Practical radiography in small animal practice III: cases with a heart murmur

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Introduction

It is well known that echocardiography is a highly dynamic technique that obtains real time images of the contracting heart. In addition, it allows the assessment of the heart's internal architecture and the blood flow from and to the major vessels. It is now a fundamental tool in the diagnostic work up of patients suffering from cardiac pathology. However, there is the trend to forget that thoracic radiography is the perfect complementary tool to echocardiography. Good thoracic radiographs will determine whether cardiogenic pulmonary oedema is present and will rule out the presence of non-cardiac lesions that could cause the clinical signs.

Both techniques, however, will be of little use without a complete history, clinical examination and ancillary tests.

Clinical concepts

A murmur can be heard, and sometimes felt, when a disruption of the normal laminar flow through the heart and/or valves to major vessels occurs and it causes vibrations with enough energy to be detected with the stethoscope, or by physical examination if very severe.

The most common causes of murmurs include (Wotton, 1998):

- Changes in the shape of the cardiac chambers or cardiac valves
- Changes in the viscosity or velocity of the blood flow through the heart

Not all murmurs are clinically significant:

- Physiological murmurs can be heard secondarily to a modification in the viscosity or the velocity of blood flow without a change in cardiac morphology. For example, in cases of severe anaemia, hypoproteinaemia, hyperthyroidism and stress.
- Innocent or functional murmurs are typically mid systolic murmurs that are detected in puppies and kittens up to 16 or 24 weeks of age or in athletic adult dogs without any concurrent pathology (Wotton, 1998).

It is very important to distinguish systolic from diastolic or continuous murmurs, as this can indicate the most likely underlying pathology. For a detailed description, consult Wotton (1998). A summary is included here:

- Systolic murmurs:
  - o Crescendo-decrescendo murmurs are usually associated with aortic or pulmonic stenosis. Less frequently they are associated with an atrial septal defect with pulmonic valve pseudostenosis or with a Tetralogy of Fallot.
  - o Plateau murmurs are usually associated with mitral or tricuspid insufficiency. Less frequently they are associated with a ventricular septal defect.
- Diastolic murmurs: these are usually in decrescendo and associated with aortic insufficiency. Note that mild pulmonic insufficiency, although frequently found on colour doppler imaging in dogs, is not usually associated with an audible murmur.
- Continuous murmur: this is usually associated with a persistent ductus arteriosus (PDA).

Knowledge of this pathophysiological process is very important in understanding the radiographic signs of those patients with significant underlying pathology:

- Generally, cases with valvular insufficiencies, atrial or ventricular septal defects or PDAs will show more obvious radiographic patterns of cardiomegaly as these pathologies will cause congestion of the chambers and vessels that receive the extra volume of blood.
- Conversely, cases of valvular stenosis may not show such an obvious cardiomegaly if concentric myocardial hypertrophy is the main pathological change associated with the abnormal flow through the valve.

The reality, however, is that most cases will not read the books and may show clinical signs associated with a combination of cardiac and respiratory pathologies. This is especially true in geriatric patients, where non specific signs like cough, dyspnoea or loss of condition could be linked to both systems. As previously stated, the presence of a cardiac murmur or an arrhythmia does not imply that a cardiac problem is behind the symptoms. A similar statement can be applied to an abnormal pulmonary auscultation, which does not imply a respiratory origin of the clinical signs.

Some general diagnostic rules that can help in this situation are:

- Cardiac conditions tend to have a faster course and tend to cause weight loss (Marks and Sisson, 2003). They should also be suspected in cases with consistent tachycardia and pulse abnormalities (Johnson and Padrid, 2000).
- Ascites should make the clinician consider a cardiac problem more likely than a respiratory problem.

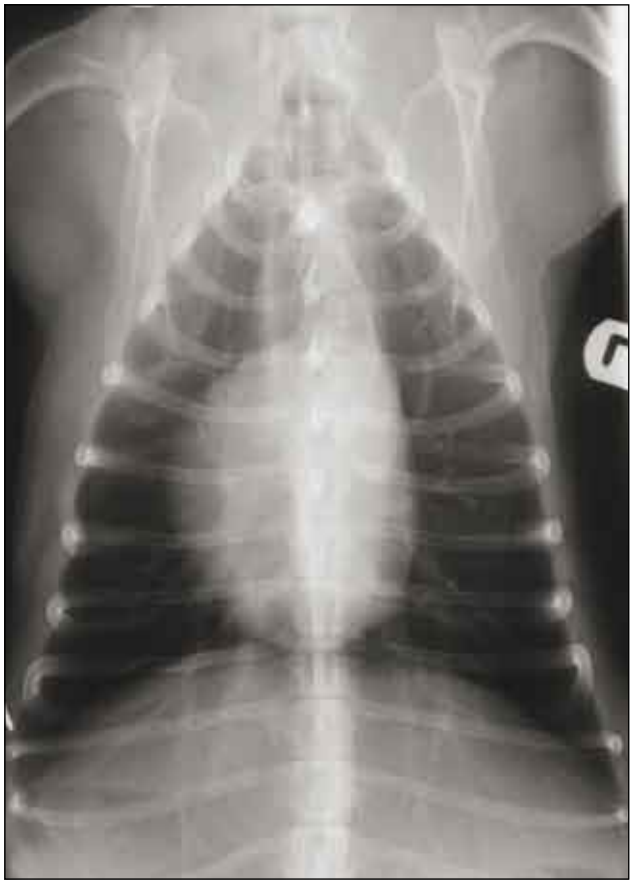

Figure 1: Manually distended dorsoventral thoracic radiograph of a 13-year-old cross breed dog taken under general anaesthesia. The radiograph is unremarkable.

Figure 2: Similarly obtained ventrodorsal thoracic radiograph of the same dog as in Figure 1. The radiograph is unremarkable.

It must be noted, however, that it is far less likely for feline patients than canine patients, to develop ascites secondary to a cardiac problem. In addition, hepatomegaly is a less common radiographic finding in cats with cardiac problems, and if ascites appears it is usually then associated with pleural effusion (Rishniw, 2000).

- Cardiogenic cough is a less frequent finding in cats. This, together with the less active lifestyle of some feline patients, can make the early stages of a cardiac problem very difficult for owners to detect, and cats can be brought to the vet when the cardiac problem has decompensated and very obvious clinical signs are now present (Rishniw, 2000).

Important radiographic technical aspects

Only two important concepts will be included here:

1. The importance of always obtaining the same radiographic projections when evaluating cardiac patients.
   - Dorsoventral and right lateral recumbent radiographs are preferred for the reasons outlined below. However, if this is not the protocol routinely used in your practice, the important concept to remember is to always evaluate the same type of projection to allow for continuity.
   - Dorsoventral projections are preferred to ventrodorsal ones to avoid magnification of the cardiac silhouette and to better evaluate the vessels to the caudal lung lobes (**Figures 1** and **2**).
   - The cardiac silhouette is larger and more rounded on a left lateral recumbent radiograph (Lamb and Boswood, 2002) (**Figures 3** and **4**).
2. Avoid, where practically possible, obtaining the radiograph at the end of expiration (**Figures 5** and **6**).

Figure 3: Normal right lateral recumbent thoracic radiograph of an 11-year-old Border Collie.

A practical approach to the radiographs of these patients

What do the books say?

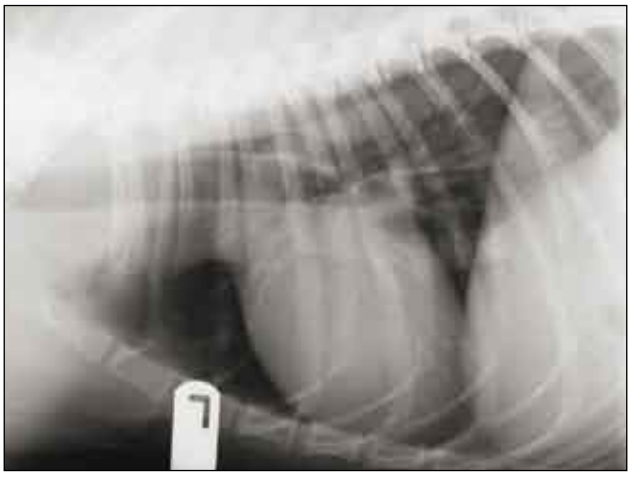

Figure 4: Normal left lateral recumbent thoracic radiograph of the same dog as in Figure 3.

Figure 5: Expiratory left lateral recumbent thoracic radiograph of an obese 13-year-old Labrador Retriever.

Figure 6: Manually distended left lateral recumbent thoracic radiograph of the same dog as in Figure 5. Note the effect that manual inflation has on the interpretation of the lung pattern and the size of the cardiac silhouette.

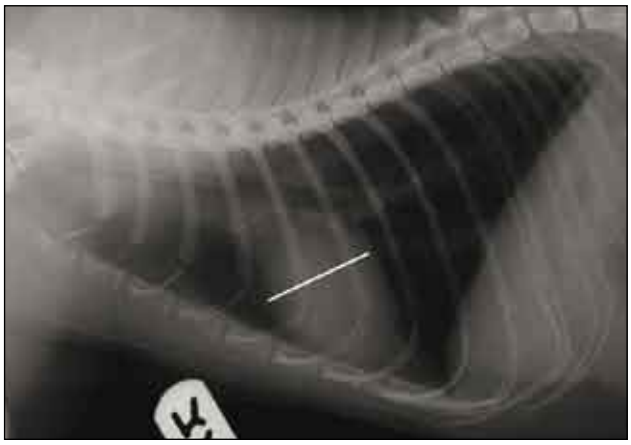

Figure 7: Normal right lateral recumbent thoracic radiograph of an eight-year-old Persian cat. The white line indicates how the measurement of the width of the cardiac silhouette is obtained in this species, accommodating for the tilting of the heart in elderly patients.

Three areas (cardiac silhouette, main vessels and the rest of the thorax - mainly the lung field and the pleural space) should always be systematically evaluated on each of the two radiographic projections obtained. If the cranial abdomen is included, radiographic signs of hepatomegaly and/or ascites, mainly in dogs, as mentioned, should be identified.

Laterolateral radiograph (Figure 3)

Cardiac silhouette

The origin of the bronchial tree should be located around the fifth intercostal space. The intrathoracic trachea should lay further away from the spine as it approaches this area. The silhouette should be ovoid. Thoracic conformation and the amount of pericardial fat should always be taken into consideration when assessing the radiograph.

The degree of sternal contact is not considered a useful radiographic sign of pathology in feline patients (Rishniw, 2000) as the cardiac silhouette tends to tilt towards the sternum in older cats as a well-recognised age-related change, together with the presence of a redundant aorta. This invalidates the use of this radiographic sign in cats.

Objective assessment:

- The craniocaudal measurement of the canine cardiac silhouette, taken at the level of the cardiac 'waist', should not exceed 3.5 intercostal spaces in a craniocaudal direction.
- The same measurement in cats should not exceed 1.3 intercostal spaces after having compensated for the tilting of the silhouette previously mentioned (the measurement is taken perpendicular to the long axis of the cardiac silhouette, but it is compared to the intercostal spaces as in dogs and starting from the cranial aspect of the fifth rib) (**Figure 7**).
- The length of the cardiac silhouette should not exceed 70% of the height of the thorax. This is not considered a very reliable assessment method, though, as many pathologies will not significantly increase the height of the silhouette (Rishniw, 2000).
- The vertebral heart scale (VHS) measures the short and long axes of the silhouette and determines the correspondence to vertebral bodies' length using the cranial border of T4 as the starting point (**Figure 8**). The normal canine scale range is 8.7 to 10.7; being 6.9 to 8.1 in cats, applicable to dogs of any age and cats older than six months of age (Buchanan, 2000).

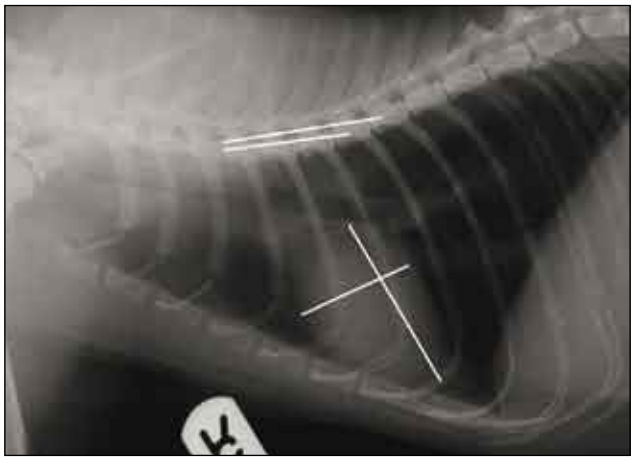

Figure 8: Same radiograph of Figure 7, showing how to calculate the vertebral heart scale in a cat. The same principle applies to dogs.

The result of this measurement generally offers only guidance rather than a definitive diagnosis, unless the measurements are really abnormal. The main problem with the VHS is that the normal range is quite broad. This makes the assessment harder as cases with mild cardiomegaly can still be at the top end of the normal range. In addition, the conformation of the thorax and the shape of the cardiac silhouette will have an effect on the final measurement, and it is now known that the VHS results for normal Boxers, Labradors and CKCS are higher than those of other breeds (Lamb *et al.*, 2001).

Feline patients show less variation in their thoracic conformation. The range is also smaller. The difficulty in these patients is to accommodate for the angulation of the mid-thoracic spine when measuring the scale.

Even if the use of the VHS has not dramatically changed thoracic radiology to the extent originally anticipated, and its use is unlikely to change the overall assessment of the radiographs (Lamb *et al.,* 2000), it is true that it can be helpful when used as another step within the work-up of the case, even with its already mentioned limitations.

From a practical point of view, the use of the VHS can be especially important when monitoring the response to therapy or the progression of the disease in the same patient. For this to work, however, it is very important to be particularly systematic and consistent when calculating the VHS. It is recommended that the long axis of the cardiac silhouette is measured starting from the ventral wall of the left main bronchus. The short axis' measurement should end at the point where the caudal border of the cardiac silhouette and the dorsal border of the caudal vena cava cross each other (Boag *et al.*, 2004).

Main vessels (Figure 3)
The lung lobe arteries are dorsal to the veins on this projection. Each vessel within an artery-vein pair should be of similar diameter, not exceeding the diameter of the proximal third of the fourth rib on both species.

From a practical point of view, one should look especially for an increase in vein diameter, as this is a sign of congestive heart failure. From a theoretical point of view, and not always seen in clinical practice, the change in vascular pattern could help to distinguish between different cardiac pathologies based on the vessel (artery vs. vein) that is abnormal. Only veins would be enlarged in cases of left sided congestion, only arteries would be enlarged in cases of pulmonary hypertension, and both would be enlarged in cases where significant shunting of blood exists, for instance in a case with a ventricular septal defect (VSD).

Other structures
As mentioned before, the presence of non cardiac pathology that causes the clinical signs should not be missed.

In cardiac patients, the assessment of other structures is directed to determining the presence of radiographic signs of cardiac failure, such as cardiogenic pulmonary oedema, or pleural effusion.

As well as those differences between feline and canine patients already cited (it is more typical to find ascites and hepatomegaly in dogs with right sided failure), other species differences include:
- Pulmonary cardiogenic oedema tends to correspond with an interstitial or alveolar perihilar lung pattern in dogs, according to the severity of the congestion, whereas in cats it can be far less structured and is not always perihilar in location.
- All pleural draining vessels end up in the right atrium in dogs. The visceral pleura drains into the left atrium in cats instead (Rishniw, 2000), with the parietal one draining into the right atrium. Therefore, cardiogenic pleural effusion can only be seen as a result of right sided failure in dogs, but it can follow both right or left sided failure in cats.

Dorsoventral radiograph (Figure 1)

Cardiac silhouette
The cardiac silhouette should be situated close to the midline, with the base being wider than the apex, which should point towards the left side of the body. The length of recumbency prior to radiography, or very expiratory radiographs, can modify the position of the silhouette. Marked deviation of the apex towards the left may be secondary to right sided enlargement and the presence of other signs compatible with this possibility should be investigated.

The use of objective measurements to determine the presence of cardiomegaly has also been proposed for this projection. For both dogs and cats, a good way of determining whether general cardiomegaly exists is to measure the width of the cardiac silhouette. It is accepted that cardiomegaly exists if this measurement is larger than two thirds of the width of the thorax at the same level. It has been determined that the width of the cardiac silhouette on the DV projection should fall in the 2.9-3.9 vertebral bodies' length when measured on the lateral radiograph (applying the same method of the vertebral heart scale previously described). This measurement, however, is far less commonly used, if used at all.

The clock face analogy allows for the easy description of focal enlargements of the cardiac silhouette on this projection:
11-1: aorta
1-2: pulmonary artery
2-3: left auricular appendage
3-6: left ventricle
6-9: right ventricle
9-11: right atrium

Main vessels
The arteries are closer to the periphery, whereas the veins are centrally positioned in this projection ('veins are central and ventral' on both projections).

The diameter of the caudal lung lobe vessels should not be larger than that of the ninth vertebra on their crossing point.

Other structures
Following the previous comments regarding the different significance of the presence of pleural effusion of cardiogenic origin in cats and dogs, it is pertinent to mention that it can be easier to detect the presence of mild pleural effusion on the dorsoventral projection of feline patients when compared to the laterolateral radiograph. The psoas muscles are responsible for the retraction of the caudodorsal lung field on a lateral projection of a feline thorax when compared to the more straight appearance in a dog (observe this area on **Figures 3** and **7**). It can therefore be harder to decide if a cat has pleural effusion on a lateral projection unless other areas of the lung field are clearly retracted away from the thoracic boundaries. The lung field will extend to the periphery of the thoracic cavity on both dogs and cats on the dorsoventral projection and, therefore, retraction on this view indicates that effusion exists.

A very practical approach
A critical overview of the use of the vertebral heart scale has already been included in this article. Those comments summarise quite well the problems that can be faced when using only the objective measurements to define whether cardiomegaly is present or not. A completely opposite approach, with only a subjective assessment of the cardiac silhouette and associated structures, can work if one is very experienced. The risk of under- or over-diagnosing cardiac

pathology using a subjective approach, however, needs to be taken into consideration.

Overall, a mixed approach is recommended, remembering particularly that the serial use of objective measurements will be very useful to monitor the progression of the disease and/or the response to therapy in cardiac patients.

A more practical approach to radiographs of patients with cardiac disease, therefore, could be the following:
After evaluating the radiographs, one should be able to determine:

1. Whether cardiomegaly exists or whether any non cardiac pathology could explain the clinical signs.
2. If the cardiomegaly is generalised or more focal in nature.
3. If more focal, whether predominantly right sided, left sided or even if a particular cardiac chamber or major vessel is affected.
   (i) In dogs (remember the previous comment regarding sternal contact in cats), significant right sided cardiomegaly is associated with increased sternal contact on the lateral projection and with a reversed-D pattern on the dorsoventral one (**Figure 9**).
   (ii) A significant left sided cardiomegaly is associated with the following changes on a lateral projection: an elongated heart with a very straight caudal border; elevation of the whole length of the intrathoracic trachea; and a prominent left atrium (**Figure 10**).

Figure 9: Close-up of the cardiac silhouette on a dorsoventral thoracic radiograph of a 10-year-old Labrador retriever with pulmonic stenosis. The 'reversed D' pattern indicates the presence of right sided cardiomegaly.

Figure 10: Close-up of the cardiac silhouette of an 11-year-old Irish setter with the typical straight caudal border indicative of left sided cardiomegaly. There is also left atrial enlargement. The radiographic changes were secondary to a long standing mitral valve insufficiency. The radiograph was obtained with the patient in right lateral recumbency.

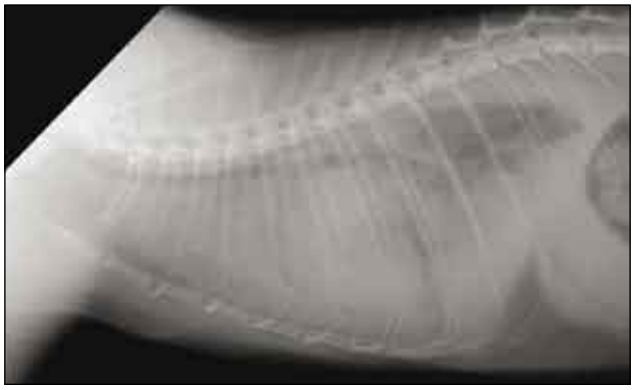

Figure 11: Right lateral recumbent thoracic radiograph of a three-year-old Ragdoll cat with advanced hypertrophic or restrictive cardiomyopathy and secondary cardiogenic pleural effusion.

The pressure of this atrium over the main left caudal bronchus is what causes cardiogenic cough in dogs. Cardiogenic cough is not usually seen in cats.

4. Whether radiographic evidence of cardiac failure exists (**Figure 11**). This is very important to decide on therapy and to obtain an impression on prognosis.

When these steps are followed, and the answers to the above questions are considered together with the history, results of physical examination and the signalment of the patient, a list of possible differential diagnoses becomes easier to formulate. Trying to decide whether a congenital or acquired problem is more likely, together with considering whether the murmur, if present, is systolic or diastolic, can be extremely useful. For instance, left sided cardiomegaly in an adult small dog with a systolic murmur points towards mitral disease.

The most common acquired cardiac pathologies include feline cardiomyopathies and canine mitral disease. The most common congenital pathologies are atrial septal defects or ventricular septal defects in cats and persistent ductus arteriosus, pulmonic stenosis or aortic stenosis in dogs.

What to do next

Even following all those steps, a radiograph is very unlikely to offer a final diagnosis. Other tests, like ECG and especially echocardiography, will be needed for this.

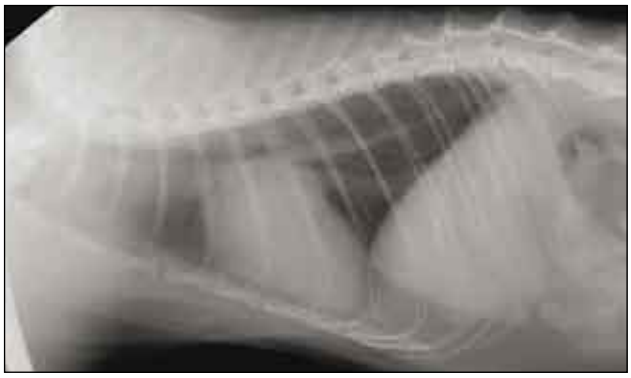

Figure 12: Right lateral recumbent thoracic radiograph of the same patient as in Figure 11 after successful therapy was initiated. The cardiac silhouette is longer than normal and shows the typical radiographic pattern associated with feline cardiomegaly.

It is important to mention, however, that there are several situations where cardiac pathology may not be associated with radiographic changes. The most typical situations for that would include either early stages of pathology or pathologies that do not cause marked morphological changes.

A more detailed list would include:

- Early stages of cardiomyopathies, especially if hypertrophic in nature
- Small shunting lesions
- Endocarditis
- Acute myocardial failure
- Arrhythmias or problems with the transmission of the electrical impulse
- Constrictive pericarditis
- Peracute traumatic haemopericardium
- Myocardial neoplasia
- Metabolic conditions with a collateral effect on the heart
- Rupture of one or more chordae tendinae

Radiographic patterns of the most common cardiac pathologies

Only the patterns of the most common acquired pathologies will be mentioned, as they are more frequent than the congenital ones.

Feline hypertrophic cardiomyopathy

If severe enough to cause radiographic changes, one would expect radiographic evidence of cardiomegaly on both projections, with signs of left atrial enlargement (**Figure 12**). This is seen as the 'ice cream cone' pattern on the lateral projection. This is due to the fact that the enlarged left atrium occupies the whole length of the cardiac base in cats, whereas in dogs the left atrium is more caudally positioned (Rishniw, 2000). This morphological change makes the feline enlarged heart appear as a valentine heart on the dorsoventral projection (**Figure 13**).

The main problem with these radiographic patterns is that they are not specific for hypertrophic cardiomyopathy. Having said that, it is noteworthy that in cats a left sided problem is much more likely than a right sided one and that left atrial enlargement is the first and more reliable sign of a cardiac problem in this species (Rishniw, 2000).

Figure 13: Post-therapy dorsoventral thoracic radiograph of the same patient as in Figures 11 and 12, showing the radiographic pattern of cardiomegaly on this projection.

Figure 14: Right lateral recumbent thoracic radiograph of a three-year-CKCS with marked cardiomegaly and enlarged left atrium secondary to mitral insufficiency due to underlying endocardiosis.

All the different types of feline cardiomyopathy (hypertrophic, dilated, restrictive, undetermined and arrhythmogenic right ventricular cardiomyopathy) can be very difficult to differentiate radiographically once they progress from the subacute to a more chronic phase, especially if congestive heart failure exists (Van Israel, 2004). Moreover, the valentine heart pattern can be associated not only with enlargement of the left atrium (which will then push the right atrium away towards the right side) but also to biatrial enlargement. Regardless of the underlying cause, this radiographic pattern is not pathognomonic for hypertrophic cardiomyopathy, as was mentioned in older references (Rishniw, 2000).

Chronic mitral disease in dogs

Typically associated with left sided cardiomegaly and left atrial enlargement of variable severity (**Figure 14**), chronic mitral disease will displace the main left caudal bronchus on the lateral projection. It will also cause a displacement of the caudal bronchi away from the midline on the dorsoventral projection. This pattern is not seen in cats as the increased craniocaudal length of the atria does not allow for such a focal mass effect on the caudal bronchi (Rishniw, 2000).

To conclude, one should remember that not all murmurs will be of clinical significance, that some severe pathologies associated with marked murmurs may not show radiographic changes to the same severity (for instance in cases of severe aortic stenosis with concentric hypertrophy of the left ventricular walls), and that radiography is only one of multiple diagnostic steps to a final diagnosis. If one wants to be extremely critical about this issue, one could say that the main or fundamental role of radiography is centred on determining whether congestive heart failure exists and to rule out the possibility of non cardiac conditions causing the clinical signs, with echocardiography being more accurate in determining the precise pathology affecting the patient.

Acknowledgements

The author wishes to thank Davies Veterinary Specialists and the Animal Health Trust for allowing the use of the radiographs and images included in this paper.

This paper originally appeared in the Spanish veterinary journal *Consulta de Difusion Veterinaria* and is reproduced with kind permission of the author and publishers.

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