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RESEARCH ARTICLE

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Clinical studies on application of veterinary bedside lung ultrasound examination (VetBLUE) for the diagnosis of thoracic affections in dogs

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The study was conducted on 18 dogs with respiratory distress with no history of trauma. The objective of the study was to evaluate different ultrasonographic windows for investigating chest affections in dogs with respiratory distress using veterinary bedside lung ultrasound examination (Vet BLUE). The animals were evaluated on the basis of history, signalment, clinical signs, haematology, biochemistry, electrocardiography, radiographic and ultrasonographic findings. The study revealed that Vet BLUE caudodorsal and perihilar sites were reliable in diagnosing pulmonary oedema conditions. Vet BLUE cranial and middle lung sites were effective in the diagnosis of pneumonia cases. All the Vet BLUE lung sites were effective in diagnosing sub-pleural consolidation in the form of tissue sign, shred sign and nodule sign.

Keywords: Dog, Radiography, Respiratory distress, Thoracic affections, Vet BLUE Lung Scan

Ultrasound of lung (LUS) has emerged as a critical diagnostic tool in modern medicine, often referred to as the 'modern stethoscope'. In human medicine, it has demonstrated superior sensitivity and specificity compared to traditional thoracic auscultation and supine chest radiography for conditions such as pneumothorax, pleural effusion, pulmonary consolidation, and pulmonary interstitial disease in emergency settings (Volpicelli, 2012). This advantage has extended into veterinary practice, where point-of-care ultrasound (POCUS) has been shown to detect thoracic injuries more quickly and accurately than thoracic radiography in emergency scenarios (Lisciandro, 2008). With technological advancements and improved understanding of sonographic artifacts related to pulmonary pathology, ultrasound has been effective in diagnosing peripheral lung diseases even in non-emergency contexts. The Veterinary Bedside Lung Ultrasound Examination (Vet BLUE) was subsequently developed, adapting the BLUE protocol from human medicine for veterinary use to facilitate the detection and monitoring of various lung pathologies (McMurray, 2016). Techniques like the Vet BLUE scan offer numerous benefits: they are rapid, non-invasive, radiation-free, relatively low-cost, require minimal patient restraint and can be performed without clipping them particularly suited for use in conjunction with other interventions at the point of care (Lisciandro, 2011).

Materials and Methods

The study was conducted on 18 non-trauma patients with respiratory distress. These patients were divided into three groups on the basis of type of conditions diagnosed with Vet BLUE lung scan. Group A included cases showing ultrasound lung rockets (ULRs)/B-Lines without subpleural consolidations (n=2), group B included cases showing ULRs with subpleural consolidations e.g. shred sign or tissue sign (n=7), and group C included cases showing subpleural consolidations without significant ULRs (n=9). The animals were evaluated based on age (yr), breed (non-specific), gender, heart rate (beats/min), respiratory rate (breaths/min), rectal temperature (°F) and mucous membrane colour (pink/ pale/ congested). The animals were subjected to estimations of haemoglobin (Hg; g/dL), total leukocyte count (TLC; µL), packed cell volume (PCV; %), platelet count (10^3/µL) and differential leukocyte count (DLC; %), liver function tests (wherever it was required) including AST (U/L), ALT (U/L), ALKP (U/L), and kidney function tests (wherever it was required) including BUN (mg/dL) and creatinine (mg/dL). Thoracic radiographs were made in lateral and ventrodorsal/dorsoventral views as per the requirement of the case. The ultrasonography was performed by parting the fur of the animal and alcohol was used as coupling medium. Animal was placed in lateral recumbency, 4 windows were evaluated on both sides. In severely distressed animal, sternal recumbency and standing position were opted. Vet BLUE was performed through 8 ultrasonographic windows as described in literature (Lisciandro, 2014) as left and right caudo-dorsal lung region, left and right peri-hilar lung lobe region, left and right middle lung region, left and right cranial lung region. All patients were subjected to vet BLUE using 5-8 MHZ micro-convex transducer of Philips affinity 70G ultrasound machine.

Results and Discussion

The study was conducted on 18 non-traumatic patients having respiratory distress**.** The animals were divided into three subgroups on the basis of type of conditions diagnosed with Vet BLUE scan. Group A included cases showing ultrasound lung rockets (ULRs)/B-Lines without subpleural consolidations (n=2); group B included cases showing ULRs with subpleural consolidations e.g. shred sign or tissue sign

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(n=7), and group C included cases showing subpleural consolidations without significant ULRs (n=9).

Group A (ULRs without subpleural consolidations (n=2)

This subgroup included 2 cases. The case 1 was a female American Bully 7 years old and weighing 20 kg presented with the history of inappetence, coughing, respiratory distress and purulent discharge from vagina. On auscultation, marked crackles were felt on both sides of thorax indicative of pulmonary oedema/exudates or pneumonia.

The case 2 was presented with the clinical signs of coughing and dyspnoea. No weight loss and no exercise intolerance were observed. The dog was a male Pomeranian aged 5 years. The body weight of the dog was 3 kg. On auscultation of thorax, heart sounds were clearly audible. Tachypnoea was evident, and the heart was not auscultable in this case. Rectal temperature of the dog was 102°F with pink mucous membrane.

In case 1, haemoglobin (Hb) and platelet were lower as compared to normal reference range. TLC was very high (> 50,000/µL) indicating leukemoid response. This could be due to cystic endometrial hyperplasia as the animal was presented with the history of purulent discharge from vagina and later on confirmed through ultrasonography. In case 2, all haematological parameters were in the normal reference range.

ECG: In the first case, the heart rate was 60 beats/min. The ECG showed unequal R-R interval indicating arrhythmia. Additionally, echocardiography showed mitral valve regurgitation indicating mitral valve degenerative disease causing left sided heart failure. In second case the heart rate was 80 beats/min. ECG showed high QRS complex suspected for ventricular hypertrophy. Bacharova *et al*. (2017) demonstrated that the high QRS voltage has been a distinctive finding in ventricular hypertrophy of left side. These ECG abnormalities are also indicative of unfavourable outcomes of cardiovascular system. Additionally, in this case, echocardiography showed left atrial enlargement and mitral valve regurgitation as well as thickening of mitral leaflets indicating mitral valve degenerative disease (Diana *et at.,* 2009).

***Radiography*:** Chest radiograph showed severe broncho-interstitial pattern in lung lobes close to the heart in first case (Fig.1). In second case chest radiograph showed cardiac silhouette rounding on lateral view. VD view showed a bulge at the area of left atrium. Trachea was elevated at the base of heart suggesting cardiac enlargement. Moderate broncho-interstitial pattern was seen in lung lobes close to the heart indicating cardiogenic pulmonary oedema. Diana *et al*. (2009) stated that cardiogenic pulmonary oedema frequently appears in the caudal lung lobes, with distribution in the hilar and caudal perivascular lung regions in dogs. According to their research, 41 out of 61 dogs (67%) with cardiogenic pulmonary oedema showed radiographically enhanced lung opacity in the form of interstitial pattern, while other dogs displayed a mixed pattern of interstitial-alveolar. They added that transudate seeps into the alveolar gaps in the late stage of cardiogenic pulmonary oedema and that an interstitial pattern indicates a beginning stage of lung involvement during heart failure.

Ultrasonography: In case 1, a Vet BLUE scan was performed bilaterally, evaluating all eight lung windows. The left and right cranial and middle lung lobes exhibited only A-lines, indicating normal lung aeration (Lisciandro, 2021). In contrast, the bilateral caudodorsal and perihilar lung regions demonstrated multiple B-lines (>3), consistent with pulmonary oedema (Fig. 2). According to Lisciandro (2014), ULR abnormalities in the caudodorsal and perihilar regions are suggestive of both cardiogenic and non-cardiogenic pulmonary oedema. In case 2, the left and right cranial, left middle, and bilateral caudodorsal lung lobes exhibited only A-lines, indicating normal lung aeration (Lisciandro, 2021). The right middle lung lobe showed a single B-line, which was considered clinically insignificant (Lisciandro, 2021). In contrast, the bilateral perihilar lung regions demonstrated multiple B-lines (>3), consistent with an abnormal interstitial-alveolar pattern (Lisciandro, 2021). Ward *et al.* (2019) reported similar findings in a dog with mild cardiogenic pulmonary oedema, in which B-lines were absent at the caudodorsal lung sites because the oedema had not extended to the peripheral lung parenchyma. In the present case, the Vet BLUE findings were consistent with the clinical examination and thoracic radiographic findings, successfully identifying cardiogenic pulmonary oedema with a diagnostic accuracy of 100%.

Group B: ULRs with sub-pleural consolidations e.g. shred sign or tissue sign (n=7)

Three of the seven dogs had displayed inappetence and five had dyspnoea. Other clinical signs included fever (n=3), weight loss (n=2), coughing and bilateral nasal discharge (n=3), retching and blood-tinged sputum (n=2). In one dog bilateral ocular and nasal discharge was noticed (n=1). One dog had the history of forced feeding (n=1). One dog had the history of change in voice and vomiting (n=1). Physical examination showed moderate to severe crackles in almost all the cases (n=7) and wheezes (n=3) on chest auscultation. Mucous membrane was pale in two cases (n=2). The clinical signs as well as physical examination pointed towards infectious or aspiration pneumonia in this group of dogs. These findings are consistent with those reported by Elgalfy *et al*. (2022), who observed that, in addition to coughing, nasal discharge, anorexia, lethargy, and fever, dogs and cats with pneumonia commonly exhibited abdominal respiration, dyspnoea, tachycardia, tachypnoea, and abnormal lung sounds. According to Dear (2014), dogs with aspiration pneumonia commonly have a history of vomiting or gastrointestinal disorders and present with dyspnoea, nasal discharge, and abnormal lung sounds, including crackles, wheezes, or harsh respira-

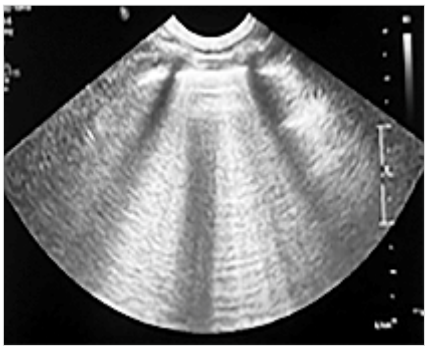

Fig.1: Multiple B lines seen at right perihilar lung lobe region.

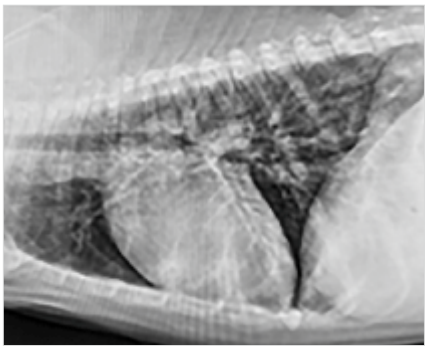

Fig. 2: Moderate to severe broncho-interstitial pattern seen close to heart indicative of cardiogenic pulmonary oedema.

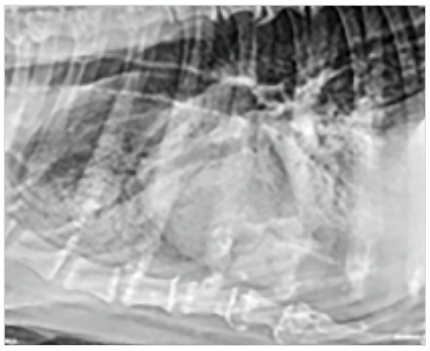

Fig. 3: Severe alveolar pattern seen in cranial and middle lung lobes with air. bronchograms.

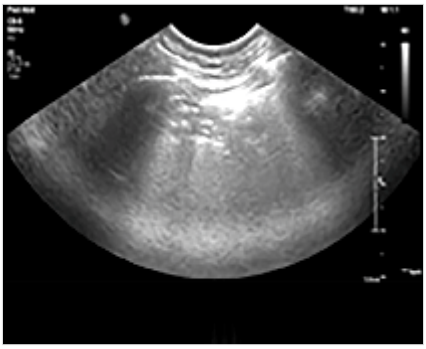

Fig. 4: Shred sign (consolidation with aeration) seen at left cranial lung lobe region.

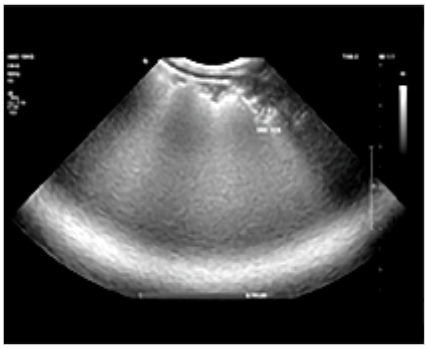

Fig. 5: Vet BLUE right cranial lung lobe site showing shred sign (consolidation with aeration.

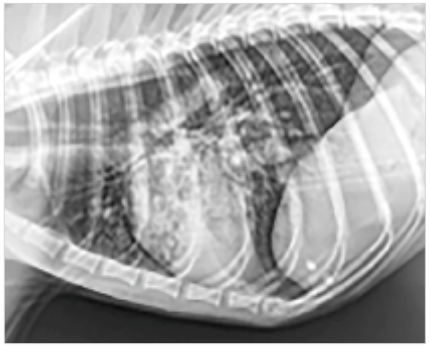

Fig. 6: Right lateral radiograph: alveolar pattern seen in cranial and middle lung lobes.

tory sounds. Similar findings were previously reported by Tart *et al*. (2010). Age of animals ranged from 0.16 to 12 yr with the median age of 4 yr. Different breeds presented were Labrador Retriever (n=2), German Shepherd (n=2), Doberman (n=1), Shih Tzu (n=1) and non-descript (n=1). Females and males were four and three in numbers, respectively.

The mean±SE of respiratory rate and rectal temperature were 52.28±6.255/min and 103.8±0.50°F, respectively, which were more than normal reference range. Similar findings were earlier reported by Elgalfy *et al*. (2022). The mean±SE of heart rate was 107.14±11.26 beats/min, which was within the typical reference range.

The mean±SE total leukocyte count (TLC) was 18,438.57±2,902.65 cells/µL, which was above the normal reference range and indicative of leukocytosis with relative neutrophilia. This finding is consistent with Elgalfy *et al.* (2022), who reported increased white blood cell and neutrophil counts, along with decreased lymphocyte counts, in dogs and cats with pneumonia. Serum BUN, creatinine, ALT, and ALKP values remained within the normal reference ranges, whereas the mean AST activity (59.57±9.88 IU/L) exceeded the reference range.

***Radiography*:** In all dogs except one, thoracic radiographs revealed a moderate-to-severe alveolar pattern with air bronchograms predominantly affecting the ventral lung lobes (n=6) (Figs. 3 and 6). The right cranial, right middle, and left cranial lung lobes are the most commonly affected sites in bronchopneumonia and aspiration pneumonia (Scrivani, 2009). In two dogs of the present study, severe consolidation of the cranial and middle lung lobes with obscuration of the cardiac silhouette was evident (Fig. 7). One dog showed no obvious pulmonary parenchymal abnormality; however, the mediastinal structures appeared unusually distinct, and the heart was elevated from the sternum, likely due to positioning. Megaoesophagus was suspected radiographically in three dogs. Similarly, Kogan *et al*. (2008) reported oesophageal disease or dysfunction as the most common underlying disorder associated

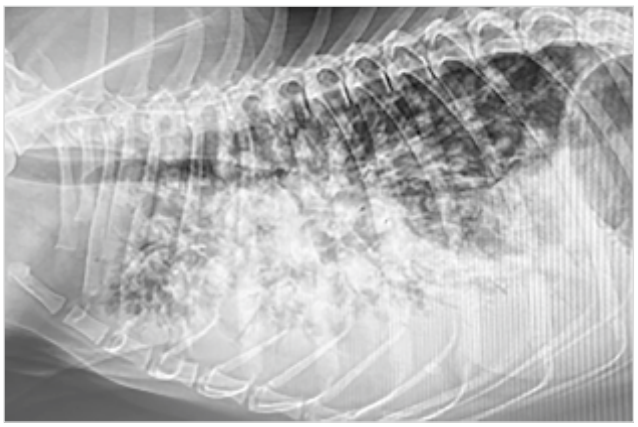

Fig 7: Severe alveolar pattern seen in cranial and middle lung lobes (right primarily) as well as broncho-interstitial pattern seen in all lung lobes. Cardiac silhouette not appreciable.

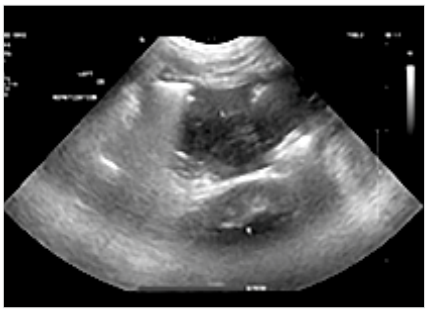

Fig. 8: Vet blue left cranial lung lobe site showing hepatisation of cranial lung lobes. L and H in the image indicate lung and heart respectively.

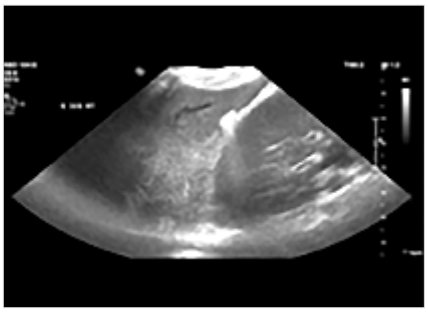

Fig. 9: Right middle lung lobe site showing hepatisation of lung. Lung parenchyma appeared similar to liver seen adjacent to lung.

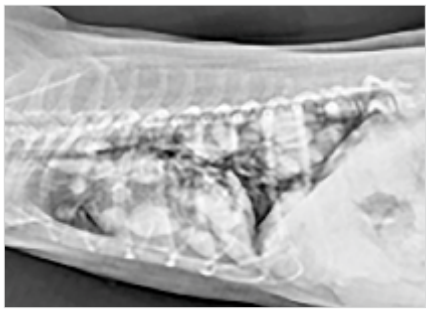

Fig. 10: Lateral radiograph showing multiple nodular opacities in all lung lobes.

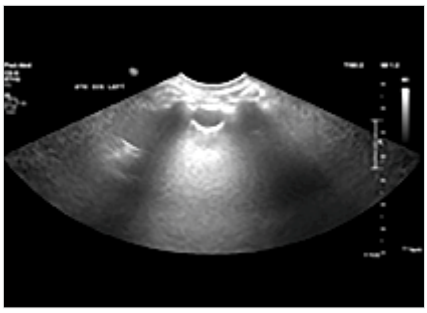

Fig. 11: Vet BLUE middle lung lobe site showing nodule sign.

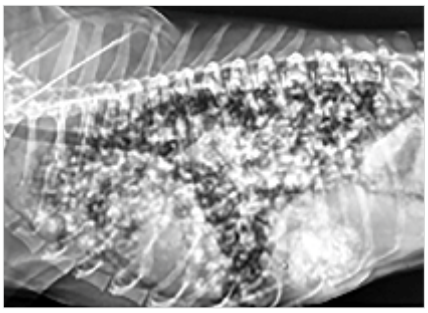

Fig. 12: Lateral radiograph thorax showing severe nodular interstitial pattern in all lung lobes.

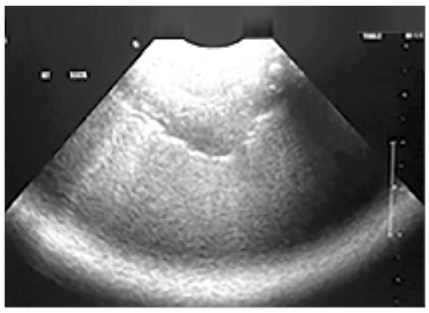

Fig. 13: Right middle lung lobe region showing tissue sign of consolidation without aeration.

with aspiration pneumonia in 35 dogs, with megaoesophagus identified as the cause in 25 of those cases. The clinical and physical examination findings were consistent with the radiographic diagnosis of pneumonia in six cases. In the remaining case, no pulmonary abnormalities were evident on thoracic radiographs despite clinical findings suggestive of pneumonia.

***Ultrasonography*:** On Vet BLUE examination, the left craniodorsal lung site demonstrated multiple B-lines (>3) with a shred sign in five cases (Figs. 4 and 6). One case exhibited confluent B-lines (white lung) without consolidation, one showed lung hepatization (Fig. 8), and one displayed only A-lines without B-lines or consolidation. At the right craniodorsal lung site, one case showed pleural effusion with lung hepatization and atelectasis, five cases demonstrated multiple B-lines (>3) with a shred sign, and one case had multiple B-lines without consolidation. The left middle lung site showed multiple B-lines with a shred sign in six cases, while one case exhibited an isolated shred sign without B-lines. Similarly, the right middle lung site revealed multiple B-lines with a shred sign in six cases, whereas one case showed lung hepatization (Fig. 9). The left perihilar lung site demonstrated multiple B-lines with a shred sign in one case. At the right perihilar site, one case showed multiple B-lines with a shred sign and another exhibited multiple B-lines without consolidation. Multiple B-lines with a shred sign were also observed at the bilateral caudodorsal lung sites in one case.

A ventral distribution of B-lines, with or without a shred or tissue sign on Vet BLUE examination, is suggestive of pneumonia (Lisciandro, 2014). These findings were consistent with the clinical, physical examination, and radiographic findings in the dogs included in this group. In one case, multiple B-lines with a shred sign were observed across all Vet BLUE lung sites. According to Lisciandro (2014), a mixed distribution of B-lines involving both ventral and dorsal lung regions may indicate pulmonary haemorrhage or inflammation. Lisciandro (2014) further stated that ULR abnormalities develop before more extensive alveolar flooding and subsequent pulmonary consolidation, characterized by shred and tissue signs. Similar findings were observed in one case in this group, where multiple B-lines along with shred and tissue signs were detected in the same animal, indicating severe acute bacterial pneumonia. Following antibiotic therapy for a defined period, follow-up thoracic radiography and ultrasonography demonstrated clinical and imaging improvement.

In six cases, Vet BLUE findings were consistent with thoracic radiographic and clinical/physical examination findings. In one case, Vet BLUE findings correlated with the clinical/physical examination findings but were inconsistent with radiographic findings. Therefore, the diagnostic accuracy of Vet BLUE was 100%, whereas thoracic radiography showed an accuracy of 85% in this group.

Group C: Subpleural consolidations without significant ULRs (>3) (n=9)

The animals in this group were presented with respiratory distress (n=9), chronic cough (n=1), mammary tumour (n=3), thoracic and ear growth (n=1), growth on the left limb and dorsum (n=1), and

neck growth suspected to be associated with metastasis (n=1). The dogs ranged in age from 2 to 12 years, with a median age of 7.8 years. The group comprised five males and four females. The represented breeds included nondescript dogs (n=4), Pomeranian (n=2), Pug (n=1), Labrador Retriever (n=1), Dachshund (n=1), and German Shepherd (n=1).

The mean±SE values of heart rate, respiratory rate, and rectal temperature were 112.4±5.8 beats/min, 35.8±4.55 breaths/min, and 100.94±0.17°F, respectively, and were within the normal reference ranges. The mean total leukocyte count (TLC) was 18,913.60±3,134.57 cells/µL, showing leukocytosis with relative neutrophilia, suggestive of systemic involvement. All other haematological and biochemical parameters remained within the normal reference ranges.

***Radiography*:** Thoracic radiography revealed a right caudal lung mass/tumour in one case. A severe nodular interstitial pattern involving all lung lobes was observed in two cases, with obliteration of the cardiac silhouette in one case (Fig. 13). Multiple nodular and soft tissue opacities suggestive of pulmonary metastasis were detected in four cases (Fig. 10). Miles *et al*. (1990) reported that, in the absence of concurrent intrathoracic disease, dogs showing one or more interstitial nodular opacities on radiographs are considered likely to have pulmonary metastatic disease.

***Ultrasonography*:** In eight cases, Vet BLUE examination revealed well-defined, hypoechoic, round-to-oval lesions with a hyperechoic distal border along the lung surface (Lisciandro, 2021). Demi *et al*. (2020) explained that, although pseudo-B-lines and B-lines are similarly produced by replacement of air-filled alveoli with fluid or soft tissue, the term pseudo-B-line is used to differentiate these lesions from true B-lines, which originate from the pleural line and are associated with interstitial-alveolar oedema. A tissue sign was observed in one case, while two cases demonstrated both tissue and nodule signs at different Vet BLUE sites (Fig. 13). In one case, thoracic radiography revealed multiple metastatic nodules in the cranial and middle lung lobes. However, Vet BLUE detected only two nodules in the left cranial lung region and one nodule in the left middle lung region. This finding is consistent with observations by Lisciandro (2014) and Ward *et al*. (2019), who reported that the nodule sign on ultrasonography is detectable only when lesions are located at the peripheral lung surface; therefore, centrally located deeper nodules may be missed during Vet BLUE examination.

This study concluded that the caudodorsal and perihilar Vet BLUE lung sites were reliable for identifying pulmonary oedema, while the cranial and middle lung sites were effective in detecting pneumonia. Additionally, all Vet BLUE lung sites were useful for identifying subpleural consolidations, characterized by tissue, nodule, and shred signs.

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