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Non-cardiac transthoracic ultrasonography in sloth bear (*Melursus ursinus*); *Bear's*-Blue

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Abstract
Like the trans-abdominal ultrasonography examination technique used to examine the visceral organs in the abdominal cavity, the non-cardiac trans-thoracic ultrasonography technique will help to examine the lungs. The lungs are located within the thoracic cavity of all mammals and are the only organs in the body to be filled with air under normal conditions. In the past, the belief was that the lung is not optimal for ultrasonography imaging because the aerated lungs creates insurmountable obstacles; therefore, people concentrated more on trans-abdominal, trans-rectal and trans-thoracic echocardiography. These methods became well established in human medicine and were gradually adopted into veterinary medicine as well. However, the ultrasonography examination of pulmonary system remained a grey area. Recent advancements and continued development in medical science has surmounted the previously thought impossible and has proven that ultrasonography is an excellent diagnostic model in regard to the anatomy of all mammalian species. Rantanen[23] was the first veterinarian to use the ultrasonography to diagnose pulmonary disease in horses, and successfully diagnosed pneumothorax in 1986. Following this discovery, awareness in the field increased and resulted in the establishment of the Bed side Lung Ultrasound Examination (BLUE) protocol in human medicine and the Vet-BLUE protocol in small animal veterinary medicine. However, these advanced technologies are not as well established or effectively utilized in wild animal medicine as they are in small animal veterinary practice globally, except for in a few research institutions and teaching universities. Therefore, adopting this advanced diagnostic procedure in wildlife is pertinent for providing the utmost care in these species. During the study, we were able to clearly document the examination of the pulmonary system of sloth bears by adopting the non-cardiac, trans-thoracic ultrasonography technique. This technique includes patient preparation, positioning, probe selection, and recording of the ultrasonography image to compare and interpret normal versus abnormal lung and its radiographs. Thus, we developed the BLUE protocol for bears (*Bear's*-BLUE). The aim of this article is to disseminate the knowledge of sloth bear lung ultrasonography to wildlife veterinarians at field level, and to encourage the neophytes to adopt this practice and improve their diagnostic ability to provide better care to the animals and develop a more effective therapeutic plan.

Keywords: *Bear's*-BLUE, Lung ultrasonography, Transthoracic ultrasonography, Sloth bear (*Melursus ursinus*), Wildlife, Pulmonary system.

1. Introduction

The classical belief in both human and veterinary medicine was that the lung is not an optimal organ for ultrasonography imaging, which led to a delay in its use of the pulmonary system for many years. Therefore, medical fields focused more in trans-abdominal, trans-rectal, and trans-thoracic echocardiography until recent years. With the recent advancements in medical technology, those within medicine have proven that ultrasonography is an excellent diagnostic tool in all species. Lung ultrasound possesses a greater sensitivity than lung auscultation and supine chest radiography for many acute and potentially life-threatening respiratory conditions in both humans and animals alike [2, 5, 13, 24, 28]. Rantanen [23] was the first veterinarian to utilize ultrasound to diagnose pulmonary and pneumothorax in horses in 1986. Following this discovery, the same techniques became an integral part of human medicine as well. In 1988, with remarkable foresight, Roy Philly dubbed the ultrasound probe as the 'modern stethoscope'. In 2011, Moor dubbed the ultrasound probe as the 'visual stethoscope,' as artifacts within the lung ultrasound are clearly distinguishable independent of patient or ambient noise. In 2008, Thoracic FAST, also known as TFAST, became the first standardized ultrasound exam of the thorax in small animals that included a chest tube site for lung surveillance and detection of pneumothorax (PTX) [17]. More recently was the establishment of Vet-BLUE [19, 20], the regional-based lung ultrasound protocol for small animals, which further enhanced the utilization of lung ultrasound to examine the complete pulmonary system. This allowed for the finding of numerous types of lung pathology, such as lung oedema, consolidation, pleural effusion and pneumothorax. The Vet-BLUE protocol covers 8 regional sites, 4 on each side, which includes the caudodorsal lung lobe region (Cd), the perihilar lung lobe region (Ph), the middle lung lobe region (Md), and the cranial lung lobe region (Cr). Although this lung ultrasound procedure is well established in small animals and equine medicine, it is not significantly utilized in wild animal medicine due to various issues such as difficulty of restraint and lack of knowledge in regards to implementation of the same system in different species. As well, little information about lung ultrasonography in wild animals is documented [22], in particular for sloth bears (family *Ursidae*). Due to this, we underwent numerous efforts to implement the existing advanced lung ultrasonography techniques in sloth bears in order to examine the normal lung and pathology; known as *Bear's*-BLUE protocol (Fig. 1).

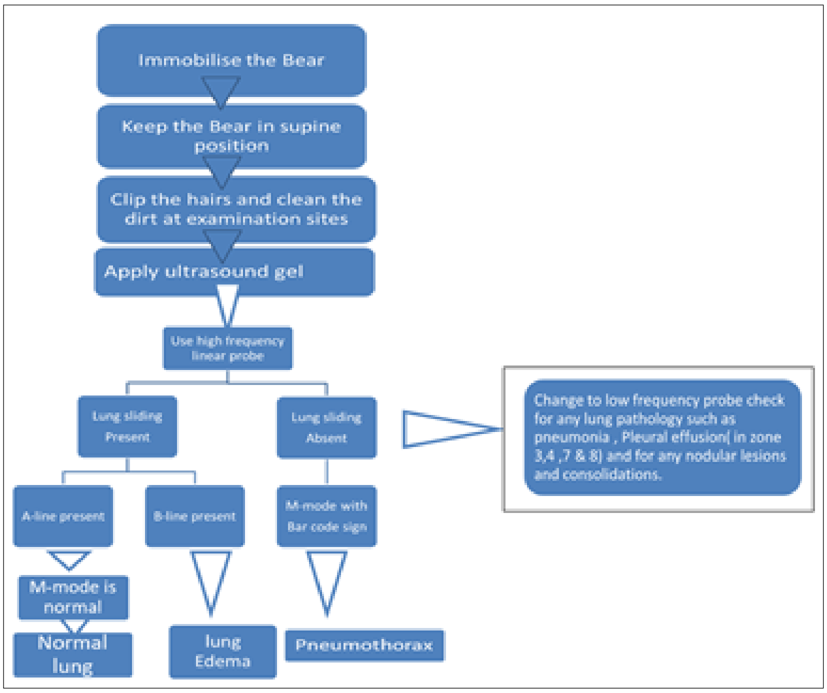

Fig 1: Bear's Bedside Lung Ultrasound Examination (*Bear's* –BLUE) Protocol

2. Materials and Methods

This study was conducted at the Agra Bear Rescue Facility (ABRF), which is managed by the NGO Wildlife SOS in Agra, India, and is home to 186 dancing sloth bears undergoing rehabilitation. As the sloth bears were rescued from street performers and are burdened with poor health and disease, being able to provide the maximum possible veterinary care by adopting recent advancements in the field of veterinary medicine is an absolute must to diagnose and treat the conditions as well as stabilize the health of those animals. The sloth bears are very prone to developing various kinds of pulmonary disorders, ranging from pneumonia to pulmonary tuberculosis. Therefore, due to its superior technique and time-saving ability in comparison to chest radiography, we adopted the lung ultrasonography procedure for the evaluation of the pulmonary system in sloth bears.

2.1 Patient preparation

Although they have been in captivity for much of their lives, the sloth bears are still wild animals and as a result their behaviour is highly unpredictable. Therefore, choosing the proper restraining method plays a pivotal role in implementing any diagnostic procedures within this species. Safety of the veterinarian, animal keepers, and various other staff is of the utmost importance. Chemical immobilization of the bear is achieved by using a mixture of xylazine and ketamine, which results in hassle-free restraint and the ability to implement any diagnostic procedures effectively. The immobilized bear is kept in a supine position on the table. The hairs on the thorax were trimmed using hair clippers, as long fur and dust will create issues with penetration of the ultrasound beam. To get a better-quality image, ultrasound gel is applied to the shaved skin to create an optimal interaction between the probe and the desired area. Four zones, on each side of the thorax, are used for examination (Fig. 2).

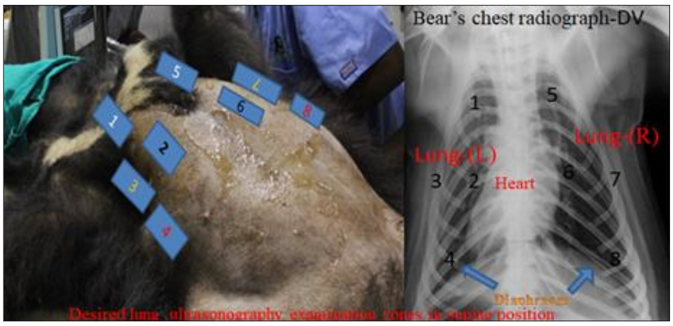

Fig 2: Bear kept in supine position. Hear clipped and gel applied to all eight zones.

2.2 Organ Anatomy

A precise knowledge of organ anatomy and its topography is essential for the sonographer to utilize the diagnostic techniques quickly and efficiently within the stipulated time. In the absence of such anatomic knowledge or past experience, identification of pathologic changes may be inaccurate or not possible. The lung anatomy of sloth bears resembles that of the human. The multi-lobulated lungs – 3 lobes on right, 2 lobes on left, and one mediastinal lobe (ML) or accessary lobe – are located inside the thoracic cavity and possess well developed visceral and parietal pleura. In the healthy lung, the interstitial thickening ranges from 5.76µm to 7µm (Fig. 3). This technique of lung ultrasonography examination and its nomenclature was previously described in both human [15] and small animal [19, 20] studies, and therefore worked well for sloth bear research with slight modification.

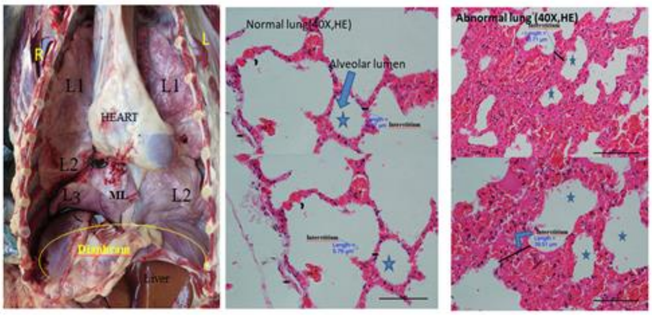

Fig 3: Lung lobes location and histology of normal & abnormal lung tissue.

2.3 Instrument & Probe selection

Selection of a good quality ultrasound machine, which has compatibility with the phased array, linear, and curved linear probes, is a prerequisite for achieving enhanced performance (Figure 4). In this case, a GE logq-E machine and the above-mentioned probes were utilized, and the images were recorded to better understand the anatomy. Image quality differs based on the probe that is used. The high frequency linear probe is used to evaluate the pleural line and visceral-parietal pleural interface (VPPI), as well as pneumothorax. This is because the linear probe has a higher resolution in comparison to the others. Both the low frequency curved linear and phased array probes are used to diagnose alveolar interstitial syndrome (CHF/ARDS), pleural effusion, consolidation, pulmonary oedema, and pneumonia, due to their having a greater penetration in comparison to the higher frequency linear probe.

Fig 4: Different kinds of Ultrasound probe used in *Bear's* –BLUE.

2.4 Probe orientation

The standard orientation of the probe is generally cranio-caudal, with the probe marker towards the head. This orientation allows for the observation of the previously described "gator sign," which is likened to a partially submerged alligator peering over the water at the sonographer [3, 19] (Fig. 5). In this way, the "gator sign" is represented by two rib heads and an interposed intercostal space – demarcated as the gator's eyes and the bridge of the gator's nose, respectively.

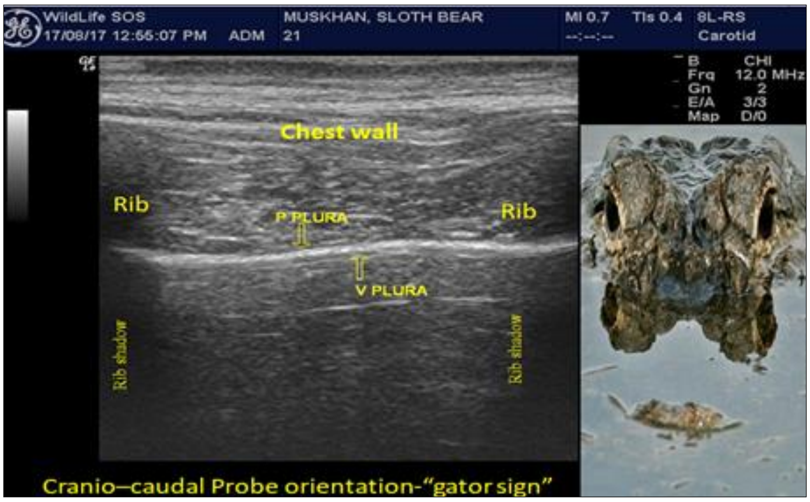

Fig 5: Cranio-Caudal probe orientation-'Gator Sign'.

2.5 Ultrasound modes

The commonly used ultrasound modes in lung ultrasonography are the "B-Mode" and "M-Mode". Both modes are described below.

- B-mode, or 'Brightness Modulation', is the display of a 2D map of B-Mode data and is the most common form of ultrasound imaging. Unlike A-Mode, B-Mode is based on the image brightness and the absence of vertical spikes. Therefore, the brightness depends upon the amplitude or intensity of the echo.
- M-mode, or 'Motion Mode' (also known as 'Time Motion' or TM-mode), is able to display a one-dimensional image, and is commonly used in cardiac and foetal cardiac imaging to analyse moving bodily organs. This can be accomplished by recording the amplitude and rate of motion in real time, by repeatedly measuring the distance of the object from the single transducer at a given moment. A single sound beam is transmitted, and the reflected echoes are displayed as numerous dots of varying intensities, thus creating lines across the screen.

The typical M-mode imaging of a healthy aerated lung follows the image of a sky, ocean, and beach, with linearity appearing on the top of the image and a more granular appearance to the bottom of the image (Fig. 6). However, a lung suffering from pneumothorax or consolidation will instead reveal a ‘barcode’ sign, which is seen by complete linearity in both the top and bottom of the image, or as a ‘stratosphere” appearance (Fig. 7). M-mode is also important in recording the ‘lung point,’ [10] which is the area along the thorax where the collapsed lung re-contacts the chest wall (Fig. 8). Finding of the ‘lung point’ increases the diagnostic certainty of pneumothorax.

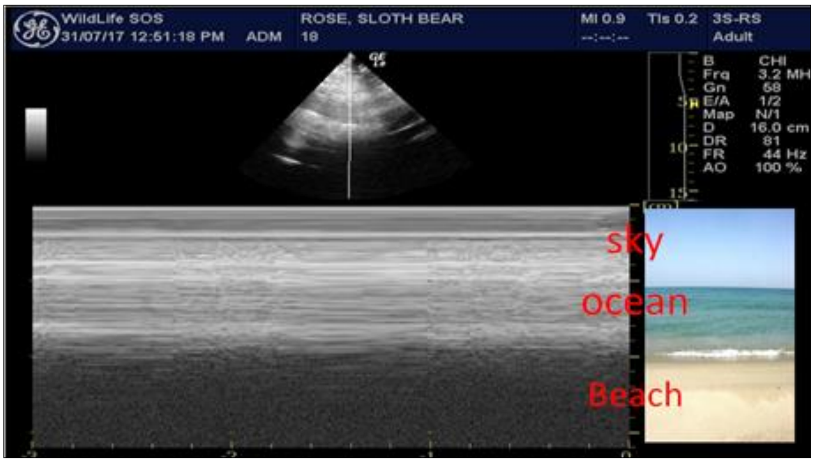

Fig 6: M-mode view of normal lung.

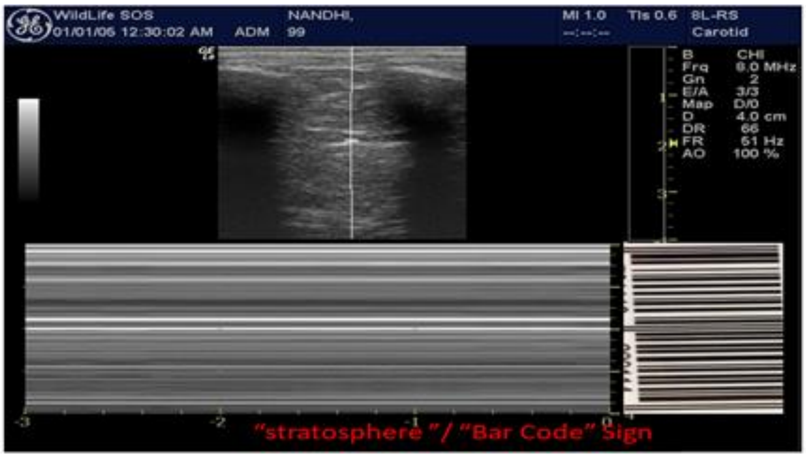

Fig 7: M-mode view of Pneumothorax.

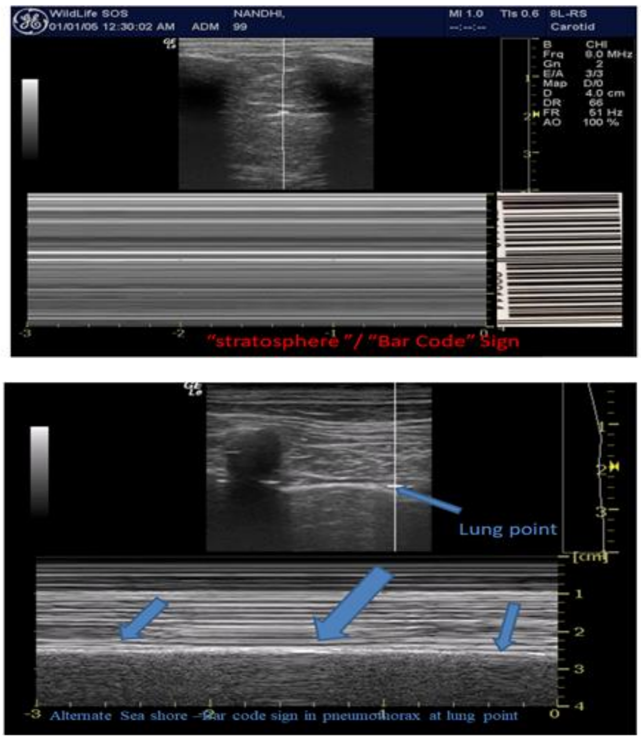

Fig 8: M-mode view Pneumothorax with ‘Lung-Point’.

2.6 Artifact analysis and interpretation

The basic principles of lung ultrasonography in acute respiratory conditions generally centre around the observation of ultrasonographic artifacts based on the dry lung. This is seen as ‘A-lines’ with a ‘glide sign’ or lung sliding, in comparison to the wet lung which shows characteristic ultrasound ‘lung rockets’ or ‘B-lines’. At the surface of the lung, the prominent element is air. The acoustic impedance of air is 0.0004 3 105 gp/cm^2 s [26], which is very different from that of bone (7 3 105 gp/cm^2 s), parenchyma (1.65 3 105 gp/cm^2 s), and water (1.48 3 105 gp/cm^2 s). The movement of the lung toward the chest wall is distinctive. The ribs are identifiable by their acoustic shadow. Between two ribs is a hyper-echogenic line that is always visible, and behind which only airy artifacts are present [14]. The inability of ultrasound to penetrate air filled structures emphasizes the importance of its use during the examination of normal lungs. Thus, ultrasound imaging is herein exclusively composed of artifacts. However, in disease states where the normally air-filled lung is collapsed, consolidated, or replaced by fluid or lesions, ultrasound waves can penetrate the thorax and display an image. This form of examination may provide valuable information to complement any radiographic findings.

Skill in lung ultrasonography is superior to the need for that in most radiographs and CT scans, and is pertinent in allowing physicians and veterinarians to diagnose pleural effusion, interstitial syndrome, and pneumothorax [7]. The diagnosis of alveolar consolidation has been in practice for many years, and the signs within an ultrasound are now standardized (Fig. 9) [9]. Various demarcations and measurements of ultrasonography are described below.

- **A-lines:** Equidistance, horizontal, repetitious lines below the pleural line. The normal aerated lungs always produce A-lines (A = air, artifact = normal lung). A-lines are horizontal reverberation artifacts indicating a normal lung surface.
- **Glide sign or lung sliding:** A to-and-fro dynamic of the pleural line. It may also be known as the ‘lung -wall interface,’ [14] indicating movement of the visceral pleura past the parietal pleura from the respiratory cranio-caudal excursion of the lung.
- **B-lines** : Vertical, hyper-echoic rays projecting from pleural line are also known as the ‘ring down artifact.’[1] These B-lines extend to the bottom of screen without fading, similar to a laser beam, and oscillate in a synchronized fashion with both inspiration and expiration [3, 8, 13, 18, 19, 23, 28]. Presence of these B-lines indicates sub-pleural interstitial edema, or ‘wet lung [6, 12, 18]. B-lines, also termed ‘lung rockets,’ are vertical reverberation artifact or ‘comet-tail artifact’ [29]. Ultrasound lung rockets are thought to be the radiographic equivalent of Kerley B-lines [12, 13, 25]. The number of ultrasound lung rockets (ULRs), and the distance between each lung rocket, is directly correlated with the degree of lung edema in humans [8, 11, 12, 21, 25, 28]. ‘White lung’ is the term used when ULRs blend into one another and become confluent, as is mentioned as ‘infinity-∞.’
- **Z-lines:** Vertical, comma-tail artifacts that differ from B-lines. Z-lines are less echogenic than the pleural lines, are ill defined, and usually taper off at after two to four centimetres. However, they do not erase the A-lines, and do not move during lung sliding [12].
- **O-lines:** The possible pattern of the O-line is the absence of any horizontal or vertical artifact. A slight movement of the probe often brings out O-lines. This pattern should be considered having the same meaning as of A-line [12].
- **Air bronchograms:** These are punctiform or linear hyper-echoic artifacts within the consolidation. ‘Dynamic air bronchogram’ is the term used for the centrifugal inspiratory dynamic of air bronchograms where movement of 1 mm is required. Alveolar consolidation is defined as an image yielding two signs. The first sign is a tissue-like image arising from the pleural line or lung line, as well as tissue-like behavior of the image with no dynamic in the depth-surface axis. The second sign is the ‘shred’ sign, which is a shredded deep border of the tissue image, as in a connection with aerated lung [13]. Both signs yield 90% sensitivity and 98% specificity regarding the diagnosis of alveolar consolidation (Fig. 10) [9].

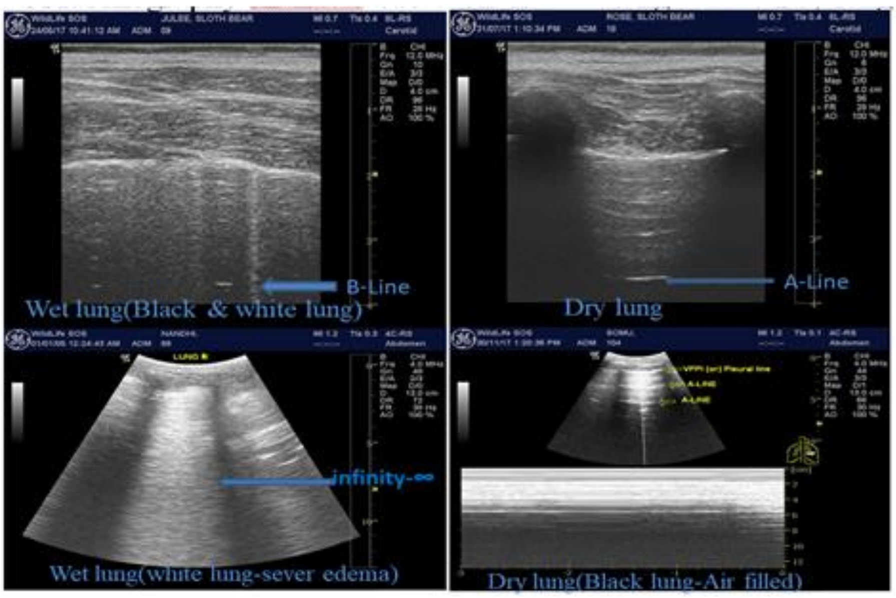

Fig 9: Ultrasonography artefacts based on the Wet lung versus Dry lung

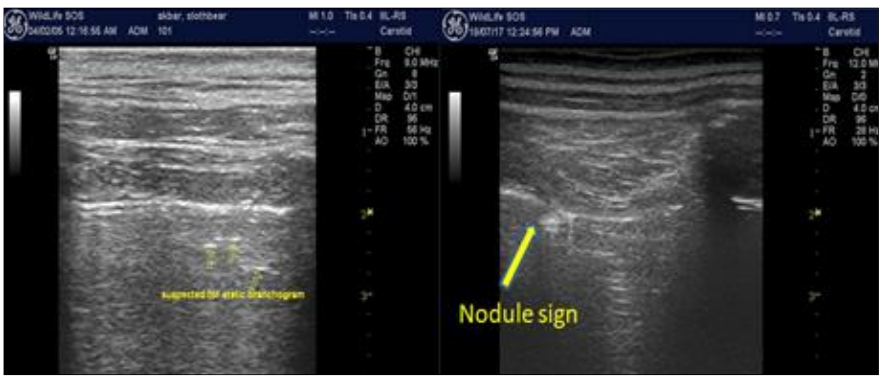

Fig 10: Lung consolidation and infiltration.

3. Result & discussion

Zones 1, 2, 5 and 6 are suitable areas for examination of pneumothorax in supine position, while zones 3, 4, 7 and 8 are suitable for plural effusion diagnosis. This is due to the fact that air is lighter than fluid, and therefore air will always rise to the top while fluid will settle at the bottom. All the zones are suitable for examination of lung pathologies such as oedema, consolidation, pneumonia and other nodular lesions due to carcinoma or tuberculosis (Fig. 11, 12 & 13). Small surface probes of 3.0 and 3.5 MHz are most suitable for this application, but 2.5, 5, and 7.5-MHz probes are equally effective[4]. Our findings of the normal lung pattern, which is characterized by horizontal and parallel A-lines, and those findings of alveolar interstitial syndrome, which yield parallel and vertical B-lines, coincides with the findings of Lichtenstein [4]. In the over 5400 mammalian species that currently exist, a wide variety of anatomic features have evolved, making knowledge of one species not necessarily applicable to another in a straightforward manner. In an ideal setting, attempts at ultrasonography should be utilized by those having a clear anatomic picture of the species involved, but this is still lacking for many species. The vast differences between species dictate the selection of the ultrasonography technique to be applied, and the quality of the images that are obtained [22].

Fig 11: Radigraphic, ultrasound immage and Postmortem lesion of lung edema.

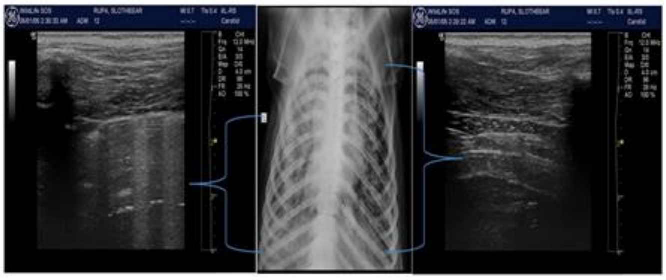

Fig 12: Radigraphic & Ultrasonographis image of sloth Bear's with lung edema and cosolitation due to Pulmonary tuberculosis.

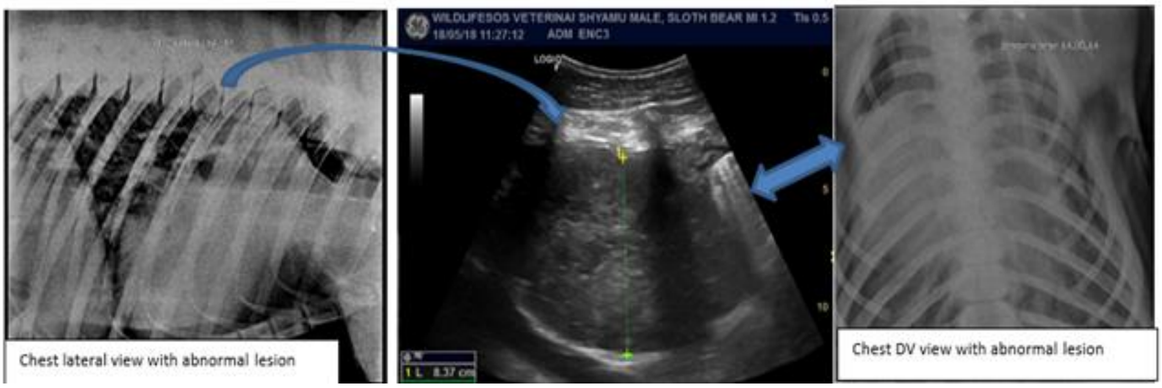

Fig 13: Radigraphic & Ultrasonograph image of sloth Bear's lung Space occupying lesion.

4. Conclusion

The simplicity and high feasibility of ultrasonography makes it an attractive and easy-to-use diagnostic tool at the bedside for lung examination. Therefore, it should be incorporated as an integral part of diagnosis for the veterinarian, as well as in routine health evaluation protocols in bears. Unlike other regions, such as the heart and intra-abdominal organs, the surface of the lung is able to be easily visualized using ultrasound, and artifact can be quickly detected. A simple portable unit without Doppler is also enough. The skills required to recognize any artifact can be easily learned. The utility of lung ultrasonography has been confirmed by a growing number of researchers and their studies, and is simple to perform, provided one thinks differently [27].

5. Acknowledgement

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