Thoracic radiography continues to play an important diagnostic role in evaluation of the canine and feline cardiorespiratory patient, with examples of clinically relevant scenarios including identifying stage B2 cardiac disease (disease producing cardiomegaly indicating cardiac remodeling), investigating the patient with respiratory signs, and identifying cardiogenic pulmonary edema. For the latter, thoracic radiography remains the clinical standard for diagnosis of congestive heart failure (CHF). Thoracic radiography lacks sensitivity in detection of mild cardiac disease in dogs and cats, but better sensitivity for detection of more advanced cardiac disease, and reasonable specificity for detection of significant left atrial enlargement in particular. Recognition of the typical radiographic findings of cardiogenic pulmonary edema is important in the patient with respiratory signs, and awareness of the differences between dogs and cats in this regard is important. Goals of this lecture include 1. review of thoracic radiographic anatomy, 2. correlation of CHF physiology with thoracic radiographic findings, 3. review of objective radiographic measurement indices, both old and new, and their applications, and 4. case review.

**Radiographic Cardiac Anatomy**

Heart size may be assessed in general by measuring the height and width of the cardiac silhouette relative to the thorax (cardiothoracic ratio) in lateral and DV views (see rules below), respectively, and localized cardiac enlargement may be appreciated using the anatomic schematics below. In cats, the cardiothoracic ratio in the DV/VD view is more commonly used than the lateral view, whereas both are used commonly in dogs.

**Lateral view:** Normal $B \leq \frac{2}{3}$ to $\frac{3}{4}$ of $A+B$

**Localized cardiac enlargement**
Objective Radiographic Cardiac Indices

The vertebral heart score (VHS) is a well-described means of assessing heart size. While originally intended to be relatively breed and conformation independent, its accuracy in identifying cardiomegaly in the individual dog has been challenged and it should be interpreted with some caution. A lateral view that clearly shows the T4-T13 vertebrae with minimal rotation of the thorax (rib arches and costochondral junctions aligned) should be used. The long axis of the heart is measured as the distance from the carina to the apex of the heart. The short axis is measured as the widest part of the heart on an axis perpendicular to the long axis and anchored at the ventral aspect of the caudal vena cava. Each of these are compared to the vertebrae by starting from the cranial edge of the T4 vertebral body and measuring the length of the axes by the number of vertebrae (to 0.1 of a vertebral body). The VHS is the sum of the length of the short and the long axes in vertebrae (VHS = long axis + short axis). The reported mean +/- SD (range) in 100 normal dogs of various conformations was 9.7 +/- 0.5 (8.5-10.6) in the original publication by Buchanan (Buchanan 1995). However, breed specific ranges should be used where available, as larger normal values are reported in several breeds including pugs, Pomeranians, Boston terriers, English bulldogs, Spitz, CKCS, Labradors, boxers, beagles, and miniature schnauzers. Larger values are also reported in right versus left lateral views. The reported mean +/- SD (range) in normal cats is 7.5 +/- 0.3 (6.7-8.1) in the lateral view (Litster 2000), and is generally unaffected by breed.

Example of calculation of vertebral heart size/score (VHS):
Current myxomatous mitral valve disease (MMVD) Consensus guidelines suggest that in small breed geriatric dogs with left apical systolic heart murmurs of 3/6 and greater, a VHS >11.5 may support the presence of stage B2 MMVD, a stage with therapeutic implications. This approach has limitations and additional radiographic indices have been investigated to increase the specificity of radiographic use in stage assessment (see below). A retrospective study of 90 dogs with coughing and clinical evidence of MMVD found that a VHS < 11.4 was supportive of a non-cardiac cause of cough, while VHS > 11.4 was indeterminate (may have had cardiac or respiratory cough, or both) (Guglielmini 2009). These findings have not been prospectively validated. Another clinically relevant use of VHS is in serial monitoring of MMVD patients – studies have shown patterns of abrupt increase in VHS in the months leading up to congestive heart failure, thus change in VHS may be a useful parameter in prediction of CHF onset (Boswood 2020; Lord 2011).

VHS has been evaluated in cats for ability to distinguish normal cats from cats with cardiac disease. A VHS cut-off of 8.2 on the lateral view was shown to be only moderately sensitive for detection of cardiac disease in cats (Guglielmini 2014). This is perhaps not surprising considering hypertrophic cardiomyopathy is the most common feline acquired heart disease and leads to concentric hypertrophy which may not produce overt enlargement of the cardiac silhouette to the same degree that chamber dilation does. VHS in cats has also been evaluated for utility in distinguishing CHF from other causes of
respiratory distress. VHS values less than 8.0 likely rule out CHF while those >9.3 are highly specific for CHF cause of acute respiratory distress in cats according to one retrospective study (Guglielmini 2015).

Several imposters for cardiomegaly may need to be considered when an enlarged cardiac silhouette is identified radiographically. Examples of conditions that may mimic true cardiomegaly include pericardial effusion, intrapericardial masses or fat, and pericardioperitoneal diaphragmatic hernia.

Additional radiographic indices targeted at detecting left atrial dilation have been proposed and evaluated, including vertebral left atrial size (VLAS) in dogs and left atrial VHS (LA-VHS) in cats. Clinically, these indices may have value in staging MMVD, assessing cats for candidacy for anti-thrombotic therapy, and helping to support a diagnosis of congestive heart failure in dogs and cats with respiratory signs. VLAS is measured by extending a line from the mid-point of the ventral carina to the caudal aspect of the left atrium where it intersects with dorsal border of the caudal vena cava (dashed line in canine radiograph below, showing left atrial dilation). A line of the same length is then extended from the cranial aspect of T4 parallel to the spine and the number of vertebrae counted to a tenth of a vertebra (in the case below, 2.9). Reported median in 15 smaller breed dogs was 2.1 (25th-75th percentiles: 1.8-2.3) whereas values ≥2.5 were consistent with LA dilation with 67% sensitivity and 84% specificity in 88 dogs with MMVD (Malcolm 2018).

VHS-LA is measured in cats by constructing a long-axis dimension on a lateral view from the ventral aspect of the carina to the left apex of the heart (dashed line below), then placing a line perpendicular to that anchored at the caudal aspect of the left atrium where it intersects with the dorsal border of the
caudal vena cava (solid line below). The length of this line is then re-created along the vertebrae starting at the cranial aspect of T4 (as for VHS) and the measure reported to a tenth of a vertebra (in the case below, 0.9). Reported median normal values for VHS-LA in cats range between 0.87 to 1.0 vertebrae (Guglielmini 2015).

Identification of Left-sided Congestive Heart Failure
The sequence of increases in hydrostatic pressure that typically precede the development of CHF can be useful diagnostically as they lead to a constellation of radiographic findings, particularly when respiratory signs are secondary to chronically progressive left-sided cardiac disease. That sequence includes increased left atrial pressure → increased pulmonary venous pressure → increased pulmonary capillary pressure → pulmonary edema. From this, it can be appreciated that the presence of left atrial dilation and pulmonary venous distension with pulmonary opacities should typically accompany CHF. Exceptions to this, where the degree of left atrial dilation and pulmonary venous distension may not be as obvious, include acute processes such as mitral valve chordal rupture, infective endocarditis, iatrogenic fluid overload, and cats (of course). Cats with left-sided CHF are reportedly less likely to show detectable left atrial dilation and pulmonary vein enlargement than dogs, and more likely to have concurrent pleural effusion, which may make these classic changes difficult to detect.

The distribution of radiographic pulmonary changes should also be considered in the differentiation of CHF from primary respiratory disease. In dogs, CHF is often worse caudodorsally though it may be diffuse when severe. However other processes can be primarily distributed caudodorsally such as non-cardiogenic edema. It is not uncommon for cardiogenic edema to lateralize or be worse on one side (more commonly the right) on a DV orVD view, so CHF should not be excluded on the basis of lateralization. Pulmonary changes that are predominantly cranioventral or lobar are more likely to be non-cardiac in origin. Cats, however, once again like to break the rules and are more likely to have non-uniform, regional, and ventral opacities when they have cardiogenic edema compared to dogs.
Cases may certainly still be encountered in which determination of whether respiratory signs and radiographic changes are due to cardiac or respiratory disease is not possible, ambiguous, or in fact a combination of the two. Examples include very small breed dogs such as Yorkies and Chihuahuas in whom normal hearts can often have the impression of being radiographically enlarged, geriatric small breed dogs who may have concurrent cardiac and respiratory disease, and cats with acute CHF. Additional diagnostics are necessary in these cases to produce the same degree of certainty.

Thoracic radiographic case examples will be reviewed in an interactive manner.

References


