CHAPTER TEN

The Vet BLUE Lung Scan

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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 AFAST[3] and TFAST[3], 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 AFAST[3] and TFAST[3] allows most

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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 AFAST^3 and TFAST^3, 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 AFAST^3 and TFAST^3, the study is referred to as global FAST^3 or GFAST^3. 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 "T^3" of AFAST^3 and TFAST^3 (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 5–10 MHz. 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 TFAST[3] 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 TFAST[3] chest tube site view applied to three additional lung lobe regions, providing more comprehensive lung information. It should be a routine add-on to TFAST[3] 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 TFAST[3] 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 TFAST[3] 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 TFAST[3] 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 (crll). Each of these sites (phll, mdll, crll) 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 TFAST[3] and Vet BLUE in all respiratory-compromised patients. A modified sternal recumbency position may be used for AFAST[3] 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 TFAST[3] at its chest tube site (CTS) view (Lisciandro 2008, 2011) (see Figures 9.2 and 9.4).

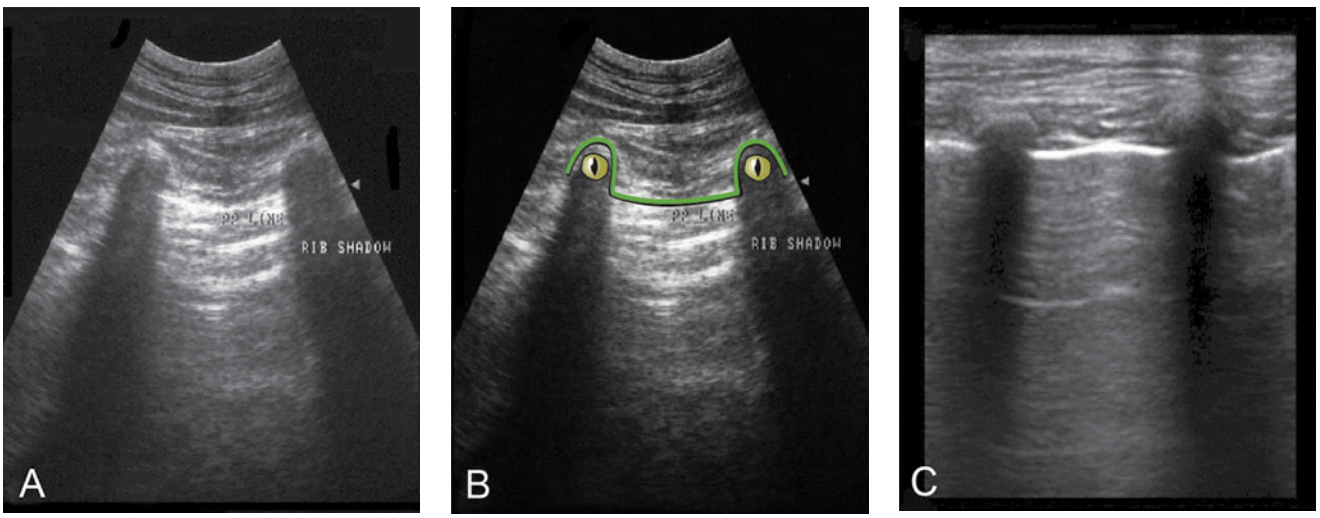


Figure 10.2. The basic orientation for all lung ultrasound is the gator sign. The orientation of the rib heads (shown as eyes) and intercostal space (shown as its bridge of nose) is likened to an alligator peering over the water at the sonographer. The depth is generally set between 4–6 cm. (A) B-mode 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 TFAST[3] and Vet BLUE; however, SQE almost always can be displaced with gentle probe pressure, allowing for visualization of the gator sign and thus TFAST[3] 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 TFAST[3] 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 TFAST[3] 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 eight 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 TFAST[3] 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).

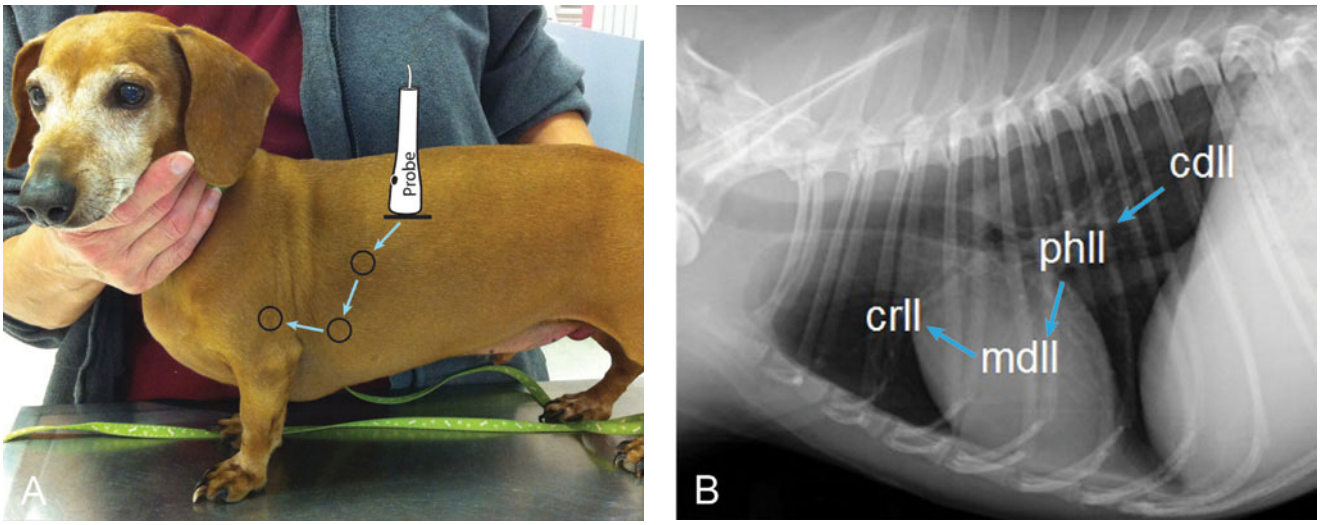


Figure 10.3. The Vet BLUE regional lung scan correlated to thoracic radiography. Shown is the same dog in Figure 10.1 with a corresponding lateral thoracic radiograph. (A) The external sites on the dog may be correlated to internal lung regions marked on (B) (the lateral thoracic radiograph). Vet BLUE begins at the caudodorsal lung lobe region (cdll), which is the same as the TFAST[3] 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

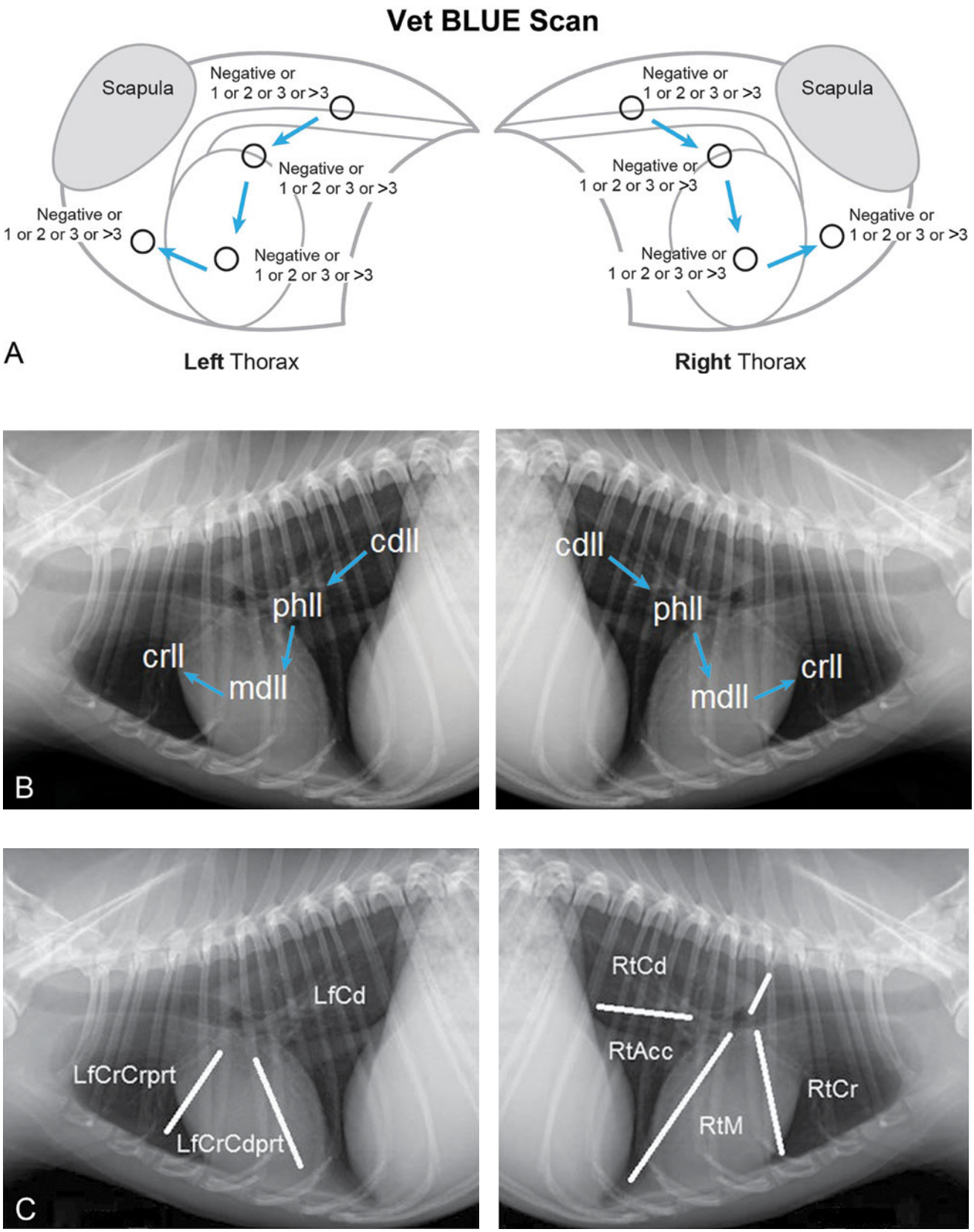


Figure 10.4. (*Continued*)

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 (crll) 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

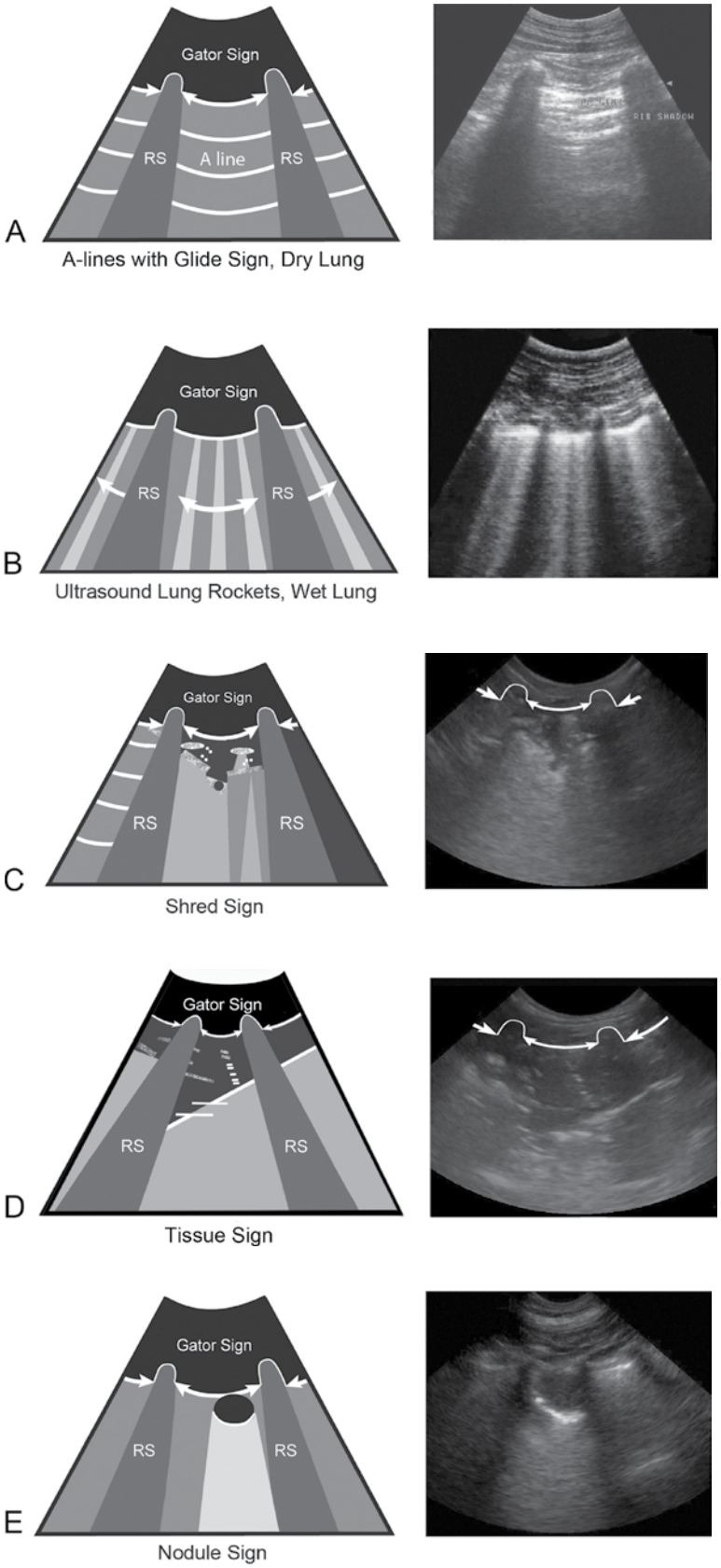


Figure 10.5. Basic lung ultrasound findings with relative degree of infiltration from least to most (top to bottom). Line drawings are in the left column and the corresponding B-mode ultrasound images are directly to the right column. (A) Dry lung. (B) Wet lung. (C) Shred sign. (D) Tissue sign. (E) Nodule sign. Courtesy of Nancy Place, San Antonio, Texas. © Gregory Lisciandro and Nancy Place

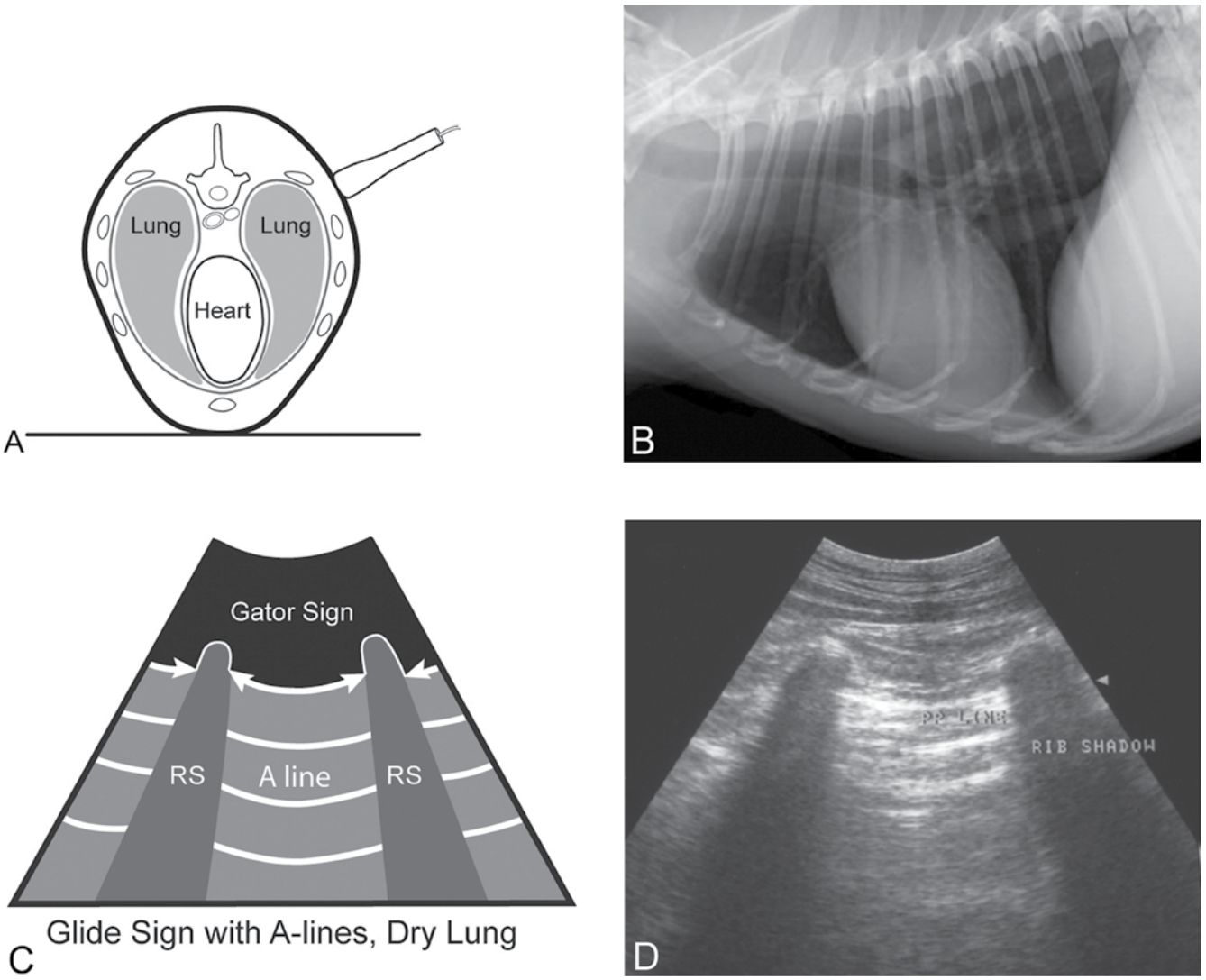


Figure 10.6. A Dry lung, A-lines with a glide sign. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST[3] CTS view. (B) Correlating unremarkable thoracic radiograph. (C) Correlating line drawing showing dry lung. A-lines (air reverberation 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.

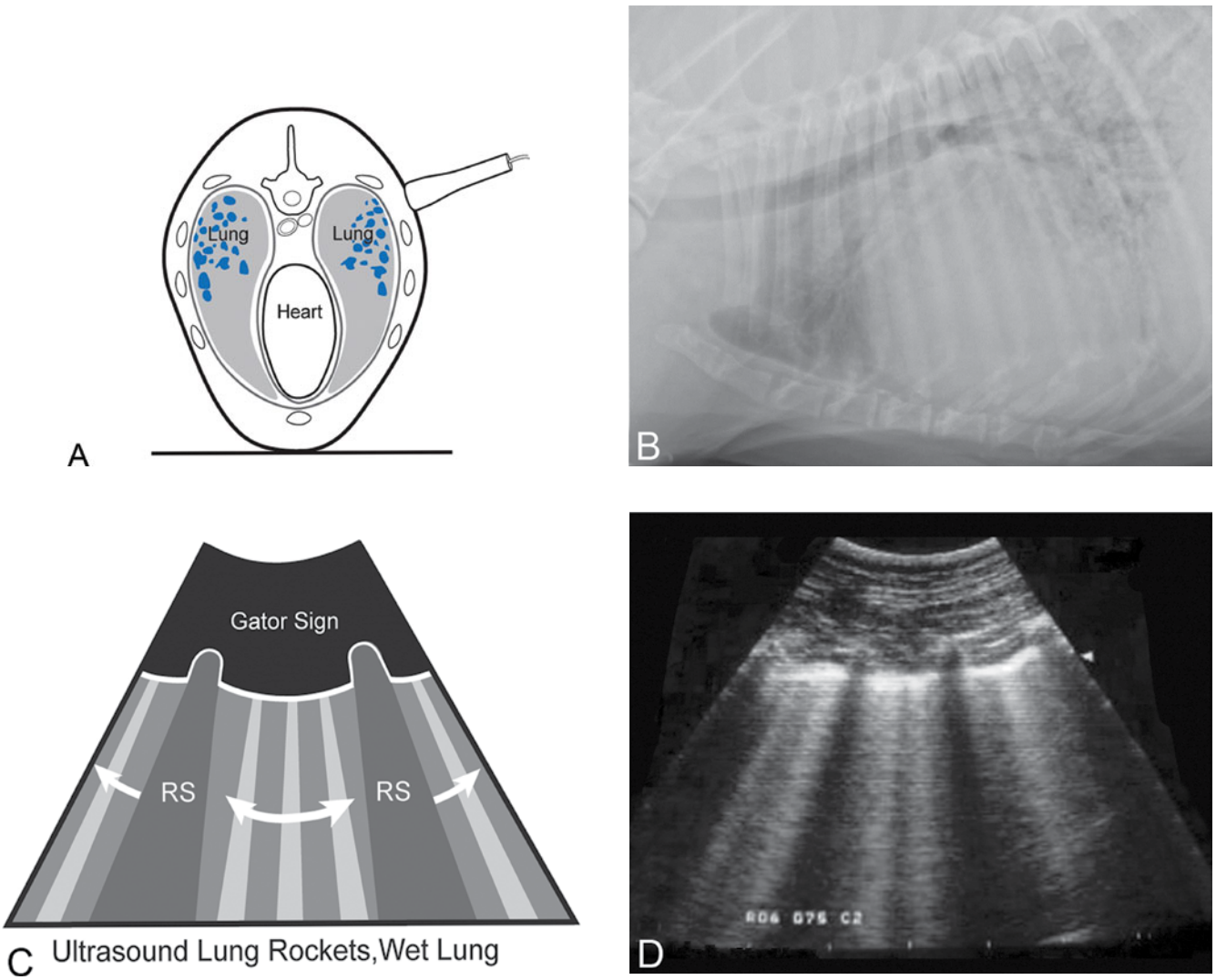


Figure 10.7. Wet lung, acute cardiogenic pulmonary edema. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST[3] CTS view. Note that the lungs have blue mottling representing interstitial edema. (B) Correlating thoracic radiograph typical 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.

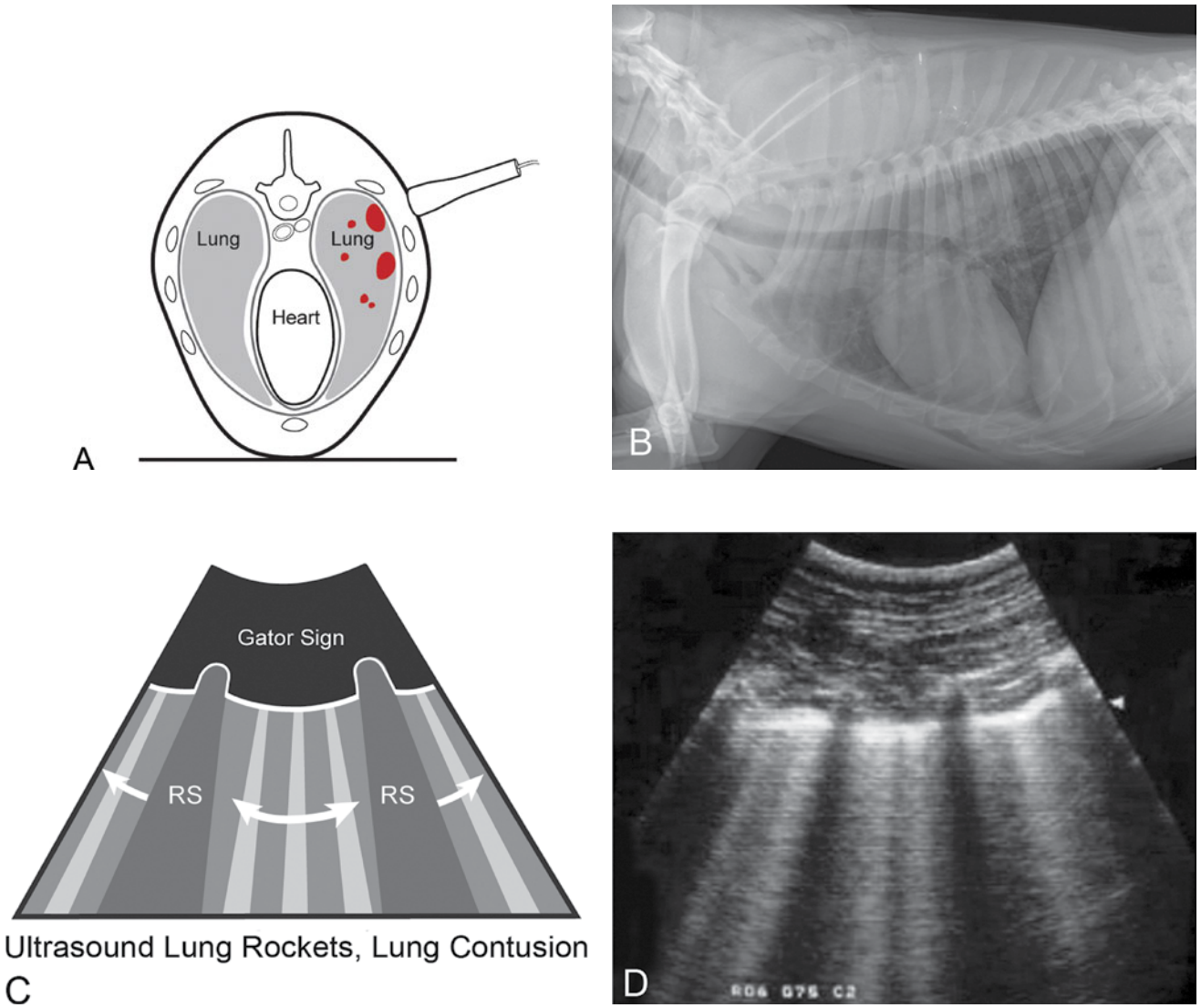


Figure 10.8. Wet lung, lung contusion. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST[3] CTS view. Note the lungs have red mottling representing pulmonary contusions (hemorrhage). (B) Correlating thoracic radiograph with subtle radiographically 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.

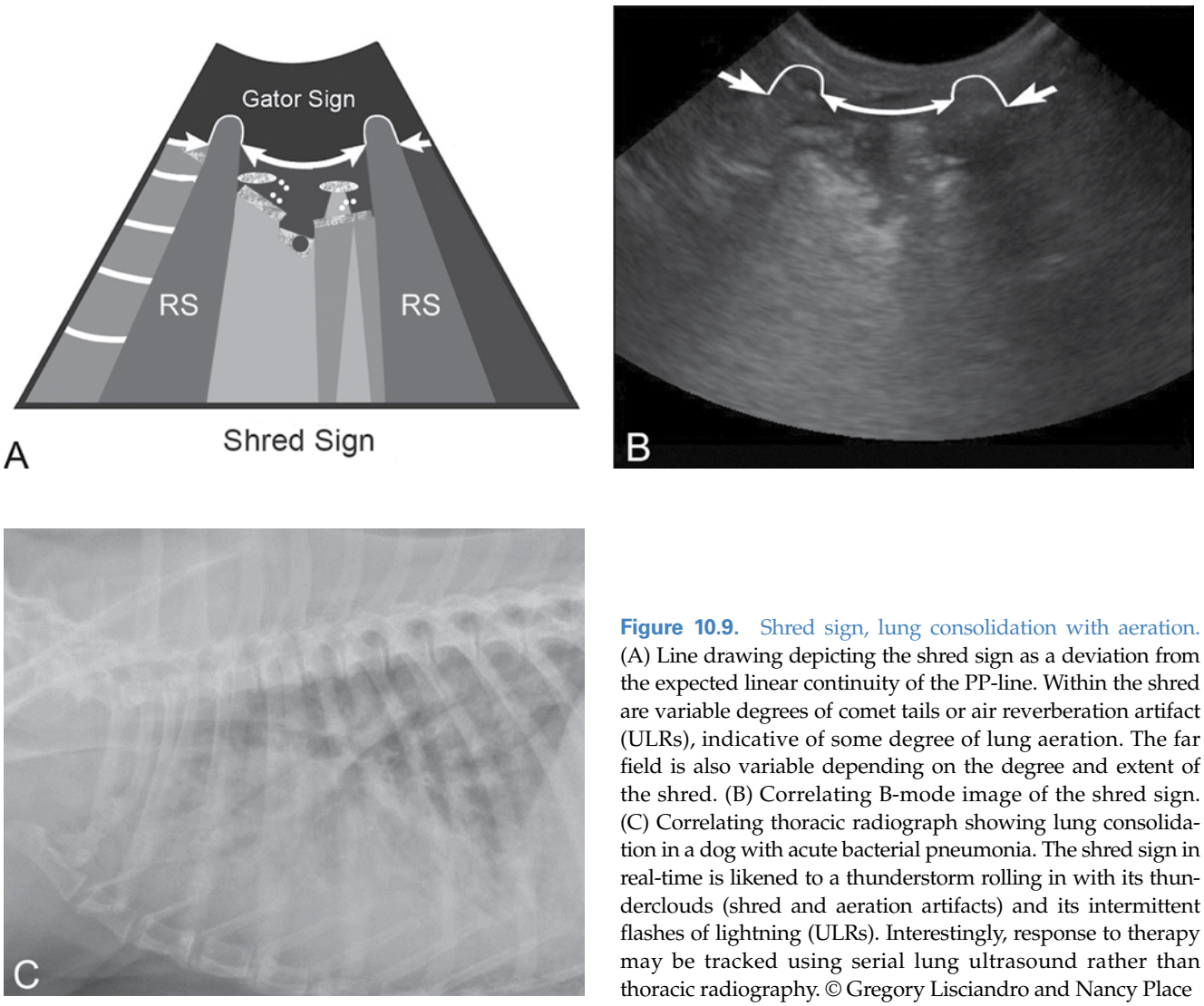


Figure 10.9. Shred sign, lung consolidation with aeration. (A) Line drawing depicting the shred sign as a deviation from the expected linear continuity of the PP-line. Within the shred are variable degrees of comet tails or air reverberation artifact (ULRs), indicative of some degree of lung aeration. 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/pseudochylous effusions tend to be more echogenic.

By using Vet BLUE as part of TFAST[3], 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 TFAST[3] 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

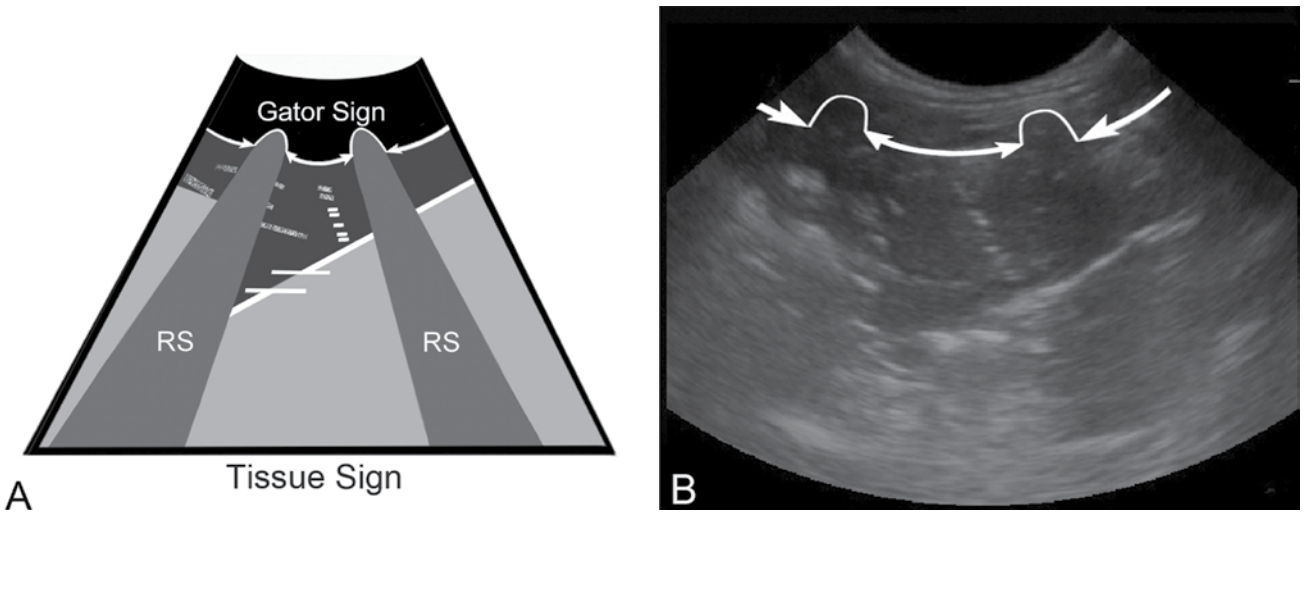


Figure 10.10. Tissue sign, lung consolidation without aeration. (A) Line drawing depicting the tissue sign as a deviation from the expected linear continuity of the PP-line. Within the tissue sign there are no comet-tails, air reverberation artifacts (ULRs) because of complete lack of aeration in the 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

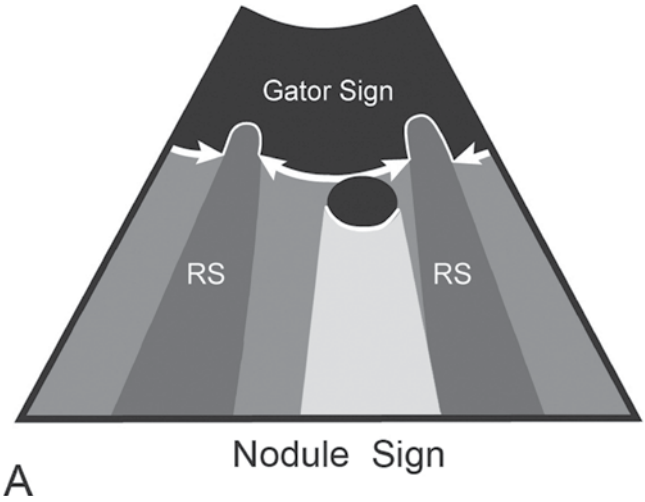
(PTX) (see below) and subcutaneous emphysema (SQE) (see Figure 9.11), when present, negate any attempts to ultrasound. However, lung ultrasound may be performed when PTX has resolved or at any regions where lung is in direct contact with the thoracic wall. SQE often can often be eliminated by applying enough probe pressure to displace the interfering subcutaneous air so that the gator sign orientation becomes visible.

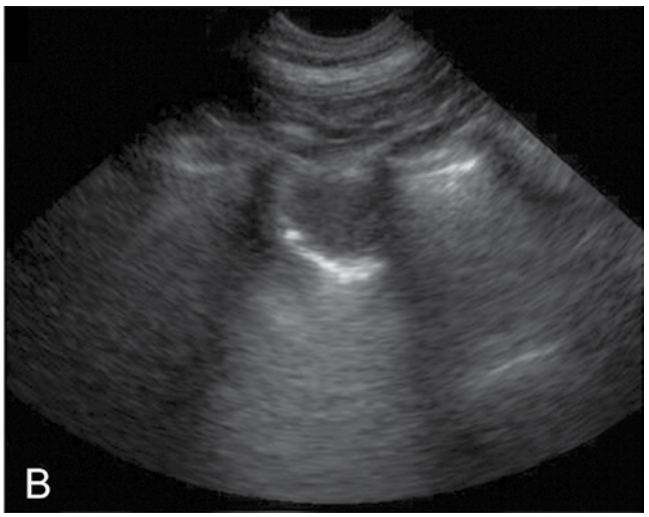
False positive, limitations: Pleural space and pericardial conditions such as diaphragmatic hernia, pericardial-peritoneal hernia, and thoracic wall disease may be confounders, creating a step sign or falsely indicating a shred sign, tissue sign, or nodule(s) sign.

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.





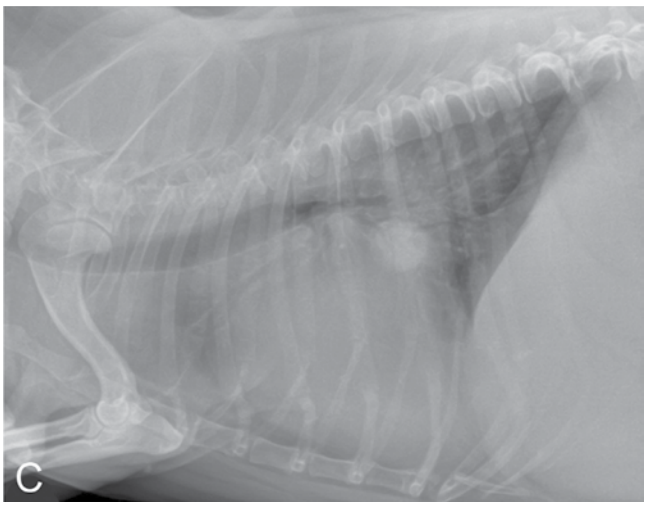


Figure 10.11. Nodule sign, single nodule. (A) Line drawing depicting the nodule sign as a deviation from the expected linear continuity of the PP-line. The finding of a circular or ovoid predominately anechoic region should raise clinical suspicion for the presence of a mass lesion. The far field is 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).

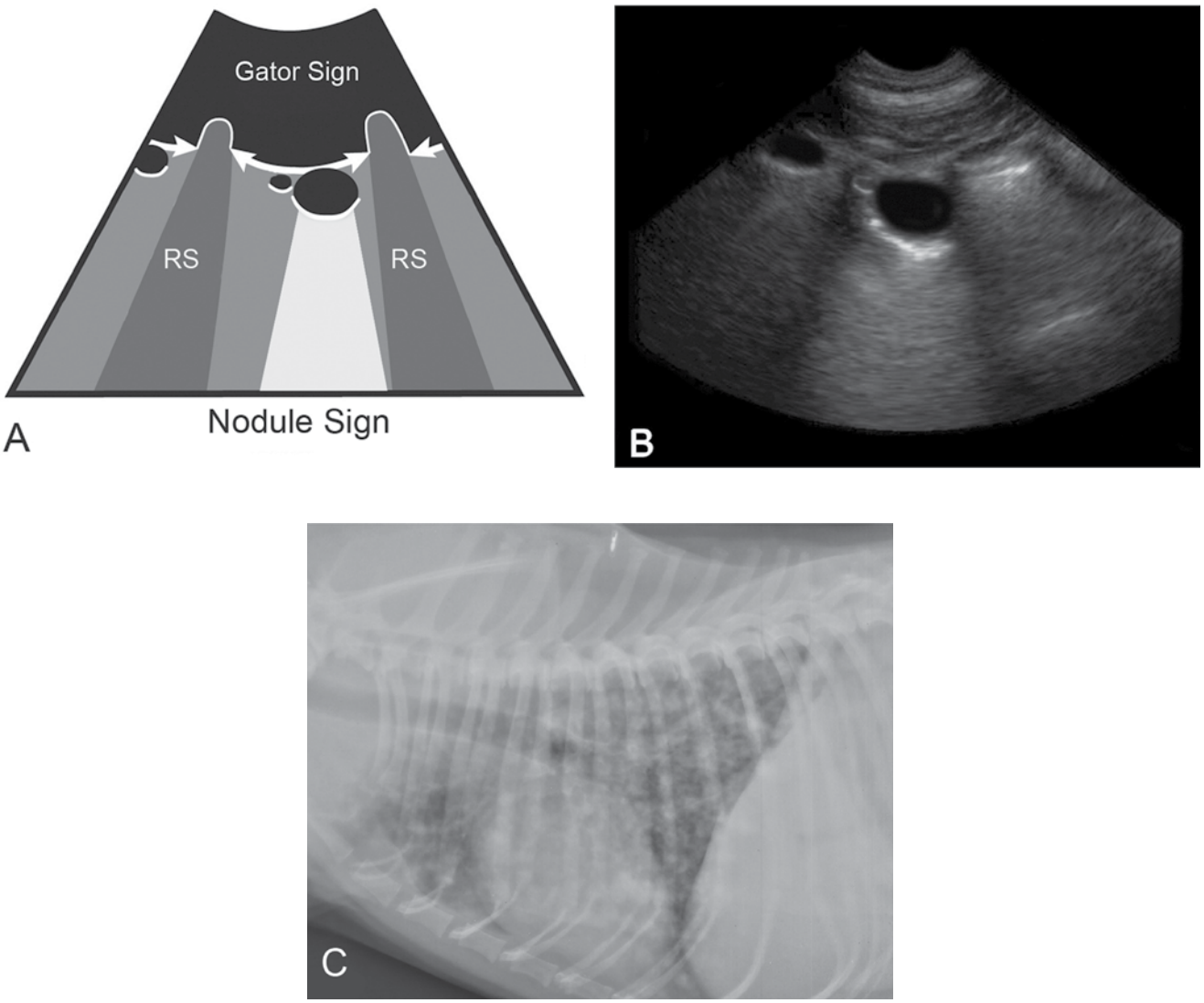


Figure 10.12. Nodule sign, multiple nodules. (A) Line drawing depicting the nodule sign as a deviation from the expected linear continuity of the PP-line. The finding of multiple circular or ovoid predominately anechoic regions should raise clinical suspicion for the presence of multiple nodules and 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

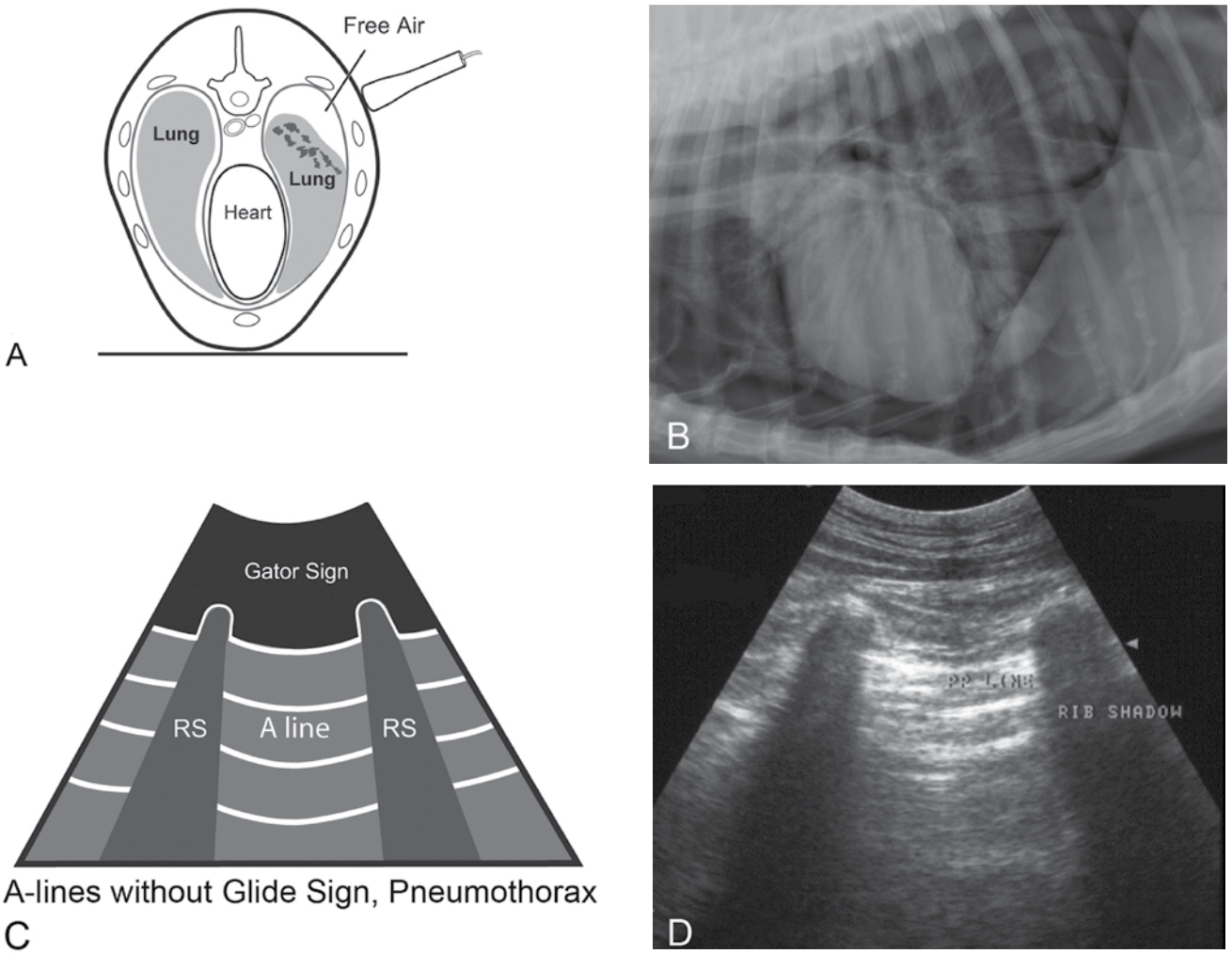


Figure 10.13. Pneumothorax, A-lines without a glide sign. (A) Probe positioning at the starting point of Vet BLUE, the caudodorsal (cdll) site, which is the same as the TFAST[3] CTS view. The lungs have fallen away from the thoracic wall (collapsed) with free air that is within the pleural space, representing 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

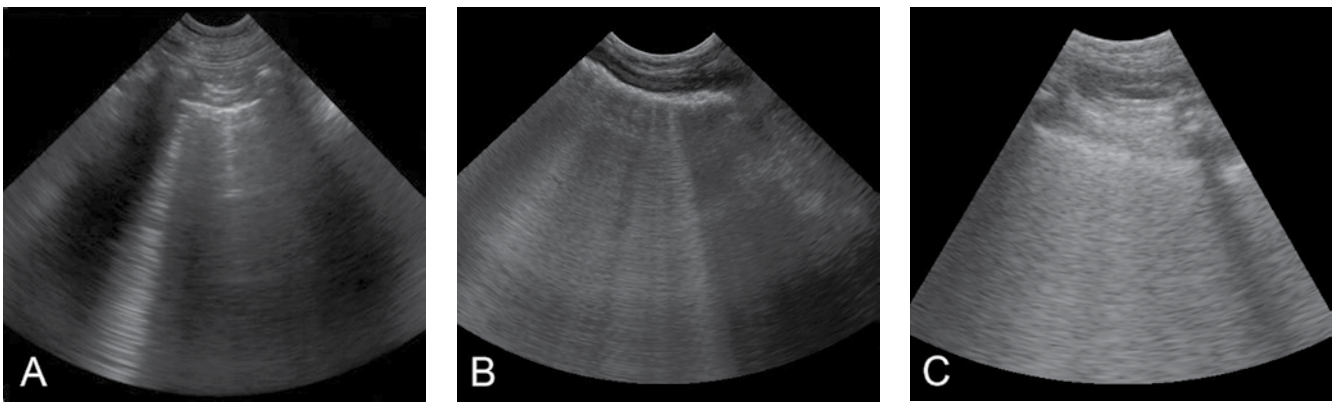


Figure 10.14. The Progression of Severity of Wet Lung using Numbers of Ultrasound Lung Rockets. The maximum number of ULRs over a single intercostal space at each respective Vet BLUE view is recorded. (A) Single ultrasound lung rockets (ULR). (B) Multiple ULRs still be seen as individual entities and 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

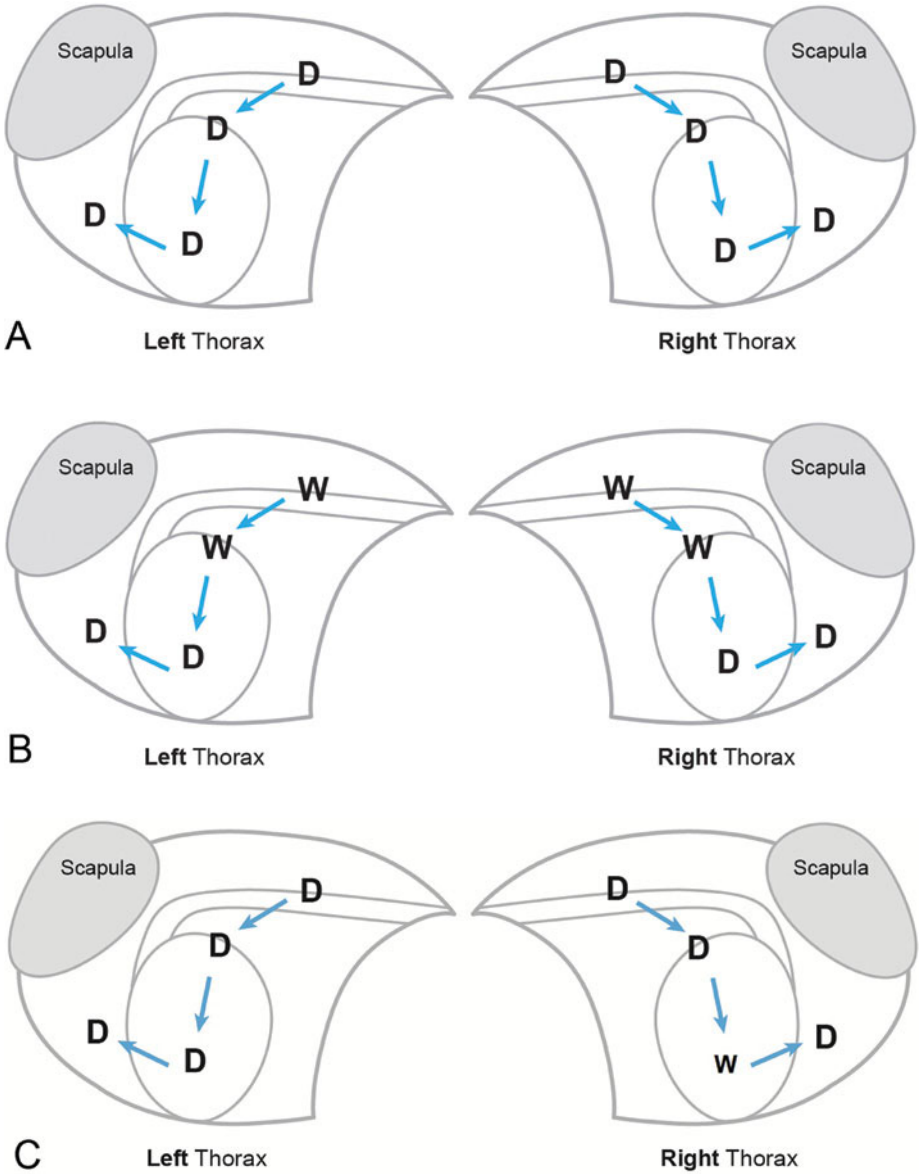


Figure 10.15. Pictorial representation for pattern-based interpretation of possible Vet BLUE findings. Shown are the left and right hemithorax, illustrating the basic use and interpretation of dry lung (A-lines with a glide sign, labeled as "D") and wet lung (ultrasound lung rockets, labeled as "W") 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 AFAST[3] and TFAST[3]).

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

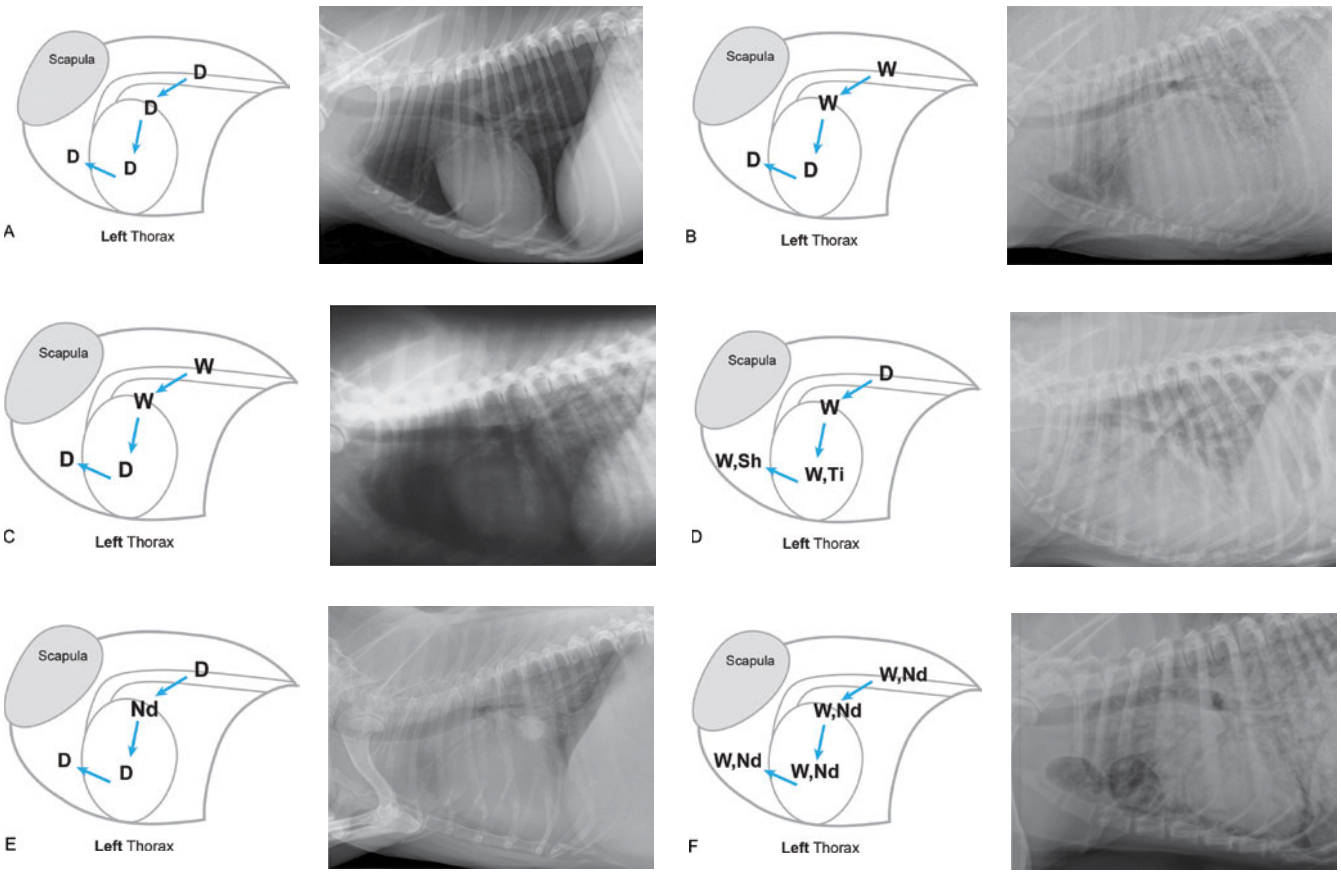


Figure 10.16. Various Vet BLUE scenarios using a regional, pattern-based approach. (A) The finding of dry lungs, all fields is indicated by "D" at each of the four Vet BLUE views with a correlating unremarkable representative lateral TXR. (B) Wet lungs, indicated by "W" in the dorsal lung fields (caudodorsal 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 FAST[3] (AFAST[3], TFAST[3], 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 is 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 TFAST[3] 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, AFAST[3]-detected causes (hemoabdomen, hemoretroperitoneum, septic abdomen, anaphylaxis), TFAST[3]-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

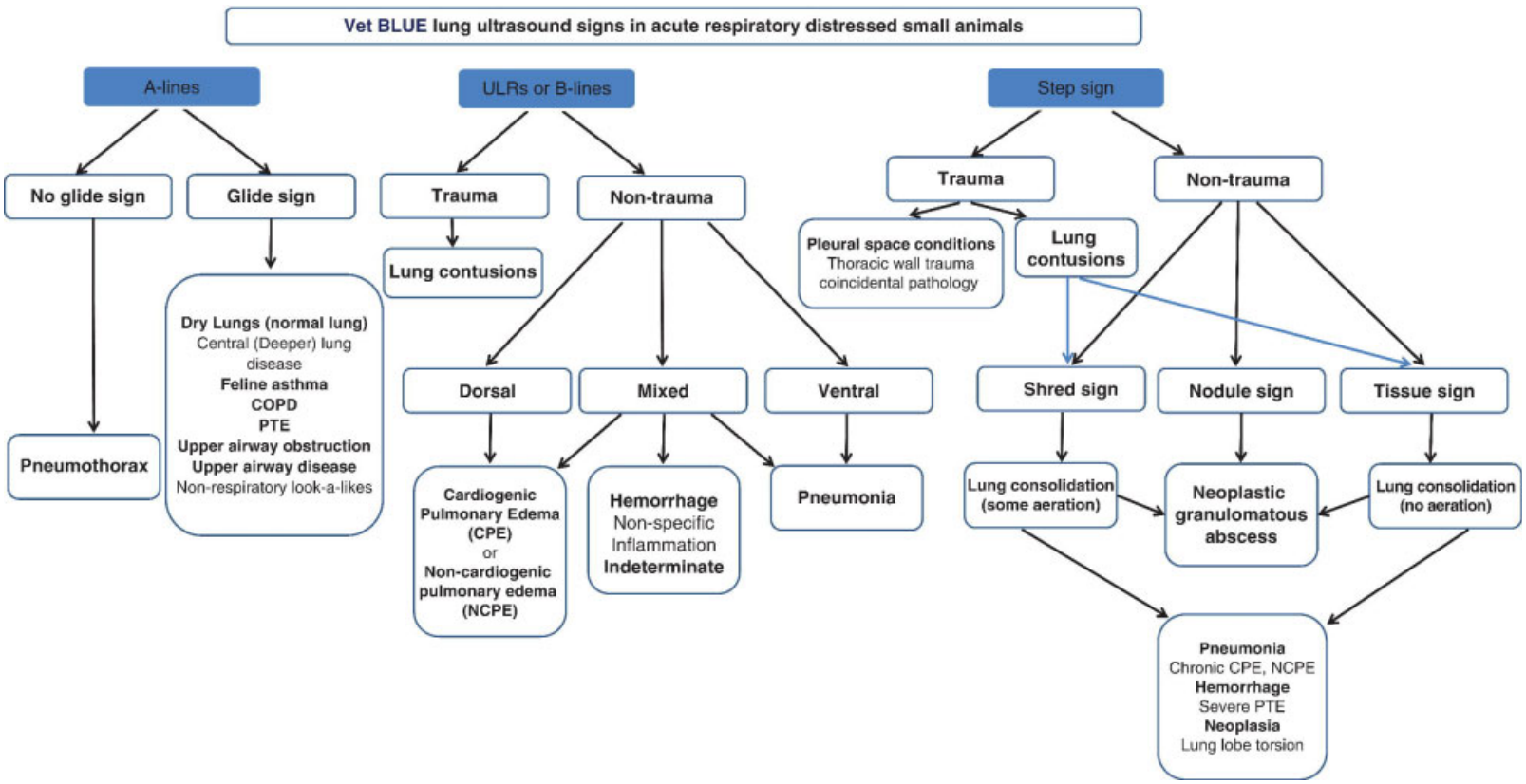


Figure 10.17. Summary of lung ultrasound signs and differential diagnoses. © Gregory Lisciandro

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 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 TFAST[3] 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.

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