RESEARCH ARTICLE

Comparison of Linear and Phased Array Transducers in Ultrasonographic Diagnosis of Pneumonia in Dogs

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Abstract

The aim of this study was to evaluate the use of linear and phased array transducers in the ultrasonographic diagnosis of pneumonia in dogs. Eleven dogs with radiographic signs suggestive of pneumonia formed the population under the study. Radiographic findings recorded in the study included alveolar pattern, bronchial pattern, lobar sign and unstructured interstitial pattern primarily distributed in the cranioventral thoracic region. Lung ultrasonography was performed as per Vet-BLUE protocol in nine acoustic windows. The prominent sonographic features observed were the B-lines, thick and irregular pleura, shred sign with air bronchogram and tissue signs. Linear transducers were able to detect these findings more extensively than phased array transducers. On B-line scoring, strong positive sites were found in the cranial and middle lung regions in 86.36% and 81.81% of sites, respectively, with the linear transducer and 36.36% and 54.54% of sites, respectively, using the phased array transducer. Higher numbers of total strong positive sites were detected with the linear transducer in 56.81% of the total sites. Shred signs, irregular pleura and tissue signs were also recorded and evaluated. The study suggested that linear transducers were superior in diagnosing superficial lung abnormalities associated with pneumonia.

Key words: B-line scoring, Dogs, Lung ultrasonography, Pneumonia

Ind J Vet Sci and Biotech (2024): 10.48165/ijvsbt.20.2.06

Introduction

Ultrasonography has been widely used in veterinary practice for decades to diagnose various disease conditions. The use of thoracic sonography was restricted due to the presence of air and limited to the study of superficial pleural conditions, such as tumors and effusions, and to guide invasive procedures. Lung ultrasonography (LUS) is a non-invasive, non-ionizing, and valuable diagnostic technique for pulmonary parenchymal and pleural diseases in small animal practice. It can be considered as a visual stethoscope and provides an auxiliary diagnostic tool to thoracic radiography (Yang *et al*., 2021). Ultrasound examination of the lungs can recognize the artifacts *viz.* pulmonary pleural line (PPl), A-lines, and B-lines. The B lines arise due to the accumulation of a small amount of fluid surrounded by air (Lin *et al.*, 2020). The presence of B-lines is indicative of various lung pathological conditions. The B line scoring system quantifies the number of B lines over each acoustic window that correlates with the degree of alveolar interstitial edema in dogs and cats (Lisciandro and Lisciandro, 2021).The Veterinary Bedside Lung Ultrasound Exam (Vet-BLUE) is a regional pattern based approach applied rapidly in animals presenting with respiratory signs. Vet BLUE protocol is suggested to be more accurate and sensitive in detecting alveolar-interstitial syndrome (AIS), lung contusions, metastatic nodules, and cardiogenic pulmonary edema in dogs compared to thoracic radiograph (Ward *et al*., 2019).

Different types of probes can be used for LUS and the use of specific transducers might be required to accurately assess the specific lung parenchymal and pleural abnormalities. Linear probes are primarily used for superficial structures, especially in cats, such as the small intestine and the kidney. They are also excellent for ophthalmic imaging due to its higher image resolution capabilities. Phased-array probes have a "pinpoint" focal foot print and excellent temporal resolution and are preferred for cardiac ultrasound (Mattoon and Nyland, 2015). Studies with regard to the use of linear and phased array transducers in diagnosing various pulmonary and pleural pathologies in dogs are scarce. Hence, the present

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How to cite this article: Mohandas, S., Unny, M., Yesudas, A., George, A., & Philip, L. M. (2024). Comparison of Linear and Phased Array Transducers in Ultrasonographic Diagnosis of Pneumonia in Dogs. Ind J Vet Sci and Biotech. 20(2), 28-32.

Source of support: Nil

Conflict of interest: None

Submitted 19/09/2023 **Accepted** 29/11/2023 **Published** 10/03/2024

study was carried out to assess the efficacy of linear and phased array transducers in the ultrasonographic diagnosis of pneumonia in dogs.

Materials and Methods

Selection of Animals

Dogs presented to Teaching Veterinary Clinical Complex, Mannuthy, KVASU, Kerala (India). With history and clinical findings suggestive of respiratory disorders were included for preliminary evaluation. The animals were subjected to detailed clinical examination. Lateral and ventrodorsal thoracic radiographs were taken using 200mA Siemens X Ray machine and Carestream Imagesuite Vita CR®. A total of 11 dogs with radiographic signs suggestive of pneumonia were selected for this study.

Procedure

Lung ultrasonography was performed using Esaote MyLabX8eXP® ultrasound machine, utilizing linear (4-15 MHz) and phased array (1-5 MHz) transducers. Lung ultrasonography was performed in standing or sternal recumbency in dogs. Hairs on the left and right thoracic area were clipped and acoustic coupling gel was applied over the skin. The imaging depth was set at 3–6 cm depending on the size of the animal and the focus position was set as close to the lung line. The image quality was optimized for each examination by adjusting the focal zone, overall gain, and near-field gain. The linear probe and phased array probes were kept at the optimum frequency as required. All the selected animals were evaluated using linear transducers followed by phased array transducers at nine acoustic windows *viz.* right and left caudodorsal lung region (Cd), perihilar lung region (Ph), middle lung region (Md), cranial lung region (Cr) and diaphragmatico-hepatic view (DH).The procedure was performed in the following order moving from dorsal to ventral and cranial: left Cd → Ph → Md → Cr view, then DH, followed by right Cd → Ph → Md → Cr views. The caudodorsal lung region is directly dorsal to the xiphoid in the upper third of the thorax in the 9th-10th intercostal space. Perihilar lung region is the point in the middle third of the thorax between the 6th and 7th intercostal spaces. Middle lung region is the lower half of the thorax over the heart between the 4th –5th intercostal spaces. If the heart obstructed the view of the lungs, the probe was repositioned dorsally within the same intercostal space to locate the lung line. The cranial lung region was identified between the 1st, 2nd, and 3rd intercostal spaces, situated cranial to the heart. To obtain a clear view of this region, the foreleg was extended forward. The DH view is immediately caudal to the xiphoid on the mid line where the probe was directed cranially towards the patient's head (Lisciandro *et al*., 2014). The sonographic appearance of the lung parenchyma was evaluated for various abnormalities *viz.* shred signs, irregular pleura and tissue signs.

B-line quantification was performed as per Lisciandro and Lisciandro (2021). The maximum number of B-lines at each acoustic window was counted and recorded as follows: 0 (negative); 1, a single discrete B-line; 2, two discrete B-lines; 3, three discrete B-lines; and more than 3 B-lines and infinity (∞), when B-lines conflued together. One to three B-lines represent mild degrees of AIS referred to as weak positive and >3 and infinity that represent moderate to more severe degrees referred to as strong positive of AIS. Presence of B-lines was indicated as a positive Vet-BLUE site.

Results and Discussion

The study population was composed of 11 dogs with radiographic signs indicative of pneumonia. The age of dogs ranged from 1 to 6.5 years. Three (27.27%) dogs were non-descript, followed by two (18.18%) Rottweiler and Spitz, and one each (9.09%) of Belgian Malinois, Doberman, AmStaff, and Dachshund. Radiographic changes indicative of pneumonia encompassed alveolar patterns, interstitial patterns, mixed alveolar-interstitial patterns, bronchial patterns, lobar signs, and air bronchograms. Among these, the most common was the alveolar pattern, found in 10 affected dogs. Unstructured interstitial pattern was observed in three dogs. Lobar sign was found in four dogs. Bronchial pattern and air bronchograms were observed in five and four dogs, respectively. The distribution pattern of lesions was primarily found in the right cranioventral lung region. This finding corroborated the observations of Rodrigues *et al*. (2022), who similarly noticed the lesions on the gravity-dependent area of the lungs in dogs with aspiration pneumonia. The LUS findings in dogs with pneumonia using linear and phased array transducers are shown in Table 1.

Table 1. Lung ultrasonographic findings of pneumonia using linear and phased array transducers

Sl. no	LUS findings	% of occurrence - Linear	% of occurrence - Phased array
1	B-line	80.68 (n=71)	45.45 (n=40)
2	Shred sign	18.18 (n=16)	5.68 (n=5)
3	Shred sign with air bronchogram	4.54 (n=4)	1.13 (n=1)
4	Irregular pleura	13.36 (n=12)	5.68 (n=5)
5	Tissue sign	11.36 (n=10)	7.95 (n=7)

n= number of sites; total number of sites =88

The prominent sonographic features observed were the presence of B-lines, thick and irregular pleura, shred sign with air bronchogram, and tissue signs. Linear transducer detected B-lines in 71 sites (80.68%) out of the total 88 sites, while the phased array detected B-lines only in 40 sites (45.45%). B-lines indicate the wet lung, which appears as a hyperechoic vertical line that arises from the pulmonary pleural line (PPI) and extends to the far field. B-lines arise due to the accumulation of fluid in the interstitial or alveolar spaces, that alters the air-fluid ratio and creates a high impedance gradient. Subpleural abnormalities like shred signs and tissue signs are strongly indicative of pneumonia. The shred sign represents the air bronchogram, suggesting consolidation of lung tissue. Aeration appears as hyperechoic flecks or foci within the consolidated lung (Fig. 1). The tissue signs referred to as hepatization of the lungs represented the complete consolidation of the lungs without aeration (Fig. 2) (Cole *et al.,* 2021). The tissue signs were observed at 11.36% and 7.92% of the sites with the linear and phased array transducers, respectively. The presence of shred signs was noticed in 18.18% and 5.68% of the total sites using the linear and phased array transducers, respectively. Lung ultrasonography using the linear transducer revealed a higher incidence of B-lines, shred signs, air bronchogram, and tissue signs on the Vet-BLUE sites compared to phased array transducers. Similarly, Łobaczewski *et al.* (2021) noted that the linear transducer has greater efficiency in identifying lung lesions due to pneumonia. In humans, most of the acute lung pathologies extend to the surface of the lungs. This could be attributed to the structural organisation of the lungs, with the secondary pulmonary lobule as the fundamental unit. Peripheral secondary pulmonary lobules were relatively large and margined by thicker interlobular septa. Lung sonography could effectively assess alterations in these peripheral septa, reflecting the spatial distribution of most pulmonary consolidations (Volpicelli, 2013). Similarly, in cats and dogs, the lung lesions extend to the periphery and can be easily detected by LUS (Lisciandro and Lisciandro, 2021).

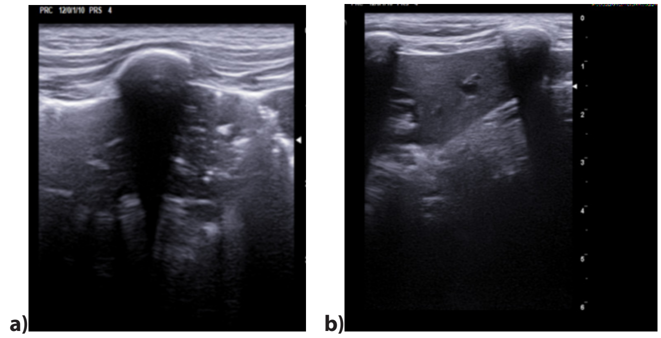

Fig. 1: Shred sign with air bronchogram a) linear b) phased array

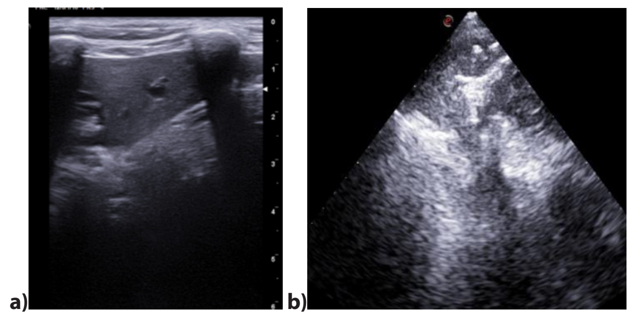

Fig. 2: Tissue sign a) linear b) phased array

B-line scoring

B-line scoring on all Vet-BLUE sites in the left and right hemithorax in 11 dogs affected with pneumonia is shown in Table 2 and Fig. 3.

Table 2: B-line quantification on Vet-BLUE site in dogs affected with pneumonia

Vet BLUE site	B-lines score	Linear		Phased array	
		% of occurrence - Left hemithorax	% of occurrence - Right hemithorax	% of occurrence - Left hemithorax	% of occurrence - Right hemithorax
Caudodorsal	0	45.45 (n=5)	54.54 (n=6)	63.63 (n=7)	90.90 (n=10)
	1	9.09 (n=1)	27.27 (n=3)	9.09(n=1)	9.09(n=1)
	2	9.09 (n=1)	0	18.18 (n=2)	0
	3	9.09 (n=1)	0	0	0
	>3	9.09 (n=1)	9.09 (n=1)	0	0
	∞	18.18 (n=2)	9.09 (n=1)	9.09 (n=1)	0
Perihilar	0	9.09 (n=1)	18.18 (n=2)	63.63 (n=7)	54.54 (n=6)
	1	0	0	9.09 (n=1)	18.18 (n=2)
	2	18.18 (n=2)	0	9.09 (n=1)	18.18 (n=2)
	3	54.54 (n=6)	27.27 (n=3)	9.09 (n=1)	9.09 (n=1)
	>3	0	18.18 (n=2)	9.09 (n=1)	0
	∞	18.18 (n=2)	36.36 (n=4)	0	0
Middle	0	9.09 (n=1)	0	18.18 (n=2)	18.18 (n=2)
	1	0	0	0	9.09 (n=1)
	2	0	0	36.36 (n=4)	18.18 (n=2)
	3	0	27.27 (n=3)	9.09 (n=1)	18.18 (n=2)
	>3	45.45 (n=5)	27.27 (n=3)	27.27 (n=3)	18.18 (n=2)
	∞	45.45 (n=5)	45.45 (n=5)	9.09 (n=1)	18.18 (n=2)
Cranial	0	18.18 (n=2)	0	27.27 (n=3)	27.27 (n=3)
	1	0	0	0	0
	2	0	9.09 (n=1)	18.18 (n=2)	0
	3	0	0	9.09 (n=1)	18.18 (n=2)
	>3	9.09 (n=1)	9.09 (n=1)	9.09 (n=1)	9.09 (n=1)
	∞	72.72 (n=8)	81.81 (n=9)	36.36 (n=4)	45.45 (n=5)

n= number of sites; total number of sites =11

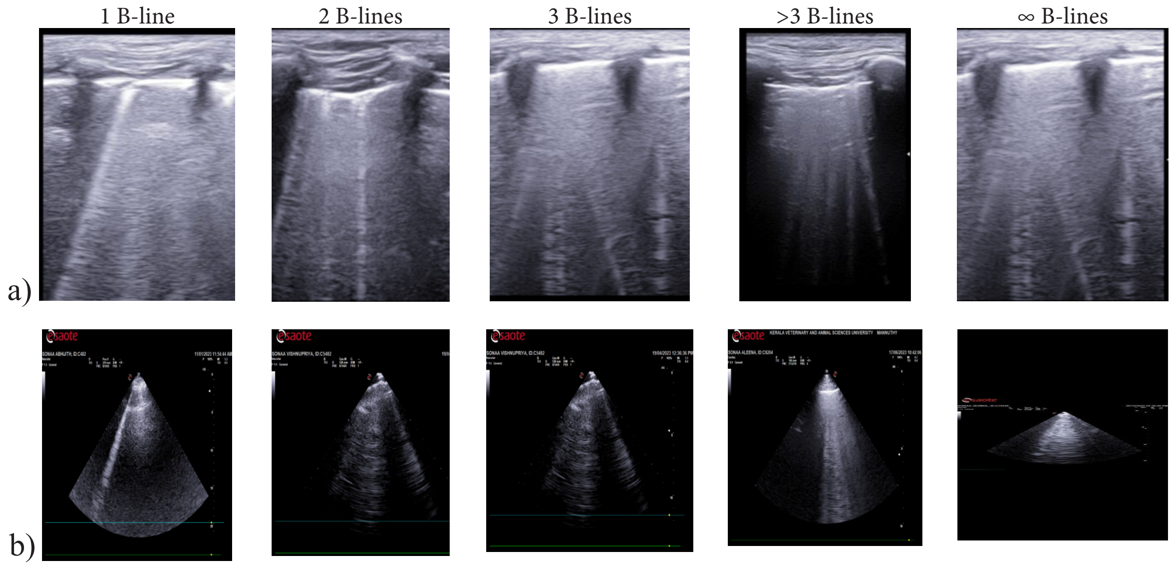

Fig. 3: B-line scoring using a) linear transducer and b) phased array transducers

The highest number of positive Vet-BLUE sites was observed on the middle and cranial lung regions using the linear transducer, whereas using the phased array transducers, it was found to be the right and left cranial lung regions. Generally, the consolidative signs were noticed in the gravity-dependent area, like the cranioventral region. Rodrigues *et al*. (2022) observed that in dogs affected with aspiration pneumonia, the lesions were primarily noticed bilaterally on the ventral lung region.

Severe AIS was found in the middle and cranial lung regions with strong positive B-lines using both transducers. Łobaczewski *et al*. (2021) found that B-line scoring was lowest at the perihilar and middle regions, whereas in the current study, the caudodorsal and perihilar regions showed more weak positive sites. For the caudodorsal, perihilar, middle and cranial lung regions, strong positive sites of 22.72%, 36.36%, 81.81% and 86.36%, respectively, were observed using the linear transducer. B-line scoring using the phased array transducer recorded strong positive sites of 4.45%, 4.45%, 36.36% and 54.54% in the caudodorsal, perihilar, middle and cranial lung regions, respectively (Table 3). The occurrence of total strong positive sites recorded was 56.81% and 25% using linear and phased array transducers, respectively (Fig. 4). These findings suggest that the linear transducer was better in identifying B-lines than phased array transducers. This concurs with the findings of Łobaczewski *et al*. (2021), who observed a lower agreement for phased array transducers compared to linear transducers. Similarly, Tasci *et al*. (2016) also observed that the linear transducers exhibited higher sensitivity and specificity compared to the phased array transducers in diagnosing interstitial syndrome. Phased-array probes have a "pinpoint" focal point and are inferior in the visualisation and enumeration of B-lines. Furthermore, it was suggested that phased array probes were less effective in evaluating images on LUS, particularly with respect to pleural-based abnormalities (Walsh *et al*., 2023). On the contrary, Ward *et al*. (2021) observed that phased array transducers showed excellent agreement for total B-line scores as compared to microconvex transducers. They opined that the image quality and experience of the sonographer can influence B-line quantification. From the DH window, none of these signs were evident using linear transducers. However, B-lines of 1, 2 and >3 were detected from the DH site using the phased array transducer (Fig. 5). The use of high-frequency transducers is constrained by their increased attenuation within the tissue, resulting in a shorter depth of penetration (Schneider and Feussner, 2017). This explanation may account for the poor performance of the high-frequency linear probe when compared to phased array probes at the DH site.

The results of this study suggest that the LUS can be used concurrently with thoracic radiography to determine the severity and extent of the lung pathology of pneumonia in dogs. The sonographic signs of pneumonia included the presence of B-lines, thickened irregular pleura, shred sign with air bronchogram and tissue signs. These changes were effectively visualized using the linear transducer compared to the phased array transducer.

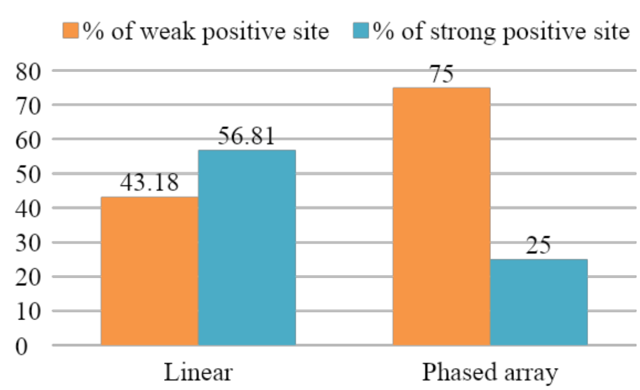

Fig. 4: Occurrence of total weak and strong positive site using linear and phased array transducers in dogs with pneumonia

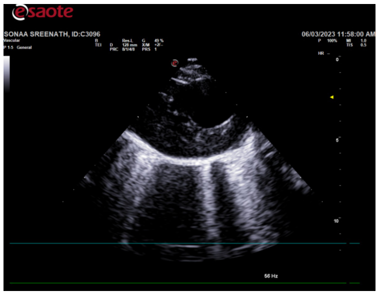

Fig.5: B-lines in DH site using phased array transducer

Table 3: Comparison of B-line scoring using linear and phased array transducers in dogs with pneumonia

	Weak positive (%)		Strong positive (%)	
Vet-BLUE site	**Linear**	**Phased array**	**Linear**	**Phased array**
Caudodorsal	77.27 (n=17)	95.45 (n=21)	22.72 (n=5)	4.45 (n=1)
Perihilar	63.63 (n=14)	95.45 (n=21)	36.36 (n=8)	4.45 (n=1)
Middle	18.18 (n=4)	63.63 (n=14)	81.81 (n=18)	36.36 (n=4)
Cranial	13.63 (n=3)	45.45 (n=10)	86.36(n=19)	54.54 (n=12)

n= number of sites; total number of sites =22

Conclusions

In the present study, the linear transducers could clearly visualize B-lines and other pathological changes in a greater number of acoustic windows in comparison to phased array transducers. Based on these findings, it is concluded that linear transducers were superior in diagnosing pneumonia compared to phased array transducers in dogs.

Acknowledgement

The authors would like to thank the authorities of Kerala Veterinary and Animal Sciences University for the facilities provided.

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