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Using Thoracic Ultrasound to Diagnose Bovine Respiratory Disease

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This review accompanies the relevant episode of the Cutting Edge veterinary podcast. In each episode of this podcast, 3rd year students in the University of Calgary's veterinary medicine program fill you in on the most up-to-date literature and evidence-based practices on topics that matter to you, the practicing veterinarian.

Introduction

Bovine Respiratory Disease (BRD) is a multifactorial disease that can result in severe bronchopneumonia or pleuropneumonia. It is the cause of 70-80% of total herd-level morbidity and 40-50% of herd-level mortality in North American feedlot cattle.[1] It is also known to be one of the leading causes of calf mortality and morbidity in pre-weaned dairy calves with an incidence of 22%.[2] The interaction between host, environment, and pathogens plays an important role in BRD risk and infections. The host's immune defenses can be altered and influenced by failure of transfer of passive immunity, nutrition, genetics, concurrent diseases, hydration status, and other factors.[3] Environment factors such as overcrowding, poor ventilation, stress, extreme weather conditions, and transportation can predispose animals to BRD. Viral infections can damage the host's tracheal epithelial cells, reduce the efficiency of the upper respiratory tract mucosa and mucociliary clearance mechanism, damage or deplete macrophages and neutrophils, and suppress the acquired immune system.[3] The most common viral respiratory pathogens involved are Bovine Viral Diarrhea Virus, Parainfluenza-3 Virus, Bovine Respiratory Syncytial Virus, Bovine Coronavirus, and Bovine Herpesvirus type 1.[3] The commensal and opportunistic bacteria believed to be associated with this costly and complicated disease are *Mannheimia haemolytica*, *Histophilus somni*, *Pasteurella multocida*, and *Mycoplasma bovis*.[1] Even though a variety of vaccines and preconditioning strategies are used to ward off this multifactorial disease, its presence in Canadian feedlots has remained relatively constant over the past 45 years.[1] It has been estimated that BRD costs the North American feedlot industry over three billion dollars annually due to mortality, reduced average daily gain (ADG), treatment costs, and other indirect costs.[1] In addition to significant morbidity and mortality in pre-weaned dairy calves, BRD has serious negative outcomes for growth and economic productivity in the dairy industry throughout many countries.[4,5,6,7]

Diagnosing Bovine Respiratory Disease

The clinical signs of BRD can range from subclinical to peracute death, depending on the severity of disease, host immunity, environmental factors, and pathogens involved, which makes detection of BRD-infected animals difficult for all involved. Clinical signs seen with BRD are depression, anorexia, ocular or nasal discharge, tachypnea, dyspnea, and head tilt.[3] Currently, auscultation of the lung field and trachea is the primary diagnostic tool used by most veterinarians, but this unfortunately has a sensitivity as low as 6%.[8] Clinical respiratory scoring (CRS), which assigns scores to a variety of animal health parameters, is another modality used to diagnose BRD. This diagnostic tool has an estimated sensitivity of 62% and specificity of 74%.[8] The DART system is a 4-point scoring system looking at an animal's mentation (depression), appetite loss, respiration character changes, and temperature elevation, and is used more in feedlot settings compared to the other scoring systems.[3] Two of the most common scoring systems include the Wisconsin BRD scoring system and the California BRD scoring system, both of which quantify nasal discharge, eye discharge, ear droop or head tilt, cough, and temperature.[9,10] Additionally, the California BRD scoring system assesses respiratory effort, while the Wisconsin BRD scoring system assesses fecal consistency.[9,10] The Wisconsin scoring system assigns a score between 0 and 3 for each parameter, where 0 is normal and 3 is most severe.[9] The California scoring system has different ranges for each category; Eye discharge, cough, respiratory effort, and temperature will be assigned a score between 0 and 2, whereas nasal discharge goes up to 4 and ear droop or head tilt ranges from 0 to 5.[10] There are currently different definitions of a positive test based on scoring. When these scoring systems were originally created, a score of 4 or more was considered diagnostic for BRD and would warrant treatment,[11] whereas others used a score of at least 5 to indicate a positive result.[12,13,14] A more recent recommendation is to classify a positive case of BRD as being a score of at least 2 in two or more of the defined categories.[15,16] This has been shown to decrease the prevalence of BRD positives based on CRS.[17] These scoring systems do not detect subclinical BRD, nor do they help differentiate between upper and lower respiratory disease, and they are limited by their low sensitivity. Therefore, alternative screening tests are required to improve early and accurate detection of BRD.[3,18] Bronchoalveolar lavage fluid (BALF) analysis is a direct and invasive method of sampling airways seldom used on farms.[19] The proportion of neutrophils and other pathogens found in the sample is analyzed and then used to determine the presence or absence of lung inflammation.[19] A study performed by Ollivett et al.[19] suggested that truly normal calves have a very low number of neutrophils in their airways and that a cut-off point of 4% BALF neutrophils should be used to diagnose a calf with respiratory disease. They concluded that using a 4% BALF neutrophil was associated with a sensitivity of 81% and a specificity of 75%. Ollivett et al.[19] also stated that many normal calves were removed from the study as they had neutrophil proportions over 10%, which is reflected in the low specificity of this testing modality. As there is currently a lack of an antemortem gold standard diagnostic test for BRD, many animals are either undiagnosed, diagnosed late in the disease process, or are falsely diagnosed with BRD, which can lead to worsening clinical symptoms, becoming chronically ill, or increasing resistance to antibiotics, respectively.[8]

Thoracic Ultrasound

Thoracic ultrasound (TUS) can be used to detect pleural effusion, lung consolidation, lung abscessation, lung necrosis, and pleural roughening, all of which are seen with clinical and subclinical bronchopneumonia often caused by BRD.[3,18] Ultrasound scans of a normal lung show a thin echogenic moving line (pleural line) with evenly spaced parallel echogenic lines deep to the pleural line (reverberation artifacts) (Figure 1).[20] Pulmonary abscesses can be seen when located on the surface of the lung, or in the case of a deep abscess, when the overlying lung tissue is compressed or atelectatic (Figure 2).[21] Lung consolidation can be seen as a hypoechoic, homogenous structure in the lung field, which is due to cellular infiltrates and cellular debris filling the lung tissue previously containing air.[18,22] When determining the extent of lung consolidation, the terms lobular and lobar lesions are used. Lobular lesions refer to discrete areas of consolidation within an aerated lobe, whereas a lobar lesion signifies a full thickness consolidation in the lung lobe.[18] With a lobular lesion, normal lung tissue can be seen both dorsal and ventral to the isolated, consolidated area (Figure 3).[23] With a lobar lesion, the hypoechoic parenchyma of the distal lung lobe is evident but no aerated lung can be seen ventral to the area of consolidation (Figure 4).[24] Diffuse pleural roughening is detected by the presence of comet tail artifacts in the lung field.[18] The lung field on cattle extends cranioventral from the tenth intercostal space (ICS) to the first ICS on the right and to the second ICS on the left.[18] The TUS technique used can be modified based on the reasoning behind the examination.[18]

A simple and efficient method of scoring TUS is by implementing a 6-point scoring system that avoids measuring lesions but rather assigns scores to lesions on each lung lobe and then sums these scores.[18] The presence of aerated lung with diffuse pleural roughening warrants a score of 1, lobular lung lesions are allotted a score of 2, and lobar lung lesions are given a score of 3 when found in one lobe and a score of 4 when found in two lung lobes.[18] This system assesses the cranial and caudal portion of the cranial lung lobe separately. Ultrasound (US) scores from 0 to 1 are considered normal and US scores higher or equal to 3 are indicative of a bacterial bronchopneumonia. Findings such as pneumothorax, pleural fluid, abscesses, and necrosis are not included in the scoring system, but the abnormalities need to be recorded.[18]

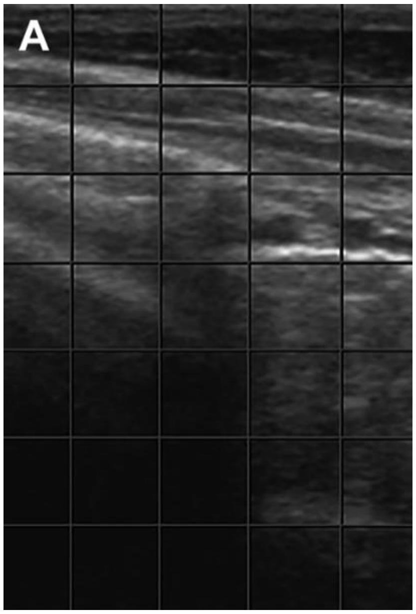

Figure 1. Normal aerated lung: Hyperechoic pleural interface and reverberation artifact can be seen in this cranial portion of the right cranial lung lobe.[20]

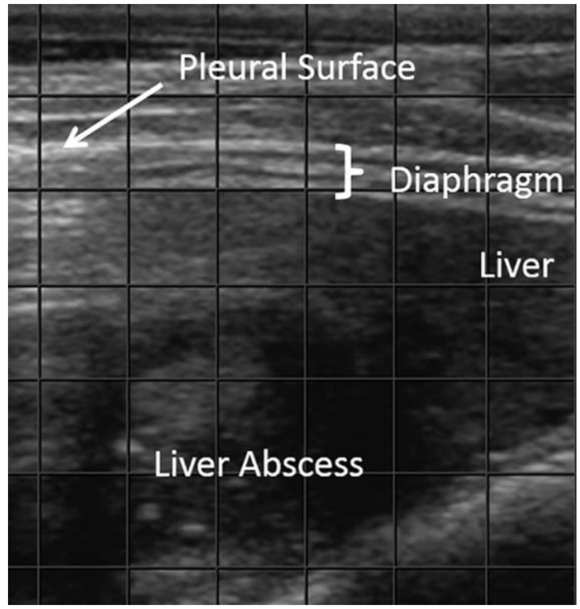

Figure 2. Liver Abscess: Seen on the ventral border of the right caudal lung lobe.[21]

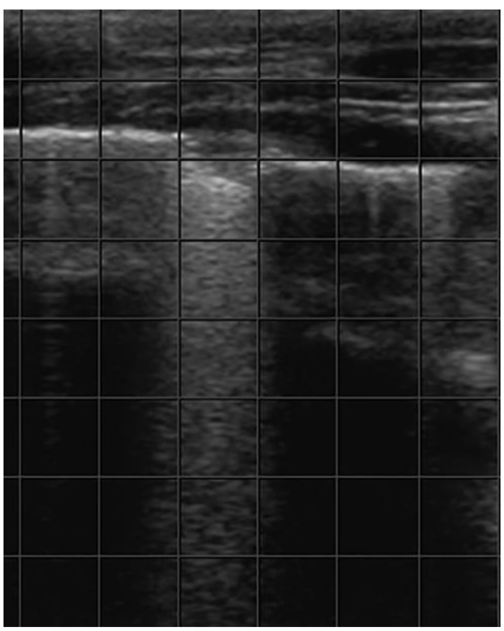

Figure 3. Lobular lung consolidation: Single discrete lobular lesion within normally aerated lung. Normal hyperechoic pleural interface with reverberation artifact seen both dorsal and ventral to the lobular consolidation lesion.[23]

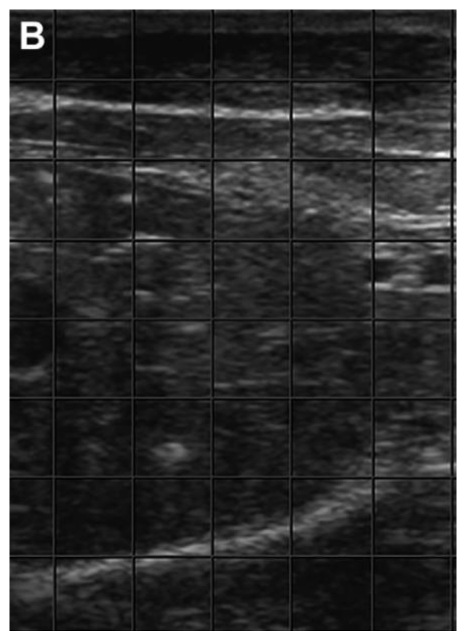

Figure 4. Lobar lung consolidation: Cranial aspect of the right cranial lung lobe with full thickness lung consolidation.[24]

There are currently variations on the way TUS is conducted in the literature. Focused lung ultrasound (FLUS) consists of scanning lung lobes that are most commonly affected by BRD, which includes the caudal portion of the cranial lobe on the right and left sides and the right middle lobe.[25] Pravettoni et al.[25] described the FLUS region as extending from the fifth to fourth ICS on both sides in order to include the lung lobes that are most likely to have lesions. The results of FLUS were compared to the more systematic TUS examination described by Ollivett and Buczinski,[18] which was considered the gold standard in this study. The TUS and FLUS were evaluated by different veterinarians, thus making it a blinded study, and the results showed that there was greater sensitivity for TUS compared to FLUS. However, a kappa coefficient was calculated to be 0.78, which indicates substantial agreement and that FLUS is an appropriate method to diagnose BRD. Another study was done using TUS on pre-weaned calves, and it indicated that including the cranial sites did not enhance the sensitivity of the test and may have actually decreased the specificity.[26] This contradicts the findings of Ollivett et al.,[19] as they extended the borders of TUS beyond the third ICS and found four calves that had severe lesions that were only cranial to the third ICS and would have been classified as normal without extending the borders of TUS cranially.

Thoracic Ultrasound versus Clinical Respiratory Scoring

Several studies have been done to evaluate CRS for the diagnosis of BRD and how it compares to the use of TUS. Lowie et al.[5] assessed the value of the Wisconsin and California BRD scoring systems compared to TUS. They assessed different production systems and breeds, including dairy, beef, and veal, for correlation of clinical signs with TUS. Depending on the type of production system, the sensitivity and specificity of the Wisconsin scoring system compared to finding lung consolidation of at least 1 cm on TUS ranged from 19 to 35.1% and 83.8 to 90%, respectively.[5] The California scoring system had a sensitivity ranging from 25.6 to 36.8% and a specificity of 70.5 to 91.6% when compared to lung lesions greater than 1 cm on TUS.[5] It is important to note that TUS is not a true gold standard and this is a limitation of the findings of this study. Porter et al.[27] did a study to compare the findings of TUS and Wisconsin scoring methods to lung pathology, which is considered a gold standard. This study used *Mannheimia haemolytica* and BRSV-infected dairy calves. They found that ultrasound scoring was more representative of lung pathology compared to Wisconsin scoring systems.[27] However, lung pathology is not necessarily indicative of an active infection but is reflective of either a current or past infection, and the pathology will change as they recover from infection. Thus, it can be difficult to distinguish between an active subclinical infection and recovering infection using TUS methods without knowing the history of clinical signs. Another study assessing the association between clinical signs and TUS in pre-weaned dairy calves found that 28% of calves had subclinical BRD that was detected using TUS, but not using CRS.[6]

Thoracic Ultrasound and Treatment Decisions

As TUS seems to be a more sensitive diagnostic test compared to CRS for identifying bronchopneumonia lung lesions, the hope is that this tool can be utilized to develop more effective BRD treatment plans.[4] In particular, researchers want to know if TUS has the potential to inform decisions around antimicrobial use in the treatment of BRD.[4] In a randomized clinical trial done by Binversie et al.,[4] dairy calves from two commercial Wisconsin dairy farms were evaluated twice-weekly from shortly after birth until weaning at 56 days old. Researchers used a combination of CRS, TUS lung scoring, fecal scoring, and heart girth measurement to evaluate the overall health and growth of the calves. Using both CRS and TUS lung scores, the first detection of BRD included a range of disease presentations: upper respiratory tract infection, subclinical and clinical lobular pneumonia, and subclinical and clinical lobar pneumonia. Upon this first detection of BRD, calves were randomized into a treatment or placebo group, with the treatment group receiving a first-line antibiotic immediately. The placebo group calves who were initially subclinical only received the first-line antibiotic if they later developed clinical respiratory disease or distress. Similarly, the placebo group calves who were initially clinical could receive the first-line antibiotic if they later progressed to respiratory distress. With this study design, researchers were hoping to determine if earlier detection of BRD and prompt antibiotic treatment would lead to improved lung health, greater ADG, and decreased pre-weaning mortality. The results of the study showed some advantages to earlier detection and treatment, including slowing the progression of lung consolidation, improved growth, decreased mortality, and decreased need for retreatment within seven days of initial BRD detection. However, calves in the treatment group did not have a decreased chance of having lung consolidation at weaning compared to the placebo group calves, and both groups had equal likelihood of undergoing a full treatment protocol using second- and third-line antibiotics. Importantly, it was noted that differences in management between the two herds likely contributed significantly to the post-treatment outcomes, including differences in nutrition, stocking density, and specific pathogen presence. These herd-level differences in outcomes are supported by the fact that 98% of deaths in calves that had BRD were from one of the two herds.[4] Cuevas-Gomez et al.[6] studied BRD incidence in male dairy calves based on diagnosis using CRS and TUS. They recognized that the differences in various management systems contribute to differences in research findings when studying the accuracy of BRD diagnostic approaches, and that male dairy calves may face different stressors involving transportation, housing and diet changes, and greater co-mingling compared to heifer dairy calves. Despite management system differences, it remains clear that TUS can be used in conjunction with other diagnostics such as CRS to detect BRD earlier in pre-weaned calves of various production systems.[4,6]

Other studies that support TUS being a more accurate way of diagnosing BRD conclude that it cannot be used singly as a tool to inform antibiotic treatment decisions.[4,5,6,7] Binversie et al.[4] showed that even if calves were treated two or three times following CRS and TUS diagnosis, 70% of those calves would still have lung lesions on TUS at weaning, which shows that TUS cannot be solely relied upon for treatment without knowing the management, health status, and history of a particular herd. Furthermore, TUS cannot be used to distinguish between acute and chronic lung lesions, and timing of pathology may vary based on the pathogens involved.[5,7] Notably, Lowie et al.[5] found that cough was the clinical sign most significantly associated with ultrasonographic lung lesions in pre-weaned calves among dairy, beef, and veal production systems in Belgium, including Holstein-Friesian and Belgian Blue breeds. Cuevas-Gomez et al.[6] also noted a moderate positive correlation between cough and a TUS score of 4 (complete consolidation in at least one lung lobe and/or pulmonary emphysema). Buczinski et al.[7] studied herd-level prevalence of TUS lung lesions and the potential associated risk factors in 39 Quebec dairy herds. The results showed that season, pre-weaned group housing, and producer-perceived problem of BRD were all associated with the presence of TUS-diagnosed lung consolidation. These findings can potentially be used to inform producers and veterinarians alike regarding monitoring for signs of respiratory disease, and to help efficiently and easily identify animals that may require further diagnostic investigation through methods such as TUS.[5] Veterinarians are educated and trained to base diagnostic and treatment decisions on the full clinical picture and not just on a single clinical sign or diagnostic test result. Therefore, TUS is an effective tool to add to veterinarians' resources to more accurately diagnose BRD.

A study done by Timsit et al.[28] showed that the severity of lung lesions on TUS can guide prognosis and management decisions. They measured the depth and area of lung consolidation lesions, the number of comet tails, and the depth of pleural effusion and compared these findings to the risk of relapse. The depth and area of lung consolidation were correlated with negative prognosis, which was defined as showing signs of BRD four days post-treatment, while the number of comet tails and the depth of pleural effusion were not predictive of negative prognosis.[28] Understanding the prognosis based on these measurements of TUS could potentially be used to guide feedlot management of BRD, although there has not been further research done on this. Furthermore, TUS shows potential for monitoring long-term herd performance, such as replacement heifer productivity.[7]

Ollivett and Buczinski[18] show that TUS is an effective tool to monitor outcomes from management changes, such as improved ventilation or vaccination protocols. First, in order to promote management changes to improve overall herd health, veterinarians can utilize TUS to demonstrate to producers if there are concerns with the BRD profile in their herd.[18] The BRD profile determines the distribution of healthy animals and animals with different BRD subtypes in a given herd, including subclinical pneumonia, clinical pneumonia, and upper respiratory disease.[18] For example, if a group of pre-weaned dairy calves has a large proportion of subclinical BRD diagnosed through TUS, the veterinarian can help the producer realize the extent of the BRD problem, investigate potential causes, and promote management changes to improve herd health and productivity. Following up with periodic TUS scans can help determine if a given BRD situation, such as a herd suffering from subclinical BRD, is improving following management changes, as shown by improved lung health on TUS.[18]

Future Applications of Thoracic Ultrasound

TUS is a promising tool that can potentially be used to inform management decisions to promote welfare, productivity, and antimicrobial stewardship. However, using TUS to guide BRD diagnosis and treatment decisions may not always be practical, as it requires more training compared to CRS methods, is difficult to perform in older animals,[16] and should not be relied on as a diagnostic tool on its own.[4,5,6,7] Based on our findings, it could be used as a herd health monitoring tool in conjunction with CRS systems in populations that are more susceptible, which would include pre-weaned dairy calves[7] and feedlot cattle.[28] It is becoming more widely used in dairy calves for monitoring BRD, but the practicality of using it in feedlot cattle appears to be a barrier. The method of FLUS is one that could be used for diagnosis in these older feedlot cattle because the inability to access the cranial aspect of the lung field creates limitations when performing TUS.[25,28] Further research about the cost effectiveness of using TUS in feedlot settings and whether it could help reduce metaphylactic treatment would be beneficial. The future applications of TUS are promising, with the hope that veterinarians, producers, and animals from various bovine production systems will benefit significantly from its utilization in BRD diagnosis and management.

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20. Ollivett TL, Buczinski S. On-farm use of ultrasonography for bovine respiratory disease. Veterinary Clinics of North America: Food Animal Practice. 2016 Mar;32(1):19–35. Fig. 7. Reverberation artifact and a hyperechoic pleural interface define the normal, aerated lung (A); p. 27. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0749072015000651
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Ultrasonographic image from the right 6th to 10th ICS at the ventral border of the right caudal lung lobe as denoted by the diaphragm and liver; p. 25. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0749072015000651
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