DETECTION OF PNEUMOTHORAX AND PLEURAL EFFUSION WITH HORIZONTAL BEAM RADIOGRAPHY

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Forty-seven patients with a known history of thoracic trauma or clinical suspicion of pneumothorax were selected for thoracic imaging. The patient population was composed of 42 dogs and five cats. Standard vertical beam (VB) left and right lateral and ventrodorsal/dorsoventral (VD/DV) projections were obtained for each patient, and at least one horizontal beam (HB) projection (VD projection made in lateral recumbency). A total of 240 images were reviewed. Subjective assessment for the presence and degree of pneumothorax and pleural effusion was made more confidently with HB projections. Pneumothorax was identified in at least one projection in 26 patients (26 dogs) and pleural effusion in 21 patients (19 dogs and two cats). Pneumothorax and pleural effusion were present concurrently in 17 dogs. Pneumothorax and pleural effusion were graded for each image as absent, mild, moderate, or severe. Right ($P<0.001$) and left ($P<0.05$) lateral HB VD projections and the standard VB left lateral projection ($P<0.05$) were significantly more likely to detect and grade pneumothorax severely than the VB VD/DV views. The right lateral HB projection had the highest rate of detection and gradation of severity for pneumothorax compared with other views. VD/DV projections had the lowest sensitivity for detection of the pneumothorax and gradation of severity for pneumothorax and pleural effusion. No significant difference in diagnosis ($P=0.9149$) and grade ($P=0.7757$) of pleural effusion were seen between views, although the left lateral HB had both the highest rate of detection and grade of severity. *Veterinary Radiology & Ultrasound, Vol. 53, No. 1, 2012, pp 38–43.*

Key words: horizontal beam, pleural effusion, pneumothorax.

Introduction

PNEUMOTHORAX IS A common outcome of thoracic trauma in dogs and cats.[1,2] Hemothorax commonly accompanies pneumothorax secondary to pleural tearing or pulmonary contusions. Pneumothorax can also be induced iatrogenically following thoracocentesis, thoracotomy, overinflation of the lungs during anesthesia, or as an extension of pneumomediastinum. Less common nontraumatic causes of pneumothorax include spontaneous rupture of pulmonary bullae, cavitary lung masses, or the presence of a gas producing organism in the pleural space.[3] Pneumothorax is not always obvious clinically but is important to recognize before intubation or positive pressure ventilation to avoid tension pneumothorax.[1,4]

Conventional radiographic evaluation of the thorax currently includes three standard vertical beam (VB) views: right lateral, left lateral, and an orthogonal view; either ventrodorsal (VD) or dorsoventral (DV). Vertical beam projections have limitations in the evaluation of pneumothorax and pleural effusion due to superimposition of fluid and soft tissue structures.[2] Horizontal beam (HB) radiography was first used in the diagnosis of human pneumothorax in 1966.[5] Commonly referred to as the lateral decubitus view, HB projections commonly supplement the standard supine AP projection in the evaluation of human pneumothorax. Although many physicians ultimately rely on ultrasound and computed tomography (CT) to aid in their diagnosis, portable bedside chest radiography is often the first modality available in the emergency setting. Supine chest radiographs are standard in patients with cervical spine precautions, orthopedic injuries, and hemodynamic instability.[6–8] Many human studies indicate that thoracic imaging completed with HB radiography is more sensitive for the detection of small volume pneumothorax and pleural effusion than the standard supine AP projection with VB imaging.[7,9–11] Erect HB chest radiographs are superior to supine VB chest radiographs for detection of pneumothorax, with sensitivities of 92% and 50%, respectively.[12] We hypothesized that detection of pneumothorax and pleural effusion would be increased utilizing HB positioning techniques with conventional thoracic radiography.

HB radiography has been mentioned as a useful tool in the diagnosis of pneumothorax and pleural effusion.[1,2,13] Detection of pneumothorax was improved by using a horizontally directed X-ray beam and placing the patient in

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a position such that the X-ray beam strikes the area of accumulation tangentially.

HB projections have not been evaluated critically in small animal radiography for their utility in detecting traumatic and spontaneous pneumothorax and concurrent pleural effusion. HB projections thus have not been evaluated as a potentially useful tool to increase detection of pneumothorax and pleural effusion in the emergency setting. Our hypothesis was that HB radiography would improve detection and more accurately determine relative volume of pneumothorax and pleural effusion compared with standard radiographic views.

Materials and Methods

Animals were patients of the emergency department. Inclusion criteria were: (1) known history of thoracic trauma or (2) pneumothorax was considered to be a major differential by the attending veterinarian based on clinical signs. Forty-two dogs and five cats were enrolled. Twenty of these 47 patients (17 dogs and three cats) met the above inclusion criteria, but pneumothorax or pleural free fluid were not seen radiographically on any projection. These animals were included as controls for subsequent analysis and to prevent evaluator bias. Thoracic radiographs were made using a digital radiography system and routine radiographic techniques. The following radiographic projections were obtained for each subject: right lateral (VB), left lateral (VB), VD or DV (VB), and at least one VD (HB) projection (taken in either right [RLHB] or left [LLHB] lateral recumbency). Five animals had only RLHB projections, seven had only LLHB projections, and 30 animals had both RLHB and LLHB projections.

Materials for HB radiography included an open cell foam pad, 5 cm thick for medium and large breed dogs, and 6.5 cm for cats and small dogs. The pad was used to elevate the patient above the tabletop to allow imaging both sides of the thorax. Technique changes for HB radiography included repositioning the X-ray tube 90° from vertical. The digital detector was positioned perpendicular to the X-ray tube against the animal's spine. The patient was placed in lateral recumbency on top of foam pad with the side of interest for pneumothorax being nondependent. The forelimbs and head were extended cranially, and the hind limbs pulled slightly caudally to keep the spine close to the cassette.[14,15] Some animals, especially large breed dogs, had multiple images available for a projection.

The mean age of dogs was 4.2 years (range 2 months to 11 years) and of cats 9.9 years (range of 10 months to 15 years). The average age of patients included in the study was 4.3 years (range of 2 months to 15 years). The mean weight of dogs was 18.9 kg (range 2.0–43.7 kg). The mean weight of cats was 4.8 kg (range = 4.5–5.0 kg). Dog breeds included: American Pit Bull Terrier, Beagle, Border Collie, Borzoi, Chihuahua, Cocker Spaniel, Coton De Tulear, Doberman, English Springer Spaniel, German Shepherd, Goldendoodle, Gordon Setter, Labrador, Maltese, Miniature Pinscher, Miniature Poodle, mixed breed, Pekingese, Pharoah Hound, Pomeranian, Rat Terrier, Samoyed, Shih Tzu, and Siberian Husky. Cat breeds were domestic short hair ($n=4$) and Persian ($n=1$).

A total of 240 images were evaluated from the 47 patients. This included 51 right lateral VB images, 51 left lateral VB images, 50 VD/DV VB images, 44 left lateral HB images, and 44 right lateral HB images. Evaluators were unaware of the animal's presenting complaint (traumatic history vs. dyspnea due to nontraumatic causes) and to the relative frequency of each complaint. The nondependent lung was evaluated for presence or absence or pneumothorax in HB views. For example, the LLHB projection was used to evaluate a right-sided pneumothorax. A consensus opinion was obtained for each individual image by two veterinary radiologists (R.O, J.M) and one radiology resident (C.O). For each image, pneumothorax and pleural effusion were graded subjectively as absent (0), mild (1), moderate (2), or severe (3). Sample images were provided to illustrate gradations of severity for both pneumothorax and pleural effusion.

Fisher's exact or χ^2-tests were performed using commercial statistical software[1] to determine whether image type had an effect on the ability to diagnose pneumothorax or pleural effusion. Kruskall–Wallis tests and Dunn's multiple comparison tests were used to make the same comparison for ordinal scale data; subjective grade of pneumothorax and pleural effusion. An $\alpha < 0.05$ was used to determine statistical significance.

Results

Pneumothorax was present in 26 of 47 patients based on positive identification of free pleural air in any available lateral, orthogonal, or HB projection. In four of 47 patients, pneumothorax was identified only in a single projection; a RLHB in two and a LLHB in two. Pneumothorax was more likely to be identified using either HB VD images (RLHB = 47.7%, LLHB = 39.1%) and standard VB left lateral images (39.2%) than using right lateral VB images (29.4%) or VD/DV VB images (12%). There was a significant difference in detection ($P = 0.0028$) (Table 1) and grading ($P = 0.0006$) (Table 2) of pneumothorax between image types. The right lateral HB projection had the highest rate of detection of pneumothorax, significantly higher than VD and right lateral VB views. Right ($P < 0.001$) and left ($P < 0.05$) lateral HB projections and the standard VB left lateral projection ($P < 0.05$) had the highest rate of detection and had higher grade of pneumothorax than the VD or DV VB projections

TABLE 1. Comparison of Pneumothorax and Pleural Effusion Detection Between Views

	RL		LL		VD/DV		RLHB		LLHB	
	N (51)	Mean	*N* (51)	Mean	*N* (50)	Mean	*N* (44)	Mean	*N* (44)	Mean
Pneumothorax	15 (29.4%)[ab]	117.09	20 (39.2%)[a]	128.95	6 (12.0%)[b]	96.02	21 (47.7%)[a]	139.25	18 (39.1%)[a]	128.85
Pleural effusion	18 (35.3%)[a]	124.21	15 (29.4%)[a]	117.09	15 (30%)[a]	117.80	15 (34.1%)[a]	122.75	17 (37%)[a]	126.22
Pneumothorax + pleural effusion	6 (11.8%)[a]	120.79	7 (13.7%)[a]	123.18	2 (4.0%)[a]	111.36	5 (11.3%)[a]	120.00	11 (23.9%)[a]	135.55

Within a row, projections with different letters show statistically significant difference. *N*, number; Mean, mean rank; RL, right lateral; LL, left lateral; VD/DV, ventrodorsal/dorsoventral; RLHB, right lateral horizontal beam; LLHB, left lateral horizontal beam.

(Figs. 1 and 2). There was no significant difference in the grading of pneumothorax between other views. VD and DV VB projections had the lowest rate of detection of pneumothorax and were graded least severe although this was not significantly different from the right lateral view.

Subjectively, the diagnosis of pleural effusion was made more confidently with HB radiography. Determination of the lung margin was made with confidence in all HB images. Pleural effusion was seen in 21 of 47 patients based on positive identification of pleural effusion in any available projection. In five of 47 patients, pleural effusion was identified only in a single projection (LLHB in two, RL in two, LL in one). In one patient, pleural effusion was identified in both HB views but was not identified in any VB view. Differences in diagnosis ($P = 0.92$) (Table 1) and grade (Table 2) ($P = 0.78$) of pleural effusion were not statistically significant, although the LLHB projection had both the highest rate of detection and highest grade of severity of all views. VD and left lateral VB projections had the lowest rate of detection of pleural effusion, although this was not statistically significant. Distinct separation of the dependent thoracic wall and dependent lung margin was more obvious than assessment of interlobar fissure formation or overall thoracic opacity on VB projections. VD VB projections also graded pleural effusion more mildly, but this was not significant. Collection of HB projections on patients during this prospective study made the evaluators more sensitive to the features of pleural effusion on VB projections.

Pneumothorax and pleural effusion were present concurrently in 17 of 47 patients (36.2%). They were diagnosed concurrently in 11.8% of right lateral images, 13.7% of left lateral images, 4% of VD and DV images, 23.9% of LLHB, and 11.1% of right lateral HB images. There was a significant difference ($P = 0.0108$) between left lateral HB images and VD and DV projections in the detection of concurrent pneumothorax and pleural effusion. Nine patients positive for pneumothorax were negative for pleural effusion. Of these patients, one was graded mild for pneumothorax, five moderate, and three severe.

Discussion

The three-view series has become the convention for thoracic imaging in veterinary medicine. However, standard VB projections of the thorax can be misinterpreted easily when evaluated critically for presence of pneumothorax and pleural effusion. In lateral views, for example, elevation of the heart from the sternum is often mistaken for pneumothorax. However, this elevation is also seen with hyperinflation, hypovolemia, emaciation, microcardia, in deep or narrow chested dog breeds or dogs in left lateral recumbency.[2,16] In traumatic thoracic injuries, lung laceration may cause individual lung lobes to collapse while unaffected lung lobes remain fully inflated. This unilateral pneumothorax may be missed in a lateral projection, as the pulmonary vascular markings of the normal lung extend to the parietal pleural surface and give the erroneous impression of a normal lung field. The collapsed lung actually becomes superimposed on the normal lung.[1] Normal body conformation of obese, geriatric, or chondrodystrophic patients may lead to the misdiagnosis of pleural effusion in the lateral or VD and DV projections.[16]

The utility of DV and VD projections has been compared in patients with pneumothorax and pleural effusion. The DV projection was preferable for evaluation

TABLE 2. Comparison of Subjective Gradation of Severity Between Views

	RL		LL		VD/DV		RLHB		LLHB	
	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean
Pneumothorax	Moderate[ab]	115.65	Severe[a]	128.57	Mild[b]	93.50	Severe[a]	142.59	Severe[a]	130.41
Pleural effusion	Severe[a]	123.57	Severe[a]	116.35	Severe[a]	115.59	Severe[a]	124.39	Severe[a]	128.58

Within a row, projections with different letters show statistically significant difference. Max, maximum rank; Min, minimum rank; RL, right lateral; LL, left lateral; VD/DV, ventrodorsal/dorsoventral; RLHB, right lateral horizontal beam; LLHB, left lateral horizontal beam.

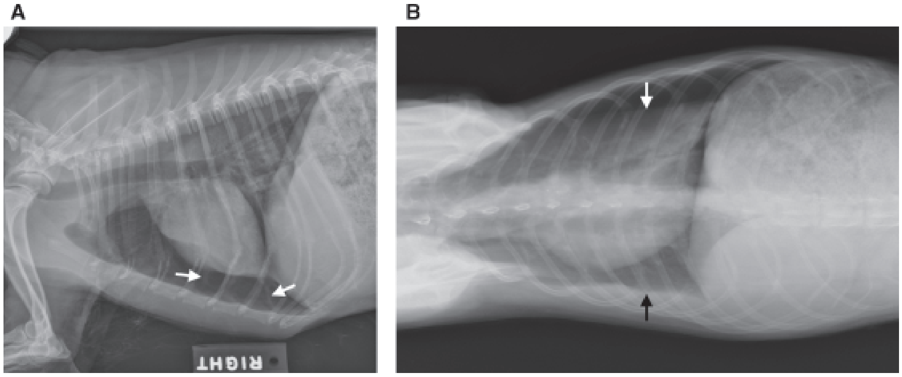

FIG. 1. Right lateral (RL) projection (A) graded mild pneumothorax and mild pleural effusion based on linear soft tissue lines ventral to the heart (white arrows). RLHB (B) revealed a moderate pneumothorax (white arrow) in the nondependent left hemithorax and moderate pleural effusion in the dependent hemithorax (black arrow). HB, horizontal beam.

of pneumothorax while the VD projection was preferable for detection of pleural effusion.[17–19] In both these views, however, mediastinal structures were obscured with a minimal amount of pleural effusion and skin folds could be misidentified as pneumothorax.[19,20] Also, typical evaluation for retraction of the caudal lung lobes from the costodiaphragmatic recesses was often obscured by superimposition of the ribs, aorta, diaphragm, and stomach.[1]

Although VB images currently dominate thoracic imaging in veterinary clinical medicine, altering the direction of the X-ray beam can assist in optimizing evaluation of thoracic structures. HB projections allow the evaluator to take advantage of the physical nature of gas and fluid within the thorax. The distribution of both pleural effusion and air are governed by the form-elasticity of the lung and gravity. Intrapleural air forces the lung to recoil toward the hilus, maintaining its shape, but moving by gravity to the lowest part of the thoracic cavity while air moves upward.[21] When the lung retracts from the thoracic wall, the pleural surfaces oriented tangentially to the X-ray beam will be outlined on one side by air in the lung parenchyma and on the other side by air in the pleural cavity. A darker, sharply defined radiolucent zone containing no vascular markings separates the lung from the thoracic wall.[1] The HB projection allows this radiolucent zone to be maximized, as the nondependent lung falls away from the thoracic wall when the animal is in lateral recumbency.

HB projections were evaluated for detection of iatrogenically induced pneumothorax.[22] Bilateral pneumothorax developed in 92% of dogs after intrapleural air injection. Expiratory views were superior to inspiratory views in the detection of pneumothorax. Left lateral VB views tended to have a greater separation of the heart from the sternum than the right lateral VB view, suggesting it may be more sensitive in detecting small amounts of air in the pleural space. Both HB VD views were better than either lateral view in detecting a small volume pneumothorax. Specifically, the HB VD right lateral recumbent view made at the end of expiration and the VB right lateral view were the more sensitive indicators of the severity of bilateral pneumothorax.

We evaluated spontaneous and traumatic pneumothorax rather than iatrogenically induced pneumothorax, but the findings were similar. Specifically, the VB left lateral recumbent and the HB VD views were the most effective radiographic views for the detection of pneumothorax, although we did not evaluate phase of respiration.

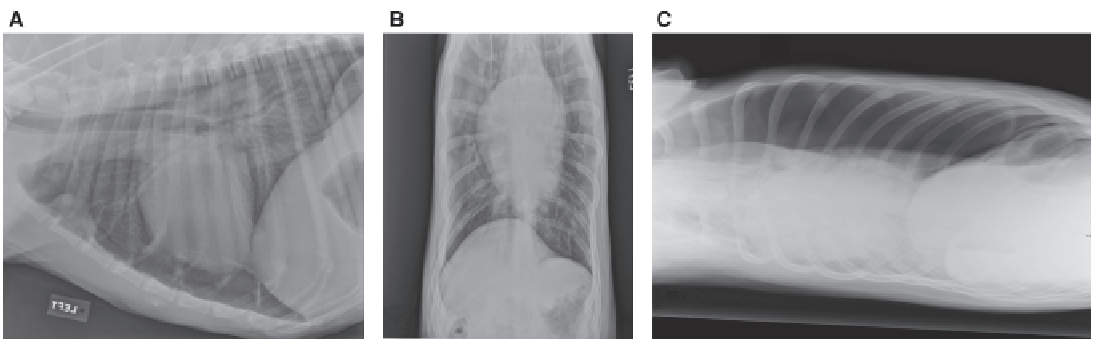

FIG. 2. Left lateral (LL) projection (A) graded mild pneumothorax. Ventrodorsal (VD) projection (B) graded absent pneumothorax. LLHB projection (C) graded severe pneumothorax. Pleural effusion was graded negative in all images. HB, horizontal beam.

HB projections were better than either lateral view in detecting pneumothorax, although there was not a statistically significant difference between the HB views and the left lateral VB views. Similarly, separation of the visceral and parietal surfaces on the HB VD view was a better indication of small amounts of air in the pleural space than separation of the heart from the sternum on the VB lateral views.

Fluid becomes most apparent radiographically when the X-ray beam strikes the fluid-lung interface directly. Therefore, more pleural effusion is typically present than predicted based on the severity of the radiographic changes because many large fluid collections are not struck head on by the X-ray beam.[2] The nature of HB radiography allows pleural effusion to collect in a dependent location, and allows the X-ray beam to strike this fluid-lung interface tangentially. This moves fluid away from potential areas of pneumothorax and allows small amounts of pleural effusion to be detected. This is especially useful because evaluation of pleural effusion in interlobar fissures can be challenging in lateral and orthogonal views due to summation of soft tissue structures. Pleural effusion may also obscure other radiographic signs of concurrent pleural, pulmonary of mediastinal disease. HB imaging is also helpful in differentiating free, trapped and encapsulated fluid from pleural lesions, pulmonary disease and mediastinal masses.[23]

Subjectively, the diagnosis of pneumothorax and pleural effusion was made more confidently with HB radiography. Distinct separation of the nondependent lung margin from the nondependent thoracic wall was more obvious than assessment of interlobar fissure formation or overall thoracic opacity on VB projections (Fig. 1). Retraction of the nondependent lung was often more distinct on HB projections than retraction of the caudodorsal lung from the dorsal-most rib margins and diaphragm. Many VD and DV VB projections underrepresented both pleural air and pleural effusion, compared with lateral VB and HB views. Collection of HB projections during this prospective study made the evaluators more sensitive to subtle features of pleural effusion on VB projections from the same patients. Wispy effusion lines ventral to the heart were evaluated more severely after completion of the project than before the study. The overall grading system may have been flawed since no attempt was made to standardize effusion amounts resulting in the same grade between VB and HB projections.

The prevalence of concurrent hydro-, presumably hemo-, thorax with pneumothorax has not been reported. Approximately one-third of patients with pneumothorax had concurrent pleural effusion. HB radiography was approximately twice as likely to identify concurrent-free fluid and air as VB radiography. Pleural effusion migrates to the dependent hemithorax in a patient placed in lateral recumbency (Fig. 1). The clinical additive effect of concurrent pleural air and free fluid has not been evaluated in traumatic patients. None of the patients in this study had thoracocentesis for dependent pleural effusion formation. All therapy was directed to the nondependent pneumothorax. This begs the clinical questions as to the utility of HB radiography for the detection of pleural effusion and possible need for pleural effusion drainage in trauma patients.

Both HB projections and VB left lateral images are significantly better for detection and gradation of pneumothorax compared with DV/VD projections. The right lateral HB projection was most sensitive for the detection of pneumothorax, and graded pneumothorax most severely when compared to all views. Although the RLHB graded pneumothorax most severely, this difference was not statistically significant when compared with the LLHB or left lateral view. The addition of a HB projection increased the overall number of pneumothorax diagnoses vs. those diagnosed by conventional radiographic projections alone.

HB radiography did not improve detection or characterization of pleural effusion. The left lateral HB projection detected the greatest number of patients with pleural effusion and grading was the most severe, compared with all projections (Fig. 1). The left lateral HB image also was statistically more likely to detect pneumothorax than VD/DV views, grade pneumothorax severely than VD/DV views, and identify concurrent pneumothorax and pleural effusion than VD/DV views. Thus the LLHB projection may be useful clinically in making the diagnosis of pneumothorax, especially when compared with the standard VD/DV projection.

A number of disadvantages with HB techniques were noted. On HB projections heart, lungs, and mediastinal structures fall dependently with gravity and become difficult to interpret due to superimposition. HB images should not be used alone for radiographic evaluation of the thorax. Personnel should adhere to rules of radiation safety to minimize the chance of radiation exposure when attaining HB projections. HB projections can be attained safely with the following techniques: using a cassette holder (wall mounted or standing), collimating the primary beam to include only the area of interest, directing the HB toward a wall or barrier, and using tape and/or sandbags to assist in patient positioning. A disadvantage of HB projections was seen in patients with insufficient foam material beneath the dependent thoracic wall. In these patients, the radiographs were nondiagnostic for assessment of pleural effusion, and were thus excluded from the study. HB images were also commonly overexposed, especially early in the study when techniques were being developed. Digital radiography allows the most detailed examination of HB images, as the viewing software has tools available to zoom in or window and level. However, HB images can also be instituted in hospitals with hard copy film if the aforementioned adjustments can be made to acquire the images.

In summary, HB projections added to the routine vertical projections for the diagnosis of pleural disease. Radiographic techniques required modification from routine VB projections and additional foam padding was necessary to adequately elevate the patient above the tabletop. Subjective assessment for the presence and degree of pneumothorax and pleural effusion was made more confidently with HB projections.

REFERENCES

1. Suter PF, Lord PF. Trauma to the thorax and cervical airways. In: Suter PF, Lord PF (eds): Thoracic radiography: a text atlas of thoracic diseases of the dog and cat. Switzerland: Wettswil, 1984;151–156.
2. Thrall DE. The pleural space. In: Thrall DE (ed): Textbook of veterinary diagnostic radiology. St. Louis, MO: Saunders Elsevier, 2007; 555–567.
3. Orton EC. Pneumothorax. In: Orton EC (ed): Small animal thoracic surgery. Baltimore: Williams and Wilkins, 1995;107–113.
4. Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: diagnostic accuracy of lung ultrasonography in the emergency department. Chest 2008;133:204–211.
5. Kurlander GJ, Helmen CH. Subpulmonary pneumothorax. Am J Roentgenol Radium Ther Nucl Med 1966;96:1019–1021.
6. Wilkerson RG, Stone MB. Sensitivity of bedside ultrasound and supine anteroposterior 363 chest radiographs for the identification of pneumothorax after blunt trauma. Acad Emerg Med 2010;17:11–17.
7. Rowan KR, Kirkpatrick AW, Liu D, Forkheim KE, Mayo JR, Nicolaou S. Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT—initial experience. Radiology 2002;225:210–214.
8. Moore MA, Wallace EC, Westra SJ. The imaging of paediatric thoracic trauma. Pediatr Radiol 2009;39:485–496.
9. Carr JJ, Reed JC, Choplin RH, Pope TL Jr, Case LD. Plain and computed radiography for detecting experimentally induced pneumothorax in cadavers: implications for detection in patients. Radiology 1992;183:193–199.
10. Moore MA, Wallace EC, Westra SJ. The imaging of paediatric thoracic trauma. Pediatr Radiol 2009;39:485–496.
11. Kocijancic I. Diagnostic imaging of small amounts of pleural fluid: pleural effusion vs. physiologic pleural fluid. Coll Antropol 2007;31: 1195–1199.
12. Ball CG, Kirkpatrick AW, Feliciano DV. The occult pneumothorax: what have we learned? Can J Surg 2009;52:E173–E179.
13. Farrow CS. Thoracic radiographic disease indicators. In: Farrow CS (ed): Veterinary diagnostic imaging: the dog and cat. St. Louis, MO: Mosby, 2003;378–383.
14. Morgan JP. Thorax. In: Morgan JP (ed): Techniques of veterinary radiography. Ames: Iowa State University Press, 1993;172–175.
15. Lavin LM. Small animal soft tissue. In: Lavin LM (ed): Radiography in veterinary technology. St. Louis, MO: Saunders/Elsevier, 2007; 211–219.
16. O'Brien RT. Pleural space disease. In: O'Brien RT (ed): Thoracic Radiology for the Small Animal Practitioner. Jackson: Teton NewMedia, 2001;98–102.
17. Aronson E, Reed L. Radiology corner pneumothorax: ventrodorsal or dorsoventral view; does it make a difference? Vet Radiol Ultrasound 1995;36:109–110.
18. Brinkman EL, Biller D, Armbrust L. The clinical usefulness 395 of the ventrodorsal versus dorsoventral thoracic radiograph in dogs. J Am Anim Hosp Assoc 2006;42:440–449.
19. Groves TF, Ticer JW. Pleural fluid movement. Vet Radiol Ultrasound 1983;24:99–105.
20. Thrall DE. Radiology corner misidentification of a skin fold as pneumothorax. Vet Radiol Ultrasound 1993;34:242–243.
21. Lams PM, Jolles H. The effect of lobar collapse on the distribution of free intrapleural air. Radiology 1982;142:309–312.
22. Kern DA, Carrig CB, Martin RA. Radiographic evaluation of induced pneumothorax in the dog. Vet Radiol Ultrasound 1994;35: 411–417.
23. Lord PF, Gomez JA. Lung lobe collapse. Vet Radiol Ultrasound 1985;26:187–195.