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Veterinary Point of Care Ultrasound (POCUS):

Abdomen, pleural space, lung, heart and vascular systems

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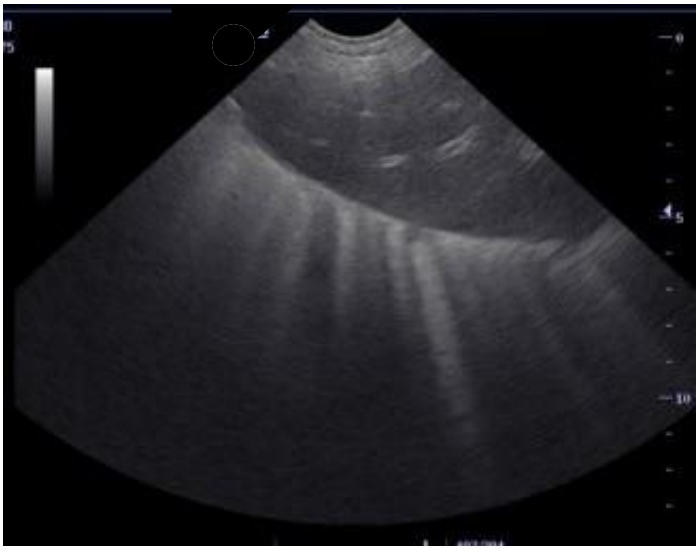

Asking binary questions to get rapid clinical answers.

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Introduction

The small animal Focused Assessment with Sonography for Trauma (FAST) exam developed at Tufts in 1999 (published in 2004 by Boysen *et al*.) was the first small animal ultrasound format to become more broadly known as Point of Care Ultrasound (POCUS). Although often used interchangeably, POCUS and FAST have different meanings and applications: FAST exams, in both human and veterinary medicine were developed to, and still primarily focus on, the search for free fluid in body cavities and pneumothorax. By contrast, POCUS is broader in scope; it incorporates all clinically driven real-time assessments that can be answered within minutes using ultrasonography. More specifically, POCUS is defined as the acquisition, interpretation, and immediate clinical integration of ultrasonographic imaging performed patient-side by an attending clinician, not by a radiologist or cardiologist, with the goal of answering a focused question or series of questions rather than assessing all structures of an organ(s). Therefore, POCUS is best applied as a problem-based assessment based on Bayes' theorem of pre-test probabilities which enables the clinician to gather key pieces of information in real time to help narrow or determine a diagnosis, streamline care, guide ongoing management, and reduce cognitive errors. The concept of POCUS as a focused ("limited" or "goal-directed") exam is in contrast to sonography performed by an imaging specialist/cardiologist (table 1).

Table 1

Formal ultrasound	**Point-of-care ultrasound**
Consultative; assessing all organs, anatomy and structures	Focused to key structures to answer specific clinical questions (often binary choice)
Often performed with non-specific findings and when multiple or an open-ended list of differential diagnosis are possible	Often performed when specific signs are present and a high pretest probability of a specific diagnosis (es) is likely (Bayes' theorem)
Requires years of training	Requires minimal experience
Often takes > 30-60 min	Performed in < 5-10 min
Usually performed by specialists: cardiologists, radiologists	Often performed by non-specialists (ER clinicians, general practitioners)
Patients often stable	Patients often unstable
Patient taken to the machine	Machine taken to the patient
Placed in lateral or dorsal recumbency	Scanned in the position the patient is most comfortable, rarely if ever dorsal recumbency
Fur is typically clipped	Fur is rarely clipped

Gel preferred as the coupling agent	Uses alcohol +/- gel as the coupling agent

Finally, POCUS provides relevant information that is otherwise unattainable on physical examination alone and is therefore complementary to triage, physical examination, and other point-of-care diagnostic and clinical tests or findings; it does not replace them. Evidence in human medicine supports that POCUS can result in improved clinical decision making, and when combined with other clinical findings, confirms the suspected clinical diagnosis in up to 50% of cases and supports a change in the initial diagnosis in 23% of cases.

Unfortunately, there is considerable variation in the veterinary profession regarding how to perform FAST exams and what should be included within a FAST exam. Recent veterinary surveys demonstrate there is little standardization of what clinicians evaluate during both abdominal FAST and thoracic FAST exams, beyond a search for free fluid and pneumothorax. The authors therefore prefer to use the term POCUS when discussing general applications of ultrasound in clinical and emergency practice settings and restrict (if used at all) the use of abdominal FAST and thoracic FAST terminology to a search for pleural effusion, pericardial effusion, and pneumothorax, respectively, as is currently recommended in the human literature. An exception to this this is the FAST ABCDE exam, which is well defined through addition of the ABCDE suffix (not covered here). In contrast to FAST exams, which are very restricted exams, POCUS is more broadly applied and incorporates assessment of injury within the abdomen, thorax as a whole, including free abdominal fluid, pneumothorax, pleural effusion, general lung pathology, basic cardiac pathology, volume and fluid responsiveness, renal pelvic dilation, gall bladder wall edema, pyometra, pneumoperitoneum, gastro-intestinal motility, and ultrasound guided procedures within minutes of patient arrival. Ultrasound guided procedures include centesis, tissue/blood sampling, and guided catheter placement. Therefore, to maintain clarity, the authors prefer the use of the term POCUS, with a clear description of the clinically driven question being answered (see templates at the end of the document), and if FAST terms are used, they be reserved for fluid and pneumothorax assessment.

Furthermore, in addition to clarifying terminology, the authors also stress an understanding of the anatomy, physiology, pathophysiology of different diseases, and principles of POCUS to answer clinically driven questions, and not the blind application of protocols, which **must** be modified in light of the binary question to answer and patient positioning. For example, the use of the chest tube site

when searching for pneumothorax lacks specificity and varies based on individual preferences on where to insert chest tubes. The site air accumulates also varies depending if the patient is in lateral or sternal recumbency, and therefore describing the “chests tube” site in both situations fails to acknowledge the impact of patient positioning on the sites to look for pathology. As opposed to choosing a fixed external thoracic site to evaluate, the authors teach an understanding of what to assess and where pathology accumulates and therefore how to modify the sites assessed based on patient position. With this approach the clinician gains an understanding of the principal that air rises, and knowing the sonographically defined anatomic boundaries allows the clinician to confidently locate and assess the most sensitive sites for free pleural air (pneumothorax) to accumulate. Furthermore, understanding the pathophysiology of pneumothorax and how pleural air disrupts normal finding and creates unique abnormal pleura and lung ultrasound findings allows the operator to arrive at a diagnosis of pneumothorax through assessment of a number of sonographic features, not just the absence of lung sliding.

The number of applications of POCUS is continually expanding as research expands (e.g., ultrasound guided nerve blocks and optic nerve sheath diameter), however, it is important to respect the clinically driven, often binary questions that can be answered with POCUS vs. formal ultrasound, which are consultative in nature and require more time and training to master. It’s also important to realize POCUS is operator dependent and one should know their limits, which can systematically be expanded with practice and training. The information provided by these exams is instrumental in the management of these patients and they can be implemented into everyday practice. Note that POCUS exams are not extensive abdominal or thoracic ultrasound nor are they echocardiograms. They are point of care rapid ultrasound techniques that are performed at the same time as the initial patient evaluation and treatment (physical exam, blood pressure, IV catheter, IV fluids, sedation, analgesia, SPO2, minimum emergency database) or as part of continued daily patient monitoring. They are repeatable and objective, and findings are often interpreted by asking simple binary questions. They are validated, evidence-based, sensitive and specific, and take under 10 minutes to complete. In essence, they are an extension of the physical examination and provide information not otherwise obtainable during patient evaluation.

In general POCUS exams are indicated in any of the following 4 clinical settings (figure A); 1) triage

POCUS is applied as a tool to rapidly identify the most immediate life threatening and critical conditions, DO NOT COMPROMISE PATIENT SAFETY – find the life threatening injury and correct it ASAP (then complete the physical exam and other POCUS evaluations) 2) serial POCUS is applied to monitor progression or resolution of any pathology, and response to therapy, 3) systemic POCUS is aimed at detecting asymptomatic conditions, new developments and/or to ensure sonographically detectable problems have not arisen prior to undertaking procedures, anesthesia or discharge ,and 4) therapeutic POCUS is used to reduce complications of interventions where applicable. In essence there are 5 T's of POCUS, with adaptation of the exam based on the setting in which it is used; trauma, triage, tracking, treatment/therapeutic and total systemic POCUS (screening) evaluation.

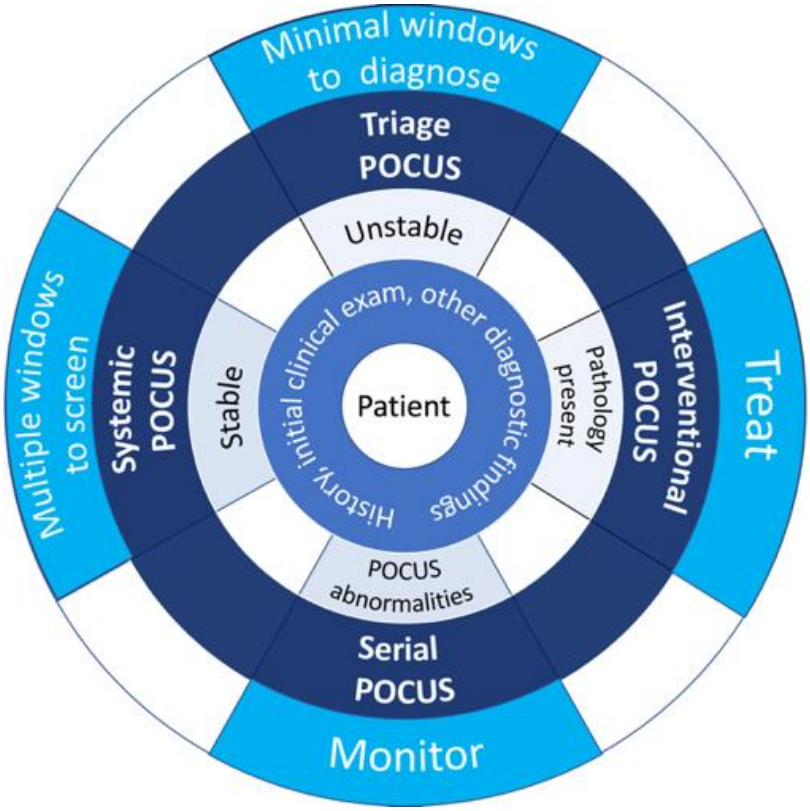


Figure A: POCUS is patient centered and targeted. It is also integrative and has 4 general applications which vary depending on the targeted-objectives of the scan, the pretest probability of a problem being present (based on history, initial clinical exam, and other diagnostic findings), and the clinical setting encountered: (1) triage POCUS uses the minimum number of windows possible to identify the most immediate life-threatening and critical conditions; (2) serial POCUS is applied to monitor progression or resolution of any pathology, and response to therapy; (3) systemic or multiorgan POCUS uses multiple windows in more stable patients (with or without specialist assistance) to detect asymptomatic conditions, new developments, and/or to ensure sonographically detectable problems have not arisen prior to undertaking procedures, anesthesia, or discharge/service transfer; and (4) therapeutic POCUS is used to reduce complications of interventions where applicable: POCUS = point-of-care ultrasound. Source: Dr. Søren Boysen, with permission.

Serial POCUS exams are warranted to: 1) monitor progression/resolution of intra-cavitary fluid in fluid positive patients, and 2) to re-assess fluid negative patients, particularly those that are unstable, and/or have received significant quantities of intravascular fluids.

POCUS exams cannot replace a physical exam and are in fact often guided by the initial findings of the triage exam (pulses paradoxes, shock, respiratory distress, muffled heart sounds, muffled lung sounds etc.); they often provide complimentary information which in many situations gives additional information to further direct diagnostics and therapies that may be lifesaving.

A key approach to learning and expanding the role of POCUS is to get comfortable asking clinically driven questions (often yes/no binary in nature). POCUS is proven to be most helpful when there is a moderate to high pre-test probability that the pathology in question exists, which stresses the value of clinical assessment and patient evaluation to drive the clinical question to answer.

- For example, a cat comes in dyspneic. If we ask, "why is this cat dyspneic", there are multiple different differentials. But if we ask a binary question such as: "in this dyspneic cat, is there pleural effusion yes/no? We can quickly and confidently rule in or out certain pathology and help our patient in a more efficient manner. Binary questions with POCUS allow the integration of specific, clinically relevant questions that help rule in or out pathology and helps guide further diagnostics and therapy.
- Don't randomly place the probe on the patient and "hope" to find something.
- The undirected temptation to "just have a look" without pre-set goals should be avoided and is best

reserved for the stable patient with more experienced operators (i.e. radiologists and cardiologists).

- By clearly defining the objectives of the rapid ultrasound, one can avoid “fishing expeditions” that are often associated with low pre-test probabilities and can lead to significant increases in the likelihood of false positive results.
- Human studies show the likelihood of false negative and false positive results are markedly decreased when asking binary questions!
- You don’t have to be a specialist to answer sonographically important clinically relevant questions that will help guide diagnostic tests and direct therapy!!
- Do a complete thorough POCUS assessment to answer the binary question being asked (if you are looking for abdominal fluid, do a complete fluid search at each site you evaluate)!
- Keep in mind the binary question to answer, and therefore the order of the POCUS exam, may vary based on initial clinical findings. In other words, if a patient presents for dyspnea, then the thoracic portion of the POCUS will be done first, and the rest of the POCUS exams may be done during or after initial stabilization.

Machine Functions and Probe Manipulations

Machine Functions

Most POCUS clinical binary questions can be answered with confidence in the absence of obtaining the "perfect image", in a short amount of time. Although ultrasound units have multiple machine functions, there are only 3 main functions that are essential to understand in performing POCUS exams; gain, depth, and frequency.

1. *Gain* controls the overall "brightness" making the image sharper to highlight different structures and pathology. A general rule is for the operator to make the image "look pretty". For pleural space and lung ultrasound (PLUS), gain is adjusted to visualize the pleural line and glide sign, keeping in mind the glide sign is easier to visualize as the pleural line is made to look "grainier". If the abdomen is scanned prior to PLUS, the gain will often need to be decreased as abdominal POCUS tends to use higher gain settings, which makes the pleural line overly hyper-echoic and detection of a glide sign more difficult to identify.
2. *Depth* is used to change how deep the ultrasound beams go and what can be visualized in the ultrasound image. For PLUS, the pleural line should be located at a distance of roughly 1/3 of the total

of the ultrasound image. With abdominal and heart scanning, the organ of interest should represent 2/3 of the visible image on the screen. Too much depth will not allow visualization of key structures as they will appear too small. Not enough depth may lead to missing pathology below the organ/area of interest. Most ultrasound machines indicate depth on one side of the ultrasound image, usually as a scale in centimeters.

3. *Frequency* affects the image quality and depth perception. The higher the frequency, the more superficial the penetration of the ultrasound beam and the better the superficial quality of the image. Higher frequency settings will not allow visualization of deeper structures. The lower the frequency, the deeper the penetration of the ultrasound beam at the expense of decreasing image resolution. With most ultrasound transducers, you can change the frequency, especially with micro-convex curvilinear transducers.

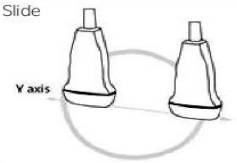
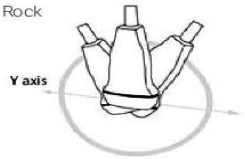
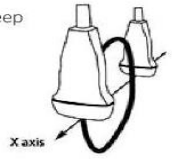
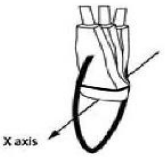
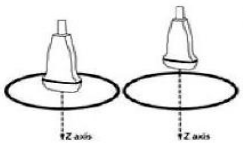
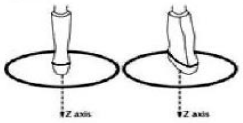
Knowledge and understanding of other ultrasound machine functions is helpful in specific situations but is not obligatory to the success of understanding and performing PLUS.

Transducer Orientation and Manipulations

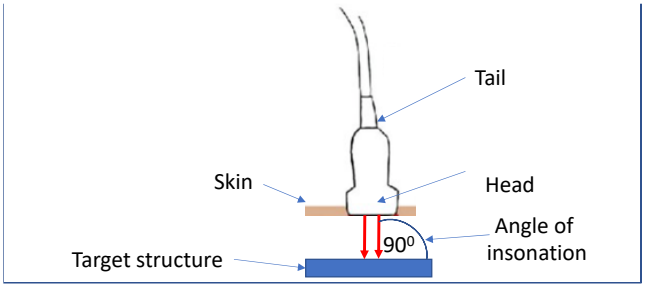
Each ultrasound transducer has an orientation marker (notch or depression) on one side which corresponds to a symbol or circle on the ultrasound image obtained on the screen. The smallest transducer movements can have a major impact on the plane in which the object is being scanned. There are 5 key transducer movements used during PLUS; fanning, rocking, sweeping, sliding and rotating. The part of the transducer that contacts the body surface is the "head" and the opposite end, where the cable attaches, is the "tail". The angle of the ultrasound beam, relative to the desired organ of interest is referred to as the angle of insonation.

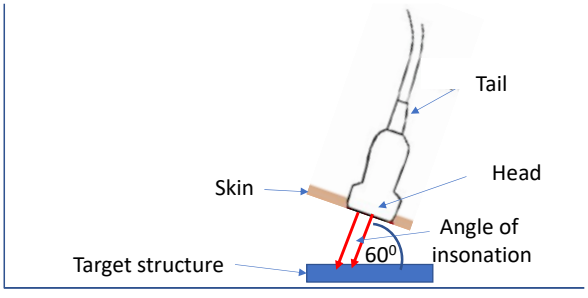
1. *Fanning* involves keeping the transducer head stationary and moving the tail of the transducer side-to-side (changing the angle of insonation) relative to the transducer's widest axis (similar to a "hand-held fan").
2. *Rocking* the transducer involves keeping the transducer head stationary and moving of the tail of the transducer side-to-side (changing the angle of insonation) relative to the transducer's shortest axis (similar to a "rocking chair").
3. *Sweeping* involves moving the entire transducer (usually a few centimeters) in the short axis direction across the body with a constant angle of insonation to the target.
4. *Sliding* involves moving the entire transducer (usually a few centimeters) in the long axis direction across the body with a constant angle of insonation to the target.
5. *Rotating* involves keeping the transducer head in one location perpendicular to the body surface and turning the transducer upon its axis in a clockwise or counter-clockwise direction.

Table 1. Redefined Set of Fundamental Transducer Motions

Slide		Motion in the long axis of the probe across the body with a consistent angle of insonation at 90° to the target
Rock		Motion in the long axis of the probe along a fixed point on the body while changing the angle of insonation away from 90°
Sweep		Motion in the short axis of the probe across the body with a consistent angle of insonation at 90° to the target
Fan		Motion in the short axis of the probe along a fixed point on the body while changing the angle of insonation away from 90°
Pressure/compression		Pressure on the probe into the body, compression of the body by applying force on the probe toward the patient's body
Rotation		Movement around the compression axis in a clockwise or counter-clockwise direction

J Ultrasound Med 2016; 35:183–188





When fanning, rocking or rotating, the transducer to body surface contact-point remains the same, and the transducer is manipulated around the point of contact. With sweeping and sliding, the transducer head moves away from the initial point of contact on the body surface.

Longitudinal (long) and transverse (short) axis

Longitudinal orientation entails placing the transducer in the "long" view relative to the organ being evaluated. *Transverse* orientation entails placing the transducer in the "short" view relative to the organ being evaluated (transverse to the organ). Short axis is obtained by rotating the transducer 90 degrees toward the right from the long axis.

- When learning POCUS it is important to note that it is often recommended to only perform one movement at a time. In other words, do not fan and slide the probe at the same time. When we fan, rock or rotate the probe, the probe contact point on the animal stays in the same location.

Abdominal POCUS

The abdominal FAST exam, developed in 1999, published in 2004, was the first POCUS exam to be validated in small animals. The study adapted a human focused assessment with sonography for trauma protocol for veterinary use. The goal was to detect free peritoneal fluid following blunt abdominal trauma, and therefor concentrated on 4 key sites of the abdomen; sites where organs were most likely to be injured following trauma (liver, spleen, kidneys and urinary bladder), and where fluid is most likely to accumulate based on patient positioning and gravitational forces. This and subsequent studies demonstrated abdominal FAST was sensitive and specific for the detection of free abdominal fluid, was more accurate at detecting free fluid than radiographs, and helps find the ideal location to perform abdominocentesis. A further study by Walters et al (2018) demonstrated a strong correlation in the comparison of CT for detection of abdominal fluid and the original 2004 abdominal FAST protocol (kappa 0.82). Although the original FAST protocol has been slightly modified by some authors, the only format to be validated against CT for detection of free abdominal fluid is the original 2004 format.

The value of using POCUS exams (including abdominal and thoracic FAST) to detect free fluid in animals in the absence of trauma was first published by McMurray *et al* in 2016. The probability of finding free fluid in a stable (as assessed by triage examination) non-trauma patient (any cavity, thorax or abdomen) is <10%. However, in unstable non-trauma patients, free fluid is found in > 75% of patients. Therefore, serious insults result in sonographically detectable findings. Centesis is recommended because fluid type varies greatly (hemoabdomen, uroabdomen, bile peritonitis, septic abdomen, non-septic exudate, and transudates, chylothorax, pyothorax, and hemothorax). This study demonstrated that abdominal (and thoracic) POCUS is an important triage tool for all patients regardless of the presenting complaint.

Patient position, probe and coupling agent

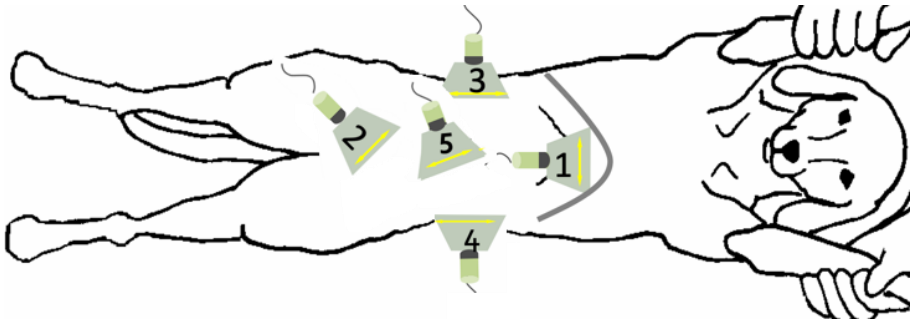
- Patients are placed in the position they are most comfortable, or if the patients allow, either left or right lateral recumbency. In unstable patients, abdominal POCUS can be performed in a sternal or standing position (consider the effects of gravity and patient positioning when looking for pathology). Minimal restraint is required.
- A microconvex/curvilinear probe is used for all abdominal POCUS scanning, with a frequency

generally between 5 MHz (patients >15 kg) and 7.5 MHz (patients < 15kg).

- Gain is adjusted to maximize detection of anechoic fluid using either bile in the gall bladder or urine in the urinary bladder as a reference echogenicity for fluid.
- Depth is adjusted as needed during the abdominal POCUS with the greatest depth setting generally at the subxiphoid location, which allows evaluation of the pleural and pericardial spaces.
- It is not wrong to shave the patient, but shaving is not required unless the patient's fur coat is too thick to allow good image resolution (e.g. Husky and Northern breeds with thick undercoats).
- Alcohol is used but it is important to part the fur before or after applying the alcohol. Gel is not necessary (but can be used with shaving if higher resolution is desired or can be applied after the fur is parted and alcohol is applied). Hand sanitizers that combine alcohol and gel can also be used.
- Unstable patients should NOT be placed in dorsal recumbency as this can compromise the patient (increased work of breathing, decreased venous return and cardiovascular collapse).

Abdominal POCUS Indications

- Trauma patients
- Unstable patients
- Emergency and/or critically ill patients
- Any patient as part of the triage exam
- Post-surgery patients not recovering as expected
- Surgery patients with difficult anesthesia
- As part of the routine daily assessment of hospitalized patients



Abdominal POCUS Protocol

Figure 1.1a: Abdominal POCUS probe positions: 1. subxiphoid view, 2. urinary bladder view, 3. right paralumbar view, 4. left paralumbar view, and the additional 5th umbilical view. Each location is evaluated in longitudinal and transvers

orientation with rocking and fanning of the probe to maximize the area evaluated and to ensure all target sites for fluid accumulation are thoroughly evaluated.

The probe is placed on 5 regions of the abdomen (figure 1.1a) in a consistent systematic approach. At each site, the probe is fanned and rocked through an angle of 45° in both long and short axis views. Sliding the probe 1 inch in cranial, caudal, left, and right directions will increase the area assessed at each site. Some abdominal protocols are limited to a single plane with the probe only directed into the gravity dependent regions of the abdomen. Although this may detect the presence of free fluid, abdominal POCUS is much more than a simple search for free fluid and the authors recommend fanning from gravity independent through gravity dependent regions with an emphasis on assessing gravity dependent regions if fluid is the main binary question to answer. Fanning, rocking and sliding the probe
increases the likelihood that abdominal fluid will be detected: **be thorough in your quest to answer the binary question being asked!**

A note on nomenclature: The authors prefer to use landmarks to help identify where to place the probe vs. internal organs as the number of structures targeted at each location has increased since the original POCUS studies were published (e.g. the pleural and pericardial space is part of the subxiphoid evaluation, but not included in the Diaphragmatico-hepatic nomenclature, nor is the gall bladder, which is also now routinely scanned as part of abdominal POCUS). Regardless of the nomenclature used it is important to be thorough and evaluate ALL target structures at each probe location in light of the binary question being asked!

The abdominal POCUS sites in more detail:

1. Subxiphoid or Diaphragmatico-hepatic (DH) site: just caudal to the xiphoid process (see figures 1.1a, 1.1b, 1.1c, 1.1d, 1.1e). **Key structures to identify include the** 1) **diaphragm**, 2) **liver**, 3) **gallbladder**, 4) ventral **stomach wall** (the latter for GI motility), 5) the areas between these structures, 6) **caudal vena cava**, 7) **pleural space** 8) **heart** and 9) **pericardial space**. See later sections on volume status for more detail on the vena cava evaluation, and the respective sections on pleural and pericardial space evaluation. To visualize this site, palpate the "V" at the xiphoid region and place the probe in long axis to the body (figure 1.1a). Then rock the probe 45 degrees until you see the diaphragm. Change the depth until you can see beyond the diaphragm and into the thoracic cavity. Note you cannot detect individual liver lobes in a normal patient.

Also note the presence or absence of mirror image artifact; Mirror image artifact distal to the diaphragm can only occur when there is air distal to the diaphragm, and therefore can be used to rule out pleural effusion at that location.

It is important to consider patient positioning and the effects of gravity when evaluating any POCUS sites, including the subxiphoid location. Be sure to fan the probe through all liver planes to ensure a thorough evaluation of the liver is complete, and to rock the probe to assess the most ventral and cranial parts of the liver, where small accumulations of fluid may gather between the liver and diaphragm (figure 1.1c).

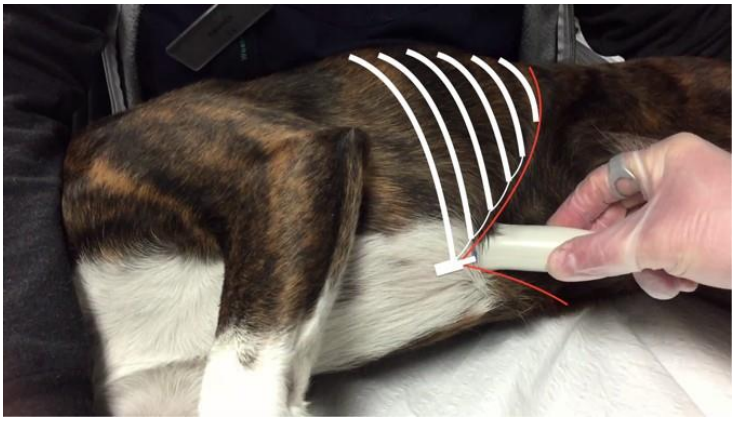


Figure 1.1b: The patient is in right lateral recumbency. The probe is positioned within the V of the subxiphoid process and "rocked" until the probe is at a 45-degree angle to the patient with the head of the ultrasound probe directed cranially.

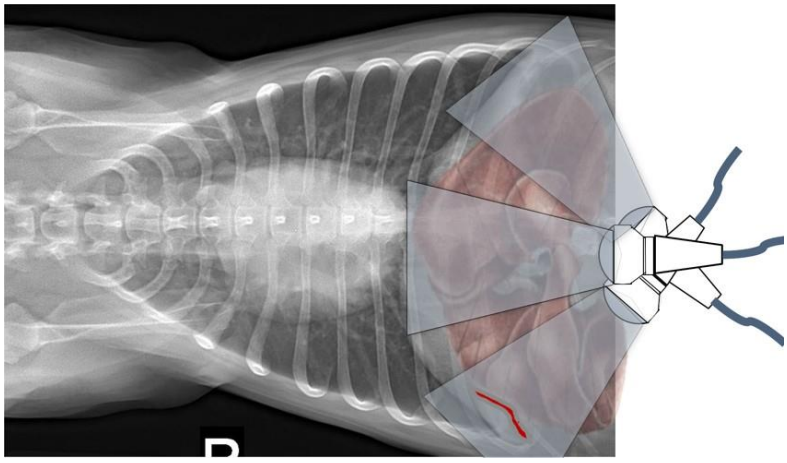


Figure 1.1c: At the subxiphoid location the probe should be fanned through all planes of the liver to ensure small

accumulations or free abdominal fluid are identified. The probe should also be rocked and turned into the transvers orientation to ensure a thorough search for fluid is completed.

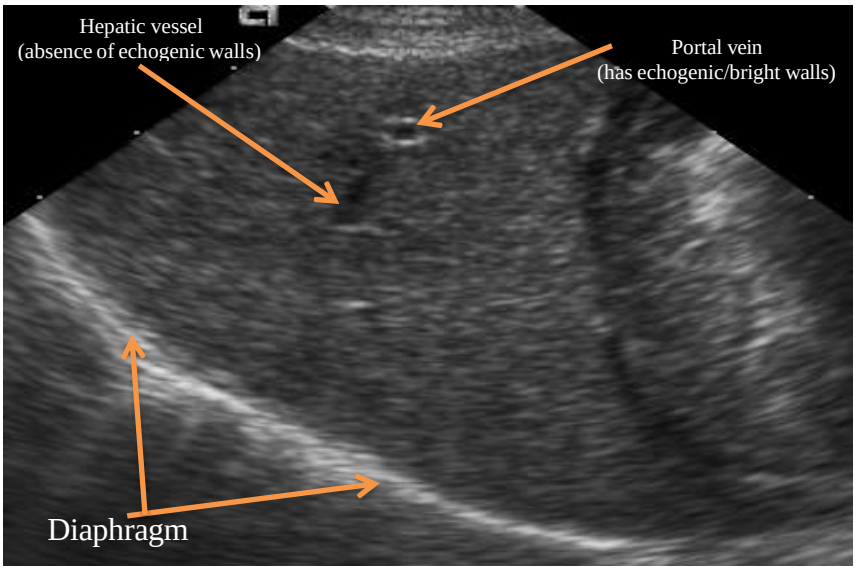


Figure 1.1d: Subxiphoid image. Liver: diaphragm, stomach, hepatic vessel, portal vessel. (Image courtesy Dr. Leanne Pack)

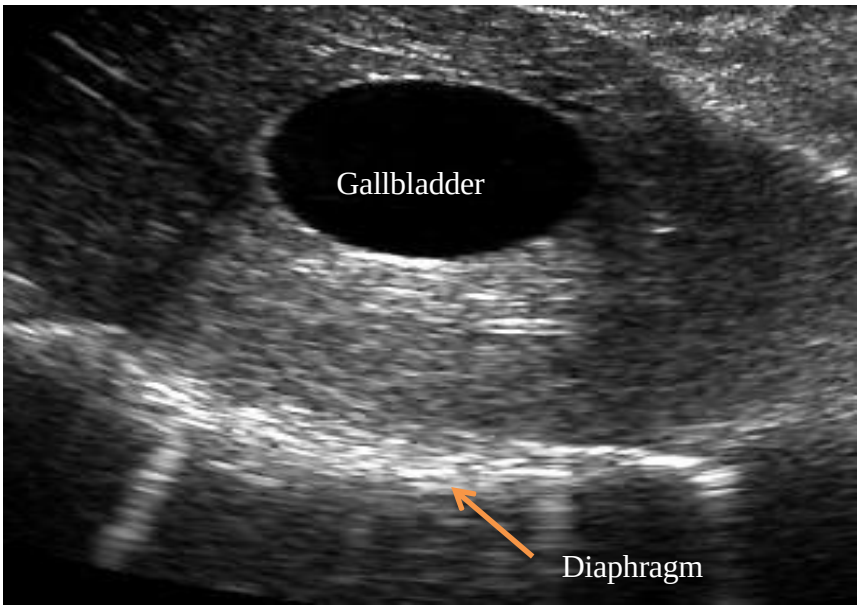


Figure 1.1e: Liver and gallbladder. The diaphragm is also seen. (Image courtesy Dr. Leanne Pack)

2. Urinary bladder or Cysto-colic (CC) site (figures 1.1a, 1.2a, 1.2b): **Key organs and structures** to identify include the 1) entire **urinary bladder**, 2) gravity and non-gravity dependent **body walls** 3) **apex of the bladder** and 4) the areas between these structures. Fluid tends to accumulate between the body wall and the bladder, at the apex of the bladder and between the bladder and the body wall. The probe is placed in long axis to the body between the pelvic limbs. Pushing too hard will

compress and can displace the bladder making it a challenge to identify. Ideally, the probe should also be placed on the non-gravity dependent side of patient and the ultrasound beam angled through the bladder and fanned to catch fluid in deeper gravity-dependent sites at the body wall (figure 1.2a). Once the bladder is found, it is important to manipulate the depth to see both dorsal and ventral walls of the bladder. The probe should then be slid cranially to locate the apex of the bladder. Once at the apex, fan the probe through all planes of the bladder. The probe is then slid caudally to evaluate the caudal/trigone region. When all regions of the bladder have been assessed in longitudinal orientation the probe is rotated into short axis (and the probe is slid cranially and caudally with a fanning motion to assess all planes in the transverse orientation) will allow visualization of abdominal effusion.

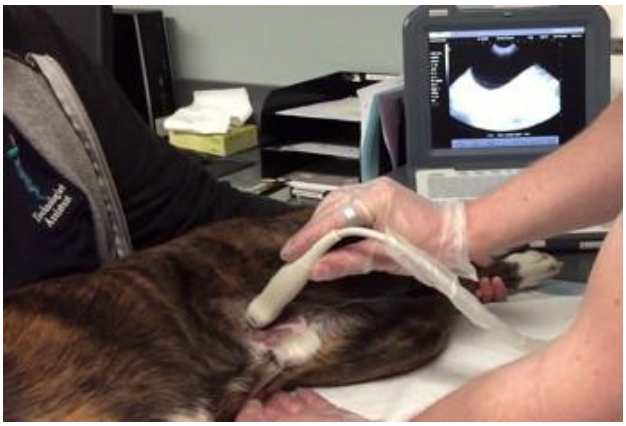


Figure 1.2a: The urinary bladder site is located in the caudal region of the abdomen. To help identify gravity dependent accumulations between the urinary bladder and body wall the probe is often placed on the non-gravity side of the bladder and angled such that the body wall (gravity dependent areas) is imaged in the far field of the ultrasound image.

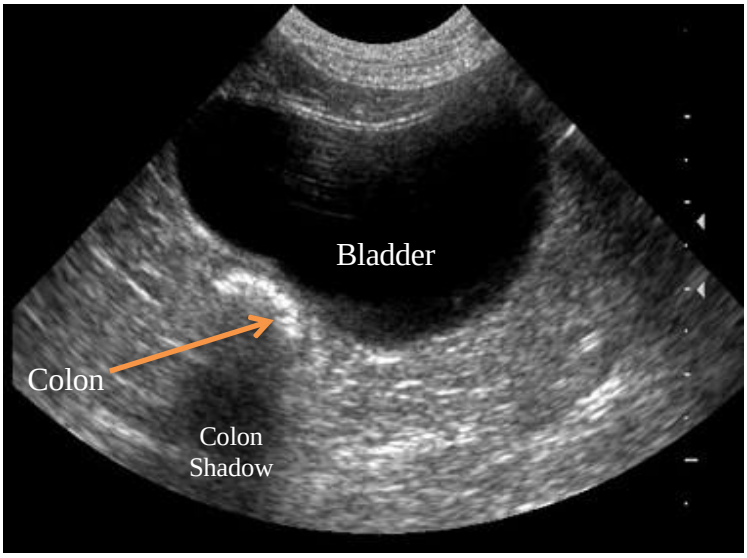


Figure 1.2b: Bladder with the apex to the left. Colon and gas shadowing can be seen below the bladder (bright boomerang- shaped region with dark shadowing below).

3. Right paralumbar or Hepato-renal (HR) site (Figures 1.1a, 1.3a, 1.3b): **Key organs/structures to identify** include the 1) **right caudal liver lobe**, 2) **right kidney**, 3) **body wall** and 4) **intestines** and 5) areas between these structures. This view can be difficult to obtain as often it is necessary to go between ribs to visualize the normal structures. It may sometimes be necessary to start in short axis to the body so that the probe can be placed within an intercostal space between ribs. In smaller dogs and in cats, the probe can be placed in long axis to the body caudal to the 13th and final rib, just below the hypaxial/lumbar muscles. In dogs, if the liver is visualized in the right paralumbar region, or between ribs, the probe can be slid caudally until the kidney is visualized. The right kidney is located quite lateral relative to midline.

Figure 1.3a: The gravity dependent kidney is the tougher image to obtain. If sufficiently stable, the dog can be rolled slightly to allow the probe to be placed under the dog to identify the right kidney. Alternatively, the kidney can be scanned after completing the remainder

of the abdominal POCUS scan with the dog rolled into a sternal position (not shown).

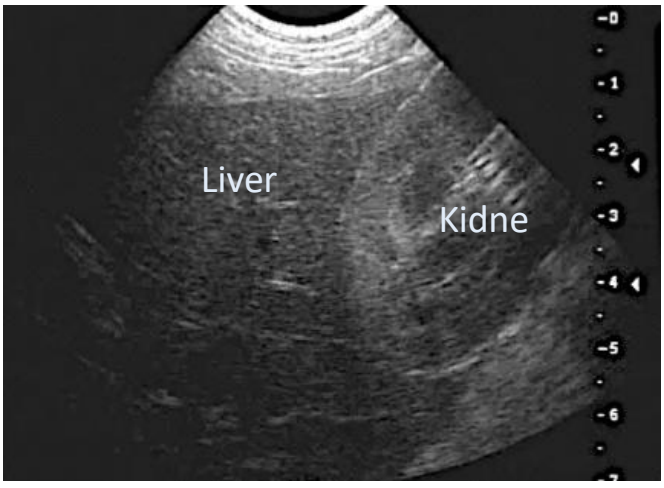


Figure 1.3b. Right paralumbar view in long axis to the body, with the kidney and liver.

4. Left paralumbar or Spleno-renal (SR) site (Figures 1.1a, 1.4a, 1.4b): **Key organs and structures** to identify include the 1) **spleen** 2) **left kidney**, 3) **intestines** 4) **body wall** and 5) the areas between these structures. The probe has to be placed quite lateral to midline to find the left kidney and spleen. The spleen is located cranial and often lateral to the left kidney. To find the left kidney, use your index finger to trace the last rib from the mid-abdominal region dorsally. The kidney is usually located at the region where the last rib encounters the hypaxial/lumbar muscle. The probe is placed in long axis to the body, and then turned to short axis once all planes in longitudinal have been assessed with fanning the probe. Sometimes it is easier to find the spleen first, and then slide the probe caudally until the left kidney is found. Fanning and rocking the probe helps to find the organs of interest.

Figure 1.4a: The left paralumbar site is located at the caudal dorsal junction of the last rib and the epaxial/lumbar muscles. The kidney may be tucked under the ribs necessitating that the probe be angled under the ribs (as shown) or the probe placed between the ribs via an intercostal view (image not shown).

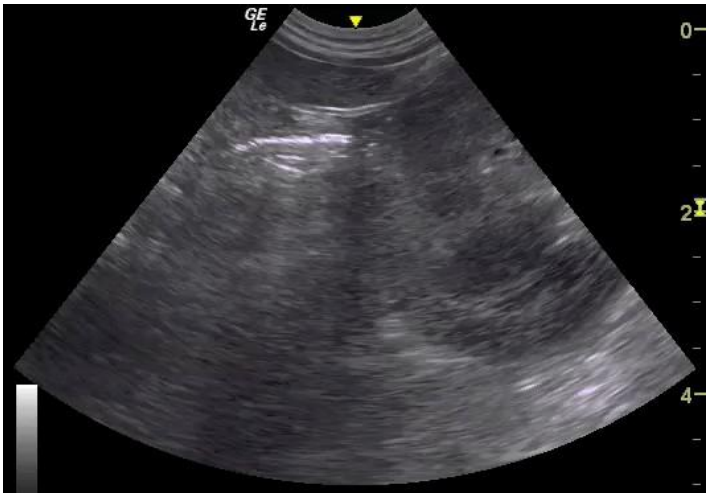


Figure 1.4b. Normal left paralumbar view with the left kidney and spleen in long axis.

5. A modified 5th view (Figure 1.5) is also recommended to ensure localization of gravity dependent abdominal effusion by placing the probe at the umbilicus. Key structures assess at this site include 1) the gravity dependent **body wall**, 2) **intestines**, 3) **spleen** and regions between these structures. The probe is placed at roughly a 45-degree angle with the head of the probe directed towards the table top. The probe should then be rocked and fanned. Assessing the umbilical site before sliding the probe under the patient to assess the gravity dependent kidney increases the chances of detecting smaller quantities of free abdominal fluid that might otherwise be displaced to either side of the probe.

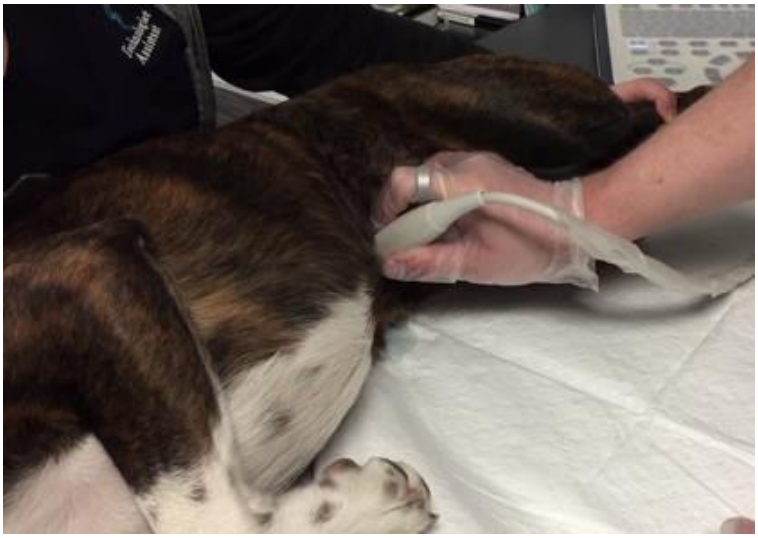


Figure 1.5: The 5th umbilical site. Note the probe is placed at an angle so as to maximize the chance of identifying fluid in the gravity dependent regions of the abdomen.

Limitations of abdominal POCUS

- Initial hypovolemia or severe dehydration could limit detection of effusion; important to reassess after adequate resuscitation (serial POCUS exams)
- Difficult to confirm rupture of the urinary bladder with ultrasound (some indirect evidence that should put rupture on the list, but often need radiographic contrast studies to confirm)
- A negative abdominal POCUS does not rule out injury

Potential pitfalls

Hepatic vessels and the gall bladder can sometimes be mistaken for fluid. It is important to remember that ultrasound is a dynamic imaging modality and therefore by fanning, rocking, sliding, changing the depth, and rotating the probe (longitudinal to transverse and vice versa) we can determine if these areas are vessels (by moving the probe it will be easier to see that these structures form vessels). Edge shadowing (figure 1.6) is where the ultrasound beams create dark shadows on the edges of an organ, which can be mistaken for fluid. It can cause the wall of a structure to disappear, which should not be confused for rupture of an organ (e.g. don't confuse edge artifact for rupture of the urinary bladder or fluid around the gallbladder).

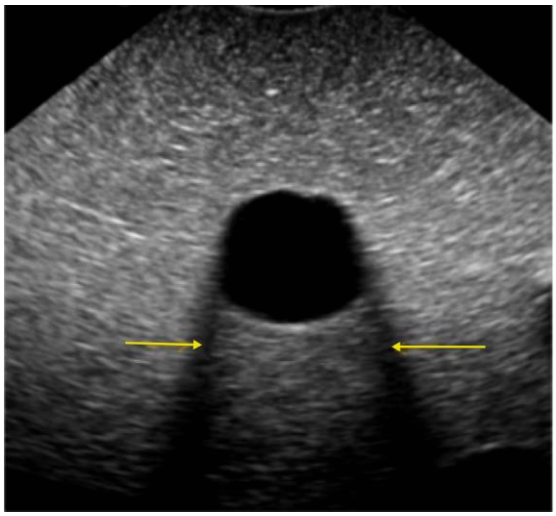


Figure 1.6: Edge shadowing (yellow arrows) from the gallbladder

Intestinal and stomach walls can also be mistaken for abnormal fluid or structures, and once again by moving the probe it will be easier to determine if the structure is intestine or stomach. Mirror image artifact of the gall bladder, or hepatic vessels, which are often distorted, can be confused for pleural effusion. Highly cellular effusion such as acute hemorrhage or septic exudates can sometimes mimic soft tissue structures or stomach contents and can be difficult to identify as fluid. Probe manipulations can sometime create "swirling" which may help differentiate cellular effusion from tissues. Fanning will also often identify "structures" within the fluid and can find sharp angles to help differentiate cellular fluid from soft tissue structures.

How accurate is abdominal POCUS?

The detection of free abdominal fluid via sonography is more sensitive than radiographs. A recent study by Walters (*JVECC 2018*), compared the original 2004 Abdominal FAST to CT for detection of free fluid by minimally trained ER docs and found excellent agreement (Kappa 0.82). Although abdominal POCUS localizes fluid to the abdominal cavity, which permits centesis and fluid analysis, it cannot identify the actual abdominal organ injured in most cases (contrast enhanced ultrasound can often identify organs injured but is not done much in veterinary medicine).

Serial POCUS exams

Serial POCUS exams are recommended to: 1) monitor progression/resolution of intra-cavitary fluid in fluid positive patients, and 2) to re-assess fluid negative patients, particularly those that are unstable, and/or have received significant quantities of intravascular fluids.

The frequency the abdominal POCUS exam is repeated depends on the patient. It should be repeated as often as required to identify the reason a patient is unstable if no identifiable cause is evident on ancillary diagnostic tests, or to determine why a patient changes from stable to unstable. If the patient is stable and the goal is to simply follow resolution or progression of underlying pathology, the POCUS scan can be repeated every 4 hours.

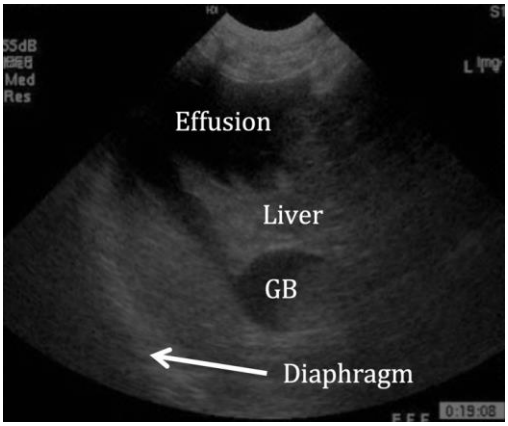
Abdominal fluid score (AFS)

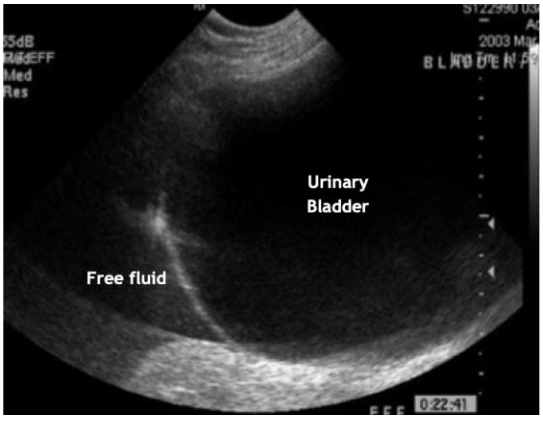
- Described in 2009 (Lisciandro *et al* 2009). Limited to patients in lateral recumbency only. Only validated for hemorrhage in post trauma patients at this time.

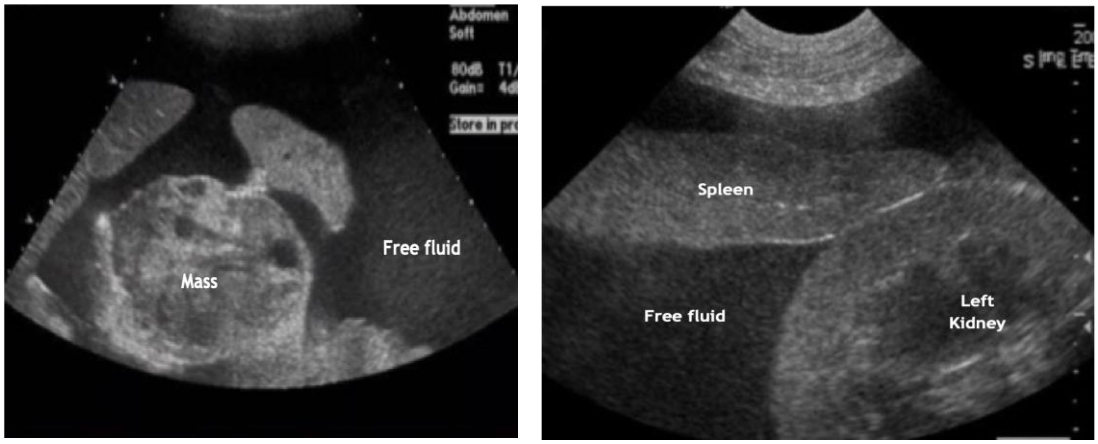
- The AFS is reported as follows; AFS 1 means presence of fluid in one of four sites, AFS 2 means presence of fluid in two of four sites, etc.
- Recording the AFS during repeat abdominal POCUS examinations provides an estimate of changes in the volume of abdominal fluid.
- In trauma patients, increasing AFS suggests ongoing intra-abdominal hemorrhage while a decrease in AFS indicates resolving hemorrhage. This has important clinical implications as dogs with higher scores are more likely to require blood transfusions. It is recommended to have blood products available, when required, for patients with and AFS of 3 or 4, and to monitor these patients closely for the need to transfuse. The decision to transfuse and/or the need for surgery should not be based on the AFS alone, but rather clinical status of the patient and overall patient assessment.

What does free abdominal fluid look like?

Free fluid in the abdomen (figures 1.7 onward) typically appears as dark (anechoic or hypoechoic) triangles/sharp angles between organs and structures, commonly visualized at the apex of the bladder, between the bladder and the body wall, at the poles of the kidneys, between the spleen and left kidney, between liver lobes, between the liver and diaphragm, between the liver and right kidney, and/or surrounding small intestinal loops. Obtaining a fluid sample is important when effusion is noted as the type of fluid can vary. In-house analysis (cytology, refractometer, parameters of sepsis) should be performed as results may dictate further immediate action (surgery, antibiotics, transfusion). Samples should also be taken to submit to a reference laboratory (cytology, culture).







Figures 1.7a-d: Positive abdominal POCUS results. The first image (1.7a) is a positive subxiphoid view in long axis. The diaphragm can be seen and a large hypoechoic (black) region can see seen with irregular angles, indicating fluid. The second image (1.7b) is a long axis view of the bladder with fluid cranial to the bladder. The thin bladder wall can be seen. The third image (1.7c) is of the right paralumbar region. In this image, normal liver is seen, as well a large complex irregular mixed echogenic mass. The last image (1.7d) is the left paralumbar region. The spleen and left kidney can be seen with significant surrounding effusion.

Specific binary questions to answer when performing abdominal POCUS

1. Does the patient have abdominal effusion at any of the sites described above Y/N? How many sites? Serial changes to the amount of fluid or number of positive sites?
2. Is there free abdominal air in the abdomen Y/N?

- Similar to detecting pneumothorax with POCUS, the detection of free abdominal air is more challenging than other POCUS binary questions that are commonly asked when assessing the abdomen. However, given many patients that have free abdominal air will present with life threatening hollow organ perforation or gas producing bacterial infections, it is recommended that clinicians become familiar with the sonographic findings of pneumoperitoneum. Studies suggest that as little as 2 ml of air in the abdomen of healthy beagles can be consistently detected with ultrasound (Kim *et al* 2014).
- Free abdominal air can be detected in many sites of the abdomen; however, it is most commonly identified at the left and right paralumbar locations with the patient in right or left lateral recumbency. Again, it is important to consider patient positioning and where free air will accumulate when searching for free abdominal air. The author prefers to have the patient remain in lateral recumbency for a few minutes to allow air to track to the non-gravity dependent locations before trying to identify pneumoperitoneum.
- **There are 3 key steps that can be followed to help detect pneumoperitoneum (figure 1.10):**

I. The peritoneal lining must be identified. This is essential so as not to confuse free air within the GI tract for free air in the abdomen. Identifying the peritoneal lining can be achieved by placing the patient in lateral recumbency and identifying structures in contact with the peritoneal lining of the non-gravity dependent body wall, such as the stomach, liver or spleen. Leaving the animal in lateral for a few minutes to allow air to rise to the non-gravity dependent body wall is recommended. It is also possible to follow the peritoneal lining caudally from the curtain sign (see notes on pleural and lung ultrasound for more information on the curtain sign). Free air can be detected between organs or within the wall of some structures, although this is more technically challenging to confirm.

II. Identify the presence of reverberation artifact that originates at the peritoneal lining. This is very important to differentiate from reverberation artifact contained within the GI tract, which again, emphasizes the importance of clearly identifying the peritoneal lining.

III. Identify the enhanced peritoneal stripe sign. This sonographic finding occurs when free abdominal air comes in contact with the peritoneal lining. At the point where free abdominal air comes in contact with the peritoneal lining it will cause the peritoneal lining to become more hyper-echoic. This is the enhanced peritoneal lining. Reverberation artifact, if it is the result of free abdominal air will originate from the enhanced peritoneal stripe sign.

- Small animal patients that have undergone elective abdominal procedures, that are very stable and comfortable on analgesics make a great model to practice finding free abdominal air.

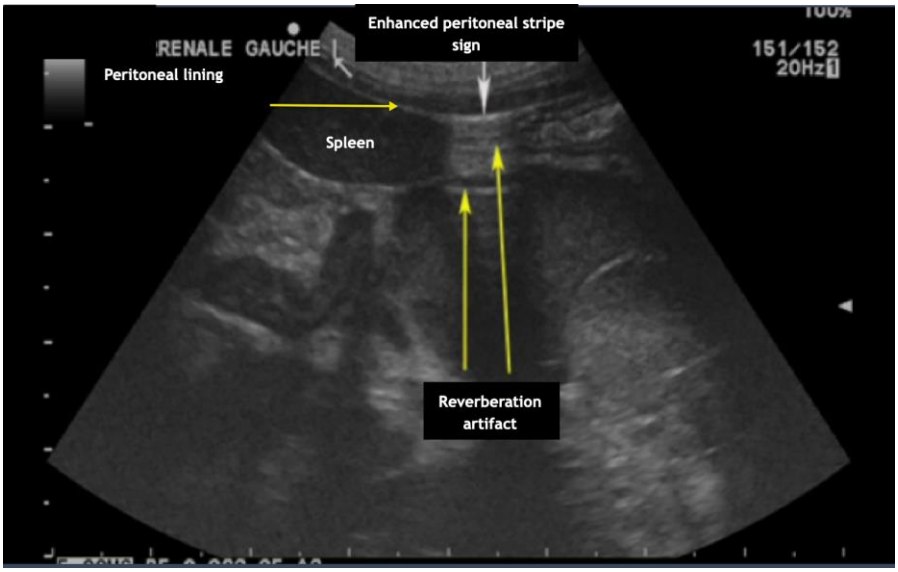


Figure 1.10: In this image, with the patient in right lateral recumbency, free air can be detected by identifying the peritoneal lining (horizontal yellow arrow), the enhanced peritoneal stripe sign (short white arrow), and reverberation artifact arising from the peritoneal lining (long vertical yellow arrows).

3. Does the patient have Ileus Y/N? Is the stomach distended and fluid filled Y/N?

- Ileus is defined as a transient cessation of gastrointestinal (GI) motility or an abnormal pattern of GI motility. It has been well established in human medicine that ileus is common in postoperative patients, and the prevalence of ileus (depending on the definition used) in people following elective surgeries can range from 10% to 25%.
- Efforts are made to rapidly identify and treat ileus in postoperative human patients because it is well established that postoperative ileus is known to cause vomiting, decreased tolerance of oral diets, increased morbidity and mortality, and prolonged recovery from surgery. Although the evidence is lacking on the veterinary side, it is reasonable to presume that ileus is also common and impacts patient outcome in dogs and cats.
- GI motility varies throughout the intestinal tract. However, the mean number of peristaltic contractions of the stomach and proximal duodenum are 4 to 5 contractions per minute. These tend to be the easiest sites to evaluate in general when it comes to identifying post-operative ileus and are part of the POCUS sites.
- It should be kept in mind that focal ileus, particularly when present with localized GI conditions (i.e. GI foreign bodies) may not result in ileus at the level of the stomach or duodenum.

- To measure the number of contractions per minute the total number of contractions is recorded over 3-minutes and divide by 3 (to give the number of contractions/minute). In the interest of time, the number of contractions is often simply calculated over 1 minute. If there are no contractions noted a diagnosis of ileus can be made.
- Food within the GI tract is a strong stimulus for GI motility, and a diagnosis of ileus can be made with greater confidence if food is noted within the GI lumen and there is an absence of GI contractions.
- Given the stomach is easily identified at the subxiphoid location of the abdominal POCUS exam (figures 1.8a, 1.8b), and the duodenum (figures 1.8c, 1.8d) is in close proximity to the right kidney on of the right paralumbar site of the abdominal POCUS exam, it is very easy to identify these structures during abdominal POCUS scanning and assess the GI tract for motility. Other areas of the small intestines can be evaluated but the number of contractions is less in these regions and identifying specific areas or small intestine can be challenging.
- If post-operative ileus is identified, measures should be taken to ascertain the underlying cause (opioids, postoperative surgery, abdominal pain, electrolyte imbalances and peritonitis) and therapeutic interventions should be implemented. Things to assess and consider include, enteral feeding soon after surgery, early ambulation, epidural analgesia vs. systemic opioids, non-steroidal anti-inflammatory agents provided there are no contraindications to NSAID use, prokinetic agents such as metoclopramide, and naso-gastric tubes and GI suctioning.
- Gastric fluid retention should also be assessed (and can be measured using a similar formula as the urinary bladder volume calculation if the stomach is fluid filled) as removal of gastric fluid contents may make patients more comfortable and reduce the risk of regurgitation and aspiration pneumonia.

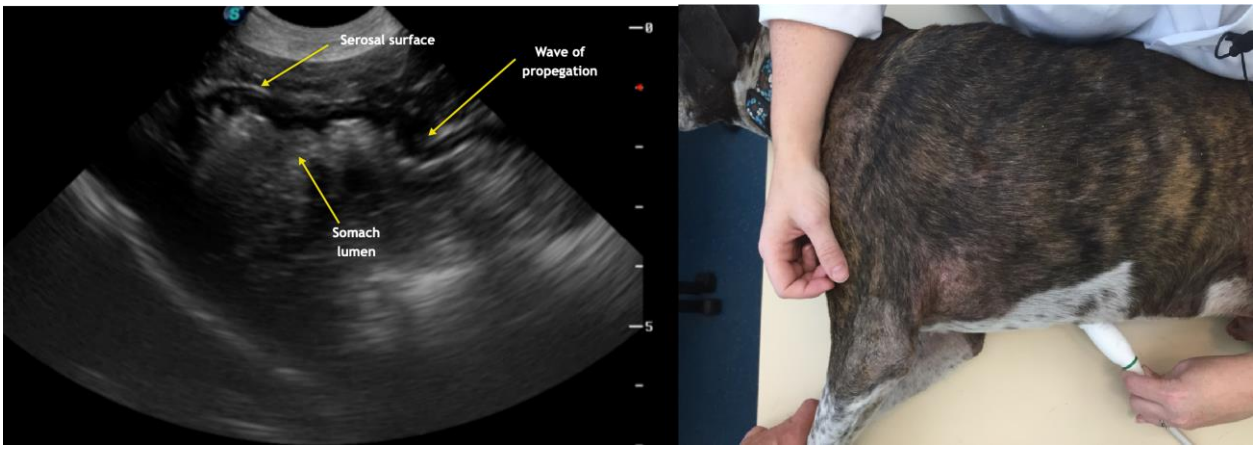


Figure 1.8a and 1.8b: Technique for identifying the stomach and assessing GI motility. GI motility can be assessed at the subxiphoid location on midline. The stomach is located just caudal to the liver. The stomach is easily identified when the probe is placed at roughly 90 degrees to the patient (as opposed to the 45-degree angle commonly used to assess the liver, diaphragm and pleural/pericardial spaces). It is important to keep your hand stationary and to maintain the area of interest in the field of view, which can be a challenge as the patient breathes. It is prudent to assess fluid content/distention of the stomach as well as wall motility. GI contractions are defined as a wave of propagation along the wall of the stomach.

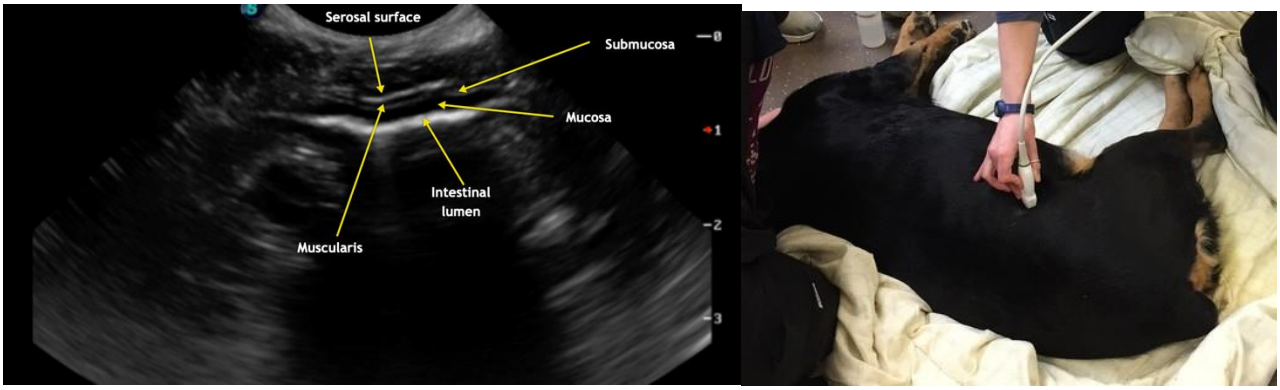


Figure 1.8c, 1.8d: Technique for identifying the duodenum and assessing GI motility. The probe is placed at the right paralumbar site and fanned laterally and medially in the longitudinal orientation until the duodenum is located.

4. Is the animal producing urine Y/N?

- It is sometimes difficult to quantitatively measure urine output in small animals due to technical challenges in placing urinary catheters, risks of urinary tract infections and/or financial constraints of owners. Although not 100% accurate, point of care ultrasound can be used to estimate urinary volume and urine production over time.
- To measure the urine volume the bladder should be fanned through its entirety in the longitudinal orientation and measurements taken at the widest part of the bladder. The probe is then rotated 90 degrees, so the bladder is scanned in transverse orientation, again fanning through its entirety

and taking measurements at its widest point. The formula length x width x height (averaged) x 0.625 is used to estimate urinary volume in milliliters (see figure 1.9).

- Indications to measure urine production include acute kidney injury, anuric and oliguric renal failure, and monitoring of fluid therapy (Atalan G *et al* 1998).

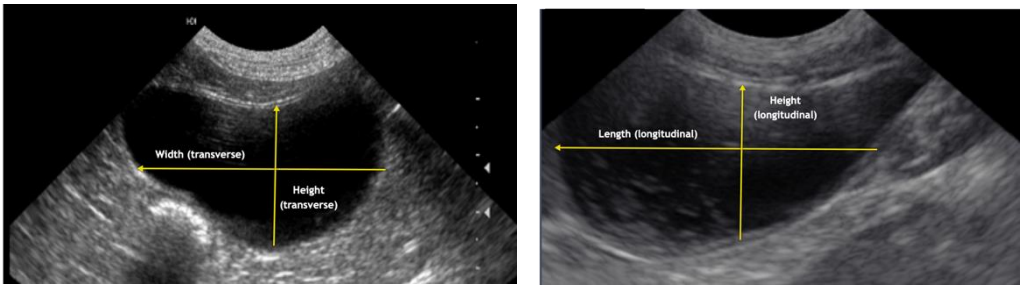


Figure 1.9: Transverse and longitudinal images of the urinary bladder. The height is measured in both transverse and longitudinal planes, then divided by 2 to get an average height. The width is measured in transverse and the length in longitudinal. The formula length x width x height (averaged) x 0.625 is then used to estimate urinary volume (in mls). Avoid applying pressure to the probe when measuring urine volume as the urinary bladder should be as round as possible when measurements are taken.

5. Does the patient have a gall bladder halo sign Y/N?

- A study by (Quantz *et al* 2009) demonstrated that patients with acute anaphylaxis often have a halo (double rimmed gall bladder wall) sign (the gall bladder wall is normally very thin or not easily visualized on ultrasound), and this can be seen during abdominal POCUS (Figure 1.11). A thicker gallbladder wall (often due to edema with or without surrounding fluid) can be seen with a "halo" effect.
- However, this is not specific for anaphylaxis and can be seen in patients with a number of conditions (anything that causes edema). However, with unstable patients presenting for collapse, the finding of a "halo" sign should prompt consideration of anaphylaxis, right-sided heart failure, pericardial effusion, fluid overload or changes to vascular permeability and sepsis. The most common cause of the halo sign varies by geographical area. In Canada and Belgium, pericardial effusion is the most likely cause in a collapsed unstable patient, while in the Southern United States anaphylaxis is probably the most common cause.

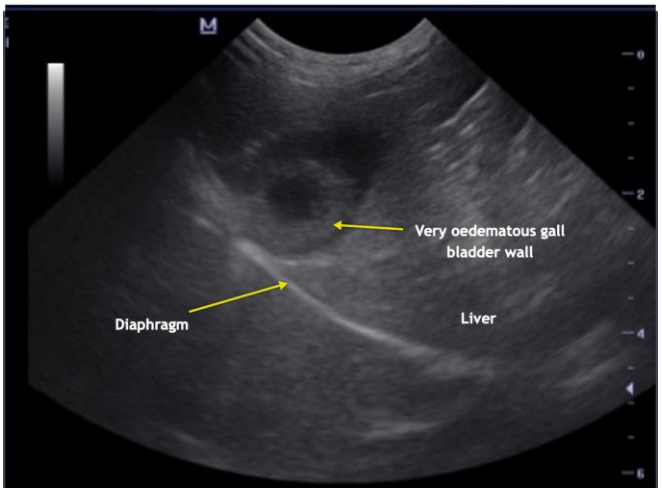
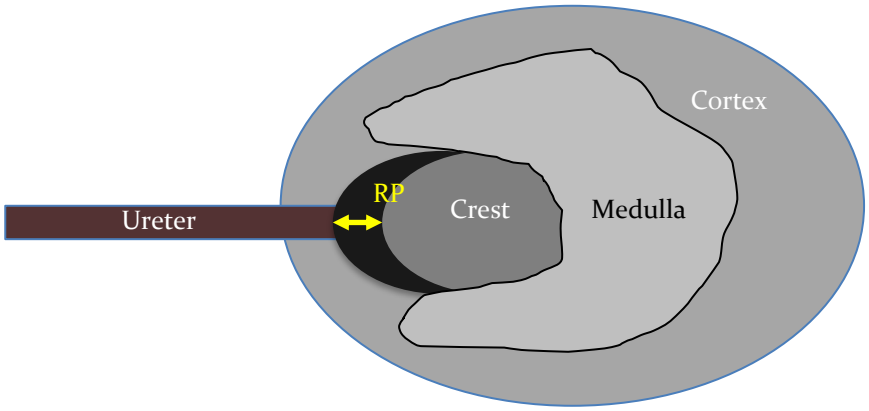


Figure 1.11: Image of a thickened edematous gall bladder wall (which is a non-specific finding but was due to anaphylaxis in this situation). In the collapsed or unstable patient, the list of differential diagnosis for the halo sign should include anaphylaxis, sepsis, pericardial effusion, and right sided heart failure.

6. Does the cat have renal pelvis dilation Y/N?

Short axis renal pelvic dilation greater than 13mm in cats has been shown to be highly indicative of obstructive disease, likely ureteral obstruction (such as ureteroliths) (Beeston et al, RVC abstract EVECC). Therefore, if a cat presents with azotemia and has a distended renal pelvis >13mm then this patient's azotemia is likely caused by obstructive ureteral disease. This is important in management and in further recommendation for this patient, as this cat may require surgery (such as the placement of a subcutaneous ureteral bypass device) vs. multiple days in hospital on IV fluids. To obtain a short axis renal pelvic measurement, scan either kidney in short axis and locate the renal crest (see diagram below). The space between the renal crest and the other side of the pelvis is the renal pelvis. The pelvic region often resembles a "Pacman" eating the renal crest! As the renal pelvis distends, it becomes more obvious. In normal cats, the renal pelvis is only 1-3mm. Other conditions can cause renal pelvis distention such as IV fluids, conditions leading to PU/PD, and especially pyelonephritis. Based on studies, a 7mm pelvic dilation was likely indicative of obstructive ureteral disease but not as sensitive or specific as greater than 13mm distention. There was also a grey zone below 13mm from the pelvic dilation caused by pyelonephritis vs. stone obstruction for instance. Also, it is important to note that the lack of pelvic distention does not always eliminate obstructive ureteral disease. Evidence of pelvic distension especially in an azotemic cat should prompt referral for a full abdominal ultrasound.



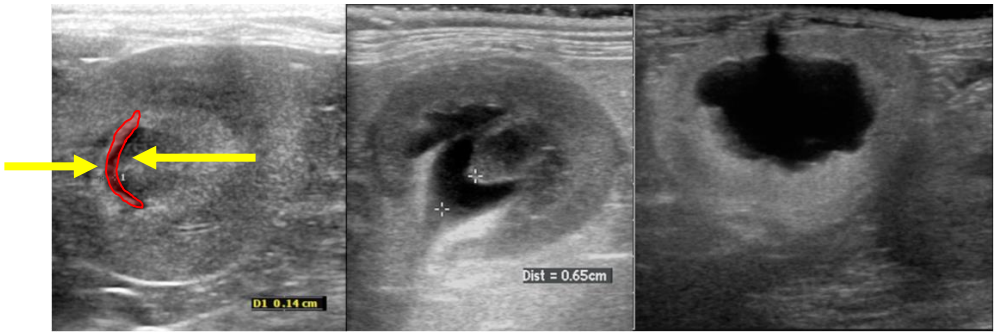


Figure 1.12: Diagram (above) and actual POCUS images of cat short axis renal pelvises. On the actual images from left to right: a normal renal pelvis measuring 1.4mm. Middle image, a pelvis measuring 6.5mm. To the far right, a measurement is not indicated but this pelvis was over 13mm in diameter indicating obstruction.

Summary Abdominal POCUS

Abdominal POCUS was initially developed for the detection of free abdominal fluid in trauma cases using abdominal FAST, but it has now evolved into a triage tool for any patient: Trauma, acute abdomen, post- surgical, critically ill, etc. Done patient-side at the same time as IV catheter placement, minimum emergency database, auscultation, oxygen, sedation and other stabilization efforts, it helps track progression, assists with abdominocentesis, and guides further diagnostics/interventions. It is non- invasive, repeatable, rapid and has been used to detect free abdominal fluid or air, ileus, gall bladder wall edema (Halo sign), renal pelvic dilation, pleural effusion, pericardial effusion, retro-peritoneal fluid, pyometra, and urine production. Binary questions help avoid errors, answer the most important clinically relevant questions first and sequentially build skill levels by mastering one question at a time.

Pleural Space and Lung POCUS

PLUS has evolved greatly over the last several years. The initial thoracic FAST study (Lisciandro et al, 2008) described 4 sites on the thorax (bilateral chest tube site, bilateral pericardial site) and was designed to detect pathology in the pleural space (pneumothorax, pleural effusion) and the pericardial space (pericardial effusion). This study was not designed to assess lung pathology, cardiac function, or volume status. In addition, the original study was done with patients in lateral recumbency while most patients presenting with dyspnea are now scanned in sternal or standing. A study by Walters et al (JVECC 2018) demonstrated there is a fair correlation between CT findings of pleural effusion and thoracic FAST (kappa 0.53), and very poor correlation between CT and pneumothorax using thoracic FAST (-0.08). The lack of correlation between thoracic FAST and CT is likely due to the fact that the original 2008 thoracic FAST protocol scanned patients in lateral recumbency. Lateral recumbency is not the best position in which to scan dyspneic patients and it may be easier to locate pathology with patients in sternal recumbency. It is also likely the original 4 sites were not as sensitive at detecting pathology as current techniques used to detect pleural effusion and pneumothorax.

Following the original thoracic FAST study, additional thoracic POCUS techniques have been developed with different objectives. A study by Rademacher et al (2014) developed a lung ultrasound protocol which was the first to demonstrate that alveolar interstitial syndrome (AIS) can be diagnosed in dogs using sonography. Subsequently multiple POCUS techniques (Ward et al, 2017; Lisciandro et al, 2014; Vezzosi et al, 2017; Armenise A, et al, 2018) have been used for the detection of AIS.
In addition to advancements in detecting lung pathology, thoracic POCUS can also detect underlying cardiac function abnormalities in cats and dogs. Recent studies clearly show cardiovascular POCUS performed by non-specialists helps to differentiate respiratory from cardiac causes of dyspnea in both cats and dogs (Ostroski C et al, JVECC 2016 abstract; Hezzell MJ et al, JVIM 2017 abstract, in press). Although point of care cardiac evaluation is arguably more difficult than other POCUS techniques there are multiple studies demonstrating non-specialist can obtain appropriate cardiac views (short axis parasternal for example) to help differentiate cardiac from respiratory causes of dyspnea (Tse Y et al,

2013). Finally, thoracic POCUS has recently been demonstrated to help detect intravascular volume changes in dogs and cats via assessment of the caudal vena cava.

With so many thoracic protocols being used in small animals there is some confusion as to what clinicians mean when they state, "I did a thoracic FAST exam" or "I assessed the thorax with sonography". It is therefore important to standardize the approach to thoracic POCUS (e.g. searching for pleural effusion, pericardial effusion, pneumothorax, basic cardiac function, volume status, etc.) so that the information stays objective and translatable. One approach to solving the confusion surrounding the ever- expanding exams incorporated into POCUS is to return to the binary questions POCUS was originally designed to answer (pleural fluid yes/no, pneumothorax yes/no etc.). This approach helps in keeping these exams standardized, as well as answering important clinical questions (hence why we do these exams). The binary question approach also allows the clinician to expand their ultrasound skills as they become more comfortable with sonography and allows newer techniques to be incorporated without drastically changing the techniques used.

Arguably, patients presenting with respiratory distress can be quite challenging as it is not always easy to differentiate cardiac, pleural space and parenchymal disease, particularly in cats. An incorrect diagnosis may result in life threatening interventions being delayed, or lead to an incorrect therapy being administered, which may cause patients to deteriorate. There are several algorithms that have been developed to help differentiate cardiac from non-cardiac causes of respiratory distress, most of which rely on radiographs and a cardiology consult if the patient is sufficiently stable, and/or physical exam findings and history if the patient is unstable. Most algorithms unfortunately do not incorporate the use of point of care ultrasound by non-specialists in differentiating causes of respiratory distress in cats or dogs.

The skills required to perform pleural space and lung point of care ultrasound are easily learned with minimal formal training and can differentiate the major causes of respiratory distress. A particular advantage of pleural space and lung ultrasound is the fact it can be performed while the patient is receiving oxygen therapy, anxiolytics, and other stabilization efforts. In general, if it's possible to auscult

the patient with a stethoscope, thoracic POCUS can also be performed, even in an oxygen cage if necessary. For standardization, we now refer to thoracic POCUS to Pleural Space and Lung Ultrasound, or simply PLUS.

Patient Position, Probe Selection and Settings for PLUS

- Patients can be in sternal (preferred position for dyspneic patients), standing or in lateral recumbency (the latter is reserved for patients that are not experiencing respiratory distress).
- Dorsal recumbency should be avoided.
- Similar to POCUS of the abdomen, shaving is not required, the fur is parted, and alcohol is used as the coupling agent, although gel can be added.
- Depth for pleural and lung ultrasound varies by body condition score but is generally set at 4-6 cm in most cases. As a general rule, the pleural line should be at the proximal 1/3 of the ultrasound image.
- A 6-10 MHz (7 MHz) microconvex probe is generally used.

Remember that the two key enemies of ultrasound, bone and air, are encountered when performing ultrasound of the pleural space and lung. This is advantageous as bone and the subsequent rib shadowing provides landmarks to work with, and artifacts are often present when the ultrasound beam encounters air. These artifacts change depending on the underlying status of the lung and pleural space. This is discussed in further detail and we will emphasize how all sonographic signs arise from the pleural line. As with abdominal POCUS, it is important to assess the patient to decide which clinically important binary questions need answering first, and also to make sure a thorough evaluation for the specific underlying pathology is undertaken for each question asked.

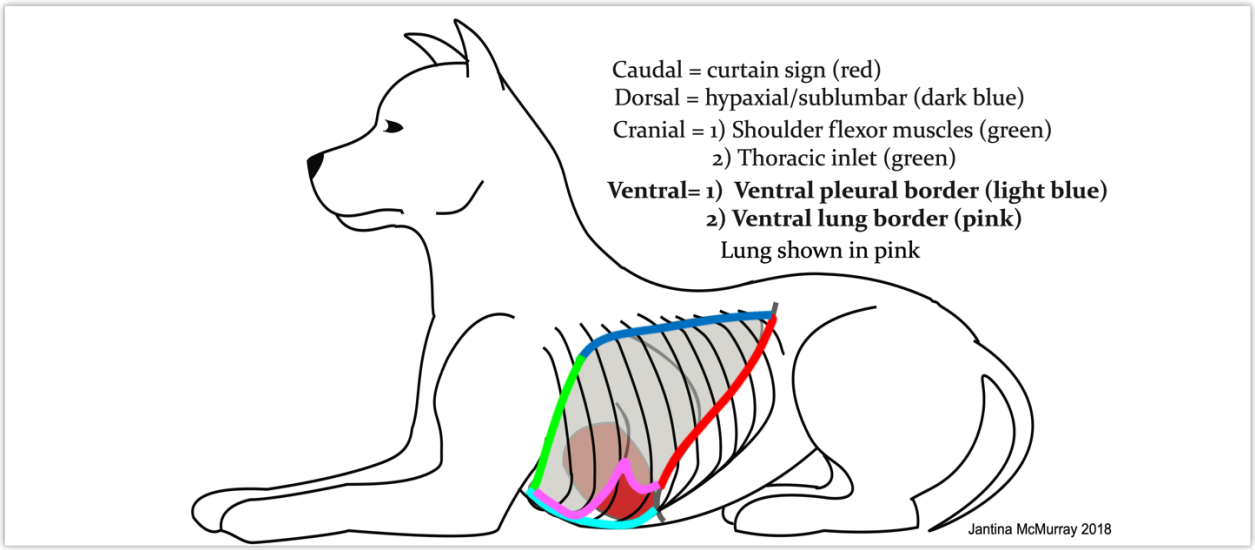
PLUS Protocol

There are multiple lung ultrasound scanning protocols that are currently used in veterinary medicine. Regardless of which protocol is used they all start at the caudal dorsal lung border and scan multiple lung regions systematically. Regardless of which protocol is chosen the subxiphoid site should be included in the evaluation of the lungs for AIS.

As a general rule of thumb, the authors' scan the lung and pleura in a sliding fashion (often from caudodorsal to craniodorsal, then mid-thorax cranial to caudal, then caudoventral to cranioventral as a large "S" pattern) on each side of the chest, plus the subxiphoid site, to ensure adequate exploration of the lungs. To do this, the authors use ultrasonographic borders of the pleura and lung to ensure the entire visible lung and pleura are visualized. There are 5 key borders of PLUS:

1. The caudal border, which is defined by the curtain sign (more to come on this below),
2. The dorsal border, which is defined by the hypaxial muscles,
3. The cranial border, which is not the true border of pleura and lung but the border that is limited by the thoracic limb,
4. The ventral pleural border,

5. The ventral lung border. There are two ventral borders because of the cardiac notch.



The image below describes the authors' protocol of preference in a sternal/standing (or lateral) patient. To achieve the "S" scanning of PLUS, the authors use the above borders to ensure the entire lung and pleura are scanned. Before going into more detail about this protocol, it is important to identify normal structures seen during lung ultrasound. Important questions to ask ourselves before scanning a patient:

- Is the animal sternal/standing or lateral? This is important because pathology (such as pneumothorax or pleural effusion) will be affected by gravity and therefore patient positioning. Therefore, to rule out these pathologies it will be important to think about how patient position affects their location. This is one of the reasons we promote a binary question approach instead of a protocol-driven approach. In other words, if you want to rule out pneumothorax in a standing patient, you will think to look caudo-dorsally vs. a patient that is lateral (where air will accumulate in the highest point of the thorax).
- What important clinically-relevant binary questions am I trying to answer (see section below on thorax binary questions to answer)?

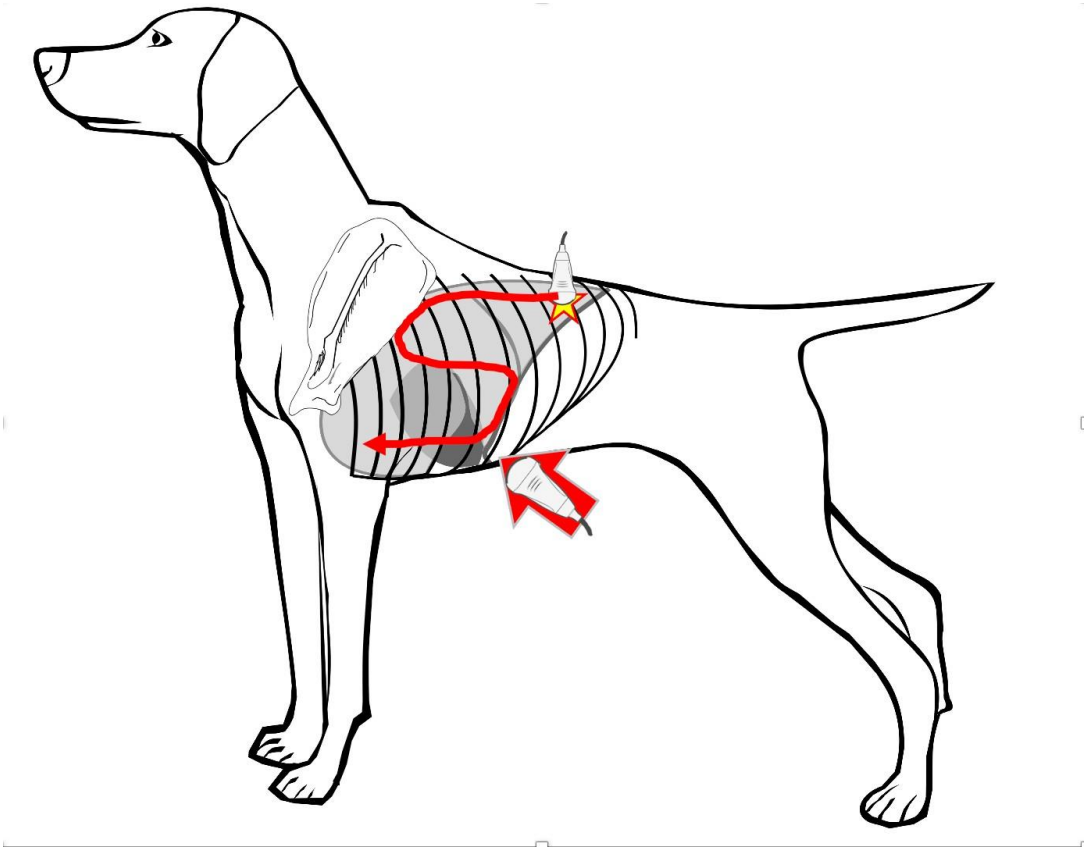


Figure 2: PLUS protocol for lung scanning in sternal/standing which includes evaluation of multiple lung regions (intercostal spaces) in the dorsal, middle and ventral third of thorax bilaterally using a sliding protocol, plus the subxiphoid site. To reliably get to the starting location (most caudodorsal site), please refer to the pneumothorax section. Briefly, the probe is placed behind the thoracic limb ½ to 2/3 of the way up the

thorax and the presence or absence of lung sliding (aka glide sign) is assessed (yes/no). If lung sliding is present, the probe is slid caudally to the curtain sign then dorsally until the pleural line is lost at the level of the hypaxial muscles (therefore, finding the caudal and dorsal borders of the thorax so it can be fully examined). This is the stie to start lung scanning. If lung sliding is present at this site (in a standing or sternal patient), pneumothorax can be ruled out for this side of the patient. The probe is then slid in a systematic fashion (dorsal, middle and ventral thirds of the thorax & subxiphoid (sx)) to detect AIS, pleural effusion, and subpleural consolidations.

Normal Findings on PLUS

For novices, placing the probe perpendicular to the ribs (figure 2.1) will aid in identifying the pleural line, which is of paramount importance when assessing pleural space and lung pathology.
There are 6 key structures that can be identified during PLUS of the pleural space and lungs in healthy animals.

1. Pleural line and Bat sign
2. Glide sign
3. A lines
4. B lines
5. Dry lung
6. Curtain sign
7. Lung pulse

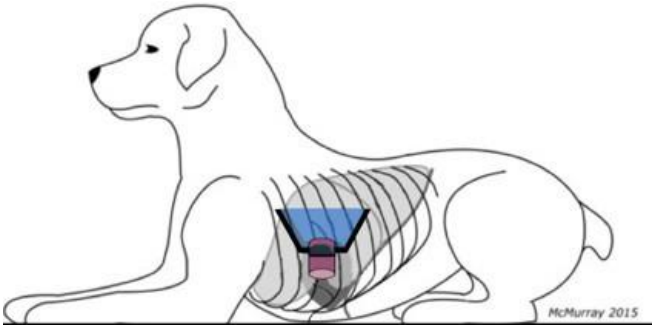


Figure 2.1: Although any probe orientation can be sued to assess the pleural space and lung, starting with the probe perpendicular to the ribs allows the "Bat" sign to be identified.

1. Pleural line and Bat sign

- Bat sign/Gator sign: When the ultrasound probe is placed over the lung and perpendicular to the ribs, we can see the rib heads, rib shadowing, and the pleural line. The image obtained is called a "bat sign" or "gator sign" as the rib heads and pleural line resemble the wings and body of a bat, or

a gator's eyes peaking above the water line, respectively. The **BAT** sign is the preferred term of the authors as the letters help identify the key features using the following pneumonic: the ultrasound beam will not traverse **B**one or **A**ir when the probe is held **T**ransverse to the ribs). The rib heads (bone) make up the wings of the bat while the pleural line (air interface) makes up the body of the bat when the probe is transverse to the ribs. Identifying the Bat sign assists novice sonographers in locating the **pleural line**; the first white line below the rib heads (Figures 2.1a, 2.1b, 2.2).

- The pleural line is essential to identify as it is the interface between the parietal pleura of the thorax and the visceral pleura of the lung and is the location we assess for most pleural and lung pathology.

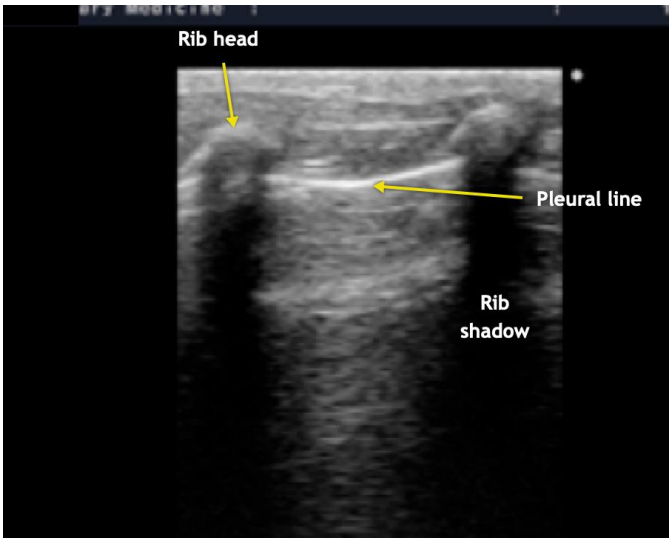


Figure 2.1a. Sonographic image obtained when the ultrasound probe is placed perpendicular to the ribs and showing the bat sign, linear array probe. The two rib heads are seen as white curved "up" lines. The first bright white line between the two rib heads is the pleural line, where the glide sign is observed. (Image courtesy Drs. Serge Chalhoub & Søren Boysen).

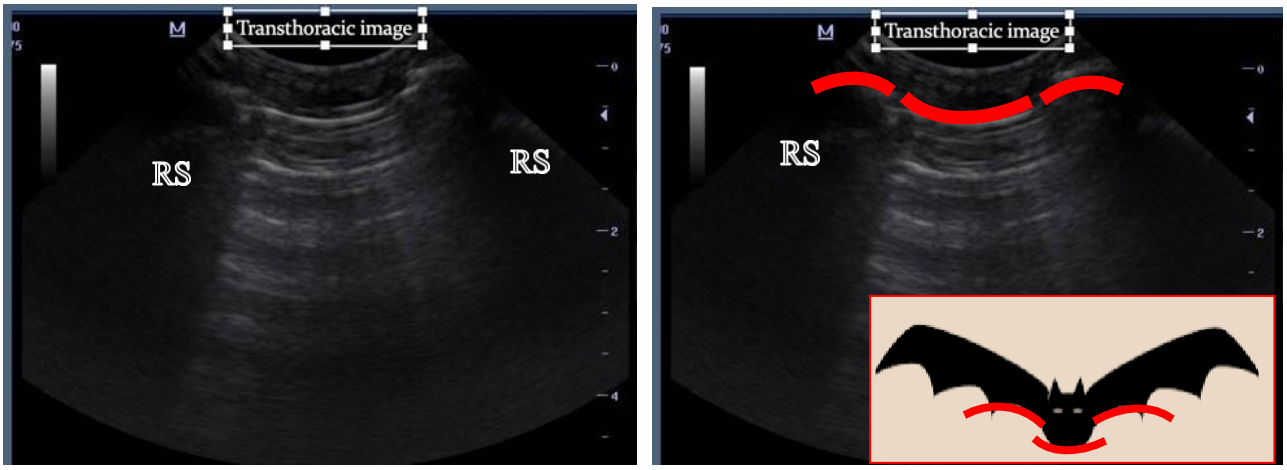


Figure 2.1b: Sonographic image obtained when the ultrasound probe is placed perpendicular to the ribs. The top image has no descriptors and the bottom image outlines the bat sign (in red). The ribs appear as the curvilinear white lines to

either side of the image with rib shadowing (RS; the bat's wings). The first white line that appears distal to the ribs, connecting the two ribs, is the pleural line (identified as the bat's body). This is the area that is assessed for the back and forth shimmering or glide sign. The reverberation artifact that causes the pleural line to be repeated in the far field of the image are known as A lines. Note that the pleural line and A lines are both present in healthy patients and patients with pneumothorax. It is the back and forth motion along the pleural line that differentiates healthy animals (glide sign present) from patients with a pneumothorax (glide sign absent). Photo courtesy Dr. Soren Boysen, modified from Emergency Critical Care, Mathews, 3rd ed, Lifelearn, in press.

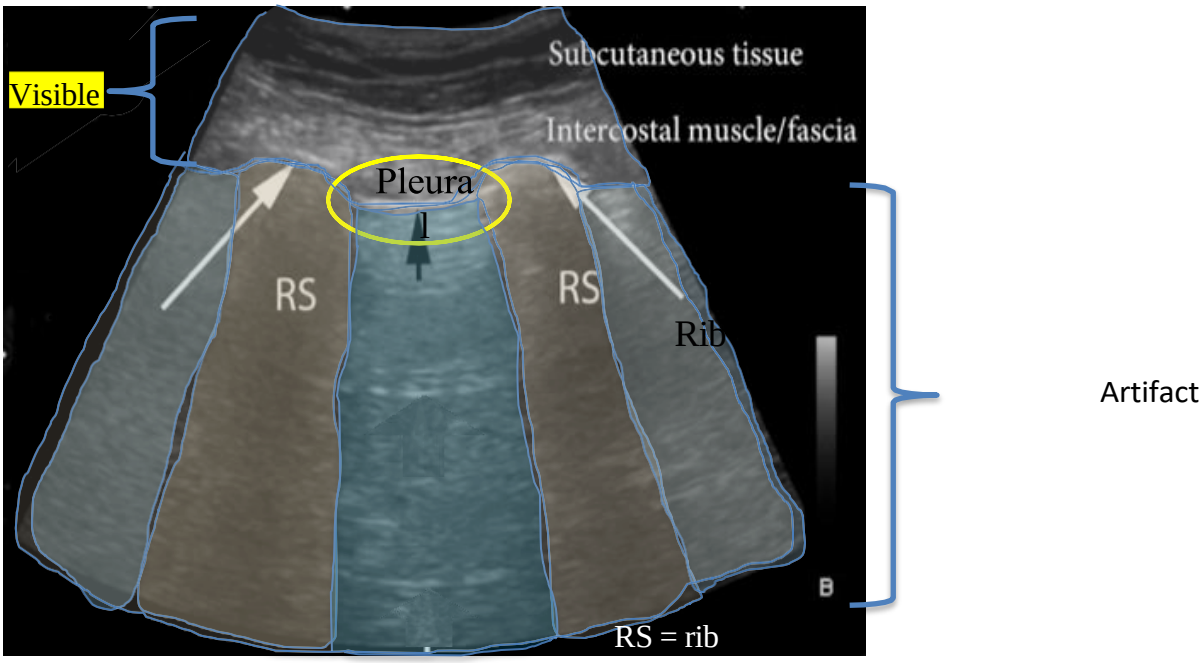


Figure 2.2: Sonographic image obtained when the ultrasound probe is placed perpendicular to the ribs. This image highlights how ultrasound beams cannot go through bone (RS, ribs) or air (normal aerated lung below the pleural line). Above the pleural line is what is normally visible when the ultrasound probe is placed perpendicular to 2 ribs (intercostal muscle/fascia). Below this, rib shadows (RS) are highlighted here in brown and aerated lung (in this case) with A lines in green. Note that the pleural line and A lines are both present in healthy patients and patients with pneumothorax. It is the back and forth motion along the pleural line that differentiates healthy animals (glide sign present) from patients with a pneumothorax (glide sign absent). Photo courtesy Dr. Soren Boysen.

2. Lung sliding, also referred to as the glide sign (Figure 2.1a-2.1b, 2.2 as still images representing the pleural line): visualized as a **shimmering** along the pleural line (pulmonary-parietal interface), which represents the normal to-and-fro motion of the lung sliding along the chest well during respiration. This is normal.

- There are two key rules to remember when assessing the glide sign: 1) the lining of the lung (visceral pleura) **MUST** be in contact with the thoracic pleura (parietal pleura) to create the shimmer of the glide sign and 2) the patient must breathe to create the shimmering glide sign.
- The glide sign is most obvious where lung movement is greatest, which tends to be the most caudal and dorsal sites of the thorax (easier to see the glide sign dorsally than ventrally). It is not always easy to identify the glide sign and making the pleural line less white and grayer and/or "grainy" will make it easier to identify the glide sign. The glide sign can be made "grainier" by changing the angle the ultrasound beam strikes the pleural line (changing the angle from perpendicular), by placing the probe over a single rib head, and by adjusting the gain setting on the ultrasound machine.
- The glide sign is difficult to identify in patients that are panting or have rapid shallow breathing. Keep your hand stationary and only interpret the glide sign when the patient is not moving (movement creates a false positive).
- The animal must take a breath to assess the glide sign - won't be seen with apnea – i.e. opioid induced, unless you are near the heart (the beating heart causes beat to beat small shifts (mini glide) of the lung along the thoracic wall known as the "lung pulse").

2. A-lines

- A-lines (Figure 2.3): A stands for air. **Air is located below the pleural line when the lungs are filled with air and when there is air in the pleural space which occurs with pneumothorax.** Therefore, A lines are seen with normal lung and when a pneumothorax is present.
- A-lines are horizontal white lines equidistant from the skin surface to the pleural line that project through the far field of the ultrasound image.
- They are a type of reverberation artifact that occurs when ultrasound beams are reflected back and forth between the probe and pleural line due to the presence of air below the pleural line
- If only A-lines are present, **AND** a glide sign is present, it means the lungs are **"dry"** at that lung site. In other words, dry lung at this region.

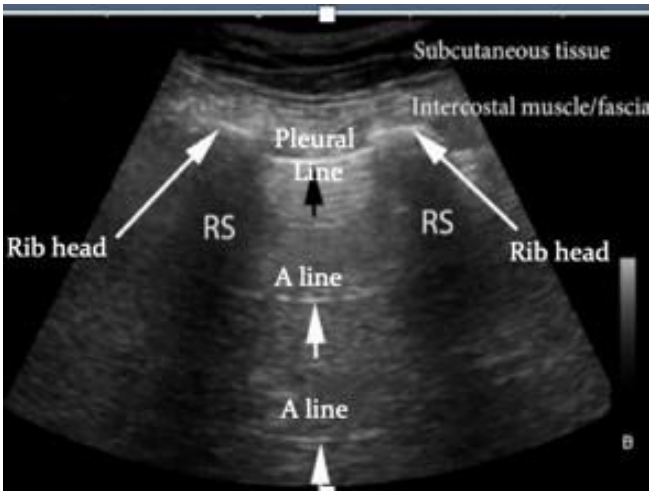


Figure 2.3: A lines are horizontal white lines equidistant from the pleural line that are reflected through the far field image and occur when air is present below the pleural line. Black arrow indicates the pleural line; white arrows indicate A lines.

3. B-lines

- B-lines (Figure 2.4): Laser like vertical white projections arising from the pleural line. Hyperechoic streaks originating from the lung surface of the pleural line, extending through the far field without fading, and swinging to-and-fro with the motion of the lung during respiration.
- B-lines occur most often as the result of air and fluid in proximity to each other at the lung surface. However, B-lines can occur because of an increased number of cells at the lung surface (more information to come).
- The presence of a small number of isolated B-lines may be normal in healthy dogs and cats (noted in 10-30% of patients). Normal b-lines are most often seen as a single B-lines but up to 3 b-lines at a single site can still be normal. Anything more than 3 B-lines at a single site is associated with pathology (AIS). B-lines are also called ultrasound lung rockets (ULRs), ring down artifact, or comet tail artifacts.
- **Key criteria to identify a B-line (ALL criteria must be present):**
  - Vertical white lines
  - Originate at the lung surface
  - Moves with the pleura
  - Extends to the far field
  - Obscures A-lines if present

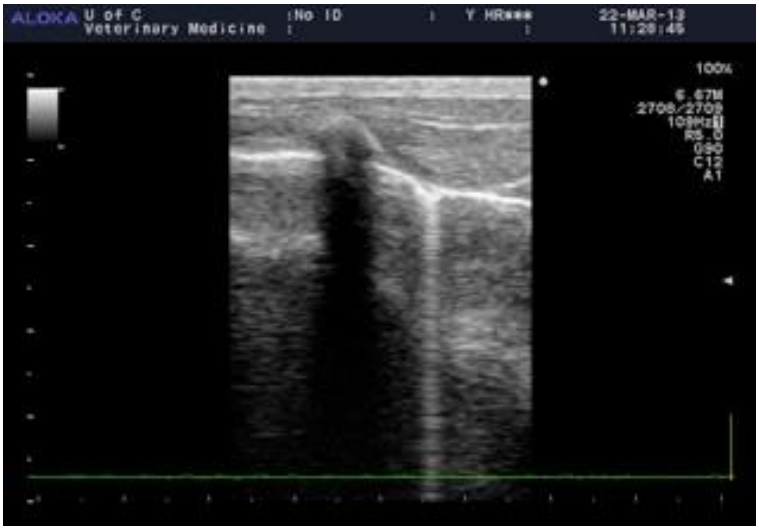


Figure 2.4. B-line. A vertical white line originating from the visceral surface of the pleural line. These lines originate at the lung surface, move with the glide, obliterate A-lines, and extend to the far field. A few scattered B-lines are normal. More than 3 at one site or multiple B lines at multiple sites is considered abnormal (Image courtesy Drs. Serge Chalhoub & Søren Boysen)

4. Dry lung

- Dry lung is identified when the following <u>2 criteria</u> are present:

i. The patient has a glide sign: As stated, this indicates the lung is in contact with the chest wall and it is therefore possible to assess if the lung surface as wet or dry – lungs should not be assessed if they are not in contact with the chest wall

ii. If there are ≤ 3 B-lines present. Up to 3 B-lines in a single window can be considered normal and therefore, ≤ 3 B-lines at a single window suggests the lungs are dry at the surface over which the ultrasound probe is located.

NOTE: The presence of only A lines (which by definition means there are ≤ 3 B-lines present) is also used to diagnose dry lung, however, given A-lines are not always visible (there presence varies depending on the angle at which the ultrasound beam strikes the pleural line and reflected back to the ultrasound probe), the authors prefer to use the criteria of ≤ 3 B-lines when making the decision the lung surface is dry.

5. Curtain sign

- <u>Curtain sign (figure 2.5 as a still image):</u> The caudal border of the thorax is located by identifying the curtain sign; the transition between the thorax and abdomen, which is easily seen with sonography

(see figure below). The abdominal structures are seen because they are soft tissue, contrary to the thorax (air and bone). The curtain sign is not the actual diaphragm. As the diaphragm curves, it detaches from the thoracic wall and therefore air will be present between it and the parietal pleura. As such, we only see the diaphragm where it is in contact with the thoracic wall. Once the diaphragm curves away from the thorax we only see the sharp vertical interface between the thorax (air causes artifact that appears as a straight line of soft tissue interface) and abdomen (soft tissues structures). It is abnormal to see the actual curved diaphragm, and therefore seeing it tells us we have pathology present, usually pleural effusion or lung consolidation (which allow the ultrasound beam to traverse them making the diaphragm visible after it curves away from the chest wall).

- When the ultrasound probe is positioned such that it is both over the thorax and the abdomen with the marker of the probe directed cranially, the cranial half of the image (thorax) will not allow the ultrasound beam to extend past the pleural line (produces A-lines), while the caudal half of the image (abdomen) allows the beam to be transmitted through the far field permitting soft tissue structures to be visible.
- It is important not to confuse the curtain sign (back and forth movement of the diaphragm) with a glide sign. The curtain sign is seen in both healthy patients and patients with pneumothorax.

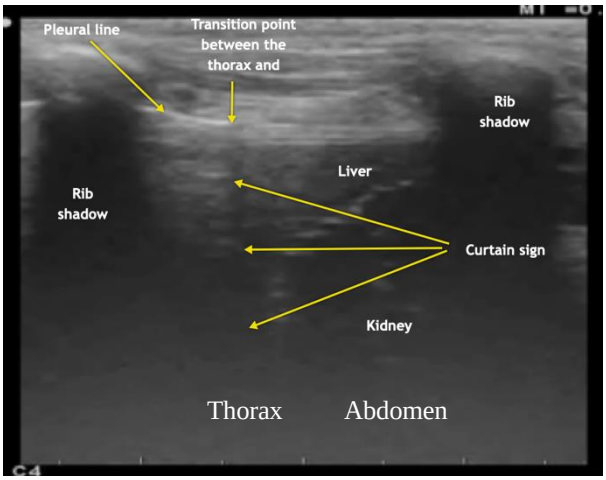


Figure 2.5: Curtain sign: In this image, obtained with a linear array probe, the interface between the thorax and abdomen is visible (arrow). With respiration, this junction will shift caudally during the inspiratory phase which creates the curtain sign. It is sometimes easier to identify the curtain sign if the depth is increased, although it should be decreased again to assess the glide sign and to search for other pathology.

6. Lung pulse

- The lung pulse is simply a “mini glide sign” that can be seen when the heartbeat radiates through the lung to the lung surface. The small beat to beat oscillation of the lung, as a result of the heartbeat, can be seen at the lung surface. The lung pulse rules out pneumothorax at this region and is most often seen in regions close to the heart.

Important binary questions to be asked when performing PLUS

- Regarding the pleural space, the broad clinically relevant questions to ask include:
  - Is there pneumothorax: is there a glide sign or B-lines (if we see b-lines originating from the pleural lune between the ribs, then we can rule out pneumothorax at this site)?
  - Is there pleural effusion?
- Regarding the lung, the broad clinically relevant questions to ask include:
  - Is there alveolar interstitial syndrome (AIS): are there an increased number of B lines?
  - Is there subpleural consolidation and/or thickening of the pleural line? Let’s look at pathology that can be found in the thorax:

Alveolar interstitial syndrome (AIS)

AIS is diagnosed when there are an increased number of B-lines (figure 2.6a,b). A few scattered B-lines at different lung field sites is considered normal. More than 3 B-lines at any single location, or multiple sites is indicative of AIS. The term “Wet lung” is often used when there are increased B lines present (>3 B lines at a single site). This is because most causes of increased B lines are the result of increased extravascular lung water (EVLW). However, it is important to note that any cause of a decrease in the ratio of aerated lung at the lung periphery can result in increased B lines (e.g. it may be the result of increased fluid in the lung (most common cause) but also by increased cell content or even a decrease in the ratio of air in the lung due to atelectasis for example (figure 2c). It is therefore extremely important to consider the causes of increased B lines (and not always assume they are due to “wet lung”) as treatment varies based on the underlying cause. The term “Dry lung” is often used when there is a glide sign and ≤ 3 B lines or only A lines are noted.

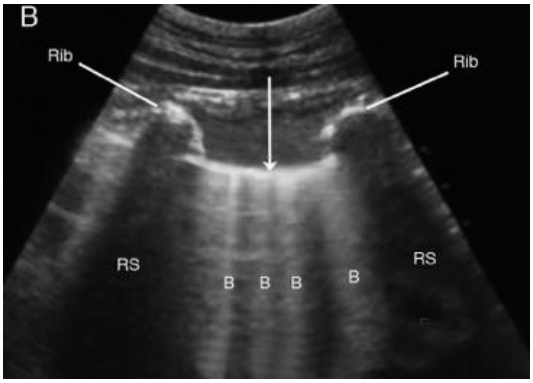


Figure 2.6a: Sonographic image obtained when the ultrasound probe is placed perpendicular to the ribs caudodorsally in a patient in respiratory distress. The ribs appear as the curvilinear white lines to either side of the image with rib shadowing (RS). The first white line that appears distal to the rib, connecting the two ribs, is the pleural line (long white arrow). In patients with interstitial/alveolar disease (e.g. pulmonary edema, contusions, etc.) vertical white lines known as B lines (B) may be noted. These originate at the pleural line, extend to the far field of the image, obliterating A lines, and will move back and forth with respirations similarly to the glide sign. Photo courtesy Dr. Soren Boysen, in Emergency Critical Care, Mathews, 3rd ed, Lifelearn.

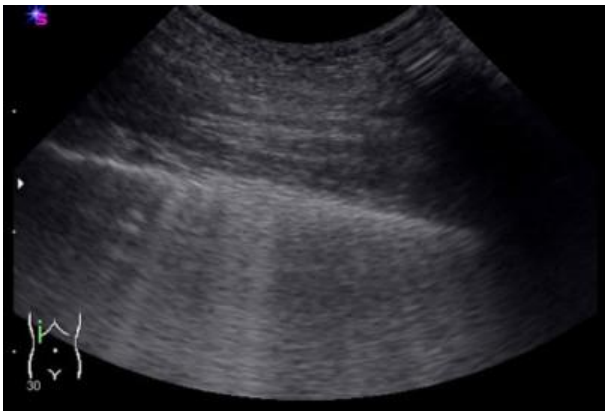


Figure 2.6b. Multiple B-lines extending vertically from the parietal/pleural interface through the far field of the image. Multiple B lines in close proximity indicate lung pathology. This image has a greater number of B-lines than figure 2.21a, indicating worse increased fluid in the lungs of this patient than the patient in figure 2.6a (Image courtesy Dr. Søren Boysen).

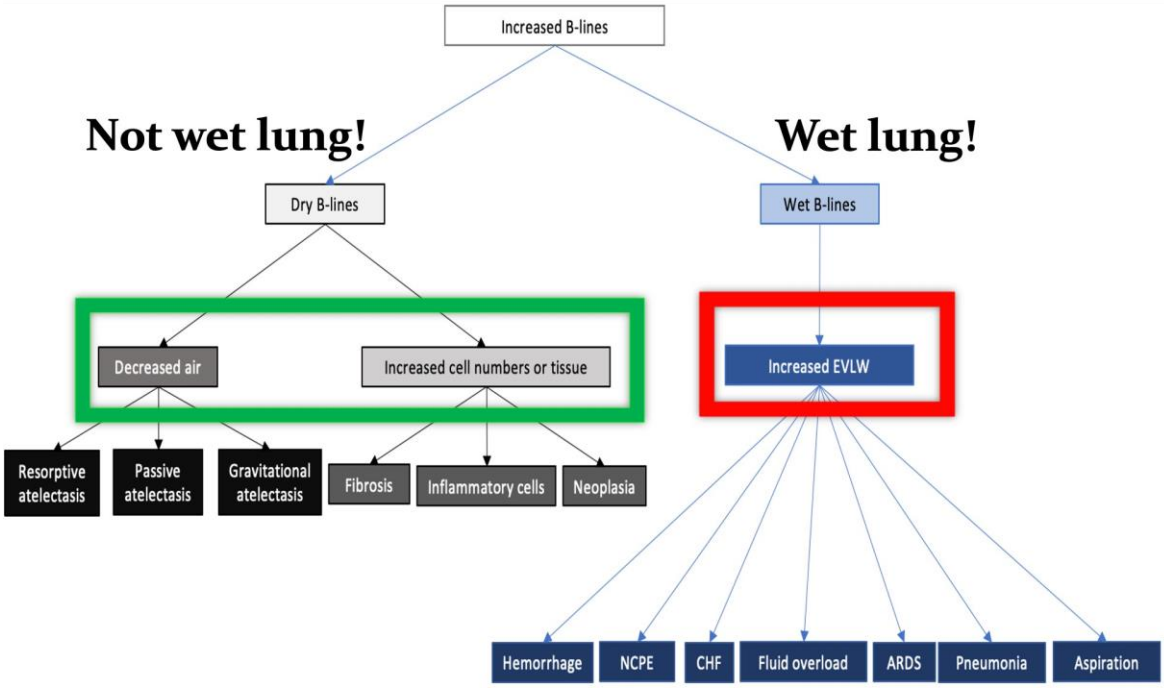


Figure 2c: Algorithm for causes of increased B lines. As therapy for "dry" B lines is different than "wet" B lines, it is important to identify the underlying cause. Wet B-lines are caused by an increase in fluid within the lung, termed extravascular lung water (EVLW). Dry B lines are caused by a decrease of air within the alveoli (atelectasis) or an increase in the cell number or tissue content. EVLW; extravascular lung water, NCPE; non-cardiogenic pulmonary edema, CHF; congestive heart failure, ARDS; acute respiratory distress syndrome.

<u>Sonographic Technique to Identify AIS (see earlier protocol for scan regions):</u>

- The thorax is generally divided into thirds from dorsal to ventral
- The dorsal third of the thorax is scanned first. Start at the same caudal dorsal location as described for identification of pneumothorax (the most caudo-dorsal site of the thorax) using lung borders
- From this site, the probe is slid cranially between intercostal spaces, pausing as necessary to assess the presence of lung pathology.
- Once the dorsal sites of the thorax have been examined (caudo-dorsal to cranio-dorsal up to the cranial PLUS border), the probe is slid ventrally within the intercostal space just caudal to the scapula until the middle third of the thorax is reached (roughly the height of the heart base or peri-hilar region). The probe is then slid caudally, pausing as necessary to assess the lung for the presence of lung pathology, until the curtain sign is encountered (caudal PLUS border).
- Lastly, the probe is slid cranially and ventrally along the curtain sign until the pericardio- diaphragmatic window is identified. The probe is then turned parallel to the ribs at this location and

slid ventrally until the sternal muscles are seen. The probe is then slid cranially a rib space at a time until the cranial thoracic inlet is identified at roughly the third intercostal space.

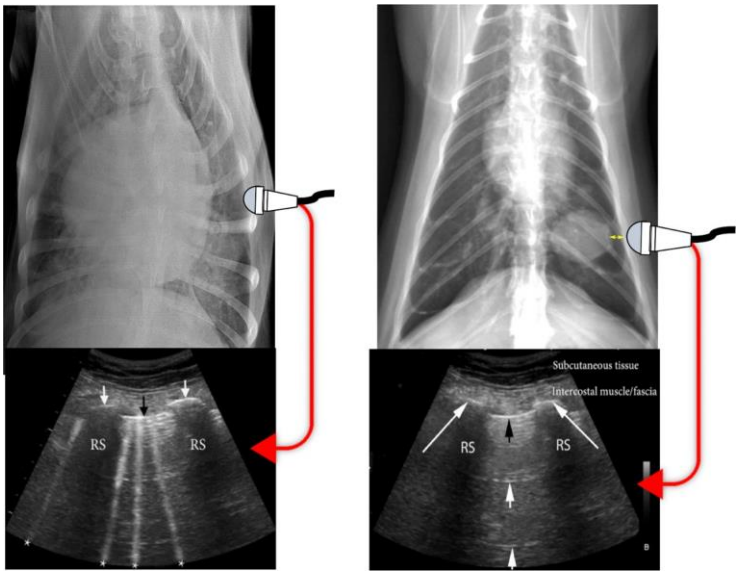
- The heart will be encountered using this technique, at which point the probe can be slid dorsally from the ventral region until lung is encountered to look for the lung pathology. The probe remains parallel to the ribs while it is slid dorsally.
- The probe is then returned to the ventral regions, remaining parallel to the ribs (to ensure pleural effusion is not missed while also looking for lung pathology) and advanced cranially until the thoracic inlet is encountered.
- The protocol essentially makes an "S" (left side) or reverse "S" (right side) shape of scanning to maximize lung and pleura examined.
- The same protocol is used on the opposite side of the thorax
- B-lines can also be identified at the subxiphoid site and this view should be included in the lung ultrasound search for B-lines.

<u>Key considerations of b-lines:</u>

- B-lines can originate anywhere, which is why it is important to scan multiple portions of the lung. See our approach at the start of this section.
- The number of B-lines correlates with the severity of AIS (the more B lines the "wetter" the lungs).
- If B lines become so numerous, they coalesce it can be difficult to identify their presence. When this occurs A-lines will not be visible, the pleural line is often irregular and if the probe is moved to other regions individual B lines will often become visible as less severely affected lung regions are encountered.
- When AIS is identified on lung ultrasound, the same differential diagnosis should be considered as an interstitial-alveolar pattern on thoracic radiographs.
    - Aspiration pneumonia in the vomiting dog, pulmonary contusions in the hit by car etc..
- Although the distribution of AIS can help with the diagnosis (e.g. a cranial ventral pattern of AIS on lung ultrasound, particularly with concurrent lung consolidation is consistent with bronchopneumonia), similar to the distribution of interstitial-alveolar syndrome on radiographs,

the differential diagnosis for AIS on lung ultrasound should be considered in light of the history and other clinical findings.

NOTE: Lung ultrasound will only detect lung pathology if the pathology is at the periphery of the lung (outer 3mm) – fortunately most diseases that cause AIS (cardiogenic pulmonary edema, trauma induced contusions, aspiration pneumonia, etc.) will reach the lung surface (figures 2.7a, b).



Figures 2.7a, b: in figure 2.7a the pathology reaches the lung surface and the subsequent artifact produced will be detected using lung ultrasound. In this case the artifact created by the underlying lung pathology is an increased number of B-lines indicative of alveolar interstitial syndrome. In figure 2.7b there is air separating the lung mass from the lung surface and therefore will not be detected on lung ultrasound. At this location, a normal pleural line and A-lines will be detected as there is air between the lung and the mass and ultrasound cannot traverse air.

<u>Some pitfalls to note when performing lung ultrasound:</u>

- <u>Z-lines</u> (figure 2.8): these lines arise from the parietal pleura (thoracic wall side of the pleural line), not the lung surface. Therefore, they do not move with the glide sign and the do not erase A-lines. They are ill-defined and disappear after 2-5 cm. Significance unknown (not associated with known pathology). They are present in > 80% of healthy dogs. They can be seen in patients with pneumothorax.

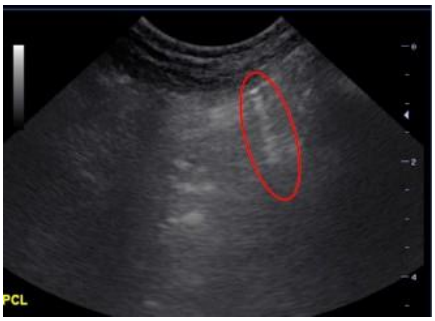
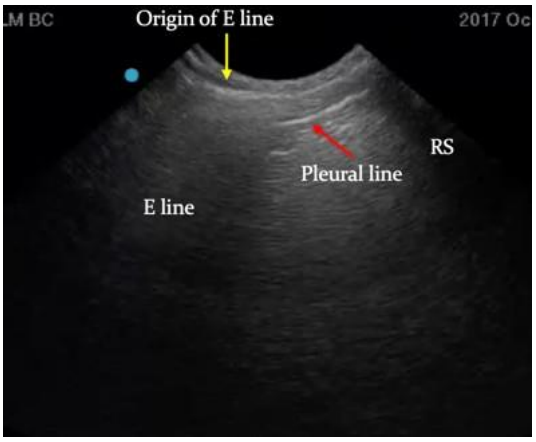


Figure 2.8: Z-lines (circled in red) arise from the parietal pleura (thoracic wall side of the pleural line), do not move with the glide sign and the do not erase A-lines. They are ill-defined and disappear after 2-5 cm.

- E-lines (figure 2.9) come from subcutaneous emphysema and they do form a comet tail like b-lines. They are identified by the fact they originate proximal (superficial) to the pleural line and therefor pass through and obliterate the pleural line. Caused by accumulation of air in the subcutaneous tissues. They do extend to the bottom of the ultrasound screen, but do not move with respirations.

Figure 2.9: E-lines come from subcutaneous emphysema and they do form a comet tail like b-lines.



- Placing the probe over the stomach or at the curtain sign and failing to realize the probe location can sometime lead to a false positive finding of B lines (figure 2.10).

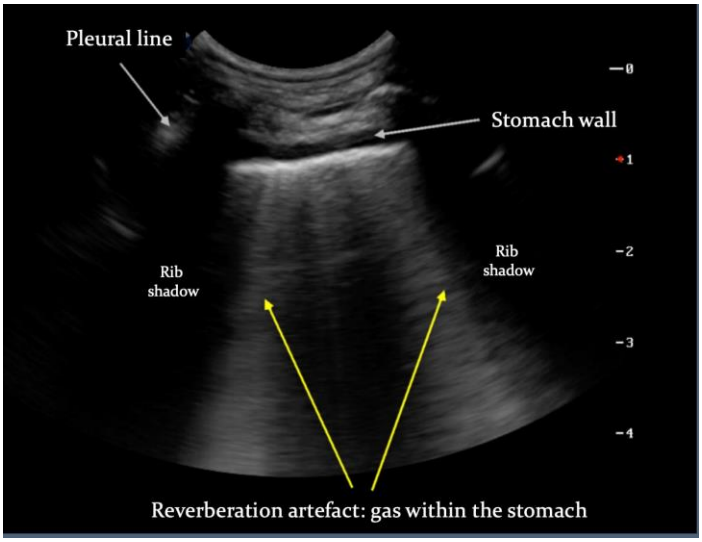


Figure 2.10: The importance of ensuring the ultrasound probe is placed over lung. In this image the probe is placed over the stomach, that is within the rib cage on the left side of the patient at the 9th intercostal space, 2/3 of the way up the thorax. The curtain sign is located behind the cranial rib and rib shadow and is therefore difficult to see. The pleural line is just visible in the cranial part of the image and more superficial than the stomach wall. The presence of gas in the

stomach can easily be confused for B lines but is easier to identify if the probe is moved caudally from lung onto the stomach.

<u>B lines summary</u>

- Occasional B lines are normal
- < 3 per site at only 1-2 sites per side of the chest
- Increased B lines indicate alveolar interstitial syndrome (AIS)
  - ▶ > or = 3 per site
  - ▶ Need to consider with history/physical exam findings
    - ■ Congestive heart failure = diffuse bilateral
    - ■ Aspiration pneumonia, initially ventral
    - ■ Can be unilateral with some pathologies
- Don't confuse Z lines or E lines for B lines

Stop and assess if they move with the glide sign and accentuate or obliterate A lines

Pleural effusion

Pleural effusion appears as hypoechoic accumulations between the thoracic wall and lungs. Often irregular in shape and distribution, forming angles. Curves up and around the diaphragm at the pericardio-diaphragmatic window. Although the lung surface and thoracic wall surface are visible on either side of the pleural fluid, because the lung and thorax wall are not in contact, a glide sign is not seen with pleural effusion. Important thoracic findings when looking for pleural effusion:

- The presence of a glide sign excludes pleural effusion at the site of probe placement, as the presence of a glide sign requires contact of the surface of the lung with the chest well (air or fluid in the chest cavity prevent the lung from contacting the chest wall).

- Pleural effusion appears as the absence of a glide sign with anechoic fluid between the chest wall and the hypoechoic lung, or as anechoic triangles adjacent to the heart and outlining the diaphragm (outside the pericardial sac).
- The two pleural POCUS regions used to identify pleural effusion include 1) subxiphoid window and

2) the transthoracic windows in the ventral regions of the thorax.

- Patient positioning is important to consider when searching for pleural effusion and different techniques are required to identify small quantities of fluid with patients in lateral vs. sternal/standing positions.
- In lateral recumbency, fluid accumulates at the widest gravity dependent sites of the thorax, generally at the pericardial window (figure 2.11).
- In sternal recumbency (preferred position to scan acutely dyspneic patients), effusion will accumulate ventrally (figure 2.12).

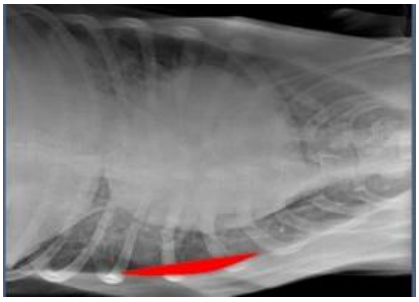


Figure 2.11: The pericardial window, with the patient in lateral recumbency, is a good place to search for pleural effusion as it is the widest most gravity dependent site.

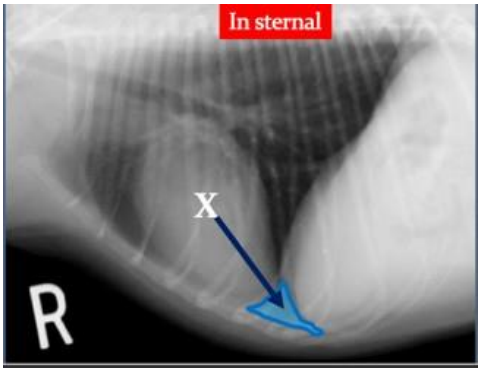


Figure 2.12: Site where small fluid accumulations are likely to accumulate with the patient in sternal recumbency. Small accumulations of pleural fluid may be difficult to locate with traditional pleural scanning techniques, and moving the probe off the pericardial regions, into the more ventral areas, will likely increase the likelihood of finding it.

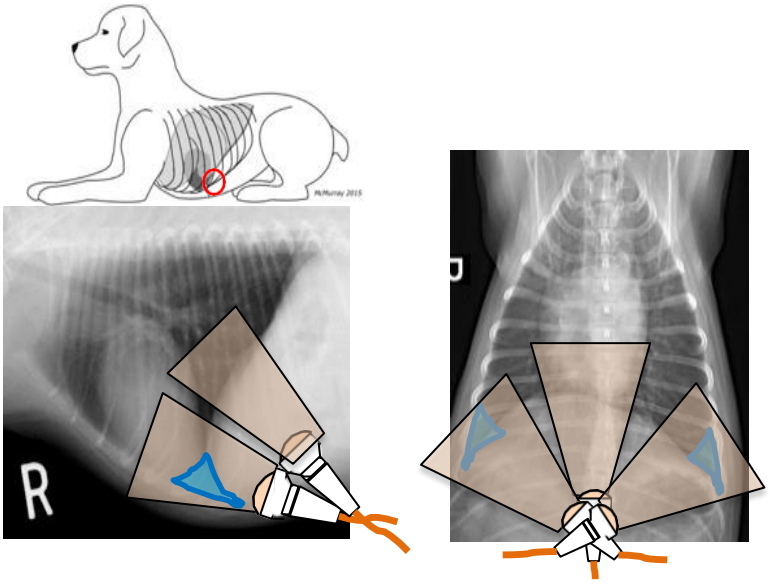
Sonographic techniques to Identify pleural effusion:

- Subxiphoid scanning (figures 2.13)

○ The subxiphoid view with the depth increased beyond the level of the diaphragm can be used to detect pleural effusion.

○ The probe needs to be more parallel in orientation (relative to the spine) and the depth setting adjusted (set deeper) compared to the angle and depth used for POCUS of the abdomen, to allow the ultrasound beam to extend into the thorax via the liver.

○ At the subxiphoid location the probe should be fanned and rocked in long and short axis to increase the chance of finding smaller accumulation of pleural fluid.



Figures 2.13: It is important to rock and fan the probe at the subxiphoid location to ensure small quantities of pleural fluid can be detected.

- Transthoracic windows

○ Transthoracic windows with the patient in lateral recumbency, at the pericardial gravity dependent and widest point of the thorax are good sites to identify pleural effusion (Figures 2.11 and 2.12).

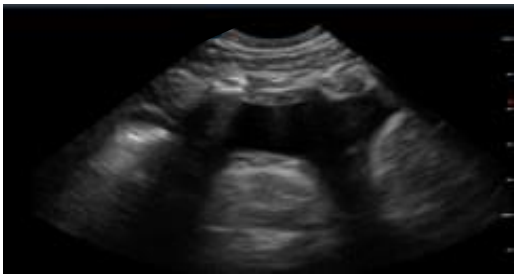


Figure 2.14: Pleural effusion scanning via the ventral parasternal widow. In this image the ultrasound probe is perpendicular to the ribs and an anechoic (black) area of fluid can be seen separating the lung from the chest wall. Note that rib shadowing is still visible in this image which makes the lung appear to be "broken" into sections.

- Sternal patient

○ With the patient in sternal recumbency, a different technique is used to identify smaller quantities of fluid.

○ Moving the probe off the heart and into the ventral regions between the heart and the diaphragm (pericardio-diaphragmatic window; using PLUS borders this would be the caudoventral site) allows easy differentiation of pleural from pericardial effusion and is a good area to identify large and small quantities of pleural effusion (figures 2.15a, b, c).

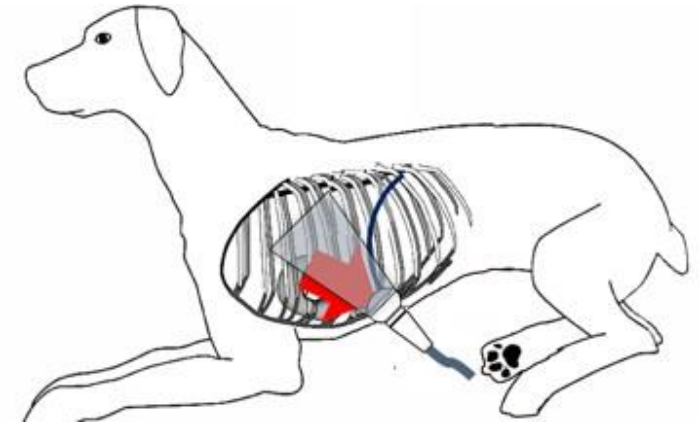


Figure 2.15a: The pericardio-diaphragmatic window can be located by placing the probe over the heart and diaphragm in the ventral region of the thorax (5th-6th intercostal space). It can be found by either sliding caudally off the heart until the curtain sign is located, or by sliding down along the curtain sign until the heart is located. Using lung and pleura border facilitates identification of this region (ventral and caudal borders).

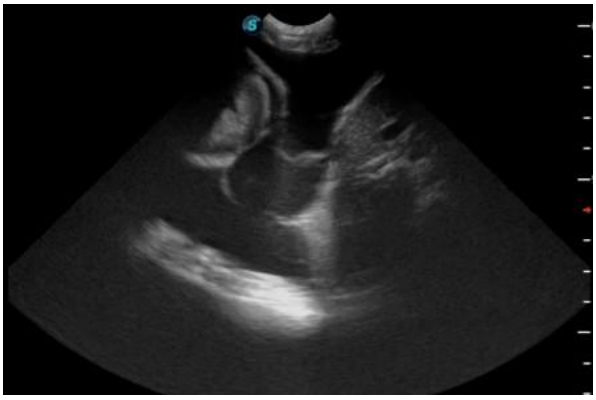


Figure 2.15b: In this image, from a cat, the probe is located just caudal to the heart where the curtain sign is also visible (pericardio-diaphragmatic window). This location helps differentiate pericardial from pleural fluid as pericardial fluid surrounds the heart while pleural fluid curves up and around the diaphragm.

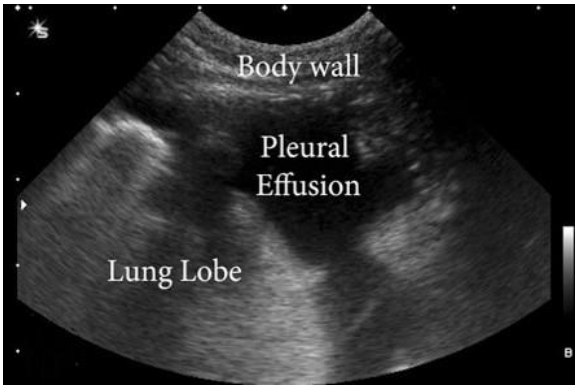
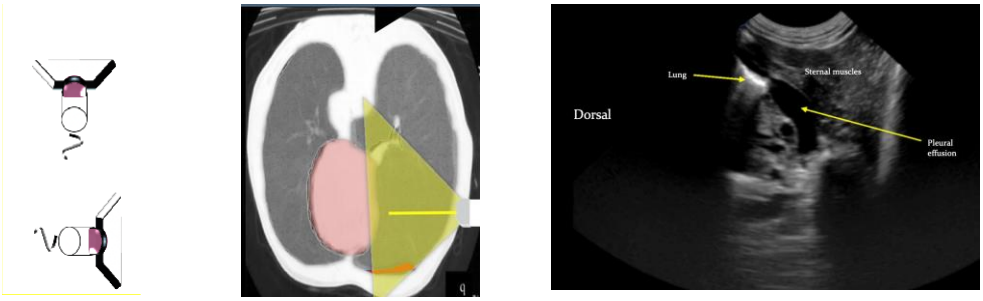


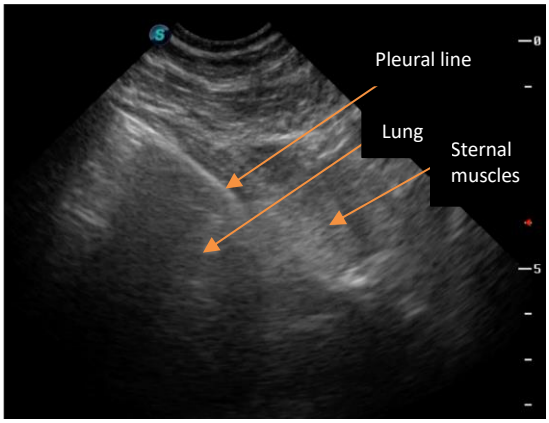
Figure 2.15c: In this image the probe is located near the pericardio-diaphragmatic junction in the ventral thorax. The heart is not visible as the probe has been fanned such that the ultrasound beam is just dorsal to the heart. Pleural effusion is visible between the lungs and the diaphragm (the diaphragm/abdomen is on the right of the image, not labeled).

- The area cranial to the heart should also be evaluated for the presence of pleural effusion.
- At the most ventral areas of the thorax, including the pericardio-diaphragmatic sites, if pleural effusion is not identified with the probe perpendicular to the ribs, the probe can be turned parallel to the ribs to try and identify smaller accumulations of fluid between the lung and ventral body wall (figures 2.16a, b, c).
- When the probe is parallel to the ribs and there is no pleural effusion, the pleura will be in contact with each other and the authors have called this the “ski slope” sign. When there is pleural effusion, the fluid will separate the pleura. The presence of fluid between the lung and ventral sternal muscles, with the probe parallel to the ribs creates a curved triangular shape similar to a sail. As the animal breathes and the lung expands and contracts the fluid

pocket increases and decreases in size giving the appearance of a sail in the wind. As such, the authors have termed this the “sail sign” (figures 2.16d, c).



Figures 2.16 a,b,c: The probe is turned from a perpendicular to a parallel orientation (relative to the ribs) to identify smaller quantities of pleural effusion 2.16a) Schematic of the ultrasound probe and beam perpendicular (upper) and parallel to the ribs (lower) 2.16b) Schematic indicating the greater ventral areas of the pleural space and thorax that can be visualized when the ultrasound beam is orientated parallel to the ribs and slid ventrally until the sternal muscles are identified. 2.16c) Pleural effusion noted at the right ventral parasternal site with the probe parallel to the ribs (marker dorsally), cranial to the heart, and just ventral to the costal chondral junction. A small amount of fluid is noted where the lung curves away from the muscles of the sternum. In a breathing patient, the filling and emptying of the lung at this region changes the distribution of the plural effusion, giving the impression of a sail flapping in the wind (“sail sign”).



Figures 2.16 d. The probe can be turned from a perpendicular orientation to the ribs to a parallel orientation to the ribs to identify smaller quantities of pleural effusion ventrally. The probe is parallel to the ribs at the level of the junction of the heart and diaphragm (pericardio-diaphragm junction). The image above is what the authors have termed the “ski slope” sign where there is no fluid separating the pleural line, and the pleural line can be seen sloping downwards.

<u>In summary, increasing sensitivity for finding pleural effusion can be achieved by:</u>

- <u>Scanning ventrally and caudally</u> between the diaphragm and the heart
- <u>Scanning ventrally and cranial to the heart</u>
- <u>Turning the probe parallel to ribs</u> in ventral areas of the thorax
- <u>Rocking and Fanning</u> the probe widely and ventrally at the subxiphoid site

Pneumothorax

It is essential that patient positioning and the underlying pathology be considered when it comes to diagnosing pleural space pathology. Air and fluid accumulate in different regions of the pleural space depending on the position in which the patient is evaluated. Fluid tends to accumulate in the most gravity dependent areas while air tends to rise to the non-gravity dependent areas of the pleural space. Adhesions and loculated fluid accumulations may contain fluid and prevent it from reaching the most gravity dependent locations with a change in patient position.

There are 3 key findings that help identify the presence of a pneumothorax, two are exclusion criteria, one is an inclusion criteria.

1) Pneumothorax appears as the absence of a glide sign. The presence of a glide sign rules out pneumothorax with confidence. Lack of a glide sign should prompt consideration of pneumothorax, but a glide sign is not always easy to identify, even in healthy patients.
2) The presence of B-lines excludes pneumothorax at those focal probe placement sites because B-lines originate from the lung surface. B lines are not always visible in healthy patients.
3) Finding a lung point confirms a pneumothorax on that side of the thorax. If the glide sign is not seen and there is strong suspicion of a pneumothorax a search for the lung point should be undertaken as identification of the lung point is pathognomonic for a pneumothorax.

The presence of a glide sign excludes pneumothorax at the probe placement site, as the presence of a glide sign requires contact of the surface of the lung with the chest well (air or fluid in the pleural space will prevent the lung from contacting the chest wall and prevent shimmer of the glide sign from occurring). It is important to hold the probe stationary on the skin surface when evaluating the glide sign, as movement of the probe along the skin surface can create a false appearance of a glide sign.

<u>Sonographically standardizing the most sensitive thoracic site to diagnose pneumothorax:</u>

Air will accumulate at the most caudal dorsal portion of the thorax when the patient is sternal recumbency or in the standing position (figure 2.17).

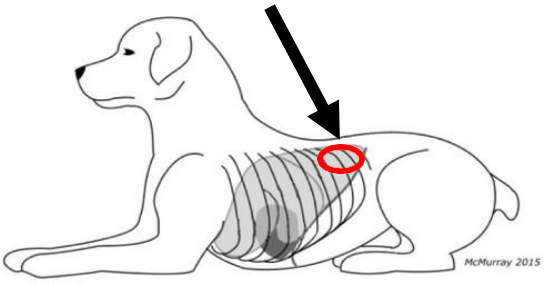


Figure 2.17: Preferred location for detection of pneumothorax when the patient is in sternal. Starting at a location too low on the thorax is probably the biggest error novice sonographers make; this identifies a glide sign and misses the presence of a pneumothorax dorsal to the probe location.

Sternal recumbency is the preferred position in which to scan acutely dyspneic patients as it minimizes respiratory distress and subsequently the work of breathing associated with restraining the patient in lateral recumbency. To begin with, the "bat" or "gator sign" should be identified by placing the probe perpendicular to 2 ribs. MAKE sure you are over lung! To ensure this, place the probe just caudal to the scapula/biceps/triceps muscles (cranial PLUS border) 1/2 to 2/3 of the way up the thoracic wall at about the 6th or 7th intercostal space to ensure the probe is initially place over lung (figure 2.18). The bat sign is confirmed, and glide sign assessed.

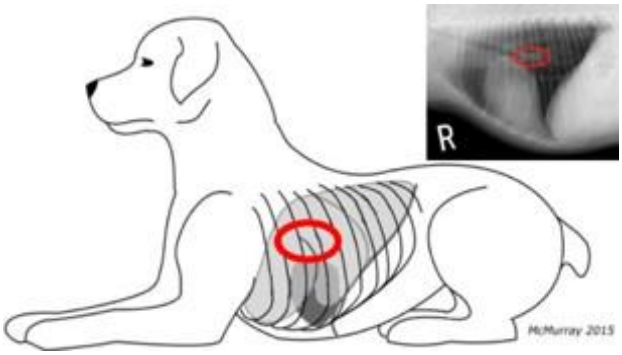


Figure 2.18: Palpate the scapula and caudal dorsal of the associated muscles about 1/2 to 2/3 of the way up the thorax (roughly the 6th intercostal space at the heart base) to ensure the probe is over lung.

If a glide sign is present, the probe is rapidly moved caudally a rib at a time until the curtain sign (caudal PLUS border) is identified (figure 2.19).

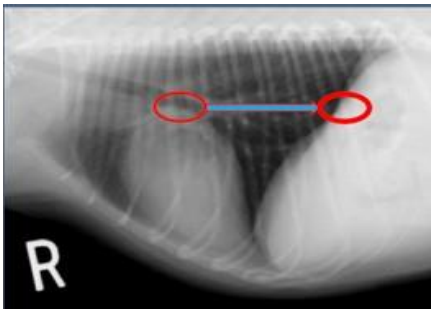


Figure 2.19: Slide the probe form the staring location over lung caudally one rib space at a time until the transition between the thorax and the abdomen is identified as a vertical line called termed the curtain sign (caudal PLUS border).

Once the curtain sign is seen, the dorsal border of the thorax is identified by sliding the probe dorsally into the epaxial muscles until the pleural line is no longer visible, then sliding the probe ventrally until the pleural line is just visible again (dorsal PLUS border) (figure 2.20).

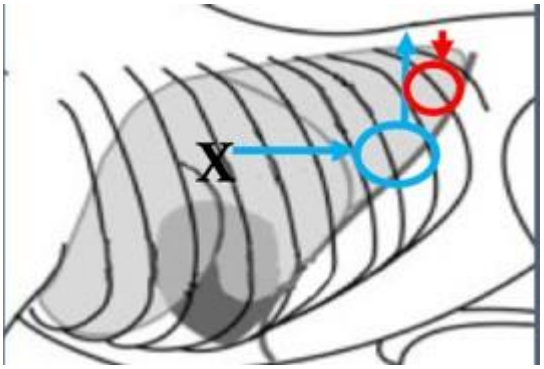


Figure 2.20: Following identification of the curtain sign (caudal lung thoracic border) the probe is slid dorsally until the pleural line disappears as a result of transitioning from lung onto the epaxial muscles. The probe is then slid ventrally again until the pleural line is just visible. This is the most dorsal and caudal site where air is most likely to accumulate and where the greatest lung movement occurs, assisting with identification of the glide sign.

Now you have identified the most caudal-dorsal site, which is the most sensitive site for air to accumulate with the patient in sternal, and also the region that has the most lung movement making it easier to identify a glide sign. If the patient is scanned in lateral recumbency air will accumulate at the widest part of the chest, and the probe location to identify free air should change to reflect this (figure 2.21). It is important not to move the probe when assessing the presence of a pneumothorax as moving the probe creates a false “glide sign”.

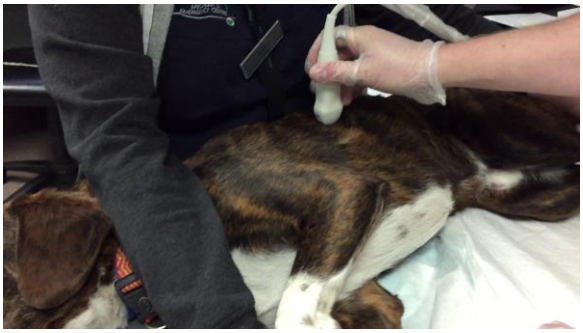


Figure 2.21: In lateral recumbency air accumulates at the widest point of the thorax, which is where the ultrasound probe should be placed to rule out pneumothorax.

Defining the lung point:

If the glide sign is identified with confidence it rules out pneumothorax. Unfortunately, it is not always easy to identify a glide sign with confidence. If this is the case, a pneumothorax can be confirmed by identifying the lung point. The lung point is defined as the site within the thorax where the lung recontacts the parietal pleura and creates an *intermittent glide sign* within half the ultrasound beam when the patient breathes. It is the exact point within the thorax where there is a return of the glide sign: movement of the probe from an area where there is no perceived glide sign, to an area where the glide sign reappears intermittently within a region of the ultrasound image (figures 2.22-2.24).

- If a glide sign is visible when the probe is initially placed on the patient (at the 6th intercostal space near the heart base) proceed with the steps described above to ensure there isn't a pneumothorax at the most caudal-dorsal site.
- If a glide sign is noted at the most caudal-dorsal site, then there is no pneumothorax on that side of the patient. Other lung pathology and pleural effusion should be sought out, but it is not necessary to look for a glide sign on that side of the thorax with the patient in sternal recumbency. Make sure to check the other side of the thorax as well.
- If there is no glide when the probe is initially placed on the patient (at the 6th intercostal space near the heart base), or the glide sign is not present at the caudo-dorsal location of the pleural space with the patient in sternal/standing, then slide the probe cranially and ventrally until the lung point is found.
- It is important to allow the patient to take a breath as the probe is moved ventrally as the lung point/glide sign is only visible during the respiratory cycle.

• To find the lung point the probe is slid cranially and ventrally (remembering that the diaphragm curves inwards and therefore the probe must be slid ventrally and cranially), until you note a point of lung reconnecting with the thorax wall OR you see a glide again (Figure 2.22).

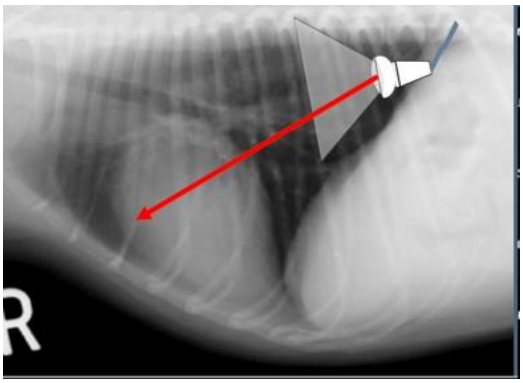


Figure 2.22: The probe is slid cranially ventrally from an area where the glide sign is not visible (in this image the most caudal dorsal site) in search of the area where the lung recontacts the chest wall (unless a severe pneumothorax is present and prevents any lung contact with the parietal pleura).

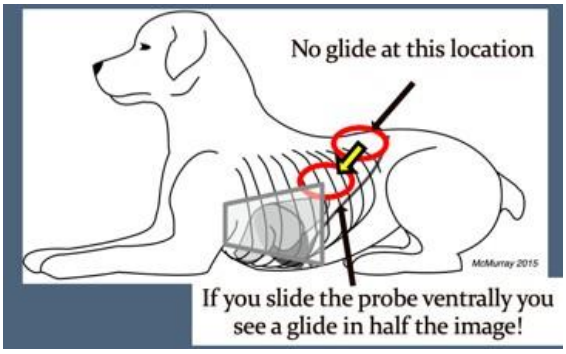


Figure 2.23: A schematic image showing the ultrasound probe location (starting point) where the glide sign is not present, and a second probe location midway down the thorax where the lung will recontact the parietal surface within the ultrasound beam creating an intermittent glide within a portion of the ultrasound image when the patient breathes.

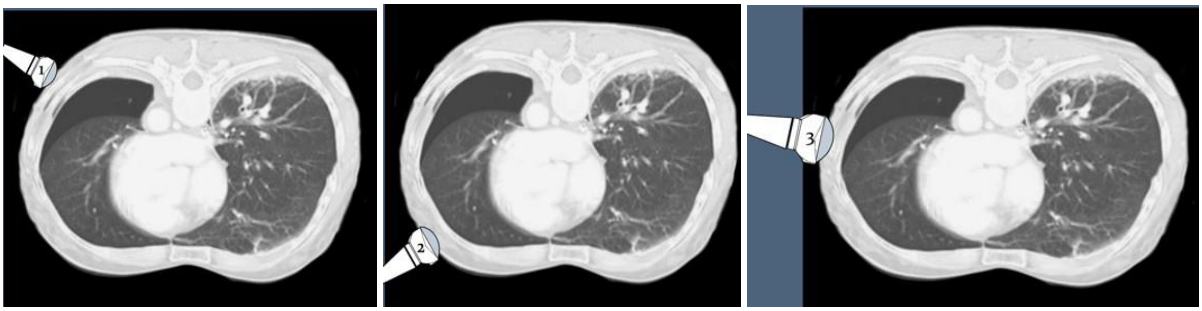


Figure 2.24: CT images of a pneumothorax. At probe location 1 the probe is placed over a pneumothorax. At this site A lines will be seen due to the presence of air in the pleural space, but a glide sign will be absent. At probe location 2 the probe is place over lung and therefore a glide sign will be noted when the patient breathes as the lung is continually in

contact with the parietal surface of the thorax. At probe location 3 the probe is placed over an area of pneumothorax close to lung. At this location, when the patient breathes, the lung will expand, reducing the size of the pneumothorax thus creating an intermittent glide as expanding lung enters and deflating lung leaves the probe site location.

Occasionally the exact location where the lung recontacts the parietal surface of the thorax is not seen (figure 2.25). In this case, if there is a pneumothorax and the lung recontacts the parietal surface of the thorax then the probe will move from the absence of a glide sign to the presence of a glide sign (intermittent glide within a portion of the ultrasound beam is not seen).

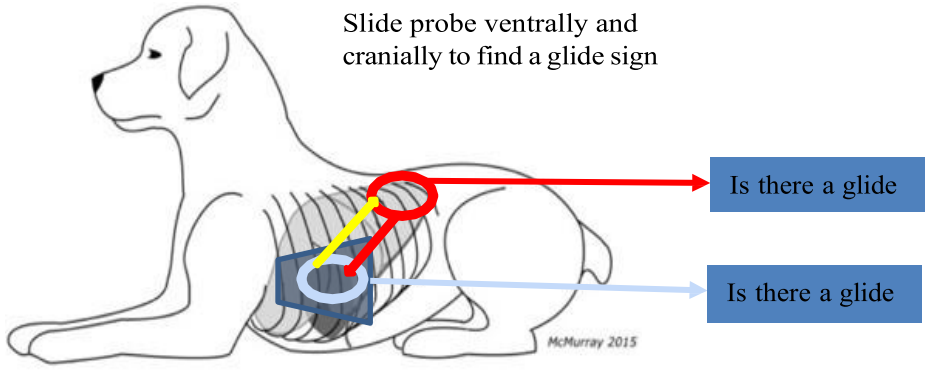


Figure 2.25: How to find a lung point or a glide from pneumothorax: sliding the probe from dorsal to ventral and looking for the reappearance of a glide (actual lung point is not seen).

It is important not to confuse the curtain sign with a lung point. The curtain sign is simply the movement of the diaphragm and it appears as a "curtain" that comes across the caudal lung fields during expiration (moves caudally with inspiration). This is a normal finding and simply indicates the transition between the thorax and abdomen. In patients with extensive pneumothorax, there will not be a lung point if the lung does not recontact the parietal pleura on that side of the thorax. Most of these patients are sufficiently dyspneic to justify thoracentesis without the need to confirm a lung point.

Lung Consolidation

Sonographically-detected subpleural consolidations can occur as a result atelectasis, bronchopneumonia, thromboembolism, neoplasia and in cases of pulmonary contusions and ARDS. The differential diagnosis for subpleural consolidation should be considered in light of the entire clinical picture, history and to some degree, the shape and distribution/severity of the consolidation.

Criteria to diagnose lung consolidation:

- Abnormal pattern should be in thorax (should be differentiated from the liver or spleen)
- Should arise from the pleural line
- There should be a tissue like pattern (similar to liver echotexture)
- Anatomic boundaries must be present:
  - Superficial boundary of consolidation
  - At the pleural line in the absence of pleural effusion
  - At the deep boundary of a pleural effusion if effusion present
  - Deep boundary of the consolidation may be irregular (aerated lung boundary: figure 2.26a) or regular (if whole lobe is consolidated: figure 2.26b)
  - Where consolidation fails to reach the deep border of the lung and comes in contact with air an irregular consolidation/air interface is created referred to as a "shred sign" (figure 2.26a), or if the border is smooth and circular-like this can represent a nodule (figure 2.26d).
  - Where consolidation extends through the entirety of the lung, from one surface to the other, hepatization or a tissue sign is seen (figure 2.26b).
- Air bronchograms can be seen within the consolidation (figure 2.26c).

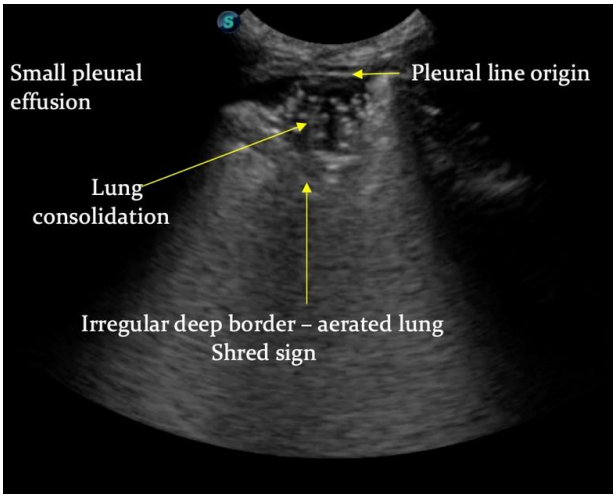


Figure 2.26a: Partial subpleural lung consolidation where aerated lung is found below the area of consolidation creating an irregular deep border to the consolidation known as a "shred sign".

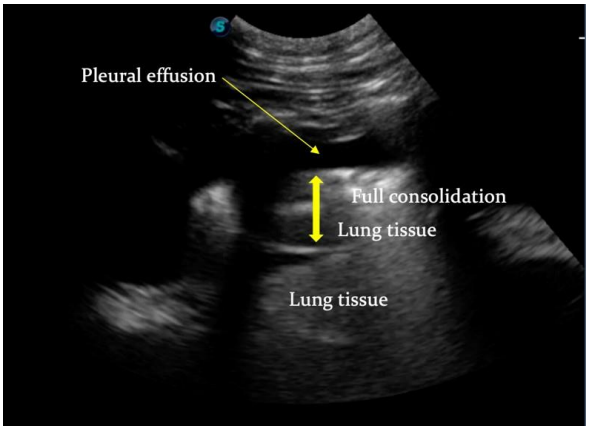


Figure 2.26b: Where consolidation extends from one surface of the lung to the other, with no air between the consolidation and the deep lung surface the consolidation is referred to as a tissue sign or hepatization.
Air bronchograms can be seen within lung consolidation appearing as white dots or lines, depending if they are visualized end on or in longitudinal planes.

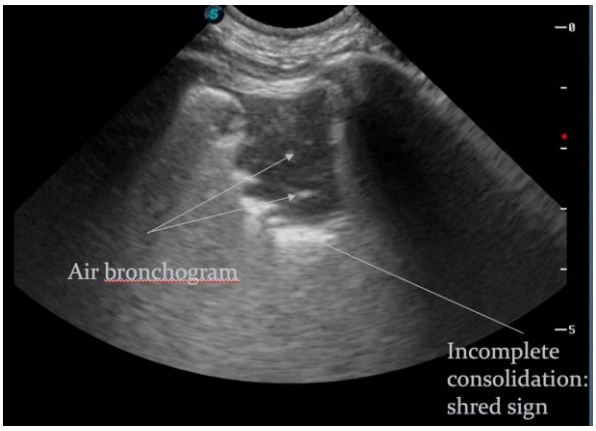


Figure 2.26c: Air bronchograms can be seen within consolidated lung as white punctate dots on cross section of the airway and lines on longitudinal planes over the airways.

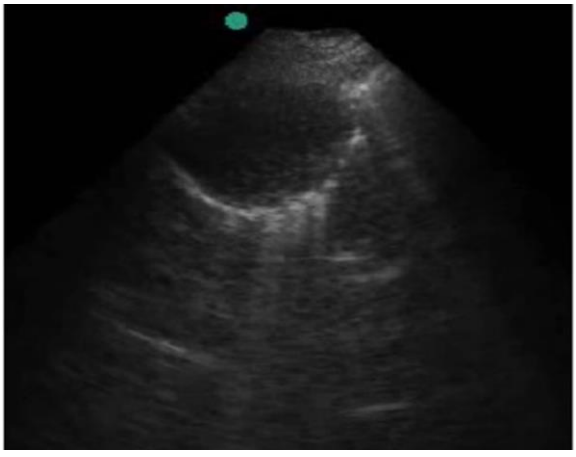


Figure 2.26d: Lung nodule. A nodule is an incomplete consolidation. Contrary to a shred, its borders are more circular and smoother.

In summary, PLUS:

- The protocol you use to examine the thorax does not matter as long as you are consistent.
- We promote a clinically-oriented binary question approach to rule out important thoracic pathology. Prior to answering these questions, you MUST first determine how patient position will affect the detection of pathology. The binary questions to answer:
  - Is there a pneumothorax Y/N?
  - Is there pleural effusion Y/N?
  - Is there AIS Y/N?
  - Is there lung consolidation Y/N?
- If a patient is sternal, below is the protocol we currently use the PLUS protocol described in Figure 2, and use PLUS borders to ensure full scanning of the lung and pleura.
- The following diagram identifies each binary question and step-by-step findings (Figure 2.27).

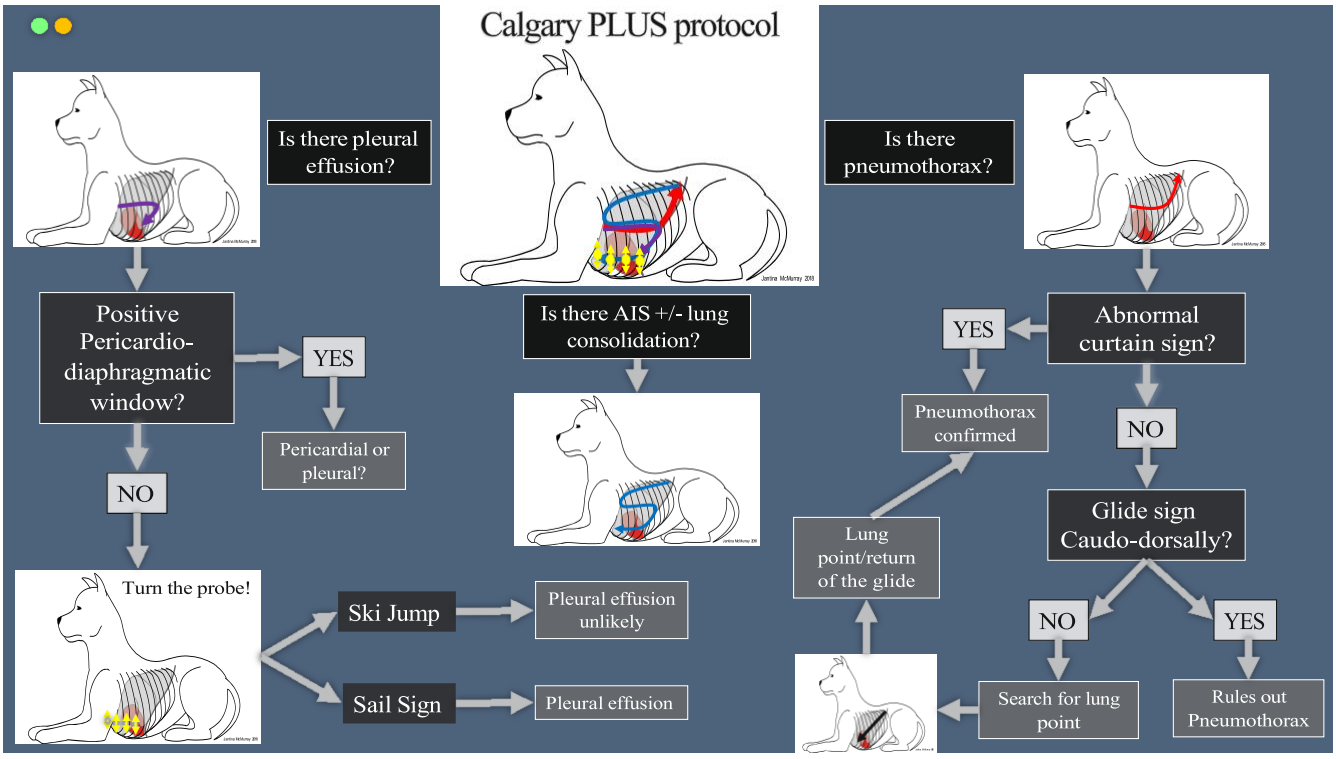


Figure 2.27. The complete Calgary PLUS protocol for pleural space and lung POCUS, with the typical binary questions asked during ultrasound of this region.

Cardiac POCUS

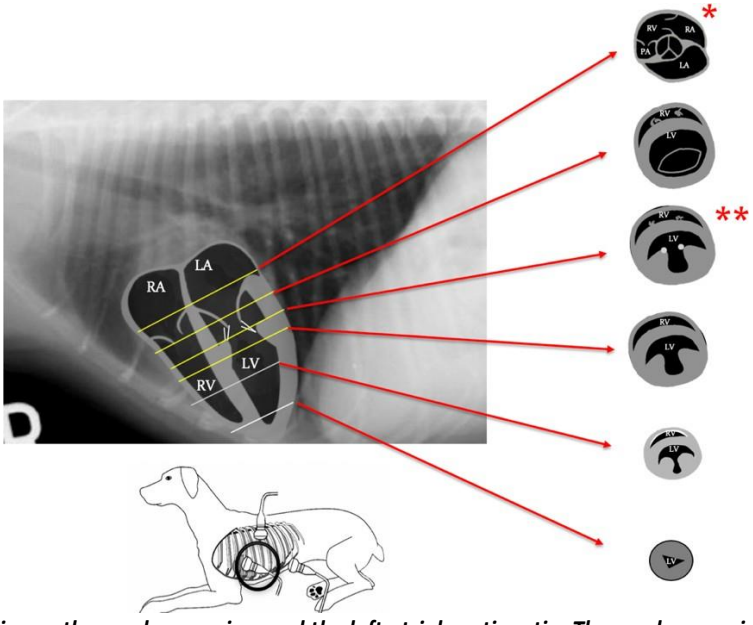
The goal of cardiac POCUS is not an extensive echocardiogram of the heart. Rather, cardiac POCUS is used as an extension of the triage exam to be able to answer clinically relevant binary questions:

- Does this patient have pericardial effusion?
- Is there decreased contractility?
- Is there volume depletion or volume overload?
- And lastly, are this patient's clinical signs more related to respiratory disease or cardiac disease with evaluation of the left atrium to aorta ratio (LA:Ao)?

<u>Normal cardiac views assessed on cardiac POCUS:</u>

There are many views that can be obtained on short axis right parasternal imaging of the heart (figure 3.1). However, there are only <u>3 key windows</u> with cardiac POCUS that will identify the majority of pathologies we are worried about: 1) the 4-chamber long axis right parasternal view (figure 3.2b), 2) the mushroom (figure 3.2a, 3.1) and 3) left atrial aortic view of the right parasternal short axis view (figure 3.1).

Figure 3.1: There are many right parasternal right axis views of the heart, however the two key views that are most important to attain are the mushroom view and the left atrial aortic ratio. The mushroom view is indicated by two red asterisks and the left atrial aortic ratio view by a single red asterisk.



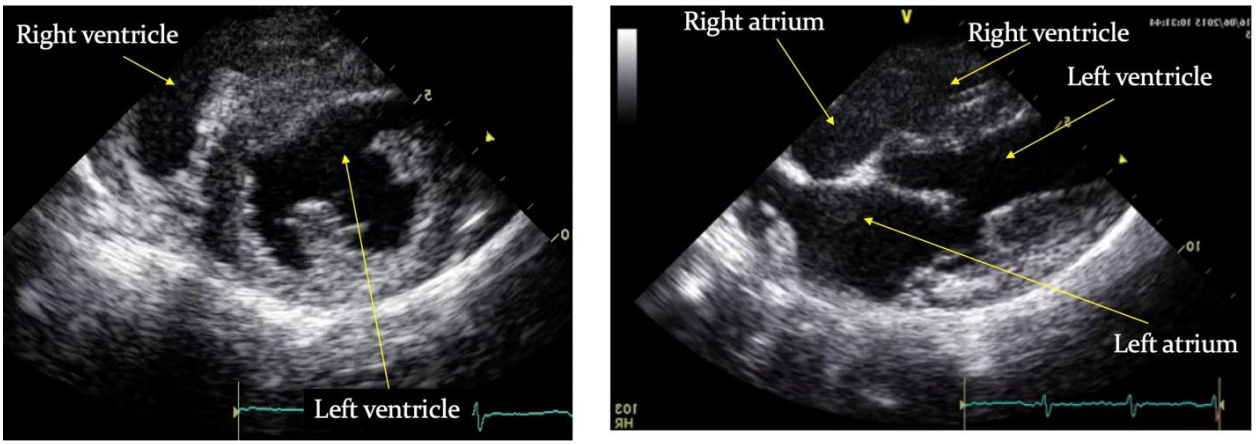


Figure 3.2a, b: Right parasternal short axis mushroom and long axis (4 chamber) views are evaluated on the abbreviated POCUS exam.

Protocol: Cardiac POCUS technique in right parasternal

- The patient can be standing or sternal and the probe placed just behind the right forelimb.
- Alternatively, if the patient is stable enough, it can be placed on an L shaped table (2 tables placed together at a 90-degree angle). The patient is positioned such that the right parasternal region lies over the opening of the L shaped table. This avoids the need for a cardiac table.
- It is often easiest to obtain a short axis view of the heart at the level of the papillary muscles, referred to as the "mushroom" view (figures 3.1, 3.2a).
- The probe is then slowly slid dorsally towards the base of the heart (a few mm at a time). The left ventricle and mitral valves will become more and more apparent, and this will lead to what we refer to as the "fish mouth view".
  - You sometimes have to switch rib spaces cranially to achieve this view.
- Once this view is attained, the probe is fanned so that the ultrasound beams are directed slowly upwards (towards the base of the heart). This will lead to the view needed for LA:Ao measurement (the "Mercedes and whale view: figures 3.1, 3.4).
- By rotating the probe further, a 4-chamber view of the heart can be obtained.

Pericardial Effusion

Pericardial effusion can be detected in different locations. One of the best places to identify pericardial

effusion is the subxiphoid view. The probe is placed in long axis in the subxiphoid and angled in a more parallel fashion to the dog. By rocking the probe until it is parallel to the patient, the ventral region of the thoracic cavity is visible (Figure 3.3).

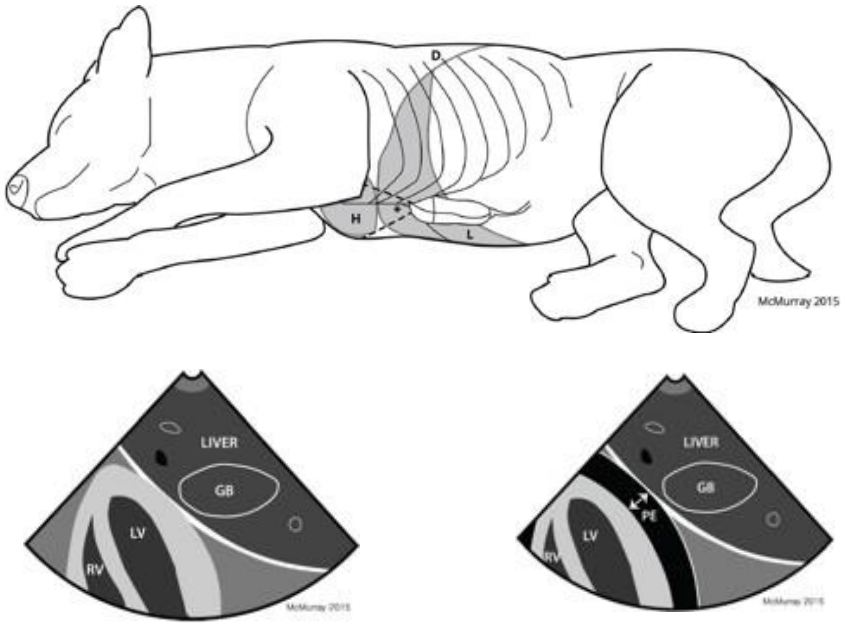


Figure 3.3. Dog in lateral recumbency with the ultrasound probe placed in long axis at the subxiphoid. The probe is rocked so that it is more parallel to the long axis of the patient. In dogs this will allow to see the pericardium contacting the diaphragm (left lower image) if no pericardial effusion, and also for pericardial effusion to be seen (right lower image).

Technique to rule out pericardial effusion from subxiphoid view:

- In the subxiphoid position, rock the probe so that the ultrasound beams are entering the thorax. You may need to fan the probe from side to side to find the heart. You can do this in both long and short axis.
  - **In dogs**, the normal pericardium usually contacts the diaphragm (5% of dogs may not have the heart contact the diaphragm, and it is therefore not possible to find the heart at the subxiphoid location).
  - Identification of the heart in healthy **cats** via the subxiphoid view is difficult as the heart does not contact the diaphragm on most cats. However, in the case of pericardial effusion (most often seen in cats with heart failure) the pericardial sac may extend to the diaphragm allowing pericardial effusion to be diagnosed at this site in cats.
- If the left ventricular free wall can be seen blending with the diaphragm or liver, then pericardial effusion is ruled out.

- If the left ventricular free wall is separated from the diaphragm by anechoic fluid, it indicates one of two things; pericardial effusion or pleural effusion.
  - To differentiate pericardial from pleural effusion, the ultrasound probe is rocked and fanned until the apex of the heart can be visualized. If the anechoic fluid arches around the apex of the heart it is pericardial effusion.
  - It is wise to assess more than one window when diagnosing pericardial effusion.

Technique to detect pericardial effusion in right parasternal view:

Pericardial effusion can also be detected in a right parasternal short axis view of the heart. By getting comfortable with the different heart chambers via the right parasternal short axis approach it is possible to differentiate pericardial fluid from cardiac chambers and/or pleural effusion. It is important to scan the heart from apex to base in short axis to make sure heart chambers are differentiated from pericardial effusion.

- Identify the chambers in short axis described above (mushroom view so that you can identify the left and right ventricles, LA:Ao view etc.). If these structures are identified it then becomes apparent when pericardial effusion is present; a circular collection of fluid surrounding the heart contained within the pericardial sac (figure 3.3b).
- By rotating the probe further, a 4-chamber view of the heart can be obtained; this can be useful to visualize cardiac tamponade (and pulmonary hypertension via increased right atrial and ventricular size)

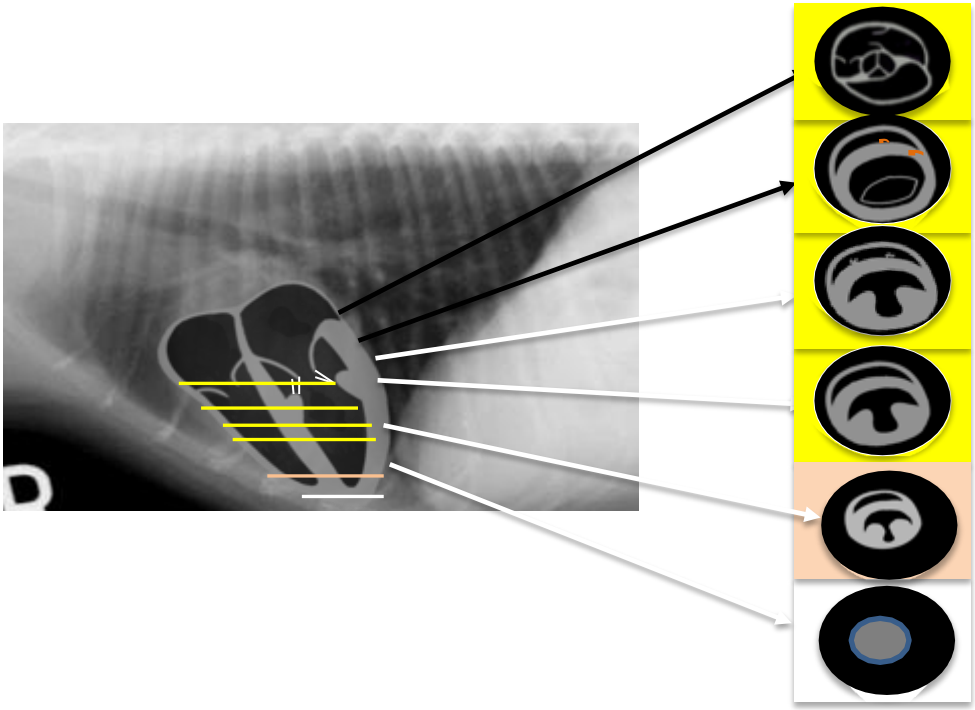


Figure 3.3a: Right parasternal short axis view of the heart. The image on the left is a right lateral thoracic radiographs with a schematic heart chamber diagram. The first lower yellow image on the right is the image obtained after successful probe placement, and this is called the "mushroom view" with the left ventricle on the bottom and right ventricle on top. Sliding the probe dorsally we obtain the same image but with papillary muscles visible in the left ventricle. Continuing to slide will give us the "fish mouth view" with the now visible atrio-ventricular valves. From there, sliding stops and the probe is fanned upwards until you obtain the "Mercedes and whale" view, depicting the left atrium as the "whale", the aorta as the Mercedes symbol. The probe can also be moved ventrally in right parasternal to go over the apex of the heart, and this can also help rule in or out pericardial effusion. Lastly, the probe can be turned further and a 4-chamber heart view can be obtained. This is a good view to observe for cardiac tamponade (see below).

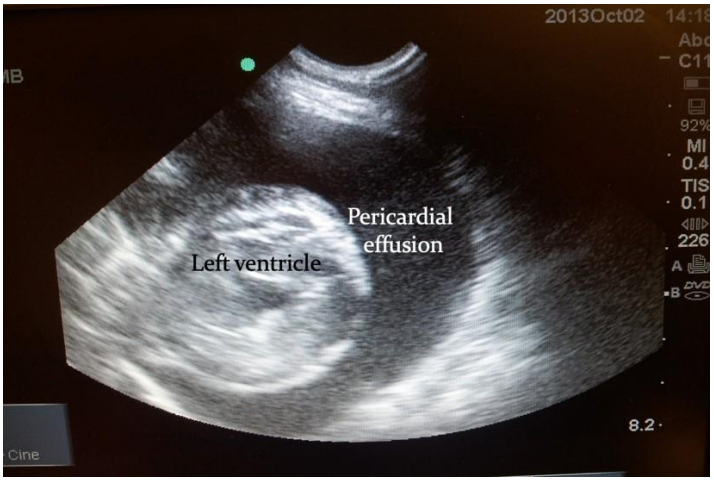


Figure 3.3b: Parasternal view of pericardial effusion in a cat. The right ventricle is not easy to identify in this image (collapsed) and to ensure the patient has pericardial effusion the probe should be slid dorsally until the right ventricle is

more visible and the effusion is indeed pericardial.

Cardiac chambers (LA:Ao ratio)

- The goal is to determine if a patient presenting with respiratory distress has signs related to congestive heart failure, primary pulmonary disease, pleural effusion or a combination of these three.
- As described above, obtain a "Mercedes and a whale" view of the heart (right parasternal short axis view (figures 3.4).
  - The chambers observed will be the left atrium (whale), aorta (Mercedes symbol), right ventricle and right atrium above, and the pulmonary artery beside the aorta.
- From this view, one can calculate the LA:Ao ratio (figure 3.4 to the right).
  - To do this, freeze the image on your machine. You can play with your cine loop function to help return to the most ideal image. The measurement should be made when the aortic valves close, and the atrium is at its largest during systole.
  - Then, draw a diagonal line through the aorta towards the left atrium, from wall to wall. This is your aorta measurement.
  - Next, draw a diagonal line through the left atrium in the same axis you drew through the aorta. Compare both lines.
- A normal LA:Ao is less than 1.3 in cats and 1.5 in dogs. There is a gray zone regarding left atrial enlargement (up to 1.7) but values above 2 should prompt serious consideration for left atrial enlargement and likely indicates significant cardiac disease (figure 3.5).
- Another subjective way to determine if the left atrium is enlarged is to ask how many aortas can fit in the left atrium. If it is 4 or more, then the left atrium is likely very enlarged.
- In cats, measurement of the widest point of the left atrium in the 4-chamber view has been investigated. A left atrium > 16.5 mm in dyspneic cat is strongly suggestive of left-sided congestive heart failure (Se-Sp: 89%: figure 3.6).

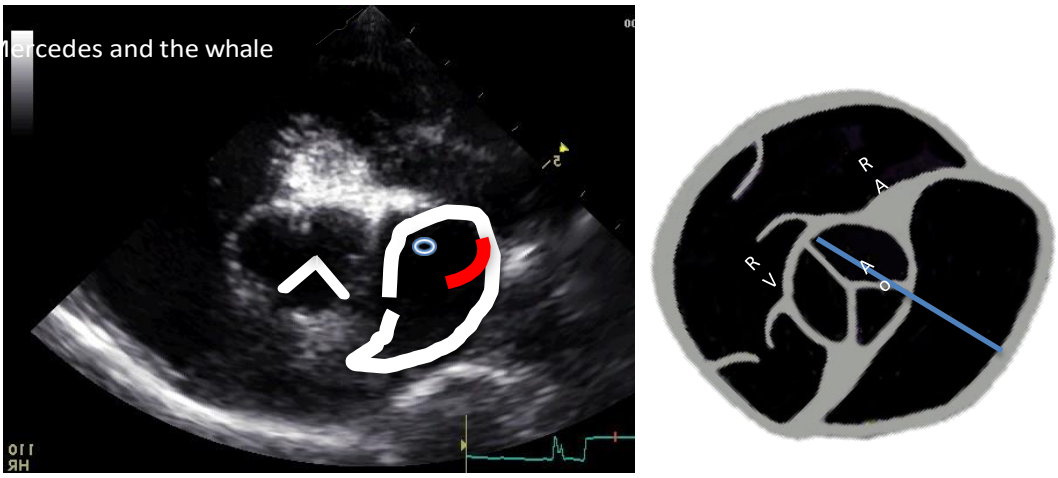


Figure 3.4. Right parasternal short axis view of the heart depicting the aorta and left atrium, as well as the right atrium, right ventricle, and pulmonary artery (image to the right). The image to the left depicts the visualized "Mercedes" symbol that appears in the aorta in this view, as well as the "whale" image of the left atrium. The blue line in the diagram on the right indicates the measurements to obtain for LA:Ao determination.

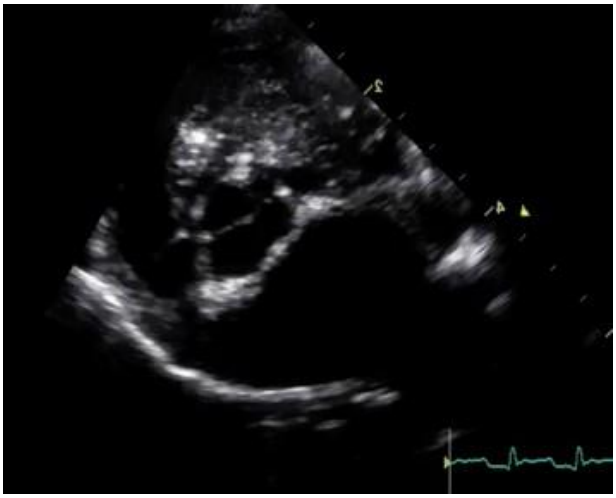


Figure 3.5: Patient with significant heart disease and in congestive heart failure. The dog presented for acute dyspnea. With this LA:Ao determination, and visualization of AIS (b-lines), the dog was immediately given furosemide and oxygen, and was eventually stabilized.

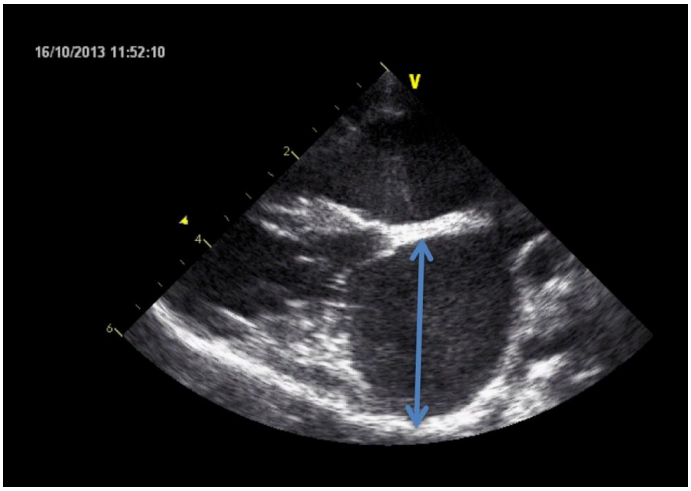
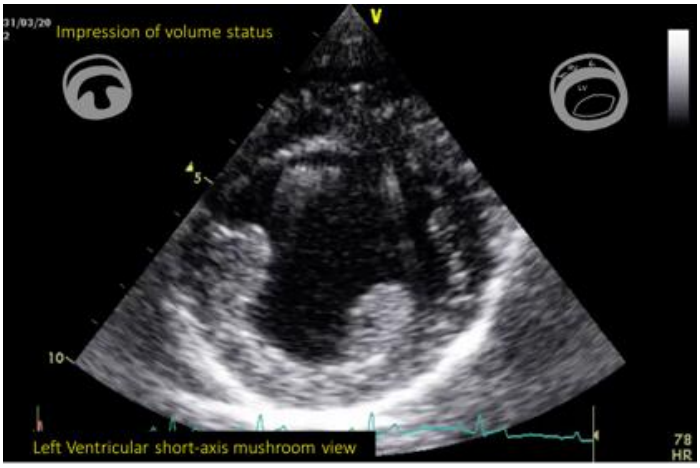


Figure 3.6: Four chamber left atrial diameter measurement used in dyspneic cats. The blue arrow indicates the widest measurement of the left atrium in the 4 chamber right parasternal window, and a measurement > 16.5 mm is consistent with heart failure in cats presenting with dyspnea.

Cardiac contractility

Cardiac contractility can be subjectively assessed with either the short axis right parasternal view or 4 chamber right parasternal view. This is difficult to demonstrate with still images and will be demonstrated using cine-loops in the didactic session. With cardiac contractility, we often aim to assess if there is decreased contractility (for example, a dog with DCM). In figures 3.7a and b, cardiac contractility can be assessed by obtaining the mushroom view of the heart. Once this view is obtained, we ask the following questions:

- Does the left ventricular (LV) wall and the interventricular septum (IVS) look thin? If they do look thin, it could be an indication of decreased contractility.
- Does the LV lumen decrease by ≤ 20%? If it does not, this could indicate decreased contractility.



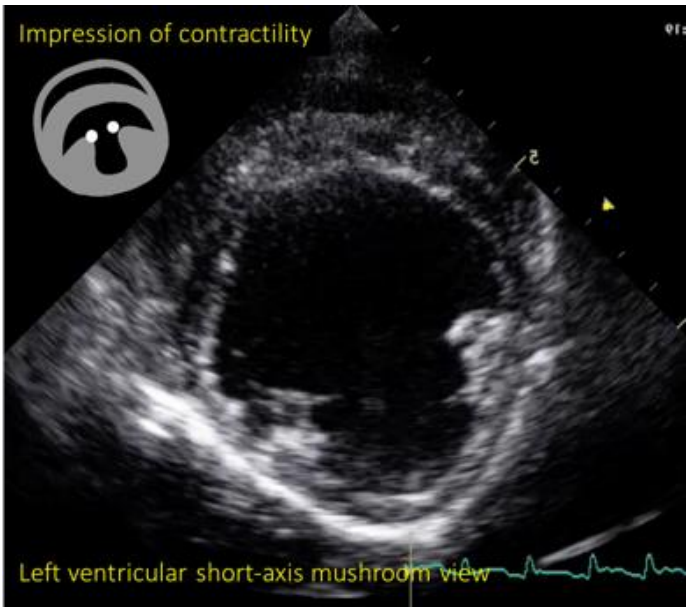


Figure 3.7a ,b. Subjective contractility can be obtained by first observing the mushroom view as described earlier (left ventricle on the bottom, right ventricle on top). The image on the top is a heart with a normal contractility, whereas the image on the bottom is a heart with significantly decreased contractility.

Cardiac assessment of volume status: hypo and hypervolemia

The right parasternal short axis views can also be used to get a feel for the volume status of the patient (figure 3.8).

<u>Hypovolemia:</u>

- In hypovolemic patients, the left ventricular lumen decreases in size, making the intraventricular septum and left ventricular wall appear thickened (figure 3.9).

- This is a transient reversible condition known as **pseudohypertrophy** and has been documented in both dogs and cats.
- To differentiate this from hypertrophic cardiomyopathy the left atrial to aortic size should be evaluated.
  - In patients with hypertrophic cardiomyopathy the left atrium is enlarged while it is equal to or smaller than the aorta in patients with pseudohypertrophy (hypovolemia).
- The volume status of the patient should be evaluated in light of clinical findings (clinical signs of hypovolemia) and in conjunction with other POCUS findings of volume status (see CVC evaluation).

<u>Hypervolemia:</u>

- Signs of volume overload can also be detected by assessment of the left atrium relative to the aorta using the right parasternal short axis window (figure 3.9).
  - With volume overload the left atrium enlarges relative to the aorta and the left ventricular lumen also enlarges concurrent with normal ventricular contractility (as opposed to decreased contractility which occurs with dilated cardiomyopathy).
- Sepsis can cause similar findings to volume overload when evaluating the ventricular lumen and it is therefore assessment of the left atrium, particularly when measured serially in conjunction with other POCUS findings (B lines, halo sign, CVC assessment, etc.) is the easier cardiac parameter to evaluate for volume overload.

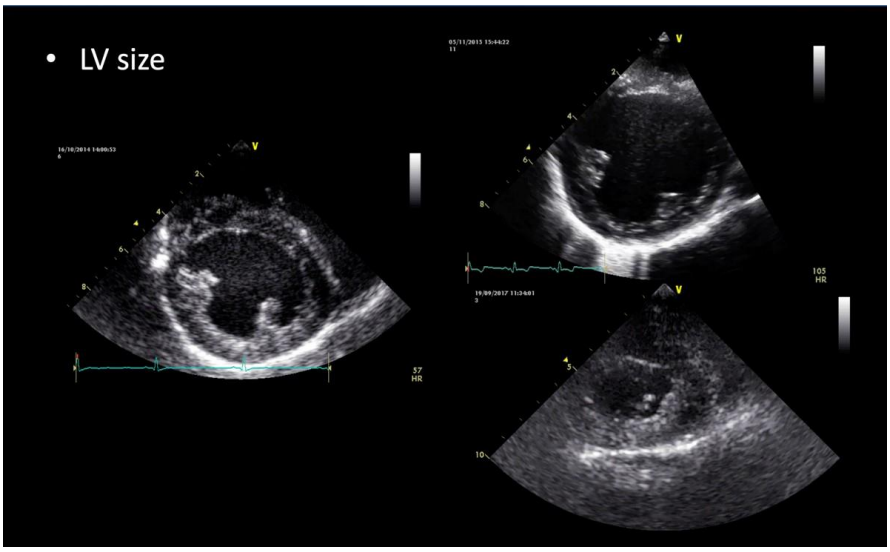


Figure 3.8: Short axis right parasternal mushroom view of the heart. Normal is shown to the left. The upper right image shows a patient with volume overload where the ventricular lumen is enlarged and the ventricular walls appear thin. Contractility is preserved but difficult to appreciate in a still image. In the lower right image, the walls of the left ventricle look thick and the ventricular lumen is very small due to hypovolemia.

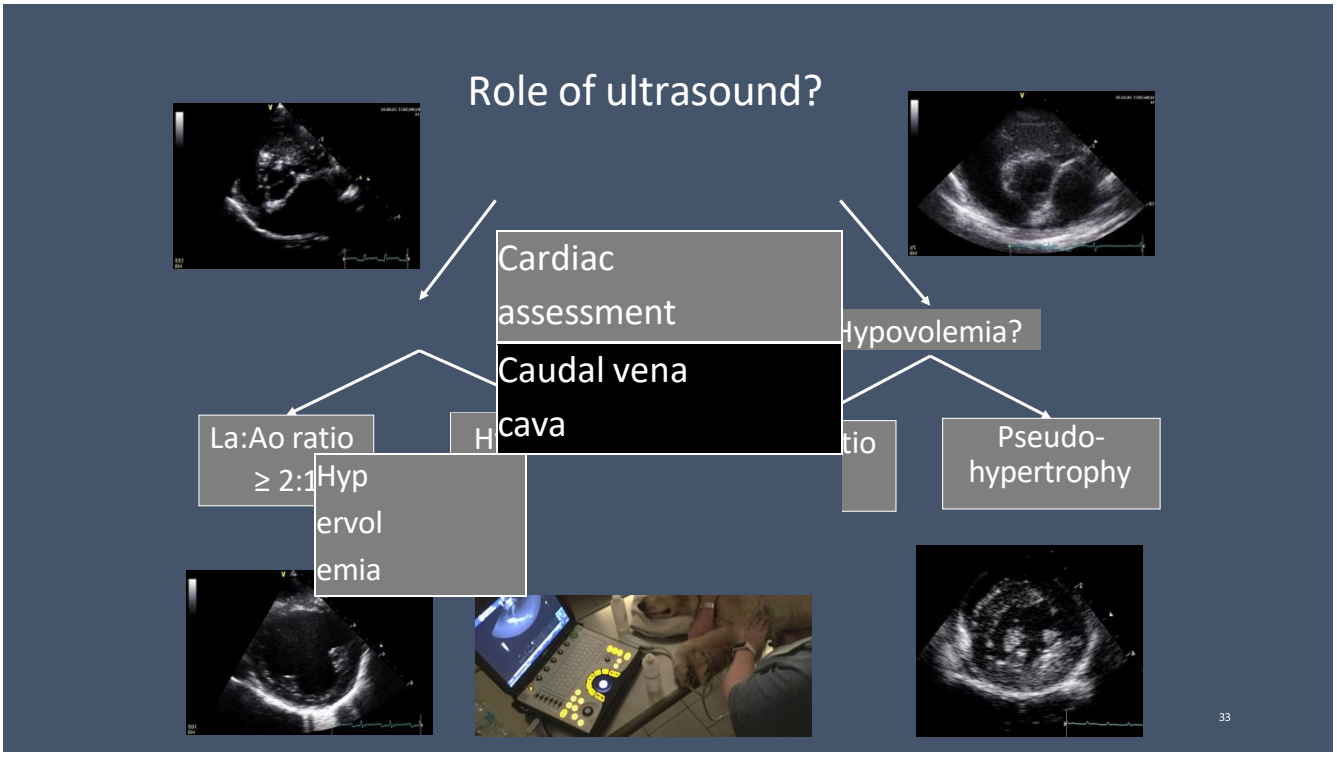


Figure 3.9: Hypervolemia and hypovolemia changes noted on mushroom view and the LA:Ao window.

Right-sided heart conditions

The size of the right atrium and ventricle, relative to the left side of the heart, and the shape of the intraventricular septum should be evaluated for right sided heart problems (figure 3.10). With pulmonary hypertension (pulmonary fibrosis, pulmonary thromboembolism, etc.) as well as pulmonary valve stenosis the ventricular septum will often flatten and the right heart chambers enlarge, often exceeding the size of the left heart chambers.

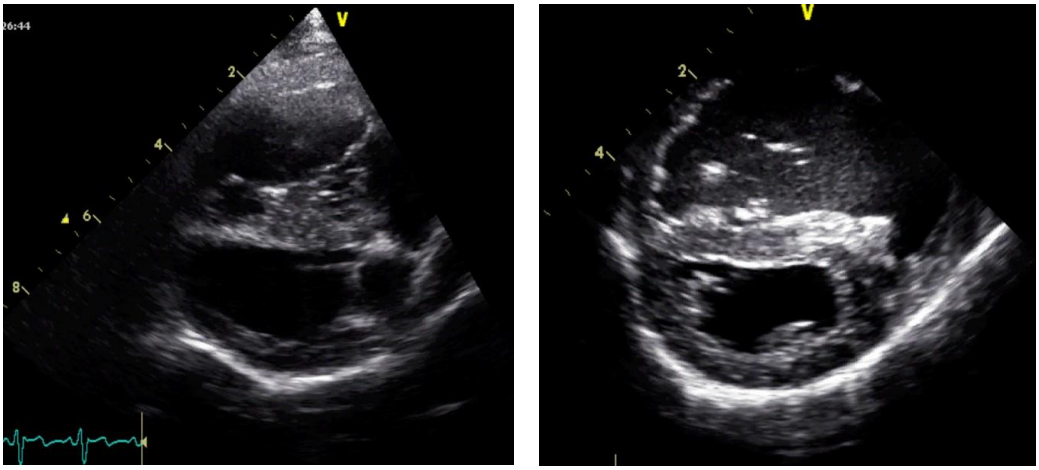


Figure 3.10: In this 4-chamber right parasternal long axis view of the heart the right ventricle (top chamber) is markedly enlarged. In the short axis parasternal "mushroom" view the right ventricle (top chamber) is also significantly enlarged and the interventricular septum can be seen as flattened. This would be consistent with increased right sided pressures as a result of either pulmonary hypertension (more common) or pulmonary stenosis.

Summary Cardiac POCUS

- With cardiac POCUS, clinically relevant questions are trying to answer are:
- Is the left atrium enlarged? If yes can it explain the patient's respiratory signs?
- Is cardiac contractility subjectively decreased?
- Is there pericardial effusion?
- What is the patient's volume status based on left ventricular lumen size and left atrial size?
- As such, these binary yes/no questions help answer clinically relevant questions that will aid in fully assessing our patient within a few minutes, and to follow-up with life-saving therapies. This is all done with minimal stress to the patient.

Vascular POCUS

Vascular POCUS

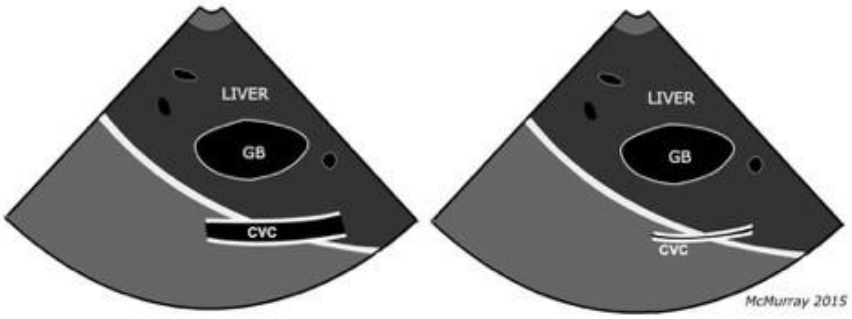
The goal of vascular POCUS is not an extensive evaluation of the great vessels. Rather, vascular POCUS, in conjunction with other clinical, history and POCUS findings (cardiac assessment of volume status, contraindication suggestive of volume overload), is used to assess changes in vena cava volume that can help us assess if we should be giving a bolus of fluids.

Protocol : Caudal vena cava volume estimation

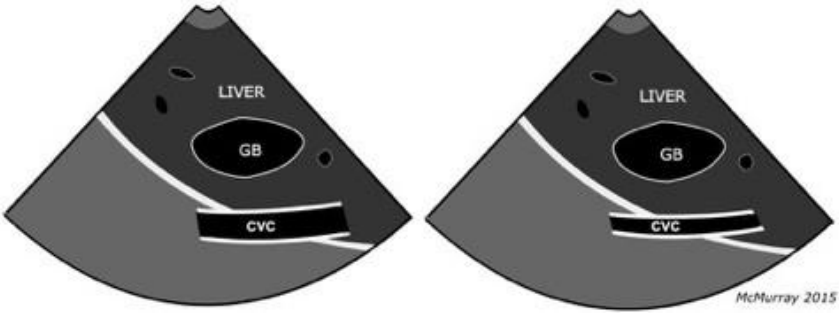
- Emergency and critical care patients are often at risk to develop hypo and hypervolemia. Unfortunately, predicting which patient can be challenging.
- Although results are preliminary, evaluating the caudal vena cava (CVC) shows promise in estimating the intravascular volume status in veterinary patients.
- By placing the probe longitudinally at the subxiphoid site and slowly tilting/fanning the probe to the right of midline the CVC can be seen crossing the diaphragm (See figures 3.10a-c).
- The caudal vena cava diameter and the change in the CVC diameter between the expiratory and inspiratory phases of respiration can be detected at this site.
- The diameter and change in diameter with the respiratory cycle reflect the patient's volume status.
- The CVC has a larger diameter at the end of expiration than it does at the end of inspiration.
- The changes between expiration and inspiration varies but is approximately 20-60%.
- In hypovolemic patients, the CVC becomes "*flatter*" than normal and may show greater collapse at the end of inspiration. For example, with hypovolemia, the CVC diameter between expiration and inspiration will likely vary by >60%, or the CVC will be extremely collapsed to start with (extreme hypovolemia) and will therefore not show much change at all during the respiratory cycle.
- The opposite is true in hypervolemic patients, or patients with increased right atrial pressures (i.e. pericardial effusion, right sided heart failure, etc.), where the CVC becomes "*fatter*" than normal, hardly changing (<20%) between expiration and inspiration.

- This is important because if the vena cava is “fatter” than normal, we should ask ourselves why and if IV fluids would be detrimental.
- If the hepatic veins are visualized (often seen at the site, they enter the CVC just caudal to the diaphragm) they are often distended as well in cases with increased right atrial pressures and/or hypervolemia.
- Example of enlarged vena cava can be seen with figure 3.11.

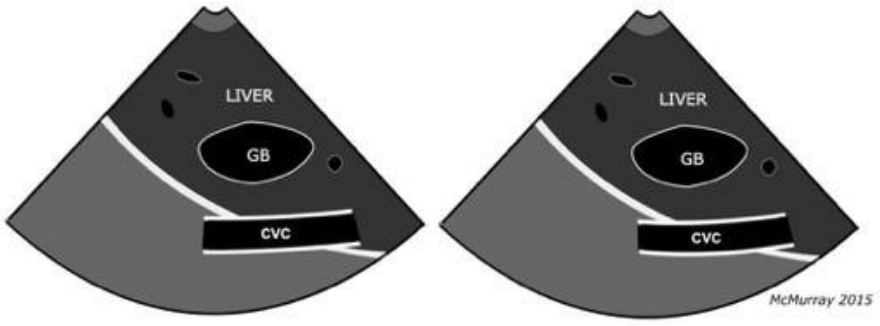
1A)



1B)



1C)



Figures 3.10a-c: Place the probe longitudinally at the subxiphoid location and gently fan the probe to the right of midline until the gall bladder is visible – continue gently fanning from this location, keeping a close eye on the diaphragm until the CVC is visible crossing it. A) With hypovolemic patients the CVC becomes “flatter” than normal and may collapse at the end of inspiration. Hypovolemic patients also have wide changes in CVC diameter between expiration and inspiration (>60%). B) In euvolemic patients the CVC width will vary between inspiration and expiration by roughly 20-60%. C) The CVC becomes fat, not changing much (<20%) between inspiration and expiration in hypervolemic patients and in patients with increased right atrial pressures. If the

hepatic veins are visualized (often seen at the site, they enter the CVC just caudal to the diaphragm) they are often distended as well. Image courtesy Dr. Jantina McMurray, in Emergency Critical Care, Mathews, 3rd ed, Lifelearn, in press.

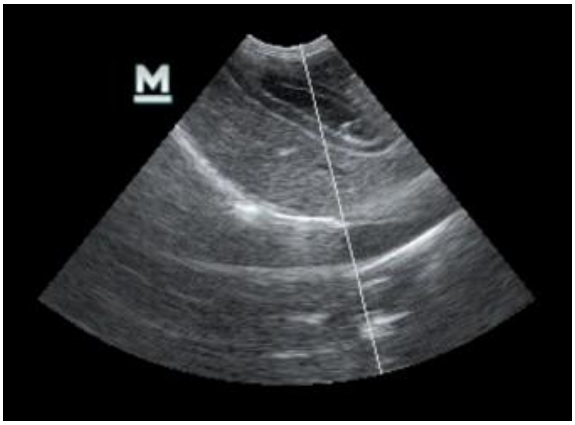


Figure 3.11: CVC with a diameter that does not ***change with breathing. This patient was in fluid overload post resuscitation. A gallbladder halo sign can also be seen from the fluid overload.***

<u>There are a number of artifacts that can make the CVC appear smaller than normal:</u>

- This includes: 1) pressure artifact, that occurs when too much pressure is placed on the probe when trying to visualize the CVC; 2) increased abdominal pressure which may occur with organ enlargement or significant abdominal effusion; and 3) increased respiratory effort which creates greater negative pleural pressure and therefore more collapse of the CVC.
- Although these factors are likely to impact euvolemic or hypovolemic patients, they are less likely to change the findings noted in patients with hypervolemia or right atrial pressure increases (FAT CVC).
- For these reasons the author tends to ask the questions, "if the patient has clinical signs suggestive of hypovolemia (tachycardia, pale mucous membranes, weak pulses etc.) is it likely to be a fluid responder"?
- If the CVC is consistent with euvolemia or hypovolemia, then a bolus of fluids is administered provided there is no contraindication to giving a bolus (ex. no increased B lines, normal left atrial: aortic ratio, no cerebral edema etc.).
- If the patient has a FAT CVC further work up is required to determine if a fluid bolus is contraindicated.

<u>Here is a condensed clinical thought process using binary questions for vena cava volume status and IV</u>

fluid boluses:

- Does the patient require IV fluids Y/N? This is a clinical assessment.
- Is there a contraindication to giving IV fluids Y/N…This is both a clinical and POCUS assessment.
  - What POCUS findings suggest caution with IV fluid therapy? Findings such as b-lines (which may indicate pulmonary edema), an enlarged LA:Ao ratio, and a gallbladder halo sign (which can be secondary to fluid overload, pericardial effusion, right-sided heart failure etc.). With these findings, caution should be taken before administering IV fluid boluses.
- Now, assessment of the CVC:
  - Is the CVC collapsed/narrow to start with Y/N? (In other words, patient would benefit from a crystalloid bolus)?
  - Does the CVC diameter change > 25% with cardiac pulsations Y/N? (Therefore, likely ok for a crystalloid bolus)?
  - Is the CVC distended with decreased cardiac pulsations Y/N? (Caution, further workup needed before bolus)?
- It is ALWAYS important to combine CVC findings with cardiac POCUS volume assessment and other clinical findings.

Summary Vascular POCUS

- The CVC can be seen by fanning the probe at the subxiphoid site.
- If the CVC appears distended, then the patient should be evaluated further prior to administering a fluid bolus.
- If the CVC changes diameter with respiration, then fluids may be safe to administer as long as the patient has no other contraindications to IV fluids.

Ultrasound-Guided Vascular Access for Difficult IV Access

Introduction

Establishing venous access and arterial or venous blood sampling is a vital part of emergency and critical care patient management but can be very challenging at times. Recent studies in the human literature have demonstrated that ultrasound guided catheter placement is a viable alternative for IV catheterization when blind percutaneous catheter attempts fail; ultrasound guidance reduces the number of attempts, time to place, and may reduce other complications associated with venous catheter placement in ECC patients, particularly those in which traditional IV placement is considered difficult. Ultrasound guidance can be used to place both central venous catheters as well as for peripheral venous catheters. Furthermore, ultrasound guidance has been used to increase the success rates for difficult vascular blood sampling and help differentiate arterial from venous or mixed blood sampling. In the human literature, clinicians who place central venous access devices (occasionally or frequently) are strongly encouraged to learn ultrasound-guided techniques, and there is no reason to believe this does not also hold true in veterinary medicine.

The following study is just one of many in the human literature demonstrating the value of ultrasound guided vascular access when traditional percutaneous IV access attempts fail:

Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access.

Costantino TG[1], Parikh AK, Satz WA, Fojtik JP. *Journal of Critical Care (2010) 25, 514–519*

The summary of this study is as follows:

- If a nurse failed to place an IV catheter after 3 attempts…
  - Emergency physicians attempt to place percutaneous IV catheter
  - One group using ultrasound guidance
  - One group using ”blind” traditional techniques
  - Success rate was greater for the ultrasonographic group (97%) versus traditional (33%)

- Less time to successful cannulation from first percutaneous puncture (4 minutes for ultrasound guided techniques versus 15 minutes using blind palpation)

There is evidence in veterinary medicine that ultrasound guided peripheral vascular access is also helpful in small animal patients. Studies have demonstrated successful ultrasound guided jugular vein catheter placement in cadaver dogs (with and without perivascular fluid present) and successful femoral artery catheter placement. With practice, it has been shown that ultrasound guided femoral artery catheter placement can be performed in less than 1 minute in dogs, with hematoma formation being reported as the most common complication with arterial catheterization.

Advantageous of ultrasound guided vascular access include (see figures 4.1-4.2):

- Selection of appropriate veins to catheterize (vessel diameter size, depth, and location of other structures, all help with decisions regarding catheter size and vein selection)
- Vessel visualization to assess for thrombosis prior to attempting placement of an IV catheter

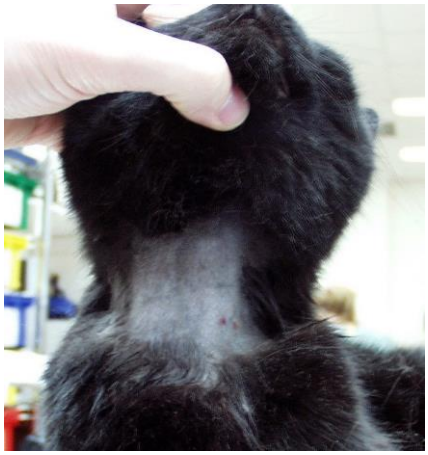


Figure 4.1. In this image a cat that had prior jugular blood sampling made blind percutaneous catheter placement difficult. Ultrasound guidance is helpful in these cases to visualize vessel patency and to help identify vessels that have perivascular hematomas. The jugular vein of cats can also be used ***for peripheral or central guided IV access if other sites prove difficult, or a central catheter is desired (e.g. dialysis).***

- Visualization of any perivascular hematomas or fluid/edema, which usually makes ultrasound guided vascular access easier!

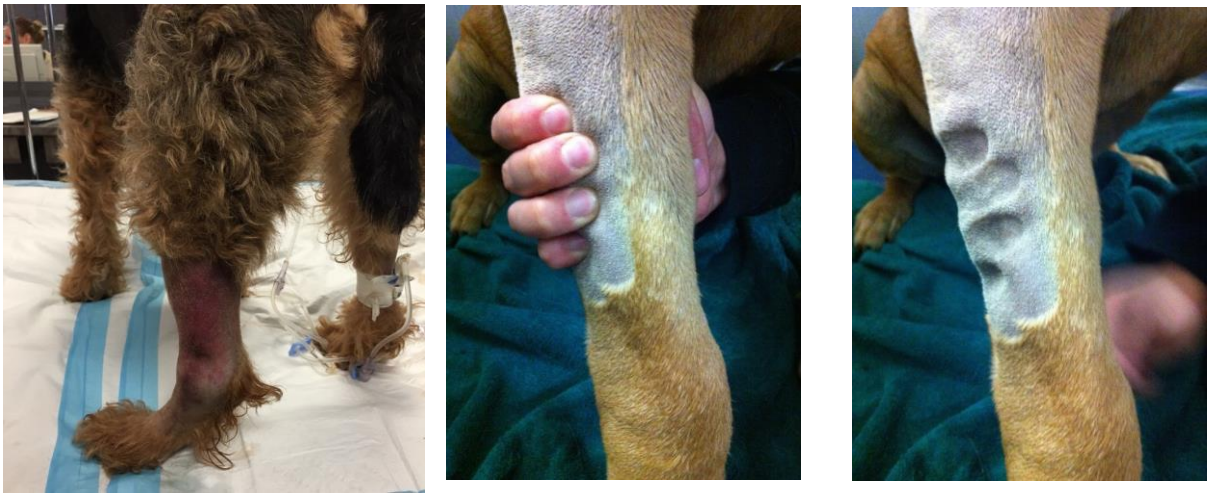


Figure 4.2. Left image: A dog with significant edema and perivascular hematoma formation in the hind limb in which blind percutaneous IV catheter attempts failed. This is a great candidate for ultrasound guided IV access if other limbs are also affected and the vein is not thrombosed at the site of catheter insertion. Centre and right images: marked peripheral edema that was present in all 4 limbs of a Labrador Retriever. This is a great case for ultrasound guided catheter placement as perivascular edema often makes it easier to visualize the vessel, vessel patency can be confirmed (absence of thrombosis) and the edema provides more soft tissue between the skin and the vessel (in which to sonographically visualize passage of the IV catheter advancement), which makes ultrasound guided catheter placement easier. In general, it is easier to pass ultrasound guided catheters when there is more than 2-3 mm of tissue between the skin surface and the superficial vascular wall.

- Differentiation of arteries from veins (veins are less pulsatile and collapse more easily than arteries with gentle steady pressure applied to the probe), which is very helpful to ensure the proper vessel is catheterized or sampled (helps ensure arterial sampling vs. mixed or venous sampling for example)
- Check the progression of the guidewire and/or the catheter into the venous system (i.e., "tip navigation")
- Rule out late complications (tip migration, catheter-related venous thrombosis).

NOTE: It should be pointed out that in an unstable emergency patient presenting in shock automated intraosseous devices (EZIO) may be preferred (if available) as there is evidence in the veterinary literature that automated IO techniques are faster than what has been reported for cut down and/or ultrasound guided catheter placement. Due to a lack of current veterinary research at this time, venous cut down procedures must also be recommended over ultrasound guided catheter placement in cardiovascularly unstable or arrested patients, at least until further studies dictate otherwise. Therefore, although ultrasound guided catheter placement can be used in hypotensive patients, it is

generally reserved for difficult IV catheter patients that are “more or less” cardiovascularly stable (e.g. difficult IV catheter placement in obese patients, patients with edema/hematomas, patients with “blown vessels”, long term hospitalized patients with thrombosed veins, etc.).

Technique

Either longitudinal (in-plane) or transverse (out-of-plane) vascular access ultrasound guided peripheral IV catheter placement can be used. The author prefers (and finds most trainees prefer) out of plane/transverse placement.

Regardless of the technique used:

- Make sure your hand is fixed on the limb or neck of the patient depending on which vessel you are attempting to catheterize (“afternoon tea technique” will be demonstrated in the lab to assist with this).
- It is very helpful to have the ultrasound machine aligned next to the vessel of interest, alongside the patient, in front of the sonographer, so that the sonographer only has to adjust their eye focus from the limb to the ultrasound screen (up and down) without having to turn their head or look over their shoulder to see the ultrasound image.
- Although micro-convex probes also work well for vascular guided access, resolution, vessel and catheter tip visualization are generally easier to appreciate with a linear array probe.
- The author prefers to slightly overset the gain (more bright than usual) to increase the visualization of the needle tip as it enters the tissues.
- Before advancing the catheter, be sure to maximize the size of the vessel by decreasing the depth as much as possible without losing sight of the vessel in the far image.
- The bevel of the stylet should be directed towards the ultrasound probe as this will maximize the reflection of ultrasound waves and enhance needle tip visualization (cut surface reflects the most ultrasound waves).
- The angle of entry relative to the skin surface varies depending how deep the vessel is within the tissues.
- The angle is much narrower (often ≤ 30 degrees) for more superficial vessels and steeper (often ≥

45 degrees) for deeper vessels.

- With both techniques the vessel should be visualized in the ultrasound window and machine setting adjusted prior to attempting catheter placement.
- The sonographer then stops looking at the ultrasound screen and focuses entirely on the skin probe interface.
- The catheter is placed 1-2 mm proximal to the most proximal contact point between the ultrasound probe and the skin.
- Once the stylet punctures the skin surface it is then advanced 1-2 mm into the subcutaneous (SQ) tissues
- Once situated a few mm into the SQ tissues (protecting the probe), the sonographer stops looking at the probe skin interface and again focuses their attention on the ultrasound screen for the remainder of the procedure.

With in-plane techniques the tip of the stylet is visualized as it enters the ultrasound image within the SQ tissues on either side of the ultrasound window (depending which side of the marker the catheter is advanced and the direction of the probe marker).

- The stylet tip and catheter are then followed in their entirety as they traverse the remaining SQ tissues and the superficial wall of the vessel to enter the lumen.
- Once in the lumen of the vessel, the angle between the skin surface and the catheter is reduced, and the catheter and stylet advanced slightly within the vessel, being careful not to traverse the deep vessel wall (Figure 4.3).

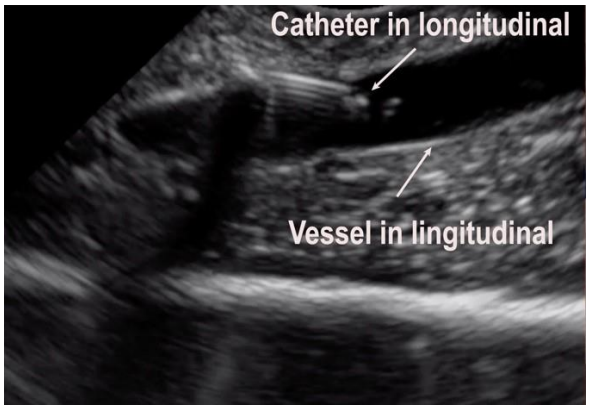


Figure 4.3. Left: In-plane ultrasound guided vascular access demonstrated on a plasticized cadaver limb, using a linear array probe. Right: Corresponding long axis (longitudinal) ultrasound image of the vessel with the catheter also visualized in long axis as it enters the vein.

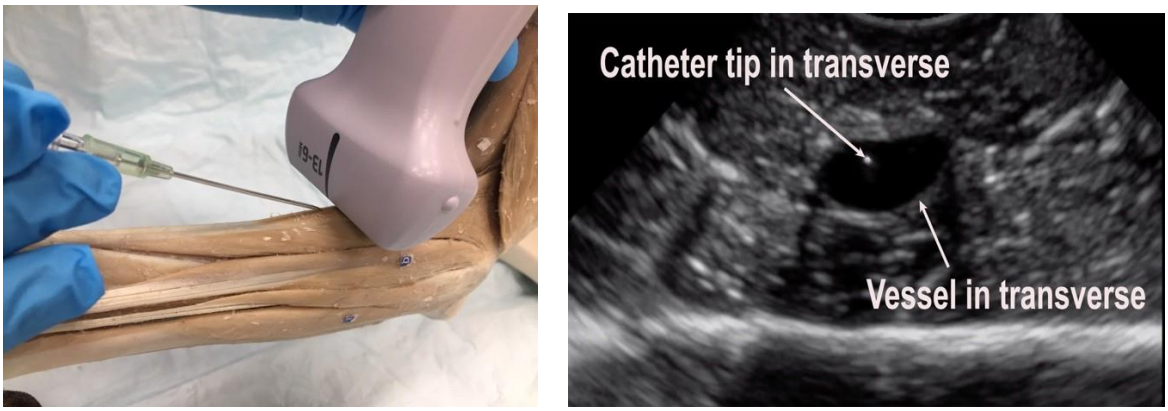
- Once the catheter (not just the stylet) is well situated in the vessel, the catheter is advanced off the stylet and down the vessel lumen.
  - The entire procedure can be visualized using in-plane techniques. The difficulty with in-plane is it does require more practice to keep the catheter perfectly aligned with the ultrasound beam, as being off plane by even 1-2 degrees, or failing to maintain the catheter directly in the center of the ultrasound probe prevents catheter visualization. This is more difficult with smaller peripheral vessels, particularly given the narrow width (1-2 mm) of the ultrasound beam projected by linear array probes. An advantage of in-plane techniques is the fact surrounding structures can be visualized at all times as the catheter is advanced.

<u>With out-of-plane techniques</u> the vessel is identified and centered within the ultrasound window. This correlates to the center mark that can be seen on many linear array probes (Figure 4.4).

- Once the vessel is centered in the image, the depth is adjusted to make the vessel as large as possible. The vessel should be followed a short distance to ensure it does not deviate left or right and to know if it becomes more superficial or deep (which will affect the angle needed to enter the vessel).
- When satisfied with the machine settings, the ultrasound probe and operator's hand are stabilized against the patient ("afternoon tea technique"). The sonographer now focuses on the probe skin interface.
- The catheter, bevel towards the ultrasound probe, is placed 1-2 mm cranial to the ultrasound probe at its center, and advanced 1-2 mm below the skin surface. The sonographer switches focus to the ultrasound screen at this point and watches very closely for the appearance of a small round focal white dot within the SQ tissues, which represent the tip of the stylet as it first traverses the ultrasound beam (Figure 4.4).
  - It is **VITAL** that the catheter stop being advanced the second the stylet tip is seen as a white dot within the ultrasound screen (the most common mistake made is advancing the catheter tip beyond the ultrasound beam, which results in loss of the catheter tip location).

- Once the white dot is seen the sonographer stops catheter advancement and now slides the probe distally, away from the stylet tip, until the white dot **COMPLETELY** disappears from view.
  - This is also a vital step as many novices fail to slide the probe completely off the stylet tip, resulting in the catheter tip being advanced beyond the ultrasound beam when they start catheter advancement again.
- The sonographer then stops sliding the probe away from catheter once the white dot (stylet tip) completely disappears. It is ok to slide a few mm beyond the stylet tip to ensure the beam is definitely beyond the tip.
- At this point the catheter is again slowly advanced until the stylet is again visible in the ultrasound image as a small white dot. The second the white dot reappears in the ultrasound image catheter advancement is halted. The ultrasound probe is then slid away from the catheter until the stylet tip is once again no longer visible. The process is repeated until the white dot can be seen entering the vessel lumen.

Figure 4.4 . Left: Out-of-plane vascular access demonstrated on a plasticized cadaver limb using a linear array probe. Right:



Corresponding ultrasound image of the vessel and catheter in short axis (transverse).

- Once in the vessel lumen, the ultrasound probe is slid off the catheter tip to orientate the sonographer to the exact location of the stylet tip within the vessel lumen. The ultrasound probe is then slid proximally until the stylet tip just reappears.
  - The angle of the catheter can be decreased at this point (white dot moves closer to the proximal vessel wall within the lumen) and any final adjustments made to center the white dot within the vessel. The stylet and catheter are advanced slightly together until the sonographer is certain both the stylet and catheter are within the vessel lumen. The catheter

can then be slid off the stylet and advanced down the vessel.

A major advantage of out-of-plane techniques is it is a lot more forgiving and the operator does not have to remain in only one plane to be able to visualize the catheter tip. It is also possible to adjust the stylet tip location within the SQ tissues to re-center the catheter over the vessel if alignment is slightly off. The disadvantage with out-of-plane techniques passing the catheter tip beyond the ultrasound beam without realizing this has occurred. A black shadow will often appear below the white dot when this occurs.

In addition to being helpful for ultrasound guided venous access, it is possible with higher frequency linear array probes to guide dorsal pedal or other arterial catheters. Finally, it is also possible to use ultrasound guidance to assist with arterial blood gas sampling, which is particularly useful at assuring the artery is sampled and not the vein. The arteries and veins are easily differentiated by looking for pulsatile and non-pulsatile vessels (although the vein will sometimes appear to pulse when it is in close proximity to the artery). Another way to tell if a vessel is an artery is to first palpate for a pulse and then place the probe over the palpable pulse. If two vessels are visible in the same window then gentle pressure can be applied to the probe to see which vessel collapses with the least pressure. Veins will collapse with very little pressure while arteries remain patent. Doppler flow can also be used.

Making a chicken breast model for practicing ultrasound-guided and Seldinger techniques

A phantom model can be made by using two raw chicken breasts, saran wrap and modelling balloons.

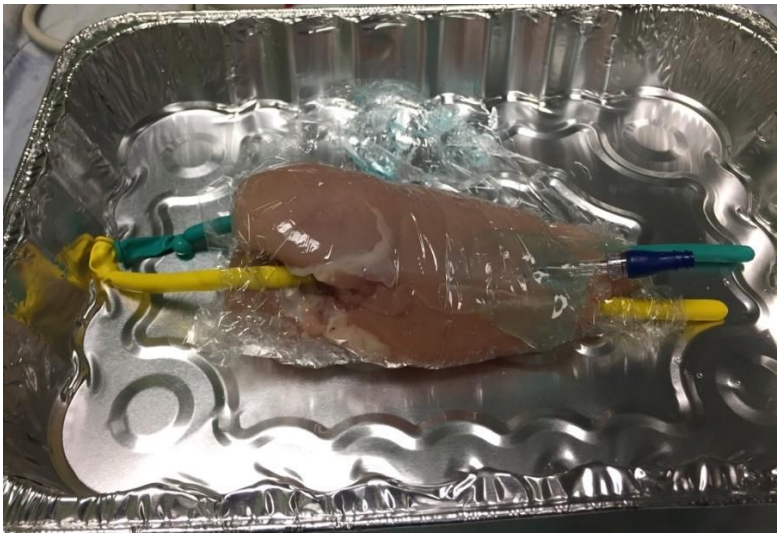
- One chicken breast is laid in the middle of a flat piece of saran wrap.

- A modelling balloon (or similar tubular structure designed to mimic a vessel e.g. very thin Penrose drain) is placed on the chicken breast (two balloons can also be used, placed next to each other).
- The second chicken breast is placed on top of the balloons to create a “sandwich” with the balloons in the middle of the two chicken breasts.
- The saran wrap is then wrapped around the chicken breasts to hold things together.

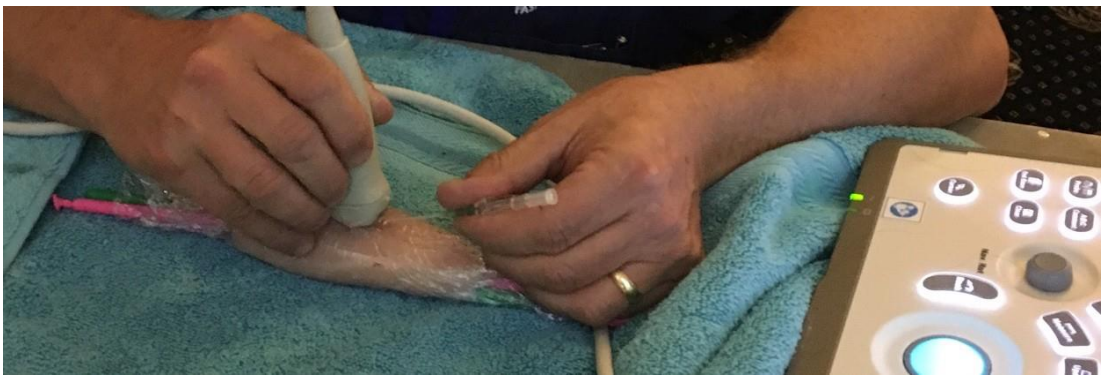
○ It is advised to remove all air from the balloon prior to filling it with fluid (air prevents good visualization with ultrasound). The balloon can also be slightly overfilled, creating an “aneurysm” that will allow air to be released without losing pressure within the balloon. Finally, the “aneurysm” also allows any residual air that might remain to become trapped in the “aneurysm” which keeps the main vessel that will be catheterized “air free”.

○ It is also advised to try and avoid overwrapping the chicken breasts with saran wrap as air can become trapped between the layers of saran wrap hampering tissue and vessel visualization. Another trick that helps keep things nicely situated within the model is to “score” the chicken breast with a scalpel or needle before placing the balloons on them. This helps keeps the balloon in one place within the scored lines when pressure is applied with the probe to the outside of the model.

○ Finally, when placing the chicken breasts against each other it is easier to keep things aligned if the thickness of the chicken breasts are reversed (place the thick side of one chicken breast in one direction and the second thick side of the chicken breast in the opposite direction).

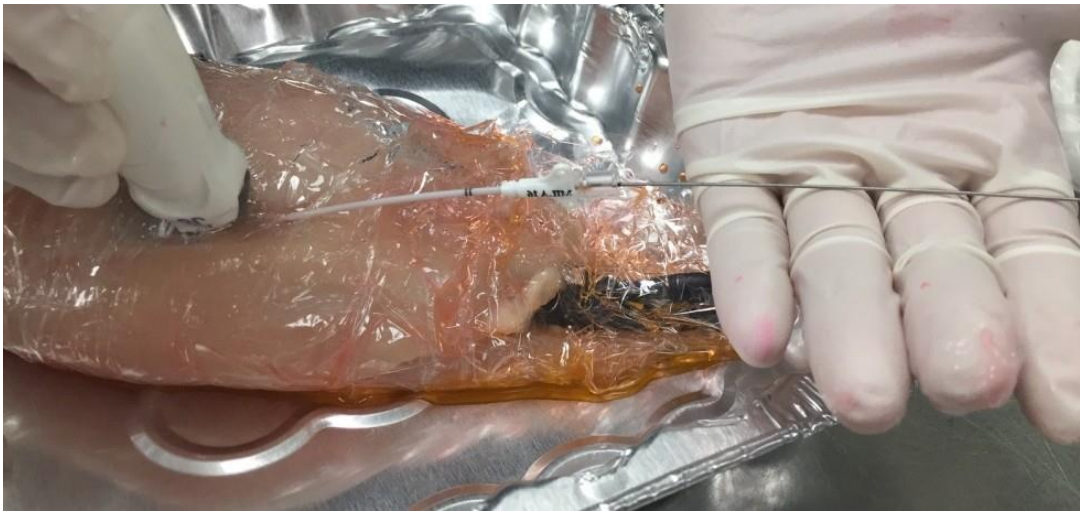


- To keep things contained, the model can be placed in aluminum tinfoil trays.



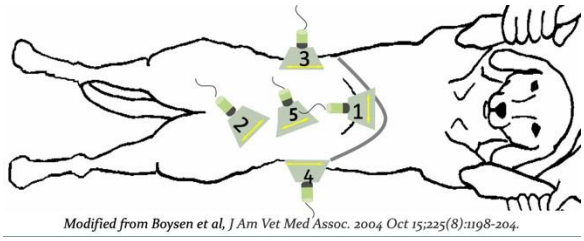
- Using ultrasound guidance (short or long axes) a catheter is passed into the balloon through the chicken breast. The chicken breast creates a more life-like tissue structure with fascial planes than many other models.

- Using the Seldinger technique, a guide wire is passed through the IV catheter into the balloon. Ultrasound is not necessary for this step (but it is cool to watch on the screen)!



The catheter is then passed over the guidewire as is normally done with the Seldinger technique. Again, ultrasound does not need to be used for this step.

POCUS: Abdomen



Modified from Boysen et al, J Am Vet Med Assoc. 2004 Oct 15;225(8):1198-204.

Date: **Time:**

Patient: **DOB:** **Species:** **Breed:** **Sex: First POCUS or Serial evaluation (circle answer)?**

Patient position (circle one):	right lateral	left lateral	sternal	standing

Site	Free Peritoneal Fluid Noted? If yes circle mild, moderate, severe	
Subxiphoid (DH)	**mild, moderate, severe**	no
Left Paralumbar (SR)	**mild, moderate, severe**	no
Bladder (CC)	**mild, moderate, severe**	no
Right Paralumbar (HR)	**mild, moderate, severe**	no

Total Number of Positive Sites (0-4) = _____(abdominal fluid score)

Abdominocentesis yes/no? (circle, note sample taken)_____

Presence of pericardial effusion at subxiphoid (DH) site (circle) ? N/A	**Yes**	**No**
Presence of pleural effusion at subxiphoid (DH) site (circle)?	**Yes**	**No**

N/A

Lung pathology at subxiphoid? Yes Describe findings: _____ No N/A

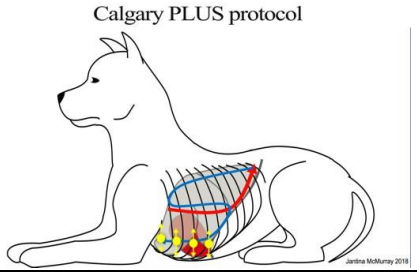
Gall bladder halo sign at subxiphoid site (DH)? Yes No N/A

GI contractions present, stomach? Yes no./minute_____ No N/A

GI contractions present, duodenum? Yes no./minute_____ No N/A

Urinary bladder volume measurements L _____cm W _____cm (DL + DW)/2 _____cm N/A

Pneumoperitoneum? Yes No N/A



POCUS: Pleural Space and Lung (PLUS)

Patient:

Patient position (circle all that apply):	right lateral	left lateral	sternal	standing

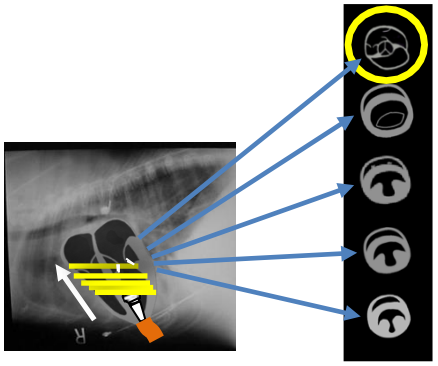
2) Regional lung scan (Sliding PLUS protocol including subxiphoid)

B lines present? **Yes (rules out pneumothorax)** **No** **N/A**

< 3 at a single site per side (normal)	**≥ 3 at any site? Interstitial/alveolar pathology present**			
Record location and quantity of B lines:	**< 3**	**> 3**	**Confluent**	
			Shred	**Nodule**
Subpleural consolidation present?	**Transloba r**			

Record location							
Pleural line thickening?			**Yes**		**No**	**N/A**	
3) Pleural effusion	**Mild**	**Moderate**	**Severe**	**No**	**Equivocal**		**N/A**
Thoracocentesis performed		**Yes**	**No**				
Location							

POCUS: Cardiac and Caudal Vena Cava



Patient:

Patient position (circle all that apply):
right lateral left lateral sternal standing

a. Pericardial effusion:	**Yes**		**N/A**
	No		
Centesis: Yes quantity _____ No			**N/A**
b. LA:Ao ratio? Subjectively enlarged Yes	**No**	**Equivocal**	**N/A**
Measured: Yes, ratio =			**N/A**
c. Subjective Contractility: Adequate	**Decreased**	**Equivocal**	**N/A**
d. Subjective volume status of heart (short axis mushroom site):			
Adequate	**Decreased**	**Equivocal**	**N/A**
e. Vena cava evaluated at subxiphoid (DH) location (just caudal to the diaphragm)			

Distended with loss of cardiac pulse

Yes: (rule out right heart conditions/tamponade/fluid overload)

No: likely ok to give IV fluid bolus if indicated and no other contra-indications (no B lines, LA:Ao normal, focused cardiac unremarkable)

N/A

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