CHAPTER NINE

The Thoracic FAST^3 (TFAST^3) Exam

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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 AFAST^3) (Rozycki 2001, Lisciandro 2011). The original TFAST acronym has evolved into "TFAST^3" with the "T^3" 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 TFAST^3 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. TFAST^3 has more recently included a more comprehensive novel lung surveillance called the Vet (veterinary) Bedside Lung Ultrasound Exam (BLUE) that extends beyond the TFAST^3 chest tube site (CTS) (see Chapter 10).

By adding the Vet BLUE to the TFAST^3 exam, the clinical utility of thoracic ultrasound now more comprehensively includes many non-trauma subsets of patients. For example, when TFAST^3 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). TFAST^3 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 AFAST^3 to TFAST^3 and Vet BLUE, a complete rapid global surveillance (called global FAST^3 or GFAST^3) 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

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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, FAST[3] 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 TFAST[3] 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 TFAST[3] 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 TFAST[3] 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, TFAST[3] should be combined with AFAST[3] and Vet BLUE (see chapters 2 and 10)
- TFAST[3] 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 TFAST[3] and used routinely as an add-on for more comprehensive lung and pleural effusion surveillance.

Indications for the TFAST[3] 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 TFAST^3. With that being said, TFAST^3 (with Vet BLUE) is more accurate and often take less time than thoracic auscultation when done by properly trained veterinarians.

Objectives of the TFAST^3 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 TFAST^3 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 TFAST^3 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 TFAST^3 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 TFAST^3 views before moving the veterinary patient to sternal for the final opposing CTS view (Figure 9.2, below). When performing AFAST^3 and TFAST^3 in tandem (referred to as combo FAST^3 or CFAST^3 [Lisciandro 2012]), six of the eight total views for CFAST^3 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 TFAST^3 CTS views (as well as Vet BLUE; also see Figure 16.1D).

> The abdominal (preset) setting works well for TFAST^3 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 TFAST3^3 (and the Vet BLUE lung scan) in all respiratory-compromised patients (Lisciandro 2008, 2011). When combined with AFAST^3 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 TFAST^3 exams.

Figure 9.1. TFAST^3 positioning for respiratory-compromised dogs and cats. (A) Photo showing how TFAST^3 (and Vet BLUE) is performed in a dog in the standing position while being masked oxygen. (B and C) Photos showing how TFAST^3 (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 AFAST^3, fur is generally not shaved for TFAST^3 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

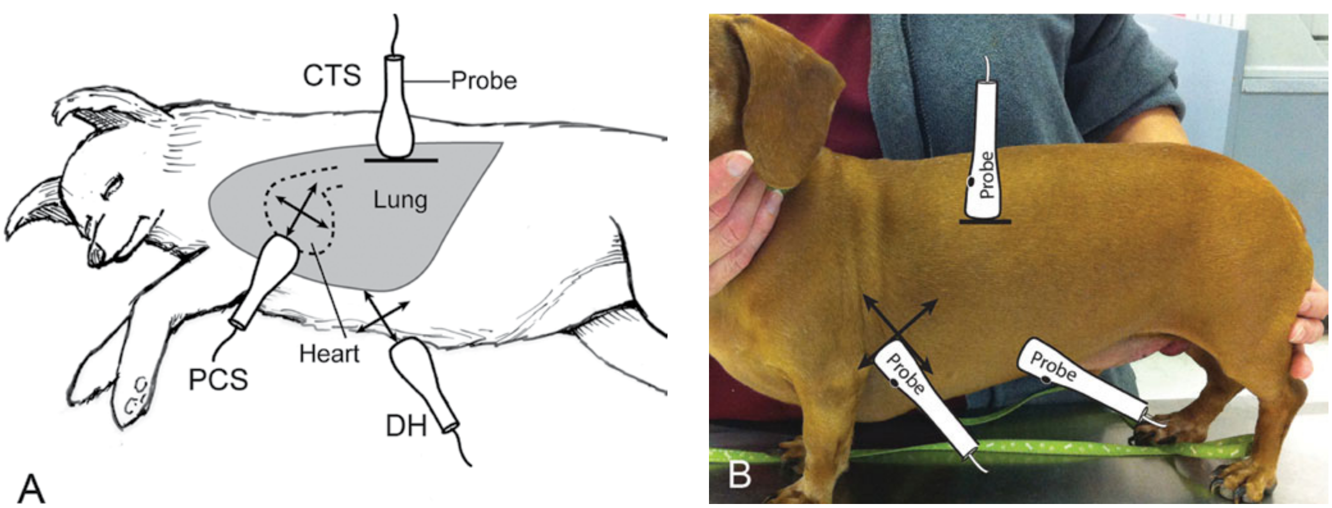


Figure 9.2. Performing the five-point TFAST³ exam. (A) TFAST³ shown in lateral recumbency on a dog. In this positioning the exam may be most efficiently performed by using similar settings for the diaphragmatico-hepatic (DH) view and both pericardial site (PCS) views before changing the ultrasound settings 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

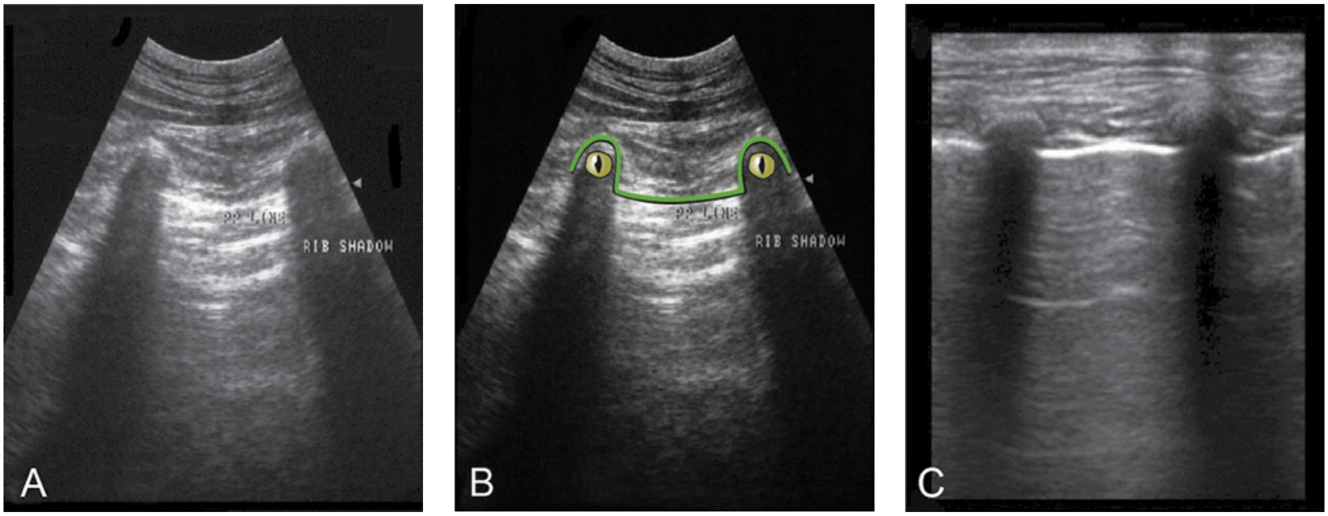


Figure 9.3. Orientation of the rib heads and intercostal space is likened to an alligator (gator) peering over the water at the sonographer. (A) The gator sign image using a curvilinear probe. (B) The gator sign schematically placed on the same image as (A) with rib heads (eyes) and the intercostal space (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 TFAST[3] 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).

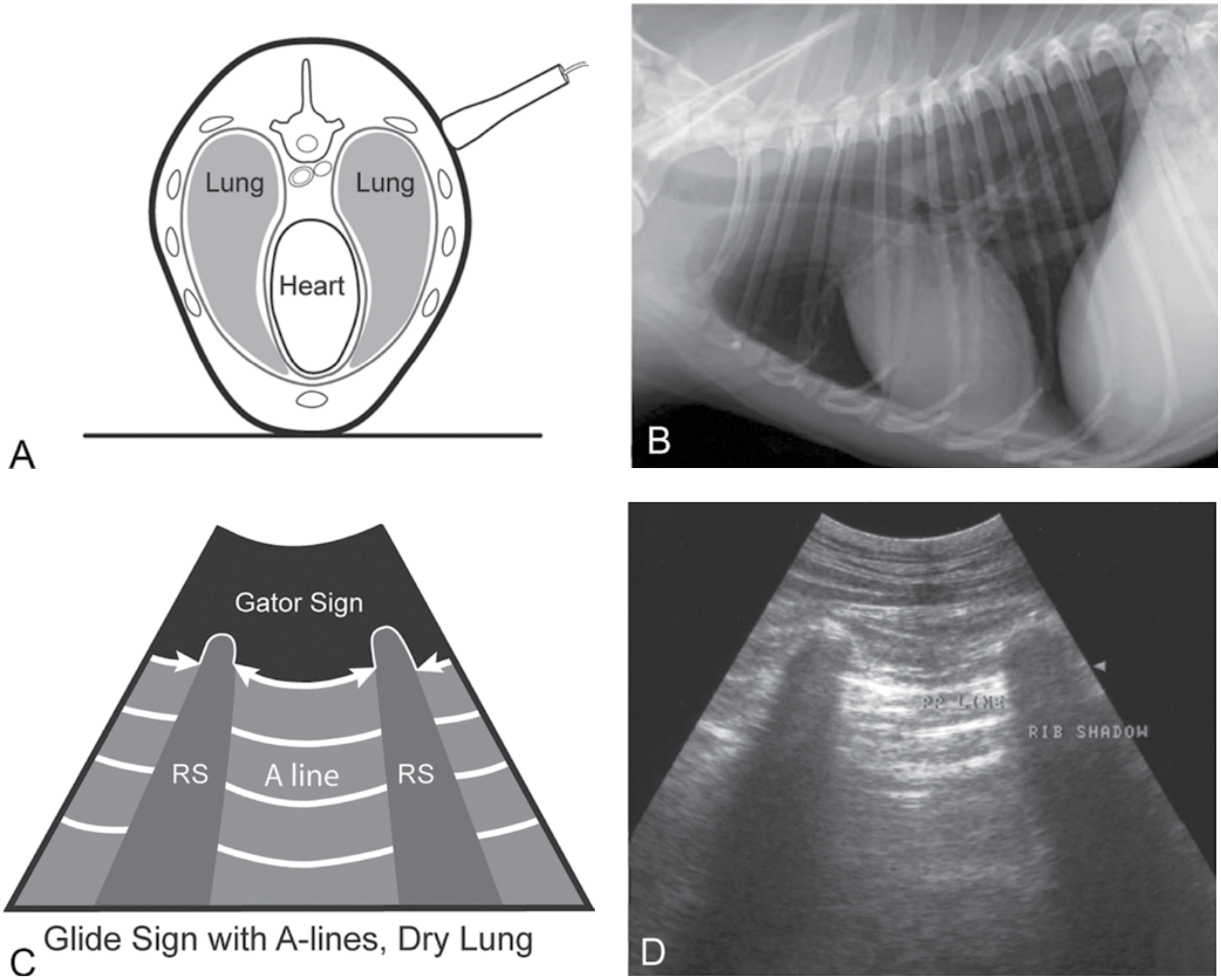


Figure 9.5. The glide sign and dry lungs. (A) Probe placement at the chest tube site view in sternal recumbency. (B) Correlating normal thoracic radiograph without intrathoracic pathology. (C) Correlating line drawing showing the gator sign from which the bright white line or PP-line is recognized as 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.

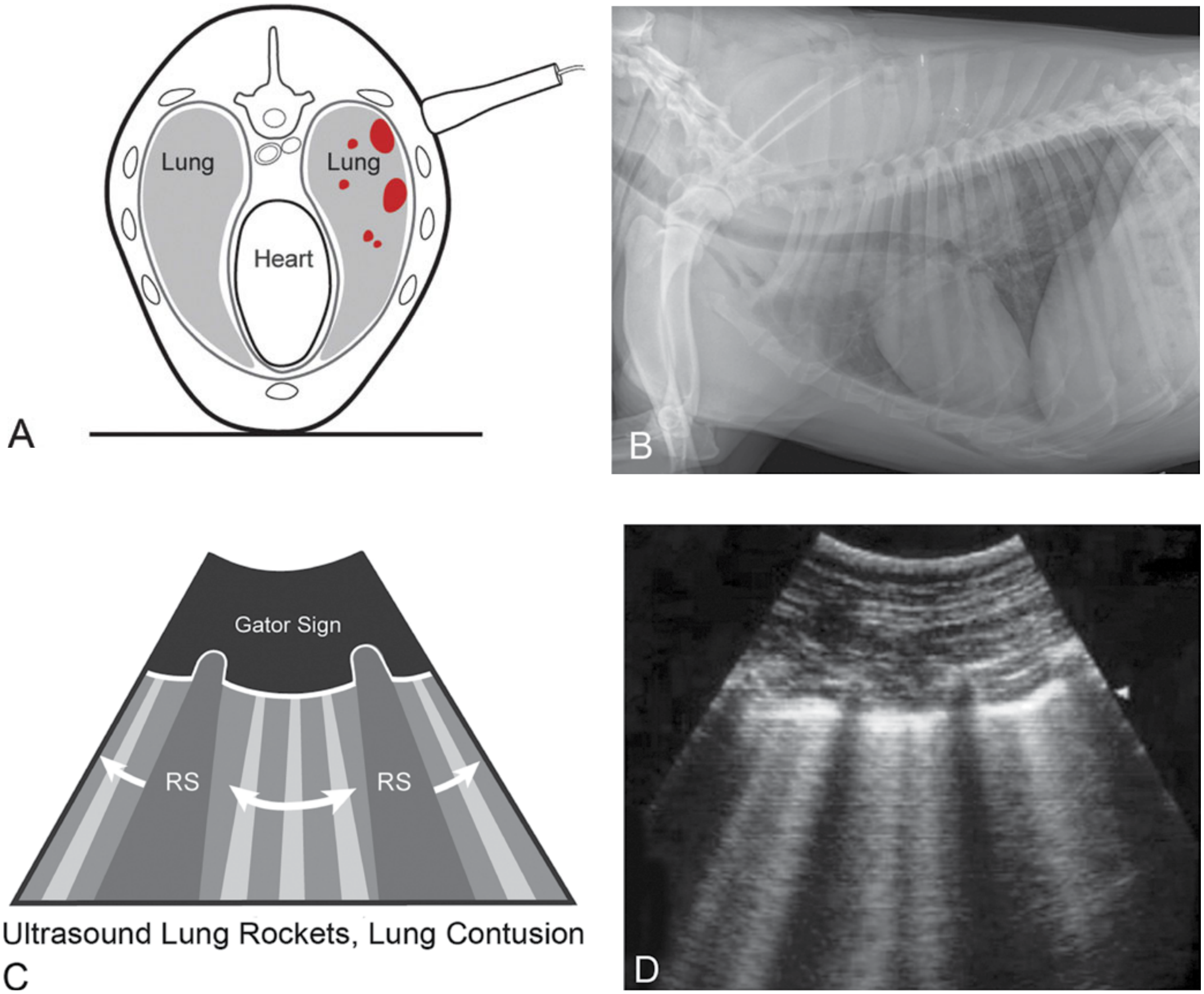


Figure 9.6. Ultrasound lung rockets and wet lung. ULRs seen in trauma cases represent lung contusions until proven otherwise. (A) Probe placement at the chest tube site view in sternal recumbency where the hemorrhage (lung contusion) is represented by the red opacities within the lung and along its periphery. (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 TFAST[3] 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).

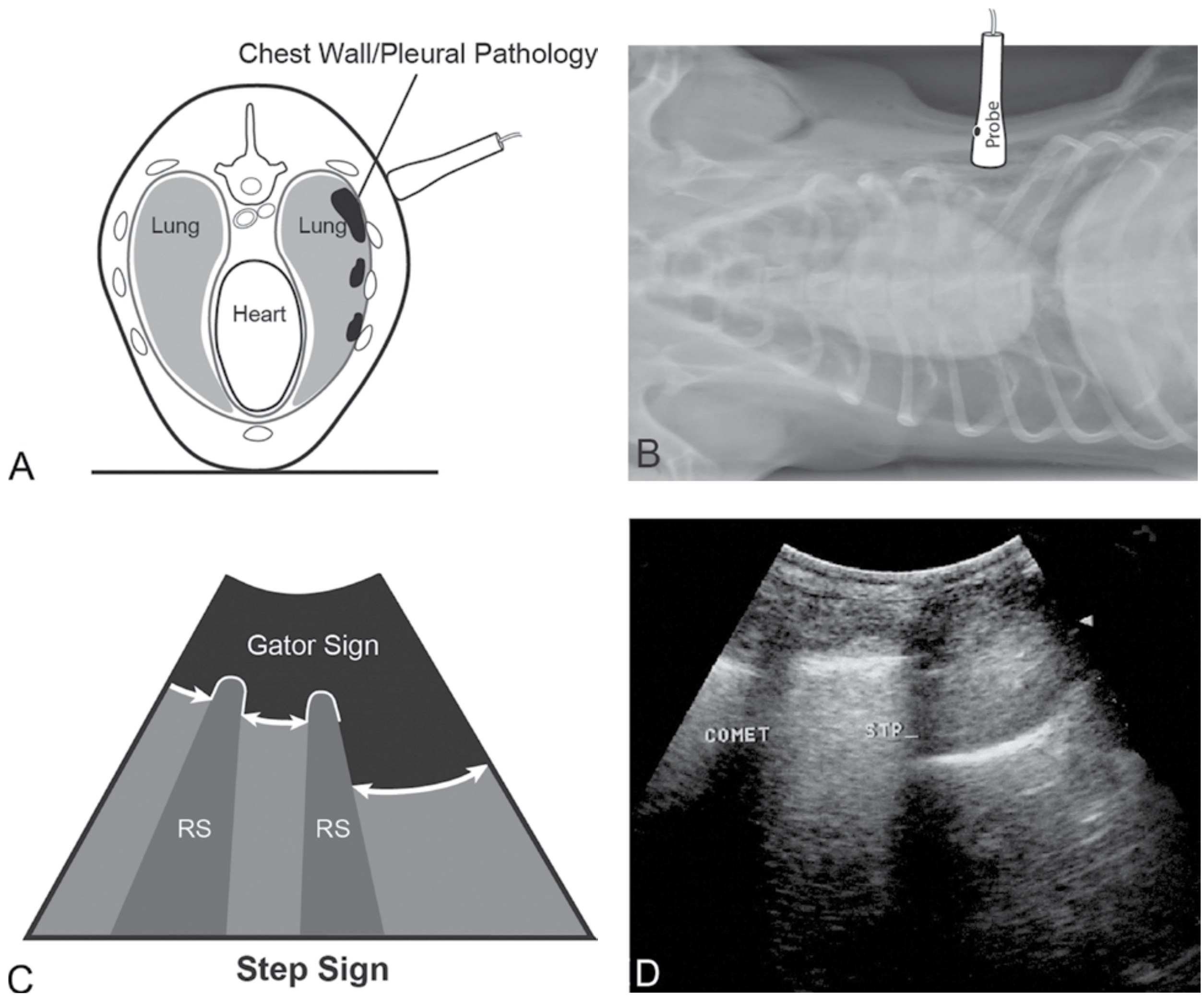


Figure 9.7. The step sign. (A) Probe placement at (CTS) view in sternal recumbency where trauma is represented by offset ribs and black opacities in the pleural space and lung. (B) Correlating thoracic radiograph in a dog with an intercostal tear best shown by tipping its ventrodorsal thoracic radiograph 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.

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.

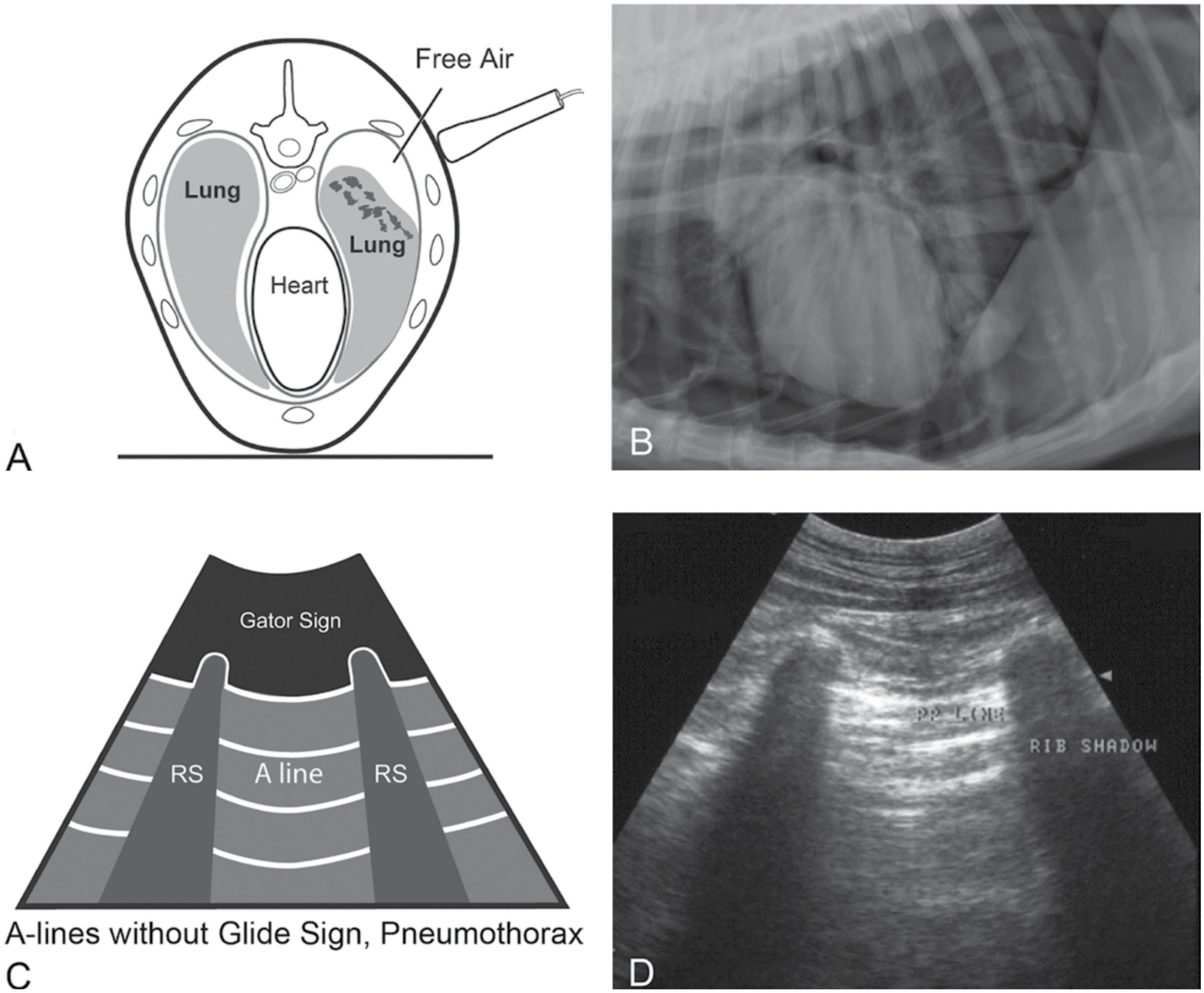


Figure 9.8. A-lines without the glide sign. (A) Probe placement at the CTS view in sternal recumbency where free air and a collapsed lung from PTX are evident. (B) Correlating thoracic radiograph showing PTX. (C) Correlating line drawing showing A-lines (reverberation artifact) without a glide sign (no 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, TFAST[3] 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

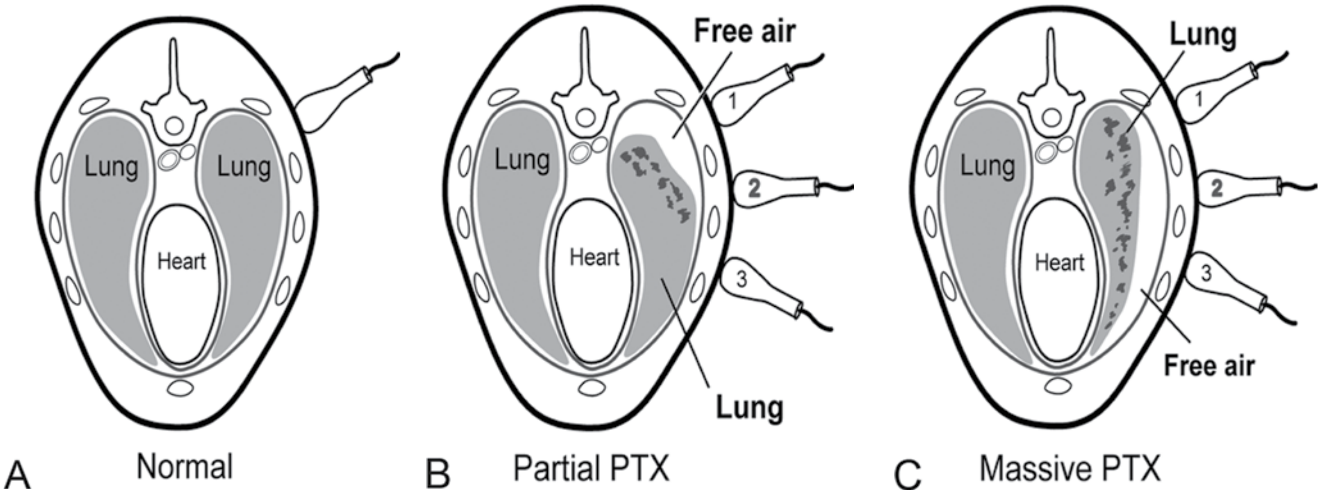


Figure 9.9. Cross-sectional canine thoraces shown in sternal recumbency. When PTX is suspected at the CTS view, the lung point should be sought. The lung point is where collapsed lung re-contacts the thoracic wall and is found by moving the probe sequentially from dorsal to ventral. The location where 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

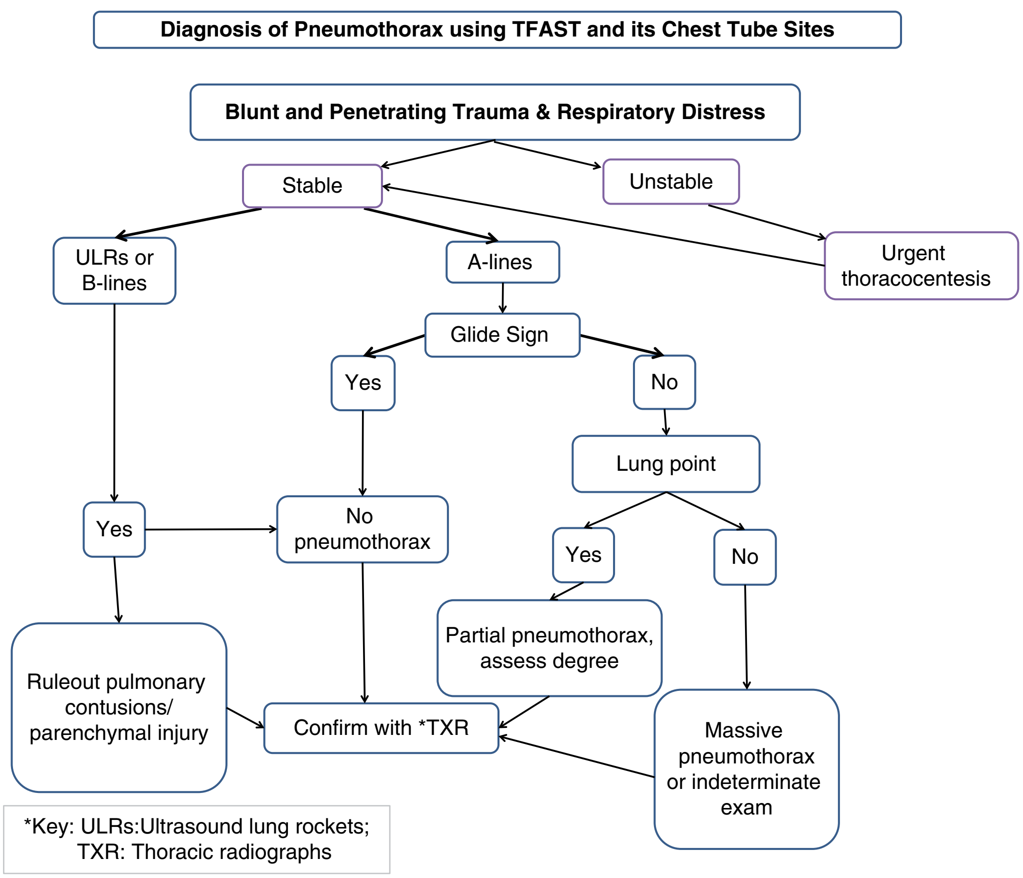


Figure 9.10. Diagnostic algorithm for the ultrasound diagnosis of pneumothorax using TFAST³. © Gregory Lisciandro

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, TFAST[3] 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.

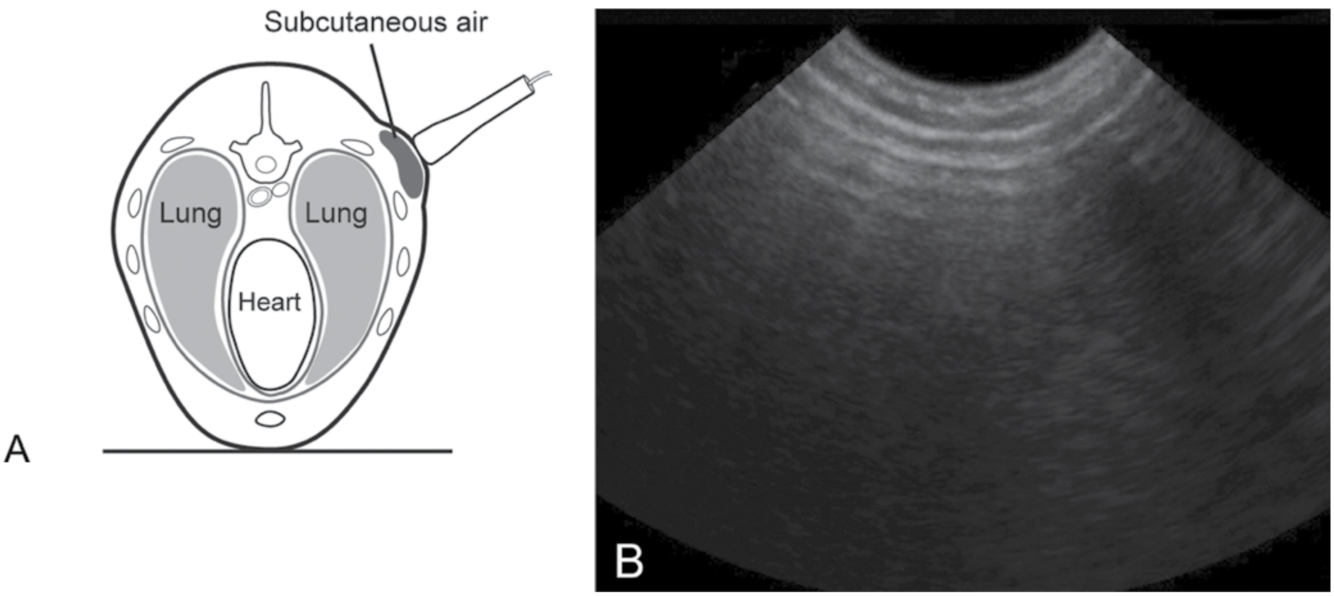
The dry lung concept is also easily mastered (A-lines with a glide sign), especially if PTX is unlikely in the respective patient (e.g., the observance of A-lines is usually sufficient). So by evaluating more than the CTS view for wet lungs vs. dry lungs regionally using the Vet BLUE lung scan, increased 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 TFAST[3] 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 TFAST[3] 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



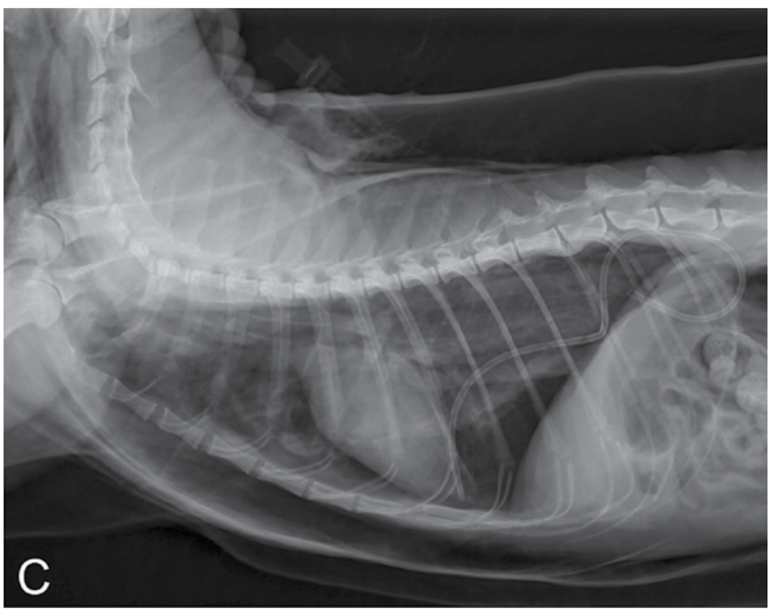


Figure 9.11. The presence of subcutaneous emphysema is common in penetrating trauma cases but rarely prohibits the use of TFAST^3 because in most instances gentle probe pressure will eliminate the SQE and allow proper orientation of the gator sign. (A) Probe placement at the chest tube site view in sternal 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 TFAST^3 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.

TFAST^3 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 TFAST^3 study (or the Vet BLUE lung scan) rarely has to be aborted because imaging of the gator sign is almost always possible.

Performing the TFAST^3 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

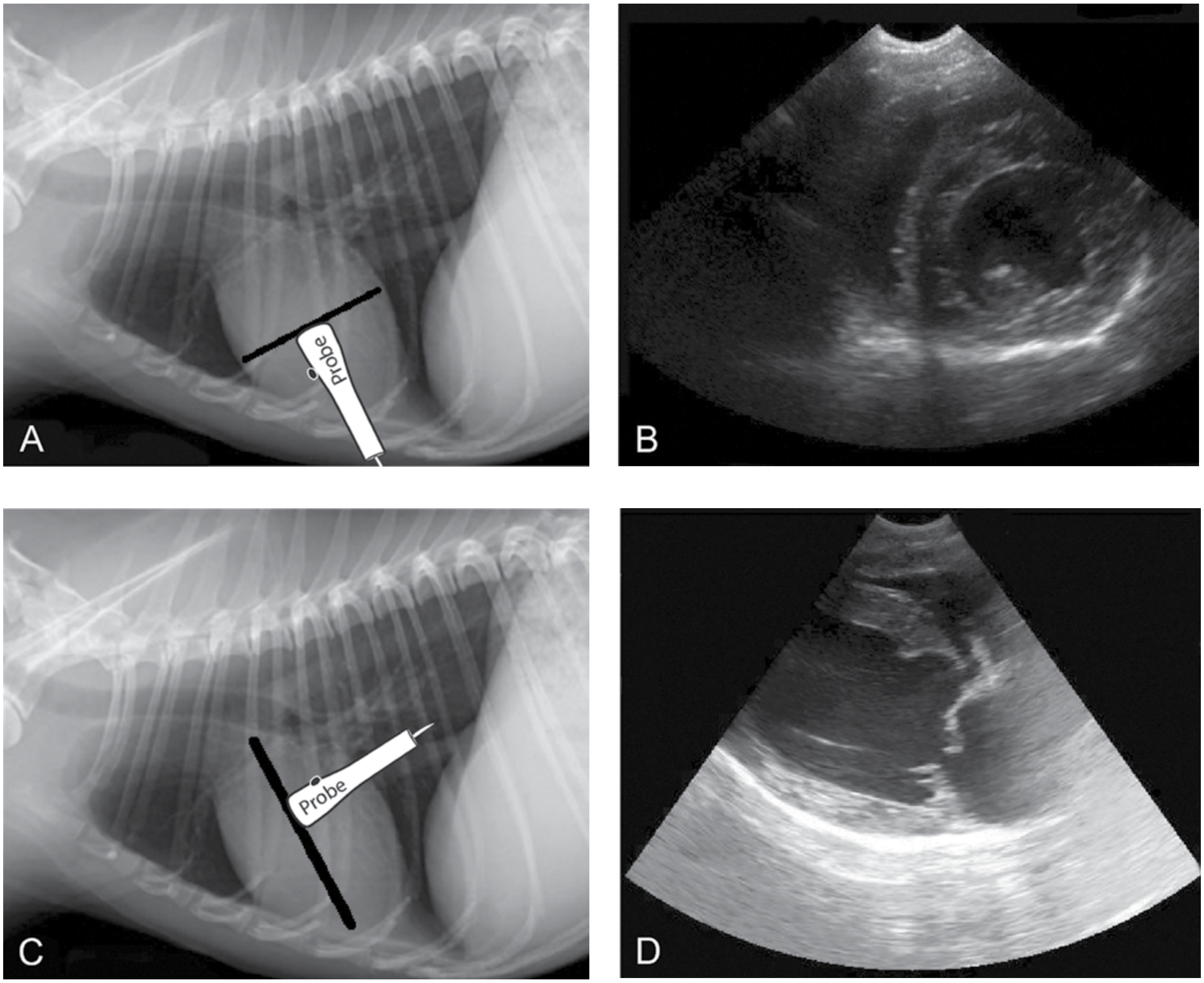


Figure 9.12. Fanning the probe at the pericardial site views. Images (A and B) correspond with each other. (A) The probe is held with the marker (black dot on probe head) toward the elbow on a bar representing probe orientation on a lateral thoracic radiograph. (B) The correlating ultrasound B-mode image 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 TFAST[3] 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

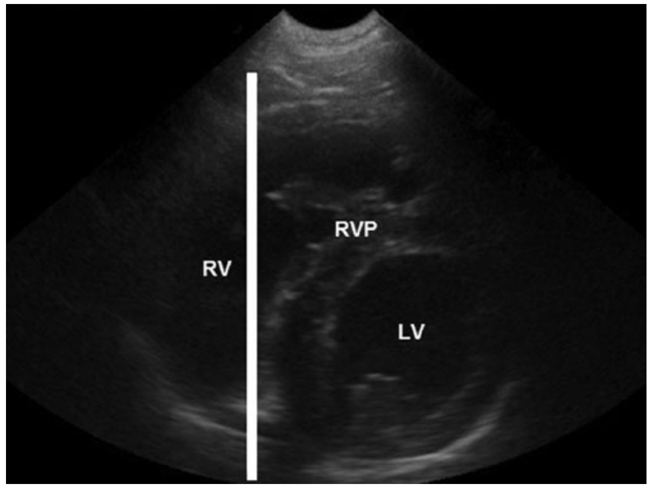


Figure 9.14. Misjudging heart chambers for pleural and pericardial effusion. A left ventricular short-axis mushroom view is shown here. It is very important to recognize that the mushroom (left ventricle; LV) has a crescent moon over it (the right ventricle; RV). To carry the analogy further, within 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

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.

Performing the TFAST³ Diaphragmatico-Hepatic (DH) Fifth View

The classic DH view (nicknamed the designated hitter because the DH is part of AFAST³ and TFAST3³) 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

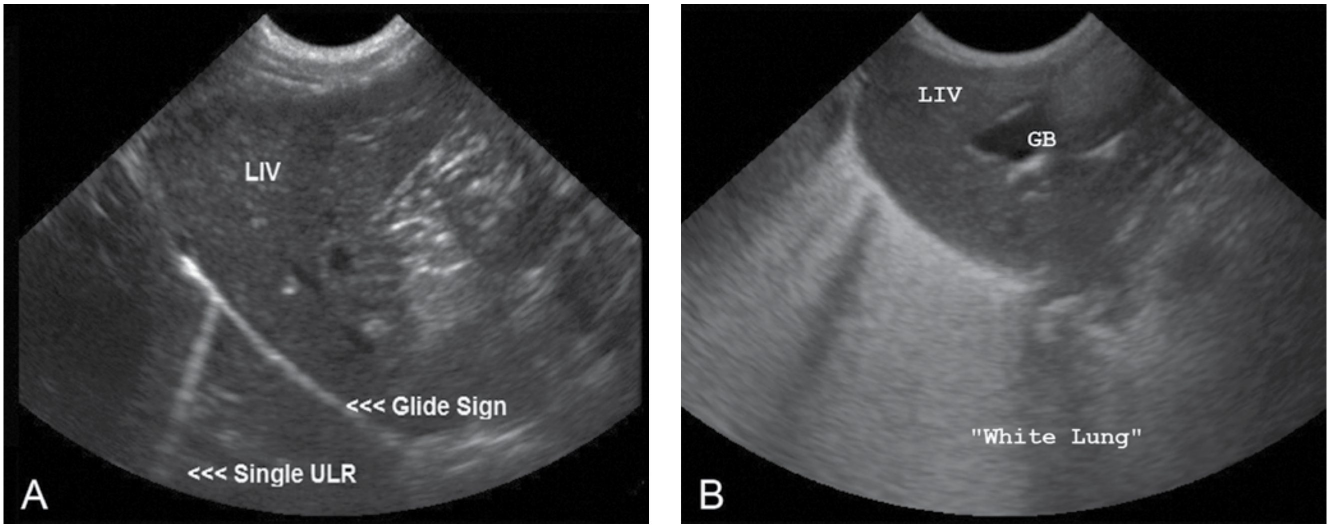


Figure 9.15. Ultrasound lung rockets (ULRs) at the diaphragmatico-hepatic (DH) view. (A) ULRs are not uncommonly seen at the DH view as no more than one or two along the diaphragm. A single ULR is shown here. Note that the depth is very good and clearly shows adequate imaging into the thorax. A glide 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, TFAST[3] and AFAST[3] rapidly ruled out obvious hemothorax, hemopericardium, and hemoabdomen, all possible conditions that could have also been contributing to patient distress. © Gregory Lisciandro

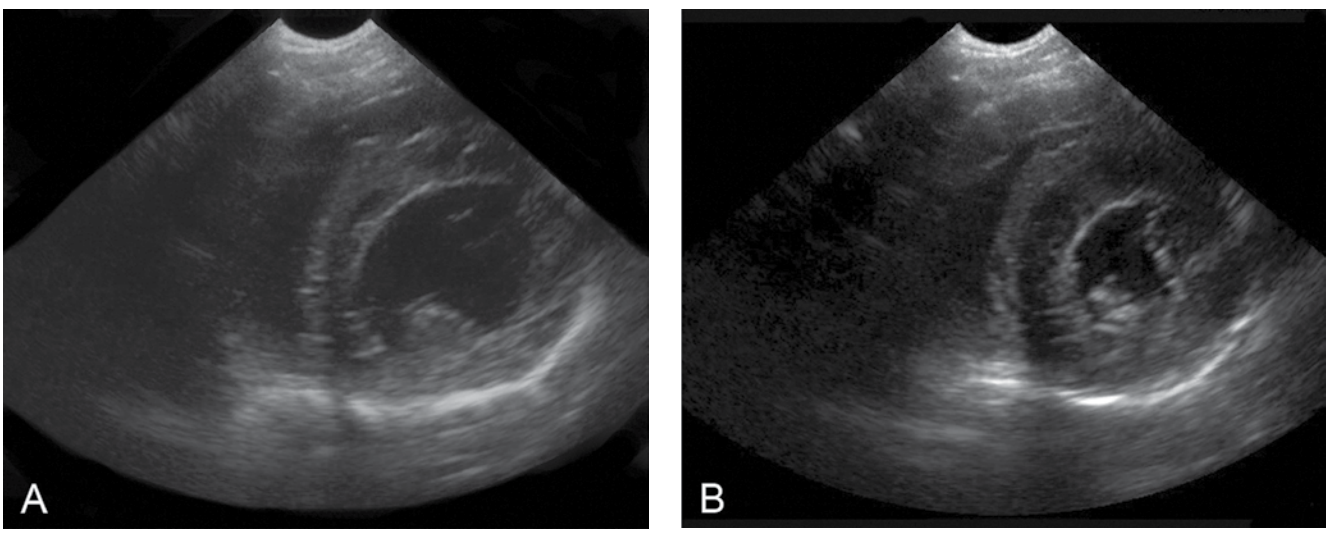


Figure 9.16. Left ventricular short-axis views are acquired at the right TFAST[3] view by directing the "marker toward the elbow." (A) B-mode image of the LV short-axis mushroom view for subjective evaluation of volume status (and contractility, see below) by the maximum excursion during diastole (filling). 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

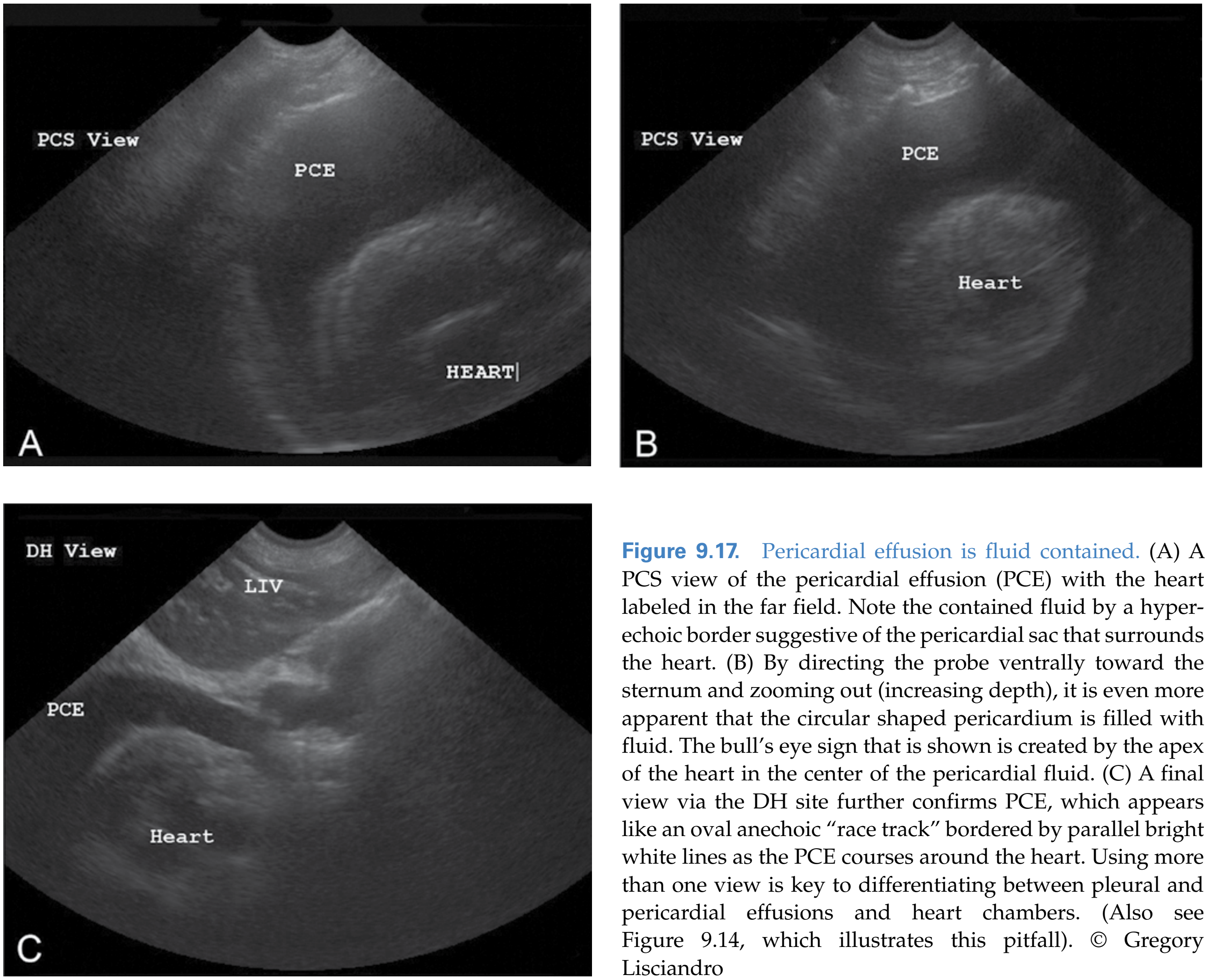


Figure 9.17. Pericardial effusion is fluid contained. (A) A PCS view of the pericardial effusion (PCE) with the heart labeled in the far field. Note the contained fluid by a hyperechoic border suggestive of the pericardial sac that surrounds the heart. (B) By directing the probe ventrally toward the 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.

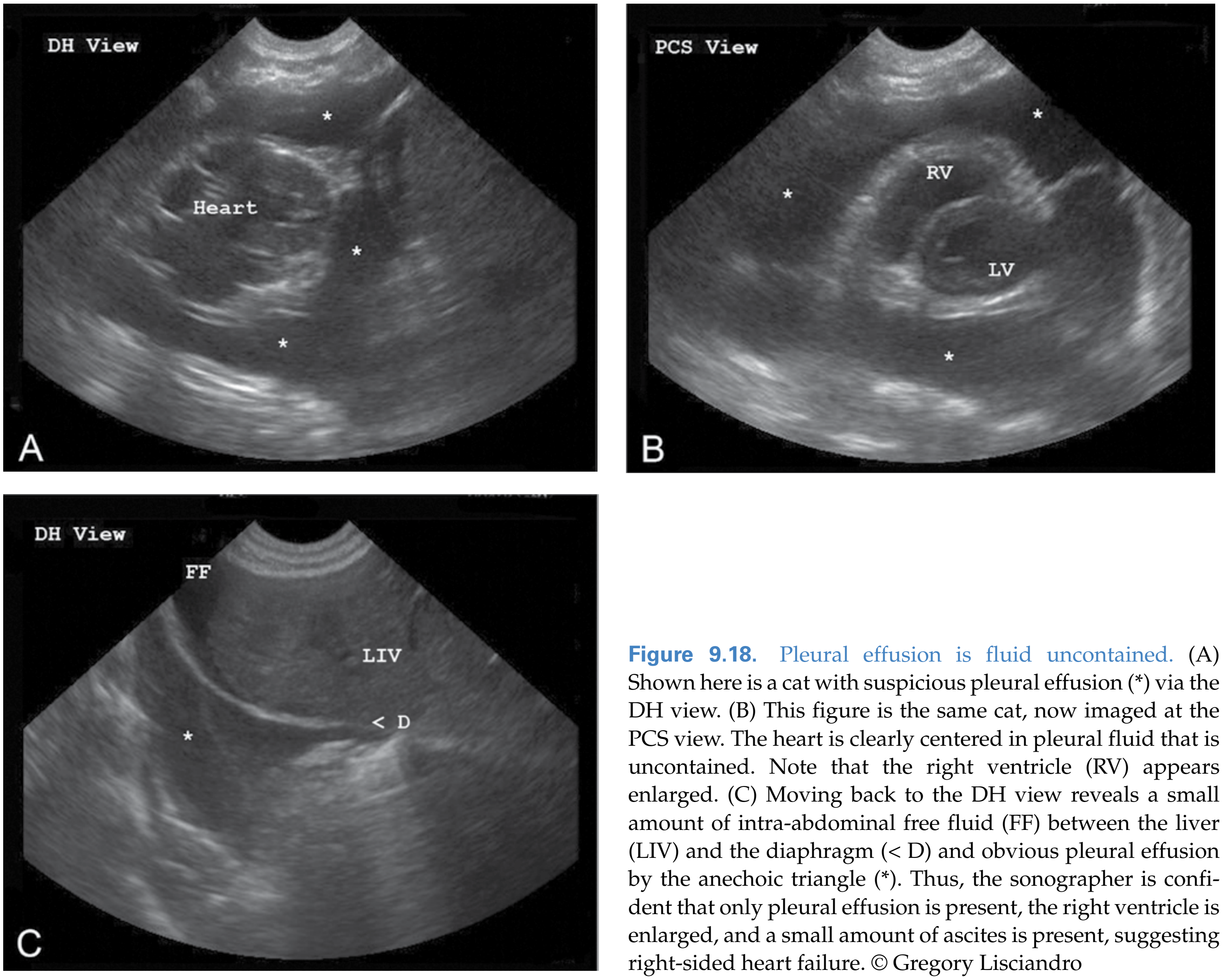


Figure 9.18. Pleural effusion is fluid uncontained. (A) Shown here is a cat with suspicious pleural effusion (*) via the DH view. (B) This figure is the same cat, now imaged at the PCS view. The heart is clearly centered in pleural fluid that is uncontained. Note that the right ventricle (RV) appears 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

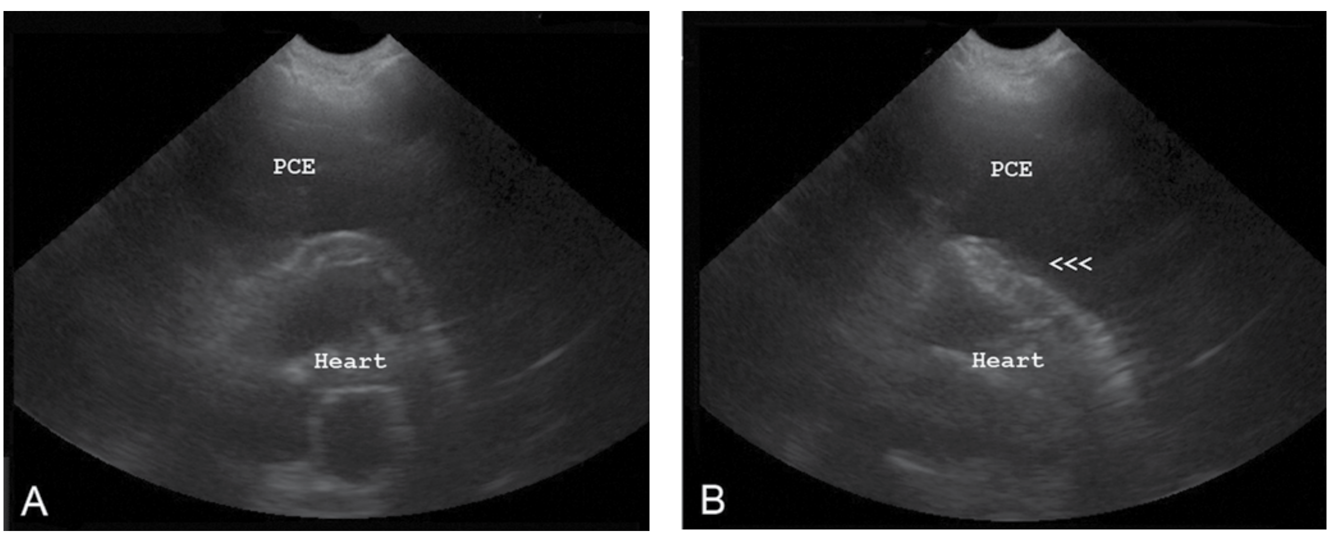


Figure 9.19. Cardiac tamponade. (A) Short-axis view of the heart in a large volume of pericardial effusion (PCE). Note that the chamber in the near field shows distension and filling. (B) In contrast, while keeping the same probe position, the chamber shows obvious collapse on itself (<<<) during diastole, 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

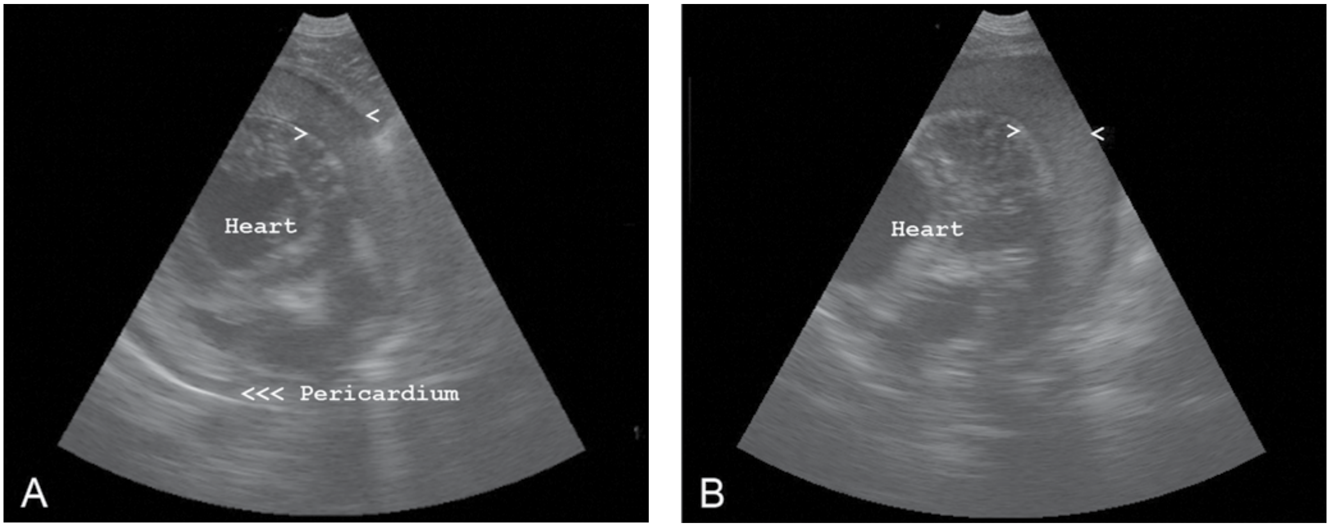


Figure 9.20. Left atrial tears (LAT) as a complication of canine mitral valve disease (MVD) are not uncommon when routinely evaluating heart failure patients with TFAST[3]. MVD cases with LAT often have occult pericardial effusion based on their thoracic radiographs (as did this dog), and thus LAT is 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 TFAST[3] (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

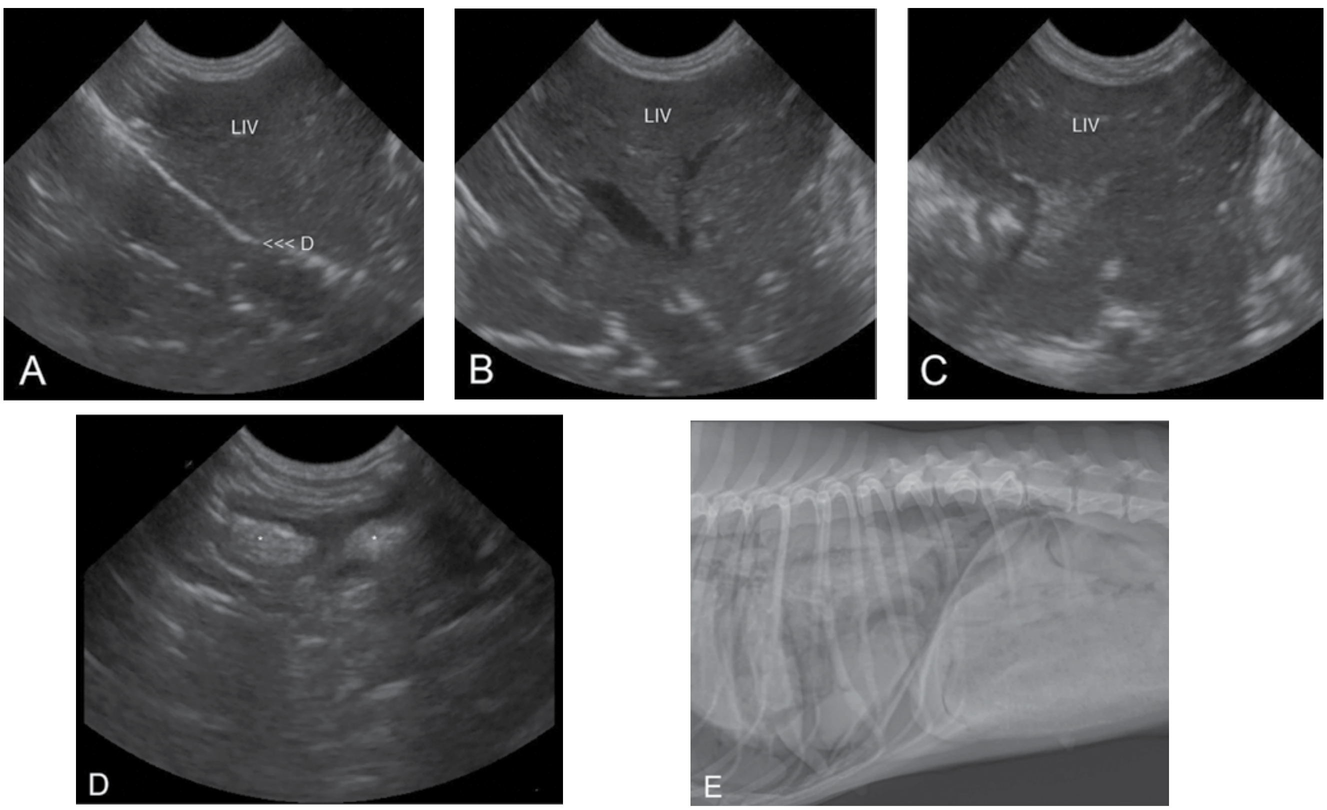


Figure 9.21. Diaphragmatic herniation. While holding the probe stationary and observing via the DH view over several consecutive breaths, the following sequence of images (A through C) were taken at triage on emergency referral. The dog had arrested during its spay procedure, was resuscitated, and continued 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. (D) The confirmatory thoracic radiograph for the suspected diaphragmatic hernia by TFAST[3] at triage. © Gregory Lisciandro

Findings at the TFAST^3 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 TFAST^3 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 TFAST^3 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 FAST^3 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-TFAST^3) to 2011 (post-AFAST^3 and TFAST^3), 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 TFAST^3 or AFAST^3 (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 TFAST^3 (Figure 9.19; also see Figure 11.15A).

TFAST^3 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).

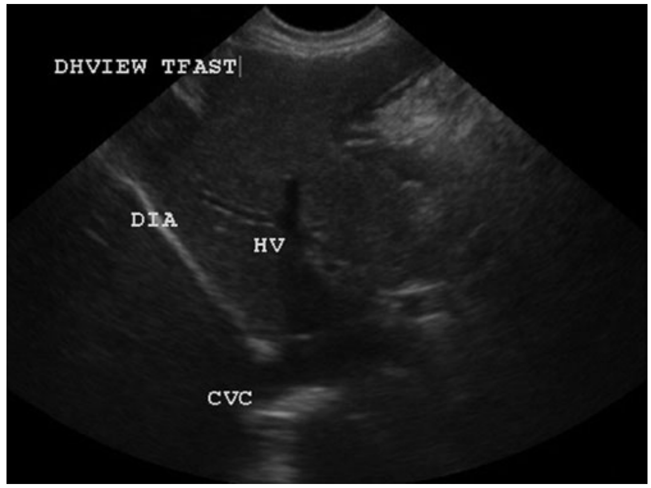


Figure 9.22. Volume status and preload. Shown is the DH view in which the caudal vena cava (CVC) passes through the diaphragm (DIA) into the thorax. Within the thorax, the CVC size reflects preload (central venous pressure). The hepatic veins (HV) are clearly identified as they branch into the CVC and 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

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 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.

TFAST^3 Revised to Now Include the Vet BLUE Lung Scan

With the addition of the diaphragmatico-hepatic (DH) view, the original TFAST^3 has now become a five-point exam. Furthermore, a more extensive lung survey extending from the TFAST^3 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 TFAST^3 and should be routinely implemented (see Chapter 10).

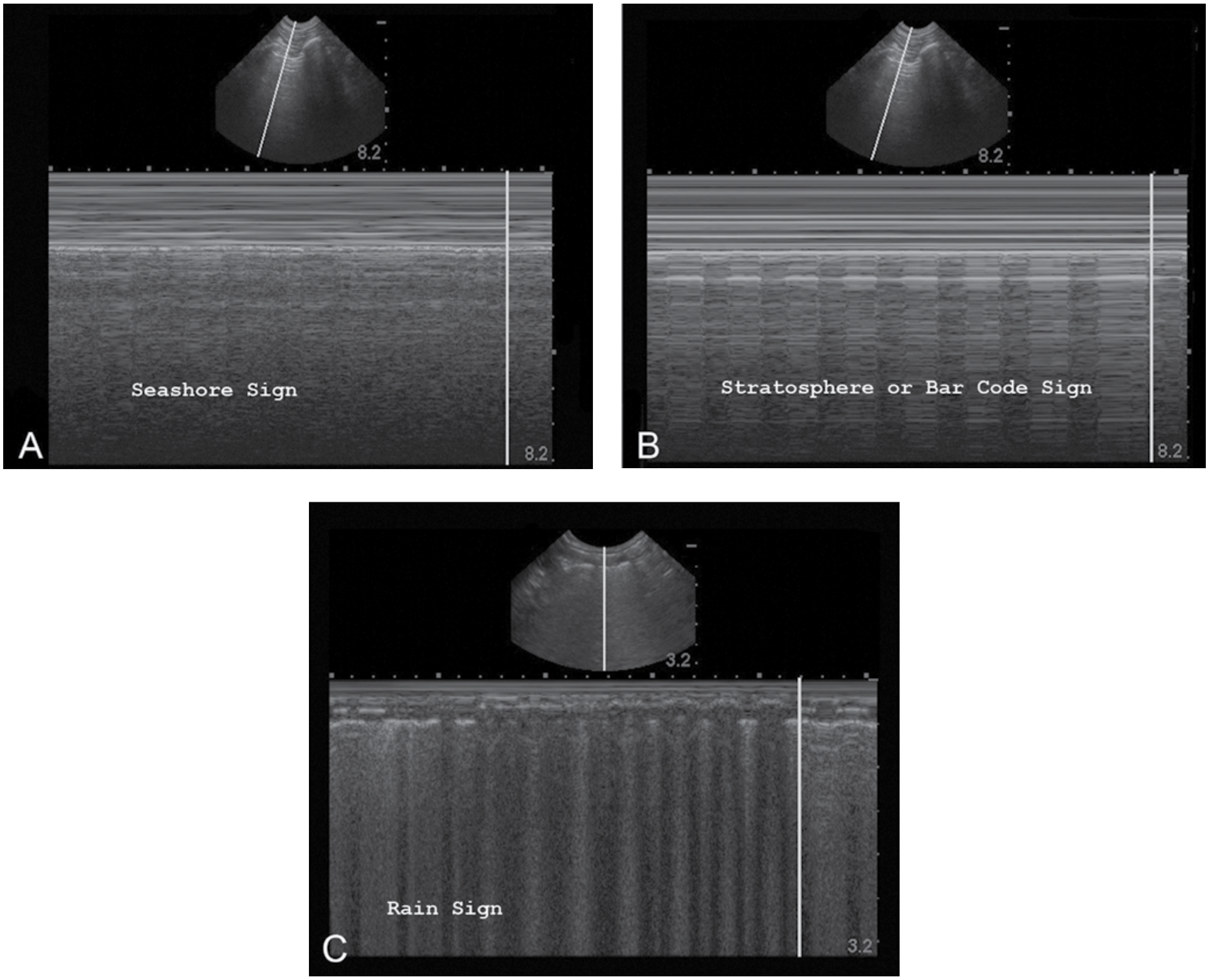


Figure 9.23. M-mode has been used in humans for documenting the presence of pneumothorax by still images (because B-mode images cannot). Attempts to use M-mode in small animals have been unrewarding because unless the animal is not moving and has controlled breathing, too much motion exists. (A) M-mode 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 TFAST[3] Findings in Medical Records

The use of standardized templates is imperative not only for communication of TFAST[3] 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 TFAST[3] 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

- TFAST[3] 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.
- TFAST[3] should be used as a first line screening test in non-trauma subsets of patients with respiratory distress, collapse, and unexplained hypotension.
- TFAST[3] should be used post interventionally to detect complications otherwise occult by traditional means of physical examination, laboratory findings, and thoracic radiography.
- TFAST[3] includes the fifth DH view (also part of AFAST[3]) 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.
- TFAST[3] 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.

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