

Ultrasound of the Thorax (Noncardiac)

Martha Moon Larson, DVM, MS

KEYWORDS

• Ultrasound • Thorax • Pleural effusion • Mediastinum • Lung

Ultrasound of the noncardiac thorax is an important supplemental imaging modality in the diagnosis of pulmonary, mediastinal, pleural, and chest wall disease. There are limitations, as there is near-total reflection of sound waves at gas interfaces, hiding pulmonary or mediastinal lesions located deep to the air-filled lung. However, if pulmonary lesions are peripheral, or pleural fluid is present to act as an acoustic window, ultrasound detection of disease is possible. The use of ultrasound to guide thoracocentesis, aspiration of masses, or lung consolidation increases efficiency and safety.

TECHNIQUE

Thoracic radiographs should always be taken before the ultrasound examination to assess disease and to determine the most appropriate scanning window. If pleural effusion is present, and the patient is stable, thoracocentesis should be delayed until after the ultrasound examination. Pleural fluid provides a valuable acoustic window to the lungs and mediastinum. Patients can be scanned in lateral or sternal recumbency, using an intercostal window. Dorsal recumbency may also be used if the patient is stable. Some patients may be more comfortable when scanned while standing. Both longitudinal (transducer perpendicular to ribs) and transverse (transducer parallel to ribs) imaging planes should be used. Lesions in the caudal thorax or mediastinum can be visualized using a transhepatic approach from a ventral or lateral abdominal location. A window through the thoracic inlet may allow enhanced visualization of the cranial mediastinum. A small footprint transducer (sector, curved microconvex, or curved linear array) fits best in restricted intercostal spaces. Transducer frequency should be based on the size of the patient and depth of the lesion.

NORMAL APPEARANCE

The chest wall is composed of skin, subcutaneous fat, and muscle. These tissues are represented by alternating layers of hyper- and hypoechogenicity in the near field, just

Department of Small Animal Clinical Sciences, Virginia-Maryland College of Veterinary Medicine, Virginia Tech University, Duckpond Drive, Phase II, Blacksburg, VA 24061, USA

E-mail address: moonm@vt.edu

Vet Clin Small Anim 39 (2009) 733–745

doi:10.1016/j.cvsm.2009.04.006

vetsmall.theclinics.com

0195-5616/09/\$ – see front matter © 2009 Elsevier Inc. All rights reserved.

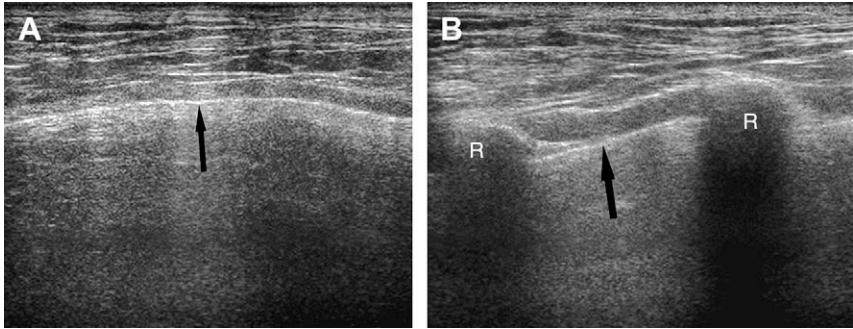


Fig. 1. (A) Transverse ultrasound scan of a normal thorax. The transducer is parallel to the ribs at the right seventh intercostal space. The chest wall is represented by alternating layers of hyper- and hypoechoogenicity in the near field. The pleura-lung interface is represented by a smooth, linear echogenic line extending across the image (arrow). Dorsal is at the right side of the image. (B) Longitudinal ultrasound scan of a normal thorax. The transducer is aligned perpendicular to the ribs at the right seventh intercostal space. Ribs (R) are seen in cross section, creating a curvilinear echogenic interface with distal shadowing. The lung-pleura interface is represented by the smooth echogenic line between ribs (arrow). Cranial is to the left of the image.

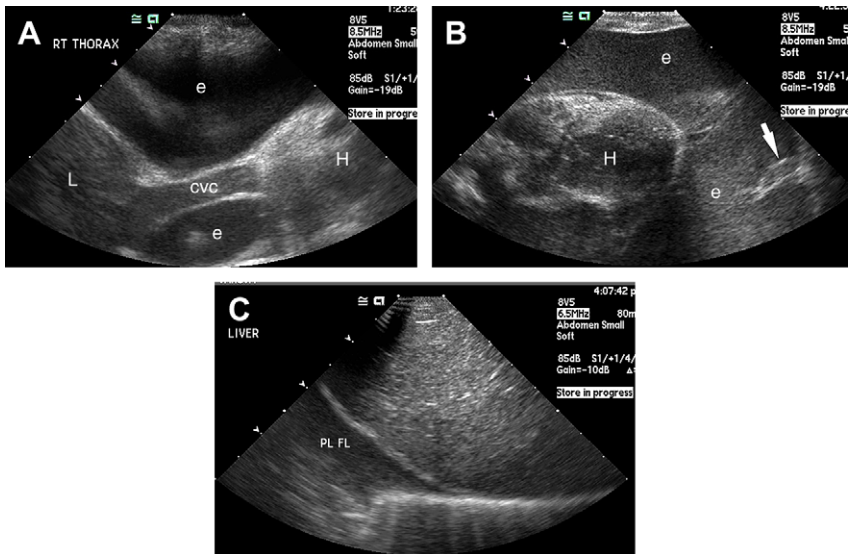


Fig. 2. (A) Longitudinal ultrasound scan of the caudal thorax in a dog with pleural effusion. The transducer is perpendicular to the ribs. Pleural effusion is present in both hemithoraces (e). The caudal vena cava (cvc) is seen extending from the liver (L) to the heart (H). Caudal is to the left of the image. (B) Longitudinal ultrasound scan of the caudal thorax of a cat with pleural effusion. The transducer is perpendicular to the ribs. Echogenic effusion (e) is seen in both hemithoraces. The heart (H) is seen cranially (to the left of the image). An echogenic fibrin strand is present caudally (arrow). Carcinomatosis was diagnosed on cytology of the pleural fluid. Note that this image is oriented the opposite of Fig. 2A. (C) Longitudinal scan of the cranial abdomen of a dog with pleural effusion. Pleural fluid (PL FL) is seen cranial to the diaphragm, with the liver located caudally. A hepatocentric window is used to detect the pleural fluid. Cranial is to the left of the image.

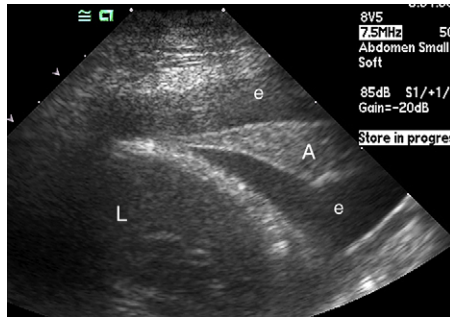


Fig. 3. Longitudinal ultrasound scan of a dog with pleural effusion. Pleural fluid (e) surrounds a small, triangular hypoechoic collapsed lung lobe (A). The liver (L) is seen caudally (to the left of the image).

beneath the transducer (**Fig. 1**).¹⁻⁵ The parietal pleural lining the thoracic wall may not be seen distinctly, and in the normal dog and cat, the visceral pleura and lung surface form a continuous echogenic line. However, the two pleural interfaces may be differentiated by the “gliding sign,” with the hyperechoic pleuropulmonary interface moving smoothly during respiration against the parietal pleura lining the chest wall.^{1,2,5,6} Normal lung tissue deep to the visceral pleural interface is obscured by shadowing and reverberation artifact. Ribs are represented by smooth curvilinear echogenic interfaces with acoustic shadowing and are seen in regular intervals as the chest wall is scanned.

PLEURAL DISEASE

Thoracic ultrasound provides reliable determination of the presence, volume, and characteristics of pleural fluid.¹⁻⁵ Pleural fluid creates an excellent acoustic window, allowing ultrasound visualization of intrathoracic anatomy, including pulmonary, chest wall, and mediastinal disease not visible radiographically (**Fig. 2**). The fluid will appear anechoic if it is a transudate, modified transudate, or chylous effusion. The fluid will appear echogenic if there are cells, fibrin, and/or protein (exudates, hemorrhage, or neoplastic effusions) within the fluid. Pleural fluid accumulates between the thoracic wall and diaphragm, surrounding and extending between lung lobes. Small or localized fluid pockets may be more difficult to see, and accompanying thoracic radiographs should always be taken to help pinpoint the location of smaller quantities of

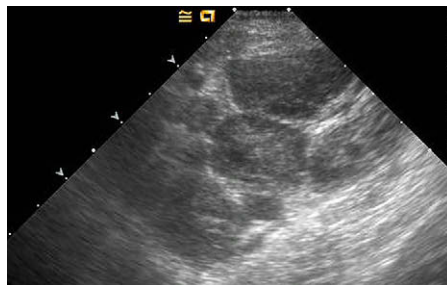


Fig. 4. Longitudinal ultrasound scan of the cranial mediastinum in a dog. A cranial mediastinal mass is seen, appearing as a coalescing mass of hypoechoic nodules. Lymphosarcoma was diagnosed on cytology from a fine-needle aspirate of the mass. Cranial is to the left of the image.

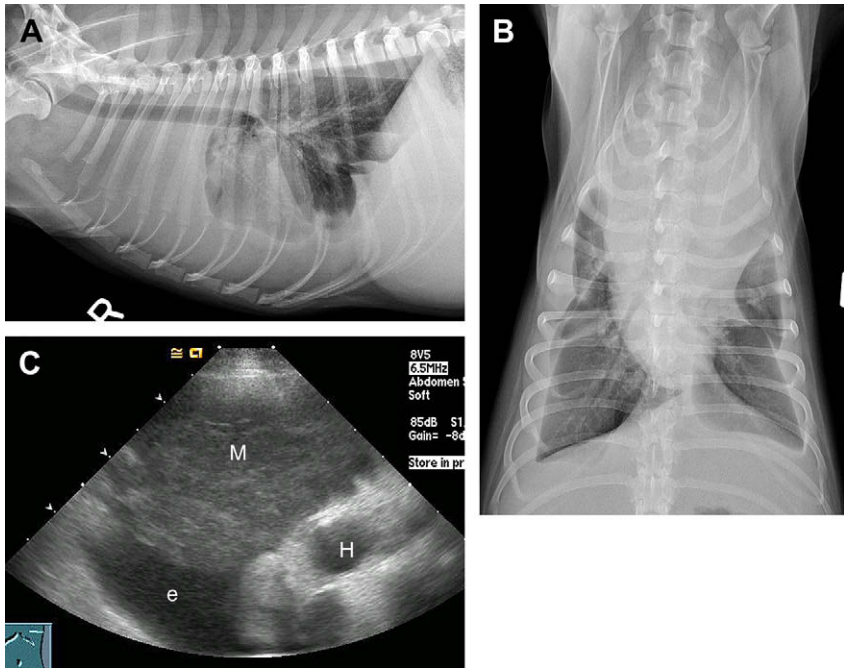


Fig. 5. (A) and (B) Lateral and ventrodorsal radiographs of a dog presented for respiratory distress. Pleural effusion is present, along with a widened cranial mediastinum seen best on the ventrodorsal view. (C) Transverse ultrasound image of the right thoracic wall of the dog in Figs. 5 A and B. A large, homogeneous, hypoechoic mass (M) is seen adjacent to the heart (H). Pleural effusion (e) is seen ventral to the mass. A thymoma was diagnosed on cytology of the mass obtained on fine-needle aspiration. Dorsal is at the right side of the image.

pleural fluid. In these cases, scanning the dependent thoracic region aids in fluid visualization. Pleural thickening, represented by a roughened, irregular surface lining the thoracic wall, may indicate pleuritis, neoplastic pleural disease, or chronic effusions. Echogenic linear fibrin strands are frequently seen with chronic effusion. Masses involving the pleura can be differentiated from pulmonary masses by the more peripheral location and lack of movement. Pulmonary masses will move with the lungs during respiration. As pleural fluid accumulates, lung lobes will collapse, forming small, wedge-shaped, or triangular structures (Fig. 3). With complete collapse, the shrunken lobes will be completely hypoechoic and appear to float within the surrounding pleural fluid. Although the cause of the pleural effusion may not always be apparent, a complete search of the thoracic wall, heart, lungs, and diaphragm should always be performed. Thoracic ultrasound can also be used in the diagnosis of pneumothorax and may be helpful as a quick initial screening tool in severely dyspneic or stressed patients.⁶ Pneumothorax is diagnosed when the normal gliding sign between pleural margins cannot be seen. The glide sign indicates normal apposition of lung against the thoracic wall and is not present with pneumothorax.^{1,2,5,6}

CRANIAL MEDIASTINUM

A parasternal or thoracic inlet approach is best for evaluating the cranial mediastinal area. Although normal mediastinal tissues can be seen in some patients, pleural

effusion creates a more effective ultrasound window to see mediastinal anatomy (**Fig. 2A**).¹⁻⁴ Large anechoic vessels extend cranially toward the thoracic inlet and may be surrounded by varying amounts of echogenic and irregular mediastinal fat. This normal fat should not be confused with a true mass, which is typically better margined and may cause displacement of adjacent structures. Ultrasound is very helpful in differentiating a true mediastinal mass from normal fat in patients with a widened mediastinum on thoracic radiographs. The thymus may be visualized as a granular, coarse echogenic structure ventral to the mediastinal vessels in young dogs and cats.¹ Normal mediastinal and sternal lymph nodes are not typically seen. Detection of mediastinal masses depends on the size and location.¹⁻⁷ Large masses that extend to the thoracic wall are easily seen. Smaller masses require the presence of pleural effusion to act as an acoustic window for detection. Mediastinal masses are found most commonly in the cranioventral mediastinum and are located primarily on the midline. Frequently these masses are diffusely hypoechoic and lobular (lymph node origin) or may have more complex heterogeneous or cystic structures (**Figs. 4** and **5**). Mediastinal masses are often accompanied by pleural effusion. Neoplastic lesions of the mediastinum, including lymphosarcoma, thymoma, neuroendocrine tumors, lymphomatoid granulomatosis, mast cell tumor, melanoma, and thyroid carcinoma, should all be considered, and the ultrasound appearance alone is insufficient for complete diagnosis (**Fig. 6**).¹⁻⁷ Mediastinal granulomas, hematomas, and abscesses occur less commonly but can appear identical to neoplastic masses.

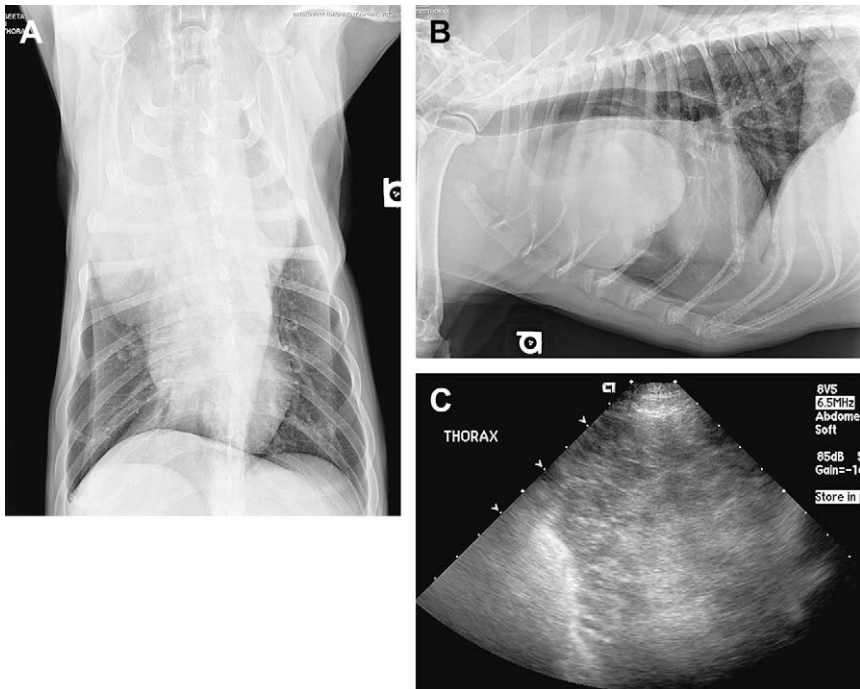


Fig. 6. (A, B) Ventrodorsal (A) and lateral thoracic radiographs of a dog with a large cranial mediastinal mass. (C) Transverse ultrasound image of the cranial mediastinal area of the dog in **Figs. 6** A and B. A large, heterogeneous mass is seen. The mass is hyperechoic, with multiple hypoechoic nodules distributed throughout. Dorsal is at the right side of the image.

I idiopathic mediastinal cysts have been reported in geriatric cats.⁸ These cysts are typically ovoid to bi-lobed in shape, with a well-marginated echogenic wall surrounding anechoic fluid (**Fig. 7**). Clear fluid with a low cell count is noted on cyst aspiration. Thymomas may also have a cystic appearance but should be thicker and more irregular. Heart base tumors, although more centrally located, can be visualized using the heart as an acoustic window. Caudal esophageal masses may be seen from a transhepatic approach. Ultrasound-guided aspiration or biopsy of mediastinal mass is essential in establishing a more definitive diagnosis and is critical when lesions are small or surrounded by adjacent vessels.

PULMONARY DISEASE

The lung parenchyma can be evaluated with ultrasound if air has been removed (atelectasis) or replaced by fluid or cells (the same process that results in increased radiographic opacity of lungs). However, the diseased lung must either extend to the lung periphery or be surrounded by fluid. Any aerated lung between the transducer and lesion is sufficient to mask the lung abnormality.

LUNG CONSOLIDATION

Infiltrative disease of the lung will cause an interruption in the echogenic linear lung interface, with hypoechoic tissue replacing air-filled lung.¹⁻⁵ With early or mild disease,

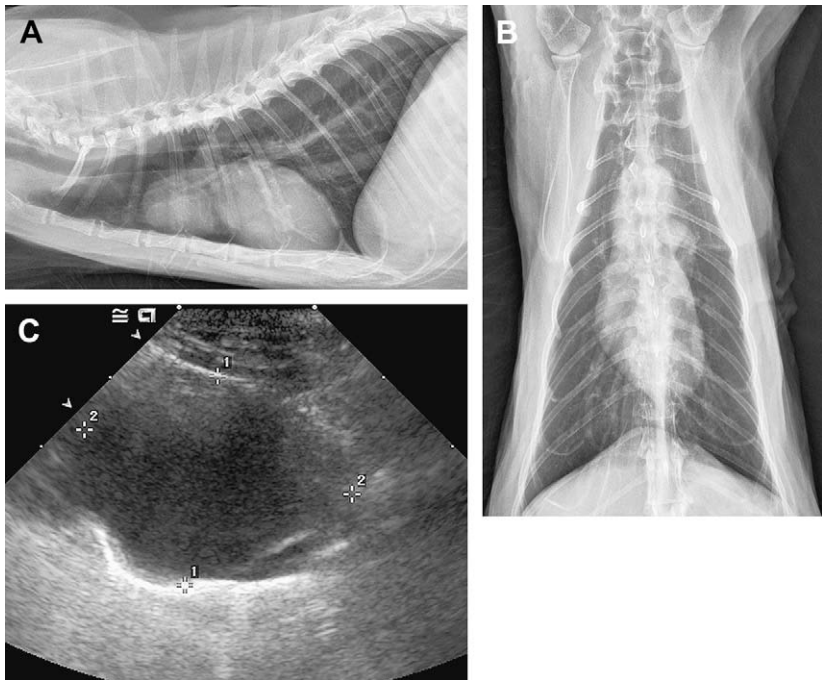


Fig. 7. Lateral (A) and ventrodorsal (B) thoracic radiographs of a 9-year-old cat. A cranial mediastinal mass is noted just cranial to the heart on the lateral view. This mass causes widening of the cranial mediastinum on the ventrodorsal view. (C) Longitudinal ultrasound image of the right cranial thoracic wall of the cat in **Figs. 7 A and B**. An anechoic, well-defined cystic structure is seen (between calipers). A clear transudate was removed on aspiration, and a benign mediastinal cyst was diagnosed. Cranial is to the left of the image.

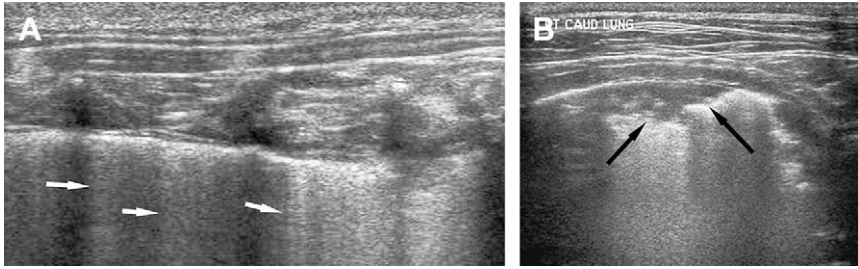


Fig. 8. (A) Longitudinal ultrasound image of the right thoracic wall in a dog presented for coughing. The normal linear echogenic lung/pleura interface is interrupted by numerous echogenic foci with hyperechoic shadows (arrows). These are termed comet tails and can indicate early pulmonary infiltrative disease. Cranial is to the left of the image. (B) Longitudinal ultrasound image of the right thoracic wall in a dog with pneumonia. A focal peripheral section of lung is hypoechoic due to fluid replacing normal aerated tissue (arrows). Normal air-filled lung is displaced deeper into the image. Cranial is to the left.

this interruption of the lung interface is seen as small hyperechoic foci with distal shadowing, termed comet tails (or perhaps, more correctly, ring-down artifact).^{9,10} These artifacts are nonspecific and can be seen with pulmonary edema, pleuritis, pulmonary fibrosis, interstitial pneumonia, and pulmonary contusion, diseases characterized by a thickening of either the pleura or the interlobular septa (Fig. 8).^{9,10} As the disease process becomes more extensive, aerated lung is displaced further and further from the chest wall. Although relatively homogeneous and hypoechoic, the diseased lung will also contain hyperechoic, shadowing linear structures resulting from residual air in the bronchi (air bronchograms), as well as more punctate echogenic foci from remaining air-filled alveoli (Fig. 9).¹⁻⁵ Fluid-filled bronchi may also be seen and can be differentiated from pulmonary vessels only by Doppler interrogation. When severe lung consolidation is present, the echogenicity and texture are similar to that of the liver, and this condition is termed hepatization (Fig. 10).¹⁻⁵ Lung consolidation can occur with pneumonia, edema, lung lobe torsion, contusions, and some lobar neoplasias.¹ With consolidation, the lung retains its normal volume, unlike atelectasis, which appears similar in echogenicity and texture but is decreased in volume. Lung lobe torsions will appear as a consolidated lobe on thoracic ultrasound, usually surrounded by pleural effusion (Fig. 11). The affected lung lobe can appear hypoechoic at the

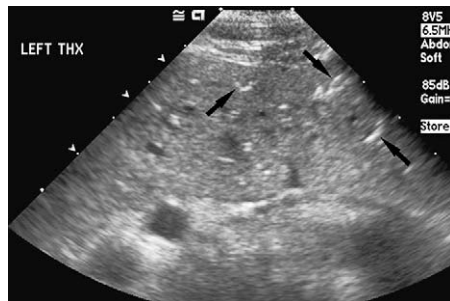


Fig. 9. Transverse ultrasound image of the left thoracic wall in a dog with severe pneumonia. A large segment of lung is consolidated and hypoechoic. Multiple air bronchograms are seen as hyperechoic linear structures (arrows). Dorsal is at the top of the image.



Fig. 10. Longitudinal ultrasound image of the right thoracic wall in a dog with severe pneumonia. The lung lobe (between calipers) has an echogenicity and texture similar to the liver, termed "hepatization." Cranial is to the left of the image.

periphery but centrally may contain multiple echogenic foci representing gas (**Fig. 12**).¹¹ This gas is consistent with the vesicular gas patterns often seen on radiographs. The torsed lobe will be normal to increased in volume, may have rounded margins, and extend in an abnormal position. Typically, there is no venous signal when lobar vessels are examined with Doppler. In some cases, a faint arterial signal may still be present.

PULMONARY MASSES

Neoplastic pulmonary disease results in homogeneous or heterogeneous lung masses that may have a smoother deep margin compared with the more irregular lung margin often seen with non-neoplastic consolidations (**Figs. 13** and **14**).¹⁻⁵ There may be

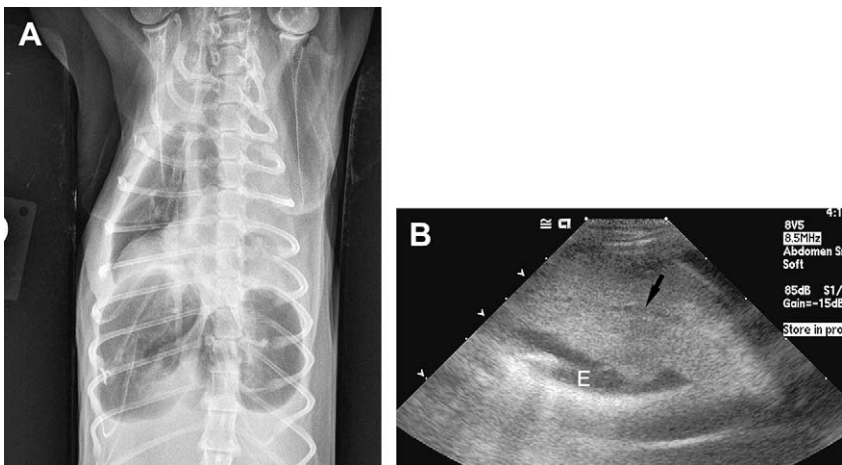


Fig. 11. (A) Ventrodorsal thoracic radiograph of an 8-year-old cat presented for respiratory distress. Pleural effusion, along with increased opacity of the right middle lung lobe is noted. (B) Longitudinal ultrasound image of the right thoracic wall of the cat in **Fig. 11A**. The right middle lung lobe is surrounded by pleural effusion (E) and is completely hypoechoic. The volume does not appear reduced, and the lobe maintains a normal shape. A fluid bronchogram runs down the middle of the lobe (arrow). Right middle lobe lung torsion was diagnosed at necropsy. Cranial is to the left of the image.

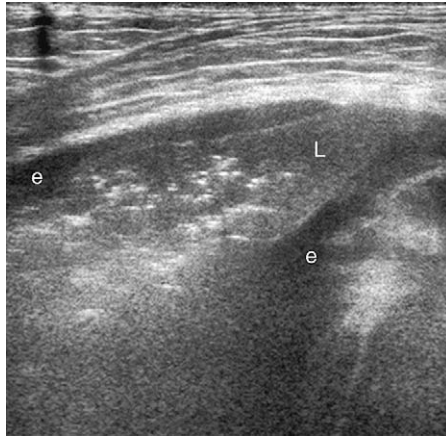


Fig. 12. Longitudinal ultrasound image of the right thoracic wall of a dog with lung lobe torsion. The torsed lobe (L) is surrounded by pleural effusion (e). The periphery of the lobe is hypoechoic, whereas the more central portion contains multiple echogenic foci representing gas. Cranial is to the left of the image.

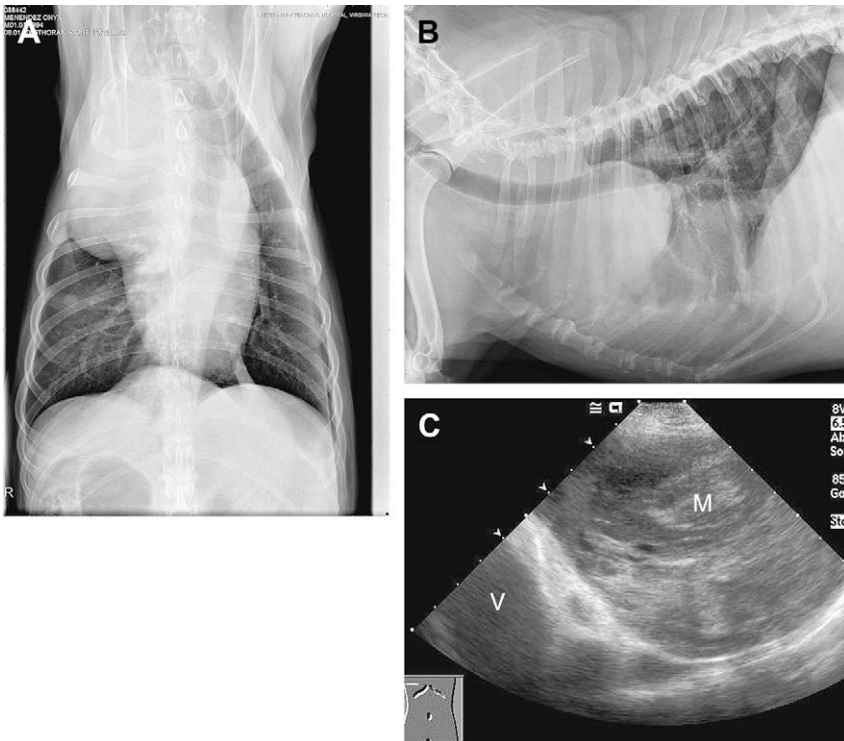


Fig. 13. (A) and (B) Ventrodorsal and left lateral radiograph of a dog with a mass in the right cranial lung lobe. (C) Longitudinal ultrasound image of the right thoracic wall of the dog in Fig. 13. A large heterogeneous mass (M) with some anechoic areas is present between the right thoracic wall and the right side of the heart (V). Pulmonary adenocarcinoma was diagnosed on cytology from a fine-needle aspirate. Cranial is to the left of the image.

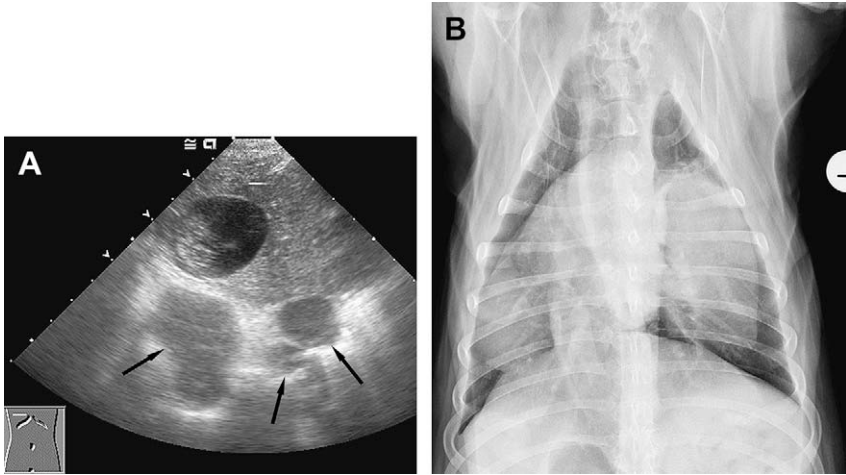


Fig. 14. (A) Transverse ultrasound image of the liver in an 11-year-old dog. This image was made from the ventral abdomen, just caudal to the xiphoid. Multiple hypoechoic nodules are visible cranial to the diaphragm (arrows). Ventral is at the top of the image, with right side at the left of the image. (B) Ventrodorsal radiograph of the dog in Fig. 14A. Large soft tissue masses are noted in the right middle, accessory, and left cranial (caudal segment) lung lobes. This dog did not present for respiratory signs, and thoracic radiographs were taken only after pulmonary masses were seen on abdominal ultrasound. Pulmonary carcinoma was diagnosed on cytology from fine-needle aspiration.

a distinct delineation between normal aerated lung and pulmonary mass. If pleural effusion surrounds the affected lung, the mass can be seen to bulge from or deform the lobe (Fig. 15). A uniform hypoechogenicity identical to lung consolidation (eg, pneumonia) may be present, and biopsy or fine-needle aspiration is necessary for a definitive diagnosis. Small pulmonary nodules such as fungal granulomas or metastatic disease, if peripheral, create well-demarcated, spherical mass lesions (Fig. 16). Like all pulmonary origin masses, they move with respiration.

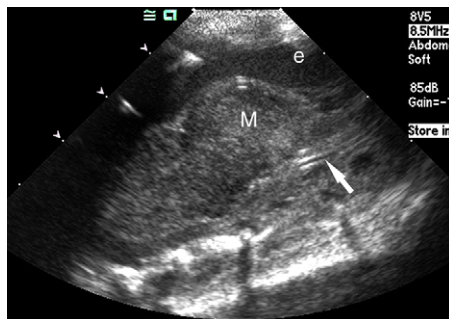


Fig. 15. Longitudinal ultrasound image of the right thoracic wall of a cat presented for respiratory distress. Pleural effusion (e) surrounds a collapsed right cranial lung lobe. A fluid bronchogram extends through the lobe (arrow). A mass (M) bulges from the lung margin. Pulmonary carcinoma was diagnosed on cytology from fine-needle aspiration. Cranial is to the left of the image.

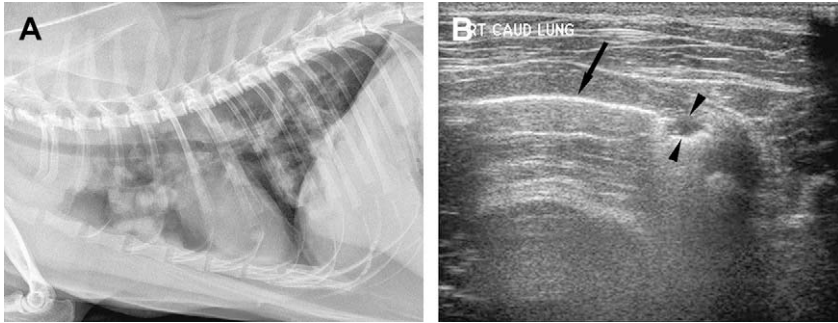


Fig. 16. (A) Lateral thoracic radiograph of a cat presented for mild respiratory distress. Multiple soft tissue nodules are present. (B) Longitudinal ultrasound image of the right thoracic wall of the cat in Fig. 16A. A normal lung/pleura interface is seen cranially (arrow) but is interrupted caudally by a small spherical hypoechoic nodule (arrowheads). Blastomycosis was diagnosed on cytology from fine-needle aspiration. Cranial is to the left of the image.

ATELECTASIS

Atelectasis secondary to pleural effusion is seen readily on ultrasound examination. The lung lobes decrease in volume, forming small triangular structures surrounded by fluid (see Fig. 3).^{1–5} Residual alveolar and bronchial air will form multifocal echogenic linear structures (air bronchograms) and foci. With complete collapse, the lobe will be uniformly hypoechoic. Atelectasis secondary to pneumothorax cannot be visualized with ultrasound due to surrounding air interfaces.

DIAPHRAGMATIC HERNIA

Radiographic diagnosis of diaphragmatic hernias can be challenging. Pleural effusion can obscure visualization of herniated abdominal viscera, or these displaced organs could mimic a pulmonary mass. Ultrasound examination, using left and right intercostal (5th–13th intercostal spaces) and transhepatic windows, can be a valuable adjunct imaging modality.^{1–5,12} The normal diaphragm (actually the diaphragm/lung interface) is visualized as a curvilinear echogenic band surrounding the cranial margin of the



Fig. 17. Longitudinal ultrasound image of the liver in a normal dog. The diaphragm/lung interface is represented by a curvilinear echogenic line along the cranial margin of the liver (arrows). A mirror image artifact (*) creates the appearance of the liver cranial to the diaphragm. Cranial is to the left of the image, with ventral at the top.

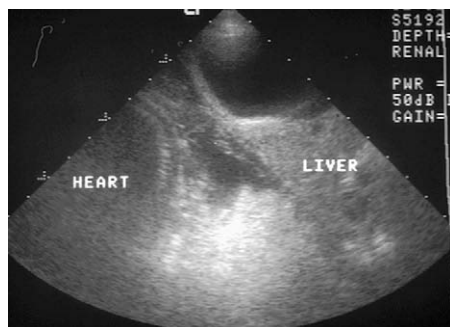


Fig. 18. Longitudinal ultrasound image of the cranial abdomen in a dog with a diaphragmatic hernia. The normal echogenic linear diaphragm/lung interface is no longer present along the cranial margin of the liver. Anechoic pleural effusion separates the cranially displaced liver from the heart. On abdominal exploration, the liver was found to be herniated above the diaphragm.

of the liver (**Fig. 17**). The true diaphragm is seen as a separate echogenic line if pleural and peritoneal effusion are present. Frequently, a mirror image artifact is present in normal dogs, giving the impression of liver on both sides of the diaphragm. The diaphragm must be intact for this artifact to occur, so recognition of this phenomenon should help to rule out a true diaphragmatic hernia in that area. Discontinuity of the diaphragm or an irregular or asymmetric cranial hepatic margin is a common finding with a diaphragmatic hernia. Cranial displacement of abdominal viscera confirms the diagnosis (**Fig. 18**). Displaced abdominal organs are usually seen lateral to the heart. It is important to differentiate consolidated lung tissue (hepatization) from the true liver. Multiple windows, both intercostal and transhepatic, are necessary for evaluation of the entire diaphragm.

Pericardial-peritoneal diaphragmatic hernias (PPDH) are congenital defects that result in varying amounts of abdominal viscera or omentum cranially displaced into the pericardial sac. Generalized cardiomegaly is typically present on thoracic radiographs. Thoracic ultrasound, using either an intercostal or cardiac window, can be used to differentiate PPDH from acquired and congenital primary heart disease. Abdominal viscera, such as liver, will surround the heart and be contained within the pericardial sac. If only a small amount of falciform fat is herniated, diagnosis becomes much more difficult. Again, a careful search for discontinuity of the diaphragm is necessary.

SUMMARY

Thoracic ultrasound is an extremely valuable imaging modality for diseases of the pleura, mediastinum, lungs, and chest wall. Pleural effusion, often a detriment for radiographic evaluation of thoracic structures, provides an excellent window for ultrasound visualization of thoracic anatomy. Ultrasound-guided aspirate/biopsy allows minimally invasive collection of cytology or histopathology for diagnosis of thoracic pathology.

REFERENCES

1. Mattoon JS, Nyland TG. Thorax. In: Nyland TG, Mattoon J, editors. Small animal diagnostic ultrasound. 2nd edition. Philadelphia: WB Saunders; 2002. p. 325–53.

2. Hecht S. Thorax. In: Penninck D, D'Anjou MA, editors. Atlas of small animal ultrasonography. Ames (IA): Blackwell Publishing; 2008. p. 119–50.
3. Reichle JK, Wisner ER. Non-cardiac thoracic ultrasound in 75 feline and canine patients. *Vet Radiol Ultrasound* 2000;41:154–62.
4. Stowater JL, Lamb CR. Ultrasonography of noncardiac thoracic diseases in small animals. *J Am Vet Med Assoc* 1989;195:514–20.
5. Saunders HM, Keith D. Thoracic imaging. In: King LG, editor. Textbook of respiratory diseases in dogs and cats. Philadelphia: WB Saunders; 2004. p. 72–93.
6. Lisciandro GR, Lagutchik MS, Mann KA, et al. Evaluation of a thoracic focused assessment with sonography for trauma (TFAST) protocol to detect pneumothorax and concurrent thoracic injury in 145 traumatized dogs. *J Vet Emerg Crit Care* 2008;18:258–69.
7. Konde LJ, Spaulding K. Sonographic evaluation of the cranial mediastinum in small animals. *Vet Radiol* 1991;32:178–84.
8. Zekas LJ, Adams WM. Cranial mediastinal cysts in nine cats. *Vet Radiol Ultrasound* 2002;43:413–8.
9. ReiBig A, Kroegel C. Transthoracic sonography of diffuse parenchymal lung disease. *J Ultrasound Med* 2003;22:173–80.
10. Louvet A, Bourgeois JM. Lung ring-down artifact as a sign of pulmonary alveolar-interstitial disease. *Vet Radiol Ultrasound* 2008;49:374–7.
11. D'Anjou MA, Tidwell AS, Hecht S. Radiographic diagnosis of lung lobe torsion. *Vet Radiol Ultrasound* 2005;46:478–84.
12. Spattini G, Rossi F, Vignoli M, et al. Use of ultrasound to diagnose diaphragmatic rupture in dogs and cats. *Vet Radiol Ultrasound* 2003;44:226–30.