THORACIC RADIOGRAPHS AND CARDIOPULMONARY DISEASE

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Respiratory and cardiac abnormalities are common in small animal practice and in emergency situations in particular. Identification of the specific underlying cause is important for both diagnostic and therapeutic success. Respiratory disease may be due to upper airway obstruction (e.g. laryngeal paralysis), pleural space disease (e.g. pleural effusion or pneumothorax), pulmonary parenchymal disease (e.g. pneumonia/edema) or a combination of any of the above. Occasionally, metabolic acidosis (with respiratory alkalosis) or fever/pain may result in signs of labored breathing without gas exchange abnormalities.

Thoracic radiographs are particularly vital in the assessment of the patient with suspected cardiac disease. Radiographs are ESSENTIAL for answering the question “Is there congestive heart failure or not?” Echocardiography is useful to better define cardiac function, and measurement of NT-proBNP also plays an important role in distinguishing between cardiac and respiratory disease, but these tools do not replace routine thoracic radiographs.

The first step in treatment of respiratory distress is usually supplemental oxygen and rest. In some cases, emergent intubation or thoracocentesis may be warranted prior to other diagnostics. However in the majority of cases, thoracic radiography will be performed to attempt to elucidate the underlying cause. In some cases, interpretation of radiographs will be immediately diagnostic as to the underlying cases. However, in other cases, radiographs will confirm an abnormality in the pulmonary parenchyma, but the specific diagnosis may not be readily apparent. In all cases, it is necessary to combine the results of diagnostic imaging with the results of the history, physical examination and signalment.

Cardiac silhouette and vessels
Evaluation of the cardiac silhouette includes an assessment of cardiac size, cardiac shape to assess which chambers are enlarged, and an assessment of the pulmonary arteries and veins, as well as the aorta and vena cava.

Cardiac size
The experienced clinician often uses subjective assessments of cardiac size for evaluation of the heart. This works well in many dogs and cat, but the subjective assessments have some limitations. Rules of thumb that can be used include the width of the heart on a dorsoventral (DV) or ventrodorsal (VD) radiographic view, with the heart occupying no more than 60% of the width of the thorax at the maximal spot. This rule, and any other rules for the DV or VD views, is highly dependent upon good patient positioning, which can be difficult to accomplish in the animal with respiratory distress. On the lateral projection, the normal cardiac size is often 3 rib spaces in the dog and usually less than 2.5 rib spaces in the cat.

Measurement of the cardiac silhouette using the Vertebral Heart Size (VHS), as described by Buchannan et al, indexes the cardiac size to the vertebral length. Using this technique, most dogs have a VHS on the lateral view of 9.5 and the vast majority of dogs with a VHS above 10.5 have significant cardiomegaly. This technique is especially helpful in dogs with a deep chest conformation (i.e., Doberman pinscher or Irish setter) and in those with a wide or barrel shaped chest (i.e., bulldog, pug, and miniature schnauzer). The author finds the VHS somewhat less accurate on the lateral view for cats with heart disease, and finds the DV view superior in many cases. For the short axis in cats, most cats with normal cardiac size have a VHS less than 8.0, and many cats with cardiomegaly have a lateral VHS > 8.5. On the DV view, the short axis measure is usually less than 3.8-3.9 and the VHS on this view is usually less than 8.8, except in obese cats.

Cardiac shape
The shape of the heart can be evaluated in a number of ways, on either the lateral view or the DV/VD view. For the DV/VD view, the heart is often likened to a clock face, and structures are noted relative to the position of numerals on the clock face. The aorta is located at the 12:1:00 location, the pulmonary artery at the 2:00 location, the left auricular appendage at the 2-3:00 site, and the left ventricle usually spans from the 3 to 5:30 or 6:00 location. The right ventricle spans from 5-6:00 site to the 9:00 position and the right atrium usually accounts for changes in the cardiac silhouette at the 9-11:00 spot. On the lateral view, the heart can roughly be divided into quadrants by a drawing a line from the carina to the left ventricular apex, with a second line perpendicular to the first which bisects the heart from top to bottom. With this scheme, the left atrium sits in the caudodorsal quadrant, the left ventricle in the caudodorsal quadrant, the right atrium in the craniodorsal quadrant, and the right ventricle in the cranioventral quadrant. When looking at the vertical line from carina to apex, when there is considerably more heart cranial to this line the right heart enlargement in present. Left atrial enlargement is almost always notable in dogs with left sided congestive heart failure (pulmonary edema). Marked cardiomegaly can also result fro either pericardial effusion or tricuspid valve dysplasia. In dogs with pericardial effusion, the shape of the heart is often very round, especially on the DV or VD view, and the edges of the heart are often very clear or crisp, owing to lack of cardiac motion artifact.

Great vessels and pulmonary vasculature
The aorta can become enlarged, especially cranial to the heart, in animals with aortic stenosis or in cases with systemic hypertension or in aged cats. Small aortic size in the mid-thoracic aorta on the lateral view is often seen in animals
with low cardiac output. The caudal vena cava becomes enlarged in cases with pericardial effusion or right-sided congestive heart failure. The ratio of the dimension of the caudal vena cava to the aorta can be used as a guide, with most normal animals having a CVC/Ao ratio of less than 1.5. In most animals with right sided cardiomegaly and an enlarged caudal vena cava, there is also both hepatomegaly on exam or radiographs and the jugular vein is either distended or there is a positive hepatojugular reflux. The pulmonary arteries and vein can also provide useful information about hydration status and cardiopulmonary health. Small pulmonary arteries and vein, especially with relatively dark lung fields and/or a small cardiac silhouette and small cava, often indicates hypovolemia. When the pulmonary vein is enlarged then left sided CHF is likely present or imminent. Pulmonary vein enlargement and tortuosity is often seen in cats on the lateral thoracic radiograph and this finding is often associated with marked left atrial enlargement. Cats with left sided CHF often have enlargement of both pulmonary arteries and pulmonary veins. When the pulmonary arteries alone are enlarged then pulmonary hypertension may be present. Enlargement of the main pulmonary artery and the PA segment alone can be seen with many cause of pulmonary hypertension, while enlargement of these segments combined with tortuosity of the distal pulmonary arteries and blunting of vessels is more common in dogs with heartworm disease. Enlargement of both the pulmonary artery and vein may indicate fluid overload, or the presence of a left-to-right shunting congenital cardiac defect.

**Lung patterns**

Radiographic patterns that may be detected upon thoracic radiography include bronchial, interstitial, alveolar and vascular. In many clinically significant diseases, there is a combination of patterns. It is prudent to review the patterns that are seen and to consult with regularly with a radiologists and cardiologists. Appropriate interpretation of radiographs requires a combination of film interpretation with the signalment, progression of disease, and clinical signs. Following radiographic assessment, clinicians should be prepared to evaluate what further clinical testing (if any) is required.

**Alveolar pattern**

Alveolar disease is readily recognized by the appearance of air bronchograms, which develop due to the inherent contrast between aerated bronchi and fluid-filled lung parenchyma. Alveolar disease most commonly represents pneumonia, pulmonary edema, pulmonary hemorrhage or pulmonary contusion. Rarely, malignancy may have focal alveolar disease, specifically with malignant histocytosis.

**Pneumonia**

Pneumonia in dogs is mostly commonly associated with an alveolar pattern located in a cranioventral location and may be associated with a gas-dilated esophagus (megaesophagus). Some pneumonias are diffuse throughout the lung parenchyma, and this is especially true of community acquired pneumonia (i.e., non aspirational pneumonia). Clinically, pneumonias are most often associated with lethargy, fever, cough and nasal discharge. Animals will often have a history of vomiting or other risk factors for aspiration such as laryngeal paralysis. Puppies, particularly those from pet stores are commonly affected with severe bronchopneumonia associated with the infectious tracheobronchitis syndrome. Importantly, cats with suspected pneumonia often have either concurrent asthma or congestive heart failure (instead of pneumonia).

**Pulmonary edema**

Pulmonary edema may be cardiogenic or non-cardiogenic. In the early stages of pulmonary edema, fluid may only be appreciated as a heavy interstitial pattern. As the fluid progresses, the alveolar spaces fill in with edema and the radiographic pattern becomes alveolar. In large breed dogs, the lymphatics flow along side the bronchi and a bronchial pattern may be evident prior to the development of overt alveolar edema. Questions for the practitioner following the identification of a radiographic pattern suspected to be pulmonary edema include:

1) Is it cardiogenic or non-cardiogenic pulmonary edema? This may be a challenging question to answer. Starting with dogs, the two most common causes of cardiogenic pulmonary edema are chronic valvular disease and dilated cardiomyopathy. Valvular disease is more common in small breed dogs, while dilated cardiomyopathy is more prevalent in large breed dogs. The cardiac silhouette is enlarged in both cases and left atrial enlargement may (should) be appreciated. Pulmonary veins are engorged. Edema fluid in dogs with heart failure is usually perihilar. In cats, cardiomegaly is often although not always appreciated and edema distribution may be patchy. Cats are often hypothermic and relatively bradycardic. Causes of non-cardiogenic edema include upper airway obstruction or seizures. In these cases, edema is most commonly appreciated in the dorsal caudal regions of the lungs. It may develop peracutely following relatively benign conditions such as pulling on a choke collar or struggling during a bath. Non-cardiogenic edema may also develop as part of an inflammatory lung condition such as acute lung injury (ALI) or acute respiratory distress syndrome (ARDS). In these cases the medical history should help to pinpoint the diagnosis.

2) What therapies are in order? Clearly, understanding of the cause of the condition is most likely to result in successful treatment. For suspected alveolar infiltrates due to heart disease, treatment is centered on diuresis (e.g furosemide) and vasodilators (ACE inhibitors, nitroprusside) as well as rest and supplemental oxygen. For non-cardiogenic edema, no specific therapy has proven beneficial beyond rest and supplemental oxygen. Mechanical ventilation may be required in severe cases.

**Pulmonary contusion**
Pulmonary contusion is another common cause of focal alveolar infiltrates. Generally, the diagnosis is straightforward based upon the medical history. However, in some cases, the trauma was unobserved. Systemic evidence for trauma includes elevated liver enzymes, particularly ALT and AST, ventricular ectopy and external wounds or frayed toenails.

1) Almost all pets with pulmonary contusion should be observed overnight for progression of signs or development of other complications. It should be appreciated that pulmonary contusions are similar to bruises in other parts of the body, with progressive infiltration of inflammatory products into the damaged tissues over the first 24-48 hours. That said, it is exceedingly rare for a pet to be relatively stable and then to acutely decompensate due to worsening pulmonary contusions. Most apparently sudden decompensation in traumatized pets is from internal hemorrhage, or potentially from severe pneumothorax.

2) Treatment of pulmonary contusion is non-specific. Diuretics are CONTRAINDICATED as pets are likely volume contracted rather than volume overloaded. Most contusions will resolve in 2-3 days with supportive care. Antibiotics are not indicated for isolated pulmonary contusion or are glucocorticoids.

**Interstitial pattern**

Interstitial diseases represent those conditions that are not alveolar or bronchial. The lung interstitium may fill with inflammatory products, edema, neoplasia or fibrosis. Interstitial diseases should not mask anatomy meaning that you should be able to see regional vessels and borders of the heart or diaphragm. If warranted, sampling from the interstitium is performed via a surgical or thoracoscopic lung biopsy or via a fine needle lung aspirate. Older dogs may have a heavy interstitial pattern without obvious pulmonary functional abnormalities. In recent years, the existence of a form of naturally-occurring pulmonary fibrosis in dogs and cats has been recognized. Significant questions for clinicians managing patients with interstitial lung disease include:

1) Is this disease the source of the pet’s problems? Most pets affected with interstitial lung disease are tachypneic with shortness of breath, particularly on exertion. Dry, non-productive cough may be present.

2) What form of further testing is warranted? With the advances in imaging technology, the high-resolution CT scan is growing in popularity as a definitive aid in identification of the underlying pathophysiology. Due to the challenges of transoral sampling, a biopsy or aspirate is often more useful.

**Bronchial pattern**

A Bronchial pattern represents the final form on pulmonary infiltrate that may be detected upon thoracic radiography. Bronchial (Not bronchiolar!) infiltrates represent disease in the medium to larger airways. The most common cause of bronchial patterns are allergic and parasitic diseases. Dogs not uncommonly develop eosinophilic bronchopathy (bronchitis) as evidenced by a marked bronchointerstitial pattern and a large number (often in excess of 20,000) of circulating eosinophils. Cats are often affected with asthma or chronic bronchitis. Due to difficulty during expiration, thoracic radiographs will also commonly appear hyperinflated with flattening of the diaphragm due to air-trapping.

Questions for the clinician following documentation of a bronchial pattern include:

1) What is the likelihood of parasites? All pets with a prominent bronchial pattern should be evaluated for occult heartworm infection and for lung worms (or dewormed with fenbendazole)

2) Airway sampling via a tracheal wash is useful for documentation of pulmonary eosinophilia and occasionally for identification of lung worms.

3) Following exclusion of parasites, most pets respond quickly to anti-inflammatory glucocorticoids.

**Pleural space disease**

Pleural space disease may be divided into fluid and air. Pneumothorax is often associated with trauma, but may also develop spontaneously due to bulla or bleb. Pleural effusion is most easily appreciated on a DV exposure by the diaphragm or in-between the lung lobes. From a cardiologist’s perspective, pleural effusion represents right sided heart failure either as a primary disease or as part of progressive L-CHF (i.e., biventricular CHF). Heartworm disease at times may causes pleural effusion but more often R-CHF is associated with ascites. Older cats with cardiomyopathy appear more likely to form pleural effusion than younger cats. Also importantly, chronic pleural effusion, especially chylos or inflammatory effusions, may lead to chronic pleuritis which can be noted by rounding of the edges of the lung lobes; this finding may significantly increase the risk of iatrogenic pneumothorax when the patient is tapped.

**Conclusions**

The presence of pulmonary infiltrates is useful to the clinician in documenting the underlying cause. A straightforward approach and step-wise fashion can help ensure that the etiology is elucidated. Treatment options reflect the underlying disease.

References available upon request.
Key Words:
Congestive heart failure
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