Thoracic Radiology

Radiographic technique

The basic requirements for good thoracic radiography are a correct positioning of the animal and obtaining the correct exposure. A straight radiograph, which is not over- or under-exposed will prevent over-reading or missing important findings.

Animals requiring thoracic radiography are often distressed and difficult to handle. Administration of a mild sedative is suggested to improve the animals’ disposition and make the positioning easier, this in turn will ensure that the radiographs are of diagnostic quality.

Thoracic studies should be taken at inspiration so that there is good contrast between the air-filled lung and the other thoracic structures.

Dorsoventral view: Usually preferred to ventro-dorsal views. Whenever possible this should be taken as first view to avoid artefactual decrease of lung volume +/- hypostatic congestion due to prolonged recumbency on one side. The dorso-ventral view is also preferred for cardiac examination as the heart sits on the sternum and has a more natural conformation. It is important that the DV view is positioned carefully and that there is no rotation. The forelimbs should be drawn forwards and the elbows adducted away from the sternum. On the radiograph the vertebral column should be superimposed to the sternum. Dyspnoeic animals should not be placed in dorsal recumbency as the breathing may become severely compromised.

Lateral view: the animals forelimbs should be drawn forward clear of the thorax. The sternum should be elevated with a foam pad so that the spine and sternum are level on the same plane. Centering should be at the caudal tip of the scapula.

When the animal lies on its side the dependant lung is relatively compressed and the uppermost lung is well inflated. If there is a lesion in the dependant lung it may not be visualised because of the lack of contrast in the dependant lung. In order to identify as many abnormalities as possible two opposing lateral studies should be taken. This is particularly important when screening for metastatic lung disease.
If the radiograph is taken at full inspiration (on a lateral view) you expect to see:

- Good contrast between cardiac silhouette, air-filled lungs and pulmonary vessels
- Ribs are widely separated
- The lung fields appear more lucent (darker)
- Greater vascular detail can be seen, especially in the caudal lung lobes
- More of the accessory lung lobe area, caudal to the heart, can be seen
- The caudal vena cava is more centrally placed and is almost horizontal (lying almost parallel to the long axis of the body)
- The diaphragm is not dome shaped, its more flattened than rounded
- Little or no contact exists between the diaphragm and the cardiac shadow

If radiograph is taken on expiration (on a lateral view):

- The caudal vena cava is toward the dorsal third of the thorax and is directed obliquely cranoventrally
- Diaphragm is dome shaped and may overlie the cardiac silhouette

Anatomical variants: There is considerable variation in the conformation of the thorax between breeds of dogs. The deep chested dogs tend to have the appearance of having an upright heart. The cardiac silhouette in shallow chested dogs occupies a large amount of the thoracic cavity. The Bassett and the Corgi have an anatomical indentation at the costochondral articulations. On the dorsoventral view this indentation gives the appearance of a double margin and may be mistaken for pathology.

Fat dogs often have a large amount of fat in the pericardial sac that may elevate the cardiac silhouette from the sternum. In addition the mediastinum which normally lies within the width of the vertebral column on the dorso-ventral view may be widened by the mediastinal fat and simulate mediastinal masses.
A sternal fat pad may be interposed between the cardiac silhouette and the sternum. This displaces the heart away from the sternum and this displacement should not be mistaken for an abnormality.
The thymus may be seen as a soft tissue triangular shape in the left cranial thorax in young animals and it should not be mistaken for a lung mass.

An anatomical variant associated with chondrodystrophic breeds is a widened mediastinum with deviation of the trachea to the right.

It is clear that a good knowledge of anatomical features and radiographic artefacts are required in order to extract as much information as possible from the thoracic studies.

ABNORMALITIES OF THORACIC STRUCTURES

The pleural space
The pleural cavity is a potential space, which is not usually identified unless it contains fluid, air or a mass.

Pleural plaques
Occasionally calcified pleural plaques also known as pulmonary osteomata should not be mistaken for miliary metastases. They occur in older animals and are very opaque focal opacities scattered throughout the lung fields. They are of no clinical significance.

Pleural effusion
Radiographic findings might vary in severity depending on the amount of fluid. The lungs become retracted from the rib margins and are seen as a scalloped undulating lung border. The fluid dissects along the pleural fissures that are clearly outlined.
The cardiac silhouette and diaphragmatic outline are obscured by the fluid. The trachea may be displaced dorsally. Fluid will be seen in the diaphragmatico-lumbar recess. It should be remembered that in the cat this recess does not extend to the vertebral margins. If the volume of fluid is small, right and left lateral studies may be useful.

On the dorso-ventral view the cranial lung lobes may be completely collapsed if there is a large volume of fluid present. The first place to identify fluid is in the costo-diaphragmatic recess.

The identification of small volumes of fluid often requires a ventro-dorsal study. The causes of the fluid accumulation may be many and thoracocentesis is advisable to establish cytological details and for bacteriological or fungal culture and sensitivity. Thoracic drainage and further radiographs can be taken and these may provide more information. If the fluid volume has not reduced sufficiently at this stage, aggressive drainage using a thoracostomy drain is advisable as pleural /mediastinal masses could be present. Ultrasonographic examination may be useful to examine the pleural cavity while fluid is present and pleural masses or a diaphragmatic hernia may be seen.

**Lung lobe torsion.**

This is an unusual condition but may be associated with pleural fluid. It is unclear whether the lung initially twists around the bronchus because it is floating in fluid or whether the torsed lung produces the fluid. If the lung becomes torsed, passive congestion and transudation ensues and pleural fluid builds up. Identification of the affected lung in the early stages is possible, as the fluid tends to collect around a single lobe, which is radio-opaque due to consolidation.

- The lung margin is rounded and the bronchus may be identified travelling in an abnormal direction.
- The right middle lobe and cranial portion of the left cranial lobe are the lobes that are more commonly affected.
Following thoracocentesis the lung lobe fails to expand and its abnormal contour and bronchial architecture may be identified.

**Pyothorax.**

This condition is more common in cats than dogs. It is often unilateral in cats. Fluid is seen in the pleural cavity. If the condition is resolving pleural thickening and permanent opacities remain.

Other causes of fluid in the pleural cavity are chyle, blood and transudates associated with systemic disorders such as cardiac or hepatic disease. Differentiation of these fluids is not possible using radiography alone.

**Pneumothorax**

Pneumothorax is a common complication of road traffic accidents. It can be uni- or bilateral. It is characterized by the accumulation of air in the pleural space, with secondary collapse of the lung lobes.

- As the heart is not held in position by the inflated lungs, it displaces into the dependant part of the thoracic cavity when the animal is placed on its side. The separation of the heart from the sternum on a lateral view is a cardinal sign of pneumothorax.
- The lung margins may be identified separated from the costo-vertebral and rib margins. Overexposed radiographs will often prevent a subtle pneumothorax from being seen.
- On the dorso-ventral view it is important that skin folds are not mistaken for lung margins, this can be difficult in deep chested dogs.

Tension pneumothorax is a life-threatening condition. This occurs when air enters the pleural cavity and is unable to escape. It may be unilateral in which case the cardiac silhouette is grossly displaced to one side (mediastinal shift). If the condition is bilateral the diaphragm is pushed caudally and its normal rounded contour becomes flattened. The lungs are seen as relatively opaque structures in the perihilar region. Occasional so called tenting of the costo-
diaphragmatic margins may be seen. This occurs when the diaphragm is displaced so far caudally that the muscular insertions become reversed and are clearly visible.

**Pleural thickening**

This may be seen in older dogs as an ageing phenomenon due to fibrosis. It may also be seen as sequelae to pleural infection or haemorrhage. The fissures are seen as thin radio-opaque lines along the lung margins travelling from the lung periphery towards the mediastinum.

**Pleural masses**

These are rare and include mesotheliomas, pleural fluid is the usual radiological feature.

**Mediastinum**

It is the virtual space between the two pleural layers. It is divided in cranial, middle and caudal compartments. All the major thoracic structures lie in the mediastinum apart from the lungs.

**Pneumomediastinum**

The causes may include trauma to the thorax or neck; due to tracheal or oesophageal rupture, or alveolar damage and occasionally it is identified in cases of paraquat poisoning.

- See mediastinal structures outlined by air. ± see cardiac shift.
- The normal air filled trachea is no longer clearly seen and is poorly defined due to the presence of free air in the mediastinum.
- Free air outlines the cranial mediastinal structures such as the brachiocephalic trunk and cranial vena cava.
• The intrathoracic aorta may be well defined and air may dissect caudally into the abdominal cavity.
• Subcutaneous emphysema can be mild to severe

**Mediastinal fluid**

Mediastinal fluid may be present for a variety of reasons including oesophageal rupture, trauma and heart failure.

Fluid in the mediastinum on the ventrodorsal view outlines the fissures from the mediastinum in a reverse direction extending laterally forming a Christmas tree pattern. On a dorso-ventral view the fluid pools in the sternal region and the cardiac silhouette may be poorly defined.

• Widened mediastinum on dorso-ventral view.
• Reverse pleural fissures on ventro-dorsal view.

**Mediastinitis**

Infection of the mediastinum may occur as a result of an oesophageal perforation. Fluid may be seen in the fissures extending from the mediastinum laterally. The mediastinum may be enlarged. If the infection is encapsulated a mediastinal mass be identified.

**Mediastinal masses**

Cranial mediastinum: The causes may include thymic or oesophageal abnormalities, lymphadenopathy, neoplasia or infection.

• enlargement of the mediastinum is identified by
• widening of the mediastinum in a lateral and dorso-ventral direction
• the trachea may be deviated dorsally or ventrally depending on the cause.
• lateral deviation may also be noted
• oesophageal displacement may also be identified
• the cardiac silhouette and tracheal bifurcation are displaced caudally. It may not be clearly outlined if the cranial mass extends caudally and contacts the cardiac border. One way of identifying where the heart is lying, is to identify the tracheal bifurcation, which occurs just dorsal to the heart base.

Masses in the middle mediastinal area would include perihilar lymphadenopathy, heart base tumours, oesophageal abnormalities and neoplasia. Signs include
• an increased opacity in the perihilar area and
• displacement or splitting of the main stem bronchii
• the trachea may be displaced ventrally
• the oesophagus may be displaced dorsally.

Caudal mediastinal masses would include oesophageal abnormalities, abscess, granuloma or neoplasia. Depending on the cause, air filled lung may highlight the lesion. If mediastinal or pleural fluid is present the lesion may be masked.

**Mediastinal shift**

Displacement of the mediastinum is usually associated with lung or pleural pathology. Causes include-pneumothorax, lung lobe collapse or removal, and diaphragmatic hernias. Rotated studies can simulate a mediastinal shift.

**Cardiac silhouette**

The cardiac silhouette usually occupies 2.5-3.5 intercostal spaces on the lateral view and approximately two thirds the depth of the thorax. On the DV view the heart is centred in the mid line with the apex directed to the left. It occupies between half and two thirds of the width of the thorax. There is considerable breed variation.
In recent years a numerical system has been devised called the Buchanan or vertebral heart score. The height of the cardiac silhouette from apex to base is measured and measured along the length of the thoracic vertebrae commencing at the cranial aspect of T4. The vertebral length is noted. At right angles to the first measurement and at the maximal heart width a second measurement is made and again laid against the thoracic vertebra commencing at T4. The two vertebral lengths are summated and the total length is the VHS for that dog. VHS have been derived for dogs in general and in recent years for specific breeds. The average VHS is 10.6 but some breeds such as the Labrador retriever the normal VHS is higher and in breeds such as the boxer the score is lower. The degree of sternal contact also varies with the breed.

In cats the normal width of the cardiac silhouette is two intercostal spaces. The heart lies at approximately 45 degree angle to the sternum. In older cats the aortic arch extends cranially beyond the cardiac outline forming a large bulbous knuckle.

For descriptive purposes normal anatomical features have been described using the clock face analogy. On the lateral and dorso-ventral views

9-11 right atrium
11-1 aorta
1-2 pulmonary artery
2-3 left auricular appendage (DV) left atrium (lateral)
3-5 left ventricle
5-9 right ventricle

It is important to obtain inspiratory studies or the cardiac outline will appear relatively large when it may in fact be normal.

**Generalised cardiomegaly**

It may be the result of a variety of cardiac conditions including valvular lesions, myocardial disease, infectious or metabolic disease. Increased fat within the pericardial sac
may cause an apparent cardiomegaly. Often the cardiac outline may be perceived within the fat.

- Rounded cardiac outline
- Increased cranio-caudal diameter
- Increased sternal contact
- Straight caudal cardiac border
- Elevation of the trachea and mainstem bronchi
- Compression of the mainstem bronchi
- Overlap of the caudal cardiac outline with the diaphragm
- The caudal vena cava is directed caudodorsally
- The cardiac apex is shifted to the left
- Reduced lung area

**Pericardial effusion:** The fluid may be blood, inflammatory exudate or transudate and may also be associated with neoplasia.

- Smooth sharp rounded cardiac outline
- Cardiomegaly-variable in size depending on degree of effusion
- Enlarged pulmonary veins
- Pulmonary vessels are well defined
- Flattened cardiac margins when in contact with the thoracic wall
- Tracheal elevation
- Ascites
- Hepatomegaly

**Cardiomyopathy:** Myocardial disease which may either primary or secondary in origin. Some breeds are more commonly affected than others. It may be dilated (DCM) or
hypertrophic (HCM). DCM is a relatively commonly acquired disease in large and giant breeds such as the St. Bernard and Doberman. HCM is relatively uncommon in the dog.

In cats the HCM form is currently more common and is often associated with hyperthyroidism. There are a variety of forms and accurate diagnosis requires a comprehensive ultrasonographic examination.

**Dilated cardiomyopathy**

- Cardiomegaly
- Enlarged left atrium and elevation of the left mainstem bronchus
- Enlarged left ventricle
- Loss of the caudal cardiac waist
- Pulmonary oedema
- Enlarged pulmonary veins
- Mitral insufficiency

**Cardiomegaly localized to specific chambers**

**Right heart failure**

- Right ventricular enlargement
- Hepatomegaly
- Pleural effusion
- Ascites

**Left heart failure**

- Left atrial and ventricular enlargement
- Elevation of the left main stem bronchus and terminal trachea
- Pulmonary venous congestion
- Perihilar or widespread pulmonary oedema-symmetrical in dogs;asymmetrical in cats
Mitral insufficiency

This is the most common acquired cardiac disease in middle and older aged dogs. Causes include endocardiosis, ventricular dilation, ruptured chordae tendinae, cardiomyopathy, endocarditis and congenital mitral valve dysplasia

- Enlarged left atrium
- Elevation +/- compression of the left mainstem bronchus
- Upright left ventricular border and loss of the caudal cardiac waist
- Increased apicobasilar length and cranio-caudal diameter
- Caudal vena cava runs caudodorsally
- Enlarged pulmonary veins
- Shift of the cardiac apex to the right
- Splitting of the mainstem bronchi on the DV view
- Left atrial margin visible beyond the cardiac outline on the DV view
- Signs of left heart failure

Tricuspid insufficiency

Incompetence may arise as a result of endocardiosis, ventricular dilation, ruptured chordae tendinae, heartworm disease, endocarditis, cardiomyopathy and congenital tricuspid valve dysplasia

- Right ventricular enlargement
- Increased sternal contact and shift of the apex to the left
- Right atrial enlargement with loss of the cranial cardiac waist
- Tracheal elevation cranial to the carina
- Signs of right heart failure

May coexist with left heart disease
Microcardia

Reduction in the cardiac size may be due to decreased circulating blood volume and with adrenocortical insufficiency. There is an impression of microcardia when there is pulmonary hyperinflation.

- Upright heart
- Reduced craniocaudal diameter
- Small pulmonary vessels

Diaphragm

The two crura of the diaphragm should be seen. On the right lateral study they are parallel to each other. On the left lateral recumbent view they intersect in the mid-thoracic region. On the dorso-ventral view the diaphragmatic outline is a smooth curve. On the ventrodorsal view sometimes the two crura are seen travelling laterally from the central vertebral insertion and the central tendinous portion is superimposed centrally. This pattern may look like the leaves of a shamrock.

Diaphragmatic Rupture/Hernia.
Disruption of the diaphragm may occur as an acquired or congenital problem.

Acquired diaphragmatic rupture.
If the traumatic injury was in the recent past then the disruption to the diaphragmatic outline may be identified. Often the injury might have occurred months before and the presence of intrathoracic fluid makes diagnosis slightly more difficult. The fluid arises from the presence of the liver within the thorax. The liver becomes congested as the diaphragm constricts the tissue. Passive transudation occurs and fluid builds up in the pleural cavity. It is the fluid compressing the lungs that accounts for the worsening clinical signs.
A diaphragmatic rupture should always be considered in the differential diagnosis when pleural fluid is identified, even without the history of trauma. Abdominal contents may be seen in the thoracic cavity. Often the abdominal radiograph holds the key to the diagnosis. Most diaphragmatic ruptures involve cranial displacement of the liver. The liver may not be seen in the thorax if it is surrounded by fluid. However if the liver is displaced cranially then the gastric silhouette will also be displaced cranially. This means that careful analysis of the abdominal cavity is advisable. If necessary as little as 2-3ccs of barium may be given, even to the most distressed dog to outline the position of the stomach.

**Congenital diaphragmatic hernia (peritoneopericardial hernia-PPH)**

This condition is seen in cats and is not that uncommon. It may be seen in young adult cats which often have a history of being normal or slightly unwell with a variety of symptoms.

- The cardiac silhouette is enlarged but well defined.
- Abdominal contents such as the intestines may be seen within the pericardial sac.
- If the liver lies within the pericardial sac then the silhouette is enlarged and has an homogenous opacity.
- However the cardiac silhouette will be seen to be continuous within the diaphragmatic outline.
- The hepatic silhouette will not be clearly seen in the abdomen and the stomach will not lie in a normal abdominal position.
Thoracic wall

Vertebrae
Congenital anomalies such as hemivertebrae or kyphosis may cause distortion of the dorsal aspect of the thorax.
Fractures of the vertebrae may be seen and callus formation observed.

Ribs
Fractures are common as a result of trauma. Soft tissue swelling and the presence of a localised fluid opacity may indicate the site of the lesion.
Neoplasia is uncommon. There may be rib expansion and periosteal proliferation. Bone proliferation or erosion may be seen. The expansion may be extracostal but more often the lesion is larger within the thorax and displaces the adjacent pleural and lung tissues. Chondrosarcoma is the commonest neoplasm. The ribs are also sites for metastatic lung disease.
Costo-chondral calcification. Mineralisation of the costo-chondral junctions can look dramatic but is usually of no clinical significance. It must not be confused with or for metastatic lung disease. It is often a feature of chondrodystrophic breeds.

Multiple cartilaginous exostosis

Hypervitaminosis A
Infection of the bony thorax may result from trauma, external foreign body, perforations or possibly by extension from intrathoracic disease. Soft tissue swelling and periosteal proliferation are features. Foreign bodies may be present.

Sternum
Fractures. Sternal fractures may be seen following trauma.
Pectus excavatum. This is often seen in cats and sometimes in dogs. There is dorsal deviation of the sternum at various points along the length of the sternum. In severe cases the caudal half of the sternum may curve dorsally towards the vertebral column. Depending on the degree of the displacement there may be displacement of the cardiac silhouette dorsally and to one side of the thorax.

Osteomyelitis Infection may result from direct penetration from a foreign body or as a complication of a sternal fracture with sequestration. Variable amounts of periosteal reaction and bone erosion may be seen. There may be a soft tissue swelling externally and a fluid or soft tissue opacity in the overlying intrathoracic region. The cardiac silhouette and lung may be displaced.

Neoplasia is rare.

Extra-pleural masses
These may arise from the diaphragm, thoracic wall or mediastinum and extend into the pleural cavity. It features a round convex mass, which projects into the thorax. It is base wide and the lung edge is displaced away from the mass. The adjacent bones may show evidence of lysis or bone proliferation.

Trachea
The trachea lies within the cranial mediastinum and is identified as an air-filled linear tube coursing from the thoracic inlet towards the heart base. Mineralisation of the trachea is usually an incidental finding.

The trachea forms an acute angle with the line of the thoracic vertebrae. The relative position of trachea will give important information about other structures. A dilated oesophagus can displace the trachea ventrally, whereas an enlarged cardiac silhouette or a mediastinal mass will displace it dorsally. In some breeds the trachea may be parallel to the spine (e.g. barrell chested dogs-corgi).
The trachea bifurcates into two primary (stem) bronchi at the level of the 5th thoracic vertebra over the base of the heart. The ridge formed between the two stem bronchi is the carina, which is not seen on radiographs. The bifurcation is seen as a rounded lucency (darkness) over the base. It represents the origin of the right cranial lobe bronchus seen end-on. A second rounded lucency may be seen that represents the origin of the left cranial lobe bronchus. Only the primary bronchi near the bifurcation are recognisable on normal radiographs. Smaller bronchi cannot be identified.

**Bronchi**

The trachea divides into left and right primary (main stem) bronchi. It’s important to know that the left stem bronchus lies over the left atrium; when the atrium enlarges, the left stem bronchus will be displaced dorsally. The left primary bronchus divides into cranial and caudal secondary bronchi. The cranial secondary bronchus divides to supply the cranial and caudal segments of the cranial lung lobe. The caudal secondary bronchus supplies the left caudal lung lobe. The right primary bronchus divides into four secondary bronchi, which supply the four lobes of the right lung, namely the cranial lobe, the middle lobe, the caudal lobe and the accessory lobe.

**Tracheal collapse.**

Normally the tracheal lumen gradually tapers in width from the caudal aspect of the larynx to the tracheal bifurcation. In the dog the tracheal rings are not complete and the dorsal margins of the cartilaginous rings are connected by the dorsal tracheal membrane. In some small breed dogs the dorsal tracheal membrane becomes floppy or enlarged and this
membrane falls into the tracheal lumen. This provokes a harsh dry coughing which sounds like a goose honking.

This collapse of the dorsal membrane occurs the intrathoracic trachea during the expiratory phase of respiration. The tracheal collapse is extrathoracic during inspiration. Therefore it is often possible to confirm the condition if inspiratory and expiratory radiographs are made. The whole trachea should be included on the radiograph. The forelimbs should not be drawn cranially but left in a relatively normal position. The dynamic motion of the trachea may be observed with fluoroscopy but this often only available in referral centres. Endoscopy may be preferred if available.

A special radiographic position has been described to provide a tangential study of the tracheal lumen. The dog is positioned in sternal recumbency. Extend the head vertical to the table and pointing towards the ceiling. Hold the head in this position with ties. Centre the x-ray beam at the thoracic inlet directing the beam in a cranio-dorsal 60 degree angle. The radiograph provides a view of the tracheal lumen. if the membrane is collapsed the normal circular lumen will appear asymmetric and flattened dorsally.

**Foreign bodies**

Unless these are radio-opaque the signs may be difficult to differentiate from a broncho-pneumonia, which often is present with chronic foreign bodies such as grass awns etc. Intraluminal foreign bodies may be seen in the trachea. However non-opaque foreign bodies may be missed and endoscopy is the only definitive method of diagnosis.

**Hypoplasia**

This is an uncommon condition except in brachycephalic dogs. The tracheal lumen is grossly narrowed throughout its length and secondary changes may be seen in the lung fields associated with chronic respiratory disease. It may be seen in young puppies or adult dogs. Exercise intolerance is a prominent feature.
Neoplasia
This is uncommon. Tumors such as chondrosarcoma or osteosarcoma may involve the trachea. Metastatic neoplasia may occur in this site.

Parasites

Oslerus osleri: This parasite is found in the tracheal lumen forming plaques and may be the cause of a recurrent and unresponsive cough. Endoscopy and a broncho-alveolar lavage are the definitive methods to identify the presence of the parasite. However radiographs may localise endotracheal masses profiled by the intraluminal air. Faecal analysis may be helpful.

Filaroides hirthii: This is a somewhat rare parasite, which lives in the bronchial tree. The animals have a recurrent cough and may develop secondary broncho-pneumonia. The trachea is normal but a patchy interstitial pulmonary infiltrate with or without alveolar changes may be seen.

Lung abnormalities
Pathologic changes in the lungs are classified into basic lung patterns according to the structures primarily involved namely,

- Alveoli------------------------alveolar pattern
- Interstitial tissues----------------interstitial pattern
- Bronchi --------------------------bronchial pattern
- Vessels---------------------------vascular pattern
Alveolar pattern

Results when alveoli become filled with: fluid, cellular debris, neoplastic infiltration or when they collapse –atelectasis. The alveolar ducts and terminal bronchioles may also become affected. The fluid or debris displace air in the alveoli and their contribution to overall contrast is thus lost

 **Radiological signs:**

- Ill-defined, radiopaque (white) “fluffy” lung opacities. These “fluffy” opacities have been likened to a “cotton wool” appearance.

- Bronchi that contain air become visible as radiolucent (dark) tubular or branching structures that contrast with the more opaque (white), “fluffy” infiltrated lung tissue. These are called air bronchograms. End-on they appear as discrete circular lucencies.

- A collapsed lung lobe appears as an almost consolidated, radio-opaque structure, usually with very clear air bronchograms through it. Although not “fluffy” it is still an alveolar pattern.

Interstitial pattern

The interstitium of the lung is the supporting structure and includes:

1. The walls of the alveoli and alveolar ducts
2. The interlobular connective tissue septae
3. The blood capillaries
4. The connective tissue supporting the lymphatics, bronchioles and pulmonary vasculature

   The interstitium provides the main background opacity in radiographs of the lungs. Abnormalities of the interstitial tissues do not involve the air space within the lung directly; the total air volume however may be reduced in such conditions by compression of the air spaces. The interstitium may be infiltrated by fibrous tissue, neoplasia or fluid.
Radiological signs: A general loss of contrast and blurring of the pulmonary vasculature is called an unstructured interstitial pattern.

In a structured interstitial pattern linear markings and nodular opacities are seen. Nodular opacities may be due to many causes, including small areas of fibrosis, neoplasia, granulomas, abscess or parasites. These nodular opacities must not be confused with the circular opacities that are exhibited by blood vessels seen end-on, which are not usually numerous, and are larger toward the hilus.

- There is a general loss of contrast in the lung fields because of an increase in opacity of the interstitial tissues
- The outlines of the pulmonary vessels become less sharp, although they may still be readily identified
- Nodular opacities that vary in size and distribution are seen.
- Nonvascular linear markings are seen within the lungs. These are line markings that are not associated with blood vessels. They are usually short and do not follow the course of blood vessels.
- The walls of the bronchioles and bronchi may appear thickened because of an increase in their interstitial component.
- A reticulated or “honeycomb” appearance, combined with ill-defined nodular structures is sometimes seen, particularly in the lungs of older dogs. These represent chronic changes in the interstitium.

Bronchial pattern

Whether or not bronchii can be seen depends on their relative opacities when contrasted with the air-filled lung tissue. Except for the larger bronchi near the hilus, the bronchial tree, the majority of bronchi cannot be recognised under normal conditions. Some smaller bronchi may be detected when seen end-on.
The branches of the pulmonary artery follow the bronchial tree. Aging and inflammatory changes cause thickening of the bronchial walls, which then become more visible.

**Radiological signs:**
- In inflammatory conditions an irregular infiltrate may surround the bronchi (peribronchial infiltration). This can be clearly seen in end-on views as a soft tissue cuff around the affected bronchus, giving it a “doughnut” appearance. Affected bronchi appear as ring-like structures. The accompanying artery is often seen end-on beside the bronchus, giving an appearance that has been described as being like a “signet ring”
- Thick cuffs suggest an acute condition
- Thin cuffs suggest chronicity
- In longitudinal profile thickened bronchial walls appear as converging linear opacities surrounding a radiolucent (dark) lumen
- Infiltration of the peribronchial tissues causes a loss of sharpness in the vasculature outlines.
- A bronchial pattern is seen in chronic bronchitis
MRI: Magnetic resonance imaging:

Like CT, MRI produces detailed cross sectional images of body regions. However the physical principles of image acquisition are different and very complicated.

The following is a simplified overview of how MRI works:

- Protons are present in all the atoms of the body.
- They are positively charged and are spinning.
- Any moving charged object produces a magnetic field around itself.
- Thus these protons are surrounded by a small magnetic field.
- If the number of protons in an atom is even, the magnetic fields cancel each other.
- If the number of protons is odd, then the atom will act like a small bar magnet.
- Commonest element in the body is Hydrogen with only one proton.
- The direction of the spin axis is random and thus the magnetic fields cancel each other.
- If the tissue is subjected to strong magnetic field the spin axes become aligned and either spin up or spin down. Slightly more choose to spin up.
- As they spin they also precess (the motion of the rotation axis of a rigid body, such as a spinning top, when a disturbing torque is applied while the body is rotating such that the rotation axis describes a cone, with the vertical through the vertex of the body as axis of the cone, and the motion of the rotating body is perpendicular to the direction of the torque). and the stronger the magnetic field the faster this precession.
- Thus when the patient is placed inside the magnetic field generated by the MRI machine, millions of protons align themselves to produce a single magnetic vector force and all precessing at a frequency similar to that of radio waves (approx. 42MHz).
- A radio signal of precisely the right frequency is then transmitted which upsets the alignment of a proportion of the spinning protons.
• As the electric field thus induced decays they return to the original state and reradiate radio signals which can be detected and recorded.
• Each tissue has characteristics related to the rate of decay of the electric field known as $T_1$ and $T_2$.
• $T_1$ & $T_2$ are used to vary the contrast between different tissues.
• The images produced may be thus either $T_1$ weighted or $T_2$ weighted.

The MRI image:

MRI images are also cross sectional. In this respect interpretation requires similar anatomical knowledge to that from diagnostic ultrasound or computed tomography images. The appearance of each tissue or fluid depends on the image weighting. Image interpretation relies in obtaining multiple sequences (examination series) with different tissue weighting and specific criteria.

For example, fluid appears generally black in $T_1$ weighted images and bright on $T_2$. Fat is bright on $T_1$ and $T_2$ and air and bone are dark on both $T_1$ & $T_2$. Also, other sequences allow for the elimination of the signal that arises from a particular tissue. This allows for example obtaining $T_2$ weighted images where the signal of CSF no longer appears. This would allow differentiation of CSF from other fluids such as oedema.

MRI allows for acquisition of slices in any plane along the body. This contrasts with CT in which the imaging plane is limited to a transverse plane.
As in CT, contrast agents are also used in MRI. The most common molecule used is Gadolinium, which due to its magnetic properties appears as a bright signal in T1 images. This is used to see the distribution of the contrast in areas of the body or lesions.

**Advantages of MRI**

Has superior soft tissue resolution than CT.

Does NOT utilize ionizing radiations.

**Disadvantages of MRI.**

Not so useful for the evaluation of bone.

Strong magnetic field used may affect pacemakers and metallic objects and create a safety hazard.

Longer scanning times.

Expensive equipment.

**Indications for MRI**

**Brain**

Epilepsy

Inflammatory brain disease-GME etc

Neoplastic brain disease

Syringohydromyelia
Nasal disease
Oral masses
Local lymph nodes

**Spine**
CNS disease-GME
Syringohydromyelia
Cord compression-intradural
Lumbosacral cord compression

**Soft tissues**
Neoplasia-extension margins
Muscles and joints
COMPUTED TOMOGRAPHY (CT)

Computed Tomography (Also known as CT, computed axial tomography or CAT) is a diagnostic imaging modality which produces cross sectional images of any body region, using X-rays.

Since its discovery, CT technology has improved dramatically. Modern multi-detector CT machines can scan an entire patient within seconds, producing slices of less than one millimetre in thickness.

**Physical principles:**

Computed tomography uses similar principles to conventional radiography. An X-ray tube mounted in a gantry rotates around the patient, generating a narrow high kV x-ray beam. The fan shaped X-ray beam passes through the patient, and is attenuated to varying extents depending on the characteristics of each tissue. A detector assembly in the opposite side of the gantry measures the intensity of the beam after passing through the patient. The data is recorded from multiple projections obtained at different angles. A computer then uses all the different projections to generate a two-dimensional cross sectional image or slice. The same process is repeated at different levels of the patient to produce consecutive CT slices.

Newer CT machines use helical technology. In this case, the X-ray tube rotates continuously while the patient is transferred through the gantry at a continuous speed generating data acquisition in a helical path. This has many advantages, particularly a decrease in scanning time and improved three dimensional image rendering.
The CT image:

Due to the high kV used, the attenuation of the X-rays is proportional to the density of the tissue. In conventional radiography, the opacities of the organs in the image depend in many other factors and we can only differentiate five opacities: air, fat, soft tissue, mineral and metal. In computed tomography, the attenuation values (Hounsfield units) of each part of the image can be accurately measured. For example, water measures 0 HU, air -1000 HU, soft tissues 50-200 HU,… As a result CT images have a high contrast resolution. This allows us to differentiate for example fluid from soft tissue, which is not possible with conventional radiography. In fact, the measurements are so accurate that it is possible to distinguish between different types of fluids such as urine, pus or blood or between different soft tissues such as liver or spleen.

The final image is made out of a grid of pixels, and each pixel has an attenuation value ranging approximately between -1000 and 2000. However, the human eye is not able to differentiate between 3000 shades of grey and the scale of attenuation values is adjusted to a grey scale during review of the images, this process is called a window level or windowing. Different window level settings will be used for evaluating different tissues such as lung, bone, brain.

The figure below shows the same image displayed with two different window levels. The image on the left is displayed using a brain window and the one on the right a bone window. Note how in the left image you can appreciate the difference between brain parenchyma and CSF in the lateral ventricles (Star). In the right image, we can not appreciate this difference but the bone detail is superior.
Multi-planar reconstruction and 3D rendering:

Another advantage of CT is the ability to produce three-dimensional images, or images in virtually any plane across the patient. To achieve this, the computer integrates all the information from the consecutive axial (transverse) slices to generate a 3D volume. This feature is particularly useful for surgical planning, as the body area can be evaluated from all the different angles. The image is a 3D image of the skull of a cat. The image below is sagittal reconstruction of the cervical spine of a dog with a disc herniation C2-C3

Advantages of CT:

- High detail cross sectional images - thus avoid superimposition seen in conventional radiography.
- Can process the image to give greater resolution of narrow contrast bands.
- The ability to reformat the information.
- Post-processing can enhance an area of special interest.

Disadvantages of CT:

- Uses long X ray exposure times.
- Contributes a radiation dose.
- Lower spatial resolution of low contrast objects.
- Expensive equipment.
Indications forComputed Tomography

Head
Nasal disease
CNS disease
Oral masses
  Local lymph nodes
Otitis externa and media
Neoplasia
Fractures

Spine
Intervertebral disc disease
Neoplasia
Fractures
Infection

Fractures
Non union of humeral condyle
Fragmented coronoid process
Neoplasia

Soft Tissues
Angiography-PSS

Grateful acknowledgement to Manuel Pinilla for his invaluable contribution to the presentation and notes