prevalence of hemangiosarcoma in anemic dogs with a splenic mass and hemoperitoneum requiring a transfusion: 71 cases (2003–2005). *J Am Vet Med Assoc* 232(4):553–558.
- Hecht S. 2008. Spleen. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D’Anjou. Ames, Iowa: Blackwell Publishing. pp 263–280.
- Laurenson MP, Hopper K, Herrera MA, et al. 2010. Concurrent diseases and conditions in dogs with splenic vein thrombosis. *J Vet Intern Med* 24:1298–1304.
- Mai W. 2006. The hilar perivenous hyperechoic triangle as a sign of acute splenic torsion in dogs. *Vet Radiol Ultrasound* 47(5):487–91.
- Nyland TG, Mattoon JS, Herrgesell et al. 2002. Spleen. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TG Nyland and JS Mattoon. Philadelphia: WB Saunders, p 132.
- Reese SH, Zekas LJ, Iazbik MC, et al. 2012. Effect of sevoflurane anesthesia and blood donation on the sonographic appearance of the spleen in 60 healthy cats. *Vet Rad & Ultrasound* In press.
- Rossi F, Leone VF, Vignoli M, et al. 2008. Use of contrast-enhanced ultrasound for characterization of focal splenic lesions. *Vet Radiol Ultrasound* 49(2): 154–164.

FOCUSED OR COAST³—KIDNEYS

Stephanie Lisciandro

Introduction

The focused use of ultrasound to evaluate the kidneys may readily answer some clinically relevant questions for the non-radiologist veterinarian and thus may help more expediently guide clinical course in a positive manner than without using ultrasound. The focused kidney exam may be especially beneficial in patients with acute kidney injury or kidney failure of undetermined cause because it may be used to screen for several recognizable ultrasonographic conditions discussed below. It is important to remember that the focused kidney exam cannot predict kidney function or response to therapy. Animals may have a normal ultrasonographic exam and have severe kidney dysfunction or may have abnormalities in the ultrasonographic appearance and have normal kidney function. In addition, the focused kidney exam is not meant to replace a complete (or formal) abdominal ultrasound study performed by a veterinarian with advanced training (the veterinary radiologist or internist). Lastly, ultrasound has inherent weaknesses, and will not necessarily replace the use of abdominal radiography, tissue and fluid sampling, bacterial culture, or other pertinent diagnostic testing.

When using any of the focused abdomen-related organ exams, assessment with an abdominal focused assessment with sonography for trauma (AFAST³) exam is recommended for wider patient assessment. By performing AFAST³, the clinician is less likely to miss concurrent effusive conditions, and by finding free fluid, the opportunity to characterize and diagnose forms of peritonitis (distinguishing medical vs. surgical conditions) to the patient's benefit.

What the Focused Kidney Exam Can Do

- Help recognize renal parenchymal disease such as cysts, nodules, and masses
- Identify kidney stones (nephroliths)
- Help determine the presence of pyelectasia
- Help determine the presence of hydronephrosis
- Help determine the presence of retroperitoneal fluid
- Help determine the presence of renal infarcts (especially cats)
- Measure kidney size and evaluate for asymmetry.
- Serial assessment may be beneficial in acute kidney injury

What the Focused Kidney Exam Cannot Do

- Cannot differentiate benign vs. malignant kidney masses
- Cannot diagnose pyelonephritis
- Cannot characterize the type of retroperitoneal fluid
- Cannot definitively diagnose ethylene glycol toxicity or other causes of acute kidney failure solely on the basis of a "halo sign" (also referred to as the medullary rim sign)
- Cannot determine kidney function or response to therapy.

Indications for the Focused Kidney Exam

- Hematuria
- Pyuria

- Abnormal urinalysis
- Polyuria and polydipsia of undetermined cause
- Acute kidney failure of undetermined cause
- Discrepancies in comparative kidney size
- Uncharacterized back pain or retroperitoneal pain

Objectives of the Focused Kidney Exam

- Recognize diffuse changes in echogenicity consistent with diffuse parenchymal disease
- Recognize focal parenchymal changes such as kidney cysts and masses
- Recognize kidney stones (nephroliths)
- Recognize renal infarcts
- Recognize pyelectasia
- Recognize hydronephrosis/hydroureter
- Recognize retroperitoneal and perirenal (subcapsular) fluid
- Determine the presence of renal agenesis

Patient Positioning and Probe Selection

Curvilinear probes are generally used for imaging the kidneys, and the ultrasound probe with the highest frequency allowing adequate penetration should be used. Higher frequency linear probes (7.5–10 MHz) provide better detail with less penetration and may be used in smaller dogs and cats. Conversely, large dogs require a lower frequency with more penetration (5 MHz) but at the expense of detail. Depth should be adjusted so the entire kidney is visualized in both the long-axis and short-axis views.

Dogs and cats may be scanned in dorsal or right and left lateral recumbency. In most small animals, both kidneys can be adequately imaged in dorsal recumbency. However, in large or deep-chested dogs, it is often necessary to also image kidneys in right lateral (for the left kidney) and left lateral (for the right kidney) recumbency due to the position of the kidneys. Left lateral recumbency using an intercostal or subcostal window is particularly helpful for the right kidney because of its more cranial, subcostal position in the abdomen. The left kidney, located caudal to the last rib, is generally easy to image in dorsal recumbency in both dogs and cats regardless of patient size. Additionally, the gastro-intestinal tract can interfere with visualization of the kidneys, particularly if there is gas in the transverse or descending colon.

The intestinal tract advantageously falls away from the non-gravity dependent kidney of interest in lateral recumbency.

Patient Preparation

Generally, it is helpful to shave the ventral abdomen for evaluation of the kidneys. If an intercostal approach is used, additional clipping may be required; however, clipping may be avoided for cosmetic reasons by parting the fur and applying alcohol to the skin in addition to acoustic coupling gel.

How to Do the Focused Kidney Exam

When the patient is in dorsal recumbency, the left kidney is visualized caudal to the stomach and medial to the spleen, which provides an acoustic window for visualization of the kidney. The spleen is visualized in the near field and the left kidney is deep to the spleen (Figure 5.1A and B). The entire kidney should be visualized on the ultrasound screen and therefore, the depth of field may need to be adjusted. The kidney should be completely scanned both in long-axis (longitudinal/sagittal) and short-axis (transverse) views. This is facilitated by obtaining the long-axis (longitudinal/sagittal) view and then gently fanning the probe medially and then laterally. The probe is then turned 90 degrees counterclockwise (turn left) to obtain the short-axis (transverse) view and then slowly moved from the cranial to caudal pole of the kidney.

Follow the spleen caudolaterally to find the left kidney.

The right kidney is generally more difficult to find due to its location, especially in large or deep-chested dogs. The right kidney is located more cranially than the left kidney and is caudal to the pyloric outflow tract and liver and adjacent to the duodenum. The right kidney sits in the renal fossa of the caudate lobe of the liver (Figure 5.1C and D). In dorsal recumbency, the right kidney may be found caudal to the costal arch. It is sometimes necessary to sweep to the right and caudally following the caudal border of the costal arch to find the right kidney. In large and deep-chested dogs, it may be necessary to angle the probe cranial in a subcostal position (up under the last rib) or to reposition the patient in left lateral recumbency for an intercostal approach. This generally will allow for a better

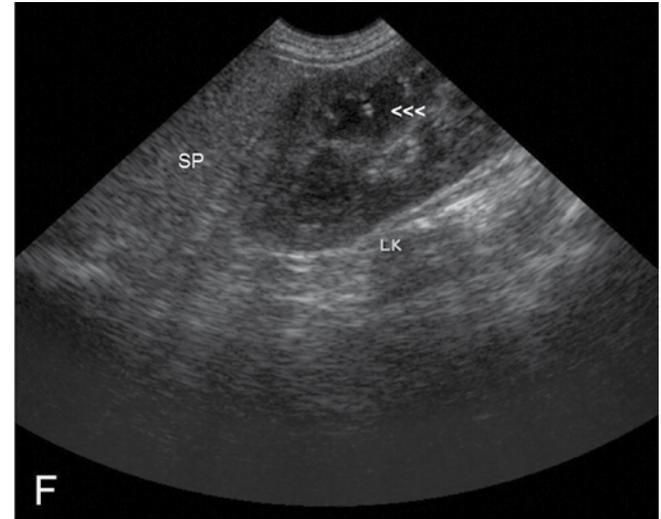
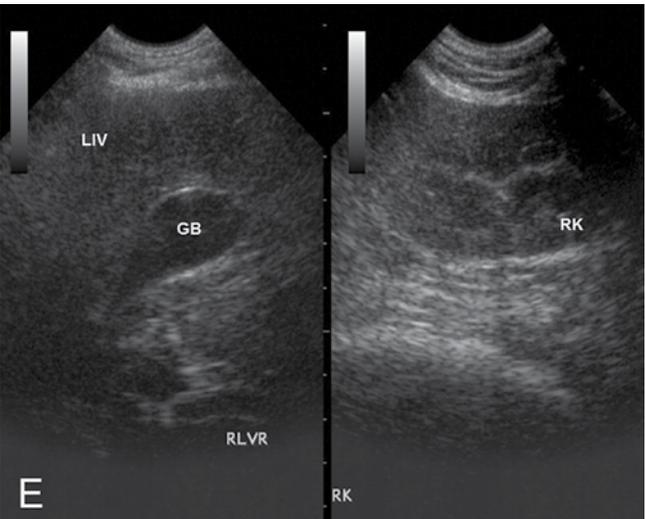
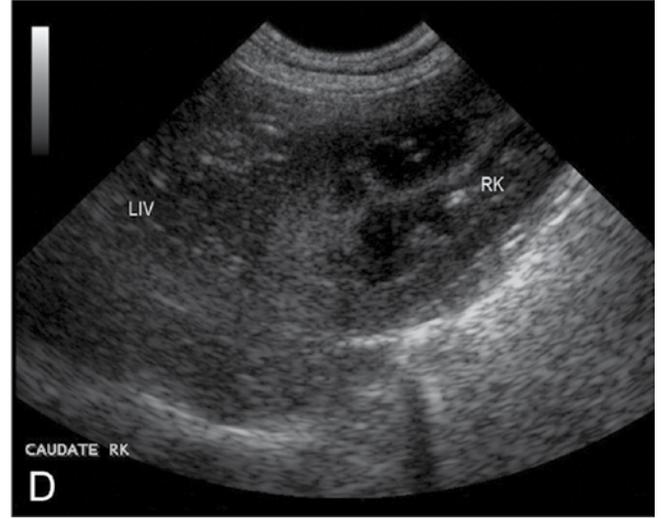
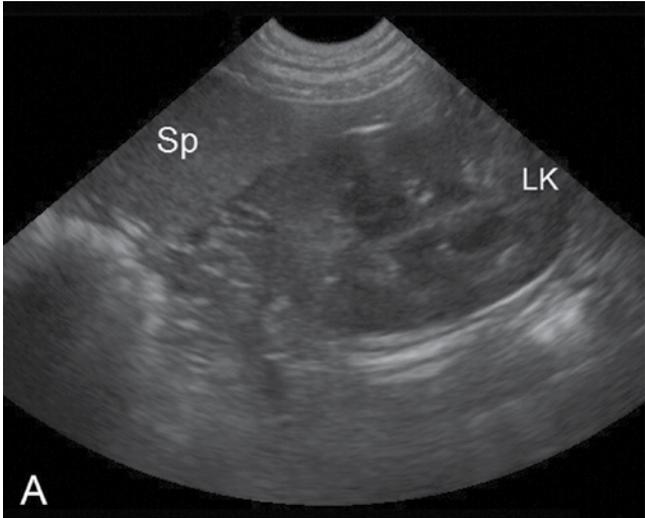


Figure 5.1.

long-axis (longitudinal/sagittal) view of the kidney between an intercostal space because the kidney often appears at an angle in the ventrolateral approach (dorsal recumbency) due to the positioning and angulation of the probe needed to acquire the image. As for the left kidney, once the desired long-axis (longitudinal/sagittal) image is obtained, the probe is gently fanned from medial to lateral to obtain images through all planes in the long-axis. The probe is then rotated 90 degrees (counterclockwise, turn left) for the short-axis (transverse) view and moved from the cranial to caudal pole to allow for evaluation of the entire kidney.

Ultrasonographic Findings in a Normal Kidney

Several basic characteristics should be assessed when determining whether a kidney is normal or has changes that may be consistent with pathology. These include three main features: anatomy, size, and symmetry.

The three kidney features to evaluate in a focused kidney exam are anatomy, size and symmetry.

Kidney Anatomy

The anatomy of the kidney is divided into three distinct regions that should be assessed: cortex, medulla, and renal pelvis. Considerations for assessment of these areas are as follows

Cortical tissue is hyperechoic, or brighter than, the medullary tissue with a distinct demarcation between the two areas, which is generally referred to as corticomedullary distinction. Corticomedullary distinction may be classified as normal or decreased to variable degrees (mild, moderate, severe). The margin of the

cortex (renal contour) is also assessed and should be smooth with a thin echogenic renal capsule. The normal echogenicity of cortical tissue is generally isoechoic (the same as) or slightly hypoechoic (darker) than normal liver, although it may also be slightly hyperechoic (brighter than) to the liver in cats (because of increased renal tubular fat) (Yeager 1989) and some dogs as a normal variation (Figure 5.1C, D, and E). Cortical tissue is generally significantly hypoechoic (darker) when compared to normal splenic tissue (Figure 5.1A and B). Apparent alteration in the normal echogenicity between adjacent organs generally indicates pathology in one or more of the organs that are compared. Echogenicity is affected by the type of probe, frequency, and gain setting. Therefore, the ability to perceive subtle differences in comparative echogenicity may require more operator experience or may not be possible. In other words, the astute sonographer must consider concurrent conditions of liver and spleen to which the cortex of the kidney is being compared to determine which, if any, can be considered ultrasonographically normal (or abnormal).

Remember the “SLiCK” mnemonic: the spleen’s (S) echogenicity is greater than that of the liver (Li), which is similar to or slightly greater than the cortex of the kidney (CK).

The medulla is hypoechoic or darker than normal renal cortical tissue and as described above, there is normally a demarcation between normal cortical and medullary tissue. The normal medullary margin generally has a symmetrical appearance with linear echogenicities due to the presence of interlobar vessels (Figures 5.1F and 5.2B and C) and pelvic diverticula (Figure 5.2D), which should be uniformly arranged

Figure 5.1. Left and right kidneys and comparative echogenicity. (A and B) are images from different ultrasound machines showing normal renal echogenicity in relation to spleen and liver. When normal, the spleen is hyperechoic (brighter) when compared to the renal cortex. The left kidney is easier to image than the right because it is more caudally located and outside the costal arch and thus more ultrasonographically accessible. The spleen is helpful in finding the left kidney by following it caudolaterally, which generally brings the left kidney into view. Moreover, the spleen serves an acoustic window, enhancing renal imaging when in the near field to the kidney. (C and D) are images from the same two ultrasound machines as in (A and B). These images show the more cranially located right kidney, which is often under the costal arch and tucked into the renal fossa of the caudate liver lobe. Intercostal and subcostal imaging and moving the patient into left lateral recumbency may be necessary for adequate imaging of the right kidney, especially in large and deep-chested dogs. The liver is slightly hyperechoic (brighter) to isoechoic (the same as) when compared to the echogenicity of the cortex of the kidney. (E) This image shows how the split screen function may be used to compare relative echogenicity between organs (left screen, liver [LIV], right screen, right kidney [RK] and gallbladder [GB]) when they are not easily imaged side by side on a single screen. (F) Image showing the highly echogenic interlobar/arcuate vessels that appear as bright white dots marked (<<<) along the corticomedullary junction of the right kidney (RK). Compare to 5.2B and C. The mnemonic “SLiCK” (see text) is a good way to remember the order of normal echogenicity. Figures (B), (D), (E), and (F) Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

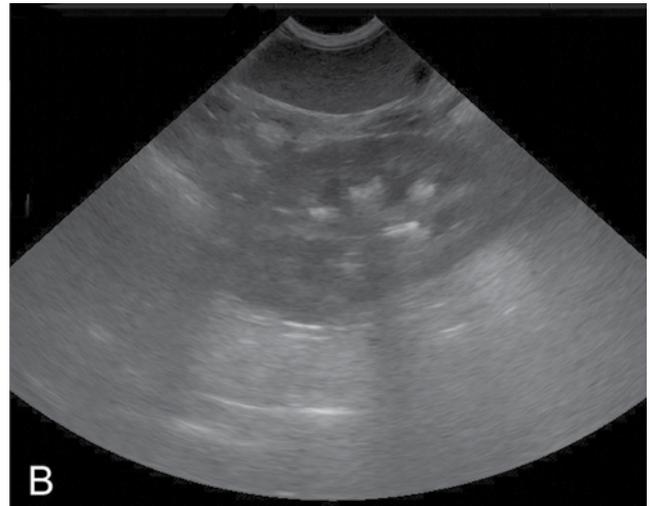


Figure 5.2. Normal cross-sectional view of the kidney. (A) The left kidney shown in longitudinal section with normal corticomedullary architecture. The appearance of a kidney in longitudinal section is likened to a tomato in cross-section. (B and C) are the same image unlabeled and labeled, respectively. The interlobar/arcuate vessels are hyperechoic (bright white) and should not be mistaken for mineralization. (C) The hyperechoic (bright white) interlobar/arcuate vessels (<) are shown. Note that there is no distal acoustic shadowing, which makes mineralization less likely. Also note how the comparative splenic echogenicity is abnormal. The spleen in the immediate near field is hypoechoic or darker than the cortex of the left kidney. Compare this image to the normal comparative echogenicity obvious in 5.1F. (D) The renal pelvic fat (identified by the sonographer by the caliper lines [+----+] showing its borders) can be prominent and very hyperechoic (bright white). As with the interlobar/arcuate vessels, this should not be mistaken for mineralization. Other good examples are Figures 5.3B, 5.6B, and 5.8A. (E) A tomato cut in cross-section mimics the longitudinal/sagittal anatomy of the normal kidney.

(like the appearance of a tomato in cross-section) (Figure 5.2A and E). In addition, some normal animals may have a thin hyperechoic (bright) medullary rim (incidental rim sign) that is clinically irrelevant (Figure 5.4C) (Penninck 2008).

The normal renal medulla appears like a tomato in cross-section.

The renal pelvis is more difficult to evaluate, especially in normal animals in which it may not be readily visualized (Figure 5.2A through D). The renal pelvis may be more apparent in animals receiving intravenous fluids or therapy with diuretics, in which case it is usually symmetrical involving both kidneys (but occasionally may be unilateral) (Felkai 1995, Pugh 1994)(see Pyelectasia and Figure 5.11, below). The pelvis may be surrounded by fat, which appears as hyperechoic (bright) tissue and may be distinguished from mineralized material or related pathology by the absence of an acoustic shadow (Figure 5.2D). The renal pelvis appears linear in longitudinal view and V-shaped in the transverse or sagittal orientation (Figure 5.11D). There is variability in both cats and dogs for normal renal pelvis measurements. Generally, a normal renal pelvis measures 1.5–2 mm with a maximum of height of 2.8 mm in cats, and 2–3 mm with a maximum height of 3.8 mm in dogs (D’Anjou 2011) (Figure 5.12A through D, below). The normal ureter is generally not visible because of its small size; thus, dilation typically indicates pathology (Figure 5.12C).

A general rule of thumb is to consider the renal pelvis abnormal, referred to as pyelectasia, if it measures 3 mm or more in cats and 4 mm or more in dogs.

Several basic characteristics should be assessed when determining whether a kidney is normal or has changes that may be consistent with pathology. These include three main features: anatomy, size, and symmetry.

Kidney Size

Kidney size should be evaluated through measurement of the long- and short-axis and it is just as important to assess symmetry between the patient’s left and right kidneys regarding both size and architecture (Figure 5.3).

The normal kidney size for cats is generally considered to be between 3 and 4.4 cm in length depending on the reference (Nickel 1973, Walter 1987).

The normal kidney size in dogs is too variable and depends on the size of the dog, so assessment of appropriate renal size is generally subjective. Therefore, assessment of symmetry between the two kidneys in dogs is most important. Asymmetry supports kidney pathology.

Because kidney dimensions vary in dogs (no established normals as in cats), it is important that canine kidneys be evaluated for symmetry when considering appropriate renal size for that individual.

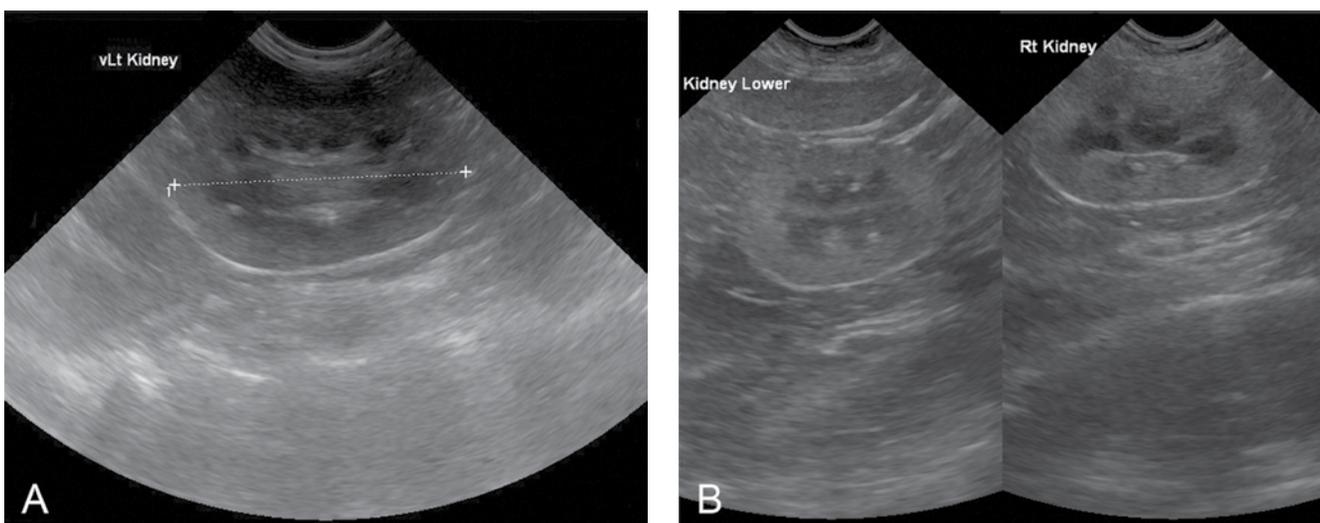


Figure 5.3. Assessing kidney size and symmetry. Normal size is established for cats and the kidneys should be symmetrical when normal. There are no established normal reference ranges for renal size in dogs; thus, comparison of symmetry is important. (A) The proper placement of calipers for renal measurement in longitudinal view. (B) Split screen B-mode images showing side by side comparisons of the left and right kidney. This is a common feature of many ultrasound machines. Note the asymmetry of the kidneys in this example.

Clinical Significance and Implications of Abnormal Kidney Findings

The goal of the focused kidney exam includes evaluation for parenchymal disorders, kidney stones (nephroliths), renal infarcts, retroperitoneal fluid, and abnormalities of the renal pelvis such as pyelectasia and hydronephrosis.

Kidney Parenchymal Disorders

Evaluation for kidney parenchymal disease should include the ability to detect the presence of diffuse abnormalities as well as focal abnormalities such as masses and cysts.

Diffuse parenchymal disease may be more difficult to detect for a less experienced sonographer. Changes

are evaluated by comparing cortical echogenicity to normal liver and splenic tissue as discussed above. Recall the “SLiCK” mnemonic for the normal degree of echogenicity between spleen, which is brighter than the liver, which is slightly brighter or the same as the cortex of the kidney (Figures 5.1A through E).

In general, disorders that result in increased echogenicity (hyperechoic or brighter cortical tissue than spleen and liver) include ethylene glycol toxicosis, other acute toxicities, glomerular disease, interstitial nephritis, end-stage kidney disease, amyloidosis, and hypercalcemic nephropathy (Figure 5.4A and B). The presence of a hyperechoic medullary rim in animals with hyperechoic cortical tissue (“halo sign” or medullary rim sign) may increase the suspicion for hypercalcemic nephropathy, ethylene glycol toxicosis, pyogranulomatous inflammation due to feline infectious peritonitis, leptospirosis, and chronic interstitial nephritis (Penninck 2008, Adams 1991)

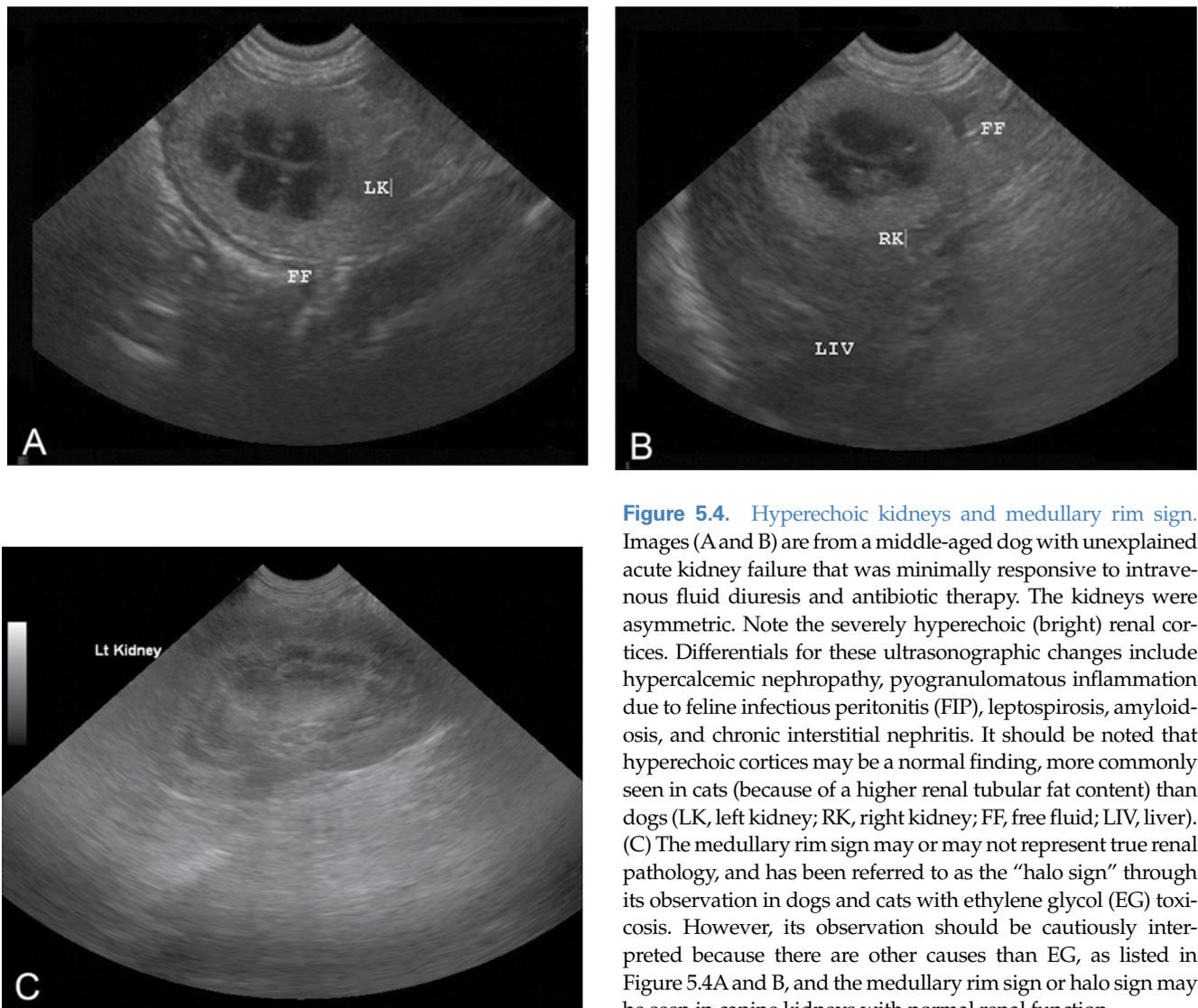


Figure 5.4. Hyperechoic kidneys and medullary rim sign. Images (A and B) are from a middle-aged dog with unexplained acute kidney failure that was minimally responsive to intravenous fluid diuresis and antibiotic therapy. The kidneys were asymmetric. Note the severely hyperechoic (bright) renal cortices. Differentials for these ultrasonographic changes include hypercalcemic nephropathy, pyogranulomatous inflammation due to feline infectious peritonitis (FIP), leptospirosis, amyloidosis, and chronic interstitial nephritis. It should be noted that hyperechoic cortices may be a normal finding, more commonly seen in cats (because of a higher renal tubular fat content) than dogs (LK, left kidney; RK, right kidney; FF, free fluid; LIV, liver). (C) The medullary rim sign may or may not represent true renal pathology, and has been referred to as the “halo sign” through its observation in dogs and cats with ethylene glycol (EG) toxicosis. However, its observation should be cautiously interpreted because there are other causes than EG, as listed in Figure 5.4A and B, and the medullary rim sign or halo sign may be seen in canine kidneys with normal renal function.

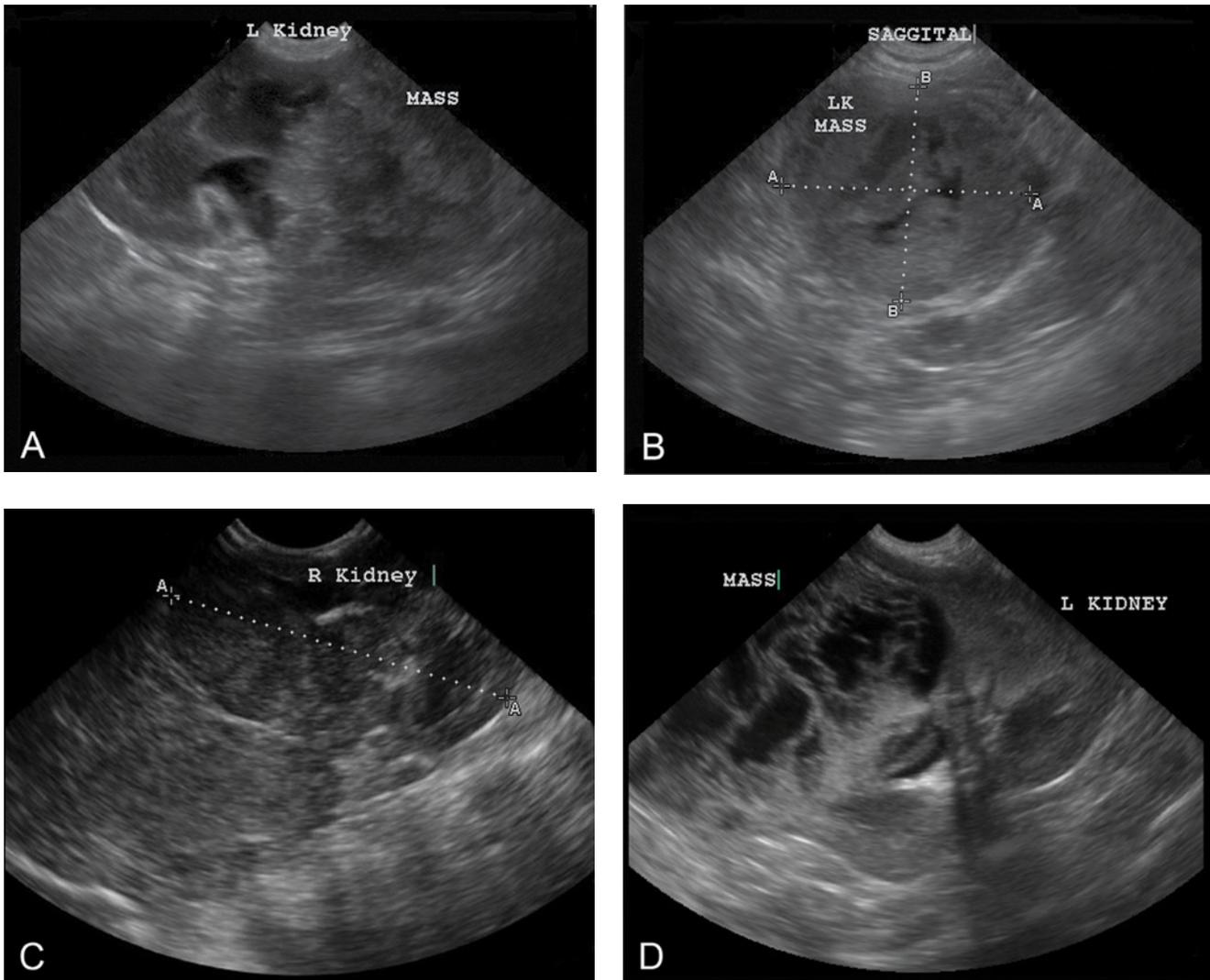


Figure 5.5. Renal masses. (A) Mass off the caudal pole of the kidney. Biopsy of the mass was renal adenocarcinoma. It is not uncommon for these tumors and other kidney-related masses to rupture and result in significant retroperitoneal hemorrhage. Neoplastic retroperitoneal effusions can also be seen. (B) Same mass as in (A), shown in transverse (short-axis). Note the lack of the normal renal anatomy. The renal origin of the mass was obvious in real-time during longitudinal and transverse interrogation. (C) Invasive mass involving the cranial pole of the kidney. The diagnosis in this young adult dog was nephroblastoma. It can be difficult to differentiate the true origin of large masses. Careful tracing and identification of other nearby structures is imperative to improve accuracy. (D) Cavitory mass of the cranial renal pole. The diagnosis in this case was hemangiosarcoma. Again, the origin of large masses can be difficult to definitively ascertain because finding an area of organ-to-mass confluence can only sometimes be achieved with ultrasonography. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

(Figure 5.4C). It must also be noted, however, that these changes (both hyperechoic cortices and hyperechoic medullary rim) can be seen in normal cats and occasionally in normal dogs (Figure 5.4C). Therefore, further assessment by an experienced sonographer as well as correlating ultrasonographic findings with the patient's clinical picture is often necessary to determine the significance of these changes as well as the pursuit of more invasive procedures (renal cortical aspirates).

Focal parenchymal conditions such as cysts and masses are easier to detect than diffuse disorders and

are subdivided into mass lesions, renal cysts, and other fluid-filled pathology.

The presence of mass lesions usually results in distortion of the renal contour. Mass lesions may be variable in appearance and should be described by size (measuring the lesion), echogenicity when compared to normal cortical tissue (hyperechoic, isoechoic, or hypoechoic), and character (complex, mixed echogenicity, homogeneous, lobulated) (Figure 5.5). It is not possible to differentiate benign from malignant processes when evaluating kidney

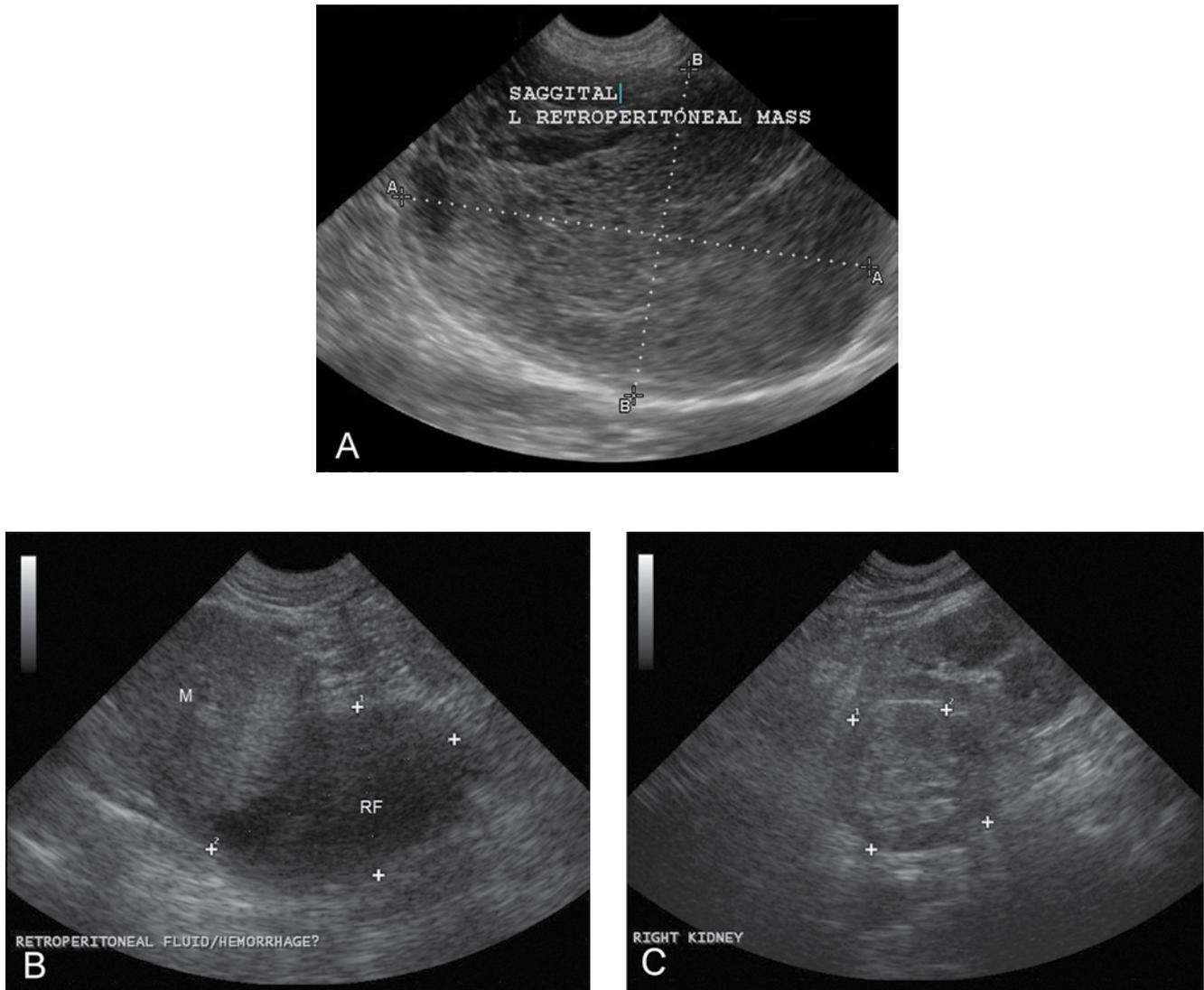


Figure 5.6. Retroperitoneal masses. (A) Large mass in the retroperitoneal space in a dog with anticoagulant (warfarin) rodenticide toxicosis. The diagnosis was retroperitoneal hematoma. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (B) A similar appearing anechoic tubular mass effect (M) off the pole of the kidney with adjacent retroperitoneal anechoic fluid (RF and marked with calipers [+]) that cannot be characterized without fluid sampling. (C) Same dog as in (B) showing that further interrogation suggests a renal mass of the cranial pole. Antemortem fine needle aspiration for cytological evaluation was considered. Post-mortem diagnosis was retroperitoneal hematoma secondary to a bleeding pheochromocytoma of the right adrenal gland eroding the caudal vena cava. Fine needle aspiration potentially could have led to significant complications including uncontrolled hemorrhage. The case stresses the point that a more thorough ultrasonographic interrogation may provide important information in the decision-making process regarding fine needle aspiration vs. exploratory laparotomy. It can be difficult to differentiate benign conditions as in (A) from malignant conditions as in (B and C) based on ultrasonographic appearance alone. (B and C) Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

masses. For example, benign processes such as retroperitoneal hemorrhage and a large blood clot can mimic mass lesions and be misinterpreted for a malignant process (Figure 5.6A through C).

Fungal diseases can also cause mass lesions in the kidney (granulomas). Consideration must be given to referring the patient for additional assessment by an

experienced sonographer who may be able to perform percutaneous biopsies and aspirates.

Renal cysts are easy to identify and may be due to benign processes or associated with functional disease. Characteristics of true cysts generally include the presence of thin walls with anechoic fluid centrally and distal acoustic enhancement. Cysts may be solitary

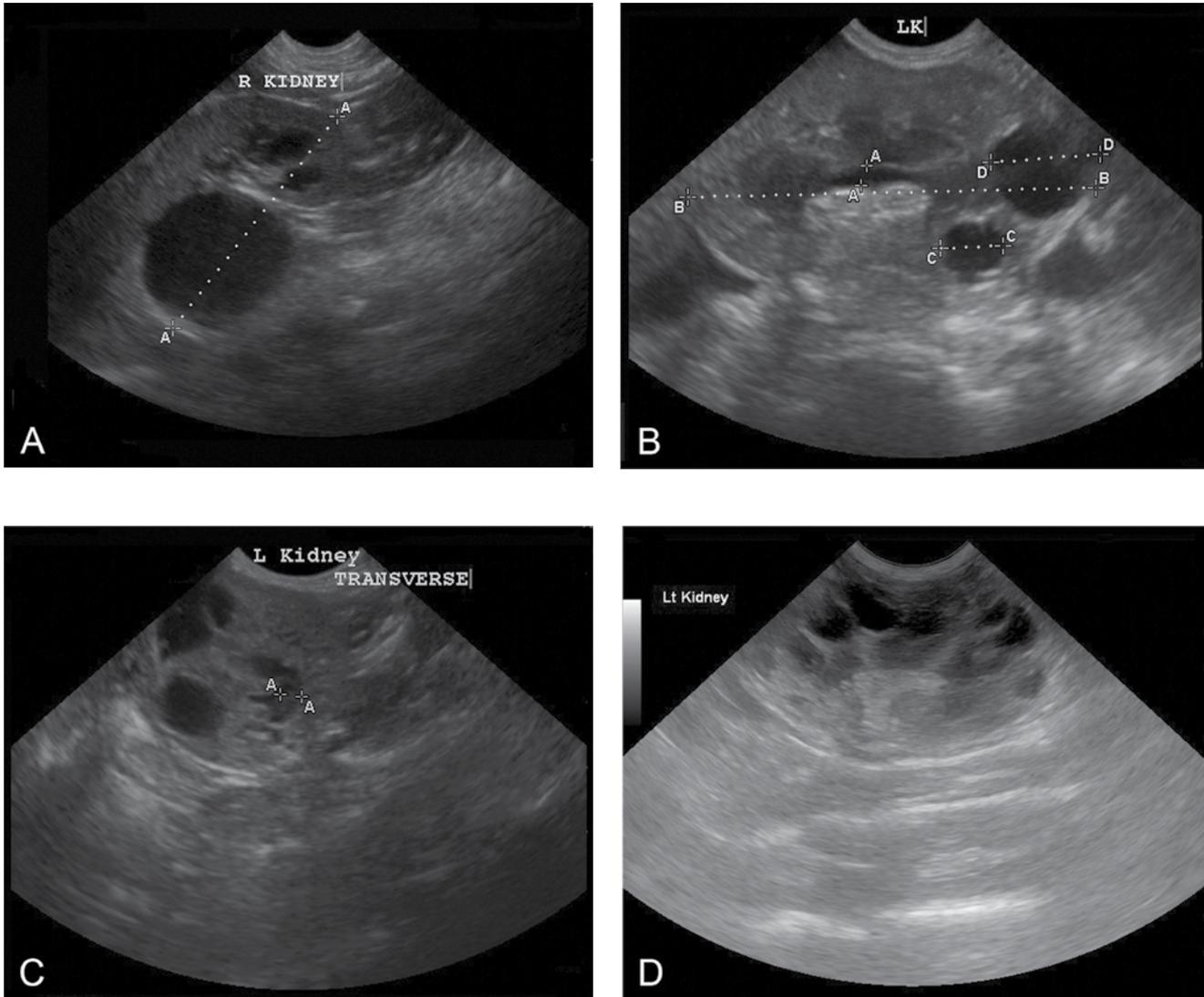


Figure 5.7. Renal cortical cysts. (A) Large renal cortical cyst. Note the thinly encapsulated, large, anechoic (black), circular structure. In real-time, one would note distal acoustic enhancement typical of fluid-filled (vs. solid masses) structures. The kidney's length is measured by calipers (A–A) at 7.10 cm. (B) Other examples of renal cortical cysts. Note the mild renal pelvic dilation (caliper marks A–A, as identified by the sonographer). Also note how the typical cortical cyst(s) (identified by the sonographer and caliper marked C–C and D–D) do not cause distortion of the inner anatomy (medulla) of the kidney. Renal length is shown by caliper marks B–B as denoted by the sonographer. The measurements in centimeters are located along the bottom of the image (not shown). (C) Polycystic renal disease. When compared to previously shown renal cortical cysts, these cysts are greater in number, distort the renal capsule, and typically distort the normal kidney architecture in a destructive manner. Figures (A through C) courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. (D) Feline polycystic kidney disease. Again, note the distortion the normal renal architecture.

or multiple and involve one or both kidneys. Generally, benign cysts are cortical, although they may be seen extending into the medulla. They have smooth margins and are round with anechoic fluid centrally (Penninck 2008). Benign cysts may result in distortion of the renal contour but are not usually associated with significant disturbance of the corticomedullary architecture. They may be relatively large, and therefore,

the significance of the presence of a cyst is not determined by the size, but more by the number (Figure 5.7A and B). In animals with polycystic kidney disease (congenital in Persian cats and Cairn Terriers), the cysts are generally more numerous and result in both distortion of the renal contour as well as distortion of the corticomedullary architecture (Penninck 2008) (Figure 5.7C and D).

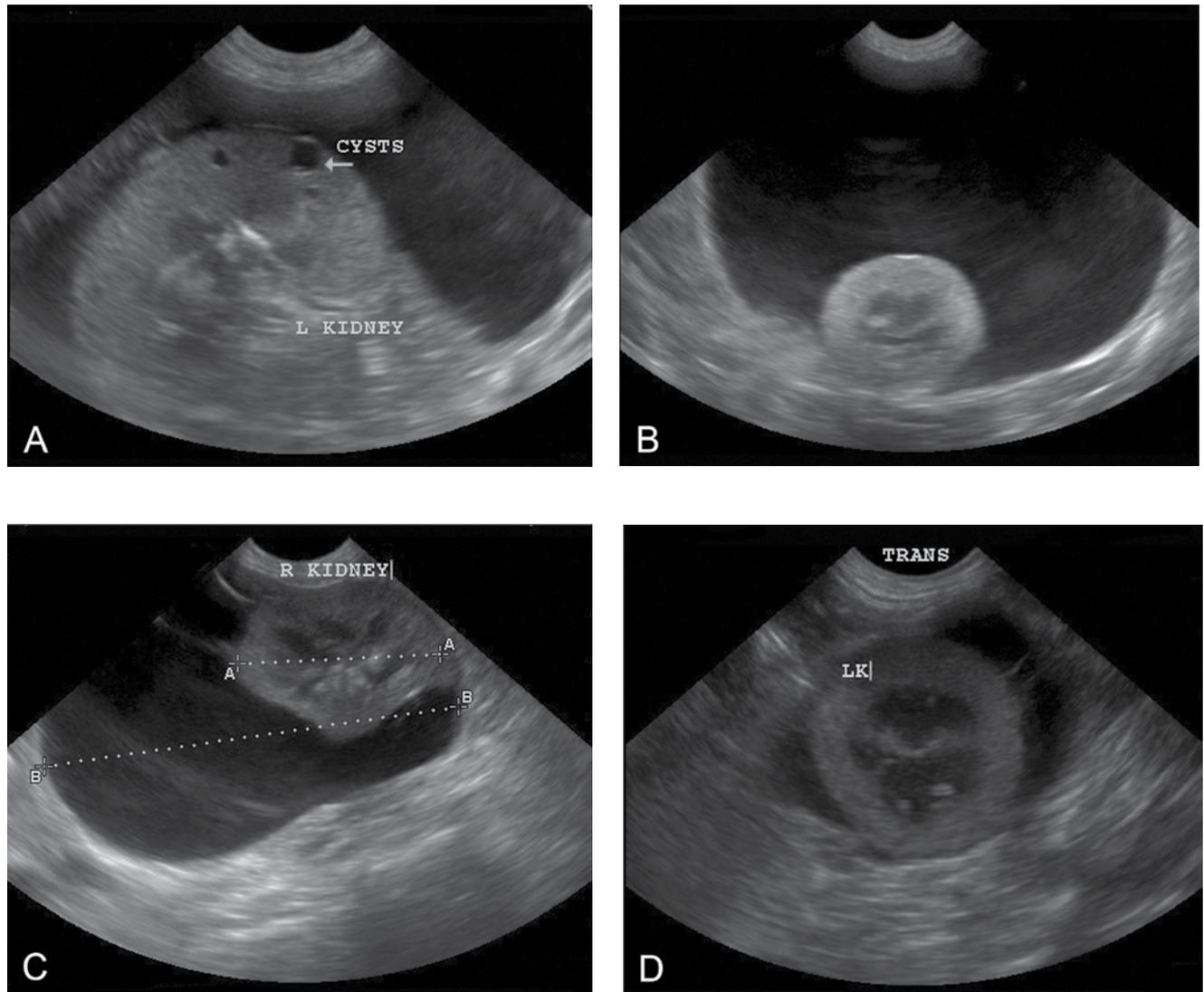


Figure 5.8. Perinephric pseudocysts. (A) Renal cortical cysts with concurrent perinephric pseudocyst. Renal cortical cysts are intraparenchymal, anechoic, and typically do not distort the renal capsule or its normal architecture. The large amount of perirenal fluid contained within the kidney's capsule is more commonly related to perinephric pseudocysts. (B) Another example of a perinephric pseudocyst. Note the lack of renal parenchymal involvement. (C) Example of a perinephric pseudocyst that distorts the renal shape and causes secondary changes in its renal architecture. The calipers (A-A) mark the right kidney in longitudinal view. The calipers (B-B) mark the cranial and caudal borders of the contained perirenal fluid. (D) Perinephric pseudocyst of a left kidney (LK) in transverse orientation (TRANS). Note that in contrast to images (B) and (C), the fluid appears less contained (shows triangulation) and thus is more problematic to define as perirenal vs. retroperitoneal. These types of cysts that may or may not completely surround the kidney have been reported in dogs and cats. Histopathologically, perinephric cysts do not have a true epithelial lining, hence the term pseudocyst. The cause of these cysts is commonly unknown and treatment generally involves intermittent drainage, surgically placed portal systems, or nephrectomy in cases of impaired renal function. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Polycystic kidney disease is most common in the Persian cat and Cairn Terrier.

Perinephric pseudocysts are uncommon but have been reported in dogs and (more frequently) cats. These

structures may or may not completely surround the kidney. Typically, there is an accumulation of anechoic (black) fluid within the renal capsule of one or both kidneys (Figure 5.8A through D). Histopathologically, perinephric pseudocysts do not have a true epithelial lining, hence the term pseudocyst. The cause of these

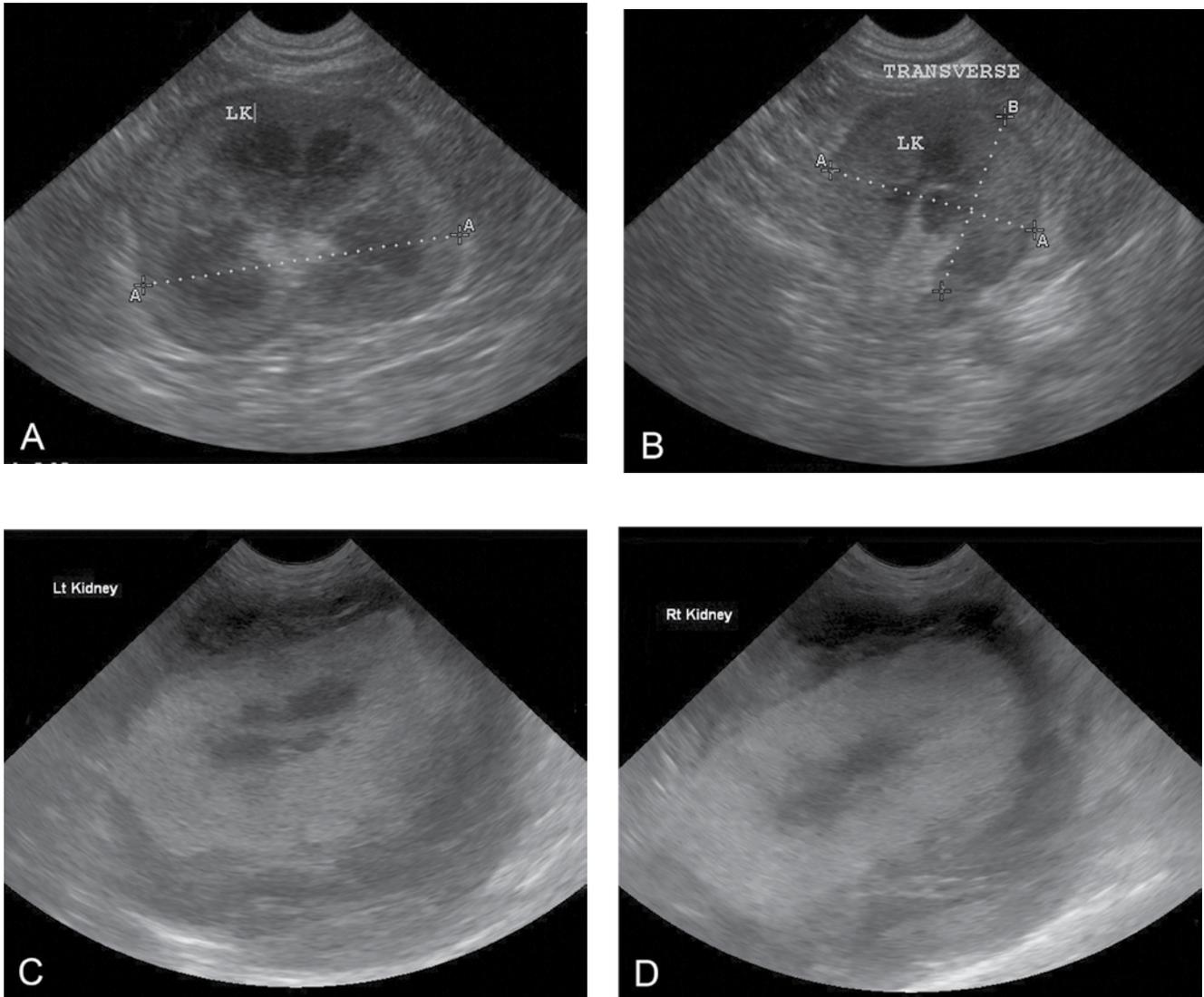


Figure 5.9. Renal lymphoma (LSA) and its variations. (A and B) illustrate homogeneously hyperechoic renal cortices. This is due to the infiltrative nature of LSA. The images show the disease state in (A) longitudinal (marked from cranial to caudal with calipers [A---A]) and (B) transverse (marked with calipers by width [A---A] and height [B---B]) planes. Both kidneys were similarly affected. (A and B) Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California. Images (C and D) show the left and right kidney of a cat with LSA. Note the variation in degrees of hyperechogenicity of renal LSA. Also note the homogeneous hyperechoic infiltration of the cortices, loss of normal renal architecture, indistinct corticomedullary definition, and various degrees of subcapsular/perirenal fluid of images (A through D).

cysts is not completely understood and treatment generally involves intermittent drainage, surgically placed portal systems, or nephrectomy in cases of impaired renal function. It should be noted that perinephric cysts have been reported to have their associated fluid wick into the pleural space, resulting in pleural effusion in cats (Rishiniw 1998) and uncommonly urine extravasation (Geel 1986, Ochoa 1999).

True cysts and perinephric pseudocysts must be differentiated from other pathological processes

such as an abscess, hematoma, or tumor. Generally, these disorders are more likely to be present if the cystic structure has a thick wall, echogenic contents, or the presence of internal septations (Figure 5.8 and 5.9C and D). One type of tumor in particular, renal cystadenocarcinoma, has been reported in German Shepherds, usually with concurrent dermatofibrosis. Classic features of renal cystadenocarcinoma include a fluid-filled cavity (or cavities) with a solid tissue component protruding inside the cyst (Penninck 2008). Aspiration

of fluid or abnormal structures or biopsy may be required to identify and characterize these disorders, and generally should be performed by an experienced sonographer.

Infiltrative conditions such as renal lymphosarcoma or diffuse renal carcinoma result in changes in echogenicity as well as distortion of the normal corticomedullary architecture (enlarged irregular kidneys and loss of symmetry) (Figure 5.9). These disorders are often accompanied by the presence of varying degrees of perinephric fluid (Figure 5.9C and D).

Kidney Stones

Kidney stones may be detected by the focused kidney exam. Kidney stones or renal calculi are usually identified by the presence of strong acoustic shadowing distal to the mineralized area (Figure 5.10A through D). The calculi may be non-obstructive or obstructive and additional assessment of the renal pelvis for the presence of dilation will help determine the significance of the calculus. Calcification, also referred to as dystrophic mineralization, may involve the parenchymal tissue, usually at the corticomedullary junction or the renal pelvis (Figure 5.10E and F). Calcification of the corticomedullary tissue must be differentiated from the normal hyperechoic tissue seen at the corticomedullary junction due to the presence of interlobar/arcuate vessels (see Figures 5.1F and 5.2B and C). These normal structures do not result in acoustic shadows. Calcification at the renal pelvis must be differentiated from the presence of renal pelvic fat.

Kidney stones or renal calculi are usually identified by the presence of strong acoustic shadowing distal to the mineralized area. This helps differentiate mineralization from normal changes seen due interlobar/arcuate vessels at the corticomedullary junction or fat in the renal pelvis. In other words, interlobar/arcuate vessels and renal pelvic fat may be hyperechoic (bright white) but generally do not cast a distal shadow.

Small nephroliths and renal mineralization may be more readily visible by abdominal radiography.

Pyelectasia

Pyelectasia is defined as renal pelvic dilation and should be characterized as unilateral or bilateral and its symmetry as symmetrical or asymmetrical in determining the significance of this finding (Figure 5.11). The normal renal pelvis is collapsed, measuring less than 2mm. However, normal renal pelvic dilation ranges from 1.5–2mm with a maximum height of 2.8mm in cats and 2–3mm with a maximum height of 3.8mm in dogs (D’Anjou 2011). Causes of pyelectasia include pyelonephritis, obstruction of urine flow, intravenous fluid therapy, diuretic usage, a distended urinary bladder, and some congenital disorders (Felkai 1995, Pugh 1994). Definitive diagnosis of pyelonephritis cannot be determined on the basis of ultrasound alone but is more likely when associated with clinical signs (polyuria/polydipsia, active urine sediment). Generally, with pyelonephritis there is mild to moderate dilation of the renal pelvis which is usually unilateral, but may be bilateral with chronic infection. The dilation is usually asymmetrical, and concurrent dilation of the proximal ureter may also be seen. The absence of pyelectasia does not rule out the presence of pyelonephritis, especially in acute disease. A general rule of thumb is to consider the renal pelvis abnormal if it measures 3mm or greater in cats and 4mm or greater in dogs.

In contrast, diuresis (either from intravenous fluid therapy or diuretic therapy) often results in mild symmetrical dilation of the renal pelvis, and therefore this symmetrical form of pyelectasia seen in these patients is generally not a concern.

Mild to moderate symmetrical pyelectasia may be seen in animals on intravenous fluid therapy or receiving diuretics and should not be over-interpreted.

Figure 5.10. Nephroliths and dystrophic mineralization. (A) Patient with obstructive hydronephrosis secondary to ureterolithiasis (not shown). Note the small nephrolith at the level of the renal diverticula (as denoted by the sonographer with the calipers) with subtle distal acoustic shadowing (arrow). Scanning and fanning in real-time imaging makes these hyperechogenicities and their shadowing more readily apparent. (B) Same patient as in (A). Large nephrolith located at the level of the renal pelvis with distal acoustic shadowing (arrow). We emphasize thorough bilateral renal sonographic evaluation to avoid missing pathology. (A and B) Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine. (C and D) Additional examples of nephroliths with more subtle acoustic shadowing. Small nephroliths may be more readily visible by abdominal radiography, and some do not readily produce acoustic shadowing. (E and F) show dystrophic mineralization (linear hyperechoic [bright white] lines) within the renal cortex that does not fit the expected pattern for interlobar/arcuate vessels or the location of renal pelvic fat. Compare to 5.1F and 5.2B through D. (C through F) Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

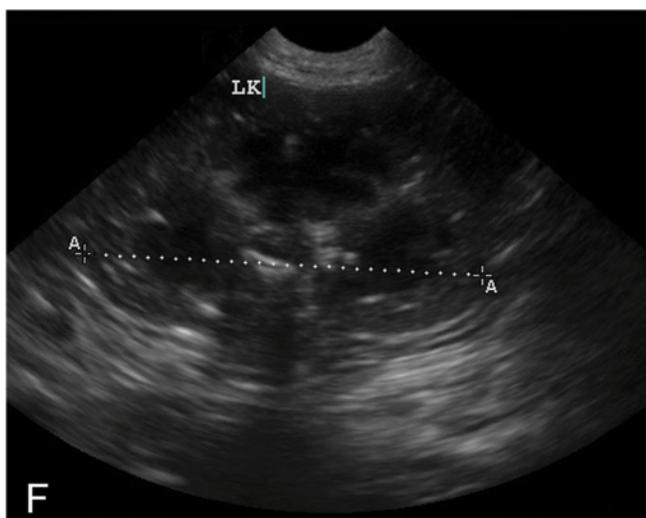
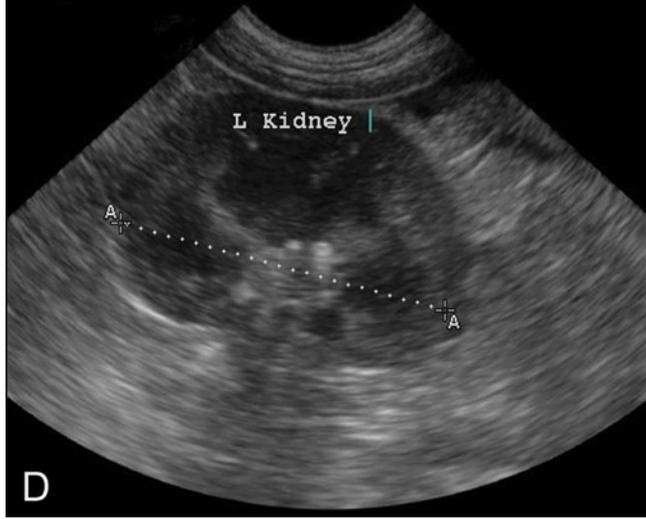
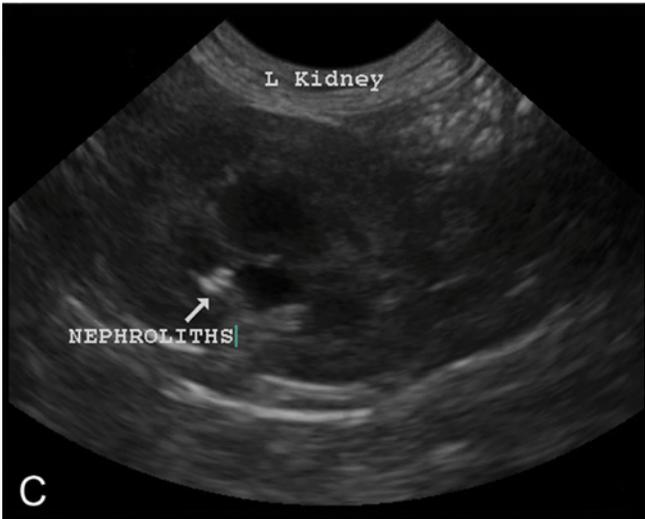
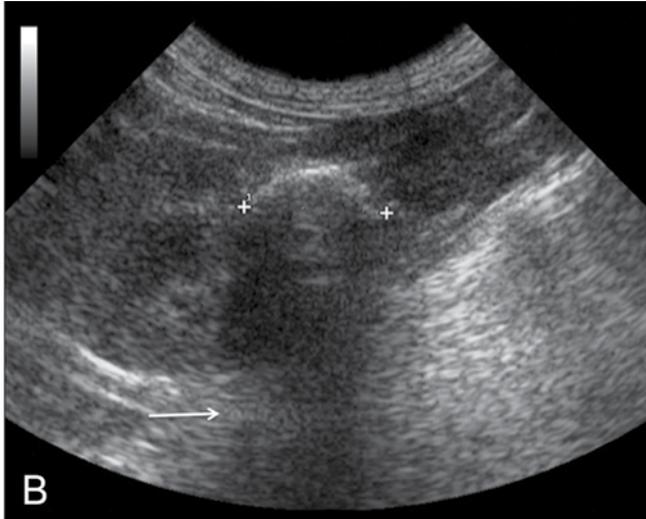
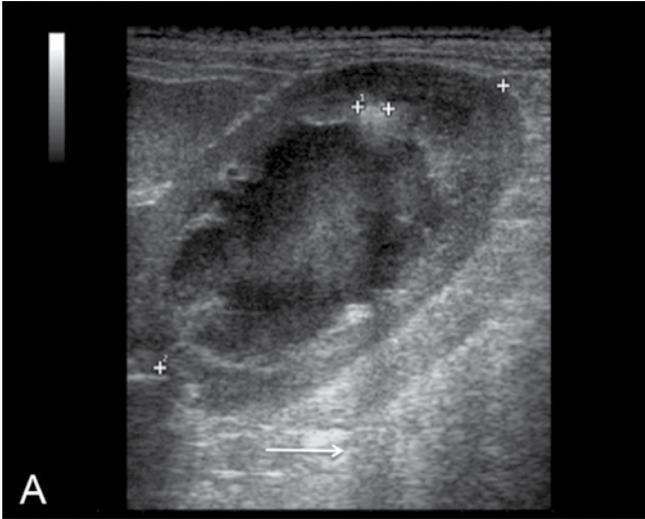


Figure 5.10.

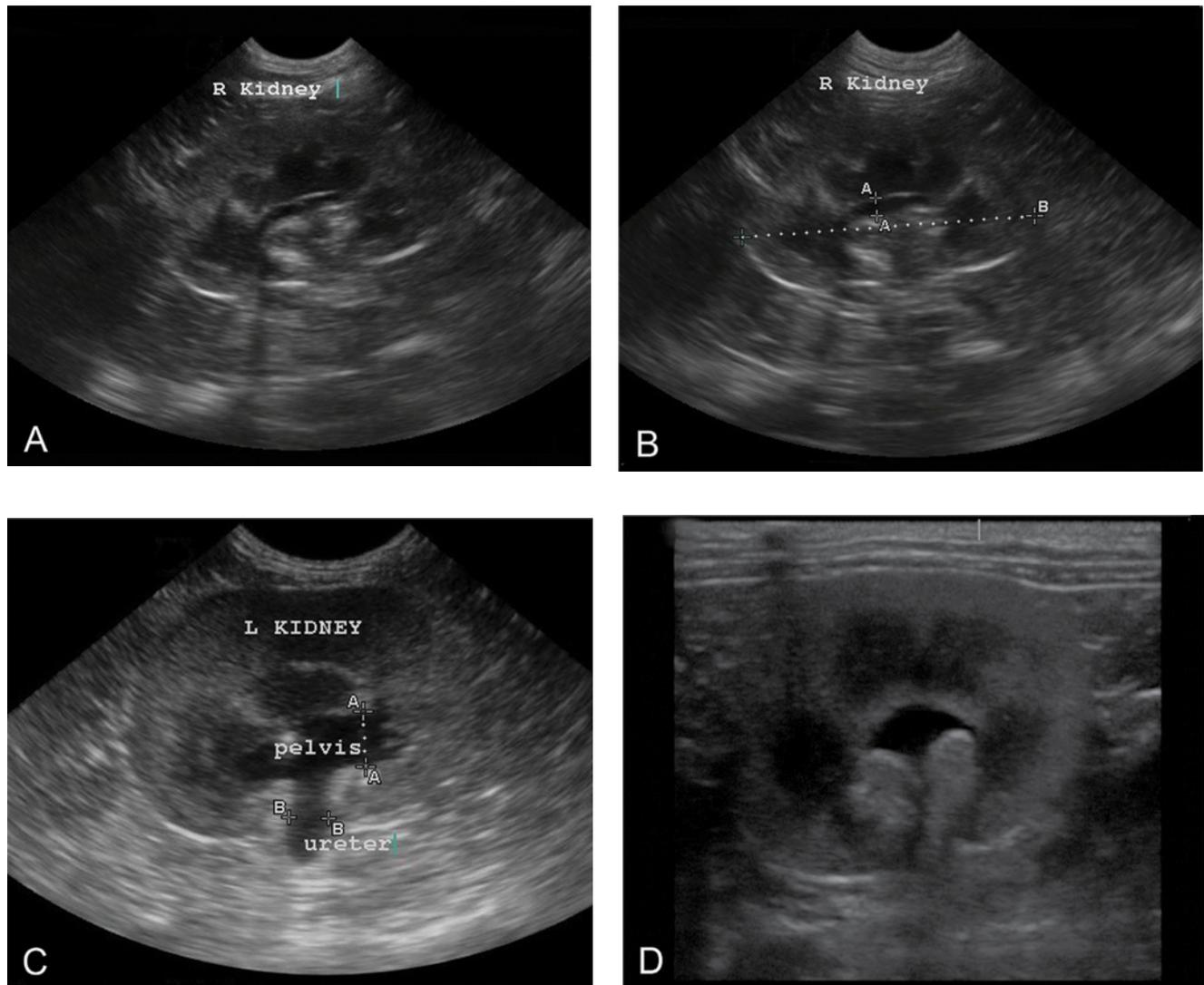


Figure 5.11. Various degrees of pyelectasia. (A) Mild pyelectasia in a right kidney (R Kidney). (B) Same image demonstrating caliper measurement of 0.36 cm of the renal pelvis (labeled A–A by the sonographer) and measurement of renal length, 5.75 cm (labeled B by the sonographer). (C) Severe pyelectasia, 0.67 cm (or mild hydronephrosis) (labeled A–A by the sonographer) with proximal ureteral distension (hydroureter). (D) Moderate to severe pyelectasia with an image from a linear probe (note the rectangular-shaped ultrasound image). Typical rule-outs for mild pyelectasia include normal variant, fluid diuresis, moderate to severely distended (full) normal urinary bladder, pyelonephritis, or diuretic therapy. Partial ureteral obstruction should also be considered, especially in cases of more moderate distension. Total ureteral obstruction is highly suspected in case of severe renal pelvic dilation or hydronephrosis, and should be ruled out with complete abdominal ultrasonography or other forms of imaging. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Pyelonephritis cannot be diagnosed on the basis of ultrasound alone, and ultrasound findings must be interpreted in light of concurrent clinical signs.

Hydronephrosis

Hydronephrosis is defined as dilation of the renal pelvis and renal collecting system and is most commonly seen with obstruction of the ureters or

lower urinary tract (Penninck 2008) (Figure 5.12). Hydronephrosis may also occasionally be seen as a congenital malformation. It is classified by varying degrees depending on severity (Penninck 2008). It is important to recognize whether or not the change is unilateral or bilateral because this greatly affects prognosis. Obstructive processes of the lower urinary tract (calculi, stricture, tumor) result in progressive dilation of the renal pelvis and ureter (hydroureter) with progressive alteration of the renal architecture.

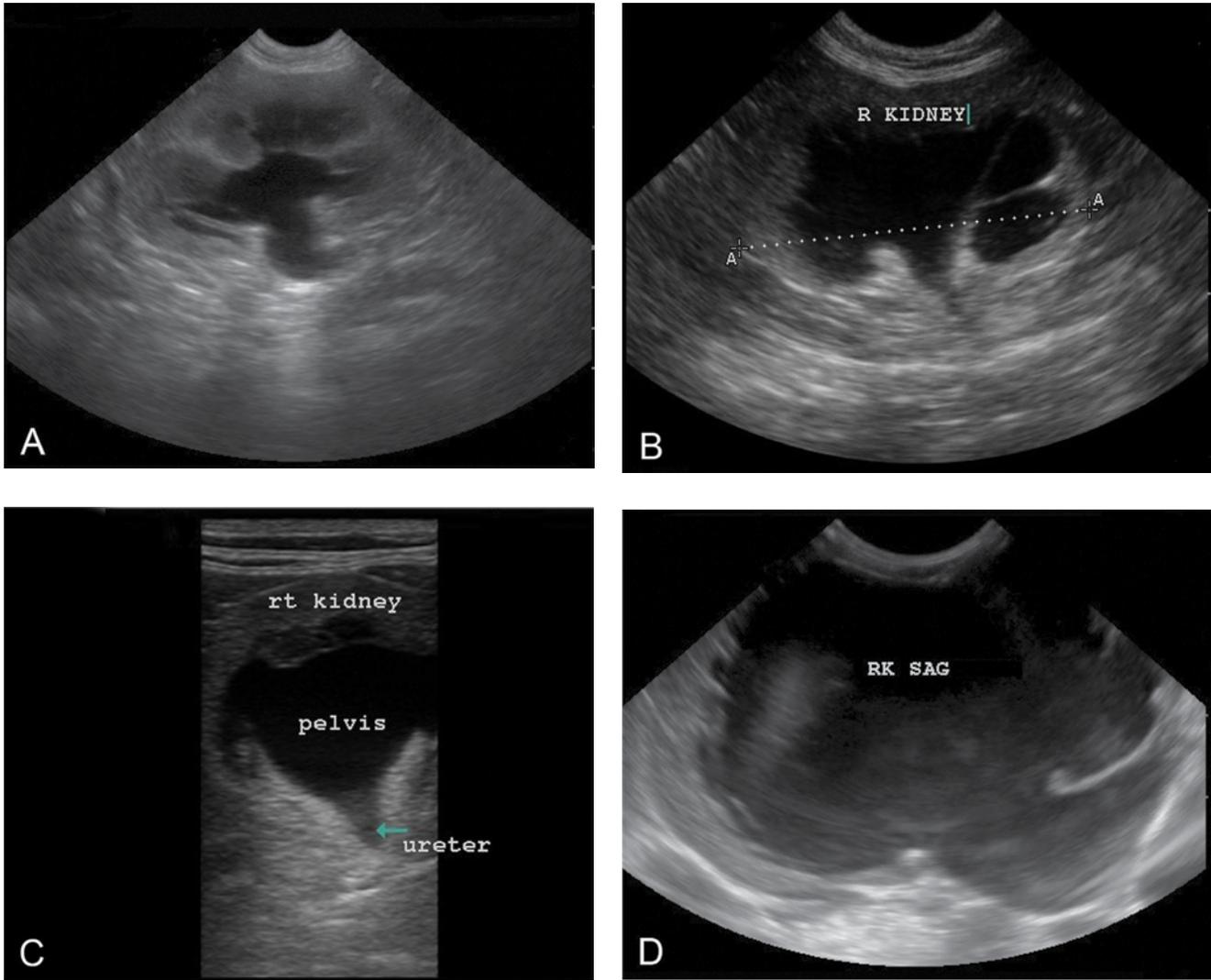


Figure 5.12. Images (A through C) depict mild to moderate hydronephrosis. A loss of normal renal architecture occurs secondary to pressure necrosis. (B and C) are the same kidney in longitudinal and saggital views using curvilinear and linear probes, respectively. (D) Severe hydronephrosis with pressure necrosis and severe loss of renal parenchyma. The difference between pyelectasia and hydronephrosis is the absence (pyelectasia) or presence (hydronephrosis) of a total obstruction to urine flow distal to the renal pelvis. Typical causes of hydronephrosis include utereral stones, obstructive masses in the retroperitoneal space between the kidney and the ureteral stoma, or tumors within the bladder wall and trigone that obstruct ureteral urine flow. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Initial changes include loss of corticomedullary distinction and progressive dilation of the renal diverticuli. There is progressive enlargement of the affected kidney with a gradual decrease in the presence of parenchymal tissue. As the renal diverticuli continue to distend, they become rounded in appearance and may be mistaken for cysts by the inexperienced sonographer. The ureter may also become progressively dilated and can often be followed toward the urinary bladder to the cause of the obstruction (calculi or tumor) (Penninck 2008).

Findings consistent with hydronephrosis should prompt additional assessment with a formal (or complete) ultrasound by an experienced sonographer looking for an obstructive lesion.

Kidney Infarcts

Kidney infarcts (Figure 5.13) generally appear as focal hyperechoic (bright) regions within the cortex. Other causes of focal hyperechoic lesions of the cortex include

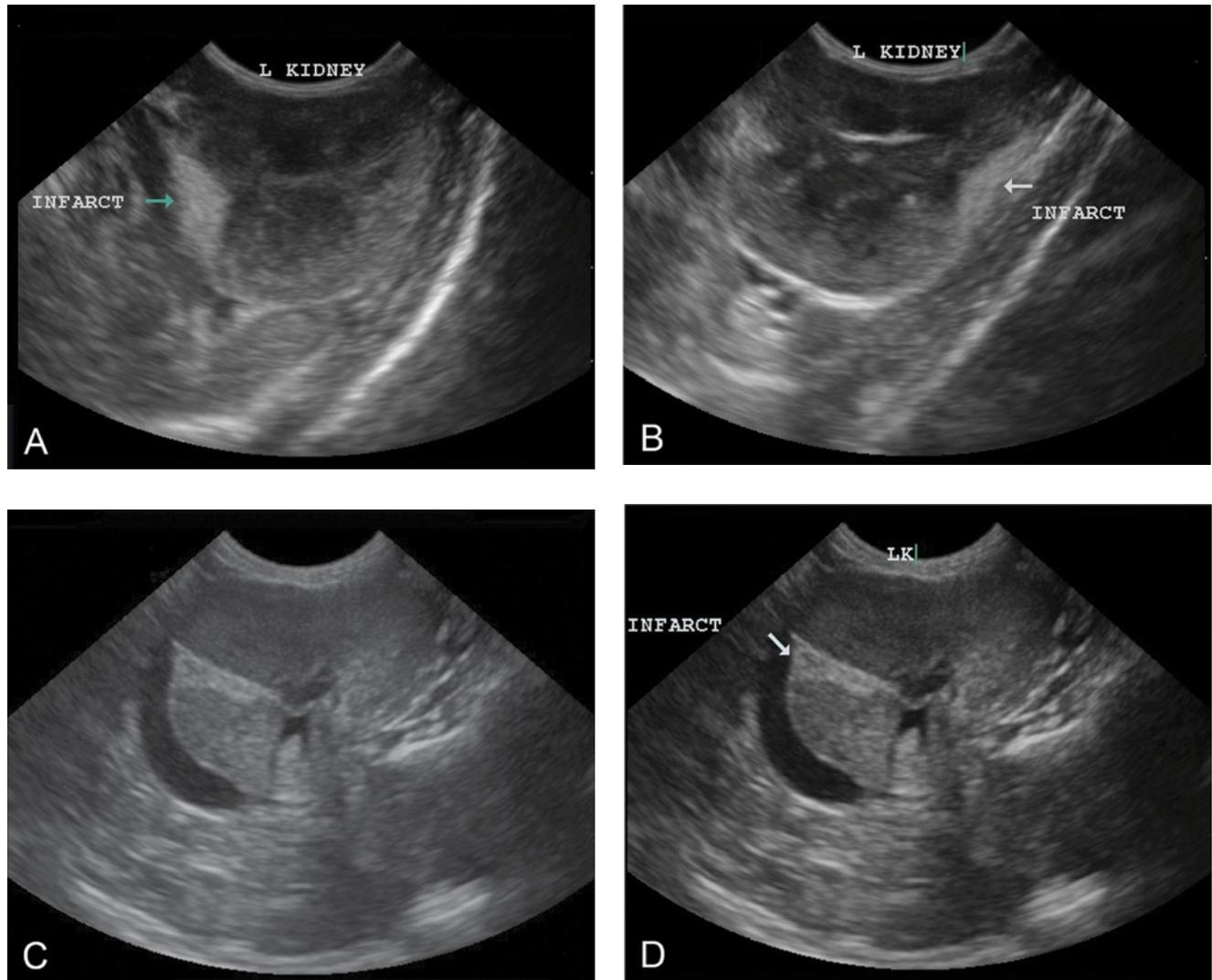


Figure 5.13. (A and B) Small renal infarcts. Infarcts are classically triangular or wedge-shaped and hyperechoic (bright), with their widest margin at the periphery of the renal cortex. There is no acoustic shadowing associated with such hyperechogenicity, thus differentiating infarcts from mineralization. Larger infarcts are shown in images (C and D). These are the same image without and with labeling (LK: left kidney). Note there is a region of anechoic subcapsular fluid located immediately outside of the infarction. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

fibrosis, calcification, papillary necrosis, and neoplasia. In general, infarcts have a wedge-shaped appearance with the widest margin near the cortical margin at the surface of the kidney and narrowing as the lesion extends toward the medulla when acute. When chronic, the infarcted tissue may cause distortion or indentation of the cortex on the surface of the kidney. Infarcts should not produce a distal acoustic shadow as is expected with calcified lesions.

Retroperitoneal and Perirenal Fluid

Retroperitoneal or perirenal fluid is generally easy to recognize but may be challenging to differentiate from each other. Retroperitoneal fluid is unrestricted

throughout the sublumbar region and more likely to have triangulated margins. Retroperitoneal effusion may be difficult to differentiate from peritoneal effusion. In contrast, perirenal fluid is subcapsular and restricted by the renal capsule, thus having rounded margins. In other words, anechoic fluid is seen between the kidney and the renal capsule, generally lacking sharp angles (Figure 5.8A through D). A helpful maneuver is to zoom out by increasing the depth to best appreciate the margins of the fluid and associated structures. Small amounts of perirenal fluid may be seen with infection including feline infectious peritonitis (FIP) and leptospirosis, inflammation, toxicities, and other causes of acute kidney injury (AKI) (Figure 5.14).

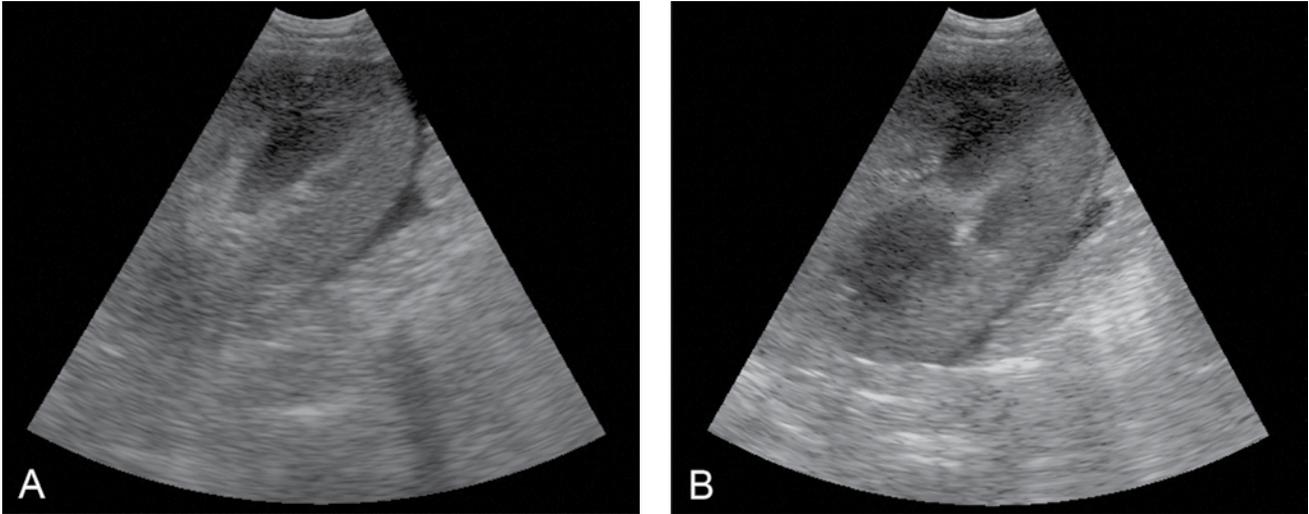


Figure 5.14. Acute kidney injury. Dog with a diagnosis of heat stroke 48 hours earlier. (A and B) show the hyperechoic cortices with a rim of perirenal fluid around each. After 24 hours of intravenous fluid diuresis the kidney values improved and the perirenal fluid resolved when evaluated on serial examination. The thin rim of fluid would not be safely amenable to aspiration: the greatest width is less than 0.5 cm (using the “eyeball method” and the centimeter scale to the right of the image, not shown). Serial renal imaging can provide great value in monitoring the progression or regression of lesions such as was the case in this patient.

Neoplasia such as renal lymphosarcoma may cause variable degrees of perirenal fluid (Figure 5.9C and D). The presence of perirenal fluid must be correlated with the appearance of the kidneys, which may help determine the cause of the change. Larger amounts of retroperitoneal fluid may be seen with causes such as perinephric pseudocysts, urine leakage from a compromised or injured urinary tract, and hemorrhage from coagulopathy or trauma-related retroperitoneal injury (see Figure 2.9). In summary, perirenal fluid may be thought of as fluid contained within the kidney’s restrictive capsule vs. retroperitoneal fluid, which is uncontained within the retroperitoneal space, with triangulating margins. However, in cases with large amounts of perirenal fluid, it may still be difficult to determine if the fluid is retroperitoneal, within the renal capsule or peritoneal. In cases associated with larger accessible amounts of fluid, fine needle aspiration of the fluid for diagnostic and therapeutic purposes may be accomplished with ultrasound guidance.

The Addition of the Focused Urinary Bladder Exam

Because the urinary bladder and kidneys are part of the urinary tract, the addition of the focused urinary bladder exam is generally indicated in many cases to

more completely survey for urinary tract abnormalities and evidence of disease (see Chapter 6).

The Routine Add-on of AFAST³ and its Abdominal Fluid Scoring System

In the author’s experience, it is extremely valuable to perform an AFAST³ exam in right lateral recumbency as part of a complete diagnostic exam. There are several reasons that the addition of AFAST³ improves the diagnostic potential of the ultrasound exam. Positioning small animals in dorsal recumbency for focused abdominal organ exams potentially misses the presence of small volume abdominal effusions and more importantly underestimates the volume of effusion present. As a result, moving the patient to lateral recumbency and performing AFAST³ along with its applied abdominal fluid score (AFS) to all complete abdominal ultrasound exams has become standard protocol by the author and is recommended for each of the focused abdominal organ exams. It is noteworthy that the addition of AFAST³ and the application of the AFS adds little time (less than two minutes) to the focused organ exam and improves diagnostic evaluation.

The early detection of abdominal effusion is clinically important and helps direct additional diagnostic

recommendations and potentially avoids serious morbidity, complications, and patient mortality in the event the effusion is missed. Although no veterinary studies have been performed comparing the detection and volume of abdominal effusions between dorsal recumbency and AFAST³ positioning, the author's experience has shown the comparison to often be remarkably different. AFAST³ is more sensitive for the detection of free fluid, especially if small volumes are present, and allows for better and less subjective assessment of the volume of fluid by also using the AFS score.

Pearls and Pitfalls, the Final Say

- Most patients can be imaged in dorsal recumbency; however, in large and deep-chested dogs, repositioning to lateral recumbency may be required, especially to image the right kidney, which is more difficult to visualize. An intercostal approach may be required in this situation.
- Changes in kidney parenchyma may be identified by comparison to adjacent organs. The renal cortex is generally isoechoic or slightly hypoechoic to normal liver and significantly hypoechoic to normal spleen. The renal cortex, however, may be hyperechoic to liver in cats and some dogs as a normal variation. Remember the pneumonic "SLiCK" (see text above) for the normal order of echogenicity from most (spleen) to least (liver and then kidney) regarding these three organs.
- Subtle changes in echogenicity of the renal parenchyma are subjective. Changes may indicate pathology either in the kidney or the comparative organ (liver, spleen) and the patient's clinical picture must be considered to avoid errors in the interpretation of ultrasound findings.
- In addition to presence of normal anatomy, the size and symmetry between the right and left kidneys should be assessed to evaluate for pathology.
- Generally, a hyperechoic medullary rim ("halo sign" or medullary rim sign) may be seen with several varying pathological conditions such as hypercalcemia, acute toxicities such as ethylene glycol, or infectious diseases such as feline infectious peritonitis (FIP) or leptospirosis. However, it is a non-specific finding and may also be seen in animals with normal renal function. Therefore, the finding must be interpreted in

association with additional clinical findings relative to the patient.

- Mineralization of the kidney results in hyperechoic changes with a strong acoustic shadow. This can be confused with the presence of hyperechoic tissue at the corticomedullary junction due to interlobar/arcuate vessels and the presence of fat around the renal pelvis. Neither of these should cause a distal acoustic shadow.
- Mild symmetrical pyelectasia may occur with intravenous fluid administration or diuretic therapy and should not be confused with or misinterpreted as pyelonephritis.
- The presence of pyelectasia and hydronephrosis should prompt additional evaluation for a cause of partial or total ureteral obstruction, respectively. Further evaluation by an experienced sonographer and/or other ancillary imaging techniques are recommended.

References

- Adams WH, Toal RL, Breider MA. 1991. Ultrasonographic findings in dogs and cats with ethylene glycol intoxication: 15 cases (1984–1988). *J Am Vet Med Assoc* 199:492.
- D'Anjou MA, Bédard A, Dunn ME. 2011. Clinical significance of renal pelvic dilatation on ultrasound in dogs and cats. *Vet Radiol and Ultrasound* 52(1):88–94.
- D'Anjou MA. 2008. Kidneys and Ureters. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D'Anjou. Ames, Iowa: Blackwell Publishing, pp 351–357.
- Felkai C, Voros Fenyes B. 1995. Lesions of the renal pelvis and proximal ureter in various nephro-urological conditions: An ultrasonographic study. *Vet Rad and Ultrasound* 39:397–401.
- Geel JK. 1986. Perinephric extravasation of urine with pseudocyst formation in a cat. *J S Afr Vet Assoc* 57(1):33–34.
- Nickel R, Schummer A, Seiferle E, et al. 1973. Urogenital System. In *The Viscera of Domestic Mammals*, Berlin: Verlin Paul Parcy, pp 291–293.
- Ochoa VB, DiBartola SP, Chew DJ, et al. 1999. Perinephric pseudocysts in the cat: A retrospective study and review of the literature. *J Vet Intern Med* 13:47–55.
- Pugh CR, Schelling CG, Moreau RE, et al. 1994. Iatrogenic renal pyelectasia in the dog. *Vet Radiol and Ultrasound* 35:50–51.
- Walter PA, Feeney DA, Johnston GR, Fletcher TF. 1987. Feline renal ultrasonography: quantitative analyses of imaged anatomy. *Am J Vet Res* 48:596–599.
- Yeager AE, Anderson WI. 1989. Study of association between histologic features and echogenicity of architecturally normal cat kidneys. *Am J Vet Res* 50:860–863.

FOCUSED OR COAST³— URINARY BLADDER

Stephanie Lisciandro

Introduction

Focused assessment of the urinary bladder is relatively easy to learn because, as with the gallbladder, fluid-filled structures are easily imaged with ultrasound. As a result, ultrasound examination is more sensitive than abdominal radiography for detection of abnormalities in the urinary bladder wall and for evaluation for radiolucent calculi and other intraluminal abnormalities. By using the focused urinary bladder exam, patient care may be improved and clinical course optimized by more timely diagnosis or recognition of abnormalities otherwise undetected by more traditional diagnostic means. However, the focused urinary bladder exam is not meant to replace a complete abdominal ultrasound study by a veterinarian with advanced training (the veterinary radiologist or internist), and a combination of ultrasonography and various radiographic studies may be needed to completely image the urinary tract in some cases.

What the Focused Urinary Bladder Exam Can Do

- Recognize abnormalities of the urinary bladder wall such as cystitis, polyps, and tumors
- Recognize abnormalities within the urinary bladder lumen such as stones (calculi), sediment, and blood clots

What the Focused Urinary Bladder Exam Cannot Do

- Cannot differentiate benign vs. malignant urinary bladder wall infiltration or masses
- Cannot diagnose urinary bladder infection (bacterial cystitis)
- Cannot account for misinterpretation of urinary bladder wall abnormalities that may be misinterpreted because of a poorly filled urinary bladder
- Cannot account for urinary bladder luminal abnormalities that may be artifactually created by the air-filled colon or the limitations of ultrasound which may result in the misdiagnosis of luminal abnormalities such as sediment, stones (calculi), or defects in the urinary bladder wall

Indications for the Focused Urinary Bladder Exam

- Hematuria, dysuria, stranguria, signs of urinary tract infection
- History of bladder or kidney stones (calculi)
- Undifferentiated caudal abdominal pain or back pain
- Unexplained retention of urine

Objectives of the Focused Urinary Bladder Exam

- Recognize urinary bladder wall abnormalities such as cystitis, polyps, and tumors
- Recognize urinary bladder luminal abnormalities such as bladder stones (calculi), sediment, and blood clots

Patient Positioning and Probe Selection

Generally, a 7.5- to 10-MHz curvilinear probe is adequate for visualizing the urinary bladder. For best imaging, the urinary bladder should be moderately distended with urine to allow for complete evaluation of the urinary bladder wall. It may be necessary to give a low dose of injectable furosemide or instill sterile saline into the bladder via catheterization to obtain adequate distention of the bladder for the exam.

Refrain from walking dogs and take away the litter box from cats if not otherwise contraindicated prior to their focused urinary bladder exam because a urine-filled bladder is helpful to optimize imaging of its lumen and wall.

The patient is positioned in dorsal recumbency and the area should be clipped, with the application of acoustic coupling gel to the skin to optimize imaging. If calculi or other intraluminal abnormalities are suspected, then it is helpful to be able to move the patient to a standing position. This maneuver is often necessary for discriminating artifact from intraluminal abnormalities such as sediment, blood clots, and bladder stones, (calculi) which unless adhered to the bladder wall, will fall to the gravity dependent side, helping to rule out artifact.

How to Do the Focused Urinary Bladder Exam

The patient is positioned in dorsal recumbency and the caudal abdomen is scanned using a transabdominal approach. The entire urinary bladder should be visualized through both longitudinal and transverse planes. This is especially important when assessing for wall thickening or mass lesions because reverberation artifacts may affect the appearance of the bladder wall and mimic abnormalities in the wall (Figure 6.1A). These artifacts can be minimized by changing probe position and imaging from a ventrolateral position. In addition, the proximal urethra should be assessed for dilation, wall thickness, and intraluminal abnormalities. The purpose of the focused exam is primarily to

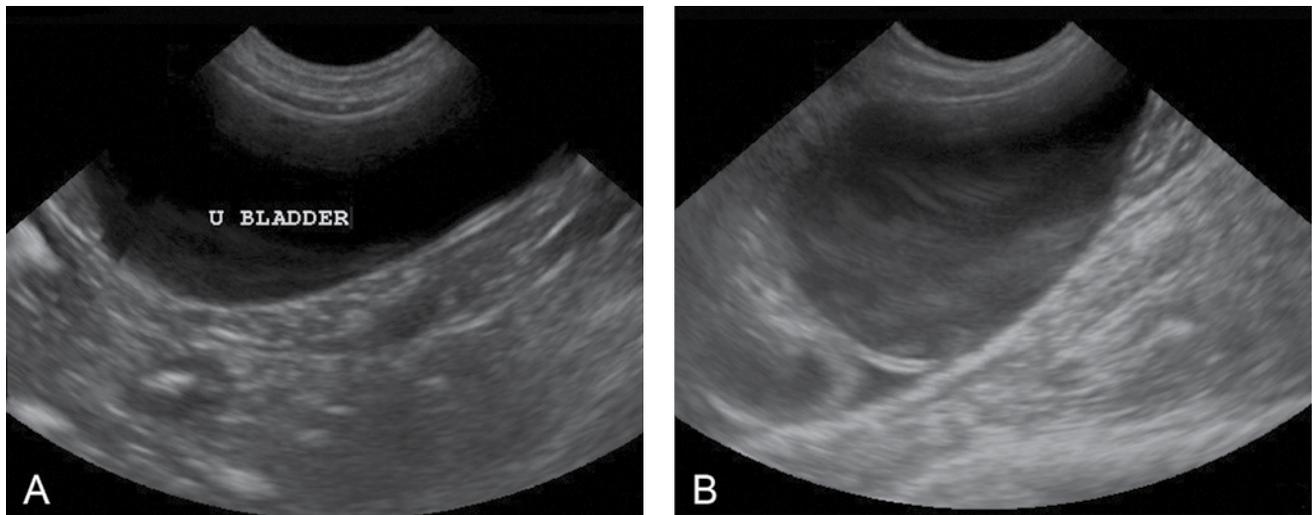


Figure 6.1. Normal urinary bladder wall. (A) A normal urine-filled (pure anechoic [black] urine) urinary bladder with subtle artifact in the far field. Notice how thin the normal urinary bladder wall is when the organ is distended. The normal wall has outer and inner hyperechoic lines with an inner hypoechoic sonolucent line (double line effect) that is most visible on the right third of the wall in the far field. (B) A normal urinary bladder in lateral recumbency with side-lobe artifact mimicking sediment. Note the urinary bladder wall is against (“kissing”) the ventral abdominal wall (bright white line in far field) and a small triangle of free fluid is present between its apex and the ventral body wall. The normal urinary bladder wall (double line) is seen only near the bladder’s apex in this image. A quick way to eliminate the suspected side-lobe artifact is to decrease gain because artifact will generally disappear vs. true sediment, which will not. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

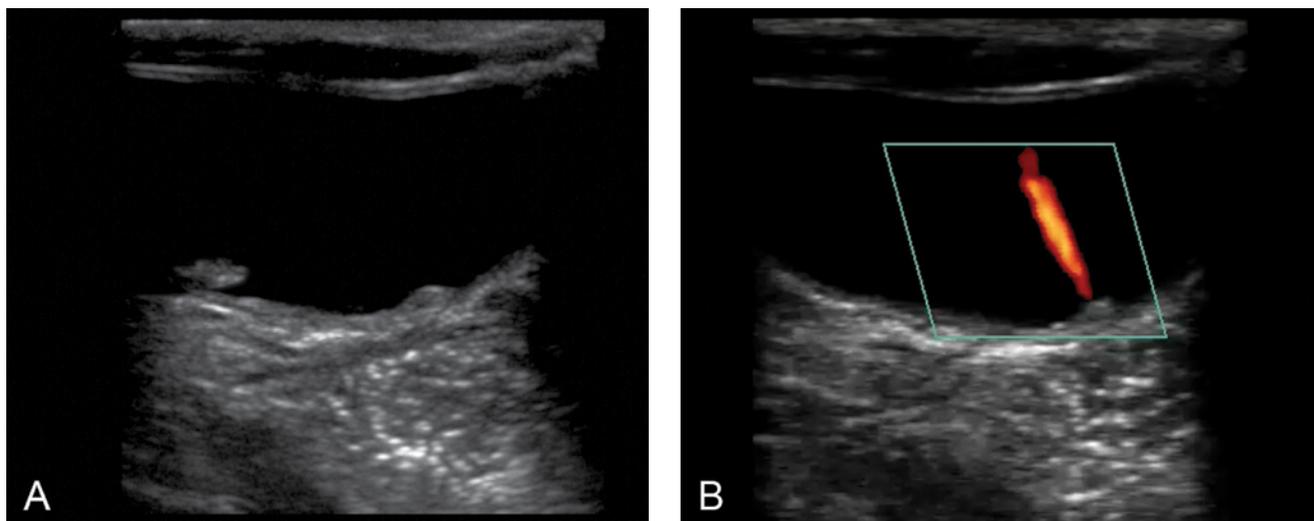


Figure 6.2. Ureteral papilla and urine jetting. (A) A linear probe ultrasound image showing the ureteral papilla. In real-time 2-dimensional B-mode, the urine can be seen swirling or jetting. (B) Swirling or jetting of urine entering the urinary bladder lumen is obvious using color flow Doppler as shown. Note that the near field in both images shows a very nice normal bladder wall (double line). Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

evaluate for obvious abnormalities of the urinary bladder wall (diffuse thickening vs. focal abnormalities) and for intraluminal abnormalities such as calculi (bladder stones), sediment, or blood clots.

Ultrasonographic Findings in a Normal Urinary Bladder

The normal urinary bladder wall consists of four layers: outer serosal layer (hyperechoic), muscularis layer (hypoechoic), submucosa (hyperechoic), and inner mucosal layer (hypoechoic). These layers are usually not well delineated and generally the appearance of the normal bladder wall appears as two thin, mildly hyperechoic layers with a thin hypoechoic center layer (Figure 6.1B).

The thickness of the urinary bladder varies depending on the degree of distention. Normal ranges for wall thickness have been reported in cats to range from 1.3 to 1.7 mm (Finn-Bodner 1995). In dogs, the reported range is from 1.4 mm in moderately distended bladders to 2.3 in minimally distended bladders (Geisse 1997). In addition, wall thickness has been reported in dogs to increase with body size, with heavier dogs having increased thickness by up to 1 mm (Geisse 1997).

Generally, dogs with urine-filled bladders should not exceed 3 mm of bladder wall thickness.

Normal urine is uniformly anechoic (pure black) in nature. The presence of echogenic material in the urinary bladder may be consistent with amorphous debris, crystals, or cellular components (or may be artifactual [side-lobe, edge shadowing]) (Figure 6.1; see Figures 1.5, 1.10).

The presence of echogenic urine is not specific for urinary tract infection or other pathology and a concurrent urinalysis should be obtained to determine the significance of the ultrasonographic finding.

Normal ureters are generally not visualized entering at the trigone; however, occasionally the ureteral papilla is seen as a small irregularity on the dorsal bladder wall (which is in the far field in dorsal recumbency) and should not be confused with a bladder wall mass (Figure 6.2). At times urine may be seen jetting into the urinary bladder from either ureter.

Artifacts Associated with the Focused Urinary Bladder Exam

It is very important to be familiar with artifacts associated with the fluid-filled urinary bladder and the closely associated potentially air-filled colon. Fluid-related artifacts include side-lobe, slice-thickness, edge shadowing, and acoustic enhancement (see Chapter 1 and Figures 1.4, 1.5, 1.6, and 1.10). Air-related artifacts include reverberation

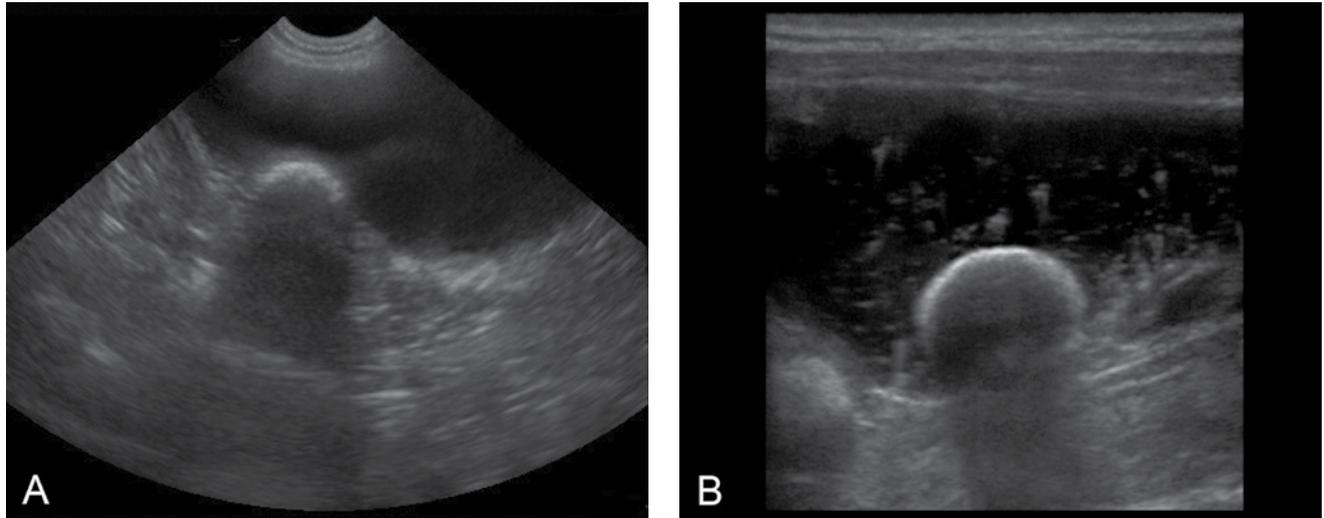


Figure 6.3. Colon shadowing compared to a bladder stone. (A) The air-filled colon can mimic bladder stones by its strong shadowing through the distal field. (B) Comparison to (A), shadowing created by a similarly shaped bladder stone rounded in the near field. Multiple views that are gravity dependent help discriminate colon artifact from true bladder stones. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

and distal shadowing, either of which can cause false abnormalities of the bladder wall and odd-shaped appearances. Both fluid- and air-related artifacts mimic pathology, and combinations of the aforementioned may confound ultrasound interpretations (Figures 6.3A and B and Figures 6.1B, 6.9, and 6.10B).

Clinical Significance and Implications of Abnormal Urinary Bladder Findings

The purpose of the focused exam of the urinary bladder is primarily to detect obvious abnormalities in the wall and/or intraluminal abnormalities.

Abnormalities of the Bladder Wall

The urinary bladder wall should be assessed for diffuse and focal changes.

Diffuse changes in the urinary bladder wall may be consistent with cystitis or infiltrative disease processes.

Cystitis is the most common cause of diffuse changes and may result in diffuse hypoechoic (darker) thickening of the wall, especially at the cranioventral and apical aspects of the bladder. Cystitis may also result in irregularity of the mucosa (Figure 6.4A and C). Polypoid cystitis is a form of cystitis occasionally seen in dogs that results in multiple small pedunculated masses projecting into the lumen (Figure 6.6B through D).

Emphysematous cystitis is an uncommon form of cystitis more often seen in diabetic animals

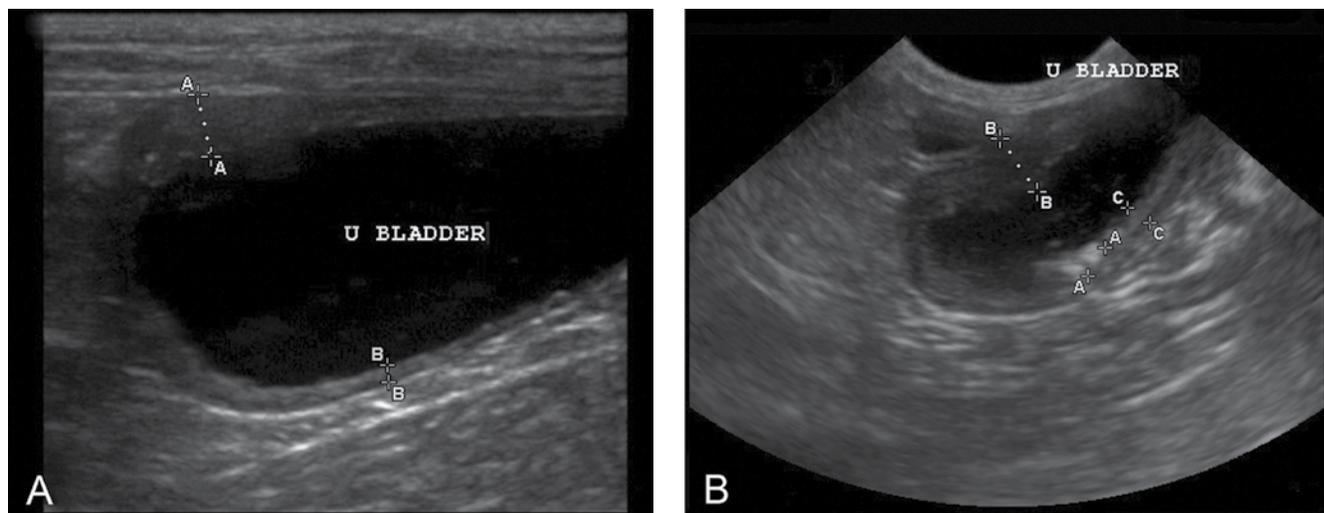


Figure 6.4. (Continued)

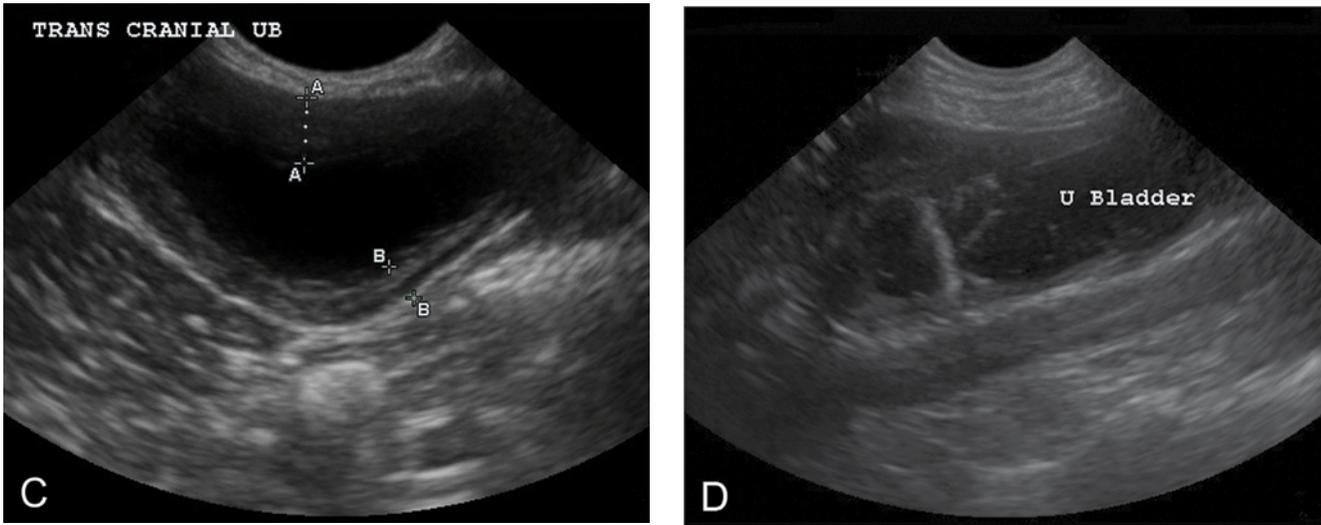


Figure 6.4. Examples of the variability of cystitis. (A) Irregular bladder wall thickening extending out to the apex is typical of bacterial cystitis. (B) Bacterial cystitis with multiple lesions evidenced by a thickened near field bladder wall (B cursor) and a thickened wall with its double line effect (C cursor), with a suspicious bladder stone or mineralized debris or wall (A cursor). (C) Another example similar to (A) of generalized irregular wall thickening. (D) A good example of how a non-distended urinary bladder wall may be difficult to interpret ultrasonographically. The image is further complicated by echogenic debris (in this case blood and clotted blood) within its lumen. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

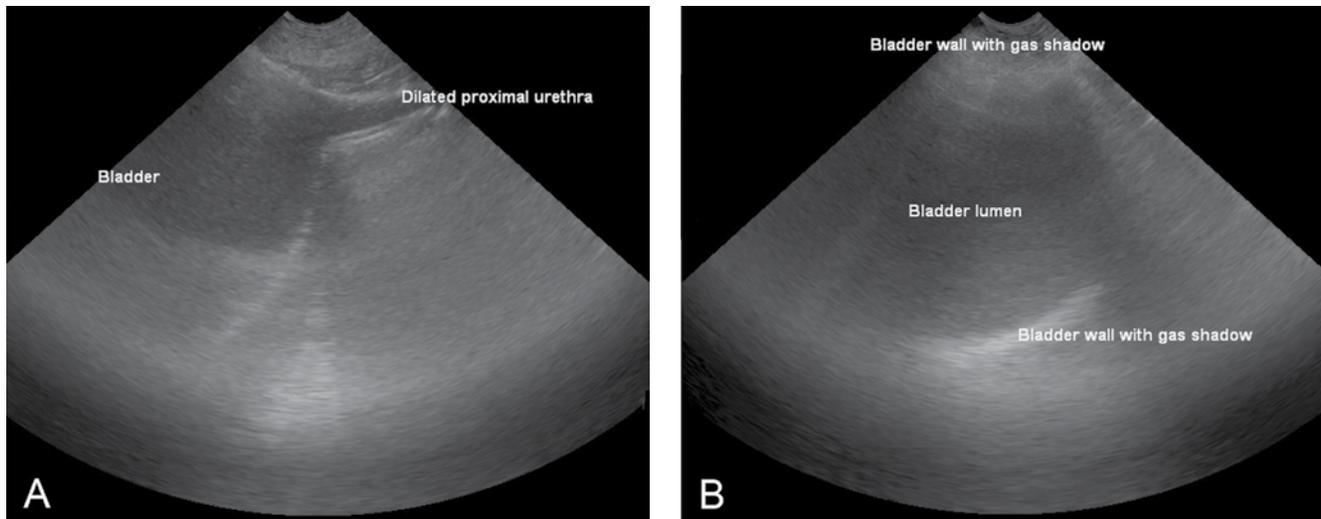


Figure 6.5. Emphysematous cystitis is an uncommon form of bacterial cystitis that is characterized by gas shadowing with an emphysematous bladder wall. The images shown here were from a dog with concurrent pituitary-dependent hyperadrenocorticism and diabetes mellitus. (A) Sagittal view with the urinary bladder lumen extending into the trigone region. (B) A transverse view of the same urinary bladder. In both views the lumen is difficult to clearly view because of the gas shadowing.

secondary to bacterial infection. It results in hyper-echoic (brighter) areas within the wall with gas shadowing artifacts (Figure 6.5). In some cases, the changes may be severe and can be confused with neoplastic changes. The appearance may be confusing for the unsuspecting sonographer because of the degree of shadowing from intramural air which

may obscure the ability to visualize the bladder altogether.

If signs and diffuse ultrasonographic changes are persistent following appropriate therapy for cystitis, then biopsies are generally required for definitive diagnosis.

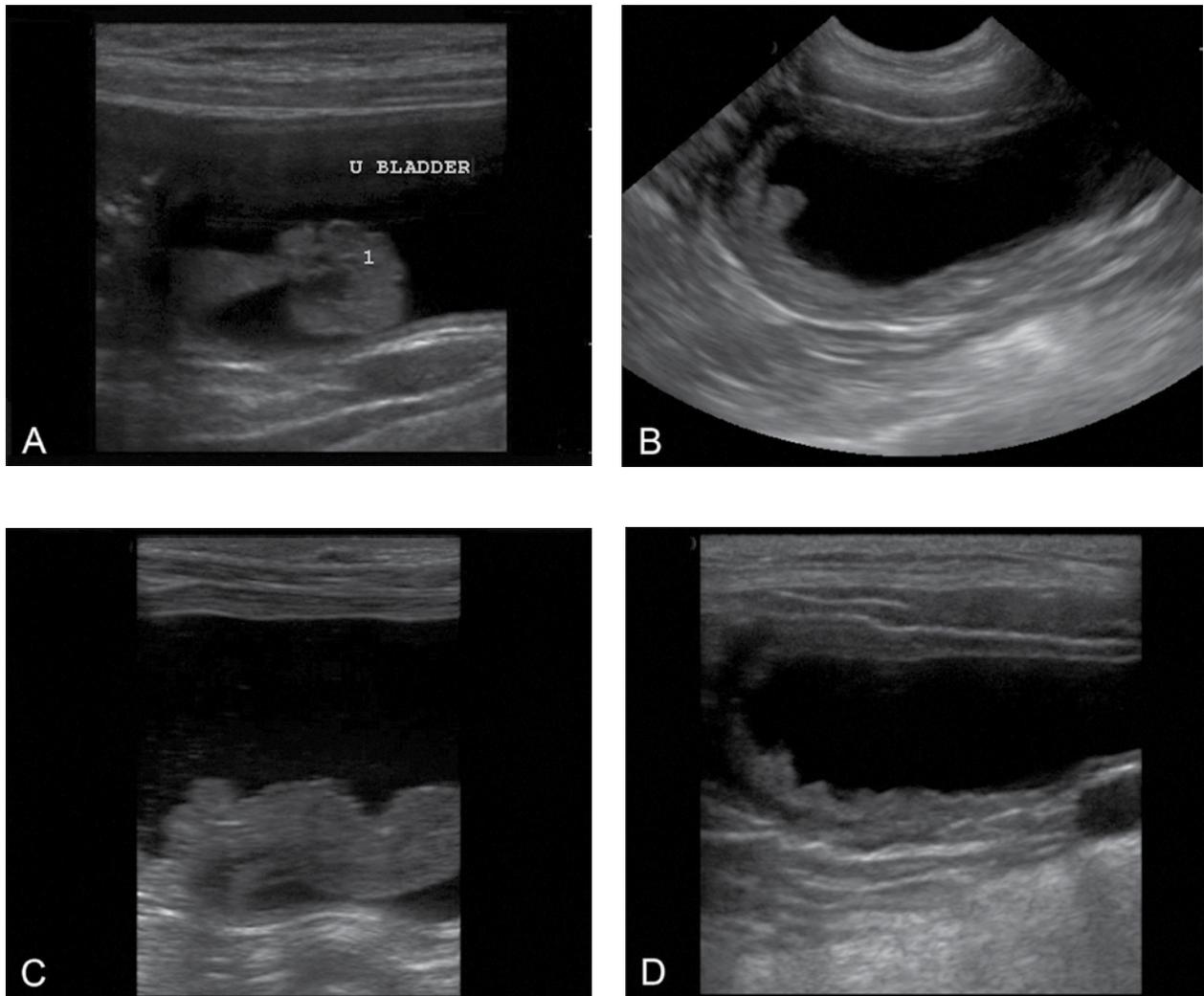


Figure 6.6. Benign polyps. (A) An image using a linear probe of a classic benign polyp appearing with its pedunculated stalk, labeled with the number “1.” (B) A small polyp extending into the bladder lumen near its apex. (C) Another example of a large mass-like polyp as in (A). (D) Diffuse benign polypoid cystitis located along the far wall of the image. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Focal irregularities in the urinary bladder wall are generally easy to detect. These changes most commonly are due to either benign polyps or neoplasia. The presence of ureteral papilla on the dorsal wall of the bladder at the trigone should not be confused with a mass lesion (Figure 6.2A and B).

Benign polyps usually have a pedunculated appearance and are attached to the mucosa by a narrow stalk (Figure 6.6B through D). However, it is not possible to distinguish between benign and malignant bladder tumors on the basis of ultrasonographic appearance alone.

The most common neoplasia in the urinary bladder is transitional cell carcinoma (TCC). The appearance is variable but generally the tumor presents as an irregular wall mass with a wide base (Figure 6.7). Other tumors seen involving the urinary bladder wall may include

squamous cell carcinoma, lymphoma, and a variety of mesenchymal tumors. Blood clots, which may appear with degrees of echogenicity similar to soft tissue (shades of gray), may appear like tumors, so additional clinical findings should always be considered and serial examinations may be helpful (Figure 6.11).

A urinary bladder wall biopsy is generally needed to determine the tumor type to guide therapy and assess prognosis.

In the dog, the most common location of TCC is near the trigone (Leveille 1992) and occasionally the tumor can be seen projecting into the lumen of the urethra (or extending from the urethra into the lumen of the bladder). TCC is more common in females. Obstruction

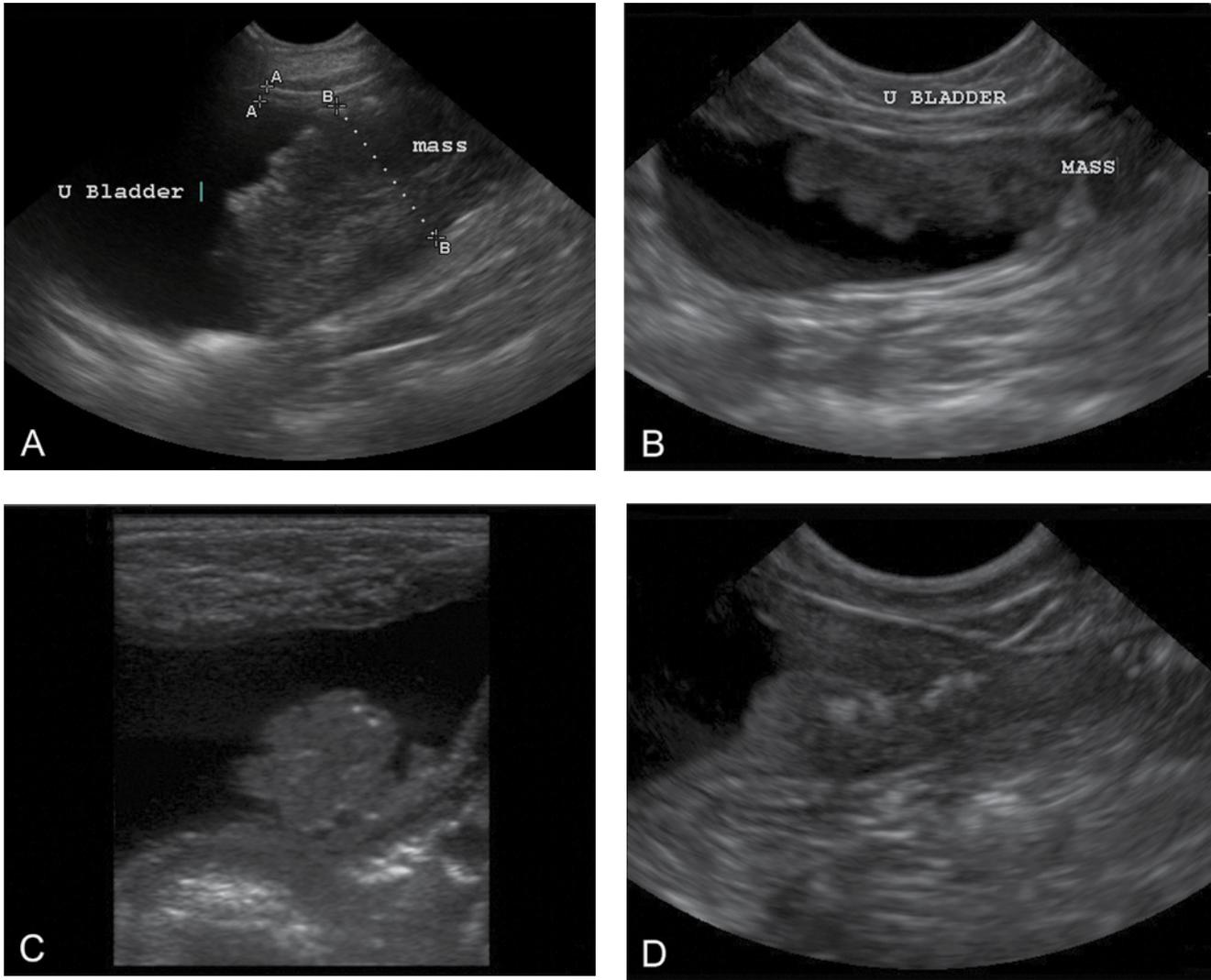


Figure 6.7. Bladder neoplasia. (A) Transitional cell carcinoma (TCC) in a dog's bladder that, in contrast to cystitis, is away from the apex and involves the region extending into the trigone. Caliper markers (A-A) identify the normal urinary bladder wall and markers (B-B) the infiltrative mass. (B) Similar to (A), the mass lesion is away from the apex and is another example of TCC. (C) An example of how TCC may look polypoid-like. (D) A final example of TCC that again is away from the bladder apex. Shown here, it involves much of the trigone region and proximal urethra. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

of the ureters may occur due to the presence of the tumor. Therefore, additional assessment of the ureters and kidney for dilation and hydronephrosis, respectively, is indicated in these patients (see Chapter 5).

In cats, TCC is less common than in dogs and more often seen in older males. In cats, TCC is more commonly located near the apex of the bladder and thus is more amenable to surgical resection.

Intraluminal Abnormalities

Intraluminal abnormalities generally include the presence of cystic calculi, blood clots, and sediment.

A urinary bladder wall biopsy is generally needed to determine the tumor type to guide therapy and assess prognosis. Percutaneous fine needle biopsy may be attempted but is generally not recommended due to the potential of regional spread of the tumor. Ultrasound-guided suction biopsy of the mass may be helpful to obtain tissue for diagnosis. Referral for a complete abdominal ultrasound with biopsies by an experienced sonographer is recommended if biopsies are to be pursued prior to or in lieu of surgical biopsies.

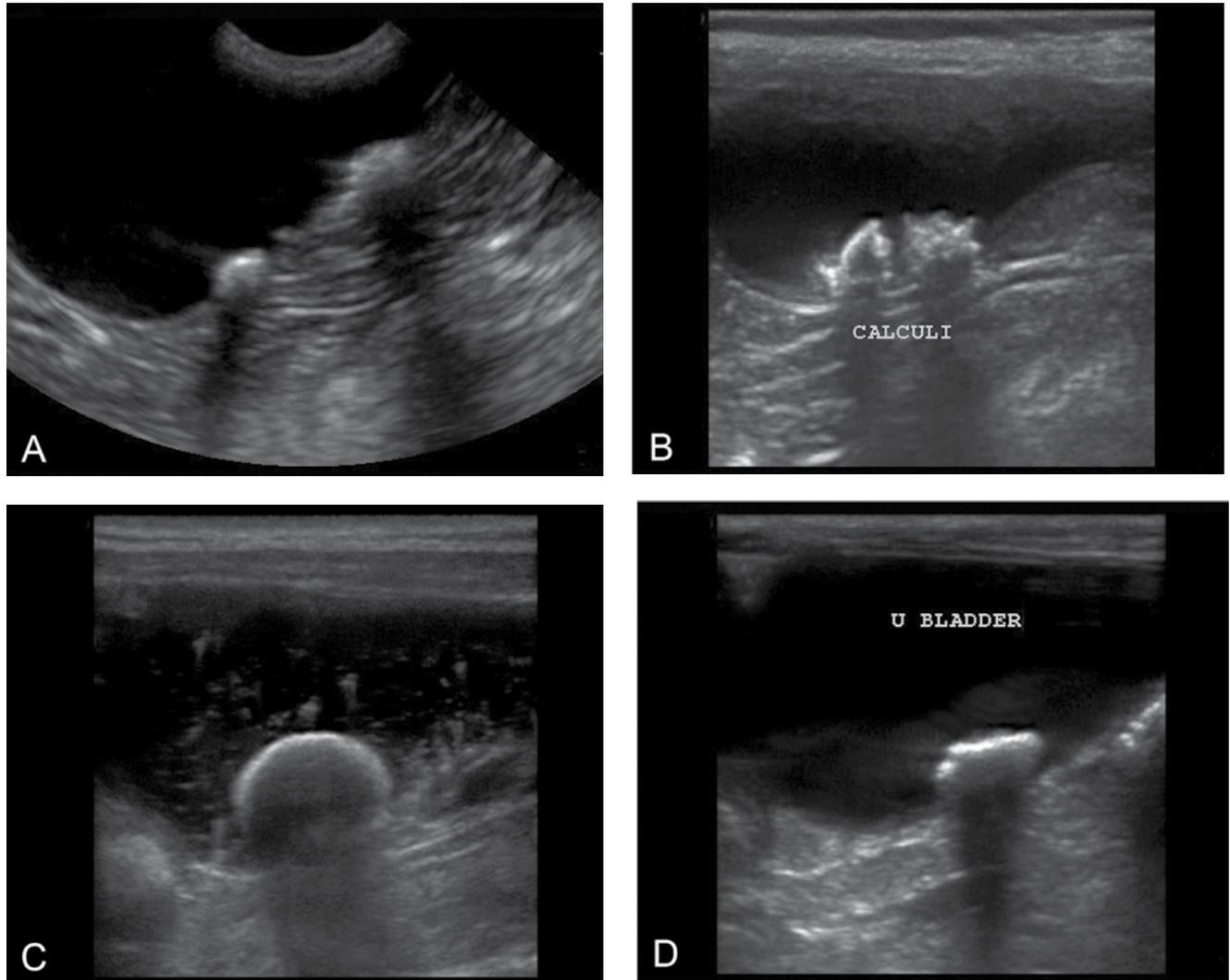


Figure 6.8. Bladder stones also referred to as cystic calculi. (A) Multiple bladder stones with a strong proximal hyperechoic (bright white) acoustic line followed by a strong distal shadow through the far field. (B) Similar to (A) but with the proximal hyperechoic line suggesting a stellate-shaped bladder stone(s). (C) Similar to (B) but with the proximal hyperechoic line suggesting a round bladder stone. (D) Similar to (C) but with the proximal hyperechoic line suggesting a flat bladder stone. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Cystic calculi (bladder stones) generally appear as focal mobile discrete hyperechoic (bright) material within the lumen of the bladder. Calculi are generally round in appearance but may be variable in shape and size, and clumped together. Calculi usually have a distal acoustic shadow but very small calculi (less than 1–2 mm) may not shadow (Figure 6.8). Evaluating size of the calculi may have clinical implications regarding therapy (i.e., Is the calculus likely to pass easily through the urethra [either spontaneously or by voiding hydro-pulsion, see Appendix IV] or is it too large?) Both approximate number and size of calculi should be recorded.

Gas in the colon dorsal to the urinary bladder may present confusion when evaluating for cystic calculi because it results in a hyperechoic (bright) artifact on the dorsal surface of the bladder with a distal shadow due to gas (Figure 6.3A and B). Repositioning the animal into a standing position is very helpful when evaluating for calculi. The calculi should fall to the gravity dependent area of the bladder. This means that the calculi are located on the far side of the bladder (dorsal wall) when the patient is in dorsal recumbency. When the patient is repositioned in standing position, the calculi should fall to the near side of the bladder (ventral wall) when the probe is placed on the ventral abdomen directed dorsally.

Blood clots may form as a result of infection, inflammation, bleeding disorders, neoplasia, or trauma (Figure 6.11; see Figure 2.18B). Blood clots form irregular focal echogenic structures within the lumen. They are generally mobile but may adhere to the bladder mucosa. They may be hyperechoic (brighter) or hypoechoic (darker) relative to the bladder wall and do not have a distal shadow. If the clot is not adhered to the wall, repositioning the animal as noted above for cystic calculi is helpful. However, if the clot is adhered to the wall, it can sometimes be difficult to differentiate from a wall mass.

The patient history should be correlated with ultrasound findings to determine the significance of the presence of blood clots in the bladder lumen (i.e., history of trauma, coagulopathy, bladder tumor, etc.).

Sediment generally appears as gravity dependent hyperechoic (bright) sand-like material in the bladder. Sediment may or may not produce an acoustic shadow depending on its composition. Agitation of the bladder (ballottement) may result in swirling of the sediment (“snow globe” appearance) and repositioning of the animal results in movement of the material to the gravity dependent surface (see repositioning for cystic calculi above). Additionally, lowering the gain (making the image darker) and placing the focus cursor directly across from the area of

interest often eliminates artifact, whereas true sediment persists. A current urinalysis is necessary to further evaluate the significance and composition of sediment seen on ultrasound examination (Figures 6.8B, 6.9, 6.10).



Figure 6.9. Bladder sediment and artifact. Toward the apex the intraluminal echogenicity is due to artifact, in contrast to the area in the middle third to right half of the bladder lumen that is actual sediment. The best way to differentiate artifact from sediment is by changing patient positions to see if sediment drops to gravity dependent areas or through ballottement to get a “snow globe” effect because sediment will swirl within the lumen (artifact will not behave this way). Additionally, lowering the gain (making the image darker) generally eliminates artifact, whereas sediment remains.

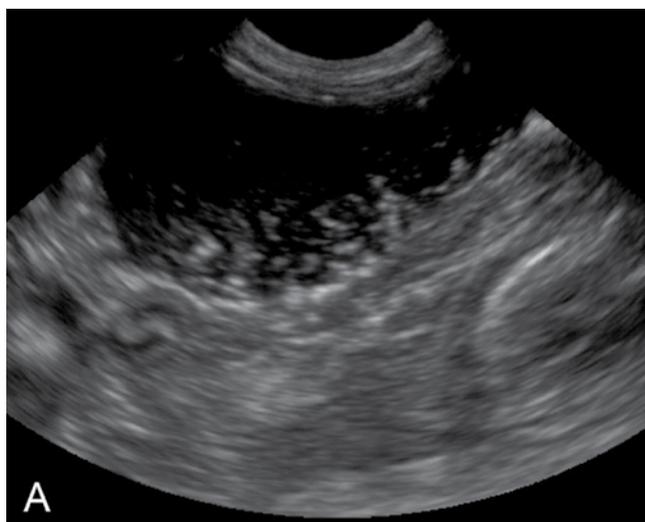


Figure 6.10. Discriminating sediment versus artifact. (A) Sediment is best appreciated in real-time and can be made up of echogenic mineralized material that again drops to the gravity dependent side with changes in patient positioning or appears as a “snow globe” effect with ballottement (artifact does not). (B) An example of mineralized sediment also referred to as sand. Note the distal shadowing extending beyond the hyperechoic (bright white) gravity dependent line of mineralized sediment. The image also shows how nearby structures, especially the colon and small bowel, can impose changes in the expected continuity of the bladder wall. Near the apex, the urinary bladder is pushed inward by adjacent intestinal tract. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

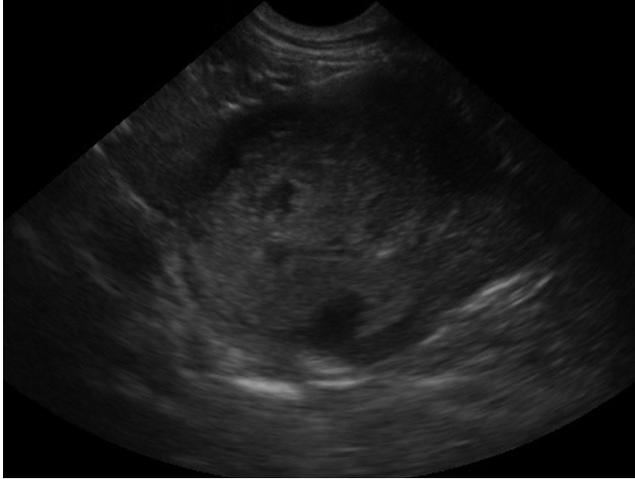


Figure 6.11. Intraluminal blood clots. The image is from a bluntly traumatized dog (hit by car) that has a blood clot filling nearly the entirety of the urinary bladder lumen. The echogenicity is similar to that of bladder wall masses.

It is important to remember that wall abnormalities and intraluminal abnormalities often occur concurrently. For example, animals with cystic calculi often have concurrent findings consistent with cystitis and animals with bladder wall tumors may have blood clots.

The Addition of the Focused Kidney Exam

Because the urinary bladder and kidneys are part of the urinary tract, including the focused kidney exam is likewise indicated in many cases to survey for additional urinary tract conditions (see Chapter 5).

The Routine Add-on of AFAST³ and its Abdominal Fluid Scoring System

In the author's experience, it is extremely valuable to perform an AFAST³ exam in right lateral recumbency as part of a complete diagnostic exam. There are several reasons that the addition of AFAST³ improves the diagnostic potential of the ultrasound exam. Positioning small animals in dorsal recumbency for focused abdominal organ exams potentially misses the presence of small-volume abdominal effusions and more importantly probably underestimates the volume of effusion present. As a result, moving the patient to lateral recumbency and performing AFAST³ along

with its applied abdominal fluid score (AFS) to all complete abdominal ultrasound exams has become standard protocol by the author and is recommended for each of the focused abdominal organ exams. Of note, the addition of AFAST³ and the application of the AFS adds little time (less than two minutes) to the focused organ exam and improves diagnostic evaluation.

The early detection of abdominal effusion is clinically important and helps direct additional diagnostic recommendations and potentially avoids serious morbidity, complications, and patient mortality in the event the effusion is missed. Although no veterinary studies have been performed comparing the detection and volume of abdominal effusions between dorsal recumbency and AFAST³ positioning, the author's experience has shown the comparison to often be remarkably different. AFAST³ is more sensitive for the detection of free fluid, especially if small volumes are present, and allows for better and less subjective assessment of the volume of fluid by also using the AFS score.

Pearls and Pitfalls, the Final Say

- The urinary bladder is generally easy to evaluate for obvious intraluminal abnormalities such as calculi or blood clots, as well as bladder wall changes.
- Moderate distention of the urinary bladder is necessary for optimal assessment of urinary bladder wall thickness and the presence of focal wall abnormalities.
- When evaluating diffuse changes, cystitis generally results in hypochoic thickening, which is more prominent at the cranioventral or apical aspect of the urinary bladder.
- In cases of severe cystitis or polypoid cystitis, it may not be possible to differentiate either from diffuse neoplastic changes. If ultrasonographic changes persist or worsen during medical therapy for cystitis, then biopsies should be pursued.
- Ureteral papilla occasionally may be seen on the dorsal surface of the bladder wall near the trigone and should not be confused with a bladder wall mass.
- The presence of gas in the colon may be mistaken for calculi or sediment, and moving the patient to a standing position will help discriminate artifact from true abnormalities because calculi (stones) and sediment, unless adhered to the bladder wall,

will fall to the gravity dependent location (artifact will not).

- The ultrasonographic interrogation of the urinary bladder is susceptible to artifacts (most commonly side-lobe, edge shadowing artifacts) which may lead to misinterpretation. Therefore, it is imperative to be familiar with these artifacts, and multiple views and/or changing patient position may be required to provide an accurate assessment of the findings.
- Blood clots may be variable in echogenicity and may be difficult to distinguish from bladder wall masses, especially if they are adhered to the wall.
- Additional diagnostic techniques may be needed following the focal urinary bladder exam to further define disorders of the lower urinary tract. This may include referral for a complete abdominal ultrasound by an experienced sonog-

rapher and/or additional radiographic studies which are especially helpful to assess the ureters and urethra.

References

- Finn-Bodner ST. 1995. The urinary bladder. In *Practical Veterinary Ultrasound*, edited by RE Cartee RE. Baltimore: Williams and Wilkins, pp200–235.
- Leveille R, Biller DS, Partington BP, Miyabayashi T. 1992. Sonographic investigation of transitional cell carcinoma of the urinary bladder in small animals. *Vet Radiol and Ultrasound* 33:103–107.
- Geisse AL, Lowry JE, Schaefer DJ, Smith CW. 1997. Sonographic evaluation of the urinary bladder wall thickness in normal dogs. *Vet Radiol and Ultrasound* 38:132–137.

FOCUSED OR COAST³— GASTROINTESTINAL AND PANCREAS

Søren Boysen and Jennifer Gambino

Introduction

Typically, a focused emergency ultrasound scan is not extensive, thorough, or complete. Rather, it provides a focused and limited examination designed to answer a brief and important clinical question in an organ system or address a symptom involving multiple organ systems (Mateer 1994). In the emergency setting, it can provide early diagnostic information that can guide treatment of the critical patient. This is especially true in situations in which positioning the patient for full ultrasonographic evaluation or radiographs might lead to further compromise.

Acute abdomen is a common emergency presentation in both humans and veterinary patients, and may be caused by several common gastrointestinal (GI) conditions, which makes focused emergency ultrasound (US) examination of the GI tract applicable to human and veterinary emergency medicine. Some of the GI-related conditions that have been evaluated with emergency US in humans include intussusception, small bowel obstruction, pyloric stenosis, appendicitis, gastric ulcers, perforated hollow viscus, acute mesenteric ischemia, and acute pancreatitis (Jang 2011, Unluer 2010, Testa 2010, Dean 2002, Rozycki 2001).

Using the AFAST³ examination technique to evaluate for the presence of peritoneal fluid has been validated in dogs (Boysen 2004, Lisciandro 2009). However, a more detailed approach to scanning of the aforementioned GI pathologies requires considerably more expertise and training, which may limit the use of US by some emergency clinicians. It must also be stressed that focused emergency GI ultrasound should not replace or preclude abdominal radiographs or a complete ultra-

sound examination in which an attempt is made to evaluate the entire peritoneal cavity. Furthermore, in humans the correlation obtained between emergency physician focused ultrasound and a gold standard (pathology confirmation) is poor for the above-mentioned GI conditions. This emphasizes the limitations of focused emergency ultrasound exams in the acute GI setting. However, abnormal ultrasonographic findings (a positive result) can be extremely valuable in providing a diagnosis and guiding initial case management. A negative emergency focused GI ultrasound exam is not uncommon and does not necessarily rule out disease (false negative), indicating the need for further testing and/or serial examinations.

It should also be noted that there are no studies comparing the efficiency, accuracy, sensitivity, or specificity of focused emergency GI ultrasound examinations performed in veterinary patients by veterinary emergency clinicians to equivalent exams by seasoned, board-certified radiologists or internal medicine specialists.

The ultrasonographic appearance of intestinal obstruction has been described (Sharma 2011). Complete abdominal ultrasonography is slightly superior in accuracy when compared to three-view abdominal radiography for the determination of small intestinal obstruction. Furthermore, specificity and sensitivity increased when a seasoned radiologist performed the scan in comparison to the novice imaging trainee. Currently, there are no guidelines or recommendations in the veterinary literature for performing focused emergency GI ultrasound examinations. The accuracy, sensitivity, and specificity of such studies have not been evaluated. The authors propose that

focused emergency ultrasonography can be adapted and/or tailored to the critical patient while providing valuable diagnostic information.

Specific focused emergency ultrasound examinations of the GI system depend on patient status, history, physical examination findings, clinical suspicion, and operator experience. The availability of an experienced sonographer or radiologist and the use of other diagnostic tests should be considered in decision making with regard to whether or not a focused emergency ultrasound examination for suspected GI disease is warranted.

In summary, ultrasound should not be considered the last line of defense in cases with acute GI conditions, but rather an initial ancillary test to supplement the history and physical examination findings to direct initial therapy and guide appropriate diagnostic testing, especially when other imaging modalities might be detrimental to the patient's critical status.

What a Focused Gastrointestinal Tract and Pancreas Exam Can Do

- Provide a preliminary evaluation of acute abdomen cases in an effort to answer a specific question when complete abdominal ultrasonography is not available
- Rapidly assess unstable acute abdomen cases in an effort to rule out significant diffuse peritoneal effusion
- Complement radiographic findings in cases of acute abdomen
- Diagnose and support the clinical suspicion of acute abdomen when focused emergency GI and pancreatic exams are positive

What a Focused Gastrointestinal Tract and Pancreas Exam Cannot Do

- Cannot substitute for a complete abdominal ultrasound examination or abdominal radiographs
- Cannot rule out focal or specific causes of acute abdomen, particularly pancreatitis, when results are negative

Indications for the Focused Gastrointestinal Tract and Pancreas Exam

Two key factors to consider when contemplating a focused emergency GI ultrasound examination include the emergency clinician's suspected underlying cause and the urgency of finding an answer to the question asked. The stable patient may get more benefit from a complete abdominal ultrasound exam, whereas the unstable patient presenting as an after hours emergency with acute GI signs is considered the ideal patient to receive a focused emergency GI US exam. The indications for and type of focused emergency GI US examination vary depending on the operator's level of experience and training, presenting complaint, physical examination findings, and suspected underlying condition of the patient.

In veterinary patients presenting with acute abdomen, focused GI US examinations could be performed to evaluate the pancreas or look for presence of peritoneal fluid that might suggest perforated intestines, peritonitis, ascites, or neoplastic effusion (AFAST³ exam). The stomach and small and large bowel are scanned to look for evidence of GI perforation, shadowing GI foreign bodies, bowel intussusception, intestinal obstruction, or ileus. Examples of scenarios in which an emergency clinician has a specific question that could potentially be answered by focused emergency GI US might include the following:

- In a patient that presents with an acute abdomen, vomiting, and unexplained hypotension, it is reasonable to ask if the patient has peritoneal effusion that may be indicative of GI perforation and septic peritonitis. In these patients an emergent AFAST³ examination may be performed to evaluate for effusion and aid in US-guided abdominocentesis to look for evidence of sepsis.
- In the same patient that presents with acute abdominal pain and vomiting but is negative for peritoneal effusion, the emergency clinician may ask if the patient has localized or indirect evidence of gastrointestinal perforation or if an intestinal foreign body is present. The clinician can then perform a focused emergency GI US exam of the intestines. This may directly uncover an ultrasonographically detectable foreign body or lead to suspicion of intestinal obstruction. Indirect evidence of obstruction, such as a severely dilated jejunum with luminal dilation measuring greater than 1.5 cm, may highlight the need for a more extensive and

complete ultrasonographic evaluation, abdominal radiographs, or exploratory surgery (Sharma 2011). The history, physical examination, and other ancillary tests should be correlated to and supportive of the findings.

- If the emergency clinician is experienced with regard to ultrasonographic evaluation of the pancreas and the patient is hypotensive with a history supportive of pancreatitis (such as exposure to high-fat meal followed by vomiting, diarrhea, and abdominal pain), then a focused emergency US scan of the pancreas can be performed to look for supporting evidence of pancreatitis. If ultrasonographic evidence supports the diagnosis of acute pancreatitis, the emergency clinician can start supportive therapy while considering further diagnostic and therapeutic options.
- In patients that have undergone GI surgery and are deteriorating, the clinician may ask if dehiscence, septic peritonitis, or post-operative ileus are present, and may elect to perform an AFAST³ examination to aid in US-guided abdominocentesis if peritoneal effusion is present.
- In the post-operative patient that fails to eat or seems uncomfortable, it is reasonable to ask if the patient has ileus and perform a focused emergency GI US exam with the specific intent of assessing GI motility. Although peri-operative gas may obscure ultrasonographic peritoneal evaluation, if post-operative ileus is present, the clinician should search for and try to correct the underlying cause in addition to considering specific therapies directed at addressing ileus.

These are only a few examples of specific focused GI US examinations designed to answer specific questions. There are many other situations that may arise depending on the experience of the operator, the presenting complaint, and physical examination findings.

Objectives of the Focused Gastrointestinal Tract and Pancreas Exam

- Identify the location, size, and shape of normal and abnormal peritoneal structures.
- Better identify the existence of pathology warranting specific treatment, especially emergent treatment, thus optimizing early diagnosis and outcomes of peritoneal disease, particularly in the unstable patient.

Patient Positioning and Probe Selection

Peritoneal Effusion

See Chapter 2 for information on patient positioning to look for the presence of peritoneal effusion.

Gastrointestinal Evaluation

Depending on the comfort of the patient and preference of the sonographer, the focused emergency ultrasound exam of the intestines may be performed in dorsal or left or right lateral recumbency. Left lateral recumbency helps with visualization of the pylorus and duodenum, whereas right lateral recumbency helps with visualization of the fundus (Penninck 2008).

Repositioning the patient may redistribute gas and fluid within sections of the intestines, allowing better evaluation of suspected areas. It has been recommended that US probes with a frequency of at least 7.5 MHz be used when evaluating the bowel (Garcia 2011, Penninck 2008).

Pancreas

Pancreatic scanning is most frequently performed in dorsal recumbency, although left and right lateral recumbency can also be used (Penninck 2008, Nyland 2002). For pancreatic evaluation, a 5- to 7.5-MHz or higher transducer is preferred because higher frequencies improve visualization of the pancreas (Nyland 2002).

Avoid examining the pancreatic area under high output or gain settings because the increased reflectivity of the pancreatic region prevents visualization of abnormalities and leads to false negative results (Hecht 2007, Nyland 2002).

Scanning Technique

Peritoneal Effusion

See Chapter 2 for information on patient positioning to look for the presence of free abdominal fluid.

Intestinal Tract

GI lesions may be difficult to identify using ultrasonography because it is difficult to consistently evaluate the entire intestinal tract. Many factors, including normal or abnormal gas accumulation in the GI tract

and operator skill, influence the success of identifying GI lesions. Therefore, it is important that the technique used be consistent and systematic to minimize the chances of false negative results.

One common technique involves starting in the region of the pylorus/stomach on the right side of the patient just caudal to the ribs and fanning the probe from the right to the left of the patient, paying specific attention to the stomach (located caudal to the xyphoid and liver) on the first pass.

Slide the probe 1–2 cm caudally when the probe is fanned to the far left side of the patient, then fan the probe back across the abdomen from the left to the right side of the patient, paying specific attention to bowel loops. Repeated fanning of the probe across the abdomen in a zig-zag pattern moving caudally aids in evaluation. The intestines are orientated in many directions.

This technique results in evaluation of many sections of small intestine being viewed in the sagittal, transverse, and various oblique planes, depending on the transducer-to-intestinal tract orientation.

Once completed, if no irregularities are found, the pylorus and descending duodenum can be evaluated in more detail by returning the probe to the right side of the patient, just caudal to the rib cage (or sometimes between the last ribs) and first locating the body of the stomach and tracing it back to the pylorus, then the descending duodenum. This is a good time to get a general and subjective impression of overall gastric and small bowel motility (see the section on ileus, below).

If a specific area of pain, mass, or foreign object is palpated on the initial physical examination, specific attention should be paid to this area, making sure both longitudinal and transverse sections of the intestines are evaluated. If abnormal findings are present, longitudinal and transverse ultrasonographic evaluation of the intestine should be performed.

Abnormal findings in close proximity to the area of suspicion might include intestinal wall structure layering abnormalities, abnormal intestinal peristalsis, focal loculations of peritoneal fluid, segmental focal dilations of small bowel, plicated bowel, target lesions or hyperattenuating/hyperechoic fat, or mesentery. Suspicious areas of intestine should be followed both orad and aborad to allow a more detailed assessment of these areas.

If structures within the GI lumen are visible, they should be carefully examined for a hyperechoic reflective interface and the presence of acoustic shadowing.

Pancreas

Several scanning techniques can be used to identify the pancreas, but a preferred technique for focused emergency evaluation has not been identified. One of the more commonly used techniques in dogs involves an initial search for the right lobe of the pancreas, because the right lobe is more easily seen than the body or left lobe and is frequently affected by acute pancreatitis (Penninck 2008, Hecht 2007, Nyland 2002).

The US probe is placed over the right kidney in transverse orientation. After identifying the right kidney the probe is slowly fanned laterally and medially until the descending duodenum is identified in transverse orientation as a target-like structure. The probe is then oriented in the sagittal plane, demonstrating that the duodenum continues in a long, straight course along the right abdominal wall. The pancreas is found dorsomedial to the duodenum, directly ventral to the right kidney, as a triangular structure that is isoechoic or slightly hypoechoic to surrounding mesenteric fat (Hecht 2007). The pancreaticoduodenal vessels and pancreatic duct may be visible as a round anechoic structure within the pancreas (see Figures 7.1 and 7.2 for comparison).

Color flow Doppler evaluation, if available, provides differentiation between the structures (Figure 7.2A and B). Visualization of the portal vein may also provide a useful landmark, because it lies left and dorsal to the pancreas. It is best visualized from a right dorsal intercostal approach (Brinkman-Ferguson 2009).

In very large or deep-chested dogs it may be easier to visualize the right limb of the pancreas through the 10th to 12th right intercostal spaces with the dog in left lateral recumbency (Hecht 2007). If the right lobe of the pancreas can be located, it may then be traced to the body and left lobe. The pancreatic body is located between the right and left lobes of the pancreas, in close proximity to the portal vein and dorsocaudal to the pylorus.

The left lobe of the pancreas is located between the stomach and transverse colon and medial to the splenic head. It is often difficult to identify these parts of the pancreas especially in normal dogs, (Hecht 2007).

It should be noted that gas within the GI tract often hampers evaluation of the pancreas. Also, excessive probe pressure may displace the duodenum, affecting its normal anatomic orientation to the right kidney. Remember that the normal pancreas may not be visible because it is often isoechoic to the surrounding mesenteric fat.

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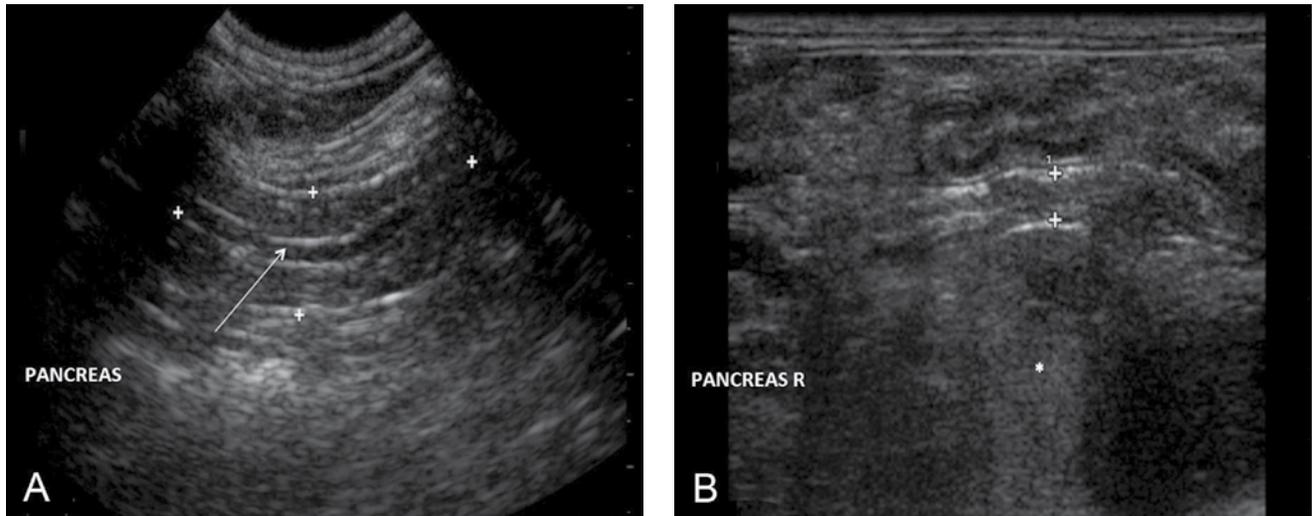


Figure 7.1. Imaging the normal pancreas. (A) Normal right pancreatic limb (labeled PANCREAS by the sonographer) in the sagittal plane in a dog (boundaries identified by [+]). Note the linear tubular hypoechoic (darker) structure within the mid pancreatic parenchyma (arrow). Color flow Doppler can aid in differentiating whether this structure is a vessel (pancreaticoduodenal artery or vein) or pancreatic duct. (B) Right pancreatic limb in the sagittal plane in a cat (boundaries identified by [+]). Note the small intestine/duodenum in the near field recognized by the hamburger-shape. The pancreas is typically isoechoic (same gray as) when compared to the surrounding mesentery (*). In the author's experience, the echogenicity of the pancreatic parenchyma can vary in normal animals without clinical signs or laboratory evidence of pancreatitis. The pancreas can range in echogenicity from mildly hypoechoic (darker) to mildly hyperechoic (brighter) when compared to the surrounding mesentery. This finding is especially dependent on the gain and acoustic output settings. Decreasing the gain settings can aid in pancreatic identification. Serosal margins of the pancreas are typically hyper-reflective and can be used to identify the organ's boundaries. Identification of the descending duodenum along the right dorso-lateral aspect of the patient while fanning and scanning medially and laterally along the length of the descending duodenum aids in identification of the right limb. The sonographer can then follow the right limb to the body of the pancreas. To identify the left limb of the pancreas, the sonographer can begin scanning and fanning in the sagittal plane along the left lateral cranial abdominal wall at the level of the last rib. Here, the gastric fundus and spleen can be easily identified and the sonographer can move caudally along the medial and lateral aspects of the spleen to the cranial pole of the left kidney in search of the organ. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

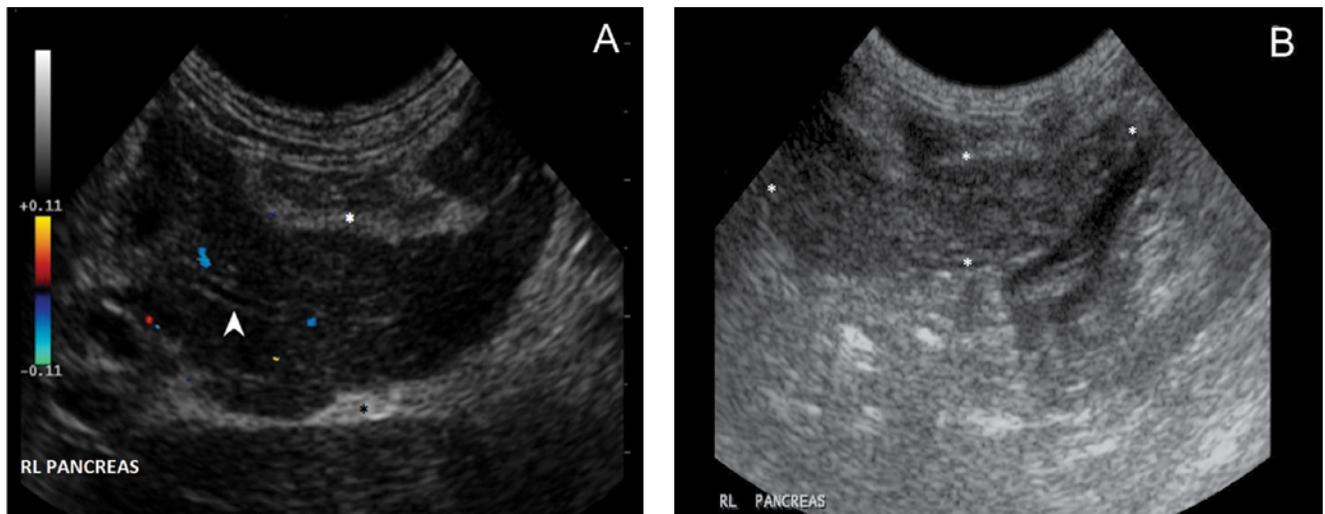


Figure 7.2. (Continued)

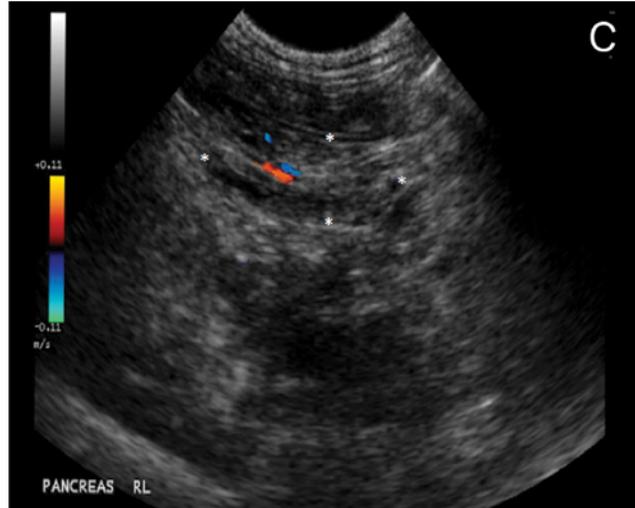


Figure 7.2. Pancreatitis. (A) Sagittal image of the right pancreatic limb (labeled RL PANCREAS by the sonographer) in an 11-year-old female spayed Shetland Sheepdog with pancreatitis. The pancreas is severely hypoechoic (darker) and subjectively enlarged. The surrounding mesentery is severely (bright) hyperechoic (*). Note the lack of color flow Doppler within the anechoic (dark) tubular structure, the pancreatic duct (arrowhead), coursing along the mid aspect of the right pancreatic limb. (B) Sagittal image of the right limb of the pancreas (labeled RL PANCREAS by the sonographer and outlined [*]) in a 7-year-old female spayed Siamese cat with pancreatitis. The patient had a history of weight loss, vomiting, and lethargy. Pancreatitis is typically found more often in the left limb of the pancreas in cats. This patient's entire pancreas was severely hypoechoic (darker) and enlarged. (C) Color flow Doppler evaluation of the right limb of the pancreas (labeled RL PANCREAS by the sonographer) in a cat with mild pancreatitis and renal disease. In this case the blue vessel represents the pancreaticoduodenal artery and the red vessel represents the flow within the pancreaticoduodenal vein. Recall that blood away from the transducer is blue (remember direction by the fact that “blue” and “away” have the same number of letters) and blood flowing toward the transducer is red. The pancreatic borders are marked (*). Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

It must be stressed that a significant number of dogs with pancreatitis will not have ultrasonographic evidence of pancreatitis, and the success of diagnosing acute pancreatitis will vary with sonographer experience. Failure to detect evidence of pancreatitis during the focused emergency pancreatic scan does not rule out acute pancreatitis, and further testing should be pursued if the history and other clinical findings support a diagnosis of acute pancreatitis.

Focused Gastrointestinal Tract and Pancreas Findings and their Significance

Small Bowel

It is important to gain familiarity with the normal ultrasonographic appearance of the bowel to be able to identify intestinal lesions. In adults, the normal small intestine typically has five ultrasonographically identifiable layers, which tend to resemble a hamburger on cross section. They include, from the lumen to the serosal surface, the hyperechoic luminal-mucosal gas

interface, hypoechoic mucosa, hyperechoic submucosa, hypoechoic muscular layer, and hyperechoic subserosa and serosa. (Figures 7.3, 7.4).

Normal small bowel looks like a hamburger on transverse orientation.

When thinking of the ultrasonographic layers of the GI tract, the mnemonic “The sun is bright and it’s dark at midnight” may be helpful in remembering that layers starting with an “s” like the sun are bright (submucosa and serosa are hyperechoic), whereas layers starting with an “m” like midnight are dark (mucosa and muscular layer are hypoechoic) on the US image.

Use the mnemonic “The sun is bright and it’s dark at midnight” to remember that layers starting with an “s” like the sun are bright (submucosa and serosa are hyperechoic [bright]), whereas layers starting with an “m” like midnight are dark (mucosa and muscular layer are hypoechoic [dark]) on the US image.

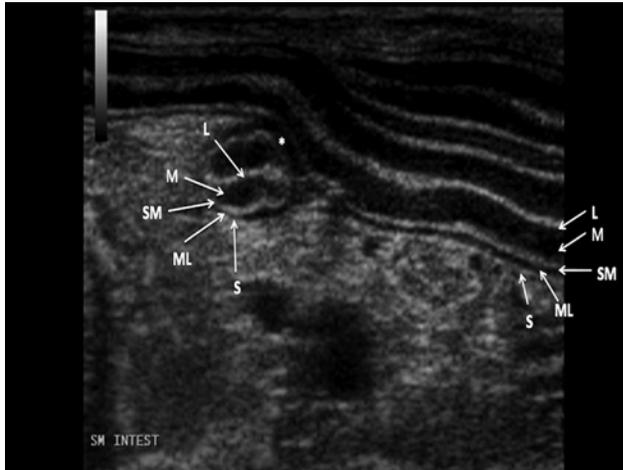
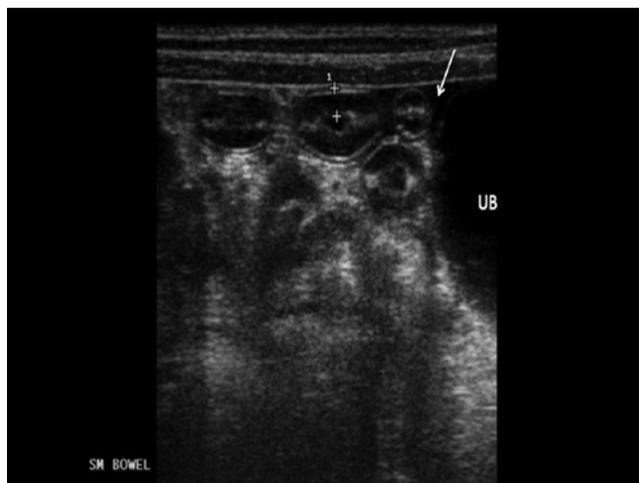


Figure 7.3. Normal image of adjacent loops of small bowel (labeled SM INTEST by the sonographer) in both sagittal and transverse planes in a 9 year-old diabetic, female spayed Miniature Pinscher who presented for acute vomiting due to pica and foreign body ingestion. Luminal contents can vary in echogenicity. In this example, the small bowel is predominantly empty with a small amount of mixed gas and chyle causing the hyperechoic lumen. The normal small intestine typically has five ultrasonographically identifiable layers. From lumen to serosal surface, the layers are as follows: luminal-mucosal layer (L) (which is hyperechoic and represents the gas-mucosal interface), hypoechoic mucosa (M), hyperechoic submucosa (SM), hypoechoic muscular layer (ML), and hyperechoic subserosa/serosa (S). A small amount of anechoic peritoneal effusion (*) was noted due to pancreatitis. Care should be taken not to confuse this finding with an increase in thickness of the muscularis layer. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.



Foreign Bodies

The acoustic appearance of GI foreign bodies detected ultrasonographically varies depending on their physical properties. Foreign objects that allow sound to pass through them can be visualized within the GI lumen, whereas objects that reflect or attenuate sound often have a hyperechoic interface and produce shadowing beyond their superficial surface (Figures 7.5 and 7.6) (Sharma 2011, Tidwell 1992).

The majority of ultrasonographically detectable GI foreign bodies typically involve a well-defined hyperechoic, hyper-reflective acoustic interface with strong distal acoustic shadowing (Garcia 2011, Tidwell 1992). This is in contrast to intraluminal gas, which tends to result in reverberation artifact (Figures 7.7 and 7.8) (Sharma 2011, Tyrell 2006, Tidwell 1992). However, there is some overlap in the shadowing seen with foreign bodies and intraluminal gas that may render the identification of a foreign body difficult (Tidwell 1992).

The acoustic shadowing of foreign bodies may be masked by air, but manipulation of bowel with the transducer and changes in patient position may allow evaluation of the suspected section of intestine.

Dilation of the intestine orad to finding a hyperechoic interface between the mucosa and lumen lends support to the presence of intestinal obstruction and suggests the need for surgical exploration (Garcia 2011).

GI foreign bodies should be considered and ruled out when ultrasonographic findings suggest mechanical obstruction or GI irritation.

In the face of appropriate history and physical exam findings, the ultrasonographic detection of peritoneal effusion, gas distension and abnormal motility (particularly hyperperistalsis with failure to advance intraluminal contents) warrants a careful

Figure 7.4. Normal image of small bowel (labeled SM BOWEL by the sonographer) in the transverse plane in a five-year-old Jack Russell Terrier with a two-month duration of vomiting and evidence of pyloric out flow obstruction on radiographs. Note the anechoic (black) luminal small bowel fluid in some of the small bowel. A urine-filled urinary bladder (UB) is to the right. A small amount of anechoic (black) peritoneal fluid was also noted (arrow) and is consistent with modified transudate. Surgical and histopathologic diagnosis was giant hypertrophic gastropathy (not shown). The small bowel was normal and the patient had a successful outcome with partial gastrectomy. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

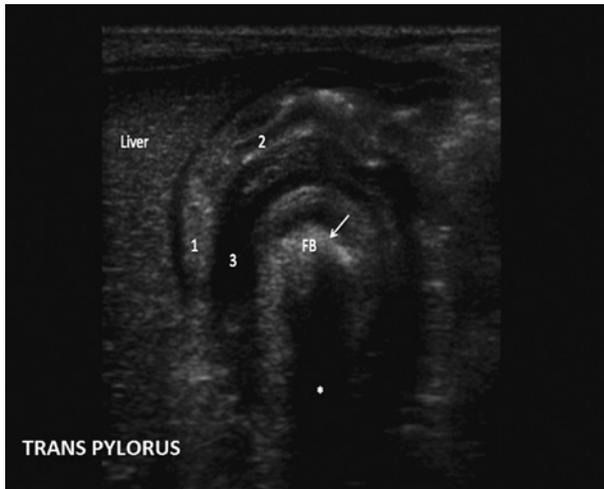


Figure 75. Pyloric foreign body. Transverse image of the pylorus (as labeled by the sonographer) in the same patient as in Figure 7.3 (nine-year-old diabetic, female spayed Miniature Pinscher with vomiting). A smoothly contoured hyperattenuating foreign body (FB) is present within the pylorus. Note the hyper-reflective (bright white) acoustic interface (arrow) associated with a well-defined band of hypoechoic (dark) distal acoustic shadowing (*). The pylorus can be found by identifying the gastric fundus in the left cranial abdominal quadrant and following the gastric wall medially and toward the right aspect of the patient. The stomach can be imaged with the patient in multiple positions (dorsal, right lateral, left lateral, and standing) for a global view. In deep-chested dogs, it may be necessary to place the animal in left lateral recumbency and image it from a right intercostal vantage. The adjacent structures are labeled as isoechoic fat (1), small bowel (2), and pyloric muscularis layer (3). Note that the muscularis layer of the pyloric region (labeled [3]) is quite thick, representing the pyloric sphincter. In cases with the suspicion of pyloric out flow obstruction or gastric foreign body, attempts should be made to evaluate the entire stomach and the gastroduodenal junction in both transverse and sagittal planes. This patient recovered well with gastrotomy, diabetic management, and supportive care for concurrent pancreatitis. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

search of the GI tract for foreign bodies (Sharma 2011, Tidwell 1992).

Linear Foreign Bodies

Linear foreign bodies often appear as persistent echogenic or hyperechoic linear structures in the center of plicated intestinal lumens that do not move with peristalsis (Figures 7.9 and 7.10).

The finding of bowel plication is strongly suggestive of a linear foreign body and should prompt careful evaluation of the intestine (longitudinal and transverse images) at sites where plication is seen

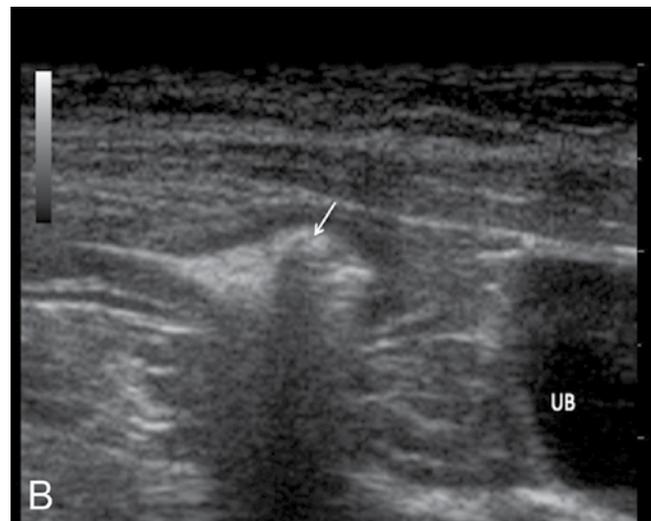
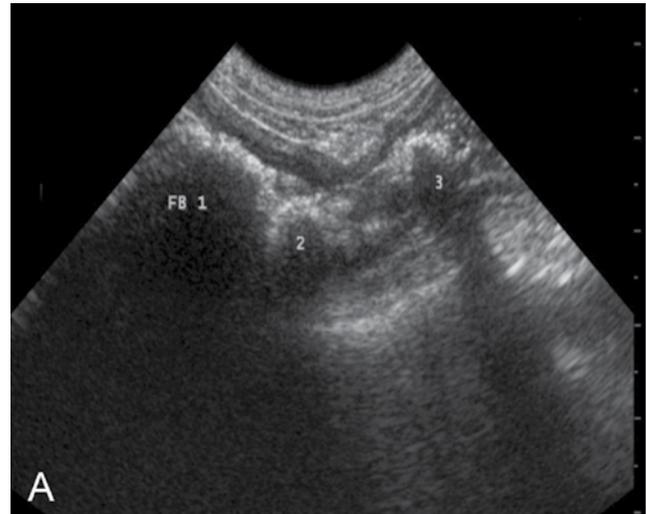


Figure 7.6. Additional examples of small bowel intestinal foreign bodies. (A) Multiple duodenal foreign objects (as labeled by the sonographer, FB 1, 2, 3) in a dog, demonstrating the proximal hyper-reflective (bright white) acoustic interface with various degrees of associated distal acoustic shadowing extending to the far field. FB 1 demonstrates the strongest and cleanest degree of shadowing. (B) Distal small bowel adjacent to the urinary bladder (UB), with an intraluminal, shadowing, incidental small intestinal foreign body (arrow) in a seven-year-old cat with sonographic evidence of unrelated renal disease. The patient did well without surgical intervention. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

(Garcia 2011, Tidwell 1992). Intestinal corrugation has also been associated with linear foreign bodies (Tidwell 1992) but is less specific than plication (Figure 7.11) (see below).

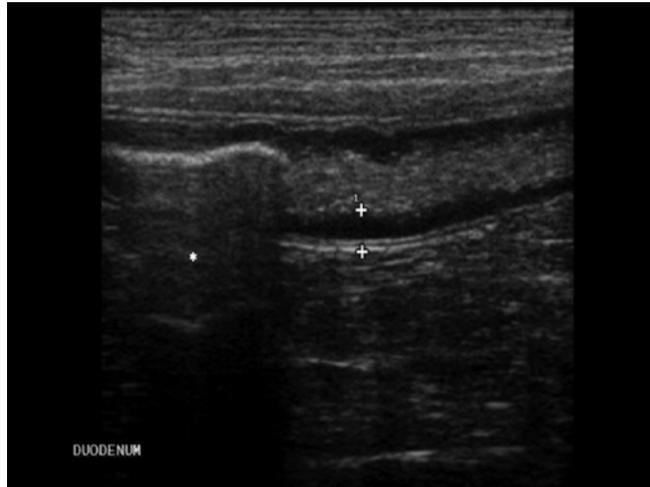


Figure 7.7. Image of normal small bowel (labeled DUODENUM by the sonographer) with normal small bowel gas. Note the dirty distal shadow (*) cast by the movement of gas within the small bowel lumen, in contrast to clean shadowing of the foreign bodies in Figures 7.5 and 7.6. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

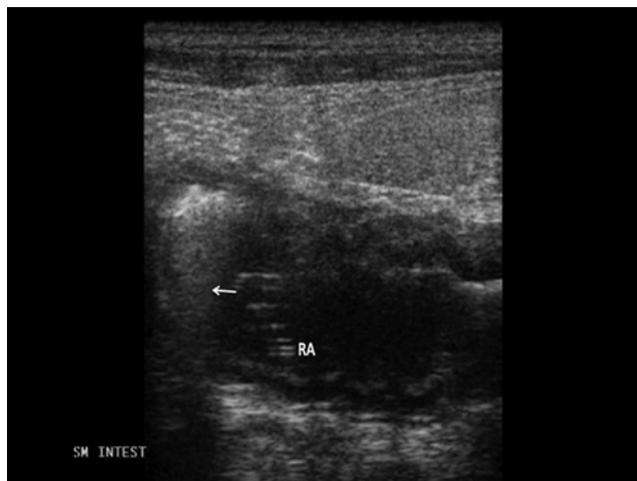


Figure 7.8. Corrugated small bowel. Sagittal image of a loop of small bowel (labeled SM INTEST) in a five-month old male Labrador Retriever with a two-day history of vomiting and diarrhea following dietary indiscretion and a diagnosis of severe enteritis. The small bowel is abnormally corrugated and fluid distended. There is a small amount of intraluminal gas (arrow) and reverberation artifact (RA). Corrugation and plication can be difficult to differentiate. It is important to evaluate the bowel from different angles in both the sagittal and transverse plane to aid in differentiation of corrugation from plication and reverberation artifact from a linear foreign body. This can be achieved in real-time with investigative fanning and scanning of the bowel loop in question. The authors recommend cine clip (a video feature on most ultrasound machines) documentation of such investigations for the medical record. A foreign body was not identified and the patient was not obstructed, and recovered with supportive care. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.



Figure 7.9. Small bowel plication in a three-month old French Bulldog with a two-day history of vomiting. An intraluminal linear foreign body (arrowheads) can sometimes be easily identified within the lumen of plicated small intestine. Note the clean acoustic shadowing (AS) distal to the linear foreign body. A toy mouse on a long string was removed surgically via multiple enterotomies. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.



Figure 7.10. Same patient as in Figure 7.9. Sagittal image of severely plicated small bowel (labeled SM BOWEL by the sonographer) secondary to linear foreign body (not shown). If this characteristic zig-zag pattern of small bowel is seen it should prompt the sonographer to carefully look for the presence of a linear foreign body (not seen in this image). The small bowel is plicated and bunched. The presence of such a pattern should also prompt strong recommendations for surgical intervention. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

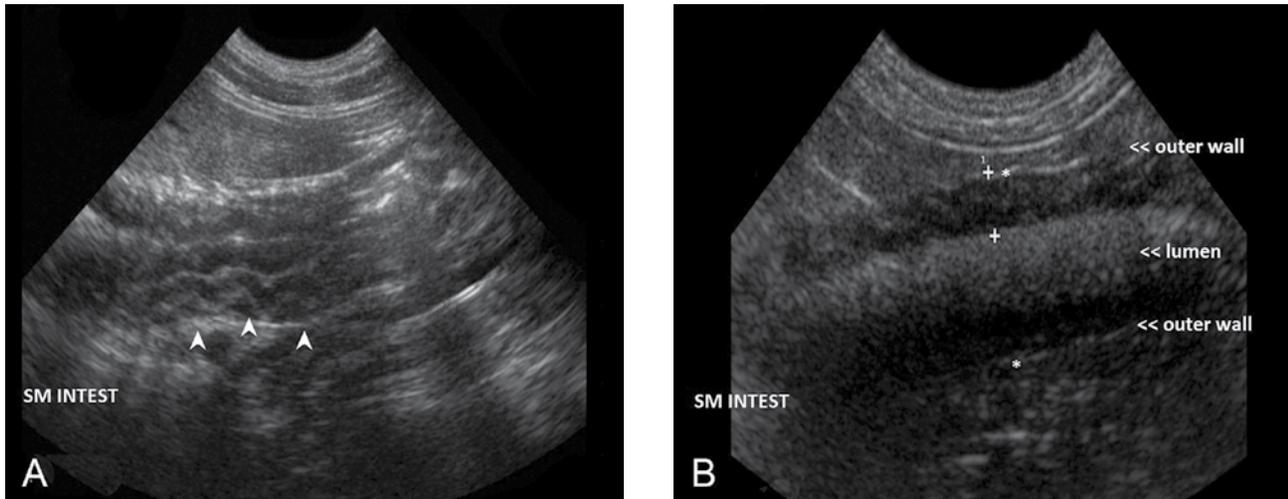


Figure 7.11. Examples of small bowel corrugation. (A) Image of the small bowel corrugation (labeled SM INTEST by the sonographer; marked along the segment of interest with arrowheads) in the same patient as in Figure 7.8. Note the various degrees of corrugation and fluid distention of the small bowel in this patient. It may be difficult to distinguish between corrugation and plication. (B) Intestinal corrugation in a 15-year-old male Rat Terrier with severe pancreatitis and pancreatic abscessation. Compare Figures 7.7–7.11. Note that corrugated bowel appears as a wavy pattern of the intestinal wall (near field wall marked [+]; outer walls marked [*] and labeled << outer wall); however, the hyperechoic (bright white) luminal contents of the associated intestine follow a straighter line (labeled << lumen). Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

Intestinal Obstruction

The ultrasonographic diagnosis of intestinal obstruction may be indirect based on the presence of a combination of findings which include segmental luminal distension (typically fluid), hypermotility in the absence of luminal content progression (Manczur 1998, Ogata 1996), observation of non-uniform intestinal peristalsis, and the presence of hypermotility and hypomotility in the same animal (Manczur 1998, Schmutz 1997).

Patients that have the above ultrasonographic findings should be carefully evaluated for the presence of foreign bodies, intussusception, or even obstructive neoplasia because their presence further supports a diagnosis of intestinal obstruction (Garcia 2011, Penninck 2008, Tidwell 1992).

The ultrasonographic presence of any two of the above findings has a reported sensitivity of 100% and specificity 98.5% for the diagnosis of intestinal obstruction in cats and dogs (Garcia 2011). However, the presence of only intestinal hyper- and hypomotility and concurrent segmental intestinal dilation without progression of luminal content may result in a false positive diagnosis of intestinal obstruction (Garcia 2011). This stresses the importance of searching for the presence of foreign bodies, intussusception, or masses to further support the suggestion that obstruction is present and exploratory surgery is warranted.

Intussusception

Intestinal intussusception is readily diagnosed with ultrasonography because it has a characteristic pattern that is easily visualized. On cross section it appears as a series of multi-layered concentric rings (bull's eye or target lesion) or as a multilayered lesion with linear streaks of hyperechoic and hypoechoic tissue on longitudinal section (Figures 7.12 and 7.13; also see Figure 13.11B) (Garcia 2011, Larson 2009, Penninck 1990).

The outer layer of affected intestine may be thickened, and signs of bowel obstruction are often present. Fluid dilation proximal (orad) to the site of invagination, increased peristalsis without signs of content progression, and signs of hypo- or normal motility distant from the intussusception may also be visible (Garcia 2011, Larson 2009).

Septic Peritonitis and Pneumoperitoneum

Septic peritonitis, which is often secondary to GI perforation, is a life-threatening emergency that is often difficult to diagnose pre-surgically. The AFAST³ exam (Chapter 2) is particularly helpful in identifying peritoneal effusion (a common finding in patients with septic peritonitis).

Moderate amounts of fluid are easily detectable via US and can subsequently be aspirated if detected

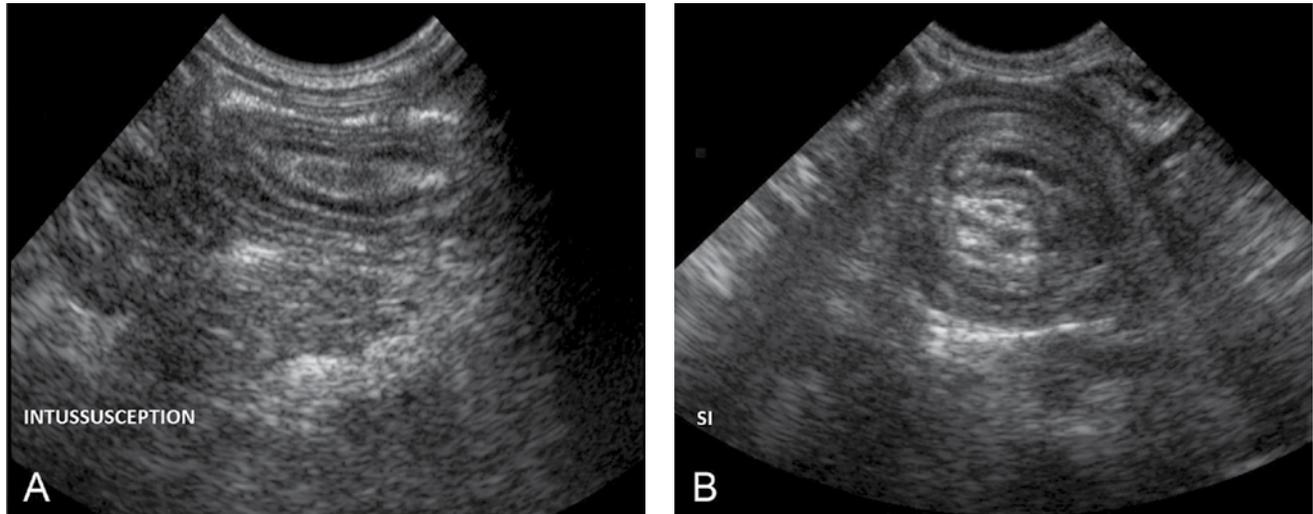


Figure 7.12. Intussusception of the small bowel (jejuno-jejunal) in the same patient as in Figure 7.10. (A) Sagittal plane image (INTUSSUSCEPTION, as labeled by the sonographer). Note the multilayered lesion with linear streaks of hyperechoic and hypoechoic tissue. Six jejuno-jejunal intussusceptions were noted during surgery and manually reduced. The patient recovered without complication. (B) A cross-sectional image of a small intestinal intussusception (labeled SI by the sonographer), in a nine-year-old Greyhound with vomiting and hematochezia. Note the series of multi-layered concentric rings (bull's eye or ring sign). Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

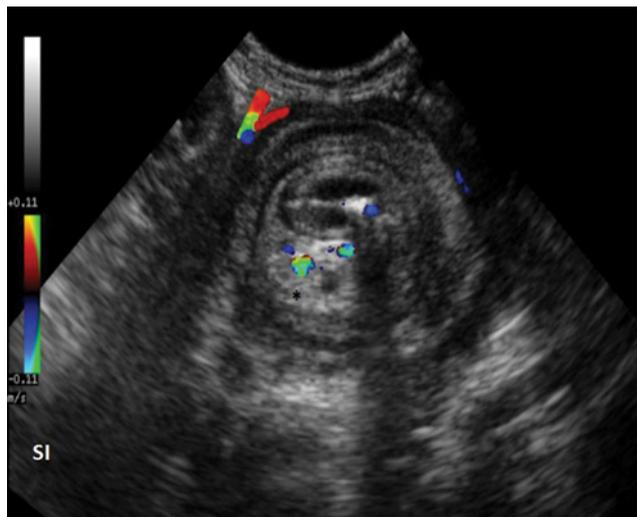


Figure 7.13. Transverse image of a small intestinal intussusception (labeled SI by the sonographer) in the same patient as in Figure 7.12 B. The final diagnosis was linear foreign body with secondary ascending duodenal intussusception. The patient recovered well following resection and anastomosis. Note the series of multi-layered concentric rings (bull's eye or ring sign) and hyperechoic invaginated mesenteric fat (*). Although not definitive, color flow or power Doppler evaluation can aid in providing information about the viability and perfusion of the intussuscepted bowel. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

(see chapters 2 and 17). In addition to the presence of fluid, which may range from being anechoic, anechoic with hyperechoic particles suspended throughout, or echogenic and swirling, US may also detect the presence of intraperitoneal gas in cases of GI or other hollow organ perforation (Boysen 2003).

Although radiographs are indicated in such patients to detect intraperitoneal gas, initial survey radiographs can fail to detect its presence and US has been used successfully to diagnose this problem in both human and veterinary patients (Boysen 2003). In dogs and cats the ultrasonographic detection of intraperitoneal gas is characterized by reverberation artifacts and comet tails interposed between the non-dependent abdominal wall and organs such as the liver and stomach or stomach and body wall (Figure 7.14) (Boysen 2003).

Although this has not specifically been evaluated using the AFAST³ technique, it is probable that dogs placed in lateral recumbency would have free air accumulate between the non-dependent abdominal wall (AFAST³ spleno-renal [SR] view in right lateral and hepato-renal [HR] view in left lateral recumbency) and underlying organs.

Scanning cranially along an imaginary line of the diaphragmatic crura and at the approximate level of the costophrenic angle, between the ribs while fanning, may aid in the detection of small amounts of gas trapped between the liver and diaphragm. If the history and physical

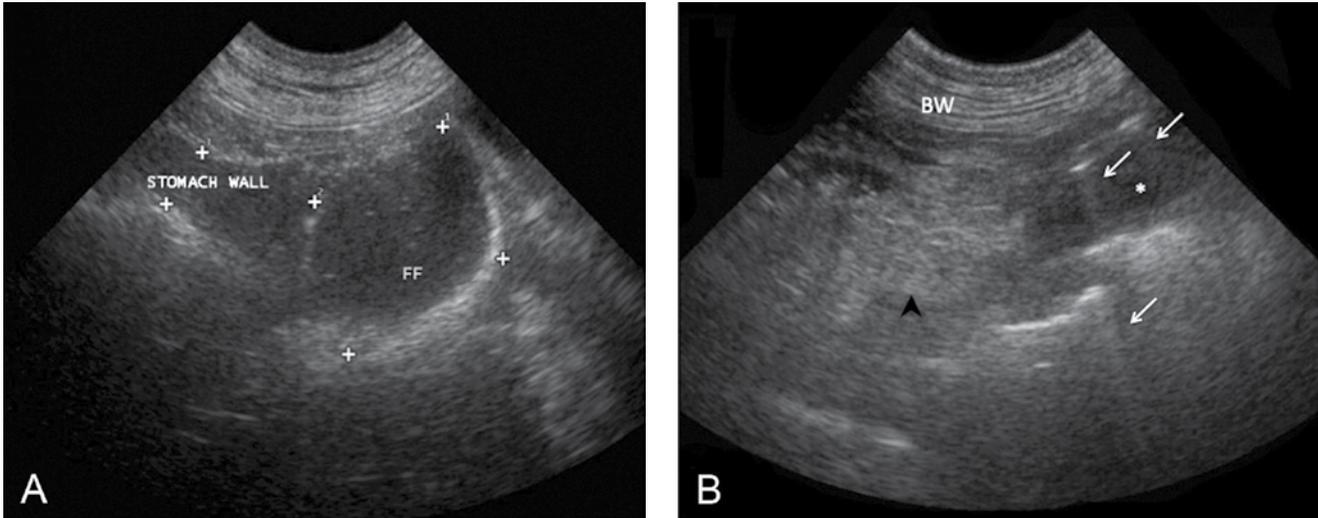


Figure 7.14. Ruptured gastric ulcer and peritonitis. Images of the left cranial abdominal quadrant of a nine-year-old English Bulldog that presented with lethargy and hemataemesis. The patient had been on chronic nonsteroidal anti-inflammatory therapy for arthritis. (A) Note the severely thickened gastric wall (labeled STOMACH WALL by the sonographer), measuring approximately 0.9 cm, which displays a loss of normal wall layering and is hypoechoic. Immediately adjacent to the stomach is a loculation of anechoic fluid with echogenic particles noted in suspension (labeled FF by the sonographer and identified by the tick marks, +). (B) Intraperitoneal gas in the same patient. Fanning and scanning of this region in real-time revealed faint echogenic streaking (reverberation artifact) and comet tails interposed between the non-dependent body wall and stomach (arrows), liver and body wall (not shown), and within the loculated fluid and mesentery (arrows). The gastric wall is indicated (*) with adjacent hyperechoic mesentery (black arrowhead), and multiple comet tails are present (white arrows), consistent with intraperitoneal gas. The patient was diagnosed surgically with a perforated gastric ulcer and had a full recovery following surgical resection and supportive care. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

examination are supportive of acute GI disease and an AFAST³ examination is performed to look for septic peritonitis, it is also reasonable to look for the presence of gas (particularly at the non-dependent body wall site) while simultaneously searching for fluid (which might alternatively be seen along the dependant aspect of the patient if in small amounts) (see Figure 13.10B).

Failure to detect gas does not rule out GI perforation. Its presence in patients with supporting history and clinical findings may expedite and assist with the decision for exploratory surgery.

Serial AFAST³ (and focused GI and pancreas) exams after resuscitation and rehydration are helpful (four hours post-admission out to 12 and 24 hours) to detect initially occult peritonitis or bowel perforation because peritoneal fluid and gas often develop as the patient becomes hydrated.

Ileus

Ultrasonographically, GI motility can be recorded as the number of gastrointestinal contractions observed over a one-minute time period. To determine the

number of contractions/minute, the number of contractions are recorded twice over a three-minute period and averaged to get the number of contractions/minute (Penninck 1989).

Normal contractility varies depending on the section of GI tract evaluated. The mean number of peristaltic contractions of the stomach and proximal duodenum are four to five contractions/minute, and the small intestine in the mid abdomen averages one to three contractions/minute (Penninck 1989).

The mean number of peristaltic contractions of the stomach and proximal duodenum are four to five contractions/minute, and the small intestine in the mid abdomen averages one to three contractions/minute.

Certain GI disorders have been associated with changes in intestinal motility including bowel obstruction, gastric ulcers, severe pancreatitis, inflammatory bowel disease, and neoplastic processes (Garcia 2011).

A generalized decrease in gastrointestinal motility is reported in small animals with functional and chronic

mechanical ileus, whereas a generalized increase in motility is most commonly reported in cases of acute mechanical obstruction (Penninck 2008). There is considerable overlap in motility changes between dogs that do and do not have small intestinal obstruction, and changes in motility alone do not indicate the need for surgery (Sharma 2011, Garcia 2011).

If the emergency clinician notes increased or decreased GI motility in a patient with clinical signs of GI disease, further diagnostics such as abdominal radiographs and a complete abdominal ultrasound examination should then be considered because several surgical conditions including foreign bodies, intussusception, and neoplasia are frequently associated with altered GI motility (Garcia 2011, Penninck 2008). A thorough evaluation of the GI tract to rule out these conditions is warranted.

Another cause of decreased intestinal motility that is commonly seen in post-operative patients is functional ileus. This condition results in a transient cessation of coordinated propulsive motility most commonly following abdominal surgery (Koscienly 2011). In humans, it is associated with abdominal distension, nausea, vomiting, and the inability to pass stools or tolerate a solid diet. In addition to the discomfort reported in humans, post-operative ileus may also predispose patients to wound dehiscence, intussusception, and pulmonary and thromboembolic complications (van Bree 2012).

Several factors have been associated with acute ileus following post-operative abdominal surgery in humans, including intestinal handling during surgery and the use of anesthetics and opioid analgesics (van Bree 2012, Kehlet 2009). Longer term ileus following abdominal surgery is believed to result from inflammation of the intestinal muscularis externa (Kalf 1999). An important feature of postoperative ileus is that the entire gastrointestinal tract may be impaired even if only part of the intestine has been handled or is inflamed (van Bree 2012).

If postoperative ileus is noted, measures should be taken to ascertain the underlying cause (opioids, post-operative surgery, abdominal pain, electrolyte imbalances, and peritonitis). Therapeutic interventions should be implemented and include feeding soon after surgery, early ambulation, epidural analgesia (decreases systemic opioid analgesia which is associated with ileus), nonsteroidal anti-inflammatory agents, and minimally invasive surgery (van Bree 2012, Behm 2003).

Corrugated Intestine

Although it is not always easy to do, it is important to differentiate corrugated bowel from plicated bowel because the two pathologies have different etiologies.

Plicated bowel is usually associated with a linear foreign body, which may indicate the need for surgery, even if the linear foreign body is not ultrasonographically detected (Tidwell 1992) (see Figure 13.9A). In contrast, corrugated bowel is a very non-specific ultrasonographic finding that suggests intestinal dysfunction which could result from several different causes.

Plicated bowel is associated with intestinal linear foreign bodies that cause the small intestine to bunch around a linear object, resulting in an asymmetric intestinal pattern (Figures 7.9 and 7.10). The loop of small intestine may weave as it is cinched together and contract around the linear foreign body.

Corrugated intestine arises from altered abnormal spastic peristalsis of the bowel resulting in an abnormal wavy (corrugated) pattern to the wall (Moon 2003). The overall direction of the intestine tends to appear straight in contrast to bunched or weaved as with plicated bowel (Figure 7.11A and B). It is most apparent in the sagittal or longitudinal section of small intestine and may be evident in a single loop or several loops at different times. If corrugated bowel is noted in the unstable patient, a focused ultrasonographic evaluation of the pancreas and a search for peritoneal fluid using AFAST³ are warranted because corrugated bowel is commonly associated with pancreatitis and peritonitis (Moon 2003). Pancreatitis is particularly common when corrugation of the duodenum is noted (Moon 2003).

If focused ultrasonographic evaluation of the pancreas and/or AFAST³ exam are unremarkable, or if the patient is stable, a complete abdominal ultrasound exam or other diagnostic tests may be indicated to search for other pathologies associated with corrugated bowel, including enteritis (parvovirus, inflammatory bowel disease, lymphocytic plasmacytic), pancreatic neoplasia, diffuse abdominal neoplasia, thrombosis/infarction, protein losing enteropathy, and acute renal failure (Moon 2003).

In differentiating corrugated from plicated bowel, the overall direction of the intestine tends to appear straight with corrugated bowel (medical causes include enteritis/pancreatitis) in contrast to bunched or weaved with plicated bowel (surgical causes include linear foreign body) (Figures 7.9 through 7.11).

Pancreatitis

Acute pancreatitis is generally a clinical diagnosis supported by history and physical examination findings. If suspected, a focused ultrasonographic exam may

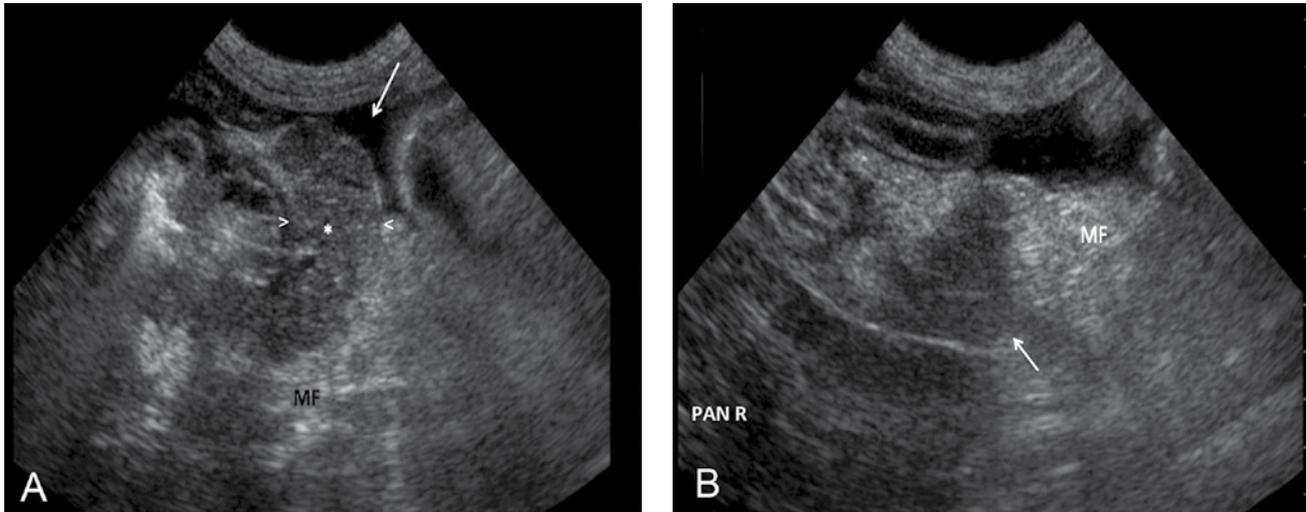


Figure 7.15. Signs of pancreatitis. (A) Image of an eight-year-old male neutered Yorkshire Terrier with acute pancreatitis. Note the enlarged and diffusely hypoechoic comma-shaped pancreatic body (*) with its borders marked (> and <). Variable amounts of peritoneal effusion may accompany pancreatitis and can be seen in proximity to the pancreas (arrow). Fluid echogenicity can vary from anechoic (black) to echogenic (shades of gray) and cellular. The surrounding mesenteric fat (labeled MF) often appears moderately hyperechoic (bright white). (B) Same patient, right limb of the pancreas (image labeled PAN R by the sonographer). The hypoechoic (dark) triangular-shaped right pancreatic limb (arrow) is surrounded by hyperechoic (bright) and hyperattenuating mesenteric fat (MF). Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine.

further support the diagnosis of pancreatitis, although pancreatitis does not consistently and reliably produce sufficient changes within the pancreas for detection by ultrasonography. A normal ultrasonographic finding does not rule out pancreatitis.

Even in cases of severe acute pancreatitis, the sensitivity of ultrasound may only be 68% (Hess 1998).

Ultrasonographic evidence of acute pancreatitis (if evident) includes an enlarged and diffusely hypoechoic to mass-like pancreas (Figure 7.15) (Hecht 2007, Lamb 1995). There may be variable amounts of peritoneal effusion adjacent to the pancreas (which may be aspirated and tested). Surrounding fat often appears moderately hyperechoic (bright) as the result of inflammation, necrosis, and saponification (Figure 7.15) (Penninck 2008, Hecht 2007).

Functional small bowel ileus or corrugated intestines may be noted (especially at the duodenum) along with pain at the scan site (Hecht 2007). The bile duct and gallbladder may be distended as a result of extrahepatic biliary obstruction. These findings in patients with appropriate history and clinical findings warrant the initiation of therapy for acute pancreatitis. One disadvantage to a focused exam in this case is that the entire biliary and pancreatic ductal system requires a greater time commitment to scan and is often beyond the skills of non-radiologist veterinarians.

If the preliminary ultrasound scan is negative, a complete abdominal ultrasound is warranted. Recheck

of the pancreas in one to two days should be considered because ultrasonographic signs may become evident with time. Sonographer experience is likely to influence results. Recheck examinations may also be used to monitor response to treatment and progression or resolution of pancreatic changes.

Peritoneal Effusion

See Chapter 2 for information about peritoneal effusion.

Pearls and Pitfalls, the Final Say

- Fasting the patient 12 hours prior to ultrasound evaluation may reduce interference with gastric contents, but is not usually feasible in the focused emergent GI scan.
- Gas in the GI tract may result in reverberation, comet tail, and acoustic shadowing artifacts, which may impede interpretation and can be difficult to distinguish from shadowing seen with some GI foreign bodies.
- The stomach is easy to identify due to the presence of rugal folds, but can be difficult to image due to stomach contents and gas that are typically present.

Luminal contents, or lack thereof, can also affect wall measurements. For example, an empty stomach may give the impression of having a thickened wall.

- In dogs, the descending duodenal wall is thicker than other small intestinal segments. The duodenal wall can normally measure up to 5 mm in large-breed dogs. For the remainder of the small bowel, greater than 4 mm in dogs and 2.5 mm in cats is generally considered as thickened (Newell 1999).
- In cats, the ileum is identified by its bright submucosal layer.
- The colon can often be differentiated from the small intestinal wall by its thinner wall and lack of motility in normal instances.
- Using an acoustic window such as the spleen can enhance imaging of the intestine.

References

- American College of Emergency Physicians. 2001. Use of ultrasound imaging by emergency physicians. *Ann Emerg Med* 38:469–470.
- American College of Emergency Physicians. 2001. ACEP emergency ultrasound guidelines—2001. *Ann Emerg Med* 38:470–481.
- Behm B, Stollman N. 2003. Postoperative ileus: etiologies and interventions. *Clin Gastroenterol Hepatol* 1:71–80.
- Boysen SR, Tidwell AS, Penninck DG. 2003. Ultrasonographic findings in dogs and cats with gastrointestinal perforation. *Vet Rad and Ultrasound* 44(5):556–564.
- Brinkman-Ferguson EL, Biller DS. 2009. Ultrasound of the right lateral intercostal space. *Veterinary Clinics of North America: Small Animal Practice* 39(4):761–781.
- Capak D, Simpraga M, Maticic D, et al. 2001. Incidence of foreign-body-induced ileus in dogs. *Berl Munch Tierarztl Wochenschr* 114:290–296.
- Dean A, Lafferty K, Villaneuva T. 2003. Emergency medicine bedside ultrasound diagnosis of intussusception in a patient with chronic abdominal pain and unrecognized Peutz-Jeghers syndrome. *J Emerg Med* 24(2):203–210.
- Garcia DA, Froes TR, Vilani OC, et al. 2011. Ultrasonography of small intestinal obstructions: a contemporary approach. *J Small Anim Pract* 52:484–490.
- Hecht S, Henry G. 2007. Sonographic evaluation of the normal and abnormal pancreas. *Clin Tech Small Anim Pract* 22:115–121.
- Heller M, Jehle D. 1995. Primary Applications of Ultrasound. In *Ultrasound in Emergency Medicine*, edited by M Heller and D Jehle. Philadelphia: WB Saunders, pp 41–134.
- Hess RS, Saunders HM, Van Winkle TJ, et al. 1998. Clinical, clinicopathological, radiographic and ultrasonographic abnormalities in dogs with fatal acute pancreatitis: 70 cases (1986–1985). *J Am Vet Med Assoc* 213:665–670.
- Jang T, Schindler D, Kaji D. 2011. Bedside ultrasonography for the detection of small bowel obstruction in the emergency department. *Emerg Med J* 28:676–678.
- Jones R. 2007. Recognition of pneumoperitoneum using bedside ultrasound in critically ill patients presenting with acute abdominal pain. *Am J Emerg Med* 25:838–41.
- Kalff JC, et al. 1999. Surgically induced leukocytic infiltrates within the rat intestinal muscularis mediate postoperative ileus. *Gastroenterology* 117:378–387.
- Kehlet H. 2008. Postoperative ileus—an update on preventive techniques. *Nat Clin Pract Gastroenterol Hepatol* 5:552–558.
- Koscielny A, Kalff JC. 2011. T-helper cell type 1 memory cells and postoperative ileus in the entire gut. *Curr Opin Gastroenterol* 27:509–514.
- Lamb CR, Simpson KW. 1995. Ultrasonographic findings in cholecystokinin-induced pancreatitis in dogs. *Vet Radiol Ultrasound* 36:139–145.
- Larson MM, Biller DS. 2009. Ultrasound of the gastrointestinal tract. *Bet Clin Small Anim* 39:747–759.
- Manczur F, Voros F, Vrabely T, et al. 1998. Sonographic diagnosis of intestinal obstruction in the dog. *Acta Veterinaria Hungarica* 46: 35–45.
- Mateer J, Plummer D, Heller M, et al. 1994. Model curriculum for physician training in emergency ultrasonography. *Ann Emerg Med* 23:95–102.
- Moon M, Biller D, Armburst L. 2003. Ultrasonographic appearance and etiology of corrugated small intestine. *Vet Radiology and Ultrasound* 44(2):199–203.
- Newell SM, Graham JP, Roberts GD, et al. 1999. Sonography of the normal feline gastrointestinal tract. *Vet Radiology and Ultrasound* 40(1):40–43.
- Nyland TG, Mattoon JS, Herrgesell et al. 2002. Pancreas. In *Small Animal Diagnostic Ultrasound 2nd ed*, edited by TG Nyland and JS Mattoon. Philadelphia: WB Saunders, pp 144–157.
- Ogata M, Materr JR, Condon RE. 1996. Prospective evaluation of abdominal sonography for the diagnosis of bowel obstruction. *Annals of Surgery* 223:237–241.
- Penninck D. 2008. Gastrointestinal tract. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D’Anjou. Ames, Iowa: Blackwell Publishing, pp 281–318.
- Penninck D. 2008. Pancreas. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D’Anjou. Ames, Iowa: Blackwell Publishing, pp 319–338.
- Penninck D, Nyland T, Kerr L, et al. 1990. Ultrasonographic evaluation of gastrointestinal diseases in small animals. *Veterinary Radiology* 31(3): 134–141.
- Penninck D, Nyland T, Fisher P, Kerr L. 1989. Ultrasonography of the normal canine gastrointestinal tract. *Vet Radiology* 30(6):272–276.
- Rozycki GS, Pennington SD, Feliciano DV, et al. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50:636–642.
- Schmutz GR, Benko A, Fournier L, et al. 1997. Small bowel obstruction: role and contribution of sonography. *European Radiology* 7:1054–1058.
- Sharma A, Thompson M, Scrivani P, et al. 2011. Comparison of radiography and ultrasonography for diagnosing

- small-intestinal mechanical obstruction in vomiting dogs. *Vet Rad and Ultrasound* 52(3):248–255.
- Testa A, Lauritano C, Giannuzzi R, et al. 2010. The role of emergency ultrasound in the diagnosis of acute non-traumatic epigastric pain. *Intern Emerg Med* 5:401–409.
- Tidwell AS, Penninck DG. 1992. Ultrasonography of gastrointestinal foreign bodies. *Vet Radiol Ultrasound* 2(33):160–169.
- Tyrrell D, Beck C. 2006. Survey of the use of radiography vs. ultrasonography in the investigation of gastrointestinal foreign bodies in small animals. *Vet Radiol Ultrasound* 47:404–408.
- Unluer E, Yavasi O, Eroglu O, et al. 2010. Ultrasonography by emergency medicine and radiology residents for the diagnosis of small bowel obstruction. *Emerg Med* 17:260–264.
- van Bree SH, Nemethova CC, Gomez-Pinilla PJ, et al. 2012. New therapeutic strategies for postoperative ileus. *Nat Rev Gastroenterol Hepatol* advance online publication.

FOCUSED OR COAST³—REPRODUCTIVE

Robert M. Fulton

Introduction

In the grand scheme of things, reproductive ultrasonography probably gets the short end of the stick since most of our patients lack their reproductive organs (testicles, ovaries, and uterus) through surgical sterilization. However, one should not assume that reproductive sterilization has taken place simply because the altered pet is more common. It is very important to confirm your patients' reproductive status because many adopted dogs and cats have unknown medical histories. For instance, a pet owner may assume his female is spayed when in reality she may have never been observed to go into heat. When sexual status is questionable, the shaving of fur and evaluation for surgical spay and neutering scars is helpful, as are other physical examination findings such as the lack of mammary development in an older female dog or cat. The males are a little easier when they have two palpable scrotal testicles; however, don't overlook cryptorchidism.

In many areas throughout the United States, dogs and cats sterilized in shelters are tattooed either within or adjacent to their surgical site. A one-fourth- to one-half-inch lime green linear tattoo is commonplace. Cats may also have a partial amputation of their left ear tip identifying them as sterilized.

Cryptorchid testosterone-producing male cats have penile spines.

Ultrasonographically, the majority of the reproductive tract may be imaged. In females, this includes the

ovaries, uterus, cervix, and mammary glands; and for males, the prostate, scrotum and testes. Of these structures, the uterus makes up the vast majority of focused reproductive exams. However, in this chapter other important conditions of the female and male reproductive tracts will be discussed.

What the Focused Reproductive Exam Can Do

- Diagnose pregnancy
- Help diagnose pyometra
- Diagnose pseudopregnancy
- Determine the presence or absence of fetal stress
- Medically manage dystocia by using serial examinations for the screening of fetal distress
- Medically manage pyometra
- Determine causes of scrotal swelling
- Screen for prostatic pathology

What the Focused Reproductive Exam Cannot Do

- Cannot definitively differentiate pyometra from mucometra and hydrometra
- Cannot provide an accurate fetal count
- Cannot consistently allow you to scrutinize every individual fetus for stress
- Cannot fully screen for intra-abdominal free fluid; thus, an AFAST³ should also be performed to best

ensure that forms of peritonitis and intra-abdominal and retroperitoneal hemorrhage are not missed

Indications for Focused Reproductive Exam

- Any ill intact female cat or dog to rule out pyometra
- Acute abdomen, especially in intact females and males with caudal abdominal pain
- Dystocia
- Vaginal discharge
- Uncertainty of pregnancy
- Mammary gland abnormalities
- Scrotal swellings
- Testicular swellings
- Cryptorchidism

Objectives of the Focused Reproductive Exam

- Image the basic features of the male and female reproductive tracts
- Identify common ultrasonographic reproductive pathology of the male and female

Reproductive Conditions of the Female

The major structure involved in most concerning conditions of the bitch or queen is the uterus, and its two major problems are pyometra and dystocia. Fortunately, the enlarged uterus is very ultrasonographically accessible and recognizable by the beginning sonographer. These conditions and other less common uterine and mammary conditions are covered below.

Patient Positioning and Probe Selection for the Female

Patients are best evaluated in dorsal recumbency with a curvilinear probe and a urine-filled bladder. Depending on the ultrasound (US) machine, use a medium or comparable abdominal preset. Primarily focusing on longitudinal orientation rather than transverse orientation is usually easier when beginning because the female anatomy is more recognizable.

Do not walk the patient (dogs) or give a litter box (cats) before the exam. The urine-filled bladder (ultrasound loves fluid) improves imaging (provides an acoustic window) and serves as a landmark in identifying caudal abdominal structures.

Imaging the Normal Uterus

Begin the exam with the bitch or queen in dorsal recumbency. Keep in mind normal caudal abdominal anatomy. The female reproductive tract lies in between the urinary bladder and colon (Feeney 2007). Place the US probe in longitudinal fashion just cranial to the pubis where you would expect to find the urinary bladder. Direct the probe caudally to the trigone of the bladder, fanning longitudinally and following urine (normally anechoic [black]) until it triangulates and narrows into the urethra. At the trigone, search for the cervix or the uterine body just cranial and dorsal to the trigone. The cervix is slightly larger than the uterine diameter with the two structures blending into one another (Figure 8.1).

The cervix may be difficult to differentiate from the uterine body so do not spend too much time attempting to precisely localize the structure.

The uterine body, which is characterized by medium echogenicity (shades of gray) and is homogeneous, is easier to identify than the cervix. The uterus appears as

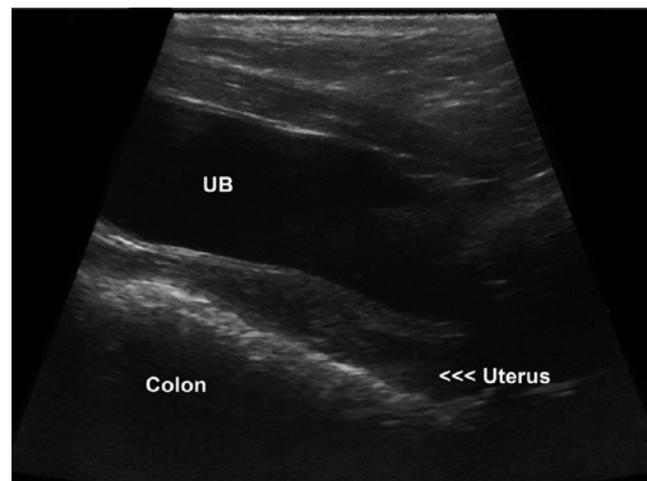


Figure 8.1. Uterus, long-axis. The canine uterus is the medium gray structure between the urinary bladder (labeled UB) and the colon in this longitudinal image. The uterus flares slightly at the junction with the cervix (<<< pointing to cervical region of the uterus). Cranial is to the left, caudal to the right of the image.

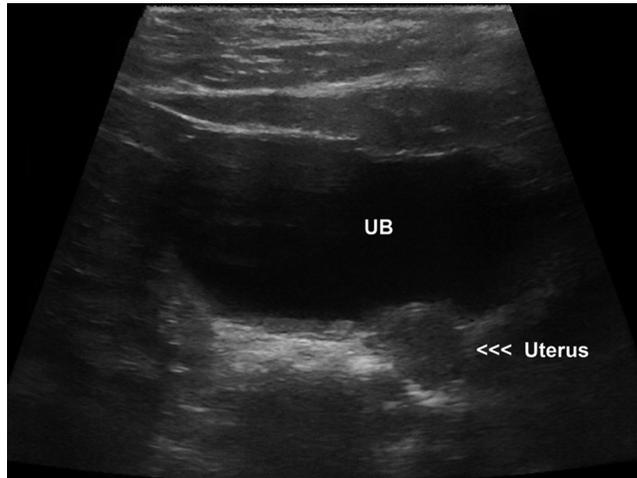


Figure 8.2. In this image the uterus is seen in short-axis as the circular medium gray structure (<<< pointing to the uterus) to the right between the urinary bladder ventrally (labeled UB in the near field) and the colon dorsally (far field).

a tubular structure similar in size to small intestine. The uterine lumen lacks a central echogenic stripe in the normal anestrous bitch (Figures 8.1 and 8.2). However, in estrus a thin, echogenic (bright) stripe within the uterine lumen may be seen (Feeney 2007).

Any free fluid within the uterus beyond the thin echogenic stripe of estrus is considered abnormal.

The uterine body will bifurcate into its two horns approximately one-third of the way along the urinary bladder depending on bladder size. Follow the uterine horns cranially as they make their way caudal to the kidneys using combinations of longitudinal and transverse views.

In the non-gravid or fluid-filled uterus it may not be possible to image the full length of the uterine horns. If you are having problems tracing the horns of the uterus then they are probably not clinically relevant.

Although rare, some females may have abnormalities of the tubular reproductive tract such as uterine atresia (not formed), which is more common in cats. Atresia may involve both horns or only one uterine horn (Johnston 2001).

Dystocia

There are three main questions regarding dystocia that need to be answered ultrasonographically:

- Is the bitch or queen pregnant?
- Are the fetuses alive?
- Are the fetuses stressed?

Question 1: Is She Pregnant?

The uncomplicated gravid (pregnant) uterus is easily recognized by the most novice sonographer because of its size, which takes up most of the abdomen in mid- to late gestation, and particularly its contents. Live fetuses are easily identified because of their body movement and easily recognizable beating hearts.

If you are having difficulty finding fetuses, then pregnancy is unlikely. Even in single pregnancies, the puppy or kitten is typically readily imaged.

Dorsal recumbency (vs. lateral recumbency) allows gravity to advantageously cause the mammary chains to fall laterally away from midline and provides the uterine horns with space to spread out. With the mammary chain out of the way, the sonographer has a clear probe path from pubis to xiphoid. Unless the bitch or queen is near term, the mammary glands are typically not enlarged.

Keep it brief and be efficient because dorsal recumbency is not only uncomfortable from intra-abdominal compression but also because it reduces lung capacity. Your pregnant patient will appreciate your consideration of flow-by oxygen and efficiency.

Begin in the region of the urinary bladder and work your way cranially along the midline from proximal pubis to the xiphoid, longitudinally fanning the probe from side to side. Upon reaching the xiphoid, return to the caudal abdomen and again fan longitudinally from caudal to cranial; however, change the course from midline to laterally along the mammary chain and the body wall ending at the caudal rib cage. Repeat the same scan on the opposite side. By adding this lateral-to-the-mammary-chain scan you will have adequately interrogated the uterus.

You may not be able to accurately distinguish between the left and right uterine horns in most patients; however, by this time you will have seen puppies or kittens if the patient is pregnant.

Upon finding a fetus, align the probe along its long-axis parallel to its spine to examine its abdominal and thoracic structures. Start with the abdomen and find the



Figure 8.3. The fetal kidney develops recognizable corticomedullary distinction around days 39–47 post-luteinizing hormone (LH) peak. The kidney shown in longitudinal/sagittal view is marked with calipers (+ - +) in this image (also see chapters 5 and 13). Courtesy of Dr. Mariana Amorim, University of Guelph.

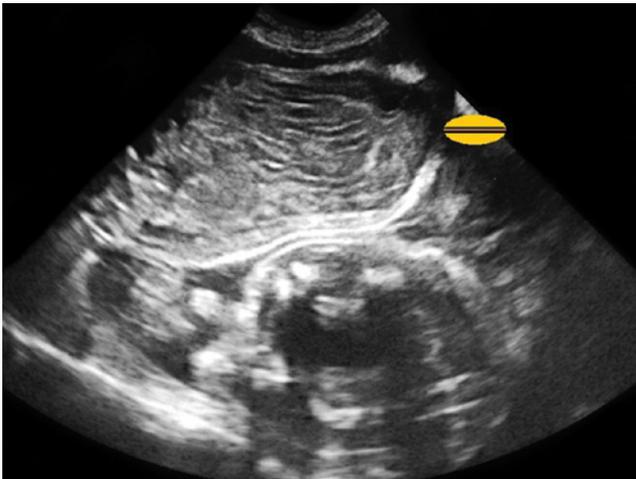


Figure 8.4. The fetal intestine is the last organ to develop recognizable features, normally between days 57 and 63 post LH peak. The normal bowel layers can be seen in this fetal abdomen. The small intestine in cross section has been referred to as looking like “hamburgers” (also see chapters 7 and 13). Courtesy of Dr. Mariana Amorim, University of Guelph.

liver, which is generally the easiest to image because of its size and location next to the thorax. Next, look caudally for the kidneys (Figure 8.3) and small intestine (Figure 8.4). These are some of the last organs to form and serve as a guide for fetal maturation. As they develop, the kidneys begin to appear similar to those of adults with distinct cortical and medullary regions (also see chapters 5 and 13). The intestines are the final organ to develop their ultrasonographic identity (Mattoon 2002) (also see chapters 7 and 13). After scanning the

fetal abdomen, look cranially into the thorax, readily identified by the rib cage. There the beating heart is readily identifiable in a live, unstressed fetus.

Term fetuses are easy to identify. With their anatomy formed in miniature, internal fetal structures are recognizable in normalcy.

Ultrasound may be used to accurately age fetuses but must be done between 19 and 37 days post-luteinizing hormone (LH) peak (Lopate 2005); aging is not addressed in this chapter.

Question 2: Are the Fetuses Alive?

The ribs will minimally and variably shadow the intrathoracic structures, although less so than the adult because of their decreased mineralization (mostly cartilage) and small size. Here the fetal heart should be easily recognized by its fluttering chambers in normalcy.

The fetal heart can be difficult to image in fetal death because of both lack of heart movement and degrees of fetal decomposition. Intrauterine gas typically representing fetal death and degrees of decomposition may also be evident ultrasonographically by shadowing and air reverberation artifacts, which further interfere with fetal cardiac imaging.

Question 3: Are the Fetuses Stressed?

The best indicator of fetal stress is heart rate. There are two methods to determine fetal heart rate. The first, the eyeball method, is simple, easy, but less accurate. Visualize the fetal heart and count the number of beats/minute. The second method uses M-mode imaging. This method is preferred because it is more accurate and allows for better documentation. The M-mode image may be digitally saved or printed for the medical record. Although it is more time consuming and technically challenging because it involves M-mode when beginning, in time this heart rate measurement method is mastered and rapid (Figure 8.5).

Normal canine or feline fetal heart rates should be greater than 180 beats/minute and are commonly well above 200 beats/minute.

Know how your US machine is set to determine heart rate. Some measure a single cycle, whereas others measure two cycles and take the average.

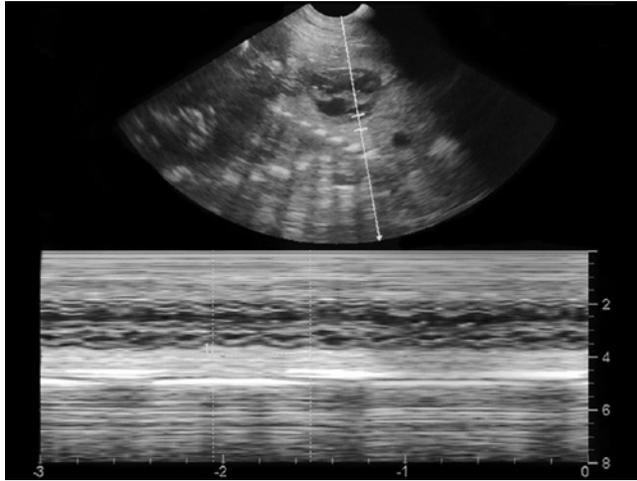


Figure 8.5. By using M-mode, the sonographer can very accurately determine fetal heart rate and eliminate the error of estimation using the eyeball method. This ultrasound machine is set to measure two cycles and can take the average for the determination of fetal heart rate. Note the ribs shadowing the far field as hypoechoic (dark) linear streaks.

Fetal Heart Rates and Fetal Stress

Decreasing fetal heart rates accompany increasing fetal stress. Fetal heart rates between 160 and 180 beats/minute indicate mild distress, and clinical intervention should be considered. Fetal heart rates between 140 and 160 beats/minute indicate moderate distress and high risk of fetal death if not delivered within the next two to three hours. Fetal heart rates less than 140 beats/minute indicate severe distress, and immediate intervention (C-section) is required because fetal death is imminent (Traas 2008).

When evaluating for fetal stress keep in mind that stress may be variable within the litter, that individuals may not represent the general status of others, and there may be fetal death in one or two fetuses, yet the others are healthy.

Never tell a client the number of puppies or kittens in a litter based on a fetal count using ultrasound because of its unreliability. The most accurate way of determining the number of puppies or kittens in a litter is by radiography (Davidson 2009).

If uterine rupture or hemorrhage is a possibility, then an AFAST³ should be performed (Chapter 2).

Clinical intervention, whether surgical or medical, should not be based solely on ultrasonographic findings because ultrasound cannot evaluate forms of dystocia. Abdominal radiography should be used to assess fetal size relative to the mother's pelvic diameter

to rule out forms of mechanical dystocia. Blood work should be used to rule out metabolic causes of dystocia. History (duration of time between births, duration of hard pushing) and physical examination findings, along with the owner's expectations, must all enter the decision-making process.

Serial Focused Reproductive Exams during Medical Management

The use of ultrasound for monitoring signs of fetal stress during medical management is superior to traditional means. Moreover, its use carries the potential to positively influence the decision-making process regarding medical vs. surgical management, thus optimizing the chance for a favorable outcome for the fetuses, the veterinarian, and the client.

Assess for fetal stress by measuring heart rates prior to each oxytocin injection, or minimally every 30 minutes (Traas 2008). See the correlation between fetal stress and heart rates mentioned above.

Cystic Endometrial Hyperplasia—Pyometra Complex

Cystic endometrial hyperplasia (CEH)-pyometra complex is the most frequent and important uterine disorder in bitches. It occurs during the luteal phase of diestrus, although there are some reports of the condition occurring during anestrus (Verstegen 2008). General classifications of the complex have been suggested according to criteria outlined by Dow and DeBosschere (Bigliardi 2004). Dow's classification scheme uses gross pathology findings and histological lesions, while DeBosschere's scheme also uses the degree of inflammatory reaction, fibroblast proliferation, and endometrium to myometrium ratio. Ultrasonography has been shown to be a valuable tool in the diagnosis of CEH-pyometra and an efficient tool in the identification of more severe disease as described in both Dow's and DeBosschere's schemes (Bigliardi 2004).

Because pyometra should be included in the differential diagnosis for any intact bitch, regardless of the presenting signs, the focused reproductive exam for pyometra is indicated for any ill intact female dog or cat. Ultrasound has a higher sensitivity for determining the presence of uterine enlargement and fluid accumulation than radiography (Feeney 2007). The

scan is similar to that for dystocia with a primary difference of searching for a fluid-filled uterus rather than a gravid (fetus-filled) uterus.

Pyometra

The initial physical exam finding of purulent vaginal discharge should be an immediate trigger for performing an ultrasound exam to determine the presence of pyometra. Conversely, the finding of a fluid-filled uterus should trigger a more thorough search for purulent vaginal discharge that may be subtle or initially overlooked.

Begin the scan in dorsal recumbency. Start over the urinary bladder in longitudinal orientation, moving along the ventral midline from the caudal abdominal region to the xiphoid, as described with the dystocia evaluation. Follow the midline evaluation with the lateral-to-the-mammary gland scan on both the left and right sides to help differentiate the fluid-filled uterus from the urinary bladder and fluid-distended small bowel. Careful scanning should be performed along each horn as thoroughly as possible to avoid a false negative evaluation for pyometra.

The amount and echogenicity of fluid can vary greatly independent of the pyometra being open (cervix open, vaginal discharge) or closed (cervix closed, no vaginal discharge), although a closed pyometra generally leads to a greater degree of fluid distention. Echogenicity of intraluminal fluid in pyometra ranges from anechoic (pure black) to viscous and echogenic (Figure 8.6). In cases with echogenic fluid, its movement may be characterized by slow, swirling patterns (Mattoon 2002).

Remember, there is no ultrasonographically detectable luminal fluid during anestrus and no more than a thin echogenic luminal stripe during estrus in the normal uterus (Verstegen 2008, Mattoon 2002).

Pus can appear anechoic ultrasonographically. Do not misdiagnose benign hydrometra or mucometra for more serious pyometra. Use the rest of your diagnostic information and physical exam clues (presence of vaginal discharge) in the decision-making process.

Pyometra is often diffuse throughout both uterine horns and appears compartmentalized; however, segmental pyometra is also possible in dogs and cats (Verstegen 2008, Johnston 2001).

One form of segmental uterine pathology that is likely misdiagnosed as CEH-pyometra has been termed pseudo-placentational endometrial hyperplasia (PEH). First reported in 1914, PEH also occurs during the luteal phase with the endometrium remodeling in such a way that is very similar to the normal histology of the endometrium at normal placentation sites in pregnancy (Schlafer 2008). While histologically different, clinical presentation and management are the same as for CEH-pyometra. PEH is likely to form approximately two months post-estrus compared to the typical two weeks post-estrus occurrence more common with CEH-pyometra.

The old adage “Don’t let the sun set on a pyometra” holds true. Often spoken by a surgeon, this does not mean that all cases of pyometra should be immediately addressed with the scalpel. The unstable, compromised, septic patient should be resuscitated before being operated upon. By optimizing patient status for anesthesia through the initiation of antibiotics and correction of hypovolemia, hypoglycemia, and acid-base and electrolyte abnormalities, a favorable outcome is more likely. Detailed pre-operative management is beyond the scope of this chapter but may be found in other reference materials (Traas 2008, Johnston 2001).

While surgery remains the best option for the vast majority of cases, medical management has been shown to be a viable therapeutic option for the valuable breeding bitch (Verstegen 2005). Because of the potent drugs and unfamiliarity with protocols by most general practitioners and emergency and critical care veterinarians, medical management is best referred to a small animal specialist in theriogenology or another veterinarian experienced in reproductive work.

Stump Pyometra

A stump pyometra should always be on the differential list of any acute abdomen in a female spayed dog no matter its age. Stump pyometra may occur following ovariectomy if a portion of the uterine horns or uterine body is not removed and the animal has increased progesterone concentrations. Progestins may come from endogenous sources such as residual ovarian tissue, sex-hormone-secreting adrenal tumors, or exogenous sources such as progestational compounds used to treat dermatitis, or they may be potentially absorbed from progestins found in creams used for treatment of menopausal symptoms in women (Howe 2006). Stump pyometra will not occur in a patient that has undergone ovariectomy because there is no “stump.” The entire uterus is left intact. Common

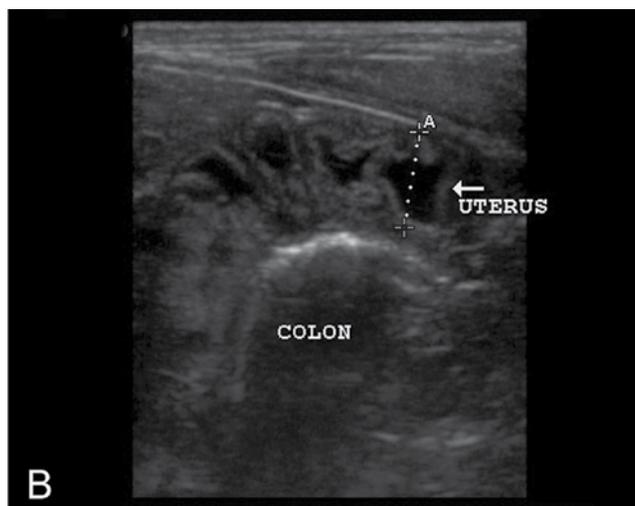
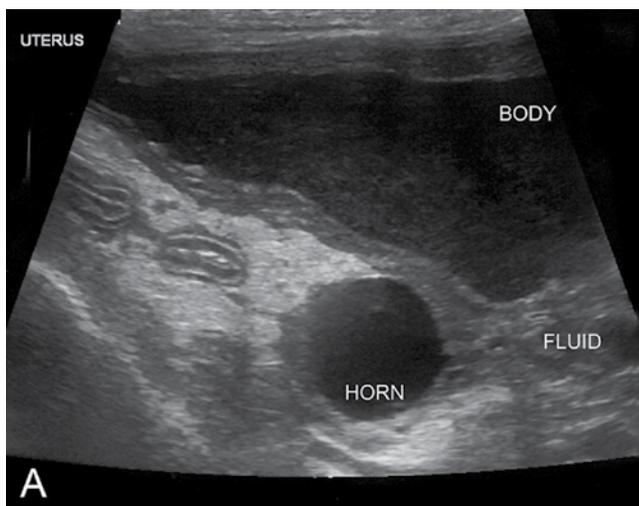


Figure 8.6. Pyometra. (A) There is severe fluid distention of the uterine body and uterine horn of this feline with pyometra. The severely hyperechoic (bright) appearance of the mesentery is consistent with peritonitis. The free fluid noted in the lower right-hand corner warrants an AFAST³ exam, abdominocentesis, and cytology for fluid characterization. This patient was determined to have a septic abdomen caused by a ruptured pyometra, confirmed at surgery. (B) The compartmentalized fluid-filled feline uterus often typical of pyometra is in the near field to the air-filled colon, helping with its identification. (C) In a severely enlarged, distended pyometra, uterine compartmentalization can be less obvious; however, the uterine wall is much different in appearance than the multi-layered small bowel. (D) A gross correlation of the ultrasound findings in (C) to the severe uterine distension found in a pyometra at surgery. (E) A final classic image from a dog showing the fluid-filled compartmentalization typical of pyometra.

in European nations, the procedure is beginning to gain popularity in the United States. The same concerns for the development of pyometra (endogenous or exogenous progestin exposure) exist as for stump pyometra but at least one study of 72 bitches that underwent ovariectomy did not show any incidence of pyometra over a six- to eight-year follow-up period (Howe 2006).

The focused reproductive exam for stump pyometra is identical to that for pyometra; however, the primary area of interest is the caudal abdomen, specifically the region between the trigone of the bladder and colon. This area should be searched for an area of mixed echogenicity indicative of complex mass effect (Davidson 2009, England 2003). Other local diseases mimicking or causing a stump pyometra include stump granuloma caused by excess residual devitalized uterine body tissue, use of inappropriate suture material, or poor surgical asepsis. Additionally, hematoma formation caused by poor surgical technique or a coagulopathy can serve as a nidus for infection. The finding of free fluid suggestive of acute hemorrhage or peritonitis is another indication for the AFAST³ scan and application of an abdominal fluid score (see Chapter 2). Free fluid may only be characterized by abdominocentesis. If the case is not urgent (i.e., does not have a septic abdomen or large bleed) then a complete abdominal ultrasound may be warranted.

Uterine Torsion

Uterine torsion in the dog and cat is uncommonly reported. However, the ultrasonographic appearance is the same as expected for pyometra. The diagnosis of uterine torsion is typically made at surgery (Misumi 2000, Chambers 2011).

Uterine torsion is an emergent surgical condition that cannot be definitively diagnosed by ultrasound.

Mounting of Post-Operative Recently Estrous Spayed Females

In-heat (estrous) spayed females should be kept away from male dogs for two weeks post-operatively because they remain receptive to interested males. Mounting post-operatively can lead to trauma and rupture of the surgical site and insemination of the peritoneal cavity, leading to potentially life-threatening sterile or septic peritonitis (Morley 2006). AFAST³ is the scan best suited for determining peritonitis (evidence of free fluid) with characterization by abdominocentesis.

Pseudopregnancy

All bitches experience the same progesterone profile whether they become pregnant or not. As the progesterone falls at the end of diestrus, some bitches experience overt signs of eminent whelping with fully developed mammary glands with milk let-down, nesting behavior, and even abdominal contractions (Johnston 2001). Although rare, the queen may also show signs of pseudopregnancy. The owners may be convinced their female dog has not been bred; however, we are all aware of unsupervised receptive females left in the backyard becoming pregnant. A focused reproductive exam will reliably confirm or refute the presence of fetuses.

Mammary Glands

The normal developed mammary gland at parturition has a homogeneous appearance. The larger blood vessels may be noted entering the gland. With disease such as mastitis and neoplasia, there is loss of the homogeneous appearance (Mattoon 2002). The ultrasonographic appearance of mammary gland neoplasia can be quite variable depending on its severity. Small mammary tumors may appear as poorly defined hypoechoic structures with acoustic enhancement artifact, and larger tumors may appear hyperechoic, sometimes with the presence of cysts (Figure 8.7). The spread of tumor tissue among the mammary glands can be successfully

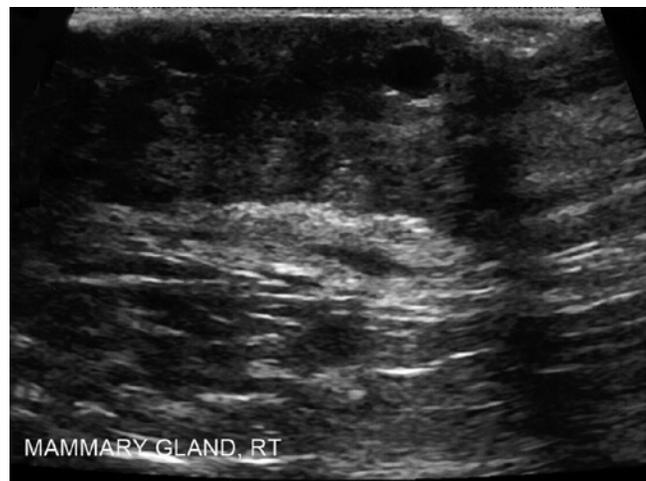


Figure 8.7. The ultrasonographic appearance of mammary gland neoplasia can be quite variable. Small mammary tumors may appear as poorly defined hypoechoic (dark) structures with acoustic enhancement artifact in the far field, and larger tumors may appear hyperechoic, sometimes with the presence of cysts. Shown here is a mammary gland adenocarcinoma from a cat with typical mixed echogenicity. Cytological or histopathological evaluation is necessary for a definitive diagnosis.

detected by ultrasound, which is very sensitive for detecting such lesions. The involvement of the regional lymph nodes (axillary and superficial inguinal) can also be successfully scrutinized for abnormal changes. Ultrasound, however, cannot determine whether lymphadenopathy is due to metastatic spread of tumor tissue or due to inflammatory reaction (Zuki 2004).

Reproductive Conditions of the Male

The male less commonly has indications for the focused reproductive exam. The technique is useful for canine prostatic, scrotal, and testicular problems, including cryptorchidism. Interestingly, most male scans are performed on dogs. The feline male seems immune to most reproductive conditions.

The Prostate

All male dogs have a prostate, neutered or not (Figure 8.8). It is the dog's only accessory sex gland and it increases in size and weight with age due to glandular hyperplasia (Johnston 2002). Interestingly, the neutered male is more prone to prostatic neoplasia (prostatic adenocarcinoma) than the intact male (Root-Kustritz 2010). The finding of an enlarged prostate in any neutered (at an early age) male should be considered neoplastic until proven otherwise. Ultrasound may be helpful as an adjunctive test (for aspirates, biopsies); however, a digital rectal

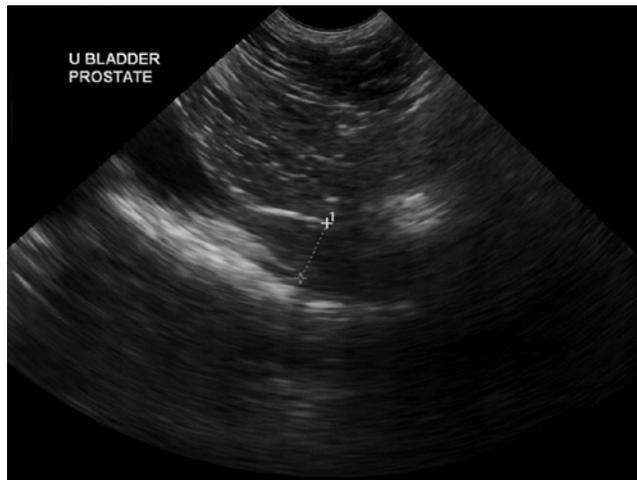


Figure 8.8. The normal prostate gland in a castrated dog. The prostate (denoted by the caliper marks, +--+) is of a medium echogenicity, similar to that of the normal canine uterus.

exam is invaluable for determining the presence of prostatic enlargement in neutered males. Intact male dogs, on the other hand, have several possible conditions such as benign prostatic hypertrophy, bacterial prostatitis, prostatic abscesses, prostatic cysts, and paraprostatic cysts. Thus, the focused reproductive exam can be helpful in sorting through these conditions.

Imaging the Prostate

To image the prostate, place the dog in dorsal recumbency. Find the prostate by locating the urinary bladder. Move your probe to longitudinal orientation and then follow caudally the bladder until it narrows into the trigone region. Now, focus on the urethra (an anechoic linear stripe in longitudinal, an anechoic circle in transverse). Once you have the urethra in the long-axis, follow it caudally a short distance to the prostate. The standing position may also be used for prostatic imaging.

Do not walk the patient (dogs) or give a litter box (cats) before the exam. The urine-filled bladder improves imaging (ultrasound loves fluid; provides an acoustic window) and serves as a landmark in identifying caudal abdominal structures.

A healthy prostate is bilobed and symmetrical. The symmetry is readily appreciated in transverse orientation. With the exception of ductal tissue, the prostatic parenchyma is homogeneous in appearance. The echogenicity is similar to the surrounding fat but it has a finer echotexture (Lattimer 2007).

A hyperechoic butterfly pattern is typically apparent in the transverse view. The butterfly corresponds with distribution of relatively more hyperechoic (brighter) ductal tissue than the hypoechoic glandular connective tissue (Davidson 2009, Mattoon 2002).

Stay transverse and assess symmetry (normal) and homogeneous echogenicity other than the butterfly. Some veterinary radiologists more easily image the prostate with the dog in a standing position.

Benign Prostatic Hypertrophy (BPH)

The ultrasonographic appearance of benign prostatic hypertrophy (BPH) is enlarged and uniformly hyperechoic with a smooth margin. The enlargement may be

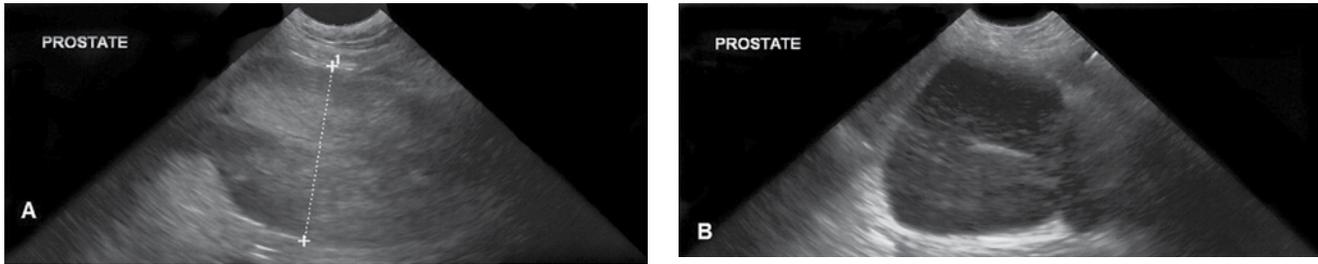


Figure 8.9. Benign prostatic hypertrophy. (A) The prostate is enlarged and relatively hyperechoic (brighter), consistent with benign prostatic hypertrophy. (B) The prostate gland is diffusely hypoechoic (darker). In this image the patient was diagnosed on cytological evaluation with prostatic lymphoma.

different between dorsal and ventral areas, but the enlargement is symmetrical when viewed in the transverse plane (Figure 8.9A). In time, the expected symmetry and uniform echogenicity of BPH may be lost as the condition progresses into the cystic stage (Lattimer 2007).

Prostatitis

The ultrasonographic appearance of prostatitis varies widely, depending on severity of disease. The shape is generally normal but the echogenicity may increase or decrease and some degree of mottling (mixed echogenicity) is appreciated. A hypoechoic rim may be evident in some dogs. If prostatitis is severe enough, surrounding fat may become hyperechoic (bright) (Lattimer 2007).

Prostatic Abscesses and Cysts

With ultrasound, abscesses and cysts may be found within or attached to the prostatic parenchyma. Each are typically thin-walled structures with either anechoic or hypoechoic centers. The presence or absence of acoustic enhancement in the far field helps differentiate fluid from soft tissue. Septation and echogenic fluid is more suggestive of prostatic abscess rather than cyst(s) (Lattimer 2007).

Paraprostatic Cysts

In contrast to prostatic cysts, which are found within the prostatic parenchyma, paraprostatic cysts are found adjacent to the gland and may appear confluent with it. They are thin-walled structures of varying size, often appearing similar to the urinary bladder. The fluid contained within the paraprostatic cyst may be anechoic to echoic with or without intraluminal debris (Davidson 2009). Paraprostatic cysts are thought to be

remnants of or associated with remnants of the Müllerian duct (Davidson 2009, Smith 2008).

When a paraprostatic cyst is suspected it is often immediately helpful to catheterize the patient and radiographically perform a positive contrast study to define the location of the urinary bladder compared to the possible paraprostatic cyst.

Prostatic Neoplasia

With ultrasound, prostatic neoplasia may show similarities to prostatitis, abscesses, or cysts (Figure 8.9B). Calcification and severe loss of symmetry suggest malignancy. Calcification results in bright echoes with strong acoustic shadowing. This finding should prompt aspiration or needle biopsy. Additionally, there is often severe loss of architecture with advanced neoplastic disease (Lattimer 2007).

The ultrasonographic appearance of the prostate should not be the sole determinant in making a specific diagnosis. Digital rectal examination provides clues to firmness, symmetry, and pain. Tissue sampling, either by aspirate or biopsy, is typically required to make the definitive diagnosis, and culture is recommended for suspected cases of bacterial infection. Fine-needle aspiration has been shown to diagnosis prostatic carcinoma in about 50% of cases, and biopsy has been reported to improve diagnosis to as high as 89% (Johnston 2001).

The Scrotum and Testicles

The descended scrotal testicles are easy to image using ultrasound (Figure 8.10). Keeping with previous probe positioning recommendations, begin with longitudinal orientation. A thin, hyperechoic line, the mediastinum testis, is easily identified in the center of the organ. By placing both testicles side by side, transverse imaging

allows for assessing differences between the testicles regarding echogenicity and texture. The epididymis begins dorsocaudally and is hypoechoic to the testicular parenchyma (Davidson 2009).

The testicular parenchyma is a medium gray with a homogeneous pattern, similar to the spleen (Davidson 2009). The testes should be the same size. The tunica albuginea, the dense white fibrous capsule that immediately covers the testicle, is hyperechoic (brighter) compared to the parenchyma (Johnson 2001).

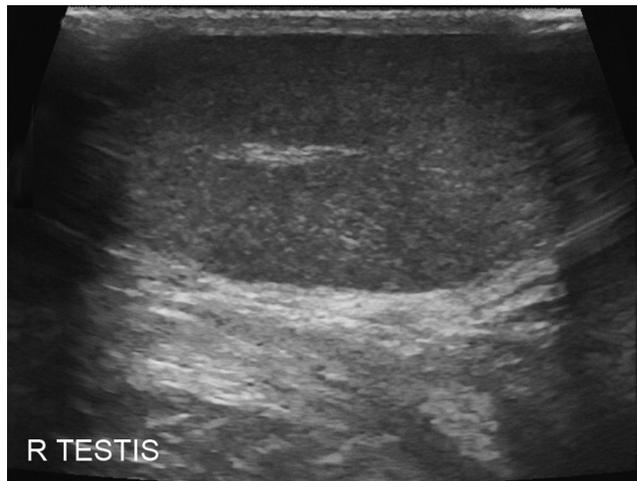
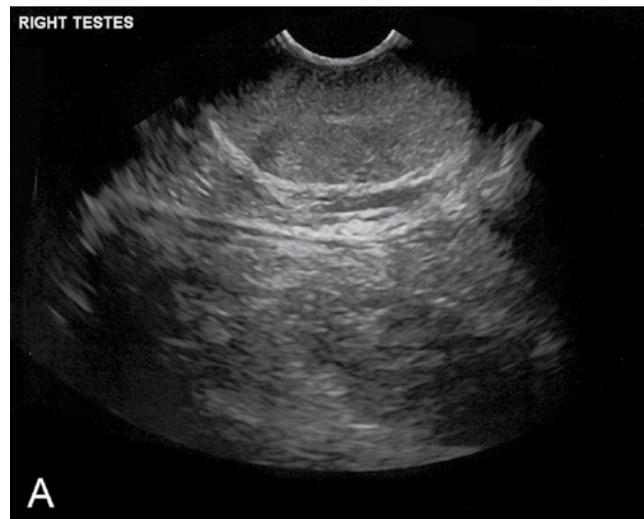


Figure 8.10. Normal canine testicle. The parenchyma is homogeneous and of medium echogenicity, similar to the spleen. The hyperechoic (bright white) line in the center represents the mediastinum testes, or the testicular landmark.



Cryptorchidism

Cryptorchidism (“hidden testis”) is a heritable, developmental defect in which descent of one or both testes does not occur by six months of age. Unilateral cryptorchidism is more common than bilateral. Retained testes are smaller than scrotal testes with size directly correlated with the degree of retention. Abdominally retained testes are smaller than inguinally retained testes (Johnston 2001).

During ultrasonographic scan, the cryptorchid testes, while smaller than the scrotal testes, often retain their normal anatomic structure, including the mediastinum testes with normal expected echogenicity. The retained testicle may be located anywhere from the inguinal canal to the ipsilateral kidney (Davidson 2009); however, the inguinal location is more common. The cryptorchid testes can be difficult to find (Johnston 2001).

The scan is performed in lateral recumbency with the contralateral side down. The ipsilateral leg is raised to allow access to the inguinal region. With the probe in longitudinal orientation, a systematic scan is advanced from the inguinal canal to the caudal pole of the ipsilateral kidney. The lateral positioning allows for gravity to pull viscera away from the inguinal and retroperitoneal areas of interest, improving ultrasonographic imaging.

Orchitis and Epididymitis

Orchitis (inflammation of the testicle) and epididymitis may occur singly or in combination and are typically painful. Acute orchitis is usually characterized by enlargement of the testicle, with the parenchyma taking on a patchy, hypoechoic texture (Figure 8.11).



Figure 8.11. Orchitis may be unilateral, as is seen in this dog. (A) Normal sized right testicle. (B) Affected left testicle. Note the irregular texture of the affected testicle as well as the degree of enlargement. Both images were obtained with the same ultrasound settings.

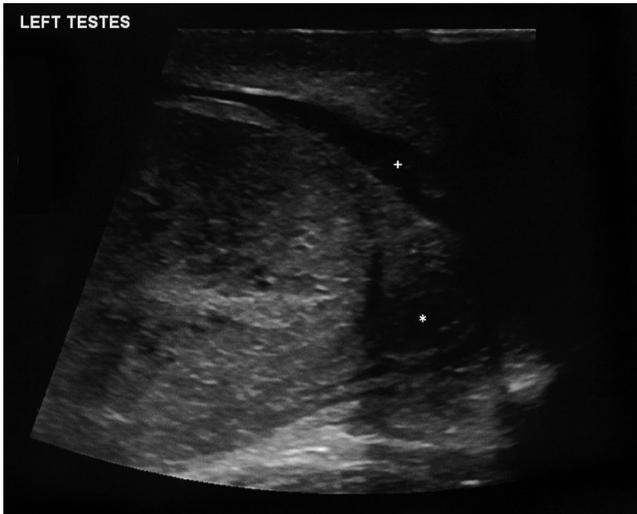


Figure 8.12. The head of the inflamed epididymis (marked with an asterisk [*]) is seen as an ovoid hypoechoic structure (dark) to the lower right of the testicle in this dog. Also note the hypoechoic (dark) rim (marked with a plus sign [+]) around the testicle.

Epididymitis is characterized by testicular enlargement with focal parenchymal changes. Fluid may be evident around the testicle or epididymis with either condition (Feeny 2007, Davidson 2009) (Figure 8.12).

The immunocompetent human tends to be more resistant to *Brucella canis* (*B. canis*) infection than other species; however, the immunocompromised individual, children, and pregnant women are considered to be of higher risk and should avoid exposure (Johnston 2001). Care must be taken to protect yourself and other members of the health care team by following standard procedures such as wearing exam gloves and avoiding contact with or aerosolization of body fluids. Proper disinfection of surfaces and equipment is mandatory. Rapid slide agglutination tests (RSAT) are available for quick screening and agar gel immunodiffusion (AGID) can be used to confirm suspected cases. Serologic tests have their limitations because *B. canis* evokes little humoral response. Recent advances in molecular biology have yielded polymerase chain reaction (PCR) tests but are not yet widely available. A positive identification of the causative organism from blood culture is the definitive proof for brucellosis (Hollett 2010).

Acute orchitis and epididymitis can be caused by zoonotic diseases including brucellosis, which should be considered in all sexually active males.

Testicular Torsion

Testicular torsion is more appropriately termed torsion of the spermatic cord. Dogs typically present with signs of an acute abdomen including abdominal pain, vomiting, dysuria, hematuria, pyrexia, anorexia, lethargy, or stiff gait. Other physical exam findings may be related to concurrent testicular neoplasia such as truncal, symmetric alopecia, or a pendulous prepuce seen with Sertoli cell tumors.

The intra-abdominal cryptorchid spermatic cord is more often affected in torsions than the scrotal cord (Johnson 2001).

The testicle of the affected cord is typically enlarged and has a uniform hypoechoogenicity. There may or may not be fluid associated with the epididymis. Absence of blood flow when interrogated with color flow Doppler or power Doppler imaging is the most telling sign ultrasonographically; definitive diagnosis is made at the time of surgery, which is the treatment of choice (Johnson 2001).

Testicular Tumors

Testicular neoplasia is the most common tumor type in male dogs, second only to skin tumors. Tumors may be unilateral or bilateral, and different tumors may be present within the same testicle. The three most common types of tumor are Sertoli cell tumor, seminoma, and interstitial (Leydig) cell tumors. Dogs with testicular neoplasia commonly present with testicular enlargement as the only sign; however, dogs with Sertoli cell tumor may present with bone marrow toxicity (anemia), symmetrical truncal hair loss, and male feminization due to excessive estrogen production (Johnston 2001). Testicular tumors may appear as focal masses of varying degrees of distinction from surrounding parenchyma with varying degrees of echogenicity (Davidson 2009). Ultrasonographic appearance is not specific for tumor cell type and cannot differentiate between benign and malignant conditions (Feeny 2007).

The enlarged testicle in the older dog in the absence of testicular pain prioritizes neoplasia over orchitis (Johnston 2001).

Miscellaneous Scrotal Swellings

Herniation of small bowel into the scrotum may be detected by finding the normal bowel layers adjacent to the testes; intestinal peristalsis may also be present,

helping with the ultrasonographic diagnosis (also see chapters 7, 13, and 15) (Mattoon 2002).

Hematomas, abscesses, and sperm granulomas may all appear similar to other extratesticular pathology. These causes of scrotal swellings often have poorly demarcated margins with variable echogenicity and texture (Foster 2010).

Hydrocele, or non-inflammatory fluid within the scrotum, may occur in cases of ascites (Foster 2010).

Pearls and Pitfalls, the Final Say

Ultrasonography is an invaluable tool in diagnosing and managing many reproductive cases. While many clinicians just consider ultrasound for pregnancy diagnosis, consider how you may incorporate the focused reproductive examinations in your practice to address concerns in both males and females:

- The cervix may be difficult to differentiate from the uterine body so do not spend too much time attempting to precisely localize the structure. Any free fluid within the uterus beyond the thin echogenic stripe of estrus is considered abnormal.
- When considering the presence of dystocia, there are three main questions regarding dystocia that can readily be answered ultrasonographically: (1) Is the bitch or queen pregnant? (2) Are the fetuses alive? (3) Are the fetuses stressed?
- If you have difficulty finding fetuses, then pregnancy is unlikely. Even in single pregnancies, the puppy or kitten is typically readily imaged.
- Term fetuses are easy to identify. With their anatomy formed in miniature, internal fetal structures are recognizable in normalcy and the layering of the small intestine is the last to form *in utero*.
- Normal canine or feline fetal heart rates should be greater than 180 beats/minute and are commonly well above 200 beats/minute. Developing fetal stress is evidenced by the fetal heart rates dropping below 180 beats/minute. Keep in mind that variability in fetal stress exists; one fetus with a normal heart rate does not mean that the entire litter is healthy and not stressed.
- Never tell a client the number of puppies or kittens in a litter based on a fetal count using ultrasound because of its unreliability. The most accurate way of determining the number of puppies or kittens in a litter is by radiography.
- The serial use of ultrasound (as frequent as every 30 minutes) for monitoring signs of fetal stress during medical management is superior to traditional means and its use carries the potential to positively influence the decision-making process regarding medical vs. surgical management, optimizing the chance for a favorable outcome for the fetuses, the veterinarian, and the client.
- Pyometra is often diffuse throughout both uterine horns and appears compartmentalized; however, segmental pyometra is also possible in dogs and cats. Keep in mind that pus can appear anechoic (homogeneous black) ultrasonographically so do not misdiagnose benign hydrometra or mucometra for more serious pyometra.
- Uterine torsion is an uncommonly reported emergent surgical condition that cannot be definitively diagnosed by ultrasound. However, the ultrasonographic appearance is the same as expected for pyometra. The diagnosis of uterine torsion is typically made at surgery.
- Pseudopregnancy is readily diagnosed with a focused reproductive exam because the by using ultrasound fetuses are readily identified.
- Do not walk the patient (dogs) or give a litter box (cats) before the exam. The urine-filled bladder improves imaging (ultrasound loves fluid; provides an acoustic window) and serves as a landmark in identifying caudal abdominal structures in both sexes.
- Stay transverse when imaging the canine prostate and assess symmetry (normal) and homogeneous echogenicity other than the hyperechoic landmark of the so-called butterfly. Some veterinary radiologists more easily image the prostate with the dog in a standing position.
- The ultrasonographic appearance of the canine prostate should not be the sole determinant in making a specific diagnosis. Digital rectal examination provides clues to firmness, symmetry, and pain. On the other hand, the tom cat appears to be immune to any and all forms of prostatic disease.
- Testicular torsion is more appropriately termed torsion of the spermatic cord. Dogs typically present with signs of an acute abdomen including abdominal pain, vomiting, dysuria, hematuria, pyrexia, anorexia, lethargy, or stiff gait. The intra-abdominal cryptorchid spermatic cord is more often affected in torsions than the scrotal cord.

References

- Bigliardi E, Parmigiani E, et al. 2004. Ultrasonography and cystic hyperplasia-pyometra complex in the bitch. *Repro Dom Anim* 39;136–140.
- Chambers B, Laksito M, Long F, et al. 2011. Unilateral uterine torsion secondary to an inflammatory endometrial polyp in the bitch. *Aust Vet J* 59(8):350–354.
- England G, Yeager A, Concannon P. 2003. Ultrasound imaging of the reproductive tract of the bitch. In *Recent Advances in Small Animal Reproduction*, edited by PW Concannon, G England, J Verstegen, C Linde-Forsberg. Ithaca, New York: International Veterinary Information Service.
- Davidson A, Baker T. 2009. Reproductive ultrasound in the bitch and queen. *Topics in Companion Animal Medicine* 24(2):55–63.
- Davidson A, Baker T. 2009. Reproductive ultrasound of the dog and tom. *Topics in Companion Animal Medicine* 24(2):64–70.
- Davidson A, Baker T. 2009. Neonatal and pediatric ultrasonography—part II. *Clin Theriogenology* 1(1):156–150.
- Feeny D, Johnston G. 2007. The uterus, ovaries, and testes. In *Textbook of Veterinary Diagnostic Radiology, 5th Edition*, edited by Thrall DE. St Louis: Saunders, Elsevier, pp 735–749.
- Foster R. 2010. Pathology of male reproductive organs. *Clin Theriogenology* 2(4):531–544.
- Hollett B. 2010. Update on canine brucellosis. *Clin Theriogenology* 1(2):257–295.
- Howe L. 2006. Surgical methods of contraception and sterilization. *Theriogenology* 66:500–509.
- Johnston S, Root-Kustriz M, Olson P. 2001. Canine parturition—eustocia and dystocia. In *Canine and Feline Theriogenology*. Philadelphia: WB Saunders, pp 105–128.
- Johnston S, Root-Kustriz M, Olson P. 2001. Disorders of the canine prostate. In *Canine and Feline Theriogenology*, edited by S Johnston, M Root-Kustriz, and P Olson. Philadelphia: WB Saunders, pp 337–355.
- Johnston S, Root-Kustriz M, Olson P. 2001. Disorders of the canine testes and epididymes. In: *Canine and Feline Theriogenology*, edited by S Johnston, M Root-Kustriz, and P Olson. Philadelphia: WB Saunders, pp 312–332.
- Johnston S, Root-Kustriz M, Olson P. 2001. Disorders of the feline uterus and uterine tubes (oviducts). In *Canine and Feline Theriogenology*, edited by S Johnston, M Root-Kustriz, and P Olson. Philadelphia: WB Saunders, pp 463–471.
- Johnston S, Root-Kustriz M, Olson P. 2001. Disorders of the mammary glands of the bitch. In *Canine and Feline Theriogenology*, edited by S Johnston, M Root-Kustriz, and P Olson. Philadelphia: WB Saunders, pp 243–256.
- Lattimer J, Essman S. 2007. The prostate gland. In *Textbook of Veterinary Diagnostic Radiology, 5th ed.*, edited by Thrall DE. St Louis: Saunders, Elsevier, pp 729–737.
- Lopate C. 2008. Estimation of gestational age and assessment of canine fetal maturation using radiology and ultrasonography: A review. *Theriogenology* 70: 397–402.
- Mattoon J, Nyland T. 2002. Ovaries and uterus. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by T Nyland and J Mattoon. Philadelphia: WB Saunders, pp 231–249.
- Misumi K, Fujiki M, Miura N, et al. 2000. Uterine horn torsion in two non-gravid bitches. *J Small Anim Pract* 41(8):465–71.
- Morley DL. 2006. Acute peritonitis secondary to traumatic breeding in the bitch. *J Vet Emerg Crit Care* 16(2) 128–130.
- Nyland T, Mattoon J, Herrgesell E, et al. 2002. Physical principles, instrumentation, and safety of diagnostic ultrasound." In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by T Nyland and J Mattoon, pp 1–18. Philadelphia: WB Saunders, pp 1–18.
- Root-Kustritz M. 2010. Pathogenesis of prostatic neoplasia in castrated dogs: why the increased risk? *Clin Theriogenology* 2(3):152–154.
- Serrano S, McMillian M. 2009. Dystocia. *Standards of Care, Emergency and Critical Care Medicine* 11(1):1–11.
- Smith F. 2008. Canine pyometra. *Theriogenology* (66):68–612.
- Smith J. 2008. Canine prostatic disease: A review of anatomy, pathology, diagnosis, and treatment. *Theriogenology* (70): 375–353.
- Traas AM. 2008. Surgical management of canine and feline dystocia. *Theriogenology* 40:337–342.
- Verstegen J, Dhaliwal G, Verstegen-Onclin K. 2008. Mucometra, cystic endometrial hyperplasia, and pyometra in the bitch: Advances in treatment and assessment of future reproductive success. *Theriogenology* 70:364–374.
- Yeager AE, Mohammed HO, Meyers-Wallen V, et al. 1992. Ultrasonographic appearance of the uterus, placenta, fetus, and fetal membranes throughout accurately timed pregnancy in beagles. *Am J Vet Res* 53:342–351.
- Zuki ABZ, Boyd JS. 2004. Ultrasonographic imaging of neoplasia of the canine mammary glands and their regional lymph nodes. *J Anim Vet Advances* 3: 604–612.

THE THORACIC FAST³ (TFAST³) EXAM

Gregory R. Lisciandro

Introduction

The clinical utility of the novel veterinary thoracic focused assessment with sonography for trauma (TFAST) scan was documented in a large prospective study of 145 dogs incurring both blunt and penetrating trauma (Lisciandro 2008). The primary objective was to determine the accuracy, sensitivity, and specificity of using TFAST, an abbreviated ultrasound scan, for the rapid detection of pneumothorax (PTX), dubbed the most preventable cause of death in traumatized people (Kirkpatrick 2004). Secondary objectives included the detection of other injuries including those within the pleural and pericardial spaces and involving the thoracic wall and lungs. The sensitivity and specificity for the detection of PTX by the most experienced sonographer was greater than 95% using thoracic radiography as the gold standard, thus proving that thoracic ultrasound (US) could be used as a first-line screening test in blunt and penetrating trauma (Lisciandro 2008).

More recently, the clinical uses for TFAST have extended beyond trauma (similar concept with AFAST³) (Rozycki 2001, Lisciandro 2011). The original TFAST acronym has evolved into “TFAST³” with the “T³” referring to its use for trauma, triage, and tracking (monitoring) (Lisciandro 2011). Patient care and clinical course is potentially improved by rapidly detecting conditions and complications in various subsets of patients by using TFAST³ as an “extension of the physical examination” (Rozycki 2001, Lisciandro 2011). In other words, this abbreviated US exam detects conditions that would be occult by traditional means of physical examination, vital signs, laboratory findings, and thoracic radiography. TFAST³ has more recently

included a more comprehensive novel lung surveillance called the Vet (veterinary) Bedside Lung Ultrasound Exam (BLUE) that extends beyond the TFAST³ chest tube site (CTS) (see Chapter 10).

By adding the Vet BLUE to the TFAST³ exam, the clinical utility of thoracic ultrasound now more comprehensively includes many non-trauma subsets of patients. For example, when TFAST³ and Vet BLUE are applied to all respiratory distress cases, it becomes possible to rapidly categorize lung conditions (upper vs. lower airway lung disease) and non-respiratory causes of distress (pleural and pericardial space conditions) vs. non-pulmonary causes (high fever/pyrexia, hemoabdomen, severe metabolic acidosis, etc., so called non-respiratory look-a-likes) (see Table 10.1, Chapter 10). TFAST³ and Vet BLUE are also helpful when applied to apparently recovered cases of uncharacterized hypotension (collapse, seizure suspects, generalized weakness) and in all hospitalized and post-interventional cases at risk for intrathoracic complications (pneumothorax, hemothorax, pyothorax, pulmonary edema, pneumonia, and others). Moreover, by adding AFAST³ to TFAST³ and Vet BLUE, a complete rapid global surveillance (called global FAST³ or GFAST³) is performed, including the interrogation of the pleural, pericardial, peritoneal, and retroperitoneal spaces and lung (see Chapter 16). In other words, it is a quad-cavity evaluation plus lung.

Finally and importantly, lung US has been considered the modern stethoscope, exceeding chest auscultation and supine chest radiography with regard to sensitivity and specificity in human patients for pneumothorax, pleural effusion, lung consolidation, and interstitial syndrome in the critical care setting (Filly

1988, Lichtenstein 2008, Volpicelli 2012) (see Chapter 10). Likewise, US is arguably the gold standard for the diagnosis of pericardial effusion (Reissig 2011).

In summary, FAST³ saves lives by rapidly detecting both life-threatening and potentially life-threatening conditions that have historically been occult or delayed in diagnosis by the traditional means of physical examination, vital signs, and laboratory and radiographic findings, and the delay in arranging complete (or formal) ultrasound scans. By using these abbreviated US techniques to rapidly answer clinical questions, patient care is positively affected (Blackbourne 2004, Ollerton 2006, Rozycki 2001, Lisciandro 2008, 2009, 2011).

What TFAST³ Can Do

- With proper training, can rapidly detect pneumothorax in traumatized dogs and cats with high accuracy, sensitivity, and specificity
- Determine the degree, or severity, of pneumothorax as partial vs. massive by finding the lung point
- Detect and monitor pleural effusion, initially and serially
- Detect and monitor pericardial effusion, initially and serially
- Detect and monitor lung contusions, initially and serially
- Detect thoracic wall, pleural space, and lung pathology through the presence of the step sign
- Assess volume status and contractility by using the TFAST³ right pericardial site (PCS) view to evaluate the left ventricular short-axis mushroom view
- When combined with the Vet BLUE, can assess left-sided cardiac status (e.g., presence of left-sided failure [cardiogenic pulmonary edema]) by the presence or absence of ultrasound lung rockets
- Assist in respiratory distress evaluation, rapidly determining pulmonary vs. cardiac causes based on regional lung ultrasound patterns, when combined with the Vet BLUE (see Chapter 10).
- When combined with Vet BLUE can assist in respiratory distress cases by rapidly supporting types of lung disease including forms of pulmonary edema (cardiogenic, non-cardiogenic), pneumonia, and neoplastic conditions (see Chapter 10) based on regional lung distribution of ultrasound signs
- Serially monitor intrathoracic conditions including pleural, pericardial, and heart and lung conditions cageside in place of serial radiography or computerized tomography (CT).

What TFAST³ Cannot Do

- Cannot characterize pleural fluid. A diagnostic thoracocentesis is necessary
- Cannot characterize pericardial fluid. A diagnostic pericardiocentesis is necessary
- Cannot fully replace thoracic radiography
- Cannot diagnose non-thoracic causes of respiratory distress (so called non-respiratory look-a-likes) such as hemoabdomen, anaphylaxis, and other causes of acute abdomen, and retroperitoneal conditions such as bleeding from adrenal, vena caval, and aortic sources. Therefore, TFAST³ should be combined with AFAST³ and Vet BLUE (see chapters 2 and 10)
- TFAST³ is limited without adding on the Vet BLUE lung scan for diagnosing lung conditions and pleural effusions.

It is important to note that Vet BLUE should be considered as an extension of TFAST³ and used routinely as an add-on for more comprehensive lung and pleural effusion surveillance.

Indications for the TFAST³ Exam

- Blunt and penetrating trauma
- All forms of respiratory distress when combined with Vet BLUE (see Chapter 10)
- Monitoring pneumothorax
- Determining the degree of pneumothorax (partial vs. massive) using the location of the lung point to assess its severity (trivial, mild, moderate to severe PTX)
- Monitoring pleural and pericardial effusive conditions
- Monitoring worsening and resolution of lung contusions, pneumonia, neoplastic conditions (response to therapy, recurrence), and cardiogenic and non-cardiogenic pulmonary edema when combined with the Vet BLUE (see Chapter 10)
- Monitoring the use of diuretics for various conditions such as left-sided heart failure, non-cardiogenic pulmonary edema, and volume overload by using the wet lung vs. dry lung principles for detecting the presence, degree of, and resolution of these causes of interstitial edema when combined with the Vet BLUE (Chapter 10)
- Surveying at-risk patients for pneumothorax and pleural and pericardial effusion, including post-interventional procedures (thoracic surgery, thoracoscopy, and lung lobe aspirates), mechanical ventilation, and general anesthesia cases

It is important to note that in unstable patients with imminent cardiopulmonary arrest, life-saving thoracocentesis trumps TFAST³. With that being said, TFAST³ (with Vet BLUE) is more accurate and often take less time than thoracic auscultation when done by properly trained veterinarians.

Objectives of the TFAST³ Exam

- Rapidly diagnose pneumothorax
- Identify the lung point
- Semi-quantitate the degree or severity of pneumothorax by the distance from the chest tube site to the lung point
- Rapidly determine the presence of pleural and pericardial space conditions
- Identify a basic lung conditions
- Assess patient volume status

Please note that Vet BLUE should be considered as an extension of TFAST³ and should be used routinely as an add-on for more comprehensive lung and pleural effusion surveillance.

Ultrasound Settings and Probe Preferences

To conduct a TFAST³ exam use a curvilinear probe with a range of 5–10 MHz. A linear probe may also be used for lung ultrasonography (see Chapter 10) and a phased-array sector probe may be used for cardiac imaging. Use either the abdominal or cardiac setting, depending on how your US machine performs. Some US machines provide better imaging on abdominal settings rather than cardiac settings. This also can vary between patients. The focus cursor, when featured, should be placed at the level of the point of interest, which is across from the pulmonary-pleural interface, while evaluating lung. The depth is generally set between 4–6 cm to get an adequate image of a complete intercostal space. In smaller dogs/puppies and cats/kittens several intercostal spaces may be apparent at this depth (also acceptable).

How to Do a TFAST³ Exam

Patient Positioning

In non-respiratory-compromised patients, right lateral recumbency (vs. left lateral recumbency) is generally preferred because it is the standard positioning

for electrocardiographic and echocardiographic evaluations, and it may be more reliable (than left lateral recumbency) for gallbladder, caudal vena caval, and hepatic venous imaging. Lateral recumbency (vs. sternal or standing) lends itself to efficiently performing four of the five TFAST³ views before moving the veterinary patient to sternal for the final opposing CTS view (Figure 9.2, below). When performing AFAST³ and TFAST³ in tandem (referred to as combo FAST³ or CFAST³ [Lisciandro 2012]), six of the eight total views for CFAST³ are performed on the same (or nearly the same) ultrasound settings while the patient is laterally recumbent. The patient is then moved to sternal recumbency (and the machine changed to less depth for lung imaging) for the remaining TFAST³ CTS views (as well as Vet BLUE; also see Figure 16.1D).

The abdominal (preset) setting works well for TFAST³ in the majority of cases. Note that the screen marker must be reversed for standard cardiac images; however, this reversing is not necessary as long as basic identification skills are applied to the respective cardiac chambers.

Sternal recumbency or standing is used for TFAST³ (and the Vet BLUE lung scan) in all respiratory-compromised patients (Lisciandro 2008, 2011). When combined with AFAST³ a modified sternal recumbency positioning is used in which the forelegs are in sternal recumbency and hind legs moved laterally to one side as the patient allows.

A tip for gaining a cardiac imaging advantage is to place a rolled towel under the forelegs of a sternally recumbent patient, thus elevating the sternum off the exam table and optimizing maneuverability of the ultrasound probe (Figure 9.1B and C).

Dorsal recumbency should never be used for several important reasons including the invalidation of the AFAST-applied fluid scoring system (validated only in lateral recumbency, see Chapter 2) (Lisciandro 2009) and the increased stress in dorsal recumbency to respiratory and hemodynamically compromised patients (Boysen 2004; Sigrist 2004, 2011; Lisciandro 2008, 2009).

Dorsal recumbency risks clinical decompensation in compromised patients and should never be used for TFAST³ exams.



Figure 9.1. TFAST³ positioning for respiratory-compromised dogs and cats. (A) Photo showing how TFAST³ (and Vet BLUE) is performed in a dog in the standing position while being masked oxygen. (B and C) Photos showing how TFAST³ (and Vet BLUE) is performed in sternal recumbency in cats with respiratory distress. By propping the cat on a roll of paper towels (or a towel), imaging the pericardial sites is facilitated and the feline (concentrating on breathing) generally incurs little stress. The scan is often faster and is more objective than traditional thoracic auscultation. Figure (C) Courtesy of Dr. Terri DeFrancesco, North Carolina State University. © Gregory Lisciandro

Patient Preparation

Similar to AFAST³, fur is generally not shaved for TFAST³ but rather parted for probe-to-skin contact with the use of alcohol and/or acoustic coupling gel. Generally the room lights are left on (not dimmed). Alcohol should not be used if electrical defibrillation is anticipated (poses serious fire hazard), and the clinician should be aware that alcohol may physically cool and be noxious to some patients. Furthermore,

its direct contact may cause probe head damage (check with the ultrasound machine manufacturer) (see Figure 1.13). When using alcohol on the patient, placing acoustic coupling gel on the probe head may be an easy protective solution.

By not shaving, the cosmetic appearance of the patient is preserved, the exam time is lessened, and imaging quality is sufficient with most newer ultrasound machines. In the original TFAST (and AFAST as well) study, no dogs were shaved and rarely were

lights dimmed. Interestingly, image quality was questioned and found to be sufficient during the use of ultrasound without dimming lights in a human cardiopulmonary arrest study (Breitkreutz 2010). All images provided by the author in Chapters 2, 9, and 10 were acquired without shaving.

When it is necessary to improve image quality, it may be faster and more cosmetically pleasing to the owner to shave small viewing windows. Set the clippers with 1 1/2- to 2-inch width and leave feathering above to cover the shaved spot after imaging.

Performing the TFAST³ Exam

TFAST³ consists of five points: bilaterally the stationary horizontally probe-positioned chest tube site (CTS) views, the dynamically spotlighted and bilaterally applied pericardial site (PCS) views, and the new fifth point, the singly applied diaphragmatico-hepatic (DH) view. The DH view, nicknamed the designated hitter, is part of both the TFAST³ and AFAST³ exams (Lisciandro 2011) (Figure 9.2).

The subxiphoid or subcostal view in human FAST scans, analogous to the veterinary FAST DH view, is considered best for the detection of both pleural and pericardial fluid because of the acoustic window (less lung, less air, recalling that ultrasound does not transmit through air) provided by the liver and gallbladder (Reissig 2011) (see Figures 2.2, 2.3, and 2.17).

Performing the TFAST³ Chest Tube Site Part of the Exam

The bilaterally applied CTS are used for the diagnosis of pneumothorax (PTX) because they are the highest point, the least-gravity dependent site (air rises), and on the thoracic wall where air would accumulate in PTX. The TFAST³ is analogous to human PTX protocols (Reissig 2011).

The CTS view is defined as directly dorsal to the xiphoid process between the eighth and ninth intercostal spaces (ICS). In barrel-chested dogs or small animals with reduced thoracic cavities due to abdominal conditions (pregnancy, ascites, large masses, etc.), move another ICS space cranial (seventh or eighth) to avoid interference from the combined effects of the lung, the diaphragm, and the liver during phases of respiration that often confound lung ultrasound and

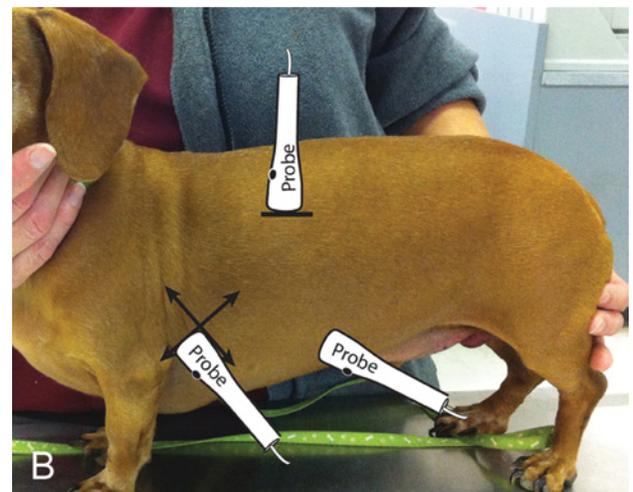
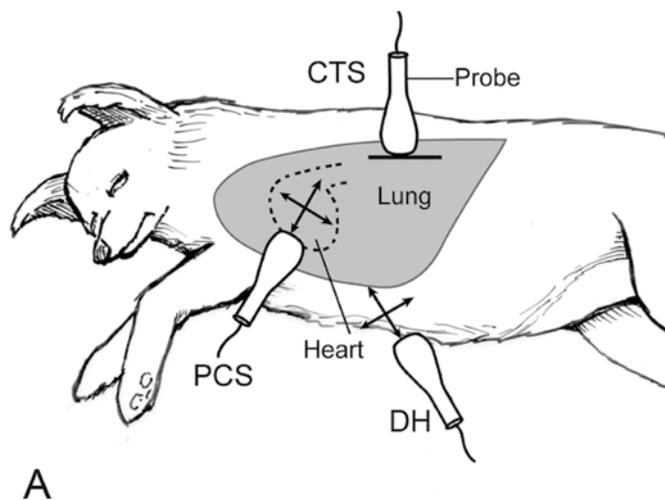


Figure 9.2. Performing the five-point TFAST³ exam. (A) TFAST³ shown in lateral recumbency on a dog. In this positioning the exam may be most efficiently performed by using similar settings for the diaphragmatico-hepatic (DH) view and both pericardial site (PCS) views before changing the ultrasound settings for the chest tube site (CTS) views (and continuing on with Vet BLUE; see Chapter 10). If air is interfering on the non-gravity dependent left PCS view, without spending too much time, move on to the gravity dependent right PCS view. At the right PCS view, the heart is closer to the thoracic wall and is more readily imaged. (Lisciandro et al. 2011) (B) The five-point TFAST³ exam shown in the standing position on a dog. The markers (black dots) on the probe heads indicate the direction they should be facing (toward the head) for proper screen orientation. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro

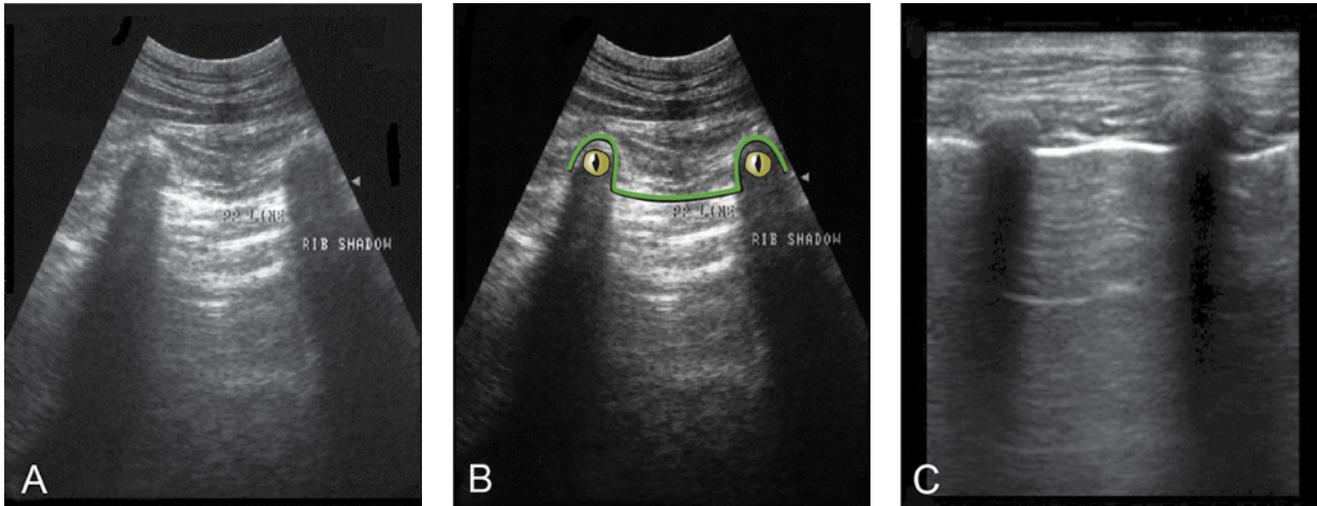


Figure 9.3. Orientation of the rib heads and intercostal space is likened to an alligator (gator) peering over the water at the sonographer. (A) The gator sign image using a curvilinear probe. (B) The gator sign schematically placed on the same image as (A) with rib heads (eyes) and the intercostal space (bridge of nose) representing the gator. (C) The gator sign image using a linear probe. The proximal bright line or pulmonary-pleural line along the gator's bridge of the nose (the intercostal space) is where lung glides along the thoracic wall in normalcy. Depth is generally set between 4–6 cm. Note in smaller dogs/puppies and cats/kittens several intercostal spaces may be apparent at this depth. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

make the observance of the glide sign problematic. Moving too far caudally creates a false positive step sign (see below).

Once at the CTS location, the gator (alligator) sign is found to define the pulmonary-pleural line (interface), which is the standard orientation for ALL lung ultrasound (Figure 9.3). The gator sign is composed of two rib heads (gator's eyes) and the interposed ICS (gator's bridge of nose). Along the pleural side of the ICS find the proximal bright white line (hyperechoic) representing the pulmonary-pleural line (PP-line). Simply, the PP-line represents anatomically where the lung should glide to and fro with inspiration and expiration along the thoracic wall. This standard orientation for all lung ultrasound is likened to a partially submerged alligator peering over the water at the sonographer.

The “gator sign” is a better representative image for CTS orientation than the bat sign term used in human patients because small animal (dog and cat) ribs are rounder than the flat ribs of people.

Observe for the to-and-fro motion at the PP-line of the glide sign like an Etch-a-Sketch[®] cursor running back and forth over the same line (lung opposed directly against the thoracic wall sliding cranially and caudally during inspiration and expiration). In human

medicine the motion has been referred to as lung sliding (Volpicelli 2012); however, in veterinary medicine the term glide sign has been used (Nyland 2002, Lisciandro 2008, Lisciandro 2011).

The glide sign may be difficult to see if the ultrasound echoes strike the air interface (PP-line) too directly (i.e., 90 degrees). A trick is to move ever so slightly while holding your probe horizontally and pivoting either dorsally or ventrally so the echoes are interpreted more obliquely by the ultrasound machine (Figure 9.4).

A second trick is to make the orientation a one-eyed gator by placing the rib head centrally and observing on both sides of the rib head for the glide sign. A third trick is to change your preset from abdominal to cardiac or vice versa.

The presence of the glide sign at the CTS view rules out PTX. However, several other possible lung ultrasound findings are possible (see below).

Make sure your patient is adequately restrained (muzzle, E collar, hand-held) while you are evaluating for the glide sign because your attention will be focused on the US screen and the patient's breathing pattern and not its mouth. Do not get bitten while watching the US screen for the glide sign.



Figure 9.4. Tricks of the trade for glide sign imaging. The photo shows the proper positioning of the ultrasound probe at the CTS view with the marker directed toward the patient's head. The probe is held horizontally, maximizing the imaging of the pulmonary-pleural interface (PP-line) at the chest tube site and is not moved (it is a stationary view). At times the ultrasound waves may be so perpendicular to the hyperechoic (bright white) PP-line that the glide sign is falsely missed. To overcome this so-called ultrasonographic glitch, ever so slightly pivot your probe as shown (arrows) while holding the stationary position and re-observe for the glide sign. © Gregory Lisciandro

Findings at the TFAST³ Chest Tube Site View

The Glide Sign

The glide sign is defined as the to-and-fro motion of the lung along the thoracic wall represented by the bright white (proximal) line or the PP-line. With aeration of normal lung (referred to as dry lung, see below), air reverberation artifact extends beyond the PP-line as equidistant parallel lines called A-lines (remember "A" for "air"). These must not be confused with the PP-line because no glide is seen along artifactual A-lines. The glide sign is a real-time finding because normal dry lung and PTX look exactly the same on standard B-mode still images (Figure 9.5 compared to Figure 9.8). The gator sign orientation is necessary for accurate assessment for the presence or absence of the glide sign (see above). The glide sign rules out PTX.

Ultrasound Lung Rockets

Ultrasound lung rockets (ULRs), also called B-lines, are newer terms for artifacts historically referred to as comet-tail (less commonly ring-down) artifacts

because ULRs are created differently. ULRs occur ultrasonographically at sites along the lung periphery where water (or fluid) is immediately adjacent to air. In contrast, comet-tail or ring-down artifacts are created by strong reflectors next to soft tissue (metal, bone, air) (also see ring-down and comet-tails in Figures 1.8, 12.8, and 17.7) Importantly, even though ULRs fill the entire ultrasound screen, they only represent a fluid-air juxtaposition within the first 1–3 mm of the lung's surface (Soldati 2011). The advantage to this artifact is several fold: (1) ULRs are easily recognizable (more obvious than the glide sign), (2) ULRs rapidly rule out PTX at that point along the thoracic wall, and (3) regional distribution patterns of ULRs can be used to diagnose lung conditions because ULRs represent forms of interstitial edema referred to as wet lung (see Chapter 10 for greater detail).

ULRs originate from the hyperechoic bright white line or PP-line; however, they differ from the glide sign in that ULRs are unfading laser-like hyperechoic (bright white) streak(s) that swing like a pendulum with the to-and-fro motion of inspiration and expiration. ULRs must extend to the far field of the US image and obliterate A-lines (Figure 9.6).

Most non-respiratory cats and dogs infrequently have ULRs (Pate 2010; Lisciandro 2013), and when ULRs are imaged they represent either lung contusions (in trauma) or various forms of interstitial edema (referred to as interstitial syndrome; see Chapter 10).

ULRs immediately rule out pneumothorax at that specific point on the thoracic wall and generally represent lung contusions in trauma and various forms of interstitial edema, referred to as interstitial syndrome in non-trauma (see Chapter 10).

The Step Sign

The term step sign was coined in the original TFAST study because a variety of trauma- and non-trauma-related conditions were evident on thoracic radiography when a disruption in the normal linear continuity of the PP-line was observed during TFAST (Lisciandro 2008). Such conditions include pleural effusion, intercostal tear(s) and rib fracture(s), subcostal hematomas, diaphragmatic hernia, anterior mediastinal mass, severe left atrial enlargement, and others (Lisciandro 2008) (Figure 9.7).

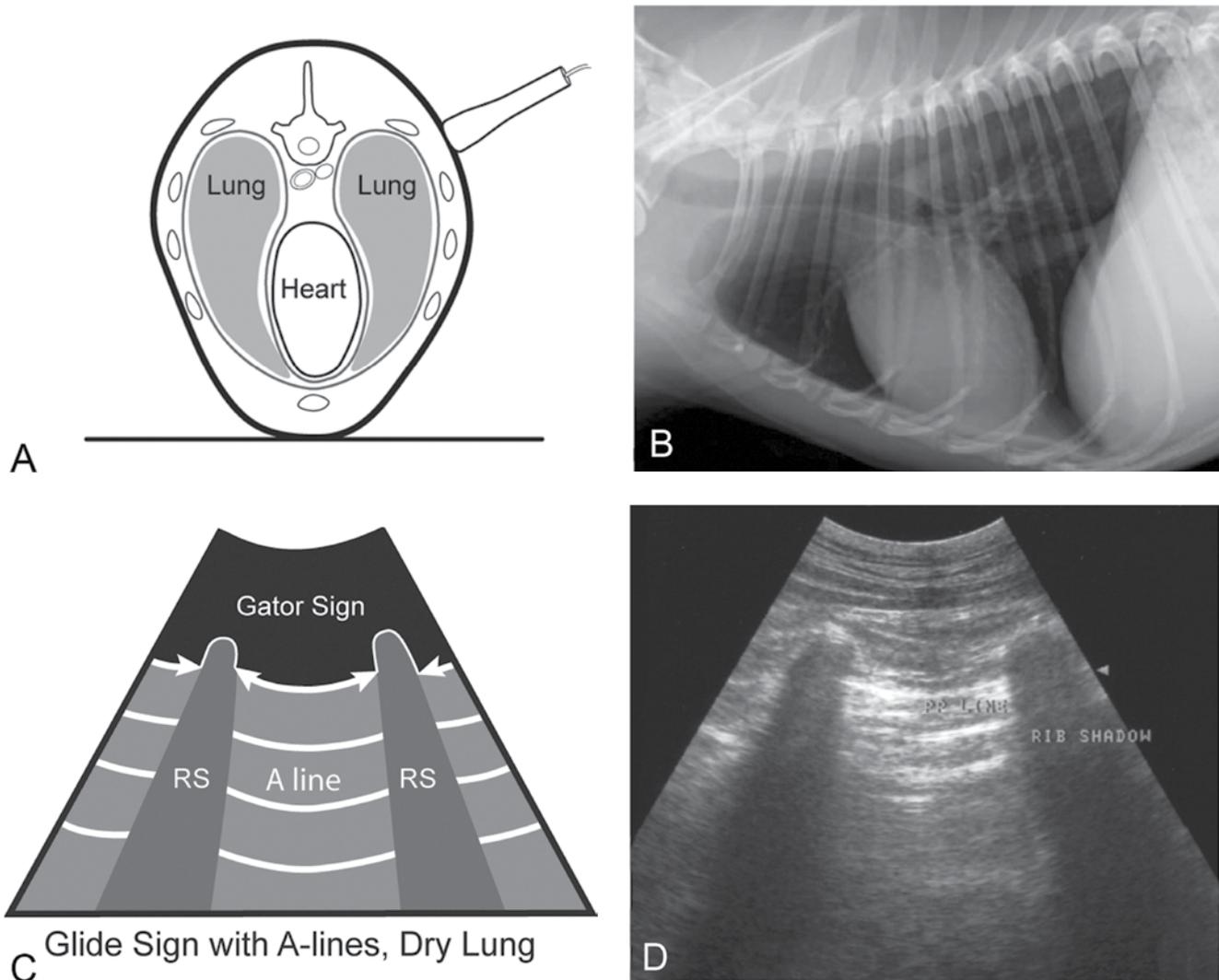


Figure 9.5. The glide sign and dry lungs. (A) Probe placement at the chest tube site view in sternal recumbency. (B) Correlating normal thoracic radiograph without intrathoracic pathology. (C) Correlating line drawing showing the gator sign from which the bright white line or PP-line is recognized as most proximal between the ribs (shown as line with arrowheads) in the intercostal space). The finding of the glide sign is a real-time observation (glide shown as line with arrowheads) and rules out pneumothorax. A-lines represent air reverberation artifact (no arrows) and will not have a glide sign. (D) B-mode images of normal dry lung and pneumothorax are identical. Compare to Figure 9.8. (Lisciandro et al. 2011) Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

The observation of the step sign should raise suspicion that an abnormality exists along the thoracic wall or pleural space, warranting further imaging (e.g., thoracic radiography).

It is important, however, to recognize that caudal to the CTS view, a step sign is artificially created (false positive) because of the dynamic changes in depth between the lungs, the reflection of the diaphragm, and the underlying liver during inspiration and expiration

(Lisciandro 2008, 2011). In barrel-chested dogs or animals with reduced thoracic cavities due to abdominal conditions (e.g., pregnancy, ascites, large abdominal masses, etc.), move another ICS space cranial (seventh or eighth) to avoid the misinterpretation of a false positive step sign.

Stay away from the region caudal to the CTS view that mistakenly makes for a false positive step sign because of the dynamic interactions of the lung, diaphragm, and liver during inspiration and expiration.

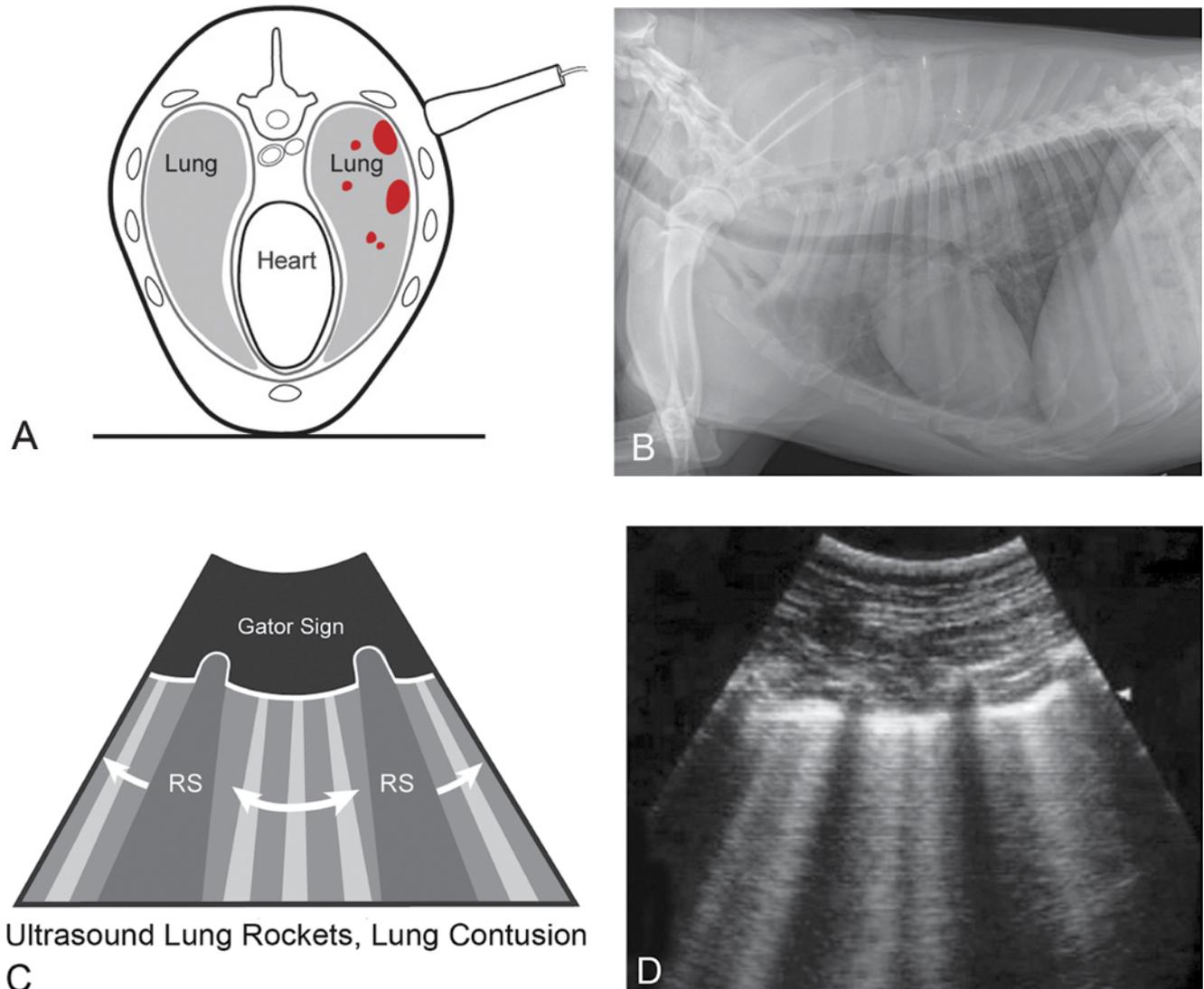


Figure 9.6. Ultrasound lung rockets and wet lung. ULRs seen in trauma cases represent lung contusions until proven otherwise. (A) Probe placement at the chest tube site view in sternal recumbency where the hemorrhage (lung contusion) is represented by the red opacities within the lung and along its periphery. (B) Correlating thoracic radiograph (TXR) in a dog with a gunshot wound to the thorax with lung contusions in the dorsal and perihilar lung fields that are difficult to see on the TXR. (C) Correlating line drawing showing ULRs, also called B-lines, which were readily apparent on TFAST³ and rapidly ruled out PTX. (D) Correlating B-mode ultrasound image of multiple ULRs. The number and distribution of ULRs over a single intercostal space may be used to assess severity and monitor clinical course (see Chapter 10 and Appendix II). (Lisciandro et al. 2011) Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

Diagnosis of Pneumothorax

Pneumothorax (PTX) is diagnosed by the presence of A-lines without a glide sign (Figure 9.8). Conversely, it is ruled out at that specific point along the thoracic wall by the presence of the glide sign or the presence of ULRs. Thus, by observing for these features at the CTS view, the highest point on the thoracic wall,

makes it unlikely that PTX would be present (Lisciandro 2008, Reissig 2011).

Always observe for PTX at the CTS view after the initial five breaths because air needs to redistribute when moving your patient into lateral or sternal recumbency (Lisciandro 2008).

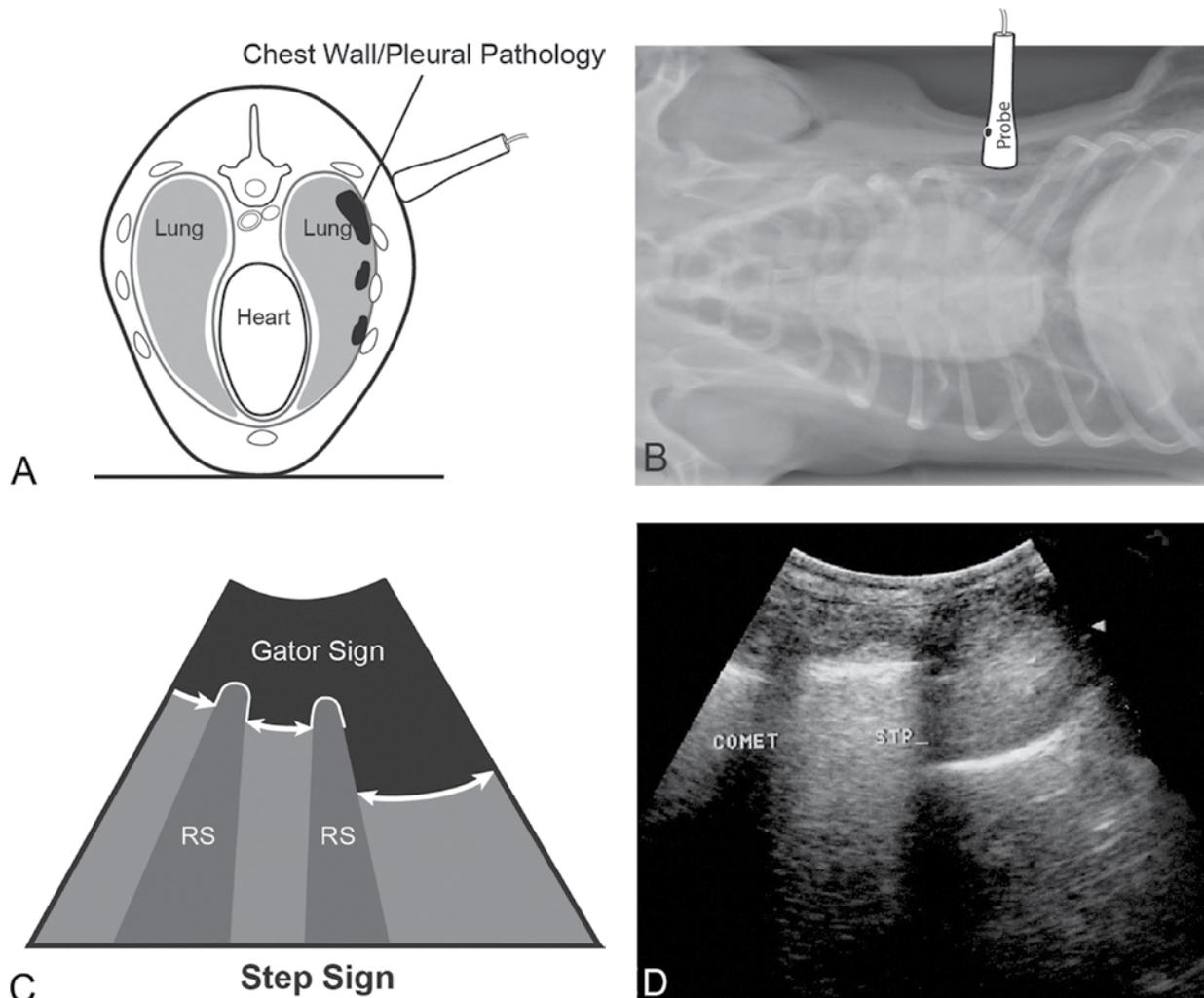


Figure 9.7. The step sign. (A) Probe placement at (CTS) view in sternal recumbency where trauma is represented by offset ribs and black opacities in the pleural space and lung. (B) Correlating thoracic radiograph in a dog with an intercostal tear best shown by tipping its ventrodorsal thoracic radiograph on its side for ease of illustration. The probe head is placed horizontally in a stationary manner with the probe marker (black dot) directed toward the head. (C) Correlating line drawing illustrating the step sign where the glide sign deviates from its expected normal linear continuity along the bright white line or PP-line, indicated by the offset arrows. A-lines may or may not be present depending on whether the lungs are dry or wet, thus the line drawing's far field shows neither lung ultrasound finding. (D) Correlating ultrasound B-mode image of an obvious large step sign that was ultrasonographically diagnosed as an intercostal tear occult by physical examination. Observation of a step sign in trauma cases suggests thoracic wall trauma, pleural space disease or conditions, and lung conditions. In non-trauma, step signs often indicate forms of lung consolidation or masses (see Chapter 10). It is important to note that in barrel-chested dogs or animals with cranial organomegaly or ascites, placing the probe too far caudally on the thorax will create a false positive step sign. (Lisciandro et al. 2011) Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

It is important to note that rapid and shallow breathing (panting) patterns make it difficult to observe the glide sign and the false positive diagnosis of PTX is possible. Options for the sonographer include calling the exam indeterminate and deferring to thoracic radiography, performing thoracocentesis based on clinical judgment, or repeating the TFAST³ exam for PTX post-analgesia (or after the

patient calms) (Figure 9.10, below). Look at the other control side of the patient to see if the glide sign is readily appreciated on your current settings, depth, and focus position. If a glide sign is seen, then it is more likely that you are seeing PTX on the opposite hemithorax. Look for the lung point (see below). Doing so allows you to subjectively assess the degree (partial vs. massive) of PTX.

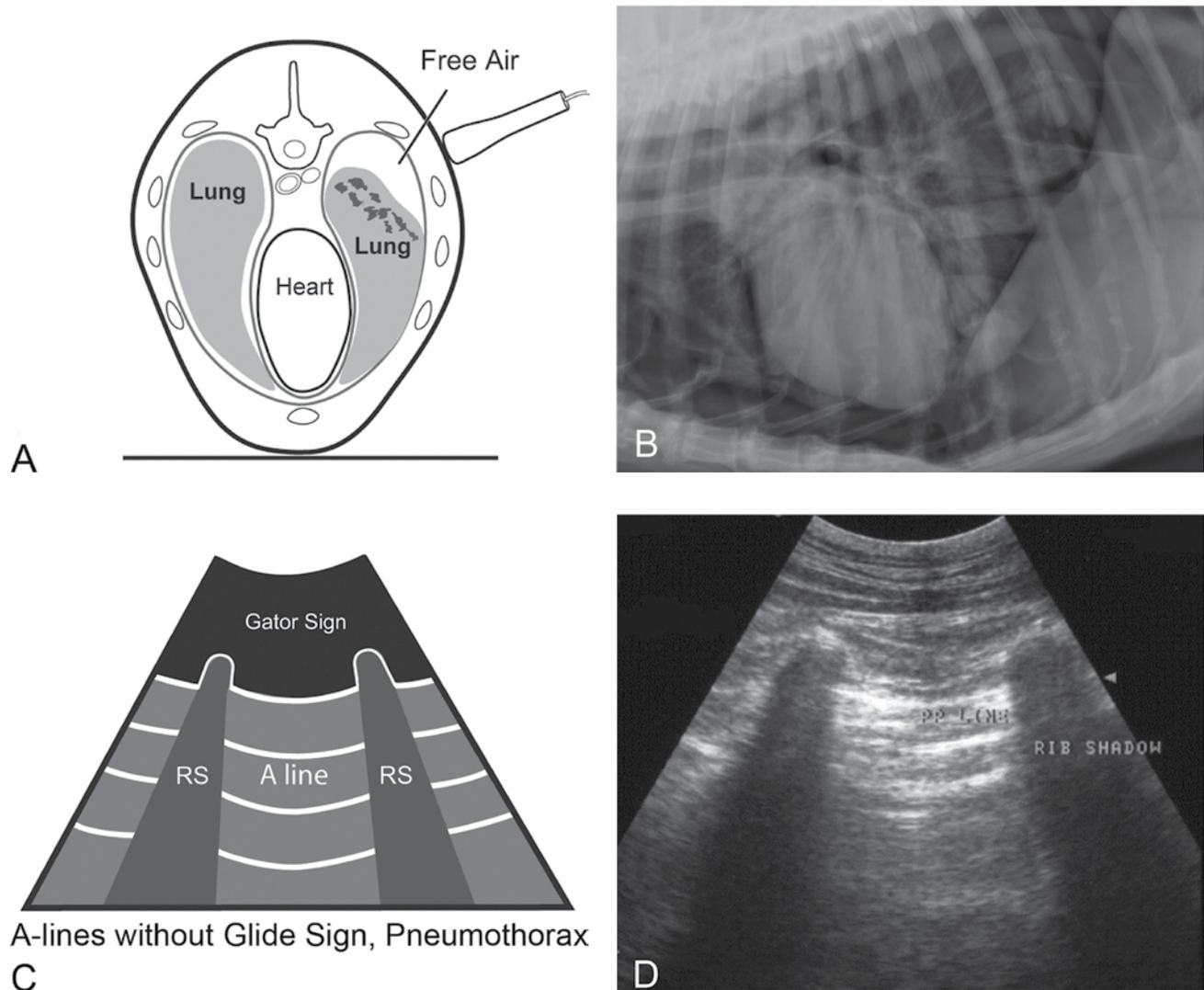


Figure 9.8. A-lines without the glide sign. (A) Probe placement at the CTS view in sternal recumbency where free air and a collapsed lung from PTX are evident. (B) Correlating thoracic radiograph showing PTX. (C) Correlating line drawing showing A-lines (reverberation artifact) without a glide sign (no arrows at the PP-line) indicating PTX. (D) Correlating B-mode still image. Note that B-mode images are the same for dry lungs as they are for PTX. The difference is the real-time observation of the glide sign. Compare to Figure 9.6. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

Thoracic radiography (depending on the patient's current status) should be performed initially to confirm or refute clinical suspicion (and evaluate for other trauma sequelae which could be occult ultrasonographically).

Once proficiency is acquired by the sonographer for diagnosing PTX, TFAST³ and Vet BLUE may replace the use of thoracic radiographs (TXR) for monitoring (tracking) clinical course.

The Search for the “Lung Point” and the Degree of Pneumothorax Historically

PTX has been considered an “all or none” phenomenon, which is untrue, because the degree (or severity) of PTX may be assessed by determining the location of the lung point. The lung point is the location where the collapsed lung resumes contact with the thoracic wall, generally evidenced ultrasonographically by either the

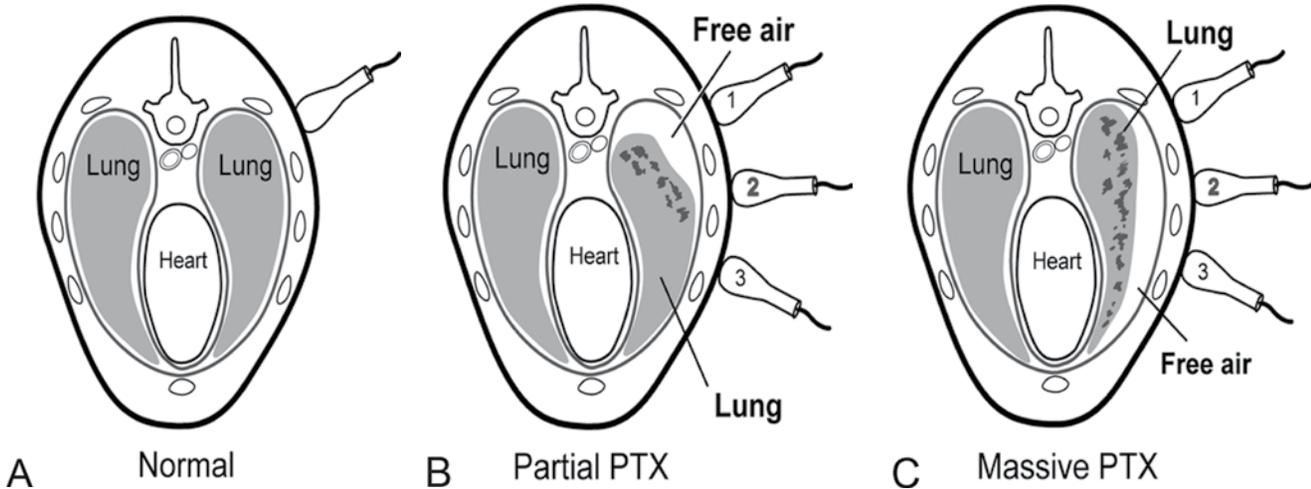


Figure 9.9. Cross-sectional canine thoraces shown in sternal recumbency. When PTX is suspected at the CTS view, the lung point should be sought. The lung point is where collapsed lung re-contacts the thoracic wall and is found by moving the probe sequentially from dorsal to ventral. The location where either a glide sign, ultrasound lung rockets, or a lung pulse is observed is where lung is re-contacting the thoracic wall. (A) Unremarkable thorax in which PTX has been excluded at the highest point, the CTS view, on the thorax. (B) PTX has been determined at the CTS view (position 1) and the lung point is determined to be at position 2. Thus, the PTX is partial and its severity assessed by its distance from the CTS view. (C) PTX has been determined at the CTS view, and a lung point is nonexistent at any of the three probe positions. PTX is thus massive or assessed as severe. Finding the lung point improves the sensitivity of diagnosing PTX, and is clinically helpful by also subjectively assessing the severity of PTX. (Lisciandro et al. 2011) Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro

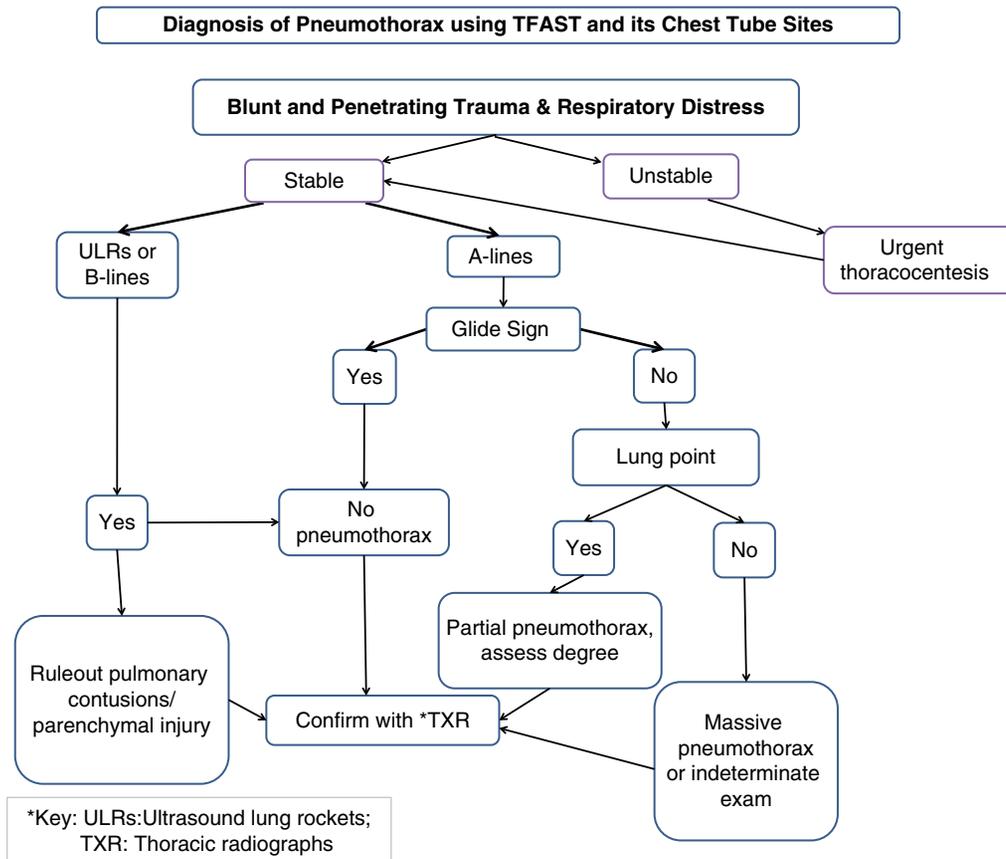


Figure 9.10. Diagnostic algorithm for the ultrasound diagnosis of pneumothorax using TFAST³. © Gregory Lisciandro

observation of the glide sign or ULRs. The lung point may also be found by observing for the lung pulse, which is a third sign that the lung is re-contacting the thoracic wall. The lung pulse looks similar to a glide sign; however, the lung glides back and forth with the heart beat rather than to and fro with respiration (Lichtenstein 2000, Volpicelli 2012). The lung pulse sign is an uncommon lung point finding in the author's experience, reported more frequently in humans with PTX.

The lung point not only confirms the presence of PTX and increases the sensitivity for the ultrasound diagnosis of PTX, but also gives the sonographer the ability to assess the degree (or severity) of PTX as partial vs. massive. Subjectively, the severity of PTX is assessed by the distance from the CTS view to the lung point (Lichtenstein 2000, Sargsyan 2001, Lisciandro 2011) (Figure 9.9). For example, if the lung point is readily appreciated in close proximity to the CTS view, the PTX is partial (trivial or mild). On the other hand, if the lung point is located in the middle or lower third of the thorax, the PTX should be considered more severe. When the lung point is far from the CTS view (lower third of the thorax) or not found and clinical presentation fits, a diagnosis of massive PTX is made. Appropriate steps such as thoracocentesis, based on the patient's clinical status and the attending's clinical judgment, should be undertaken (Figure 9.10). Any ultrasonographic suspicion of PTX warrants close serial monitoring (tracking). Finally, TFAST³ and the search for the lung point may be used immediately pre- and post thoracocentesis (and post-interventionally in any at-risk cases, (e.g., lung lobe aspirate, thoracotomy, thoracoscopy, etc.) as well as serially for limited restraint, point-of-care monitoring (tracking) of PTX during hospitalized care.

The Wet Lung vs. Dry Lung Concept

The wet lung (ULRs, also called B-lines) vs. dry lung (A-lines with a glide sign) concept is easily mastered by the novice lung sonographer. ULRs are similar to the Kerley B lines (representing interlobar edema) of lung radiography (Soldati 2011, Lichtenstein 2004), and correlate with the presence of a variety of lung conditions generally representing lung contusions in trauma or various forms of interstitial edema in non-trauma cases. Generally speaking, ULRs in traumatized patients are pulmonary contusions until proven otherwise (Soldati 2006, Ball 2009) (Figure 9.6), and in

non-trauma represent different types of lung conditions (cardiogenic and non-cardiogenic pulmonary edema and others) depending on their regional lung distribution (Lichtenstein 2008, 2010; Volpicelli 2012) (see Figures 10.7, 10.8, 10.15, and 10.16 and Chapter 10).

ULRs in traumatized patients are lung contusions until proven otherwise, and in non-trauma represent different types of lung conditions (cardiogenic and non-cardiogenic pulmonary edema and others) depending on their regional lung distribution.

The dry lung concept is also easily mastered (A-lines with a glide sign), especially if PTX is unlikely in the respective patient (e.g., the observance of A-lines is usually sufficient). So by evaluating more than the CTS view for wet lungs vs. dry lungs regionally using the Vet BLUE lung scan, increased lung water or interstitial edema (wet lungs) may be surveyed for in advance of clinically overt signs (Lichtenstein 2009, 2012) (see Figures 10.6, 10.7, 10.8, 10.15, and 10.16). The strategy is especially helpful in patients at risk for volume overload (acute kidney injury) or those with compensated heart disease receiving fluid therapy.

Moving beyond the TFAST³ CTS view is advantageous for a more global assessment of lung status. Thus, the more thorough Vet BLUE (see Chapter 10) was created to detect lung complications earlier and prior to overt clinical signs. In people, lung ultrasound is superior to chest auscultation and supine chest radiography in detecting interstitial syndrome and lung consolidation (Gargani 2007, Peris 2010, Lichtenstein 2008, 2010, Volpicelli 2012).

ULRs represent interstitial edema and precede alveolar edema (which is more serious), providing a clinical advantage over traditional means (art of chest auscultation and thoracic radiography) by using the ultrasound probe as a stethoscope (see Chapter 10).

The Presence of Subcutaneous Emphysema and TFAST³ Imaging

The presence of subcutaneous emphysema (SQE) is potentially problematic because ultrasound does not transit (image) through air, and therefore proper orientation of the gator sign is not possible, invalidating a

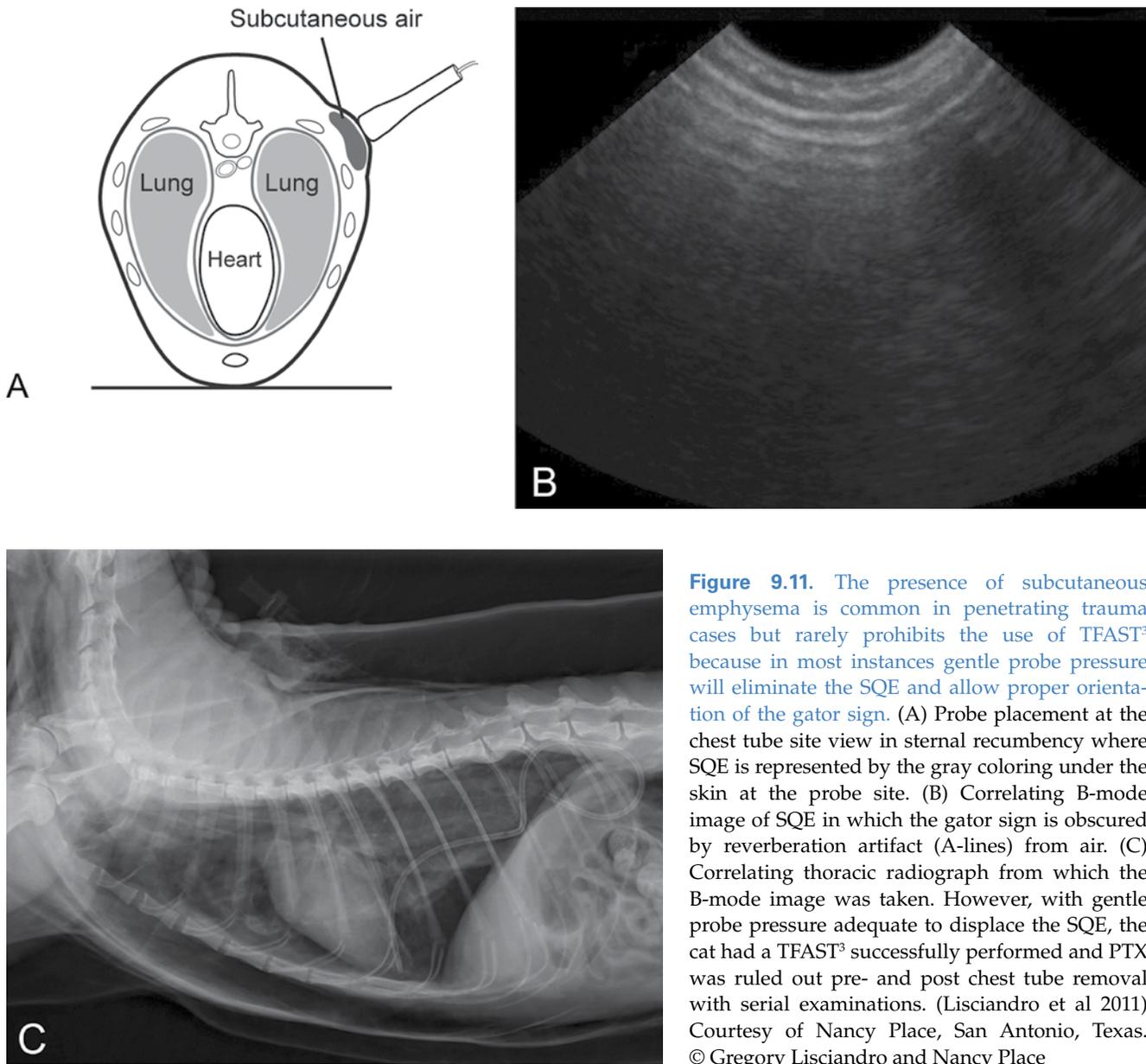


Figure 9.11. The presence of subcutaneous emphysema is common in penetrating trauma cases but rarely prohibits the use of TFAST³ because in most instances gentle probe pressure will eliminate the SQE and allow proper orientation of the gator sign. (A) Probe placement at the chest tube site view in sternal recumbency where SQE is represented by the gray coloring under the skin at the probe site. (B) Correlating B-mode image of SQE in which the gator sign is obscured by reverberation artifact (A-lines) from air. (C) Correlating thoracic radiograph from which the B-mode image was taken. However, with gentle probe pressure adequate to displace the SQE, the cat had a TFAST³ successfully performed and PTX was ruled out pre- and post chest tube removal with serial examinations. (Lisciandro et al 2011) Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

TFAST³ study (or Vet BLUE lung scan) at that point of interest (Figure 9.11). In reality, however, the gator sign orientation (Figure 9.3) is almost always possible by applying sufficient probe pressure to displace the SQE (Lisciandro 2008).

By placing enough probe pressure, SQE is adequately displaced and the TFAST³ study (or the Vet BLUE lung scan) rarely has to be aborted because imaging of the gator sign is almost always possible.

Performing the TFAST³ Pericardial Part of the Exam

The pericardial sites (PCS) are bilaterally applied in the region of the third, fourth, and fifth intercostal spaces at the costochondral junctions, and are similar to the parasternal views of echocardiography (Lisciandro 2008, 2011). These PCS views are dynamic, and the mantra is “marker toward the elbow” and then rotate the “marker toward the spine” to gain competence for obtaining the short- and long-axis views of the heart, respectively, while searching for pleural and

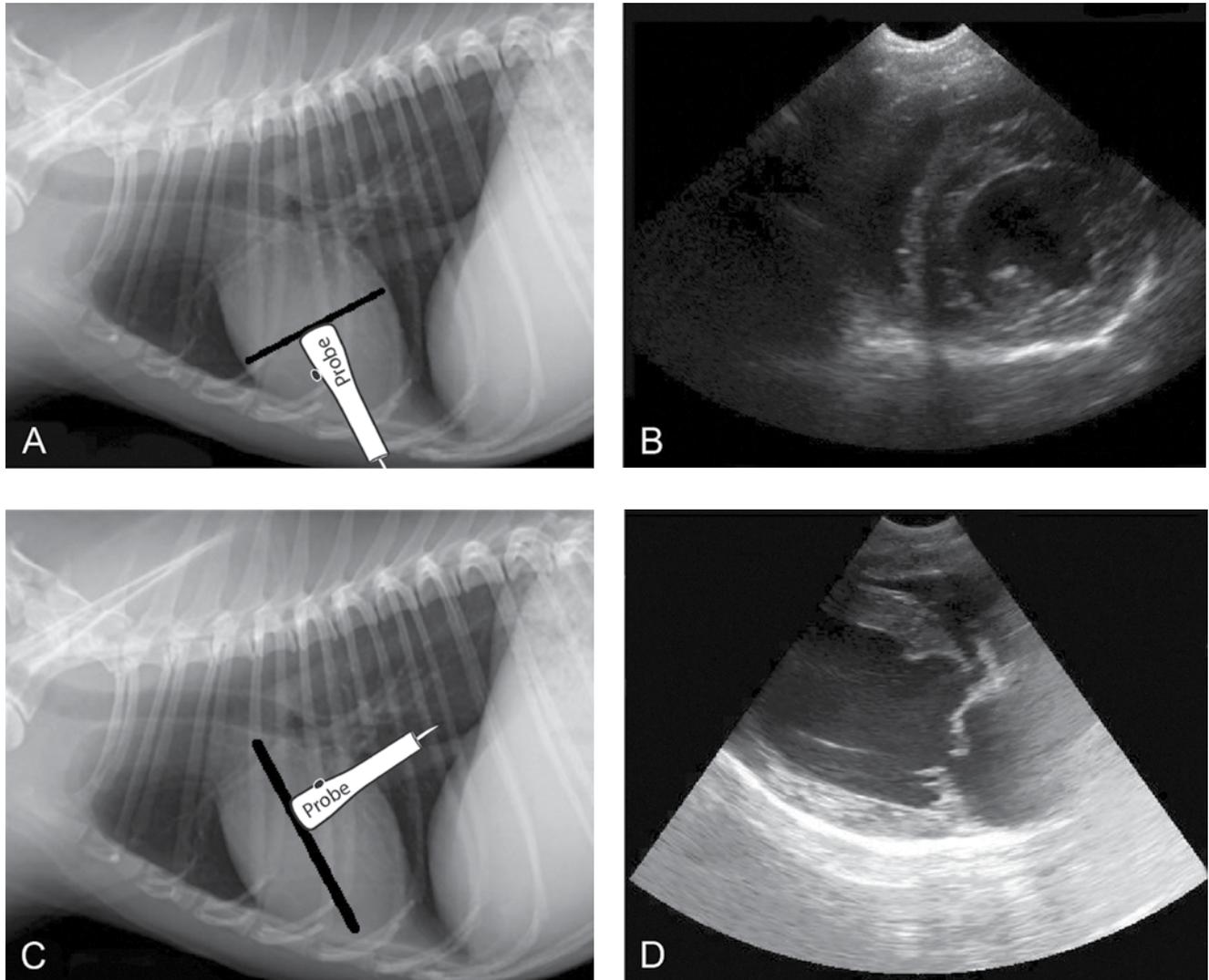


Figure 9.12. Fanning the probe at the pericardial site views. Images (A and B) correspond with each other. (A) The probe is held with the marker (black dot on probe head) toward the elbow on a bar representing probe orientation on a lateral thoracic radiograph. (B) The correlating ultrasound B-mode image showing the left ventricular short-axis mushroom view of the heart. Images (C and D) correlate with each other. (C) The probe is held with marker (black dot on probe head) toward the spine on a bar representing probe orientation on a lateral thoracic radiograph. (D) The correlating ultrasound B-mode image showing the long-axis or 4-chamber view. By repeating this probe maneuver on every TFAST³ exam, proficiency will be quickly gained in acquiring these basic heart views while also observing for pleural and pericardial effusion. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

pericardial effusions (Figure 9.12, also see Figures 11.1 and 11.2 and Chapter 11).

The easiest way to find the heart is to take your hand and place it around the sternum (laterally recumbent) or on the thoracic wall (sternally recumbent) and feel for the heart beat. If you cannot appreciate a palpable heart beat, the next most reliable attempt is to place the probe on the gravity dependent PCS view in lateral recumbency because the heart will drop against the thoracic wall, displacing air-

filled lung. Right lateral recumbency is preferred because the right PCS view is the standard view for echocardiography and the cardiac notch (less lung) provides a better acoustic window than left lateral recumbency (Figure 9.13).

Another quick way is to move the elbow to the costochondral junction (landmark for cardiac injections) and place your probe there. Wait through several breaths because your cardiac window may be intermittent (especially in sternal or standing patients) between



Figure 9.13. The position of the probe on the underside of a dog in right lateral recumbency for the pericardial site view. The right PCS site gives the best overall view of the heart and is analogous to the standard right pericardial view used during complete echocardiography. The non-gravity dependent left PCS view is often low yield because of lung and its air interference. Thus, time should be limited at the non-gravity dependent PCS view because it is better spent at the higher-yielding gravity dependent right PCS view. © Gregory Lisciandro

inspiration and expiration from lung (air) interference. Image the short-axis and long-axis views of the heart by using the mantra “marker toward the elbow” and “marker toward the spine.” The habitual use of the probe in this manner accelerates the learning curve for heart imaging (Figure 9.12; also see Figures 11.1, 11.2, and 11.4). Identifying the cardiac chambers prevents mistaking normal cardiac anatomy for pleural or pericardial effusions, and zooming out (by increasing the depth) to gain a complete heart image is ideal (Figure 9.14). This may not be possible in large dogs depending on the depth limitations of your US machine.

The left ventricular short-axis “mushroom” view (easily mastered with minimal training) allows the sonographer to subjectively evaluate contractility and volume status pre- and post resuscitation (Figure 9.16). In time skills are developed for learning the more advanced quick peek cardiac view of the left atrial (LA) to aortic (Ao) ratio for evidence of left-sided heart disease (see Figures 11.2, 11.4). Pleural and pericardial effusion (see below) in the majority of trauma cases will be anechoic (clear black) because the fluid will be non-clotted blood (Figures 9.17, 9.18, 9.19, and 9.20; also see Figures 2.3, 2.17, 11.12, 11.13, and 11.15). Other effusive pleural and pericardial conditions may have various degrees of echogenicity (hydrothorax vs. pyothorax vs. chylothorax vs. neoplastic vs. other, with combinations thereof also possible), and rarely air.

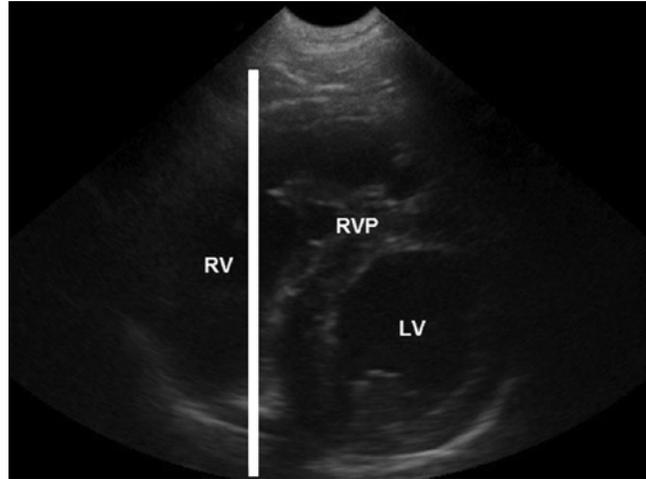


Figure 9.14. Misjudging heart chambers for pleural and pericardial effusion. A left ventricular short-axis mushroom view is shown here. It is very important to recognize that the mushroom (left ventricle; LV) has a crescent moon over it (the right ventricle; RV). To carry the analogy further, within this moon (RV) is a notch (the RV papillary muscle; RVP) which can look like abnormal tissue. The line drawn shows how it is easy to mistake the right ventricular chamber for pleural or pericardial effusion by limiting the field of view. For example, to the right of the line it appears that there is pleural or pericardial effusion with a mass. By including the entire image it is less likely to make this potentially catastrophic mistake if centesis is erroneously pursued. Zooming out or increasing depth is imperative as well is adhering to the sage axiom that “One view is no view” and adding on the DH view (or other PCS view) to further interrogate the pleural and pericardial spaces. (Boysen and Lisciandro 2013) © Gregory Lisciandro

Performing the TFAST³ Diaphragmatico-Hepatic (DH) Fifth View

The classic DH view (nicknamed the designated hitter because the DH is part of AFAST³ and TFAST³) begins with imaging the gallbladder “kissing” the diaphragm. The depth is increased sufficiently to image into the pleural and pericardial spaces (see Figures 2.2 and 2.3). However, in respiratory-compromised sternally (or standing) positioned small animals, the subxiphoid location is modified to accommodate the patient. If the subxiphoid site is too cumbersome or stressful the US probe may be moved paracostally for imaging the pleural and pericardial spaces from either the left or right side (or both) (Figure 9.2B; also see Figure 11.7).

The DH view should be used advantageously (less lung [air] interference) as an acoustic window (via the

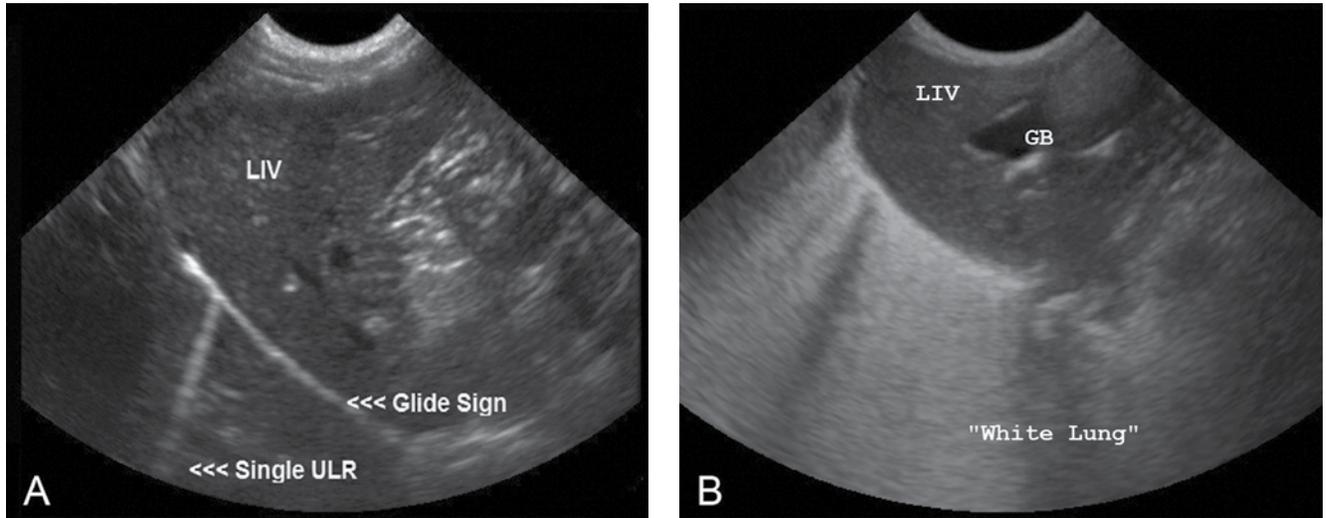


Figure 9.15. Ultrasound lung rockets (ULRs) at the diaphragmatico-hepatic (DH) view. (A) ULRs are not uncommonly seen at the DH view as no more than one or two along the diaphragm. A single ULR is shown here. Note that the depth is very good and clearly shows adequate imaging into the thorax. A glide sign is present along the diaphragm, so PTX could be determined along this view; however, the chest tube site (CTS) view, being the highest on the thoracic wall, is the preferred site. The mirror image of the liver into the thorax rapidly rules out pleural effusion. (B) ULRs are seen at the DH view in abundance and are so numerous they blend together, which is referred to as confluent or white lung. This is recorded as the infinity symbol (∞). The image is taken from a puppy that was stepped on by the owner. Confluent ULRs were also found at the CTS views (and all Vet BLUE sites). Based on these lung ultrasound findings, the unstable oxygen-dependent puppy was rapidly diagnosed with severe pulmonary contusions on the triage table. Furthermore, TFAST³ and AFAST³ rapidly ruled out obvious hemothorax, hemo-pericardium, and hemoabdomen, all possible conditions that could have also been contributing to patient distress. © Gregory Lisciandro

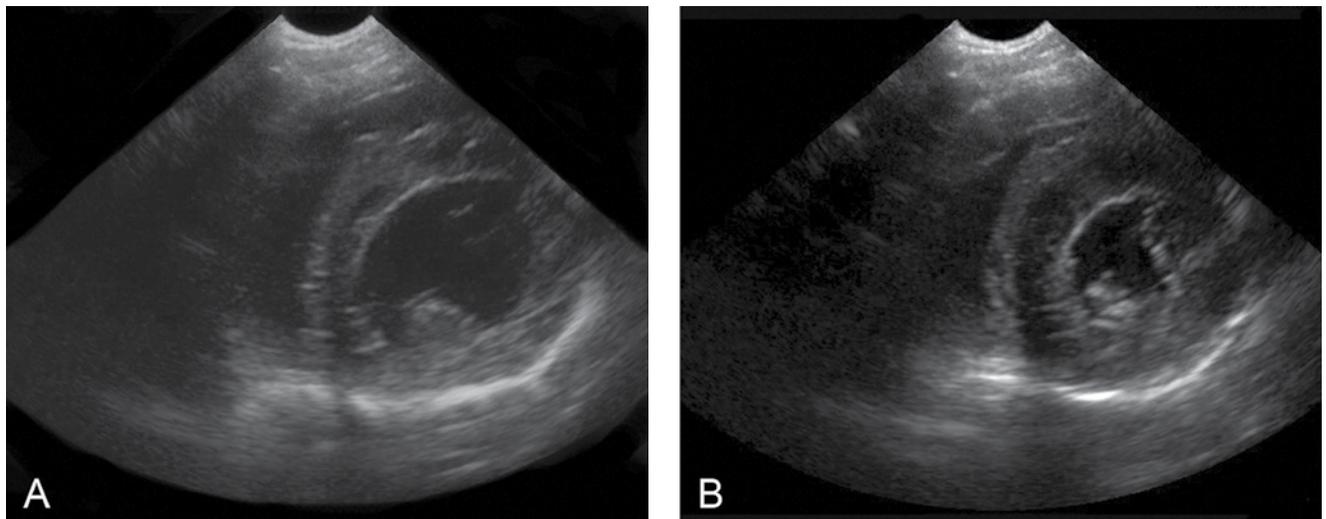


Figure 9.16. Left ventricular short-axis views are acquired at the right TFAST³ view by directing the “marker toward the elbow.” (A) B-mode image of the LV short-axis mushroom view for subjective evaluation of volume status (and contractility, see below) by the maximum excursion during diastole (filling). Here volume is subjectively assessed as adequate. In (B) the maximum excursion is shown and volume status is assessed as inadequate. Compare (A) to (B). In severe hypovolemia the papillary muscles, also called the waist of the mushroom, may actually touch or “kiss” one another. The evaluation of the LV short-axis mushroom view may be made pre- and post resuscitation to help guide fluid therapy. It also may be used to subjectively assess LV contractility (and fractional shortening) by observing the difference in mushroom size from maximum (diastole) to minimum (systole). © Gregory Lisciandro

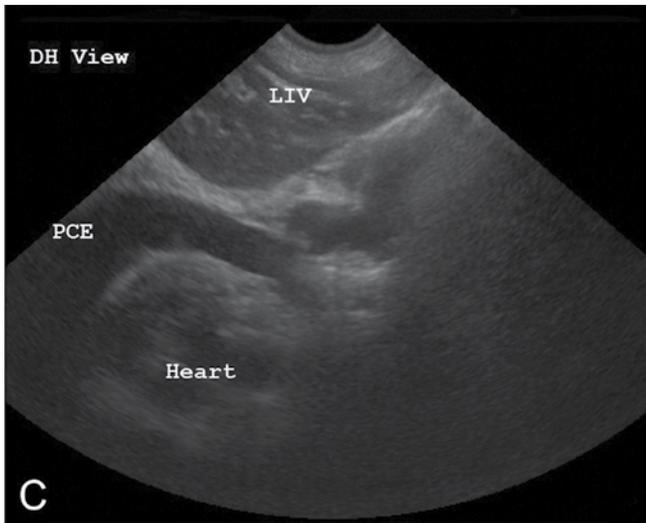
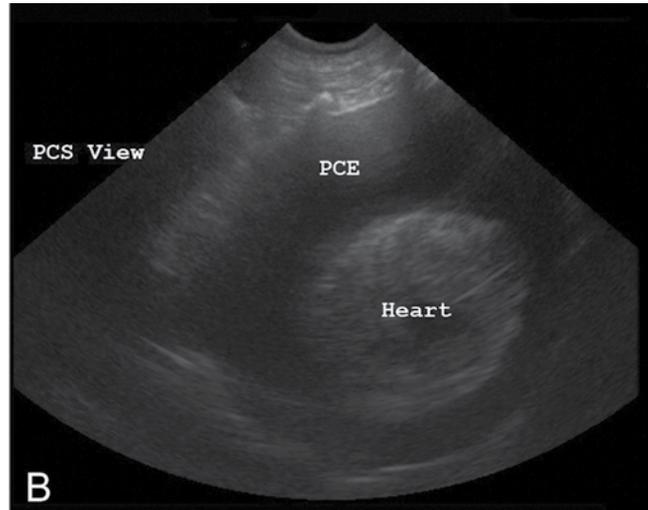
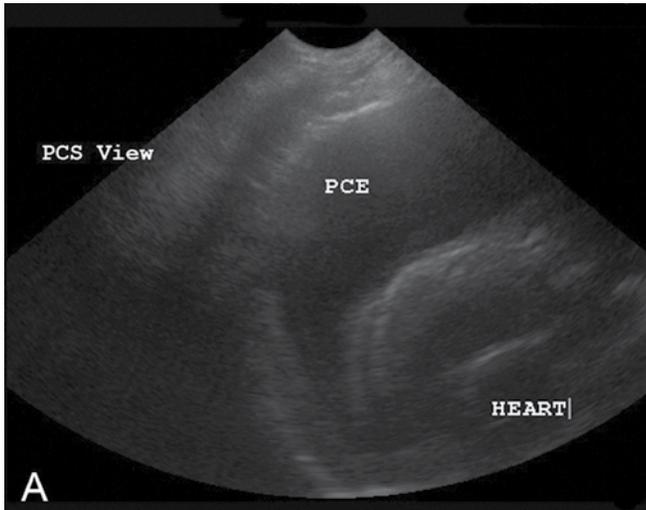


Figure 9.17. Pericardial effusion is fluid contained. (A) A PCS view of the pericardial effusion (PCE) with the heart labeled in the far field. Note the contained fluid by a hyperechoic border suggestive of the pericardial sac that surrounds the heart. (B) By directing the probe ventrally toward the sternum and zooming out (increasing depth), it is even more apparent that the circular shaped pericardium is filled with fluid. The bull's eye sign that is shown is created by the apex of the heart in the center of the pericardial fluid. (C) A final view via the DH site further confirms PCE, which appears like an oval anechoic “race track” bordered by parallel bright white lines as the PCE courses around the heart. Using more than one view is key to differentiating between pleural and pericardial effusions and heart chambers. (Also see Figure 9.14, which illustrates this pitfall). © Gregory Lisciandro

liver and gallbladder) into the thorax, and depth should be adjusted on your machine so that the thorax is approximately 25%–33% of the far field. In some cats and smaller dogs, the heart may be imaged in both short- and long-axis by the DH view. Attempts should always be made to image the pleural and pericardial spaces on every exam. This may not be possible in larger dogs depending on the depth limitations of your US machine (Figure 9.15; also see Figures 2.2 and 2.3).

Because the canine and feline pericardial sac do not normally rest on the diaphragm (as in humans), it may not be reliably visualized in the absence of pericardial effusion. However, if the pericardial sac is not visualized because of lung (air) interference with adequate depth settings, the likelihood of clinically relevant pericardial effusion being missed is low (Lisciandro 2012, unpublished data), and at least one PCS view should always be used.

The analogous subxiphoid view in human ultrasound imaging (to the DH view) has been shown to be more reliable than the transthoracic views because of its acoustic window through the gallbladder and liver (less air interference) (Riessig 2011).

Once the thorax (pleural and pericardial spaces) has been interrogated, fanning through the liver lobes and observing for ascites and any abnormalities of the gallbladder should take place. Furthermore, the sonographer should assess the size and dynamics of the caudal vena cava during respiration and check for the presence or absence of hepatic venous dilation for volume assessment and right-sided heart status (Figure 9.22, below; also see Figures 11.8, 11.9, and 16.2). Volume status is discussed in more detail in Chapter 11, and signs of left-sided volume overload using lung ultrasound strategies are discussed in Chapter 10.

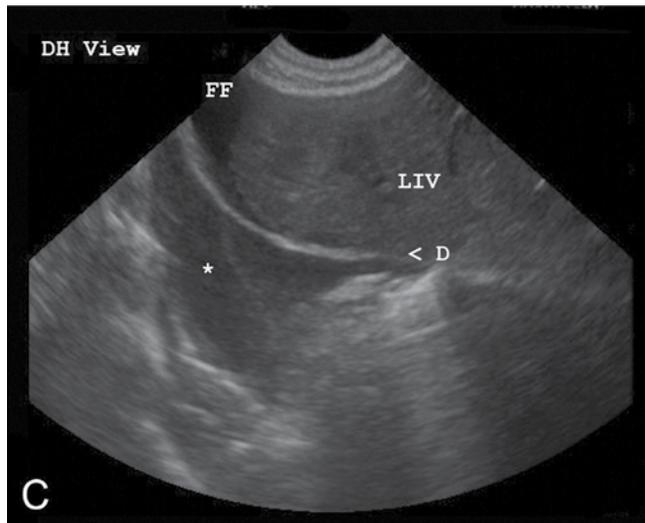
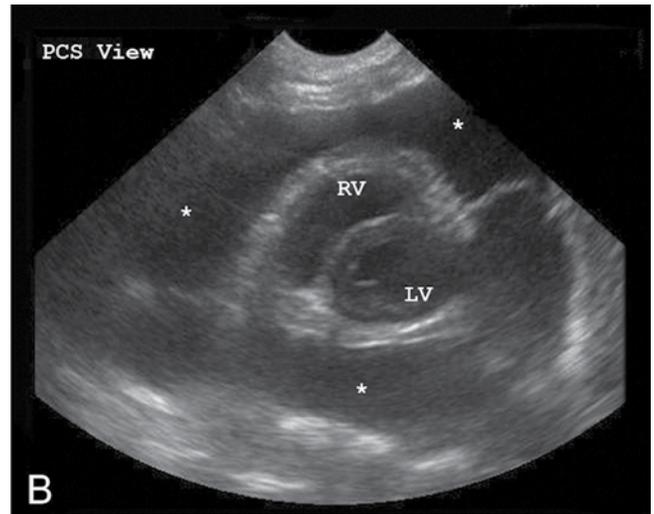
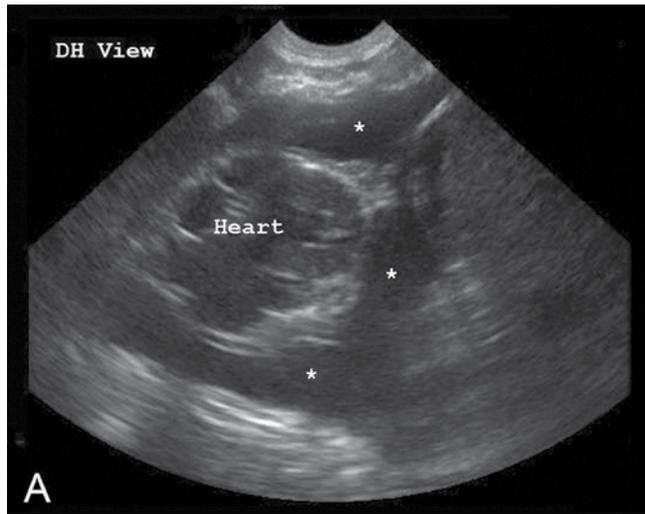


Figure 9.18. Pleural effusion is fluid uncontained. (A) Shown here is a cat with suspicious pleural effusion (*) via the DH view. (B) This figure is the same cat, now imaged at the PCS view. The heart is clearly centered in pleural fluid that is uncontained. Note that the right ventricle (RV) appears enlarged. (C) Moving back to the DH view reveals a small amount of intra-abdominal free fluid (FF) between the liver (LIV) and the diaphragm (< D) and obvious pleural effusion by the anechoic triangle (*). Thus, the sonographer is confident that only pleural effusion is present, the right ventricle is enlarged, and a small amount of ascites is present, suggesting right-sided heart failure. © Gregory Lisciandro

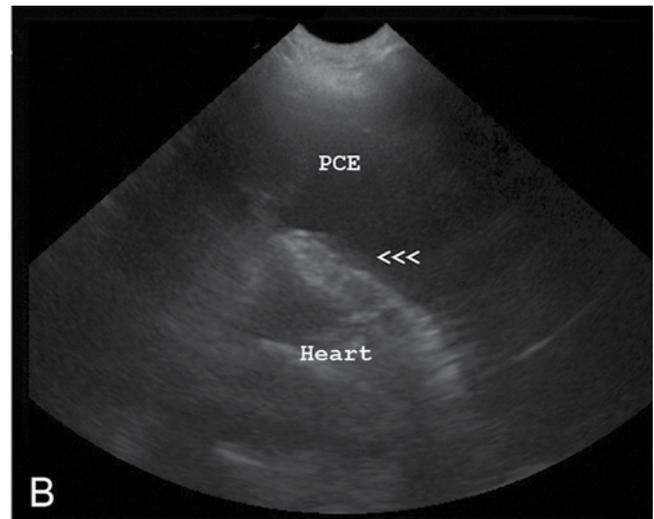
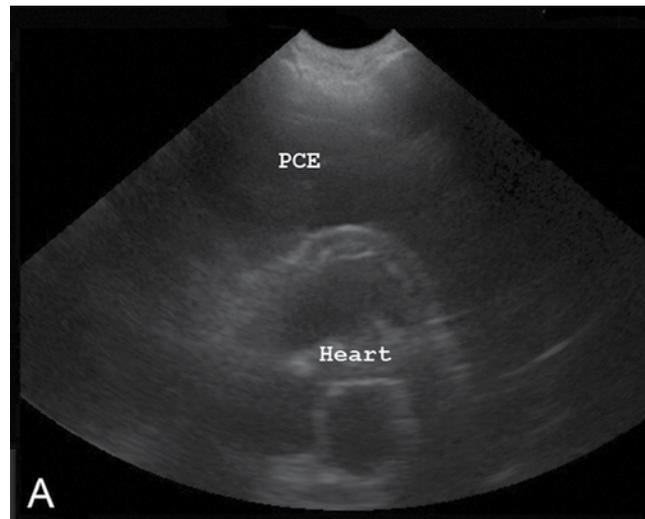


Figure 9.19. Cardiac tamponade. (A) Short-axis view of the heart in a large volume of pericardial effusion (PCE). Note that the chamber in the near field shows distension and filling. (B) In contrast, while keeping the same probe position, the chamber shows obvious collapse on itself (<<<) during diastole, diagnosing cardiac tamponade, an indication for emergent pericardiocentesis. This is generally easy to appreciate in real-time because pericardial effusion (ultrasound loves fluid) enhances ultrasound imaging of the heart (also see Figure 11.15A). © Gregory Lisciandro

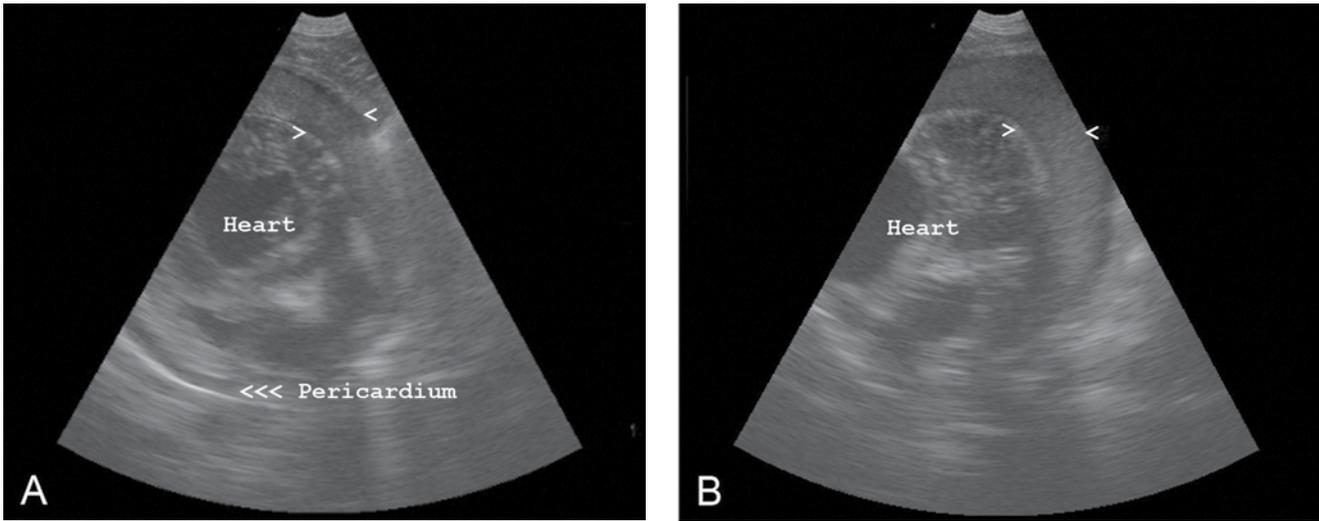


Figure 9.20. Left atrial tears (LAT) as a complication of canine mitral valve disease (MVD) are not uncommon when routinely evaluating heart failure patients with TFAST³. MVD cases with LAT often have occult pericardial effusion based on their thoracic radiographs (as did this dog), and thus LAT is missed. Moreover, ultrasound is the gold standard for the diagnosis of PCE. (A) A dog that was poorly responsive to standard heart failure therapy that ruptured its left atrium six hours post-admission when examined with serial TFAST³ (serially PCE [marked with ><] developed). Its thoracic radiograph at the time of admission showed severe left atrial enlargement and perihilar edema. (B) Another view of the same dog. Note that the PCE is characterized by homogeneous isoechoic material (blood clot) in contrast to anechoic free fluid seen in Figures 9.17 and 9.18. The hallmark of MVD dogs with LAT is that the majority have PCE with clotted blood in their pericardial sac. © Gregory Lisciandro

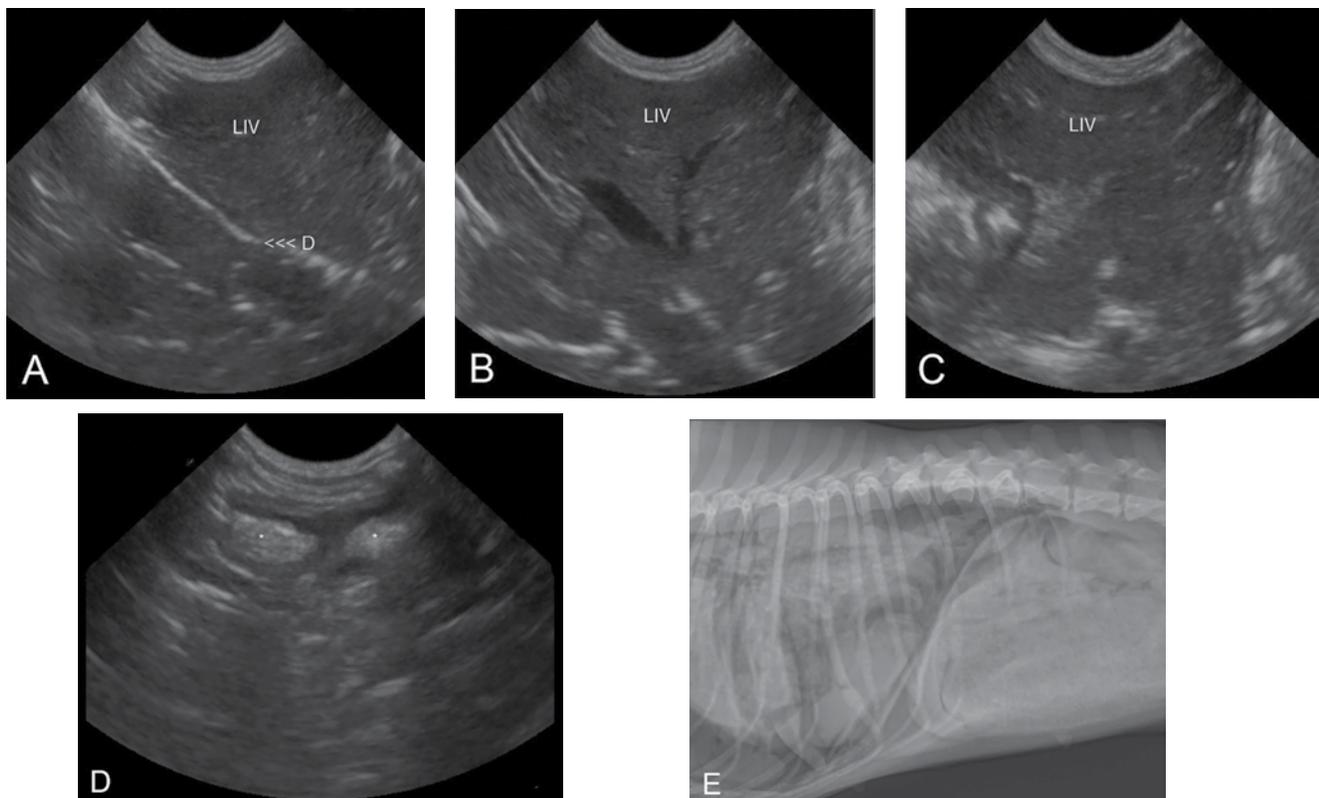


Figure 9.21. Diaphragmatic herniation. While holding the probe stationary and observing via the DH view over several consecutive breaths, the following sequence of images (A through C) were taken at triage on emergency referral. The dog had arrested during its spay procedure, was resuscitated, and continued with severe respiratory distress after the surgeon aborted the surgery. Note how the expected hyperechoic curvilinear continuity of the diaphragm (<<< D) is not present in (A). Rather, it is represented by a hyperechoic straight line, followed by loss of the hyperechoic line in (B), and then liver (LIV), extending beyond the observed expected hyperechoic line in (C). (D) Moving to the PCS view, two loops of small bowel (marked with [*]) are clearly seen where heart would be expected and readily appreciated in real-time. (E) The confirmatory thoracic radiograph for the suspected diaphragmatic hernia by TFAST³ at triage. © Gregory Lisciandro

Findings at the TFAST³ Pericardial Site View

In addition to searching for pleural and pericardial effusion (see below), the sonographer may begin to subjectively evaluate contractility and volume status via the left ventricular short-axis mushroom view (Figure 9.16). In time, he or she may continue to build skills for evaluating the quick-peek left atrial (LA) to aortic (Ao) view and determining the LA:Ao ratio for signs of left-sided heart disease (see Chapter 11). However, left-sided heart failure may be more easily ruled out by finding that all regional lung fields are dry. Moreover, dry lungs may be more easily mastered than the quick-peek cardiac view.

In people, the dry lung strategy has been found to have high sensitivity and specificity (greater than 98%) in ruling out clinically relevant left-sided heart failure (cardiogenic pulmonary edema) and left-sided volume overload when all lung fields are dry (Lichtenstein 2008, 2009, 2012). The finding of dry lungs in all fields also holds true in dogs and cats, and the wet lung vs. dry lung concept is also used during heart failure management to guide diuretic usage (Pate 2010, Lisciandro 2013) (see Figures 10.14, 10.16, and 16.2).

Determining Pleural from Pericardial Effusion

The detection of either or both pericardial and pleural effusion will seem a little tricky when beginning. However, some key principles apply that will build confidence, especially the axiom that “One view is no view.” By using multiple views (at least one of the PCS views and the TFAST³ DH view), mistakes are less likely, especially confusing pleural or pericardial effusions with a normal or dilated heart chamber (Figure 9.14).

Pericardial Effusion, Fluid Contained Around the Heart

Zoom out (increase depth), or in other words, move away from the suspected fluid, so that the heart may be seen in its entirety. This is not always possible in large dogs, depending on the depth limits of your US machine (Figures 9.17, 9.20; also see Figures 11.13A and 11.15A). In these cases move the probe paracostally to get closer to the heart as a modification of the DH view. Observe for the hyperechoic (bright white) pericardial

sac that typically will be marginated from the cardiac silhouette in circular or oval fashion in the short- and long-axis views, likened to a race track. The pericardial sac attaches at the heart base around the atrium (also see Figures 11.13A and 11.15A and Chapter 11).

Certain cardiac conditions may produce a small rim of hemodynamically benign pericardial fluid (often less than 5 mm) (see Figure 11.13A). Pericardiocentesis is often far too risky and not indicated with small volume effusions unless rarely cardiac tamponade is present.

If pericardial effusion remains uncertain at the PCS view, fan ventrally toward the sternum toward the apex of the heart and look for the bull’s eye sign. This image is created by the round isoechoic heart apex (shades of gray) centered (and swinging to an extent) within the thin circular pericardium evidenced by a bright white hyperechoic rim (Figure 9.17B). Finally, to further confirm the presence of pericardial effusion, go to the DH view (“One view is no view”) and look for similar discriminating evidence. If necessary, then move to the opposite PCS view (Figure 9.17C). If cardiac tamponade is present (see below, Figure 9.19; also see Figure 11.15A), an emergent pericardiocentesis is indicated. The procedure is described in Chapter 17.

If pericardial effusion remains an uncertainty, and the patient is hemodynamically stable, then arrange for complete echocardiography for confirmation (or perform serial TFAST³ examinations for detection of developing tamponade or do both).

A small amount of pericardial effusion should be left for complete echocardiography to enhance the imaging for the detection of a pericardial or heart base mass (Scansen 2011).

Pleural Effusion, Fluid Uncontained

Typically the “One view is no view” method will quickly diagnose the presence of pleural effusion because fluid is not contained within a circular or oval pericardial sac; rather, it is seen as triangulations within the pleural space with the wafting lung (Figure 9.18; also see Figures 2.3 and 11.12). In haste, however, and surprisingly even to the experienced sonographer, it is possible for a normal or enlarged cardiac chamber, especially the right ventricle with its papillary muscle, to be mistaken for pericardial or pleural effusion, and for the papillary muscle to be

mistaken for a mass, lung, or inflammatory material such as fibrin (see Figure 9.14).

Zoom out by increasing depth (the same concept for detecting pericardial effusion) because it is best to move away from the suspected fluid so that the heart may be seen in its entirety (not always possible in large dogs). Observe for triangulating fluid at both PCS views and the DH view until you are certain of your conclusions.

If you cannot confidently diagnose pleural effusion, the use of thoracic radiography should be incorporated in the work-up, or complete echocardiography should be done, or both.

Determining the Presence of Cardiac Tamponade

Cardiac tamponade is a life-threatening condition that occurs when intrapericardial pressure exceeds the filling pressure of the right atrium and ventricle. It may be observed by either of the PCS views or the DH view or combinations of each. The waving (collapse with diastole) of the right ventricular or right atrial free wall in the short-axis or long-axis views are classic and often easily recognizable to the sonographer (Figure 9.19; also see Figure 11.15A and Chapter 11). The presence of cardiac tamponade is an indication for immediate, emergent pericardiocentesis in the hemodynamically compromised (collapsed) patient; however, causes of cardiac tamponade differ. Left atrial tears and other effusions with clotted blood are generally unamenable (clotted blood cannot be aspirated) or variably responsive to pericardiocentesis (Figure 9.20). Ultrasound-guided pericardiocentesis is described in Chapter 17.

When performing pericardiocentesis, leave a small volume of fluid in the pericardial sac if complete echocardiography will be subsequently performed because the small volume of pericardial fluid provides an acoustic window for the detection of a pericardial or heart-based mass (Scansen 2011) (see Figure 11.15B).

The Use of the Diaphragmatico-Hepatic View for Pericardial Effusions

The veterinarian incorporating the FAST³ protocols into his or her practice should review the causes and treatment of pericardial effusion, including left atrial tears secondary to mitral valve disease. Comparing 2005 (pre-TFAST³) to 2011 (post-AFAST³ and TFAST³),

the incidence in detecting pericardial effusion was dramatic (two cases vs. 24, annual caseload approximately 11,000). Moreover, of the 24 cases, 21 (88%) were recognized by the diaphragmatico-hepatic (DH) view, either during TFAST³ or AFAST³ (see Figures 2.3A and B, 2.17C, and 9.17C). Approximately 50% of these cases had pericardiocentesis performed, and cardiac tamponade could be diagnosed by the DH view in some instances (Lisciandro 2012, unpublished data). Generally, in real-time ultrasound imaging, this life-threatening condition can be easily recognized by the non-radiologist veterinarian using TFAST³ (Figure 9.19; also see Figure 11.15A).

TFAST³ is also used to stage hemoabdomen cases that are hemangiosarcoma suspects to rule out pericardial effusion, which is often occult on thoracic radiography. Moreover, the Vet BLUE lung scan is additionally used to screen for metastatic lung lesions in this same subset of patients. It is unknown to the author's knowledge, but likely, that ultrasound is more sensitive than radiography for the detection of small neoplastic nodules (see Chapter 10).

Characterization of Pleural and Pericardial Effusions

Importantly, ultrasound cannot accurately characterize or diagnose the etiology of the fluid, and only fluid acquisition via thoracocentesis or pericardiocentesis with analysis will potentially provide such diagnostic information (along with the patient's entire clinical picture). Before pursuing sample acquisition, the risks and benefits must be weighed by the attending veterinarian. Ultrasound-guided or assisted thoracocentesis or pericardiocentesis are described in Chapter 17.

The Use of the Diaphragmatico-Hepatic View for Types of Diaphragmatic Herniation

Through repetition in performing the DH view, the loss of the normal expected curvilinear continuity of the diaphragm will generally be appreciated in the presence of both traumatic and congenital types of diaphragmatic herniation. Additionally not finding the gallbladder at its expected location can also be helpful, triggering suspicion that it is herniated (or ruptured). The axiom of "One view is no view" is also helpful

because often visualization of the heart is obscured by solid organs or viscus structures (air-filled/fluid-filled) including bowel and stomach, which become readily apparent with minimal training by the non-radiologist sonographer (Figure 3.2F and G). Furthermore, this observation will help guide therapy and help avoid blindly performing thoracocentesis into abdominal structures until a confirmatory thoracic radiograph is acquired (Figure 9.21).

Determining Volume Status and Contractility by the Left Ventricular Short-Axis View

Volume status may be subjectively assessed by observing the size of the left ventricular short-axis mushroom view via the (right preferred) PCS view (Durkin 2005) (Figure 9.16) and distension of the hepatic veins via the DH view (Figure 9.22). Contractility may be viewed by the dynamic changes in maximum and minimal size of the left ventricular short-axis mushroom view in systole and diastole (Figure 9.16; also see Figures 11.2 and 11.4). A more global approach to volume status is discussed in Chapter 16 (see Figure 16.2).

The Use of M-mode for Lung Ultrasound

The demand for still image documentation of PTX in humans has resulted in the diagnostic use of M-mode and power Doppler. Using M-mode, dry lung is represented by the seashore sign, likened to the graininess of sand along the shoreline because movement beyond the PP-line results in this ultrasonographic pattern. In contrast, when no movement is present past the PP-line in PTX, a stratosphere sign or bar code sign is seen (Lichtenstein 2007). Finally, when ULRs or wet lung are present, their pendulous motion results in the rain sign (author's term), in which vertical streaks resembling pouring rain move across the screen in real-time (Figure 9.23). Power Doppler has also been used and the glide sign has been referred to as the "power slide" with color stippling representing the to-and-fro motion of the lung and its absence in the presence of PTX (Cunningham 2002). In the author's experience, M-mode is unreliable in most cases because of excessive patient motion and lack of control of breathing by small animals, both of

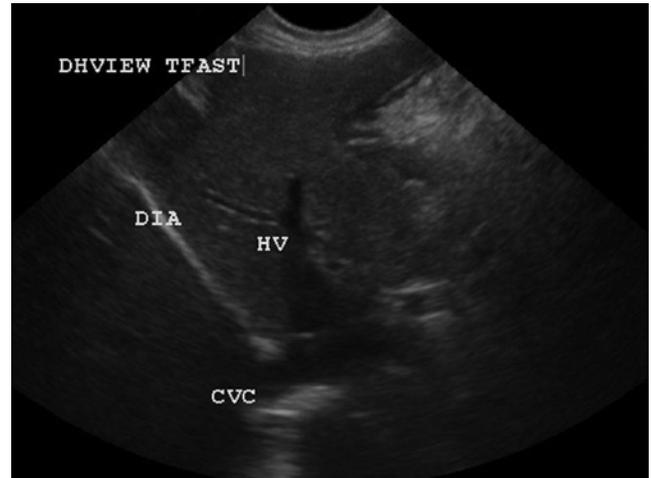


Figure 9.22. Volume status and preload. Shown is the DH view in which the caudal vena cava (CVC) passes through the diaphragm (DIA) into the thorax. Within the thorax, the CVC size reflects preload (central venous pressure). The hepatic veins (HV) are clearly identified as they branch into the CVC and are obviously distended, appearing like tree trunks, supporting right-sided volume overload. Differentials involving right-sided cardiac dysfunction and volume overload that fit the patient's clinical profile should be investigated. © Gregory Lisciandro

which can be potentially controlled in spontaneously breathing human patients (asking humans to be still while they breathe in and out on command). These techniques, however, may prove helpful in dogs and cats that are intubated or undergoing mechanical ventilation.

TFAST³ Revised to Now Include the Vet BLUE Lung Scan

With the addition of the diaphragmatico-hepatic (DH) view, the original TFAST³ has now become a five-point exam. Furthermore, a more extensive lung survey extending from the TFAST³ chest tube site (CTS) called the Vet BLUE lung scan (see Chapter 10) should be used in most cases. This extension of regional lung ultrasound serves to increase the sensitivity and specificity for the detection of intrathoracic conditions including lung pathology and pleural effusion. Vet BLUE is now considered an extension of TFAST³ and should be routinely implemented (see Chapter 10).

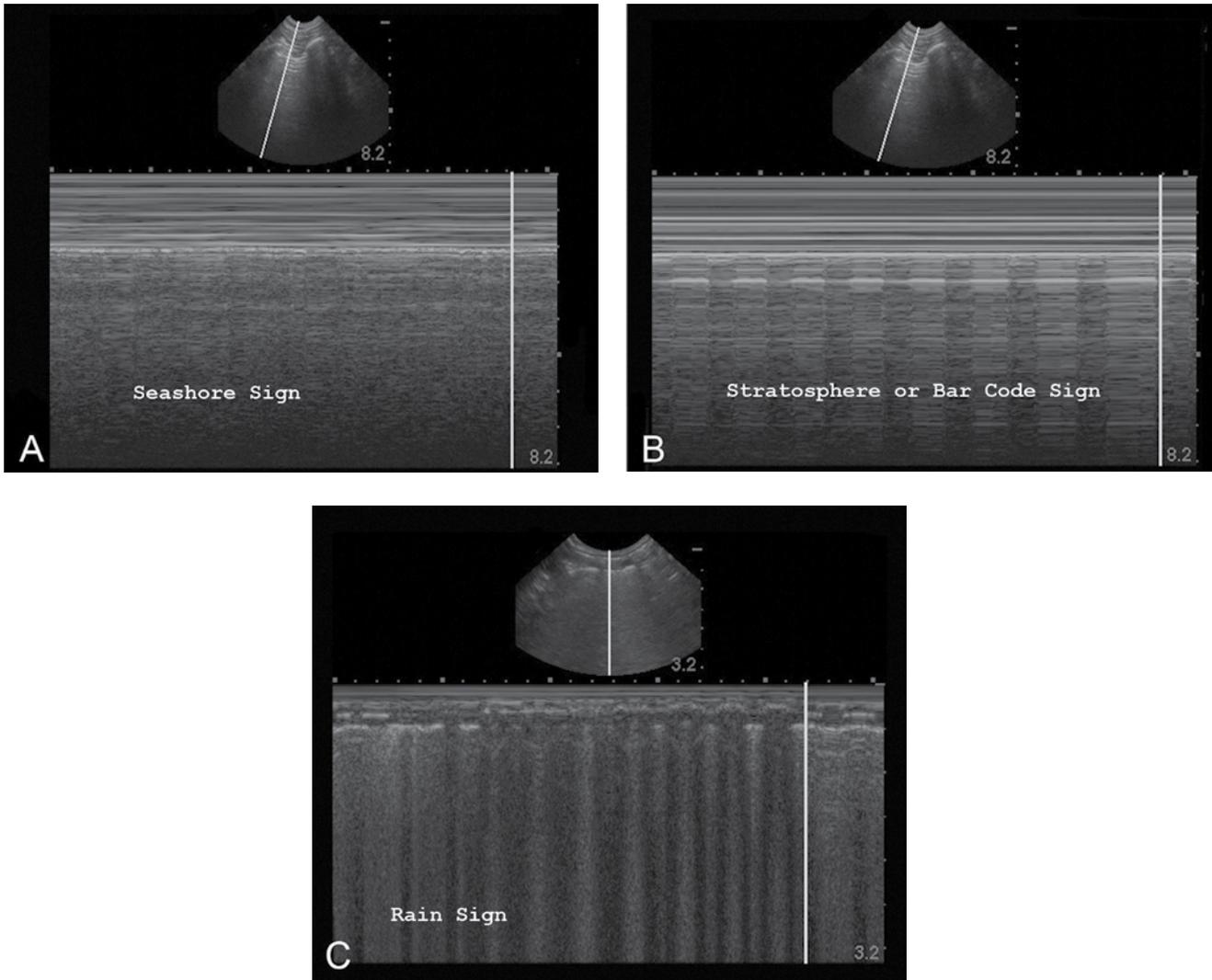


Figure 9.23. M-mode has been used in humans for documenting the presence of pneumothorax by still images (because B-mode images cannot). Attempts to use M-mode in small animals have been unrewarding because unless the animal is not moving and has controlled breathing, too much motion exists. (A) M-mode image of the seashore sign ruling out PTX. Note the A-lines on the B-mode image (above) and the graininess on the M-mode image (below), likened to a sandy beach. (B) M-mode image of the bar code sign, also referred to as the stratosphere sign, on the same patient. This appears more like PTX. In contrast to (A), hyperechoic parallel lines extend from the near field and continue past the PP-line. (C) M-mode image on the same patient as (A and B) showing wet lung by the confluent ULRs (also called white lung) on the B-mode image (above). The M-mode image shows the confluent ULRs as the perpendicular lines called the “rain sign” by the author. In contrast to its poor performance in detecting whether PTX is present, M-mode can reliably document ULRs (author’s experience) in spontaneously breathing animals (although often to no advantage over B-mode). © Gregory Lisciandro

TFAST³ Summary of Views and their Clinical Utility

TFAST³ now consists of five views that are bilaterally applied (CTS, PCS) except for the TFAST³ DH view.

The CTS view is best used to rule out pneumothorax and survey for lung pathology (adding the Vet BLUE lung scan is even better; see Chapter 10).

The PCS view is best used to scan for the presence of pleural and pericardial fluid and may be used subjectively for volume status and contractility assessment via the left ventricular short-axis mushroom view.

The DH view may be the most sensitive of the views for pericardial and pleural effusion because of less lung interference using the acoustic window of the liver and gallbladder. The DH view may also be used

to assess right-sided heart function and volume status. Hepatic venous dilation suggests the presence of right-sided heart dysfunction and/or volume overload, and the intrathoracic caudal vena cava reflects central venous pressure [CVP](Nelson 2010). As experience is gained, the PCS view may be used to assess left atrial size and the LA:Ao ratio (see Chapter 11).

Documenting TFAST³ Findings in Medical Records

The use of standardized templates is imperative not only for communication of TFAST³ findings between veterinarians but also for evaluating serial findings. The use of standardized templates that are goal driven also accelerates the learning curve and disciplines the sonographer by making him or her look at certain aspects of the target organs (e.g., looking into the thorax for pleural and pericardial effusion via the DH view), look at the hepatic veins for venous dilation (congestion), and looking for evidence of cardiac tamponade. Finally, the TFAST³ protocol and its strengths and weaknesses may be evaluated by clinical research and improved upon with recorded data.

Suggested goal-directed templates for medical records are in Appendix II.

Pearls and Pitfalls, the Final Say

- TFAST³ should be used as a first-line screening test for both blunt and penetrating trauma for rapid detection of PTX, pleural and pericardial effusions, as well as other trauma sequelae.
- TFAST³ should be used as a first line screening test in non-trauma subsets of patients with respiratory distress, collapse, and unexplained hypotension.
- TFAST³ should be used post interventionally to detect complications otherwise occult by traditional means of physical examination, laboratory findings, and thoracic radiography.
- TFAST³ includes the fifth DH view (also part of AFAST³) and should always be used to look into the pleural and pericardial spaces because the liver and gallbladder provide an acoustic window (less lung [air] interference) into the thorax.
- TFAST³ should also incorporate the Vet BLUE lung scan in all scans because it increases the sensitivity for the detection of pleural effusion and allows for more thorough lung scrutiny.

- The lung point should be searched for in all PTX suspects to not only increase sensitivity but also to determine the severity of the PTX (partial vs. massive) subjectively by the distance between the CTS view and the lung point.

References

- Ball CG, Ranson KM, Rodriguez-Galvez M, et al. 2009. Sonographic depiction of posttraumatic alveolar-interstitial disease: the handheld diagnosis of a pulmonary contusion. *J Trauma* 66(3):962.
- Boysen SR, Lisciandro GR. 2013. The use of ultrasound for dogs and cats in the emergency room. *Vet Clin North Am Small Anim Pract* 43(4):773–797.
- Cunningham J, Kirkpatrick AW, Nicolaou S, et al. 2002. Enhanced recognition of “lung sliding” with power color Doppler in the diagnosis of pneumothorax. *J Trauma* 52:769–772.
- Blackbourne LH, Soffer D, McKenney M, et al. 2004. Secondary ultrasound examination increases the sensitivity of the FAST exam in blunt trauma. *J Trauma* 57:934–938.
- Breitkreutz R, Price S, Steiger HV, et al. 2010. Focused echocardiographic evaluation in life support and periresuscitation of emergency patients: A prospective trial. *Resuscitation* 81: 1527–33.
- Brockman DJ, Puerto DA. 2004. Pneumomediastinum and pneumothorax. In *Textbook of Respiratory Diseases in Dogs and Cats*, edited by LG King Philadelphia: WB Saunders Company, pp. 617–621.
- Gargani L, Lionetti V, Di Cristofano C, et al. 2007. Early detection of acute lung injury uncoupled to hypoxemia in pigs using ultrasound lung comets. *Crit Care Med* 35(12):2769–2774.
- Hyacinthe AC, et al. 2012. Diagnostic accuracy of ultrasonography in the acute assessment of common thoracic lesions after trauma. *Chest* 141(5):1177–1183.
- Kirkpatrick AW, Sirois M, Laupland KB, et al. 2004. Handheld thoracic sonography for detecting post-traumatic pneumothoraces: the extended focused assessment with sonography for trauma (EFAST). *J Trauma* 57:288–295.
- Koegelenberg CF, von Groote-Bidlingmaier F, Bolliger CT. 2012. Transthoracic ultrasonography for the respiratory physician. *Respiration* 84(4):312–8.
- Kolata RJ, Dudley EJ. 1975. Motor vehicle accidents in urban dogs: a study of 600 cases. *J Am Vet Med Assoc* 167:938–941.
- Lichtenstein DA. 2010. Should lung ultrasonography be more widely used in the assessment of acute respiratory disease? *Expert Rev Respir Med* 4(5):533–538.
- Lichtenstein DA. 2007. Ultrasound in the management of thoracic disease. *Crit Care Med* 35(S5):S250–S261.
- Lichtenstein D. 2012. Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol). *Expert Rev Respir Med* 6(2):155–62.

- Lichtenstein DA, Meziere GA. 2008. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 134(1):117–25.
- Lichtenstein D, Meziere G, Lagoueyte JF, et al. 2009. A-lines and B-lines: lung ultrasonography as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. *Chest* 136:1014–1020.
- Lichtenstein D, Karakitsos D. 2012. Integrating lung ultrasound in the hemodynamic evaluation of acute circulatory failure (the fluid administration limited by lung sonography protocol). *J Crit Care* 27(5):533.
- Lichtenstein DA, Lascos N, Meziere GA, et al. 2004. Ultrasound diagnosis of alveolar consolidation in the critically ill. *Intensive Care Med* 30: 276–281.
- Lichtenstein D, Meziere G, Biderman P, et al. 2000. The “lung point”: an ultrasound sign specific to pneumothorax. *Intensive Care Med* 26:1434–1440.
- Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–122.
- Lisciandro GR, Lagutichik MS, Mann KA, et al. 2009. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma in 101 dogs with motor vehicle trauma. *J Vet Emerg Crit Care* 19(5):426–437.
- Lisciandro GR, Lagutichik MS, Mann KA, et al. 2008. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 18(3): 258–269.
- Lisciandro GR. 2012. Evaluation of initial and serial combination focused assessment with sonography for trauma (CFAST) examinations of the thorax (TFAST) and abdomen (AFAST) with the application of an abdominal fluid scoring system in 49 traumatized cats. Abstract. *J Vet Emerg Crit Care* 22(S2):11.
- Lisciandro GR. 2012. The clinical utility of the AFAST diaphragmatico-hepatic view for the detection of pericardial effusion. Unpublished data.
- Lisciandro GR, Fosgate GT, Fulton RM. 2013. The frequency and number of ultrasound lung rockets (B-lines) using a regionally-based lung ultrasound examination named Vet BLUE (Veterinary Bedside Lung Ultrasound Exam) in dogs with radiographically normal lung findings. *Vet Radiol and Ultrasound*, accepted.
- Nelson NC, Drost WT, Lerche P, et al. 2010. Noninvasive estimation of central venous pressure in anesthetized dogs by measurement of hepatic venous blood flow velocity and abdominal venous diameter. *Vet Radiol and Ultrasound* 51(3):313–323.
- Nyland TC, Mattoon JS. 2002. Thorax. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TC Nyland TC, JS Mattoon JS. Philadelphia: WB Saunders Company, p. 335.
- Ollerton JE, Sugrue M, Balogh Z, et al. 2006. Prospective study to evaluate the influence of FAST on trauma patient management. *J Trauma* 60:785–791.
- Pate J, Rademacher N, Pariaut R, et al. 2010. Comet-tail artifacts in normal dogs and dogs with cardiogenic pulmonary edema. Abstract. *J Vet Intern Med* 24(3):729.
- Powell LL, Rozanski EA, Tidwell AS, et al. 1999. A retrospective analysis of pulmonary contusions secondary to motor vehicle accidents in 143 dogs: 1994–1997. *J Vet Emerg Crit Care* 9(3):127–136.
- Peris A, Zagli G, Barbani F, et al. 2010. The value of lung ultrasound monitoring in H1N1 acute respiratory distress syndrome. *Anaesthesia* 65(3):294–297.
- Reissig A, Copetti R, Kroegel C. 2011. Current role of emergency ultrasound of the chest. *Crit Care Med* 39(5): 1–8.
- Sargsyan AE, Hamilton DR, Nicolau S, et al. 2001. Ultrasound evaluation of the magnitude of pneumothorax: a new concept. *Am Surg* 67:232–235.
- Scansen BA. 2011. Interventional cardiology for the criticalist. *J Vet Emerg Crit Care* 21(2):123–36.
- Sigrist NE, Doherr MG, Spreng DE. 2004. Clinical findings and diagnostic value of post-traumatic thoracic radiographs in dogs and cats with blunt trauma. *J Vet Emerg Crit Care* 14:259–268.
- Simpson SA, Syring R, Otto CM. 2009. Severe blunt trauma in dogs: 235 cases (1997–2003). *J Vet Emerg Crit Care* 19(6): 588–602.
- Soldati G, Sher S, Testa A. 2011. Lung and ultrasound: time to “reflect.” *European Rev Med Pharmacol Sci* 15:223–227.
- Soldati G, Testa A, Silva FR, et al. 2006. Chest ultrasonography in lung contusion. *Chest* 130(2):533–538.

THE VET BLUE LUNG SCAN

Gregory R. Lisciandro

Introduction

The Vet BLUE lung scan, so-called because of “blue” for cyanosis (respiratory distress) and “BLUE” for bedside lung ultrasound exam (Lichtenstein 2008), is a novel abbreviated lung ultrasound exam. For ease of communication it will be referred to as “Vet BLUE” hereafter. The Vet BLUE is designed so that regionally based ultrasonographic lung findings may be correlated to thoracic radiographs (TXR), consistent with how most veterinarians interpret thoracic radiography. Moreover, the simplicity of the Vet BLUE is remarkable because lung ultrasound findings of wet vs. dry lung are an obvious “all or none” ultrasonographic phenomenon.

In people, an analogous lung scan called the BLUE Protocol has shown high sensitivity and specificity in many acute respiratory conditions (Lichtenstein 2008, Volpicelli 2012); it may be used advantageously for rapid clinical impression for causes of respiratory distress as well as monitoring response to therapy (Lichtenstein 2008, Pate 2010, Soldati 2011, Volpicelli 2012). Vet BLUE is clinically helpful in dogs and cats for classifying respiratory vs. non-respiratory causes as well as further discriminating between lower- and upper-airway conditions and respiratory and cardiac causes and directing the search for non-respiratory distress look-a-likes (e.g., hemoabdomen, pericardial effusion/tamponade, acute abdomen, severe metabolic acidosis, fever/pyrexia, and others). Based on many recent clinically based lung ultrasound studies in human patients (Lichtenstein 2008, 2009, Lichtenstein 2012, Volpicelli 2012) and ongoing clinical research by the author, lung ultrasound (Vet BLUE) will become a practice-changer for the evaluation of respiratory

distress and monitoring in small animals through the use of the ultrasound probe as a stethoscope.

Traditionally, small animal veterinarians have made clinical decisions related to respiratory distress based on insensitive information such as history, thoracic auscultation, and breathing patterns (Sigrist 2004, 2011). Frequently, patients are too unstable to undergo the stress of thoracic radiography (TXR) or incur delay due to lack of resources (e.g., unavailability of technical support or an overburdened radiology department). Thus, an evidence-based working diagnosis is delayed (because TXR is the mainstay for diagnosis). As a result, therapeutic decisions are often made on a shotgun or best-guess basis. In other words, the veterinary patient is ultimately treated with several different drugs to cover several differentials and this strategy is not always in the patient’s best interest. The advantage of lung ultrasound, compared to the art of chest auscultation, is that it is rapid, safe (radiation-sparing), available at the point of care, and unaffected by environmental and patient noise, and provides an objective lung evaluation in the hands of a properly trained sonographer (Volpicelli 2012).

As with AFAST³ and TFAST³, the Vet BLUE may be performed on the triage table during the first minutes of patient evaluation, at the point of care, or while interventional procedures (acquiring vital signs, supplementing oxygen, placing intravenous catheters, and administering intravenous fluids and medications) are taking place. With proper training, these THREE exams are fast (median time of AFAST and TFAST is three minutes or less [Lisciandro 2008, 2009, 2011]; Vet BLUE is two minutes or less). Furthermore, Vet BLUE in combination with AFAST³ and TFAST³ allows most

life-threatening non-respiratory look-a-likes to be rapidly and confidently ruled in or ruled out.

Veterinarians must appreciate several points when using Vet BLUE and lung ultrasound:

- It is suspected but not fully known that significant, clinically-relevant, pulmonary disease extends to the lung periphery in dogs and cats, similar to in people (and is thus accessible by lung ultrasound) (Lichtenstein 2008, Lichtenstein 2010, Soldati 2011, Volpicelli 2012, Lisciandro 2013)
- Centrally, deeper located lung disease will not be detected (occult) by lung ultrasound because ultrasound cannot image through aerated lung (Soldati 2011, Volpicelli 2012).
- In most instances ultrasound lung rockets (ULRs, also called B-lines) represent forms of interstitial edema referred to as interstitial syndrome (cardiogenic and non-cardiogenic pulmonary edema [non-trauma]) and in trauma patients, lung contusions (Ball 2009, Soldati 2006, Volpicelli 2012).
- Interstitial edema (less serious, as evidenced by ULRs) precedes alveolar edema (more serious, as evidenced by lung consolidation) and ULRs may be used clinically as an early warning sign to alter therapeutic course (Lichtenstein 2009, 2010, 2012, Jambrik 2010, Soldati 2011).
- Infiltrative lung conditions such as lung consolidation and nodular disease are ultrasonographically visualized by observing the shred sign, tissue sign, and nodule(s) sign, but only if these lesions are located at or extend to the lung's periphery (Lichtenstein 2009, 2010, 2012, Volpicelli 2012, Lisciandro 2013).

The Vet BLUE, combined with AFAST³ and TFAST³, has many clinical applications in trauma and non-trauma subsets of veterinary patients including those that are critically ill, at risk and hospitalized, and in respiratory distress at triage or during hospitalized care. When Vet BLUE is combined with AFAST³ and TFAST³, the study is referred to as global FAST³ or GFAST³. These abbreviated techniques have been referred to as “extensions of the physical examination” and the ultrasound probe as “the modern stethoscope” in human and veterinary medicine (Rozycki 2001, Filly 1988, Lisciandro 2011). By applying the same principles of the “T³” of AFAST³ and TFAST³ (representing trauma, triage, and tracking [i.e., monitoring]) to Vet BLUE, there is less need for an onslaught of acronyms for similar abbreviated ultrasound exams as has occurred in the human literature (Lisciandro 2011).

What Vet BLUE Can Do

- Rapidly rule out any clinically significant interstitial edema by the finding of dry lungs (A-lines with a glide sign) in all lung regions
- Rapidly detect signs of interstitial syndrome (cardiogenic and non-cardiogenic pulmonary edema) using the wet lung (ultrasound lung rockets) principle
- Rapidly and potentially preemptively (before overt clinical signs or detection by traditional means) detect the development of interstitial syndrome using the wet lung principle in at-risk patients for volume overload (fluid resuscitation, transfusion administration, mechanical ventilation, kidney failure, hypoalbuminemia, heart disease, etc)
- Rapidly and potentially preemptively (before overt clinical signs or detection by traditional means) detect the development of acute lung injury/acute respiratory distress syndrome and its related subsets
- Detect lung patterns that support pulmonary contusions in trauma patients
- Detect regionally based lung patterns in non-trauma subsets of respiratory-distressed patients that support feline asthma, chronic obstructive pulmonary disease, acute aspiration pneumonia, and other forms of pneumonia, pulmonary thromboembolic disease, and neoplasia
- Semi-quantitate the degree of lung contusions or forms of pulmonary edema by counting the number of ULRs and recording their distribution at Vet BLUE sites (0, 1, 2, 3, greater than 3, ∞ [infinity])
- Monitor the response to therapy (serial exams) in many lung conditions including cardiogenic and non-cardiogenic pulmonary edema, pulmonary contusions, pneumonias, neoplasia, and granulomatous disease

What Vet BLUE Cannot Do

- Cannot give a diagnosis because Vet BLUE provides pattern-based evidence for certain lung conditions similar to interpretative conclusions using thoracic radiography
- Is limited to lung disease that has made it to the lung periphery; thus, Vet BLUE is not able to detect centrally (deeper) located lung disease
- Cannot fully replace thoracic radiography

Indications for the Vet BLUE Exam

- Preemptive screening for patients with respiratory compromise or distress or hospitalized patients at risk for respiratory complications
- Rapid assessment at point of care in animals too unstable for thoracic radiography or computerized tomography (CT), or when radiography is delayed because of lack of resources
- Monitoring response to therapy in many respiratory patients as a rapid, non-invasive, radiation-sparing, and point-of-care imaging modality
- Guide for fluid resuscitation or for early detection of volume overload (cardiogenic pulmonary edema) in at-risk hospitalized and critically ill animals

Objectives of the Vet BLUE Exam

- Apply simple wet lung and dry lung ultrasound concepts in a pattern-based approach, and thus categorize respiratory-distressed patients into probable causes including upper airway vs. lower airway, lung disease vs. heart failure vs. non-respiratory (so-called respiratory look-a-likes) causes
- Recognize additional lung conditions through the recognition of the shred sign, tissue sign (degrees of consolidation), and nodule(s) sign (neoplastic, granulomatous, abscessation)
- Preemptively anticipate thoracic radiographical findings by using basic lung ultrasound findings
- Make more evidence-based decisions regarding therapeutic course (initial assessment as well as monitoring) in respiratory-diseased or -affected animals

Ultrasound Settings and Probe Preferences

Curvilinear (or linear) probes may be used within a frequency of 5–10MHz. The focal zone cursor, featured on most ultrasound (US) machines, should be placed directly across from the bright white (hyperechoic) line, also referred to as the pulmonary-pleural line (PP-line), which is identified by the “gator sign” orientation. The gator sign is the same intercostal orientation as for the TFAST³ chest tube site (CTS) view. Generally, the depth setting should be set between 4–6 cm. In small dogs/puppies and cats/kittens several intercostal spaces may be apparent (also acceptable if the number of lung rockets over a single intercostal space may be counted). This described method is used for all lung ultrasound (see

also Chapter 9). See the subsequent probe orientation section below for additional detail.

Consider Vet BLUE as an extension of the TFAST³ chest tube site view applied to three additional lung lobe regions, providing more comprehensive lung information. It should be a routine add-on to TFAST³ or may be used as its own stand-alone technique.

How to do a Vet BLUE Exam

Patient Positioning

The patient is evaluated in sternal recumbency or in a standing position with each view being stationary, similar to the TFAST³ CTS view (Figure 10.1). Similarly, fur is generally not shaved but rather parted for probe-to-skin



Figure 10.1. The Vet BLUE regional lung scan externally depicted on a dog. Consider Vet BLUE as an extension beyond the TFAST³ chest tube site (CTS) view, shown here as a single black bar. The Vet BLUE caudodorsal lung lobe region is the same site as the CTS view, and imaging of Vet BLUE sites is identical to performing TFAST³ at the CTS view. By holding the probe horizontally, ultrasonographic imaging of the pleural-pulmonary interface (PP-line) is maximized (vs. holding the probe vertically [not recommended]). The probe marker (black dot) is directed toward the patient’s head for standard orientation. After imaging the caudodorsal lung lobe (cdll) region in Vet BLUE, the probe is moved (blue arrows) to the perihilar lung lobe region (phll), then to the middle lung lobe region (mdll), and finally to the cranial lung lobe region (crl). Each of these sites (phll, mdll, crl) is represented by black circles. The final crll view is achieved by gently pulling the foreleg forward to get into the axilla and its second and third intercostal spaces. The same scan is repeated on the opposite hemithorax. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

contact with the use of alcohol and/or acoustic coupling gel. Alcohol should not be used if electrical defibrillation is anticipated (poses serious fire hazard). The clinician should be aware that alcohol may physically cool and be noxious to some patients and may cause probe head damage. By not shaving (or limiting shaving to small viewing windows), the cosmetic appearance of the patient is preserved (happier clients), the exam time is lessened, and imaging quality is generally sufficient. In the published TFAST (and AFAST) study, no dogs were shaved and lights were rarely dimmed for the ultrasound exams (Lisciandro 2008, 2009). In a recent human prospective study evaluating the efficacy of US during cardiopulmonary resuscitation (CPR), similar favorable conclusions regarding ambient light were made (Brietkrutz 2010).

Sternal recumbency or the standing position is used for TFAST³ and Vet BLUE in all respiratory-compromised patients. A modified sternal recumbency position may be used for AFAST³ in which the forelegs are sternal and the hind legs moved to lateral as the patient allows. A tip for gaining a cardiac imaging advantage (especially for cats) is to place a rolled towel under the forelegs of a sternally recumbent patient, thus elevating the sternum off the exam table and optimizing maneuverability of the ultrasound probe (also see Figures 9.1 and 9.2).

Dorsal recumbency should never be used. The AFAST-applied fluid scoring system is invalid in dorsal and sternal recumbency, and distressed patients may decompensate in dorsal recumbency (Sigrist 2004, 2011, Lisciandro 2009, 2011).

Probe Orientation

The standard orientation for all lung ultrasound begins with the observation of the gator sign (Figure 10.2). The gator sign is created by the rounded rib heads (gator's eyes) with a proximal hyperechoic (bright white) line in between (gator's bridge of nose), creating the image of a partially submerged alligator peering over the water at the sonographer. The space between the rib heads (gator's eyes) is the intercostal region, with the bright white line (gator's bridge of nose) created by the strong air-soft tissue interface representing the PP-line where lung normally glides along the thoracic wall.

The gator sign orientation is the focus for all lung ultrasound and for observing the to-and-fro motion of the glide sign representing the lung sliding like an Etch-a-Sketch[®] cursor along the thoracic wall. This orientation is the same as previously described using TFAST³ at its chest tube site (CTS) view (Lisciandro 2008, 2011) (see Figures 9.2 and 9.4).

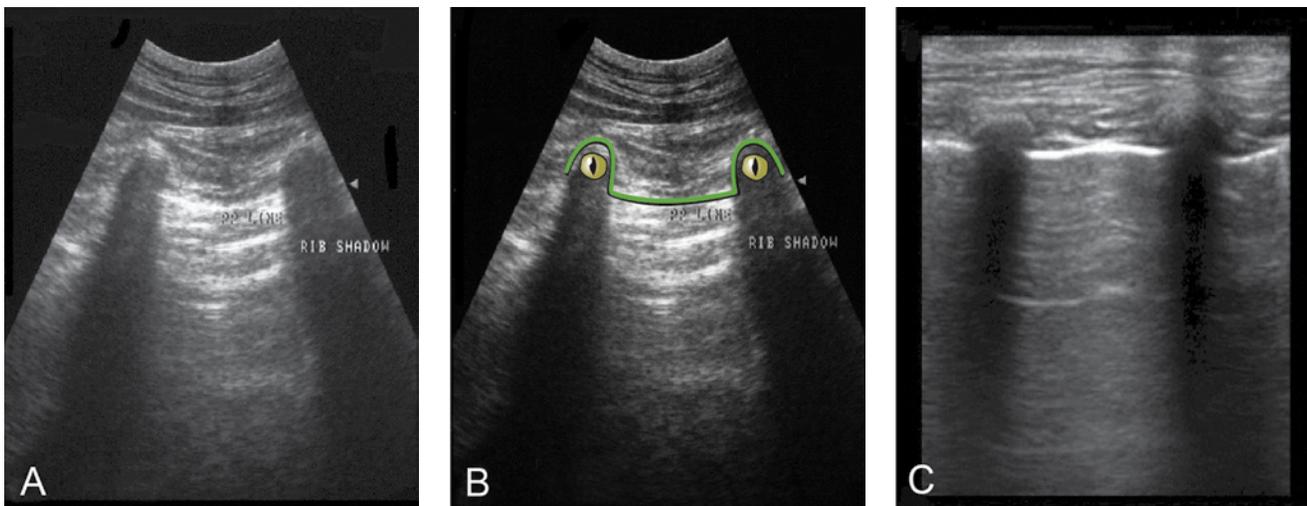


Figure 10.2. The basic orientation for all lung ultrasound is the gator sign. The orientation of the rib heads (shown as eyes) and intercostal space (shown as its bridge of nose) is likened to an alligator peering over the water at the sonographer. The depth is generally set between 4–6 cm. (A) B-mode ultrasound image using a curvilinear US probe. (B) The “gator sign” placed pictorially on the B-mode still image. The gator eyes represent the rib heads and through the far field note the clean acoustic shadowing because ultrasound does not transmit through bone. The bridge of its nose represents the intercostal space where the pulmonary-pleural interface (PP-line) and the glide sign or to-and-fro real-time motion of lung sliding along the thoracic wall is observed. (C) The B-mode image using a linear probe. A-lines (“A” for air) represent air reverberation artifacts which parallel the PP-line and extend from it into the far field. They are not to be confused with the most proximal bright white line, the PP-line, because the glide sign cannot be observed within these artifactual A-lines. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

The presence of subcutaneous emphysema (SQE) prevents orientation of the gator sign, thus negating the use of TFAST³ and Vet BLUE; however, SQE almost always can be displaced with gentle probe pressure, allowing for visualization of the gator sign and thus TFAST³ and Vet BLUE can be satisfactorily performed (Figure 9.11).

Performing the Vet BLUE

The Vet BLUE is performed with the probe stationary and horizontally positioned as with the TFAST³ CTS view and similarly acquiring the gator sign orientation (Figure 10.2) with a depth setting of generally between 4–6 cm. The more comprehensive lung surveillance of Vet BLUE, however, includes four regional lung locations—or rather three additional lung locations beyond the CTS view. The Vet BLUE lung scan begins with the caudodorsal lung lobe region (cdll) (this is the same as the TFAST³ CTS view), then moves on to the perihilar lung lobe region (phll), followed by the middle lung lobe region (mdll), and finally the cranial lung lobe region (crll) (Figure 10.3). The cranial lung lobe region requires pulling the foreleg slightly forward to access the second and third intercostal spaces in the axilla.

These same four regions, performed on both the right and left sides, are defined as follows:

Caudodorsal lung lobe region (cdll): directly dorsal to the xiphoid between the eighth and ninth intercostal spaces near the highest point (upper third of thorax) to access the pleural space. The cdll site is the same as the TFAST³ CTS.

Perihilar lung lobe region (phll): the point mid-thorax (central third of thorax) between the sixth and seventh intercostal spaces approximating the perihilar region.

Middle lung lobe region (mdll): the lower thorax over the heart (lower third of thorax) in the fourth to fifth intercostal spaces. If the heart is in view and obscuring lung, move an intercostal space(s) caudally for the mdll view.

Cranial lung lobe region (crll): the second to third intercostal space cranial to the heart (lower third of thorax). The foreleg often needs to be gently pulled forward to get this view. If the heart is in view and obscuring lung, move an intercostal space(s) cranially for the crll view.

The Vet BLUE views are illustrated externally on a dog and correlated to a lateral TXR (Figure 10.3). It is important to note that Vet BLUE sites are referred to as regions because they do not specifically correlate to an actual anatomic lung lobe (Figure 10.4).

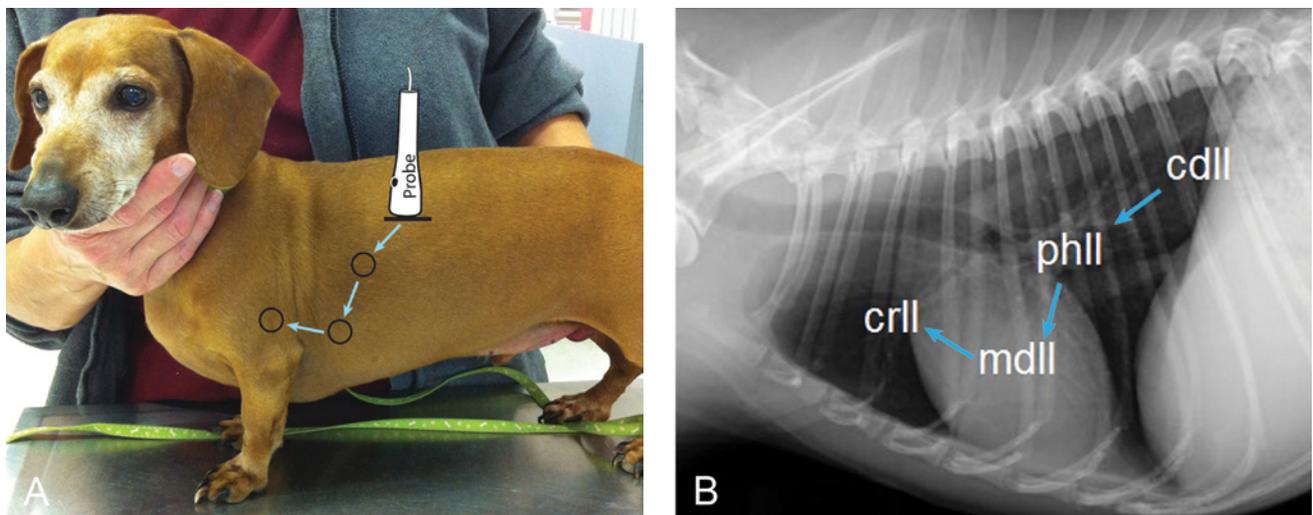


Figure 10.3. The Vet BLUE regional lung scan correlated to thoracic radiography. Shown is the same dog in Figure 10.1 with a corresponding lateral thoracic radiograph. (A) The external sites on the dog may be correlated to internal lung regions marked on (B) (the lateral thoracic radiograph). Vet BLUE begins at the caudodorsal lung lobe region (cdll), which is the same as the TFAST³ CTS view. From the cdll the probe is then moved (arrows) to survey the perihilar lung lobe region (phll) and then to the middle lung lobe region (mdll) and then finally to the cranial lung lobe region (crll). The foreleg must be gently pulled forward for evaluation of the crll (see text for the definitions of each Vet BLUE site). The Vet BLUE is repeated on the opposite hemithorax. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

Vet BLUE Scan

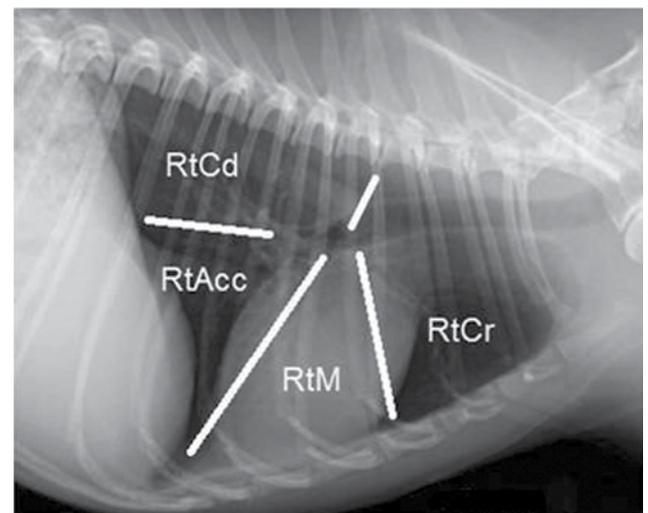
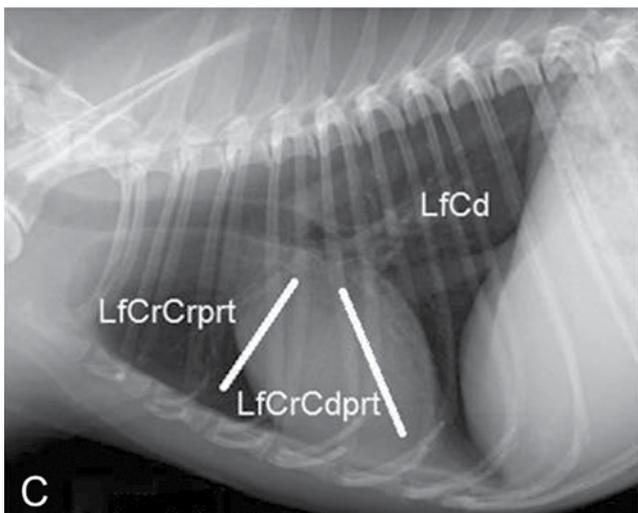
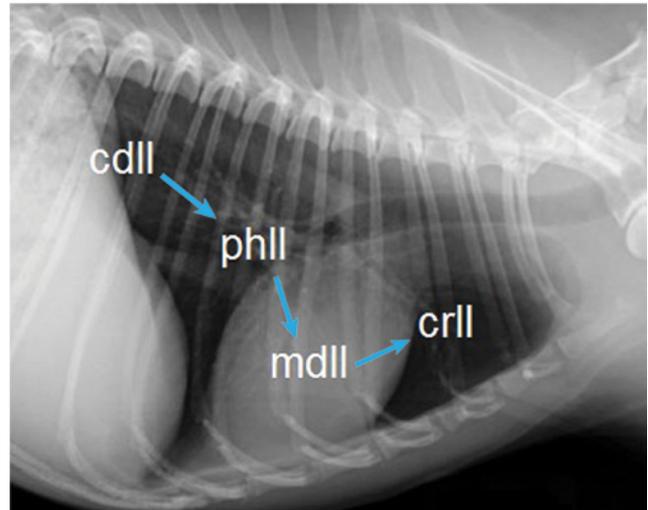
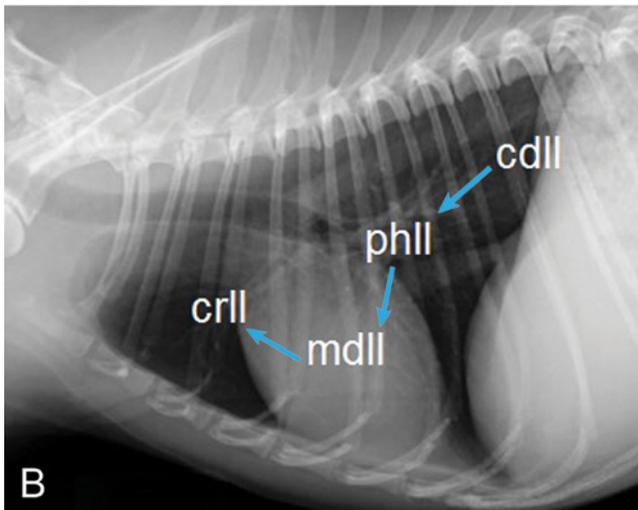
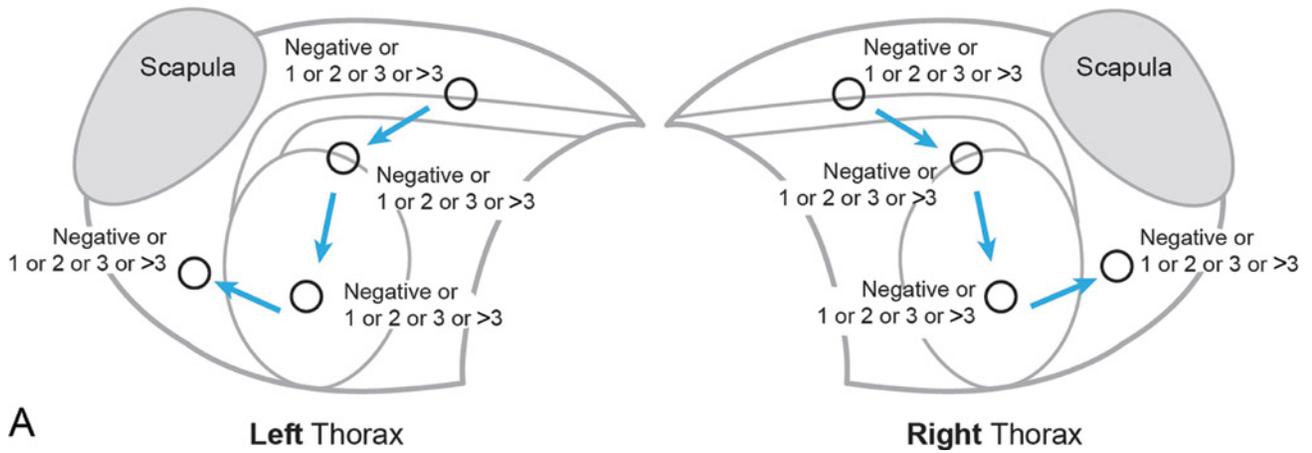


Figure 10.4. (Continued)

Lung Ultrasound Findings: Dry Lung, Wet Lung, Shred Sign, Tissue Sign, and Nodule(s) Sign

The Wet Lung vs. Dry Lung Principle

The Vet BLUE is primarily based on the concept of wet lung vs. dry lung and the standard orientation of the gator sign, which is the same orientation of the CTS of TFAST³ (Lisciandro 2009, 2011). However, there are additional lung ultrasound signs that correlate with lung abnormalities. Basic lung US signs, listed in succession from least to most infiltrative conditions (Figure 10.5), are as follows:

Dry Lung, Glide Sign with A-lines

Dry lung is defined by the presence of the glide sign and reverberation artifact called A-lines (equidistant hyperechoic [bright white] parallel lines to the PP-line) (Figure 10.5A, Figure 10.6).

The major confounder of dry lung is pneumothorax, which looks identical to dry lung (A-lines) without the presence of a glide sign. However, in cases unlikely to have PTX, and in which Vet BLUE is being used to detect forms of interstitial edema, the direct observance of the glide sign with A-lines becomes less important (the observance of A-lines is often adequate).

Wet Lung, Ultrasound Lung Rockets

Wet lung is represented by ultrasound lung rockets (ULRs), also called B-lines, and are defined as hyperechoic laser-like lines that do not fade and originate from the PP-line or pulmonary surface. These move to and fro, oscillating with inspiration and expiration, and must extend to the far field, obliterating A-lines.

The majority of clinically relevant wet lung conditions in the acute care setting include cardiogenic and non-cardiogenic pulmonary edema (non-trauma), lung contusions (trauma), lung hemorrhage (non-trauma, coagulopathic), and acute pneumonias (Figures 10.5B and 10.7, and 10.8). Their regional ULR distribution helps discriminate among these conditions (also see Figure 10.16). In dogs and cats without respiratory disease, ULRs are detected in low numbers or not at all during a Vet BLUE exam (Lisciandro 2013; Pate 2010).

ULRs are sentinels of evolving lung edema (increased lung water) because they generally represent interstitial edema in non-trauma patients, referred to as interstitial syndrome (and in trauma patients, lung contusion). ULRs occur prior to the development of alveolar flooding (which is more serious) and subsequent lung consolidation (shred and tissue sign). By recognizing their presence, the attending clinician has an opportunity to modify the clinical course (or investigate the cause) before clinical signs are overt and the patient decompensates (also see Figure 10.14).

Wet lung is only ultrasonographically apparent if the condition extends to the lung periphery. Centrally located (deeper) lung consolidation will be occult (missed) using lung ultrasound.

Forms of Lung Consolidation

The following are additional lung ultrasound signs considered subsets of the step sign. Each is recognized by inconsistencies in the normal expected linear continuity of the PP-line.

Shred Sign, Lung Consolidation with Aeration

The shred sign is defined as a significant deviation from the expected linear continuity of the hyperechoic PP-line by hypoechoic, echo-poor tissue indicating peripheral lung consolidation (Figure 10.9). Within the

Figure 10.4. The Vet BLUE lung scan and lung lobe anatomy. (A) The Vet BLUE shown pictorially on the left and right hemithorax of a dog or cat. The locations and movement of the probe are shown starting at the caudodorsal lung lobe (cdll) region (same site as the TFAST³ chest tube view) and carrying on through the perihilar region (phll), middle lung lobe (mdll) region, and finally the cranial lung lobe (crl) region. Each represents a lung lobe region and thus lung US findings may be translated to how patterns are interpreted on thoracic radiography. Numbers of ULRs at each site are recorded by counting the maximum number over a single intercostal space from 0 (none) to 1, 2, 3, and then >3 (can individually count more than 3) to the highest number of infinity (∞ , symbol not shown in figure; ULRs in such high numbers that they are confluent/uncountable). See examples in Figure 10.14A through C. (B) Below each respective hemithorax with Vet BLUE lung lobe regions are (C) the anatomic divisions of the right and left lung lobes, emphasizing the difference between the regionality of Vet BLUE and the actuality of lung anatomy (not to be confused). Abbreviations for Vet BLUE are the same for the right and left sides as follows: cdll, caudodorsal lung lobe region; phll, perihilar lung lobe region, mdll: middle lung lobe region, crll: cranial lung lobe region. Abbreviations for anatomic divisions of right and left lung are as follows: LfCd, left caudal lung lobe; LfCrCdprt, left cranial lung lobe caudal part; LfCrCrprt, left cranial lung lobe cranial part; RtCd, right caudal lung lobe; RtAcc, right accessory lung lobe (inaccessible [too deep] ultrasonographically); RtM, right middle lung lobe; RtCr, right cranial lung lobe. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

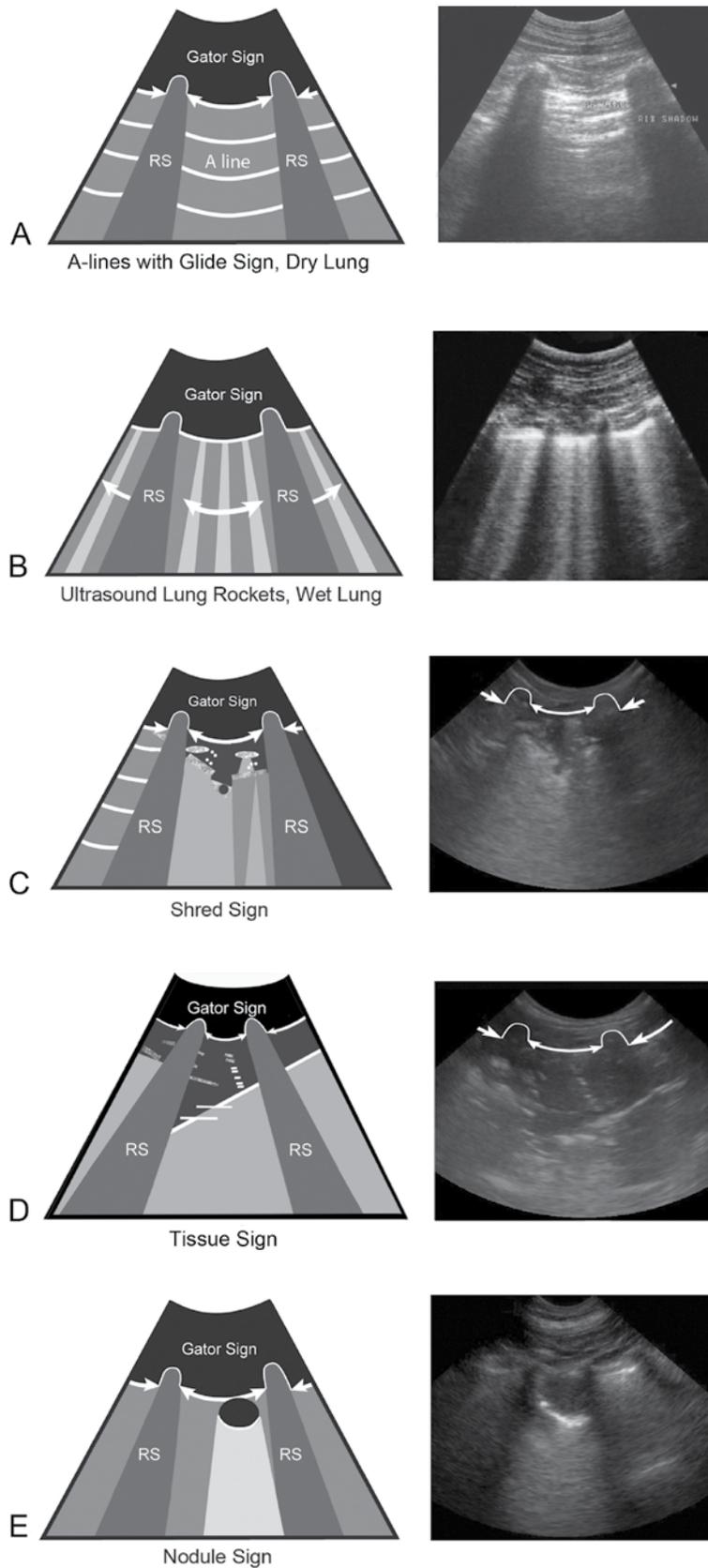


Figure 10.5. Basic lung ultrasound findings with relative degree of infiltration from least to most (top to bottom). Line drawings are in the left column and the corresponding B-mode ultrasound images are directly to the right column. (A) Dry lung. (B) Wet lung. (C) Shred sign. (D) Tissue sign. (E) Nodule sign. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

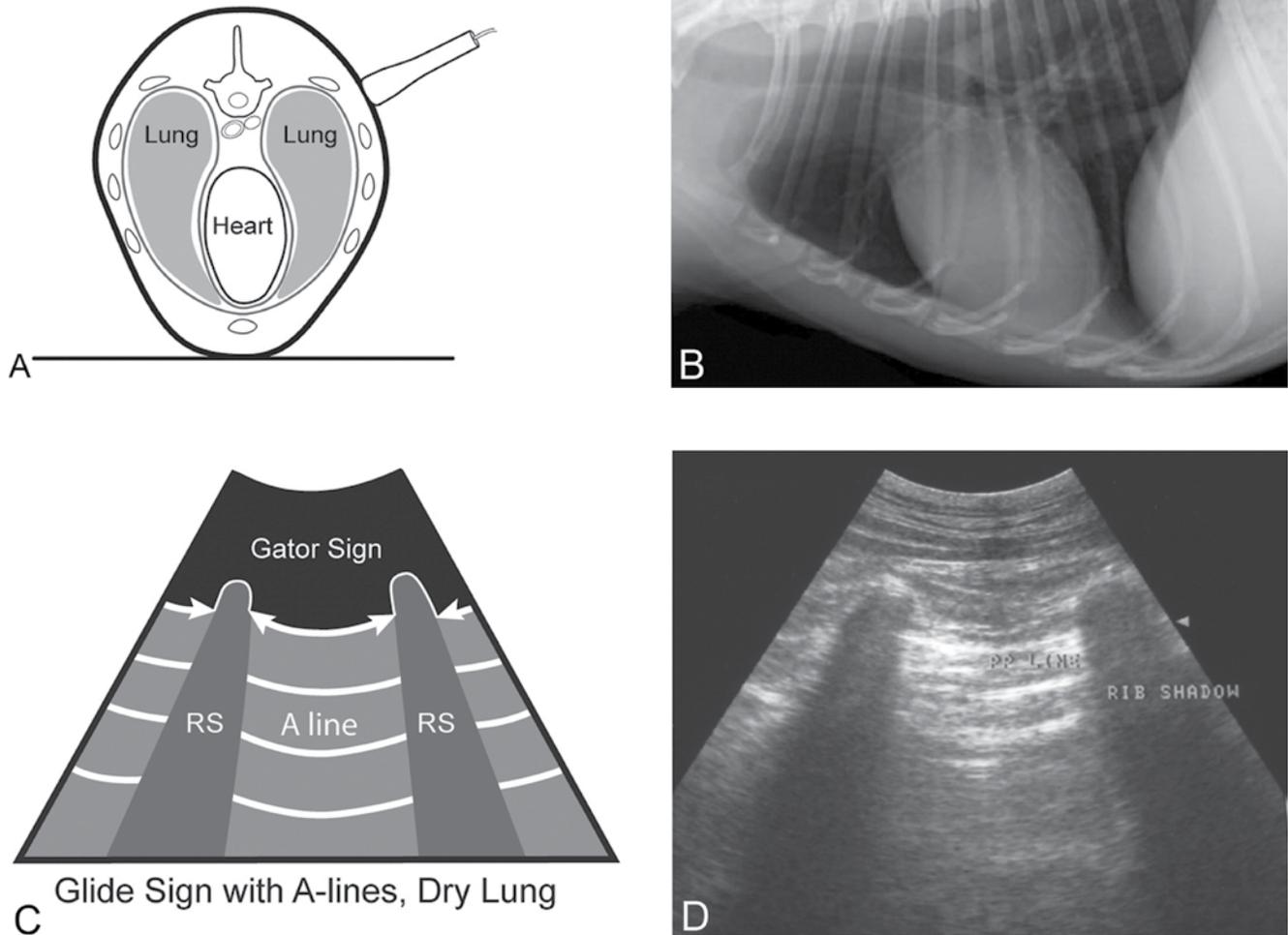


Figure 10.6. A Dry lung, A-lines with a glide sign. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST³ CTS view. (B) Correlating unremarkable thoracic radiograph. (C) Correlating line drawing showing dry lung. A-lines (air reverberation artifact) with a glide sign (arrows at the proximal bright white line [PP-line]) and rib shadowing (RS). (D) Correlating B-mode still image that is not diagnostic for dry lung because the glide sign cannot be depicted on a still image. The dynamic real-time finding of the glide sign rules out PTX because both “dry lung” and PTX appear the same on still B-mode images. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

shred sign, hyperechoic foci (partially aerated lung), ULRs, and small minimally moving comet tails (not true ULRs because they do not extend to the far field) may be present.

Generally speaking, the shred sign represents significant lung consolidation with some degree of aeration from various causes including significant pulmonary hemorrhage, pneumonia, cardiogenic and non-cardiogenic pulmonary edema, neoplastic conditions, and severe pulmonary thromboembolic disease as shown in people (Volpicelli 2012) (also see

Figure 10.5C). The shred sign in real-time is likened to a thunderstorm rolling in with its thunderclouds (shred and aeration artifacts) and its intermittent flashes of lightning (ULRs).

The shred sign is only ultrasonographically apparent if the lung consolidation extends to the lung periphery. Centrally located (deeper) lung consolidation will be occult (missed) using lung ultrasound.

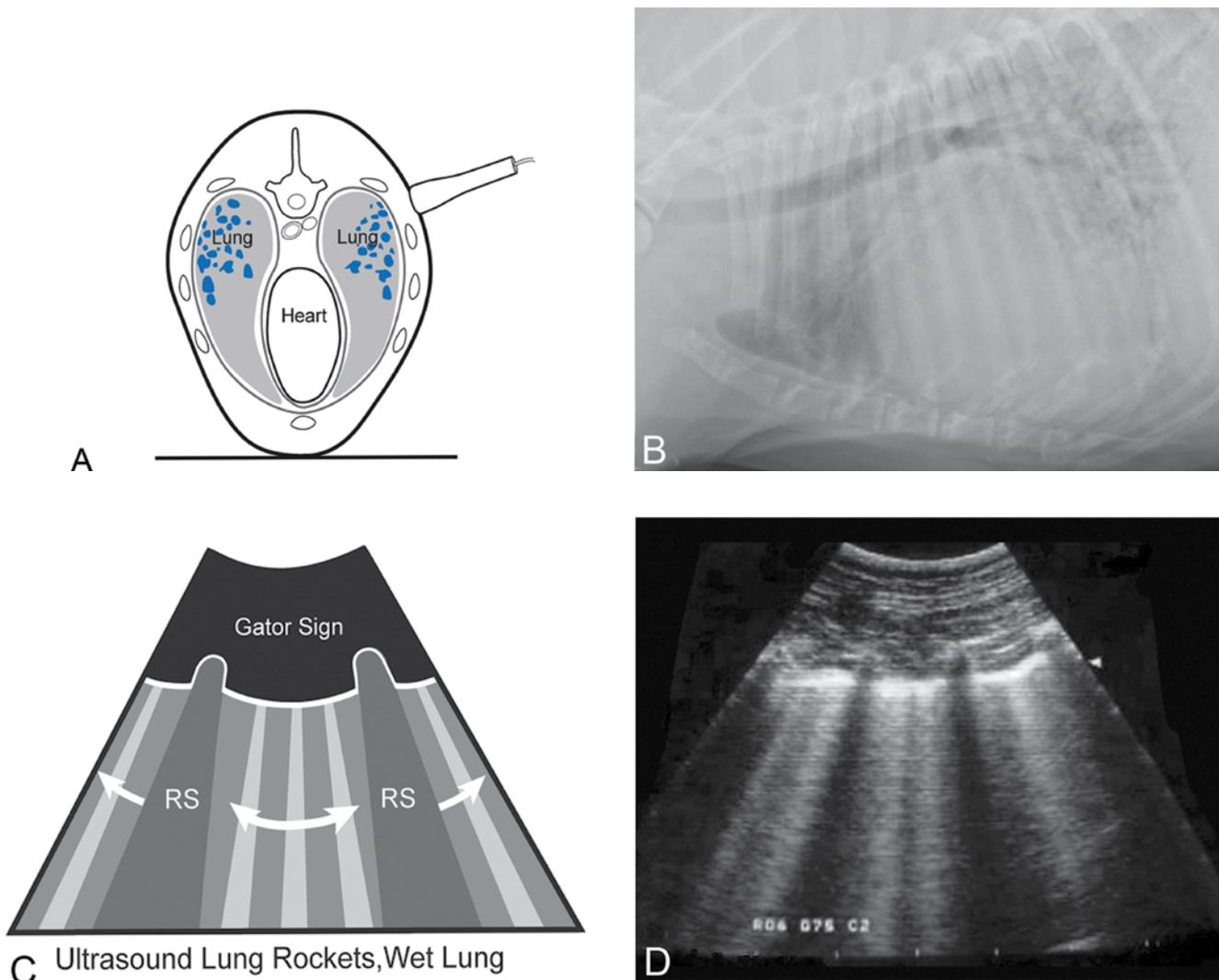


Figure 10.7. Wet lung, acute cardiogenic pulmonary edema. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST³ CTS view. Note that the lungs have blue mottling representing interstitial edema. (B) Correlating thoracic radiograph typical of left-sided heart failure with cardiogenic pulmonary edema. (C) Correlating line drawing depicting wet lung as ultrasound lung rockets (ULRs). These are shown as laser-like projections from the PP-line through the far field, obliterating A-lines and oscillating or swinging like a pendulum in synchronization with inspiration and expiration (arrows). (D) Correlating B-mode still image that captures individual ULRs. Note this same pattern would also reflect forms of non-cardiogenic pulmonary edema (e.g., choking, electrocution, neurogenic conditions, and others). Interestingly, response to therapy may be tracked using serial lung ultrasound rather than thoracic radiography. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

Tissue Sign, Lung Consolidation with No Aeration

The tissue sign represents more severe lung consolidation with the complete lack of aerated lung (airways are fluid-filled or flooded) with an echo-poor ultrasonographic appearance of lung similar to tissue (Figure 10.10). The tissue sign has been referred to as hepatization of lung in some veterinary ultrasound texts (Nyland 2002, Penninck 2008) (also see Figures 10.5D, 10.16D). This is a more severe sign of

consolidation than the shred sign because the lung completely lacks aeration. Distinguishing the shred sign from the tissue sign may be difficult to determine and clinically irrelevant in many cases.

The tissue sign is only ultrasonographically apparent if lung consolidation occurs at the periphery of lung. Centrally located (deeper) lung consolidation will be occult (missed) using lung ultrasound.

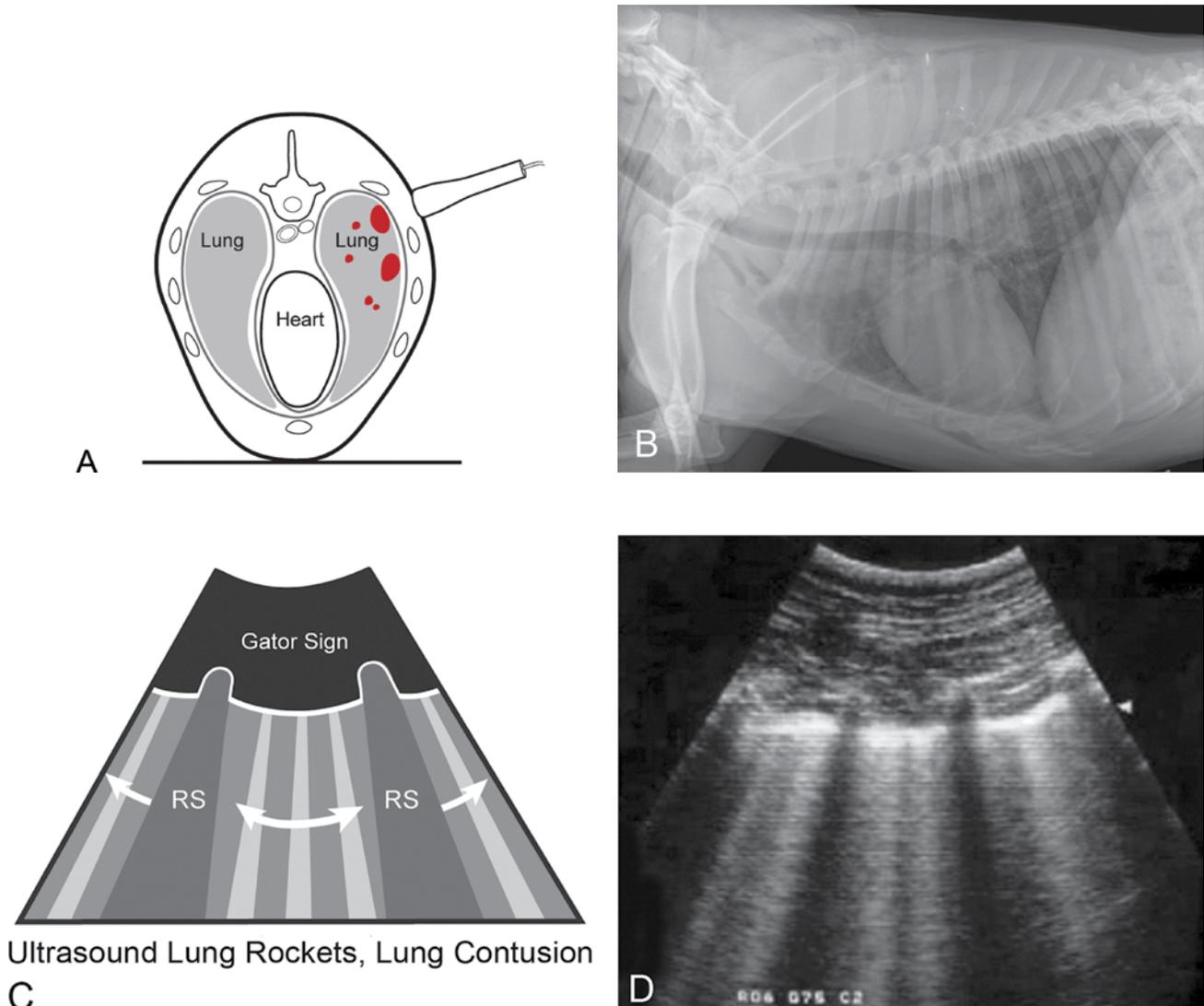


Figure 10.8. Wet lung, lung contusion. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST³ CTS view. Note the lungs have red mottling representing pulmonary contusions (hemorrhage). (B) Correlating thoracic radiograph with subtle radiographically evident lung contusions in the caudodorsal and perihilar lung fields (dog with a gunshot wound). (C) Correlating line drawing showing wet lung as ultrasound lung rockets (also called B-lines). (D) Correlating B-mode still image that captures individual ULRs or B-lines. Lung contusions may be graded in severity by counting ULRs and recording any signs of consolidation at each Vet BLUE site, and then monitored during clinical course in the same manner. The dog with the gunshot wound had easily recognizable lung ultrasound findings of ULRs along with a large focal shred sign at its Vet BLUE phll view (in contrast to a more benign TXR), and PTX was ruled out. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

Nodule Sign, Lung Mass

The nodule sign often appears as a focal, well-marginated or circular hypoechoic structure(s) surrounded distally or more deeply by air-filled lung (Figures 10.11 and 10.12). Nodules may range in size from a few millimeters to several centimeters and occur singly or in large numbers (Figures 10.5E). In some instances, nodules may be associated with nearby inflammation

(edema, hemorrhage) and thus be associated with ULRs (see Figure 10.16F).

The nodule sign is only ultrasonographically apparent if nodules are located at the periphery of lung. Centrally located (deeper) nodules will be occult (missed) using lung ultrasound.

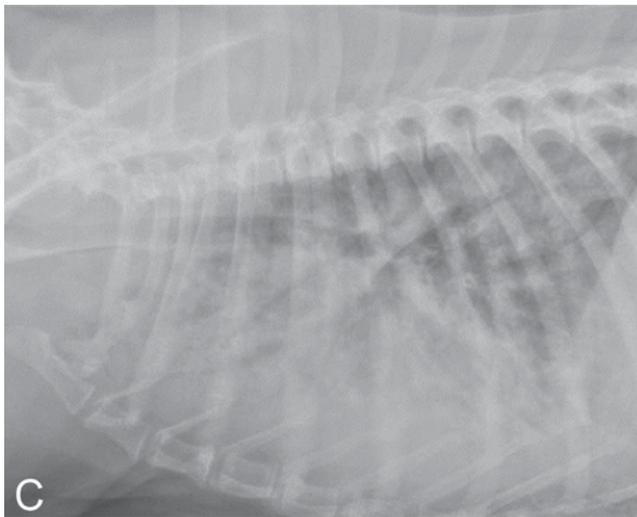
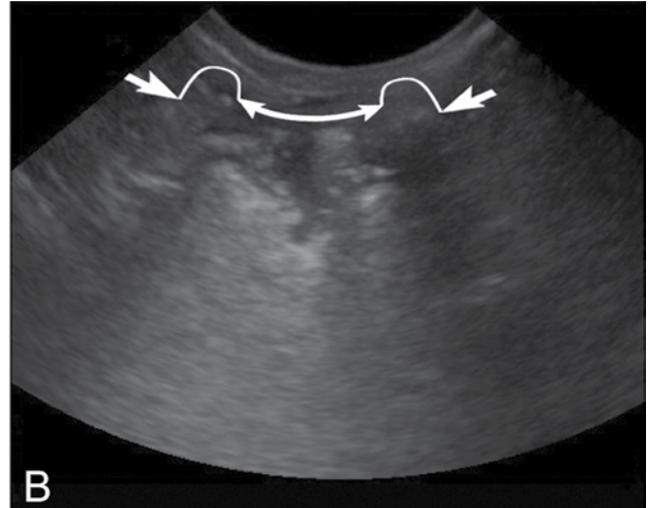
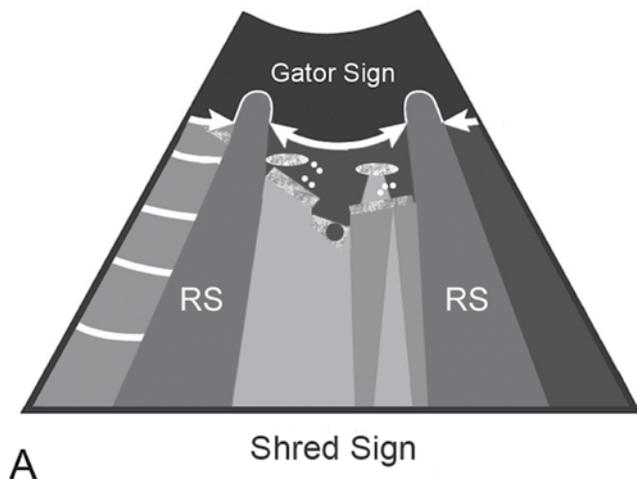


Figure 10.9. Shred sign, lung consolidation with aeration. (A) Line drawing depicting the shred sign as a deviation from the expected linear continuity of the PP-line. Within the shred are variable degrees of comet tails or air reverberation artifact (ULRs), indicative of some degree of lung aeration. The far field is also variable depending on the degree and extent of the shred. (B) Correlating B-mode image of the shred sign. (C) Correlating thoracic radiograph showing lung consolidation in a dog with acute bacterial pneumonia. The shred sign in real-time is likened to a thunderstorm rolling in with its thunderclouds (shred and aeration artifacts) and its intermittent flashes of lightning (ULRs). Interestingly, response to therapy may be tracked using serial lung ultrasound rather than thoracic radiography. © Gregory Lisciandro and Nancy Place

In summary, these basic lung ultrasound signs are summarized and arranged from top to bottom by degree of lung infiltration/consolidation (wet lung, dry lung). They are followed by degrees of lung consolidation (shred sign, tissue sign, nodule(s) sign) (Figure 10.5A through E). It is noteworthy that combinations of these basic signs may be concurrently present in severely diseased dogs and cats.

Fluid Sign, Pleural Effusion

Pleural effusion may be associated with any of the previously mentioned ultrasonographic lung signs (see Figures 2.3, 9.18, and 11.12). It is indicated by the fluid sign and ranges in echogenicity from anechoic (black) to medium/moderate echogenicity (shades of gray) related to the degree of viscosity and cellularity of the

effusion. Blood and transudates tend to be anechoic, whereas exudates and chylous/pseudo-chylous effusions tend to be more echogenic.

By using Vet BLUE as part of TFAST³, the sensitivity in detecting pleural effusion and lung conditions is increased (because more lung points, and thus points along the thorax, are surveyed than by TFAST³ alone).

Pitfalls, False Negatives, False Positives, and Limitations of Vet BLUE

False negative, limitations: Centrally located (deep to the lung's periphery) lung disease is ultrasonographically inaccessible (missed or occult). Pneumothorax

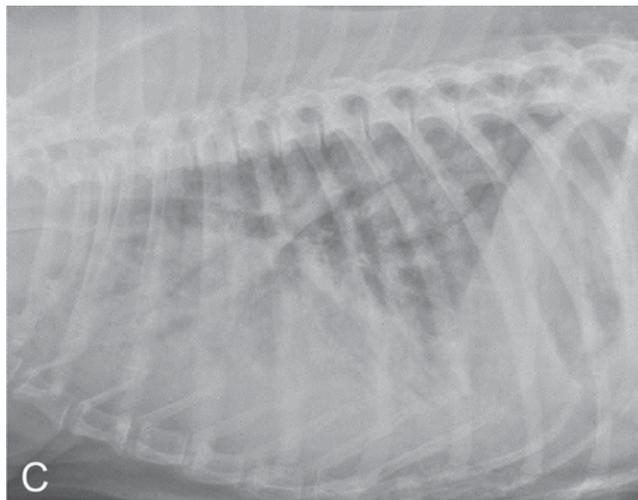
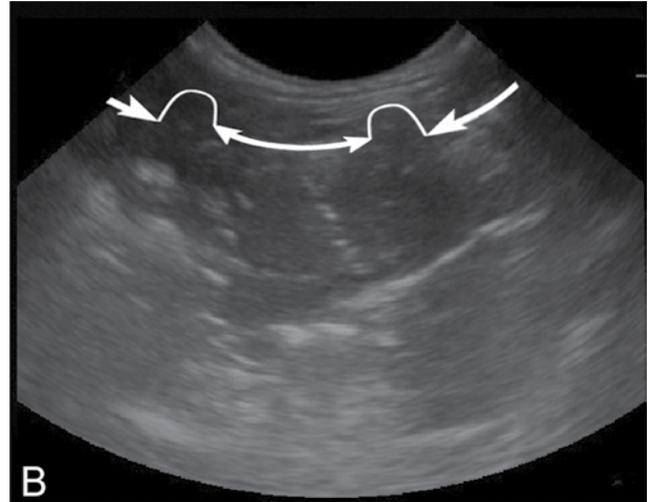
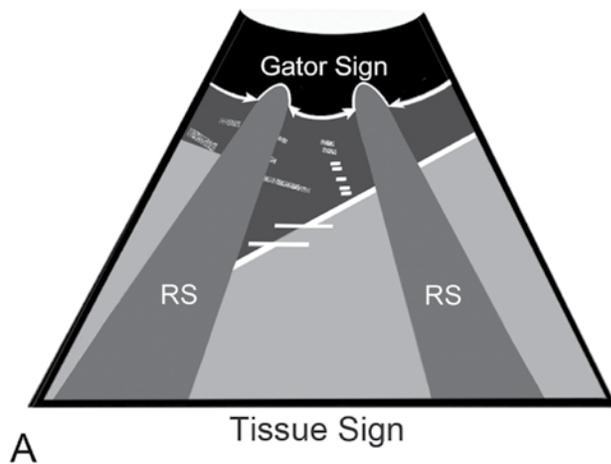


Figure 10.10. Tissue sign, lung consolidation without aeration. (A) Line drawing depicting the tissue sign as a deviation from the expected linear continuity of the PP-line. Within the tissue sign there are no comet-tails, air reverberation artifacts (ULRs) because of complete lack of aeration in the severely consolidated lung. The term hepatization has been used to describe such lung. The far field is also variable depending on the character of nearby lung. (B) Correlating B-mode image of the tissue sign. (C) Correlating thoracic radiograph showing lung consolidation. Interestingly, the degree of initial lung consolidation and response to therapy may be better assessed using initial and serial lung ultrasound (Vet BLUE) than thoracic radiography. © Gregory Lisciandro and Nancy Place

(PTX) (see below) and subcutaneous emphysema (SQE) (see Figure 9.11), when present, negate any attempts to ultrasound. However, lung ultrasound may be performed when PTX has resolved or at any regions where lung is in direct contact with the thoracic wall. SQE often can often be eliminated by applying enough probe pressure to displace the interfering subcutaneous air so that the gator sign orientation becomes visible.

False positive, limitations: Pleural space and pericardial conditions such as diaphragmatic hernia, pericardial-peritoneal hernia, and thoracic wall disease may be confounders, creating a step sign or falsely indicating a shred sign, tissue sign, or nodule(s) sign.

It is important for the sonographer to acknowledge that a false positive step sign, shred sign, and tissue

sign may be created and misinterpreted by placing the probe too far caudally where the lung, diaphragm, and liver dynamically change their depth relative to one another during inspiration and expiration. Additionally, this dynamic area may occur more cranially than expected in barrel-chested breeds (Pugs, Bulldogs, etc) and in dogs and cats with abdominal distension (e.g., ascites, cranial organomegaly, etc.) leading to the sonographer mistaking liver for lung pathology.

Abbreviations of Basic Lung Ultrasound Signs

Lung ultrasound signs are abbreviated as follows: dry, D; wet, W; shred, Sh; tissue, Ti; nodule(s), Nd; and free fluid, Ff.

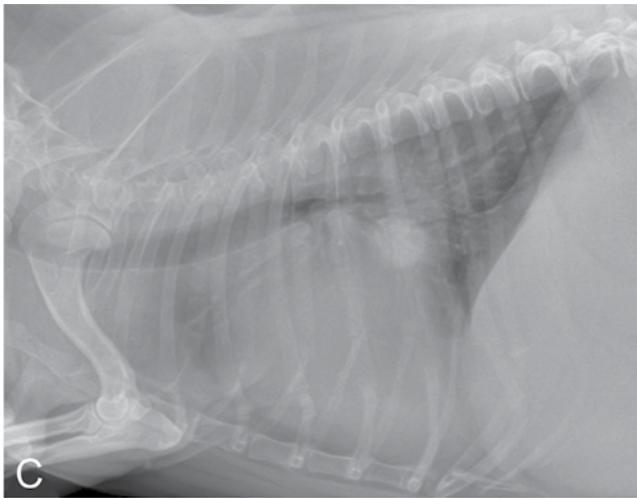
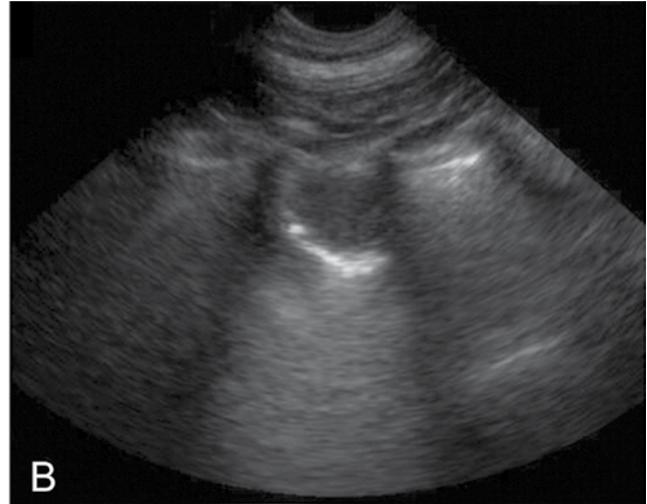
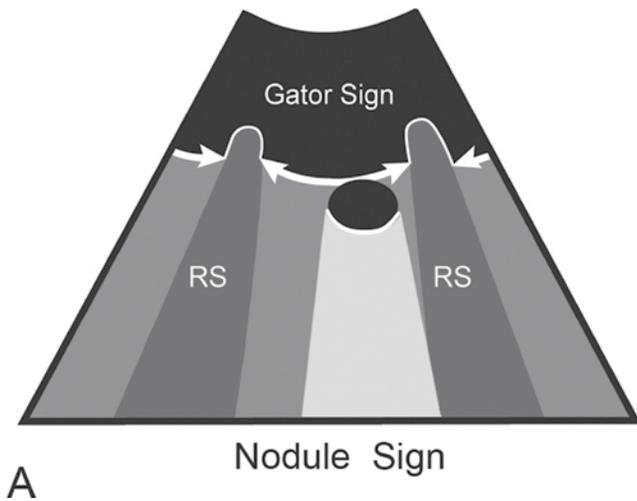


Figure 10.11. Nodule sign, single nodule. (A) Line drawing depicting the nodule sign as a deviation from the expected linear continuity of the PP-line. The finding of a circular or ovoid predominately anechoic region should raise clinical suspicion for the presence of a mass lesion. The far field is also variable depending on the character of nearby lung. The lung shown here is relatively dry (no ULRs). (B) Correlating B-mode image of the nodule sign. (C) Correlating thoracic radiograph showing a single lung lobe nodule. This is the same case that is discussed in Figure 10.16E. Interestingly, response to therapy (dependent upon the primary disease) may be monitored using serial lung ultrasound. © Gregory Lisciandro and Nancy Place

Pneumothorax, A-lines Without a Glide Sign

Pneumothorax may be diagnosed with high sensitivity, specificity, and accuracy by non-radiologist veterinarians (Lisciandro 2008). Lung findings in PTX are A-lines without a glide sign (Figure 10.13). By using the highest point on the thorax, the TFAST CTS view (the same as the Vet BLUE caudal lung lobe site), PTX is rapidly ruled out by using a single view bilaterally. When PTX is supported at the CTS view, the lung point should be sought by moving the probe ventrally along the thoracic wall in sternal recumbency. The distance from the CTS view to the lung point allows an estimation of the severity of the PTX. A small distance to the lung point suggests a trivial or mild PTX vs. a great distance or the lack of a lung point (moderate to severe/massive PTX). Finally, the presence of ULRs rapidly rules out PTX. The search for the lung point is more thoroughly described in Chapter 9.

Recording Vet BLUE Findings

Dry lung (D) has no ULRs by definition (glide sign with A-lines). Regarding wet lung (W), the maximum number of ULRs over a single intercostal space at each Vet BLUE site is recorded as follows: 0, 1, 2, 3, > 3, ∞ (infinity symbol). The ">3" notation means that ULRs are still recognizable as individual ULRs. In contrast to ">3" ULRs, the ∞ symbol is used when ULRs are in such great numbers that they have become confluent (blended) and are no longer recognizable as individual ULRs. The ∞ symbol reflects the greatest or most severe degree of interstitial edema and has been referred to as "white lung" (Volpicelli 2012) (Figure 10.14C). Numbers of ULRs seem to correlate with the degree of "wetness" or severity of interstitial edema (or hemorrhage in lung contusion cases). Although it seems complicated, the recording Vet BLUE findings is easily mastered (also see Appendix II) (Figures 10.15 and 10.16A through F).

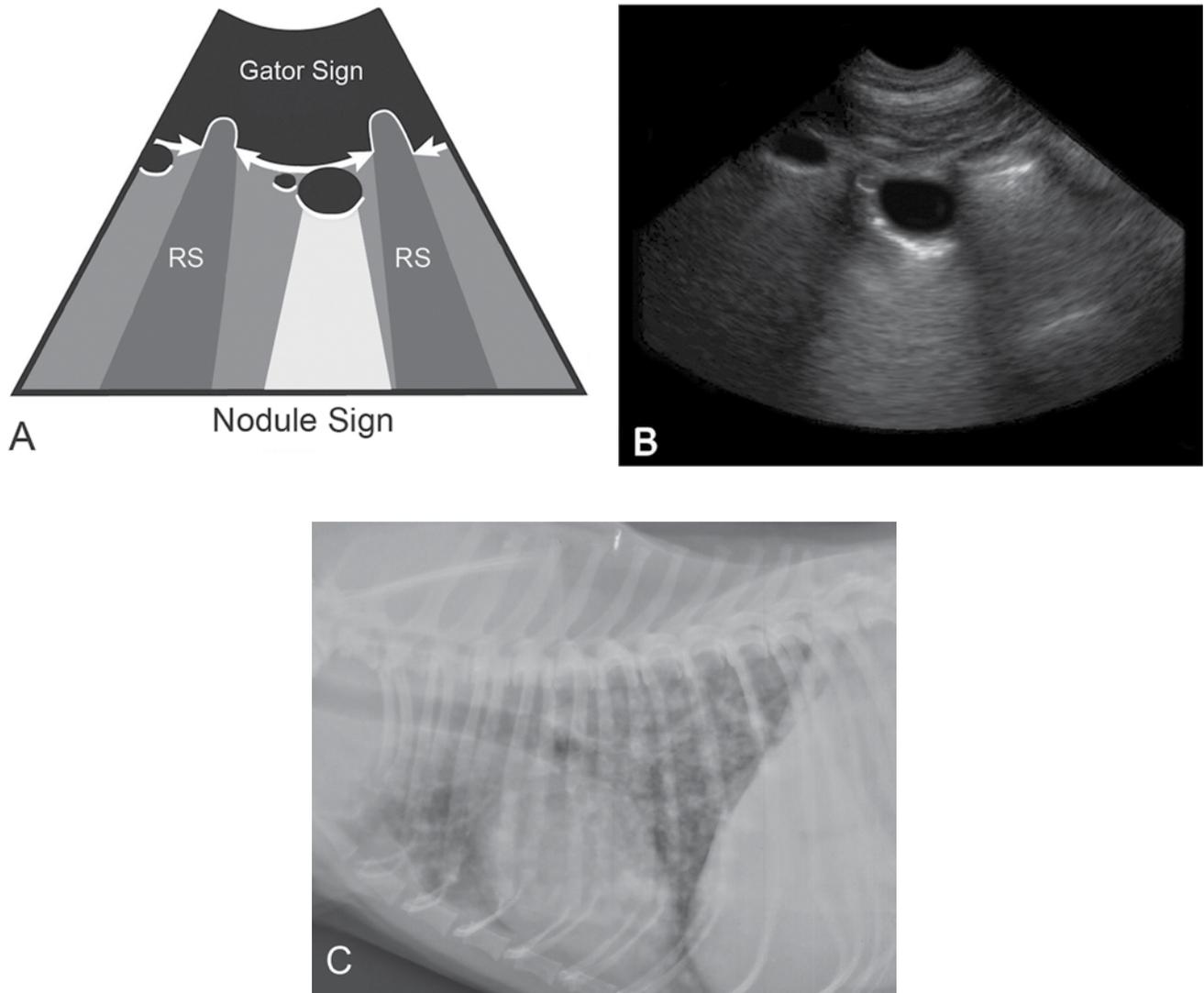


Figure 10.12. Nodule sign, multiple nodules. (A) Line drawing depicting the nodule sign as a deviation from the expected linear continuity of the PP-line. The finding of multiple circular or ovoid predominately anechoic regions should raise clinical suspicion for the presence of multiple nodules and the possibility of metastatic disease. The far field is also variable depending on the character of nearby lung. The lung shown here is relatively dry (no ULRs). Compare to Figure 10.16F in a dog with highly inflammatory metastatic (undifferentiated) carcinoma in its lungs with nodules and ULRs at all Vet BLUE sites. (B) Correlating B-mode image of the nodule(s) sign in metastatic disease. (C) Correlating thoracic radiograph showing metastatic lung lobes in a dog with pancreatic carcinoma. Interestingly, response to therapy (dependent upon the primary disease) may be tracked using serial lung ultrasound. © Gregory Lisciandro and Nancy Place

Case-Based Vet BLUE Patterns and Their Clinical Relevance

It is important to keep in mind that sensitivity, specificity, and accuracy for Vet BLUE patterns is currently being prospectively studied and is not yet known. However, Vet BLUE's principles are clinically useful in dogs and cats suffering from acute respiratory

distress, and the patterns may be used for general impressions to help rule in or out respiratory and non-respiratory causes. An example of a dog with dry lungs (D) all fields is shown pictorially (Figure 10.15A) and used for comparison for all other Vet BLUE findings.

Let's work through the following example of a dog that has choked on a rawhide. The dog is at risk for non-cardiogenic pulmonary edema (NCPE) and acute aspiration pneumonia. NCPE is diagnosed by finding

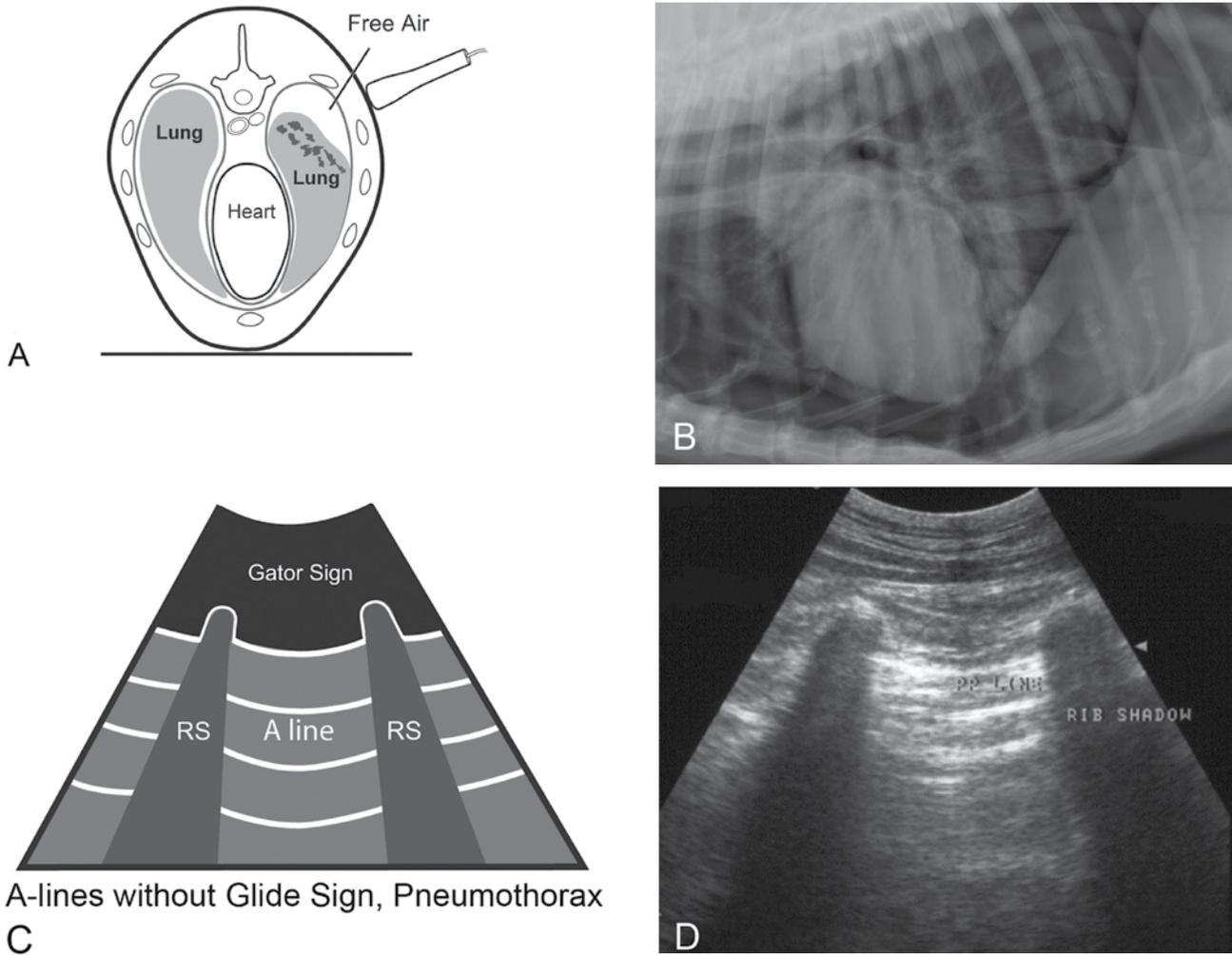


Figure 10.13. Pneumothorax, A-lines without a glide sign. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST³ CTS view. The lungs have fallen away from the thoracic wall (collapsed) with free air that is within the pleural space, representing pneumothorax (PTX). (B) Correlating thoracic radiograph. (C) Correlating line drawing showing A-lines without a glide sign (no arrows on the PP-line). (D) Corresponding B-mode still image that shows A-lines, or air reverberation artifact. The dynamic real-time absence of glide sign diagnoses PTX. Compare to Figure 10.6 (dry lungs). Courtesy of Nancy Place, San Antonio, Texas. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

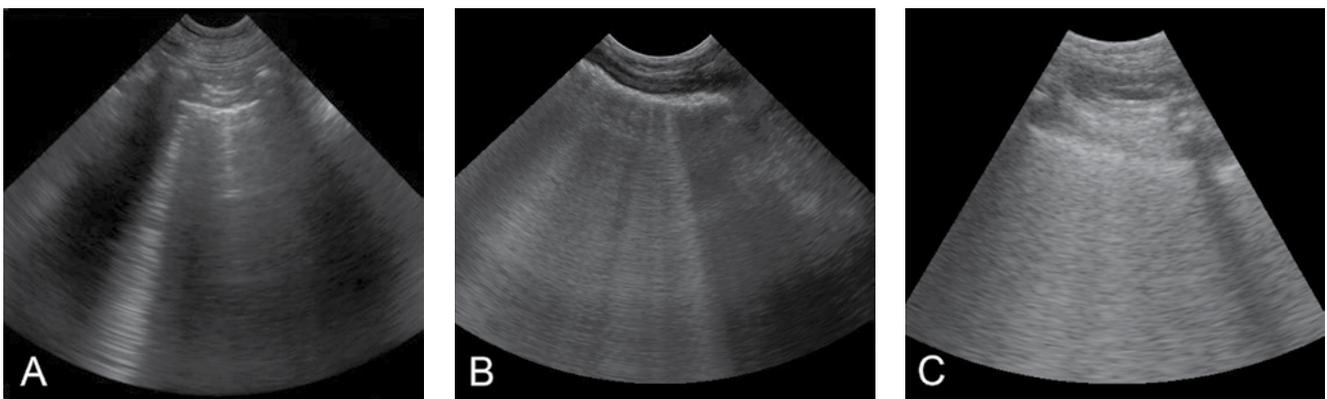


Figure 10.14. The Progression of Severity of Wet Lung using Numbers of Ultrasound Lung Rockets. The maximum number of ULRs over a single intercostal space at each respective Vet BLUE view is recorded. (A) Single ultrasound lung rockets (ULR). (B) Multiple ULRs still be seen as individual entities and thus countable (recorded as a number). (C) Multiple ULRs in such great number they blend together. This finding is referred to as “confluent” ULRs or “white lung” and because they are uncountable, recorded as the infinity [∞] symbol. “White lung”, difficult to appreciate on a still B-mode image, is readily apparent in real-time. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

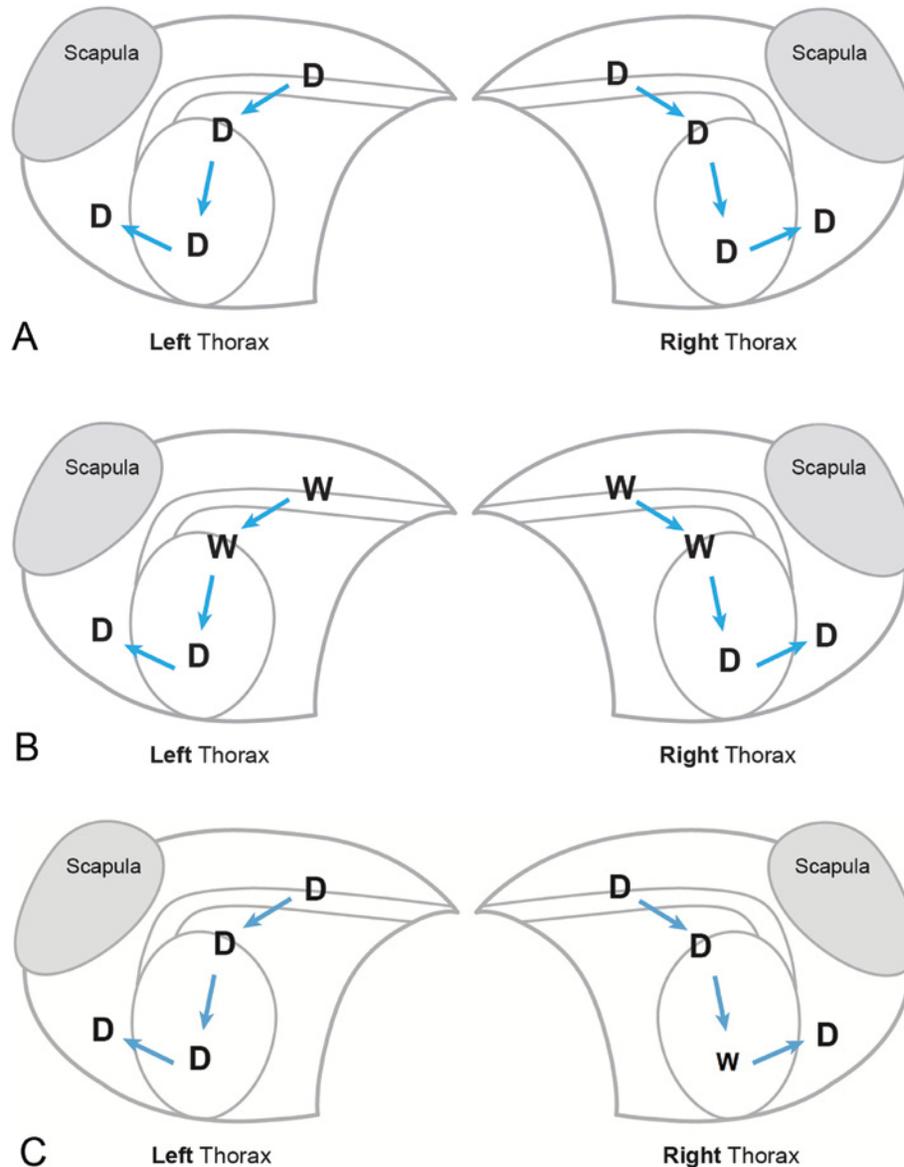


Figure 10.15. Pictorial representation for pattern-based interpretation of possible Vet BLUE findings. Shown are the left and right hemithorax, illustrating the basic use and interpretation of dry lung (A-lines with a glide sign, labeled as “D”) and wet lung (ultrasound lung rockets, labeled as “W”) findings in a dog that choked. (A) This illustration depicts dry (D) in all fields or unremarkable lungs. (B) This illustration shows wet (W) lungs in the caudodorsal and perihilar regions, suggesting non-cardiogenic pulmonary edema. (C) This image shows that the lungs are dry in all lung fields except for the right middle lung lobe, supporting the diagnosis of acute aspiration pneumonia. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

ULRs in the caudodorsal lung fields (Figure 10.15B). On the contrary, if ULRs are only found at the right middle lung lobe region, then aspiration pneumonia is diagnosed (Figure 10.15C). However, if all lung fields are dry (and reconfirmed with serial exams), then neither pathologic condition is likely present. Because the treatment varies dramatically between these three scenarios, Vet BLUE findings are clinically relevant and potentially helpful in directing the

patient’s clinical course. However, if clinical suspicion remains that lung pathology exists, but was initially occult or missed by Vet BLUE, serial exams should be used (similar to recommendations for AFAST³ and TFAST³).

Continuing with the same thought process of wet vs. dry lungs, let’s continue with some additional clinical scenarios. For ease of illustration, only the left hemithorax is shown in Figure 10.16 (the Vet BLUE

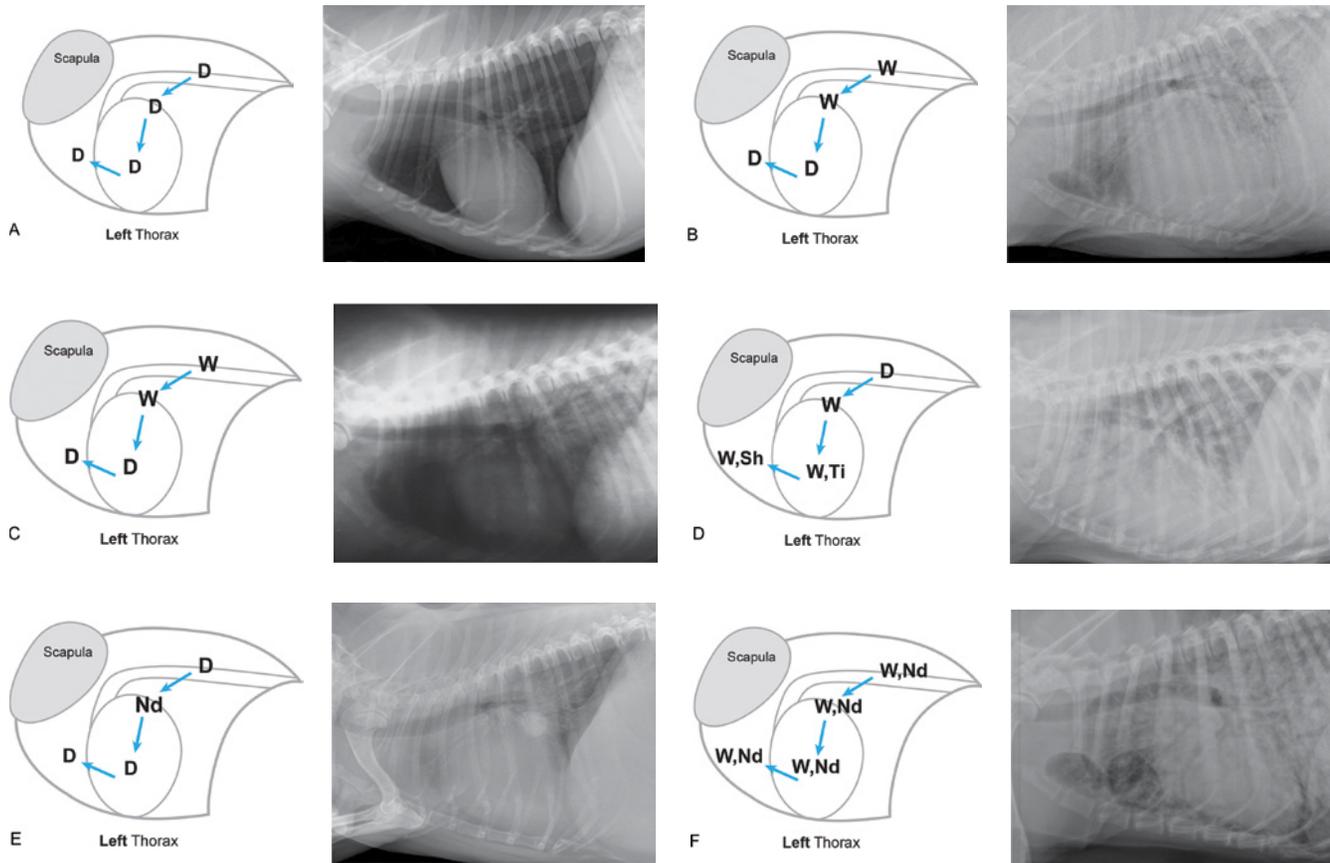


Figure 10.16. Various Vet BLUE scenarios using a regional, pattern-based approach. (A) The finding of dry lungs, all fields is indicated by “D” at each of the four Vet BLUE views with a correlating unremarkable representative lateral TXR. (B) Wet lungs, indicated by “W” in the dorsal lung fields (caudodorsal and perihilar views). The diagnosis is cardiogenic pulmonary edema. (C) Non-cardiogenic pulmonary edema. (D) Wet lungs, (indicated by “W”) with severe lung consolidation with shred sign (Sh) and tissue sign (Ti) in the ventral lung fields. The diagnosis is severe acute bacterial pneumonia. (E) Single nodule (Nd) with dry lungs (D), diagnosed as solitary lung lobe mass with no inflammation. (F) Multiple nodules (Nd) with associated wet lungs (W), diagnosed as metastatic neoplasia with marked inflammation. Courtesy of Nancy Place, San Antonio, Texas. © Nancy Place

hemithorax is located to the left and the correlating thoracic radiograph (TXR) to its right).

“Dry lungs, all fields” is shown by “D” at each of the four Vet BLUE views with a corresponding unremarkable representative lateral TXR (Figure 10.16A). The finding of “Dry lungs, all fields” rules out clinically relevant cardiogenic and non-cardiogenic pulmonary edema, acute pneumonias, and inflammatory conditions, and suggests upper airway disease/conditions, feline asthma/chronic obstructive pulmonary disease/acute bronchoconstriction, and non-respiratory look-a-likes (Table 10.1).

Wet lungs, shown by “W” in the dorsal lung fields (caudodorsal and perihilar views) in acute conditions, is generally considered to be representative of cardiogenic or non-cardiogenic pulmonary edema.

Figure 10.16B is an example of left-sided heart failure. Figure 10.16C is an example of non-cardiogenic

pulmonary edema (NCPE) in a dog that was choked by collar entanglement with another dog. It had a normal pulse oximetry (SpO₂) of 98% in room air and had no crackles on thoracic auscultation. However, preemptively on admission prior to TXR, Vet BLUE determined the presence of marked NCPE.

Wet lungs, shown by “W” in the ventral lung fields in acute conditions, is generally considered pneumonia. Figure 10.16D shows a puppy with parvoviral enteritis that had been hospitalized for three days before developing acute respiratory distress. The critically ill puppy was being serially monitored every 12-hours for signs of volume overload using Vet BLUE. The pattern here (wet lungs in the ventral fields [and shred signs]) clearly supported acute severe aspiration pneumonia as the dog was dry in all fields 12 hours earlier. Note how different the pattern is from

Table 10.1.

Causes of respiratory distress likely to be detected using global FAST³ (AFAST³, TFAST³, and Vet BLUE).

AFAST ³	TFAST ³	Vet BLUE
*Hemoabdomen	Pneumothorax	%Cardiogenic pulmonary edema
*Hemoretroperitoneum	*Hemothorax	%Non-cardiogenic pulmonary edema
*Septic abdomen	*Pyothorax	%Pulmonary contusions
§Anaphylaxis	*Pericardial effusion/tamponade	%Pneumonia, acute aspiration
	*Other effusive pleural space conditions	%Pneumonia, other forms
	Diaphragmatic hernia	%Pulmonary thrombo-embolism
	Peritoneal-pericardial hernia	%Feline asthma
		%COPD
		%Neoplastic disease including metastatic disease

*Ultrasound cannot characterize effusions, which requires centesis and fluid analysis for diagnosis.

§The gallbladder halo sign can be caused by conditions other than anaphylaxis. In the acute setting always rule out pericardial effusion with or without cardiac tamponade (see Figure 2.17).

%Vet BLUE is a pattern-based approach similar to the interpretation of TXR findings and cannot definitively diagnose lung conditions.

Figure 10.16B, which would be more typical of volume overload, or Figure 10.15C, with milder aspiration into a single lung lobe.

A single nodule, shown by “Nd,” is clearly evident in the perihilar region with all other fields dry (D). Figure 10.16E depicts an older dog that was referred for continued treatment of acute decompensated left-sided heart failure. Clearly by using Vet BLUE, aggressive diuretics were no longer needed since the lungs were dry in all fields. The nodule was a coincidental yet important finding. It triggered taking a TXR as well as scheduling a complete abdominal ultrasound to look for a primary tumor, which was found in the urinary bladder.

Multiple nodules as “Nd” throughout Vet BLUE along with inflammation detected by associated wet lung (W). Figure 10.16F is an older, large breed dog with metastatic undifferentiated carcinoma diagnosed by cytological evaluation of the pleural effusion combined with Vet BLUE and TXR findings. The dog presented in acute respiratory distress. The pleural fluid, nodules, and ULRs were recognized on the triage table by performing TFAST³ and Vet BLUE within the first several minutes of presentation. Compare to Figure 10.16E (and Figure 10.12) in which single and multiple (metastatic) nodules are ultrasonographically visualized with no associated inflammation (nodule(s) and dry lungs).

The difference between historical uses of lung ultrasound and these examples is that by using the Vet BLUE format proactively and preemptively, clinically relevant lung information is acquired which would be otherwise delayed while awaiting thoracic radiography or missed

by not performing TXR or by relying on less sensitive means of thoracic auscultation and breathing patterns.

Dry Lung vs. Wet Lung Concept and Basic Lung Ultrasound Signs and Differentials

The following is a summary of lung ultrasound findings (Figure 10.17).

Dry Lungs or A-lines with a Glide Sign

Respiratory: lower airway: acute feline asthma chronic obstructive pulmonary disease (COPD); pulmonary thromboembolism; upper airway: upper airway obstruction (laryngeal paralysis, collapsing trachea, mass, foreign body, nasopharyngeal polyp [cats], granulomatous laryngitis [cats], severe upper airway inflammation, and others), upper respiratory infections (infectious tracheobronchitis and others) (Figures 10.6, 10.15A, and 10.16A)

Non-respiratory: fever/pyrexia, severe metabolic acidosis, AFAST³-detected causes (hemoabdomen, hemoretroperitoneum, septic abdomen, anaphylaxis), TFAST³-detected causes (cardiac tamponade), and others (gastric dilatation-volvulus [GDV]), these being the so-called respiratory distress look-a-likes (Table 10.1)

False negatives, limitations: centrally located (deep to the lung periphery) lung disease is ultrasonographically inaccessible (missed or occult)

False positives, limitations: pneumothorax

Vet BLUE lung ultrasound signs in acute respiratory distressed small animals

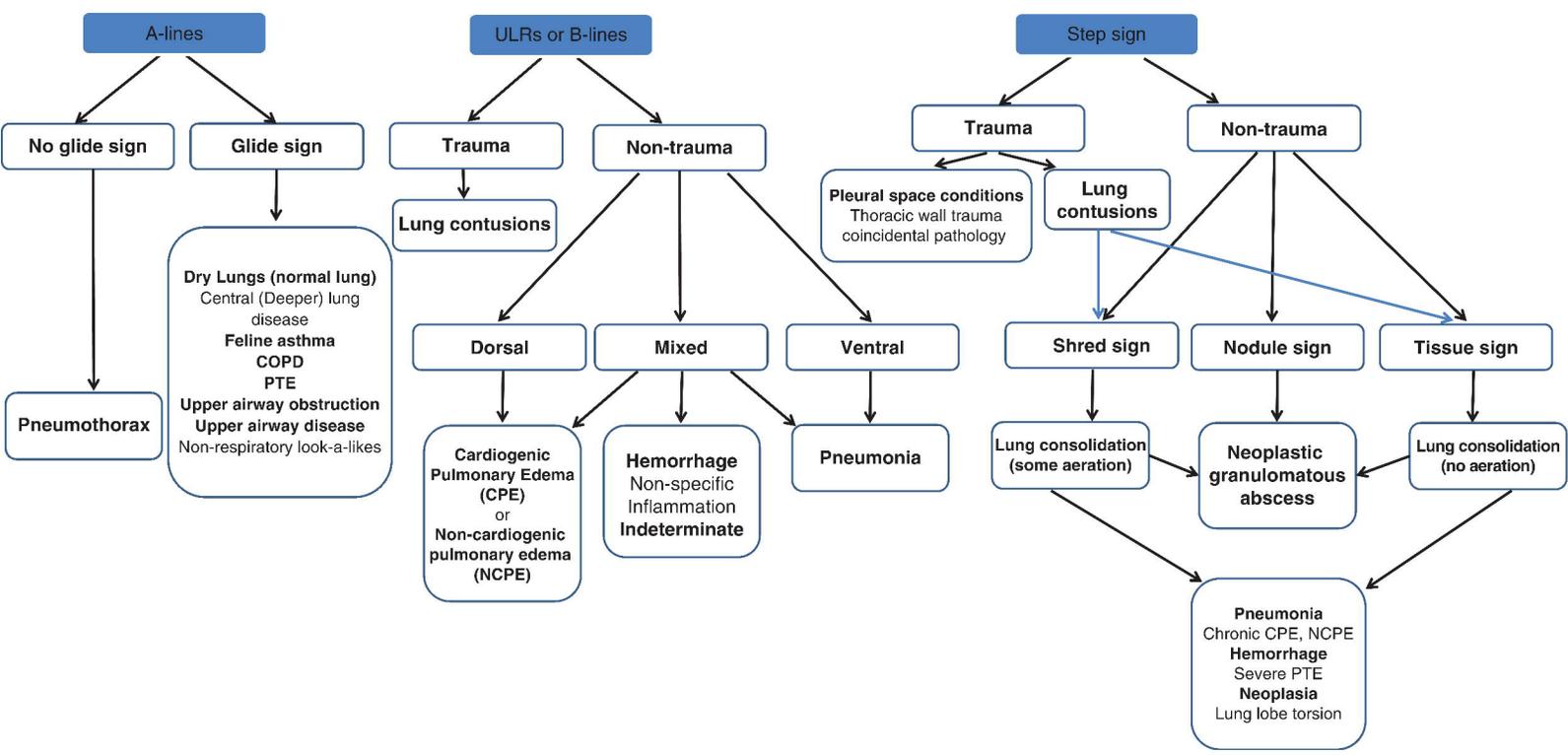


Figure 10.17. Summary of lung ultrasound signs and differential diagnoses. © Gregory Lisciandro

False Dry Lungs or A-lines Without a Glide Sign

Respiratory: pneumothorax (partial vs. massive). If unsure if PTX is present (A-lines without a glide sign) look for the lung point (where lung re-contacts the thoracic wall, evidenced by a glide sign or ULRs or the lung pulse) (see Figure 9.9). If the lung point is found close to the CTS or caudodorsal (cdll) Vet BLUE site, then PTX is likely not clinically significant (needs serial evaluations but not thoracocentesis). However, always consider your patient's respiratory status. If unstable, then thoracocentesis should be pursued to the veterinarian's discretion vs. moving the patient to radiology for thoracic radiography (see Figure 9.10)

Always look for the lung point and use the opposite hemithorax as a control for the glide sign. However, in cases of bilateral PTX, a glide sign may be lacking bilaterally.

False positives, limitations: failure to identify the glide sign may be due to confounding (rapid shallow) breathing pattern, ultrasound settings, or inexperience, or by focusing incorrectly on an A-line which will not have a glide sign because it is a reverberation artifact

False negatives, limitations: falsely identifying the glide sign may be due to confounding (rapid, shallow) breathing patterns, ultrasound settings, or inexperience, or by mistaking PP-line movement for a glide sign

If the patient becomes less anxious or changes to a slower breathing pattern from therapy (including sedation, analgesia), the scan may be repeated. Serial exams and finding the lung point improve sensitivity, specificity, and accuracy for the detection of PTX.

Wet Lungs or Ultrasound Lung Rockets, or B-lines

Respiratory: ULRs in upper lung fields (caudodorsal and perihilar) suggest cardiogenic pulmonary edema (left-sided heart failure, volume overload [over-resuscitated, transfusion-related, fluid therapy-related]) and forms of non-cardiogenic pulmonary edema (choking, electrocution, neurogenic conditions, smoke inhalation, forms of acute lung injury/acute respiratory distress syndrome) (Figures 10.7, 10.15B, and 10.16B and C). In contrast, ULRs in lower lung fields suggest acute aspiration pneumonia (Figures 10.15C and 10.16D). ULRs sporadically may represent pulmonary

hemorrhage/contusions (trauma-related, coagulopathic, neoplastic) and pulmonary thromboembolism and must be placed within the clinical context of the patient (Figures 10.8 and 10.16).

False negatives, limitations: centrally located (deep to the lung's periphery) lung disease is ultrasonographically inaccessible (missed or occult)

Shred, Tissue, and Nodule(s) Signs

Combinations of shred, tissue, or nodule(s) signs help clarify the severity of wet lung and dry lung and must be placed into clinical context. However, these signs also prove helpful in directing diagnostics and therapy.

Nodule(s) Sign, Single and Multiple

A dog with single or multiple nodular disease with dry lungs all fields likely has little inflammation associated with the disease (Figures 10.11, 10.12, and 10.16E). In contrast, a dog with nodules and wet lungs likely does have inflammation or hemorrhage associated with its lung disease (Figure 10.16F). By finding the nodule(s) sign it is then known that lung lobe aspiration may be a prudent next diagnostic step because nodules may only be viewed ultrasonographically when they are immediately adjacent to the thoracic wall (in contrast to finding a nodule(s) on a TXR where its accessibility may be less clear). Vet BLUE may also be used to monitor response to therapy by measuring changes in the size and numbers of nodule(s) (neoplastic, fungal, or other types of granulomas).

False positives, limitations: The herniation of abdominal contents in the pleural or pericardial spaces and masses off the thoracic wall may confound the sonographer. Furthermore, dogs with small thoracic cavities (e.g., Pugs, Bulldogs) or those with abdominal distension (e.g., ascites or cranial organomegaly) may have abdominal contents further cranially than expected.

False negatives, limitations: False negatives are much less of a problem if the definitions for lung ultrasound signs are adhered to by the sonographer.

The Clinical Relevance of Vet BLUE and Left-Sided Heart Failure and Volume Overload

Vet BLUE can be used effectively to determine whether clinically relevant left-sided heart failure is present. In dogs and cats with dry lung fields at all Vet BLUE views (dry lungs all fields), clinically

relevant left-sided heart failure is the unlikely cause of distress (and thus diuretics are not indicated or at least not aggressively administered). The finding of dry lung all fields, ruling out clinically relevant left-sided heart failure, is supported by the author's experience and by 2 veterinary studies (Pate 2010, Lisciandro 2013), and has been shown to be highly reliable (sensitivity and specificity greater than 98%) in ruling out left-sided heart failure in humans (Lichtenstein 2008, 2009, Volpicelli 2012). In summary, ULRs are easily recognized with minimal ultrasound training in contrast to the skill necessary to perform the quick peek LA:Ao cardiac views, and their presence or absence as well as their distribution and numbers should be used for evidence-based determination of left-sided heart failure either from heart disease or volume overload (Lichtenstein 2008, 2012).

Another clinically useful way to use Vet BLUE in cats with pleural effusion (right-sided failure) caused by heart disease is to evaluate the lungs for evidence of ULRs (left-sided failure), which can help guide therapy and direct the degree of diuretic usage in patient management. Finally, ULRs may be used as indicators of volume overload secondary to fluid resuscitation or transfusion(s), and may help detect lung failure from a variety of causes because ULRs represent increased total lung water (acute lung injury [ALI], acute respiratory distress syndrome [ARDS], and its subsets) (Gargani 2007, Peris 2010, Jambrik 2010).

The Use of M-mode and Power Doppler for Lung Ultrasound

The demand for still image documentation of PTX in humans has resulted in the reporting of the diagnostic use of M-mode and power Doppler ultrasonography. Briefly, when using M-mode, dry lung is represented by the seashore sign, likened to the graininess of sand along the shoreline because movement beyond the PP-line results in this pattern. In contrast, when no movement is present past the PP-line as in PTX, a stratosphere sign or bar code sign is seen (Lichtenstein 2007). Lastly, when ULRs or wet lung are present using M-mode, their pendulous motion results in the rain sign in which vertical streaks extending from the PP-line through the far field move across the screen in real-time, likened to pouring rain (see Figure 9.23A through C). Power Doppler has been likewise been used for still image documentation. The glide sign, referred to as the power slide, appears with color

stippling along the PP-line representing the to and fro motion of the lung. In PTX, colored stippling along the PP-line is absent (Cunningham 2002). In the author's experience M-mode is unreliable in most cases because of excessive motion during respiration coupled with the inability to control breathing patterns in spontaneously breathing dogs and cats (whereas human patients may be asked to remain still and breathe in and out on command). These techniques, however, may prove helpful in dogs and cats that are intubated or undergoing mechanical ventilation.

The Future of Lung Ultrasound in Small Animals

The use of Vet BLUE is a bold attempt to initiate the clinical use and applications of ultrasound for lung conditions in dogs and cats. Moreover, Vet BLUE serves as a platform for clinical research regarding the sensitivity, specificity, and accuracy of the regionally-based lung scan for acute and chronic respiratory conditions, and it accelerates the long overdue general use of lung ultrasound in small animals.

Pearls and Pitfalls, the Final Say

- Lung ultrasound has been considered the modern stethoscope, exceeding chest auscultation and supine chest radiography with regard to sensitivity, specificity, and accuracy in human patients (Filly 1988, Lichtenstein 2008, Volpicelli 2012).
- Lung pathology is primarily based on the distinction between wet lung (ULRs) vs. dry lung (A-lines with a glide sign).
- Non-respiratory dogs and cats have a low frequency of ULRs using the Vet BLUE lung scan (Lisciandro 2013, Pate 2010).
- A-lines with a glide sign, ULRs (also called B-lines), and the step sign and its subsets (shred, tissue, nodule[s]) are basic lung ultrasound signs.
- More recently, attempts have been made in human lung ultrasound to further establish a vocabulary for communicating lung ultrasound findings and propose the terms shred sign, tissue sign, and nodule(s) sign for types of lung consolidation.
- Lung ultrasound will become an important part of patient evaluation for animals that are respiratory-distressed or compromised or are at-risk for respiratory complications, and Vet BLUE should be

considered an extension of TFAST³ for a more comprehensive thoracic lung exam.

- The Vet BLUE lung scan is a starting point for lung ultrasound use that has been historically ignored by the small animal practitioner.

References

- Ball CG, Ranson MK, Adamicza A, et al. 2009. Sonographic depiction of posttraumatic alveolar-interstitial disease: the hand-held diagnosis of a pulmonary contusion. *J Trauma* 66(3):962.
- Cunningham J, Kirkpatrick AW, Nicolaou S, et al. 2002. Enhanced recognition of "lung sliding" with power color Doppler in the diagnosis of pneumothorax. *J Trauma* 52:769–772.
- Filly RA. 1988. Ultrasound: the stethoscope of the future, alas. *Radiology* 167:400.
- Gargani L, Lionetti V, Di Cristofano C, et al. 2007. Early detection of acute lung injury uncoupled to hypoxemia in pigs using ultrasound lung comets. *Crit Care Med* 35(12):2769–2774.
- Jambrik Z, Gargani L, Adamicza A, et al. 2010. B-lines quantify the lung water content: a lung ultrasound vs. lung gravimetry study in acute lung injury. *Ultrasound Med Biol* 36(12):2004–10.
- Hecht S. 2008. Thorax. In: *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D'Anjou. Ames, Iowa: Blackwell Publishing, pp 119–150.
- Lichtenstein DA. 2007. Ultrasound in the management of thoracic disease. *Crit Care Med* 35(S5):S250–S261.
- Lichtenstein D. 2010. Should lung ultrasonography be more widely used in the assessment of acute respiratory disease? *Expert Rev Respir Med* 4(5):533–38.
- Lichtenstein D. 2012. Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol). *Expert Rev Respir Med* 6(2):155–62.
- Lichtenstein D, Karakitsos D. 2012. Integrating lung ultrasound in the hemodynamic evaluation of acute circulatory failure (the fluid administration limited by lung sonography protocol). *J Crit Care* 27(5):533.
- Lichtestein DA, Meziere GA. 2008. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest* 134(1):117–25.
- Lichtenstein D, Meziere G, Lagoueyte JF, et al. 2009. A-lines and B-lines: lung ultrasonography as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. *Chest* 136: 1014–1020.
- Lisciandro GR, Lagutchik MS, Mann KA, et al. 2008. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 18(3):258–69.
- Lisciandro GR, Lagutchik MS, Mann KA, et al. 2009. Evaluation of an abdominal fluid scoring system determined using abdominal focused assessment with sonography for trauma in 101 dogs with motor vehicle trauma. *J Vet Emerg Crit Care* 19(5):426–37.
- Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–22.
- Lisciandro GR. 2012. Evaluation of initial and serial combination focused assessment with sonography for trauma (CFAST) examinations of the thorax (TFAST) and abdomen (AFAST) with the application of an abdominal fluid scoring system in 49 traumatized cats. Abstract. *J Vet Emerg Crit Care* 22(S2):11.
- Lisciandro GR, Fosgate GT, Fulton RM. 2013. The frequency and number of ultrasound lung rockets (B-lines) using a regionally-based lung ultrasound examination named Vet BLUE (Veterinary Bedside Lung Ultrasound Exam) in dogs with radiographically normal lung findings. *Vet Radiol and Ultrasound*, accepted.
- Lisciandro GR, Fulton RM, Fosgate GT. 2013. Frequency of ultrasound lung rockets using a regionally-based lung ultrasound exam named Vet BLUE (Bedside Lung Ultrasound Exam) in 54 non-respiratory dogs. *J Vet Emerg Crit Care*, accepted.
- Lisciandro GR, Fulton RM, Fosgate GT. 2013. The frequency of ultrasound lung rockets using the Vet BLUE Lung Scan in non-respiratory cats. Unpublished data.
- Nyland TC, Mattoon JS. 2002. Thorax. In *Small Animal Diagnostic Ultrasound, 2nd ed*, edited by TC Nyland and JS Mattoon. Philadelphia: WB Saunders Company, pp 335.
- Pate J, Rademacher N, Pariaut R, et al. 2010. Comet-tail artifacts in normal dogs and dogs with cardiogenic pulmonary edema. Abstract. *J Vet Intern Med* 24(3):729–30.
- Peris A, Zagli G, Barbani F, et al. 2010. The value of lung ultrasound monitoring in H1N1 acute respiratory distress syndrome. *Anaesthesia* 65(3):294–297.
- Reef VB. 1998. Thoracic ultrasonography: non-cardiac imaging. In *Equine Diagnostic Ultrasound*, edited by V Reef. WB Saunders Company; Philadelphia, pp 187–214.
- Rozycki GS, Pennington SD, Feliciano DV. 2001. Surgeon-performed ultrasound in the critical care setting: its use as an extension of the physical examination to detect pleural effusion. *J Trauma* 50:636–42.
- Sigrist NE, Doherr MG, Spreng DE. 2004. Clinical findings and diagnostic value of post-traumatic thoracic radiographs in dogs and cats with blunt trauma. *J Vet Emerg Crit Care* 14:259–268.
- Sigrist NE, Adamik KN, Doherr MG, et al. 2011. Evaluation of respiratory parameters at presentation as clinical indicators of the respiratory localization in dogs and cats with respiratory distress. *J Vet Emerg Crit Care* 21(1): 13–23.
- Simpson S, Syring R, Otto CM. 2009. Severe blunt trauma in dogs: 235 cases (1997–2003). *J Vet Emerg Crit Care* 19(6):588–602.
- Soldati G, Sher S, Testa A. 2011. Lung and ultrasound: time to "reflect." *Eur Rev Med Pharmacol Sci* 15(2):223–7.
- Soldati G, Testa A, Silva FR, et al. 2006. Chest ultrasonography in lung contusion. *Chest* 130(2):533–8.
- Volpicelli G, Elbarbary M, Blaivas M, et al. 2012. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med* 38:577–91.

FOCUSED OR COAST³—ECHO (HEART)

Teresa DeFrancesco

Introduction

Focused (echocardiography) ECHO is used to describe a limited two-dimensional (2D) B-mode ultrasound examination of the heart performed by non-cardiologist/non-radiologist veterinarians in symptomatic or at-risk small animal patients in the acute care setting. Unlike formal or complete echocardiography, the focused ECHO exam is limited to investigating the causes of the patient's clinical signs to make immediate treatment decisions by rapidly diagnosing potentially life-threatening conditions (Labovitz 2010). More recently, related abbreviated ultrasound exams have shown clinical utility and have thus emerged as a diagnostic tool in the veterinary and human acute care setting (Lisciandro 2008, Arntfield 2012). Frequently, the focused ECHO is part of a more comprehensive thoracic ultrasound including interrogation of the pleural space, anterior mediastinum, and lungs (also see chapters 9 and 10).

A recent joint consensus statement by the American Society of Echocardiography and the American College of Emergency Physicians supported the use of the focused cardiac ultrasound exam to expedite the diagnosis and management of life-threatening conditions in the emergency room setting (Labovitz 2010). With minimal didactic and hands-on echocardiography training, it has been shown very recently that non-cardiologist or non-radiologist veterinarians can achieve proficiency in identifying pleural and pericardial effusions and detecting the presence of left atrial enlargement (Tse 2012). In veterinary patients, achievable goals discussed in this chapter include the detection of pleural and pericardial effusion, left atrial enlargement, assessment of contractility and volume

status, and identification of obvious masses and right-sided-heart disease. Similar to other focused ultrasound exams, the focused ECHO provides portable, point-of-care, safe (radiation sparing), non-invasive, and rapid assessment of patients, and is indicated in dogs and cats presenting with respiratory signs or distress, heart failure, and persistent or episodic hemodynamic collapse, especially to rapidly rule out cardiac tamponade and heart failure.

Moreover, the author finds the focused ECHO particularly useful for cats in respiratory distress to differentiate heart failure from other causes (also see Chapter 10) because physical examination and radiographic findings are notoriously non-specific in felines. In fact, up to 30% of cats in heart failure have no murmur or gallop sound on initial cardiac auscultation (Rush 2002). Furthermore, the distribution of radiographic lesions is variable in cats with cardiogenic pulmonary edema caused by left-sided heart failure (vs. the predictable perihilar distribution in dogs); and pleural effusion, a common manifestation of feline heart failure, obscures the cardiac silhouette making radiographic assessment of heart size difficult. On the other hand, ultrasound is superior in detecting pleural (and pericardial effusion [arguably the gold standard]) (Riessig 2011), and cardiac imaging is enhanced when effusions are present rather than diminished compared to thoracic radiography. Thus, a cat with pleural effusion may be clearly imaged with ultrasound with minimal stress, allowing more accurate assessment of heart chamber dimensions and specifically left atrial size.

In conclusion, the added diagnostic value of the focused ECHO exam was highlighted by a study in which the diagnostic accuracy of minimally trained first-year medical students performing bedside echocardiography was superior to that of board-certified cardiologists performing

cardiac physical examinations for the detection and evaluation of selected valvular and non-valvular cardiac abnormalities (Kobal 2005). The improved diagnostic accuracy of abbreviated echocardiography in certain conditions over the cardiac physical examination along with the add-on of lung ultrasound (see Vet BLUE, Chapter 10) is the reason why point-of-care thoracic ultrasound has been coined the “visual stethoscope of the 21st century” (Moore 2011).

What Focused ECHO Can Do

- Identify severely enlarged cardiac chambers, even in the presence of pleural effusion, thus providing useful and timely corroborative evidence for either left- or right-sided heart failure
- Assess left ventricular contractility by either eyeball assessment or by measurement of fractional shortening, thus helping with detection of left ventricular systolic failure and diagnosis of dilated cardiomyopathy
- Detect obvious thickened mitral or tricuspid valves, and possibly ruptured chordae tendineae
- Assess severe left ventricular concentric hypertrophy (thickening), thus helping with the diagnosis of hypertrophic cardiomyopathy in cats
- Detect left atrial enlargement and screen for left atrial thrombus or “smoke” in cats with aortic thromboembolism (ATE)
- Detect heartworms in the right atrium or ventricle in cats or in dogs with caval syndrome
- Detect pleural effusion and characterize its distribution
- Estimate the amount of pleural fluid and its location(s), identify a suitable site for thoracocentesis, and track (monitor) for recurrence of effusion
- Detect pericardial effusion and determine the presence of cardiac tamponade
- Estimate the amount of pericardial fluid, identify a suitable site for pericardiocentesis, and track (monitor) for recurrence of effusion
- Detect severe hypovolemia by initial or serial assessments of cardiac chamber dynamics in addition to size and degree of respiratory variation of the caudal vena cava

What Focused ECHO Cannot Do

- Cannot be used as a stand-alone diagnostic test for the definitive diagnosis of heart failure (echocardiography by itself can only diagnose heart disease,

not failure; however, lung ultrasound can help, see Vet BLUE, Chapter 10)

- Cannot replace formal or complete echocardiography by a veterinary cardiologist or radiologist; and sonographers should know their limitations
- Cannot provide proficient use of color flow, pulsed, continuous wave or tissue Doppler echocardiography (not covered)

Indications for the Focused ECHO Exam

- Respiratory distress, respiratory compromise, or uncharacterized tachypnea or dyspnea
- Congestive heart failure (left- and right-sided) suspects
- Pericardial effusion with or without cardiac tamponade suspects
- Uncharacterized persistent or intermittent hemodynamic instability or collapse
- Uncharacterized syncope, collapse, or generalized weakness
- Uncharacterized tachycardia (rapid heart rate) or arrhythmia with clinical signs
- Feline aortic thromboembolism (ATE)
- Cardiovascular assessment of volume status and heart contractility
- Tracking (monitoring) using serial exams for recurrence of pericardial or pleural effusions post centesis or during course of therapy

Objectives of the Focused ECHO Exam

- Perform the basic echocardiographic views of the short- and long-axis at the right and left parasternal and the subcostal sites
- Recognize normal heart anatomy including the atria; ventricles; and associated valves, walls, and papillary muscles
- Identify a severely enlarged left atrium (LA) in small animals with suspected left-sided heart failure
- Identify severe right heart enlargement and hepatic venous distention secondary to chronic pulmonary hypertension/cor pulmonale with respiratory signs in dogs and those with right-sided heart failure
- Measure left ventricular fractional shortening (FS%) and thus assess various degrees of left ventricular (LV) systolic function including those that are normal or hyper- or hypodynamic

- Measure the LV wall thickness in diastole, LV lumen in systole and diastole, and left atrial (LA) and aortic (Ao) dimensions, and know cut-off values for normal and abnormal
- Assess volume status by initial and serial cardiac measurements in response to intravenous fluid resuscitation and therapy
- Identify pericardial effusion and cardiac tamponade
- Identify pleural effusion
- Identify masses of the heart base, right auricle, and pleural space, triggering confirmation by complete echocardiography or other advanced imaging techniques or procedures

Ultrasound Settings and Probe Preferences

The cardiac setting (presets) on your ultrasound (US) unit generally provides more contrast in echogenicity, making identification of cardiac chambers and assessment of their motion (valves and walls) easier (than abdominal presets). US machines (or settings) with high frame or sampling rates further enhance image quality of these cardiac structures. Inadequate (too slow) frame or sampling rates are recognized by a real-time image that is choppy.

The curvilinear or phase-array sector probes (3–10MHz) are ideal for imaging the heart between ribs (creating an acoustic window). Linear probes generally do not image well because they cannot avoid interference with the ribs (US does not transmit through bone) (see Figure 1.12). Increase the depth (zoom out) to best allow imaging of the entire heart with the focus setting placed at its furthest (or distal) edge. In large or giant breeds this may require a depth of up to 30cm and thus may not be possible in many laptop format US machines. Position the heart so that it is adequately sized within the image. Importantly, if the depth setting is too high relative to the heart size (small heart at top of image with a large void in the far field), a mirror (double image) artifact may result (and be confusing to the sonographer) (see Figure 1.7).

If you are unable to image the entire heart, chamber enlargement (or even normal sized anatomy) may be easily misinterpreted for pleural and pericardial effusions leading to the potentially catastrophic mistake of performing centesis on a heart chamber (also see Chapter 9, Figure 9.14), and cardiac chamber dimensions may not be accurately measured.

Adhere to the axiom “One view is no view” to avoid misinterpreting normal heart anatomy for pleural or pericardial effusions, especially when the necessary depth for imaging the heart in its entirety is not possible on your US machine (also see Chapter 9).

How to do a Focused ECHO Exam

Patient Positioning and Preparation

Depending on patient stability and comfort, the focused ECHO exam can be performed with the patient in either lateral or sternal recumbency (or standing). For example, if the patient is in respiratory distress, the exam is performed in sternal recumbency (or standing) while receiving flow-by oxygen (see Figure 9.1A).

The heart is best visualized when closest to the thoracic wall because of less lung (air) interference (US does not transmit through air). Thus, lateral recumbency with the probe positioned on the thorax of the patient’s recumbent side is ideal (Figures 11.1, 11.2). The heart can be visualized from the non-recumbent side of the thorax, especially if the animal has a narrow thoracic confirmation (Figure 11.5, below).

Place rolled up towels or a blanket under the cranial thorax to tilt the patient upward in either sternal or lateral recumbency to allow more probe maneuverability and permit better visualization of the heart, particularly the heart base (Figure 11.3).

The focused ECHO exam can be performed on a special table designed for cardiac ultrasound that elevates the patient off the table top and has a cutout hole where the heart is, facilitating probe maneuverability and enabling a more comfortable and complete focused evaluation.

Typically, generous amounts of alcohol and acoustic coupling gel are applied while parting the fur to allow the coupling agents to reach the skin. Shaving is usually unnecessary but may be warranted if the patient has extremely thick fur. Shaving minimizes the amount of alcohol and acoustic coupling gel needed to obtain acceptable US images, and because of the cooling effects of alcohol, may be best for hypothermic patients. The use of alcohol is contraindicated if the use of electrical defibrillation is anticipated (ventricular fibrillation, cardiopulmonary arrest) because the alcohol presents a serious fire hazard.

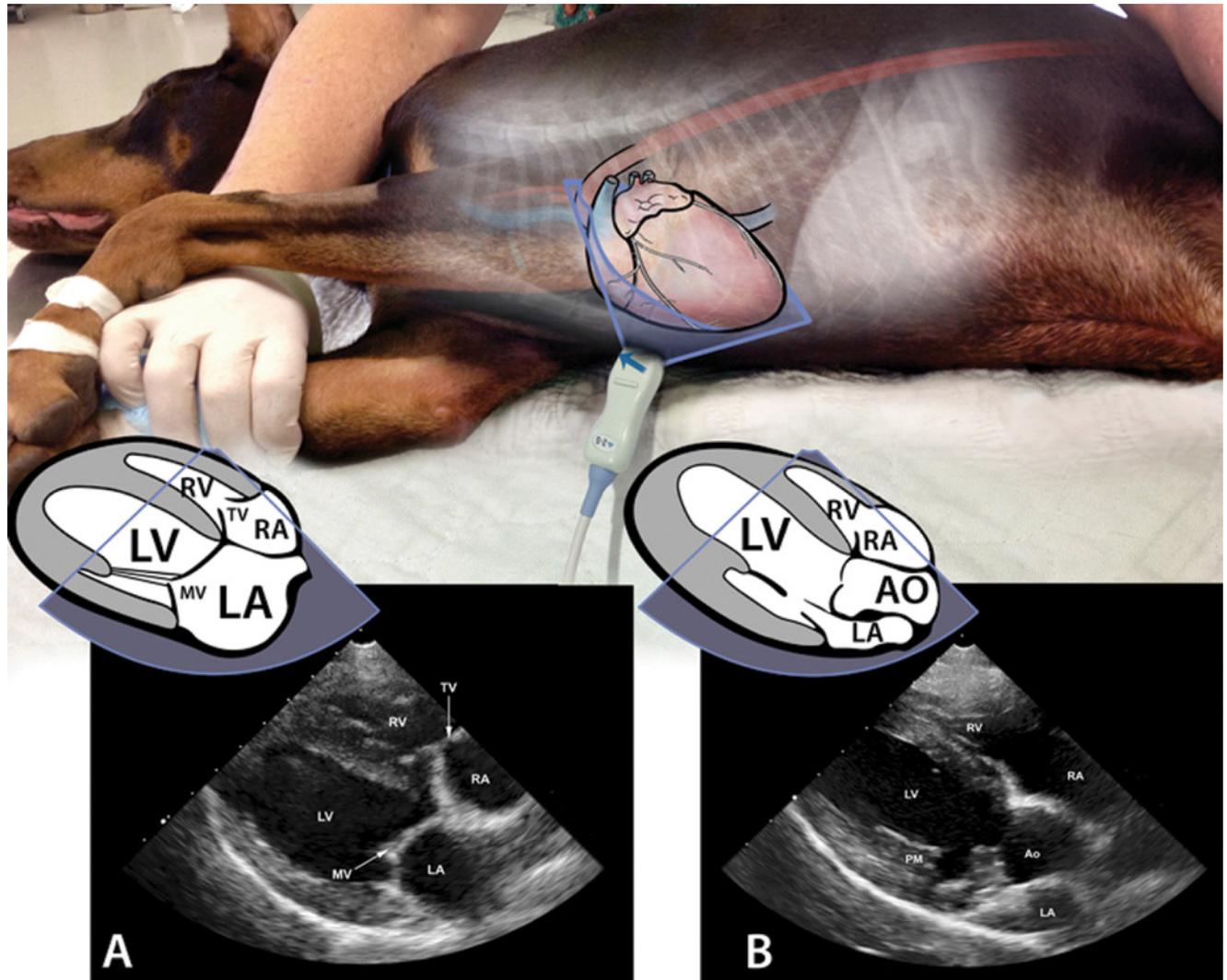


Figure 11.1. Transducer probe positioned on the recumbent right side with the patient's thorax near the edge of the table. The probe is shown with the marker toward the head for long-axis views with slice(s) of the heart. (A) Corresponding schematic drawing for the echocardiogram of a normal right parasternal long-axis view showing the four-chamber view. (B) Corresponding schematic drawing for the echocardiogram of a normal five-chamber view with the addition of the left ventricular outflow tract into the aorta acquired by tipping the probe slightly dorsally from the four-chamber view. (LA, left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve; Ao, aorta; PM, papillary muscle). Courtesy of Alice MacGregor Harvey, North Carolina State University College of Veterinary Medicine.

Performing the Focused ECHO Exam and the Three Main ECHO Windows

Right Parasternal Long-Axis Views

The right parasternal long-axis views are ideally obtained in right lateral recumbency starting at the right fourth to fifth intercostal space near the costochondral junction or at the site where there is a palpable heart beat (place your hand on the patient's

thorax), preempting probe placement. The marker on the probe is pointed toward the spine to obtain the long-axis view with the probe angulated slightly caudally (Figures 11.1 and Figure 9.12). These same views may be obtained in the respiratory-compromised or -distressed small animal on the right thorax in sternal or standing recumbency; however, the heart will be more challenging to image not only because of lung (air) interference (US does not transmit through air) but also because of the limited heart views due to quick peeks as the lung moves to and fro.

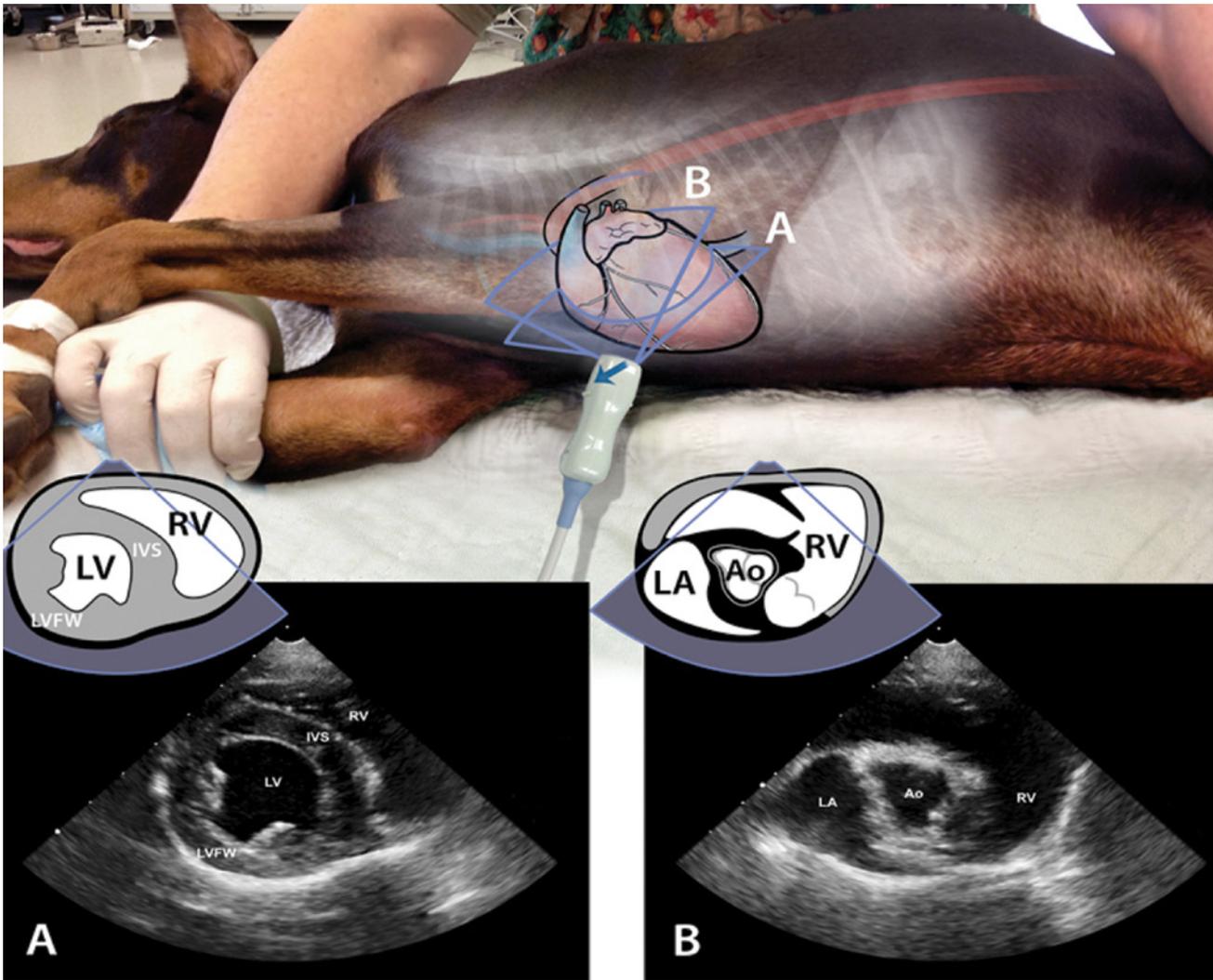


Figure 11.2. Transducer probe positioned on the right recumbent side with the patient's thorax near the edge of the table. Probe showing the marker toward the elbow for short-axis views with slice(s) of the heart labeled as "A" and "B" on the dog. (A) Corresponding schematic drawing for the echocardiogram labeled "A" in the upper image of a normal right parasternal short-axis view of the left ventricle or mushroom view used for the assessment of patient volume status and heart contractility. (B) Corresponding schematic drawing for the echocardiogram labeled "B" in the upper image of a normal short-axis view of the heart base, also called the quick peek view used for supporting evidence of left atrial dilation and left-sided heart disease (LA:Ao ratio). The view is acquired by tipping the probe from "A" to "B" as shown on the dog. (IVS, interventricular septum; LV, left ventricle; LVFW, left ventricular free wall; RV, right ventricle; LA, left atrium; Ao, aorta). Courtesy of Alice MacGregor Harvey, North Carolina State University College of Veterinary Medicine.

Begin by placing the probe where you feel the heart beat the best (right side in right lateral recumbency) or where the point of the elbow meets the thorax if the patient is in a sternal or standing position.

Once you have found the best image or acoustic window of the heart between the ribs, the probe generally is not moved other than rotated and fanned to visualize the various cardiac chambers. Image quality may be improved in obese animals by increasing probe pressure.

Unlike abdominal ultrasonography, the probe position during echocardiography is typically static because of the interference of the ribs and lung. The right (and left) parasternal long-axis views are most helpful to estimate

the size and relative proportions of the right and left heart. In normalcy, the left ventricle (LV) should be three to four times bigger than the right ventricle (RV) in the right parasternal four-chamber view (see Figure 9.12).



Figure 11.3. A cat in sternal recumbency with a rolled up towel under the forelegs to elevate the thorax and facilitate focused ECHO views.

The interventricular septum is generally straight (Figure 11.1A). The LV should contract uniformly and its papillary muscles should appear symmetrical. If the RV is the same size as the LV, severe right ventricular enlargement can be diagnosed.

Remember that in the long-axis view the ratio of right to left ventricle is 1:3 (the right ventricle is much smaller because it only pumps blood to the lower pressure pulmonary circulation).

Be cautious about over-interpreting irregular echogenicities within the right ventricle. These may be normal trabeculae or its papillary muscles, either of which can look abnormal as pathology when either is in fact of no clinical significance (see Figure 9.14).

In normalcy, the left and right atria are approximately the same size (1:1) with a neutral (non-deviated) interatrial septum. In normalcy, all cardiac valves should be thin with no evidence of prolapsing or areas of focal thickening. The atrioventricular valves (the mitral and tricuspid) are generally easier and less challenging to evaluate than the aortic and pulmonary semilunar valves by the inexperienced sonographer.

A semi-quantitative assessment of left ventricular contractility, mitral valvular anatomy, and pericardial and pleural effusion can also be assessed in the overall long-axis assessment by the non-cardiologist or non-radiologist sonographer.

With slight angulation of the probe toward the animal's head, you can also image the ascending aorta, aortic valves, left atrium, and left ventricular outflow

tract (Figure 11.1B). The left atrium and aorta in this view should be approximately the same size (LA:Ao should be 1:1).

Right Parasternal Short-Axis Views

To obtain the LV short-axis views, start with the long-axis (marker to the spine) view and simply rotate the probe about 90 degrees so that the marker on the probe is pointing toward the elbow (marker toward the elbow) (Figure 11.2A and B and Figure 9.12). Now rotate the probe slightly until the image of the LV short-axis mushroom view is as symmetrical as possible.

Within this acoustic window, angulate or fan the probe just below and then through and above the mitral valve to get the various views.

The LV short-axis view just below the mitral valve, also called the LV mushroom view, is most helpful for the assessment of contractility and left ventricular chamber dimensions (Figure 11.2A). The LV mushroom view should normally have a circular appearance and the RV should be crescent shaped (Figure 11.2A). Flattening of the interventricular septum (IVS) suggests right ventricular volume or pressure overload (Figure 11.14A).

Now fan upward above the mitral valve to visualize the heart base in short-axis view. In other words, from the LV mushroom view angulate or tilt the probe upward toward the cervical spine until the aorta in cross-section is in view, recognizable as the Mercedes Benz sign (looks like the peace sign or "Y"). The cross section of the aorta should be round and all three cusps of the aortic valves should be visible (Figure 11.2B).

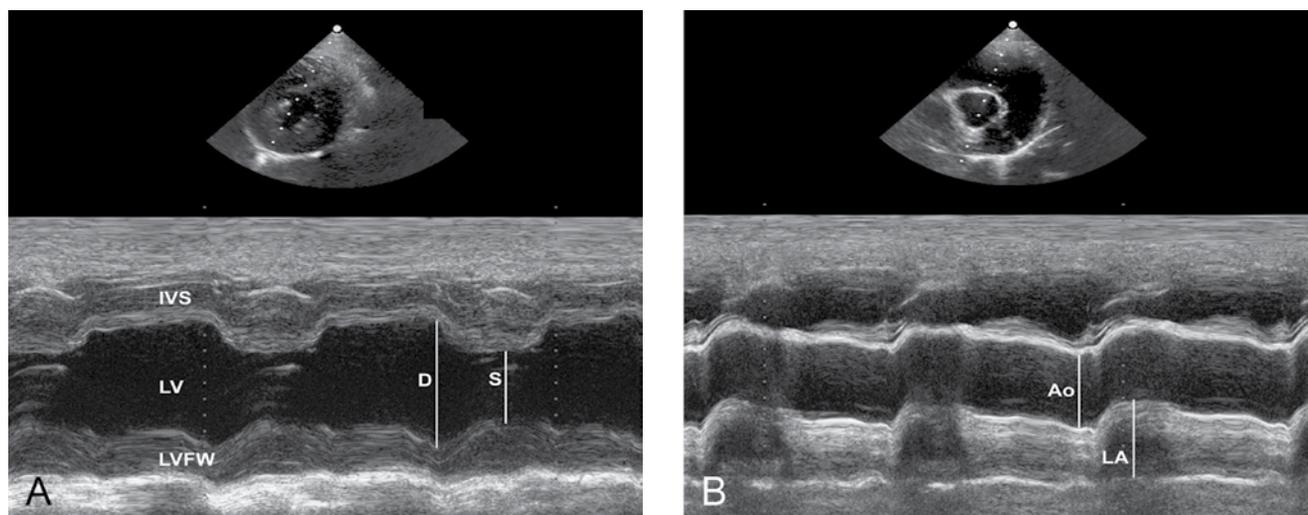


Figure 11.4. M-mode interrogation of the left heart. (A) Normal M-mode of the left ventricle. (B) Normal M-mode of the left atrium (LA) and aorta (Ao) with a normal LA:Ao ratio. (D, diastole; S, systole; IVS, interventricular septum; LV, left ventricle; LVFW, left ventricular free wall; LA, left atrium; Ao, aorta).

Table 11.1.

Normal mean echocardiographic values (cm) in dogs.

BW(kg)	LVEDD	LVESD	IVSD	LVFWD	Ao	LA
3	2.0	1.1	0.5	0.6	1.1	1.3
5	2.4	1.3	0.6	0.7	1.3	1.5
10	3.0	1.8	0.7	0.8	1.6	1.8
15	3.4	2.1	0.8	0.8	1.9	2.0
20	3.8	2.4	0.9	0.9	2.1	2.2
25	4.0	2.6	0.9	0.9	2.1	2.4
30	4.3	2.8	1.0	1.0	2.4	2.5
35	4.5	3.0	1.0	1.0	2.5	2.6
40	4.7	3.1	1.0	1.0	2.6	2.7
45	4.9	3.3	1.1	1.1	2.7	2.8
50	5.0	3.4	1.1	1.1	2.8	2.9

BW, body weight; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVSD, interventricular septal thickness in diastole; LVFWD, left ventricular free wall thickness in diastole; Ao, aortic diameter; LA, left atrial diameter (Used with permission, Kittleson and Kienle 1998)

Normally, the diameters of the LA and Ao in this view, whether 2D B-mode or M-mode, are similar in size (LA:Ao is 1:1) (Figures 11.2B and 11.4B). If the left atrium is greater than 1.3 times the aorta in dogs, then the left atrium is enlarged (Figure 11.13B); the same is true if the left atrium is greater than 1.6 in cats (Abbott 2006, Rishniw 2000).

A left atrial diameter that is twice the aortic diameter is very suggestive of left-sided heart failure in an animal with consistent clinical signs.

Normal canine cardiac chamber dimensions vary based on body weight and breed (Table 11.1). In contrast

to dogs, normal feline cardiac chamber dimensions do not vary significantly based on body weight (Table 11.2). To obtain cardiac chamber dimensions, freeze a loop (cine function) and scroll between systole (when the LV lumen is the smallest) and diastole (when LV lumen is the biggest) to obtain a fractional shortening (FS%) using 2-D B-mode and to measure LV wall thicknesses. Alternatively, M-mode echocardiography can be used. The M-mode view is an “ice pick” view with the cursor placed in the center of the LV short-axis mushroom view. Use of M-mode enhances assessment of both LV contractility and its wall thickness (Figure 11.4A).

LV wall thickness, both the interventricular septum (IVS) and LV free wall (LVFW), is measured in diastole

Table 11.2.

Normal ranges of echocardiographic values (cm) in cats.

Cardiac parameter	Normal range
LVEDD	11.0–17.5
LVESD	0.40–1.0
IVSD	0.35–0.55
LVFWD	0.35–0.55
Ao	0.7–0.13
LA	0.9–0.15
FS%	33–66%

LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVSD, interventricular septal thickness in diastole; LVFWD, left ventricular free wall thickness in diastole; Ao, aortic diameter; LA, left atrial diameter; FS% fractional shortening percentage.

with either 2D B-mode or M-mode echocardiography. Normally, the RV free wall thickness (RVFW) is about half of the thickness of the LV free wall (LVFW). Normal values are stratified by body weight in dogs (see Table 11.1). In contrast, size is independent of weight in cats and thus feline IVS and LVFW thickness in diastole should be approximately 3–4 mm. LV wall thickness in diastole greater than 6 mm is diagnostic for left ventricular hypertrophy (Table 11.2; Figure 11.13A).

Cardiac chamber dimensions and LV systolic function can be influenced by the breed of dog, the patient's volume and hydration status, the presence of tachy- or bradyarrhythmias, and systemic inflammation.

Interpretation of LV systolic function and cardiac size should be interpreted in the context of the patient's complete clinical picture with attention given to these confounding factors: breed, volume and hydration status, arrhythmias, and systemic inflammation.

Keep in mind that normal fractional shortening values (FS%) can vary by breed and loading (approximate volume status) conditions. In general, normal FS% is 28%–45% in the dog and 30%–50% in the cat. A FS% below 20% suggests severe myocardial systolic failure, and a FS% above 55% is considered hyperdynamic LV function (Tables 11.1 and 11.2).

The formula for calculating fractional shortening as a percentage (FS%) is the difference between left ventricular internal dimension (LVID) in diastole and systole divided by the LVID in diastole multiplied by 100:

$$\text{FS\%} = \frac{\text{LVID (diastole)} - \text{LVID (systole)}}{\text{LVID (diastole)}} \times 100$$

Finally, the views at the heart base are helpful in assessing left atrial, pulmonary artery size, and presence of a heart base mass (e.g., chemodectoma) (Figures 11.14B and 11.15C). The aorta and main pulmonary artery are normally the same diameter (Figure 11.2B).

Be cautious not to overinterpret normal fat at the heart base as a mass lesion. Adipose or fat tissue is quite hyperechoic (bright) with irregular borders. A heart base mass usually has a smooth border and is less echogenic.

Left Parasternal Apical and Cranial Views

The left cranial or apical views allow additional and excellent views of the aorta, pulmonary artery, left atrium, and right atrium and ventricle. These views are obtained with the probe positioned at the third to fourth intercostal spaces on the left side (Figure 11.5A and B). Image quality is best when moving the patient to left lateral recumbency so the heart falls against the thoracic wall (moving lung [air] out of the way since US does not transmit through air). However, depending of the dog's thoracic conformation, left-sided views could be obtained with the dog remaining in right lateral recumbency immediately after obtaining their right parasternal views. Not having to reposition the animal saves time. The main reasons to image from the left side are to further assess the right heart, further assess valvular anatomy and motion, discriminate pleural from pericardial effusions when present, and search for possible masses when indicated.

The left four- and five-chamber apical views are obtained with the probe marker pointing toward the spine with the probe angulated up toward the neck, about the fifth intercostal space near the costochondral junction. The left four-chamber apical view allows simultaneous visualization of both right and left ventricles and their atria. The RV tricuspid and LV mitral valves should be thin with no evidence of prolapsing (Figure 11.5A). The left five-chamber apical view is obtained with a slight angulation toward the head and a slight rotation of the marker toward the head until the aorta comes into view (Figure 11.6).

From the left apical view, the probe is moved one or two intercostal spaces cranially with the probe marker toward the spine, angulated slightly to optimize the visualization of the right atrium and ventricle

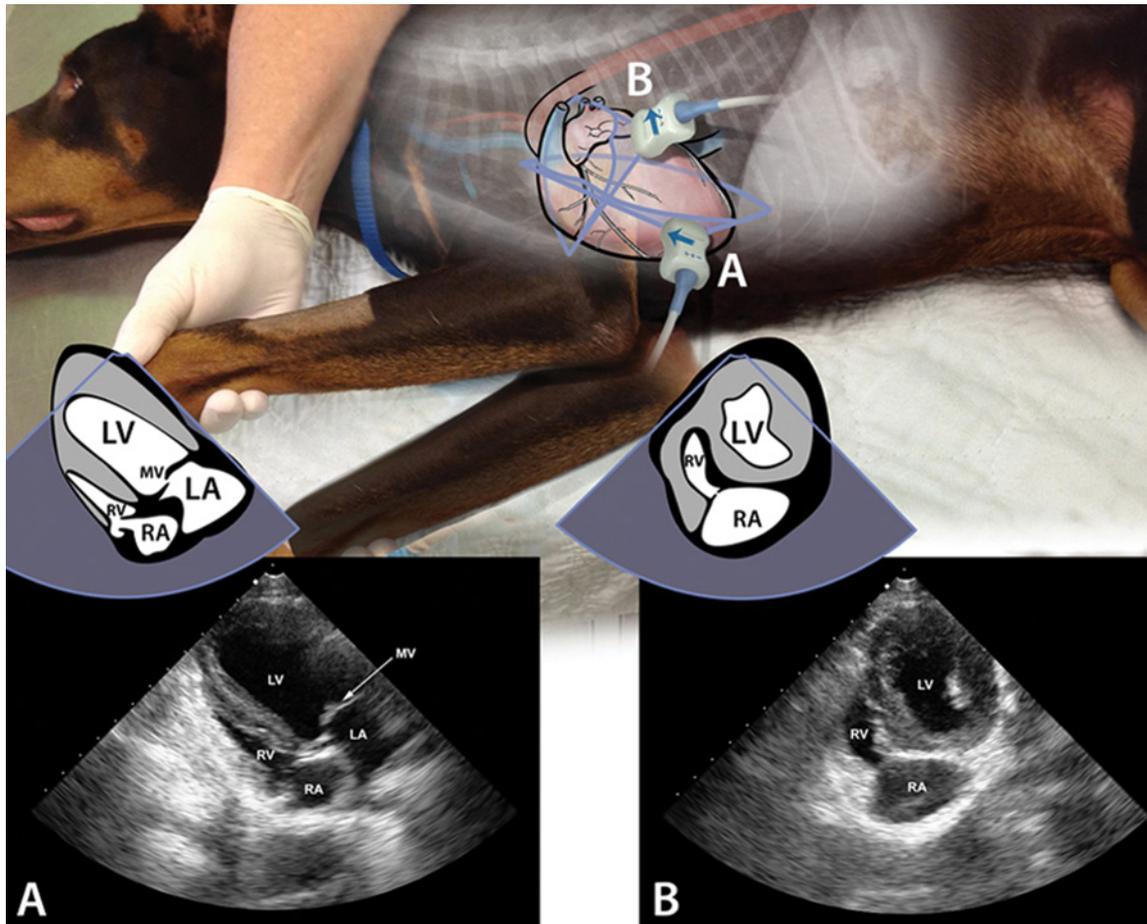


Figure 11.5. Probe positioned on the left hemithorax (non-recumbent side) to obtain the left-sided focused ECHO views while in right lateral recumbency. (A) Corresponding schematic drawing labeled “A” with marker toward the head for the echocardiogram showing a normal left apical four-chamber view. (B) Corresponding schematic drawing labeled “B” with probe marker toward the spine and the probe rotated clockwise for the echocardiogram showing a normal left cranial view for optimal imaging of the right atrium and ventricle, looking for right heart pathology including masses. (LA, left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle). Courtesy of Alice MacGregor Harvey, North Carolina State University College of Veterinary Medicine.

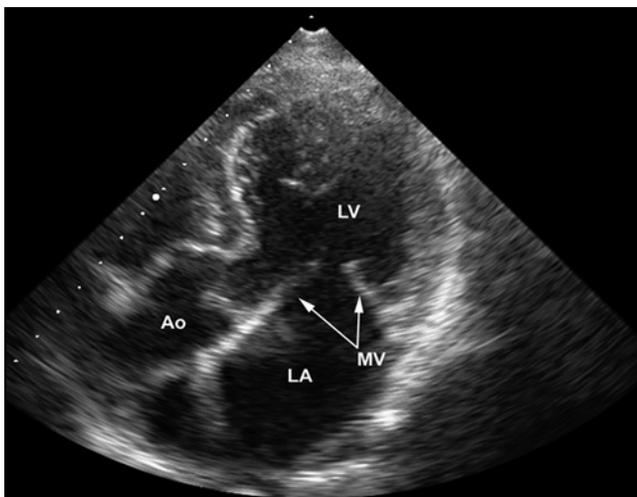


Figure 11.6. Normal two-dimensional B-mode image of the left ventricular outflow tract from a left apical view. (LA, left atrium; LV, left ventricle; MV, mitral valve; Ao, aorta)

(Figure 11.5B). The left cranial view allows for optimal visualization of the right heart, including the right auricle and tricuspid valve. This is the best view to visualize a small right auricular mass in a dog with pericardial effusion and cardiac tamponade.

Subcostal View

The transducer is positioned just caudal to the xiphoid, typically with the patient in right lateral recumbency similar to the TFAST³ and AFAST³ diaphragmatico-hepatic (DH) view (Figure 11.7; also see Figures 2.2 and 9.2). The marker is pointed toward the elbow and the probe angulated toward the head almost parallel with the body wall. Adjust the depth and rotate the probe until a four- or five-chamber view is seen (Figure 11.7A; also see Figure 2.2). Note: The view may not be possible in some very large dogs depending on the depth limits of your US machine.

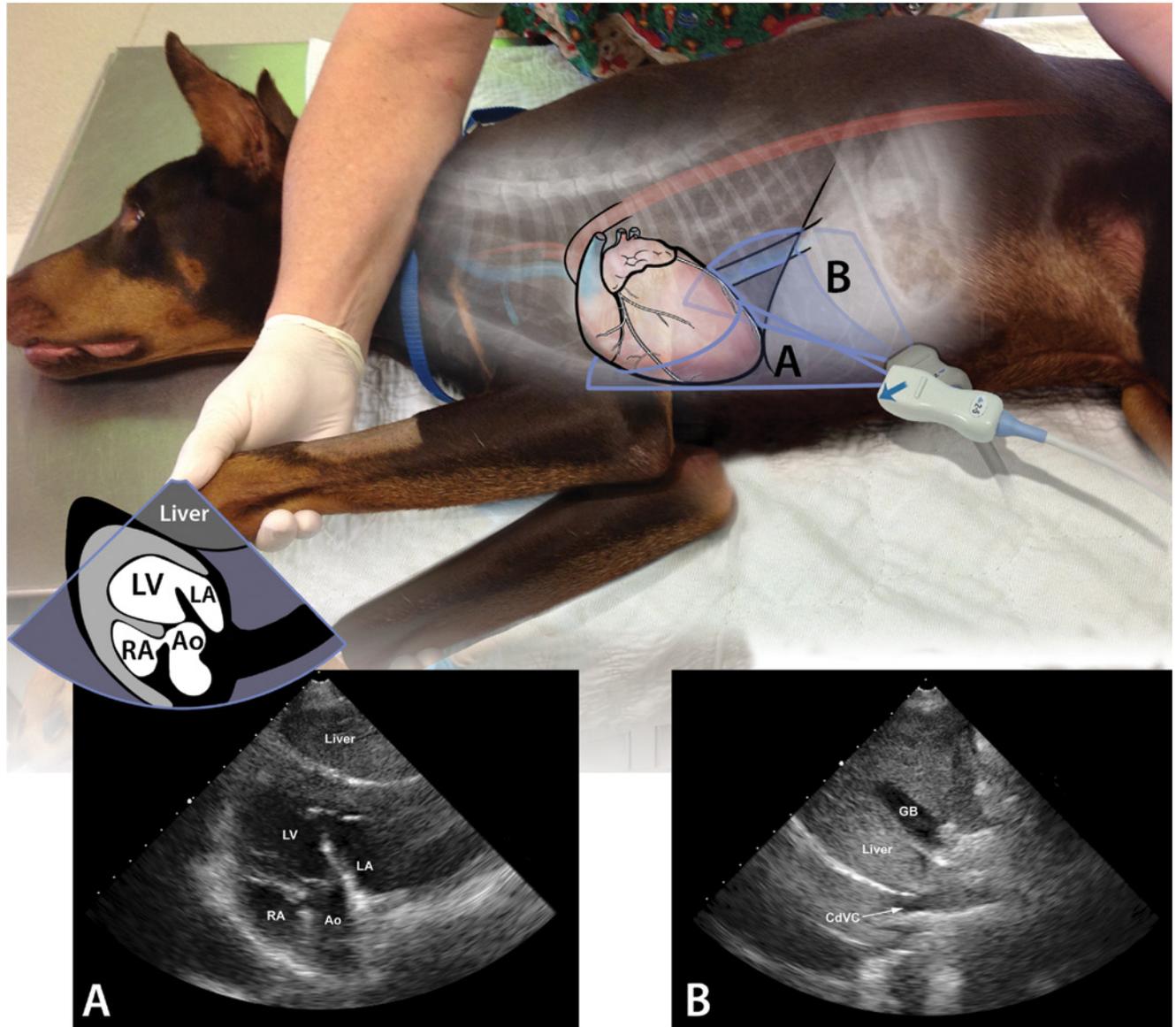


Figure 11.7. Dog positioned for subcostal views with probe positioned just below the xiphoid at the midline. The probe marker is toward the elbow and the probe is pointed toward the dog's head. (A) Corresponding schematic drawing for the echocardiogram labeled "A" of a normal subcostal LV outflow tract view. (B) Rotation of the probe toward liver and diaphragm on the dog, shown as "B," will result in an ultrasound (labeled B) image of the caudal vena cava and liver. (CdVC, caudal vena cava; GB, gallbladder; LA, left atrium; LV, left ventricle; Ao, aorta; RA, right atrium) Courtesy of Alice MacGregor Harvey, North Carolina State University College of Veterinary Medicine.

From the subcostal cardiac views, angulate the probe and decrease the depth to visualize the liver and hepatic veins (Figure 11.7B). The liver is assessed primarily for passive congestion (signs of right-sided failure) as evidenced by hepatic venous distention (Figure 11.8) and ascites between the liver lobes (also see Figures 2.2, 3.3, 3.10, 9.22, 16.2, and 16.8A) (Nelson 2010).

Hepatic venous distention is judged subjectively. The ability to see large anechoic vessels, larger branches, and then smaller branches extending periph-

erally into hepatic tissue is compatible with enlarged hepatic veins. The concurrent findings of ascites and an enlarged and hypoechoic liver further add to the diagnosis of right-sided heart failure (see Figures 2.2, 3.3, 3.10, 9.22, 16.2, and 16.8A). Hepatic veins can be differentiated from portal veins in the liver because they have much less echogenic vessel walls and portal veins have hyperechoic (much brighter) walls (see Figures 3.10 and 13.1D). When measured at the same depth, portal veins and hepatic veins should be about the same size.

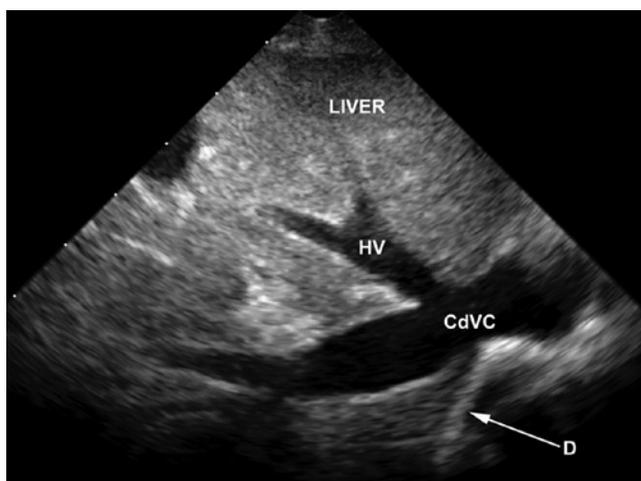


Figure 11.8. Subcostal view of severe caudal vena caval and hepatic venous distention in a dog with right heart failure. (CdVC, caudal vena cava; D, diaphragm; HV, hepatic vein).

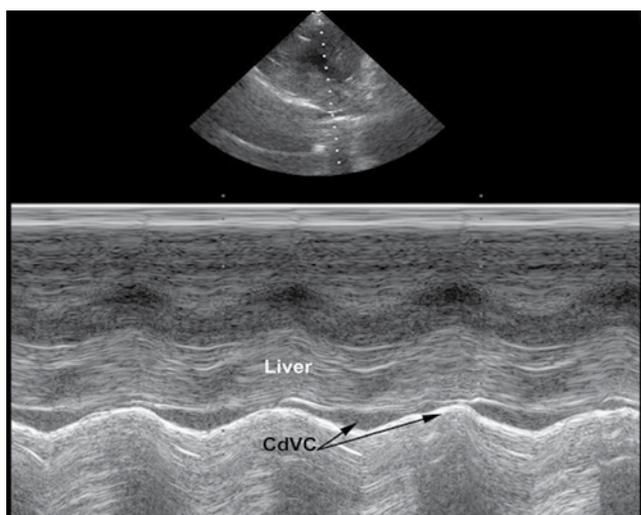


Figure 11.9. Subcostal view of fluctuations of the caudal vena caval diameter during respiration using M-mode (CdVC, caudal vena cava).

Now obtain an image of the caudal vena cava near the diaphragm from this sub-xiphoid view. The probe is angulated almost perpendicularly toward the spine with slight upward tilting of the tail of the probe as the caudal vena cava is slightly to the right of midline just below the spine (Figure 11.7B; also see Figures 9.22 and 16.2).

Alternatively, in left lateral recumbency, the probe can be placed at one of the last intercostal spaces on the right side (more dorsal on the thoracic wall) where only liver and not the left kidney or lung is imaged. The caudal vena cava is ventral and more right-sided than the pulsating aorta. The caudal vena cava can be assessed for respiratory fluctuation in size as an indicator of volume status. Respiratory fluctuations are greater in animals

that are volume depleted (generally greater than 50% fluctuation) (Figure 11.9). No respiratory fluctuations, only static distention, of the caudal vena are seen in animals that have high right atrial pressure (Feisel 2004, Nelson 2010).

Focused ECHO Findings in Common Cardiac Diseases

Mitral Valve Disease

Mitral valve disease (MVD) is the most common cause of heart disease in dogs. It has been estimated that MVD accounts for 75%–85% of all heart disease in dogs; consequently, it is the most common cause of canine heart failure. MVD is most prevalent in older, small breed dogs but can also affect large breed dogs to a lesser degree. Commonly affected breeds include the Cavalier King Charles Spaniel, Dachshund, Chihuahua, Toy Poodle, Beagle, Cocker Spaniel, Maltese, Pomeranian, Shetland Sheepdog, Miniature Schnauzer, and Whippet. MVD causes progressive degeneration and thickening of the mitral valve leading to backward blood flow from the LV to the LA due to mitral valve insufficiency. Over time, chronic mitral valvular insufficiency may lead to left-sided congestive heart failure. Occasionally, MVD can manifest with acute fulminant heart failure as a result of a chordae tendineae rupture and left atrial tears with pericardial effusion (see Figure 9.20). Thickened mitral valve (MV) leaflets occur with possible prolapsing of an MV leaflet, usually the anterior mitral valve leaflet (Figure 11.10).

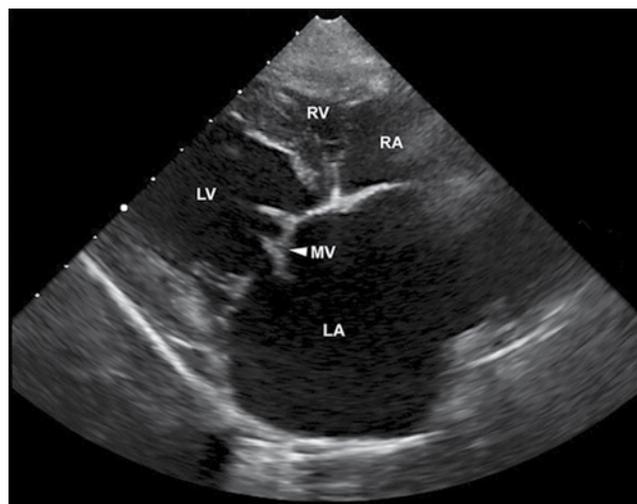


Figure 11.10. Right long-axis view of severe left atrial enlargement in a dog with mitral valvular disease. The arrowhead highlights prolapsing of the anterior mitral valve leaflet. (RV, right ventricle; RA, right atrium; LV, left ventricle; LA, left atrium; MV, mitral valve)

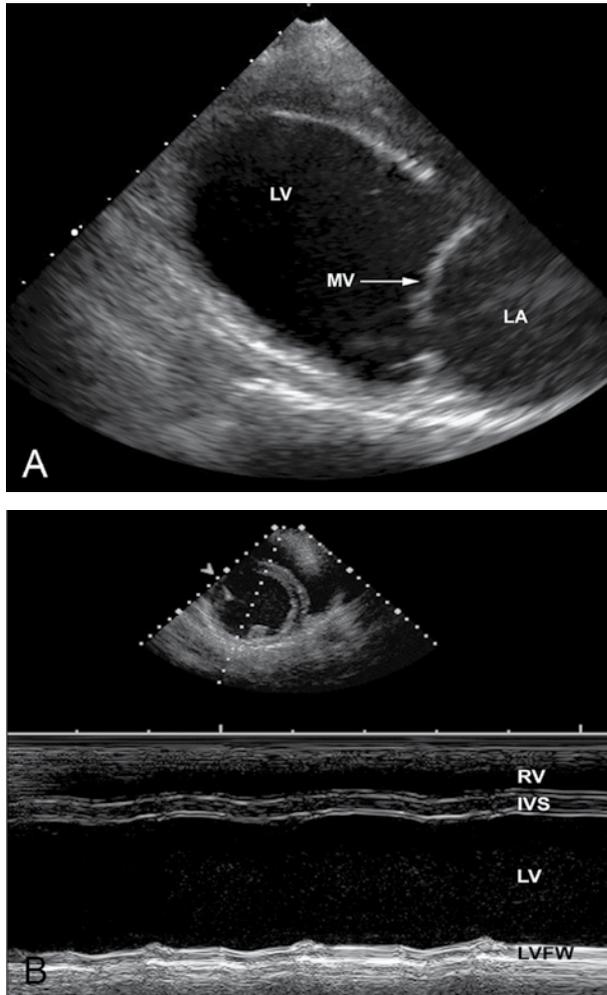


Figure 11.11. Canine dilated cardiomyopathy. (A) Right long-axis view of left atrial and left ventricular dilation in a dog with dilated cardiomyopathy. (B) Severely hypodynamic (low fractional shortening [FS%]) left ventricular wall motion seen in an M-mode view of the left ventricle in a dog with dilated cardiomyopathy. (LV, left ventricle; MV, mitral valve; LA, left atrium; RV, right ventricle; RA, right atrium; IVS, interventricular septum; LVFW, left ventricular free wall)

In left-sided heart failure, severe left atrial enlargement occurs with typically a LA:Ao ratio of greater than 2:1. In early left-sided volume overload, the left ventricle maintains its systolic function and may appear to be hyperdynamic (higher than normal FS%). In later, end-stage MV disease, myocardial function becomes diminished.

Many older small breed dogs with respiratory disease have concurrent mitral valve disease. The size of the left atrium may be used to determine if respiratory clinical signs are due to heart disease or respiratory disease as well as the presence of cardiogenic pulmonary edema (see Chapter 10).

The left atrial size in a dog with acute chordae tendineae rupture may not be severely enlarged. However, these dogs typically have severe pulmonary edema and clinical signs.

Mitral valve disease, or endocardiosis, affects older small breed dogs that typically have a history of a murmur prior to clinical signs of heart failure.

Pericardial effusion in a dog with congestive heart failure and cardiogenic shock may be a result of left atrial rupture as a complication of severe mitral valve disease and left atrial dilation (see Figures 9.20A and B).

Dilated Cardiomyopathy

Dilated cardiomyopathy (DCM) is a common cause of heart disease and heart failure in certain large and giant breed dogs. It is uncommonly diagnosed in cats. DCM causes myocardial failure and cardiac dilatation. DCM is often breed associated and is usually identified when a dog is symptomatic with congestive heart failure. Commonly affected breeds include Doberman Pinchers, Great Danes, Boxers, Irish Wolfhounds, Labradors, and Golden Retrievers. Dogs with DCM may be young, middle-aged, or older, and males are more commonly affected than females. Cardiac arrhythmias are often associated with DCM. A dilated left ventricle with a classic spherical appearance is shown in B-mode along with its corresponding M-mode image in the long-axis view. The dilated left ventricle is markedly hypodynamic with poor left ventricular systolic function (poor contractility), readily appreciated in real-time imaging (Figure 11.11).

Fractional shortening is typically less than 20% (Figure 11.11B). The left atrium is dilated. Not uncommonly, all four cardiac chambers may be dilated, especially if biventricular heart failure is present. The MV anatomy is normal with reduced MV motion.

Tachyarrhythmias and sepsis syndrome may also markedly diminish myocardial function causing misinterpretation of echocardiographic findings. Re-evaluation of myocardial function once arrhythmias and sepsis have resolved is advised.

Hypertrophic Cardiomyopathy

Hypertrophic cardiomyopathy (HCM) is the most common cause of heart disease and heart failure in cats. HCM is defined as LV hypertrophy in the absence

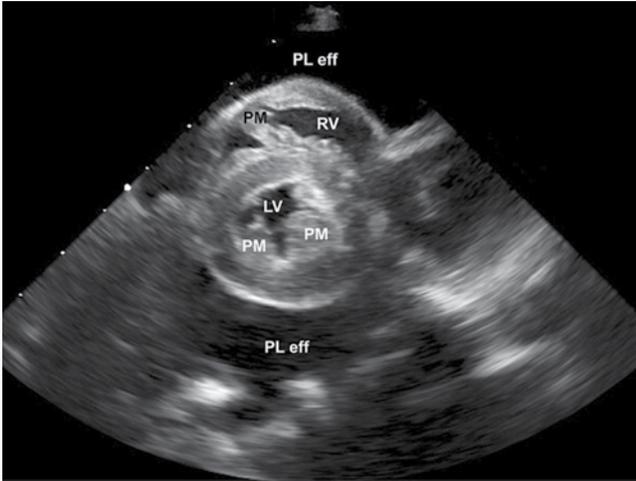


Figure 11.12. Feline hypertrophic cardiomyopathy. Short-axis view of left ventricular hypertrophy and pleural effusion in a cat with hypertrophic cardiomyopathy and congestive heart failure. (LV, left ventricle; PL eff, pleural effusion; PM, papillary muscles; RV, right ventricle)

of diseases that can lead to hypertrophy such as hyperthyroidism and hypertension. HCM generally affects young to middle-aged cats and more commonly affects males than females. Although the most commonly affected cat is the mixed breed cat, certain breeds, such as the Maine Coon, Ragdoll, Bengal, British Shorthair, Sphinx, and Persian, have a high prevalence of HCM.

Concentric LV hypertrophy can be either symmetrical or segmental (Figure 11.13). A LV wall in diastole that measures equal to or greater than 6mm is generally considered hypertrophic. In some cats with chronic disease, LV walls may be high normal thickness because of a phenomenon referred to as LV remodeling.

In a cat with suspected heart failure, the left atrium is severely dilated, typically with an LA:Ao greater than 2 (Figure 11.13B). Variable amounts of pleural effusion are often a manifestation of heart failure in cats (Figure 11.12; also see Figure 9.18).

A small amount of pericardial effusion (typically less than 5mm) without evidence of cardiac tamponade

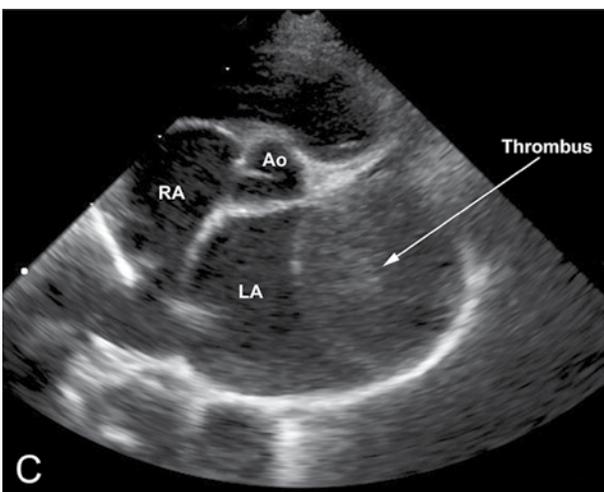
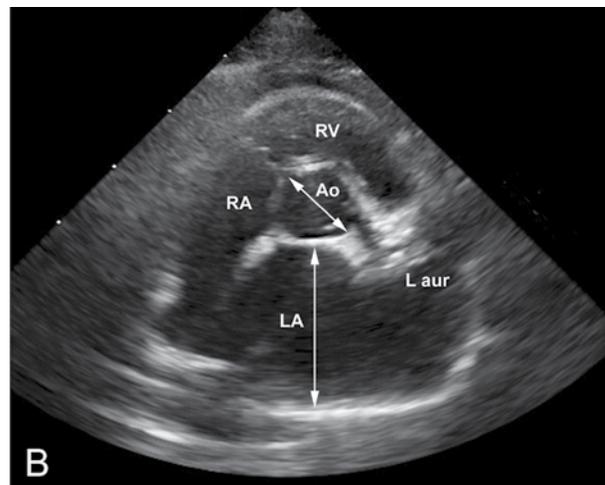
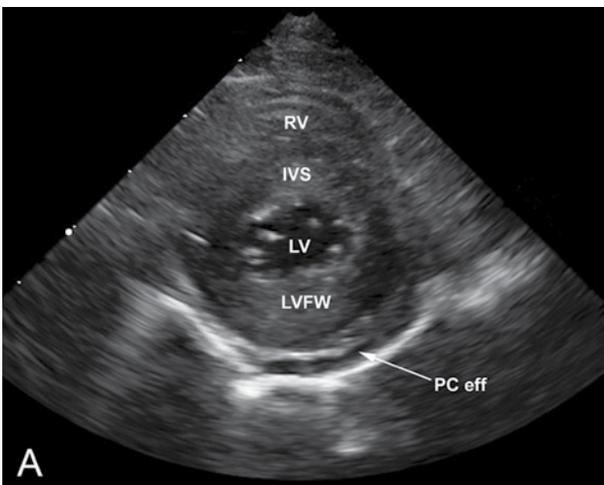


Figure 11.13. Feline hypertrophic cardiomyopathy and its complications (short-axis views). (A) Left ventricular hypertrophy in a cat with hypertrophic cardiomyopathy and heart failure. A small amount of pericardial effusion is noted. (B) Severe left atrial enlargement in a cat with hypertrophic cardiomyopathy and heart failure. (C) Large left atrial thrombus in a cat with aortic thromboembolism and congestive heart failure due to hypertrophic cardiomyopathy. (PC eff, pericardial effusion; IVS, interventricular septum; LV, left ventricle; LVFW, left ventricular free wall; LA, left atrium; L aur, left auricle; Ao, aorta; RV, right ventricle; RA, right atrium)

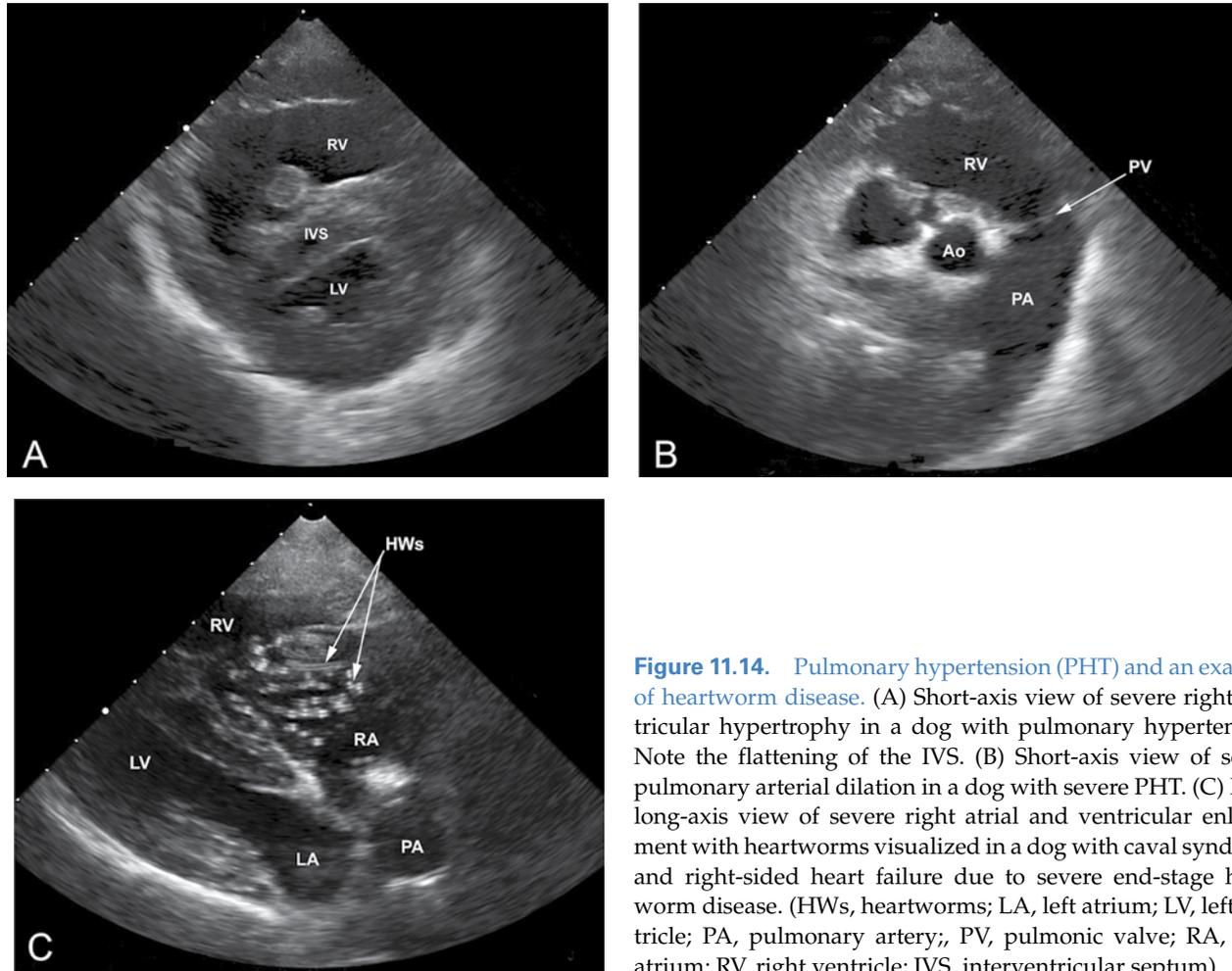


Figure 11.14. Pulmonary hypertension (PHT) and an example of heartworm disease. (A) Short-axis view of severe right ventricular hypertrophy in a dog with pulmonary hypertension. Note the flattening of the IVS. (B) Short-axis view of severe pulmonary arterial dilation in a dog with severe PHT. (C) Right long-axis view of severe right atrial and ventricular enlargement with heartworms visualized in a dog with caval syndrome and right-sided heart failure due to severe end-stage heartworm disease. (HWs, heartworms; LA, left atrium; LV, left ventricle; PA, pulmonary artery; PV, pulmonic valve; RA, right atrium; RV, right ventricle; IVS, interventricular septum)

may be seen in cats with congestive heart failure as a consequence of their heart failure and not due to pericardial disease. In fact, the most common cause of pericardial effusion in cats is heart failure (Figure 11.13A). Typically HCM cats have hyperdynamic (high FS%) LV function. However in end-stage or remodeled HCM, LV function can be diminished (lower FS%). Possible left atrial thrombus, most commonly within the left auricle, may be present. The thrombus can be adhered to the atrial wall or freely mobile (Figure 11.13C). “Smoke,” or a swirling appearance of blood in the left atrium, can be seen in cats with severe left atrial enlargement and stagnant blood flow. This finding, known as spontaneous echo contrast, may be seen in cats that have suffered an aortic thromboembolism (ATE) or are at high risk for thromboembolism.

HCM is diagnosed when LV hypertrophy is present in the absence of hyperthyroidism, hypertension, severe hypovolemia, or aortic stenosis.

Left atrial thrombus has clear edges and is not hazy. Be cautious not to overinterpret a reverberation artifact in the left atrium for a thrombus.

Pulmonary Hypertension

Pulmonary hypertension can result in RV and interventricular septal hypertrophy. Look for flattening of the IVS in the LV short-axis mushroom view (Figure 11.14A). Right atrial dilation and caudal vena caval and hepatic venous distention may be seen in severe PHT and right-sided heart failure (Figure 11.8). Typically in severe cases, the main pulmonary artery is enlarged and (larger than the aorta; Figure 11.14B) the LV is small suggesting poor filling of the LV and low cardiac output due to the PHT (see Figures 9.16B, 16.2).

In dogs with severe PHT due to heartworm disease, heartworms may be seen as double-lined structures within the pulmonary artery. With caval syndrome (a

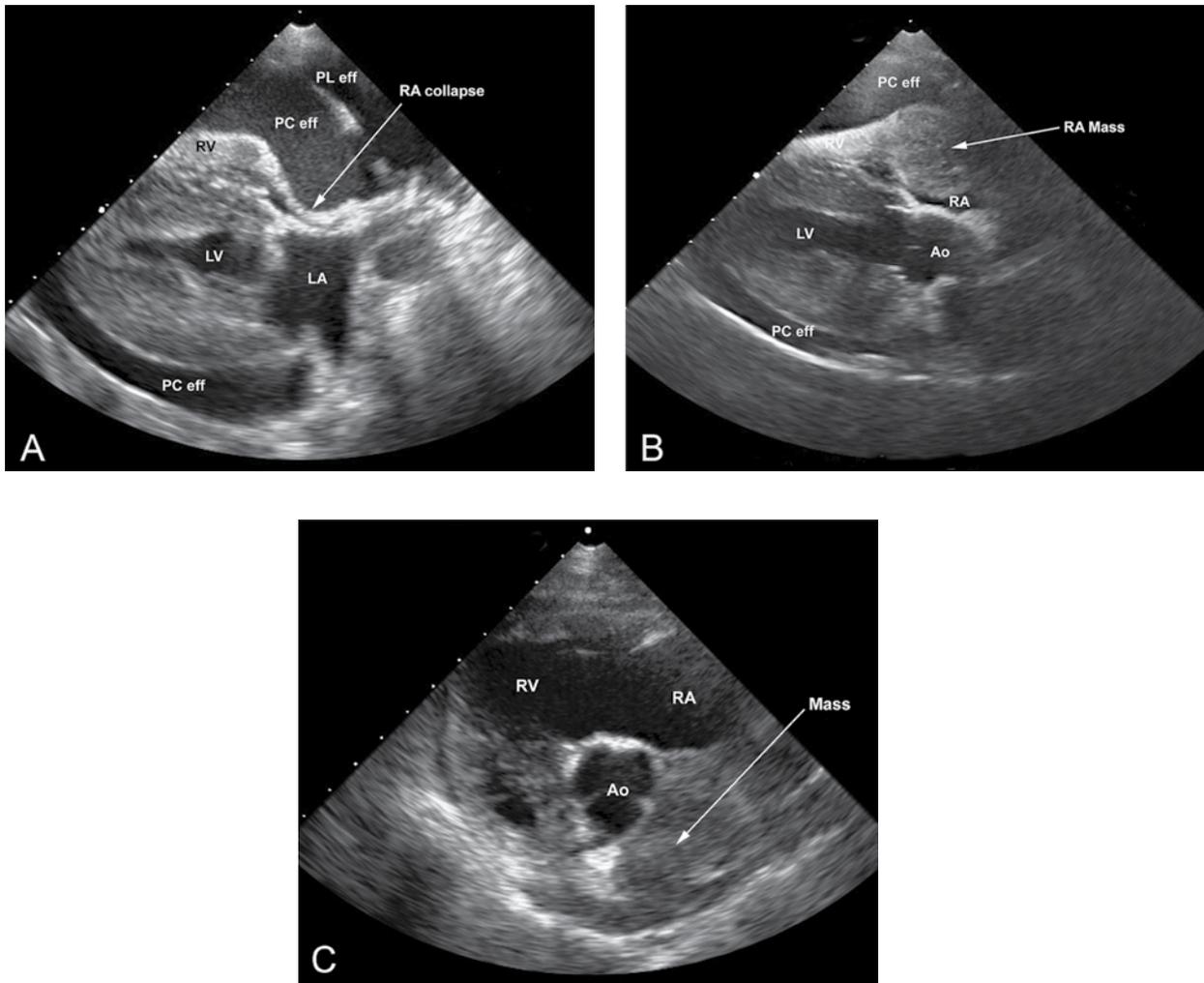


Figure 11.15. Pericardial effusion with tamponade and typical heart-associated masses. (A) Right long-axis view of pericardial effusion and cardiac tamponade showing clear right atrial collapse. (B) Right long-axis view of a right atrial tumor, most likely hemangiosarcoma, in a dog with pericardial effusion. (C) Right short-axis view of a heart base tumor, most likely chemodectoma. (LA, left atrium; LV, left ventricle; PC eff, pericardial effusion; PL eff, pleural effusion; Ao, aorta; RA, right atrium; RV, right ventricle; RA Mass, right atrial mass)

severe form of heartworm disease), the heartworms will be seen in the right atrium and ventricle and caudal vena cava (Figure 11.14C).

Echocardiographic findings of right-sided heart failure typically include right ventricular and atrial enlargement, hepatic venous distention, and ascites.

Pericardial Effusion

Multiple views of the heart are key to not mistaking normal anatomy for pericardial (or pleural) effusions, thus leading to the most catastrophic procedures of performing centesis on the heart. The axiom

of “One view is no view” is sage advice when diagnosing pericardial effusion (see also Chapter 9, TFAST³ and Chapter 2, AFAST³ [the DH View]).

Causes of pericardial effusion in the dog most commonly include neoplasia and idiopathic pericardial effusion. Less commonly, pericardial effusion may be caused by coagulopathies, left-atrial tear (mitral valve disease dogs), foreign bodies, infectious diseases, and penetrating and blunt trauma and others.

Pericardial effusion resulting in life-threatening cardiac tamponade occurs when the intrapericardial pressure is higher than the right ventricular filling pressure. This pressure discrepancy results in hemodynamic changes that cause poor right ventricular filling, signs of low cardiac output, and right heart failure with collapse of the patient. It is not the

amount of effusion but rather the rate of its formation that determines the degree of hemodynamic compromise. An animal can have cardiac tamponade and poor cardiac output with a small amount of pericardial effusion if the rate of accumulation of the effusion was fast.

Pericardial effusion is characterized by anechoic fluid around the heart that is delineated by the pericardium (which appears as a bright white linear echo in the far field, mostly because of acoustic enhancement) (see Figures 9.17 and 9.20). Cardiac tamponade is a life-threatening condition that is a frequent consequence of pericardial effusion in the dog (see Chapter 17). The echocardiographic criteria for cardiac tamponade are right atrial and right ventricular diastolic collapse (Figure 11.15A; also see Figure 9.19A and B).

Neoplasia, most commonly right auricular hemangiosarcoma and heart base chemodectoma, is the most common cause of pericardial effusion in an older dog. The presence of a possible cardiac mass is generally better evaluated prior to pericardiocentesis depending on patient stability (e.g., the need for emergent pericardiocentesis). A heart base mass is usually best visualized in the right sided short-axis parasternal view (Figure 11.15C), whereas a right atrial or auricular hemangiosarcoma is typically best seen from a left-sided parasternal view optimized for the right atrium and auricle. If a mass is very large, it can be seen in any view and may compress the atria or great vessels, impinging the inflow or outflow of blood.

Pericardiocentesis is often aided by the use of ultrasound to optimize the location of the centesis and ensure proper placement of the centesis catheter (see Chapter 17).

Pleural Effusion

Pleural effusion is often present concurrently with pericardial effusion. The distinction between pleural and pericardial effusion can be challenging. The pericardium is usually the most hyperechoic (brightest) structure within the thorax. To distinguish pleural effusion, turn down the gain of the US machine and generally the last linear echo structure is the pericardium. If no pericardial effusion is present, then pericardium (the last white line) should be adjacent to the epicardial surface of the heart. Additionally, pericardial fluid should taper as it nears the left atrial-left ventricular junction in the long-axis views. The dorsal aspect of the LA is extra-pericardial; thus, pericardial effusion should not extend much

beyond this junction, whereas pleural effusion will (see Figures 9.17, 9.19, and 9.20). Finally, pleural effusion is gravity dependent and will shift to the recumbent side. As previously mentioned, multiple views are key for interrogation of the pleural and pericardial spaces (also see Chapter 9 and Figure 9.18).

Some very obese cats have a large fat deposit on their pericardium that can be misdiagnosed as pericardial effusion or a mass. Fat has a more echogenic (brighter) appearance than fluid.

Assessment of Intravascular Volume

Because of normal variation in cardiac chamber size, especially in the dog, measurement of cardiac chambers is generally not a reliable index to assess patient volume status. The only exception is severe hypovolemia (Lamia 2007, Charron 2006). Monitoring of left ventricular internal chamber size, the LV short-axis “mushroom” view, serially over time during fluid resuscitation may provide additional evidence of volume status (Durkan 2005), in addition to other clinical parameters (also see chapters 10 and 16).

In severe hypovolemia, the left ventricular and right ventricular internal dimensions are small with higher than normal left ventricular wall thickness (see Figures 9.16A and B and 16.2C); left ventricular function is hyperdynamic and left atrial and right atrial size are normal to small.

Extreme hypovolemia causing pseudohypertrophy of the left ventricle can be confused for hypertrophic cardiomyopathy in the cat.

Left atrial size should be enlarged in a symptomatic HCM cat, whereas left atrial size is normal to small in hypovolemia.

Caudal vena caval diameter and its respiratory variations can be used to estimate patient volume status (Feisel 2004). Respiratory fluctuations in the caudal vena cava are only seen when right atrial pressure (RAP) is not elevated. If RAP is greater than 15 mmHg, consistent with hypervolemia or right heart failure, no fluctuations are noted. A variation greater than 50% in caudal vena caval diameter with respiration predicts positive hemodynamic response to volume expansion with intravenous fluids (Figures 11.7B and 11.9).

Pearls, Pitfalls, the Final Say

Focused ECHO can provide vital and non-invasive detailed information about cardiac structure and function beyond the capabilities of the physical examination and thoracic radiographs. This valuable information can result in the rapid diagnosis and improved management of a hemodynamically unstable patient. Even with limited experience, significant cardiac abnormalities such as marked chamber enlargements, pericardial effusion, and myocardial failure can be determined as well as patient volume status. Finally, the add-on of the Vet BLUE lung scan, Chapter 10, can rapidly rule out evidence of left-sided heart failure using the wet vs. dry lung principle (Lisciandro 2013).

References

- Abbott JA, MacLean HN. 2006. Two-dimensional echocardiographic assessment of the feline left atrium. *J Vet Intern Med* 20:111–9.
- Arntfield RT, Millington SJ. 2012. Point of care cardiac ultrasound applications in the emergency department and intensive care unit—a review. *Curr Cardiol Rev* 8:98–108.
- Charron C, Caille V, Jardin F, et al. 2006. Echocardiographic measurement of fluid responsiveness. *Curr Opin Crit Care* 12:249–54.
- Durkan SD, Rush JE, Rozanski EA, et al. 2005. Echocardiographic findings in dogs with hypovolemia. Abstract. *J Vet Emerg Crit Care* 15:54.
- Feissel M, Michard F, Faller JP, et al. 2004. The respiratory variation in inferior vena cava diameter as a guide to fluid therapy. *Intensive Care Med* 30:1834–7.
- Kittleson MD, Kienle RD. 1998. *Small Animal Cardiovascular Medicine*, Mosby: St. Louis, p 104.
- Kobal SL, Trento L, Baharami S, et al. 2005. Comparison of effectiveness of hand-carried ultrasound to bedside cardiovascular physical examination. *Am J Cardiol* 96:1002–6.
- Labovitz AJ, Noble Ve, Beirig M, et al. 2010. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr* 23:1225–30.
- Lamia B, Ochagavia A, Monnet X, et al. 2007. Echocardiographic prediction of volume responsiveness in critically ill patients with spontaneously breathing activity. *Intensive Care Med* 33:1125–32.
- Lisciandro GR, Lagutchik MS, Mann KA, et al. 2008. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 18:258–69.
- Lisciandro GR, Fosgate GT, Fulton RM. 2013. The frequency and number of ultrasound lung rockets (B-lines) using a regionally-based lung ultrasound examination named Vet BLUE (Veterinary Bedside Lung Ultrasound Exam) in dogs with radiographically normal lung findings. *Vet Radiol and Ultrasound*, accepted.
- Moore CL, Copel JA. 2011. Point of care ultrasonography. *N Eng J Med* 364:749–57.
- Nelson NC, Drost WT, Lerche P, et al. 2010. Noninvasive estimation of central venous pressure in anesthetized dogs by measurement of hepatic venous blood flow velocity and abdominal venous diameter. *Vet Radiol and Ultrasound* 51(3):313–323.
- Rishniw M, Erb HN. 2000. Evaluation of four 2-dimensional echocardiographic methods of assessing left atrial size in dogs. *J Vet Intern Med* 14:429–35.
- Scansen BA. 2011. Interventional cardiology for the criticalist. *J Vet Emerg Crit Care* 21(2):123–36.
- Tse Y, Bulmer B, Cunningham S, et al. 2012. Evaluation of a training course in focused echocardiography for the non-cardiology house officer. Abstract. *J Vet Emerg Crit Care* 22;S2:s10.
- Reissig A, Copetti R, Kroegel C. 2011. Current role of emergency ultrasound of the chest. *Crit Care Med* 39(5): 1–8.
- Rush JE, Freeman LM, Fenollasa NK, et al. 2002. Population and survival characteristics of cats with hypertrophic cardiomyopathy: 260 cases (1990–1999). *J Am Vet Med Assoc* 220:202–7.

FOCUSED OR COAST³—CENTRAL VENOUS AND ARTERIAL LINE PLACEMENT, BIG ARTERIES, AND VEINS

Scott Chamberlin

Introduction

Ultrasound-guided placement of central venous catheters has been repeatedly shown to be both best-practice and standard of care in human medicine for both adult and pediatric patients (Froelich 2009, Miller 2002, Milling 2005, Wigmore 2007). Likewise, it has been determined to be a safe, acceptable practice for arterial catheterization (Ringold 2008). Moreover, ultrasound (US) guidance for vascular access is non-invasive and relatively unaffected by patient size, obesity, local hematoma formation, and peripheral edema (Ringold 2008). Although sparsely reported in the veterinary literature, US-guided central line placement and femoral arterial catheterization have been described in dogs (Chamberlin 2012, Ringold 2008).

In comparison to traditional blind catheterization, also referred to as the landmark technique, US-guided methods have documented greater success rates with fewer complications in the emergency, critical care, and anesthesia settings (Miller 2002, Karakitsos 2006, Pirotte 2007, Theodoro 2010). Additionally, US guidance is advantageous over surgical cut-down techniques which are invasive, often sacrifice the vessel, and risk neuropraxia (Ringold 2008). Most importantly, it has been shown

that the benefits observed with US-guided vascular access techniques are still present when applied by minimally trained non-radiologist physicians (Froehlich 2009, Miller 2002) and veterinarians (Ringold 2008, Chamberlin 2012).

The only published veterinary study regarding US guidance for central venous catheter (CVC) placement demonstrated that CVC placement was technically easy and rapid (median time was 1.9 minutes without hematoma and 4.3 minutes with hematoma formation) and had a relatively shallow learning curve among various non-radiologist residents and faculty (Chamberlin 2012). Despite complications such as iatrogenic perivascular hematoma and cardiovascular collapse post cardiac arrest, US-guided CVC placement was readily achievable with a high success rate (Chamberlin 2012).

The most common site in veterinary medicine for arterial catheter placement is the dorsal pedal artery, but in very small or unstable patients under anesthesia in which direct blood pressure and respiratory and acid-base monitoring are critical, the femoral artery is an excellent alternative. US guidance may be used to place femoral arterial catheters in veterinary patients when arterial access is required and more traditional sites are compromised or insufficient for procedure requirements (cardiac

catheterizations, interventional radiology, etc.) (Kweon 2012, Ringold 2008).

Perivascular hematomas are far more common with arterial sampling attempts (whether successful or not); this complication does not hinder ultrasound (US) imaging, providing a huge advantage over the landmark method. In fact, near-field fluid (hematoma) actually enhances US visualization of the far-field target (vessel of interest) by an artifact referred to as acoustic enhancement, and the insertion of the stylet, guide wire, and catheter may likewise be imaged real-time (Ringold 2008, Chamberlin 2012). Direct imaging of both the vessel and catheter stylet is why US-guided vascular access has been repeatedly shown to be a best-practice technique.

Regarding distal, more peripherally located vessels, US-guided catheterization at sites such as the cephalic vein or dorsal pedal artery in cats and dogs is generally of minimal benefit due to their small limb radius and the shallow depth of tissue between skin surface, vessel of interest, and underlying bone coupled with the inability of US to image that closely in the near field. Acoustically-permeable “stand-off” blocks facilitate diagnostic US of non-compressible tendons and other structures, but are generally cumbersome and not advantageous when evaluating and cannulating distal limb (peripheral) vessels in dogs and cats.

With increasing user proficiency and access to multiple probes for detailed imaging at closer depths, US may become more helpful as a surveillance technique (proven in people) for arterial and venous thromboembolism as well as deep vein (peripheral) thrombosis (DVT). This pathology is relatively unstudied in veterinary medicine but is a major contributor to morbidity of critically ill humans (Crisp 2010). Arterial thromboembolism is not uncommon in veterinary patients, but US diagnosis is particularly technically demanding. Although a detailed discussion is beyond the scope of this chapter, the condition is briefly addressed at the end of this chapter.

In summary, US guidance has the potential to facilitate the placement of both arterial and venous catheters which provide multiple benefits for patient care. Central venous catheters allow more rapid fluid and drug delivery to the central circulation over peripheral lines (Emerman 1998), provide a means to evaluate patient volume status via central venous pressure (CVP), and ease blood sampling in critically ill or fractious patients intolerant of restraint. Arterial catheters are used to obtain blood samples for respiratory and acid-base monitoring, measure direct arterial blood pressure,

and are necessary for many interventional radiology techniques (Ringold 2008).

What the Focused Central Venous and Arterial Line Placement, Big Arteries, and Veins Can Do

- Rapidly identify the jugular vein or femoral artery for catheterization independent of vascular collapse, peripheral edema, obesity, patient size, and local hematoma formation
- Guide central venous or femoral arterial catheter placement, preventing damage to adjacent structures unrecognized via the more traditional landmark catheterization method
- Facilitate the use of central venous catheters, which allow more rapid fluid and drug delivery to the central circulation, simplify repeated blood sampling (more comfortable, less restraint for patient), enable administration of hyperosmolar or other fluids too irritating for peripheral veins, allow for otherwise incompatible fluid administration via multilumen CVCs, and enable early goal-directed therapy including CVP measurement and central venous oxygen saturation (Rivers 2001, Prittie 2006)
- Facilitate the use of arterial catheterization for arterial blood sampling, direct arterial blood pressure measurements, and interventional radiology techniques
- Confirm safe and successful cannulation of the desired vein or artery
- Possibly afford some veterinary clinical utility for venous and arterial thrombosis surveillance

What the Focused Central Venous and Arterial Line Placement, Big Arteries, and Veins Cannot Do

- Cannot guide cannulation of superficially located small veins and arteries
- Cannot replace adequate ultrasound training because vascular ultrasound techniques are operator dependent
- Cannot overcome unknown/questionable reliability for the non-radiologist or minimally trained sonographer with regard to accurate diagnosis of arterial and venous thromboembolism

Indications for Focused Central Venous and Arterial Line Placement, Big Arteries, and Veins

- Failure or anticipated failure in obtaining any vascular access by traditional blind landmark techniques due to cardiovascular collapse, hypotension, or hematoma formation
- Inability to identify the target vessel (central vein or femoral artery) due to cardiovascular collapse, hypotension, or hematoma formation
- Requirement for rapid lifesaving central venous access for urgent intravenous fluid administration and drug delivery
- Requirement for central venous access for administration of caustic or high osmolarity drugs poorly suited for peripheral administration, and/or administration of parenteral nutrition and multiple incompatible drugs or transfusion products by use of multilumen CVCs
- Requirement for frequent blood sampling for critically ill and fractious animals which might otherwise require repeated venipuncture with increased stress, pain, and risk of phlebitis and other complications
- Requirement for arterial sampling and access for direct arterial blood pressure readings and/or respiratory and acid-base monitoring where traditional distal arterial sampling sites are compromised or unavailable
- Requirement for large arterial cannulation for interventional radiology and other special procedures

Objectives for Focused Central Venous and Arterial Line Placement, Big Arteries, and Veins

- Ultrasonographically recognize the regional vasculature and anatomy of the neck
- Use US guidance for CVC placement using the jugular vein
- Ultrasonographically recognize regional vasculature of the hind limbs
- Use US guidance for femoral arterial catheterization and direct arterial sampling
- Be cognizant of potential future applications for peripheral and internal arterial and venous thromboembolic surveillance

Placement of an US-Guided Central Venous Jugular Catheter (CVC)

Ultrasound Settings and Probe Preferences

Ideally, linear array probes with a minimum frequency availability of 7.5MHz are preferred by clinicians in human medicine because of their superior detail at shallow depths. Curvilinear (microconvex) 5- to 8-MHz probes with the ability to magnify to a depth of less than 4cm (more common probe type in veterinary practices) are also effective. Some US machines have a needle-enhancement feature; this can be helpful but is currently only included with linear probes. Probes should be cleaned and disinfected according to manufacturer guidelines prior to and after use in US-guided CVC placement.

Using “small parts” or “vascular” settings can improve imaging detail.

For aseptic US use, the probe may be placed in a sterile acoustic coupling gel-filled surgical glove or sterile obstetric sleeve as a protective barrier (Figure 12.1).



Figure 12.1. Sterile probe preparation using a sterile glove barrier. Acoustic coupling gel is on the probe inside the glove. Alcohol with or without sterile acoustic coupling gel is applied to patient’s skin for optimal imaging at the probe-skin interface.

Equipment

Different styles of central venous catheters (CVC) are available, including the through-the-needle Venocath® (Hospira, Inc. Lake Forest, IL) and Seldinger-type designs (Mila International, Erlanger, KY; Cook Incorporated, Bloomington, IN), which come in variable lengths with variable numbers of lumens (single, double, triple). It is important to note that advancing the central line too far possibly places the catheter into the right heart and/or pulmonary artery and may potentially cause serious complications including direct injury to the heart or coiling and knotting of the central lines, rendering them irretrievable (Mitchell 1979, Kusminksy 2007).

In general it is best to use a 16-gauge CVC for larger dogs (greater than 7.5 kg) and an 18-gauge CVC for smaller dogs and cats.

Pre-measure the catheter to the fourth or fifth rib on the patient and note the length on the catheter (most CVC have length demarcations printed on them). Confirm the CVC location with post procedure radiographs.

The Seldinger CVCs are preferred; however, both designs can be unquestionably foreign and intimidating to the novice. Sacrifice a Venocath® or single-lumen Seldinger CVC for familiarity with the device; the latter includes several components including a needle or stylet, a guide wire, a dilator, and the actual CVC (used sequentially). Some excellent step-by-step descriptions are available including Silverstein and Hopper's *Small Animal Critical Care Medicine*, Hackett and Mazzaferro's *Veterinary Emergency and Critical Care Procedures* (the 2012 edition includes online videos), as well as other video demonstrations available on YouTube.

Sacrifice a Venocath® or single-lumen Seldinger CVC for familiarity with the device.

How to Place an US-guided Central Venous Jugular Catheter

Procedure

As with any medical procedure, there are multiple described US-guided vascular techniques available to the veterinarian. Each technique has inherent

advantages and disadvantages with regard to comfort, efficacy, and safety. The points for US-guided CVC placement reviewed below relate to how much the probe is used during actual catheter placement (static vs. dynamic real-time placement vs. combinations thereof) and probe orientation (transverse vs. longitudinal vs. combinations thereof). Because needle guides (devices that attach to the probe) are too cumbersome for vascular access techniques, only free-hand descriptions are used in this text (Ringold 2008, Chamberlin 2012).

The static technique uses US as a screening tool to localize structures (vessels, etc.) prior to blindly placing the catheter in the traditional landmark manner. This technique has been described in the human literature as acceptable, though less successful, than the dynamic technique. The static technique may be an option for the novice who has difficulty coordinating both the probe and the stylet as guided by the US image during CVC introduction.

In the dynamic technique, US is used to actually guide the catheter into the vessel using US in real-time. Because this method tracks the target vessel and the surrounding structures in relation to the sharp stylet, it is safer and typically more successful than the static technique (Milling 2005), especially when a single operator manipulates both the catheter and the US probe. The novice sonographer performing the dynamic technique may be tempted to have an assistant maneuver the probe; however, communication and coordination between the person placing the catheter and the person holding the probe is often a source for error. With minimal training to develop comfort with US imaging and coordinating both the probe and stylet, the one-person technique will quickly prove more successful and lead to less errors (Milling 2005, Chamberlin 2012) than the static or two-person options. Homemade models using Jello or commercially available phantoms are great practice options (Wells 2010).

Traditionally, jugular vein catheterization is abandoned when hematomas obscure palpable and visual landmarks. However, US becomes more effective when imaging through fluid in such circumstances (see Chapter 1, Figure 1.6) and permits continued attempts for CVC placement at the discretion of the attending veterinarian. Moreover, stylets, needles, and catheter components may be ultrasonographically visualized in real-time, providing distinct advantages over both the static and blind landmark methods.

The dynamic real-time technique is described below. Keep in mind the aforementioned options because it is not uncommon for any veterinary procedure to become modified based on the particular circumstances at that

time (i.e., bailing on the dynamic technique because the static technique lends itself better to the situation at hand).

Anatomy

Place the patient in lateral recumbency consistent with typical positioning for jugular catheterization, then clip fur and aseptically prep the skin as fully as possible depending on patient stability.

The external jugular veins are the preferred CVC sites in veterinary patients. Each jugular vein runs ventrolaterally on the left and right sides of the neck superficially under the skin along an angle from the angle of the mandible to the thoracic inlet. Each jugular vein is bounded throughout its slightly angulated course ventrally by the sternocephalicus muscle and laterally by the cleidocervicalis muscle.

Patient Preparation

All attempts should be made to adequately shave over the jugular furrow (ventrolateral cervical region) to give ample room to aseptically prep the skin over the CVC insertion site and comfortably protect the site post insertion (neck wrap). Liberal local use of 70% isopropyl alcohol, either by itself (which is often sufficient) or in combination with acoustic coupling gels mentioned below, improves probe contact and greatly enhances image quality while maintaining a clean CVC insertion site. However, the attending

veterinarian should keep in mind the following precautions: Alcohol-induced hypothermia (external cooling) may occur in any patient, especially smaller animals. The inherent flammability of alcohol is environmentally dangerous (fire hazard) and poses burn risks to the patient in the event of electrical defibrillation. Sterile acoustic coupling gels are commercially available and ideal (Aquasonics, Parker Laboratories, Fairfield, NJ). Although it lacks viscosity and tends to fall off the site, sterile K-Y® Jelly (Johnson and Johnson, New Brunswick, NJ) serves as a replacement option to sterile commercially available acoustic coupling gel.

Excess alcohol should be wiped off the fur and skin as soon as it is no longer needed while maintaining sterility at the catheter insertion site.

Orientation

Verify the US probe-to-screen marker orientation so that direction is accurate during the procedure (see Figure 1.11). The US monitor must be located in a comfortable line of sight. With the non-dominant hand of the person placing the CVC, the US probe is placed in the jugular groove in transverse orientation just caudal to the desired catheter entry point on the skin, searching for the anechoic (black) circles of the vessels (Figure 12.2A, 12.7, 12.8).

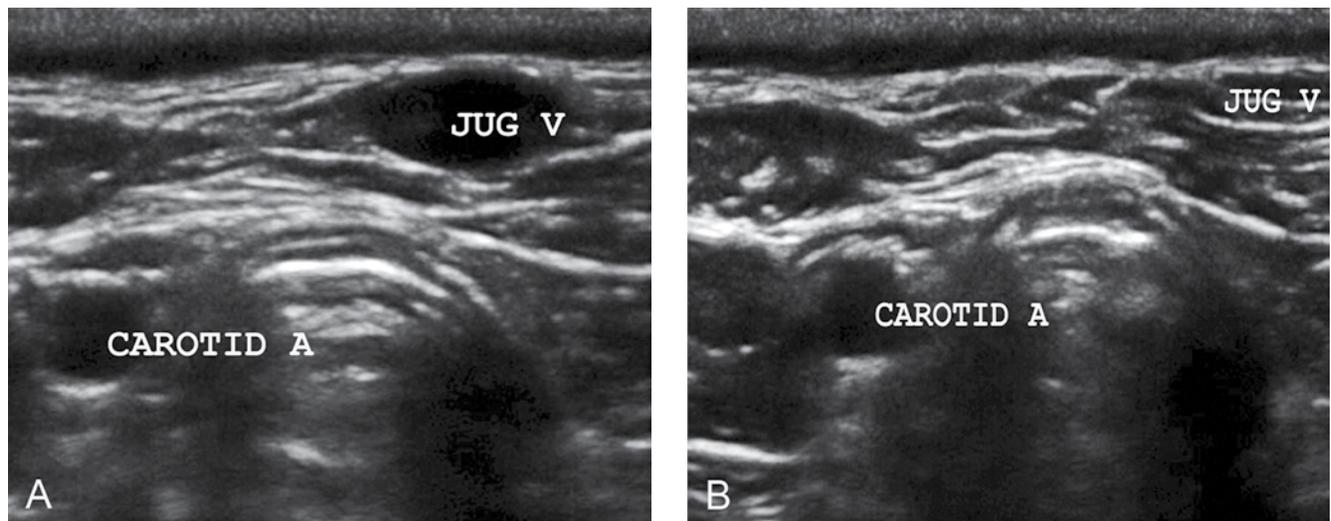


Figure 12.2. Compression technique to discriminate jugular vein from carotid artery. (A) Transverse image depicting normal probe pressure (no significant compression) with both the jugular vein and carotid artery visible. (B) Transverse image depicting the disappearance of the jugular vein with gentle probe pressure (compression) while the lumen of the carotid artery remains visible (circular). The compression technique is effective and reliable in discriminating between arteries and veins.

It is difficult, potentially hazardous, not to mention fatiguing and uncomfortable (to the sonographer), to insert a CVC (or arterial catheter) when craning to look over your shoulder at the US screen (Bowra 2006).

Structures (particularly artery vs. vein) are most easily identified by their anatomic location and by intermittent gentle probe pressure (compression techniques) because veins collapse (flatten), whereas arteries do not (not flatten, but remain relatively circular) (Figure 12.2A and B).

As with traditional landmark techniques, having an assistant hold off the jugular vein by applying digital pressure at the thoracic inlet can prove helpful in visualizing as well as cannulating the jugular vein.

B-mode color flow Doppler US, when available, may be helpful in the learning phases to gain confidence in differentiating vein from artery. However, Doppler US is not required because proficiency may be obtained without it, and in fact it is not recommended in several larger published human studies and protocols (Bowra 2006). Color flow Doppler does not identify artery and vein by color but rather is generally coded as red flowing toward the probe and blue flowing away.

Color flow Doppler US imaging for pulsatile arterial flow is not 100% reliable because the artery's jump can transmit misinterpreted motion to the nearby vein causing misidentification.

The sonographer can either remain in transverse orientation throughout the catheter placement (often easier for the novice and advantageous in short-necked animals) (Blaivas 2003), rotate the probe 90 degrees to a longitudinal alignment, obtaining an anechoic (black) linear tract representative of the jugular vein (Figure 12.3), or use combinations of transverse and longitudinal views. In either transverse or longitudinal views, the probe is placed just caudal (closer to the heart) to the desired catheter entry point on the skin. For safety and by convention regarding longitudinal orientation (very important), the US probe marker should point rostrally, thus positioning the probe marker on the same side as the catheter insertion site.

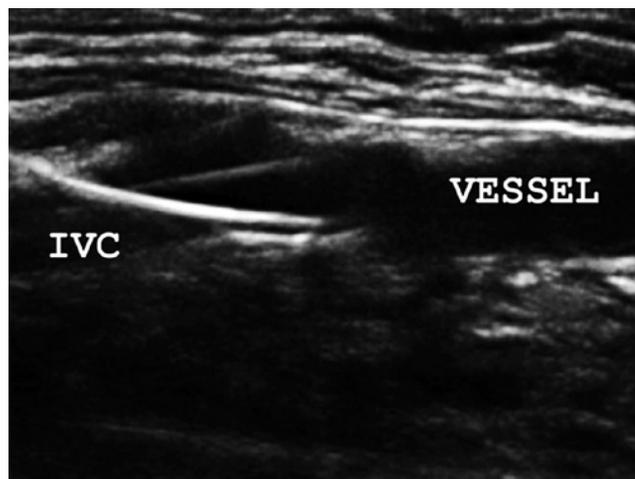


Figure 12.3. Ultrasound-guided central line placement. Longitudinal view showing the horizontally aligned anechoic (black) lumen of the jugular vein. The central venous catheter is seen within the vessel. The anechoic (black) perivascular fluid immediately superficial to the jugular vein is due to hematoma formation. Ultrasound actually images better through fluid making it advantageous when hematoma formation occurs and allowing for the procedure to continue, whereas the blind landmark technique would need to be aborted.

Transverse Orientation

With the jugular vein identified, move the US probe and alter image depth and focus so that the vessel appears in the center of the US screen as an anechoic circle (transverse orientation), thus landmarking the jugular vein's position (Figure 12.4A). With the dominant hand, insert the stylet (or needle in some Seldinger kits; "stylet" will be used hereafter for simplicity) through the skin directly over the jugular vein and approximately 1–2 cm rostral to the US probe. Placing the stylet 1–2 cm rostral to the US probe keeps the sharp point of the stylet from damaging the rubber US probe head (Figure 12.5).

The maneuver of placing the stylet 1–2 cm rostral to the US probe keeps the sharp point of the stylet from damaging the rubber US probe head.

Using a number-11 scalpel blade or an 18-gauge needle to nick the skin 3–5 mm lateral to the jugular vessel facilitates getting the stylet through otherwise tough skin. This nick can then be moved directly over the jugular vein for the subsequent introduction of the stylet into the vessel (Crowe 2009). Once the stylet is through the skin (not yet puncturing the jugular vein), slide the probe rostrally to visualize the tip of the hyperechoic (bright) stylet and the anechoic (dark)

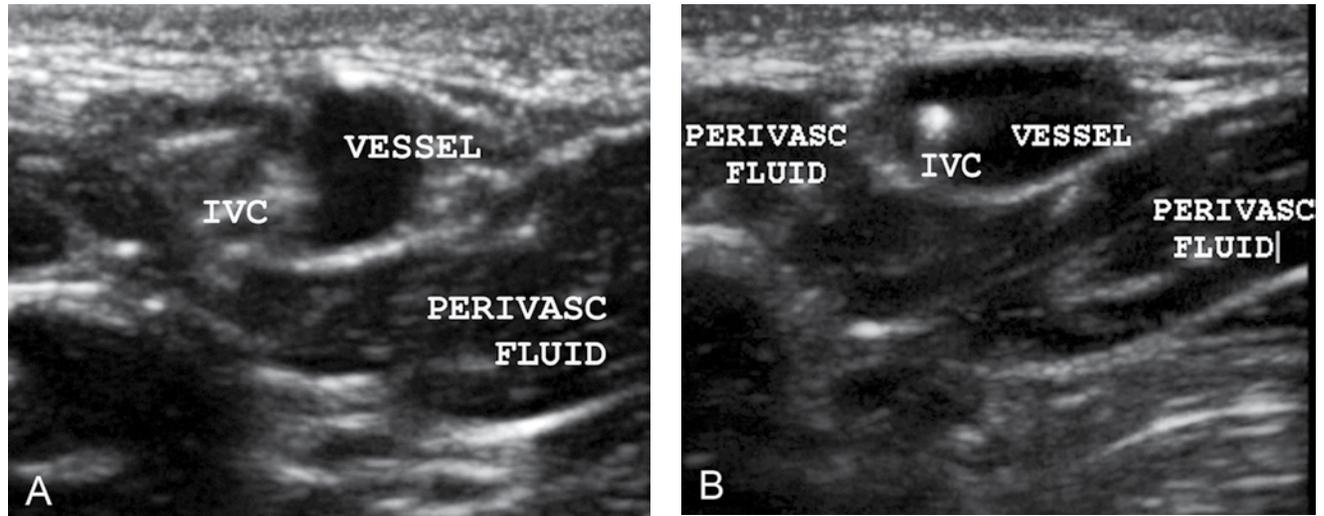


Figure 12.4. A and B. Ultrasound-guided central line placement. (A) Transverse view of stylet (labeled IVC) beside the jugular vein, indenting but not penetrating the vessel lumen. The direction of approach of the stylet is directly down from the top of the figure while the vessel has “rolled” and “tented” laterally. (B) Transverse view showing successful vascular access with the stylet (labeled IVC) in the vessel. The presence of perivascular fluid (labeled) is due to hematoma formation. Ultrasound actually images better through fluid, making it advantageous when hematoma formation occurs and allowing for the procedure to continue, whereas the blind landmark technique would need to be aborted.



Figure 12.5. Probe head damaged by chronic needling during US-guided aspirates and biopsies. Courtesy of Dr. Stephanie Lisciandro, Hill Country Veterinary Specialists, San Antonio, Texas.

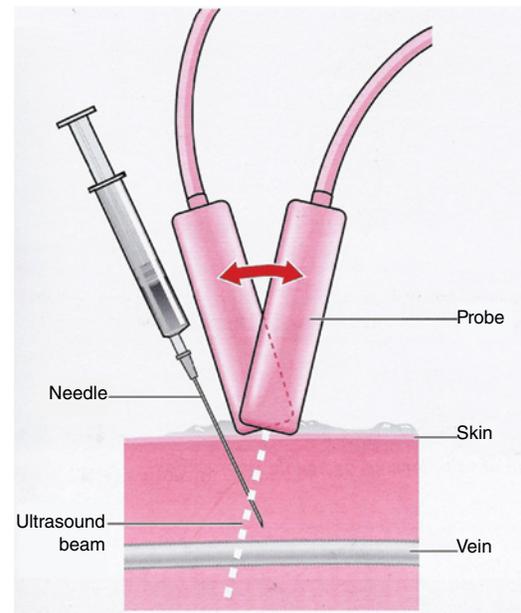


Figure 12.6. Change the probe angle until the target vessel and needle are visualized. (Bowra 2006)

vessel simultaneously in the middle of the screen. Use the image to direct the stylet and penetrate the proximal wall of the jugular vein and cannulate the vessel (Figure 12.4).

Inserting the stylet at a slightly steeper angle to the skin (than typically angled for traditional blind landmark CVC placement) helps ensure that the

needle tip intersects the jugular vein in the field of view (or plane) of the US image. This steeper angle prevents overshooting the vein and is recommended in human CVC placement guidelines to increase patient safety by facilitating the accurate tracking of the stylet tip (Bowra 2006) (Figure 12.6). Rotating the probe slightly (partially between transverse and

longitudinal orientations, so the target vessel appears oval vs. circular) may also help maintain both the jugular vessel and the stylet tip in the US field of view.

Watch for tenting of the vessel's superficial wall inward as the stylet encounters the jugular vein while maintaining positioning of the stylet dorsal to the vein. The vessel may tent even if it rolls away. When this occurs, slightly withdraw the stylet to reposition more advantageously mid-dorsal to the vein (Figure 12.4). When the jugular vein's lumen is penetrated, tenting should diminish even if you don't see the stylet in the vessel, and you should get a flash of venous blood. Note: The stylet tip may or may not be visible within the vessel's lumen on the US screen because the US beam is quite narrow and you may have moved out of the field of view.

As with the traditional blind landmark technique, a sharp yet smooth and deliberate motion may be needed to get the stylet through the dorsal superficial wall of the vessel and into its lumen.

Further advance the stylet a few millimeters after getting the flash of venous blood, and confirm jugular luminal placement by observing continuous blood exiting the stylet and/or by blood aspiration into a syringe attached to the stylet (or catheter) (Figure 12.7). Now lessen the angle to the jugular vein for feeding the next component (guide wire followed by the venous dilator for Seldinger technique or the central venous catheter for the Venocath® technique)



Figure 12.7. Transverse placement of the ultrasound probe for identifying and then gaining jugular central venous access. Jugular venous blood is aspirated to confirm successful vascular access. Note that the dog's head is to the right and the catheter is directed caudally.

depending on the CVC style used (as with the blind landmark technique). Once the CVC is completely placed, it is secured to the skin (usually sutured) via the manufacturer's provided butterfly adapters or similar devices, and the entry site covered with a sterile Telfa pad with triple antibiotic ointment followed by a few gauze sponges and a light protective cervical wrap.

Correct placement may also be confirmed (if needed) by visualizing a ring-down artifact of streaking hyperechoic (bright white) lines emanating from the metal stylet or guide wire from their surface through the far field (Figure 12.8).

Longitudinal Orientation

With the jugular vein identified in transverse orientation, move the probe and alter the image depth and focus so that the jugular vein appears in the center of the screen as an anechoic (black) circle. Now, slowly rotate the probe 90 degrees into longitudinal orientation, ending with the jugular vein as an anechoic (black) linear tract in the middle of the screen and the probe marker pointing rostrally, closest to the point of desired catheter insertion (Figure 12.3). By keeping the target vessel (jugular vein) centered on the US screen, the sonographer is less likely to lose the

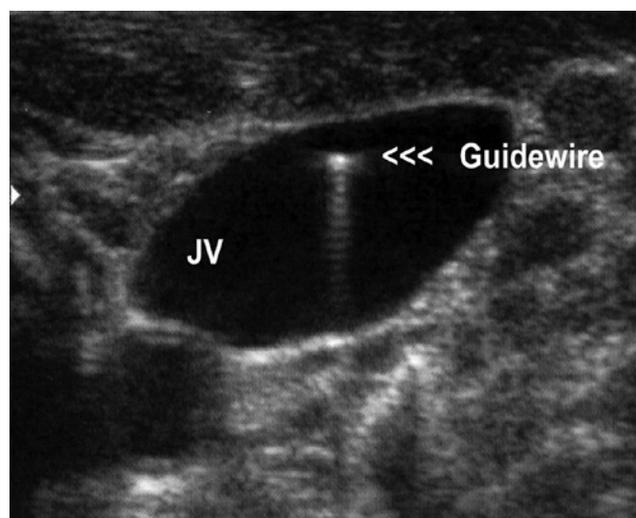


Figure 12.8. Ultrasound-guided needle location. Transverse view showing successful vascular access with ring-down artifact depicting the guide wire in the jugular vein (JV). Any metallic strong reflector of ultrasound will create the same artifact, including needles, stylets, implants, and foreign bodies. (Bowra 2006)

visualization and misidentify the jugular vein for another structure (Figure 12.3).

As with the traditional blind landmark technique, a sharp yet smooth and deliberate motion may be needed to get the stylet through the dorsal superficial wall of the vessel and into its lumen.

Watch for tenting of the vessel's superficial wall inward as the stylet encounters the jugular vein while maintaining positioning of the stylet dorsal to the vein. The vessel may tent even if it rolls away. When this occurs slightly withdraw the stylet to reposition more advantageously mid-dorsal to the vein (Figure 12.4). When the jugular vein's lumen is penetrated, tenting should diminish even if you don't see the stylet in the vessel, and you should get a flash of venous blood. Note: The stylet tip may or may not be visible within the vessel's lumen on the US screen because the US beam is quite narrow and you may have moved out of the field of view. Further advance the stylet a few millimeters after getting the flash of venous blood, and confirm jugular luminal placement by observing continuous blood exiting the stylet and/or by blood aspiration into a syringe attached to the stylet (or catheter) (Figure 12.7).

Now lessen the angle to the jugular vein to feed the next component (guide wire followed by the venous dilator for Seldinger technique or the central venous catheter for the Venocath® technique) depending on the CVC style used (as with the blind landmark technique). Once the CVC is completely placed, it is secured to the skin (usually sutured) via the manufacturer's provided butterfly adapters or similar devices, and the entry site covered with a sterile Telfa pad with triple antibiotic ointment followed by a few gauze sponges and a light protective cervical wrap.

Optional Use of a Short Temporary Peripheral Jugular Catheter

In emergency resuscitation situations in which time is critical for rapid venous access and a full-length CVC may be too cumbersome, an excellent rapid option is to use US guidance to percutaneously place a short large-bore (18-gauge or larger) 1.5-inch catheter in the jugular vein. The temporary short catheter permits rapid administration of resuscitative fluids through a large central vein (jugular). When a short catheter is used in place of a long CVC, it may be temporarily secured with any combination of tape,

adhesive catheter covers, or preferably one or two sutures in loop fashion, incorporating both the catheter's hub and the patient's skin.

It is easy to dislodge the short catheter with any significant movement, especially in larger patients or those with lots of skin mobility. Moreover, this temporary short option lacks the advantages of a CVC and should be replaced with a true CVC as soon as possible.

Be smart! The short, large-bore catheter may be used after initial stabilization as a conduit for the CVC kit's guide wire for a long central line, taking advantage of this temporary catheter to complete a modified Seldinger technique with a single or multilumen CVC or the Venocath®. Time and patient stability permitting, a true CVC may be placed at the outset (see above). The responsible use of CVCs is a welcomed addition to patient care in any emergency and critical care center or 24-hour general practices. Please note, however, that significant hemorrhage or other complications can occur if the catheter is dislodged or severed, so 24-hour veterinary surveillance and monitoring is warranted.

In general it is best to use 16-gauge CVC for larger dogs (greater than 7.5kg) and 18-gauge CVC for smaller dogs and cats. See the equipment section above.

Placement of Ultrasound-Guided Femoral Arterial Catheters and Sampling

Ultrasound Settings and Probe Preferences

See Placement of an US-Guided Central Venous Jugular Catheter (CVC), above.

Equipment

For special procedures such as cardiac catheterization, use equipment (stylets, catheters) designed for that procedure. For general blood pressure monitoring and sampling (including via the femoral artery), arterial access can be maintained with standard short catheters (18–24 gauge, 1–1.5 inches) commonly used for peripheral (cephalic, saphenous) venous access.

It is extremely important to secure any arterial catheter via tape and/or padding around the limb to prevent dislodgement and life-threatening hemorrhage while moving anesthetized or even awake patients.

How to Place an Ultrasound-Guided Femoral Arterial Catheter or Obtain an US-Guided Femoral Artery Sample

Procedure

The dynamic real-time technique with combinations of longitudinal and transverse orientation is described here, as briefly outlined under the central venous catheter section.

Anatomy

The femoral artery is a continuation of the external iliac artery and courses along the medial aspect of the femur. Proximally, the femoral artery lies cranial to the femoral vein and caudal or medial to the saphenous nerve. Within the femoral triangle (formed by the sartorius muscle cranially, the pectineus muscle caudally, and the iliopsoas and vastus lateralis muscle laterally), the femoral artery is covered only by the deep medial femoral fascia and a thin layer of skin, thus providing a convenient place for vascular access. Distal to the femoral triangle, these vessels are covered by the caudal belly of the semimembranosus muscle and course caudodistally in relation to the femur, crossing the mid to distal third of the femoral diaphysis at an angle of approximately 35 degrees (Ringold 2008).

Patient Preparation

Place the patient in lateral recumbency with the non-dependent hind limb abducted, extended, and immobilized by tethering it to the table by appropriate restraint devices to allow access to the dependent limb's inguinal region (proximal medial thigh). Shave the medial thigh, giving ample room to aseptically prep the skin over the femoral artery insertion site.

Liberal local use of 70% isopropyl alcohol either by itself (which is often sufficient) or in combination with

the gels mentioned below improves probe contact and greatly enhances image quality while maintaining a clean CVC insertion site. However, the attending veterinarian should keep in mind the following precautions: Alcohol-induced hypothermia (external cooling) may occur in any patient especially smaller animals, and the inherent flammability of alcohol is environmentally dangerous (fire hazard) and poses burn risks to the patient in the event of electrical defibrillation.

Excess alcohol should be wiped off the fur and skin as soon as it is no longer needed while maintaining sterility at the catheter insertion site.

Sterile acoustic coupling gels are commercially available and ideal (Aquasonics, Parker Laboratories, Fairfield, NJ). Although it lacks viscosity and tends to fall off the site, sterile K-Y[®] Jelly (Johnson and Johnson, New Brunswick, NJ) serves as a replacement option to sterile commercially available acoustic coupling gel.

Orientation

Verify the US probe-to-screen marker orientation so that direction is accurate during the procedure. The US monitor must be located in a comfortable line of sight.

It is difficult and potentially hazardous to insert a CVC or arterial catheter when craning to look over your shoulder at the screen (Bowra 2006).

Using the non-dominant hand, place the US probe over the femoral triangle in transverse orientation relative to the axis of the proximal limb, proximal to the desired entry point on the skin, searching for the anechoic (black) circles of the vessel lumens (Figure 12.9).

Structures (particularly artery vs. vein) are most easily identified by anatomic location (femoral artery is cranial to the femoral vein) and by intermittent gentle probe pressure because veins flatten (collapse) and arteries remain relatively circular (maintain their lumen and not collapse) (Figures 12.10). Moreover, the pulsatile motion of the artery is often observable in B-mode without the use of color flow Doppler. B-mode color flow Doppler US, when available, may be helpful in the learning phases to gain confidence in differentiating femoral artery from vein. Remember that the colors do not identify the vessel but rather are generally coded as red with flow toward the probe and blue as flow away from the probe.

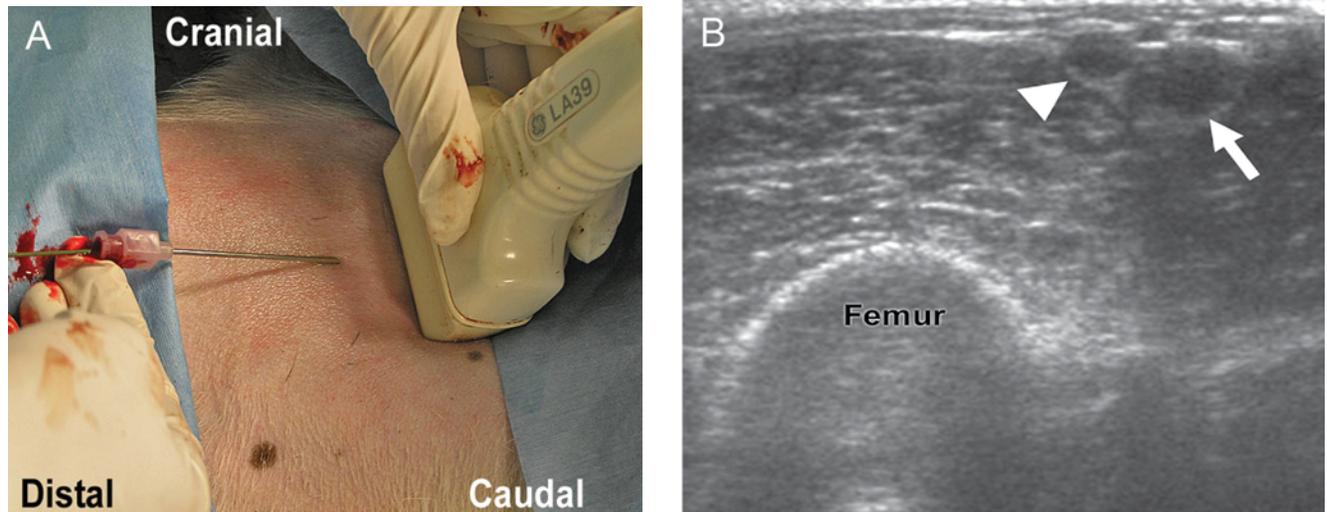


Figure 12.9. Femoral artery catheterization. (A) Orientation of the ultrasound transducer and introducer needle during catheterization of the femoral artery in a dog. (B) Transverse image of the femoral artery (arrowhead) and vein (arrow) with 12-MHz transducer at the level of the mid-femoral diaphysis. The medial surface of the femur is seen as a curvilinear, hyperechoic (bright white) line. (Ringold and Kelmer 2008)

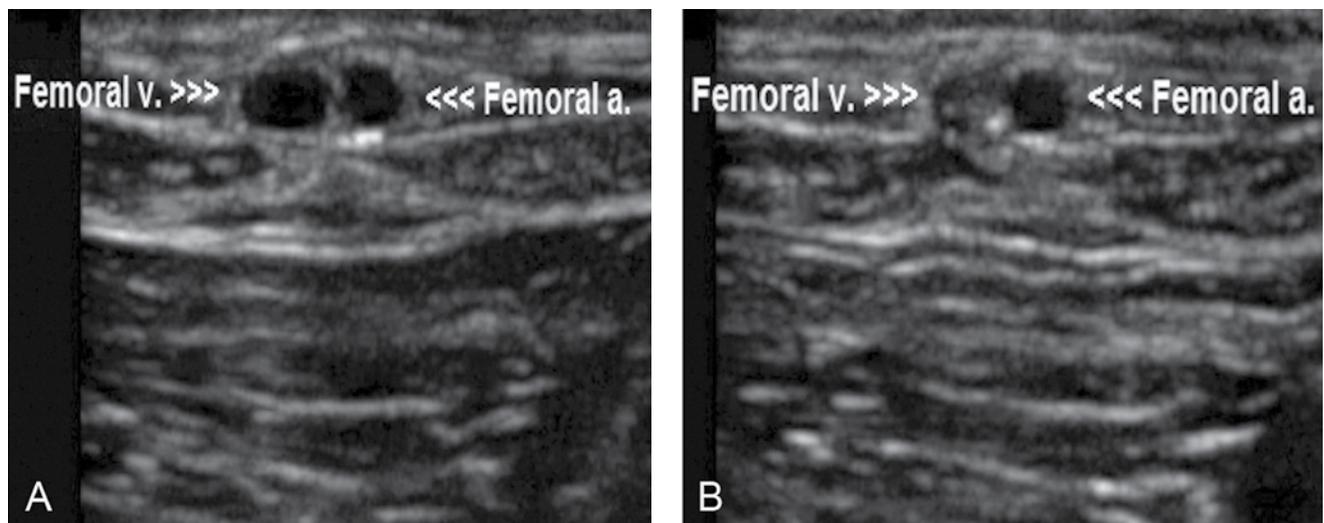


Figure 12.10. Compression technique for discriminating femoral vein from femoral artery. (A) Transverse image depicting normal probe pressure (no compression) with both femoral vein and artery visible. (B) Transverse image depicting disappearance of femoral vein with gentle probe pressure (compression) while femoral artery lumen remains an anechoic (dark) circle. The patient is in left lateral recumbency, so cranial is to the right. The compression technique is effective and reliable in discriminating between arteries and veins. Courtesy of Dr. Gregory Lisciandro, Hill Country Veterinary Specialists, San Antonio, Texas.

Color flow Doppler US imaging for pulsatile arterial flow is not 100% reliable because the artery's "jump" can transmit misinterpreted motion to the nearby vein causing misidentification (Bowra 2006).

Once the artery is identified, move distally along the femoral triangle to approximately mid-diaphysis

of the femur in case multiple attempts are needed. By starting distally, the proximal femoral artery is spared and may be used for repeated attempts if necessary. Using a number-11 scalpel blade or an extra 18-gauge needle to nick the skin 3–5 mm lateral to the vessel may facilitate getting the stylet through tough skin. The skin can then be moved over to set up the subsequent introduction of the stylet into the vessel (Crowe 2009).

With the probe in transverse orientation on the proximal (inguinal) side of the puncture site, the stylet (or needle) is then passed through the tented skin 1–2 cm away from the probe head at an approximate angle of 10–30 degrees between the stylet and the plane of the skin, avoiding prematurely puncturing the femoral artery (stay superficial and off to its side).

By keeping the stylet's tip 1–2 cm away from the probe, the maneuver also keeps the sharp point from damaging the rubber probe head.

With the femoral artery re-identified, move the probe and alter the image depth and focus so the vessel appears in the center of the screen as an anechoic circle (transverse orientation), landmarking the femoral artery's position similar to the CVC procedure previously described. The sonographer can either remain in transverse orientation, maintaining the anechoic (black) circle of the femoral artery throughout catheter placement (which is often easier for the novice), rotate the probe 90 degrees to a longitudinal alignment, obtaining an anechoic (black) linear tract (representing the femoral artery), or use combinations of transverse and longitudinal orientation while keeping the femoral artery centered in the field of view. In either transverse or longitudinal orientation, the probe is placed just proximal (inguinal side) to the desired catheter entry point on the skin; however, in longitudinal orientation (very important), by convention for safety, the probe marker should be on the same side as the stylet or needle insertion.

With the needle tip and artery visualized, maneuver the stylet and advance the tip into the femoral artery with a smooth and deliberate motion (to prevent it rolling away). If rolling occurs, withdraw the tip minimally to reposition the tip over the artery and re-perform the advancement steps noted immediately above.

For arterial catheterization, further advance the needle tip a few millimeters after getting the flash of bright red pulsatile blood from penetrating the artery's lumen. The tip of the stylet or the catheter may or may not be visible in the vessel's lumen, depending upon the relationship of the stylet and the US beam and resultant echo interpretation by the US machine. Arteries do not tent as much as veins (see CVC placement, above) due to their stiffer, more muscular walls. Backflow of pulsatile red blood is the best confirmation of successful arterial catheterization along with visualization of the stylet in the vessel lumen.

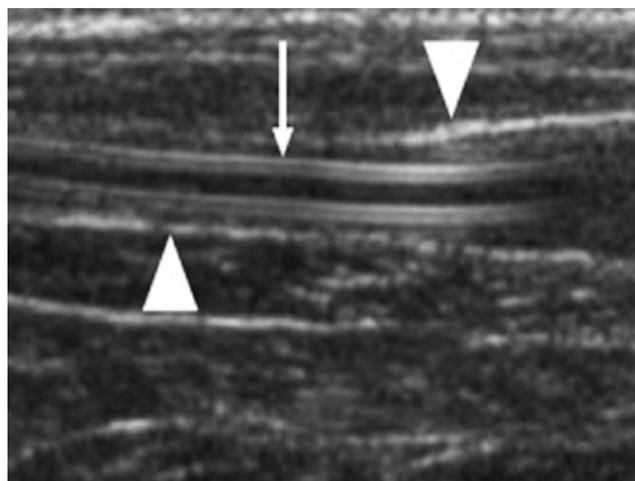


Figure 12.11. Longitudinal ultrasound image for the arterial catheter (arrow) inside the femoral artery (its wall is delineated by the solid triangle). (Ringold and Kelmer 2008)

As with the traditional blind technique, a sharp yet smooth and deliberate motion may be needed to get the stylet through the superficial wall of the vessel and into the vessel's lumen.

Now lessen the angle of the stylet to the artery and feed the catheter off into the vessel (for standard monitoring and sampling with a short catheter) or proceed with the Seldinger technique or other steps as required for special procedure equipment. Correct stylet placement in the femoral artery is confirmed via pulsatile red blood flow. Correct placement can also often be confirmed by visualizing a ring-down artifact of streaking hyperechoic (bright white) lines emanating from the metal stylet or guide wire if performing the Seldinger technique (Figure 12.8), or if a short catheter has been placed visualization of the arterial catheter is possible (Figure 12.11).

It can be harder to advance an arterial catheter off the stylet than the same (familiar) procedure in a peripheral vein. A moderately steady push will generally overcome the arteriospasm and allow the catheter to slide off the stylet. If the catheter remains in the lumen, pulsatile red blood will flow when the stylet is removed.

It is extremely important to secure any arterial catheter via tape and/or padding around the limb to prevent dislodgement and life-threatening hemorrhage while moving anesthetized or even awake patients.

General Comments Regarding Transverse vs. Longitudinal Orientation

As with any intravascular catheter placement, regardless of US guidance, the most challenging aspect of the procedure after finding the vein or artery is penetrating the superficial vessel wall without the vessel sliding or rolling away.

The longitudinal approach provides direct visualization of the stylet entering the skin while directing the stylet toward the jugular vein and during penetration of the lumen. It is easier to maintain visualization of the sharp tip of the stylet and relevant structures using the longitudinal orientation, avoiding complications such as inadvertent puncturing of the vessel's far wall and damage to other structures. The longitudinal approach is thus considered the safest orientation because it allows visualization of the stylet tip through the entire CVC placement process.

On the other hand, the longitudinal approach can be more difficult in redirecting the catheter if the vessel rolls away because of the difficulty discerning in real-time which direction the stylet goes relative to the target vessel (medial vs. lateral). Once this occurs the sonographer may need to partially or fully rotate back to transverse orientation to determine how to redirect the stylet into the target vessel.

Keep the stylet and target visible in the US field of view at all times by using a combination of transverse and longitudinal orientation.

The transverse approach provides better visualization of the vessel of interest relative to other structures and more efficiently helps visualize redirection of the stylet when the vein or artery rolls. Moreover, transverse orientation is better suited where space is limited (i.e., for smaller or short-necked patients). However, there is a greater risk of losing track of the stylet's sharp tip and thus inadvertently damaging surrounding structures.

On the other hand, if the probe is placed too far rostrally over the stylet's midpoint or even as high as the hub (which can definitely occur while the clinician's attention is divided between the probe, the stylet, and the US image), then visualization of the sharp tip of the stylet within the narrow fan of the ultrasound beam will be lost. It is easier to lose track of the tip of the stylet in transverse than longitudinal orientation as mentioned above, thus risking damage to other structures.

Use a slightly steeper approach angle to the skin with the stylet (than the traditional blind or landmark technique), and keep the stylet and jugular vein visible in the field of view at all times by using combinations of transverse orientation and longitudinal orientation (Figure 12.6).

Arterial Thromboembolism and Deep Venous Thrombosis

Arterial Thromboembolism

Reliable identification of arterial thromboembolism (ATE) reported in dogs and cats often requires Doppler imaging capability, especially because clots can be anechoic or poorly echogenic in the early stages of the thrombus formation (Szatmári 2001, Zwingenberger 2008). Another requirement specific to Doppler involves patient cooperation because panting, trembling, struggling, and other movement potentially cause motion artifact and compromise the image. Other strategies used by physicians using US for ATE surveillance include looking for "smoke" representing proximal turbulent flow and proximal dilation of the vessel. With that being said, the identification of ATE in dogs and cats may be made with caution by non-radiologists, keeping in mind that mistakes may unfavorably impact patient prognosis because of the severity of underlying disease in dogs and cats (Lake-Bakaar 2012). Readily identifiable aortic thrombi in a dog is shown without the use of color flow Doppler (Figure 12.12) and a saddle thrombus is shown in a cat with (or using) color flow Doppler (Figure 12.13).

If ATE is suspected but not confirmed by traditional means, a complete abdominal ultrasound evaluation by a veterinary radiologist or specialist skilled in ultrasound or other advanced imaging (CT, MRI) may need to be pursued. Further study is needed regarding the sensitivity, specificity, and accuracy regarding the ultrasonographic diagnosis of ATE in dogs and cats by non-radiologists.

Central and Deep Venous Thrombosis

Central venous thrombosis is seen in small animals, often in the vena cava (Figure 12.14) and splenic veins. It is relatively unstudied in terms of prevalence and causes. Recently, splenic thrombosis in dogs has been reported to be most commonly associated with lymphosarcoma (Laurenson 2010).

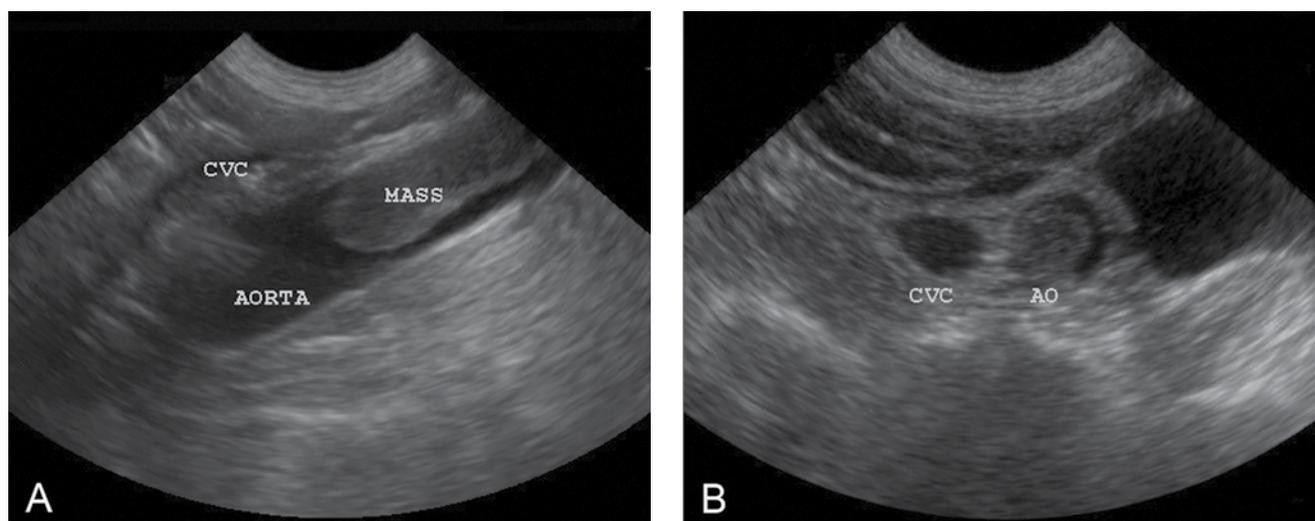


Figure 12.12. Aortic thrombus in a dog. (A) Longitudinal view. (B) Transverse view. (CVC, caudal vena cava; AO, aorta) Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

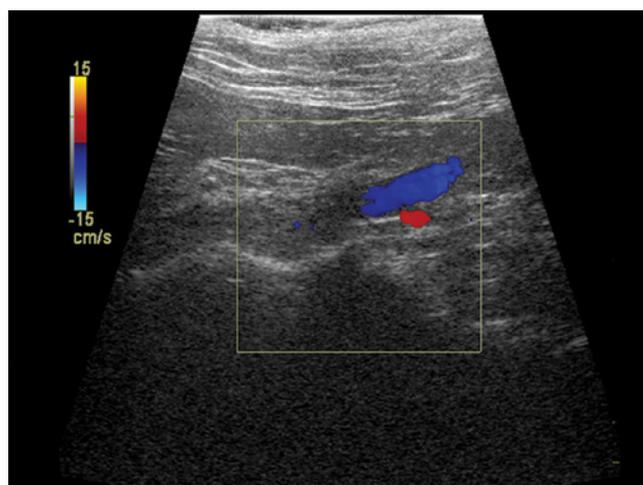


Figure 12.13. Aortic thrombus at the bifurcation of the femoral arteries, often referred to as a saddle thrombus. Courtesy of Dr. Gary Norsworthy, Alamo Feline Health Center, San Antonio, Texas.



Figure 12.14. The thrombus associated with an adrenal tumor (not shown) is nearly occluding all of the caudal vena caval (CVC) lumen as evidenced by the attenuation of color flow Doppler around the thrombus. Courtesy of Dr. Sarah Young, Echo Service for Pets, Ojai, California.

Deep venous thrombosis (DVT) is a common and severe problem in human medicine, reportedly annually affecting one to five patients out of every 1,000 in the United States (White 2003). More recently it was reported that 2 million people are affected annually resulting in 600,000 hospitalizations. Of these, 200,000 deaths result from the most dreaded complication of pulmonary thromboembolism (Crisp 2010).

Interestingly, a recent study demonstrated that emergency physicians who have undergone a 10-minute training session on two-point compression ultrasonography could detect DVT with a sensitivity

and specificity of 100% and 99%, respectively (Crisp 2010). In another prospective study, intensivists performed bedside compression ultrasonography and findings were compared to a formal vascular study (the gold standard) with high sensitivity and specificity of 86% and 96%, respectively, and accuracy of 95%. Importantly, bedside-intensivist ultrasonographic compression scans could be performed promptly, whereas formal vascular studies took a median time of 13.8 hours from ordering to their execution by a radiologist. In addition, formal vascular studies involve radiation,

are invasive, and carry some risk for complications (Crisp 2010, Kory 2011).

To our knowledge, no studies have reported DVT as a significant problem in veterinary medicine. It seems plausible that DVT does exist but is unrecognized in small animals, and may explain sudden death or rapid deterioration in critically ill small animal patients. By building skills of vascular evaluation through CVC and arterial catheter placements, the attending clinician may become proficient at screening for this currently unreported condition.

Excellent references are provided at the end of this chapter for those interested in further reading of both arterial thromboembolism and deep vein thrombosis (Dean 2008, Szatmári 2001). Future studies are required to determine whether focused (or cageside) vascular techniques will be helpful in diagnosing these conditions in small animals.

Pearls and Pitfalls, the Final Say

Real-time US-guided vascular access can be technically challenging at first, but has a relatively shallow learning curve. It has been shown that proficiency may be readily mastered by the non-radiologist veterinary sonographer with minimal training, is fast, and has the potential to become an invaluable asset to your practice. A few key points:

- Place the US screen in a line of vision that is comfortable for you. This is safest for your patient as well.
- Liberal use of 70% isopropyl alcohol is generally sufficient for good image quality; however, some probe heads will incur damage (check manufacturer's guidelines), and alcohol may excessively cool the patient (hypothermia) and increase risk of burns if electrical defibrillation is required.
- For initial emergency resuscitation, a short, large-bore (18-gauge, 1.5-inch) catheter can be placed in the jugular vein for rapid easy vascular access and high fluid rates. The short catheter also provides an excellent conduit after initial stabilization for a guide wire and replacement with a true CVC using a modified Seldinger technique.
- Color flow Doppler can sometimes be helpful but is not required for vasculature structure identification, and it has some inherent artifactual problems if a patient is uncooperative because movement compromises its diagnostic utility. The

compression technique during B-mode is often adequate to discriminate veins (which collapse with compression) from arteries (do not collapse).

- Focus on keeping the sharp tip of the stylet and the target vessel visible in the field of view at all times for success and for safety. Using combinations of transverse orientation and longitudinal orientation is often helpful. Remember: the fan of the ultrasound beam emitted by the probe is actually quite narrow.
- Move the stylet (or needle in some kits, see above) slowly, and look for tenting as the tip lands on the superficial proximal wall of the vessel.
- Models or phantoms can be made with Jello or other materials (Wells 2010), incorporating embedded objects (grapes) as targets. Phantoms also can be purchased for practice of stylet orientation and tracking. Starting with a large dog with more easily recognized and larger sized anatomy instead of a pug or a cat may also be helpful.
- Obesity, hematomas, hypotension, etc. do not appear to affect success rates or perceived difficulty for US-guided vascular access techniques, and the learning curve is shallow (Chamberlin 2012, Ringold 2008).
- The axiom, "See one, do one, teach one" works well in training multiple members of the staff to become confidently proficient.

References

- Blaivas M, Brannam L, Fernandez E. 2003. Short-axis versus long-axis approaches for teaching ultrasound-guided vascular access on a new inanimate model. *Acad Emerg Med* 10(12):1307–1311.
- Bowra J. 2006. Central venous access. In *Emergency Ultrasound Made Easy*, edited by J Bowra, RE McLaughlin. Edinburgh: Churchill Livingstone Elsevier, pp. 59–72.
- Chamberlin S, Sullivan L, Boscan P. 2012. Evaluation of ultrasound-guided vascular access in dogs. *J Vet Emerg Crit Care*, accepted 2013.
- Crisp JG, Lovato LM, Jang TB. 2010. Compression ultrasonography of the lower extremity with portable vascular ultrasonography can accurately detect deep venous thrombosis in the emergency department. *Ann Emerg Med* 56:601–610.
- Crowe DT. 2009. Patient triage In *Small Animal Critical Care Medicine*, edited by D Silverstein and K Hopper. St. Louis: Saunders, pp 5–9.
- Dean A, Ku B. 2008. Deep venous thrombosis In *Ultrasound Guide for Emergency Physicians*, edited by B Hoffmann. <http://www.sonoguide.com/dvt.html>.
- Emerman CL, Pinchak AC, Hancock D, et al. 1988. Effect of injection site on circulation times during cardiac arrest. *Crit Care Med* 16(11): 1138–1141.

- Froehlich CD, Rigby MR, Rosenberg ES, et al. 2009. Ultrasound-guided central venous catheter placement decreases complications and decreases placement attempts compared with the landmark technique in patients in a pediatric intensive care unit. *Crit Care Med* 37(3):1090–1096.
- Kory PD, Pellecchia CM, Shiloh AL. 2011. Accuracy of ultrasonography performed by critical care physicians for the diagnosis of DVT. *Chest* 139(3):538–42.
- Karakitsos D, Labropoulos N, De Groot E, et al. 2006. Real-time ultrasound-guided catheterization of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. *Crit Care* 10(6):R162.
- Kusminsky RE. 2007. Complications of central venous catheterization. *J Am Coll of Surg* 204(4):681–96.
- Kweon MV, Bhamidipaty A, Holden A. 2012. Antegrade superficial femoral artery versus common femoral artery punctures for infrainguinal occlusive disease. *J Vasc Interv Radiol* 23(9): 1160–4.
- Lake-Bakaar GA, Johnson EG, Griffiths LG. Aortic thrombosis in dogs: 31 cases (2000–2010). *J Am Vet Assoc* 241(7):910–915.
- Laurenson MP, Hopper K, Herrera MA, et al. 2010. Concurrent diseases and conditions in dogs with splenic vein thrombosis. *J Vet Intern Med* 24:1298–1304.
- Miller AH, Roth BA, Mills TJ, et al. 2002. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. *Acad Emerg Med* 9(8):800–805.
- Milling Jr TJ, Rose J, Briggs WM, et al. 2005. Randomized, controlled clinical trial of point-of-care limited ultrasonography assistance of central venous cannulation: The Third Sonography Outcomes Assessment Program (SOAP-3) Trial. *Crit Care Med* 33(8):1764.
- Mitchell SE, Clark RA. 1979. Complications of central venous catheterization. *Am J of Roentgenology* 133(3):467–76.
- Pirotte T, Veyckemans F. 2007. Ultrasound-guided subclavian vein cannulation in infants and children: a novel approach. *Brit J of Anaesth* 98(4):509–514.
- Prittie J. 2006. Optimal endpoints of resuscitation and early goal-directed therapy. *J Vet Emerg and Crit Care* 16(4):329–39.
- Ringold SA, Kelmer E. 2008. Freehand ultrasound-guided femoral arterial catheterization in dogs. *J Vet Emerg Crit Care* 18(3):306–311.
- Rivers E, Nguyen B, Havstad S, et al. 2001. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N Engl J Med* 345(19):1368–77.
- Szatmári V, Sótonyi P, Voros K. 2001. Normal duplex Doppler waveforms of major abdominal vessels in dogs: a review. *Vet Rad and Ultrasound* 42(2):93–107.
- Theodoro D, Bausano B, Lewis L, et al. 2010. A descriptive comparison of ultrasound-guided central venous cannulation of the internal jugular vein to landmark-based subclavian vein cannulation. *Acad Emerg Med* 17(4):416–422.
- Wells M, Goldstein L. 2010 The polony phantom: a cost-effective aid for teaching emergency ultrasound procedures. *Int J of Emerg Med* 3(2):115–118.
- White RH. 2012. Identifying risk factors for venous thromboembolism. *Circulation* 125(17):2051–3.
- Wigmore TJ, Smythe JF, Hacking MB, et al. 2007. Effect of the implementation of NICE guidelines for ultrasound guidance on the complication rates associated with central venous catheter placement in patients presenting for routine surgery in a tertiary referral centre. *Brit J of Anaesth* 99(5):662–665.
- Zwingenberger A, Wisner ER. Neck In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D’Anjou. Ames, Iowa: Blackwell Publishing, pp 102–105.

FOCUSED OR COAST³—PEDIATRICS

Autumn P. Davidson and Tomas W. Baker

Introduction

Pediatric patients are commonly presented to the veterinarian and hospitalized due to signs referable to the abdominal cavity. Abdominal conditions can become serious rapidly in pediatric dogs and cats; anorexia or fasting can result in hypoglycemia, vomiting can result in aspiration pneumonia, diarrhea can result in intussusception, and perforation from a foreign body can cause peritonitis.

Congenital anomalies can first become clinically apparent in the pediatric patient. Dietary indiscretions are common. Parasitic infestation and viral infectious disease have the greatest incidence in pediatric patients. Contagious diseases result in confinement in an isolation ward.

Rapid, accurate diagnostic evaluation permits timely effective intervention. Physical examination findings; fecal examination for cytology, parasites, and viral antigens; fecal culture for pathogenic bacteria; and abdominal radiography can all contribute useful diagnostic information. Cageside abdominal ultrasound provides valuable clinical information about the peritoneal cavity, great vessels, abdominal viscera, and lymph nodes, and can usually be obtained without sedation or anesthesia unless the patient is markedly painful. Ultrasound thus greatly facilitates prompt diagnostic evaluation of the pediatric patient with abdominal disease.

What Focused Pediatrics Can Do

- Support or negate clinical suspicions based on less sensitive evaluations of physical

examination, laboratory testing, and abdominal radiography

- Confirm the presence of an absolute indication for surgery (e.g., intussusception, obstructive foreign body, perforated bowel)
- Provide support for further diagnostics (suspected vascular anomaly, upper urinary tract disease)

What Focused Pediatrics Cannot Do

- Cannot replace a complete abdominal ultrasound performed by a veterinary radiologist or trained specialist

Indications for Focused Pediatrics Exam

- Acute abdomen
- Abdominal free fluid (urine, blood, transudate, exudate)
- Protracted vomiting or diarrhea not responsive to supportive care
- Unexplained clinical deterioration

Objectives for Focused Pediatrics Exam

- Perform a basic ultrasound exam in a structured format
- Answer important clinical questions, especially in confirming or refuting clinical suspicions based

on physical examination, laboratory findings, and abdominal radiography to better direct pediatric care

- Answer important clinical questions when there are delays in scheduling a complete abdominal ultrasound by a veterinary radiologist or trained specialist

Equipment

Pediatric patients are best evaluated using an ultrasound (US) machine equipped with a curvilinear variable frequency scanhead (6.0–8.0MHz)(Nyland 2002). Many portable machines now have a high frequency linear scanhead (8.0–10.0MHz) which will improve image quality and allow evaluation of even smaller superficial anatomy, but these are not essential. Portability permits cageside evaluation.

Patient Preparation

The pediatric patient should be gently placed in dorsal recumbency, ideally in a small padded V-trough, and restrained by assistant(s) holding the fore and hind limbs (Figure 13.1A). Permit the pediatric patient to become accustomed to this restraint before initiating clipping or scanning; this usually minimizes struggling and resultant aerophagia. If sedation or analgesia is required, the use of a potentially reversible narcotic agent such as hydromorphone or butorphanol is preferable.

Panting, commonly seen in adult dogs under narcotic sedation, is less prevalent in pediatric dogs and cats.

Clipping is usually minimally necessary in the pediatric patient. Clipping the cranioventral abdominal hair, using a quiet set of electric clippers with a number-40 blade in the direction of hair growth rather than against it, minimizes cutaneous trauma. Wetting the clipped skin with tepid water, tincture of zephiran, or 70% isopropyl alcohol, followed by a liberal amount of US gel, permits the best acoustic coupling of the scanhead to the patient, improving the image obtained. Care should be taken to avoid excessive chilling of pediatric patients secondary to the application of cool,

room temperature liquids and gels followed by evaporation.

Electronic warming devices (warm water blankets) may cause electronic interference with the US equipment; warm water blankets or fluid bags are superior for preventing hypothermia (Baker 2006, Penninck 2002).

Fasting as much as is safely possible in the pediatric patient minimizes gastric ingesta obscuring imaging of the liver and gastrointestinal gas accumulation interfering with visualization of other abdominal viscera. Preventing urination immediately prior to the examination permits better evaluation of the urinary bladder and dorsal sublumbar structures. Nauseated patients should be closely monitored for vomiting or regurgitation and immediately repositioned to ventral recumbency with the head lowered should it occur to prevent aspiration pneumonia.

Serial evaluations can provide useful information when the clinical status of the pediatric patient has changed. Clinicopathologic deterioration, progressive lethargy or obtundation, acute or progressive pain, changes in abdominal palpation findings, or refractory vomiting or diarrhea warrant repeat evaluation for ultrasonographic findings indicating that gastrointestinal obstruction, intussusception, visceral perforation, and/or peritonitis may have occurred.

Serial examinations are very helpful and should be used in patients with worsening signs when US findings are initially equivocal or indeterminate.

Ultrasound of the Normal Pediatric Abdomen

Regardless of the clinical history, the abdomen should always be evaluated completely and methodically in a clockwise direction starting with the liver. Performing a complete abdominal scan in an organized fashion saves time and often identifies disorders that might otherwise be missed if only a focused study (i.e., bladder scan) is done. The complete scan should only take 10–15 minutes (Baker 2009).

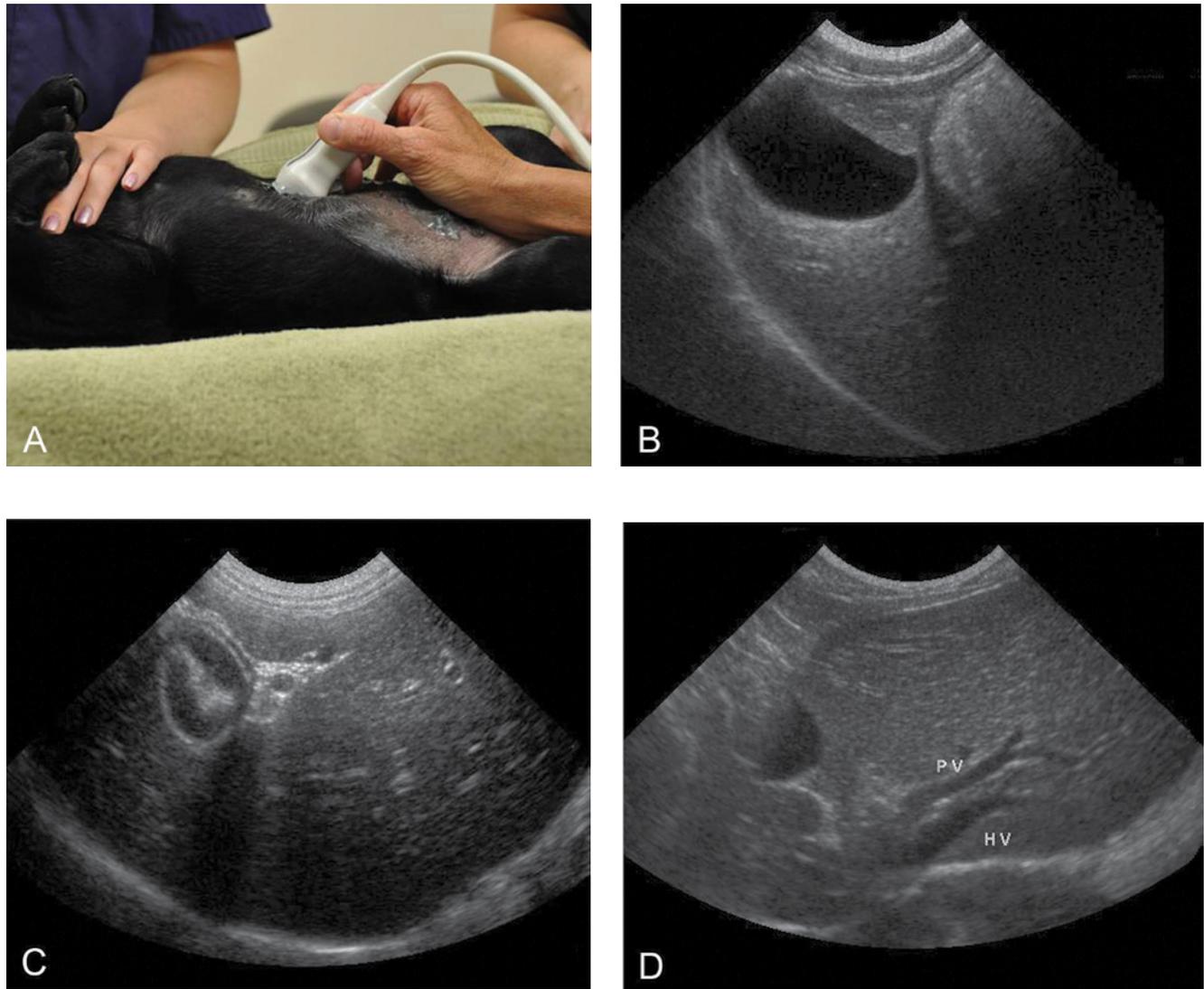


Figure 13.1. Scanning the cranial abdomen. (A) Scanning the pediatric canine in a comfortable, warm trough. (B) Sagittal image of normal gallbladder, liver, and stomach. (C) Transverse image of the liver and duodenum. (D) Walls of the hepatic veins (HV) are less echogenic than portal veins (PV).

Always do the pediatric exam in the same manner each time, going in a clockwise direction.

To begin, place the scanhead under the xiphoid with the beam in the sagittal plane. The liver is visualized by fanning the beam from the patient's right to left. The gallbladder is seen on the right, the left liver lobes are seen ventral and sometimes caudal to the stomach (Figure 13.1B). Turning the beam to transverse allows for visualization of the liver between stomach and gallbladder. This view is good for evaluation of the hepatic border and echogenicity of hepatic parenchyma and the portal architecture (Figure 13.1C). The portal vessels have more echogenic walls than the hepatic veins (Figure 13.1D).

Portal veins have more echogenic walls than hepatic veins.

Remember "SLiCK" for the order of echogenicity between spleen, liver, and kidney. In other words, the spleen (S) is more echogenic (brighter) than the liver (Li), which is equal or slightly more echogenic (brighter) than the cortex of the kidney (CK) in normalcy, or "SLiCK."

Resuming the sagittal plane, scan to the left of the dog past the stomach to the spleen. The spleen will be visualized ventrally in the near field, confirmed by the splenic vein (Figure 13.2A). Splenic border, parenchyma and shape should be evaluated. Following

the spleen transversely down the left body wall, you will see the left kidney.

The tail of the spleen often rests near the left kidney: follow the spleen caudolaterally to the left kidney.

Once the left kidney has been visualized, turn to the sagittal plane and evaluate the renal border, cortical echogenicity, and pelvic architecture (Figure 13.2B). Dilatation of the renal pelvis is best seen in the transverse plane. Keep in mind that mild renal pelvic dilation can be associated with fluid loading and diuresis (Figure 13.3; also see

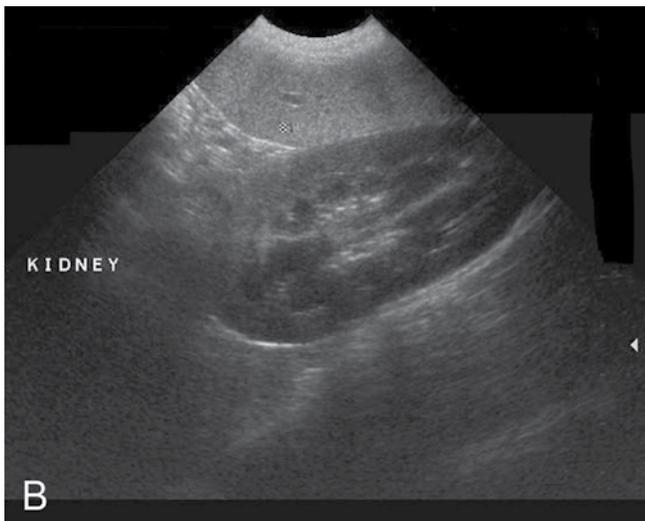


Figure 13.2. The spleen and left kidney. (A) Normal spleen, splenic vein (SV). (B) Normal left kidney in sagittal plane.



Figure 13.3. The left kidney. (A) Normal left kidney in transverse plane with normal renal pelvis. (B) Dilated renal pelvis (arrow). (C) Diuresis-induced renal pelvic dilation.

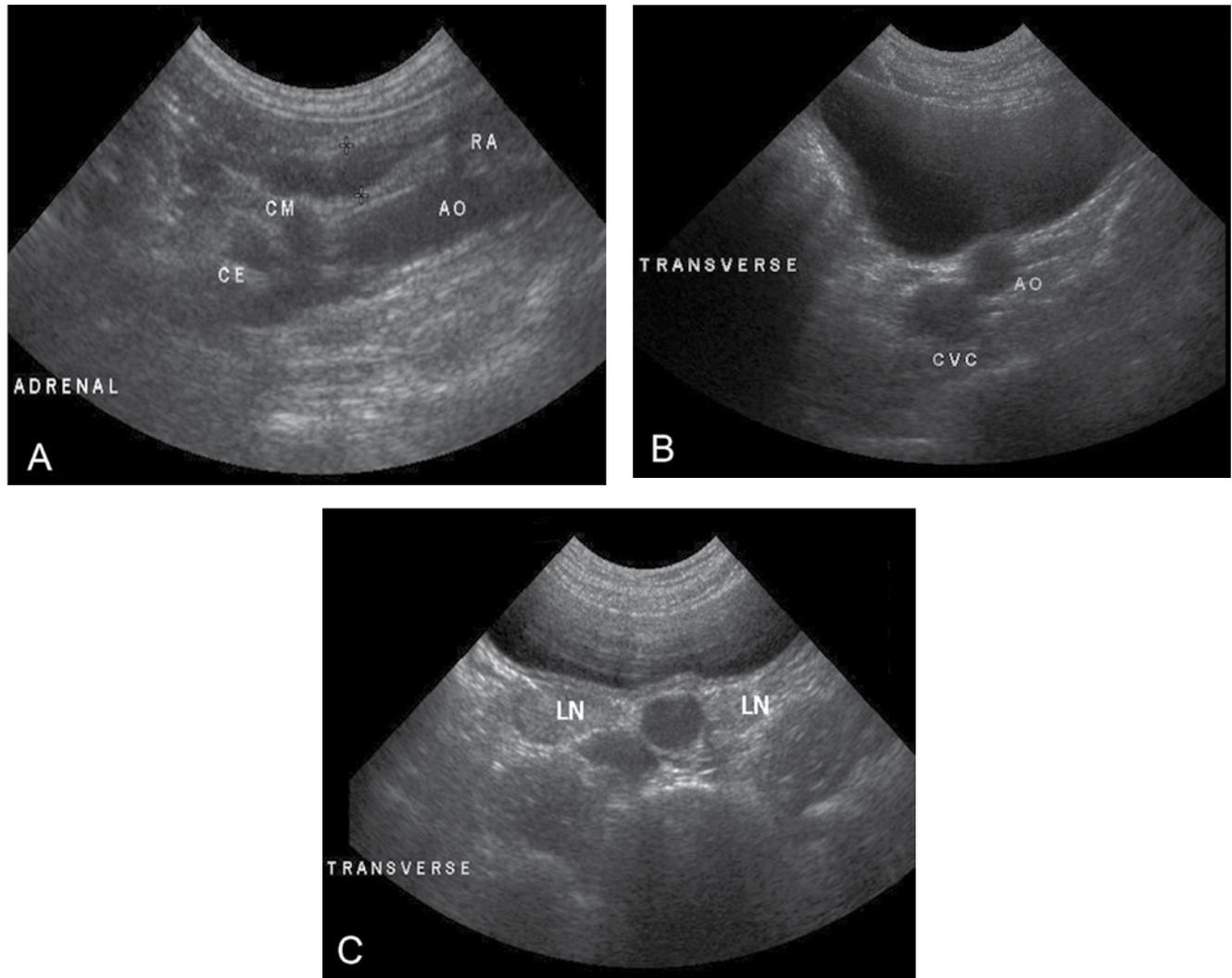


Figure 13.4. The left adrenal gland, mesenteric root, and sublumbar regions. (A) Left adrenal gland (cursors) surrounded by celiac artery (CE), cranial mesenteric artery (CM), aorta (AO), and renal artery (RA). (B) Urinary bladder in transverse; aorta (AO) and caudal vena cava (CVC) dorsally. (C) Normal pediatric sublumbar lymph nodes (LN).

Figure 5.11A through D). The adrenal gland is located medial to the cranial pole of the kidney. In the sagittal view, scan medially from the kidney to visualize the linear aorta and the renal artery. The left adrenal gland is located cranial to the left renal artery and caudal to the left cranial mesenteric artery. The left adrenal gland is visualized as a bilobed structure with the phrenicoabdominal vein at its waist (Figure 13.4A).

With a transverse beam back in the middle of the abdomen, scan caudally to the urinary bladder, a large hypoechoic structure. Evaluate bladder wall and lumen contents, and, dorsal to the bladder, the major vessels (caudal vena cava and aorta)

(Figure 13.4B). Sublumbar lymph nodes will be seen at the aortic bifurcation into the iliac arteries, adjacent to the bladder wall. The abdominal lymph nodes are readily visible in pediatric patients due to nonspecific immune stimulation at that period of development; this is usually considered normal if their appearance is homogenous (Figure 13.4C). The bladder should be scanned in both the transverse and sagittal planes. Sagittal scanning of the urinary bladder caudally will allow visualization of the proximal urethra (and pediatric prostate in the male) (Figure 13.5A). The pediatric uterus is best seen in transverse, dorsal to the bladder and adjacent to the colon (Figure 13.5B). The testes should

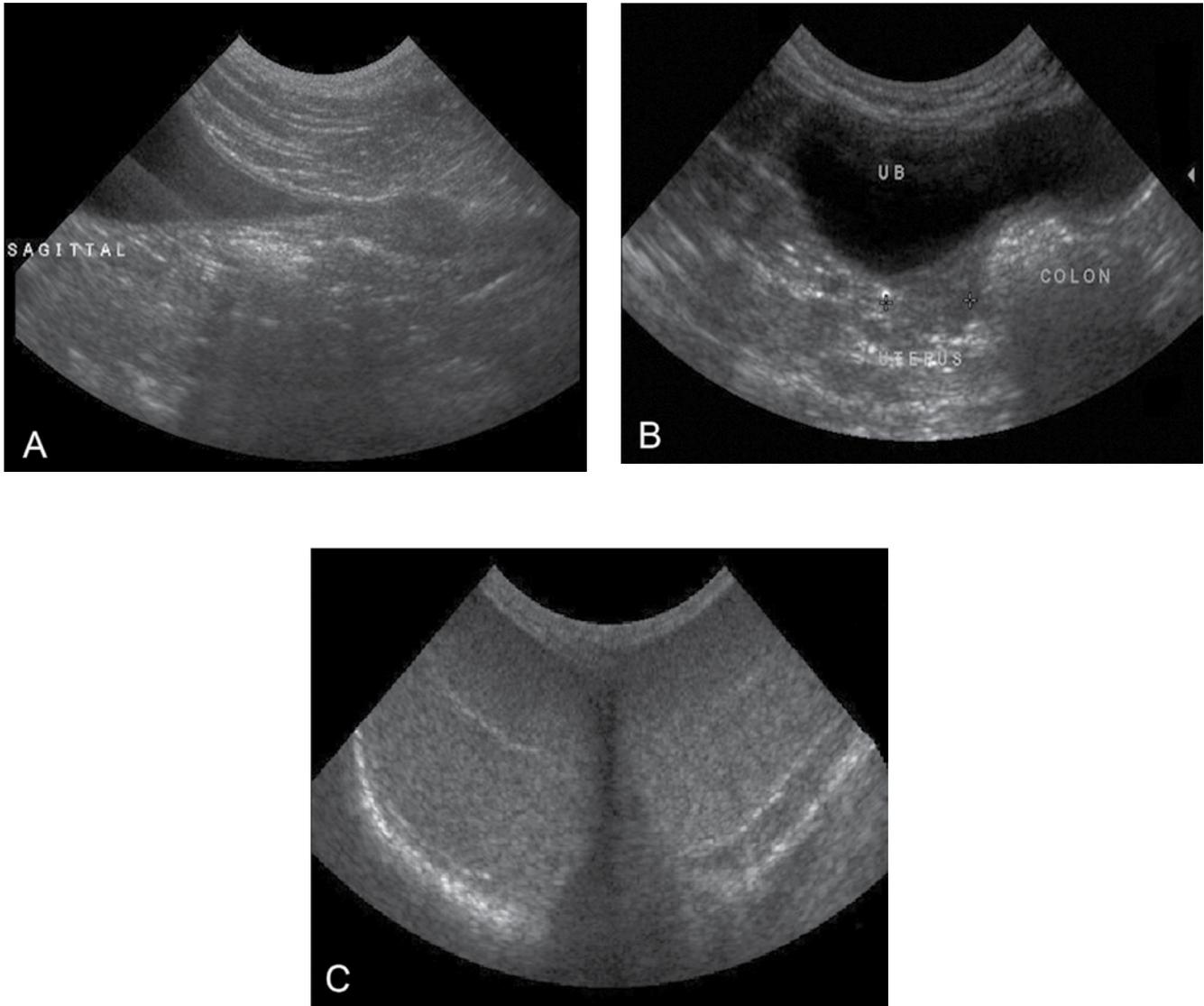


Figure 13.5. The male reproductive system. (A) Pediatric prostate gland in sagittal. (B) Pediatric uterine body (UB) in transverse (cursors). (C) Pediatric testes; note hyperechoic mediastinum testis in each.

be found in the scrotum after six weeks of age (Figure 13.5C).

The right kidney will be found at the edge of the right ribcage, within the renal fossa of the liver. The right kidney should be evaluated as was the left (renal border, cortical echogenicity, and pelvic architecture). By scanning sagittally between the right kidney and the caudal vena cava using a fanning technique, the right adrenal is visualized just lateral to the caudal vena cava (Figure 13.6A).

In transverse, return to the right kidney and find the duodenum lateral to the kidney. The right limb of the pancreas will be at the cranial end of the kidney adjacent to the duodenum. The right pancreatic limb is identified by visualizing the caudal pancreatico-

duodenal vein (Figure 13.6B; also see Figure 7.1A and B). The right limb of the pancreas is best seen in sagittal in the kitten, caudal to the gallbladder and the duodenum (Figure 13.6C). The pancreatic body is seen caudal to the stomach, cranial to the splenic vein. The left limb is found caudal to the splenic vein and midline to the cranial pole of the left kidney (Figure 13.6D).

Returning to the transverse plane in the cranial mid abdomen at the mesenteric root, scan for mesenteric lymph nodes and small bowel wall architecture. It may take two to three craniocaudal passes to thoroughly evaluate the entire bowel. Canine and feline small bowel have distinct layering and motile ingesta in the lumen. Normally, the small bowel appears sonographically as

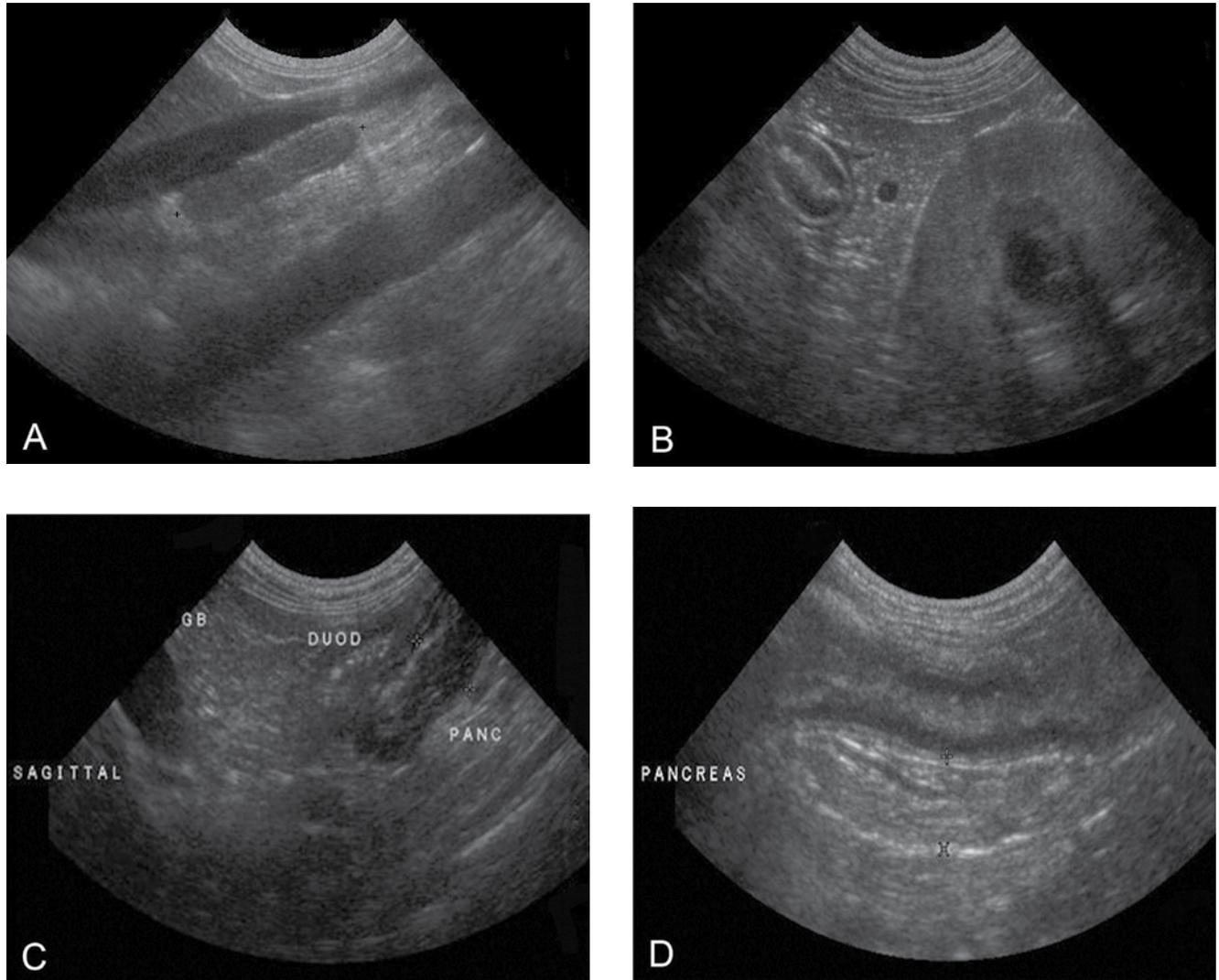


Figure 13.6. The right adrenal gland and pancreas. (A) Sagittal image of right adrenal gland (marked with [+]) between the aorta (dorsal) and vena cava. (B) The pancreaticoduodenal vein (anechoic [black] circle) identifying the right limb of the pancreas. (C) Feline right limb of the pancreas (PANC) caudal to the duodenum (DUOD). The gallbladder (GB) has anechoic (black) contents to the image's far left. (D) The pancreatic body (cursors).

four distinct layers. The bowel lumen appears hyperechoic, as the mucosal interface is echogenic. The compression of gas and ingesta also visually strengthens this hyperechoic line. The layer just outside the lumen is the mucosa; it is hypoechoic and normally the thickest appearing section. Outside the mucosa is the submucosa. It is hyperechoic to the mucosa and about one-third the thickness. The muscularis, the bowel muscle layer, is outside of the submucosa and appears as a very thin hypoechoic black line. The outermost layer, the serosa, is not seen as linearly as the other wall layers, but is very hyperechoic and about the same thickness as normal muscularis (Figures 13.17A and B, also see Figure 7.3).

Use the mnemonic “The sun is bright and it’s dark at midnight” to remember that layers starting with an “s” such as the sun are bright (submucosa and serosa are hyperechoic [bright]), while layers starting with an “m” such as midnight are dark (mucosa and muscular layer are hypoechoic [dark]) (also see Figure 7.3).

Mesenteric lymph nodes are readily visible in pediatric patients, but are likely normal when other enteric abnormalities are lacking. Look for mesenteric lymph nodes at the confluence of the renal vessels and the

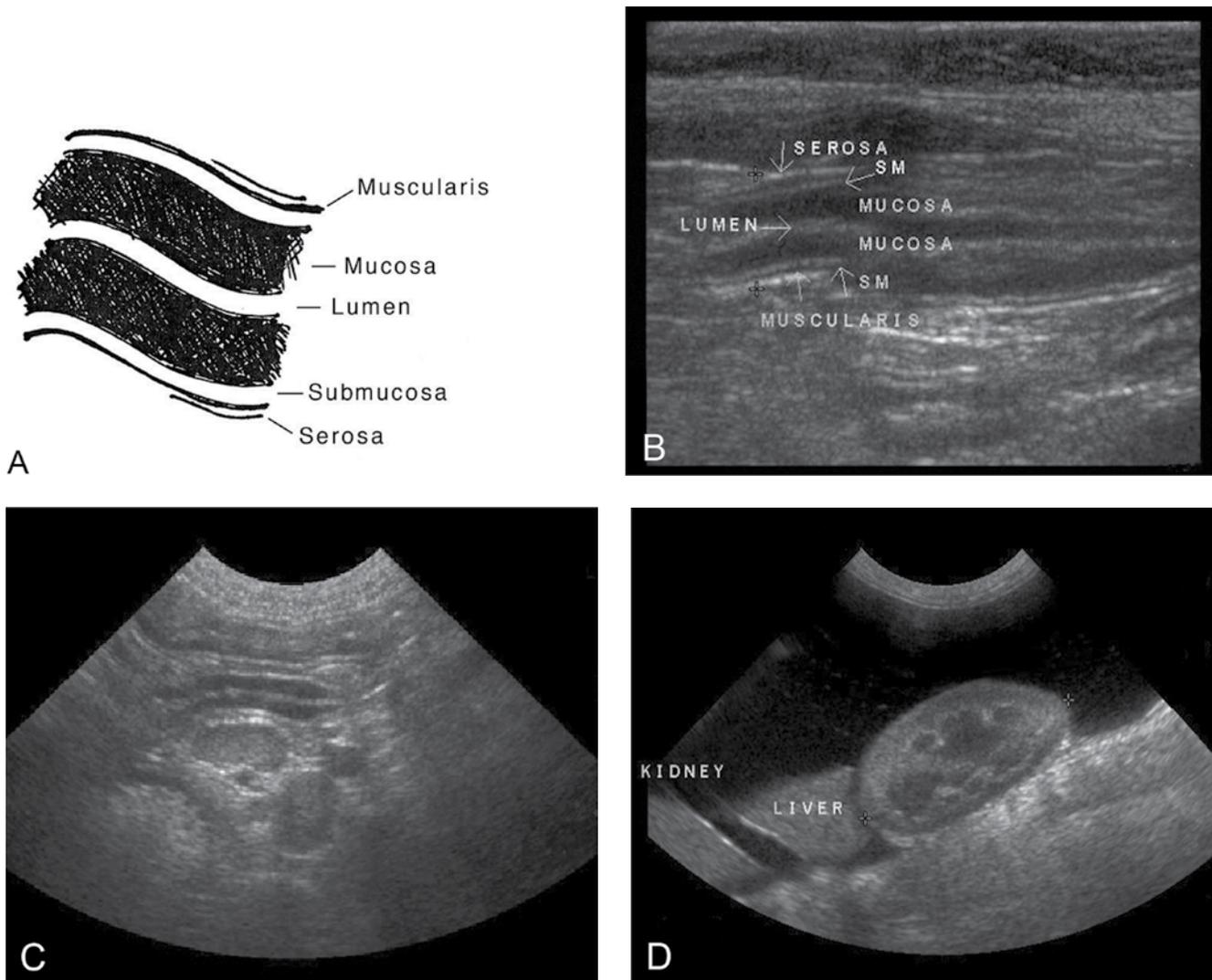


Figure 13.7. Normal small intestine and example of anechoic ascites. (A) Schematic of normal small bowel wall layering. (B) Normal small bowel wall layering (SM, submucosa). (C) Normal pediatric mesenteric lymph nodes. (D) Ascites, as anechoic (black) fluid, likely representing a pure or modified transudate seen in the region of the right kidney.

major vessels (aorta and caudal vena cava). Transverse scanning midline to the kidneys in a focused routine pattern will help with the visualization of normal mesenteric nodes (Figure 13.7C).

Document your findings by storing images. Labeling images is ideal but time consuming; if the abdominal scan is always performed in the same clockwise order, labeling is not essential (i.e., the left kidney is always scanned before the right).

If the abdominal scan is always performed in the same clockwise order, labeling is not essential because organs will be viewed in the same order on every focused or cageside pediatric exam.

Common Pediatric Abdominal Disorders

Gastrointestinal Disease

Abdominal ultrasonography provides additional and complementary information about the presence or absence of fluid in the peritoneal cavity (hemorrhage, effusion), intra-abdominal gas suggesting bowel perforation (or post-operative), the appearance of gastrointestinal contents (appropriate vs. foreign), gastrointestinal tract motility (ileus vs. hyperkinetic), gastrointestinal wall morphology (infiltrative, disrupted, or edematous), and mesenteric lymph node appearance (anticipated pediatric reactivity vs. pathologic) (also see Chapter 7).

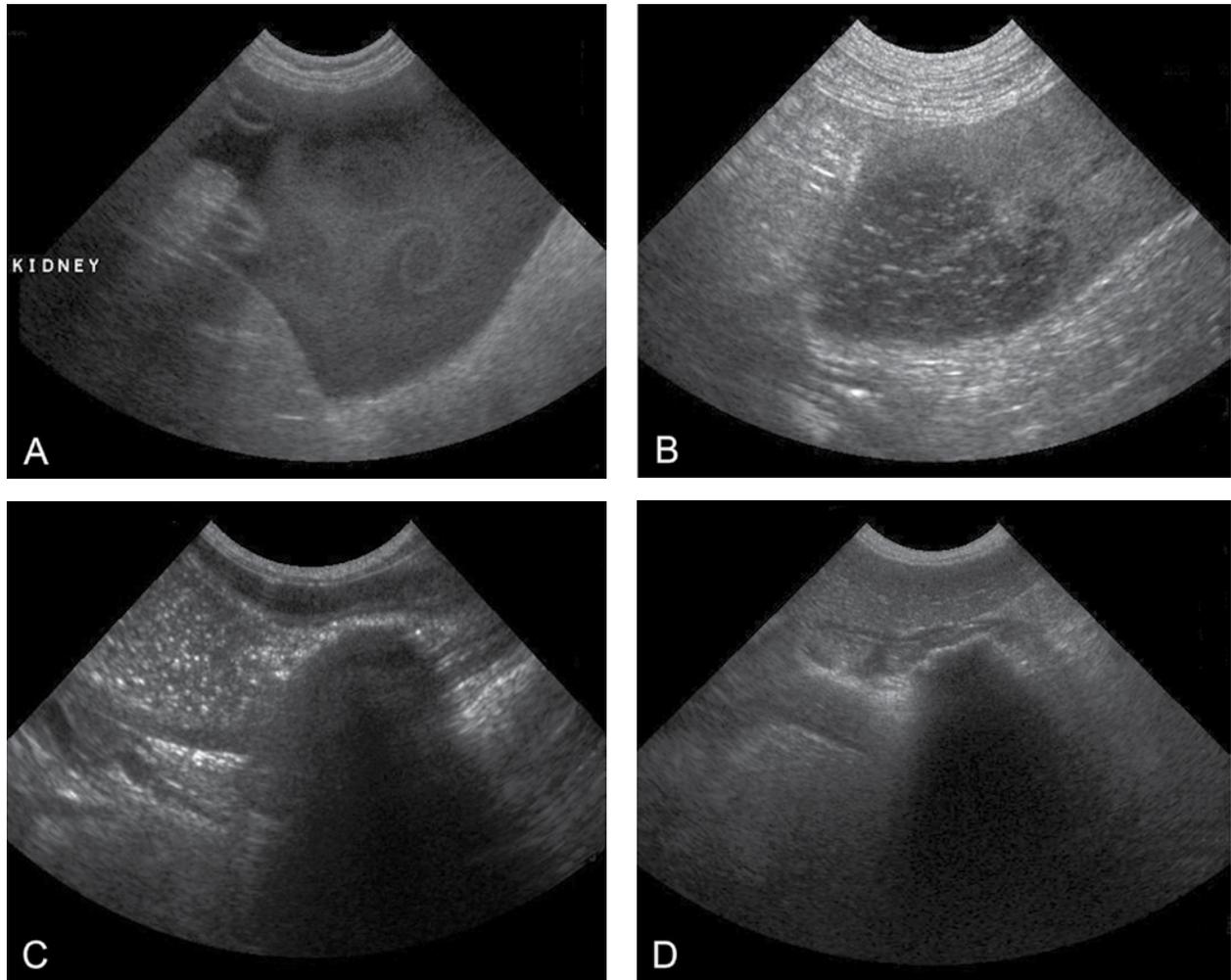


Figure 13.8. Example of echogenic ascites, splenic infarction from trauma, and colonic and pyloric foreign bodies. (A) Echogenic ascites, likely representing an exudate, seen adjacent to the right kidney. (B) Splenic infarction; typical hypoechoic parenchyma with echogenic slashes. (C) Colonic foreign body (oval ball) showing hard shadowing and fluid distension of the proximal bowel. (D) Hard shadowing associated with an irregularly shaped foreign body causing partial obstruction of the pylorus.

Peritonitis/Peritoneal Effusion

Pediatric patients have a small amount of free, scant, anechoic peritoneal fluid that appears in an abdominal ultrasound (best visualized lateral to the spleen) and represents normalcy (also see Chapter 2). Increased fluid volume or echogenicity can indicate hemorrhage, septic peritonitis (exudative), transudative ascites, or rupture of the gallbladder or urinary tract. Septic peritonitis and biliary or urinary tract rupture are usually accompanied by evidence of inflammation causing progressively increased echogenicity (brightness) of the serosal surfaces over time (Figures 13.7D and 13.8A; also see Figures 3.15C and D and 7.14A and B).

Blunt trauma resulting in hemoabdomen is best evaluated with ultrasound (see Chapter 2). Rupture or crushing trauma to the liver or infarction of the spleen is readily differentiated from normal homogeneous

parenchyma (Figure 13.8B; also see Figure 2.18A). The localization and normal appearance of fluid-filled viscera (bladder, gallbladder) can be reassuring but does not eliminate the possibility of an occult rupture; serial evaluation is advised along with the accumulation of clinical data (e.g., ultrasound-guided centesis for peritoneal fluid evaluation) (Baker 2012, Penninck 2002).

Gastrointestinal Foreign Body: Non-Obstructive vs. Obstructive

A common clinical dilemma results from the ingestion of foreign objects by pediatric patients. Foreign bodies can cause gastrointestinal inflammation and perforation even if they are not obstructive. Obstruction and/or perforation are absolute indications for laparotomy, albeit an invasive and expensive procedure. On the other hand, an unnecessary (negative) laparotomy in the pediatric

patient can increase morbidity and mortality from anesthetic events, hypotension, hypovolemia, and surgical trauma, and is less likely to be tempered by the acquisition of meaningful biopsies as would be in the adult pet.

Unless radiopaque, gastrointestinal foreign bodies are often difficult to confirm radiographically. They are usually suspected clinically based on intraluminal gas and fluid accumulation proximal to the mechanical obstruction caused by their presence. Serial radiography can support progression of a non-obstructive foreign body but requires time. Contrast radiography can complicate subsequent endoscopy or laparotomy, and can be difficult to accomplish in the vomiting patient. Ultrasonography can provide supportive information and sometimes confirm the diagnosis if the foreign body has a characteristic appearance (such as a ball, a trichobezoar, or a linear foreign body).

Ultrasound is now considered the best clinical tool for a noninvasive diagnosis of intestinal obstruction.

Typically, a bright interface associated with strong shadowing suggests a foreign body. Fluid distension and peristalsis proximal to the object can confirm the suspicion. Balls have a rounded interface with uniform acoustic shadowing (Figure 13.8C; also see Figure 7.6A and B), whereas other foreign bodies may have more irregular hyperechoic borders with distal shadowing (Figure 13.8D). Trichobezoars have irregular bright interfaces and strong shadowing. Linear foreign bodies produce bowel plication recognized as undulation (Figure 13.9A; also see Figure 7.10) and must be differentiated from corrugation of the bowel wall (see Figure 7.11A and B), which more commonly represents forms of enteritis. Complete

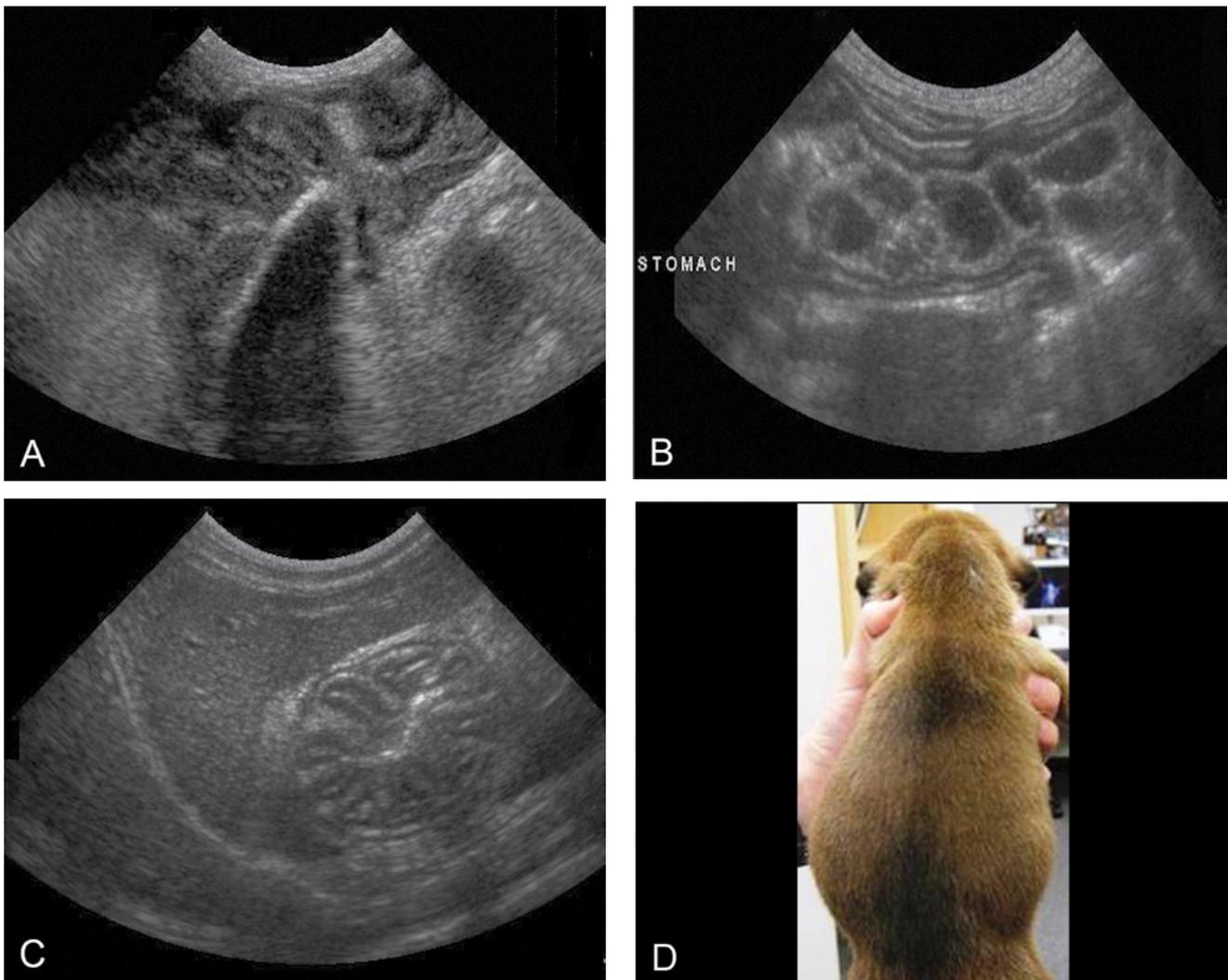


Figure 13.9. Linear foreign body with bowel plication, normal stomach with and without ingesta, and abdominal distension secondary to imperforate anus. (A) Linear foreign body producing plication of adjacent small bowel. (B) Kibble within the gastric lumen. (C) Normal gastric rugae in the pyloric antrum. (D) Marked abdominal distension in a three-week-old Boxer puppy with an imperforate anus.

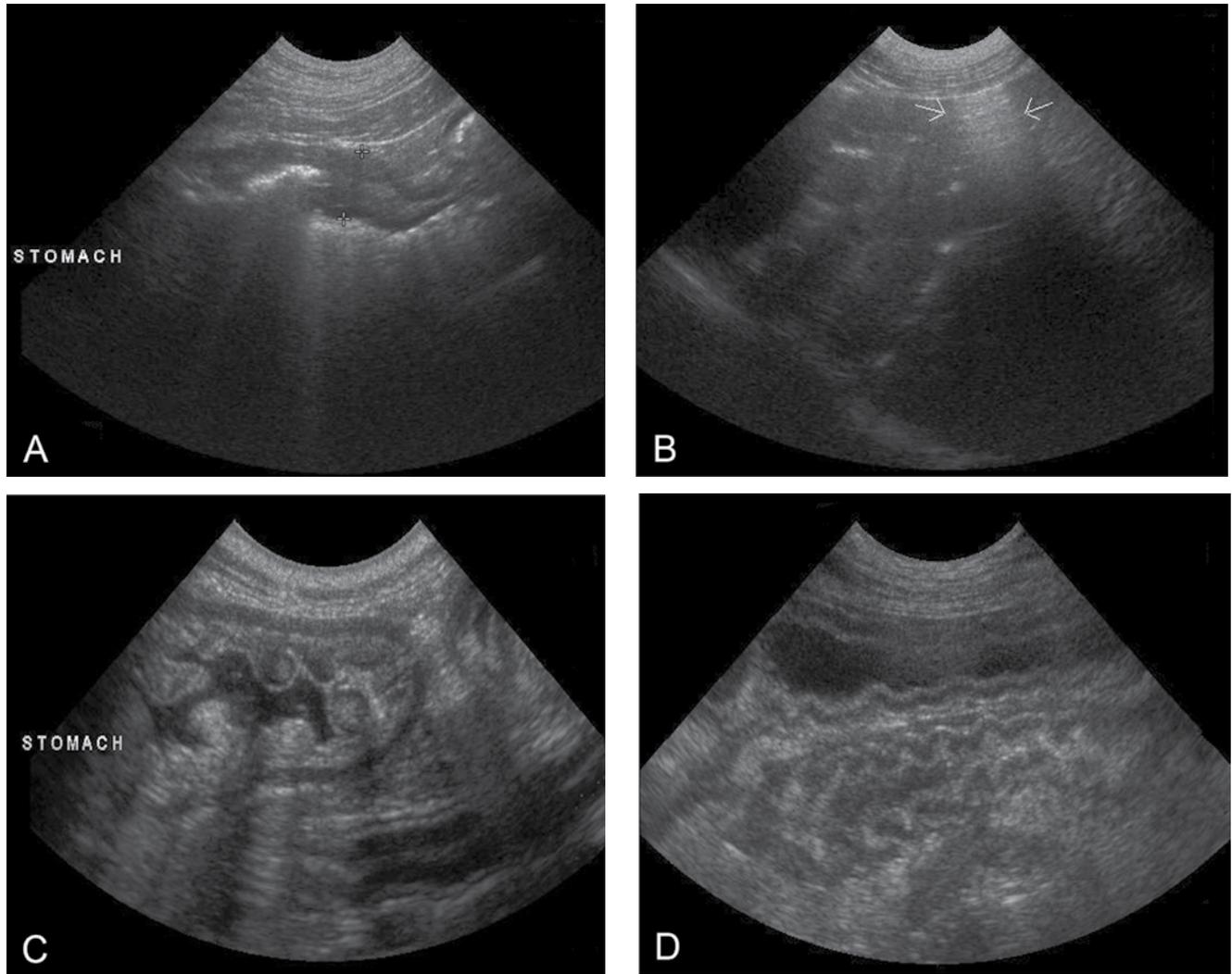


Figure 13.10. Bowel perforation with pneumoabdomen, and stomach wall edema, and corrugated small bowel from gastrointestinal disease. (A) Disrupted bowel wall (cursors) secondary to perforation. (B) Free air (arrows) within the peritoneal space, visualized ventral to the spleen. (C) Edema of the gastric wall associated with viral gastroenterocolitis in a puppy. (D) Increased fluid in the small bowel lumen and corrugated appearance of the bowel wall with hemorrhagic viral enteritis.

obstruction results in pronounced dilation of the bowel cranial to the object. Pyloric obstruction can result in gastric atony and distension (Baker 2006, Penninck 2002) (see Figure 7.5). Do not mistake gastric ingesta as a foreign body (Figure 13.9B), or an empty stomach with prominent rugal folds as abnormal (Figure 13.9C).

Do not mistake gastric ingesta as a foreign body or an empty stomach with prominent rugal folds as abnormal.

Anatomic Obstruction

Enteric duplication or agenesis can be confirmed ultrasonographically in pediatric patients. Duplication is rare and can occur anywhere in the intestinal tract, and the clinical signs may be nonspecific (abdominal distension, discomfort) (Figure 13.9D). A fluid-filled jux-

taintestinal formation with variable peristalsis and contents can be seen. Enteric agenesis usually results in severe, life-threatening clinical signs in the neonatal period. Ultrasonographic findings usually include marked fluid and gas distention of bowel proximal to the defect.

Pyloric stenosis secondary to hypertrophic gastritis has been reported in the pediatric dog. Focal circumferential thickening of the pylorus primarily involving the muscularis is typical (Baker 2006, Penninck 2002).

Bowel Perforation

Intestinal perforation can result in focal changes in bowel wall layer ratios, with thickening of the muscularis and submucosal layer due to inflammation and edema. A focal hypoechoic mass can be visualized

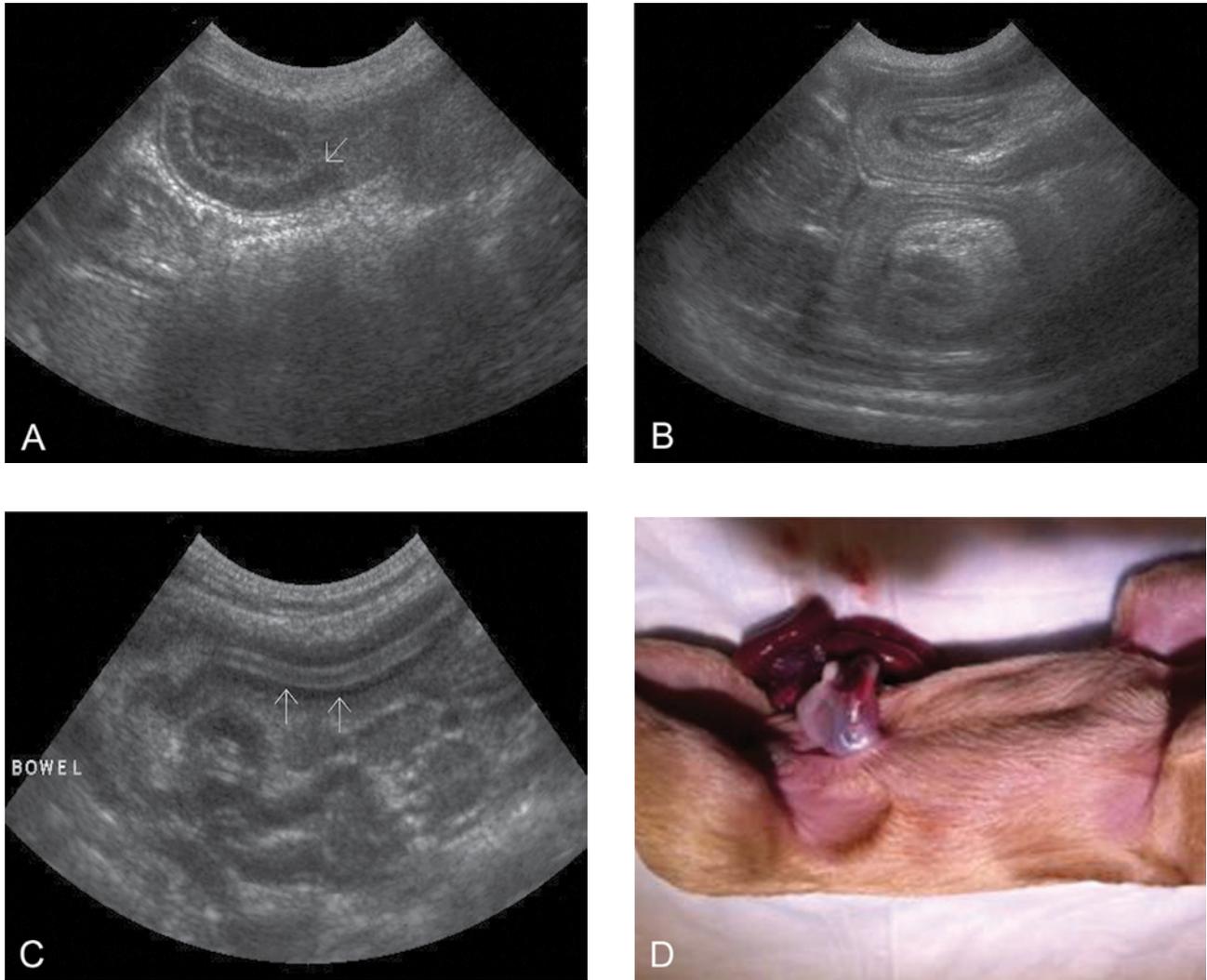


Figure 13.11. Intestinal wall edema, intussusception, intraluminal ascarid, and omphalocele. (A) Small bowel wall thickening and loss of normal layering (arrow). (B) Intussusception in two bowel segments; typical bowel within the bowel appearance. (C) Ascarid (arrows) in small bowel. (D) Omphalocele.

where total effacement has occurred (Figure 13.10A; also see Figure 7.14A and B). Hyperechoic slashes within the hypoechoic wall can represent gas trapping. Free abdominal air denotes bowel perforation unless the patient has recently undergone a laparotomy or has a penetrating abdominal wall wound. Free abdominal air is best visualized ventral to the spleen when the patient is in dorsal recumbency (Figure 13.10B; also see Figure 7.14A and B) and in non-gravity dependent lateral sites when in lateral recumbency (Baker 2011, Penninck 2002).

Abdominal radiography should be used to definitively document free abdominal air.

Gastroenterocolitis

Mild to moderate thickening of the gastrointestinal wall with preservation of wall layering and moderate mesenteric lymphadenomegaly are the most common ultrasonographic findings with non-specific pediatric gastroenterocolitis, such as that resulting from dietary indiscretion or bacterial overgrowth. More severe pathology, such as extensive bowel edema or hemorrhage accompanying infectious gastroenterocolitis, can be associated with changes in fluid volume within the bowel lumen, wall thickening, and loss of normal wall layering (Figures 13.10C and D and 13.11A). These changes can be regional or diffuse. Fluid distention of the bowel with generalized decreased motility can be seen with functional ileus accompanying gastroenterocolitis.

Several breeds of dogs have a reported genetic predilection to small intestinal disease. An immunoproliferative enteropathy is seen in the Basenji breed, which is characterized by lymphangectasia, intermittent diarrhea, weight loss, hypoalbuminemia and hyperglobulinemia, and lymphoplasmacytic mucosal infiltrates throughout the GI tract. Histopathology is diagnostic; however, abdominal ultrasonography can identify bowel in which disruption of the normal layering has occurred. Chinese Sharpei dogs have been identified with a lymphoplasmacytic-eosinophilic infiltrative enteropathy that is characterized by poor weight gain, weight loss, or intermittent diarrhea episodes, with onset of signs typically between two and six months of age. Infiltrative enteropathies can be characterized ultrasonographically as having changes in the normal bowel wall echogenicity and layering (Baker 2006, Penninck 2002).

Intussusception

Intussusception is not uncommon in young dogs and cats, occurring most frequently at the ileocecolic junction in dogs and in the jejunum in cats (see Figures 7.12A and B and 7.13). Pediatric patients are prone to intussusception because they lack the intrinsic enteric neural mechanisms for aboral motility present in adult animals; instead, gastrointestinal motility is pressure dependent and based on the sequential ingestion of food. Fasting or vomiting results in ileus and increases the risk of intussusception.

The classic transverse ultrasonographic appearance of intussusception is a multilayered series of concentric rings representing the invaginated bowel wall layers. The outer layer can be edematous (hypoechoic) and the inner layers more normal in appearance (Figure 13.11B; also see Figures 7.12A and B and 7.13). Discomfort is typically displayed when scanhead pressure is placed over the affected area of bowel. Doppler evaluation of the bowel and associated mesenteric vessels can provide information about bowel viability. Serial examinations are important when evaluating the pediatric patient with a palpable abdominal mass, unanticipated clinical deterioration, or increased abdominal pain (Baker 2006, Penninck 2002).

If an intussusception is diagnosed in the pediatric veterinary patient in a timely fashion, reduction rather than resection might be possible.

Enteric Parasites

Enterocolitis from intestinal parasites can be severe in pediatric patients with high worm burdens. Small

bowel helminths can be visualized ultrasonographically as double-walled structures within the fluid-filled lumen (Figure 13.11C). Movement of helminths can be appreciated with real-time ultrasonography (Penninck 2001).

Enteric Thrombosis

A serious consequence of hypercoagulopathic enterocolitis is mesenteric thrombosis resulting in bowel ischemia. Doppler imaging is necessary to identify the thrombus; the resultant hypoechoic bowel wall appearance is visible with real-time ultrasonography (Baker 2009) (also see Chapter 12).

Congenital Herniation

A developmental anomaly resulting in extrusion of a portion of the gastrointestinal tract outside of the body wall, occurring within the umbilical canal (omphalocele) or lateral to the umbilical canal (gastroschisis), has been reported in humans and occurs in both dogs and cats (Figure 13.11D). The condition is usually hopeless in small pediatric patients presented to the veterinarian hours after birth; however, a 30%–70% survival rate is reported in humans with immediate postpartum surgical intervention. Diagnosis is made pre-partum with abdominal ultrasound, based on the recognition of fetal gastric wall (rugal) structures or intestinal contents in an abnormal location. Earlier surgical intervention before inevitable septic contamination occurs may improve the prognosis in veterinary patients.

Congenital peritoneopericardial diaphragmatic hernias occur in both the dog and cat. Ultrasonography provides an additional modality for their diagnosis (see Figure 3.2F). As with other diaphragmatic hernias, careful evaluation for continuity of the echogenic diaphragm differentiates a true hernia (see Figure 9.21A through E) from mirror image artifacts (see Figures 1.7 and 3.9D). Evaluation of the pericardial contents can be made from the subcostal (across the liver) or intercostal (using the heart as an acoustic window) approach (Figure 13.12A). Abnormal pericardial contents can include falciform fat, liver, gallbladder, and/or intestines.

Umbilical hernias can be significant if large enough to permit bowel evisceration and strangulation. Omentum can become trapped in an open umbilical hernia in immature dogs and cats; closure of the hernia then results in a benign mass effect that is often alarming to clients. Evaluation of a painful or enlarging umbilical mass usually permits differentiation of

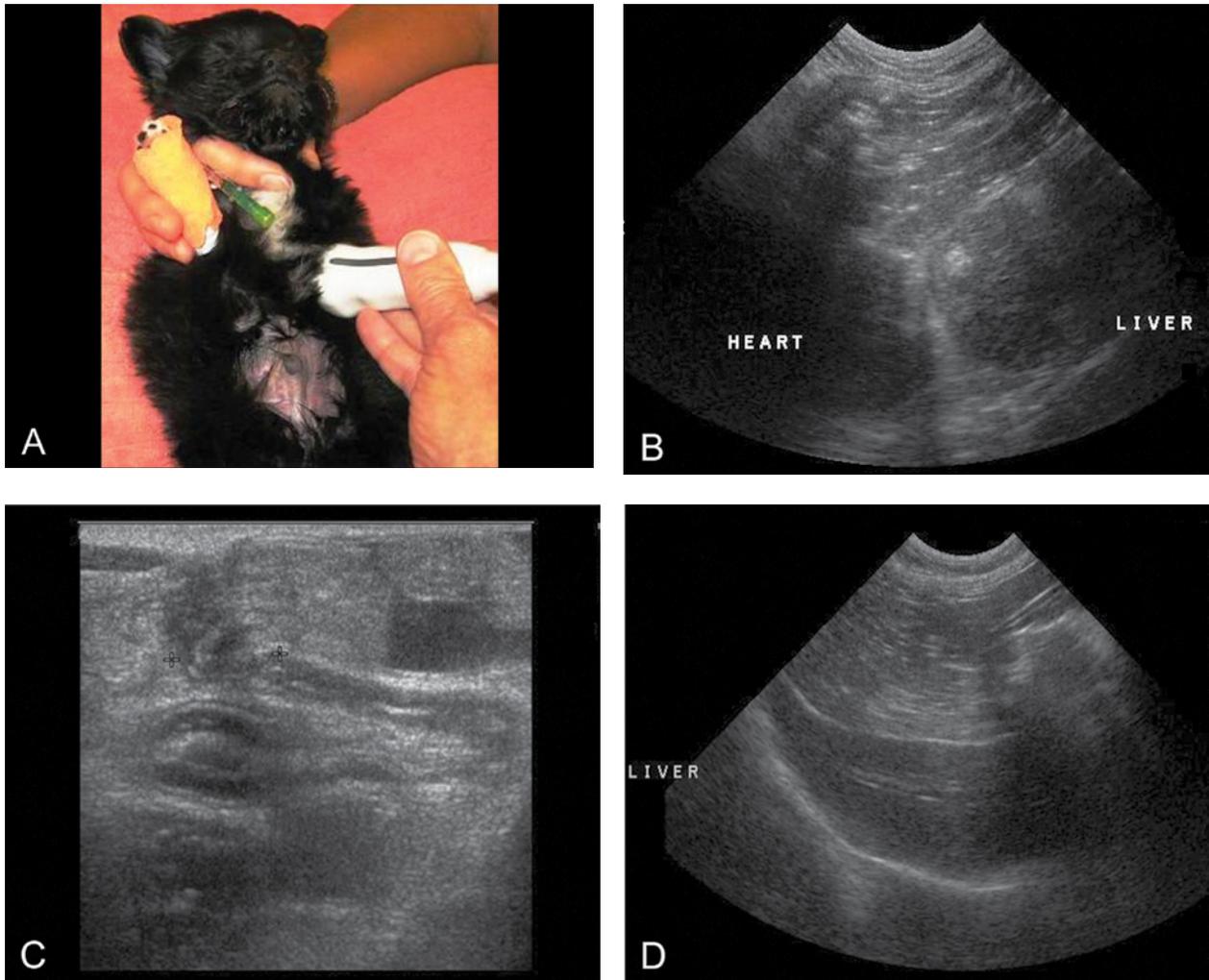


Figure 13.12. Intercostal imaging for peritoneopericardial diaphragmatic hernia, and also inguinal hernia with bowel entrapment, and microhepatica. (A) Intercostal imaging in the pediatric canine. (B) Peritoneopericardial diaphragmatic hernia. (C) Inguinal hernia showing entrapment of omentum; small bowel remains within the peritoneal cavity. (D) Microhepatica; falciform fat is seen ventral to the hepatic border.

omentum from entrapped bowel, which has a typical enteric appearance.

Congenital inguinal hernias can similarly be confirmed by ultrasonographic identification of intestinal structures within the subcutaneous space of the affected groin. This can be a dynamic finding. Mesenteric fat may alternatively be entrapped through the hernia and sometimes becomes strangulated (Figure 13.12B; also see Figure 15.3A through C).

Congenital hiatal hernias are more difficult to confirm with ultrasound because of the inherent difficulty imaging the gas-filled stomach and the intermittent nature of the disorder. However, a stomach wall with its characteristic rugal folds imaged crossing the diaphragm into the thoracic cavity supports the diagnosis (Baker 2006, Suter 1984).

Fluoroscopic evaluation can be more informative in hiatal hernia suspects.

Acquired Herniation

Traumatic diaphragmatic herniation can result in the presence of stomach, liver, spleen, intestines, and falciform fat in the thorax, usually accompanied by effusion of fluid, which enhances imaging (Figure 13.12C). Failure to identify a contiguous diaphragmatic image supports the diagnosis.

Thoracic radiography or positive contrast peritoneography can be used to confirm the diagnosis if ultrasound findings are not conclusive (Suter 1984).

Metabolic Conditions of the Pediatric Patient

Congenital Portosystemic Shunts

Portosystemic shunts are congenital malformations of the hepatic portal venous drainage system and can have either a familial (i.e., genetic or random occurrence). Congenital portosystemic shunts can be intrahepatic or extrahepatic; breed predilections for extrahepatic shunts include Yorkshire Terrier, Maltese, Poodle, Miniature Schnauzer, Dachshund, Lhasa Apso, Pekingese, Pug, and Shih Tzu, whereas intrahepatic shunts are more commonly identified in large breed dogs such as Golden Retrievers, German Shepherds,

Irish Wolfhounds, Irish Setters, and Samoyeds. Portosystemic shunts are uncommon in cats.

Ultrasonography provides a rapid and noninvasive method for screening patients suspected to have congenital portosystemic shunts. Although scintigraphy is considered the most reliable noninvasive method of documenting a portosystemic shunt, its availability is limited to specialty and university practices, and its use dictates special handling of the radioactive patient for at least 12 hours. The liver may be small and difficult to image in patients with congenital portosystemic shunts (Figure 13.12D). Imaging the liver from the standard ventral approach can be improved in some cases by using the left ventral intercostal or right dorsal intercostal approaches (Figure 13.13A). The presence

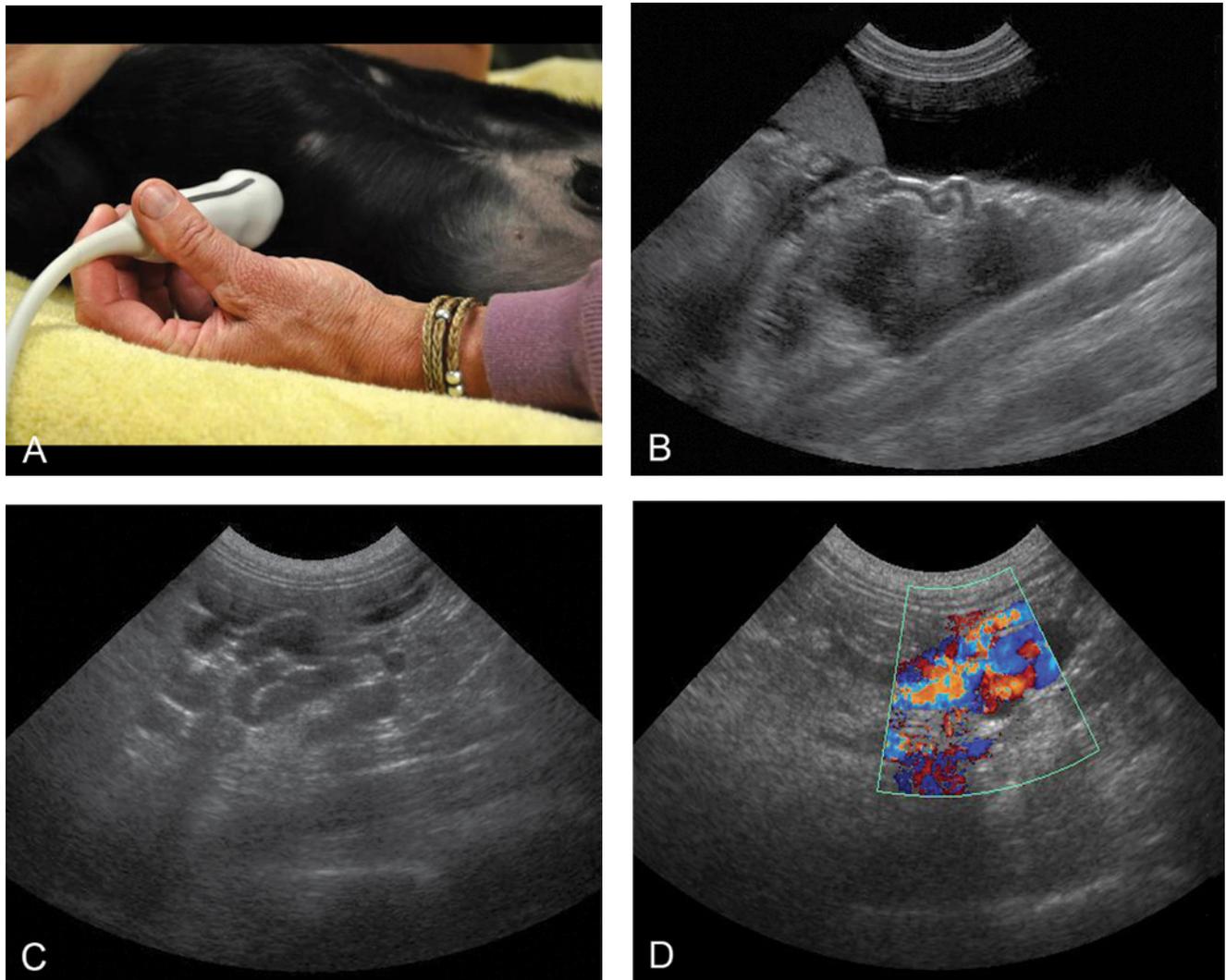


Figure 13.13. Vascular interrogation and various extrahepatic anomalies associated with the liver. (A) Intercostal approach for imaging patients with a very small liver. (B) Tortuous extrahepatic shunt vessel seen caudal to the spleen; note ascites. (C) Hairpin extrahepatic shunt vessel. (D) Doppler imaging of extrahepatic shunt showing turbulence.

of ascites can facilitate the study, as can adding fluid to the stomach and positioning the patient to shift gas away from the scanhead and shift abdominal organs caudally (Figure 13.13B). Ultrasound evaluation of portosystemic anomalies can be facilitated by positive pressure ventilation under anesthesia for the same reason.

Extrahepatic shunts most commonly arise from the portal vein, splenic vein, or left gastric vein in the dog, and from the left gastric vein in the cat. Identification of a shunting vessel emptying into the caudal vena cava is difficult but confirmatory. These shunts are often tortuous, and Doppler helps identify altered blood flow (Figures 13.13C and D). Intrahepatic shunts can be more difficult to identify because of patient size, bowel gas, and liver size. Clipping the hair coat intercostally on the right can allow for transverse vessel

stacking (of the aorta, vena cava, and portal vein) and allow visualization of ductal shunts (Figures 13.14 A to C). There can be right and left shunting of the ductus (Baker 2006, 2009, Nyland 2002, Hager 1985).

Seizure Disorders

Pediatric patients with focal, partial, or grand mal seizures for which no metabolic or toxic etiology can be identified can benefit from intracranial ultrasound. Scanning the brain through the fontanelle, usually partially open in pediatric patients, permits noninvasive evaluation of the ventricles (Baker 2012, personal communication). Evaluation of a normal littermate facilitates recognition of excessive cerebral spinal fluid accumulation by serving as a control (Figure 13.15A and B).

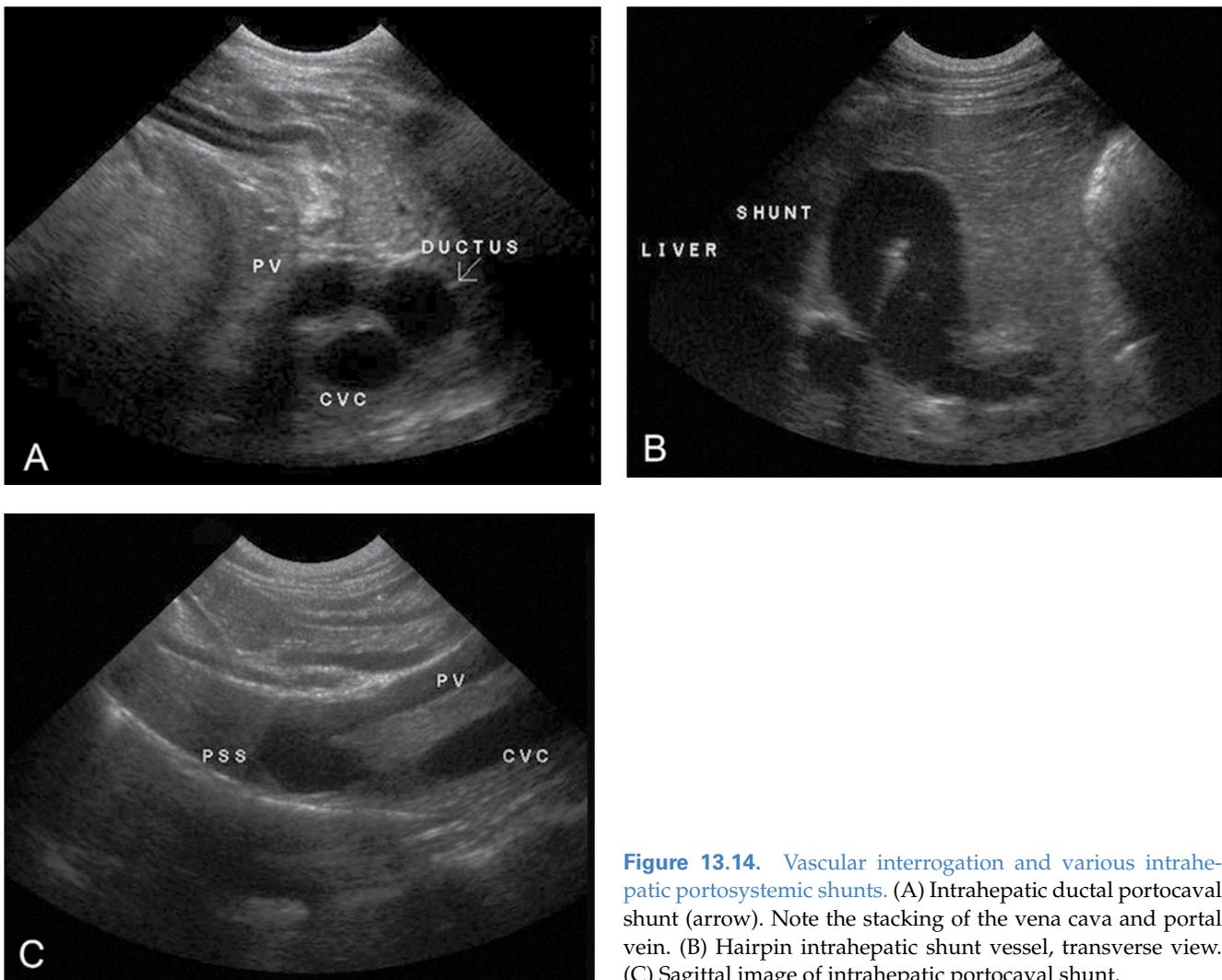


Figure 13.14. Vascular interrogation and various intrahepatic portosystemic shunts. (A) Intrahepatic ductal portocaval shunt (arrow). Note the stacking of the vena cava and portal vein. (B) Hairpin intrahepatic shunt vessel, transverse view. (C) Sagittal image of intrahepatic portocaval shunt.

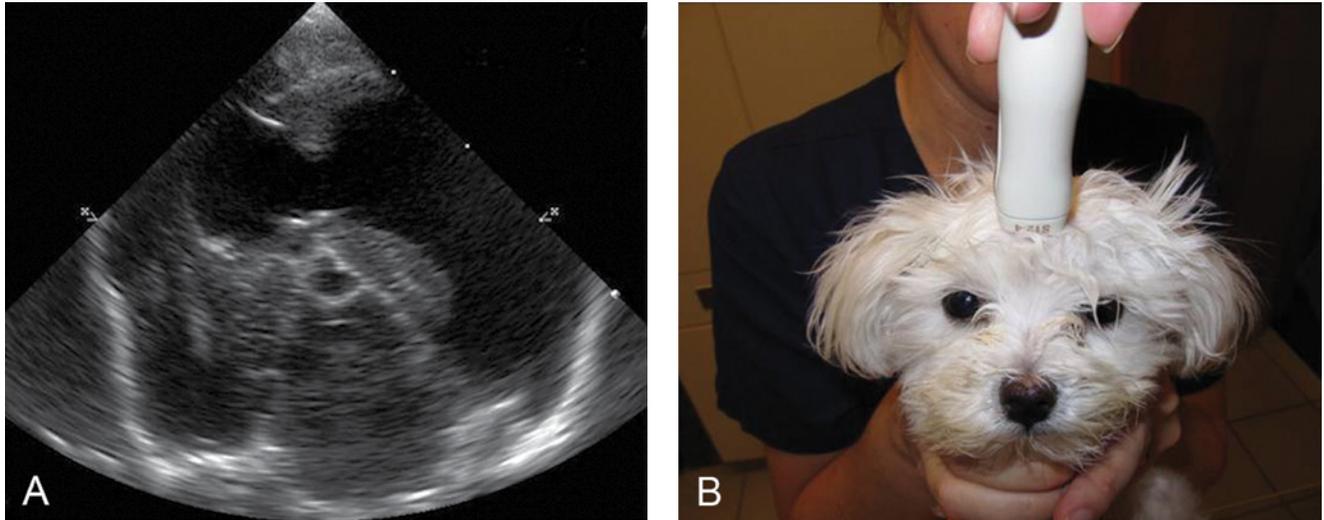


Figure 13.15. Imaging the neurological patient with suspect hydrocephalus through an open fontanelle. (A) Increased fluid within the ventricles of a hydrocephalic puppy, scanned through the fontanelle. (B) Scanhead placement for imaging through the open fontanelle.

Evaluation of a normal littermate facilitates recognition of excessive cerebral spinal fluid accumulation by serving as a control.

Genitourinary Disorders

Young dogs and cats are commonly presented to the veterinarian for perceived genitourinary system disorders. While gastrointestinal disorders account for most acute presentations, perceived urogenital disorders account for many others. Clinical differentiation between the characteristics of normal pediatric housebreaking and immature renal function and true urogenital disease can be challenging and is facilitated with ultrasound (also see chapters 5, 6, and 8).

Renal Agenesis

Congenital renal agenesis resulting in the absence of a kidney can be confirmed with ultrasound, but is usually an incidental finding. The contralateral kidney typically has normal internal anatomy, but is enlarged as a consequence of obligatory hypertrophy (Baker 2006).

Renal function of the pediatric patient does not equate that of the adult until four to six months of age. Compensatory renomegaly may not be apparent until that time.

Renal Dysplasia

Until reliable genetic markers are available for all of the various breed-specific congenital renal dysplasias, ultrasound provides the best method of screening young dogs and cats for these likely heritable disorders. Early ultrasonographic screening is possible in breeds in which morphologic changes are grossly evident (i.e., Persian cats, Cairn Terriers, German Shepherd Dogs). The kidneys lack normal corticomedullary interface, and the renal border can be irregular (Figure 13.16A). The condition is usually bilateral (Baker 2009).

Severe pyelonephritis can mimic the ultrasonographic appearance of renal dysplasia. Clinical differentiation with urinalysis and urine culture helps discriminate between these conditions.

Urogenital Ectopia

Congenital ectopic placement of the distal ureter into the urethra, vestibule, or vagina is usually associated with ureteral dilation with or without renal pelvic dilation. Dilation of the ureter improves the sensitivity of the ultrasound study; however, the diagnosis can still be elusive. Visualization of a nonvascular fluid-filled structure with a hyperechoic wall passing dorsal to the urinary bladder, or obvious insertion of the structure into the proximal urethra, suggests the diagnosis. Ectopic ureters display peristalsis if monitored for a few moments (see Figure 6.2). Visualization of the

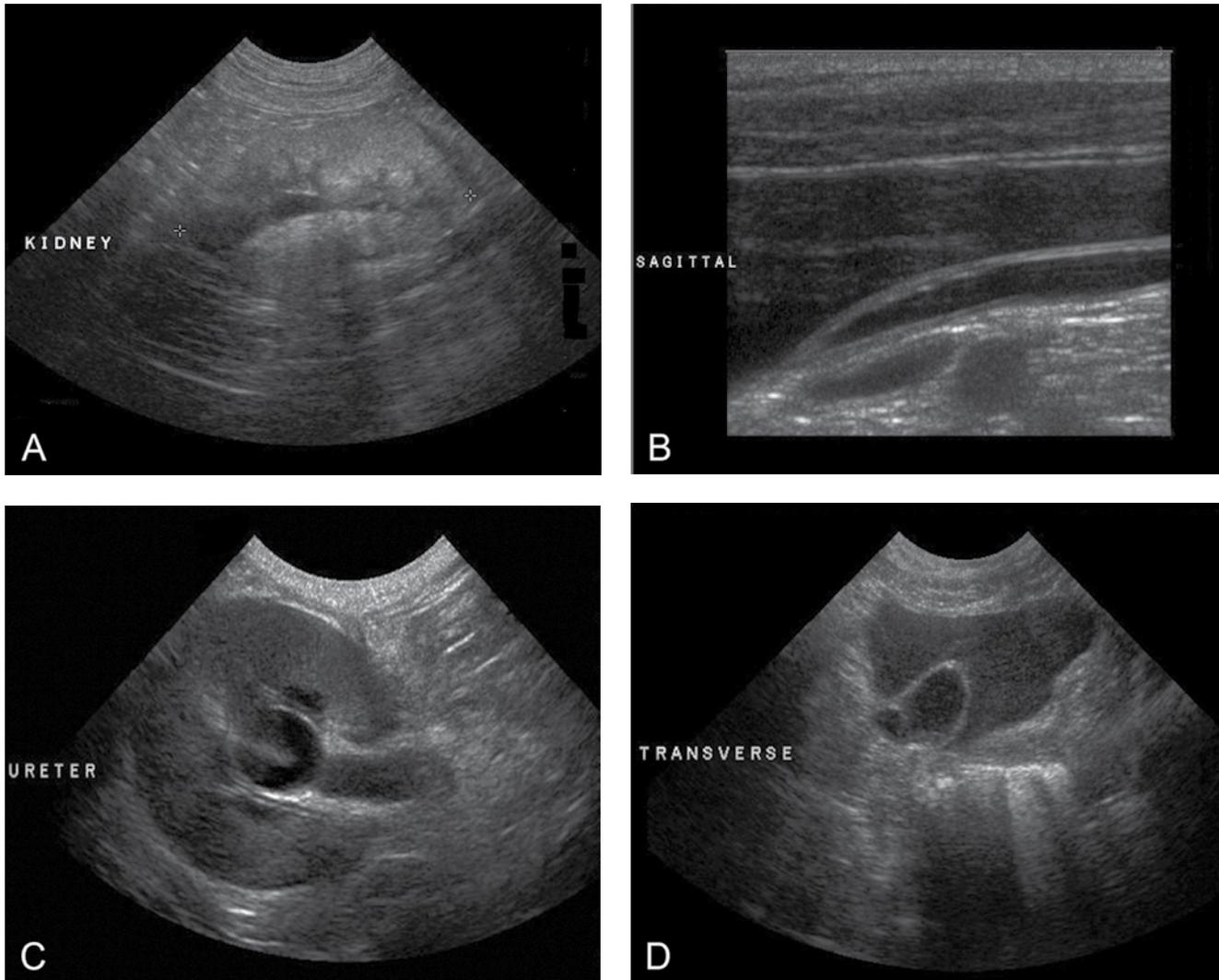


Figure 13.16. Urinary tract anomalies of renal dysplasia, ectopic ureter, hydronephrosis, and ureterocele. (A) Renal dysplasia; note the loss of normal corticomedullary interface (thickened cortex). (B) Ectopic ureter dorsal to urinary bladder; note hyperechoic walls. (C) Hydronephrosis, with proximal hydroureter. (D) Transverse image of a ureterocele seen in the dorsal right urinary bladder.

ureteral jets in the bladder suggests normalcy (see Figure 6.2A and B); however, some ectopic ureters insert initially into the bladder and additionally tunnel distally to terminate in an abnormal site. Visualization of the dilated ureter usually occurs near the urinary bladder (Figure 13.16B). Visualization of the bladder neck and proximal urethra may be obscured by pubic bone, making identification of such termination difficult.

Hydronephrosis can eventually result from an uncorrected ectopic ureter due to flow impedance at the abnormal site of insertion (Figure 13.16C; also see Figure 5.12A through D). Urinary tract infection is commonly associated with ectopia, due to accompanying

urethral sphincter mechanism anomalies, and if not detected and treated, can progress to pyelonephritis and ureteritis. Infection and its associated inflammation in the tract can further alter the ultrasonographic appearance of the kidneys, bladder, ureters, and urethra (also see chapters 5 and 6).

Contrast enhanced computed tomography is the most sensitive and specific modality for the diagnosis of ectopia, but, like double contrast radiography, requires anesthesia, making initial evaluation with ultrasound desirable when ectopia is suspected clinically. The condition is thought to be heritable, and is more common in females (Baker 2006, 2009, Lamb 1988, Nyland 2002).

Ureterocele

A ureterocele is an uncommon congenital dilation of the ureter near the bladder, appearing as a cystic structure within the bladder lumen or wall. The ureterocele occurs most commonly in association with an ectopic ureter. Diagnosis can be made by scanning the urinary bladder in the transverse plane and watching for strong peristalsis of the tunneling ureter (Baker 2006, 2009, Nyland 2001, Lamb 1988) (Figure 13.16D).

Urinary Tract Infection

Puppies are frequently presented to the veterinarian because of owner concerns about difficulty achieving housebreaking and the perception that urination in exces-

sively frequent (pollakuria). Historical differentiation between a history of true pollakuria and dysuria associated with cystourethritis and the normal frequency of urination in pediatric dogs with immature renal concentrating abilities can be difficult. A urinalysis/urine culture, with urine obtained by ultrasound-guided cystocentesis, can be diagnostic. The bladder can appear normal in acute urinary tract infection. Chronic urinary tract infection can induce bladder wall thickening (greater than 1–2 mm in a fully distended bladder), especially in the cranioventral portion of the bladder (Figure 13.17A; also see Figure 6.4A through D). Similarly, early pyelonephritis can have a normal ultrasonographic appearance; chronic pyelonephritis can produce a dilated renal pelvis, sometimes accompanied by poor corticomedullary definition, increased echogenicity, reduction in renal size, increased echogenicity, reduction in renal size,

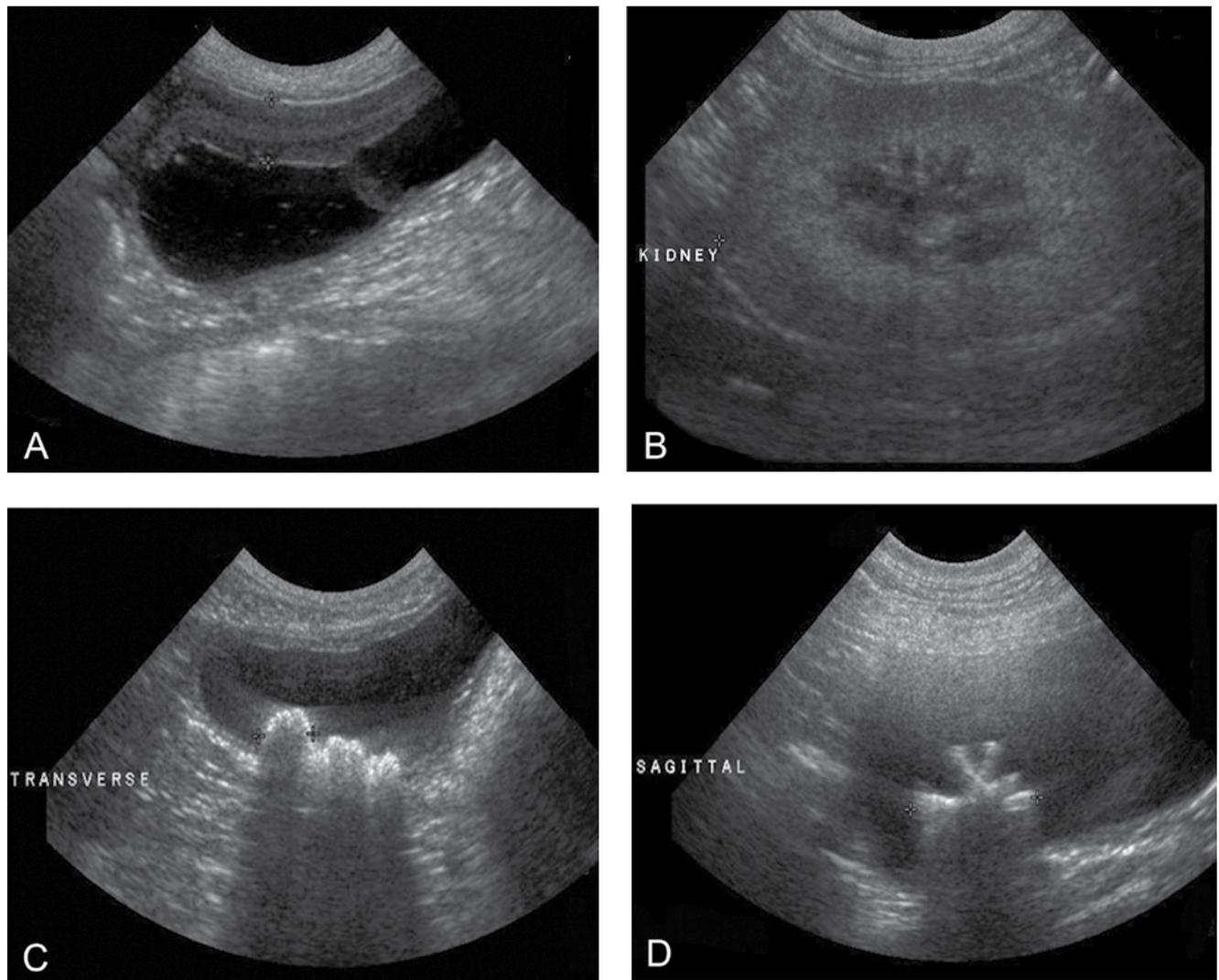


Figure 13.17. Urinary tract abnormalities of cystitis, pyelonephritis, and different types of bladder stones. (A) Thickened urinary bladder wall (cursors) associated with cystitis. (B) Pyelonephritis left kidney. Note the poor corticomedullary interface, thickened cortex, and structural dilation of the renal pelvis. (C) Multiple cystic calculi (cursors) identified by strong distal shadowing. (D) Jackstone cystic calculi (cursors).

and irregular renal contour (Baker 2006, Nyland 2002) (Figure 13.17B; also see Figure 5.11A through D).

Urolithiasis

Cystic calculi (radiopaque or radiolucent), visualized as discrete hyperechoic focal echogenicities in the dependent portion of the bladder, occur most commonly in pediatric patients with urinary tract infection (struvite or triple phosphate uroliths) and portosystemic shunts (ammonium biurate uroliths). The presence of a cystic calculus without urinary tract infection in the pediatric patient should actually prompt evaluation for developmental hepatic vascular anomalies. Both urinary tract infection and cystic calculi are more common in female pediatric patients (Baker 2006, Nyland 2002) (Figure 13.17C and D; also see Figure 6.8A through D).

Both urinary tract infection and cystic calculi are more common in female pediatric patients.

Patent Urachus

The urachus permits the flow of urine from the bladder into the allantoic sac of the fetus, and normally atrophies at birth. A patent urachus in the neonate is characterized clinically by urine dribbling from the umbilicus. The fluid-filled urachus can be identified ultrasonographically, extending cranially from the cranioventral bladder wall (Figure 13.18A). If an incompletely patent urachus is present in the neonate, a urachal diverticulum may result, seen as a divot in the apex of the bladder (Figure 18B). Urachal diverticula

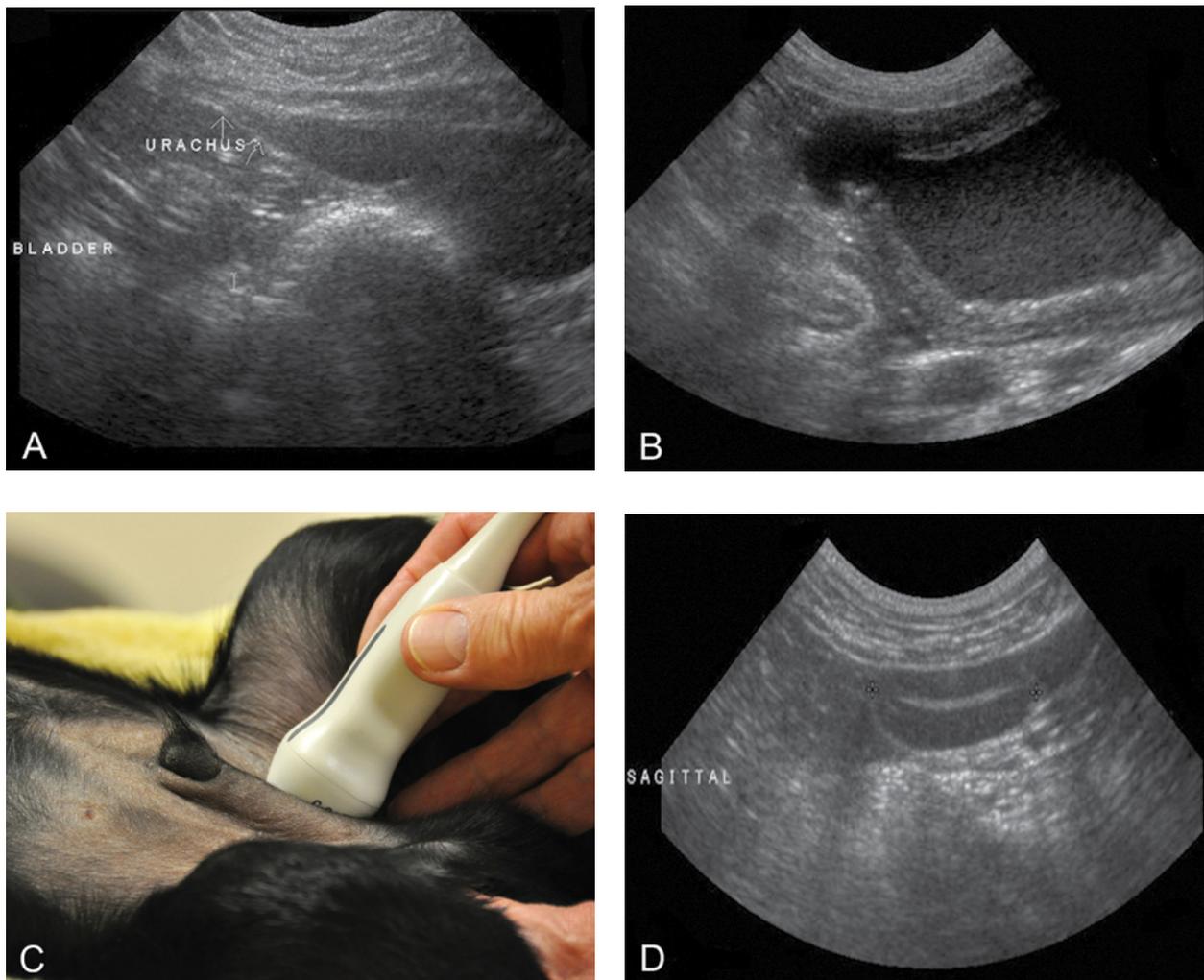


Figure 13.18. Urogenital anomalies of patent urachus, persistent diverticulum, and cryptorchidism. (A) Patent urachus imaged sagittally at the apex of the bladder (arrows). (B) Urinary bladder wall persistent diverticulum resulting from incomplete regression of the urachus. (C) Sagittal scanning lateral to the prepuce to localize a cryptorchid testis. (D) Cryptorchid testis (cursors); note hyperechoic mediastinum testis.

can predispose the bladder to recurrent infection because of abnormal bladder flow in the region, and surgical excision can be indicated (Baker 2006, Nyland 2001).

Cryptorchidism

Ultrasound localization of cryptorchidism can confirm the condition in pediatric patients with bilateral involvement whose neutering status is unknown, and assist the surgeon in planning the approach (i.e., inguinal vs. cranial abdominal). Retained testes can torsion and present as an acute abdomen. The retained testis can be positioned anywhere between the ipsilateral kidney and the scrotum. A systematic evaluation of the region from the caudal renal pole to the inguinal canal can identify an oval, homogeneously echogenic structure with a mildly hyperechoic border representing the parietal and visceral tunics (Figure 13.18C; also see Figure 8.10, 8.11). The epididymis is usually distinctly less echoic than the testicular parenchyma, as in the scrotal testis. The cryptorchid testis will maintain the anatomic structure, the mediastinum testis (a hyperechoic slash), and normal testicular echogenicity despite being reduced in size as compared to a scrotal testis (Baker 2006, Eilts 1988) (Figure 13.18D; also see Chapter 8).

Pearls and Pitfalls, the Final Say

A focused or COAST³ pediatrics exam performed in a structured manner following basic ultrasonographic principles has the potential to expediently answer important clinical questions when radiographic and laboratory testing are inconclusive or need more definitive confirmation, or, conversely, ultrasound findings trigger additional laboratory testing or ancillary

imaging, or there are delays in scheduling a complete ultrasound exam by a veterinary radiologist or specialist to improve pediatric care. The use of the focused or COAST³ pediatric evaluation importantly has the potential to improve pediatric patient care.

References

- Baker TW. 2012. *What's Next? A Guide to Veterinary Ultrasound of the Eye, Neck and Shoulder and Guided Sampling Techniques*. Lakewood, CO: AAHA Press.
- Baker TW. 2009. *What's That? A Guide to Basic Veterinary Abdominal Ultrasound*. Lakewood, CO: AAHA Press.
- Baker TW, Davidson AP. 2006. Pediatric abdominal ultrasonography. *Vet Clin Small Anim* 36, 641–655.
- Eilts BE, Pechman RD, Hedlund CS. 1988. Use of ultrasonography to diagnose Sertoli cell neoplasia and cryptorchidism in a dog. *J Am Vet Med Assoc* 192:533–534.
- Lamb CR. 1988. Ultrasonography of the ureters. *Vet Clin North Am Small Anim Pract* 28:823–848.
- Nyland TG, Mattoon JS, Herrgesell EJ, Wisner ER. 2002. Physical principles, instrumentation, and safety of diagnostic ultrasound. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TG Nyland, JS Mattoon. Philadelphia: WB Saunders, pp 1–18.
- Nyland TG, Hager DA. 1985. Sonography of the liver, gallbladder, and spleen. *Vet Clin North Am Small Anim Pract* 15:1123–1148.
- Nyland TG, Mattoon JS, Herrgesell EJ, Wisner ER. 2002. Urinary tract. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TG Nyland, JS Mattoon. Philadelphia: WB Saunders, pp 158–195.
- Penninck DG. 2002. Artifacts. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TG Nyland, JS Mattoon. Philadelphia: WB Saunders, pp 19–29.
- Penninck DG. 2002. Gastrointestinal tract. In *Small Animal Diagnostic Ultrasound, 2nd ed.*, edited by TG Nyland, JS Mattoon. Philadelphia: WB Saunders, pp 207–230.
- Suter PF. 1984. Abnormalities of the diaphragm. In *Thoracic Radiography: A Text Atlas of Thoracic Disease in the Dog and Cat*, edited by PF Suter, PF Lord. Wettswil, Switzerland, pp 180–204.

FOCUSED OR COAST³—EYE

Jane Cho

Introduction

The non-ophthalmologist veterinarian is often faced with the challenges of having to assess eye conditions that require urgent attention (i.e., those that might need emergent referral and/or specific medications or surgery to save vision or the globe). Ocular ultrasonography to obtain evidence-based information and increase the probability of an accurate diagnosis over traditional clinical diagnostic means is an underutilized option for non-ophthalmologist veterinarians in busy general or emergency and critical care practices. While a complete ocular ultrasound exam by a veterinary ophthalmologist or radiologist may be indicated when there is ocular opacity and/or extraocular inflammation or injury, a focused eye exam can help alleviate the practitioner's frustration of not being able to visualize intraocular and periorbital structures. The use of ocular ultrasonography by non-ophthalmologist veterinarians can answer important clinical questions quickly when a complete clinical eye examination alone does not reveal a diagnosis.

- Expedite referral for salvage of vision or the globe by detecting otherwise occult conditions
- Assist in providing an initial prognosis for vision and the globe

What the Focused Eye Exam Cannot Do

- Cannot substitute for a full clinical ocular examination
- Cannot provide a diagnosis in the absence of a basic level of clinician skill and knowledge of ocular anatomy and disease
- Cannot overcome any inherent mechanical limitations of your ultrasound machine and probe
- It is noteworthy that while ocular ultrasound can significantly assist in diagnosis, it cannot always allow for a specific etiologic diagnosis due to variations in ultrasound appearances and a wide variety of possible pathology

What the Focused Eye Exam Can Do

- Provide a diagnostic window into an eye not amenable to direct examination by traditional means
- Provide anatomic information about an opaque or inaccessible eye without resorting to more costly imaging methods
- Diagnose or support a clinical diagnosis of anterior or posterior lens luxation, intraocular and retrobulbar masses, retinal detachments, and scleral rupture

Indications for the Focused Eye Exam

- Structural opacity, which prevents visualization through the cornea or anterior chamber (Figures 14.1, 14.2)
- Differentiation between exophthalmos (the protruding normal-sized globe) and buphthalmos (the enlarged globe), and determination of the presence and sonographic characterization of a retrobulbar mass (Figure 14.3)



Figure 14.1. Various types of corneal opacity can make directly viewing the intraocular structures difficult or impossible. (A) Corneal edema. (B) Corneal pigmentation. (C) Corneal scarring.



Figure 14.2. Various types of pathology can render the anterior chamber cloudy or opaque, obscuring the rest of the intraocular structures. (A) Hyphema. (B) Hypopyon. (C) Fibrin.

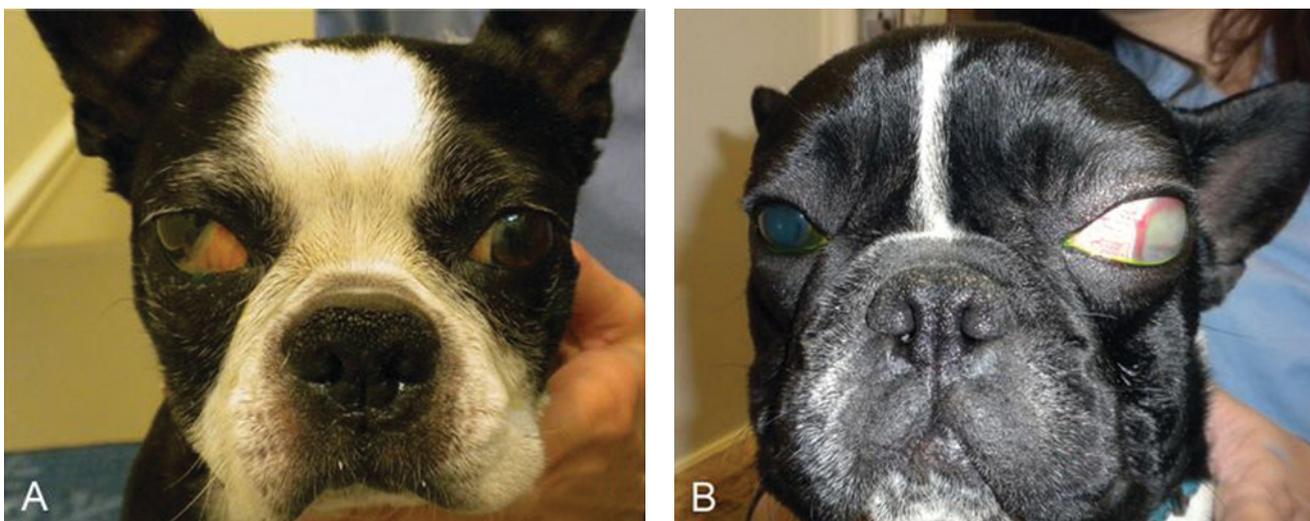


Figure 14.3. The bulging eye. Exophthalmos (A) and buphthalmos (B) can clinically look very similar on initial inspection. Both dogs in this figure have one eye that is bulging, but further examination would be needed to differentiate a globe that is merely large vs. one that is being pushed out of the orbit. It may not be easy to discern a difference in globe size or position even when one exists. Ocular ultrasound can help determine the nature of the problem through ultrasonographic measurement of the globe with comparison to the other unaffected eye, and thus the correct course of action is better pursued.

- Examination of the traumatized eye, especially with swollen periocular structures, to evaluate for injury to the globe or its structures (use with great caution) (Figures 14.1, 14.2, and 14.22).

Objectives of the Focused Eye Exam

Identify the location, size, and shape of normal and abnormal ocular and periocular structures, and better identify the existence of pathology warranting specific treatment, especially emergent treatment, thus optimizing preservation of vision and the globe.

Ultrasound Settings

The ultrasound probe with the highest frequency available should be used to image the globe. A 7.5- to 10-MHz probe is preferable. A 7.5-MHz probe is adequate for imaging deeper structures (orbit). A 5-MHz probe may be acceptable for detecting deeper large lesions at the expense of losing detail. Higher MHz provides better detail in the nearer fields. A probe with a small scan head diameter (linear or sector) is preferred.

If the machine allows, a “small parts” or “eye” setting or similar setting optimizing focus in the very near field (1–5 cm) is preferred. Reduced depth of the image (using a depth dial if present on your machine) also helps to magnify small structures. If the machine has a foot pedal, install it prior to the eye exam to allow hands-free freezing of images. Gain can be turned up or down during the exam to highlight certain structures.

Patient Eye Preparation

Ideally, a sterile, viscous, aqueous-based ultrasound gel that is nontoxic to the eye and ocular surfaces should be used. The author routinely uses Aquasonic 100 (Parker Laboratories, Fairfield, NJ) ultrasound gel, a very commonly used and readily available ultrasound gel, on the intact ocular surface, with no ill effects (Dziezyc 1988). Aquasonic is also available in sterile form. Gel such as K-Y Jelly, (which is less viscous and thus tends to fall off the eye, making its use more difficult) or ophthalmic 2.5% methylcellulose gel can be used. Clean the probe well and dry it according

to the manufacturer’s instructions before placing it on the eye. In cases of possible globe rupture, a sterile gel such as individual packets of K-Y Jelly should be used and the probe should be placed on intact skin and not the eye.

If a standoff is needed for imaging the anterior, most superficial parts of the eye, either a thicker layer of gel or a water-filled glove may be used, though the latter can be unwieldy to handle. All gel should be gently and completely flushed off the ocular surfaces with sterile saline eyewash immediately after the exam. Fluorescein staining of the cornea after the exam is also recommended to ensure that no corneal damage has occurred in the examination.

How to Do the Focused Eye Exam

First, topically anesthetize the cornea with several drops of ophthalmic proparacaine, tetracaine, or another appropriate topical ophthalmic anesthetic. Note that this is likely stored in the refrigerator. If adequate topical anesthetic effect is not achieved with 10–15 drops over two minutes, additional chemical restraint may be needed. This should be tailored to the patient, and titrated to the lightest sedative/anesthetic plane needed. No specific sedation or anesthetic protocols are required, although a reversible one may be preferable.

Unless the patient is excessively mobile or very painful, sedation and/or general anesthesia are typically unnecessary, and may make examination more difficult due to resulting changes in globe position.

Second, the animal should be able to sit, lie sternal, or stand normally in a comfortable position. If sitting or standing, make sure the animal is not allowed to scoot or slide backward. At least one assistant is needed to hold the animal’s head still. Either that assistant or the sonographer can hold the eyelids open. An additional assistant may be needed to work the freeze button (Figure 14.4).

Third, avoid pressing the probe directly onto the cornea. Maintain a layer of ultrasound gel 3–10 mm thick between the probe and the cornea (Figures 14.5 and 14.6). Be mindful of the direction of the patient’s gaze. By keeping the probe correctly oriented you will be more likely to properly localize ocular and periocular structures.



Figure 14.4. An assistant should hold the patient in a comfortable position in which the patient cannot slide backward. This person can also hold the patient's eye open for the exam. Another assistant should be available to freeze the image if needed.



Figure 14.6. The initial view should be with the probe held vertically, dividing the globe into lateral and medial halves, and either tilting the probe from side to side or moving the probe from side to side (changing the contact point on the eye) to image the whole structure. Note the thick layer of gel that is maintained between the probe and the eye.



Figure 14.5. Apply a large amount of coupling gel that is safe for eyes to the ultrasound probe before applying to the eye. Do not use alcohol-based gel, which may be harmful to the cornea. The probe should not be pressed onto the eye, but held with a 3- to 10-mm standoff layer of gel between the probe and the cornea if possible, to allow for better imaging of the most superficial structures.

Maintain a layer of ultrasound gel 3–10mm thick between the probe and the cornea. This technique will allow better imaging of the near fields (cornea, anterior chamber, iris) and be more comfortable to the patient.

Look at the position of the other eye and the facial muscles for help in orienting the images of the eye being evaluated.



Figure 14.7. The view with the horizontal probe position divides the globe into upper and lower halves, providing additional directional information on intraocular structures.

Fourth, several views can be used, including vertical, horizontal, and lateral, and behind the orbital ligament (viewing posterior to anterior). Begin by placing the probe vertically (bisecting the globe into medial and lateral halves) on the central cornea (Figure 14.6) to image the globe from the anterior to the posterior pole. Sweep the probe, moving the point of contact from one side of the cornea to the other, imaging the entire globe. Alternately, pivot the angle of the probe while keeping the probe contact point stationary.

A second viewing angle to consider is horizontal, with the probe placed parallel to the floor (bisecting the globe into top and bottom halves). The probe is then swept/angled from top to bottom (Figure 14.7).



Figure 14.8. The lateral probe position places the probe so that it divides the globe into anterior and posterior sections. It is easiest to access from the lateral sclera where the limbus is most exposed. This view is not commonly used but may allow for further orientation and interrogation of intraocular structures.



Figure 14.9. Probe position from behind the orbital ligament. If possible, palpate the orbital ligament and feel for the slight depression behind it. You may need to palpate the other side to locate the ligament, because orbital injury is often what necessitates this view. Shaving or completely wetting down the skin in this area before applying gel will improve the image. Orient the probe forward. Note that the probe will be in contact with the skin and a thick gel layer is not necessary with this view. The quality of the images obtained using this view will be inferior to those obtained with corneal contact.

A third (and less commonly used) view places the probe parallel to the iris from the lateral aspect of the globe (bisecting the globe into anterior and posterior halves), which is swept/angled from front to back (Figure 14.8).

A fourth possible angle is a retrobulbar one from behind the orbital ligament, producing a lower quality image directed from the back to the front of the eye (Figure 14.9). This view may be worth considering if the cornea might be ruptured, or the lids are extremely thickened or swollen; however you need to proceed with caution to prevent causing additional damage.

If imaging through skin, shaving or thoroughly wetting down the fur improves the image quality.

It is important to note that in cases in which globe rupture is suspected (gross hyphema, hypotony [low intraocular pressure], or visible globe deformation/deflation), yet imaging is still required, it is preferred to image through closed lids or intact skin, rather than through the cornea, to prevent contamination of the intraocular space. Do not press on the globe or lids because this will easily further damage the eye.

In summary, these additional views can provide further information as to the location and orientation of lesions if needed, although generally all views are not necessary to make most urgent clinical decisions. Performing the scan first at higher gain, then at lower gain, will allow for differentiation of smaller, more subtle, and lower-intensity lesions.

Ultrasonographic Findings in a Normal Eye

When imaging using the vertical or horizontal probe position, the most superficial structure seen under your layer of gel will be the cornea, represented by two very thin bright parallel curved lines (the anterior and posterior corneal surfaces) about 1 mm apart (Figure 14.10) or (depending on your probe frequency) a single bright 1 mm thick curved line. If there is not enough standoff space between the probe and eye, it may not be visible at all. Just posterior to this is the anechoic anterior chamber. This should always be anechoic because it is filled with the aqueous humor, an acellular solution, and is normally about 3–5 mm deep in the central axis (Cottrill 1987). It is bordered posteriorly by the iris and axial anterior lens capsule, and peripherally by the iridocorneal angle (which is not typically seen in any detail). See Tables 14.1 and 14.2 for information on normal and abnormal findings.

The normal anterior chamber is always anechoic (clear black).

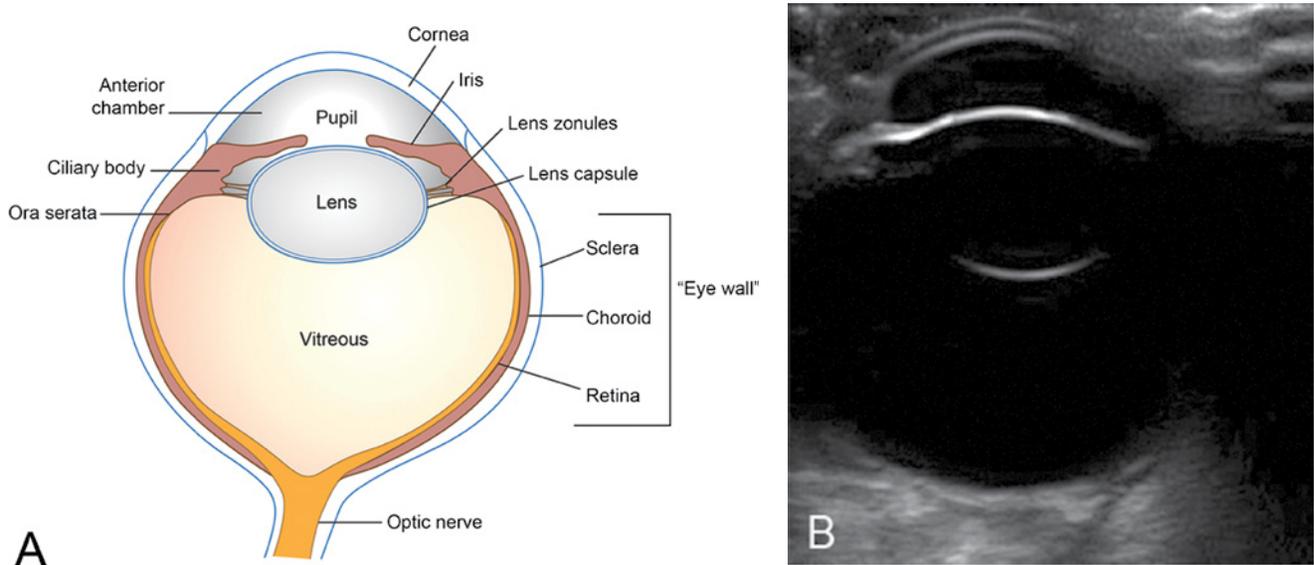


Figure 14.10. Anatomy of the eye. (A) Illustration of normal ocular anatomy. (B) Ultrasound image of a normal eye. Note the bright concave curved cornea with two thin bright parallel lines (which may be seen as a single echogenic band, or not at all) anteriorly (at the top of the image), the anechoic anterior chamber behind it, the bright iris (seen here peripherally on the left) and bright thin curved anterior and posterior lens capsules (axially), the anechoic vitreous, and the bright convex posterior eye wall. A band of hypoechoic retrobulbar muscle is visible behind the globe to the right of the visual axis. This still image does not show the ciliary body or peripheral eye wall well, because all parts of the eye may not be visualized at any one time.

Table 14.1.
Normal findings.

	Structure	Echo appearance
Should always see:	Anterior chamber	Should be anechoic
	Axial anterior and posterior lens capsule (axial= along the central visual axis)	Thin bright line of specular reflection curving backward and forward (though often cannot see where they meet peripherally)
	Vitreous	Should be anechoic
	Axial posterior eye wall	Smooth curved bright white line with no hyperechoic adjoining structures
Will often see:	Cornea	Linear, uniform, moderately echogenic structure forming anterior eye wall; usually not visible unless using a thick layer of gel or a standoff is used
	Retrobulbar extraocular muscle cone	Hypoechoic muscle bellies originating in a ring around the optic nerve and converging at the back of the orbit, forming a cone
	Frontal bone	A bright hyperechoic angled line behind and ventromedial to globe
Might see:	Iris	A very thin hyperechoic linear structure peripheral and anterior to, but not often distinguishable from, the anterior lens surface
	Optic nerve	A straight or curved hypoechoic linear structure from just below the globe's posterior pole with parallel linear borders, surrounded by fat and the retrobulbar extraocular muscle cone
Should not see:	Fat around optic nerve	Hyperechoic material around the hypoechoic optic nerve
		Any bright structures in the anterior chamber or vitreous
		Any anechoic structures in the orbit (behind the globe)

Table 14.2.

Types of abnormal ultrasonographic findings and possible causes.

Deep anterior chamber	True deep anterior chamber due to chronic glaucoma and buphthalmos Posterior lens luxation Prior lens removal surgery (aphakia)
Shallow anterior chamber	Mass in anterior chamber (Figures 14.17, 14.18, 14.20) Anterior synechiae Intumescent (swollen) cataract (Figure 14.12) Iatrogenic (compressing cornea with probe) Ruptured cornea with loss of aqueous humor Aqueous misdirection syndrome (rare and only in cats)
Echogenic material in anterior chamber	Anterior lens luxation (Figure 14.15) Blood, fibrin, and/or cells in anterior chamber Cysts in anterior chamber Anterior synechiae Iris (or other) mass (Figures 14.17, 14.18, 14.20) Anteriorly displaced vitreous (would be very weakly echogenic) Foreign body (rare)
Echogenic lens (other than axial lens capsules)	Cataract (varying degrees and distribution of echogenicity possible) Nuclear sclerosis Gain turned too high Artificial intraocular lens implant due to prior cataract surgery (lens implant would be thinner than a normal lens, and highly echogenic) Dense lens sutures
Abnormal lens shape or size	Hyper mature cataract (lens smaller than normal) Intumescent cataract (lens larger than normal) (Figure 14.12) Cells or other material adherent to lens surface (e.g., as occurs with lens capsule rupture or persistent hyaloid remnant) Lenticonus (rare)
Abnormal lens location	Lens subluxation or luxation (Figures 14.13, 14.15)
Echogenic structure(s) in posterior segment	Vitreous degeneration (forming strands, membranes, clumps, and/or dots in vitreous) Asteroid hyalosis (usually poorly defined and in central vitreous) (Figure 14.19) Vitreous hemorrhage and fibrin Posterior lens luxation (lens-shaped mass in vitreous, may be mobile and in a dependent position) (Figure 14.13) Retinal detachment (Figure 14.16) Retinal hemorrhage Mass or other abnormal accumulation of cells in posterior segment Foreign body (rare) Hyaloid vessel remnant (hyperechoic linear structure oriented along a line from posterior pole of lens to posterior pole of globe, possibly patent with blood flow; rare) Marked optic nerve head swelling (slightly raised echogenic structure at optic nerve head protruding into vitreous)
Abnormal globe shape	Scleral or corneal rupture Phthisis bulbi Large intraocular or scleral mass deforming globe Retrolental mass (indenting globe focally) (Figure 14.21) Staphyloma or coloboma (a focal bulge in eye wall; rare) Scleral thickening
Abnormal globe size	Buphthalmos due to chronic glaucoma (larger globe) (Figure 14.20B) Phthisis bulbi or microphthalmos (smaller globe)
Mass-like structure in or around eye	Neoplasia (Figure 14.21) Inflammation/granuloma Blood clots and hemorrhage Foreign body (rare) Displaced, enlarged, or swollen normal tissue Cystic structure
Poor image quality	Air under lids or in gel Eye or patient motion Inadequate amount of gel Settings on machine (gain, probe type, zoom, etc.) require adjustment Technical probe or machine issues

The iris might be visible as an area of increased echogenicity at the peripheral anterior lens but is often not distinguishable from the adjacent structures (Figure 14.10). It should be thin with an approximately flat anterior surface, with no asymmetrical thickness (medial vs. lateral), though it may be slightly thicker when the pupil is dilated and thinner when the pupil is constricted.

The lens is directly behind the iris, and the anterior lens capsule may not be distinguishable from the iris where they are in contact. The lens capsule is a thin bright line surrounding the lens in an oval shape. It should be smooth and curvilinear, though it appears brightest along the central axis of the image (at the central anterior and posterior lens capsules, when the vertical and horizontal views are used) and often “disappears” towards the periphery (Figure 14.10). The ability to see even a part of the lens capsule with its characteristic appearance allows sonographer to reliably locate the lens, especially when the lens is not in a normal position. The lens material inside the capsule is generally fairly echolucent, but it can be more echogenic than the aqueous in front of it and the vitreous behind it, and may not be uniform. Nuclear sclerosis and cataracts may appear as variable echogenic structures within the normally hypoechoic lens. The lens should always be centered in the visual axis.

The lens zonules, small structures that attach the lens equator to the ciliary body, are generally not visible on ultrasound. The ciliary body, which is the posterior continuation of the iris, may be seen as a small mound of echogenic tissue peripheral to the lens equator, but is also often not easily distinguishable from the iris, or even visible. The posterior chamber is defined as the space between the iris and the lens (not the retina), and as such is actually a very small and thin space in front of and to the sides of the lens that is not easily discernible on ultrasound.

Posterior to the lens is the large, gel-like, uniformly echolucent vitreous body, comprised mainly of water and collagen fibers. No echogenic structures should be present in the vitreous (Figure 14.10). However, various vitreal abnormalities (asteroid hyalosis, vitreal strands) may be ultrasonographically present without being a clinically significant cause for disease.

Posterior to the vitreous is the posterior eye wall, a smooth and echogenic curved line representing the back of the globe. The posterior eye wall is made up of three thin layers (the retina, choroid, and sclera) that are normally so closely opposed to each other as not to be distinguishable from each other.



Figure 14.11. Just ventral to the posterior pole of the globe is the optic nerve, which should be uniformly hypoechoic with parallel sides (arrowheads). It may be straight or slightly curved, and may be surrounded by a thin layer of bright fat that highlights its borders. The optic nerve is always surrounded more widely by the hypoechoic retractor bulbi muscle bellies, which are oriented in a cone shape toward the posterior orbit. It might also be possible to identify vessels on either side of the optic nerve using Doppler. The optic nerve can be very difficult to image clearly. This is the same image as 14.19, and in this plane the lens is not well imaged.

In the vertical and horizontal views, all ocular structures should be symmetrical within the globe; asymmetry is abnormal.

Behind the globe, it may be possible to identify the hypoechoic optic nerve, originating just ventral to the back of the globe and sometimes appearing as two thin parallel and occasionally curved lines extending toward the posterior orbit (Figure 14.11). It may also appear as a hypoechoic linear (or possibly curvilinear) structure without the brighter borders. It is often surrounded by a thin layer of bright fat and the hypoechoic extraocular muscle bellies, all oriented as a cone toward the posterior orbit. In general, these structures are not nearly as easy to discern as the intraocular structures.

Finally, a very bright line representing the ventromedial bony wall of the orbit may be seen behind these retrobulbar soft tissue structures. This is a smooth and bright line that curves away from the globe ventrally.

Imaging the other eye for comparison is often very helpful for distinguishing lesions and better identifying what is normal for that animal.

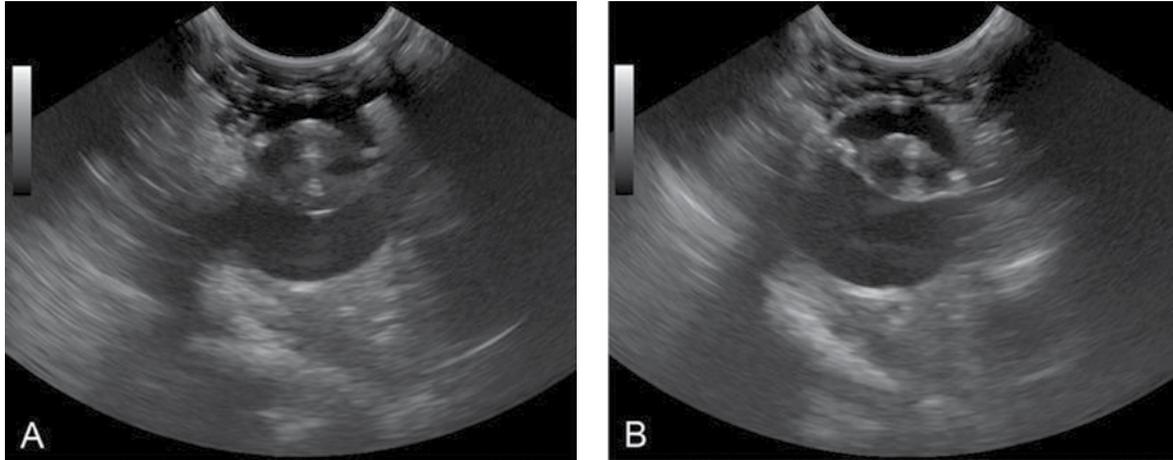


Figure 14.12. Anterior chamber assessment. (A) Eye with a shallow anterior chamber. Compare with (B), which is the fellow eye of the same dog. The difference in anterior chamber depth is due to the size of the lens. The lens in (A) is an intumescent (swollen) cataract, and the lens in (B) is a normal-sized cataract.

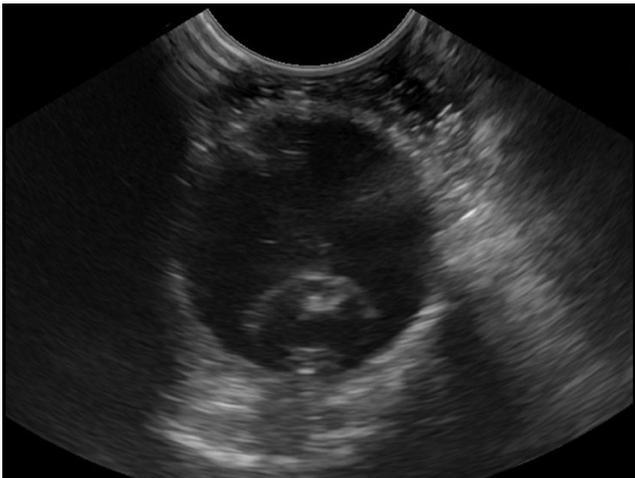


Figure 14.13. Posterior lens luxation. In this eye with chronic glaucoma and buphthalmos, the lens zonules have broken down, allowing for the lens to become mobile and rest in the dependent part of the globe along the posterior eye wall. Note that there is no lens visible in its normal location.



Figure 14.14. Anterior lens luxation. This three-year-old Jack Russell Terrier presented with acute ocular pain and cloudiness. Note the dilated pupil, very mild focal corneal edema, and a relucent (brightly reflective) rim indicating the equator of the lens in the anterior chamber. This rim can be highlighted by shining a light from the side of the anterior chamber. The IOP is 64 mmHg. In this case the cornea is still clear so that the lens is visible, but in some cases the corneal opacity can be so pronounced that the lens may not be directly visible and ultrasound may be necessary.

Clinical Significance and Implications of Abnormal Findings

Anterior Lens Luxation

Clinical Findings

- History: acute change in the eye (trauma is not required)
- Signalment: Terrier breeds and Poodles are most commonly affected, but can occur in any dog breed; cats may also be affected

- Eye exam: corneal edema is usually most pronounced in the center or wherever the lens is touching the cornea; may not be able to visualize iris or anterior chamber well; directing focal light from the side may highlight a relucent (brightly reflective) rim of the luxated lens in the peripheral anterior chamber (Figure 14.14); pupil dilated with a poor pupillary light response (PLR); cannot see fundus well; high intraocular pressure (IOP), often over 30–40 mmHg.

Ultrasonographic Findings

- Lens in anterior chamber (usually can only see the thin bright line of the axial anterior lens capsule just behind the cornea, or the posterior lens capsule just in front of pupil); sometimes can see an echolucent lens-shaped structure with a thin bright border in the anterior chamber right behind the cornea and anterior to the normal lens location (Figure 14.15)
- No lens in normal location (posterior lens capsule not just anterior to center of globe)
- Mobile, thin, somewhat amorphous strands in vitreous (in posterior segment) might be present
- Possible retinal detachment (see below)

Actions

- Measure IOP (preferably with an applanation or rebound tonometer, not with a Schiøtz tonometer). Avoid using the center of the cornea where the lens is likely to be touching the cornea inside. If acute glaucoma (IOP greater than 25 mmHg) is present (onset of ocular pain and high IOP less than 24 hours), immediately refer to ophthalmologist for evaluation and possible surgery. Vision might be able to be saved if the lens can be surgically removed before the retina has been permanently damaged by high IOP.

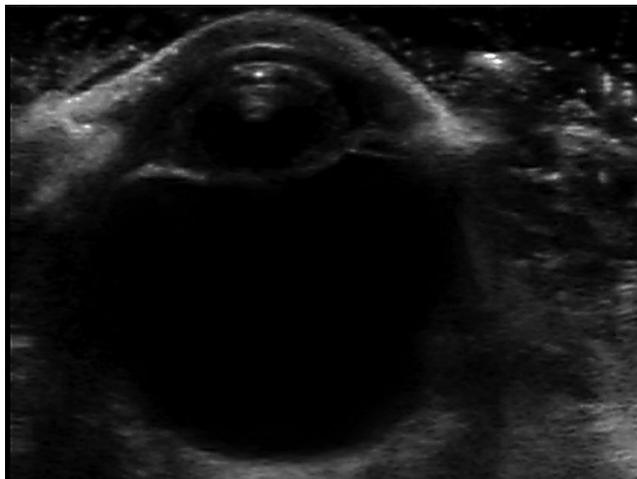


Figure 14.15. Anterior lens luxation. The lens, highlighted by its relatively bright lens capsule, is in the anterior chamber just behind the cornea, and is more anterior than it should be. Note that the posterior lens capsule is not visible in its normal location in the center of the globe (compare to Figure 14.10B). Courtesy of Dr. Andra Voges, Veterinary Imaging Center, San Antonio, Texas.

- If available, start the antiglaucoma medications 0.5% timolol q 12 hours and/or 2% dorzolamide q 8 hours (or the combination drop timolol/dorzolamide q 8 hours), and oral methazolamide 1 mg/lb up to q 8–12 hours. The latter may be difficult to find and can be considered optional.
- Do not give mydriatics (tropicamide, atropine) because this may exacerbate glaucoma. Do not give miotics (latanoprost, pilocarpine, etc.) because these will block the normal flow of aqueous humor, trapping the lens in the anterior chamber and exacerbating glaucoma.

All of the above ophthalmic medications are human drugs, and drops are generally available at human pharmacies.

Most of the above ophthalmic medications are human drugs, and drops (solution formulations) are generally available at human pharmacies.

In addition, consider the following on an individual basis:

- Analgesia, systemic pain medications
- Make patient nothing per os (NPO) for referral as applicable for possible surgery
- Place E-collar to prevent self-trauma

Please note that if the IOP is not reduced shortly (approximately 24–48 hours depending on IOP level), the eye will not only remain painful but will also become irreversibly blind.

If the globe is already enlarged (buphthalmos) and blind, then the glaucoma has been chronic and is not an emergency.

Retinal Detachment

Clinical Findings

- History: possible acute or subacute vision loss
- Signalment: variable
- Eye exam: reduced or absent PLR, menace, and dazzle; hyphema (blood in anterior chamber); resting mydriasis (in affected eye), especially with anisocoria; possible retinal hemorrhages or generalized red color from behind pupils; visible retinal detachment seen on fundic exam (best seen using indirect ophthalmoscopy, rather than direct ophthalmoscopy) (for examination techniques see Cho 2011).

In the absence of trauma, two of the most common causes for spontaneous hyphema in older dogs are retinal detachment and intraocular neoplasia.

Ultrasonographic Findings

- If hyphema is present, diffuse echogenic material will be present in the anterior chamber.
- Retinal hemorrhage might be seen as indistinct echogenic areas of variable size and location within the normally echolucent vitreous and in front of the retina.
- The retinal detachment itself is seen as a thin bright continuous curvilinear structure in the posterior segment that can be followed back to the optic nerve head, often making a V- or Y-shape or “gull wing” appearance (Figure 14.16A). This linear structure is almost always attached at the ora serrata (junction between retina and ciliary body) (Figure 14.16B).
- Retinal detachments are often accompanied by other echogenic structures (vitreous strands, hemorrhage, asteroid hyalosis) in the posterior segment.
- Retinal detachments may be bullous (retina separated from the posterior eye wall) or flat (retina close to the posterior eye wall) (Figure 14.16C).
- Retinal detachments may be completely detached (only attached at the optic nerve head and ora

serrata) or partially detached (still attached to the choroid in some areas).

- It is possible, but not common, to see discontinuities (tears or holes) in the detached retina.
- The subretinal space is more often echolucent (indicating a serous retinal detachment) than echogenic (indicating subretinal blood, cells, or a mass), and is very often more echolucent than either the retina or the posterior eye wall.

Actions

- Measure blood pressure, especially if retinal detachment is non-traumatic and bilateral; treat systemic hypertension (systolic blood pressure greater than 180 mmHg) if present and consistent with clinical signs.
- Look for signs of anterior or posterior uveitis (miosis, aqueous flare, hypotony, iris hyperemia, etc.). If present and cornea is fluorescein negative, and if patient will not be seen by a veterinary ophthalmologist within 48–72 hours, begin topical treatment (e.g., NeoPolyDex drops or ointment or 1% prednisolone acetate suspension q 6–12 hours), and systemic nonsteroidal anti-inflammatories. If patient will be seen immediately, therapy may be delayed until examination.
- If hyphema is present, measure IOP and treat with antiglaucoma medications if IOP greater than

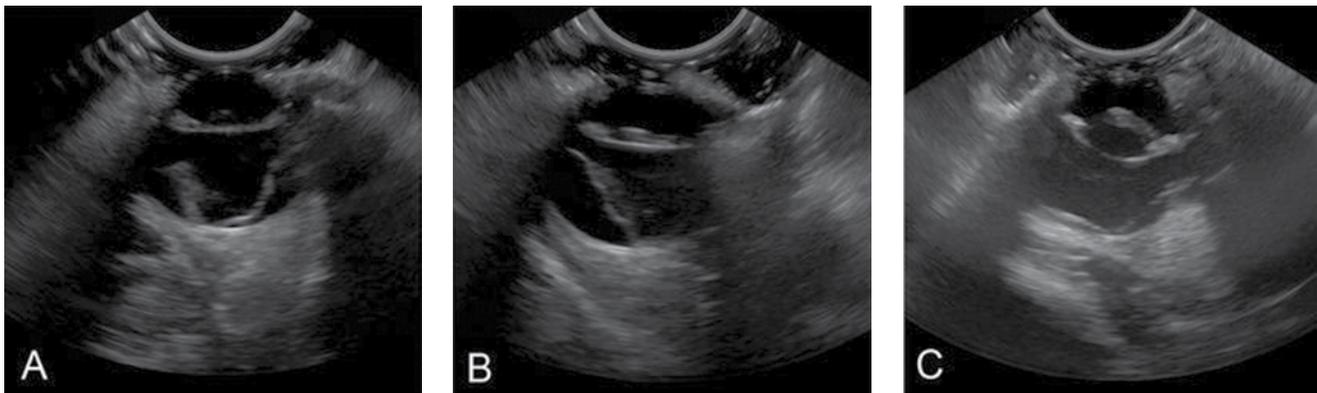


Figure 14.16. Retinal detachments. (A) Note the curvilinear bright line in a “gull wing” shape that connects to the optic nerve head at the back of the globe. The space between the retina and the choroid/sclera is echolucent here, as is often the case in serous retinal detachments. The posterior lens capsule is also seen in this image, but the anterior lens capsule is not. (B) In this alternate view of the same eye as in 14.16A, on the left of the image, the retina is seen as a thin bright membrane attached posteriorly at the optic nerve head at the back of the globe, and anteriorly extending toward the ora serrata (the junction between the ciliary body and retina), both natural anatomic attachment points. The full lens is not seen at this angle. (C) This retinal detachment (a different patient from 14.16A and B) is less pronounced than in the previous figures, because the retina is much closer to the posterior eye wall (a so-called flat detachment). Note the thin separation of the retina on the left side of the image. The presence of an echogenic space between the retina and the eye wall confirms this to be a retinal detachment.

25 mmHg (0.5% timolol q 12 hours and/or 2% dorzolamide q 8 hours, or the combination drop timolol/dorzolamide q 8 hours) and oral methazolamide 1 mg/lb up to q 8–12 hours.) The latter may be difficult to find and can be considered optional.

- All of the above ophthalmic medications are human drugs, and drops are generally available at human pharmacies
- Note that other differentials for retinal detachment include systemic disease (systemic infection, neoplasia) as well as idiopathic/immune-mediated pathologies, so a complete physical exam and/or additional laboratory testing and imaging (thoracic radiographs, with or without abdominal radiographs or ultrasound) for systemic disease may be indicated if other clinical signs are abnormal.
- Consider referral to a veterinary ophthalmologist for further evaluation and possible additional advanced treatment.

Retinal reattachment surgery, while not as commonly performed in animals as it is in humans, is increasingly available for animals.

The prognosis for vision is better if the subretinal space is echolucent (transudate) and worse if echogenic (blood, cells, mass). The prognosis also worsens with increasing duration of the detachment.

If retinal detachment is present and associated with trauma, the prognosis for vision is guarded to poor (Book 2008).

Intraocular Masses

Clinical Findings

- History: variable; many owners are unaware of the eye looking abnormal and the eye is often not painful until either glaucoma or hyphema develops; signs referable to the latter are often the presenting complaint
- Signalment: variable, but generally middle-aged to older animals
- Eye exam: variable but any of the following: deformed globe in advanced cases (outward focal bulging of eye wall); hyphema; focal peripheral corneal edema if mass is touching inside of cornea (Figure 14.17A); dyscoria; iris thickening; presence of a visible mass in either anterior or posterior segment (pigmented or nonpigmented, and especially near eye wall); lens subluxation; focal retinal detachment associated with a solid-looking structure; any of the above with glaucoma

Ultrasonographic Findings

- A bulge in the normally spherical eye wall might be seen in advanced cases, with a mass as described below just under the area of the bulging eye wall.

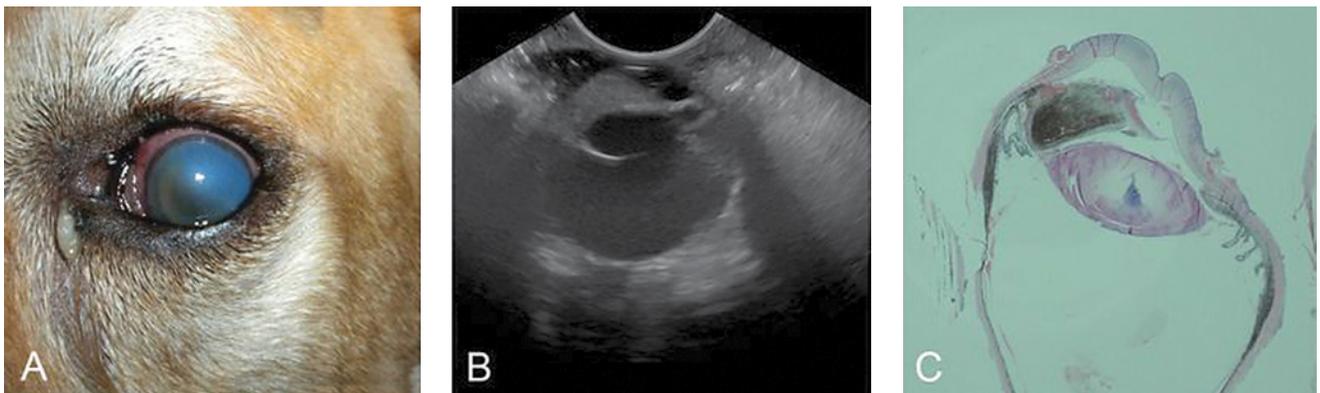


Figure 14.17. Anterior chamber mass in a dog. (A) The left eye of this nine-year-old dog has focal corneal edema, obscuring a large dark mass of the iris. The corneal edema has resulted from the mass growing large enough to contact and damage the corneal endothelium. The eye is buphthalmic and blind, and the IOP is 43 mmHg. (B) A large, uniformly echogenic mass is present in the anterior chamber of the same eye, originating from the iris and slightly pushing the lens to the right side of the image. Note the rounded, relatively distinct border between the mass and the anterior chamber and lens. The lens itself, as well as the vitreous, is otherwise normal and echolucent. Left is lateral in this image. (C) Subgross photo of the globe in (A) and (B). The eye was enucleated and a large, solid, pigmented mass is visible in the lateral anterior chamber. Some distortion of the corneal shape is present but this is a processing artifact. The mass was diagnosed histopathologically as a uveal melanocytoma.

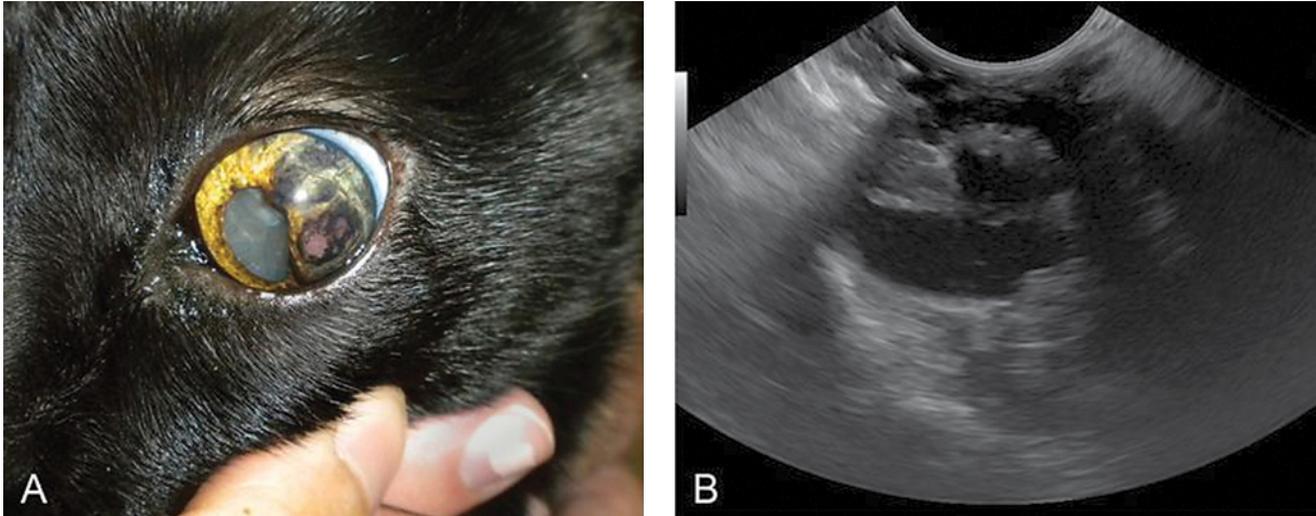


Figure 14.18. Anterior chamber mass in a cat. (A) In this adult cat, the lateral iris is clearly distorted. The lateral iris face is raised, discolored, and causing dyscoria (abnormal pupil shape). There is also a cataract, blocking direct viewing of the inside of the eye. (B) An ocular ultrasound was done to better identify the extent of the iris mass effect. The ultrasound shows gross thickening of the area of the iris and ciliary body (left is lateral in this image). The iris mass appears to be uniformly echogenic, suggesting a mass and not a cystic structure, and in this case does not extend posteriorly.

- Hyphema might be seen as indistinct, echogenic material in the anterior chamber.
 - Dyscoria is difficult to appreciate on ultrasound, but an area of iris thickening might be seen if thickening is marked (Figure 14.18).
 - The most common type in dogs (uveal melanoma) usually appears as an attached, rounded, uniformly echogenic structure in the area of the iris or ciliary body with a sharp border, possibly slightly pushing the lens off center (Figure 14.17B and C).
 - Differentiate masses from uveal cysts, which are very thin-walled, echolucent within, and either free floating or attached to the posterior iris, pupil margin, or ora serrata.
 - Masses are often broad-based (on the eye wall) and not pedunculated.
 - Doppler might show blood flow within a mass, but absence of Doppler-confirmed blood flow does not rule out neoplasia.
 - Masses may also be seen with vitreal hemorrhage, vitreal strands, and possibly retinal detachment.
 - Intraocular masses are rarely associated with a foreign body.
- Actions**
- Look for signs of uveitis and hyphema; if anterior uveitis or hyphema is present and cornea is fluorescein negative, begin topical anti-inflammatories (e.g., NeoPolyDex drops or ointment, or 1% prednisolone acetate suspension q 6–12 hours). If patient will be seen by a veterinary ophthalmologist immediately, topical therapy can be delayed until examination.
 - Measure IOP. If glaucoma is present (IOP greater than 25 mmHg), begin antiglaucoma medications (e.g., 0.5% timolol q 12 hours, 2% dorzolamide q 8 hours, or dorzolamide/timolol q 8 hours) if not being seen by an ophthalmologist within 24 hours. Do not give mydriatics (tropicamide, atropine) because this may exacerbate glaucoma.
 - All of the above ophthalmic medications are human drugs, and drops are generally available at human pharmacies.
 - Most intraocular neoplasms (such as melanoma, adenoma) are primary and late to metastasize; however, a minimal systemic work-up with baseline blood work, urinalysis, and thoracic radiographs, with or without abdominal imaging (ultrasonography, radiography), is indicated if systemic illness is present because intraocular neoplasia (such as lymphosarcoma, hemangiosarcoma, etc.) may represent metastatic disease.
 - Enucleation may ultimately be needed for both diagnostic and therapeutic purposes.
 - Consider timely referral to a veterinary ophthalmologist as necessary for confirmation and definitive therapy.

Vitreous Hemorrhage

Clinical Findings

- History: variable (trauma not necessary)
- Signalment: variable
- Eye exam: hyphema; red or red-black haze visible inside eye from behind iris and lens; inability to visualize any fundic details; pupil may be any size and may still be responsive to light. Because the possible causes of a vitreous hemorrhage include retinal detachment, posterior segment mass or injury, trauma, systemic hypertension, coagulopathy, and possibly vascular disease, accompanying history and clinical signs vary with the underlying cause

Ultrasonographic Findings

- Variably-sized and -shaped structure(s) within the vitreous with poorly-defined borders that are semi-mobile (try jiggling the eye) but not completely gravity dependent; can be multifocal; may be densely and uniformly echogenic, anechoic, hypoechoic, or heterogenous; may be comprised of multiple pointlike echoes; are often near eye wall (where the original bleeding occurred)
- Differentiate on ultrasound from asteroid hyalosis, which tends to have a lucent peripheral vitreal border and is generally uniform (Figure 14.19), but both have partial mobility and may also have concurrent vitreal strands



Figure 14.19. The optic nerve and asteroid hyalosis. Asteroid hyalosis, a common finding in older dogs, is typically seen as an amorphous, fairly uniform, semi-mobile echogenic material in the normally echolucent vitreous. It is often denser in the center of the vitreous, leaving the more peripheral vitreous echogenic. This is the same image as 14.11.

- May be associated with retinal detachment, intraocular masses, and scleral rupture (see corresponding sections in this chapter)
- Need to differentiate from a solid intraocular mass, which is not mobile at all, is always attached to the eye wall, and typically has a more distinct interior border than a hemorrhage

Actions

- Look for signs of hyphema and uveitis (aqueous flare, miosis, hypotony); if uveitis is present and cornea is fluorescein negative, start topical steroids (e.g., NeoPolyDex drops or ointment or 1% prednisone acetate q 6–12 hours), and consider systemic anti-inflammatories.
- If not associated with trauma, and especially if seen with hyphema, pursue a timely work-up for coagulopathy including clotting times, platelet count, etc.
- If not associated with trauma, and seen with retinal detachment, especially if bilateral, measure blood pressure; if hypertensive (systolic blood pressure greater than 180 mmHg), then start systemic anti-hypertensive therapy.

Vitreous hemorrhage in and of itself is not a major health issue for the eye, and is usually not treated per se, but is generally associated with other ocular conditions that may be serious. Timely referral to a veterinary ophthalmologist is indicated to determine the primary cause and prognosis.

Suspected Retrobulbar Masses/Exophthalmos

Distinguishing between exophthalmos and buphthalmos is key to choosing the right treatment plan when the eye is bulging (see Figure 14.3).

Clinical Findings of Exophthalmos (The Pushed-Out Eye)

- History: variable, may be acute or gradual onset
- Signalment: variable due to the varying etiologies
- Eye exam: globe protrudes and has reduced retro-pulsion (compare to the other side by palpating gently with an index finger on each closed eye) but is not enlarged (see below); globe deviation, often without strabismus; elevated nictitans; secondary lagophthalmos and central corneal exposure; indentation of sclera may be seen on fundic exam, but fundus is otherwise normal; variable changes

in vision and in IOP (most cases still have intact vision and normal IOP)

- Physical exam: also look for possible ipsilateral dental disease or evidence of inflammation in soft palate; pain on opening mouth (variable); local lymphadenopathy; ipsilateral nasal disease

Clinical Findings Supportive of Buphthalmos (The Large Eye, as Opposed to Exophthalmos, Above)

- History: gradual or chronic onset
- Signalment: for dogs, a breed predisposed to primary glaucoma (e.g., any Terrier breed, Bassett Hound, Cocker, Beagle, Shar Pei, Siberian Husky, Shih Tzu, Dalmatian, Great Dane, etc.). For cats, clinical signs and history of chronic or recurrent uveitis. Secondary glaucoma can occur with any age or breed having prior intraocular disease
- Eye exam: enlarged (and not just pushed out) globe; signs of chronic glaucoma including blindness, episcleral injection, diffuse corneal edema, corneal striae, negative PLR, mydriasis, high IOP, hyperreflective tapetum, thin retinal vessels, dark and/or cupped optic nerve head
- Note: Differentiate exophthalmos from buphthalmos using ultrasound by measuring globe at widest front-to-back diameter and compare to normal eye (normal typically around 19–21 mm) (Figure 14.20). Buphthalmos is only caused by glaucoma, and is thus distinctly different in pathology from exophthalmos

Cases of buphthalmos still warrant a timely referral to a veterinary ophthalmologist for glaucoma treatment for the affected blind eye and glaucoma prophylaxis for the remaining sighted eye.

Ultrasonographic Findings of Retrobulbar Mass/Exophthalmos

- Affected globe is normal size
- Globe indentation by the mass may be seen (Figure 14.21 B and C)
- Mass effect of variable echotexture behind the globe (Figure 14.21B and C)
- Variably discrete mass borders

Indentation is more consistent with a mass or cyst rather than cellulitis.

Echogenicity vs. echolucency is often not predictive of the etiology of a retrobulbar mass (Mason 2001).

Cellulitis/abscesses usually have very indistinct borders and variable echogenicity, and obliterate/obscure normal structures; cystic structures typically are more sharply margined with anecholuculent/anechoic interior; neoplastic masses tend to be more discrete (than cellulitis/abscess) and more uniform, but may have cavitation, indistinct borders, and variable echogenicity, and even be occult via ultrasonography (Mason 2001).

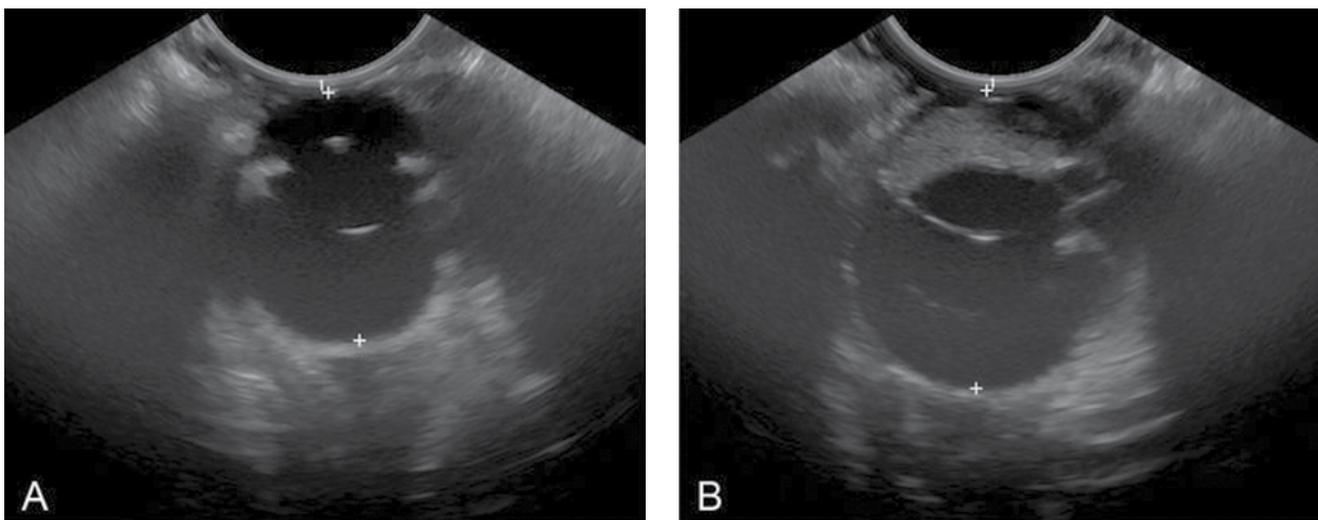


Figure 14.20. Measuring globe size. The probe has been placed so that the maximal length of the globe from anterior to posterior (the A-P diameter) can be measured, and the image frozen for measurement. (A) The normal eye, with an A-P diameter of 2.10 cm. (B) The fellow eye, which is glaucomatous and blind, with an A-P diameter of 2.57 cm. These are additional images from the dog in 14.17.

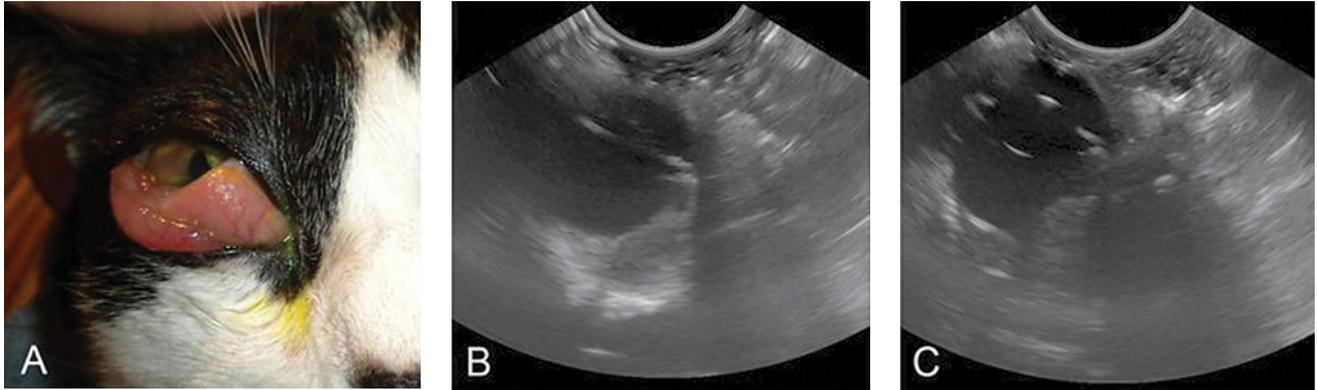


Figure 14.21. Retrobulbar mass/exophthalmos. (A) This 10-year-old cat has had progressive exophthalmos for three to four weeks. Note the exophthalmos, elevated nictitans, chemosis, and globe deviation dorsally. The globe is so exophthalmic that the lids cannot close (lagophthalmos), causing a small corneal exposure ulcer and secondary uveitis with mild miosis. The marked chemosis and hyperemia of the bulbar conjunctiva and nictitans are due to the protruding globe causing tight compression of the lower lid against the globe. (B) Ocular ultrasound shows a distinct rounded echogenic mass behind the globe on the right side of the globe, which is on the left side of the image. Note that the mass is slightly indenting the globe, which is causing a visible indentation that can be seen when viewing the fundus. The full lens is not imaged well at this angle but is normal. (C) In this second view of the same mass, a larger, more echolucent area is seen to extend from the mass, causing even more distortion to the normal globe contour. This mass was most likely neoplastic, but further diagnostics were declined by the owner.

- The mass may be attached to or separate from the globe

Check ultrasonographically or on fundic exam, if visible, for any motion of the mass relative to the globe; if the mass stays separate from the globe when the gaze is redirected, it is more likely to be non-inflammatory (neoplasia or a cystic structure).

- Most common differentials include abscesses (generally acute onset and very painful on opening mouth), soft tissue or bony neoplasia (generally gradual onset and of varying degrees of pain; may not be painful at all)
- Other less likely differentials include cysts (including sialoceles), foreign bodies, cellulitis or inflammation of retrobulbar tissues (sialoadenitis, extraocular muscle myositis), bony orbital masses, hamartomas, vascular anomalies, parasitic disease

A lateral orbital location may be more suggestive of abscess than neoplasm.

- Bony destruction is more indicative of neoplasia, and may be more easily detected using radiography

Actions

- If neoplasia is suspected, initiate a work-up to screen for metastatic disease including baseline blood work, urinalysis, skull and thoracic radiography with or without abdominal imaging (ultrasonography, radiography); referral to a veterinary ophthalmologist or surgeon may be necessary.
- If an orbital abscess is suspected and supported by findings of pain, ipsilateral soft palate swelling, gross dental disease, leukocytosis, lethargy, with or without fever, perform an oral exam and appropriate imaging (e.g., dental and skull radiographs) with applicable dental treatment; if found, perform oral abscess exploration, drainage, cytology, biopsy, and culture as indicated; prescribe systemic antibiotics and analgesics; referral to a veterinary ophthalmologist, surgeon, or dentist, as per clinical impression may be necessary. Fine needle aspiration of suspected retrobulbar masses is risky due to the possibility of hemorrhage, iatrogenic globe puncture, or nerve damage, but is often diagnostic for neoplasia and infection when the needle is appropriately placed. Aspiration aided by simultaneous ultrasound can reduce these risks. Vascular anomalies, although extremely rare, may develop significant bleeding when aspirated or biopsied, and may not be amenable to typical hemorrhage control maneuvers. Most cases of primary orbital/periorbital

neoplasia are malignant (e.g., nasal or third eyelid adenocarcinoma, soft tissue sarcomas, osteosarcoma, squamous cell carcinoma, meningioma, glioma, lymphoma) (Kern 1985, Attali-Soussay 2001).

Suspected Globe Rupture

Clinical Findings

- History: suspected or known trauma (vehicular trauma; being struck by objects such as doors, furniture, or toys; fights with other animals including clawed cats and larger dogs, etc.)
- Signalment: variable
- Eye exam: acute ocular pain; globe deformation, gross hypotony, chemosis, subconjunctival hemorrhage; other periocular injuries, lid swelling and bruising; hyphema and/or anterior uveitis (Figure 14.22, also see Figure 14.2); blood, fibrin,



Figure 14.22. Traumatic globe rupture. This dog was kicked by a moose, causing major ocular injury. Note that the corneal contour of the left eye is not spherical but rather appears squashed into a flatter shape by the eyelids. This is because the globe has lost its tension and shape due to a presumptive rent in its wall. Hyphema obscures all the intraocular structures, but a carefully performed ocular ultrasound (not shown) from behind the orbital ligament might reveal the location of the rent and the presence of a retinal detachment, lens luxation, or lens extrusion. It is important to note that in cases of suspected globe rupture, extreme caution should be taken when considering ocular ultrasonography. Avoid any direct contact with the suspected ruptured area, and if ultrasound imaging is necessary (to confirm or clarify clinical suspicion) use only sterile gel after adequate topical anesthesia, or the retrobulbar view, if at all. Any pressure at all to the globe or resistance by the patient will cause further eye damage. The patient may be better served by avoiding ultrasound altogether and simply referring to an ophthalmologist for definitive care.

and dark brown-black uveal tissue may be mounded externally at site of rupture (which might be located somewhere behind the front exposed part of the eye and thus not visible externally); orbital or skull fractures

Ultrasonographic Findings

Extreme care should be used in approaching ocular ultrasonography in cases of suspected globe rupture, if at all. Avoid any direct contact with the suspected ruptured area. Use sterile gel and adequate topical and anesthesia (see above) or the retrobulbar angle, and avoid any pressure at all to the globe and excessive restraint.

The findings include:

- Globe not spherical as is normal
- Globe may be smaller than the other eye (compare diameter of each eye)
- Eye wall may not clearly visible in all views; intraocular structures may seem to blend in with adjacent extraocular structures consistently in one location
- Will often be accompanied by sonographic evidence of retinal detachment, vitreal hemorrhage, and/or lens luxation or loss (see above corresponding sections)
- The interior of the whole globe may appear heterogeneously echogenic (due to the presence of blood and fibrin) except for the lens, which will remain echolucent against this echogenic background if present

If the eye is too painful to be imaged with topical anesthesia and other clinical signs suggest globe rupture, the patient may be better served by avoiding ultrasound altogether due to the potential for causing further damage.

Actions

- Evaluate first for life-threatening trauma such as skull fractures, traumatic brain injury, cavitary hemorrhage, lung contusions, pneumothorax, etc. with a basic trauma work-up.

Stabilize the critical patient before addressing the ocular component.

- Do not aggressively clean off adherent mucus-like material from the eye surface. This may be fibrin that is actually sealing the defect, and removing it may cause a re-leak of intraocular contents as well as acute pain.
- Administer systemic pain medications, systemic anti-inflammatories and analgesics, systemic antibiotics, and topical ophthalmics (antibiotics, atropine; drops preferred, avoid ointments) as dictated by patient.
- Adjust the magnification (depth) to a level adequate to distinguish lesions.
- Adjust the gain both by increasing and decreasing to help discern real findings from artifacts.
- Unless you are very comfortable with your diagnosis and treatment plan, then it is wise to adhere to the following statement: If an eye is diseased enough to require ultrasound, it should most likely be referred to an ophthalmologist for follow up.

The owner's ability to give topical medications may be limited due to patient pain. Due to the possibility of further injury in the act of topical drug administration, topical meds may not be worth the trouble.

- Very carefully place an Elizabethan collar to prevent self-trauma.
- If a penetrating foreign body is seen, leave it in place if immediate, timely referral is possible. If a foreign body is clearly visible, very mobile, and loose enough to fall out on its own before referral to an ophthalmologist is possible, it may be very carefully removed in the clinic under clean conditions with at least topical anesthesia; however there is risk of damaging the eye and causing leakage of intraocular contents, allowing for intraocular infection, bleeding, and increased risk of loss of the eye.
- Many cases will require enucleation; however, referral to a veterinary ophthalmologist may provide options for salvaging the globe and possibly vision.

Pearls and Pitfalls, the Final Say

- It is important to correlate ultrasound findings with clinical ophthalmic signs. Always do a complete ocular examination first when presented with an ocular complaint.
- It is very helpful to compare the abnormal eye to the other eye as a control, especially when the other eye is unaffected.

References

- Attali-Soussay K, Jegou J, Clerc B. 2001. Retrobulbar tumors in dogs and cats: 25 cases. *Vet Ophthalmology* 4(1): 19–27.
- Bayón A, Tovar MC, Fernández del Palacio MJ, et al. 2001. Ocular complications of persistent hyperplastic primary vitreous in three dogs. *Vet Ophthalmology* 4(1): 35–40.
- Book BP, van der Woerd A, Wilkie DA. 2008. Ultrasonographic abnormalities in eyes with traumatic hyphema obscuring intraocular structures: 33 cases (1991–2002). *J Vet Emerg Crit Care* 18(4):383–387.
- Cho J. 2011. Ophthalmic Examination. In *Veterinary Clinical Advisor, 2nd ed.*, edited by E. Cote. St. Louis: Elsevier Mosby, pp 1313–1315.
- Cottrill NB, Banks WJ, Pechman RD. 1989. Ultrasonographic and biometric evaluation of the eye and orbit of dogs. *Am J Vet Research* 50(6):898–903.
- Dietrich UM. 2007. Ophthalmic examination and diagnostics, part 3: Diagnostic ultrasonography. In *Veterinary Ophthalmology, 4th ed.* edited by KN Gelatt. Ames, Iowa: Blackwell Publishing, pp 507–519.
- Dziezyc J, Hager DA. 1988. Ocular ultrasonography in veterinary medicine. *Seminars in Veterinary Medicine and Surgery (Small Animal)* 3(1):1–9.
- Gonzalez EM, Rodriguez A, Garcia I. 2001. Review of ocular ultrasonography. *Vet Radiol and Ultrasound* 42(6): 485–95.
- Kern TJ. 1985. Orbital neoplasia in 23 dogs. *J Am Vet Med Assoc* 186:489–491.
- Mason DR, Lamb CR, McLellan GJ. 2001. Ultrasonographic findings in 50 dogs with retrobulbar disease. *J Am Anim Hosp Assoc* 37:757–762.
- Rampazzo A, Eule C, Speier S, et al. 2006. Scleral rupture in dogs, cats and horses. *Vet Ophthalmology* 9(3):149–155.
- Spaulding, Kathy. 2008. Eye and orbit. In *Atlas of Small Animal Ultrasonography*, edited by D Penninck and MA D'Anjou. Ames, Iowa: Blackwell Publishing, pp 49–90.
- Williams J, W DA. 1996. Ultrasonography of the eye. *Compendium of Continuing Education for the Practicing Veterinarian* 18:667–678.

FOCUSED OR COAST³— MUSCULOSKELETAL

Gregory R. Lisciandro

Introduction

The focused or COAST³ musculoskeletal exam opens an avenue into another new relatively unexplored field in small animal ultrasonographic imaging. The focused musculoskeletal exam is helpful in the rapid detection of fractures, characterization of soft tissue swellings, and use of local and regional nerve blocks. Many of the skills necessary to perform such ultrasound (US) evaluations have been covered in other chapters.

There are anatomical regions that may be radiographically problematic due to the need for multiple views (and potentially difficult patient positioning). There is also risk associated with physical and chemical restraint, along with the inherent level of radiation exposure to technicians performing the studies, and combinations of the aforementioned. However, the use of US may be used advantageously for fracture assessment at the point of care. A good example is head trauma in which skull fractures are suspected; however, the patient is too unstable to take to radiology or is too uncooperative for proper imaging without risky chemical restraint. Furthermore, it may be (and often is) difficult to tell with certainty by standard radiographic views that a fracture exists. Even though US does not penetrate bone, smooth bony surfaces serving as strong reflectors make it fairly reliable to detect fractures with minimal US training. Moreover, in the presence of soft tissue swelling or hematomas that may obscure radiographic imaging, ultrasound performs even better. By scanning along these strongly reflective (bright white) surfaces, inconsistencies from the expected normal linear continuity (looking for “steps” representing fractures) are readily appreciated by non-radiologists.

In considering soft tissue, swellings may be characterized as herniations (small bowel, intra-abdominal organs), abscesses (fluid-filled with air pockets), or solid or fluid-filled masses, thus helping guide therapeutic and diagnostic procedures. Moreover, the detection of foreign bodies within swellings may be made using US (strong shadowing or actual foreign body imaging) (Hosomi 2012, Teng 2012, Bradley 2012).

US is being used in this manner in people because it is safer (radiation sparing), can be delivered at the point of care, is non-invasive, and is less expensive than advanced imaging. Furthermore, US seems to be reliable and advantageous over radiography in many instances.

Finally, US-guided local and regional nerve blocks have improved the efficacy and safety of these procedures. Specific US-designed needles that are readily apparent in soft tissue and US skills developed in identifying vessels (Chapter 12) should help expand types of analgesia available for veterinary patients (brachial plexus, sciatic, distal limb, and other regional nerve blocks).

Due to limitations of the textbook, the primary focus of this chapter is fracture diagnosis with a basic mention of soft tissue swellings.

What the Focused Musculoskeletal Exam Can Do

- Detect fractures of bones that are ultrasonographically accessible, which includes most of the appendicular skeleton and the skull

- Help with evaluating joint effusions and directing diagnostic and therapeutic joint aspiration
- Help differentiate soft tissue swelling such as tumors, abscesses, and herniations
- Help characterize herniated contents and thus make clinical decisions in patient management
- Detect foreign bodies within swellings such as a nail in a paw or a stick in a foreleg using indirect methods including acoustic shadowing principles and artifacts of strong reflectors (ring-down and A-lines)
- Administer US-guided nerve blocks (not covered here)

What the Focused Musculoskeletal Exam Cannot Do

- Limitations for fracture diagnosis along the vertebral column, near joint articulations, and other areas where bone interfaces are irregular
- Cannot replace hands-on ultrasound training for the recognition of various masses including hematomas, abscesses, foreign bodies, tumors, herniation, and others

Indications for the Focused Musculoskeletal Exam

- Evaluation of any undifferentiated or uncharacterized soft tissue swellings prior to fine needle aspiration, biopsy, or surgical exploration
- Evaluation of suspected fracture sites
- Survey of soft tissue swellings for foreign bodies
- Survey of soft tissue swellings for abscess formation
- Survey of soft tissue swelling for herniation

Objectives of the Focused Musculoskeletal Exam

- Recognize fracture sites
- Recognize foreign bodies
- Recognize abscesses
- Recognize herniations
- Determine if a soft tissue mass is fluid-filled or solid

Patient Positioning and Probe Selection

A high-frequency (10–12 MHz) linear probe with various small parts settings including nerves, small parts, and vasculature is ideal. However, curvilinear probes (ideally set on the small parts preset) with variable frequencies from 5–10 MHz are also effective, depending on the area of interest. Shaving over the area is ideal and often performed regardless of whether US is being used (for example, shaving injured soft tissue or skin over injuries or swellings for better inspection, aspiration, exploration, and biopsy, etc.). However, as with other abbreviated exams, particularly the FAST³ exams, imaging is often acceptable by parting the fur and applying 70% isopropyl alcohol and/or applying acoustic coupling gel to the probe head and region of interest.

How to Do the Focused Musculoskeletal Exam

Soft Tissue Swellings

Scan the area of interest through longitudinal and transverse views and through various planes. In a sequential manner, start from the outermost portion and work inward or start at the most central area and work to the periphery. Most important is to be thorough in the interrogation of the area of interest.

In some instances, holding the structure still is helpful while scanning to minimize motion artifact and misinterpretation.

Fracture Site Suspects

Scan the site by first orientating the field of view and optimizing the gain setting for a proximal or near-field hyperechoic border of the bone surface of interest. Once appreciated, follow the bone along its long-axis for deviations from the expected linear continuity of this hyperechoic proximal line (or anterior bright white line), keeping in mind any and all normally present irregularities (protuberances, joint surfaces, ligamentous attachments between bones). In suspect areas that may not be obvious fracture sites, additionally sweep along the bone's short-axis for further clarification.

Ultrasonographic Normal Findings in a Focused Musculoskeletal Exam

Soft Tissue Swellings

Generally speaking, a soft tissue swelling is considered to be abnormal until proven otherwise with wide ranges in clinical significance and prognosis. Thus, there are no “normal” findings to soft tissue swellings.

Normal Bone

Ultrasound does not transmit through bone, so bone itself may not be directly imaged. However, by taking advantage of the strongly reflective surface of bone, referred to as the proximal or anterior hyperechoic bright white line, its cortex may readily be surveyed ultrasonographically (Figures 15.1 and 15.2). The non-radiologist sonographer can easily detect abnormalities from the normal expected linear continuity of many flat and long bones in dogs and cats to ultrasonographically detect fractures. Although not well-studied in small animals, use of US for fracture detection has been recently studied in humans (especially children [long bones, ribs, and skull]) in the emergency department (used by non-radiologist emergency physicians) (Adeyemo 2011, Ramirez-Schrempp 2011, Barata 2012, Ogunmuyiwa 2012, Parri 2012) and in foals (ribs) (Picandet 2007), and has been shown to have high sensitivity, specificity, and

accuracy. In fact, ultrasonography has fared well and even outperformed standard radiography in some cases including pediatric skull fractures complicated by hematomas, long bone fractures, and maxillofacial fractures (Adeyemo 2011, Barata 2012, Ogunmuyiwa 2012, Parri 2012, Ramirez-Schrempp 2011).

Clinical Significance and Implications of Abnormal Findings

Soft Tissue Swellings

Some questions should be routinely answered with each soft tissue swelling evaluation: Is the structure solid? Is it fluid-filled? Or organ-filled? The echogenicity of the soft tissue swelling should be ascertained to answer these questions.

Obvious solid swellings image as homogeneous echogenic structures. However, solid swelling may be more difficult when it is of mixed echogenicity. With that being said, ruling out herniation (occult or suspected by physical examination or radiography) containing obvious ultrasonographically recognizable internal organs or structures prior to aspiration or biopsy proves safer for the patient. Radiography should always be a standard part of the work-up for suspicious herniation.

Obvious fluid-filled structures, especially sterile cysts, generally have decreased echogenicity; however,

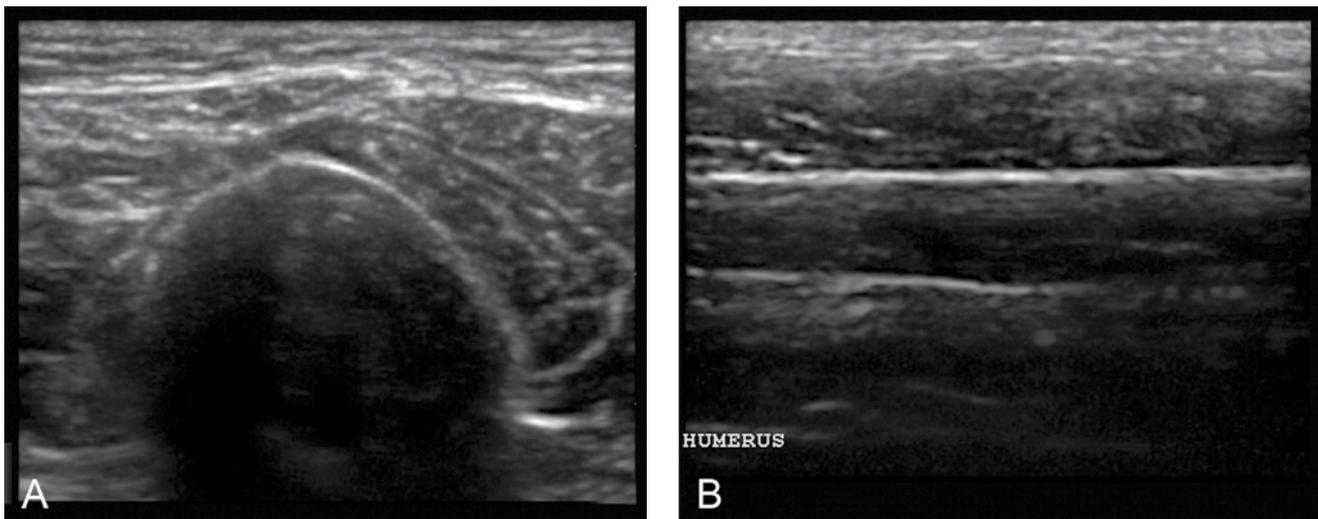


Figure 15.1. Normal scan of the humerus. Using a linear probe, the humerus is imaged along its short-axis (transverse) (A) and its long-axis (B). Note that the proximal (also referred to as anterior) hyperechoic (bright white) line along the cortical bone is obvious and may be followed along its course looking for deviations called step signs that would indicate fracture site(s).

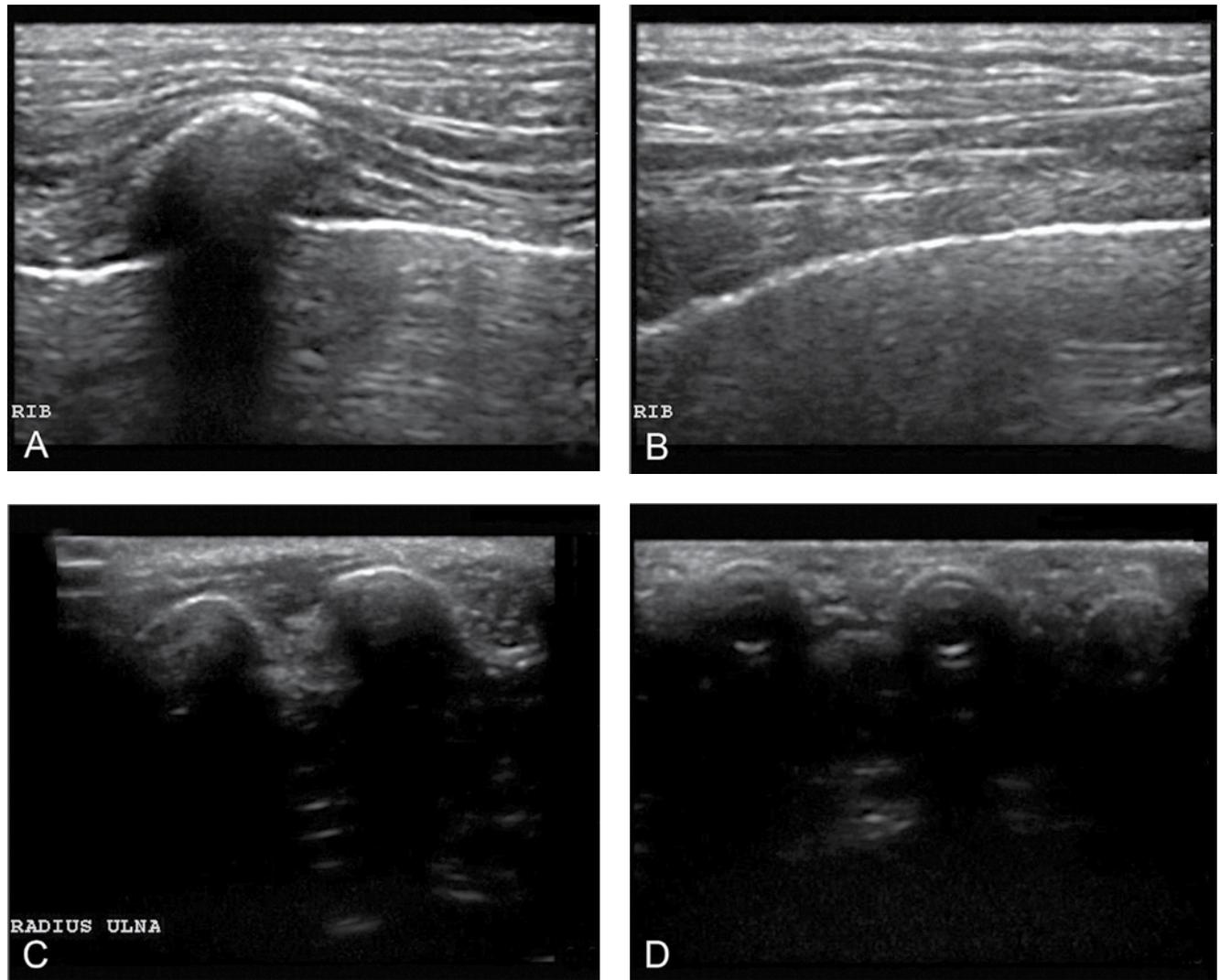


Figure 15.2. Normal scan of the ribs, radius and ulna, and metacarpals. Using a linear probe, the rib is imaged along its short-axis (transverse) (A) and its long-axis (B). Note that the proximal (also referred to as anterior) hyperechoic (bright white) line along the cortical bone is obvious and may be followed along its course looking for deviations called step signs that would indicate fracture site(s). (C) Short-axis or transverse view of the radius and ulna where similarly the proximal hyperechoic line may be scrutinized for fracture site(s). (D) Short-axis or transverse view of the metacarpals where similarly the proximal hyperechoic line may be scrutinized for fracture site(s).

with some abscesses and cysts the fluid may be as echogenic (isoechoic) as adjacent soft tissues. Two tricks of the trade are to remember that (1) ultrasound loves fluid and thus fluid-filled structures create an acoustic enhancement artifact distal to their far border (see Figure 1.6), and (2) that the classic feature of an abscess is the presence of air within the swelling, recognized by shadowing, small comet-tails, or air reverberation artifacts (see examples in Figures 1.4 through 1.8, 12.8, 17.4, and 17.7; and see chapters 1, 6, 7, and 8).

Organ-filled (herniation) structure is an important scenario to rule out to minimize complications (e.g., prior to percutaneous fine needle aspiration or biopsy, or surgical lancing or exploration of the site). On the other hand, prompt recognition of herniation will maximize the correct clinical course with confirmatory radiographic studies (if needed) along with appropriate surgical management (Figure 15.3). In many instances it should be possible to use the target-organ approach of AFAST³ and focused skills of the various intra-abdominal and intrathoracic organs

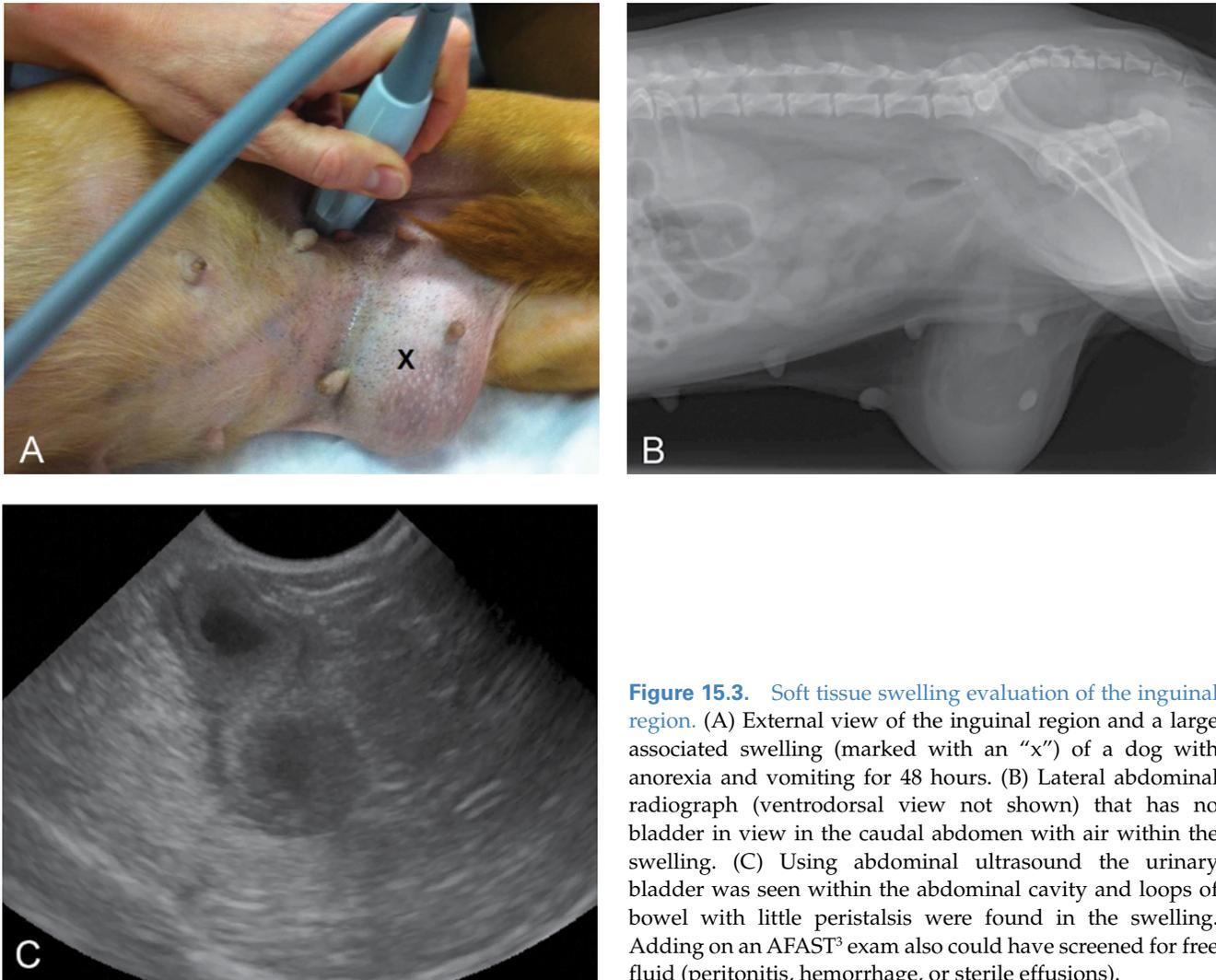


Figure 15.3. Soft tissue swelling evaluation of the inguinal region. (A) External view of the inguinal region and a large associated swelling (marked with an “x”) of a dog with anorexia and vomiting for 48 hours. (B) Lateral abdominal radiograph (ventrodorsal view not shown) that has no bladder in view in the caudal abdomen with air within the swelling. (C) Using abdominal ultrasound the urinary bladder was seen within the abdominal cavity and loops of bowel with little peristalsis were found in the swelling. Adding on an AFAST³ exam also could have screened for free fluid (peritonitis, hemorrhage, or sterile effusions).

and vascular structures to recognize or rule out organs such as the intestines, urinary bladder, kidney, spleen, etc. and vasculature structures within soft tissue swellings (see chapters 3 through 8 and Chapter 12; also see Figures 15.3A through C and Figure 13.12C).

Foreign bodies may be recognized by their direct imaging or more often by the artifacts they create, either by shadowing (similar to that of intestinal foreign bodies and calculi in the urinary bladder, gallbladder, and kidneys) or ring-down or reverberation artifacts (similar to intestinal foreign bodies and needles used in US-guided procedures, chapters 12 and 17)(see Figures 1.4 through 1.8, 12.8, 17.4, and 17.7). Many US images of these artifacts are presented throughout the textbook. An example of good use of

the focused musculoskeletal exam is a case of soft tissue swelling of a foreleg that has an occult (by physical examination) nail or stick foreign body. The nail would likely be detected by radiography; however, the stick may not (and radiography may be declined due to cost by the client). The nail would certainly be a strong reflector (similar to stone [calculi] and bone), creating shadowing or a ring-down artifact (see Figures 1.4 through 1.8, 12.8, 17.4, and 17.7). The stick may possibly be directly imaged or would more likely create similar artifacts. In this scenario, point-of-care imaging during wound inspection and care carries the potential to trigger more aggressive local exploration and foreign body removal as well as the opportunity to again present the client with the need for radiographic imaging. It has only been recently

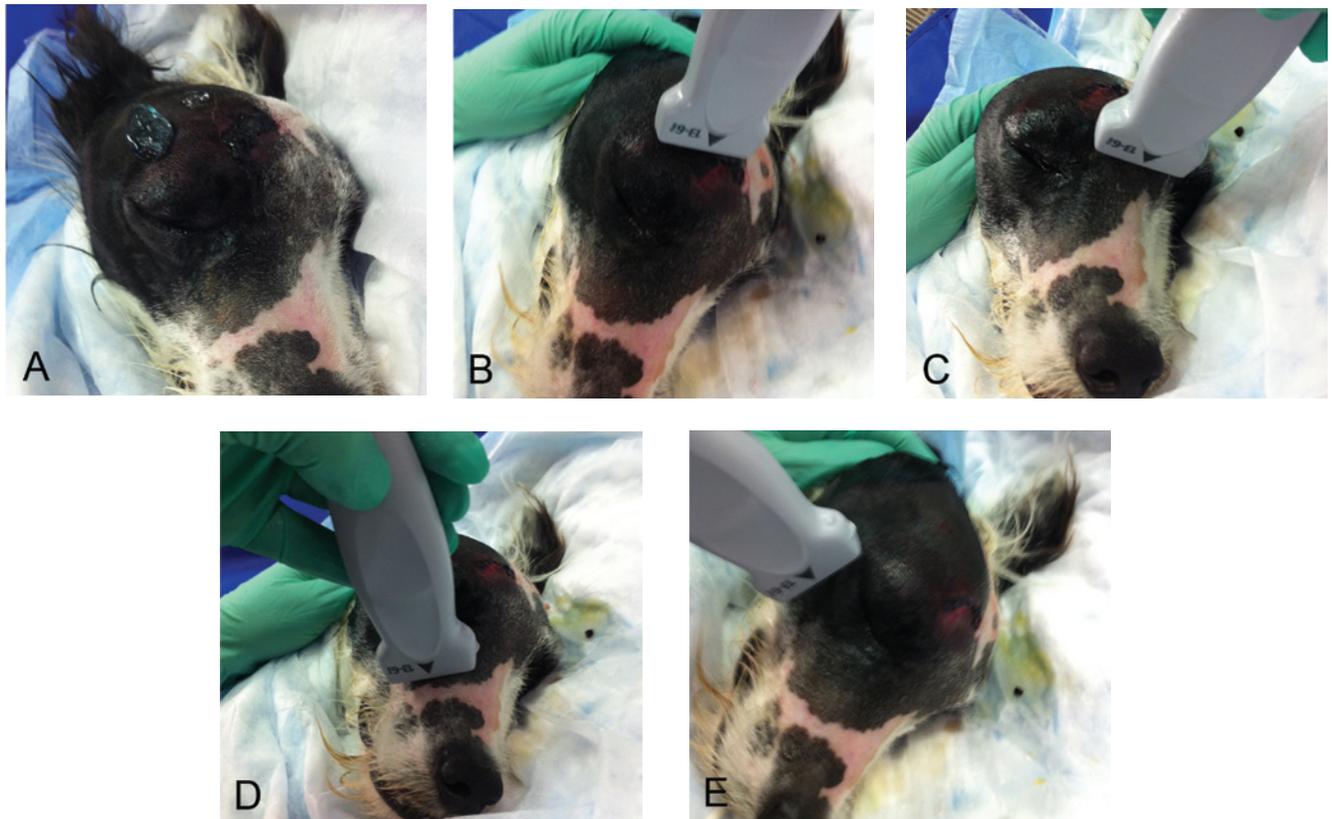


Figure 15.4. Skull fracture protocol. A dog kicked by a horse presented with a large, painful hematoma over its temporal region. The dog was lightly sedated and wound care was performed without knowing whether a fracture was present prior to arranging radiography. A four-point skull survey was performed at the point of care on the treatment table. (A) Shaved head (from wound care) with acoustic coupling gel on the temporal region. (B) Probe placement and survey using ultrasound over the temporal area. (C) Probe placement and survey over the frontal bones. (D) Probe placement and survey over the maxilla. (E) Probe placement and survey over the zygomatic arch region.

that the use of ultrasound in these cases has been found to be effective in people (Hosomi 2012, Teng 2012, Bradley 2012).

Bone and the Detection of Fracture(s)

Long and flat bones are amenable to ultrasonographic imaging because their smooth surfaces yield a proximal or anterior hyperechoic (bright white) line (similar to the PP-line of lung). This proximal bright white line representing the cortex of the bone may be followed along its course for any changes from the expected linear continuity of its surface. These ultrasonographic changes, called steps, are easily recognizable and have shown high sensitivity and specificity in humans and horses. Ultrasound is especially safe in children because it is radiation sparing. The author has used this approach (and found it helpful) for rib, skull, and long bone fractures of the front

and hind legs, especially in the humeral and femoral bones.

As an example, a dog kicked by a horse had a large hematoma on its head and some signs of traumatic brain injury. During wound care the head was gently shaved and cleaned and evaluated prior to radiography. Figure 15.4 shows a four-point skull bone ultrasound survey, including the temporal, frontal bone, maxilla, and zygomatic arch regions. An analogous scan for rib fractures is also shown (Figure 15.5).

The use of ultrasound has also been shown to be superior to radiography with certain fracture types. Importantly, the sonographer should keep in mind that US is most accurate when applied to flat bones (ribs, skull) and for diaphyseal fractures (vs. metaphyseal and epiphyseal fractures). Although the true sensitivity and specificity of US for fracture detection in small animals is unknown, US use for



Figure 15.5. Rib fracture protocol. Shown is a dog with thoracic trauma that may be scanned using ultrasound by moving the probe head along the long-axis of each rib (or those suspected of being fractured). In humans and foals, scanning for rib fractures has proven as reliable or has outperformed standard radiography. The major ultrasonographic confounder in people causing false-positives results from the misinterpretation of white lines along the ribs and their intercostal spaces. However, familiarity with the gator sign in lung ultrasound (see Figure 9.3 and Chapters 10 and 11) should help avoid this in veterinarians skilled in the abbreviated thorax-related techniques.

fractures of flat and long bones in their respective areas of linear smooth continuity should prove reliable. Figures 15.6 and 15.7 show the detection of skull fracture through the four-point skull survey with non-fractured and fractured areas through a hematoma.

Pearls and Pitfalls, the Final Say:

The future of ultrasound use in the musculoskeletal system for fracture detection and soft tissue swelling evaluation is bright and holds far more potential than

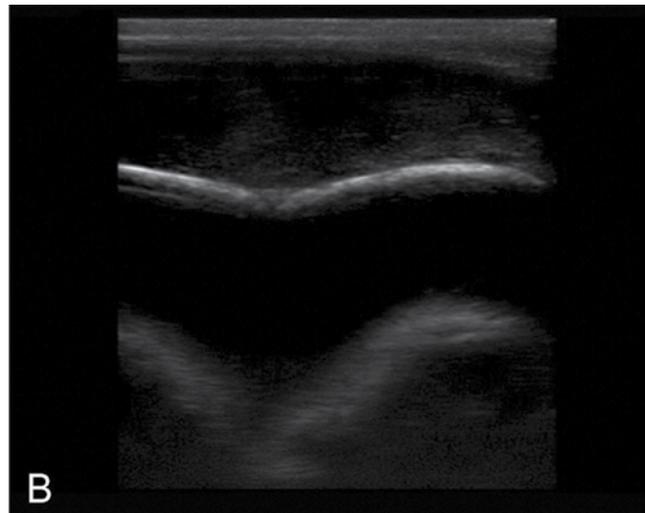
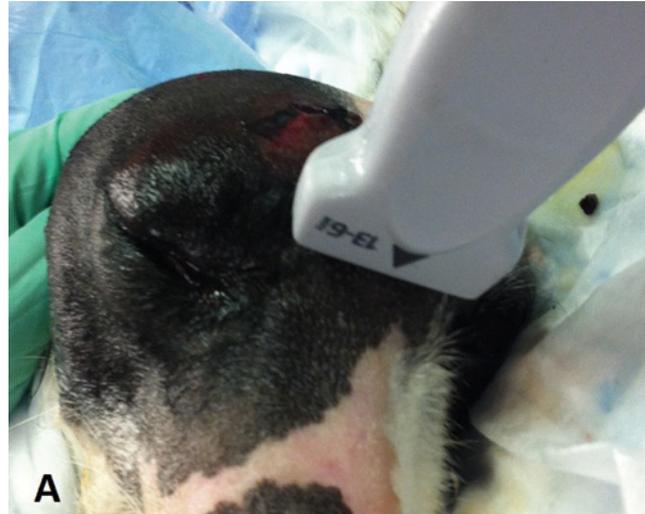


Figure 15.6. Skull fracture frontal bone scan. (A) Probe placement. (B) Corresponding B-mode image of the linear continuity of the proximal hyperechoic line of the normal contour of the frontal bone.

stated in this chapter. Additional future uses include nerve blocks and orthopedic conditions (joint effusions). Through the skills acquired in the basic chapters of the textbook, evaluation of soft and hard tissues should be achievable for basic information that may not be definitive based on physical examination and initial patient evaluation or by radiography during case work-up.

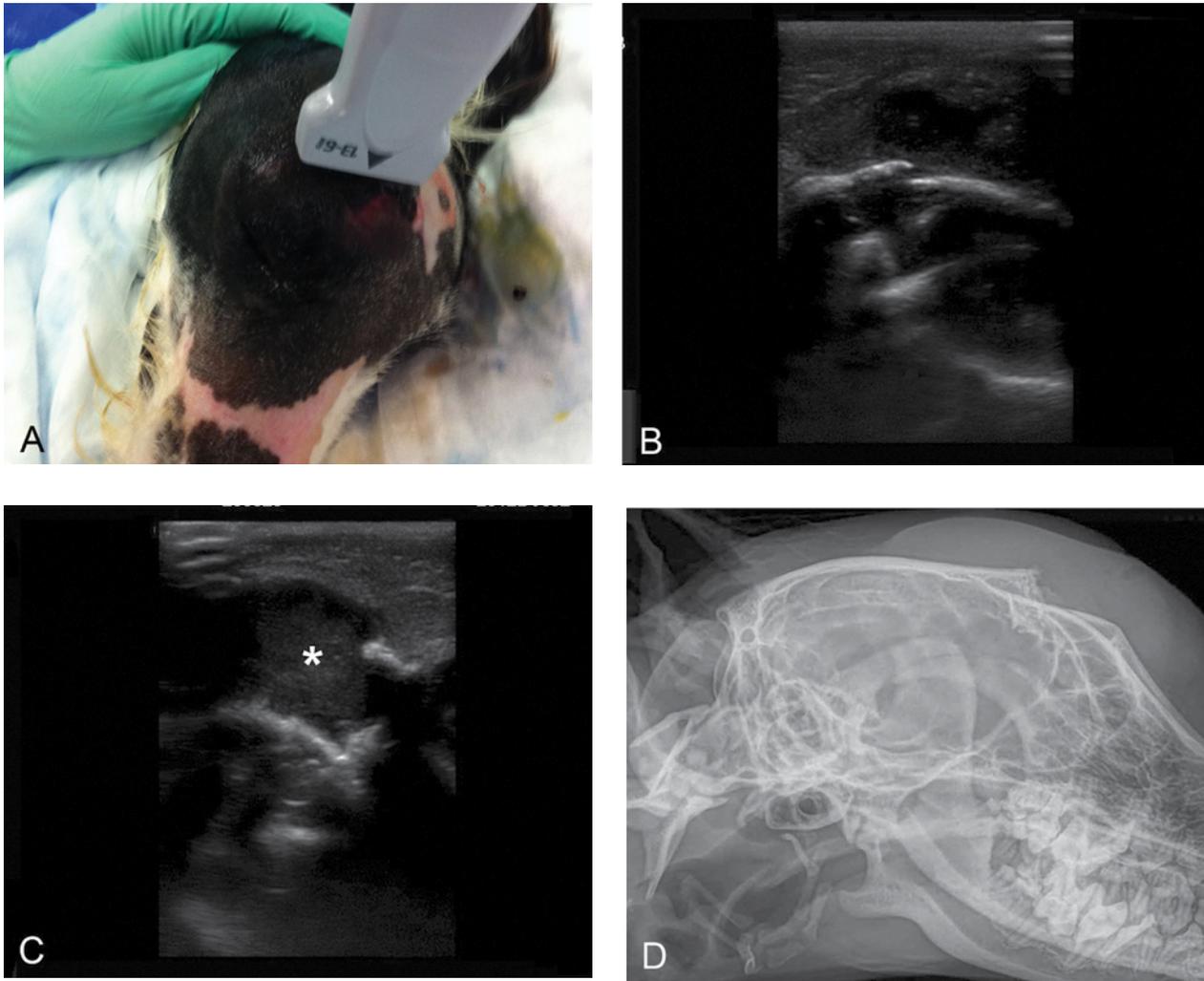


Figure 15.7. Skull fractures with confirmatory skull radiograph. (A) Probe placement and (b and c) the corresponding B-mode images in which there is clear disruption of the expected linear continuity of the proximal hyperechoic line, indicating that a skull fracture is present. The asterisk (*) marks the hematoma (anechoic area). (D) The confirmatory skull radiograph is shown.

References

- Adeyemo WL, Akadiri OA. 2011. A systematic review of the diagnostic role of ultrasonography in maxillofacial fractures. *J Oral Maxillofac Surg* 40(7):655–61.
- Barata I, Spencer R, Suppiah A, et al. 2012. Emergency ultrasound in the detection of pediatric long-bone fractures. *Pediatr Emerg Care* 28(11):1154–57.
- Bradley M. 2012. Image-guided soft-tissue foreign body extraction—success and pitfalls. *Clin Radiol* 67(6):531–4.
- Hosomi S, Rinka H, Watanabe Y, et al. 2012. Cervical impalement injury to a child by a chopstick diagnosed with computed tomography and ultrasonography. *J Anesth* 26(4):598–600.
- Ogunmuyiwa SA, Fatusi OA, Ugboko VI, et al. 2012. The validity of ultrasonography in the diagnosis of zygomaticomaxillary complex fractures. *Int J Oral Maxillofac Surg* 41(4):500–5.
- Parri N, Crosby BJ, Glass C, et al. 2013. Ability of emergency ultrasonography to detect pediatric skull fractures: A prospective, observational study. *J Emerg Med* 44(1):135–41.
- Picandet JD, Macieira S, Beauregard G, et al. 2007. Detection of rib trauma in newborn foals in equine critical care unit: a comparison of ultrasonography, radiography and physical examination. *Equine Vet J* 39(2): 158–63.
- Ramirez-Schrempp D, Vinci RJ, Liteplo AS. 2011. Bedside ultrasound in the diagnosis of skull fractures in the pediatric emergency department. *Pediatr Emerg Care* 27(4): 312–14.
- Teng M, Doniger SJ. 2012. Subungual wooden splinter visualized with bedside sonography. *Pediatr Emerg Care* 28(4):392–4.

FOCUSED OR COAST³— CARDIOPULMONARY RESUSCITATION (CPR), GLOBAL FAST (GFAST³), AND THE FAST-ABCDE EXAM

Gregory R. Lisciandro and Andrea Armenise

Introduction

The use of focused ultrasound (US) for cardiopulmonary resuscitation (CPR) recently has become an important player in rapidly addressing primary causes of cardiopulmonary arrest (CPA) that would otherwise be occult or suspect (Breitkreutz 2007, 2010). The American Heart Association's (AHA) CPR Guidelines have an important table entitled "Treatable Causes of Cardiac Arrest: The H's and T's" that lists potentially treatable causes of CPA (Neumar 2010). The FAST³ and focused formats can rapidly and non-invasively rule in and rule out at the point of care many of the "T"s including tension pneumothorax (PTX), tamponade (cardiac), thromboembolism (pulmonary thromboembolism [PTE]), thrombosis (cardiac), and trauma (authors' addition which includes hemorrhage in spaces [e.g., hemoperitoneum, hemoretroperitoneum, hemothorax, hemopericardium] occult by physical examination and radiography) by applying veterinary FAST³ and focused formats (Neumar 2010). These rapidly identifiable "T"s as causes of CPA are not addressed in veterinary CPR guidelines (Boller 2012), nor is the use of ultrasound for rapid diagnosis and monitoring as outlined in this chapter.

Recently the positive influence of US during CPR has been demonstrated as has US use in related studies including the US confirmation of endotracheal tube

placement, more accurate confirmation of pulseless electrical activity (PEA) and asystole over electrocardiography and physical exam, and the determination of return of spontaneous circulation (ROSC) over capnography. Much of the latter findings were documented in the Focused Echocardiography Evaluation for Life Support (FEEL Protocol) (Zechner 2011, Breitkreutz 2010).

In the previous chapters including AFAST³, TFAST³, Vet BLUE, focused heart, focused eye, and US-guided procedures (central lines and interventional), the reader has been exposed to clinically helpful ultrasound formats having relevant applications during CPA/CPR. Such US applications not only rapidly answer clinical questions as to cause, but also serve for better diagnosing and resuscitating the veterinary patient. Recently a FAST-ABCDE format was evaluated that incorporated AFAST³, TFAST³, and Vet BLUE (referred to as global FAST³ or GFAST³), as well as focused eye and heart exams (Armenise 2012).

The FAST-ABCDE protocol was first developed in human medicine to identify, manage, and treat the most common injuries in trauma patients (Neri 2007) and recently has been translated to veterinary patients (Armenise 2012). FAST-ABCDE is an US extension of the AFAST³, TFAST³, and Vet BLUE as follows: Starting with the upper airways (A), look for any lesions including laryngeal or tracheal problems. Check the

breathing (B), looking for major injuries within the thorax including pneumothorax, pleural effusion, pulmonary-thromboembolism, pulmonary contusion, alveolar-interstitial syndrome and diaphragmatic lesions. Check the thoracic circulation (C) for intrathoracic conditions including pericardial effusion, cardiac tamponade, valvular lesions, and ventricular contractility and filling. Check the abdominal circulation (C), looking for intra-abdominal and retroperitoneal hemorrhage, and volume status via hepatic venous distension and caudal vena caval diameter and its responsiveness to fluid resuscitation. Look for disability (D) using optic nerve sheath diameter (ONSD) for the detection of intracranial hypertension as well as eye lesions. End with exposure (E), which includes serial exams that look for any missed life-threatening lesions, monitor response to resuscitation, and detect complications (Neri 2007, Armenise 2012).

The veterinary FAST-ABCDE protocol has been applied to canine trauma patients and preliminary data show that it has higher accuracy compared to conventional radiology in the diagnosis of trauma lesions (Armenise 2012), similar to prospective AFAST and TFAST studies (Lisciandro 2008, 2009). FAST-ABCDE consists of serial exams often completed in less than 10 minutes, similar to findings in human applications (Neri 2007). After mastering the skills needed for TFAST³, AFAST³, Vet BLUE, and focused eye and heart exams, the FAST-ABCDE add-on evaluations of the eye and upper airway should be achievable for the non-radiologist veterinarian.

Interestingly, mastering the focused eye exam (see Chapter 14) and the “D” of FAST-ABCDE may prove helpful in determining the presence or absence of intracranial hypertension by measuring optic nerve sheath diameter (ONSD), which has been shown to be helpful in traumatized people (Geeraerts 2007). Although normal US ranges for dogs and cats are not well-studied (normal generally considered less than or equal to 3 mm in dogs) (Spaulding 2008), its sensitivity, specificity, accuracy, and clinical relevance is currently being prospectively evaluated (Armenise 2012). Additionally, focused US techniques may be used during resuscitation for rapid central line placement (see Chapter 12), during therapeutic and diagnostic US-guided centesis (see Chapter 17), and to evaluate the return of spontaneous circulation (ROSC) through direct visualization of the heart for coordinated contractions and thus rule out pulseless electrical activity (PEA) (Brietkreutz 2010).

According to the American Heart Association CPR Guidelines, PEA in people is often caused by treatable underlying conditions if such conditions are detected

quickly before the patient incurs significant complications or dies. Moreover, a recent prospective CPR study documented that 75% of people diagnosed with PEA (51% of the total CPR study population) and 35% of people with asystole had echocardiographically demonstrable coordinated cardiac wall motion. As a result, the terms “true PEA” and “true asystole” (those without wall motion on US) have been applied because victims with cardiac wall motion or “pseudo PEA” and “pseudo asystole” had increased survival (Brietkreutz 2010). From these findings and the known high sensitivity and specificity of US for many of the “T”s (rule outs for CPR mentioned above), it has been recommended that US become a standard part of advanced life support protocols for people (Brietkreutz 2010) and similarly veterinary patients (Mann 2013).

In summary, AFAST³ and TFAST³ (referred to as combination FAST³ or CFAST³) (Lisciandro 2012), along with Vet BLUE (together known as Global FAST³ or GFAST³), make up focused CPR. The advantages of GFAST³ are a shorter exam with less technically challenging goals and the use of a single ultrasound probe (and often on the same abdominal presets for AFAST³ and TFAST³ and Vet BLUE). The advantages of FAST-ABCDE are the evaluation of the upper airways, additions to the heart scan, and the evaluation of the optic nerve sheath diameter (ONSD) as a marker for intracranial hypertension. Both GFAST³ and FAST-ABCDE are far more helpful than traditional means, and with proper training can be mastered by the non-radiologist veterinarian, potentially improving CPR efforts and post-CPR management.

What the Focused CPR (GFAST³) and the FAST-ABCDE Can Do

- Rapidly detect several of the “T”s of CPA including tension PTX, tamponade (pericardial effusion), trauma (bleeding in large spaces such as pleural, peritoneal, retroperitoneal), and possibly thromboembolism (lung) and thrombosis (heart [myocardial infarction and its sequelae of ventricular fibrillation])
- Rapidly assist in diagnosis through the triggering of interventional ultrasound-guided procedures (see Chapter 17)
- Determine ROSC by direct visualization of synchronized heart contractions
- Differentiate between ROSC and PEA

- Confirm whether “pseudo” or “true” asystole is present, as has been shown in humans who have flatline ECG tracings yet have coordinated heart movements on focused heart scans
- Assist in resuscitation by detecting the presence or loss of ROSC and determining the volume status and contractility (left-ventricular short-axis [“mushroom” view] and long-axis views), left-sided volume status (Vet BLUE—presence of ultrasound lung rockets [ULRs]), and right-sided volume status (diaphragmaticohepatic [DH] view—caudal vena caval responsiveness and size, and degree of hepatic venous distension)
- Potentially assist in resuscitation by detecting the presence of intracranial hypertension by measuring optic nerve sheath diameter
- Monitor for complications of CPR such as PTX, pulmonary edema or lung contusions, bleeding into any major spaces, hypovolemia, the development of intracranial hypertension, and others
- May be able to indirectly characterize interstitial edema as blood (lung contusions) vs. forms of pulmonary edema by correlating lung US findings and their distribution with the patient’s clinical profile

What the Focused CPR (GFAST³) and the FAST-ABCDE Cannot Do

- Cannot detect several of the “H”s of CPA including electrolytes, blood glucose, body (or core) temperature disturbances, and hypoxemia
- Cannot replace blood pressure and electrocardiographic monitoring
- Cannot replace arterial venous blood gas and other respiratory monitoring
- Cannot characterize effusions based on echogenicity

Indications for Focused CPR (GFAST³) and the FAST-ABCDE Exam

Focused techniques are helpful in any CPA/CPR event and should be incorporated as resources dictate for resuscitation

Objectives of the Focused CPR (GFAST³) and the FAST-ABCDE Exam

Perform the outlined focused exams as they pertain to CPA/CPR management during the event and post resuscitation.

Ultrasound Settings, Probe Preferences, and Patient Positioning

Global FAST or GFAST³

A curvilinear probe with a range of 5–10MHz is usually acceptable for most dogs and cats. Use standard abdominal settings with depth adjustment to be able to visualize the standardized AFAST³, TFAST³, and Vet BLUE views (Figure 16.1; also see chapters 2, 9, and 10). AFAST³ settings may be maintained through the beginning of the TFAST³ exam and its pericardial site (PCS) views, thus completing six of eight of the points with little change in depth or gain in most cases (Figure 16.1D). After completing the TFAST³ PCS views, increase the depth (zoom closer generally 4–6cm for lung) for the final TFAST³ CTS views and the Vet BLUE Lung Scan (see chapters 9 and 10).

Right lateral recumbency is preferable for AFAST³ and the TFAST³ pericardial (PCS) views. The patient should then be moved to sternal recumbency for the TFAST³ chest tube site (CTS) views and the Vet BLUE lung scan. A modified sternal recumbency may be used for AFAST³ in respiratory-compromised patients by allowing sternal recumbency in the forelegs and swinging both hind legs toward the sonographer in lateral recumbency. Sternal recumbency is used in all respiratory-distressed patients; however, the abdominal fluid scoring system is not valid with this positioning. Dorsal recumbency is never used for these exams due to the high prevalence of intrathoracic and lung injury in traumatized dogs and cats that will be compromised in dorsal recumbency. Refer to each individual chapter regarding AFAST³, TFAST³, and Vet BLUE for more detail. Briefly, no sites are shaved but rather the fur is parted and 70% alcohol or acoustic coupling gel is applied. Please note that 70% isopropyl alcohol should not be used if electrical defibrillation is anticipated because alcohol poses a burn hazard to the patient and a serious fire hazard to the hospital environment.

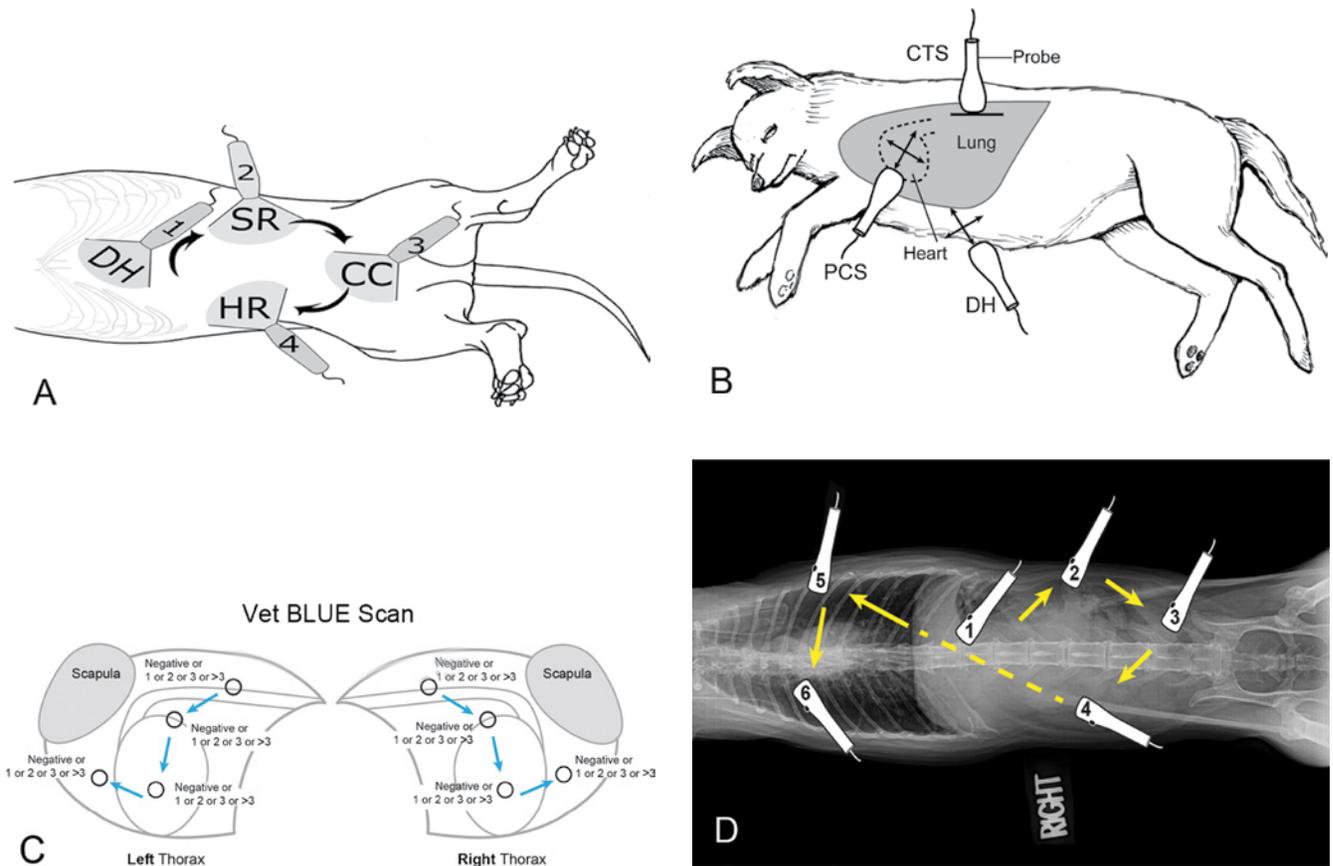


Figure 16.1. Global FAST³. (A) Abdominal FAST³ (Lisciandro 2011, see Chapter 2 for more detail). (B) Thoracic FAST³ (Lisciandro 2011, see Chapter 9 for more detail) © Gregory Lisciandro and Nancy Place (C) Vet BLUE lung scan (Lisciandro 2013, see Chapter 10 for more detail). Vet BLUE serves as a more comprehensive lung scan than TFAST³ alone and should be considered an extension of the TFAST³ chest tube site (CTS) view using the same settings and probe orientation. Vet BLUE typically adds only 90 seconds or less onto TFAST³. © Gregory Lisciandro and Nancy Place (D) A ventrodorsal radiograph of a feline turned to appear as if in lateral recumbency. The numbered probes and arrows show that AFAST³ may be efficiently combined with TFAST³ (called combo FAST³). Advantageously, six of eight views of combo FAST³ are rapidly performed (less than three to four minutes) using nearly the same ultrasound settings (depth, gain) on the abdominal preset. Global FAST³ generally only requires changing ultrasound settings a final time for the TFAST³ CTS view and Vet BLUE (by decreasing depth [4- to 6-cm range] for the lung scan portion). Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

The author (GL) does not shave patients or dim the lighting and generally continues with the abdominal setting for heart and lung when performing GFAST³. Regarding environmental lighting the Focused Echocardiographic Evaluation in Life (FEEL) Support protocol showed that US imaging was not compromised by ambient light (Breitkreutz 2010).

FAST-ABCDE Exam

The ultrasound settings and probe preferences are similar to those used with focused CPR (GFAST³). However, a phased-array (also called sector) probe (see Figure 1.12) is preferred for the heart to better

evaluate cardiac performance, and a linear probe (see Figure 1.12) is preferred (over curvilinear) for optic nerve sheath diameter (ONSD) evaluation. The remaining FAST-ABCDE scans may be performed with a multifrequency microconvex (curvilinear) probe (5–8 MHz), which allow adequate evaluation of both superficial and deep structures over a wide range of patient sizes. If necessary, the same multifrequency microconvex (curvilinear) probe can be used to assess the heart and the eye, although with a less resolution.

The patient positioning is generally the same as for focused CPR (GFAST³) with the same concerns regarding minimizing the stress of respiratory-compromised patients by allowing sternal recumbency. Lateral recumbency is acceptable as noted in

Focused CPR (GFAST³). Fur is often clipped (not so in GFAST³ because imaging is often adequate and the patient maintains a cosmetically pleasing appearance for the owner) to reduce artifacts. Solutions of 70% isopropyl alcohol should not be used if electrical defibrillation is anticipated because alcohol poses a burn hazard to the patient and a fire/explosion hazard to the hospital environment. Alternately the author (AA) has used acoustic coupling gel or a saline solution.

How to do the Focused CPR and the FAST-ABCDE Exam

Focused CPR

Focused CPR includes the combination of AFAST³, TFAST³, and Vet BLUE (GFAST³). If the patient is not shaved or is minimally shaved (which is typically not necessary), GFAST³ may be performed in several minutes. These techniques are shown in Figure 16.1 and discussed in great detail in Chapters 2, 9, and 10. GFAST³ also may be used for guiding fluid resuscitation including patient volume status and right- and left-sided cardiac status by evaluating for forms of pulmonary edema (presence of ultrasound lung rockets [ULRs]), left-sided volume and contractility (left ventricular short-axis “mushroom” view), and right-sided preload (caudal vena caval size and hepatic vein distension) (Figure 16.2A, C, H, I; also see Figures 11.8 and 11.9) (Brietkreutz 2010, Lichtenstein 2012, Lichtenstein and Karakitsos 2012, Lisciandro 2011).

The FAST-ABCDE Exam

Airway (A): Ultrasound airway assessment begins with a rapid transverse scan of the larynx and the trachea and then proceeds distally to the thoracic inlet. The larynx normally appears ultrasonographically as a hyperechoic (bright) structure behind the thyroid cartilages (Figure 16.3A and B). In contrast, the trachea appears as one or two hyperechoic (bright) curves surrounding a hypoechoic (dark) space followed by air reverberation artifact (several A-lines due to the presence of free air) (Figure 16.3C and D). Endotracheal placement may also be confirmed using US as follows: directly by looking for the presence of a hyperechoic linear artifact below the normal tracheal appearance (Chou 2011), by visualizing an improperly placed endotracheal tube in the esophagus next to the trachea (double track sign) (Figure 16.4A and B), or indirectly by looking for the presence of the glide sign (Weaver 2006, Zechner 2011). The latter has been shown to be

faster and equally or more reliable than chest auscultation and capnography for confirming tracheal intubation in people (Pfeiffer 2012).

The complete upper airway evaluation is performed in less than 1.5 minutes providing important information regarding the presence or absence of normal regional anatomy (muscles, veins and arteries, thyroid); and the integrity of upper airway structures. In particular, the upper airway evaluation helps in ruling in or ruling out laryngeal paralysis by routinely observing for laryngeal motion during respiration; and the diagnosis of tracheal collapse by direct visual estimates and comparison between the diameter of the first and most distally accessible cervical tracheal rings during the phases of respiration (Rudorf 2001, Eom 2008) (Figure 16.5A and B).

Breathing (B): Thoracic evaluation consists of a full scan of both hemithoraces that surveys the thorax in upper, middle, and lower thirds on both the right and left sides between the fourth and ninth intercostal spaces. This is similar to the regional evaluation of caudodorsal lung (upper third), perihilar lung (middle third), and middle and cranial lung (lower third), but with a little more scrutiny as you move through adjacent intercostal spaces at each of the upper Vet BLUE regions (Figure 16.1C). The “B” exam is essentially the Vet BLUE lung scan with more detail along intercostal spaces cranially and caudally.

By using lung ultrasound in this manner, the sonographer can better characterize the type of lung injury including pneumothorax (A-lines with no glide sign), pulmonary contusions (ULRs, also referred to as B-lines), forms of pulmonary edema (ULRs in the clinical context of trauma patients [pulmonary contusions are generally more common than lung edema]), and lung consolidation (shred sign, tissue sign [severe pulmonary contusions]) (see Chapter 10; Figures 10.5, 10.9, 10.10, and 10.16D).

The importance of evaluating the thorax in thirds is especially important when PTX is present to determine the location of the lung point and thus assess the degree of PTX as partial (degree of partial based on where the lung point is found on the thoracic wall) or massive (not found) (Figure 16.6A and B) (Lisciandro 2011, Volpicelli 2012). The lung point is the physical location along the thorax where aerated lung reopposes the thoracic wall, most commonly determined by finding the resumption of the glide sign (see Figure 9.5) or ULRs (see Figure 9.6). However, the lung pulse is a third, more subtle lung US finding, defined as collapsed lung directly against the thoracic wall gliding rhythmically with the heart beat (Volpicelli 2012) rather than with inspiration and expiration. The

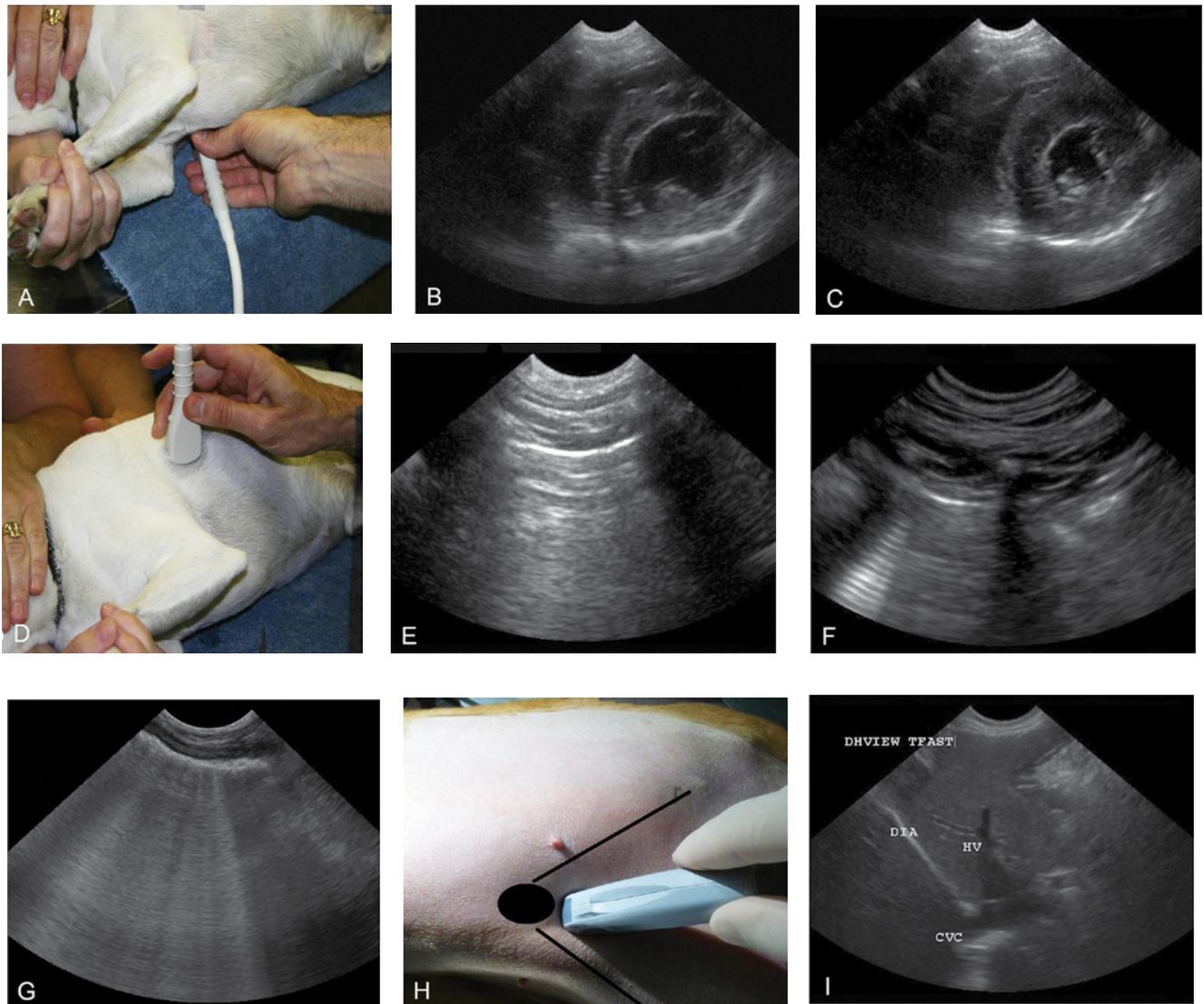


Figure 16.2. Demonstration of how volume status may be assessed using standard GFAST³ views. (A) Probe position at the right pericardial view of TFAST³ for the left ventricular (LV) short-axis “mushroom” view of the heart. Contractility and volume status may be subjectively assessed by observing the minimum and maximum sizes of the mushroom. (B) Good volume status (maximum distension of the LV short-axis view). (C) Poor volume status compared to (B). In severe hypovolemia the LV papillary walls (the waist of the mushroom) may be seen touching or “kissing” one another. (D) Probe position and horizontal stationary TFAST³ chest tube site. By surveying the CTS view and continuing with the Vet BLUE lung scan, ultrasound lung rockets (ULRs) representing left-sided volume overload are easily recognized. (E) “Glide sign” in real-time with A-lines representing dry lungs. (F) Single ULR representing interstitial edema, which is considered an early sign of pulmonary edema from left-sided volume overload during resuscitation. (G) Multiple ULRs still seen individually in real-time. When worsening beyond this state (not shown), ULRs will blend together (see Figure 10.14 and Chapter 10). Importantly, the finding of ULRs (US is more sensitive than thoracic auscultation [the stethoscope] and thoracic radiography) represents interstitial edema, which precedes more serious alveolar edema (flooding of alveoli) and thus gives the opportunity for the attending veterinarian to modify therapy accordingly. (H) Placement of the probe at the diaphragmatico-hepatic (DH) site (right lateral recumbency) for the evaluation of the caudal vena cava (CVC) as it passes through the diaphragm for right-sided (cardiac) volume status. The gallbladder is viewed by first directing the probe slightly toward the table top from the position shown at the xiphoid (black oval). The black V-shaped lines represent the costal arch (head to left). The CVC and branching hepatic veins are generally viewed by then directing the probe either slightly farther toward (sometimes slightly away) the table top or deeper along the diaphragm. Notice how the CVC as it passes through the diaphragm looks like a bright white (hyperechoic) equal (=) sign. (I) A single example of the FAST³ diaphragmatico-hepatic (DH) view showing the CVC as it passes through the diaphragm (DIA) and the congested branching hepatic veins (HV), likened to tree trunks. Dynamic responsiveness of the CVC as well as hepatic venous distension may be used to determine patient volume status (pre-load) and response to fluid resuscitation, and as evidence of right-sided heart dysfunction (overload). Normally the hepatic veins are small and unremarkable when surveying the DH view. Importantly, using these views, GFAST³ volume assessment may be used before, during, and after resuscitation. Figures 16.2A-G © Gregory Lisciandro

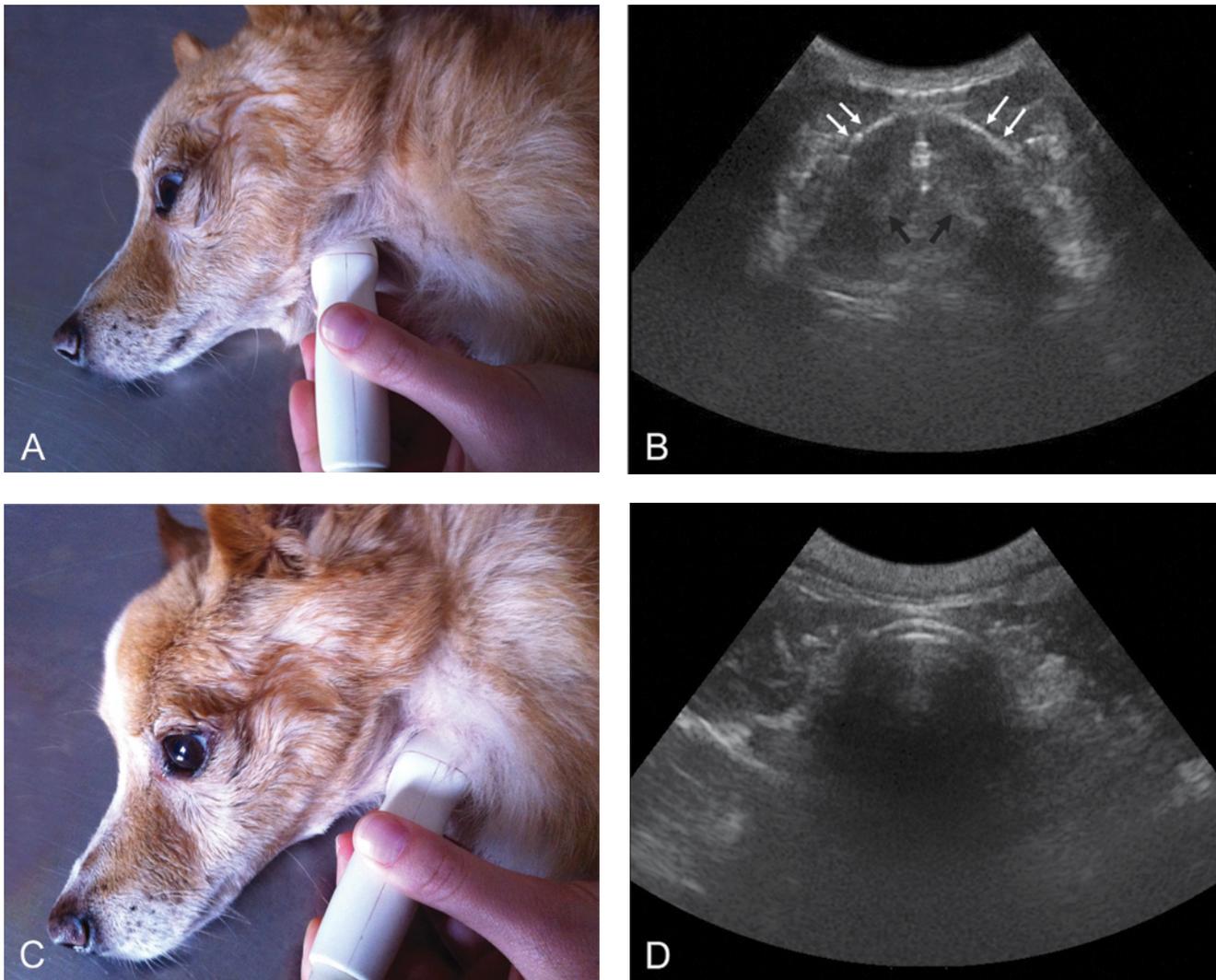


Figure 16.3. Upper airway evaluation using FAST-ABCDE. (A) External probe position on the neck of a dog for laryngeal evaluation. (B) Transverse image of a normal canine larynx. The hyperechoic linear structure is the thyroid cartilage (white arrows). The bilaterally isoechoic structures are a part of the arytenoid cartilage (black arrows). (C) External probe position on the neck of a dog for tracheal evaluation which continues from the caudal laryngeal region to the thoracic inlet. (D) Transverse image of a normal canine trachea (also see Figure 16.5). The trachea appears as two hyperechoic (bright) curves surrounding a hypoechoic (dark) space. Only the ventral aspect of the trachea can be visualized when it is air-filled. This is characterized by a near field hyperechoic (bright white) line followed by air reverberation and strong distal shadowing.

FAST-ABCDE breathing evaluation usually requires less than three or four minutes (Armenise 2012).

Circulation (C), thoracic: Thoracic circulation views are identical to the TFAST³ pericardial site (PCS) views (and parasternal echocardiographic views) located along the right fourth to sixth intercostal space on the ventrolateral thoracic wall between the sternum and costochondral junctions. The right PCS is used for both long-axis (four-chamber) and short-axis (right and the left ventricular mushroom view) of the heart. The same

scan is applied bilaterally again for the analogous cardiac views (Figure 16.7A through D). These views rapidly provide important information regarding the presence of pericardial and pleural effusions, heart contractility, heart valve integrity, and subjective heart chamber dimensions for volume status (also see chapters 9 and 11).

Circulation (C), abdominal: The abdominal circulation evaluation includes the AFAST³ for the detection of hemoabdomen, hemoretroperitoneum,

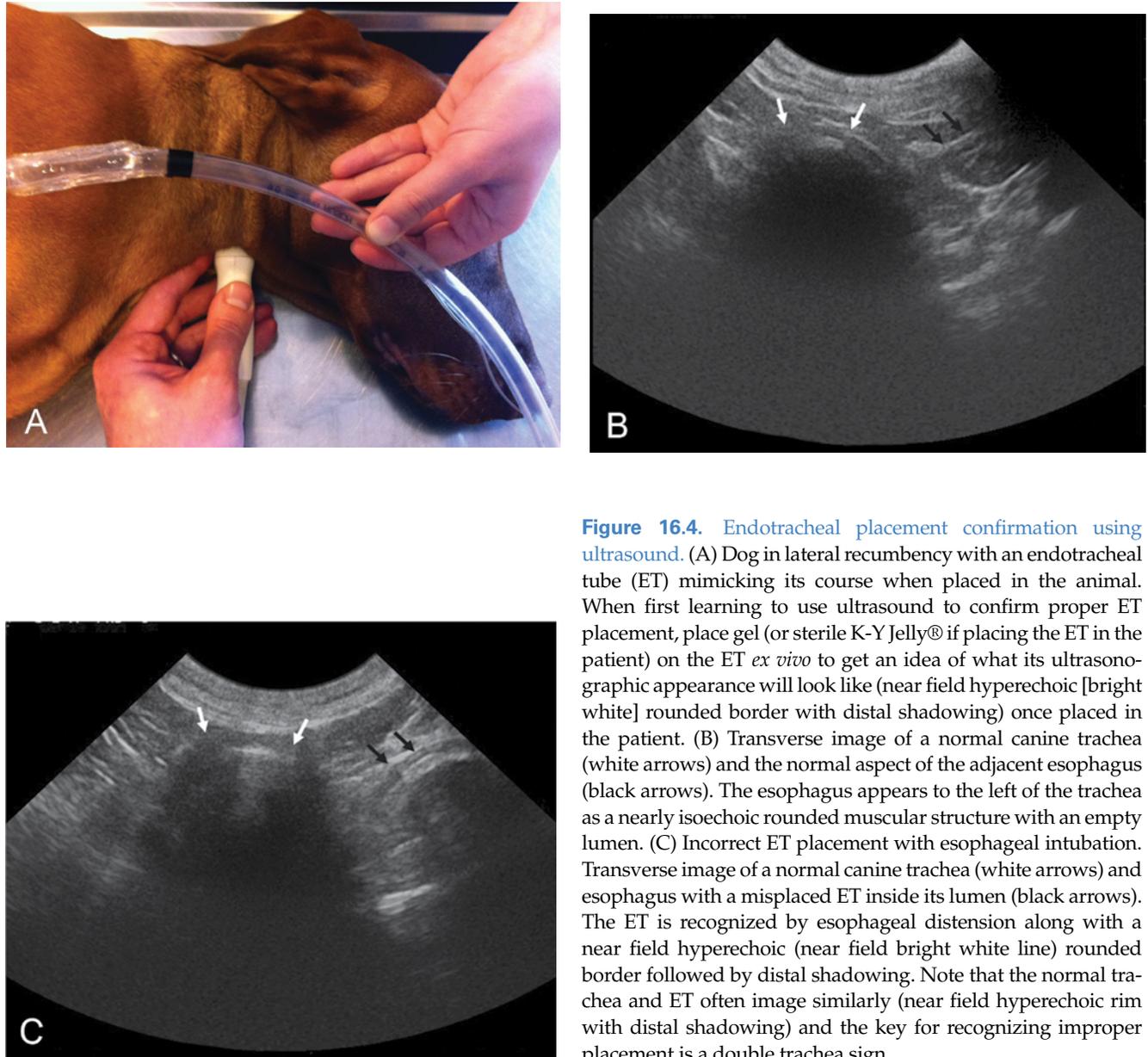


Figure 16.4. Endotracheal placement confirmation using ultrasound. (A) Dog in lateral recumbency with an endotracheal tube (ET) mimicking its course when placed in the animal. When first learning to use ultrasound to confirm proper ET placement, place gel (or sterile K-Y Jelly® if placing the ET in the patient) on the ET *ex vivo* to get an idea of what its ultrasonographic appearance will look like (near field hyperechoic [bright white] rounded border with distal shadowing) once placed in the patient. (B) Transverse image of a normal canine trachea (white arrows) and the normal aspect of the adjacent esophagus (black arrows). The esophagus appears to the left of the trachea as a nearly isoechoic rounded muscular structure with an empty lumen. (C) Incorrect ET placement with esophageal intubation. Transverse image of a normal canine trachea (white arrows) and esophagus with a misplaced ET inside its lumen (black arrows). The ET is recognized by esophageal distension along with a near field hyperechoic (near field bright white line) rounded border followed by distal shadowing. Note that the normal trachea and ET often image similarly (near field hyperechoic rim with distal shadowing) and the key for recognizing improper placement is a double trachea sign.

and other effusions (Figure 16.1A), and the AFAST³ diaphragmatico-hepatic (DH) view for a subjective look at caudal vena caval (CVC) diameter and its responsiveness to fluid therapy (see Chapter 2 for more detail). The latter uses the FAST³ (DH) view to image the CVC passing through diaphragm and branching into hepatic veins (Figure 16.2H and I and Figure 16.8A). The general rule in human resuscitation is that fluid resuscitation continues as long as the inferior vena caval diameter shows responsiveness during fluid challenges by distending (larger diameter) and contracting (smaller diameter) with pre- and post-fluid boluses, respectively. Once the inferior vena

cava remains distended, losing this dynamic change, patient preload has been maximized (Moretti 2010, Machare-Delgado 2011). A veterinary paper similarly demonstrated that intrathoracic CVC diameter (reflecting central venous pressure) and hepatic venous distension were markers of preload volume in experimentally resuscitated dogs. Furthermore, the gallbladder develops a halo sign and the pancreas develops edema with volume overload (Nelson 2010) (Figure 16.8).

Disability (D): The disability evaluation consists of measuring the optic nerve sheath diameter (see details for eye preparation and the mandated use of safe,

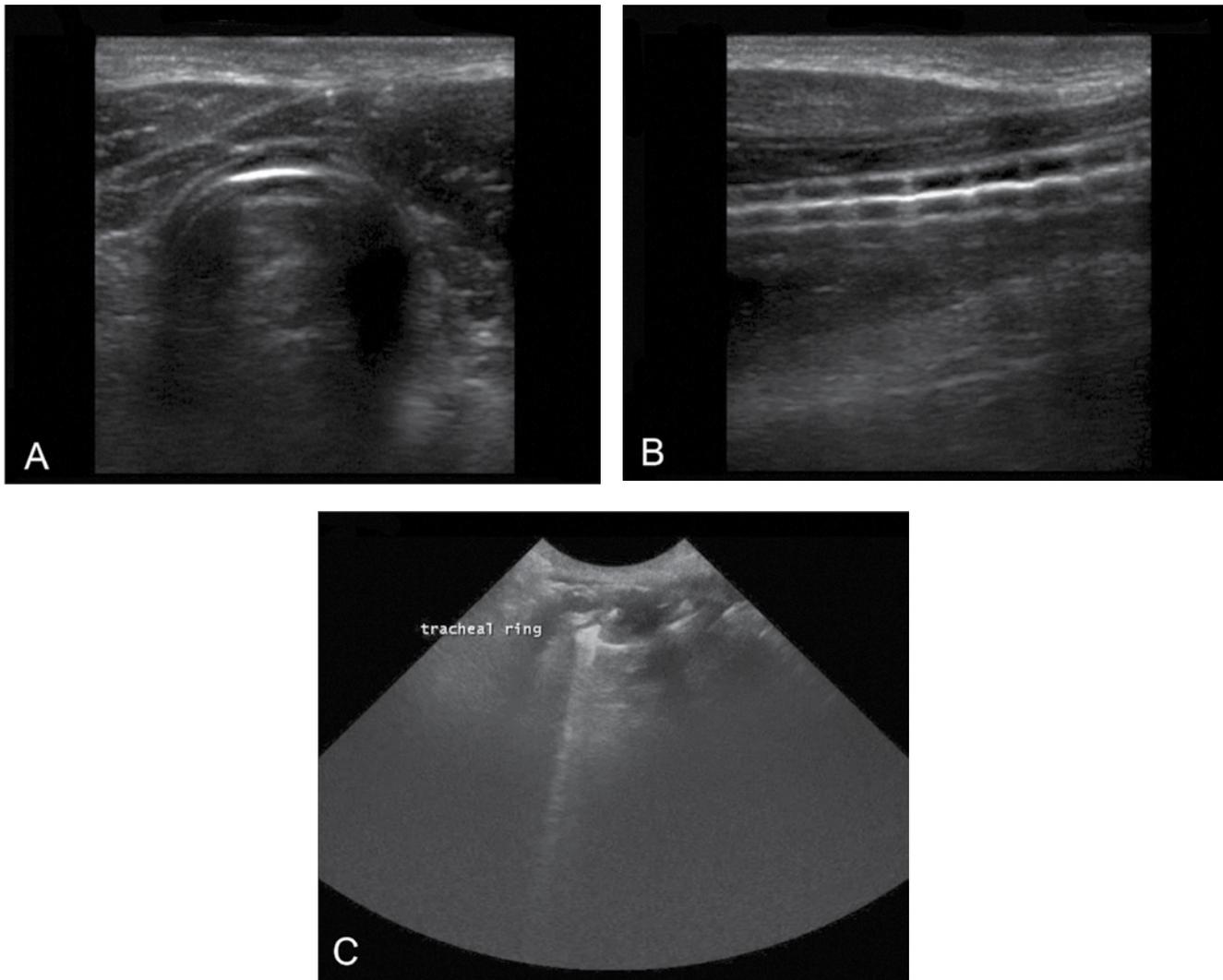


Figure 16.5. Upper airway evaluation using FAST-ABCDE. (A) Using a different ultrasound (US) machine than in Figures 16.3 and 16.4, the near field hyperechoic rim is similar in transverse but doubled with a second parallel line. (B) The longitudinal view of the same trachea shows the spacing of tracheal rings and the linear continuity in very good detail. The point is to be familiar with how your US machine images the trachea to maximize correct US interpretation. (C) Tracheal rupture, laceration, or other injury is recognized by observing disruption of the normal continuity of the trachea's near field (bright white line) border. Here in transverse (using the same machine as in Figures 16.3 and 16.4), the trachea's normal linear continuity is not visualized because of tracheal rupture and its associated deviations and shadowing from maligned cartilaginous tracheal rings. © Gregory Lisciandro

aqueous-based ultrasound gel in Chapter 14). The ONSD is measured 3 mm behind the globe using a caliper oriented perpendicular to the optic nerve's long-axis axis (Figure 16.9). Once the technique is mastered, it should be standardized by scanning in the same manner to achieve the best results. The author (AA) evaluates the left eye with a horizontal view through the ventral eyelid, thus visualizing the optic nerve to the right of the screen when the probe marker is directed to the sonographer's left while facing the

patient (Figure 16.9A). The optic nerve has a curved course as it leaves the posterior eye, and it appears as an isoechoic line bordered by a hypoechoic line, both laterally and medially (Figure 16.9). Alternately, the ONSD scan may be performed directly on the cornea (Chapter 14, see Figures 14.5, 14.6, 14.7).

The optic nerve is an extension of the central nervous system (CNS) because of the intraorbital sub-arachnoid space that surrounds it. Thus, it is subject to the same pressure changes as the intracranial

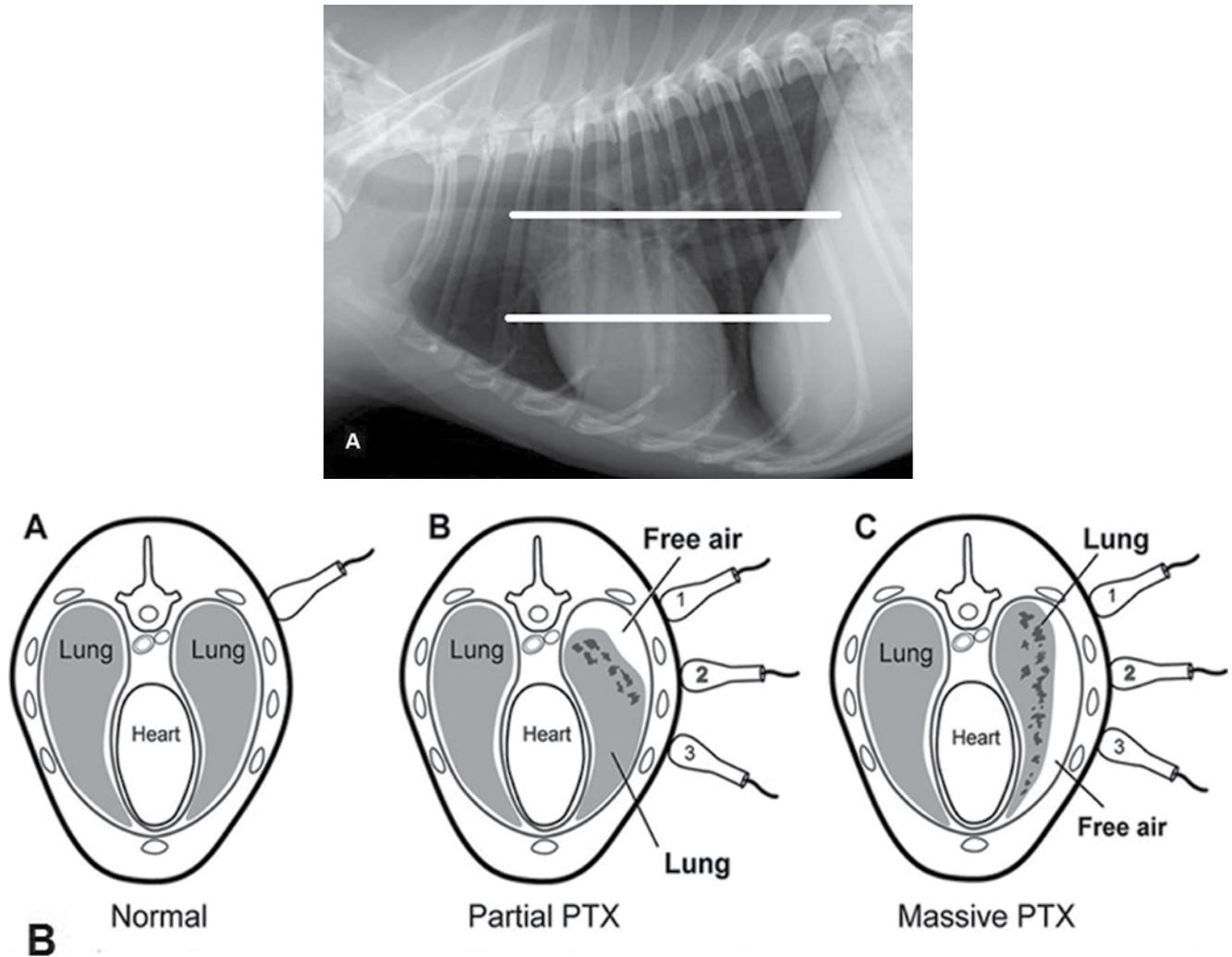


Figure 16.6. Finding the lung point for degree of pneumothorax, partial vs. massive. (A) A normal lateral thoracic radiograph of a dog divided into upper, middle, and lower thirds by the solid white parallel bars on the image to didactically help with understanding the search for, and clinical relevance of, the lung point in cases of pneumothorax (PTX). If the lung point is found in the upper thorax, relatively close to the TFAST³ CTS, it is considered as partial and smaller volume than a lung point in the lower third of the thorax (larger volume PTX). The absence of a lung point in true PTX (and not a false positive) is considered massive. (B) Pictorial representation of the search for the lung point by moving the probe along the thoracic wall from the TFAST³ CTS (highest point where air would accumulate in PTX) to the sternum to determine degree of PTX as partial vs. massive (Lisciandro 2011). Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro

compartment (Geeraerts 2007). The ONSD may be used as an ultrasonographically visible marker for the detection of increased intracranial pressure (ICP) by measuring its diameter as well as any increases in width (it conversely decreases with lower ICP). In patients with pathologically elevated ICP, called intracranial hypertension, perineural cerebrospinal fluid (CSF) is displaced into the intraorbital sheath enlarging their ONSD. In dogs, a normal ONSD measured 3mm from the eye's posterior wall is equal to or less than 2.7mm; 3.0mm or greater is considered abnormal

(Armenise 2012) (Figure 16.9). Management to decrease ICP is urgently warranted in dogs with abnormally measured ONSD and clinical signs related to intracranial hypertension. Importantly, response to therapy may be monitored by serial ONSD measurements. The use of the ONSD is especially helpful in heavily sedated or anesthetized veterinary patients unable to have accurate mentation assessment.

Exposure (E): Serial FAST-ABCDE evaluations for exposure are clinically helpful because serial FAST³ exams have been shown to increase the sensitivity

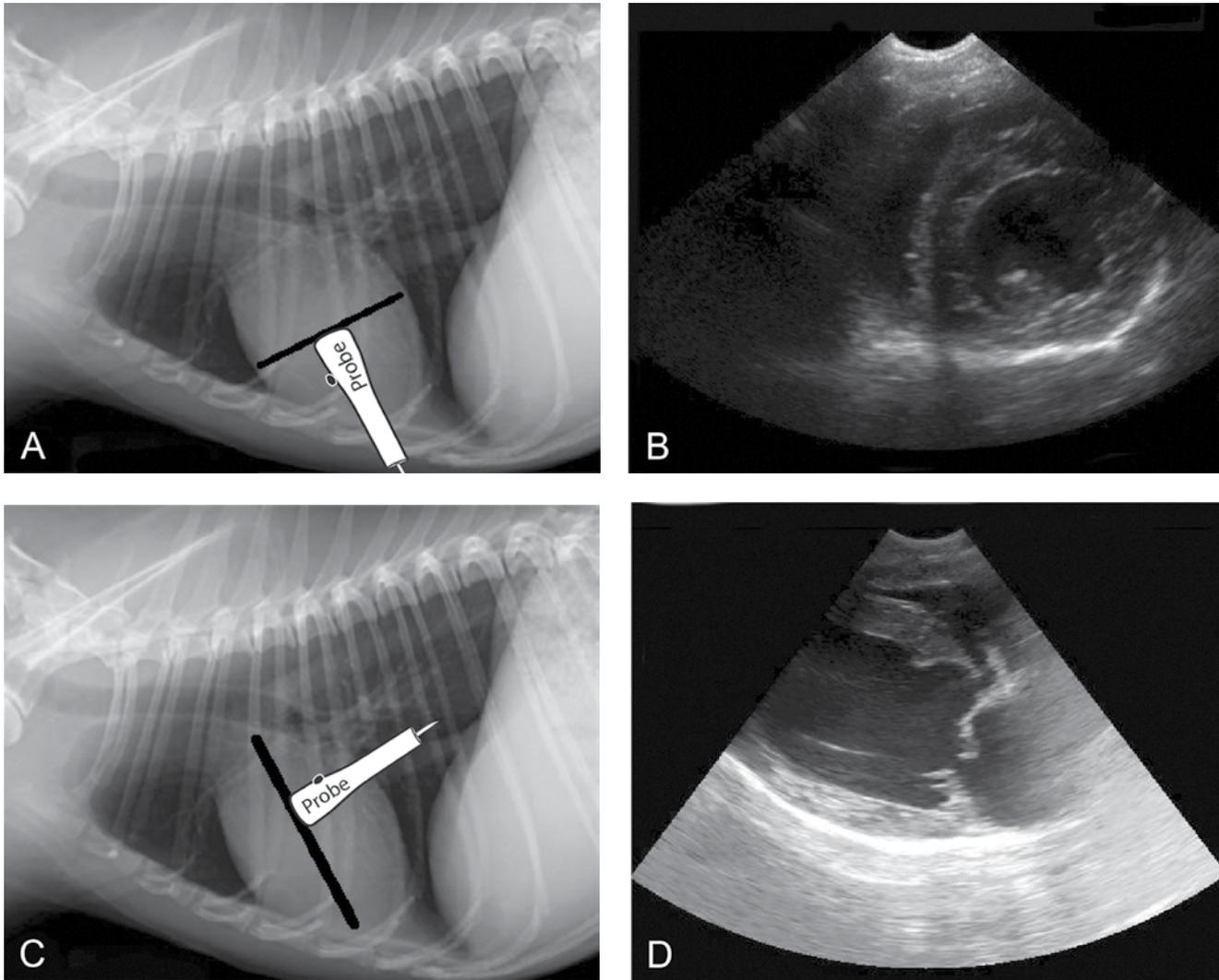


Figure 16.7. Probe orientation for short-axis and long-axis heart views. (A and B) Probe marker (dot on probe) toward the elbow for the left ventricular short-axis mushroom view. (C and D) Probe marker toward the spine for the long-axis four-chamber view. It is important to note that by keeping the screen reference the same from AFAST³ to TFAST³, heart orientation will be backwards from echocardiographic views. However, as long as the sonographer recognizes the normal ultrasonographic anatomy, specifically heart ventricles and atriums, either orientation is acceptable. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

by detecting occult or missed potentially life-threatening injuries and conditions on initial scans. Moreover, serial exams may be used to detect complications and to monitor response to therapy. Serial FAST-ABCDE examinations (as well as the GFAST³ format) should be performed in all stable patients four hours post admission as recommended by the American College of Emergency Physicians, and sooner in unstable patients, as often as every 15 to 30 minutes.

Clinical Significance and Implications of Abnormal Focused CPR (GFAST³) and FAST-ABCDE Exam Findings

The focused CPR (GFAST³) and FAST-ABCDE format represent an important clinical tool for the non-radiologist emergency physician, trauma surgeon, intensivist, anesthesiologist, and other pertinent

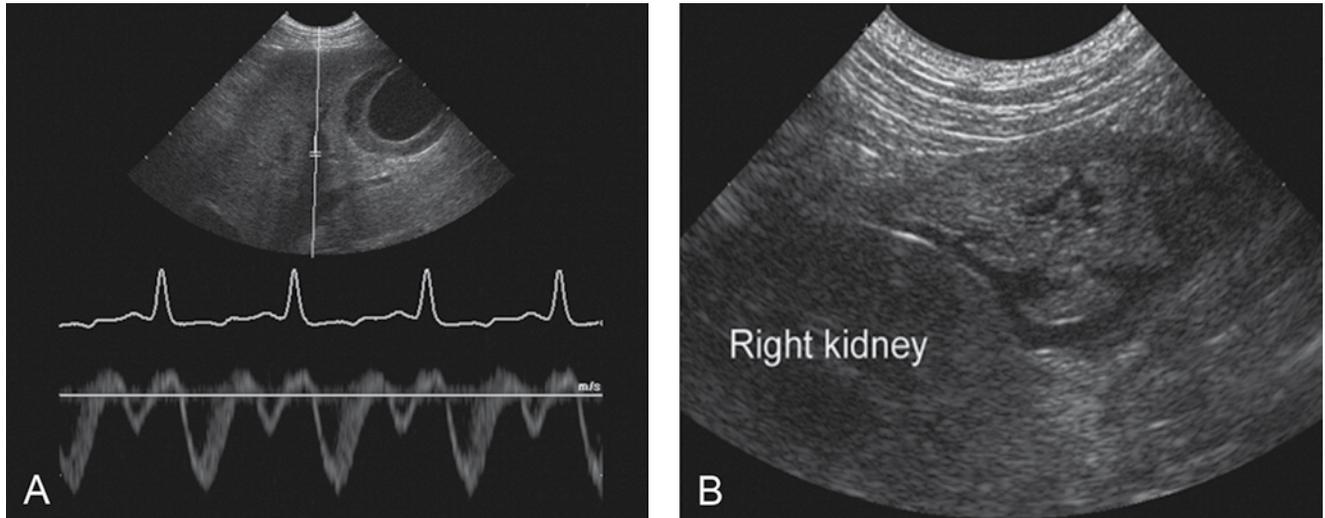


Figure 16.8. Caudal vena caval and hepatic venous distension from volume overload during fluid resuscitation in a dog. (A) Duplex Doppler image. Note the relationship of the right medial hepatic vein, quadrate hepatic vein, and gallbladder. The 2-mm Doppler gate is placed within the right medial hepatic vein, approximately 1 cm from the bifurcation from the quadrate vein. This is also the site of hepatic vein diameter measurement, perpendicular to the long-axis of the vessel. The gallbladder wall (at the upper right of the B-mode image) is thickened. The pulsed wave Doppler display is below the B-mode image. A simultaneous electrocardiogram tracing is also recorded. (B) Transverse B-mode image of the right lobe of the pancreas. The pancreas is enlarged, triangular in shape, and has internal and peripheral hypoechoic (dark) striations. A transverse section of the right kidney is visible at the bottom left of the image. When volume overload occurs as a result of intravenous fluid therapy, the gallbladder and pancreas become edematous. The gallbladder develops a halo sign and the right lobe of the pancreas becomes readily obvious ultrasonographically (also see chapters 2 and 3). (Nelson et al. 2010)

specialists. Both protocols are used to assess the 3 “T”s (T³; representing trauma, triage and tracking) to expediently diagnose and better manage life-threatening injuries that would otherwise be occult or speculated based on traditional means. They also are used for US-guided interventions (see Chapter 17) and as applications during and after CPR.

In dogs, the FAST-ABCDE exam has been helpful in diagnosing and managing similar conditions as those for which AFAST³, TFAST³, and Vet BLUE are used. The FAST-ABCDE exam also is helpful in the following areas.

Airway

Confirmation of endotracheal tube placement may be made in two ways: directly by the double trachea sign or indirectly by observing for the glide sign with positive pressure ventilation (see Chapter 9). With the direct method, improperly placed ET tubes may be recognized by observing the double trachea sign in which two hyperechoic (bright white) curved structures (the trachea and the misplaced esophageal-located ET tube) are side by side (Figures 16.4–16.6).

Upper airway obstruction is suspected by loss of normal A-lines extending beyond the tracheal rings due

to echogenic material displacing air in the near field. Echogenically, luminal soft tissue may reflect more benign conditions such as significant intratracheal secretions or foreign bodies vs. more concerning conditions such as soft tissue masses. In either case, secretions/foreign material vs. masses may be indistinguishable without more formal US study, additional imaging, or direct visual examination (by sight or fiberoptically).

Laryngeal paralysis may be diagnosed through the absence or the asymmetry of movement of the arytenoid cartilages.

Tracheal rupture can be detected through recognized deviations from the expected curved or linear continuity of the trachea throughout its cervical course (Figure 16.6A through C).

Regional hematomas/masses may be detected by the presence of echogenic irregularities in adjacent soft tissues and their displacement of the trachea, veins, or arteries.

Jugular veins and carotid artery abnormalities may be detected by the presence of thrombi or aneurisms.

Breathing

Dry lungs are diagnosed by the presence of A-lines and a glide sign (Figure 16.2E).

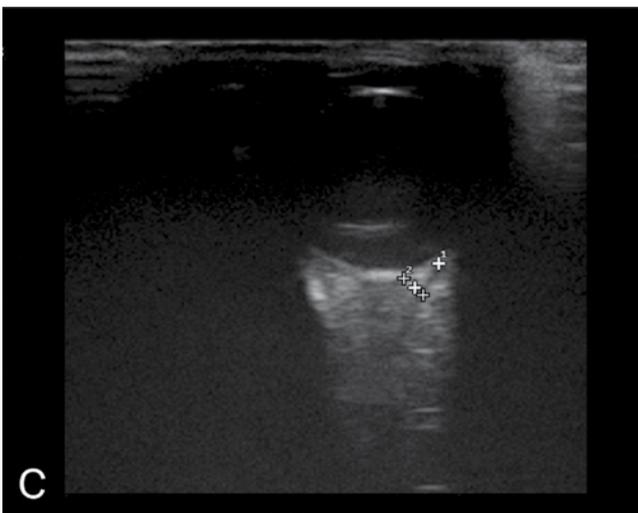
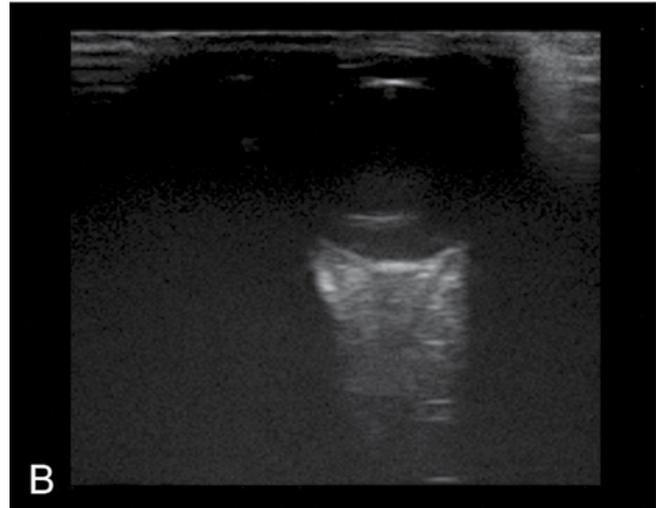


Figure 16.9. Probe positioning and orientation for optic nerve imaging for optic nerve sheath diameter measurements. (A) Horizontally oriented image of a normal canine left eye. The transducer was placed on the ventral eyelid with the probe marker to the sonographer's left when looking at the dog (the probe's orientation marker is the black line on the probe head in the photograph). (B) The optic nerve is visualized as an isoechoic (shades of gray similar to adjacent soft tissue) linear structure surrounded by two hypoechoic (dark) lines which represent the intraorbital subarachnoid space. Discrimination between extraocular muscles and the optic nerve, which can look similar, may be made using color flow Doppler because the optic nerve has blood vessels on either side. (C) Calipers showing correct measurement of the ONSD. Calipers mark the optic nerve course 3 mm caudal from the globe (1+----+). At the 3-mm distance, the ONSD diameter is determined by the transverse (perpendicular to the optic nerve's long-axis) measurement as shown by the calipers (2+----+).

Wet lungs are diagnosed by ultrasound lung rockets (ULRs) (also referred to as B-lines) representing lung contusion (trauma) and forms of interstitial edema (forms of cardiogenic and non-cardiogenic pulmonary edema, pneumonias, other inflammatory conditions) depending on the clinical picture (Figure 16.2F and G; also see Chapter 10).

Pneumothorax (PTX) is diagnosed by A-lines and no glide. A lung point is searched for to determine the degree of PTX as partial (and to what degree) or massive (no lung point) (see Figures 9.8, 9.9, and 10.13).

Lung consolidation is suspected by the shred sign or tissue sign and may represent severe lung contusion or a variety of lung conditions including pneumonias, neoplasia, severe inflammation, and severe alveolar

edema (see Figures 10.5, 10.9, 10.10, and 10.16D). Lung neoplasia is suspected by the presence of the nodule(s) sign. The nodule sign may also represent non-neoplastic conditions such as fungal (or other) granulomas and lung abscesses (see Figures 10.5, 10.11, 10.12, and 10.16E and F).

Lung ultrasound assumes that central disease has made it to the lung's periphery, which probably occurs with most clinically relevant conditions. However, central disease (deep to the lung periphery) may be missed. Lung ultrasound findings should be interpreted in a pattern-based manner to optimize a prudent working diagnosis prior to additional imaging and lung diagnostics (see Chapter 10).

Circulation, Thoracic

Global cardiac assessment may be subjectively made by assessing volume status, systolic and diastolic function, and valvular function by performing short and long-axis views (Figure 16.7A through D). The diagnoses of pericardial effusion with or without cardiac tamponade and pleural effusion are made using TFAST³ and Vet BLUE (Figure 16.1A and B; also see chapters 9 and 11). US-guided pericardiocentesis is performed as dictated (see Chapter 17).

Volume Status may be assessed by visual estimation of left ventricular filling (short-axis mushroom view) before the beginning of a new contraction (or its maximum size). In the hypovolemic state, the mushroom maximally is small, appearing empty, and the left ventricular short-axis mushroom view may show the “kissing walls” appearance in which its papillary muscles touch themselves during systole (Figure 16.2A through C; also see Figure 9.16).

Systolic function may be subjectively evaluated by visual estimation of left ventricular contraction and changes in its chamber diameter (systole-diastole) on the short-axis view (Figure 16.2A through C; also see Chapter 11).

Valvular function may be evaluated particularly for mitral and tricuspid abnormalities by looking for the presence of any degenerative proliferation and insufficiency.

Volume overload, or the development of pulmonary edema, may be detected by looking for wet lungs (ULRs) on initial and serial Vet BLUE exams before clinical signs are overtly apparent (Figure 16.2D through G). The formation of ULRs has been shown to correlate with increased pulmonary artery occlusion pressure and to anticipate left-sided volume overload in people (Lichtenstein 2007).

Pericardial effusion and tamponade may be easily diagnosed. Cardiac tamponade is present if there is right atrial collapse during diastole (see Figures 2.3, 2.17, 9.17, 9.19, 9.20, 11.12, 11.13A, and 11.15A; also see chapters 2, 9, and 11).

Pleural effusion may be easily diagnosed by the presence of free fluid between the visceral (lung, pericardium, diaphragm) and parietal (thoracic wall) pleura (see Figures 2.3, 9.18, and 11.12; also see chapters 9 and 11).

Circulation, Abdominal

Significant volumes of intra-abdominal and retroperitoneal free fluid may be detected by using AFAST³ (Figure 16.1A; also see Chapter 2). Furthermore, subjectively evaluating CVC size and its responsiveness during fluid

resuscitation (FAST³ DH view) along with the degree of hepatic venous distension allows for volume (preload) estimation. US-guided or -assisted abdominocentesis is performed as dictated (see Chapter 17).

Intra-abdominal free fluid must be characterized when deemed prudent and safe (small pockets may not be readily accessible)(see Figures 2.2, 2.6, 2.10, and 2.11).

An AFAST³-applied abdominal fluid scoring system (AFS) helps predict the degree of anemia by the small bleeder (AFS 1, 2) vs. big bleeder (AFS 3, 4) concept (see Figure 2.15). They system may also be used to semiquantitate and monitor any effusive condition of the abdomen (see Chapter 2).

Retroperitoneal free fluid (see Figure 2.9; also see Chapter 5) is characterized when deemed prudent and safe (small pockets may not be readily accessible). Imaging both kidneys (AFAST³ spleno-renal [SR] and hepato-renal [HR] views) confidently determines that the left and right retroperitoneal spaces were at least partially interrogated (both kidneys lie outside the abdomen). Retroperitoneal fluid is not part of the abdominal fluid score (see Chapter 2); however, the greatest depth/dimensions determined by the eyeball method or actual caliper measurements may be recorded for monitoring.

Volume (preload) status and fluid resuscitation responsiveness may be made by subjectively evaluating the degree of distension and contraction of CVC size pre- and post fluid challenges (Figures 16.2H and I, 16.8A; also see Figures 11.8, 11.9). When the CVC diameter no longer changes, then preload has been maximized (Moretti 2010, Machare-Delgado 2011). A less challenging preload volume measure is done by subjectively assessing hepatic venous distension where these veins branch into the CVC (see Figures 11.8 and 11.9). Normally, hepatic venous distension is not obvious unless excessive preload (volume overload) or mechanical obstruction between the liver and right atrium is present (Figure 16.2H and I and 16.8A). Finally, it has been shown that the gallbladder halo sign (its thickening) occurs in over-resuscitated dogs (Nelson 2010) (Figure 16.8B; also see Chapter 2).

The classic FAST³ DH view is consistently obtained in right lateral recumbency by first imaging the gallbladder kissing the diaphragm and then directing the ultrasound probe slightly more toward the table top (sometimes slightly away) looking deep along the diaphragm for the linear anechoic (black) CVC passing through the diaphragm (its hyperechoic near and fall walls look like a bright white equal [=] sign) and from the CVC the hepatic veins (see Chapter 2).

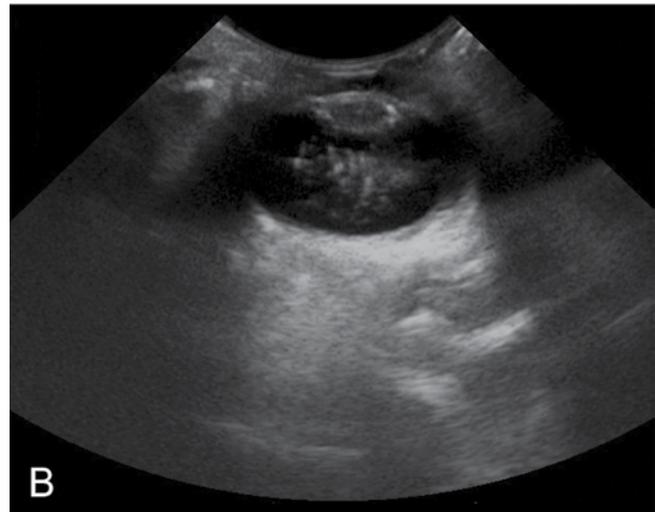


Figure 16.10. Eye evaluation and examples of abnormalities found during the FAST-ABCDE exam. (A) Ultrasound image of the normal canine eye in horizontal probe orientation (also see figures in Chapter 14). Note the hyperechoic (bright white curve) cornea in the near field followed by the anechoic (pure black) anterior chamber, the hyperechoic (bright white lines) curved lines representing the anterior and posterior aspects of the lens, and an anechoic (pure black) vitreous to the posterior wall. The eye requires non-toxic aqueous-based acoustic gels (see Chapter 14.) (B) Vitreal hemorrhage recognized by the echogenic material within the posterior chamber. Note that artifacts and some benign conditions may also appear similar. (C) Retinal detachment as evidenced by a hyperechoic (bright white) irregular line extending and reconnecting to and from the posterior eye wall (also see Chapter 14). Courtesy of Dr. Jane Cho, Veterinary Eye Specialists, Ardsley, New York. © Gregory Lisciandro

Disability

ONSD measurement serves as a marker for intracranial hypertension and focused eye ultrasound for ocular trauma. In fact, ocular ultrasound has been shown to be superior in some respects when compared to computerized tomography for many trauma-related conditions (Ritchie 2012).

ONSD greater than 3mm suggests intracranial hypertension and warrants urgent therapy in the context of the dog's clinical picture. ONSD may also be used serially to monitor response to therapy. The normal ONSD for cats has not been established.

ONSD has not been evaluated in cats, and its full clinical utility in dogs for intracranial hypertension remains under study.

Intraocular hemorrhage from trauma or coagulopathy may be suspected (Figure 16.10A through C).

Intraorbital foreign body may be detected by artifact such as ring-down reverberation extending beyond the foreign body (see Figures 1.8B and 12.8).

Retinal detachments may be readily detected (Figure 16.10C, also see Figure 14.16). Traumatic lens luxations also may be readily detected (see Figures 14.13 and 14.15)

Intraocular and extraocular masses may be detected (see Figures 14.17, 14.18, 14.21).

See Chapter 14 for greater details about safely performing focused eye ultrasound.

Fractures and herniation may also be detected on the triage table using ultrasound when radiography is either

not readily available or the patient is not acceptable for transport (see Chapter 15). Ultrasound has been shown to have good sensitivity and specificity for certain fracture types (see Figures 15.1, 15.2, and 15.4 through 15.7).

Exposure

Serial focused, COAST³, and FAST³ exams often exceed traditional means of laboratory testing, radiographic imaging, and physical examination when attempting to determine significant injury or pathology and detecting potentially life-threatening conditions and complications. In stable veterinary patients a serial exam should be performed four hours post admission and as often as every 15 to 30 minutes in unstable animals.

Pearls and Pitfalls, the Final Say

The FAST-ABCDE exam is a more recent ultrasound format that is similar to global FAST³ in most respects with the most notable exceptions of upper airway and ocular evaluations. However, as noted in Chapter 15, the presence of skull, rib, and long bone fractures (adding an “F” to “ABCDE”) may also be detected using focused musculoskeletal (FAST-ABCDEF). The FAST-ABCDE format, although placed in the Focused CPR chapter, is used in T³ fashion for trauma, triage, and tracking and serially to optimize veterinary patient care (as with GFAST³).

Focused CPR (GFAST³) and FAST-ABCDE are safe (radiation-sparing), non-invasive, point-of-care techniques that may be mastered with proper training by the non-radiologist veterinarian, and are becoming part of CPR’s Advanced Life Support (ALS) in people and is becoming part of the Veterinary Advanced Trauma Life Support (VATLS) Curriculum. Both GFAST³ and the FAST-ABCDE protocols should be used as an extension of the physical exam (as is the case with all focused, COAST³, and FAST³ exams) for trauma, triage, and tracking (monitoring) in emergency and critical care cases.

The FAST-ABCDE exam presents some new technically challenging ultrasound evaluations that require more training and expertise to perform, including its heart, eye, and upper airway evaluations.

Adding focused musculoskeletal techniques creates the letter “F”, e.g. FAST-ABCDEF, for fracture assessment to even more fully evaluate compromised veterinary patients at the point of care or cageside.

References

- Armenise A, Neri L, Storti E, et al. 2012. Evaluation of a FAST-ABCDE protocol (Focused Assessment with Sonography for Trauma- Airway, Breathing, Circulation, Disability, and Exposure) to detect multiple injuries in canine trauma patients: Preliminary data. Abstract. *J Vet Emerg Crit Care* 22(S2):S20.
- Armenise A, Ricciardi M, Giannuzzi AP, et al. 2012. Ultrasonographic measure of the optic nerve sheath in canine patients with signs of raised intracranial pressure. A preliminary study. Abstract. *J Vet Emerg Crit Care* 22(S2):S20.
- Boller M, Fletcher DJ. 2012. RECOVER evidence and knowledge gap analysis on veterinary CPR. Part 1: Evidence analysis and consensus process: collaborative path toward small animal CPR guidelines. *J Vet Emerg Crit Care* 22 (S1):S4–S12.
- Breitkreutz R, Price S, Steiger HV, et al. 2010. Focused echocardiographic evaluation in life support and peri-resuscitation of emergency patients: A prospective trial. *Resuscitation* 81:1527–33.
- Breitkreutz R, Walcher F, Seeger FH, et al. 2007. Focused echocardiographic evaluation in resuscitation management (FEER): Concept of an advanced life support–conformed algorithm. *Crit Care Med* 35(S5):1527–33.
- Eom K, Moon K, Seong Y, et al. 2008. Ultrasonographic evaluation of tracheal collapse in dogs. *J Vet Sci* 9(4):401–5.
- Geeraerts T, Launey Y, Martin L, et al. 2007. Ultrasonography of the optic nerve sheath may be useful for detecting raised intracranial pressure after severe brain injury. *Intensive Care Med* 33:1704–1711.
- Lichtenstein D. 2012. Fluid administration limited by lung sonography: the place of lung ultrasound in assessment of acute circulatory failure (the FALLS-protocol). *Expert Rev Respir Med* 6(2):155–62.
- Lichtenstein D, Karakitsos D. 2012. Integrating lung ultrasound in the hemodynamic evaluation of acute circulatory failure (the fluid administration limited by lung sonography protocol). *J Crit Care* 27(5):533.
- Lisciandro GR. 2011. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care* 21(2):104–22.
- Lisciandro GR. 2012. Evaluation of initial and serial combination focused assessment with sonography for trauma (CFAST) examinations of the thorax (TFAST) and abdomen (AFAST) with the application of an abdominal fluid scoring system in 49 cats. Abstract. *J Vet Emerg Crit Care* 22(S2):S11.
- Lisciandro GR, Fulton RM, Fosgate GT. 2013. Frequency of ultrasound lung rockets using a regionally-based lung ultrasound exam named Vet BLUE (Bedside Lung Ultrasound Exam) in 54 non-respiratory dogs. *J Vet Emerg Crit Care*, accepted.
- Lisciandro GR, Fulton RM, Fosgate GT. 2013. Frequency and number of ultrasound lung rockets (B-lines) using a regionally-based lung ultrasound examination named Vet BLUE (Veterinary Bedside Lung Ultrasound Exam) in

- dogs with radiographically normal lung findings. *Vet Radiol and Ultrasound*, accepted.
- Machare-Delgado E, Decaro M, Marik PE. 2011. Inferior vena cava variation compared to pulse contour analysis as predictors of fluid responsiveness: a prospective cohort study. *J Intensive Care Med* 26(2):116–24.
- Mann FA, Crowe T, Devey J, Lisciandro GR, Powell L. Veterinary Advanced Trauma Life (VATL) Support Guidelines Committee, American College of Veterinary Emergency and Critical Care. Unpublished.
- Moretti R, Pizzi B. 2010. Inferior vena cava distensibility as a predictor of fluid responsiveness in patients with subarachnoid hemorrhage. *Neurocrit Care* 13(1):3–9.
- Nelson NC, Drost WT, Lerche P, et al. 2010. Noninvasive estimation of central venous pressure in anesthetized dogs by measurement of hepatic venous blood flow velocity and abdominal venous diameter. *Vet Radiol and Ultrasound* 51(3):313–323.
- Neri L, Storti E, Lichtenstein D. 2007. Toward an ultrasound curriculum for critical care medicine. *Crit Care Med* 35(5 Suppl):S290–304.
- Neumar RW, Otto CW, Link MS, et al. 2010. Part 8: Adult advanced cardiovascular life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 122:S729–S767.
- Pfeiffer P, Bache S, Isbye L, et al. 2012. Verification of endotracheal intubation in obese patients—temporal comparison of ultrasound vs. auscultation and capnography. *Acta Anaesthesiol Scand* 56:571–576.
- Ritchie JV, Horne ST, Perry J, et al. 2012. Ultrasound triage of ocular blast injury in the military emergency department. *Mil Med* 177(2):174–8.
- Rudorf H, Barr FJ, Lane JG. 2001. The role of ultrasound in the assessment of laryngeal paralysis in the dog. *Vet Radiol Ultrasound* 42(4):338–43.
- Spaulding K. 2008. Eye and orbit. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D'Anjou. Ames, Iowa: Blackwell Publishing, pp 61.
- Volpicelli G, Elbarbary M, Blaivas M, et al. 2012. International evidence-based recommendations for point-of-care lung ultrasound. *Int Care Med* 38(4):577–591.
- Weaver B, Lyon M, Blaivas M. 2006. Confirmation of endotracheal tube placement after intubation using the ultrasound sliding lung sign. *Acad Emerg Med* 13:239–244.
- Zechner PM, Breitkreutz R. 2011. Ultrasound instead of capnography for confirming endotracheal tube placement in emergency? *Resuscitation* 82(10):1259–61.

INTERVENTIONAL ULTRASOUND-GUIDED PROCEDURES

Søren Boysen

Introduction

Ultrasound-guided interventional techniques are generally classified as indirect, free-hand, and mechanical-guided.

With the indirect method, ultrasound (US) is used to determine the location and depth of the target (usually fluid). A needle trajectory is imagined, but the needle is not visualized in real-time during the procedure. The indirect method is commonly used for pericardiocentesis, thoracocentesis, and abdominocentesis in veterinary patients. With free-hand US-guided centesis, the location and depth of the target are determined and real-time US is used to visualize and help guide the needle tip into the desired target. The free-hand method is often preferred because it is less expensive and allows greater flexibility in angling the needle and changing its location to perform more precise aspiration or centesis (Del Cura 2010). In other words, this flexibility allows the attending clinician to move the needle/needle tip through different planes relative to the US beam, in contrast to the mechanical-guided US method.

With the mechanical US-guided system, a rigid US probe attachment is used to help guide the needle/needle tip into the target, be it a cavity or tissue, using real-time visualization. The attachment typically contains a slot for the needle which fixes the needle track to the angle of the slot. The fixed path of the device ensures that the needle remains in the plane of the US beam and thus facilitates real-time US visualization of the needle/needle tip. On the other hand, the fixed path of the attachment has the disadvantage of limiting the number of needle/needle tip entry angles that may be used (Del Cura 2010).

Pericardiocentesis

Ultrasound-Guided vs. Blind Pericardiocentesis

Ultrasound is a rapid, sensitive, and non-invasive technique for the emergent detection of pericardial effusion with or without tamponade or concurrent pleural effusion, as well as the detection of underlying causes (masses, foreign bodies) (Tibbles 2004). Ultrasound is arguably the gold standard for the diagnosis of pericardial effusion over computerized tomography and allows real-time visual guidance during pericardiocentesis.

Typically, pericardiocentesis has been performed blindly or by using indirect US-guidance in veterinary medicine. However, several studies in humans have demonstrated reduced complications with free-hand US-guided pericardiocentesis compared to blind techniques (Tsang 2002, Taavitsainen 1991, Clarke 1987, Callahan 1985). Reported complications include ventricular or atrial penetration, coronary artery laceration, pneumothorax (PTX), dysrhythmias, and inadvertent penetration of the diaphragm and abdominal organs (Clarke 1987). Given the anatomic differences in veterinary patients compared to humans, it is unknown if US-guided pericardiocentesis would result in fewer complications. In cases of small-volume effusion causing tamponade, or compartmentalized fluid, free-hand US-guided pericardiocentesis may be particularly helpful. By direct visualization of structures and fluid, US-guided techniques should prove safer than blind techniques.

Under certain pathological conditions fluid may accumulate in the pericardial space and become life

threatening (this is called cardiac tamponade), requiring emergent pericardiocentesis. Cardiac tamponade is defined as an increased pericardial pressure to the point that ventricular filling is impaired and hemodynamic instability occurs, often resulting in rapid deterioration of the patient (Tayal 2003). The time required for cardiac tamponade to occur depends on the quantity of fluid, rate of its accumulation, and the distensibility of the pericardium (see Figures 9.17, 9.19, 9.20, and 11.15A) (Tibbles 2004).

In cardiovascularly stable cases of pericardial effusion without cardiac tamponade, emergent pericardiocentesis may be delayed until a thorough evaluation of the underlying cause is investigated. When neoplasia is suspected as the cause of pericardial effusion, leaving some pericardial fluid may improve tumor diagnosis by providing an acoustic window for formal or complete echocardiography (Brown 2008, Scansen 2011). Finally, pericardial effusion may occur secondary to coagulopathies, which should be considered as a possible cause. When coagulopathy is present and pericardiocentesis is deemed necessary, the coagulopathy should ideally be corrected with rapid plasma administration prior to performing pericardiocentesis.

Indications for Pericardiocentesis

Pericardiocentesis is indicated to remove fluid from the pericardial space, both for diagnostic and therapeutic purposes, and is the lifesaving treatment of choice when cardiac tamponade is present (Tibbles 2004).

Leaving a small volume of pericardial effusion provides an acoustic window and helps with the detection of pericardial or heart-based masses if formal or complete echocardiography is to be subsequently scheduled (Scansen 2011).

Scanning Technique for Pericardiocentesis

Clip the fur and apply acoustic coupling gel or alcohol. Place the US probe between the fourth and fifth ribs on the right side of the patient at the level of the costochondral junction, or alternately at the location of the strongest palpable heartbeat if the heart can be easily palpated through the thoracic wall. Move the US probe cranial and caudal one to two rib spaces and ventrally and dorsally 2–3 inches until the widest accumulation of pericardial fluid has been identified. Limit the survey to only several seconds in unstable patients.

Depending on patient stability, measure or approximate the distance from the skin to the pericardium and

the greatest width (cm) of the pericardial effusion by using the centimeter scale to the right of the ultrasound image of your screen. This will help determine a safe distance the catheter can be advanced from the skin into the pericardial effusion.

Be familiar with the centimeter (cm) scale on your US machine, which is typically located on the right side of the screen, to rapidly approximate these measurements.

Imagine the needle pericardiocentesis angle and trajectory path that allows the safest penetration into the pericardial space (Figure 17.1A), which is usually over the site where the effusion is closest to the thoracic wall, thus minimizing lung trauma and associated complications.

Measure the width of the pericardial effusion before and serially after pericardiocentesis to monitor for resolution or recurrence rates of the effusion.

Ultrasonographic Findings for Pericardial Effusion

- Look for an anechoic area surrounding the heart by a hyperechoic (bright white) pericardium from the left to right atrium (Figure 17.1A; also see Figures 9.17, 9.19, 9.20, 11.13A, and 11.15A).
- Pericardial effusion must be differentiated from pleural effusions and a distended cardiac chamber, the latter being the most potentially catastrophic mistake in the event that a heart chamber erroneously undergoes pericardiocentesis (Figure 17.1A; see Figures 2.3, 2.17, 9.14, 9.18, 11.12, 11.13A, 11.15A).
- Zooming out by increasing the depth allows visualization of the entire heart, helping to differentiate pericardial from pleural effusions. Using the diaphragmatico-hepatic (DH) view of FAST³ also increases the accuracy of diagnosis by using multiple views (especially helpful in barrel-chested and obese dogs) (see Figures 9.17, 9.18, 9.19, 9.20, 11.12, 11.13A, and 11.15A).

Pericardial effusion is fluid contained (vs. pleural effusion, which is variably distributed throughout the pleural cavity) in the rounded pericardial sac that surrounds the heart from the left to right atrium; it is best diagnosed by multiple views and with increased (zooming out) depth (see Figures 9.17, 9.18, 11.13A, and 11.15A).

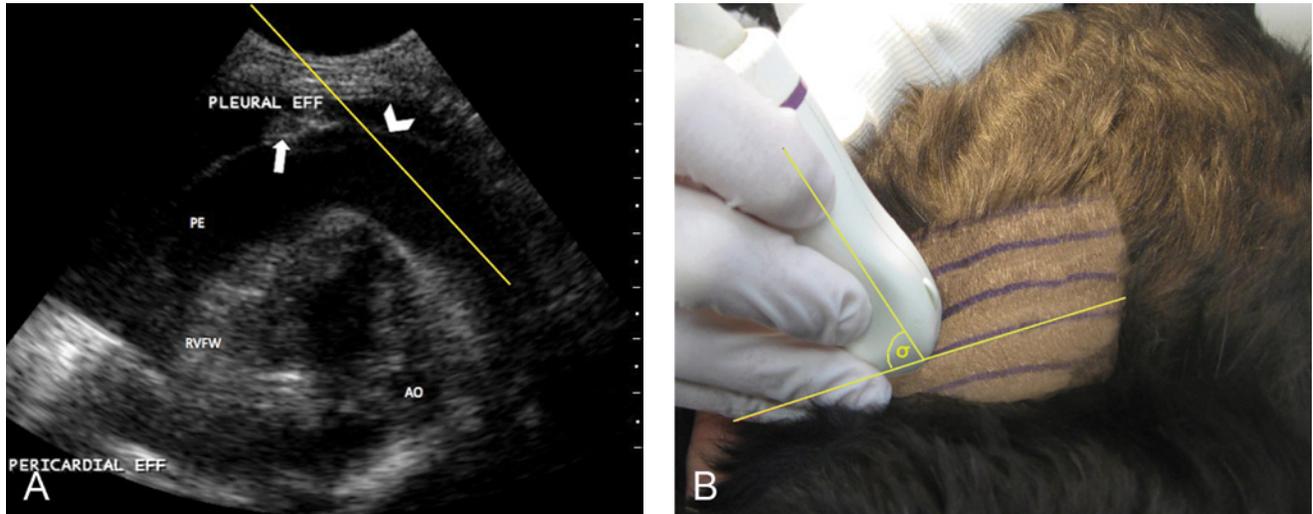


Figure 17.1. Indirect ultrasound-guided pericardiocentesis in a dog with pericardial and pleural effusion. Note that the width of the effusion may be approximated using the centimeter (cm) scale located on the far right shown in (A) (e.g., approximately 1.5 cm width in this case). (A) Right parasternal short-axis view at the level of the cardiac base of a 10-year-old female spayed Miniature Schnauzer with a history of idiopathic pericardial effusion of eight months duration. In real-time, the patient was in cardiac tamponade with secondary pleural effusion (denoted as PLEURAL EFF by the sonographer). The right ventricular free wall (RVFW) and aorta (AO) are also labeled. The arrowhead demonstrates the thin echogenic pericardium. A small amount of echogenic pericardial fat is seen (arrow) and should not be misinterpreted as neoplasia. The image is labeled by the sonographer in the lower left hand corner as pericardial effusion (PERICARDIAL EFF). The yellow line indicates the imaginary needle pericardiocentesis trajectory path. A formal echocardiogram ruled out the macroscopic presence of cardiac neoplasia. The patient recovered well from a subsequently performed pericardial window with histopathological evaluation. Courtesy of Dr. Jennifer Gambino, Mississippi State College of Veterinary Medicine. (B) Probe-to-skin angle (σ) identifying the widest pericardial fluid accumulation, which also represents the imaginary needle-pericardiocentesis trajectory angle.

Materials to Perform Pericardiocentesis

- Clippers and antimicrobial scrub
- Sterile gloves
- Number-11 scalpel blade
- 14- to 16-gauge, 2- to 6-inch over-the-needle catheter (Angiocath™, BD, Franklin Lakes, NJ) depending on patient size
- Intravenous extension set
- Three-way stopcock
- 35- or 60-cc syringe
- A receptacle for fluid collection (i.e., kidney bowl)
- Red (plain) and lavender (EDTA) topped tubes for collection of sterile fluid samples
- Injectable lidocaine for local anesthesia and arrhythmia control
- Electrocardiogram (ECG) monitor
- US machine with variable frequency curvilinear probes (a linear probe may be used in smaller animals)

Procedure for Performing Pericardiocentesis

The pericardial space has historically been approached from the right side for anatomic reasons including the minimization of left coronary artery laceration and lung trauma (cardiac notch). However, the procedure may be successfully performed from the left side, although conversely, the left coronary artery (major heart artery) is more vulnerable and there is more lung (no window through the cardiac notch). The difference in right- vs. left-sided approaches is a more important consideration in smaller effusions with a right-sided approach considered safer.

An advantage of left-sided pericardiocentesis is that if the heart is inadvertently penetrated blood is bright red (arterial and oxygenated) vs. dark (venous and unoxygenated). Most pericardial effusions are similar to dark venous blood; thus, cardiac puncture during a right-sided approach may not be readily apparent to the attending veterinarian.

Place an intravenous (IV) catheter in case complications develop that may require IV volume expansion or the emergent control of arrhythmias using injectable medications.

The patient may be given light sedation if needed. The opioids are generally safest because they are cardiovascularly sparing and may be reversed with naloxone.

Connect the patient to an ECG continuous monitor because ventricular arrhythmias are not uncommon if the catheter or stylet contacts the heart during the procedure.

For right-sided pericardiocentesis, the patient is placed in sternal or left lateral recumbency (independent right-sided approach).

Some clinicians prefer to place the patient in right lateral recumbency on an echocardiography table and perform the procedure from the underside of the patient (dependent right-sided approach) through the table's cut-out window because gravity assists in moving the heart, pericardium, and pericardial fluid closer to the thoracic wall while also pushing away lung.

The procedure should be performed aseptically using sterile technique and sterile gloves. Clip the fur and aseptically prep the skin on the right side of the thorax from the third to seventh intercostal spaces, extending 3–4 inches ventrally and dorsally from the costochondral junction.

Confirm the pericardiocentesis site using US; it is typically located near the fifth intercostal space at its costochondral junction. However, the optimal location may vary depending on the volume and where the widest accumulation of pericardial fluid exists (Figures 17.1A and B).

Attach a 14- or 16-gauge, 2- to 6-inch over-the-needle catheter, depending on the size of patient, to an IV extension set, three-way stopcock, and 35- or 60-cc syringe. One or two additional side holes may be cut in larger bore catheters to improve drainage of the pericardial space. Care must be taken to preserve the integrity of the catheter, ensuring that the tip does not break off and remain within the pericardial sac, creating a potentially serious complication.

It is recommended to stagger and not exceed 50% of the circumference of the catheter when making one or two additional side holes. Often, creating side holes is not necessary and poses some risk by weakening the catheter.

Apply a local lidocaine block at the pericardiocentesis site determined by US. Lidocaine should be infused into the subcutaneous space and intercostal muscles down to the level of the pleura. Make a small stab incision through the lidocaine-infiltrated skin using a number-11 scalpel blade to facilitate advancing the pericardial catheter through the soft tissues.

Place the US probe parallel to the ribs at the previously determined intercostal space noted to contain the widest accumulations of pericardial fluid. Gently rock and fan the probe back and forth to determine the safest imaginary needle-pericardiocentesis trajectory path (Figures 17.1). Now move on to the appropriate US-guided technique of interest, either the indirect-US guided or free-hand US-guided technique, to complete the procedure.

Indirect Ultrasound-Guided Pericardiocentesis

1. Make a mental note of the site, angle, and imaginary needle-pericardiocentesis trajectory path to follow with the catheter and stylet.

The stylet and catheter should be passed on the cranial side of the rib to avoid nerves and vessels on the caudal aspect of the ribs.

2. Using the angle determined by US (Figure 17.1B), penetrate the skin and subcutaneous tissue with the catheter and stylet at the same angle.
3. Apply gentle negative pressure to the syringe when the stylet and catheter have been advanced into the subcutaneous tissues.
4. Continue to advance the catheter and stylet along the imaginary needle-pericardiocentesis trajectory path until fluid is noted within the hub of the stylet and IV extension tubing.
5. Continue to step 7, below.

Free-Hand Ultrasound-Guided Pericardiocentesis

1. Slide the US probe 1–3 cm below the perceived site where the stylet and catheter will be advanced through the skin and subcutaneous tissues.
2. Tilt the probe such that it will be at a 60- to 90-degree angle to the imaginary needle-pericardiocentesis trajectory path. It is important to note that if the desired imaginary needle-pericardiocentesis trajectory path is more perpendicular to the skin, the US probe-to-skin angle can be decreased; however, image quality may diminish with decreased probe-to-skin contact.



Figure 17.2. Free-hand ultrasound-guided probe orientation for pericardiocentesis. Place the ultrasound probe parallel to the ribs 1–3 cm below the determined pericardial site at an angle of approximately 60 degrees to the skin. The catheter-to-skin angle is approximately 60 degrees, which creates a catheter-to-probe angle of approximately 60 degrees.

3. Following the predetermined skin site and imaginary needle-pericardiocentesis trajectory path, advance the stylet and catheter through the skin into the subcutaneous tissues. The US probe should be at a 60- to 90-degree angle to the catheter and stylet (Figure 17.2). The catheter and tip of the stylet should be visible within the subcutaneous tissues.
4. Apply gentle negative pressure to the syringe when the stylet and catheter have been advanced into the subcutaneous tissues.
5. Use real-time US guidance to advance both the stylet and catheter through the tissues until the catheter tip is visualized to enter the pericardial space. Be sure to keep the stylet and catheter in the same plane as the ultrasound probe.

The catheter tip may be easier to visualize if the bevel is directed toward the US probe.

Completing Both the Indirect and Free-Hand Ultrasound-Guided Pericardiocentesis Techniques

6. As the tip of the stylet enters the pericardial sac, fluid should be observed in the hub of the stylet and IV extension set. Pericardial fluid is typically dark red, similar to venous blood.
7. Once the stylet has penetrated the pericardial space, advance the stylet and catheter another 2–4

millimeters to ensure the catheter, in addition to the stylet, has entered the pericardial space. Do not advance the sharp stylet any farther.

8. Advance the catheter off the sharp stylet and into the pericardial space. It is not always necessary to completely advance the catheter into the pericardial sac; however, it should at least be advanced a few centimeters to ensure that it is well-seated within the pericardial sac along with all of the catheter's side holes, if present.

If sustained ventricular arrhythmias occur during pericardial catheter advancement, retract the catheter slightly. If this fails to resolve the arrhythmia, administer a bolus (2 mg/kg) of lidocaine intravenously. Most ventricular arrhythmias are intermittent and self-limiting.

9. Once the catheter is seated within the pericardial sac, disconnect the IV extension set from the stylet, remove the stylet from the catheter, and quickly reconnect the IV extension set to the catheter.
10. Drain fluid from the pericardial sac into an appropriate receptacle (i.e., kidney bowl) using the three-way stopcock and syringe.
11. Aseptically collect samples of the fluid into red and lavender topped tubes for further analysis. An additional second red top tube sample should be collected to observe for clot formation because hemorrhagic pericardial effusions should typically not clot. If clotting is observed, then fresh blood contamination should be suspected and the complication of aspiration of one of the cardiac chambers (most likely the right atrium), coronary artery laceration, or left atrial tear may have occurred.
12. Following the procedure, re-evaluate the pericardial sac ultrasonographically to be sure cardiac tamponade has resolved, and note the presence and quantity of any residual pericardial fluid by caliper measurement (or approximate by using the scale on the right side of the ultrasound screen) of the greatest width (cm).

It is helpful to leave a small volume of pericardial effusion to provide an acoustic window if formal or complete echocardiography in search of a mass or foreign body is to be subsequently performed.

13. Repeat the US evaluation in 12–24 hours (or sooner as clinical course dictates) to look for reaccumulation of pericardial fluid. Measuring and recording the greatest width (cm) of pericardial effusion is helpful in determining the degree of recurring effusion in the pericardial space.

Some patients have concurrent pleural effusion, which typically appears straw-colored and is often encountered as the catheter and stylet pass through the pleural space prior to entering the pericardial sac. Pericardial fluid typically appears dark red, similar to venous blood.

Pearls, Pitfalls of Ultrasound-Guided Pericardiocentesis

- US-guided pericardiocentesis allows the operator to visualize the catheter tip as it traverses the pleural space, thus avoiding confusion of pleural with pericardial fluid when both are present (Figure 17.1A).
- In patients with cardiac tamponade without respiratory distress, pericardiocentesis should take priority over evacuation of pleural fluid. The assistant should be instructed to release negative pressure on the syringe until the tip of the stylet is visualized within the pericardial space, at which time negative pressure is applied.
- Patients that have clinically relevant pleural and pericardial effusions may have thoracocentesis and pericardiocentesis performed simultaneously.
- When continuous negative pressure is applied during catheter advancement in patients with pleural and pericardial effusions, the fluid will often change in color from straw (typical pleural) to dark red (typical pericardial) as the catheter and stylet are advanced from the pleural space into the pericardial sac.

Thoracocentesis

Ultrasound-Guided vs. Blind Thoracocentesis

In the emergent veterinary patient with life-threatening pleural effusion or pneumothorax (PTX), the objective is to remove pleural fluid/air and stabilize the patient as quickly as possible. Blind thoracocentesis is usually the method of choice in these circumstances.

In the more stable patient with pleural fluid, however, US advantageously demonstrates the presence of loculated or compartmentalized fluid accumulations indicating that thoracocentesis at multiple sites may be necessary (unrecognized by the blind technique). Additionally, US not only allows for the identification

of lung within pleural fluid but also helps identify the deepest pocket(s) of fluid, thereby increasing the likelihood of success and minimizing complications (Nicolaou 2007). Studies in human medicine have shown higher success rates for pleural effusions when using US-guided compared to blind thoracocentesis, and that following failed blind thoracocentesis attempts, US-guided was successful in 88% of these patients (Weingardt 1994).

In addition to lung, other vital structures such as the heart and great vessels may lie in proximity to focal fluid accumulations which can be avoided by direct visualization during US-guided thoracocentesis. Complication rates with blind thoracocentesis in humans vary from 20% to 50% and include PTX, inadvertent placement of the needle into the abdominal cavity across the diaphragm or into consolidated lung, or misplacement of the needle above fluid accumulations (Dewitz 2003, Jones 2003). Although complications are still possible with US guidance, rates in humans are reported to be lower when compared to blind techniques (Jones 2003). For example, the incidence of post-thoracocentesis PTX in humans is reported to be 1.3%–2.5 % vs. 4%–30% for US-guided and blind techniques, respectively (Jones 2003).

Although US has very good diagnostic ability in detecting the presence of PTX, there is little benefit to US-guided over blind thoracocentesis given the difficulty in identifying intrathoracic structures when PTX (free air in pleural space) is present because US does not image through air. However, as is demonstrated in chapters 10 and 11, US is valuable in serially monitoring for the presence and degree (partial vs. massive by finding the lung point; see Figure 9.9) of PTX.

Indications for Thoracocentesis

- Provide a therapeutic benefit whenever pleural effusion (fluid in the pleural space) or PTX (air in the pleural space) is present and causing respiratory compromise or distress.
- Diagnostic purposes to characterize pleural effusion.

Scanning Technique for Thoracocentesis

The US probe is placed on either side of the thorax, perpendicular to the ribs, and moved cranially and caudally over several intercostal spaces in the lower third of the thorax. Following identification of the intercostal space containing the deepest fluid pocket, the US probe is then moved dorsally and ventrally at

this site to further clarify the deepest fluid pocket. Once this site has been identified, the US probe can once again be moved cranially and caudally to reconfirm the deepest fluid pocket and identify the presence of any obvious adjacent structures that should be avoided (heart, great vessels, lung, diaphragm, liver).

The depth of the fluid pocket will help determine the chance of success because smaller fluid accumulations are more difficult to successfully and safely access.

The depth of the fluid pocket should be measured or easily approximated using the centimeter scale to the right of the US screen to help guide the length of needle or catheter insertion to safely perform thoracocentesis. The width of the pleural fluid may vary during the respiratory cycle and should be assessed with US to minimize complications and maximize success.

Freeze the image to take an accurate caliper measurement from the skin surface to the desired location within the pleural fluid accumulation or approximate using the centimeter scale on the right side of the US screen.

Changing the US probe angle during the respiratory cycle and moving the needle tip away from aerated lung will help minimize lung puncture when pleural fluid depths change during the respiratory cycle.

Ultrasonographic Findings

- Pleural effusion appears as anechoic or hypoechoic areas depending on its contents and is generally located in gravity dependent sites of the pleural cavity.
- Pleural effusion must be differentiated more commonly from pericardial fluid and cardiac chambers but also from other intrathoracic structures including masses and intra-abdominal structures in case of occult diaphragmatic herniation.
- Use multiple views including at least a single pericardial view and the diaphragmatico-hepatic view of FAST³ to help distinguish pleural effusion from pericardial effusion and cardiac chambers (see Figures 2.3, 2.17, 9.14, 9.17, 9.18, 9.20, 11.12, 11.13A, and 11.15A).

Materials to Perform Thoracocentesis

- Clippers and antimicrobial scrub
- 18- to 22-gauge, 1- to 2-inch butterfly needle; IV catheter; or hypodermic needle
- IV extension set if using an IV catheter or hypodermic needle
- Three-way stop cock
- 10- to 60-ml syringe depending on patient size and the amount of pleural effusion present
- Receptacle for fluid collection (i.e., kidney bowl)
- US machine and appropriate US probes
- Sterile culturettes
- Lidocaine for a local anesthetic block if elected
- Sedation if needed

Procedure for Performing Thoracocentesis

- Thoracocentesis should be performed using the aseptic technique.
- Any existing coagulopathies should ideally be corrected prior to performing the procedure unless the patient is in overt respiratory distress, in which case urgent life-saving thoracocentesis should be performed.

In cases of hemothorax, blood may be collected and autotransfused back to the patient using in-line filters or blood administration lines.

- Some sedation is generally beneficial to calm the patient, decrease the need for restraint, and lessen the work of breathing in respiratory-compromised patients.
- A local anesthetic block using lidocaine may be given but is not usually necessary.
- Patients may be placed in lateral or sternal recumbency depending on patient stability and clinician's preference.

Sternal recumbency is generally best for respiratory-compromised patients because it is less stressful and allows more comfortable breathing (vs. lateral recumbency), and in the author's experience maximizes successful thoracocentesis.

With the assistance of US, look for the deepest pocket of fluid that is superficial to the lungs and not in proximity to vital structures such as the heart. Use the location of the deepest fluid pocket to identify the side

of the patient, the intercostal space, and how far ventrally or dorsally thoracocentesis may be performed. Once the site of thoracocentesis has been identified, the fur should be clipped and the shaved skin aseptically prepped over this site. In cases of overt life-threatening distress the fur can be parted and alcohol applied to the skin surface to allow for rapid, urgent thoracocentesis.

Pressure atelectasis from pleural effusion follows pressure volume curves, thus clinical improvement can be substantial, even if all fluid cannot be removed in difficult patients or circumstances.

Attach the three-way stopcock and syringe to the butterfly needle or attach an IV extension set, three-way stopcock, and syringe to the hypodermic needle or stylet of the IV catheter, depending on clinician's preference.

The following section describes the use of a hypodermic needle attached to a three-way stopcock and IV extension set in both perpendicular and parallel US probe placement. When placed perpendicular to the ribs, the marker of the US probe is oriented cranially in standard fashion (see Chapter 1).

Perpendicular Probe Placement for Thoracocentesis

1. Start by finding the gator sign orientation so that rib heads and the intercostal space are accurately identified (Figure 17.3). A 20- or 22-gauge needle attached to an IV extension set and a three-way stopcock and syringe are placed dorsal to the US probe at an angle of about 30 degrees to the skin, bevel toward the US probe, starting about 1 cm dorsal to the probe.

To perform real-time US-guided thoracocentesis, the US probe may be oriented perpendicular to the ribs using the "gator sign" view (Figure 17.3) or parallel to the ribs.

2. The needle should be inserted just caudal and dorsal to the center point of the US probe to avoid the nerves and vessels that run caudal to the ribs (Figure 17.4B). The orientation marker on the US probe is directed cranially.
3. The needle tip is visualized within the subcutaneous space.
4. An assistant can apply gentle negative pressure to the syringe at this time. As the needle is slowly advanced, the US probe is slid ventrally to follow the needle to the level of the parietal pleura.

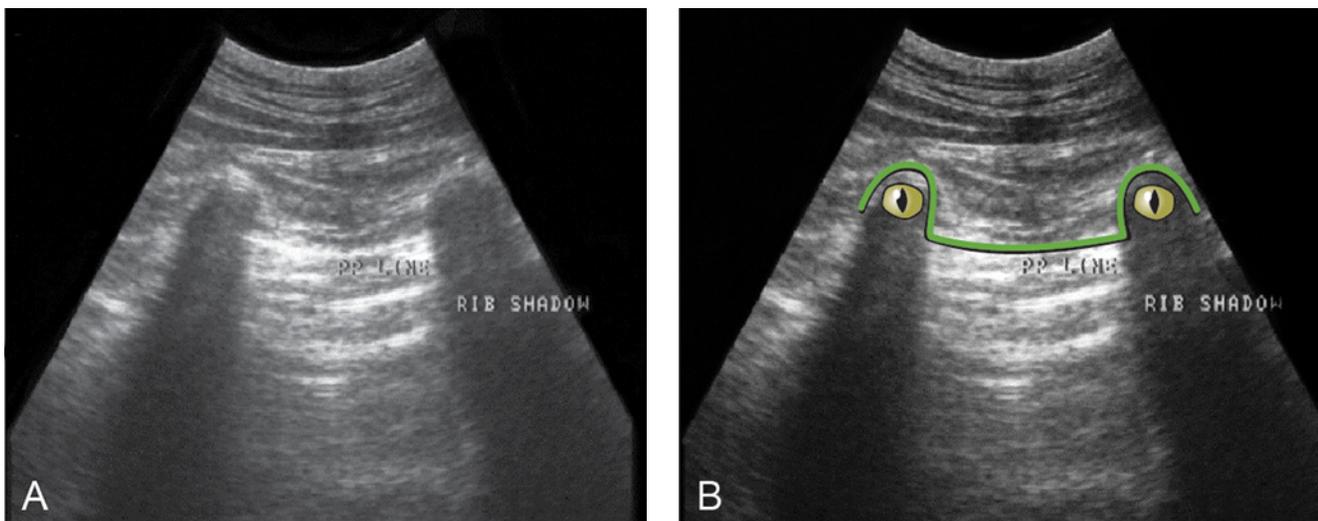


Figure 17.3. Gator sign, B-mode image. (A) Image without gator sign illustration. (B) Image with gator sign illustration. When the probe is correctly oriented perpendicular to the ribs, a classic gator sign image is formed by the rib heads (alligator's eyes) with the interposed intercostal space (alligator's bridge of nose). The proximal hyperechoic (bright white) line representing the bridge of the alligator's nose is the pulmonary-pleural interface (PP line); thus, by placing a needle past this point it has entered into the pleural space/thoracic cavity. The intercostal space (and pericardiocentesis) is to be performed, avoiding the caudal aspect of the ribs where artery, vein, and nerve lie. The clean acoustic shadowing extending beyond the rib heads is labeled (Rib Shadow). See Chapter 9 for further details regarding the gator sign. Courtesy of Dr. Gregory Lisciandro, Hill Country Veterinary Specialists, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

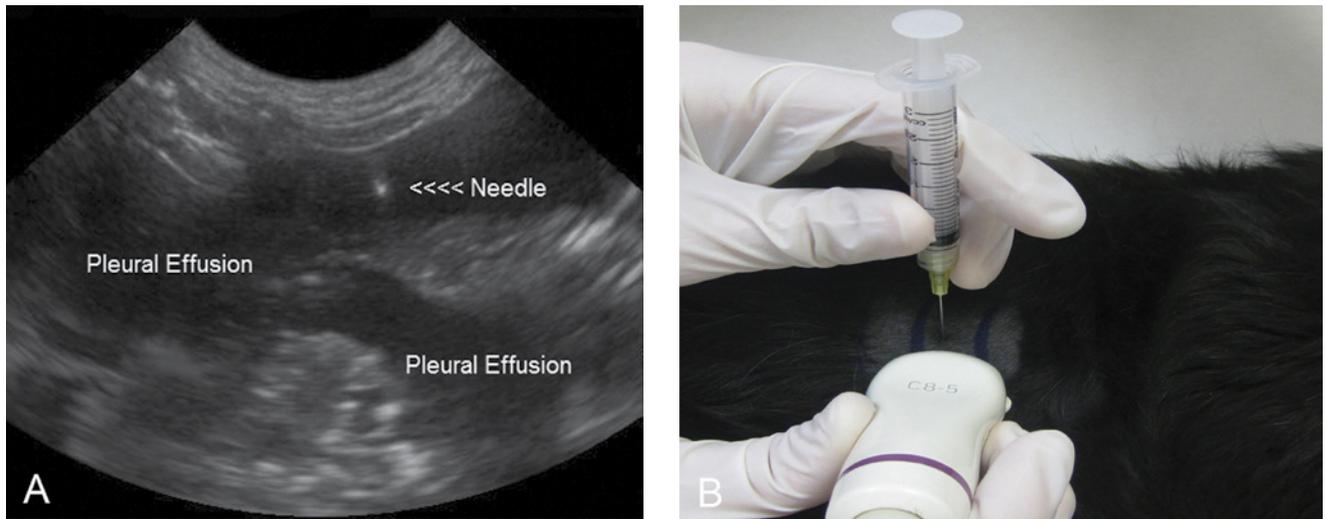


Figure 17.4. Free-hand ultrasound-guided thoracocentesis, short-axis. (A) The needle appears as a small white dot (arrow) on short-axis view. Courtesy of Dr. Greg Lisciandro, Hill Country Veterinary Specialists, San Antonio, Texas. (B) The ultrasound probe is placed at an angle of 90 degrees to the skin, perpendicular to the ribs. The needle should be inserted at an angle of 30 degrees to the skin (60 degrees to the probe), just caudal and 1–2 cm dorsal to the center point of the probe to avoid the nerves and vessels that run caudal to the ribs. The orientation marker on the probe is directed cranially.

- The needle is advanced a little farther until the tip is seen within the pleural fluid (Figure 17.4A). At this time fluid will be noted in the hub of the needle and IV extension set. To confirm the tip of the needle within the pleural fluid, the probe can be moved slightly proximal and distal to the needle. The needle tip will appear as a small, hyperechoic (bright white) dot on short-axis view (Figure 17.4A) with or without a ring-down artifact (see Figures 1.8B and 12.7).

The needle will appear as a small hyperechoic (bright white) dot when viewed in short-axis (Figure 17.4A) with or without a ring-down artifact (see Figures 1.8B and 12.7).

- At this point, the needle can be angled ventrally so that it is lying against the thoracic wall with the bevel of the needle facing away from the thoracic wall.

Parallel Probe Placement Thoracocentesis

- When the US probe is placed parallel to the ribs, it should be placed slightly caudal to the center of the rib space to avoid nerves and vessels that run along the caudal border of the rib cranial to the needle insertion site (Figure 17.5A).

- Orient the US probe such that the orientation marker is directed dorsally.
- A 20- to 22-gauge hypodermic needle attached to an IV extension set, three-way stop cock, and syringe should enter the thorax parallel to the long-axis of the probe at an angle of 30 to 45 degrees to the thoracic wall.
- The needle should enter the thorax 1–2 cm dorsal to the US probe with the bevel of the needle oriented toward the US probe (Figure 17.5A). A lower angle will keep the needle more perpendicular to the US probe, improving visualization of the needle/needle tip as it traverses the subcutaneous tissues and enters the pleural space (Figure 17.5B).
- Once the needle/needle tip is seen to enter the subcutaneous space, an assistant may apply gentle negative pressure while the needle continues to be advanced through the intercostal muscles to the level of the pleura. The tip of the needle will typically indent the parietal pleura before piercing it and entering the pleural cavity.

The tip of the needle will typically indent the parietal pleura, which may be used to help orientate the US probe to better ultrasonographically locate the needle tip.

- As the needle tip is seen entering the pleural effusion, fluid should simultaneously enter the needle

hub and extension set with the exception of viscous exudates. Now the needle should be angled ventrally toward the sternum so that it is lying against the thoracic wall with its bevel facing toward the pleural effusion and away from the thoracic wall.

7. In cases of a therapeutic thoracocentesis, aspiration of the pleural space should continue until negative pressure is established, as the patient allows. Once fluid is obtained, samples should be collected into red and lavender topped tubes for diagnostic analysis.
8. If a hemothorax (HTX) is suspected, a sample should be placed within a second red topped tube and checked after several minutes for clotting because most true non-iatrogenic HTX will not clot. The sample should also be analyzed and the packed cell volume (PCV) compared to peripheral PCV for more definitive diagnosis of HTX. Clotting often indicates accidental aspiration of a vessel or a cardiac chamber.

The diagnosis of hemothorax (HTX) is made by a non-clotting sample with its packed cell volume (PCV) comparable to the peripheral PCV of the patient. It is very easy to visually overestimate the PCV by looking at a hemorrhagic sample. Always spin the fluid and measure the PCV.

Post-Thoracocentesis Use of Ultrasound for Tracking (Monitoring)

Ultrasound should be used post thoracocentesis to monitor for the recurrence of pleural effusion and any complications including HTX and PTX. Measuring the widest aspect with the calipers or by approximation using the scale on the right side of the screen provides more accurate reassessments, especially if multiple veterinarians are involved in case management. As a general rule of thumb, stable post-thoracocentesis cases should have TFAST³ and Vet BLUE performed at least once four hours post procedure and then serially with time intervals determined by the patient's clinical course and the suspected condition (see Chapter 9).

The use of thoracic and lung US has been shown to be superior to chest auscultation and chest radiography in humans for pleural effusion, PTX, and many lung conditions (see Chapters 9 and 10).

Abdominocentesis

Ultrasound-Guided vs. Blind Abdominocentesis

Using real-time scanning, the trajectory path of the needle and nearby organs can be visualized during abdominocentesis. Thus the needle may be directed into the fluid pocket more accurately with less risk of puncturing nearby intra-abdominal organs, reducing the risk of complications (Bard 1986). Although the complication rate with conventional blind abdominocentesis is rare (0.9% in humans, with hematoma formation being the most common complication), the morbidity associated with complication can be significant (Dewitz 2003, Runyon 1986). False-positive results have been reported with accidental aspiration of abdominal organs such as the spleen or bowel, while false-negative results may be reported in cases in which fluid is compartmentalized or present in small volumes, or the needle is entrapped within omentum or other intra-abdominal organs (Walters 2003, Crowe 1984, Bjorling 1983). The frequency of false-positive and -negative results can be reduced with real-time US-guided abdominocentesis; furthermore, US-guided abdominocentesis has a higher success rate when compared to blind abdominocentesis (Boysen 2004, Lisciandro 2009). This is especially true when there are small volumes of peritoneal fluid and when peritoneal fluid is compartmentalized (Patal 2012, Nazeer 2005).

Indications for Abdominocentesis

The process of aspirating or acquiring fluid from the peritoneal cavity is termed abdominocentesis. In general, veterinary patients with undifferentiated ascites should have their effusion characterized if acquisition may be safely performed at the attending veterinarian's discretion.

It is important to note that peritoneal effusion, also referred to as ascites, is always abnormal in mature dogs and cats; however, juvenile kittens and puppies may have small-volume effusions that are purely anechoic (black) and considered normal (Chapter 13).

The indications for abdominocentesis are as follows:

- Characterization of ascites for diagnostic information
- Characterization of ascites as septic or sterile with the former typically considered life-threatening and an indication for emergent exploratory laparotomy

- Therapeutic relief of symptoms such as respiratory compromise/ distress or discomfort from large-volume ascites

Scanning Technique for Abdominocentesis

The abdomen is quickly scanned, typically using the AFAST³ technique (see Chapter 2) to identify and localize fluid accumulations.

In cases of suspected peritonitis based on physical examination and history, in which a rapid AFAST³ scan is negative, a more focused emergency scan such as the COAST³ or focused gastrointestinal and pancreas exam (Chapter 7) may be additionally performed. Using additional abbreviated focused or COAST³ exams may help find otherwise occult small amounts of focal or localized ascites and any obvious intra-abdominal abnormalities.

AFAST³ should be repeated after resuscitation and rehydration. Because serial exams increase the sensitivity of FAST, repeat exams should generally be performed at least once four hours post-admission in stable patients (sooner as clinical course dictates) and considered out to 12–24 hours.

Ultrasonographic Findings

- Free fluid in the peritoneal cavity often appears ultrasonographically as anechoic (black) triangles or sharply angled images rather than anechoic stripes, which are typically loops of small bowel or the great vessels.
- Free fluid can approximate the echogenicity (grays) of soft tissue structures, particularly when blood clots or highly cellular free fluid such as septic/suppurative effusions are present.
- Consideration should always be given to the possibility for free fluid (in any cavity or space) to be due to a coagulopathy and specific testing dictated accordingly.

Free fluid is typically seen as anechoic triangles or sharply angled areas unlikely to occur in normal fluid-filled structures and unlikely to image as anechoic stripes, which are generally small bowel or great vessels (see Figures 2.2, 2.6, 2.9, 2.10, and 2.11; Chapter 2).

- Peritoneal fluid generally appears more anechoic than the echogenicity of the abdominal wall.

- Smaller quantities of free fluid typically form triangles or sharp angles between other more echogenic intra-abdominal structures (see Figures 2.2, 2.6, 2.9, 2.10, 2.11).
- With larger quantities of fluid, depending on location, the echogenic bowel, omentum, and spleen may appear to be wafting or floating within the fluid (see Figures 2.2, 2.6, 2.9, 2.10, and 2.11).
- Echogenic strands may occasionally be noted within the free fluid.

False positives occasionally occur with large necrotic centers within mid-abdominal masses, a fluid-distended stomach or urinary bladder, or an enlarged uterus (pyometra). The attending veterinarian should consider such possibilities (see Figures 2.3, 4.5, and 8.6).

Materials to Perform Abdominocentesis

- 20- to 22-gauge, 1- to 2-inch hypodermic needles
- Clippers for long-haired patients
- Antimicrobial scrub and solution
- Red (plain) and lavender (EDTA) topped tubes for sterile fluid collection
- Sterile culturettes
- 3- or 6-ml syringes
- US machine and appropriate US probe

Procedure to Perform Abdominocentesis

The following is a general overview regarding positioning, site preparation and approximating needle length. Abdominocentesis may be performed with the animal in left or right lateral recumbency, dorsal recumbency, or standing, depending on patient comfort and clinician's preference. It should be performed using aseptic technique. Free-hand US-guided abdominocentesis is typically preferred because it allows greater flexibility in choosing access sites and is not limited to a single plane.

The abdomen should be rapidly scanned to identify the largest pocket of fluid, ascertain the location of other abdominal organs in proximity to the fluid, and help determine the possible cause of the abdominal fluid. The depth of the subcutaneous tissues and peritoneal fluid can be measured using the US machine's calipers or by approximating using the centimeter scale to the right of the screen to help ascertain the length of needle required, potentially improving patient safety. Once the largest fluid pocket has been identified, the abdominocentesis can be performed in longitudinal or transverse views.

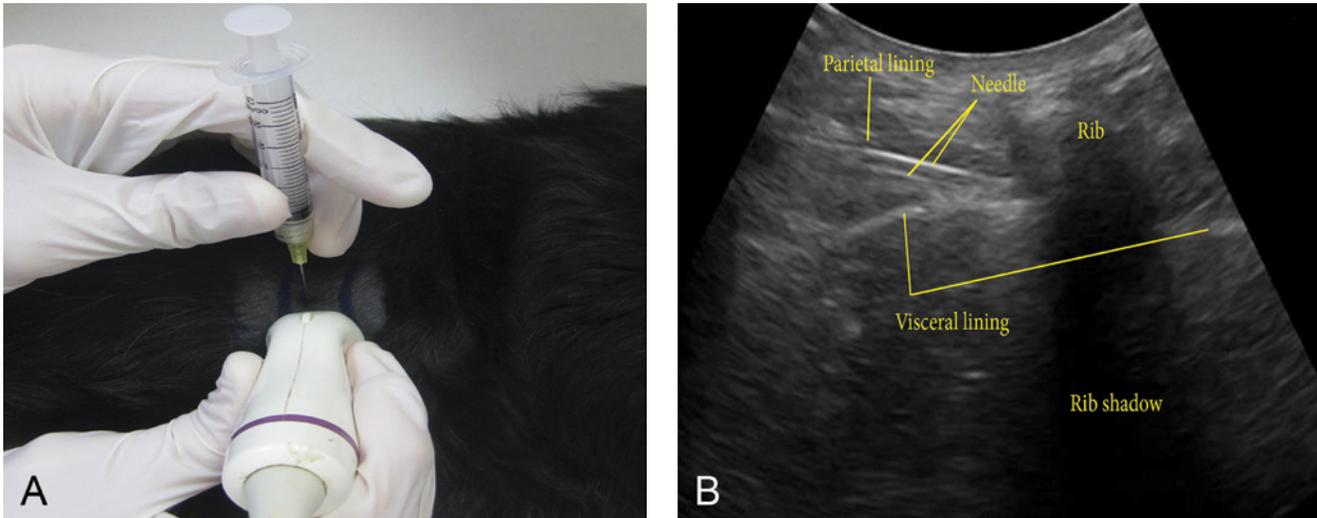


Figure 17.5. Free-hand ultrasound-guided thoracocentesis, long-axis. (A) The ultrasound probe is placed at a 60-degree angle to the skin. The needle is oriented at an angle of 60 degrees to the skin (60 degrees to the ultrasound probe) and should enter the thorax 1–2 cm dorsal to the ultrasound probe with the bevel of the needle oriented toward the probe. (B) The needle appears as a long white structure between the pleura lining (parietal and visceral) in the longitudinal plane.

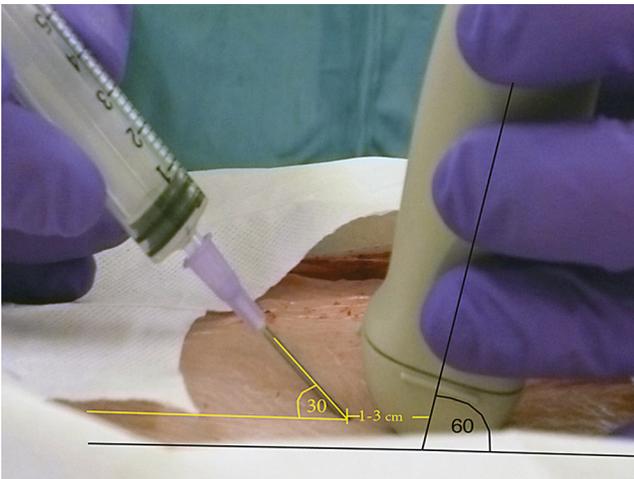


Figure 17.6. Free-hand ultrasound-guided abdominocentesis. The probe is positioned at a 60-degree angle to the skin. Keeping the needle in the plane of the ultrasound probe, angle the needle 30–60 degrees to the skin (60–90 degrees to the ultrasound probe) 1–3 cm from the notched side of the probe.

US-Guided Abdominocentesis

1. Verify the location of the probe marker. It should be directed toward the head of the patient or to its right for longitudinal and transverse views, respectively, thus helping with orientation of the US probe relative to the needle.
2. For abdominocentesis in the longitudinal view, place the probe at a 60-degree angle to the skin with the US probe marker directed cranially (Figure 17.6).

3. Connect an 18- to 22-gauge hypodermic needle to a syringe.
4. Keeping the needle in the plane of the US probe, angle the needle 30–50 degrees to the skin and 1–3 cm from the side of the US probe with the probe marker (Figure 17.6).
5. Point the bevel of the needle toward the US probe. Using real-time US-guided assistance, the tip of the needle can be visualized as it passes through the subcutaneous tissues and into the peritoneal cavity.

If the needle is not visible ultrasonographically, the US probe should be moved slightly to either side of the needle to try and visualize it. Rapidly moving the needle by advancing and retracting it a couple of millimeters may also help localize the needle because it will typically result in tissue movement near the needle.

6. Look for the tip of the needle because it often can be seen indenting the peritoneal lining before it enters the peritoneal cavity. The tip of the needle appears as a hyperechoic (bright) structure either as a dot or line with or without ring-down artifact (Figures 17.4A, 17.5B; and also see Figures 1.8B, 12.8).
7. Track the trajectory of the needle tip until it is lying within the peritoneal fluid to be aspirated (Figure 17.7).
8. Apply gentle pressure to the syringe once the tip of the needle is confirmed to be in the desired location. The presence of fluid in the needle hub and syringe helps confirm proper location of the needle tip.

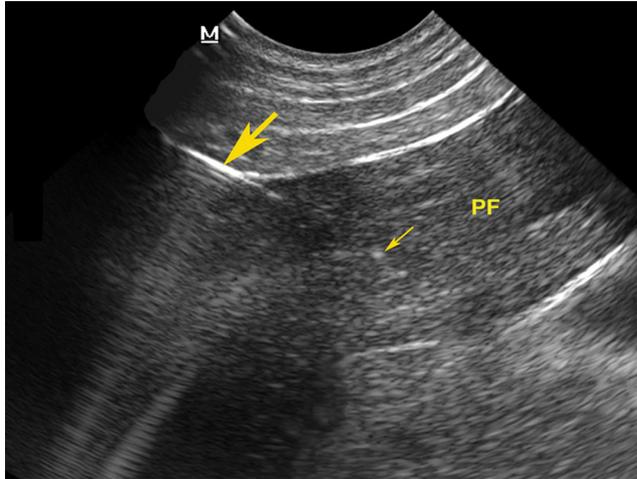


Figure 17.7. Free-hand ultrasound-guided abdominocentesis. The trajectory of the needle (large arrow) and needle tip (small arrow) should be tracked with ultrasound until the needle tip is lying within the peritoneal fluid (PF) to be aspirated. The peritoneal fluid in this patient is particulate and echogenic, suggesting a cellular effusion such as an exudate or hemorrhage. A diagnosis of hemoabdomen was made based on evaluation of the aspirated abdominal fluid.

9. Release negative pressure on the syringe before withdrawing the needle from the peritoneal cavity.

Alternately, the needle may be left open without an attached syringe and fluid acquired through capillary and gravitational flow.

10. Collect sterile samples of peritoneal fluid into sterile red and lavender topped tubes.

Modified Ultrasound-Guided Diagnostic Peritoneal Lavage (MUG-DPL)

Ultrasound-Guided vs. Blind Diagnostic Peritoneal Lavage

Diagnostic peritoneal lavage (DPL) has been advocated in cases of blunt and penetrating abdominal trauma, acute abdominal pain, and cases of suspected peritonitis when abdominocentesis has resulted in a negative tap (Walters 2003). US has essentially replaced the need for DPL in most trauma patients. In humans, US has a similar sensitivity and specificity to DPL for diagnosing intra-abdominal injury, but is less invasive, associated with fewer complications, and allows for collection of undiluted fluid samples

via US-guided abdominocentesis, even when the quantity of peritoneal fluid is very small (Singh 2010, Tso 1992).

However, US-guided abdominocentesis may not be feasible in some clinical situations in which peritoneal fluid is present in very small quantities, is walled off, or is located in proximity to vital organs. In these situations, DPL may still prove diagnostically useful. Unfortunately, complications and failure to obtain a fluid sample are common in veterinary and human patients undergoing traditional DPL. For these reasons, the author prefers to use a modified US-guided diagnostic peritoneal lavage (MUG-DPL) technique which is minimally invasive. Furthermore, MUG-DPL may reduce the complication rate while increasing the success rate of obtaining a fluid sample compared to blind traditional DPL techniques.

Indications for MUG-DPL

The MUG-DPL technique is reserved for use in patients with acute abdominal pain or peritonitis with only small quantities of peritoneal fluid that cannot be aspirated by direct US-guided abdominocentesis, are unlikely to have advanced imaging, and samples of the fluid are urgently needed (and cannot wait for serial US exams).

In these patients, the quantity of peritoneal fluid is too small to tap or is located near vital organs that preclude direct US-guided abdominocentesis. By adding additional sterile fluid to the peritoneal cavity, it may be possible to identify and characterize small amounts of pre-existing peritoneal fluid or inflammation. Importantly, serial AFAST³ examinations after resuscitation and rehydration often detect larger and more accessible fluid pockets in cases of initially US-occult or inaccessible regions of peritonitis. Delaying the decision to perform MUG-DPL until after resuscitation should be considered in such cases because large enough accessible pockets of fluid may develop, lending themselves to abdominocentesis, which is technically easier, requires less time, and is less invasive.

MUG-DPL and traditional DPL confound subsequent imaging because of the introduction of free fluid and possibly free air. Thus, MUG-DPL should be delayed until after serial ultrasound or computerized tomography or other imaging modalities have been performed.

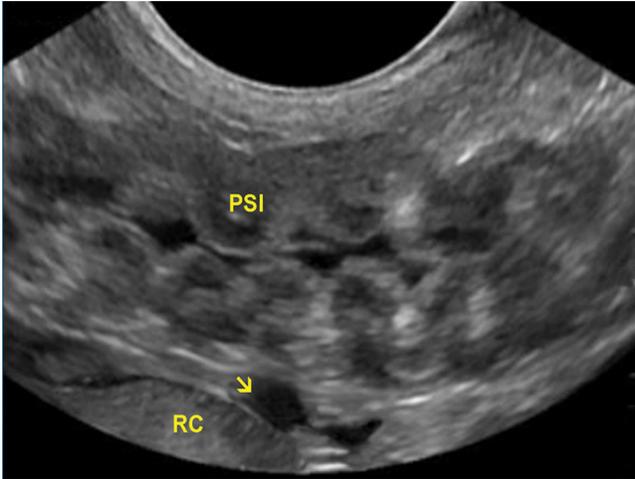


Figure 17.8. Indications for MUG-DPL. Small quantity of fluid (arrow) adjacent to plicated small intestine (PSI) and the renal cortex (RC) that is inaccessible to ultrasound-guided abdominocentesis due to the small quantity and its location.

Scanning Technique for MUG-DPL

See the scanning technique for abdominocentesis (above) and the COAST³ or focused gastrointestinal and pancreas exam (Chapter 7).

Ultrasonographic Findings

The ultrasonographic findings are similar to those of abdominocentesis, although the quantity of fluid will be very small and/or localized to an area that is not easily accessible by direct US-guided abdominocentesis (Figure 17.8).

Supplies Needed for MUG-DPL

- US machine and US probes
- Sterile, warmed 0.9% saline
- Intravenous fluid administration set
- 16- to 22-gauge, 1- to 4-inch over-the-needle catheters
- Clippers
- Antimicrobial scrub and solution
- 3- to 6-ml syringes
- Red (plain) and lavender (EDTA) topped tubes
- Culturettes
- Number-11 scalpel blade
- Lidocaine for local anesthetic block if needed

Procedure to Perform MUG-DPL

The aseptic technique should be used and coagulopathies should be ruled out or corrected prior to performing MUG-DPL.

Sedation and/or local anesthetic blocks may be used to calm the patient, although it is not usually necessary unless large-bore catheters are used. The patient can be placed in left or right lateral or dorsal recumbency depending on patient comfort and clinician preference.

Ultrasonography is used to localize small pockets of free abdominal fluid or areas of suspect focal peritonitis (see Chapter 7 regarding findings of focal peritonitis) that cannot be aspirated using US-guided techniques.

MUG-DPL

1. Clip the fur and aseptically prep the shaved skin over the site where peritoneal fluid was noted with US.
2. Similar to performing abdominocentesis, use free-hand US guidance to pass an over-the-needle catheter and stylet into the peritoneal cavity toward the identified focal fluid accumulation, taking care to avoid abdominal organs (Figure 17.9A).
3. Additional side holes may be made into the catheter, although care should be taken not to damage the integrity of the catheter because it may break off and leave the tip in the abdominal cavity, creating complications.

If one to three side holes are added to the catheter, it is recommended to stagger the holes and not exceed 50% of the circumference of the catheter.

4. A small stab incision can be made into the skin of the abdomen using a number-11 scalpel blade, but this is not usually necessary unless a 16-gauge catheter or larger size is used.
5. Once the stylet and catheter tip are within the abdominal cavity, the catheter can be advanced off the stylet and directed as close to the area of interest as possible using real-time US guidance (Figure 17.9B). In some instances it may be easier to reach the area of interest if the stylet is carefully advanced with the catheter.
6. Once the tip of the catheter is at the desired location, attach an IV extension set connected to a bag of warmed 0.9% saline solution to the catheter (Figure 17.9C).
7. Approximately 3–5 ml/kg of sterile saline is allowed to flow through the catheter via gravity (Figure 17.10).

The area of interest within the abdominal cavity can be monitored with real-time US as the sterile saline enters the abdomen to directly see if the infusate is reaching the site of interest.

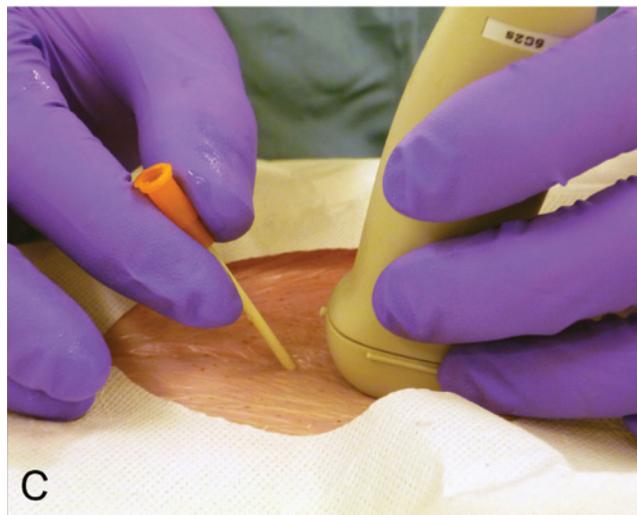
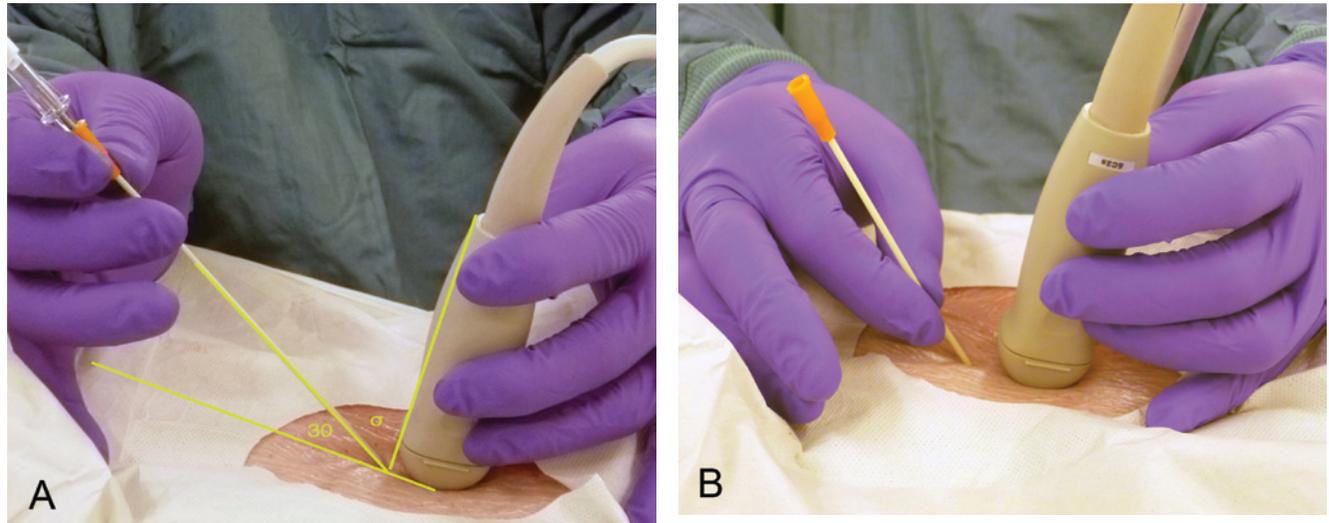


Figure 17.9. MUG-DPL procedure. (A) A 60-degree angle (σ) between the probe and catheter for placement of a 16-gauge, 4-inch over-the-needle catheter and stylet into the peritoneal cavity. In this diagram the probe is positioned at 90 degrees to the skin and the catheter and stylet are placed at approximately 30 degrees to the skin. (B) The catheter is advanced off the stylet and directed toward the identified focal fluid accumulation. (C) Final placement of the catheter prior to fluid administration.

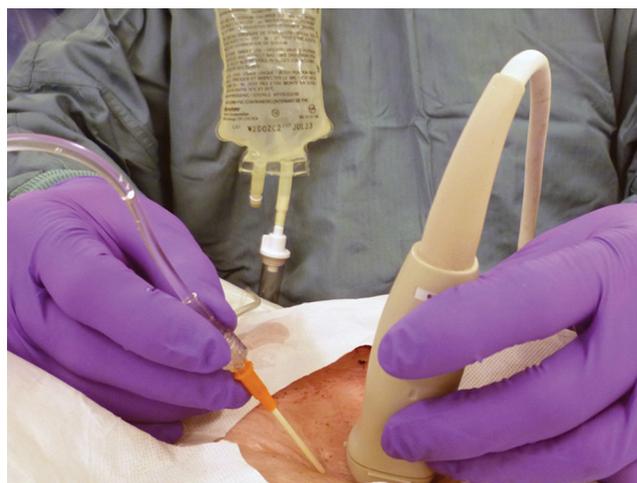


Figure 17.10. MUG-DPL fluid connection. A sterile bag of 0.9% warmed saline is connected to the catheter via an IV fluid administration set and approximately 3–5 ml/kg of saline is allowed to flow through the catheter via gravity.

8. If the infusate does not appear to reach the area of interest (no swirling of fluid or increase in size of the fluid pocket), or the size of the desired fluid pocket remains inaccessible via US-guided abdominocentesis, an additional 3–5 ml/kg saline aliquots (up to 20 ml/kg) may be administered through the catheter via gravity until it becomes possible to obtain a sample of abdominal fluid that is continuous with the area of interest.
9. Monitor the patient for respiratory distress or discomfort when using larger quantities of sterile saline. Discontinue the infusion of fluid if discomfort or respiratory distress is noted.
10. If the fluid pocket is continuous between the area of interest and the catheter tip, as determined by real-time US, a sample can be directly aspirated via the catheter.

To prevent excessive dilution and thus obtain a more representative sample of the site in question, the author often aspirates a sample of fluid from as close to the site of interest as possible using a separate needle and real-time US guidance (see the abdominocentesis procedure and Figure 17.11).

11. Alternately, remove the infusion catheter and directly aspirate a sample of fluid from the area of interest using real-time US-guided abdominocentesis (see above) (Figure 17.11). A 20- to 22-gauge, 1.5- to 2-inch hypodermic needle connected to a 3 to 6ml syringe may be used. In the event the fluid is deeper than 2 inches, a spinal needle or the stylet from an intravenous catheter may be used with caution.

In the event infusate does not appear to have reached the area of interest as determined by real-time US despite the maximum administration of 20ml/kg, remove the catheter and reposition the patient by gently rolling him or her from side to side. If necessary, reposition by standing or walking the patient while concurrently massaging and balloting the abdomen to help additionally redistribute the infused fluid.

12. Following the mixing of the infused fluid with pre-existing free abdominal fluid, repeat the ultrasonography and if necessary take the opportunity to aspirate any visible fluid pockets

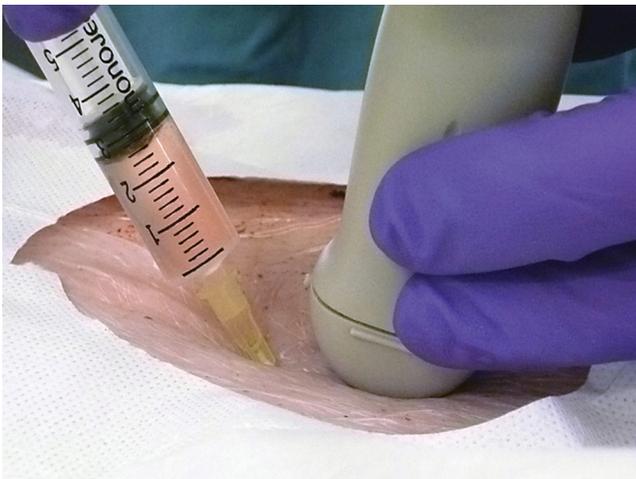


Figure 17.11. MUG-DPL free-hand ultrasound-guided abdominocentesis. When sufficient fluid has been infused, the catheter is removed and a sample of fluid is directly aspirated from the area of interest using real-time ultrasound-guided abdominocentesis and a 20-to 22-gauge, 1.5- to 2-inch hypodermic needle connected to a 3- to 6-ml syringe (see the abdominocentesis procedures).

(particularly those closest to the site of interest) with real-time US guidance (Figure 17.11). Fluid should be collected into red and lavender topped tubes and culturette for appropriate diagnostic analysis.

Pearls and Pitfalls, the Final Say

With the evolving ubiquitous use of US among non-radiologist physicians and veterinarians, the demand for newer technologies to improve the success of US-guided techniques has increased.

Some final comments regarding US-guided techniques and improving needle visibility:

- Needle visualization depends on the complex interaction between the needle, the tissue type, and the degree of reflection of the US beam (McGahan 1986). The closer the echogenicity of the tissue is to the needle, the more difficult it is to visualize the needle. Because fluid is anechoic, it provides a good contrast to the echogenicity of the needle, which often allows the needle or needle tip to be more readily visible within fluid-filled structures or spaces (McGahan 1986).
- In general, larger needles are easier to ultrasonographically visualize than smaller ones (Chapman 2005). To improve visualization, several companies have created US needles that are scored or marked, creating a more intense reflection of US waves back to the US probe and thus improving visualization of the needle (Figure 17.12).
- Pointing the bevel of the needle up toward the US beam has been reported to improve needle tip visualization by creating two echogenic foci at the needle tip as opposed to one when the bevel is not directed toward the probe (Bondestam 1992). The needle tip tends to be easier to visualize because it has an irregular surface as a result of the bevel being machine cut (Chapman 2005). Moreover, the bevel is reported to be even more visually enhanced when the needle tip is within fluid.
- The angle of the needle relative to the US beam impacts the ability to see the needle and its tip during US-guided centesis (Bradley 2001). Ultrasound



Figure 17.12. Schematic diagram of a notched needle to improve visualization.

waves reflected back from the needle or its tip result in greater visibility of the needle during real-time imaging. The greatest number of US waves reflected back to the US probe occur when the needle is placed perpendicular to the probe. Unfortunately, most fluid-filled structures (with the exception of superficial vessels or lesions) are located too deep to allow the needle to be passed in this manner.

Experimentally, when aspirating deeper structures, the optimal needle/probe angle has been demonstrated to be 55–60 degrees (a needle-skin angle of 30 degrees if the probe is perpendicular to the skin) with a distance between the needle insertion and probe of 2–3 cm (Bradley 2001).

- Quick, short 2- to 4-mm jabs of the needle facilitate visualization, as does rocking the US probe surface toward the needle. However, the benefit of rocking the US probe is lost if the skin-probe interface contact is diminished.
- It is helpful to look at the US probe as well as the needle while performing free-hand US-guided procedures. For example, the needle should lie in the same plane as the US beam when using the longitudinal technique. To improve longitudinal visualization, the probe should be slowly moved above and below the longitudinal axis of the needle. As previously mentioned, it is helpful to also rapidly advance and withdraw the needle 2–4 mm because this creates visible movement of tissues adjacent to the needle. The probe angle then can be adjusted to attempt to maximize visualization at the site of tissue movement.
- Finally, several companies, such as Ultrasonix (British Columbia, www.ultrasonix.com), have developed software (Sonix GPS) that allows sensors within the US probe to track sensors placed within needles. These tracking systems allow predetermined trajectory tracks to be visualized on the US screen and trace the needle outline as it is advanced through tissues, making the exact location of the needle tip and needle much easier to see.

References

- Bard C, Lafortune M, Breton G. 1986. Ascites: ultrasound guidance or blind paracentesis? *Can Med Assoc J* 135(3):209–210.
- Bjorling DE, Latimer KS, Rawlings CA, et al. 1983. Diagnostic peritoneal lavage before and after abdominal surgery in dogs. *Am J Vet Research* 44(5):816–820.
- Bondestram S. 1992. The needle tip echo. *J Ultrasound Med* 11:253–256.
- Bradley MJ. 2001. An *in-vitro* study to understand successful free-hand ultrasound guided intervention. *Critical Radiology* 56:495–498.
- Brown D, Gaillot H. 2008. Heart. In *Ultrasound of Small Animal Ultrasonography*, edited by D Penninck and MA D'Anjou. Ames, Iowa: Blackwell Publishing, pp 151–208.
- Callahan JA, Seward JB, Tajik AJ. 1985. Cardiac tamponade—pericardiocentesis directed by two-dimensional echocardiography. *Mayo Clin Proc* 60(5):344–7.
- Chapman GA, Johnson D, Bodenham AR. 2006. Visualization of needle position using ultrasonography. *Anaesthesia* 61:148–158.
- Clarke DP, Cosgrove DO. 1987. Real-time ultrasound scanning in the planning and guidance of pericardiocentesis. *Clin* 38(2):119–122.
- Crowe DT. 1984. Diagnostic abdominal paracentesis techniques: clinical evaluation in 129 dogs and cats. *J Am Anim Hosp Assoc* 20:223–230.
- Del Cura JL, Zabala R, Corta C. 2010. US-guided interventional procedures: what a radiologist needs to know. *Radiologia* 52(3): 198–207.
- Dewitz A, Frazee B. 2003. Soft tissue applications. In *Emergency Ultrasound*, edited by OJ Ma and J Mateer. New York: McGraw-Hill, p 3619.
- Field R. 2004. Ultrasound guided biopsies: Tricks, needle tips, and other fine points. *Ultrasound Q* 20(3): 91–99.
- Jones PW, Moyers JP, Rogers JT, et al. 2003. Ultrasound-guided thoracentesis: is it a safer method? *Chest* 123(2):418–423.
- Lichtenstein D, Hulot JS, Rabiller A, et al. 1999. Feasibility and safety of ultrasound-aided thoracentesis in mechanically ventilated patients. *Intensive Care Med* 25(9):955–958.
- McGahan JP. 1986. Laboratory assessment of ultrasonographic needle and catheter visualization. *J Ultrasound Med* 5:373–377.
- Nazeer SR, Dewbre H, Miller AH. 2005. Ultrasound-assisted paracentesis performed by emergency physicians vs. the traditional technique: a prospective, randomized study. *Am J Emerg Med* 23:363–367.
- Nicolaou S, Talsky A, Khashoggi K, Venu V. 2007. Ultrasound guided interventional radiology in critical care. *Crit Care* 35(5): s186-s197.
- Patel PA, Ernst FR, Gunnarsson CL. 2012. Evaluation of hospital complications and costs associated with using ultrasound guidance during abdominal paracentesis procedures. *J Medical Economics* 15(1): 1–7.
- Runyon BA. 1986. Paracentesis of ascitic fluid: A safe procedure. *Arch Intern Med* 146(11):2259–61.
- Scansen BA. 2011. Interventional cardiology for the criticalist. *J Vet Emerg Crit Care* 21(2):123–36.
- Singh G, Arya N, Safay R, et al. 1997. Role of ultrasonography in blunt abdominal trauma. *Injury* 28:667–670.
- Taavitsainen M, Bondestram S, Mankinen P, et al. 1991. Ultrasound guidance for pericardiocentesis. *Acta Radiol* 32(1):9–11.

- Tayal V, Moore C, Rose G. 2003. Cardiac. In *Emergency Ultrasound*, edited by OJ Ma and J Mateer. New York: McGraw-Hill, pp 89–127.
- Tibbles CD, Porcaro W. 2004. Procedural applications of ultrasound. *Emerg Med Clin N Am* 22: 797–815.
- Tsang TS, Enriquez-Sarano M, Freeman WK, et al. 2002. Consecutive 1127 therapeutic echocardiographically guided pericardiocentesis: clinical profile, practice patterns, and outcomes spanning 21 years. *Mayo Clin Proc* 77(5):429–36.
- Tso P, Rodriguez A, Cooper C et al. 1992. Sonography in blunt abdominal trauma: a preliminary progress report. *J Trauma* 33:39–44.
- Walters JM. 2003. Lavage. *Clin Tech in Sm Anim Pract* 18(1):32–38.
- Weingardt JP, Guico RR, Nemcek AA Jr, et al. 1994. Ultrasound findings following failed, clinically directed thoracentesis. *J Clin Ultrasound* 22(7):419–26.

SETTING UP AN ULTRASOUND PROGRAM

Introduction

With the widespread use of ultrasound (US) in private practice by non-radiologist veterinarians, it behooves the general practitioner, emergency clinician, or other non-radiologist veterinarian to develop a structured ultrasound program for their practice or institution. The following are the key points for establishing an ultrasound program.

Key Points

- Establish a point person
- Establish accessibility
- Establish goal-directed templates
- Establish quality control
- Establish a fee structure for FAST and focused or COAST³ exams

Establish a Point Person

It is imperative that one individual take the lead and oversee the implementation of the program. That individual should be (1) properly trained, through basic ultrasound courses, with understanding not only of basic ultrasound principles but also of its limitations, (2) an effective communicator and motivator, and (3) able to implement quality control.

Establish Accessibility

Accessibility is important on several fronts, including the following:

Accessible US machine: The US machine needs to be in the treatment or triage area, where patients are

being examined, to optimize accessibility and convenience.

Accessible recording of exam findings: FAST³ and focused or COAST³ objectives should be clear. Ultrasound exam findings should be easily entered into the medical record either as separate forms (which need to be readily accessible [placed on the US machine stand]) or as established templates within electronic medical records.

Saving US images for clients and the medical record is somewhat controversial because of the subjectivity in interpretation of still images (vs. video clips). In human medicine, US images are typically not saved and only results are recorded. We inform our clients that ultrasound images are not archived. Our findings are recorded in the medical record using standardized template(s) (see Appendix II). Check with your state board to see if there are any requirements pertaining to archiving US images.

That being said, saving images is very helpful when reviewing cases (see Establishing Quality Control, below). Whether your practice chooses to save images for didactic purposes or for patient archiving, the author finds it easiest to record images in the same order every time. For example, when performing AFAST³, the standard order is followed for each of its four views with a representative image saved from each site. Thus, labeling is often unnecessary. Other options include labeling each AFAST³ view using the text function or marking the body icon function featured on your US machine.

Accessible fee structures: Established fees should be simple, consistent, and comprehensible. All abbreviated exams should be considered legitimate and charged a fee when performed by trained sonographers. “No fee” exams, or the so-called practice exams, should be discouraged because they lack accountability

and in the long run are harmful to your ultrasound program.

In beginning an ultrasound program it is wise to start with AFAST³ exams and include a four-hour post-admission serial exam in the upfront fee for all hospitalized patients. The four-hour post-admission serial FAST exam is recommended by the American College of Emergency Physicians for all stable human patients (repeating sooner if the patient is unstable) (www.acep.org). This not only improves patient care but also accelerates your practice's ultrasound training because the attending veterinarian must perform a serial exam as a standard of care (and the fee has already been assessed). AFAST³ serves as a platform for proficiency in all focused or COAST³ intra-abdominal exams by using the target-organ approach. By repeatedly looking through and near target-organs for free fluid, the attending clinician rapidly gains US experience during every single AFAST³ exam while searching for free fluid.

TFAST³ and Vet BLUE may be initiated in a similar manner with initial and serial exams. Vet BLUE is very helpful because the wet lung vs. dry lung concept is readily mastered by beginners and may be compared with thoracic radiographs for learning. The glide sign and the additional lung ultrasound signs (shred, tissue, and nodule sign[s]) become less intimidating with successive Vet BLUE exams because deviations along the PP-line at the gator sign orientation become readily apparent as the sonographer's eyes grow accustomed to easily learning the most basic wet lung vs. dry lung principles.

Establish Goal-Directed Templates

Goal-directed templates (GDTs) are of utmost importance to standardize your practice's FAST³ and focused ultrasound exam(s). GDTs also assist in training. These templates often evolve over time for individual practices as proficiency is gained through US experience. See Appendix II for examples.

Establish Quality Control

Quality control should be overseen by the ultrasound program director. Quality can be controlled by taking the following steps:

Saving images for case review: Saving images for review at your staff meetings reaps rewards beyond measure by demonstrating to the entire practice the value of ultrasound in case management and how it positively affected patient outcome. Remember, every life saved is an asset to your practice.

Training individuals: Encouraging and facilitating time off and financial support for continued ultrasound training is imperative for a healthy and stimulating ultrasound program. Compensating individuals motivates them to acquire ultrasound proficiency and creating an overall fund as a percentage of the ultrasound income is a way to budget for such training.

Communicating with clients and colleagues: A clarifier at the end of your GDT is a means to communicate the intents of your focused and FAST³ exams. In general, these abbreviated exams are designed to rapidly detect certain conditions and help guide diagnostics and therapy. They are not meant to replace a formal (or complete) ultrasound exam. See Appendix II for suggestions.

Establishing a consensus: Involve everyone who actually performs the abbreviated ultrasound exams in periodically (at least bi-annually) reviewing your ultrasound program regarding its strengths, weaknesses, and strategies to improve the program.

Ensuring quality control and conducting periodical reviews: Ideally, the ultrasound director should institute a multi-tiered approach; each ultrasonographer should be trained with lectures and hands-on time, complete a minimum number of proctored exams (12–25 are suggested by the author), and then undergo periodic reviews of cases thereafter. Periodic case reviews (monthly at staff meetings are suggested) and bi-annual overall program assessments are also imperative to ensure quality control. As previously noted, the use of standardized GDTs and the saving of US images on both interesting and routine cases help pinpoint deficiencies. These quality control strategies help direct training and motivate colleagues to improve their ultrasound skills.

FAST³ and focused ultrasound saves lives!

GOAL-DIRECTED TEMPLATES FOR MEDICAL RECORDS

Refer to the individual chapters as well as Appendix IV for the respective references.

Abdominal Focused Assessment with Sonography for Trauma, Triage, and Tracking (AFAST³)

The AFAST³ is an ultrasound exam used to detect the presence of free abdominal fluid and other conditions to better direct resuscitative efforts and veterinary patient care. AFAST³ allows assessment for evidence of intra-abdominal injury or disease, and in many instances intrathoracic injury or disease. The AFAST³ exam is not intended to replace a complete (or formal) abdominal ultrasound exam. Guidelines for humans recommend at least one serial four-hour post-admission FAST exam in all stable patients (www.acep.org). See Chapter 2 for more information.

Patient positioning:

- Right lateral recumbency (right preferred)
- Left lateral recumbency
- Modified sternal recumbency

Gallbladder:

- Visualized:** Yes or no
- Contour, lumen, and wall:** Normal or abnormal and halo sign: Yes or no
- Comments:** None or _____.

Urinary bladder:

- Visualized:** Yes or no
- Contour, lumen, and wall:** Normal or abnormal
- Comments:** None or _____.

Diaphragmatico-hepatic (DH) view:

Pleural effusion:

- Absent
- Present mild or moderate or severe
and greatest width ____cm.
- Indeterminate

Pericardial fluid:

- Absent
- Present mild or moderate or severe
and greatest width ____cm.
- Indeterminate

Hepatic veins:

- Unremarkable/normal or distended
or indeterminate

Positive or negative at the four views (0 negative, 1 positive)

- Diaphragmatico-hepatic (DH) site: 0 or 1
- Spleno-renal (SR) site: 0 or 1
- Cysto-colic (CC) site: 0 or 1
- Hepato-renal (HR) site: 0 or 1

Total Score: _____.

Abdominal fluid score (AFS): 0–4 (0 negative all quadrants to a maximum score of 4 positive all quadrants)

Normally there is no abdominal or retroperitoneal free fluid in adult cats and dogs (AFS=0); juvenile puppies and kittens may have a small volume anechoic effusion considered as normal.

Small bleeder (AFS 1, 2) vs. big bleeder (AFS 3, 4) concept in acute hemorrhage: AFS 1, 2 dogs (initially and serially) will generally not experience significant anemia if they had no pre-existing anemia, are not bleeding at another site, or not experiencing hemodilution from large fluid volumes. AFS 3, 4 dogs (initially or serially) in contrast predictably become anemic in time, and increasing (AFS) score signifies ongoing

hemorrhage. Unless the bleed is catastrophic, there is an initial compensatory period in which the packed cell volume stays normal. Approximately 20%–25% of AFS 3, 4 dogs will become severely anemic (PCV less than 25%) and need a blood transfusion(s). The predictive value of the AFS for anemia is generally unreliable in cats.

Overall clinical impression and comments:

None or _____.

Chapter 3: Focused or Cageside (COAST³)—Liver and Gallbladder

The Focused or cageside (COAST³) liver and gallbladder exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients. It is not intended to replace a complete abdominal ultrasound exam.

Gallbladder:

***Bilobed?** Yes or no *Note that bilobed is a normal variation that is more common in cats.

Degree of gallbladder filling: Small or moderate or large

Luminal contents:

*Normal expected anechoic bile

Abnormal : Sediment non-shadowing or shadowing or calculi or mucocele

Measurements of any calculi and approximate number: _____.

Wall abnormalities (thickening):

None or focal or multifocal or diffuse or mass effect or halo sign

Location(s): _____.

Measurement(s): _____.

Normal measurements of gallbladder wall:

cats less than 1 mm; dogs less than 3 mm; normal contents: *generally homogeneous anechoic bile, although degrees of gallbladder sludge may be considered as clinically irrelevant or may indicate cholestasis based on the patient's clinical profile.

Liver:

***Overall size** (subjective, *radiography is a more sensitive evaluation):

Unremarkable

Enlarged (hepatomegaly suggested by rounded edges and hepatic lobes [especially left side] extending past the

costal arch): Mild or moderate or severe

*Note that abdominal radiography provides a more reliable assessment for hepatomegaly.

Overall liver echogenicity:

Unremarkable

Abnormal : Hyperechoic or hypoechoic or mixed echogenicity **that is** focal or uniformly diffuse or multifocal/patchy

Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic/brighter) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK); this is remembered as $S > Li \geq CK$ or "SLiCK."

Nodule (s):

Absent

Present single or multiple

Measurements and approximate number: _____.

Echogenicity of nodule(s): _____.

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 4: Focused or Cageside (COAST³)—Spleen

Spleen:

The focused or cageside (COAST³) spleen exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients. It is not intended to replace a complete abdominal ultrasound exam.

Overall size (dogs, subjective; cats, normal under 10 mm thickness; in cats the spleen is never folded over unless it is enlarged [splenomegaly]):

Unremarkable

Enlarged : Mild or moderate or severe

Overall splenic echogenicity:

Unremarkable

Abnormal : Hyperechoic or hypoechoic or focal **that is** inhomogeneous/patchy or diffuse or lacy

Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic/brighter) than the

liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK); this is remembered as $S > Li \geq CK$ or “SLiCK.”

Nodule (s):

Absent present single or multiple
 Measurement (s): _____cm.
 Echogenicity of nodule(s): _____.

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 5: Focused or Cageside (COAST³)—Kidney

The Focused or Cageside (COAST³) Kidney Exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients and is not intended to replace a complete abdominal ultrasound exam.

Kidney:

Overall echogenicity:

Unremarkable
 Abnormal : Hyperechoic or hypoechoic
 that is focal or multifocal/patchy
 or diffuse/homogeneous

Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic/brighter) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK); this is remembered as $S > Li \geq CK$ or “SLiCK.”

Overall corticomedullary distinction (subjective):

Unremarkable or abnormal (decreased)

Kidney size (measure both width \times length, but length used for normal size in cats) (cats, normal length 3.0–4.4 cm; dogs, no established normal size so must compare sizes of left to right [or defer to radiographic measurements]):

Left: _____ \times _____ cm.

Right: _____ \times _____ cm.

Symmetrical or asymmetrical

Renal pelvis size: There is variability in both cats and dogs. The height is measured. Generally, normal in the cat is 1.5–2 mm with maximum height of 2.8 mm, and normal in dogs is 2–3 mm with a maximum height of 3.8 mm. A general rule of thumb is to consider the renal pelvis abnormal (pyelectasia) if it measures 3 mm or greater in cats and 4 mm or greater in dogs.

Renal pelvis measurement (s) (height):

Left: _____mm.

Right: _____mm.

Nodule (s): Absent or present and single or multiple

Measurement (s) and approximate numbers of nodules: _____.

Echogenicity of nodules: _____.

Cysts (s): Absent or present and single or multiple and location: cortical or corticomedullary or both

Measurement (s) and approximate numbers of cysts: _____.

Retroperitoneal fluid: Absent or present and trivial or mild or moderate or severe

Echogenicity of retroperitoneal fluid: Anechoic or hyperechoic and homogeneous? Yes or no

Measurement: Greatest width _____cm.

Subcapsular fluid: Absent or present and trivial or mild or moderate or severe

Echogenicity of subcapsular fluid: Anechoic or hyperechoic and homogeneous? Yes or no

Measurement greatest width _____cm.

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 6: Focused or Cageside (COAST³)—Urinary Bladder

The focused or cageside (COAST³) urinary bladder exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients and is not intended to replace a complete abdominal ultrasound exam.

Urinary bladder:

Degree of urinary bladder filling: Small or moderate or largely distended

Luminal contents (normal expected appearing urine generally dogs, uniformly anechoic [black] urine, and in cats the same appearance, however, intraluminal “sparkles” representing lipid droplets can also be normal): Normal or sediment that is non-shadowing (non-mineralized) or shadowing (mineralized) and calculi or thrombus (blood clot) or indeterminate

Measurements of any calculi and approximate number: _____.

Wall abnormalities: None or focal or multifocal or diffuse **that are** mass-like? Yes or no and polypoid? Yes or no

Location (s): _____.

Measurement (s): _____mm.

Normal measurements of urinary bladder wall with moderate bladder distension: Cats, 1.3–1.7mm; Dogs, 1.4–2.3mm but may be as thick as 3mm in large dogs.

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 7: Focused or Cageside (COAST³)—Gastrointestinal and Pancreas

The focused or cageside (COAST³) gastro-intestinal and pancreas exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients and is not intended to replace a complete abdominal ultrasound exam.

Stomach:

Visualized: Yes no or indeterminate

Stomach Lumen:

Gas-filled or fluid-filled **with** ingesta **that is** shadowing dirty (gas and fluid or possible foreign body) or shadowing clean (possible foreign body) or other/indeterminate _____.

Wall: Unremarkable or abnormal

Normal stomach wall thickness: Dogs, 3–5mm (higher in some giant breeds); cats, 2mm inter-rugal [up to 4.4mm if rugal fold is measured]; measured from the hyperechoic outer serosal margin to inner mucosoluminal surface.

Stomach size (subjective): Unremarkable or obviously distended or indeterminate

General stomach overall clinical impression and comments:

Unremarkable or _____.

Small bowel:

Small bowel lumen:

Normal, unremarkable

Abnormal and gas-filled or fluid-filled **with** ingesta **that is** shadowing dirty (gas and fluid, or possible foreign body) or shadowing clean (possible

foreign body) or other/indeterminate _____.

Peristalsis observed: Yes or no or indeterminate **that is** normal frequency or abnormal or indeterminate

Normal peristalsis: Stomach, 4–5 contractions/minute; small bowel, 1–3 contractions/minute; large bowel, no movement; each counted over three minutes and averaged.

Obvious small bowel dilatation (small bowel lumen distention of greater than 1.5cm, measured from serosal surface to serosal surface):

No dilatation or yes dilatation **that is** focal or multifocal or diffuse or indeterminate

Small bowel wall normal thickness other than duodenum: Dogs, 4mm or less; cats, 2.5mm or less, measured from the hyperechoic outer serosal margin to inner mucosoluminal surface.

Normal or abnormal or indeterminate

Small bowel wall measurement (s): _____mm.

Overall clinical impression and comments on small bowel:

Unremarkable or _____.

Pancreas:

Dogs, right limb easier to identify and image; cats, left limb easier to image: Unremarkable (normally not easily observed) or observed

Measurement if observed (height × width [transverse view]): _____×_____cm.

Any peripancreatic abnormalities:

Free fluid? Yes or no

and greatest width _____cm.

Peripancreatic structures: Unremarkable or hyperechoic (bright)

Overall clinical impression and comments on pancreas:

Unremarkable or _____.

Chapter 8: Focused or Cageside (COAST³)—Reproductive

The focused or cageside (COAST³) reproductive exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary

patients and is not intended to replace a complete abdominal ultrasound exam.

Focused reproductive male exam: Prostate, testicles, epididymis

Prostate: Unremarkable or abnormal

Symmetry of lobes: Symmetrical or asymmetrical

Echogenicity: Normal (homogeneous with the appearance of a hyperechoic "butterfly" in the transverse plane) or hyperechoic or hypoechoic with mixed echogenicity? Yes or no that is mineralized? Yes or no or indeterminate

Cysts: Parenchymal or paraprostatic or indeterminate

Nodule (s): Hyperechoic or hypoechoic with mixed echogenicity? Yes or no with approximate number and measurement (s) _____ cm.

Testicles:

Symmetry: Symmetrical or asymmetrical or indeterminate (retained and not accessible)

Right testicle location: Scrotal or inguinal or intra-abdominal

Right echogenicity: Normal (homogeneous with the linear hyperechoic mediastinum testes) or hyperechoic or hypoechoic or mixed echogenicity

Right nodules: Absent or nodule (s) with approximate number and measurement (s) _____.

Right measurement (length × width): _____ × _____ cm.

Right epididymis: Unremarkable or enlarged with fluid accumulation? Yes no or indeterminate

Left testicle location: Scrotal or inguinal or intra-abdominal

Left echogenicity: Normal (homogeneous with the linear hyperechoic mediastinum testes) or hyperechoic hypoechoic or mixed echogenicity

Left nodules: Absent or nodule (s) with approximate number and measurement (s) _____.

Left measurement (length × width): _____ × _____ cm.

Left epididymis: Unremarkable or enlarged with fluid accumulation? Yes no or indeterminate

Overall clinical impression and comments:

Unremarkable or _____.

Focused or cageside (COAST³) reproductive female exam

The focused or cageside (COAST³) reproductive exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients and is not intended to replace a complete abdominal ultrasound exam.

Uterus (present/absent): Unremarkable or abnormal

Uterine fluid score (0–4): _____.

0=No fluid present, normal.

1=Mild fluid present, minimal uterine distention.

2=Moderate fluid and uterine distention.

3=Severe fluid and uterine distention, consistent with closed pyometra. Note: The uterus should be considered fragile and at risk for rupture. Stabilize patient and proceed with directed medical or surgical care.

4=Uterine fluid present with free abdominal fluid and may indicate uterine rupture and secondary peritonitis. Prompt surgery may be indicated based on remainder of clinical signs and patient status.

Focused or cageside (COAST³) reproductive dystocia

Fetuses: Present or absent

***Fetal heart rate:** lowest _____ (bpm) and general impression _____ (bpm).

***Note:** Use both lowest heart rate (HR) obtained and overall general impression because variability can be remarkable (e.g., one dead and others alive).

HR greater than 180=normal

HR 180–160=early fetal stress; prompt intervention required

HR 160–140=moderate fetal stress; C-section generally warranted for optimizing fetal survival

HR under 140=severe fetal stress, reduced fetal viability; immediate surgical intervention generally required for optimizing fetal survival

***Fetal Development:** Small bowel evident with normal layering: Yes or no

***Note:** Small bowel development with normal layering and appearance indicates term or near-term fetuses. Other ultrasonographic parameters for fetal development are not mentioned here but are available (Mattoon 2002).

Chapter 9: Thoracic FAST³ (TFAST³)

The TFAST³ is an ultrasound exam used to help detect thoracic wall, lung, and pleural and pericardial space problems to better direct resuscitative efforts and veterinary patient care. TFAST³ is not intended to replace thoracic radiographs or a complete echocardiography.

Thoracic focused assessment with sonography for trauma, triage, and tracking (TFAST³)

Key: CTS=chest tube site; PCS=pericardial site; LV = left ventricle, PTX=pneumothorax.

Left CTS glide sign:

Present (dry lungs, no pneumothorax [PTX])

Absent *pneumothorax suspected

***Search for the lung point:** upper third (mild) middle third (moderate to severe) ventral third (severe) placing within clinical context since a semi-quantification

Indeterminate

Left CTS lung rockets:

Present (wet lungs, rules out PTX) suspect interstitial lung fluid (i.e., edema, hemorrhage)

Absent no interstitial lung fluid (i.e., edema, hemorrhage)

Indeterminate

Left CTS step sign:

Absent

***Present** suggests thoracic wall, pleural space conditions, or lung pathology.

*Further characterize lung pathology, if suspected, as shred, tissue, or nodule and by conducting a more comprehensive scan by adding the Vet BLUE scan.

*Right CTS glide sign:

Present (dry lungs, no pneumothorax [PTX])

Absent *pneumothorax suspected

***Search for the lung point:** upper third (mild) middle third (moderate to severe) ventral third (severe) placing within clinical context since a semi-quantification

Indeterminate

*Right CTS lung rockets:

Present (wet lungs, rules out PTX) suspect interstitial lung fluid (i.e., edema, hemorrhage)

Absent no interstitial lung fluid (i.e., edema, hemorrhage)

Indeterminate

*Right CTS step sign:

Absent

***Present** suggests thoracic wall, pleural space conditions, or lung pathology.

*Further characterize lung pathology, if suspected, as shred, tissue, or nodule signs and by conducting a more comprehensive scan by adding the Vet BLUE lung scan.

Left PCS view fluid?

Absent no pleural or pericardial fluid

Present

Pleural: None or mild or moderate or severe **with a** greatest width _____cm.

***Pericardial:** None or mild or moderate or severe **with a** greatest width _____cm.

***Cardiac tamponade?** Yes or no or indeterminate

Indeterminate for presence of fluid

*Right PCS view fluid?

Absent no pleural or pericardial fluid

Present

Pleural: None or mild or moderate or severe **with a** greatest width _____cm.

***Pericardial:** None or mild or moderate or severe **with a** greatest width _____cm.

***Cardiac tamponade?** Yes or no or indeterminate

Indeterminate for presence of fluid

Overall LV filling (short-axis mushroom view):

Adequate suggesting normovolemia

Inadequate suggesting hypovolemia

Indeterminate

Overall LV contractility (short-axis mushroom view):

Unremarkable

Inadequate and hyperdynamic or hypodynamic

Indeterminate

Diaphragmatico-Hepatic (DH) View (free fluid):

Absent no pleural or pericardial fluid

Present

Pleural: None or mild or moderate or severe **with a** greatest width _____cm.

***Pericardial:** None or mild or moderate or severe **with a** greatest width _____cm.

***Cardiac tamponade?** Yes or no or indeterminate

Indeterminate for presence of fluid

Overall clinical impression and comments:

Unremarkable or _____
_____.

Chapter 10: The Vet Blue Lung Scan (VBLS or Vet Blue)

The Vet Blue

KEY: cdll=caudodorsal lung lobe region, phll=perihilar lung lobe region, mdll=middle lung lobe region, crll=cranial lung lobe region, ULR=ultrasound lung rocket (see Vet BLUE Scan)

Format, (Figure 10.4A through D).

Left VBLS (cdll, phll, mdll, crll):

***Right VBLS** (cdll, phll, mdll, crll):

Record maximum ULRs over a single intercostal space at that lung lobe region: 0, 1, 2, 3, greater than 3, ∞ (infinity symbol)

KEY: 0=no ULRs, 1=single ULR, 2=two ULRs, 3=three ULRs, **greater than 3 (>3)**=more than three but still seen as individual ULRs, ∞=too many ULRs that no longer can be counted individually (referred to as confluent or white lung)

***Add notations after the number of ULRs for other lung findings using abbreviations:** Shred sign (Sh), tissue sign (Ti), nodule (s) sign (Nd), and free fluid (Ff) for each respective lung lobe region (see Chapter 10 for definitions, Figure 10.5A through E).

***Note:** There may be more than one sign associated with each site.

Always do the exam in the same order of lung regions for a simple system for recording. Start with the left side and go in the order of the examples. Next, do the right side. Finish with TFAST³ heart views when concurrently doing TFAST³, which is very easy, efficient, and rapid.

Left (cdll to phll to mdll to crll): ?, ?, ?, ?

***Right** (cdll to phll to mdll to crll): ?, ?, ?, ?

Example: Dry lung, all fields (see Figure 10.8A, normal dry lungs):

Left (cdll, phll, mdll, crll): 0, 0, 0, 0

***Right** (cdll, phll, mdll, crll): 0, 0, 0, 0

Example: Wet lung in upper lung regions (see Figure 10.8B, cardiogenic pulmonary edema):

Left: >3, >3, 0, 0 or ∞, ∞, 0, 0

***Right:** >3, >3, 0, 0 or ∞, ∞, 0, 0

Example: “Nodule sign” in a region of dry lungs (see Figure 10.8E, solitary lung lobe nodule):

Left: 0 (Nd), 0, 0, 0

***Right:** 0, 0, 0, 0

Example: Shred sign, tissue sign, and fluid in wet lungs (see Figure 10.8C, severe bacterial bronchopneumonia):

Left: 0, 0, 2 (Sh, F), >3 (Ti)

***Right:** 0, 0, >3 (Sh), 0 (Ti)

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 11: Focused or Cageside (COAST³)—Echo (Heart)

The focused or cageside (COAST³) echo exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients and is not intended to replace complete echocardiography or non-cardiac thoracic ultrasound exam.

Quantitative assessment:

Cardiac parameter	Measurement
LVEDD	
LVESD	
IVSD	
LVFWD	
Ao	
LA	
LA:Ao ratio	
FS%	

Qualitative assessment:

Left atrial size: Small or normal or enlarged

Left ventricular size: Small or normal or enlarged

Left ventricular function: Hypodynamic or normal or hyperdynamic

***Right atrial size:** Small or normal or enlarged

***Right ventricular size:** Small or normal or enlarged

***Right ventricular function:** Hypodynamic or normal or hyperdynamic

Pulmonary artery size: Small or normal or enlarged

Pleural effusion: None or mild or moderate or severe with greatest measured width _____ cm.

Pericardial effusion: None or mild or moderate or severe with greatest measured width _____ cm.

Cardiac tamponade present: Yes or no or equivocal or indeterminate

Cardiac tumor present: Yes or no or suspicious or indeterminate

Caudal vena cava size: Small or normal or enlarged

Caudal vena cava respiratory fluctuations: Greater than 50% or less than 50%

Hepatic venous distension: None or mild or moderate or severe

***Ascites:** None or mild or moderate or severe

***Note:** The abdominal fluid scoring system (AFS: 1-4) may also be used for monitoring degree of ascites.

Overall clinical impression and comments:
Unremarkable or _____.

Chapter 13: Focused or Cageside (COAST³)—Pediatrics

It is suggested that you incorporate the abbreviated exams listed in Chapter 13 in a format tailored to your practice's skill level.

Chapter 14: Focused or Cageside (COAST³)—Eye

The focused or cageside (COAST³) eye exam is a screening test designed to identify and characterize specific clinical conditions to better treat veterinary patients, and is not intended to replace a complete ocular ultrasound performed by a specialist with advanced training.

Template for ocular ultrasound using horizontal or vertical views only:

Cornea:

Shape, contour: Rounded and intact (normal) or abnormal (describe) _____ or indeterminate

Anterior chamber:

Depth: Shallow or normal or deep or indeterminate

*Echogenicity (normal anechoic): Unremarkable or abnormal (describe) _____ or indeterminate

***Note:** If echogenic material is in the anterior chamber, note the location, size, shape, orientation, degree of mobility, and degree of echogenicity.

Iris: Flat (normal) or irregular (describe) _____ or indeterminate .

Lens:

Location: Central lens capsules visible in normal location? Yes no _____ or indeterminate .

Contour: Central lens capsules have normal contour? Yes no _____ or indeterminate .

Lens echogenicity: Lens material within capsules: Hypoechoic or hyperechoic or indeterminate

***Vitreous echogenicity:** Unremarkable or abnormal (describe) _____ or indeterminate .

***Note:** If echogenic material is in the vitreous, note the location, size, shape, orientation, degree of mobility, and degree of echogenicity _____.

***Note:** Use cautious interpretation because clinically irrelevant conditions may be present in an echogenic vitreous.

Posterior eye wall:

Contour: Normal distinct contour or abnormal (describe) _____ or indeterminate .

Retrobulbar space: Hypoechoic extraocular muscle cone or abnormal (describe) _____ or indeterminate .

Optic nerve: Observed and width if measured (taken 3mm from posterior eye wall) _____ mm or indeterminate .

Optic nerve sheath diameter (dogs only), measured 3mm posterior to the eye: 2.7mm or less is considered normal; greater than 3mm is considered abnormal and suggests increased intracranial pressure.

Overall clinical impression and comments:

Unremarkable or _____.

Chapter 16: Focused CPR—Global FAST³ (GFAST³) and FAST-ABCDE

Focused CPR—Global FAST³ (GFAST³)

Use the AFAST³, TFAST³, and Vet BLUE templates.

The global FAST³ or GFAST³ exam is an ultrasound exam that combines AFAST³, TFAST³, and Vet

BLUE for comprehensive, global patient evaluation for the rapid detection of potentially life-threatening thorax-related, abdomen-related, retroperitoneal, and lung conditions to rapidly diagnose and better direct resuscitative efforts and urgent veterinary patient care. GFAST³ is not intended to replace thoracic and abdominal radiographs or complete echocardiography or complete abdominal ultrasonography.

Focused CPR—FAST-ABCDE

The FAST-ABCDE exam is an ultrasound exam that combines AFAST³, TFAST³, Vet BLUE, and focused eye and ECHO (and adds on an upper airway evaluation) for comprehensive, global patient evaluation. FAST-ABCDE is suited for the rapid detection of potentially life-threatening thorax-related and lung, abdomen-related, retroperitoneal, upper airway, eye, and heart problems or conditions to better direct resuscitative efforts and veterinary patient care. FAST-ABCDE is a recently studied abbreviated ultrasound format that is not intended to replace thoracic and abdominal radiographs or complete echocardiography or complete abdominal ultrasonography.

A: Airway (upper airway)

Laryngeal movements: Unremarkable or abnormal or indeterminate (describe): _____.

Tracheal integrity (scan larynx to thoracic inlet): Unremarkable or abnormal or indeterminate (describe): _____.

B: Breathing (lower airway)

***Thoracic wall scan** looking for step signs and characterizing them when found as chest wall injury (intercostal tear, rib fractures) or pleural space problems (hemothorax, subcostal hematomas, diaphragmatic hernia).

***Comments** _____.

Vet BLUE template for lung findings.

C: Circulation

Thoracic circulation: Use TFAST³ template & Focused ECHO template

Abdominal circulation: Use AFAST³ template

Major abdominal organ injuries: None or describe _____.

D: Disability (screen for intracranial hypertension, eye conditions)

***ONSD** (optic nerve sheath diameter) measurement (if measured): _____mm.

Focused Eye template (eye lesions, injury) for eye findings.

***Optic nerve sheath diameter (ONSD):** Measured 3mm posterior to the eye (normal=2.7mm or less, abnormal=greater than 3mm, suggesting increased intracranial pressure).

E: Exposure (list any other relevant findings).

Overall clinical impression and comments:

Unremarkable or _____.

*See Individual Chapters for the Respective References and also Appendix IV- Quick References of Normal Values & Rules of Thumb.

ABBREVIATIONS, TERMINOLOGY, AND GLOSSARY

Abbreviations

AFAST:	Abdominal focused assessment with sonography for trauma	IVS:	Interventricular septum
AFAST³:	Abdominal focused assessment with sonography for trauma, triage, and tracking (monitoring)	LA:	Left atrial
AFS:	Abdominal fluid score	LA:Ao:	Left atrial to aortic ratio
ALI:	Acute lung injury	LV:	Left ventricular
A-lines:	Reverberation artifact	LVFW:	Left ventricular free wall
Ao:	Aortic	mdll:	Middle lung lobe region
ARDS:	Acute respiratory distress syndrome	MUG-DPL:	Modified ultrasound-guided DPL
AXR:	Abdominal radiographs	MVD:	Mitral valve disease
B-lines:	Same as ULRs	NCPE:	Non-cardiogenic pulmonary edema
BLUE:	Bedside lung ultrasound exam	Nd:	Nodule(s) sign
CC:	Cysto-colic	PCE:	Pericardial effusion
cdll:	Caudo-dorsal lung lobe region	PCS:	Pericardial site
CPE:	Cardiogenic pulmonary edema	PE:	Pleural effusion
crll:	Cranial lung lobe region	phll:	Perihilar lung lobe region
CT:	Computed tomography	PP-line:	Pulmonary-pleural line
CTS:	Chest tube site	PTX:	Pneumothorax
DCM:	Dilated cardiomyopathy	RV:	Right ventricular
DH:	Diaphragmatico-hepatic	RVFW:	Right ventricular free wall
DPL:	Diagnostic peritoneal lavage	Sh:	Shred sign
ECG:	Electrocardiography	SQE:	Subcutaneous emphysema
FAST:	Focused assessment with sonography for trauma	SR:	Spleno-renal
Ff:	Free fluid sign	T³:	Trauma, triage and tracking (monitoring)
GI:	Gastrointestinal	TFAST:	Thoracic focused assessment with sonography for trauma
HCM:	Hypertrophic cardiomyopathy	TFAST³:	Thoracic focused assessment with sonography for trauma, triage, and tracking (monitoring)
HR:	Hepato-renal	Ti:	Tissue sign
		TXR:	Thoracic radiographs
		ULRs:	Ultrasound lung rockets (same as B-lines)

Terminology and Glossary

Abdominal fluid scoring system: Applied fluid scoring system in which each positive site, called the abdominal fluid score (AFS), is scored as a 1 with a maximum score of 4. Under this system, dogs with a score of AFS-1, 2 rarely become anemic from their intra-abdominal hemorrhage (if there is no pre-existing anemia). Dogs with a score of AFS 3, 4 predictably become anemic, with 20%–25% of these dogs requiring a blood transfusion due to severe anemia (packed cell volume [PCV] less than 25%). When AFS-3, -4 dogs present close to the time of their injury, almost all have compensated with normal PCVs despite large-volume hemorrhage more commonly becoming anemic on serial examinations (routinely performed four hours post-admission in all stable dogs and sooner in unstable dogs). The AFS in cats is unreliable for predicting anemia, but is helpful in tracking ongoing or resolving hemorrhage and effusions.

AFAST³: Abdominal FAST³ is made up of target-organ views rather than external locations as follows: diaphragmatico-hepatic view (DH), spleno-renal view (SR), cysto-colic view (CC), and hepato-renal view (HR). Note that these AFAST³ sites similarly parallel the following veterinary FAST external views: subxiphoid, left flank, midline over the bladder (prepubic) and right flank.

A-lines: Equidistant parallel lines that originate from the pulmonary surface or from a strong air-ultrasound interface when pneumothorax is present. A-lines represent air reverberation artifact.

B-lines: Synonymous with ultrasound lung rockets (ULRs). B-lines indicate the presence of interstitial fluid immediately next to aerated lung. They indicate “wet lung,” or the presence of interstitial edema or lung contusions in trauma patients, and rule out PTX at that respective point of evaluation on the thorax. B-lines are hyperechoic, laser-like streaks that do not fade, extending from the pulmonary surface to the far field, and obliterating A-lines. B-lines oscillate with the to-and-fro motion of inspiration and expiration.

CFAST³: Combination FAST³ is the term used when AFAST³ and TFAST³ are used in tandem.

COAST³: Cageside organ assessment with sonography for trauma, triage and tracking (monitoring). It is an alternate term to focused or cageside organ exams. For example, one may say that a COAST³ (or focused or cageside) Gallbladder exam was performed.

Complete (or formal) abdominal ultrasound: This term should be used in lieu of “diagnostic abdominal

ultrasound” because the abbreviated focused, cage-side, or COAST³ exams; the FAST³ exams; and the Vet BLUE lung scan are also potentially diagnostic.

Complete (or formal) echocardiography: This term should be used in lieu of “diagnostic echocardiography” because the abbreviated focused, cageside or COAST³ exams; the FAST³ exams; and the Vet BLUE lung scan are also potentially diagnostic.

Dry lung: When A-lines with a glide sign are present, the lung is considered to be “dry lung” at that respective point of evaluation on the thorax. When there are A-lines without a glide sign, that respective point represents pneumothorax.

FAST: Focused assessment with sonography for trauma.

FAST³: Focused assessment with sonography for trauma, triage, and tracking (monitoring).

FAST-ABCDE: New FAST format in which “A” stands for airway (upper), “B” stands for breathing (lower airway), “C” stands for circulation, “D” stands for disability (neurological survey using optic nerve sheath diameter), and “E” stands for exposure (serial examinations). FAST-ABCDE is similar to GFAST³; it uses AFAST³, TFAST³, and Vet BLUE, with add-on surveys of the eye, upper airways, and heart. It also is used in similar situations as GFAST³.

Fluid sign (Ff): Vet BLUE sign when there is free fluid at that lung lobe region.

Focused ultrasound exam: Alternate term to cage-side or COAST³ that represents a focused abbreviated exam interrogating a specific organ. For example, one may say that a Focused Gallbladder exam was performed.

Gator sign: The basic intercostal orientation for all lung ultrasound is the gator sign, which resembles a partially submerged alligator peering over the water at the sonographer. The eyes of the gator are the rib heads and the bridge of the nose represents the intercostal space in between where the pulmonary-pleural line is located. The pulmonary-pleural line (PP-line), or bright white proximal line, is where the normal to-and-fro motion of the lung glides along the thoracic wall called the “glide sign.”

GFAST³: Global FAST³ is the term used when CFAST³ and Vet BLUE are used in tandem.

Glide sign: The to-and-fro motion with inspiration and expiration of the lung sliding along the pulmonary-pleural interface when pneumothorax is not present at that respective point on the thorax. The veterinary term glide sign is referred to as “lung sliding” in the human literature.

Lung point: The location where the lung recontacts the thoracic wall either by the recognition of a “glide

sign” or ULRs (also called B-lines) or a “lung pulse.” The lung point confirms the presence of PTX and subjectively allows for the assessment of the degree or severity of PTX from its distance away from the chest tube site (partial vs. massive). For example, a short distance (upper third of the thorax) suggests a trivial or mild (partial) PTX, whereas a longer distance (middle to lower third) suggests a moderate to severe (massive) PTX.

Lung pulse: The lung pulse is where a glide sign or ULRS (also called B-lines) are observed that are not in concert with the to-and-fro of inspiration or expiration, but rather are observed to move in concert with the heartbeat. This generally represents severe collapsed or consolidated lung.

MUG-DPL: Modified ultrasound-guided diagnostic peritoneal lavage.

Mushroom view: The right parasternal left ventricular short-axis view just below the mitral valve that appears like a mushroom. The view is used subjectively for patient volume status.

Nodule sign (Nd): This Vet BLUE lung ultrasound sign is a homogeneous relatively anechoic (or of low echogenicity) round (nodular) region with a hyperechoic border along its far side, suggesting a nodule(s) within that lung lobe region’s periphery. The finding of the nodule(s) sign likely represents either neoplasia or granuloma(s), abscess(es), and possibly other forms of lung consolidation.

Pneumothorax (PTX): A-lines without a glide sign are the hallmark of PTX. When PTX is suspected, a lung point should be searched for to determine the degree (or severity) of PTX. When A-lines are not present in the absence of a glide sign, lung consolidation or other pleural space conditions are likely.

Shred sign (Sh): This Vet BLUE lung sign is an irregular deviation from the normal expected linear continuity of the PP-line representing lung consolidation. Moreover, within the shred sign, there is evidence of lung aeration with hyperechoic “sparkling” or other air-related artifacts such as comet tails or ULRS within the shred area. A descriptive analogy likens the shred sign to thunderstorm clouds rolling across the screen (partially aerated consolidated lung) with flashes of lightning distal to the shred (ultrasound

lung rockets representing interstitial edema). Causes of lung consolidation should most commonly be considered types of pneumonia in non-trauma cases.

T³: Abbreviation for trauma, triage, and tracking (monitoring) that encompasses all subsets of patients to benefit from the abdominal or thoracic FAST exams and the cageside organ assessment exams (COAST³).

TFAST³: Thoracic FAST³ is a five-point thoracic scan that includes bilaterally the chest tube sites (CTS) and pericardial sites (PCS) and the single diaphragmatico-hepatic (DH) view.

Tissue (Ti): The Vet BLUE lung sign that appears like liver (hepatization) with no “sparkling” or obvious air artifacts. It indicates a more severe form of lung consolidation than the shred sign because the airways are filled with fluid or solids (airless). Causes of severe lung consolidation should be considered.

Ultrasound lung rockets (ULRs): Synonymous with B-lines. ULRs indicate the presence of interstitial fluid immediately next to aerated lung. ULRs indicate wet lung or the presence of interstitial edema. Their presence also rapidly rules out PTX at that respective point of evaluation on the thorax. ULRs are hyperechoic, laser-like streaks that do not fade extending from the pulmonary surface to the far field, obliterating A-lines. ULRs oscillate with the to-and-fro motion of inspiration and expiration.

Vet BLUE lung scan (Vet BLUE): Blue (cyanosis) refers to respiratory distress, and BLUE is an acronym for bedside lung ultrasound exam. The Vet BLUE is a regionally-based lung scan that includes the caudal dorsal (cdll), perihilar (phll), middle (mdll), and cranial lung lobe (crll) regions for rapid detection of lung pathology. Serial Vet BLUE exams may be used to monitor response to therapy in place of thoracic radiographs in many lung conditions. The regional format is consistent with the manner in which veterinarians interpret lung findings on thoracic radiographs.

Wet lung: The presence of ultrasound lung rockets (ULRs) or B-lines generally represent forms of interstitial edema including pulmonary contusions in trauma cases and forms of interstitial edema in non-trauma. Representing interstitial edema, ULRs or B-lines precede more serious lung edema (alveolar flooding) represented by the shred and tissue signs.

QUICK REFERENCES OF NORMAL VALUES AND RULES OF THUMB

Chapter 2: Abdominal FAST³ (AFAST³)

- Free fluid is always abnormal in adult dogs and cats; however, puppies and kittens can have small quantities of anechoic free fluid in normalcy.
- The abdominal fluid scoring system's abdominal fluid score (AFS) ranges from 0 (negative) to a maximum of 4 (positive at all four AFAST³ sites).
- "Small bleeders" are defined as dogs with an abdominal fluid score of 1 or 2 (AFS 1, 2). They are unlikely to become anemic from their intra-abdominal bleed if they had no previous anemia and have no other sites of hemorrhage.
- "Big bleeders" are defined as dogs with an abdominal fluid score of 3 or 4 (AFS 3, 4). They are very likely to become anemic from their intra-abdominal bleed, and approximately 20%–25% will become severely anemic and require blood transfusion(s) (Lisciandro 2009).
- "Big bleeder" hit-by-car dogs often need blood transfusion(s); they uncommonly require exploratory laparotomy for control of their intra-abdominal hemorrhage because bleeding often stops without surgery (Lisciandro 2009).
- "Big bleeder" post-interventional cases (post-operative laparotomy, laparoscopy, percutaneous biopsy procedures, etc.) that are non-coagulopathic (normal clotting times) may or may not need blood transfusion(s) depending on their current clinical status and degree of compensation. However, these cases generally need exploratory surgery for definitively control of their intra-abdominal bleeding, and delaying surgery on a "big bleeder" leads to increased morbidity, complications, and expense because of ensuing anemia (Lisciandro, author experience).
- The big bleeder vs. small bleeder concept applied to non-traumatic, non-coagulopathic cases (e.g., ruptured splenic mass) helps direct decision making regarding surgery ahead of overt decompensation in acute bleeds. For example, big bleeders even without anemia generally should be explored, and acute small bleeders without anemia may be serially monitored and medically managed (as long as they remain small bleeders) for a more complete work-up (vs. taking to surgery), depending on client and veterinarian expectations. In small bleeders that have significant anemia, a more subacute to chronic process leading to anemia should be considered because often self-limiting, intermittent, low-grade bleeds have been occurring.
- The big bleeder vs. small bleeder concept, when applied to non-traumatic, coagulopathic cases (e.g., ruptured splenic mass), helps direct decision making regarding the need for blood transfusion(s) because compensated big bleeders predictably become anemic in time.
- In the majority of cases pericardial and pleural effusion can be diagnosed via the AFAST³ diaphragmatico-hepatic (DH) view. Approximately 88% of clinically relevant pericardial effusion (and cardiac tamponade) can be detected via the DH view (Lisciandro 2012, unpublished data). Always look into the thorax when performing the DH view.
- **Anaphylaxis and the gallbladder "halo sign."** Ultrasound is helpful in making the rapid diagnosis of anaphylaxis by the finding of a thickened gallbladder wall, referred to as the gallbladder "halo sign" (Quantz 2009). However, pericardial

effusion/cardiac tamponade similarly can result in a gallbladder halo sign because of venous congestion. Both conditions have similar presentations of acute collapse. Always rule out pericardial effusion/cardiac tamponade when observing a gallbladder halo sign, and be familiar with other possible causes (e.g., congestive heart failure, volume overload, gallbladder disease, pancreatitis, hypoalbuminemia).

Chapter 3: Focused or Cageside (COAST³)—Liver and Gallbladder

- *Liver assessment is subjective. Edges of the liver lobes should be sharply pointed. Rounded margins of liver lobes and hepatic extension (especially the left lobes) beyond the costal arch suggest enlargement. *Abdominal radiography is more reliable for the determination of hepatomegaly.
- **Target lesions:** Single target lesions have a high predictive value for malignancy. When multiple-target lesions are seen, the positive predictive value of malignancy increases from 74% to 81% (Cuccovillo 2002).
- Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK). This is remembered as $S > Li \geq CK$, or by the mnemonic “SLiCK.”
- Gallbladder wall thickness is normally less than 1 mm in cats and less than 2–3 mm in dogs (Hittmair 2001, Spaulding 1993, Quantz 2009).
- Gallbladder luminal content is generally homogeneous, anechoic bile, although degrees of gallbladder sludge in dogs may be considered as clinically irrelevant or may indicate cholestasis based on the patient’s clinical profile (Tsukagoshi 2012).
- The gallbladder being fluid-filled is subject to several artifacts including side-lobe, edge shadowing, and acoustic enhancement in the far field, as well as the liver and gallbladder being adjacent to the strong soft tissue-air interface between the diaphragm and the aerated lung, which is subject to mirror image artifact.
- In cats, tortuosity of the bile duct can be a normal variation; however, a bile duct greater than 4 mm is considered to be consistent with extrahepatic biliary obstruction (Penninck 2007).

Chapter 4: Focused or Cageside (COAST³)—Spleen

- Spleen size is subjective. A spleen that extends to a small or medium sized urinary bladder is considered enlarged.
- A folded spleen in a cat is always abnormal and indicates splenomegaly (Penninck 2008).
- The normal cat spleen thickness is less than 10 mm (Reese 2012).
- Benign nodular hyperplasia usually consists of nodules that are of homogeneous echotexture and are either hypoechoic or hyperechoic.
- Single-target lesions have a high predictive value for malignancy. When multiple-target lesions are seen, the positive predictive value of malignancy increases from 74% to 81% (Cuccovillo 2002).
- Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK). This is remembered as $S > Li \geq CK$, or by the mnemonic “SLiCK.”

Chapter 5: Focused or Cageside (COAST³)—Kidney

- The normal kidney size for cats is generally considered to be 3.0–4.4 cm in length, depending on the reference (Nickel 1973, Walter 1987).
- The normal kidney size in dogs is variable and depends on the size of the dog, so assessment is generally subjective. Therefore, assessment of symmetry and size between the two kidneys is particularly important in dogs; and abdominal radiography can prove additionally helpful.
- The normal renal pelvis size (height in mm) varies in both species. As a general rule of thumb, consider the renal pelvic size as abnormal if it is 3 mm or greater in cats and 4 mm or greater in dogs (Normals: cat, 1.5–2 mm with maximum of 2.8 mm; dogs, 2–3 mm with a maximum of 3.8 mm) (D’Anjou 2011).
- Normal echogenicity rule of thumb: The spleen (S) is more echogenic (hyperechoic) than the liver (Li), which is the same or slightly more echogenic (brighter) than the cortex of the kidney (CK). This is remembered as $S > Li \geq CK$, or by the mnemonic “SLiCK.”

Chapter 6: Focused or Cageside (COAST³)—Urinary Bladder

- The thickness of the urinary bladder wall varies depending on the degree of distention.
- The normal range for urinary bladder wall thickness in cats is 1.3–1.7 mm (Finn-Bodner 1995).
- The normal range for urinary bladder wall thickness in dogs ranges from 1.4 mm in moderately distended bladders to 2.3 mm in minimally distended bladders (Geisse 1997). However, wall thickness in dogs has been reported to increase with body size, with heavier dogs having increased thickness by up to 1 mm or a maximum normal thickness of 3 mm or less (Geisse 1997).
- Voiding urohydropulsion (VUH) guidelines are as follows (Defarges et al. 2013):
 - Female dogs (greater than 2 kg) can typically void stones less than 3–4 mm (the ease in passing a 9-French urinary catheter correlates with the successful voiding of 3-mm stones).
 - Female cats may be able to void stones less than 3 mm (the ease in passing a 9-French urinary catheter correlates with the successful voiding of 3-mm stones).
 - Male dogs weighing 5–10 kg may be able to void stones less than 2–3 mm, and male dogs greater than 10-kg stones less than 3 mm (the ease in passing a 9-French urinary catheter correlates with the successful voiding of 3-mm stones).
 - Male cats, VUH is not recommended.
- The urinary bladder, being fluid-filled, is subject to several artifacts including side-lobe, edge shadowing, and acoustic enhancement in the far field.

Chapter 7: Focused or Cageside (COAST³)—Gastrointestinal and Pancreas

Gastrointestinal

- The normal stomach wall thickness in dogs is 3–5 mm (higher in some giant breeds); in cats it is 2 mm inter-rugal (up to 4.4 mm if rugal fold is measured) (Nyland 2002). Measure from the hyperechoic outer serosal margin to the inner hyperechoic mucosoluminal surface.

- In dogs, the descending duodenal wall is thicker than other small intestinal segments and can normally measure up to 5 mm in large-breed dogs (Newell 1999). Measure from the hyperechoic outer serosal margin to the inner hyperechoic mucosoluminal surface.
- Small bowel wall measurements (other than the duodenum) of greater than 4 mm in dogs and 2.5 mm in cats are generally considered to be abnormally thickened (Newell 1999). Measure from the hyperechoic outer serosal margin to the inner hyperechoic mucosoluminal surface.
- Use the mnemonic “The sun is bright and it’s dark at midnight” to remember that layers starting with an “s” (like the sun) are bright (submucosa and serosa are hyperechoic [bright]), whereas layers starting with an “m” (like midnight) are dark (mucosa and muscular layer are hypoechoic [dark]) on the US image.
- **Direct evidence of GI foreign bodies.** The majority of ultrasonographically detectable gastrointestinal foreign bodies typically involve a well-defined hyperechoic, hyperreflective acoustic interface with strong distal acoustic shadowing (Garcia 2011, Tidwell 1992).
- **Linear foreign bodies: Plication vs. corrugation.** The finding of bowel plication is strongly suggestive of a linear foreign body and should prompt careful evaluation of the intestine (longitudinal and transverse images) at sites where plication is seen (Garcia 2011, Tidwell 1992). Intestinal corrugation has also been associated with linear foreign bodies (Tidwell 1992) but is less specific than plication.
- **Differentiating “corrugated” from “plicated” bowel.** The overall direction of the intestine tends to appear straight with corrugated bowel (medical causes include enteritis/pancreatitis), in contrast to bunched or weaved intestines with plicated bowel (surgical causes include linear foreign body).
- Indirect evidence of obstruction, such as a severely dilated jejunum with luminal dilation measuring greater than 1.5 cm, may highlight the need for a more extensive and complete abdominal ultrasonographic evaluation, abdominal radiographs, or exploratory surgery. Measure from serosal surface to serosal surface.
- Determine the number of contractions/minute by recording the number of contractions over a three-minute period and averaging them (Penninck 1989).
- The mean number of peristaltic contractions of the stomach and proximal duodenum is four to five contractions/minute (Penninck 1989).

- The mean number of peristaltic contractions of the small intestine (jejunum) is one to three contractions/minute (Penninck 1989).
- The large bowel (colon) normally has no peristalsis.
- A generalized decrease in gastrointestinal motility is reported in small animals with functional and chronic mechanical ileus, whereas a generalized increase in motility is most commonly reported in cases of acute mechanical obstruction (Penninck 2008). However, because of considerable overlap in motility, motility alone does not indicate the need for surgery (Sharma 2011, Garcia 2011).
- Normal ultrasonographic layering of the small bowel in the fetus may be used as a guideline for full-term maturation of puppies and kittens (Mattoon 2002).
- In anestrus there is no uterine luminal fluid in normalcy; however, in estrus there may be a thin echogenic stripe that is also considered a normal finding (Mattoon 2002, Verstegen 2008).
- Abdominal radiography is the most accurate way of determining the number of puppies or kittens in the litter (Davidson 2009). Never tell clients numbers in the litter based on ultrasound because of its inaccuracy.

Pancreas

- The right pancreatic limb is generally easiest to image in dogs and the is more common lobe affected by pancreatitis (Penninck 2008, Hecht 2007, Nyland 2002).
- The left pancreatic limb is generally easiest to image in cats.
- The identification of the pancreas can be challenging for the novice sonographer because the pancreas is isoechoic (same shades of gray) to adjacent tissues. As a result, its identification commonly relies on the observance of its duct and vasculature.
- Historically it has been thought that a normal pancreas is generally not seen; however, the normal pancreas is in fact frequently imaged with high-frequency transducers and newer machines.
- Pancreatitis is particularly common when corrugation of the duodenum is noted (Moon 2003).
- Even in cases of severe acute pancreatitis, the sensitivity of ultrasound may only be 68% (Hess 1998).

Chapter 8: Focused or Cageside (COAST³)—Reproductive

- Fetal heart rates greater than 180, normal; 180–160, early fetal stress, prompt intervention required; 160–140, moderate fetal stress, C-section warranted in next two to three hours; HR under 140, severe fetal stress, reduced fetal viability, immediate surgical intervention required (Traas 2008). Note that there is variability in litters; in some cases a fetus may be severely distressed and another normal.

Chapter 9: Thoracic FAST³ (TFAST³)

- A-lines with a glide sign rule out pneumothorax (PTX) and support dry lung at the lung periphery (Lisciandro 2009).
- Ultrasound lung rockets (also known as B-lines) rule out PTX and support wet lung at the lung periphery (Lisciandro 2011, 2013).
- A-lines without a glide sign, with or without a lung point, diagnose PTX (Lisciandro 2009).
- Arguably the best view for evaluating pleural and pericardial spaces is the diaphragmatico-hepatic (DH) view because there is less air interference when imaging through the acoustic window of the liver and gallbladder (Reissig 2011).
- Visualization of the heart via the DH view varies with body type and the depth limits of your ultrasound machine.

Chapter 10: Vet BLUE

- A-lines with a glide sign (dry lung), ultrasound lung rockets (ULRs, wet lung), and the step sign and its subsets (including the shred sign, tissue sign, and nodule[s] sign with these named subsets referred to as forms of lung consolidation), are the basic lung ultrasound signs (Lichtenstein 2010, Hecht 2008, Lisciandro 2009, 2011).
- In normalcy, dogs and cats rarely have ULRs counted on a Vet BLUE lung scan (Lisciandro 2013). Single ULRs sporadically at one or two Vet BLUE sites in a dog or cat without respiratory disease are generally considered clinically irrelevant (Lisciandro 2013); however, depending on the patient's clinical profile (e.g., susceptibility to

forms of pulmonary edema, the development of pneumonia, or lung hemorrhage), serial examinations may be warranted.

- ULRs (also called B-lines) in dorsal lung fields generally represent forms of cardiogenic and non-cardiogenic pulmonary edema in acute respiratory distress (Lisciandro 2013).
- ULRs in ventral lung fields generally represent pneumonia in acute respiratory distress (Lisciandro 2013, unpublished data).
- ULRs are counted (maximum number) over a single intercostal space at each respective Vet BLUE view as 1, 2, 3, or greater than 3 when still recognized as individual ULRs, and ∞ (infinity symbol) once the ULRs blend together so they are no longer recognized individually because there are too many. The ∞ finding is referred to as “confluent (ULRs)” or “white lung” (Lisciandro 2013).
- ULRs in trauma patients represent lung contusions until proven otherwise (Soldati 2006, Lisciandro 2011).

Chapter 11: Focused or Cageside (COAST³)—ECHO (Heart)

- In normalcy, the left ventricle (LV) should be three to four times larger than the right ventricle (RV) in the right parasternal four-chamber view (3–4:1).
- Feline interventricular septum (IVS) and left ventricular free wall (LVFW) thickness in diastole should be approximately 3–4 mm. LV wall thickness in diastole greater than 6 mm is diagnostic for left ventricular hypertrophy.
- Extreme hypovolemia causing pseudohypertrophy of the left ventricle can be misinterpreted as hypertrophic cardiomyopathy in the cat.
- If the RV is same size as the LV, then severe right ventricular enlargement can be diagnosed (and its various rule-outs considered).
- In normalcy, the left and right atria are approximately the same size or 1:1 with a neutral (non-deviated) inter-atrial septum.
- In normalcy, the left atrium (LA) and aorta (Ao) in the short-axis right parasternal view should be the nearly the same size (1:1).
- If the left atrium is greater than 1.3 times the aorta in dogs, then the left atrium is enlarged; if it is greater than 1.6 times in cats (LA:Ao > 1.3 dogs; LA:Ao > 1.6 cats) then left-sided heart disease is suggested (Abbott 2006, Rishniw 2000).
- In general, normal fractional shortening (FS%) is 28%–45% in the dog and 30%–50% in the cat.

- FS% below 20% is suggestive of severe myocardial systolic failure and FS% above 55% is considered hyperdynamic LV function.
- Neoplasia and idiopathic pericardial effusion are most common causes of pericardial effusion (PCE) in dogs. Heart failure is the most common cause of PCE in cats.
- The left parasternal cranial view allows for optimal visualization of the right heart, including the right auricle and tricuspid valve. It is also the best view to examine a small right auricular mass in a dog with pericardial effusion and cardiac tamponade.

Normal mean echocardiographic values (cm) in dogs.

BW(kg)	LVEDD	LVESD	IVSD	LVFWD	Ao	LA
3	2.0	1.1	0.5	0.6	1.1	1.3
5	2.4	1.3	0.6	0.7	1.3	1.5
10	3.0	1.8	0.7	0.8	1.6	1.8
15	3.4	2.1	0.8	0.8	1.9	2.0
20	3.8	2.4	0.9	0.9	2.1	2.2
25	4.0	2.6	0.9	0.9	2.1	2.4
30	4.3	2.8	1.0	1.0	2.4	2.5
35	4.5	3.0	1.0	1.0	2.5	2.6
40	4.7	3.1	1.0	1.0	2.6	2.7
45	4.9	3.3	1.1	1.1	2.7	2.8
50	5.0	3.4	1.1	1.1	2.8	2.9

BW, body weight; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVSD, interventricular septal thickness in diastole; LVFWD, left ventricular free wall thickness in diastole; Ao, aortic diameter; LA, left atrial diameter

With permission (Kittleson and Kienle 1998)

Normal ranges of echocardiographic values (cm) in cats.

Cardiac parameter	Normal range
LVEDD	11.0–17.5
LVESD	0.40–1.0
IVSD	0.35–0.55
LVFWD	0.35–0.55
Ao	0.7–0.13
LA	0.9–0.15
FS%	33%–66%

LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; IVSD, interventricular septal thickness in diastole; LVFWD, left ventricular free wall thickness in diastole; Ao, aortic diameter; LA, left atrial diameter; FS%, fractional shortening %

Chapter 13: Focused or Cageside (COAST³)—Pediatrics

- Juvenile puppies and kittens may have a small amount of anechoic (pure black) free intra-abdominal fluid that is considered normal.

Chapter 16: Focused or COAST³—CPR and the FAST-ABCDE Exam

- The optic nerve sheath diameter (ONSD) measured 3 mm from the posterior eye should be equal to or less than 3 mm in dogs. The normal for cats is unknown. Values greater than 3 mm may correlate with intracranial hypertension (Armenise 2012).

Reference

Defarges A, Dunn M, Berent AC. 2013. New alternatives for minimally invasive management of uroliths: Lower urinary tract uroliths. *Compendium* 35(1).

In addition, see individual chapters for the respective references.

ULTRASOUND RESOURCES AND COMPANIES

Online Resources for Ultrasound Training

www.fastvet.com provides teaching modules for many of this book's exams including case-based AFAST³, TFAST³, and Vet BLUE presentations.

Several of the companies listed below also offer ultrasound course training.

Online Access to the General Practitioner Ultrasound Group

http://www.gpultrasound.org/workgroup_document.html: General Practitioner Ultrasound Group: Mattoon J, Moon M, Lisciandro G, Young S, Kelpel R.

Veterinary Ultrasound Companies

The following is an incomplete list of ultrasound companies that serve the veterinary community:

Core Ultrasound
908 West River Center Drive, Suite E
Comstock Park, MI 49321
616-785-2673
www.core-imaging.com

E.I. Medical Imaging
110 12th Street SW, Unit 102
Loveland, CO 80537
970-669-1793
www.eimedical.com

Hitachi Aloka Medical
10 Fairfield Boulevard
Wallingford, CT 06492
203-269-5088
www.hitachi-aloka.com

Sound-Eklin
6359 Paseo Del Lago
Carlsbad, CA 92011
800-268-5354
www.soundeklin.com
<http://www.soundeklin.com/academy-of-imaging>

Universal Imaging
299 Adams Street
Bedford Hills, NY 10507
800-842-0607
www.universalultrasound.com

Vet Imaging
16 Technology Drive, Suite 138
Irving, CA 92618
800-618-5081
www.vetimaging.com
www.gpultrasound.org

Vetel Diagnostics
4850 Davenport Creek Road
San Luis Obispo, CA 93401
805-781-0890
www.veteldiagnostics.com

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