Determination of hydration status in feedlot cattle treated for respiratory disease and associations with treatment outcome

Lilli Heinen,[1] DVM; ***Brad J. White**,[1] DVM, MS; **Robert L. Larson**,[1] DVM, PhD, DACT, DACVPM (Epidemiology), ACAN; **Miles Theurer**,[2] DVM, PhD; **Matt D. Miesner**,[3] DVM, MS, DACVIM

[1] Beef Cattle Institute, Department of Clinical Sciences, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506
[2] Veterinary Research and Consulting Services, Hays, KS 67867
[3] Livestock Services, Department of Clinical Sciences, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506
***Corresponding author**: Dr. Brad White, **bwhite@vet.k-state.edu**

Abstract

Feedlot cattle are evaluated visually for signs of disease and to determine subsequent treatment, often without further diagnostics. Hydration status is difficult to measure in feedlot cattle, and reference ranges are often based on other cattle production systems. The objective of this study was to determine the association of clinical markers of hydration at the time of treatment with packed cell volume (PCV) as an indicator of hydration status and treatment outcomes. Cattle treated for respiratory disease (n = 107) were examined to determine eye globe recession, skin tent, mucous membrane quality, capillary refill time, rectal temperature and weight. Dehydration was defined as a PCV greater than 46% (n = 9). Animals were followed for 90 days post-enrollment to determine outcomes. Treatment failure was defined as a retreatment for any reason or death due to any cause. Final outcome (died or survived) was also evaluated. Associations between predictor variables and these 3 outcomes (dehydration, treatment failure, final outcome) were determined in 3 generalized linear mixed models. There were no significant associations between predictors and dehydration. Weight less than 700 lbs (317 kgs). was associated with an increased treatment failure probability, and abnormal mucous membrane quality was associated with a higher probability of death within the 90 days. This study shows that common markers of hydration status may not be useful in determining dehydration in feedlot cattle. However, weight and mucous membrane quality could be useful indicators of outcome. A larger sample size with a more diverse cattle population is needed to validate these results.

Key words: dehydration, feedlot, diagnosis, bovine respiratory disease

Introduction

Hydration status in cattle is often evaluated via clinical examination of several parameters including skin tent time and eye globe recession. Other parameters such as mucous membrane quality and capillary refill time can also be used, but may be less specific for dehydration as these markers can be abnormal in other conditions such as shock.[1] Additionally, blood parameters such as packed cell volume (PCV) and total protein (TP) are also assessed when determining hydration status in cattle, but are more labor-intensive to collect.[2] Hydration status of cattle has been investigated in other management systems such as dairy production or in calves.[1,3] Often, reference ranges for relevant blood parameters are reported for mature adult cattle with no consideration for production system.[4] Packed cell volume measures the percentage of red blood cells per volume of blood and is often used to contribute to hydration status assessment in addition to other clinical observations.

Abnormalities in PCV and TP can be categorized broadly into values below reference range and values above reference range. Biologic causes contributing to a decreased PCV include hemorrhage, RBC parasites, bacterial infection of the RBCs, toxins such as copper or onion, nutrient deficiencies, chronic disease or bone marrow disorders.[5] An insufficient blood sample in a potassium EDTA tube may also cause a lower-than-normal PCV due to red blood cell shrinkage.[5] PCV values above reference range are most commonly caused by dehydration but can also be caused by stress. Dehydration and stress are referred to as relative polycythemias because they do not lead to a true increase in RBC mass. Causes that increase RBC mass and lead to increased PCVs are rare, but include chronic pulmonary disease and living at high altitudes.[5] Elevated TP in cattle can indicate acute or chronic inflammation (via the increase of inflammation-associated proteins in circulation) or dehydration. The difference is especially difficult to sort out when using plasma to measure protein instead of serum, as serum does not contain fibrinogen (a major acute phase protein).[6] Protein loss through diseased kidneys and/or gastrointestinal tract can become severe enough to lead to a decreased TP in the blood. Additionally, low TP may be seen in neonatal calves who have received insufficient colostrum.[6] Hepatic disease can cause both an elevated TP or decreased TP, depending on disease severity and chronicity.[6] The causes of abnormalities in either PCV or TP are abundant and should be considered alongside other subjective and objective clinical measures.

Diagnosis of illness on the feedlot is often based on visual appraisal of clinical signs by pen riders and hospital staff. Few objective diagnostics are applied before treatment. Studies have evaluated the application of different diagnostic tools to improve diagnostic specificity compared to relying on clinical observations consistent with bovine respiratory disease (BRD); however, many are expensive, labor-intensive or difficult to apply in an efficient manner before treatment is applied.[7-9] While still subjective, other clinical measurements could be made in addition to observation of the visual clinical signs stated above. These include simple tests often made to determine hydration status including globe recession, mucous membrane quality, skin tent time and capillary refill time (CRT). These clinical measurements, similar to blood parameters like PCV and TP, are not specific to any one disease process or biological disturbance (such as dehydration). For example, prolonged CRT can be indicative of dehydration or peripheral vasoconstriction.[2] However, evaluation of these blood parameters and clinical measurements could indicate severity of disease and therefore be useful prognostic tools.

Few studies have investigated the correction of hydration and its effect on post-BRD treatment outcomes. Oral fluid boluses in beef feedlot calves at the time of arrival have been shown to increase morbidity due to BRD, but did not affect second or third BRD morbidity risk.[10] A potential reason for this negative association could be aspiration of the oral hydration therapy during administration. Additionally, increased transmission of BRD pathogens could have occurred due to sharing of the apparatus used to administer the fluids. Another study showed that oral fluid boluses with concurrent respiratory vaccination affected rumen temperature. Beef calves administered oral fluids at arrival demonstrated a peak in rumen temperature at day 6 vs. the control group which peaked at day 8. Additionally, calves administered oral fluids at arrival did not experience an increase in rumen temperature following vaccination in contrast to calves that were vaccinated but did not receive oral fluids.[11] These findings suggest that oral fluid administration may influence various body systems. However, both of these studies administered fluids regardless of disease status. A full evaluation of hydration status would likely take too long to complete in a commercial feedlot setting, but using simple clinical markers might help elucidate information about an animal's hydration status. The objective of this study was to determine hydration status of cattle using PCV at treatment for respiratory disease and to determine the association of clinical markers of hydration with hydration status determined by PCV. We also sought to determine the association of the aforementioned clinical markers with treatment failure and mortality. We hypothesized that hydration status based on PCV would be associated with one or more clinical markers of hydration. We also hypothesized that abnormal clinical markers of hydration status would be associated with treatment failure and poor outcomes.

Material and methods

This study was approved by the Institutional Animal Care and Use Committee at Kansas State University. The study population consisted of cattle on feed at a feedlot in the U.S. central High Plains region. The cattle on feed at the time of this study ranged in age from recently weaned (4-6 months of age) to animals nearing their slaughter endpoint (14-18 months of age). A multitude of cattle types were fed at this feedlot including purebred beef, mixed beef breed, and mixed beef and dairy breed cattle. A variety of cattle sources was also represented including ranch-sourced and auction-sourced cattle. Morbidity risk of cattle at the time of feedlot arrival was assessed by feedlot staff, and processing protocols were adjusted accordingly, but this information was not available to the authors of the current study. Cattle were housed in open-air, drylot pens with continuous access to water and feed. Animals were observed daily by experienced pen riders for signs of illness.

Data collection

Cattle were selected for enrollment if they were determined to have BRD as identified by pen riders based on visual appraisal of typical clinical signs of BRD including depressed mentation, nasal discharge, coughing, respiratory difficulty and isolation from the group. No restrictions based on sex, breed or stage of feeding phase were made. Following identification by pen riders, rectal temperature was measured at the hospital barn. A temperature cut-off of 104 °F (40 °C) was used by the feedlot personnel to determine if the animal would receive antimicrobial treatment but cattle were not restricted from enrollment in the study based on rectal temperature. Cattle were also not restricted from enrollment by BRD treatment number, meaning an animal could be enrolled in the study no matter how many times it had been treated for BRD. The antibiotic administered at the time of treatment was decided by feedlot staff dependent on animal weight, risk class determined at feedlot arrival and treatment number. This decision was based on protocols and was not influenced by measurements collected by the authors of the current study. Protocols were written by consultant veterinarians and are proprietary information.

The hydration status of the cattle in this study was determined by PCV of a blood sample collected at the time of BRD treatment. Approximately 5 milliliters of blood were collected from the coccygeal vein and stored in a potassium EDTA tube until analysis. At the end of each collection day, each blood sample was used to fill a microhematocrit tube and spun at a rate of 10,000 rpm for 5 minutes. A standard microhematocrit tube reader card was used to obtain the PCV for the blood sample. A refractometer was then used to measure the total protein (TP) in grams per deciliter of the plasma for each blood sample. Blood parameters were recorded for each animal along with a number of clinical markers of hydration obtained at the chute at the time of treatment.

Clinical markers of hydration were collected by a trained individual and included eye globe recession, mucous membrane quality, capillary refill time (CRT), and skin tent time, as outlined in Table 1. Breed category was also assigned based on visual appraisal of dominant characteristics and was split into 2 categories: *Bos taurus* and *Bos indicus*.

Following data collection at the time of treatment, feedlot records for 90 days on feed after the day of enrollment were evaluated for individual outcomes: treatment outcome (treatment failure or treatment success) and final outcome (died or survived). There were no animals that were culled ahead of their cohort (commonly called railing or realizing). An animal was classified as a treatment failure if it was re-treated for any disease or died due to any cause within the 90-day post-enrollment period-of-risk. Post-mortem diagnosis was determined for each animal that died via gross examination at necropsy by a trained individual. Per feedlot protocol, cause of death diagnosis was broadly characterized as BRD with subcategories to indicate chronicity, gastrointestinal tract-related, musculoskeletal or other. In addition to the treatment and final outcomes, dehydration (yes or no) was evaluated. Hydration status was determined by a PCV cutoff based on the reference range for cattle.[4] Animals with a PCV greater than 46% were considered dehydrated. Exclusion criteria included animals with icteric or hemolyzed plasma and animals whose tag numbers did not match feedlot treatment records. Additionally, cattle were removed from the study if complete records

Table 1: Description of variables at the time of enrollment including hydration markers, blood parameters and cattle demographic data.

Variable	Description
Packed cell volume (PCV)	The volume of red blood cells given as a percentage of the whole blood. Measured by centrifugation of the blood sample followed by visual assessment of the height of the packed cell portion and estimation based on a standardized reader.
Total protein (TP) by refractometry	The estimation of the plasma protein content in a blood sample by evaluation of its refractive index given in g/dL.
Globe recession	Recession of eye globe into socket measured by pulling down the lower eyelid and visual estimation of distance between globe and mucocutaneous junction. Three categories: • Within normal limits (WNL) = less than 1 mm • ~3 mm recession = width of the head of cotton applicator tip • ~ 5 mm recession or greater = width of a #2 pencil eraser
Mucous membrane quality	A subjective evaluation of the color and texture of the mucous membranes of the vulva/prepuce. Moisture (moist or tacky), color (pink or pale), and temperature (warm or cool) were evaluated. Moist, pink, and warm mucous membranes were considered within normal limits.
Capillary refill time (CRT)	The amount of time in seconds the mucous membranes take to return to a normal color following application of sufficient pressure to cause blanching of the tissue. A CRT of less than 2 seconds was considered within normal limits.
Skin tent time	The amount of time in seconds a pinched-up fold of skin takes to return to its normal appearance evaluated on the skin of the neck, approximately halfway between the head and the shoulder. A skin tent time of less than 3 seconds was considered within normal limits
Event weight	The weight of the animal at the time of treatment was measured in pounds obtained from the treatment records available from the feedyard's data system.
Event temperature	The rectal temperature of the animal at the time of treatment was measured in degrees Fahrenheit obtained from the treatment records available from the feedyard's data system.
Breed (*Bos taurus or Bos indicus*)	A visual appraisal of the dominant facial features to categorize the animal as more heavily *Bos taurus*- or *Bos indicus*-influenced.

were not available for the period prior to enrollment and for the 90-day observation period after enrollment. Mucous membrane quality, skin tent and globe recession were dichotomized (within normal limits and abnormal). Event weight was categorized as ≤ 700 lbs (317 kgs) and > 700 lbs. Only 2 categories for event weight were constructed due to the small sample size. Event temperature was categorized as ≤ 104 °F (40 °C) and > 104 °F (40 °C). This cutoff represents the feedlot's threshold for BRD treatment and was used to include treatment protocol effects in the model.

Sample size for this study was based on numbers needed for a different unpublished study being conducted in the same group of animals. That study was selected for the sample size calculation due to little information available about the range of PCV values in this population, and because investigators believed this study would require fewer animals to detect a difference. The following assumptions were used: a type I error probability of 0.05 (alpha = 0.05), power of 80%, a probability of outcome in the exposed group of 0.4, and a probability of outcome in the unexposed group of 0.15. Calculating the sample size for a 2-sided significance level yielded a sample size of 98 animals total with 49 per exposure group. Investigators determined this sample size would also be sufficient for the present study.

Three separate generalized linear mixed models were built using the glmer() function[12] in R software,[13] one for each outcome. The binomial outcomes evaluated in this study were as follows: dehydrated (0 = PCV ≤ 46%, 1 = PCV > 46%), treatment failure (0 = no retreatment or death in the next 90 days, 1 = retreated or died in the next 90 days), death (0 = did not die in the next 90 days, 1 = died within the next 90 days). Fixed effects included event weight in 2 categories, event temperature in 2 categories, breed (*Bos taurus* and *Bos indicus*), TP, treatment number and the dichotomized clinical markers of hydration. Lot ID was included as a random intercept to account for lack of independence within lot. The treatment failure and death models had the dichotomous variable capturing hydration status (as determined by PCV) included as a covariate. All models were run first with all covariates. Then, backward step-wise elimination approach was utilized to select covariates for the final model with the lowest Akaike information criterion for each outcome of interest.

Results

In total, 107 animals were enrolled in the study. Following application of exclusion criteria, 14 animals were removed, leaving 93 animals in the final analysis. Descriptive statistics of all the variables included in the analysis are in Table 2. PCV values are shown in Figure 1. No animals in this study experienced a PCV below the lower end of the reference range (23%). The breed distribution of cattle in this population heavily favored *Bos taurus*-influenced cattle with approximately 75% of the study population in that category and ~25% among the *Bos indicus*-influenced cattle. The majority of enrolled animals were sampled at their first treatment for BRD (n = 67), with fewer sampled at second (n = 18) and third (n = 8) treatments. Approximately 73% (n = 68) of animals were at or above the temperature cutoff of 104 °F (40 °C) for treatment by feedyard staff.

Figure 1: Histogram of packed cell volume (PCV) distribution. The dashed line represents the PCV cut-off of 46%.

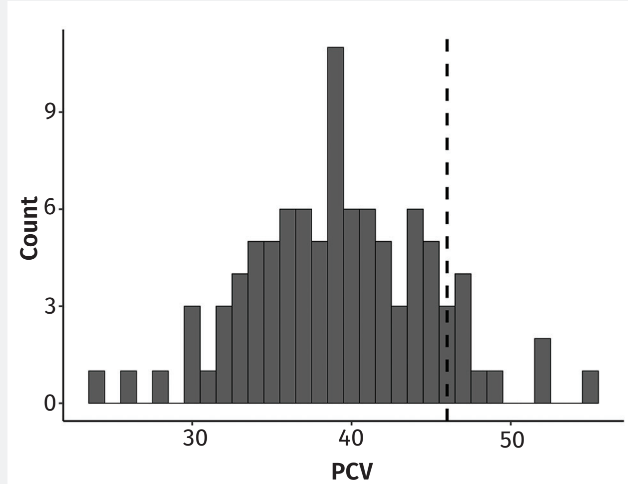

Table 2: Descriptive statistics of variables collected at the time of treatment including hydration markers and outcome variables. WNL = within normal limits

Variable	Summary
Event weight (lbs)	Mean: 650
	SD: 255
Event temperatures	Mean: 104.8 °F (40.4 °C)
	SD: 1.3 °F (0.1 °C)
Globe recession	WNL: 59.1% (55/93)
	Abnormal: 40.9% (38/93)
Skin tent	WNL: 93.5% (87/93)
	Abnormal: 6.5% (6/93)
Mucous membrane quality	WNL: 91.4% (85/93)
	Abnormal: 8.6% (8/93)
Capillary refill time (CRT)	WNL: 98.9% (92/93)
	Abnormal: 1.1% (1/93)
Breed	*Bos taurus*: 75.3% (70/93)
	Bos indicus: 24.7% (23/93)
Treatment number	First: 72.0% (67/93)
	Second: 19.4% (18/93)
	Third: 8.6% (8/93)
TP (g/dL)	Mean: 6.6
	SD: 0.95
Hydration status	Dehydrated: 9.7% (9/93)
	Normal: 90.3% (84/93)
Final outcome	Mortality: 20.4% (19/93)
	Lived: 79.6% (74/93)
Treatment outcome	Treatment failure: 32.3% (30/93)
	Treatment success: 67.7% (63/93)

Dehydration Model

Only 9/95 animals in this dataset were dehydrated using the cutoff of 46% PCV. The final model included breed and total protein. The association between breed and dehydration was not significant ($P = 0.12$). Calves with a normal hydration status tended (P-value = 0.06) to have a larger total protein value.

Treatment Failure Model

The treatment failure risk in this study was 32.3% (n = 30). The treatment failure model showed significant associations with event weight category, event temperature category, and mucous membrane quality. A lower weight at the time of treatment was significantly associated with a higher probability of treatment failure (P-value = 0.001). Cattle below 700 lbs (317 kgs) at treatment had a model estimated means percent probability of treatment failure of 35% (SE = 20%). Cattle above 700 lbs (317 kgs) had a 6.1% probability of treatment failure (SE = 6.2%). An event temperature at or above 104 °F (40 °C) was associated with an increased risk of treatment failure (P-value = 0.03). Animals with a rectal temperature below 104 °F (40 °C) had a 7.6% model estimated percent probability of treatment failure compared to cattle above that temperature with a 30% risk of treatment failure. Finally, an abnormal mucous membrane quality resulted in a significantly higher (P-value = 0.006) probability of treatment failure. Abnormal mucous membranes resulted in a 44% percent probability of treatment vs. 4.2% in cattle with normal mucous membranes. Treatment number ($P = 0.5$), skin tent ($P = 0.4$), eye globe recession ($P = 0.07$), and TP ($P = 0.06$) were all not significantly associated with the treatment failure outcome.

Death Model

Of cattle included in the study, 19 animals died within their 90-day observation period after enrollment. All animals were necropsied, and their causes of death were all determined to be due to BRD. Of the mortalities, 9 out of 19 were determined to have chronic BRD. Event temperature category and mucous membrane quality were associated with the death outcome. Event temperature was not significantly associated ($P = 0.1$) with death. Mucous membrane quality was significantly associated

(*P*-value = 0.04) with the final outcome with an abnormal mucous membrane quality at the time of treatment demonstrating a higher probability of that animal dying before the end of the 90 days. Model estimated means percent probability of mortality was 12.9% (SE = 4.8%) with normal mucous membrane quality. Mortality percent with abnormal mucous membrane quality was 41.7% (SE = 18.7%).

Discussion

Our study sought to determine associations between clinical markers of hydration and common blood parameters used to assess hydration status objectively. Clinically, determination of dehydration is made through a variety of physical exam and bloodwork findings. Experimentally, mild dehydration (less than 5%, indicating the animal requires replacement of 5% of its body weight in fluids to overcome its dehydration) has been associated with globe recession of 1 mm, dry mucous membranes, and a prolonged skin tent time in calves.[1] Clinically, these changes may be more difficult to appreciate at a single time point and may best be monitored over time. Changes associated with dehydration are more easily observed in calves than mature cattle. As our study was performed in immature but not newborn cattle, we sought to fill knowledge gaps on the utilization of blood parameters and clinical measurements used to determine hydration status.

Little research has been performed to diagnose and quantify dehydration in feedlot cattle especially when applied to clinical BRD cases.[14] Megahed et al. evaluated urine specific gravity (USG) in dairy cows for determination of dehydration. They concluded that USG is an accurate method for assessing urine concentration and may be useful for detecting dehydration in dairy cows; however, that study did not evaluate associations with common bloodwork findings associated with dehydration (elevated PCV and TP).[3] Urine concentration has not been evaluated as a marker of hydration in feedlot cattle and may be an area of future research.

Skin tent time, mucous membrane quality, capillary refill time and eye globe recession are physical examination parameters commonly used to estimate hydration status in animals. We saw no significant associations between dehydration based on PCV and each of these parameters. Only 6 animals demonstrated abnormal skin tent times, and 8 animals exhibited abnormal mucous membrane qualities. Skin tent time can be highly variable in cattle due to the subjective nature of the measurement and variations in conformation among breeds. Mucous membranes are difficult to assess in cattle, especially those in the oral cavity. Severe circulatory derangements, such as shock, may need to be present, to produce noticeable changes in the mucous membranes.[2] Abnormal mucous membrane quality could have been significantly associated with death and treatment failure within the 90-day post-treatment interval because of the presence of a more severe disease process occurring in those animals. More animals demonstrated abnormalities in globe recession (55 normal, 38 abnormal) than the other physical examination parameters of hydration. However, many of the population sampled demonstrated heavy *Bos indicus* influence in their physical characteristics, which could have contributed to an eyelid conformation that could be misinterpreted as a greater degree of eye globe recession. Based on these data, common clinical markers of hydration status are not associated with an elevated PCV. However, a greater sample size with a lower proportion of *Bos indicus*-influenced cattle is needed to confirm this finding. Additionally, few animals in this study were dehydrated according to our PCV cut-off, limiting our statistical power.

The 90-day treatment failure risk in this study was 32.3% which is similar to other published treatment failure risks in the literature.[11,12] Weight at treatment of less than 700 lbs (317 kg) was significantly associated with an increased probability of treatment failure. Lower weight at treatment is a negative prognostic indicator in other studies investigating risk factors for treatment failure in feedlot cattle.[15,16] Lighter weight cattle are typically young animals that may have a naïve immune system incapable of mounting a sufficient response to the pathogens, increasing their risk for treatment failure.[17] Additionally, increased rectal temperature (at or above 104 °F/40 °C) was associated with a higher probability of treatment failure in this study, as previously demonstrated.[15,16] A higher rectal temperature could be due to a more severe disease process, thus leading to a higher treatment failure risk.

While this study provided useful information about hydration status in feedlot cattle with BRD, there are several limitations. First, the sample size was limited by resources. Calculation of sample size was based on a different unpublished study. Additionally, during study design, it was estimated that a larger proportion of the study population would be dehydrated. Thus, it is possible the findings reported here suggest that the current study is underpowered and could benefit from a larger sample size. Second, animals were only sampled once, and it is possible that additional samples over time would have been more reflective of hydration status of that individual animal. Third, measuring hydration status involves multiple subjective and objective measures and simplifying to one objective measurement might not capture that animal's hydration status fully. Despite these limitations, this study provides new information about abnormal PCV values in feedlot cattle.

The current study aimed to evaluate common clinical markers of hydration status and their association with hydration status determined by PCV. We found no significant associations, indicating that eye globe recession, skin tent time, mucous membrane quality, and capillary refill time might not be useful in determining hydration status of feedlot cattle. However, we were limited by a small sample size and the inability to evaluate subjects at more than one point in time. Abnormalities in mucous membrane appearance could be associated with advanced or severe disease processes and could explain why abnormal mucous membrane quality was significantly associated with death and treatment failure within 90 days. A light bodyweight and high rectal temperature at the time of treatment has been associated with an increased risk for treatment failure in previous work, and this finding was repeated in our study.

Acknowledgements

We acknowledge Erick Angulo and the rest of the feedlot staff at Hy-Plains Feedyard for their help with this project.

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