Lung Ultrasound

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Introduction and History

The use of lung ultrasound dates back into the late 1980s, notably with the ultrasound diagnosis in 1987 of pneumothorax (PTX) by a veterinarian, an equine practitioner, Dr Norman Rantanen. Within a year, the ultrasound diagnosis of PTX was similarly described in human medicine. In 1988, Dr Roy Philly dubbed the ultrasound probe the "modern stethoscope," a remarkable foresight made unbelievably 27 years ago.

More recently, the ultrasound probe has been dubbed the "visual stethoscope" (Moore 2011) because lung ultrasound artifacts are objectively and clearly discernible independent of patient or ambient noise. Moreover, lung ultrasound has been definitively shown to exceed traditional means of chest auscultation and supine chest radiography in humans with common respiratory conditions (Volpicelli 2012; Lichtenstein 2008). As long ago as 1997, the lung ultrasound finding, then referred to as comet tails, representing forms of interstitial edema was documented in humans by Lichtenstein and colleagues.

After that time, it seemed that the focus of lung ultrasound over the next several years changed from the pursuit of lung pathology to further characterization of the ultrasound diagnosis of pneumothorax (PTX). Several comparative studies clearly showed that PTX could be accurately diagnosed, rapidly and point-of-care, by lung ultrasound; and that lung ultrasound exceeded the accuracy, sensitivity, and specificity of supine chest radiography. Furthermore, ultrasound-diagnosed PTX was shown to compare quite favorably with computerized tomography (CT), considered the gold standard for the diagnosis of PTX. During this same time, a structured lung ultrasound format was developed called "EFAST" for "extended FAST" by Kirkpatrick and colleagues (2004). EFAST was named as such since it was an additional FAST scan that extended from the FAST abdominal views.

Because PTX was a real-time finding during B-mode use, other ultrasound modalities were created to document PTX in medical records including the "Power Slide" using power Doppler (Kirkpatrick) and the "seashore sign" and "stratosphere sign" using M-mode (Lichtenstein and colleagues), representing dry lung and PTX, respectively. Again, power Doppler and M-mode were primarily modes for documenting PTX and not diagnosing PTX. The author has found in small animal medicine there often is too much movement to effectively use these documenting modalities. In addition to clearly demonstrating the ultrasound diagnosis of PTX, Lichtenstein and colleagues showed how the search for the "lung point," where lung re-contacts the chest wall, not only helped determine the degree of PTX, but also increased the sensitivity of diagnosing PTX using ultrasound (2000). The "lung point" debunked the myth that the ultrasound diagnosis of PTX was an "all or none" diagnosis by showing that partial vs. massive PTX could be determined using lung ultrasound. Another off-shoot of the use of lung ultrasound in trauma, was the finding that lung contusions, also referred to as lung blast, could be easily recognized by non-radiologist sonographers (Soldati 2006; Ball 2009).

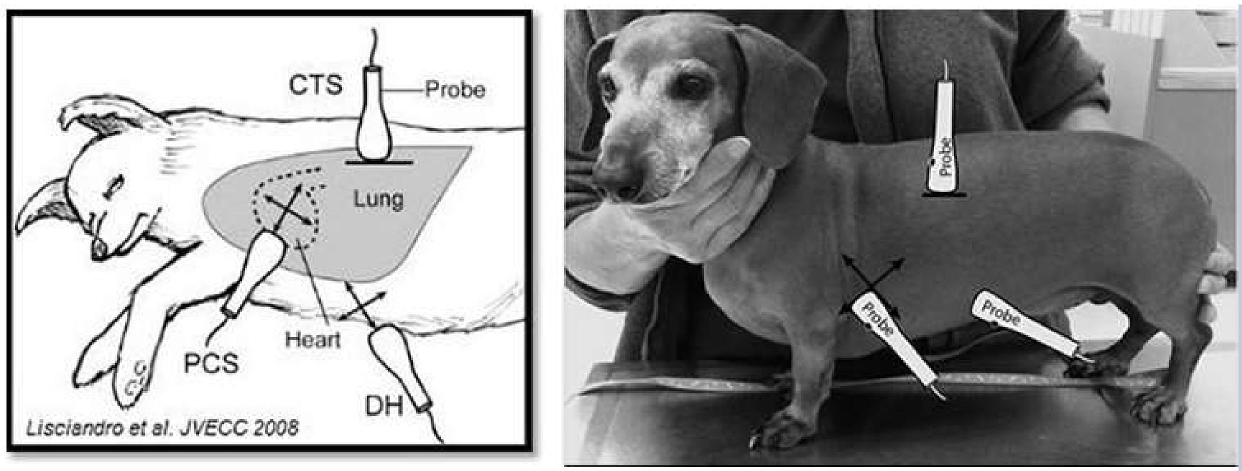
In 2004 Jambrik and colleagues refocused lung sonographers on the pursuit of lung pathology in non-trauma subsets of human patients. In 2006 Volpicelli and colleagues re-enforced a scanning format and additionally showed that the counting of ultrasound lung rockets (also called B-lines) correlated with the degree of lung edema found on computerized tomography. In *Chest* 2008, Lichtenstein and colleagues published a clinical paper in which they showed that a pattern-based, regional approach, called the BLUE protocol, could diagnose the most common presenting causes of respiratory disease in human patients with high sensitivity, specificity and accuracy including asthma, COPD, lung edema, PTE, and pneumonia. The BLUE protocol had a remarkable overall accuracy of 90.5%; and the BLUE exam only took minutes helping direct clinical course and diagnostics without the insensitivities of traditional means of physical examination and chest auscultation; and without the delays of waiting for chest radiography and other testing.

In another Lichtenstein publication (2009), they found a correlation between pulmonary capillary wedge pressure (invasive) and the presence of lung edema (B-lines or ultrasound lung rockets); and conversely they found that in the absence of lung edema (B-lines or ultrasound lung rockets) that clinically relevant left-sided heart failure could be rapidly ruled out (minutes) with high sensitivity and specificity, point-of-care, and within minutes of patient presentation: a remarkably powerful capability for such a simple, safe, radiation-sparing, point-of-care portable imaging modality, called lung ultrasound. In 2012, an international lung ultrasound consensus statement was made by a group of international lung ultrasound experts. In an evidence-based document, statements were developed regarding the efficacy and clinical utility of lung ultrasound use for various respiratory conditions, re-affirming the positive diagnostic and monitoring potential of lung ultrasound.

However, the use of terms such as lung sliding (glide sign in veterinary medicine), A-lines, B-lines, C-lines, and PLAP continue to thwart the evolution and widespread use of lung ultrasound. These terms are confusing and difficult to grasp in contrast to analogous terms proposed by the author and still appearing in the human literature including glide sign (veterinary term, same as lung sliding in human medicine), A-lines (same, air reverberation artifact), ultrasound lung rockets (B-lines in human medicine), and shred sign, tissue sign, and nodule sign for lung consolidation/infiltration (called C-lines, PLAP, in human literature). These terms have been proposed in the veterinary literature in a clinical review (Lisciandro 2011), textbook (*Focused Ultrasound Techniques for the Small Animal Practitioner*. Wiley 2014), and in peer-reviewed clinical study by Lisciandro and colleagues (2014).

USE OF LUNG ULTRASOUND FORMATS IN SMALL ANIMALS

The reluctance to pro-actively apply lung ultrasound to small animals with respiratory distress is irrational in many respects. The overriding belief that air-filled lung creates insurmountable obstacles, and the continued belief in small animal medicine that imaging lung is difficult to perform leading to mistakes, perpetuate lung ultrasound's delayed use in small animals (dogs and cats). Thoracic FAST, called TFAST (Lisciandro *et al*. 2008), was the first standardized, abbreviated, ultrasound exam of the thorax that included the chest tube site (CTS) for lung surveillance for detection of PTX. Because of the finding of lung pathology found during TFAST^3, the author extended lung surveillance from the TFAST^3 CTS with the addition of 6 more lung views. The name of this novel regionally-based lung ultrasound exam is Vet BLUE ("Vet" for veterinary and "BLUE" for cyanosis and bedside lung ultrasound exam) (Lisciandro *et al*. 2014). The Vet BLUE regional sites include the caudodorsal lung lobe region (cdll), the perihilar lung lobe region (phll), the middle lung lobe region (mdll), and the cranial lung lobe region (crll). Each is named as a region because the naming does not directly correlate with anatomical names of lung lobes.



The thoracic FAST^3 (TFAST^3) exam.
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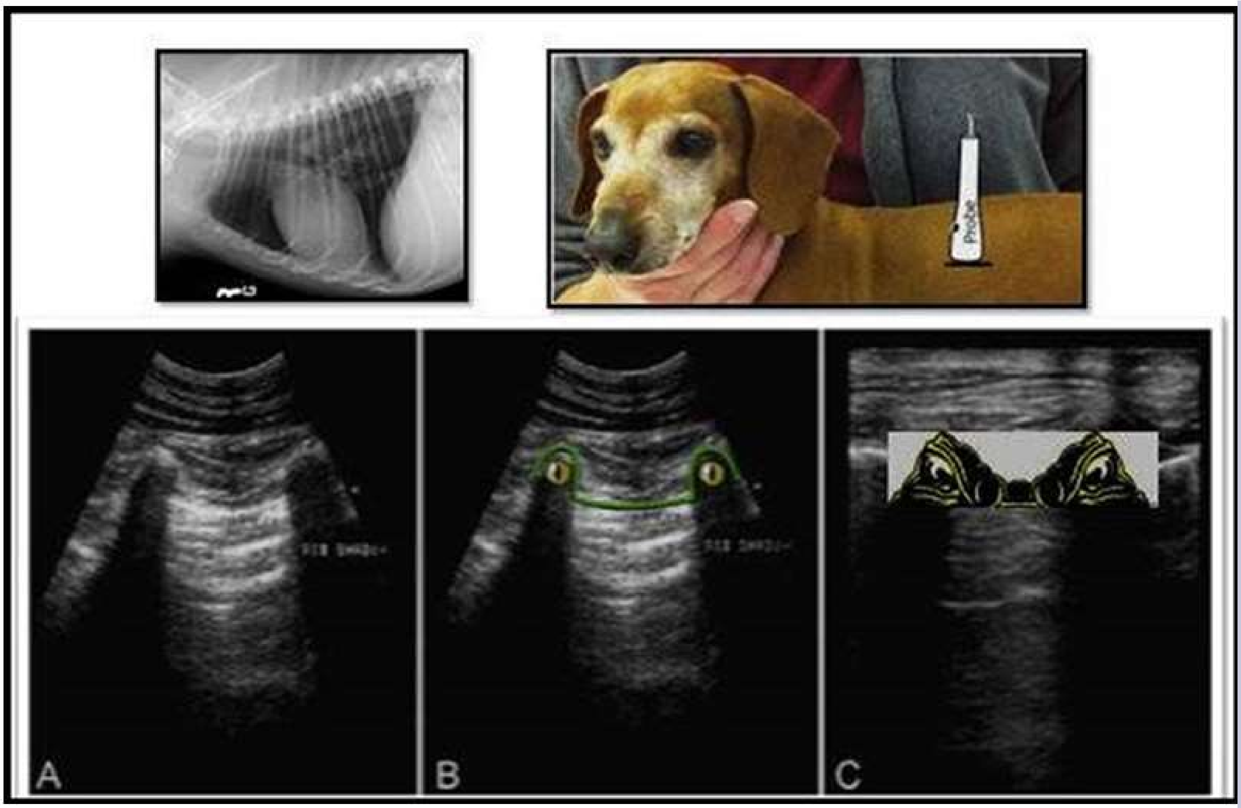
Patient Preparation

No sites are shaved! All images shown by the author are unshaved sites at which the fur is parted and alcohol is applied to the skin and a small amount of acoustic gel to the probe head (most ultrasound manufacturers warn against placing alcohol on the probe head because of alcohol's damaging effects - check with your ultrasound machine manufacturer). **No images from cases in this talk were shaved.**

Patient Positioning

TFAST^3 and **Vet BLUE** are **performed in sternal recumbency or standing in respiratory distressed or compromised small animals**. TFAST^3 consists of 5-points as follows: the stationary horizontally probe-positioned **left and right** chest tube site (CTS) view; the dynamically spotlighted **left and right** pericardial site (PCS) view; and the **newer 5th point DH view**(Lisciandro 2011), for the rapid detection of pleural and pericardial effusion and in some instances of lung pathology (Lisciandro 2014).



The "gator sign" - basic lung ultrasound orientation.
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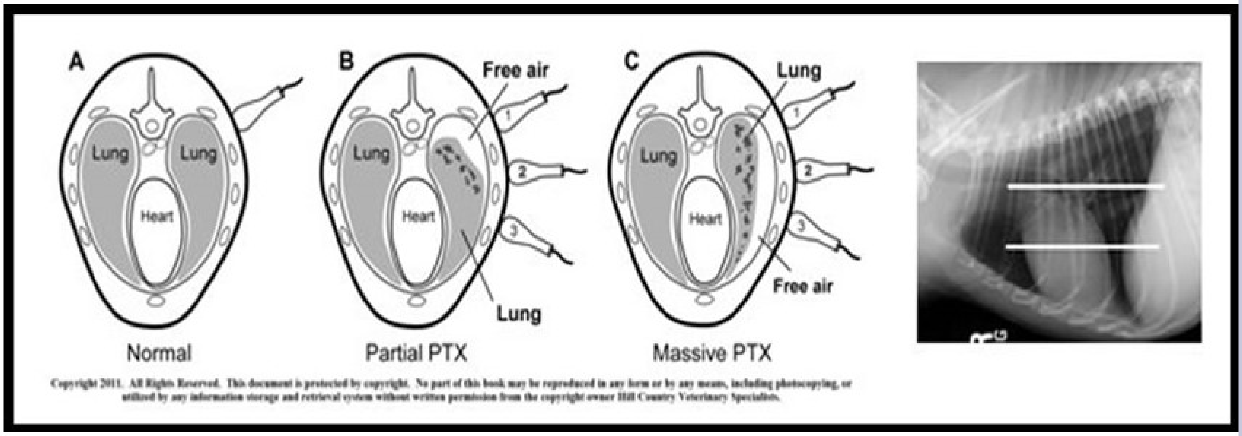
Probe Orientation

Lung ultrasound orientation is **always the same** with the visualization of the **gator sign** to **properly identify the pulmonary-pleural interface** or **the "lung line"** (the surface of the lung). The **probe is held** perpendicular to the long-axis of the ribs; **depth** is generally set between **4–6 cm**; **frequency** is generally set between **5–10 MHz**; and **a microconvex probe** is preferred over a linear probe because the probe is acceptable for AFAST[3], TFAST[3] and Vet BLUE (Global FAST[3]). A phase-array or sector probe is not recommended because its focal point is too small. A liner probe may be used; however, it is not ideal for the AFAST[3] and TFAST[3] portions of Global FAST[3] (GFAST[3]). The rounded rib heads are likened to the eyes, and the pulmonary-pleural (PP-line) interface to the bridge of its nose, as a partially submerged gator (alligator) peers at the sonographer. The proximal white line is the focus of **all** lung ultrasound. The major orientation error is looking beyond the PP-line (or "lung line") and mistaking A-line artifacts for the PP-line or "lung line."



Search for the "lung point" - the degree of pneumothorax.
A) Thorax in which pneumothorax (PTX) has been excluded. **B)** PTX has been determined at position 1 and the lung point is found at position 2 (PTX is partial). **C)** PTX has been determined and a Lung Point is nonexistent at any of the 3 probe positions (PTX is massive). Reproduced with permission from Lisciandro, *JVECC*. 2011;21(2):104–122.

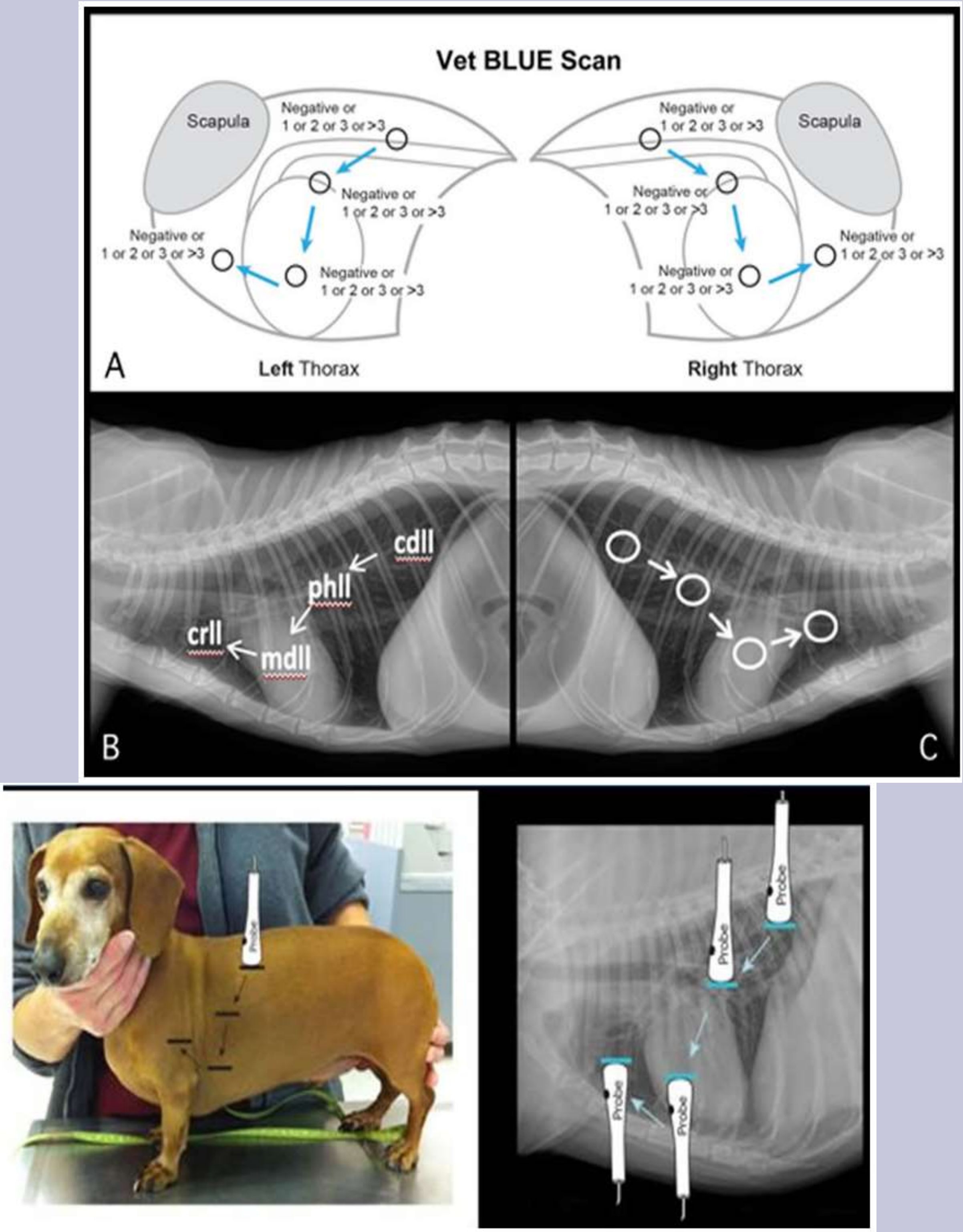
The Lung Point

The search for the "lung point" is an extremely important concept to understand. The "lung point" is the position along the thorax where the collapsed lung recontacts the chest wall. The finding of the "lung point" increases the sensitivity of PTX. The "lung point" is determined by finding either a glide sign with A-lines or ultrasound lung rockets or other lung ultrasound findings supporting lung against the thoracic wall. The **"lung pulse"** has been described in people and its frequency is unknown in veterinary medicine. The "lung pulse" is the finding of lung against the thoracic wall; however, because of severe collapse, the glide sign does not move with inspiration and expiration but rather with the heartbeat.

Key Point

By dividing the thorax into thirds when searching for the "lung point" a subjective assessment of partial vs. massive PTX may be made. Do not move in small increments when searching for the "lung point," rather drop the probe down to the middle third then lower third then your way back toward the CTS to determine the "lung point" position relative to the CTS. Recording the distance is a way to monitor PTX (worsening, improving, and resolution). Moreover, when PTX is suspected at the CTS view, by locating the "lung point" sensitivity is increased and smaller pneumothoraces may be monitored by using/recording the distance from the CTS to the lung point.

Vet BLUE examination



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The **Vet BLUE lung examination** is a **screening test** performed identically as the probe is positioned at the CTS view of TFAST[3]. The probe is then moved through regional locations that are bilaterally applied as follows: **caudodorsal lung lobe region** (cdll - same as the TFAST[3] CTS view, upper third, 8–9th intercostal space), **perihilar lung lobe region** (phll - 6–7th intercostal space, middle third), **middle lung lobe region** (mdll - 4–5th intercostal space, lower third), and **cranial lung lobe region** (crll - 2nd–3rd intercostal space, lower third). The **maximum number of ULRs** over the respective single intercostal space at each view is recorded. The counting system is as follows: **1, 2, 3, > 3** (when ULRs are still recognized as individuals), and **infinity** ∞ (when the ULRs blend into one another becoming confluent [also called white lung]).

Key Point

Perform the Vet BLUE the same way every time. We suggest that you begin on the **left** and go from dorsal to ventral, move to the right side and do the same, dorsal to ventral. This allows you to think about the pattern in the same manner every time and helps you remember the findings at each site. Also, by completing the Vet BLUE at the right cranial lung lobe region (crll) region increase your depth, and do your right TFAST pericardial view and proceed with the increased depth to AFAST and Global FAST (GFAST) is finished in < 4 minutes by the appropriately trained sonographer!

VET BLUE FOR RESPIRATORY DISTRESS - 5 BASIC LUNG ULTRASOUND FINDINGS

"Wet Lung" vs. "Dry Lung" - Basic Lung Ultrasound 101

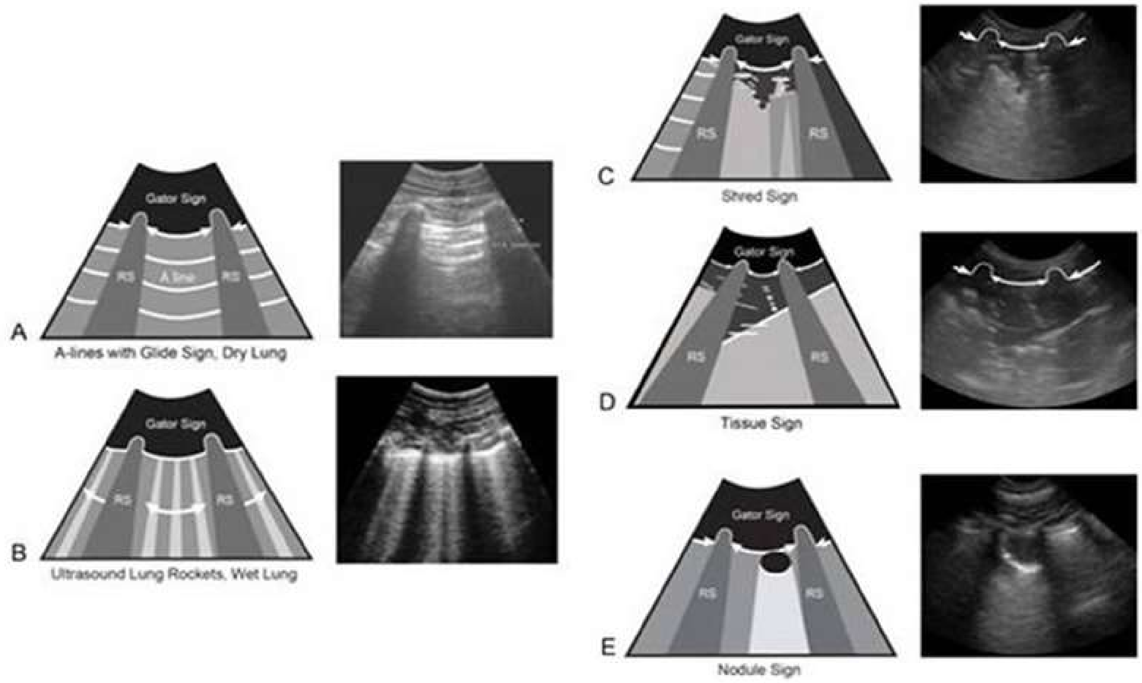
Shred Sign, Tissue Sign, Nodule Sign - Advanced Lung Ultrasound 202

Wet vs. Dry Lung

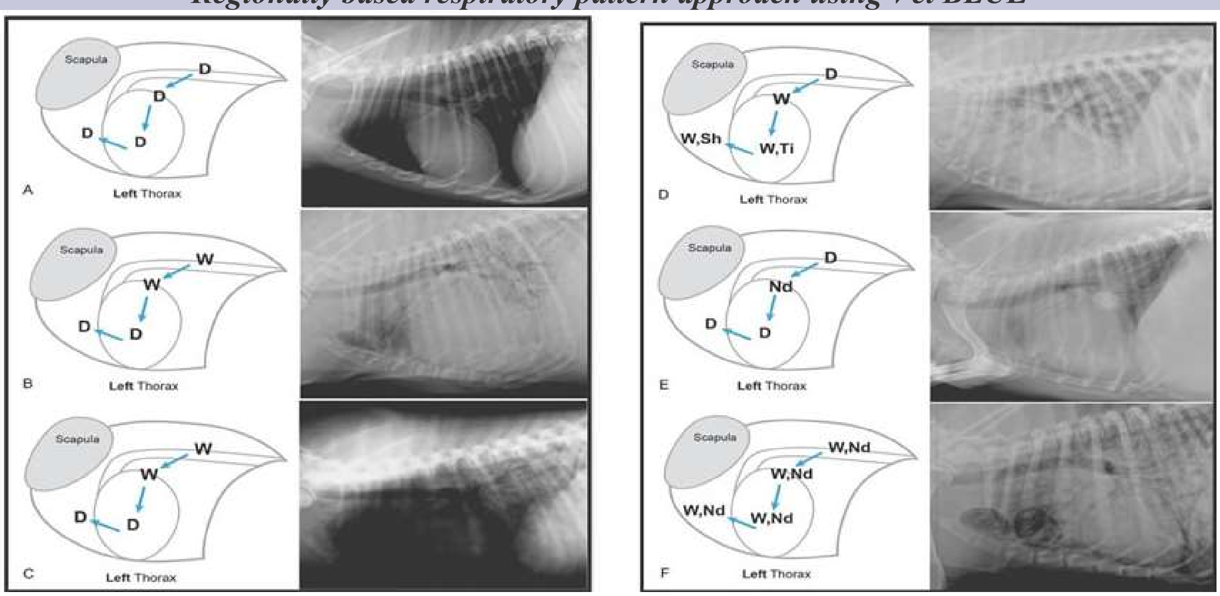
Basic easily recognizable lung ultrasoundfindings are categoriazed into **the wet lung** vs. **dry lung concept** (Lisciandro 2011). A glide sign with A-lines (reverberation artifact) at the lung line is considered **"dry lung"** only to be confounded with PTX (A-lines and no glide sign). However, many patients in which the probability of PTX is very low, then spending additional time finding the glide sign becomes less important and A-lines alone suffice. **Ultrasound lung rockets (ULRs)** are considered **"wet lung"** and oscillate to and fro with inspiration and expiration and must extend to the far field obliterating A-lines (Lisciandro 2011).

Order of Lung Ultrasound Consolidation and Infiltration

A) Dry Lung **B)** Wet Lung **C)** Shred Sign **D)** Tissue Sign **E)** Nodule Sign



Regionally based respiratory pattern approach using Vet BLUE



Clinical Cases

Examples of Vet BLUE regionally-based patterns (See Figure above):
A) Dry lung all fields rules out clinically relevant left-sided heart failure, suggests upper airway obstruction, feline asthma, COPD, PTE and non-respiratory look-a-likes.
B) Wet lung in dorsal, perihilar, and middle lung lobe regions suggests cardiogenic lung edema (left-sided heart failure, volume overload from intravenous fluids).
C) Wet lung in dorsal lung lobe regions suggests forms of non-cardiogenic lung edema.
D) Wet lungs in ventral fields with or without signs of consolidation (shred sign/tissue sign), suggest pneumonia.
E) Solitary nodule.
F) Multiple nodules suggest metastatic disease or granulomatous disease.

Vet BLUE diagnostic algorithm for respiratory distress and conditions

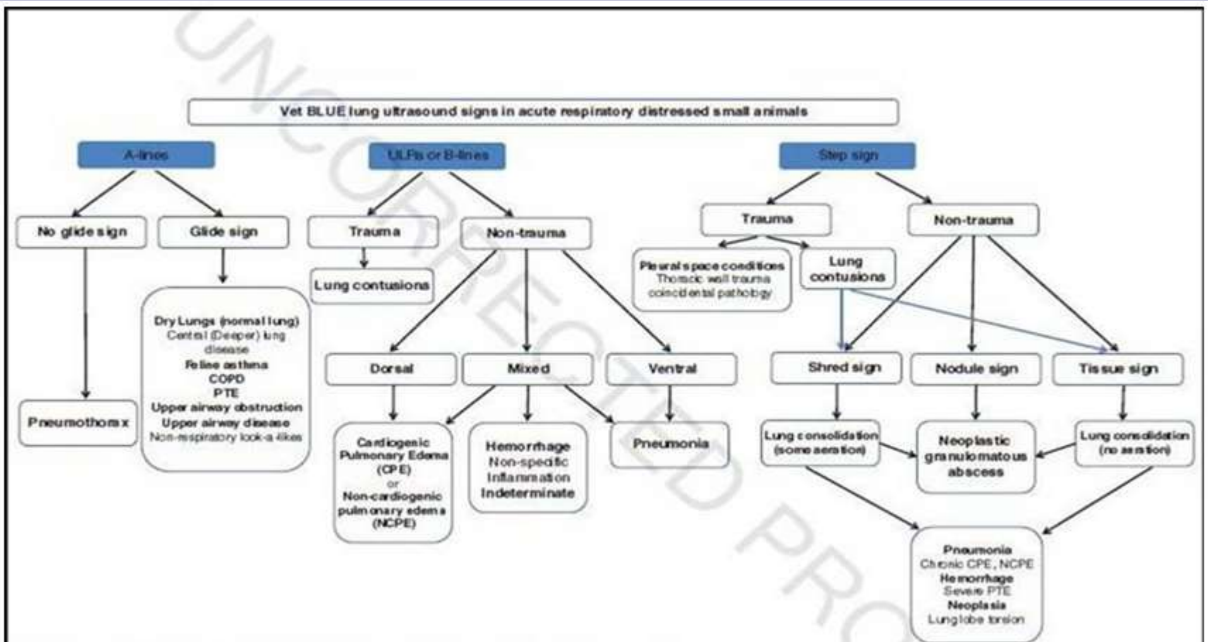
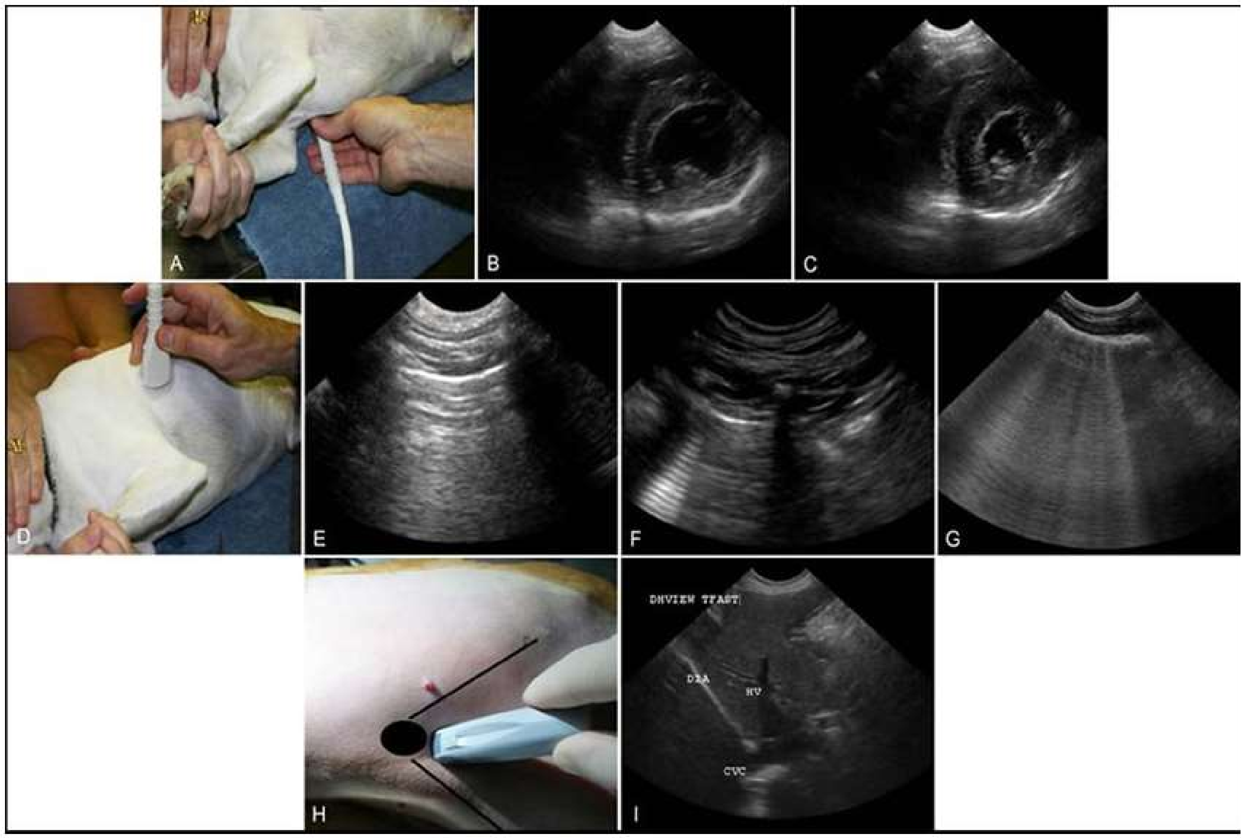


Figure 10.17. Summary of lung ultrasound signs and differential diagnoses. © Gregory Lisciandro

The Global FAST triad for volume status



1) Top row - the left ventricular short-axis "mushroom" view (TFAST^3 right PCS view) for volume status [~ preload] and contractility). **2) Middle row** - dry lung vs. wet lung help determine the absence or presence of clinically relevant non-cardiogenic and cardiogenic pulmonary edema (Lichtenstein, Karakitsos 2012); and numbers of ULRs correlate with degree of interstitial-alveolar edema. **3) Bottom row** - caudal vena cava at the diaphragm (using the characterization of FAT, flat or bounce) and hepatic vein (HV) distention or "tree trunks" (TFAST^3/AFAST^3 DH view for right-sided cardiac status and volume [preload]); normally, the hepatic veins **are not** readily apparent as they drain into the caudal vena cava (CVC).

Global FAST^3 should be used for rapid evaluation of patient volume status pre-, during, and post- fluid resuscitation by using the "GFAST^3 Triad" (similar to Ferrada *et al*. 2013). The use of CVP via central lines for fluid resuscitation and its teaching "should be abandoned" (Marik *et al*. 2013).

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