UNIVERSITY OF CALGARY
FACULTY OF VETERINARY MEDICINE

This review accompanies the relevant episode of the Cutting Edge veterinary podcast. In each episode of this podcast, 3rd year students in the University of Calgary's veterinary medicine program fill you in on the most up-to-date literature and evidence-based practices on topics that matter to you, the practicing veterinarian.

POCUS for Life: An Ultrasound-based Diagnostic Approach to Left-Sided Congestive Heart Failure in Unstable Patients Presenting with Respiratory Distress

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Introduction

Left-sided congestive heart failure (L-CHF) is a common cause of respiratory distress in small animal patients. Point of care ultrasound (POCUS) is a patient side diagnostic tool that is tailored to patient presentation and integrated with clinical findings. It can allow for rapid diagnosis of pulmonary edema secondary to L-CHF, while concurrently assessing other differentials. Such an approach allows for targeted treatment on an emergency basis. Numerous studies demonstrate non-specialist veterinarians can sonographically identify both normal cardiac anatomy and recognize L-CHF with minimal training (1–4). However, confidence in cardiac POCUS remains limited by general practice clinicians (5). This paper serves to highlight how to initially address patient stabilization when presented with respiratory distress, differentials, and the use of POCUS to confirm the diagnosis of L-CHF. Ideally, this paper will improve the confidence of clinicians in using POCUS to address L-CHF presenting as respiratory distress.

A general approach to stabilization of patients presenting with respiratory distress

Small animals that present in respiratory distress are true emergency cases that require rapid stabilization and diagnostics (6). Such cases are a common component of emergency practice, but also within general practice settings. Respiratory distress presents with various differentials, requiring tailored treatments based on underlying cause; however, acute stabilization procedures are often similar. One of the most studied applications of POCUS in the clinical setting is L-CHF(1). Rapid recognition of the clinical signs of respiratory distress helps guide stabilization efforts. Clinical signs of respiratory distress include dyspnea, nasal flaring, orthopnea, tachypnea, open mouth breathing, paradoxical breathing patterns, cyanosis, and syncope (6). Being able to generate differentials and obtain a working diagnosis using patient side diagnostics is essential. Stabilization must be a balanced act, as excessive patient stress during stabilization can exacerbate the patient's condition and lead to cardiopulmonary arrest (CPA) (1). As such, clinicians must be effective and prepared to minimize negative outcomes using patient appropriate examination and diagnostics. In general, stabilization involves oxygen therapy, and sedation while concurrently preparing for emergency intubation if needed. A targeted history should be collected from the owner during stabilization including previous medical history and the progression of clinical signs. Such information will guide further treatment. Additionally, triage examination, clinical findings and diagnostics during stabilization will indicate targeted treatments to the underlying cause.

Oxygen - This is the cornerstone of stabilization. Respiratory distress results in hypoxemia which is treatable with oxygen supplementation. Common methods of administration include nasal flow-by, a face mask, oxygen muzzles, oxygen cages, and improvised oxygen hoods made out of E-collars (6). Oxygen should be administered in the least stressful method possible.

Sedation - Respiratory distress results in patients that are tachypneic with increased work of breathing. This increases oxygen demand and decreases the efficiency of ventilation. In addition it generates increased negative pressures within the respiratory tract that can cause laryngeal edema further exacerbating distress. The rationale for sedation is to decrease patient stress, thereby decreasing the work of breathing, and improving oxygenation. Selections of sedatives include butorphanol (0.1-0.2 mg/kg) and/or acepromazine (0.005-0.02 mg/kg). Sedatives may be given IV or IM, but achieving IV access can add to patient stress and should be avoided in critically unstable patients, especially in cats (7). Dexmedetomidine should be avoided until the underlying cause is determined, due its negative effect on cardiac output.

Patient History - Patient history should be collected concurrently during stabilization and triage exam. Focus on previous medical history, previous clinical signs before presentation, progression of clinical signs, and chronicity. Traumatic injuries may be more obvious, however a history of trauma should be explored. Following stabilization a more comprehensive history can be obtained, including regional dependent deworming protocols.

Emergency intubation - Equipment should be prepared and clinicians and technicians should be aware of their location and trained in their use. Equipment includes a laryngoscope, a variety of ET tube sizes, lubricant, an ET tube catheter, lidocaine spray, and tube ties as well as an appropriate anesthetic protocol to achieve successful intubation. If an airway cannot be accessed conventionally, emergency tracheostomy may be indicated.

Clinical findings - Targeted vitals should be collected on physical exam that are pertinent to the patient signalment, presentation, history collected, and should guide further treatment decisions. Clinicians should be effective and systematic while minimizing patient stress. Vitals that should be assessed include respiratory pattern, respiratory auscultation, cardiac auscultation, temperature (if feasible, especially in cats, due to the stress associated with measuring), mucus membranes, capillary refill time (CRT), and pulse strength and quality. Hyperthermia may be secondary to respiratory distress and should be treated with appropriate patient cooling. Targeted diagnostics that the patient can tolerate during the initial physical exam are also critical in dictating further treatment decisions.

Additional drugs - due to the wide variety of differentials for respiratory distress, a variety of additional drugs can be used that are aimed at treating the underlying cause. These drugs are not without risk and should be considered in patients that are at a high risk of CPA due to the stress of intervention, especially in cats. Steroids at an anti-inflammatory dose (dexamethasone at 0.1 mg/kg IV/IM) can reduce inflammation associated with or the cause of respiratory distress. Additionally, cats in respiratory distress who do not tolerate a basic triage examination and diagnostics due to the stress of handling can benefit from a non-specific cocktail of drugs for treatment of common causes of respiratory distress. This includes terbutaline (0.01 mg/kg IV/IM) for bronchodilation, anti-inflammatory dexamethasone dose (0.1 mg/kg IV/IM), and furosemide (1-2 mg/kg IV/IM) for diuresis to decrease potential pulmonary edema. This cocktail will address a wide variety of causes of respiratory distress including asthma, CHF, and upper airway inflammation. However, steroids increase the intracellular concentration of glucose resulting in increased intravascular hydrostatic pressure which can exacerbate CHF. Additionally, undue diuresis with furosemide can cause electrolyte imbalances and contribute to hypovolemia. Once administered, continue oxygen supplementation while minimizing stress and continue monitoring. Additional diagnostics to dictate further treatments are indicated once the patient is stable enough to tolerate handling to diagnose and address the underlying cause. If available, rapid POCUS of the pleural space and lung can often identify underlying causes without causing stress, allowing tailored therapy and negating the need for a "cocktail" approach.

Common differentials

During and after stabilization, differentials for respiratory distress should be considered and a working diagnosis should be established to provide effective treatment. There are many causes of respiratory distress which can make rapid diagnosis difficult in patients. In addition many diagnostics during stabilization can compromise patient stability and cause additional stress. Diagnostics should be minimally invasive and be tailored to the patient's presentation. As such, targeted diagnostics are ideal. These differentials should be kept in mind upon presentation when focused on ruling-in and -out diseases.

In general differentials can be broken down into the following categories, with species differences shown:

General Category	Canine	Feline
Upper airway	- Neoplasia - Brachycephalic obstructive airway	- Neoplasia - Rhinitis - Foreign body

	disease - Foreign body - Tracheal collapse - Laryngeal paralysis	- Inflammatory polyps - Granulomatous diseases
Lower airway	- Bronchitis - Tracheal collapse - Neoplasia	- Asthma - Neoplasia
Parenchyma	- Hemorrhage - Edema - Neoplasia - Infectious	
Thoracic wall	- Rib fractures - Neoplasia - Penetrating trauma	
Pleural space	- Pleural effusion - Diaphragmatic hernia - Pneumothorax - Neoplasia	
Pulmonary hypertension	- Pulmonary thromboembolism - Left sided heart disease (L-CHF) - Heartworm	
Abdominal enlargement	- Neoplasia - Organomegaly - Peritoneal fluid - Pregnancy	
Non-cardiopulmonary disease	- Neurological disease - Acidosis - Anemia - Hyperthermia - Pain	

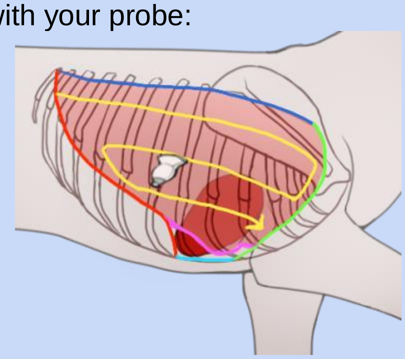
Clinicians are responsible for rapid diagnosis of the cause of respiratory distress based on signalment, presentation, history, and clinical signs. Diagnosis is essential for effective treatment of respiratory distress and should be completed as soon as possible without compromising patient status, ideally concurrently with stabilization. Low stress diagnostics that can rapidly rule-in and rule-out differentials during examination should be used and tailored to the patient's presentation. One such tool is Point-of-Care Ultrasound (POCUS).

POCUS for Diagnosis of L-CHF

POCUS is a rapid and targeted ultrasound examination of thoracic and abdominal structures aimed at answering relevant binary questions (8). POCUS is performed patient side and is directed based on clinical presentation of the patient. POCUS can guide triage, interventional, and monitoring decisions with patients. This tool can rapidly differentiate between common causes of respiratory distress and guide further treatment decisions. Of particular focus is diagnosis of cardiogenic pulmonary edema secondary to left-sided congestive heart failure (L-CHF). Using POCUS on an emergency basis can help to diagnose cardiovascular disease that is the cause of respiratory distress. Conventional approaches to diagnosis of L-CHF history, clinical signs, physical exam findings, and both radiographs and often specialist performed echocardiography for definitive diagnosis (9). Unfortunately, radiographs are contraindicated in unstable patients, complicating diagnosis. Additionally, many clinicians are not trained in the intricacies of advanced echocardiography. POCUS provides an alternative rapid means of diagnosis that is available to most practitioners. POCUS has also been demonstrated within the human literature to reduce the time before onset of treatment and improve patient outcomes (10). Additionally, diagnosis of L-CHF is enabled through cardiac POCUS assessment of left atrial enlargement (3,11). Research has demonstrated that didactic-based and hands-on practical teaching of POCUS can be readily adopted by practitioners that are not imaging specialists to generate relevant cardiac images and interpret them with accuracy (2–4,12).

Diagnostic Criteria for L-CHF using POCUS

Shown below are the relevant images, their interpretation, and the anatomic site for pleural space, lung space, and cardiac POCUS to assess for L-CHF when presented with patients with respiratory distress. These sites will provide diagnostic criteria for L-CHF, while concurrently decreasing the likelihood of other causes of respiratory distress.

Pleural space and lung space (PLUS)		
Ultrasound Term	**Ultrasound image**	**Probe Location**
Curtain Sign: A normal and important finding to define the caudal lung border. When a probe is held in place at the costophrenic recess, this will appear as a "curtain" opening and closing as the patient respires (white arrow). This represents the mismatch between the soft tissue opacity of the liver(right), and aerated lung(left) and it signifies to the sonographer that they have reached the caudal-most portion of the lung, beyond which is abdominal contents (13).		1. Define the sonographic borders of the lung with your probe:  Caudal: Curtain sign Dorsal: Hypaxial/sublumbar Cranial: Shoulder flexors/thoracic inlet Ventral: Ventral lung border

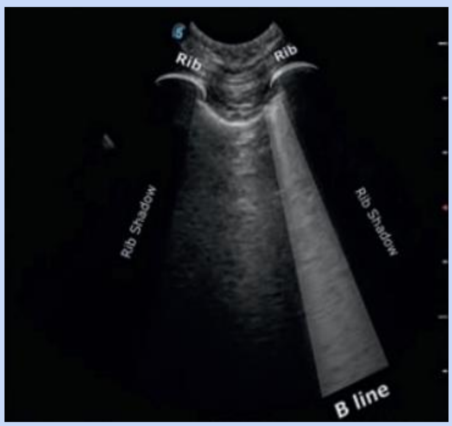
Glide Sign: A normal finding on thoracic POCUS. It appears as a shimmering bright horizontal line between rib shadows where the visceral and parietal pleura glide across each other as the patient respires (white arrow).
The presence of a glide sign means the pleura are in contact, and thus rules out pneumothorax at the probe location.

Also in this image are **A-lines** (black arrow), a normal finding and artifact of the soft tissue to air interface (14).

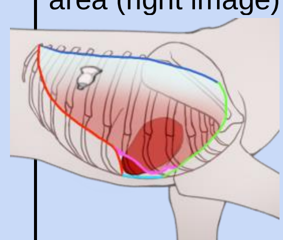
***Note:** If you have a high clinical suspicion of L-CHF; start on the right side of the patient.

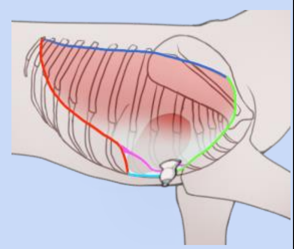
2. After defining your sonographic borders of the lung, follow the yellow arrow to scan the entire lung field on each hemithorax with the probe perpendicular to the ribs. Search for B-lines and note how many probe sites where they are present.

B-Lines: Referred to as "comet tails" or "lung rockets". More than three B-lines seen in one window, or B-lines seen in more than two locations in a hemithorax (diffuse and bilateral) is suggestive of decreased aeration caused most commonly by fluid (cardiogenic pulmonary edema). They may also be secondary to cellular infiltrates or atelectasis. They rule out pneumothorax at the probe location, and are used to track response of cardiac patients to furosemide (8) .



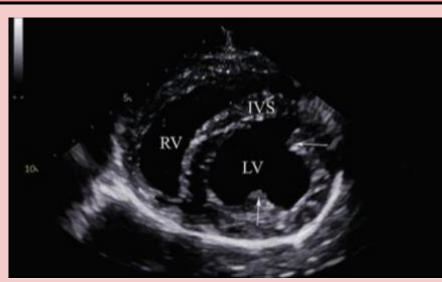
3. Pneumothorax would appear at the most gravity independent area (left image), while pleural effusion will be located at the more gravity dependent area (right image).





Cardiac POCUS

'Mushroom':
Often the first view to be obtained. Represents the left ventricle; in which dilation may be seen with cardiac failure or fluid overload. The contractility of the papillary muscles (white arrows) can be assessed as well (8,15).

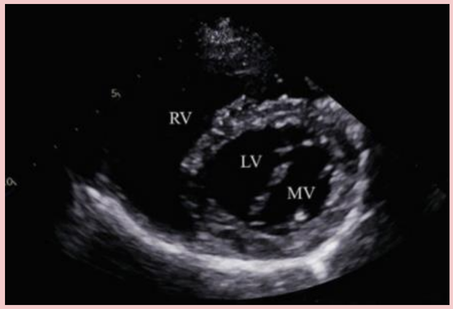


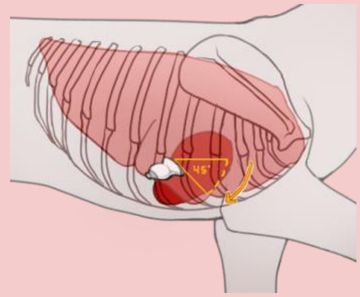
Right parasternal view (short axis):

1. Place the probe at a 90º angle to the thoracic wall, perpendicular to the ribs, and rotate it to the 4 o'clock position (30-45º) so that the marker of the probe is aimed towards the elbow to obtain a cross section of heart (mushroom view).

'Fish Mouth':

This is a good landmark to find the other views in the right parasternal short axis; it also shows the function of the mitral valve. It is found by fanning the probe towards the base of the heart from the mushroom view (8).



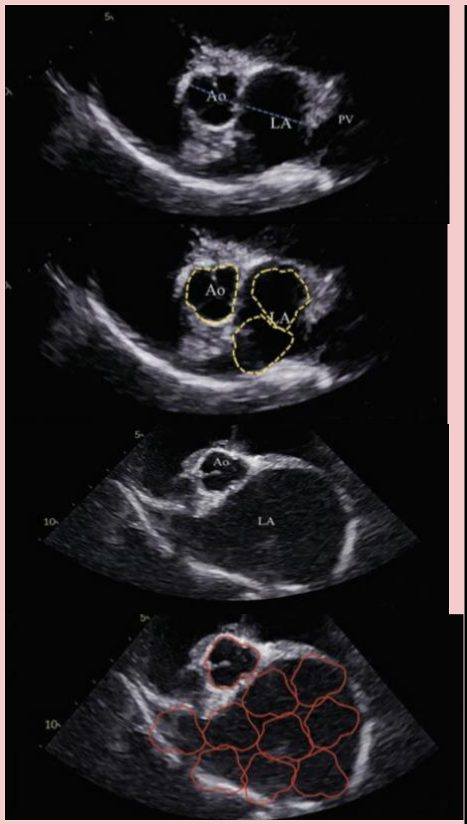


Left Atrium:Aorta (La:Ao) Ratio:

Often referred to as "the mercedes/peace sign (aorta) and the whale (left atrium)". The La:Ao is normally ~1:1. A ratio of >1.5:1 is considered enlarged, and a ratio of >2:1 in a patient with respiratory distress is strongly suggestive of left atrial dilation associated with left-sided congestive heart failure or fluid overload (11)

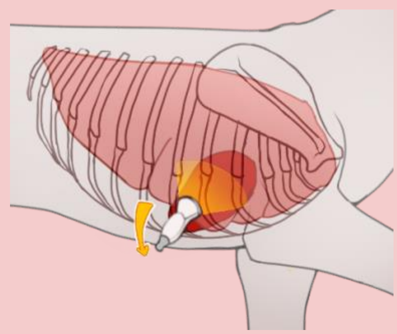
The two images on top represent a normal La:Ao, where no more than two aortas (2 yellow circles) could fit into the space offered by the left atrium.

The two images on the bottom represent left atrial enlargement suggestive of congestive heart failure, as can be seen by the many aortas (9 red circles) that can fit into the space in the dilated left atrium (8,15).



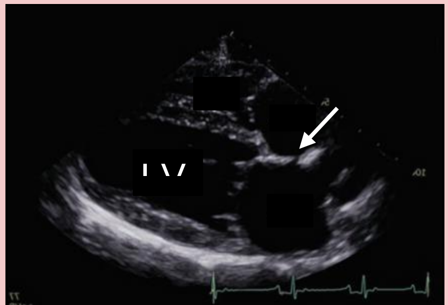
The probe should be over the point of maximal intensity of the heart in the 4th-6th intercostal spaces on the right side of the animal's thorax at the level of the costochondral junction.

2. **Fan** the probe towards the base of the heart from the mushroom view through the fishmouth view to find the LA:Ao view.

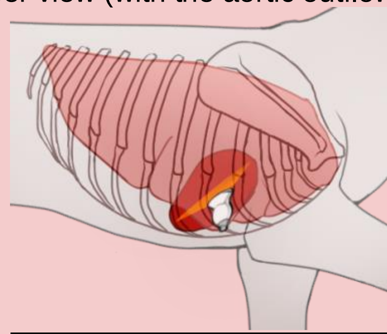


4-Chamber view: This view is obtained by rotating the probe from short to long axis in the right parasternal location. This may be used to assess the 4 main chambers of the heart. Compare chamber sizes and wall thicknesses with the short axis view for consistency. Normally, the ratio of left atrium:right atrium should be ~1:1 and the intra-atrial septum (white arrow) should be a straight horizontal line and not bulging into either atria (8).

5-Chamber view: This view offers the additional view of the left ventricular outflow tract through the aorta (8).



Right parasternal view (long axis): Go back to the mushroom view and rotate the probe to have the marker towards 6 o'clock to obtain the 4 chamber view, and then another 5” clockwise to obtain the 5 chamber view (with the aortic outflow).



To diagnose L-CHF following patient presentation with respiratory distress the following POCUS criteria should be identified. These criteria are listed in recommended order to identify first for diagnosis of L-CHF:

Canine

Lung: Positive glide sign. Positive diffuse bilateral B-lines.

Pleural space: Possible mild pleural effusion.

Cardiac: Enlarged LA:Ao ratio greater than 2:1. Dilated left ventricle and abnormal contractility on the mushroom view.

Feline

Lung: Positive glide sign. Positive diffuse bilateral B-lines.

Pleural space: Possible pleural effusion.

Cardiac: Enlarged LA:Ao ratio greater than 2:1. Likely left ventricular concentric hypertrophy. Possible pericardial effusion.

The most important criteria for diagnosis of L-CHF in patients with respiratory distress are the identification of diffuse bilateral B-lines with a concurrent enlarged LA:Ao ratio greater than 2:1. Additionally, a “gray zone” exists in diagnosis in which the LA:Ao ratio is enlarged (greater than >1.5:1) but less than less than 2:1. If a LA:Ao ratio is identified within this interval, the presence of diffuse bilateral B-lines should be considered, along with additional diagnostic tests such as

NT-proBNP, to assist in diagnosis and guide treatment decisions (11). Treatment with furosemide and reassessment may be considered in patients that have sonographically identifiable pulmonary edema and this particular LA:Ao ratio. Other causes of respiratory distress can also be diagnosed on POCUS. These differentials are not the focus of the paper, but are listed here to provide information to clinicians. This list is not exhaustive and additional resources to diagnose these differentials are available (8,16).

Other Possible Differentials	**POCUS findings**
Pleural effusion	- Negative glide side - Fluid effusion deep to parietal pleura - Gravity dependent
Pneumothorax	- Negative glide sign - Asynchronous curtain sign - Gravity independent
Diaphragmatic hernia	- Gas filled peritoneal viscous in pleural space - Can't trace curtain sign
Pericardial effusion	- Fluid effusion within the pericardial sac - Negative to minimal pericardial effusion
Feline Asthma (suggestive if history of coughing)	- Positive glide sign with negative B-lines - Negative for the above other differentials - Negative atrial enlargement

POCUS vs Radiographs

Radiographs are currently the reference standard for the diagnosis of cardiogenic pulmonary edema in dogs and cats (17). Most practitioners are familiar and comfortable with radiograph acquisition and interpretation and they have a sensitivity of 85% and a specificity of 87%, making them a good diagnostic tool for CPE (18). Diagnosis of CPE on radiographs differs between cats and dogs (18,19). In dogs, two criteria are defined, cardiomegaly and the presence of perihilar to caudodorsal interstitial-alveolar pulmonary opacities (18). Cats are more variable, as they often present with diffuse or localized distribution of pulmonary opacities with no predilection to site (19). Additionally, cats in cardiac failure often develop pleural effusion, leading to a loss of the cardiac silhouette along with any underlying lung edema (19). Furthermore, generalized cardiomegaly is not a consistent finding in cats with CPE; instead, cats consistently present with left atrial enlargement (19). However, performing radiographs on an unstable patient increases the risk of further decompensation and even death, and serial treatment monitoring requires repeated exposure of veterinary staff to radiation (17).

POCUS is a safe and reliable tool that clinicians can use to work up an unstable patient. Most POCUS exams can be completed within 10 minutes and are well tolerated by the patient, providing the practitioner with information to help rule in or out differentials without causing further harm to the patient (17). Scanning for the presence of B-lines in acutely dyspneic patients has been demonstrated to be an effective method to diagnose CPE in both dogs and cats (17, 18, 20). Finding three or more B-lines in 2 or more locations (or numerous B-lines) on the lungs had been demonstrated to have a sensitivity ranging from 84% - 90% and a specificity from 74% - 93% in diagnosing CPE in acutely dyspneic patients (18, 20). This is comparable to radiographic diagnosis of CPE, yet has the added benefits of being able to be performed cageside and having the same diagnostic criteria in both dogs and cats (17, 18). After performing the lung scan, POCUS can be used to assess the size and contractility of the left ventricle (mushroom view), the mitral valves (fish mouth view) and the La:Ao ratio to rule in or out the various etiologies of L-CHF (8, 15). An La:Ao of ≥2:1 is indicative of atrial enlargement and L-CHF (8, 15). POCUS also offers the additional benefit of serial monitoring to track the responsiveness of a cardiac failure patient to treatment with furosemide (a decrease in the number of B-lines after treatment with furosemide indicates pulmonary edema has decreased and thus the patient's state is improving) (8).

Addressing Confidence Using POCUS as a General Practitioner

While the literature states that pleural space and lung-POCUS, or PLUS is a useful tool to diagnose cardiovascular causes of respiratory distress in an emergency setting (17, 18, 20, 21), about 60% of practitioners do not feel comfortable utilizing PLUS to diagnose pathologies in practice (22). Specifically, only 35.6% of Canadian veterinarians scanned the LA:Ao ratio when performing POCUS (5). In agreement with a study by McDonald *et al*., only about 60% of the 36% respondents that performed POCUS were confident in their ability to diagnose pathology when assessing the La:Ao (5). Thus, practitioners are excluding a valuable tool to diagnose cardiovascular disease in many patient workups. Indeed, a lack of confidence and training in veterinary curricular programs is reported as one of the main reasons why practitioners do not perform complete POCUS scans, or ultrasound at all (5). Interestingly, more Canadian practitioners are confident in their ability to perform and diagnose pathology on abdominal POCUS (5). Pelchat *et al.* 2020, suggests that the lack of a standard protocol for thoracic POCUS exams has led to confusion over how to properly perform it, as well as how to diagnose pathology in the obtained images. This speaks to the need for additional training to be provided, through both CE and DVM programs. Additionally, a standardized protocol should be readily available for general practitioners, so they can improve their comfort in incorporating this valuable diagnostic tool in emergency settings.

The above images aim to provide this in a readily accessible manner so that practitioners can be confident in diagnosing cardiac causes of respiratory distress in an emergency setting. By answering binary questions, practitioners can rapidly determine if furosemide is indicated. Furthermore, minimal training is required for veterinarian general practitioners to be confident in their ability to utilize POCUS in their practice as an additional modality to diagnose CPE secondary to L-CHF (1, 2, 8, 12, 23) . Simple yes or no answers to a series of questions enable the practitioner to rapidly rule in or out differentials.

The presence of pulmonary edema is indicated through the presence of B-lines, while pneumothorax can be ruled out through the presence of a glide sign. A study by Burnotte *et al.* (2020), assessed the ability of veterinarians with little ultrasound experience to answer binary (yes/no) questions related to lung ultrasound. With a 5 hour course and 3 months of clinical practice using lung POCUS, general practitioners were able to correctly answer (over 75% of the time) binary questions related to whether B-lines and the glide sign was present or not. Similarly general practitioners were able to accurately assess patient's hearts after an 8-hour POCUS training session (23). As mentioned, assessing the LA for enlargement is key to identifying whether L-CHF is the cause of PE. Agreement with echocardiograms performed by a cardiologist was 98% for the LA, and 84% for the LV, indicating that cardiac POCUS is an easy to learn tool for the diagnosis of L-CHF in general practice (23). Combining the recognition of L-CHF with the presence of PE points practitioners towards a diagnosis of CPE secondary to L-CHF.

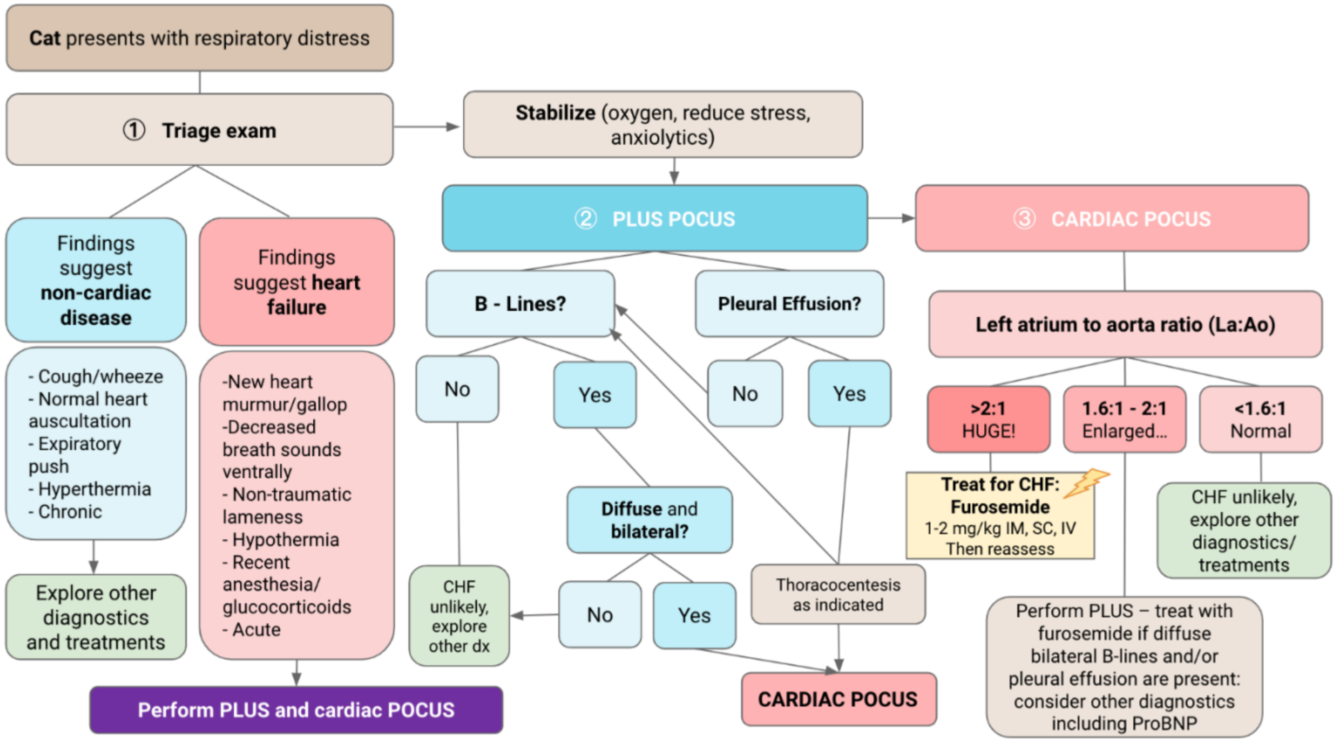
Treatment Overview

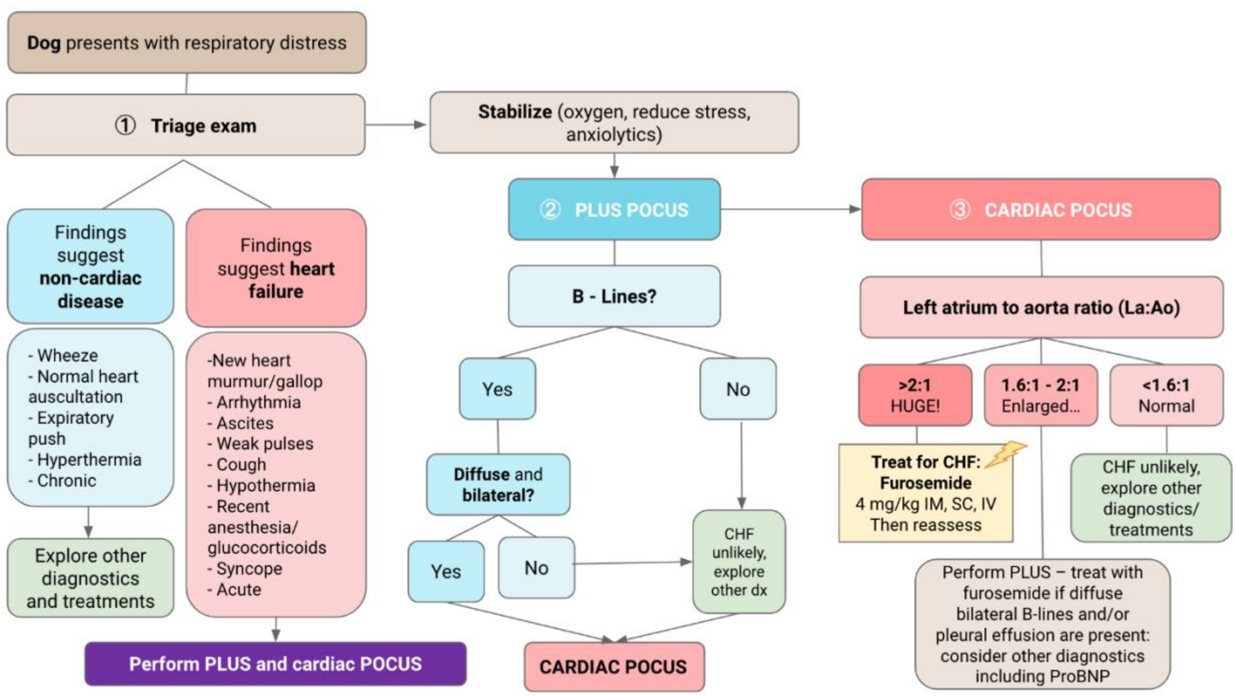
The goal of this paper is to highlight to clinicians how to diagnose L-CHF using POCUS in patients presenting with respiratory distress. However, a brief overview of treatment will be covered. The hallmark of treatment is to decrease hydrostatic pressure within the pulmonary circulation that is the cause of cardiogenic pulmonary edema. This should be initiated as soon as reasonably possible and may coincide with patient stabilization. Furosemide, a loop diuretic, is the standard drug to decrease cardiac preload and thus hydrostatic pressure within pulmonary circulation. However, treatment of L-CHF may be complex depending on the severity of the patient's clinical signs and response to initial treatment. Treatment may require hospitalization with continuous in-hospital reassessment or referral to tertiary centers. Additionally, these patients will require chronic treatment once stabilized. Refer to the following for further guidelines on treatment in both canine (24, 25) and feline patients (26, 27).

Conclusion

Respiratory distress is a life-threatening emergency within veterinary practice. Clinicians are responsible for recognizing associated clinical signs and being able to rapidly stabilize and diagnose presenting patients. POCUS is a diagnostic instrument that can be learnt by any veterinarian to rapidly respond to respiratory distress. We hope that this paper has provided clinicians the confidence and foundations on POCUS to diagnose L-CHF.

Diagnostic Algorithms





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