BILDDIAGNOSTIK

Thorax and heart

I den sjätte och sista delen i Svensk Veterinärtidnings artikelserie om bilddiagnostik har turen kommit till bröstkorg och hjärta. I tidigare delar har medarbetare som jobbar eller har jobbat med bilddiagnostik på SLU berättat om teknikerna datortomografi och magnetresonanstomografi inom smådjursdiagnostiken samt vilka omständigheter som är viktiga att beakta vid val av bilddiagnostisk metod. Tidigare i serien har vi fokuserat på hjärna, huvud, nacke, muskuloskeletala strukturer, rygg och buk. Koordinator för artikelserien är Margareta Uhlhorn, leg vet, DipECVDI, CertVR, SLU (UDS).

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Intro

Computed tomography (CT) has a major role in advanced imaging of the lungs, mediastinum, thoracic wall and heart. The major advantage of CT over radiology is the high-resolution cross-sectional images and the three-dimensional data that CT produces. Without this summation in the image, it is possible to detect smaller masses in the lungs and define separate mediastinal and thoracic wall structures from the lungs. A full CT examination of the thorax gives information about all structures in the entire volume of the thorax, and this makes CT the technique of choice for complex diseases and injuries that involve multiple thoracic tissue types and multiple locations in the thorax.

In many regions of the body the definition of soft tissue structures is better in magnetic resonance imaging (MRI) compared to CT, but gas in the lung tissue means that excellent definition of soft tissue structures is possible in the lungs with CT. The thorax also contains a large number of vascular structures and these structures can be investigated in detail using CT with the use of intra-venous contrast.

Motion is an important issue in imaging the structures of the thorax, since it can cause severe artefacts in the images, and so fast image acquisition times are important. The development of multislice CT, where multiple image slices can be acquired simultaneously has resulted in this imaging technique dominating cross-sectional diagnostic imaging of the thorax. It is possible with multislice CT to take images of the entire thorax of a dog between breaths, and even images of the heart can be made with minimal effect from cardiac motion. In comparison, MRI methods for examining the thorax in a clinical situation are currently restricted to examination of the heart where information from an ECG recorded during the scan is used to overcome the effects of cardiac movement. Respiratory motion is more variable and timing less predictable so at this stage due to severe motion artefacts MRI scans of the lungs and soft tissues that move with breathing are not done, and thus will not be discussed in this article. Real-time MRI, where a live moving MRI image is produced is currently available as a tool for research. If this technique becomes possible for clinical scanners it will likely revolutionize thoracic diagnostic imaging.

Figure 1a. Pulmonary foreign body in a 3-year-old Wachtelhund. Transverse plane CT in a lung window showing a focal area of soft tissue attenuation consolidation (red arrow) containing multiple gas filled cavities in the ventral margin of the right caudal lung lobe. The foreign body (Fig. 1c) cannot be defined but the lung lesion is typical for abscess/granuloma formation and together with the location of the change gives a very high suspicion for foreign body.

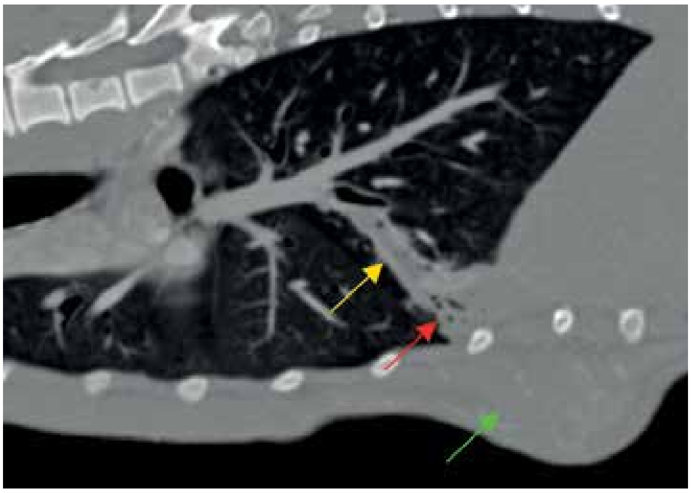

Figure 1b. Oblique parasagittal multiplanar reconstruction CT in a bone window showing the localization a fluid filled bronchus (yellow arrow) passing to the area of the lung lesion (red arrow) and thickening of the soft tissues in the adjacent thoracic wall (green arrow) where a fistulous tract containing multiple small foreign bodies was identified with ultrasound.

Figure 1c. The foreign body (pine twig/grankvist) removed from the bronchus of the right caudal lung lobe.

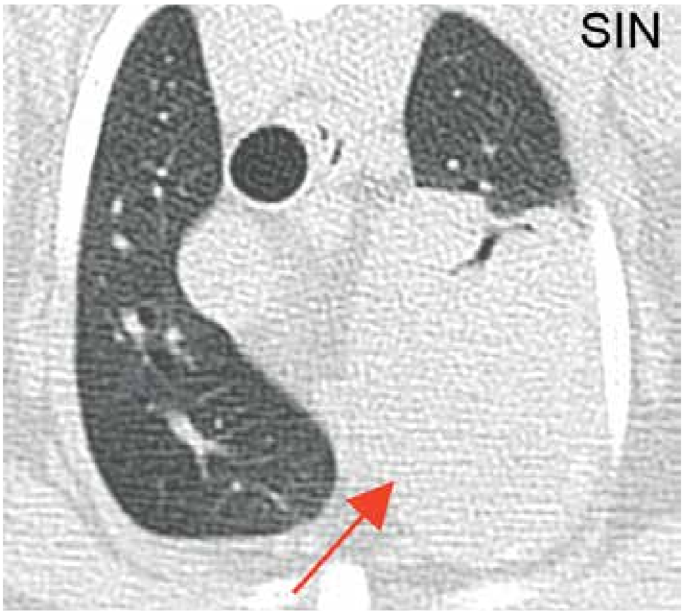

Figure 2a.

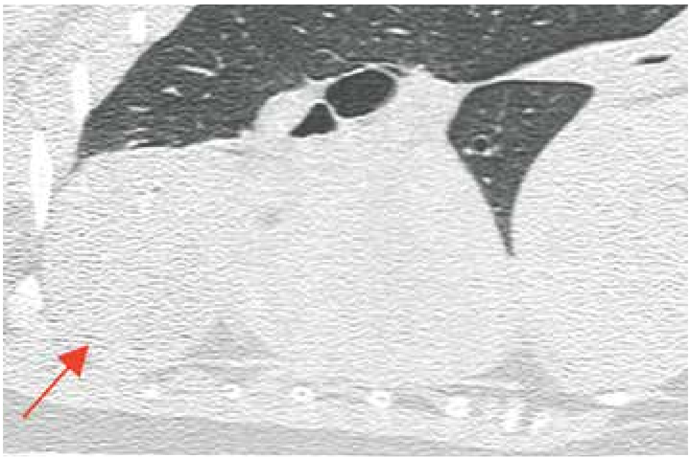

Figure 2b. Primary lung neoplasia (carcinoma) in the cranial part of the left cranial lung lobe in a 12-year-old Fox Terrier (red arrow). Transverse (a) and sagittal (b) plane CT images displayed in a lung window. In the transverse plane image (a) mild rightward displacement of the cranial mediastinum by soft tissue attenuating mass (red arrow) is seen.

THORACIC CT

Thoracic CT technique

Multislice CT machines are ideal for thoracic imaging, the more slices the better! Control of the patients respiration during the CT examination helps to minimise motion artefacts in the images, although with multislice machines scan quality is usually very good even in dogs that are only sedated, and satisfactory images can even be obtained in conscious non-sedated patients.

Positional atelectasis (collapse of normal lung tissue caused by the patient position and exacerbated by sedation and anaesthesia) can be a problem in some patients and usually occurs in the dependent margin regions of lung lobes. Atelectasis is minimised by positioning the patient in sternal recumbency and using positive pressure ventilation if the patient is intubated or scanning the patient as soon it is suitably sedated. If positional atelectasis is suspected then a patient can be repositioned so that the atelectic region is closest to the highest point of the thorax, and often the region of atelectasis will reinflate.

In some thoracic examinations, particularly metastasis checks, detection of very small soft tissue nodules within the lungs is important. For these examinations high-resolution techniques using thin slices and high frequency algorithms can be used to minimise partial volume artefacts [1].

Intra-venous non-ionic iodine based contrast has an important role in thoracic CT for the evaluation of the heart, thoracic blood vessels and soft tissue masses. For optimal images the timing of image acquisition after contrast injection, injection rate of contrast and volume of contrast injected are critical. Automated power injectors are ideal for thoracic studies since they allow for precise timing and rate of contrast injection. The timing of image acquisition can be determined by timing low volume test boluses using dynamic scans or by using automated bolus tracking software and there are now many excellent articles published giving detailed descriptions of contrast protocols.

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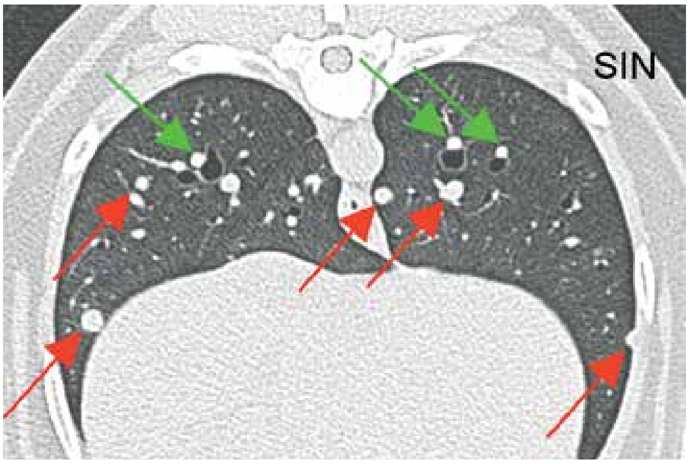

Figure 3. Lung metastasis (red arrows) in an 8-year-old Golden Retriever with an oral malignant melanoma. Transverse plane CT image displayed in a lung window in the caudal thoracic region. Multiple well defined, round, soft tissue attenuating nodules are seen in the lungs (red arrows) and one convex focal subpleural soft tissue attenuation (red arrow) were metastases. Note the similar appearance of blood vessels (green arrows), which can be differentiated from the metastases due to their tubular shape (that can be seen by scrolling through the images or evaluating the images in sagittal or dorsal planes) and location adjacent to airways.

Figure 4a.

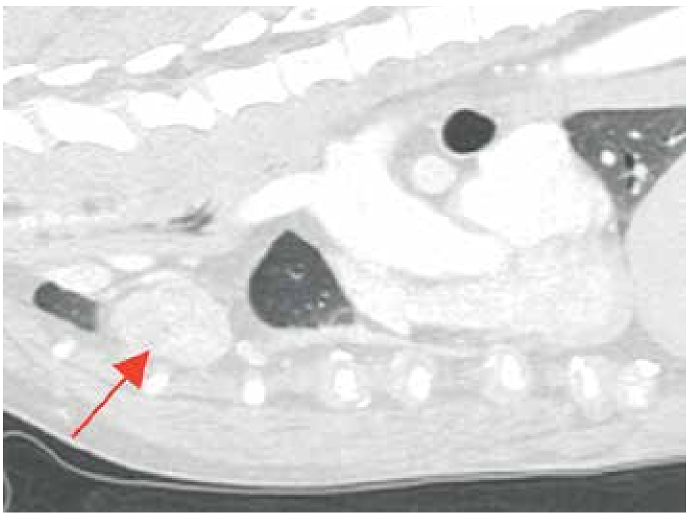

Figure 4b. Enlarged sternal lymph node (red arrow) in an 11-year-old cross-bred dog, suspected to be a metastasis from a mammary gland adenocarcinoma. Transverse (a) and sagittal (b) plane CT images displayed in a lung window. The well-defined soft tissue attenuating mass (red arrow) is located within the ventral aspect of the cranial mediastinum in the location of the sternal lymph nodes.

THORACIC CT INDICATIONS

Lungs

Very high-resolution images cross-sectional images of the lungs are possible with CT. The airway, vascular and interstitial structures of the lung can be well defined and if the appropriate techniques are used then these structures can be examined in multiple planes of view. This means that CT can be an excellent diagnostic method for animals with lung disease. An excellent review of CT lung morphology in dogs, and investigation and comparison of the CT appearance of several canine lung diseases with histology is available [2]. Lung pattern descriptions in CT follow similar principles to lung radiography, however there are specific additional CT lung patterns described, including terms such as ground-glass opacity, 'crazy paving' and 'tree in bud' patterns [2-4]

Contrast can be used during CT examinations of the lungs to assess the pulmonary vasculature or to assess the contrast uptake patterns of lung masses. CT angiography is a highly sensitive and specific technique for detecting pulmonary embolism [5]. Uptake patterns in lung masses can help differentiate fluid filled cavities such as abscesses and pneumatocoeles (lack of central enhancement) from soft tissue masses such as neoplasia and granulomas.

Pulmonary foreign bodies can be identified in CT images, particularly when they are in a large airway [6]. However, the size and particularly the density of the foreign body determines whether it can be defined from a surrounding granuloma/abscess. In cases where the foreign body is the same attenuation as the surrounding lung tissue it is occasionally possible to identify the foreign body by an area with lack of contrast enhancement with a characteristic foreign body shape. However, in many cases foreign bodies cannot be clearly defined and it is the finding of a focal lung granulomas/abscesses particularly in a caudal lung lobe that gives a high suspicion of a foreign body (Fig. 1).

Abnormalities of the larger airways such as tracheal and bronchial collapse are shown well with CT [7, 8], although the possibility for dynamic airway studies with CT is currently limited to repeating the 'static' scans several times. CT is also excellent for the evaluation of bronchiectasis and normal values are available for bronchial diameter [9, 10]. CT is also an excellent method for diagnosis lung lobe torsion when it has not been possible to make the diagnosis with certainty from radiographs [11].

Complete investigation for primary and metastatic neoplasia in the thorax is possible with CT. Solitary lung masses (Fig. 2) can be identified and localised so that ultrasound or CT guided fine needle aspirates or biopsies can be obtained. Sampling of lung masses is important since it is not possible to differentiate primary lung tumours from granulomas with certainty in CT images. Normal size values are available for thoracic lymph nodes, and these values, together with contrast uptake patterns can be used to assess for spread of neoplasia to the thoracic lymph nodes [12]. It is possible to detect smaller pulmonary nodules with greater diagnostic confidence and accuracy using CT compared to thoracic radiography [13] and CT is especially recommended for detecting lung metastasis (Fig. 3) in large breed dogs [14]. Since CT gives multiplantar images of all structures in the thorax it is particularly good for staging neoplasia, since lymph nodes, lungs and any primary thoracic tumours can all be assessed in the one image series. This also makes CT ideal for planning of thoracic surgery, particularly lung lobectomy, since relationships between adjacent structures can be seen in multiple planes and three-dimensional reconstructions of the surgical region are often

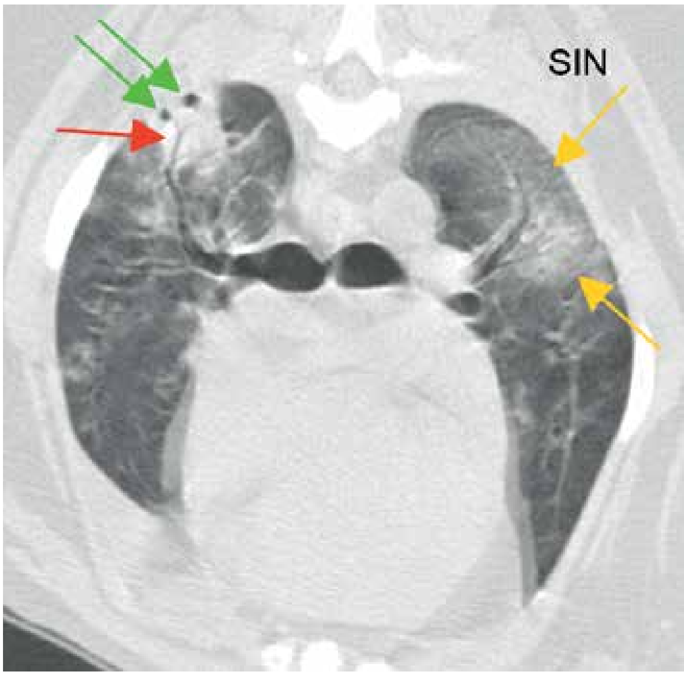

Figure 5. Thoracic CT of an awake 9-year-old Rough Collie. Due to the critical clinical status of this patient, this CT examination was done without sedation or aneasthesia and the dog restrained with positioning straps. The image shows moderate motion artefacts, which are seen as blurring and double contours. However, the study gave important diagnostic information including presence of gas filled subpleural blebs (green arrows), focal region of alveolar pattern with air bronchograms (red arrow) and regions of ground glass attenuation (yellow arrows), important for the immediate stabilization and investigation of the patient.

possible. Margins for resection can be planned in detail before the surgery, accurate measurements of lesion dimensions and estimates of lesion margins can be made.

Mediastinum

If there is uncertainty of whether a disease process is localised to the mediastinum or if it within the lung, then CT can almost always provide a certain answer. Figure 4 shows a mass in the cranial thorax, and when the transverse plane image is examined, it is certain that the mass is within the cranial mediastinum. Compare this to figure 2b where a mass in the cranial thorax is clearly seen to be part of the cranial part of the left cranial lung lobe. Compared to CT, thoracic radiographs do not give as detailed information about the specific location of masses in the cranial thorax.
The differentials, treatment options and prognosis for a cranial mediastinal mass are quite different to those for a lung mass, thus knowing the exact location of this change is important.

The lymph nodes of the thorax are located within the medistinum. Evaluation of these lymph nodes is particularly important when primary neoplasia is suspected in the thorax (part of staging), and also to help rank possible causes of generalised thoracic disease. Mild to moderate changes of these lymph nodes may be difficult or impossible to detect in thoracic radiographs, but CT allows detailed evaluation of the lymph nodes and normal size values are published [12, 15].

Pleural space

Many patients with disease of the pleural space present in an unstable or critical condition. It is important to stablise these patients before CT is performed and careful planning of the

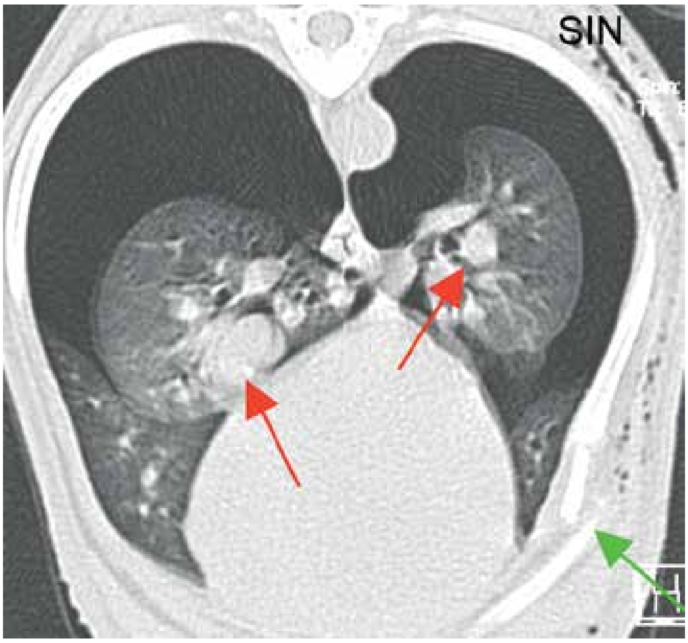

Figure 6a.

Figure 6b. Pneumothorax in a 2-year-old Dachshund that had been bitten by another dog and had multiple wounds and rib fractures (green arrow) of the left thoracic wall. Transverse (a) and dorsal (b) plane CT images displayed in a lung window. The lungs are severely retracted from the thoracic wall and gas fills the pleural space. Regions of hyper-attenuation in the lungs (red arrows) indicate pulmonary hemorrhage (contusions) and atelectasis, and there is extensive subcutaneous emphysema in the left thoracic wall and axilla.

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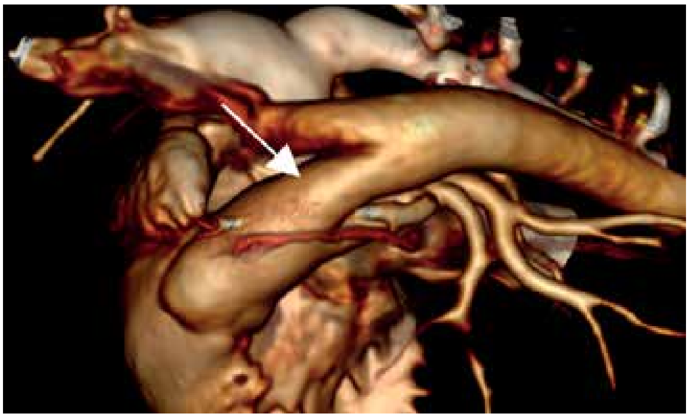

Figure 7. Patent ductus arteriosus (white arrow) in an 8-year-old Bichon Frise shown as a post contrast three-dimensional volumetric reconstruction CT image.

examination is required to ensure the patients clinical condition is not compromised by the examination. It is possible to examine selected patients without sedation or anaesthesia (Fig. 5), and a specific device has been designed for doing CT thorax examinations of awake cats [16].

Identifying the cause of pleural effusion can be challenging and here CT can help. Due to the superior resolution and lack of summation of the pleural fluid opacity on the lungs in CT it is possible to see subtle lung changes even when a significant amount of pleural fluid is present. The presence of pleural fluid can make diagnosis of diaphragmatic ruptures uncertain, difficult or impossible in thoracic radiographs. In these cases, CT can help to reach a certain diagnosis, and if a diaphragmatic rupture is present then the CT can be very useful for surgical planning of the repair. Measuring the Hounsfield units of pleural fluid has been found useful for differentiating transudate and chylous effusions (HU < 14) from exudate, modified transudate and haemorrhage (HU >14) in dogs, but not in cats [17]. Post contrast CT studies can be used to differentiate soft tissue masses (neoplasia/abscess/granuloma) that are surrounded by the pleural fluid and thus often not visible in radiographs. Several methods have been described for doing contrast studies of the thoracic duct in cases of chylothorax, with some of these studies successfully using contrast injection into popliteal lymph nodes [18-22].

Pneumothorax (Fig. 6) is usually clearly visible in thoracic radiographs, but particularly in cases of recurrent or tension pneumothorax, it can be important to establish the location of the leakage into the thorax. CT is better than radiography at detecting blebs and bullae (Fig. 5) causing spon-taneous pneumothorax [23]. However, a recent study found that CT has a low sensitivity and positive predictive value for detection of ruptured pulmonary bullae causing spontaneous pneumothorax and suggested that CT is potentially an ineffective preoperative diagnostic technique for dogs undergoing exploratory thoracotomy for spontaneous pneumothorax [24]. The causes and extent of pneumomediastinum are often shown clearly in CT images.

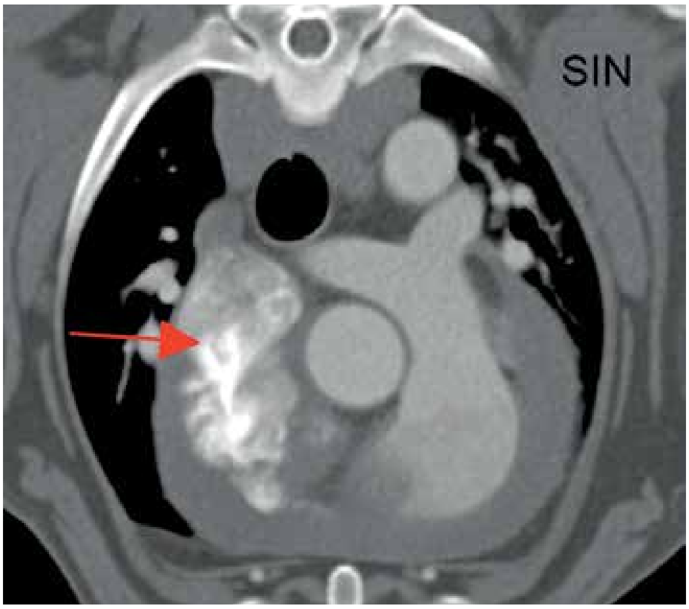

Figure 8a. Right atrial mass (red arrow) in a 6-year-old cross-bred dog that was suspected to be hemangiosarcoma. Post contrast transverse (a) and dorsal (b) plane CT images displayed in a lung window. Heterogeneous contrast enhancement of a focally thickened region of the wall of the right atrium (red arrow) that includes the region of the right auricle, and filling defects of the contrast in the lumen of the right atrium that are suspected to be caused by the mass extending into the lumen.

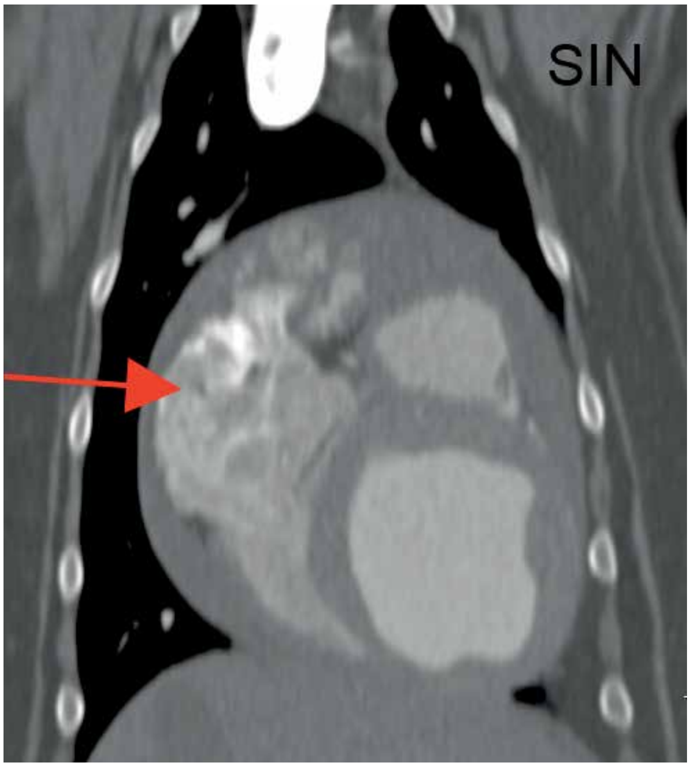

Figure 8b.

Thoracic wall

Full evaluation of thoracic wall disease and injuries is often possible with radiology and ultrasound, but in cases of complex lesions or injuries and for surgical planning for removal of region of the thoracic wall then CT can be valuable. The high sensitivity of CT to changes in the skeleton means it is very useful for determining the size and margins of bone lesions, and the multi-plantar and three-dimensional images that can be made can be a great help in surgical planning.

Heart

Due to the constant motion of the heart scan times for cardiac CT must be as fast as possible and contrast is used to define the blood vessels and cardiac chambers of interest. The development of multislice CT has resulted in much faster scan times and with a 64-slice machine it is possible to scan all cats and most dogs hearts in one gantry rotation. For detailed CT examinations of the heart ECG gating techniques are available and drugs can be used to slow the heart rate to reduce the effect of motion artefact. The correct dose and injection rate of intravenous non-ionic iodine based contrast, and correct timing of post-contrast acquisitions are vital for cardiac CT. The contrast study protocol varies depending on the cardiac structure of interest, and in most cases the contrast protocol has to be adapted to each individual patient either using test boluses or automated bolus tracking.

The major indication for cardiac CT is the investigation of complex vascular malformations. Patent ductus arteriosus (Fig. 7) and vascular ring anomalies are two of the most common intra-thoracic vascular malformations and a recent article shows the great potential of CT to provide information that is important for the diagnosis and surgical planning [25].

Imaging of the coronary arteries is another potential application of cardiac CT [26], particularly for detecting coronary artery malformations if pulmonic valve balloon dilation is being considered for Bulldogs with pulmonic stenosis [27].

Heart base masses and cardiac neoplasia can be fully evaluated with CT and this can be used as part of the staging procedure for oncological patients. In these cases intravenous contrast is used not only to evaluate the morphology of the blood vessels surrounding, compressed by or involved in the mass, but also to investigate the extend of invasion of the mass in to surrounding soft tissues (Fig. 8).

There is currently only very limited use of clinical cardiac MRI in dogs and cats, which is in contrast to human medicine where cardiac MRI is used commonly. The main reason for the high cost for MRI equipment that are suitable for doing cardiac examinations. MRI has slower acquisition times compared to CT, thus ECG gating required for all cardiac MRI examinations, and high-field MRI equipment is required to minimize acquisition times. •

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