Radiology of thoracic trauma in the dog and cat

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Radiography is an important modality for patients with thoracic trauma because it enables rapid initial assessment of most thoracic structures, is widely available, and can be used repeatedly to monitor changes during case management. Thoracic radiography is indicated in all animals involved in a road traffic accident. This article describes the radiographic signs that might be seen following thoracic trauma and highlights those lesions that might require further investigation using ultrasonography or computed tomography.

Initial considerations

It is important that acute patients considered candidates for radiography are sufficiently stable. Only in exceptional circumstances should radiography be carried out at the expense of stabilisation. In particular, respiratory dysfunction can be aggravated by restraint or recumbency for radiography, and hence a period of stabilisation (eg, intravenous fluid therapy, oxygen) may be prudent before radiography of critical patients. In dyspnoeic patients, a dorsoventral thoracic radiograph with the patient in sternal recumbency should be taken before lateral recumbency is attempted. In distressed patients, sedation and/or analgesia before radiography may facilitate positioning. Manual restraint may be necessary when a patient cannot be safely and adequately restrained using sedation and positioning aids.

The thorax is normally well suited to radiography because the air in the respiratory tract and the bones provide high inherent contrast. Orthogonal projections (left or right lateral and dorsoventral views) using a high kV/low mAs technique will usually be most informative. If looking for fractures, a lower kVp/higher mAs technique may be preferred. Both right and left lateral radiographs may be necessary to optimally examine the lung (eg, in deep-chested dogs that cannot be positioned symmetrically for ventrodorsal or dorsoventral radiographs, possibly because of concurrent injuries).

Thoracic trauma is a common reason for emergency admissions, particularly as a result of road traffic accidents (RTAs). Injuries such as fractured ribs, pneumothorax and pulmonary contusions are therefore familiar to most veterinary surgeons in first-opinion practice. Blunt thoracic trauma causes injury to underlying structures by inertial forces, the spalling effect or implosion (Berkwitt and Berzon 1985). The spalling effect is caused by a shock wavefront passing through the interfaces between air, alveolar tissue and blood vessels, which leads to burst blood vessels and torn alveolar septa.

Although thoracic radiographs are essential when assessing thoracic injuries, they can sometimes be misleading because certain injuries may not be recognised immediately after trauma. Pneumothorax may initially be the only radiological abnormality in patients with gradual haemorrhage into the pleural cavity or lung, whereas radiographs taken four to six hours later may clearly show signs of haemothorax and pulmonary contusion. Similarly, respiratory failure may not occur until 24 to 48 hours after injury (Berkwitt and Berzon 1985). Obtaining repeat radiographs may be useful when an initially stable patient deteriorates.

Radiography, ultrasonography or CT?

Radiography is probably the single most useful imaging modality for animals with thoracic trauma, and is a logical first choice for such patients. Other imaging modalities (eg, ultrasonography and computed tomography [CT]) may enable more detailed assessment of injuries that are not fully elucidated radiographically.

Classification of thoracic trauma

Thoracic injuries can be divided anatomically into the following categories:

- Damage to the thoracic wall;
- Pleural space-occupying conditions such as pneumothorax, haemothorax or diaphragmatic rupture;
- Pulmonary contusion, laceration or collapse;
- Mediastinal abnormalities such as pneumomediastinum, haemorrhage or tracheal avulsion.

The most frequent thoracic injuries in dogs occurring as a result of RTAs are (in decreasing order) pneumothorax, pulmonary contusions, rib fractures,

(above) Radiograph of a dog showing multiple rib fractures that are markedly displaced due to lacerations of the intercostal muscles. There is pneumothorax and a large volume of air within the thoracic wall. (right) Close-up view of multiple segmental rib fractures in a cat. Fractures allowing mobility of adjacent portions of the ribs could result in 'flail chest'

pneumomediastinum, haemothorax and diaphragmatic rupture. In one study, thoracic injuries tended to occur more frequently in dogs with fractures cranial to the thoracolumbar junction than those with fractures caudal to the this junction (odds ratio 1·8, P=0·08) (Spackman and others 1984), but another similar study did not detect this difference (Houlton and Dyce 1992). The idiosyncratic nature of trauma leads to unpredictable injuries, so it is necessary to make a careful and comprehensive assessment of all trauma patients.

Careful examination of the cortical margins of each rib should enable radiological diagnosis of most fractures. Some radiologists also deliberately turn thoracic radiographs into an unfamiliar orientation when examining the ribs in an attempt to help them concentrate better on the ribs than when viewing the radiographs in normal orientation. The costal cartilages are often irregularly or incompletely calcified (particularly in cats), the appearance of which could mimic a fracture.

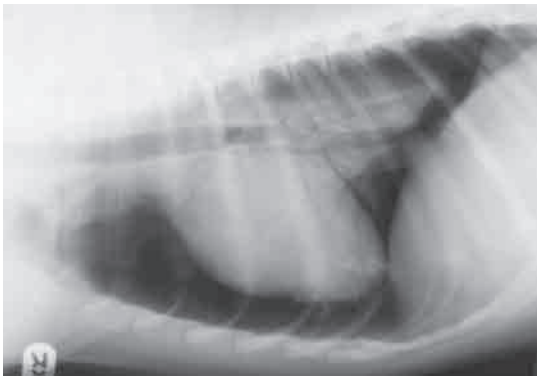
Radiographic signs of thoracic injuries

Injuries affecting the thoracic wall may appear radiographically as:

- Subcutaneous emphysema;
- Malpositioned ribs as a result of intercostal muscle laceration;
- Rib fracture or luxation;
- Vertebral or sternal fracture, or luxation;
- Herniation of viscera.

Rib fractures may be a source of pain and can cause secondary damage to intercostal arteries and the adjacent lung, depending on the degree of displacement. Instability of the thoracic wall occurring as a result of multiple rib fractures may result in a 'flail chest'. Flail chest is a specific injury in which a portion of the thoracic wall moves paradoxically during respiration. This means that, during inspiration, the negative pleural pressure draws in the unstable portion of the thoracic wall and, during expiration, it is pushed outwards. This has the effect of reducing tidal volume, which exacerbates any respiratory insufficiency associated with pneumothorax or pulmonary haemorrhage.

Radiograph showing a paracostal rupture in a dog that has allowed displacement of the gastric fundus into a subcutaneous position



Lateral thoracic radiograph showing the typical appearance of pneumothorax in a dog. The lung lobes are collapsed, and the lung lobes and heart are separated from the thoracic wall by a lucent space

Pneumothorax

Pneumothorax may appear radiographically as:

- Lucent space between the heart and sternum and/or between the lung lobes and thoracic wall;
- Increased opacity of the lung.

Pneumothorax may occur as a result of air leaking into the pleural cavity either through a defect in the thoracic wall or – more often – through a defect in a lung lobe or bronchus. Pneumothorax is most consistently visualised on lateral radiographs; it may not be visible on dorsoventral radiographs unless a relatively large volume of pleural air is present. Small volumes of pleural air may be difficult to detect radiographically. Deliberately exposing a radiograph during the expiratory pause may increase sensitivity for small volume pneumothorax.

Pneumothorax occurring as a result of thoracic trauma is nearly always bilateral, but may be asymmetrical if pulmonary lesions are present. In dogs and cats, the right middle lobe is normally most prone to collapse because of its lack of collateral ventilation and high surface area to volume ratio, so pleural air (or fluid) frequently collects around this lobe. Pulmonary contusions exacerbate any lobar collapse and therefore promote collection of pleural air around the affected lobes.

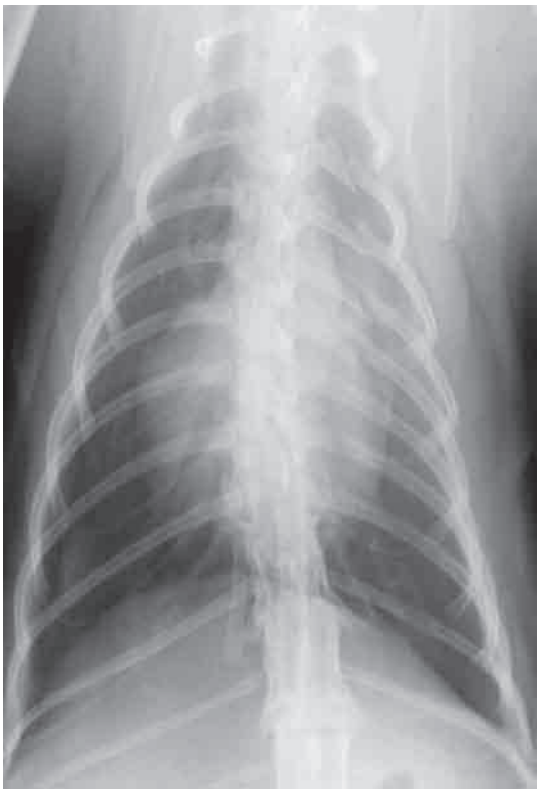
Tension pneumothorax is pneumothorax with supra-atmospheric pleural pressures. This occurs when a valve-like tracheal or pulmonary lesion allows air into the pleural cavity during inspiration but does not allow it to escape during expiration, thus increasing pleural pressure and causing progressive, life-threatening pulmonary collapse. Radiographically, the combination of a large volume of pleural air, marked pulmonary collapse and a flattened diaphragm are suggestive of tension pneumothorax, the appearance of which should prompt immediate thoracocentesis.

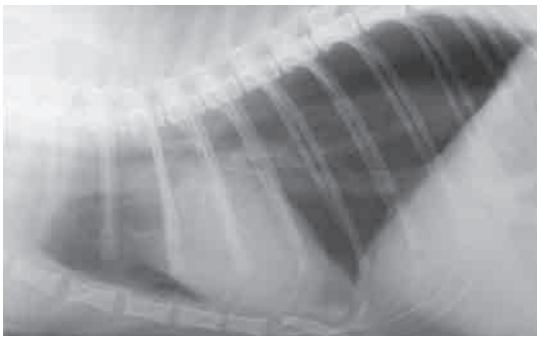
Pleural haemorrhage

Pleural haemorrhage may appear radiographically as:

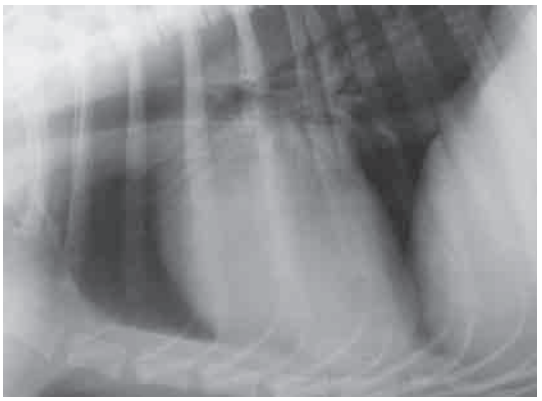
- Generalised increased opacity of the thorax;
- Obscured cardiac and diaphragmatic borders;
- Uniform soft tissue opacity between lung lobe borders and the thoracic wall;
- Widened interlobar fissures.

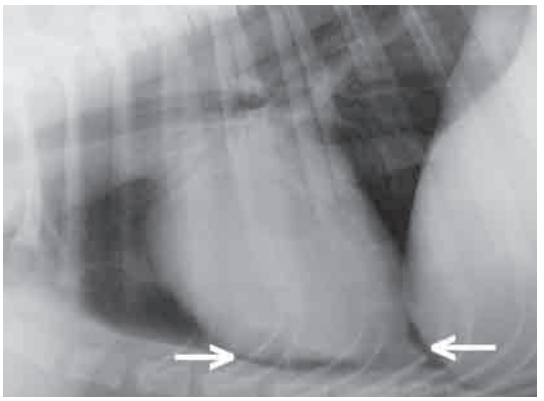
Pleural fluid after trauma is usually blood (haemothorax). While watery pleural effusions tend to be



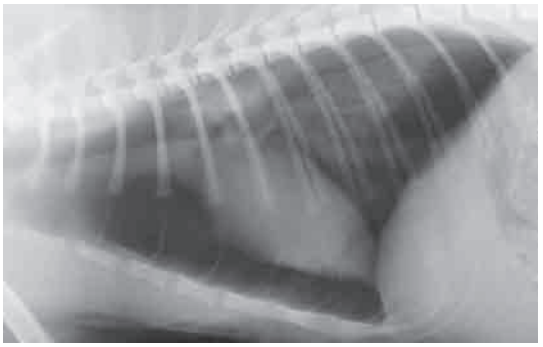


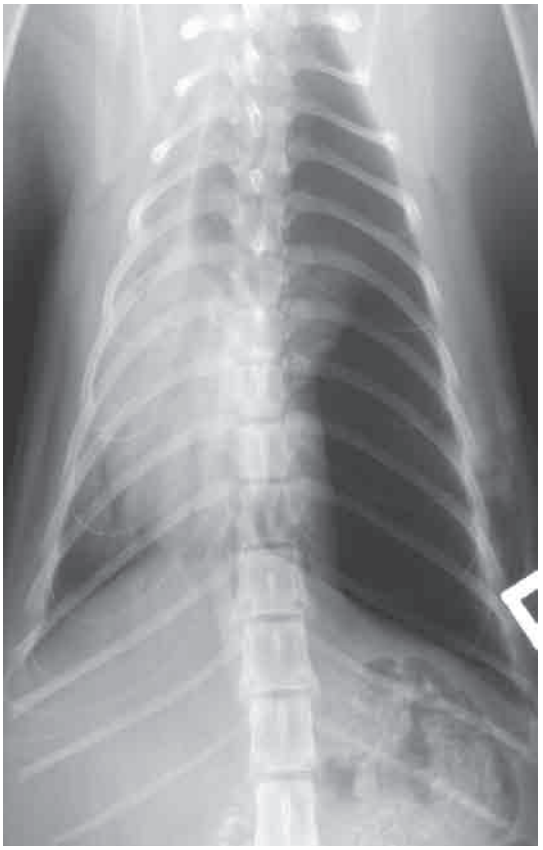
In contrast to dogs, in which pleural air is usually visible between the heart and the sternum, cats have a more variable distribution of pleural air. In this cat, pleural air has collected mainly around the caudal lung lobes. This case illustrates the importance of obtaining both lateral (left) and dorsoventral (right) radiographs in animals with thoracic trauma: the pneumothorax is clearly visible only on the lateral view, while the fractures of ribs 4 to 7 on the left hand side are only evident on the dorsoventral image





Small volumes of pleural air can be difficult to detect radiographically. In this dog, which was hit by a car, the right lateral radiograph (left) appears normal, while the left lateral view (right) shows pleural air (arrows) around the cardiac and diaphragmatic borders





(above and right) Radiographs showing tension pneumothorax in a cat. A large volume of air is visible in the left pleural cavity. Additional signs of increased pleural pressure include marked lobar collapse, mediastinal shift to the right and a flattened left hemidiaphragm

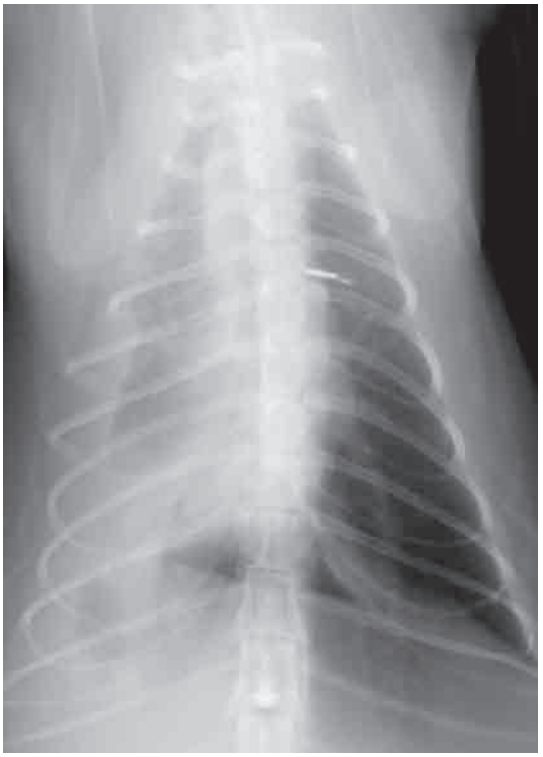
bilateral and evenly distributed, pleural blood may be localised and may form cavities of variable shape if there is concurrent pleural air. Haemothorax can resolve radiographically within a few days.

Diaphragmatic rupture

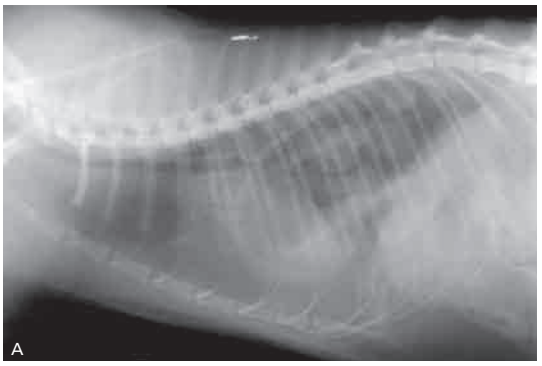
Diaphragmatic rupture may appear radiographically as pleural fluid, alone or in combination with:

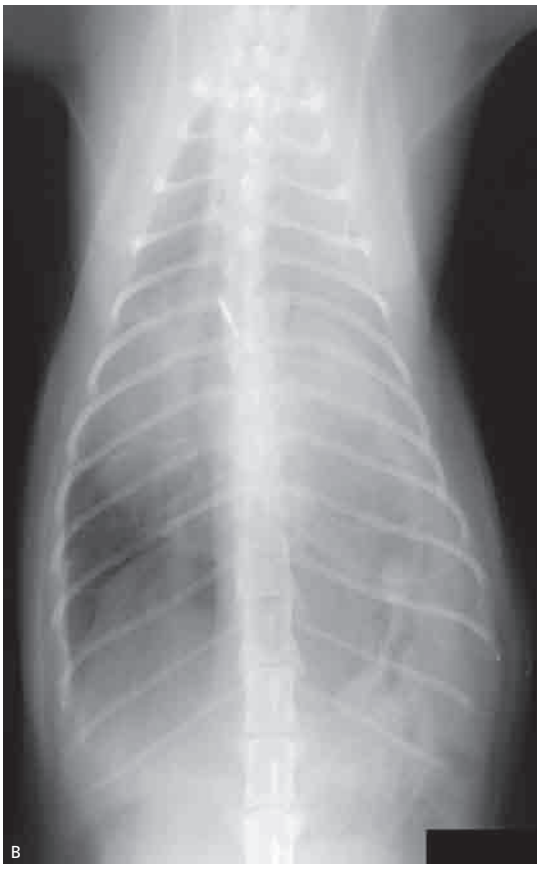
- Displacement of thoracic viscera;
- Cranial displacement of abdominal viscera;
- Lack of viscera in the abdomen.

Radiographic diagnosis of diaphragmatic rupture is straightforward if there are recognisable portions of the gastrointestinal tract in the thorax. In many cases, radiographic diagnosis is more challenging because pleural fluid (blood in acute cases or modified transudate in subacute/chronic cases) tends to obscure intrathoracic structures, including the diaphragm and any displaced viscera. In trauma patients, pleural fluid alone is not a reliable sign of diaphragmatic rupture; diagnosis should be based on signs that suggest cranial displacement of abdominal viscera. In fact, when a

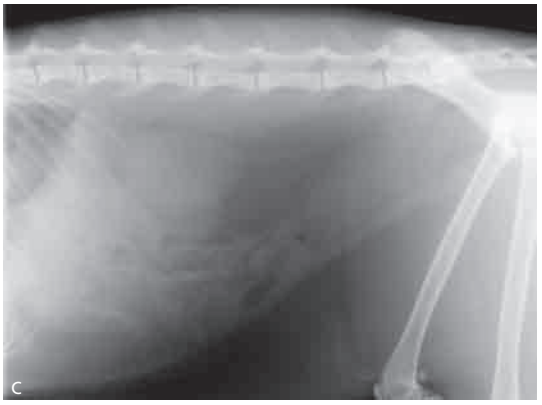


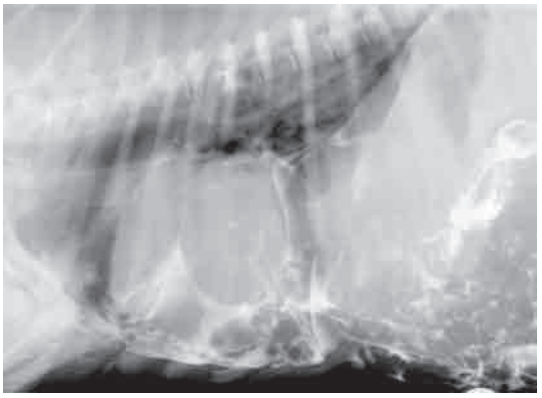
(left) Ventrodorsal radiograph showing haemothorax in a cat hit by a car. Localised pleural fluid and minimally displaced fractures of ribs 5, 6 and 8 can be seen on the right hand side of the thorax. (right) Dorsoventral radiograph showing an obvious diaphragmatic rupture in a cat that was dyspnoeic after being hit by a car. Multiple gas-filled small intestinal loops can be seen within the thorax





Typical radiographic signs of diaphragmatic rupture in a cat. (A, B) Normal intrathoracic anatomy is obscured in these images, but a heterogeneous structure occupying the left hemithorax and a mediastinal shift to the right can be seen. The abdominal radiograph (C) shows a lack of liver, stomach and small intestine, and the large intestine is in an abnormally cranial position

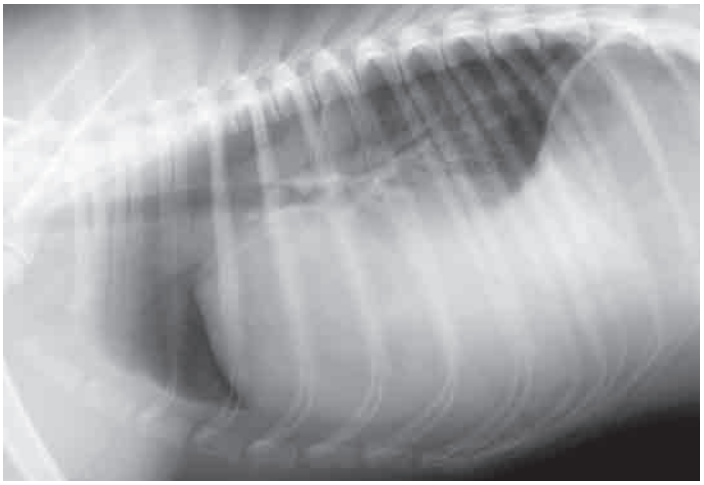


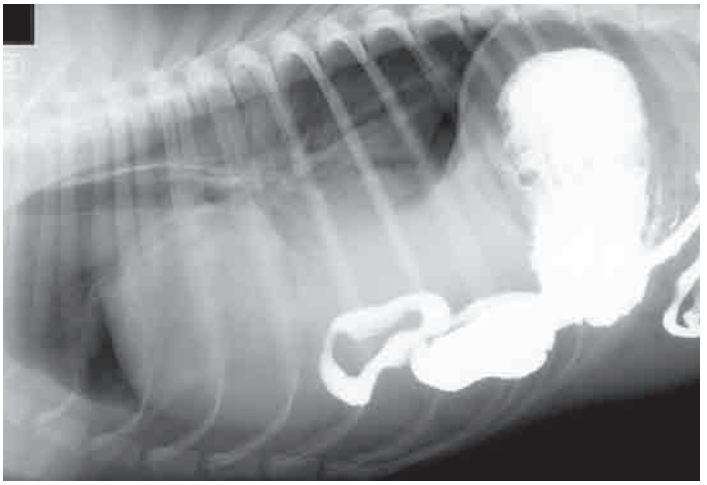


Positive contrast peritoneography was used to confirm a ruptured diaphragm in this dog in which gastrography was negative. Contrast medium injected into the peritoneal cavity has flowed into the thorax, outlining the boundaries of the pleural cavity

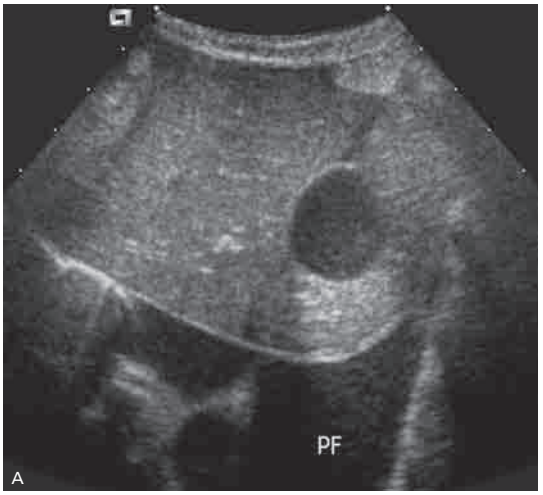
ruptured diaphragm is suspected, abdominal radiography should be considered because it is frequently easier to recognise a lack of abdominal organs on an abdominal radiograph than to recognise abdominal organs within the thorax in corresponding thoracic radiographs. Positive contrast gastrography or peritoneography should also be considered in patients with suspected diaphragmatic rupture or an unexplained pleural effusion.

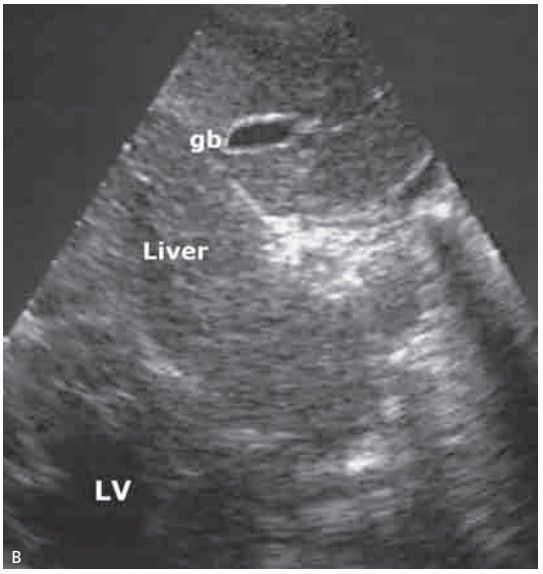
In obese animals, the diaphragm may be directly visualised, so a loss of this structure is sometimes a sign of diaphragmatic rupture (Lamb 2004). The diaphragm may also be examined ultrasonographically. Use of an abdominal (transhepatic) approach is recommended as a means of rapidly determining the integrity of the diaphragm (Spattini and others 2003).

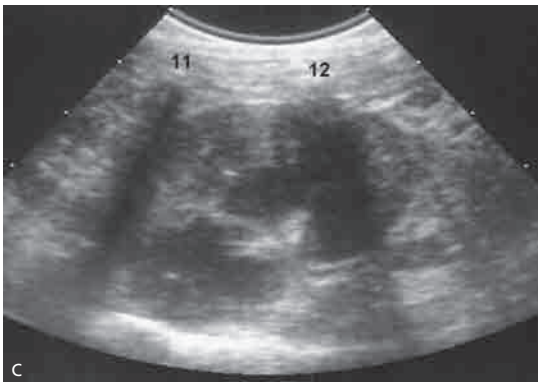




(left) Survey radiograph showing a caudal thoracic soft tissue lesion that has obliterated the caudal cardiac and diaphragmatic borders. (right) The use of positive contrast gastrography in this case shows the proximal duodenum within the thorax, which is diagnostic of a ruptured diaphragm







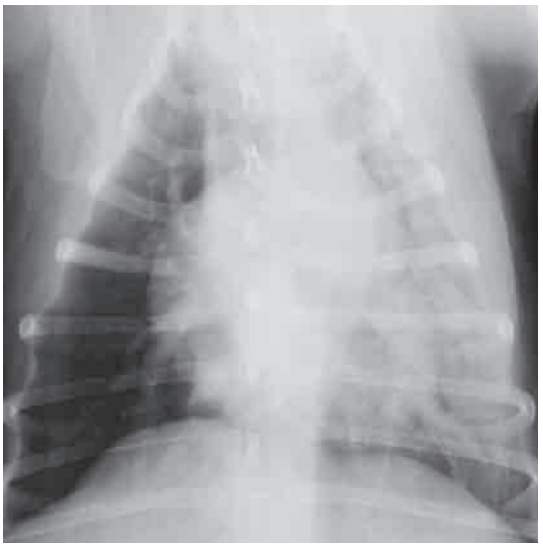
(A) Transhepatic ultrasound image of the cranial abdomen of a dog with pleural fluid following blunt trauma. The normal position and regular curved cranial aspect of the liver rule out diaphragmatic rupture. Pleural fluid (PF) is visible cranial to the diaphragm. (B) Similar transhepatic ultrasound image in a different dog that was hit by a car. The normal position of the diaphragm is not visible and part of the liver is displaced into contact with the heart. A ruptured diaphragm was confirmed surgically. gb Gallbladder, LV Left ventricle. (C) Intercostal ultrasound image of a cat with a ruptured diaphragm. Acoustic shadows are visible originating from ribs 11 and 12 on the right (11, 12). The underlying tissue is recognisable as the right kidney. This image has been reproduced, with permission, from *Journal of Small Animal Practice* (2000) volume 41, p 383

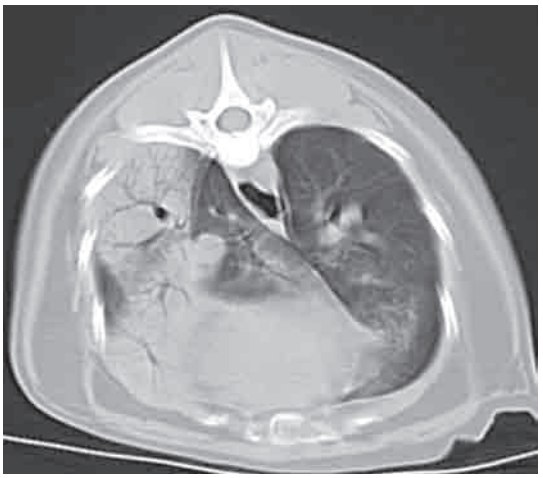
Identification of intrathoracic viscera may be attempted either via a transhepatic or intercostal approach.

Pulmonary contusion

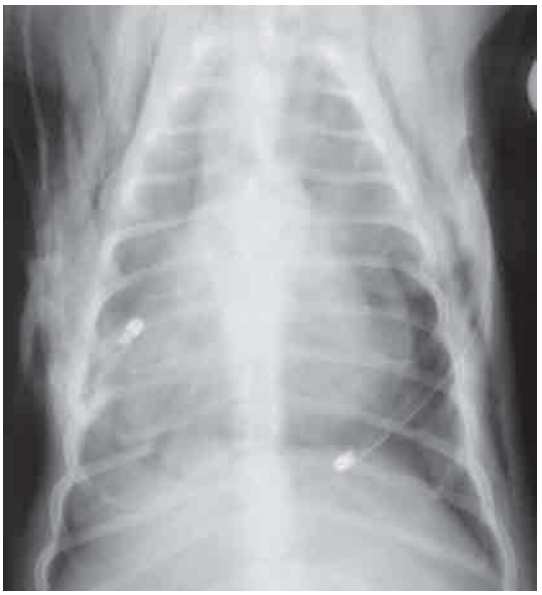
Pulmonary contusion is bruising caused by rapid compression and decompression of the lungs that results in haemorrhage and oedema affecting the alveoli and interstitium without any gross tearing of lung tissue. It may appear radiographically as:

- A spectrum of increased pulmonary opacity from a slight hazy or indistinct infiltrate to completely consolidated lung, sometimes with air bronchograms;
- Focal or multifocal, lobar or generalised pulmonary lesions;
- Pulmonary lesions adjacent to thoracic wall injuries.

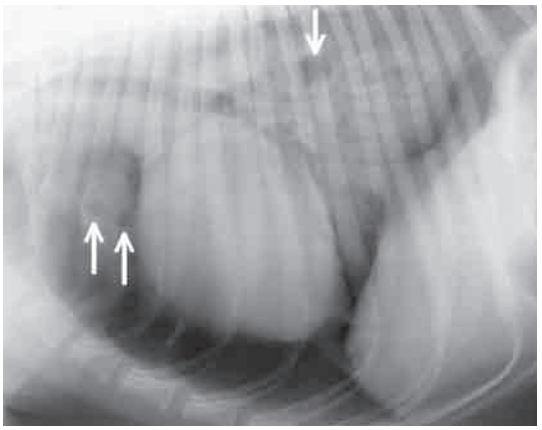




(left) Radiograph showing extensive pulmonary contusion in a dog hit by a car. There is a marked increased opacity affecting the entire left lung, which is obscuring the left cardiac border. Marked inspiratory effort (negative pleural pressure) is evident by the concave pleural border in each of the intercostal spaces on the right. (right) CT scan of the thorax of a cat with pulmonary contusion mainly affecting the right caudal lobe. The affected lung is consolidated, which is compatible with extensive haemorrhage, and air bronchograms are visible. Less marked infiltration affecting the ventral aspects of the accessory lobe and the left caudal lobe may also reflect pulmonary haemorrhage



It is frequently difficult to assess the lung in animals with thoracic trauma because of superimposed pleural haemorrhage and thoracic wall injuries. Specifically, it is difficult to know if an increased pulmonary opacity is the result of partial collapse alone or if there is also some haemorrhage. (left) Dorsoventral thoracic radiograph showing bilateral pleural drains, residual pneumothorax and generalised increased opacity. The contributions of pleural haemorrhage, pulmonary collapse and pulmonary contusion to this appearance cannot be distinguished. (right) CT (using a minimum intensity projection) eliminates the problem of superimposition and, in this case, shows generalised pulmonary collapse associated with pneumothorax and a more marked increased opacity affecting the right caudal lobe (arrow), which is indicative of pulmonary contusion



Lateral thoracic radiograph of a dog that was hit by a car, showing pneumothorax, pulmonary collapse and several focal cavitary lesions ('traumatic lung bullae') (arrows), which represent pulmonary lacerations

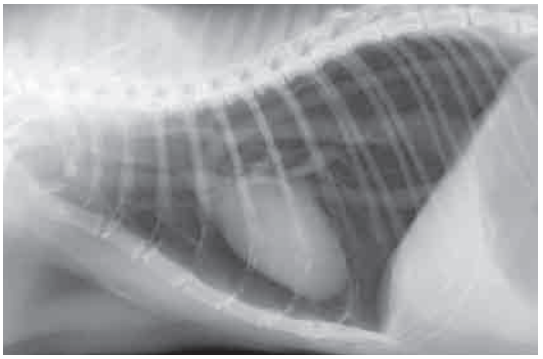
Pulmonary contusions may become more marked clinically and radiographically in the four to six hours following trauma. They may be difficult to recognise radiographically when there is also a degree of pulmonary collapse as a result of pneumothorax or pleural haemorrhage. CT is a better imaging modality than survey radiography for examining the lung because it eliminates the problem of superimposition, thus allowing a clearer view of the lung.

Pulmonary lacerations

Pulmonary lacerations may appear radiographically as:

- Focal or multifocal cavitary lesions containing variable proportions of air and fluid (blood);
- Lesions in the periphery of the lung.

(left) CT scan of a dog that was hit by a car, showing a small volume pneumothorax and focal cavitary lesion affecting the lateral aspect of the right cranial lobe. The lesion contains air and blood. (right) A repeat study carried out five days later showed a reduction in the size of the lesion and resolution of the pneumothorax



(left) Lateral thoracic radiograph of a cat with a penetrating cervical wound. The heart, major vessels, azygos vein and oesophagus have unusually clear margins because of the adjacent air. (right) CT scan of a dog with pneumomediastinum, left-sided pneumothorax and subcutaneous emphysema. The volume of air in a pneumomediastinum may appear much greater in CT images than in corresponding radiographs

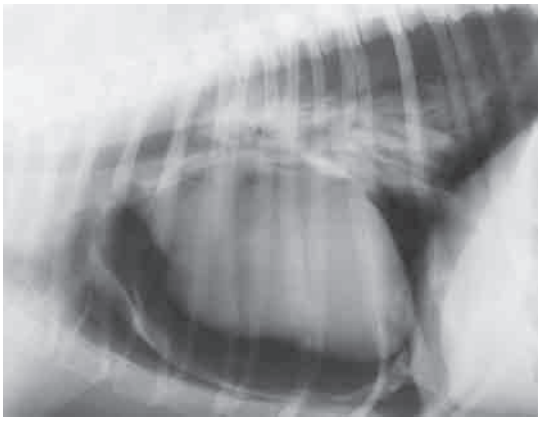
Locally extreme deformation of the lung occurring during penetrating or blunt trauma can lacerate (tear) the lung, resulting in a cavity that subsequently fills with blood and air. Radiographically, such a lesion may appear poorly marginated and could be considered a haematoma, or may be well-delineated by surrounding aerated lung and described as a traumatic bulla. Pulmonary lacerations appear to resolve radiographically within a few days.

Pneumomediastinum

Pneumomediastinum may appear radiographically as:

- Visualisation of the outer borders of the oesophagus, trachea and mediastinal blood vessels;
- Pneumopericardium;
- Concurrent pneumoretroperitoneum and cervical emphysema (by direct extension).

Pneumomediastinum may occur as a result of rupture of the wall of the trachea or terminal bronchiole, perforation of the oesophagus or by extension from a penetrating cervical wound. Pneumomediastinum is not usually clinically significant, although large volumes of mediastinal air can contribute to respiratory insufficiency in the same way as any other thoracic space-occupying lesion. Also, mediastinal air may break through into the pleural cavity where it is liable to cause more marked pulmonary collapse.



Lateral (above) and dorsoventral (right) radiographs showing pneumothorax and pneumopericardium in a dog that was hit by a car

Mediastinal haemorrhage

Mediastinal haemorrhage may appear radiographically as:

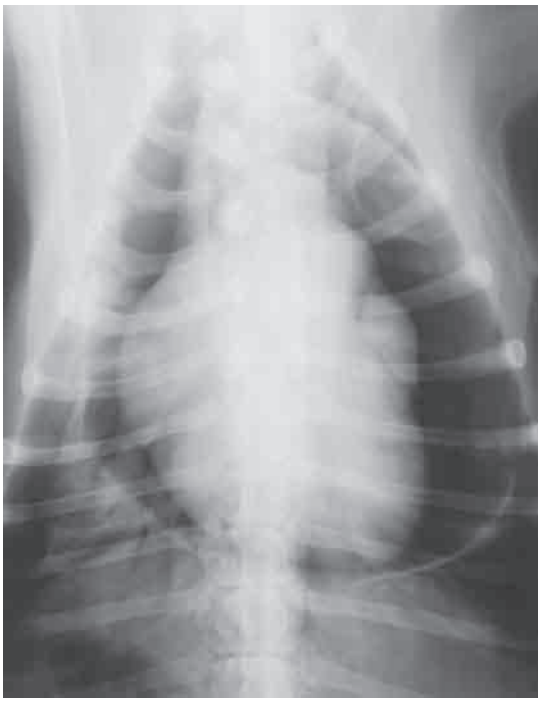
- Generalised widening of the cranial mediastinum;
- Dorsal or ventral displacement of the trachea.

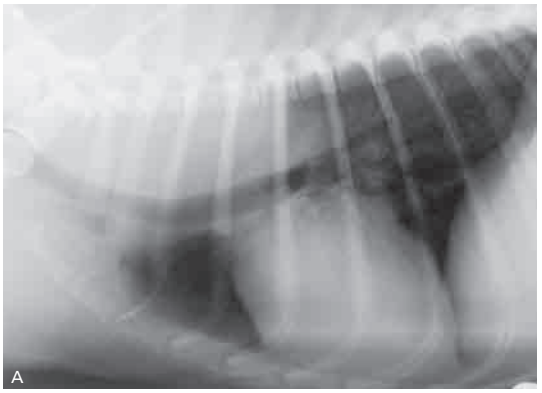
Mediastinal haemorrhage is particularly likely when an animal experiences sudden deceleration (eg, when it runs into an object or runs to the extent of a tether and is suddenly pulled back by the neck). When this happens, the soft thoracic viscera slide relative to the bones, which can result in tearing of the vertebral arteries supplying the mid-thoracic vertebrae. Such arterial haemorrhage can be rapidly fatal (Mason and others 1990).

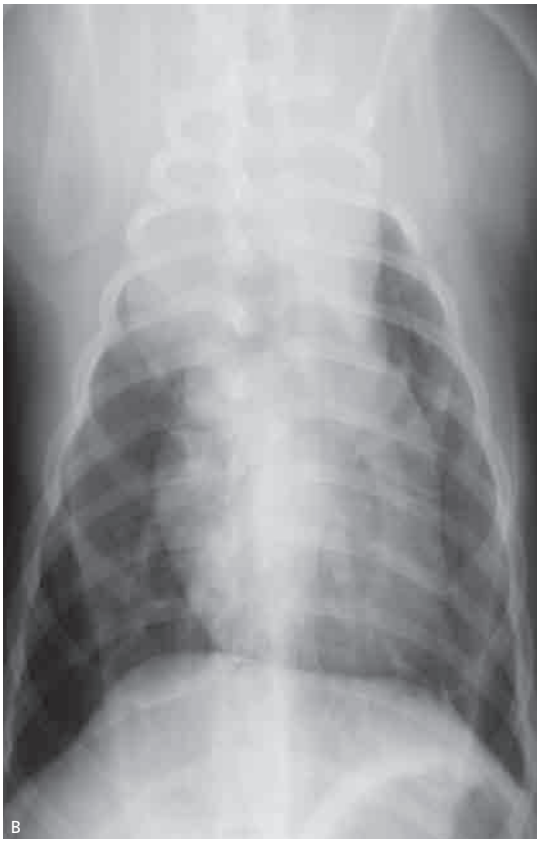
Tracheal avulsion

Tracheal avulsion may appear radiographically as:

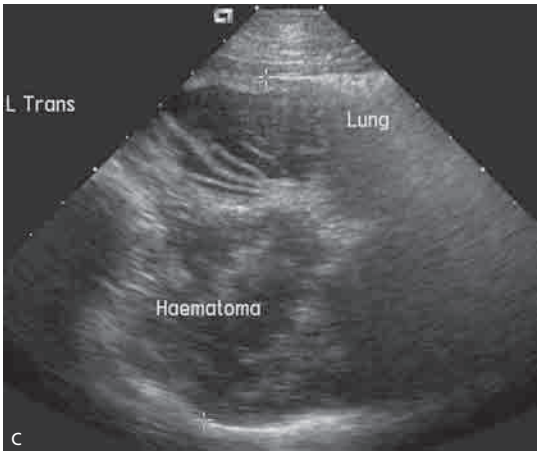
- Focal air-filled cavities superimposed on the trachea that enlarge with positive pressure ventilation;
- Focal deviation and/or narrowing of the tracheal lumen;
- Pneumomediastinum.

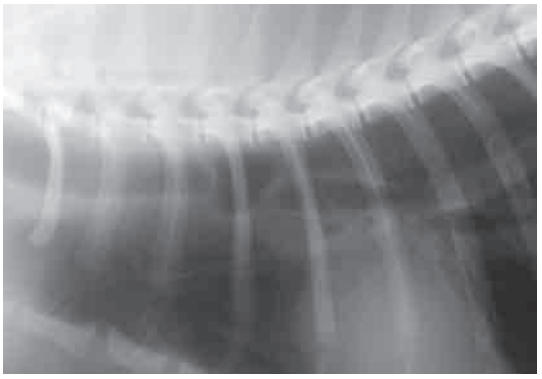


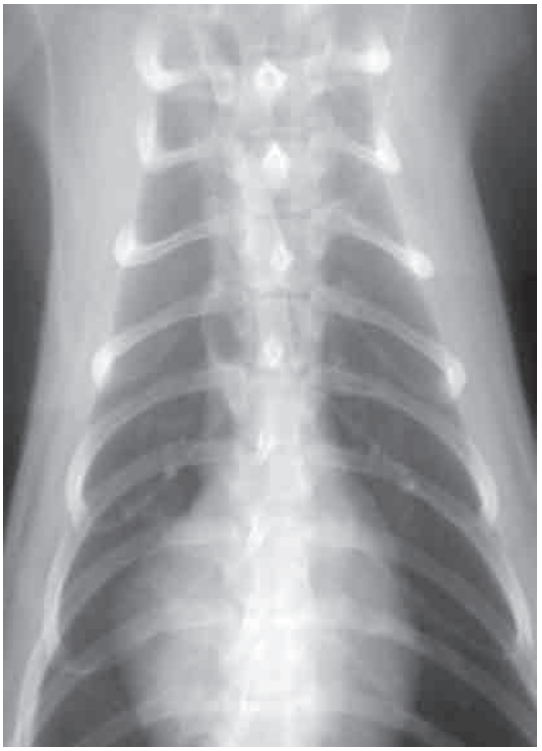




Lateral (A) and dorsoventral (B) thoracic radiographs from a dog that ran into a tree, showing a large dorsal mediastinal mass and a fractured rib 1 on the left. (C) Ultrasound image from the same animal obtained through a left intercostal space showing a heterogeneous mass with a layered component that is compatible with haematoma. This lesion was not visible on repeat radiographs obtained two weeks later







Lateral (above) and dorsoventral (right) thoracic radiographs from a cat with a tracheal avulsion showing a focal thin-walled lucent structure superimposed on the trachea; this is most clearly visible in the lateral view. This structure, which will enlarge under positive pressure ventilation, is formed by air that has escaped from the trachea but is trapped by an intact tracheal adventitia or mediastinal fascia

Tracheal avulsion has been observed most frequently following RTAs in cats. Affected cats present with signs of dyspnoea up to two to three weeks after known trauma. The trachea usually ruptures in the mid-thorax, at the junction of the fixed section of the trachea and the more freely mobile portion. The radiographic appearance represents air that has passed between separated tracheal rings and is trapped by an intact tracheal adventitia or mediastinal fascia (White and Burton 2000).

Summary

Thoracic trauma is a multifarious phenomenon that causes a wide range of thoracic injuries and radiographic signs. Radiography is a logical first step for vets managing patients with suspected thoracic trauma. It is important to make sufficient radiographs and to know what signs to look for. Ultrasonography and CT may enable more detailed assessment of injuries that are not fully elucidated radiographically.

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Notes