

# Utilization of point-of-care evaluation to determine prognosis in feedyard cattle with multiple previous respiratory disease treatments

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## Abstract

Determining prognosis to differentiate recoverable and non-recoverable cattle is a critical knowledge gap impacting animal welfare and economic sustainability. Point-of-care (POC) diagnostics could provide prognostic insight. This study aims to determine potential associations between negative outcomes (mortality/culling) and POC evaluations of chronic respiratory cases. A cross-sectional study evaluated commercial beef feedyard cattle at their third or greater treatment for respiratory disease (n = 98, 799 ± 16 lb [362 ± 7 kg]; Steer, n = 37; Heifer, n = 61). Post-evaluation outcomes were classified as did not finish (DNF) (DNF = mortality/culling) or recovered (still present in feeding system) 60-days post-enrollment. Captured POC parameters were: sex, days on feed, body weight, pulse oximetry, pulmonary auscultation score at cranio-ventral lobe/caudo-dorsal lobe, and targeted thoracic lung ultrasound imaging. Multivariate logistic regression was used to evaluate potential associations between DNF and POC parameters. Only ultrasound variables (B-line count, moth sign and B-line area) were significantly ( $P < 0.05$ ) associated with DNF. Cases with B-line count  $\geq 3$  had higher probability of DNF (84% ± 5%) compared to cases with  $< 3$  B-lines (34% ± 22%). Presence of moth sign was associated with higher DNF (78% ± 13%) compared to cases with no moth sign (43% ± 15%). Average B-line area was higher (18.7 ± 1.2 cm<sup>2</sup>) in DNF cases compared to recovered cases (9.6 ± 1.2 cm<sup>2</sup>). Strategic use of targeted thoracic POC ultrasound has potential usefulness for determining prognosis for chronically ill respiratory cases; offering valuable insights for treatment and management decisions in feedyard cattle health.

**Key words:** bovine respiratory disease, chuteside diagnostics, feedlot cattle, thoracic ultrasonography

## Introduction

Respiratory diseases in feedyard cattle represent a significant challenge to both animal welfare and the economic sustainability of the livestock industry. Bovine respiratory disease (BRD) is the leading causes of morbidity and mortality in feedyard operations, resulting in substantial financial losses due to decreased productivity, increased veterinary costs, and mortality.<sup>1-3</sup> The complex etiology of respiratory conditions in cattle, often involving a combination of viral and bacterial pathogens, environmental stressors and management practices, complicates both diagnosis and prognosis.<sup>2,4-6</sup> There is a need for estimating the degree of pulmonary injury to be able to choose the correct treatment strategy and management interventions. Treatment decisions are made at the point-of-care (POC), which is chuteside, and the inability to provide an accurate prognosis for pneumonia is a problem.

The economic impact of chronically diseased BRD cattle can be substantial. Defining chronic disease varies among operations; yet, cattle treated 3 or more times for BRD are often considered chronic. A study has shown carcasses of cattle treated multiple times were worth \$54.01 less compared to cattle that were never treated.<sup>7</sup> Another study calculated net return (\$/animal) of -\$227 for cattle treated  $\geq 3$  times for bovine respiratory disease, accounting for slaughter value, processing costs, treatment costs, feed costs and other costs.<sup>8</sup> Booker discussed salvage slaughter of chronically diseased cattle and estimated a gross return of 25-50% of the original purchase cost, which would not cover feed costs, treatment cost and any expense invested on that animal.<sup>9</sup> Economic losses from chronic illness can be substantial; however, identifying cattle as recoverable or non-recoverable allows operations to make informed decisions impacting both animal welfare and economic sustainability. The substantial economic impact of chronically ill cattle shows the need for effective management, making the use of chuteside diagnostic tools crucial for improving prognostic accuracy and treatment decisions.

Diagnostic tools, such as rectal temperature,<sup>10,11</sup> facial infrared thermography,<sup>10,11</sup> pulse oximetry,<sup>12</sup> computer-aided lung auscultation,<sup>13</sup> traditional auscultation,<sup>10,14</sup> and POC ultrasound, have shown promise in enhancing the accuracy of respiratory disease diagnosis in cattle.<sup>15-21</sup> Diagnostics at POC is a promising approach for real-time evaluation of diseased cattle, which facilitates the identification and improved prognostic accuracy for different respiratory conditions.<sup>22-24</sup> While research has been conducted in cattle at the first treatment for respiratory disease,<sup>24</sup> no work has been published describing prognostic factors for cattle with multiple previous BRD treatments. After feedyard cattle have received multiple treatments, the overall prognosis is worse than at initial treatment,<sup>25,26</sup> and evaluation of cattle being treated for the third or greater time is an important decision point to determine if the animal is recoverable or non-recoverable. While several POC tools are available, little work has evaluated potential relationships with specific cattle outcomes such as the probability to finish the feeding phase.

This study aims to evaluate prognostic ability of quick POC measures by determining potential associations between the probability of DNF outcome (mortality or culling) with POC parameters (pulmonary ultrasound, pulse oximetry, lung auscultations, and cattle demographics) observed at the time of treatment in feedlot cattle with chronic (treated 3 or more times) BRD. Fast and more accurate prognosis enables deployment of strategic therapeutic and management decisions ultimately improving animal welfare and economic sustainability.

## Materials and methods

The study was approved by the Kansas State University Animal Care and Use Committee (IACUC #4897).

### Experimental design and enrollment criteria

This experiment was designed as a cross-sectional observational study with individual cattle as the experimental unit ( $n = 98$ ). Feedyard cattle respiratory morbidities were evaluated at the time of third or greater BRD treatment by the use of various POC approaches by a trained veterinarian (LF). Data collection took place from July to December 2023, at one feedyard in the High Plains region of the United States.

Cattle enrolled in the study were evaluated at the time of treatment for chronic respiratory disease. Chronic respiratory disease was defined as feedyard cattle that had been treated previously for any respiratory disease and the cumulative respiratory disease treatment events at time of POC was 3 or greater. A total of 98 animals were enrolled in the study based on this criterion, with 51% (51/98) third BRD pull; 43% (42/98) fourth BRD pull; and 5% (5/98) 5<sup>th</sup> BRD pull. Variables collected were: targeted thoracic POC ultrasound (TT-POCUS) at the level of the right caudodorsal lung lobe, pulse oximetry (SPO2 and pulse rate per minute), pulmonary auscultation on the right cranioventral lung field and right caudodorsal lung field, and individual animal demographics (sex, body weight and days on feed). Feedyard personnel were blinded to the POC evaluation, and any management decision regarding treatment, re-treatment and culling for the cattle observed in this cross-sectional study at time of treatment and after were made solely by feedyard personnel using existing protocols in place. Furthermore, animals enrolled in this study were not submitted to a different operational protocol, including treatment regimen, cattle monitoring and any other management decision.

### TT-POCUS

In this study, enrolled commercial feedyard cattle underwent a TT-POCUS method, with cattle restrained in a hydraulic squeeze chute. Due to the fast-paced environment of the commercial feedyard, each ultrasound examination was limited to 60 seconds. The evaluation focused on the right caudodorsal lung lobe, with the probe positioned between the 8<sup>th</sup> and 11<sup>th</sup> ribs. The ultrasound unit<sup>a</sup> had a frequency range of 1 to 10 MHz and featured a specialized point-of-care probe with a 5 cm x 3 cm footprint, the preset utilized for these evaluations was the “Lung” preset, which is optimized for lung assessments. To prepare the scanning area, 70% isopropyl alcohol was applied to the animal in the area to be scanned, and no hair trimming or shaving was utilized.

The TT-POCUS procedure was accomplished with probe placement between the ribs (short-axis orientation), starting at the 11<sup>th</sup> intercostal space. The probe was moved from the proximal aspect of the intercostal space, just ventral from the transverse processes, sliding the probe ventrally to visualize the liver, diaphragm and caudal portion of the lung. This process was repeated from the 11<sup>th</sup> to 8<sup>th</sup> intercostal space. In addition to sliding the probe, a “fanning” technique was employed, adjusting the probe angle relative to the skin to enhance the visualization of pulmonary tissue between ribs.

Real-time data collection from the TT-POCUS evaluation was conducted by a trained veterinarian (LF), examples of TT-POCUS images are displayed on Figure 1. The collected variables

included ultrasound lung scores (ULS), B-line count, A-line count and the presence or absence of pleural effusion and pleural abnormalities (moth sign). A-line is an ultrasound artifact that is characterized by a hyperechoic horizontal line that is defined to be reverberation of the pleural line; this artifact is observed in abundance on normally aerated lung. B-line is also an artifact that presents vertically in a beam like projection, often starting at the pleura line going across the lung field, 3 or more B-lines in a lung field is generally associated with lung injury and poor aeration. The ULS were classified as follows: Score 1 – presence of fewer than 3 thin B-lines (indicative of healthy lung); Score 2 – presence of 3 or more thin B-lines; Score 3 – merged B-lines; Score 4 – multiple wide/merged B-lines with abnormal pleural findings (moth sign); Score 5 – consolidated lung. B-line count was determined by counting the number of B-lines on the lung field with the most apparent abnormalities; A-lines were counted using the same criteria as B-line count, with the only difference being A-lines are reverberation of the pleural line (horizontal artifacts), and B-line are vertical beams that go across the lung field. Moth sign and pleural effusion were determined by having presence or absence of these abnormalities during scanning of 8<sup>th</sup> to 11<sup>th</sup> intercostal spaces. Post-hoc variables included measures of image brightness and B-line width, specifically pixel intensity density, average gray value, and B-line area (cm<sup>2</sup>). These measurements were obtained from a single frame of the 60-second video clip using ImageJ 1.54b software,<sup>b</sup> focusing on the frame with the most noticeable tissue abnormalities to assess injury within the caudodorsal lung region.

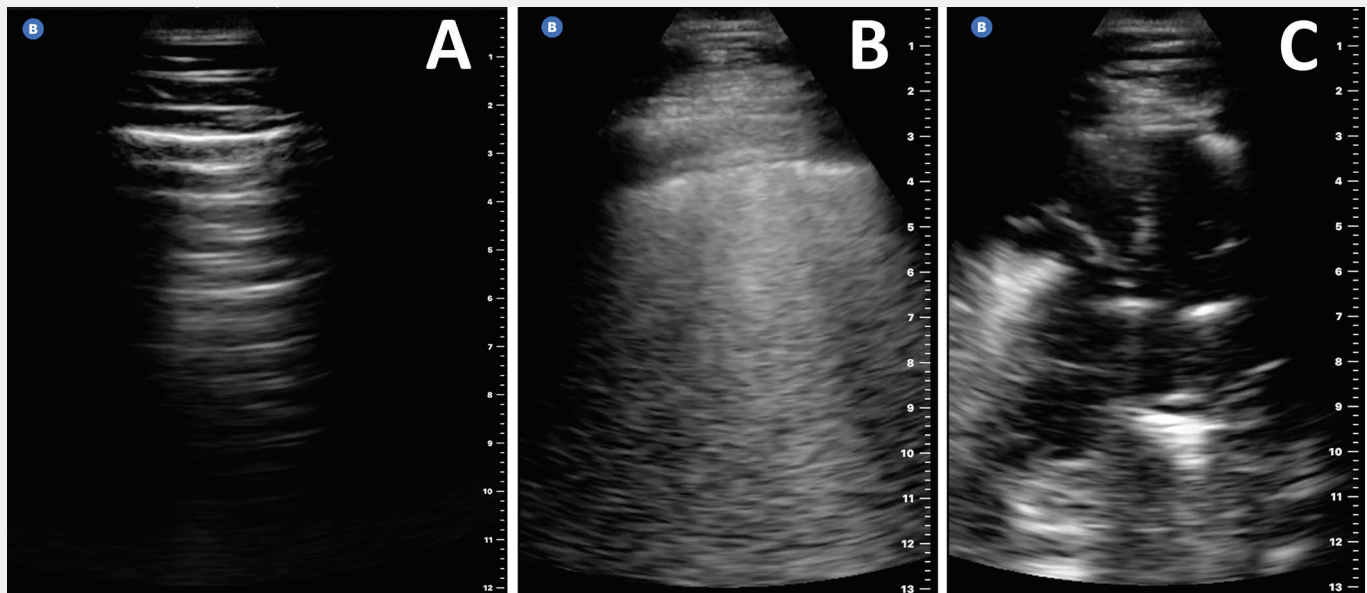
### Pulse oximetry

Cattle restrained in the squeeze chute were evaluated with a pulse oximeter unit<sup>c</sup> equipped with a transreflectance sensor<sup>d</sup> to collect blood oxygen saturation (SPO2) and pulse per minute (PPM) data. After cleaning debris and cerumen, the sensor was placed midway between the ear ribs by a trained veterinarian (LF); within 15 seconds, the transreflectance signal would stabilize to allow for data annotation. The external ear was chosen as the area for evaluation due to the safe and quick access to bare skin.

### Pulmonary auscultation score

Feedyard cattle were restrained in a squeeze chute, and auscultation scores for examinations lasting < 30 seconds for each of 2 fields (caudodorsal and cranioventral) were recorded. Stethoscope<sup>e</sup> placement for these evaluations took place on the right caudodorsal and cranioventral lung fields. In this study, lung auscultation for both fields and all cattle were carried by the same trained veterinarian (LF). Specifically, the cranioventral pulmonary assessment score took place between the 4<sup>th</sup> and 5<sup>th</sup> rib on the right side of the animal, caudal to the radio-ulnar joint (CVPAS). The other auscultation field, the caudodorsal assessment, took place between the 8<sup>th</sup> and 9<sup>th</sup> rib on the right side of the animal at the level of the proximal third of the intercostal space (CDPAS). Pulmonary auscultation score (PAS), was defined in a modified score system based on previous published work,<sup>10</sup> where scores were condensed from the range 1 to 10, to 1 to 5, where: 1 – normal lung sounds; 2 – presence of mild crackles/rales; 3 – presence of moderate crackles/rales; 4 – presence of severe crackles/rales; 5 – presence of severe diffuse crackles/rales.

**Figure 1:** (A-C) Targeted thoracic point-of-care ultrasonography (TT-POCUS) images displaying different ultrasonographic artifacts and degrees of lung injury. Figure 1A TT-POCUS-obtained image showing a normal lung observation: pleural reflection (A-lines), absence of B-lines, and smooth pleura, which would be classified as ultrasound lung score (ULS) of 1; Figure 1B shows merged B-lines, diffuse hyperechoic lung, with an overall ultrasound lung score (ULS) 3; Figure 1C displays TT-POCUS-obtained image showing lung consolidation, absence of A-lines, and an overall (ULS) 5.



The primary outcome of this study was DNF, which was determined 60 days post-enrollment (POC day). The three possible outcomes at 60-days were: culled, died or lived. The DNF outcome was a combination of cattle that failed to recover from respiratory disease in the 60-day interval (culled + died). Treatment interventions or culling decisions were solely determined based on feedlot personnel assessment, which were blinded to the POC evaluations.

## Statistical analysis

Microsoft Excel<sup>f</sup> (Microsoft Excel, Microsoft 365) and RStudio<sup>g</sup> (RStudio, version 2023.12.1) were utilized for data management, processing and analyses. For descriptive analysis, a table comparing the outcome variables was constructed using the “dplyr” and “tidyr” packages in RStudio.

The variables body weight, days on feed, B-line count, and A-line count were categorized prior to data analysis to avoid assumption of linear relationships with the primary outcome of did not finish (DNF). Body weight (BW) categories were: < 600, 600-799, 800-1,000, > 1,000 lb (< 272, 272-361, 362-453, and > 453 kg), and days on feed (DOF) were categorized similar to previous work into early (0-42), mid (43-71), and late (> 71) DOF.<sup>27</sup> The B-line count was categorized into less-than or greater-than-or-equal-to 3 B-lines similar to previous work.<sup>28</sup> Finally, A-line count categories were categorized as < 3 and ≥ 3 similarly to B-line categories. Other categorical variables were: sex, pleural effusion, moth sign, ULS and PAS. Variables analyzed as continuous were: pixel intensity density, average gray value, B-line area, SPO2 and PPM.

The data analysis employed a generalized linear mixed-effects model implemented through the ‘glmer’ function from RStudio’s ‘lme4’ package. To appropriately address the binomial response variable, the ‘logit’ function in RStudio was applied, the degree of significance was set at  $P < 0.05$ . The primary

outcome of interest was the 60-day status, specifically assessing the association of POC parameters with the odds of DNF. Cattle lot was used as a random effect in all models to account for a lack of independence in cattle managed and housed in similar fashions. Model development involved using the ‘scope’ parameter to ensure that fixed variables (sex and days on feed) were consistently included across model iterations. Stepwise selection was performed in a backward direction using the ‘stepAIC’ function from the ‘MASS’ package in RStudio, iteratively removing the least significant variables based on the lowest AIC values. Multicollinearity (VIF) was also assessed when final model was determined using the ‘car’ package in RStudio. Variables were considered to have high collinearity when a coefficient was estimated to be > 2.5.<sup>29</sup> The log-odds from the logistic regression model was then converted to probabilities using the package ‘emmeans’ in RStudio.

## Results

### Descriptive statistics

At the time of third or greater respiratory treatment event, 98 cattle were POC evaluated. Pull count breakdown in this population was: 51% (51/98) third BRD pull; 43% (42/98) fourth BRD pull; and 5% (5/98) fifth BRD pull. Only 72 of the 98 cattle were evaluated with pulse oximetry and pulmonary auscultation due to a protocol deviation where these parameters were added to the study after 26 cattle were already enrolled. There were 61 heifers (62%), and 37 steers (38%) enrolled with descriptive statistics listed in Table 1. There were 19 cases (19%) in the early feeding phase (0-42 DOF) category, 39 cases (40%) in the mid feeding phase (43-71 DOF) category, and 40 cases (41%) in the late feeding phase (> 71 DOF) category. Seventy-five percent of the 98 cases were within the 600-799 lbs (272-361 kg) and 800-1,000 lbs (362-453 kg) categories. Most cases DNF ( $n = 63$ , 64%) within the 60-day post-evaluation period and 35 cases were deemed recovered (36%).

**Table 1:** Descriptive statistics of cattle according to their demographics (sex, weight and days on feed categories), real-time chuteside evaluations (ultrasound lung score, blood oxygen saturation, pulse, auscultation scores, A-line count categories, B-line count categories, pleura effusion, moth sign; and post-hoc evaluations [B-line area, gray value, intensity density]).

	60-day outcome	
	Recovered <sup>1</sup>	DNF <sup>2</sup>
Enrolled cattle	35	63
Sex		
Heifer	22	39
Steer	13	24
Days on feed at enrollment categories		
0 to 42	6	13
43 to 71	18	21
> 71	11	29
Body weight, average (SD), lb	831.48 (± 155.0)	779.68 (± 152.8)
Body weight, categories, lb		
< 600	4	9
600 to 799	9	26
800 to 1,000	18	21
> 1,000	4	7
Real-time measurements		
Ultrasound lung score, head*		
1	5	0
2	11	9
3	13	22
4	5	27
5	1	5
Blood oxygen saturation (SD), %* <sup>§</sup>	86.5 (± 7.5)	82.2 (± 9.6)
Pulse, average (SD), PPM* <sup>§</sup>	78 (± 20.3)	72 (± 19.8)
Auscultation score (cranioventral), head* <sup>§</sup>		
1	2	0
2	7	1
3	11	13
4	7	10
5	3	18
Auscultation score (caudodorsal), head* <sup>§</sup>		
1	9	3
2	12	10
3	5	11
4	3	11
5	1	7
A-line count, head*		
0 to 2	6	31
≥ 3	29	32

**Table 1 Cont'd.**

B-line count, head*		
0 to 2	18	2
≥ 3	17	61
Pleural effusion, head*		
Absent	28	50
Present	7	13
Moth sign <sup>†</sup> , head*		
Absent	29	35
Present	6	28
Post-hoc measurements <sup>‡</sup>		
B-line area, cm <sup>2</sup> , average (SEM)	9.6 (± 1.2)	18.7 (± 1.2)
Gray value, average (SD)	100.8 (± 47.5)	110 (± 40.4)
Intensity density, average (SD)	16 (± 7)	18 (± 7)

<sup>1</sup> Cattle that were alive 60-days post-evaluation.

<sup>2</sup> Cattle that were culled or dead within 60-day post-evaluation.

\* Variables collected at chuteside real-time.

<sup>†</sup> Moth sign is noted when the pleural line shows irregularities like pleural thickening and indentations.

<sup>‡</sup> Post-hoc measurements were performed by using the ImageJ 1.54. Measurements were taken from a still image, where the frame of choice was the frame with most ultrasonographic artifacts and abnormalities.

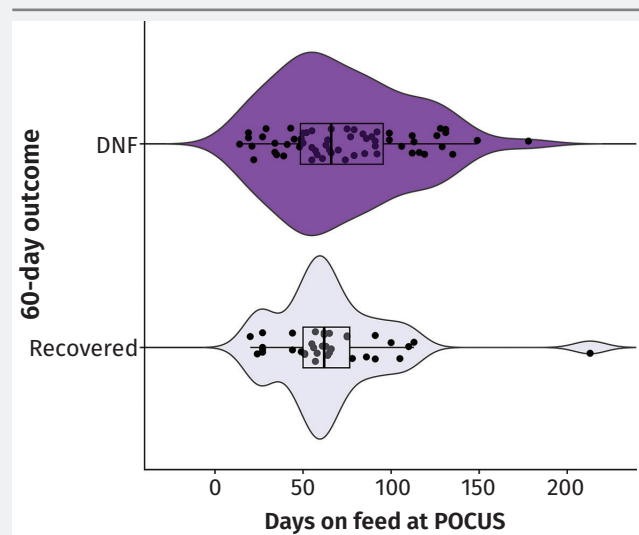
<sup>§</sup> Only cattle enrolled in the fall (n = 72) were evaluated with pulse oximetry and pulmonary auscultations.

The distribution of cases enrolled by DOF at time of treatment grouped by 60-day outcome indicate that DNF cases occurred dispersed throughout the feeding period (median of 66 DOF and interquartile range [IQR] 19-113 DOF). In contrast, recovered cases display an apparent narrower distribution with a median of 62 DOF and IQR 36-88 DOF (Figure 2).

Descriptive statistics for POC measures are listed in Table 1. Assessment by TT-POCUS revealed most cases (73/98, 74%) were ULS 3,4 or 5. Most cases also had ≥ 3 A-lines (61, 62%) and B-lines (78, 79.5%). Blood oxygen saturation (%) averaged 86.5% ± 1.4% for cattle that recovered and DNF cases averaged 82.2% ± 1.5%. Pulse (PPM) averaged 78 ± 4 PPM for cattle that recovered and 72 ± 3 PPM for DNF. Cranioventral PAS indicated that 10% of cattle placed in scores 1 and 2 had a DNF outcome, whereas, 56% of cattle with scores 3 and 4 DNF; 86% of cattle with cranioventral PAS of 5 had an outcome of DNF. Caudodorsal PAS indicated that 40% of cattle placed in scores 1 and 2 DNF, while, 73% of cattle with scores 3 and 4 DNF; and 87% of cattle with caudodorsal PAS of 5 DNF.

The multivariate logistic regression identified only 3 variables associated with DNF: B-line count category, moth sign and B-line area ( $P = 0.02$ ,  $P = 0.03$  and  $P = 0.04$ , respectively). Although, included in the model as fixed variables, sex and DOF were not significantly associated with DNF ( $P = 0.75$  and  $P = 0.20$ , respectively). Variables not significantly associated with DNF outcome and therefore not selected by the study's multivariate logistic regression were: BW, ULS, A-line category, presence of pleural effusion, pixel intensity density, average gray value, SPO<sub>2</sub>, pulse rate, and both PAS scores ( $P > 0.05$ ). No variables were removed from the final model due to collinearity.

**Figure 2:** Raincloud-boxplot displays temporal distribution of the days on feed at time of chuteside evaluations (POC) on individuals enrolled in this study (n = 98). Sixty-day outcome of DNF = did not finish (cull/death), recovered = cattle that were alive at the 60-day post-evaluation. Box-plot represent the upper and lower quartiles, and the line within the box represents the median.



Tukey-adjusted probabilities using the fitted model showed the probability of DNF was lower when B-line < 3 (34% ± 22%) compared to when B-line ≥ 3 (84% ± 5%). Presence of moth sign displayed higher probability of DNF (78% ± 13%) compared to when moth sign was absent (43% ± 15%). The post-hoc continuous variable B-line area showed an average of 18.7 ± 1.2 cm<sup>2</sup> for cattle that did not finish compared 9.6 ± 1.2 cm<sup>2</sup> for cattle that recovered.

## Discussion

Chronic respiratory disease represents a significant challenge in cattle management including differentiating between cattle likely to recover and cattle likely to be unresponsive to further treatment.<sup>30-32</sup> This study evaluated multiple POC modalities in chronically diseased cattle to determine potential associations with the likelihood of DNF. While several POC metrics were not associated with clinical outcomes, some of the TT-POCUS variables could provide insight to improve prognostic accuracy. Accurate prognosis classification is crucial for improving animal welfare and economic sustainability.

An accurate description of, or industry-wide acceptance of, a chronically diseased respiratory case-definition is lacking. Some reports define chronic cases based on extent of pulmonary lesion as identified by ultrasonography,<sup>30,31</sup> while other reports define chronic cases by the use of a computer-aided auscultation device,<sup>13</sup> and others define chronic cases as cattle with repeated unsuccessful treatment interventions.<sup>7,33,34</sup> In this study, chronic BRD disease was defined as 3 BRD treatments or greater. A majority (64%) of outcomes for cattle in this study population were classified as DNF, meaning enrolled cattle had either died or were culled within the 60-day evaluation period. These numbers are similar to previous work: in 2020, Blakebrough-Hall et al observed 58% mortality in cattle deemed chronic (≥ 3 treatments).<sup>8</sup> The current study population was representative of chronically diseased feedyard cattle.

The results of our multivariate logistic regression analysis identified key variables significantly associated with the DNF outcome. In this multivariate logistic regression, variables were selected based on the best model fit, using Akaike Information Criterion (AIC) as the selection criterion. During the stepwise selection process, if one variable had a stronger association with the outcome, another variable with a weaker or redundant association might have been dropped from the model due to its lack of additional predictive value. This occurs because AIC-based selection prioritizes the optimal model, retaining only variables that significantly contribute to model fit while eliminating those with overlapping or weak effects. Among all the variables tested, the three variables associated with the model were derived from TT-POCUS: B-line category, presence of moth sign, and B-line area. The presence of more than 3 B-lines was associated with higher likelihood of DNF compared to cattle with fewer than 3 B-lines and the results illustrated a good distinction from the baseline overall DNF risk. Results agreed with several reports illustrating the importance of B-line and pleural observation in thoracic ultrasound evaluation in both human and veterinary medicine.<sup>28,35-38</sup> Studies in human medicine have similarly demonstrated that increased B-line counts are strongly correlated with severe lung diseases and poorer prognoses, which supports our findings in cattle.<sup>38,39</sup> Utilizing a POC B-line count could provide information on prognosis in chronically diseased cattle.

The presence of moth sign was another significant indicator of poor prognosis, with a 78% probability of DNF when the moth sign was present, compared to 43% when it was absent. Moth sign is often associated with advanced pulmonary pathology, including consolidation, sub-pleural fibrosis, and severe interstitial changes, which are difficult to reverse, particularly in chronically affected cases.<sup>28,38,39</sup> Finally, the post-hoc variable B-line area revealed a significant difference between cattle that did not finish (DNF) and those that recovered. Merged B-lines (coalescent or fused), could be indicative of extensive lung pathology thereby contributing to poor outcomes. Interestingly, the post-hoc B-line area did not display collinearity with B-line count categories, suggesting that B-line area can provide additional context, perhaps accounting for B-line merging. Both B-line count and B-line area provided separate pieces of information to the final multivariable model; however, B-line count remains the more feasible and easily interpretable metric for field application.

Pulse oximetry parameters, including blood oxygen saturation (SPO2) and pulse rate, were not associated with the DNF outcome despite being relevant indicators of respiratory function in clinical settings.<sup>23,40</sup> The lack of association in this study could also be attributed to the site utilized to place the sensor (external ear). In 1999, Coghe et al. evaluated the accuracy of different sites for sensor placement in cattle, where he observed that nasal septum, tail and genital mucosa in females provided stable and strong signals.<sup>40</sup> In 2019, Baruck and associates also evaluated SPO2 to assess bovine respiratory disease progression; where it was observed that SPO2 could provide an objective measure of lung consolidation; their creative apparatus allowed for sensor placement intranasally to reach nasal folds.<sup>23</sup> Another potential limitation is that pigmented hide or skin has been often reported to be a contributing factor for inaccuracies, since majority of the cattle investigated were Angus-cross cattle with predominately black hides.<sup>41-43</sup> The type of measurement may not be the only factor influencing the relationship between SPO2 and outcomes as previous work that measured SPO2 from arterial blood also displayed no relationship between SPO2 and the level of lung lesions at necropsy.<sup>44</sup> Findings from this work did not illustrate a relationship between SPO2 or pulse and predicting accurate prognosis in chronically ill cattle.

Pulmonary auscultation scores (PAS) for both the cranioventral and caudodorsal lung areas did not demonstrate a significant association with DNF outcomes in our multivariate model. Buczinski et al. (2014), tested the ability of pulmonary auscultation to detect lung consolidation and observed sensitivity of < 6% and 97% specificity.<sup>18</sup> Previous research has also indicated that auscultation is valuable for detecting bovine respiratory disease,<sup>10,14</sup> although, it may lack the sensitivity needed to predict long-term outcomes in chronic cases.<sup>18</sup> One reason PAS may not have been included in the final multivariable model is the inclusion of findings from TT-POCUS captured similar information as PAS related to associations with DNF.

Necropsies were not performed to verify whether mortalities were explicitly associated with BRD, representing a limitation of this study. Additionally, only variables that were available at the time of chuteside evaluation in this study were included, restricting interpretation of animal weights solely to enrollment values without context of arrival weights or average daily gain. Future research could incorporate such data to potentially strengthen predictive accuracy and contextual relevance.

This study evaluated several potential POC technologies and only TT-POCUS findings were significantly associated with DNF. While other traditional metrics such as pulmonary auscultation were not significantly associated with outcomes in this study, the strong associations observed with TT-POCUS variables suggest that these features should be prioritized in clinical evaluations. The ability to gather this valuable information at the time of disease treatment to accurately predict DNF outcomes could significantly enhance decision-making in feedyard management; potentially improving the overall health and productivity of the herd. Further research is warranted to refine these techniques and validate their applicability across diverse feedyard operations.

## Endnotes

<sup>a</sup> Butterfly iQ+ Vet, Butterfly Network Inc., Burlington, MA

<sup>b</sup> ImageJ, U. S. National Institutes of Health, Bethesda, MD

<sup>c</sup> Masimo Rad 87, Masimo Corp., Irvine, CA

<sup>d</sup> Masimo Transflectance 3531 M-LNCS TF-I AH, Masimo Corp., Irvine, CA

<sup>e</sup> 3M Littmann Cardiology III, Maplewood, MN

<sup>f</sup> Excel 365, Microsoft, Redmond, WA

<sup>g</sup> RStudio, R Foundation, Vienna, Austria

## Conflicts of interest

Authors declare no conflict of interest.

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## Author contributions

Conception and design, L.F., B.W., R.L. and T.S.; data acquisition, L.F., B.W. and T.S.; data analysis, L.F., B.W., R.L.; interpretation, all authors; primary manuscript drafting, L.F.; critical review and revision of the manuscript, all authors; approval of the final published version, all authors.

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