Relationship between rectal temperature at first treatment for bovine respiratory disease complex in feedlot calves and the probability of not finishing the production cycle

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Objective—To determine the relationship between rectal temperature at first treatment for bovine respiratory disease complex (BRDC) in feedlot calves and the probability of not finishing the production cycle.

Design—Retrospective data analysis.

Animals—344,982 calves identified as having BRDC from 19 US feedlots from 2000 to 2009.

Procedures—For each calf, data for rectal temperature at initial treatment for BRDC and various performance and outcome variables were analyzed. A binary variable was created to identify calves that did not finish (DNF) the production cycle (died or culled prior to cohort slaughter). A mixed general linear model and receiver operating characteristic curve were created to evaluate associations of rectal temperature, number of days in the feedlot at time of BRDC diagnosis, body weight, quarter of year at feedlot arrival, sex, and all 2-way interactions with rectal temperature with the probability that calves DNF.

Results—27,495 of 344,982 (7.97%) calves DNF. Mean rectal temperature at first treatment for BRDC was 40.0°C (104°F). As rectal temperature increased, the probability that a calf DNF increased; however, that relationship was not linear and was influenced by quarter of year at feedlot arrival, sex, and number of days in the feedlot at time of BRDC diagnosis. Area under the receiver operating characteristic curve for correct identification of a calf that DNF was 0.646.

Conclusions and Clinical Relevance—Rectal temperature of feedlot calves at first treatment for BRDC had limited value as a prognostic indicator of whether those calves would finish the production cycle. (*J Am Vet Med Assoc* 2014;245:1279–1285)

Bovine respiratory disease complex is the most economically consequential disease affecting the beef feedlot industry.[1] Identification of calves with BRDC is routinely performed on the basis of visual observation of signs of depression, nasal discharge, lack of rumen fill, and anorexia.[2] Those clinical observations have low sensitivity and specificity for identification of calves with BRDC.[3,4] Rectal temperatures are routinely obtained for calves with signs of BRDC to improve diagnostic specificity, and the final decision to treat a calf may be made on the basis of a rectal temperature that exceeds a predetermined threshold. Rectal temperature of a calf with BRDC might also influence the selection of the antimicrobial used to treat that calf.

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Abbreviations

BRDC	Bovine respiratory disease complex
DNF	Did not finish
ROC	Receiver operating characteristic

Despite the frequency with which rectal temperature is used as a determinant for the diagnosis of BRDC, published literature on how to most effectively use rectal temperature as a metric for BRDC in feedlot calves is sparse. Results of 1 study[5] indicate that rectal temperature at the time of initial diagnosis of BRDC is positively associated with retreatment and case-fatality risks. Most analyses have assumed a linear relationship between rectal temperature and case outcome. Because of the positive association between environmental temperature and rectal temperature of cattle, some investigators[6] have suggested seasonal changes to the rectal temperature threshold used to identify calves with BRDC to improve diagnostic accuracy. However, to our knowledge, studies to establish seasonal rectal temperature thresholds for diagnosis of BRDC in feedlot cattle have not been performed.

The primary objective of the study reported here was to determine the relationship between rectal temperature at time of first treatment for BRDC and the probability of feedlot calves not finishing the production cycle with their cohort (ie, died or prematurely culled or removed from the cohort prior to slaughter). In most production systems, early removal of individual animals from a cohort is associated with poor performance caused by chronic disease conditions. A secondary objective was to create an ROC curve to determine overall model predictive accuracy of rectal temperature at time of first treatment for BRDC as an indicator for a calf not finishing the production cycle with their cohort. We hypothesized that rectal temperature would be positively associated with the risk of feedlot cattle not finishing the production cycle with their cohort and that the overall predictive ability of the model with all input variables included would be high.

Materials and Methods

Feedlot data set—Health data for individual cattle from 19 US feedlots from 2000 to 2009 were obtained. The study population consisted of calves that had clinical signs consistent with BRDC and were treated with an antimicrobial. The case definition for BRDC was determined by feedlot personnel, and treatments were administered in accordance with established feedlot protocols (ie, case definition for and treatment of BRDC were not standardized).

Data extracted for each calf included sex, body weight at feedlot arrival, quarter of year at feedlot arrival, rectal temperature at initial BRDC diagnosis, number of days in the feedlot at the time of initial BRDC diagnosis, and total number of days in the feedlot. A binary outcome variable was created to distinguish between calves that finished and DNF the production cycle with their cohort. Calves classified as DNF included those that died or were removed (culled) from their cohort prior to slaughter of that cohort.[7,8]

Data management—Extreme values were removed from the analysis to limit potential data entry errors and confine the external validity to the reference range or industry standard for each variable. Therefore, data for calves with rectal temperature ≤ 38.3°C (≤ 101°F; n = 1,508) and > 41.7°C (> 107°F; 2,748) and that were initially treated for BRDC at > 126 days at the feedlot (9,499) were removed prior to analysis. Calf records from cohorts identified as Holstein (n = 10,108) and with arrival weights < 136 kg (< 300 lb; 12,144) and > 408 kg (> 900 lb; 4,504) were also removed prior to analysis as were those from cohorts identified as mixed sex (ie, only data from cohorts that consisted exclusively of male or female calves were analyzed; 20,425).

Statistical analysis—Data for rectal temperature at first treatment for BRDC (rectal temperature) were categorized into 12 categories (≤ 38.6°C [≤ 101.5°F], > 38.6° to 38.9°C [> 101.5° to 102.0°F], > 38.9° to 39.2°C [> 102.0° to 102.5°F], > 39.2° to 39.4°C [> 102.5° to

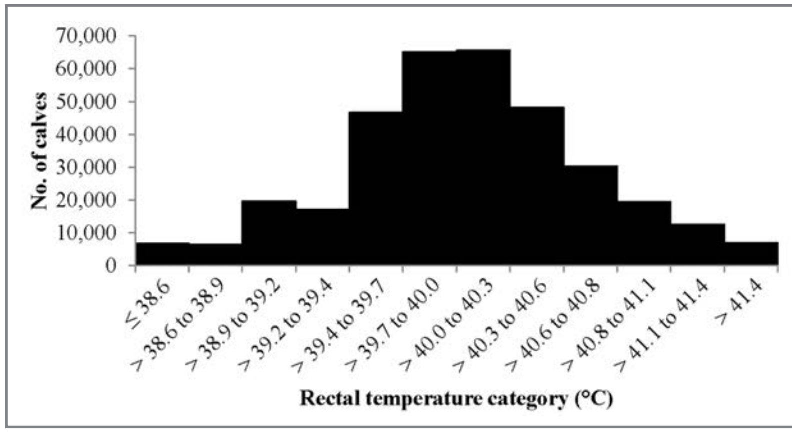

Figure 1—Histogram of rectal temperature at time of first treatment for BRDC for 344,982 feedlot calves identified with BRDC by feedlot personnel from 19 US feedlots from 2000 to 2009.

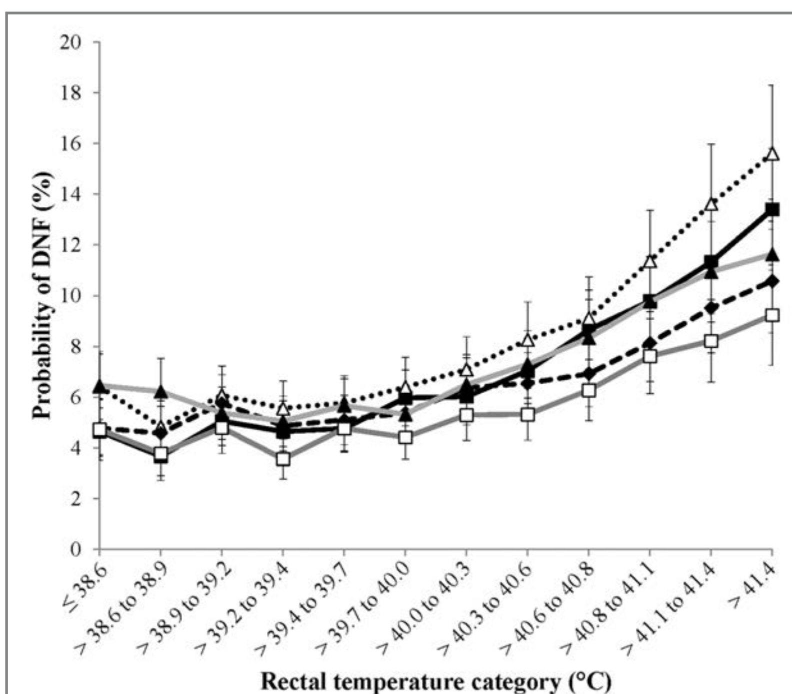

Figure 2—Model-adjusted least squares mean ± SE probability that calves of Figure 1 would be classified as DNF (probability of DNF) by rectal temperature category and number of days in the feedlot at the time of BRDC diagnosis (≤ 10 days [black line with black squares], 11 to 20 days [dotted line with white triangles], 21 to 30 days [dashed line with black diamonds], 31 to 40 days [gray line with white squares], and > 40 days [gray line with black triangles]). Fixed effects included in the model were rectal temperature category, category of body weight at feedlot arrival, quarter of year at feedlot arrival, sex, and all significant ($P \leq 0.05$) 2-way interactions between rectal temperature and the other fixed effects. The interaction between rectal temperature category and number of days in the feedlot at the time of BRDC diagnosis was significant ($P = 0.01$).

103.0°F], > 39.4° to 39.7°C [> 103.0° to 103.5°F], > 39.7° to 40.0°C [> 103.5° to 104.0°F], > 40.0° to 40.3°C [> 104.0° to 104.5°F], > 40.3° to 40.6°C [> 104.5° to 105.0°F], > 40.6° to 40.8°C [> 105.0° to 105.5°F], > 40.8° to 41.1°C [> 105.5° to 106.0°F], > 41.1° to 41.4°C [> 106.0° to 106.5°F], and > 41.4°C [> 106.5°F]). Data for body weight at feedlot arrival were categorized into 6 categories (≤ 180 kg [≤ 397 lb], > 180 to 226 kg [> 397 to 498 lb], > 226 to 272 kg [> 498 to 600 lb], > 272 to 318 kg [> 600 to 701 lb], > 318 to 363 kg [> 701 to 800 lb], and > 363 kg [> 800 lb]). Number of days in the feedlot at time of first treatment for BRDC was categorized into 5 categories (≤ 10 days, 11 to 20 days, 21 to 30 days, 31 to 40 days, and > 40 days). Months during which calves arrived at the feedlot were categorized into 4 categories (quarter 1 = January through March, quarter 2 = April through June, quarter 3 = July through September, and quarter 4 = October through December).

A mixed general linear model was used to determine the probability that calves DNF the production cycle with their cohort. Fixed effects included in the model were categorized data for rectal temperature, body weight at feedlot arrival, number of days in the feedlot at time of first treatment for BRDC, sex, quarter of feedlot arrival, and all 2-way interactions with rectal temperature. Random effects were included in the model for year, feedlot, and lot number. The model was constructed by including all potential effects and removing nonsignificant ($P > 0.05$) effects 1 at a time in a stepwise manner; the final model included only variables with values of $P \leq 0.05$ as determined by type 3 likelihood tests. All analyses were performed with commercial statistical software.[a]

ROC curve analysis—A parametric ROC curve was created for the final mixed general linear model to determine its overall accuracy for predicting that calves would be classified as DNF.[9] The ROC curve allowed for evaluation of sensitivity and specificity. Sensitivity was defined as the frequency with which the model correctly identified calves that DNF. Specificity was defined as the frequency with which the model correctly identified calves that finished the production cycle with their cohort. Sensitivity and 1 – specificity were plotted against each other, and the area under the curve determined the overall accuracy of the model.

Results

Following the removal of calf records with extreme values, records of 344,982 calves treated for BRDC by feedlot personnel were included in the analysis, and 27,495 (7.97%) of those calves were classified as DNF. Rectal temperatures at the time of first treatment for BRDC were nor-

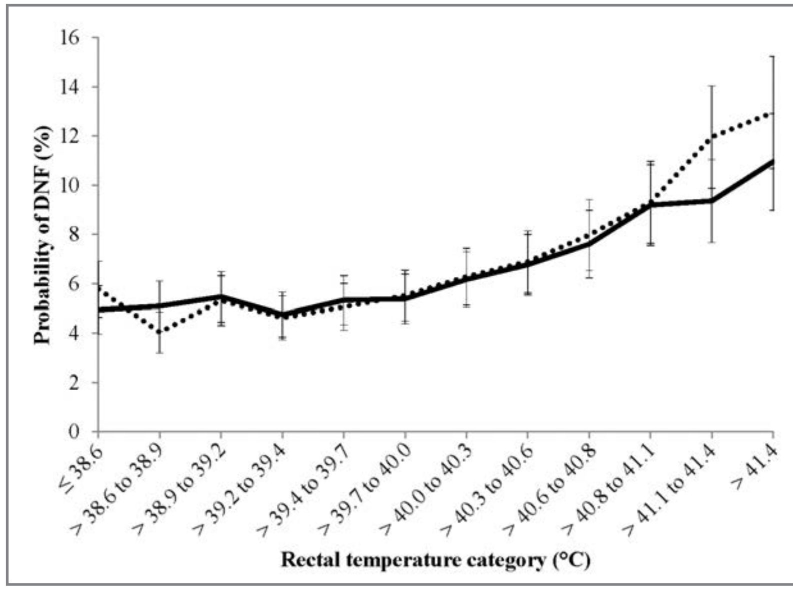

Figure 3—Model-adjusted least squares mean ± SE probability of DNF for the calves of Figure 1 by rectal temperature category at time of first treatment for BRDC and sex (male [solid line] or female [dotted line]). The interaction between rectal temperature category and sex was significant ($P = 0.01$). *See* Figure 2 for remainder of key.

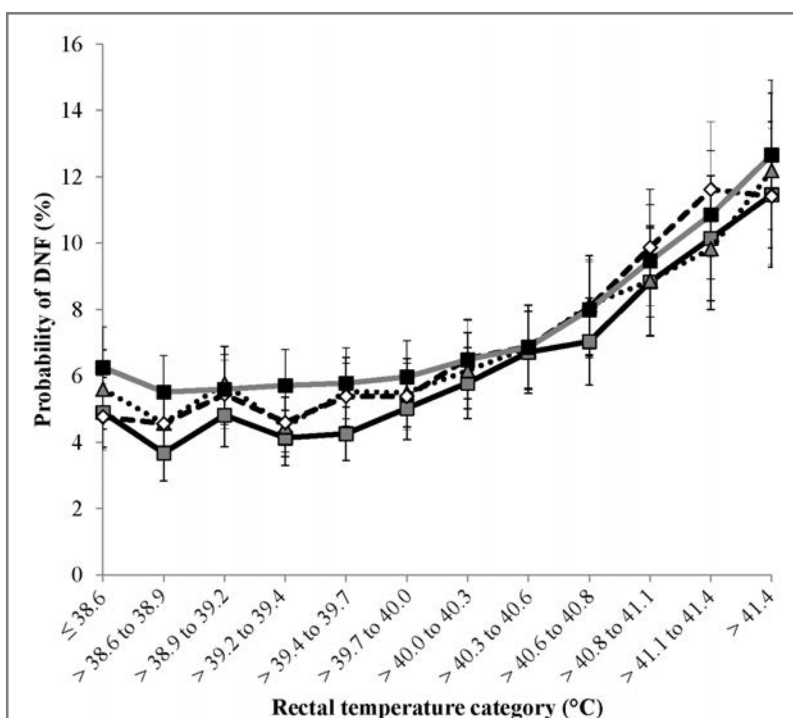

Figure 4—Model-adjusted least squares mean ± SE probability of DNF for the calves of Figure 1 by rectal temperature category at time of first treatment for BRDC and quarter of year at feedlot arrival (quarter 1, January through March [black line with gray squares]; quarter 2, April through June [dotted line with gray triangles]; quarter 3, July through September [dashed line with white diamonds]; and quarter 4, October through December [gray line with black squares]). The interaction between rectal temperature category and quarter of year at feedlot arrival was significant ($P < 0.01$). *See* Figure 2 for remainder of key.

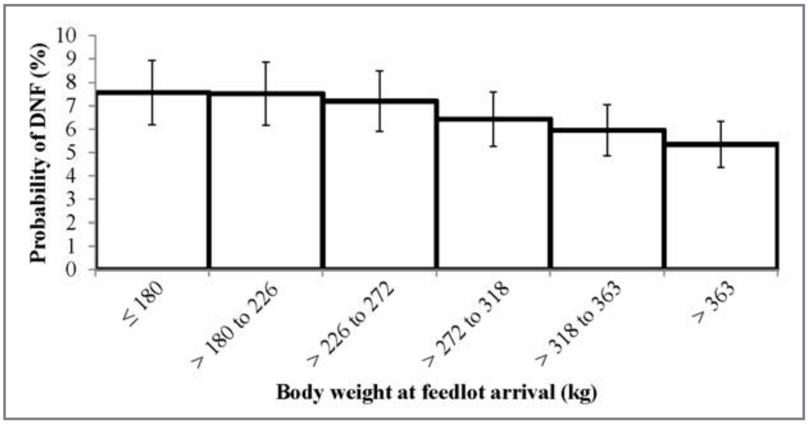

Figure 5—Model-adjusted least squares mean ± SE probability of DNF for the calves of Figure 1 by category of body weight at feedlot arrival. The interaction between rectal temperature category and category of body weight at feedlot arrival was not significant ($P = 0.55$). *See* Figure 2 for remainder of key.

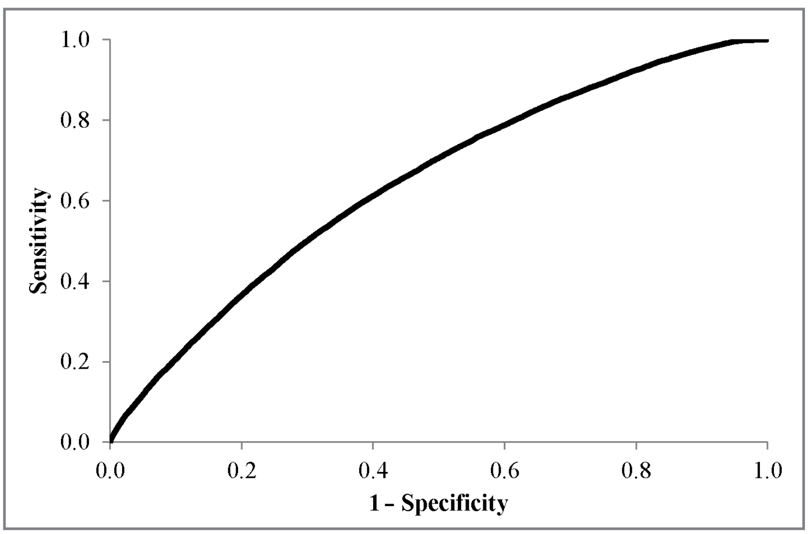

Figure 6—Parametric ROC curve for accuracy of the mixed general linear model described in Figure 2 to identify calves that were classified as DNF. Random effects included in the model were year, feedlot, and lot number. Area under the ROC curve was 0.646. *See* Figure 2 for remainder of key.

mally distributed, with a mean and median of 40.0°C (**Figure 1**).

The probability that a calf would be classified as DNF (probability of DNF) was significantly associated with the interaction between rectal temperature and number of days in the feedlot at the time of first treatment for BRDC ($P < 0.01$; **Figure 2**), interaction between rectal temperature and sex ($P < 0.01$; **Figure 3**), interaction between rectal temperature and quarter of the year during which the calf arrived at the feedlot ($P < 0.01$; **Figure 4**), and body weight at feedlot arrival ($P < 0.01$; **Figure 5**). The interaction between rectal temperature and body weight at feedlot arrival was not significantly ($P = 0.55$) associated with the probability that a calf was classified as DNF. The area under the ROC curve for the final multivariable model was 0.646 (**Figure 6**).

Discussion

The present study was conducted to assess the relationship between rectal temperature of feedlot calves at the time of first treatment for BRDC and the probability that those calves would not finish the production cycle with their cohort (ie, died or prematurely culled or removed from the cohort prior to slaughter). Elucidation of this relationship was important to determine whether rectal temperature at the time of first treatment for BRDC could be used as a prognostic indicator for feedlot calves. Results of this study indicated that rectal temperature of feedlot calves at first treatment for BRDC had limited valued as a prognostic indicator of whether those calves would be classified as DNF. Case-fatality rate has commonly been used to evaluate the success of BRDC treatment protocols.[10] Net economic returns for feedlot cattle with chronic BRDC that do not die but that fail to be marketed with their arrival cohort are significantly lower than those for untreated healthy feedlot cattle.[11]

Rectal temperatures are a common component of health monitoring protocols for feedlot calves and often influence treatment decisions.[12] Rectal temperatures of cattle have a diurnal pattern and are positively associated with ambient temperature during periods of extreme heat.[6,13] In the present study, the rectal temperature for calves at the time of initial treatment for BRDC was normally distributed with a mean and median of 40.0°C. Prior to the analysis, we assumed that most calves with BRDC would be pyrectic and the distribution of the rectal temperature data would be skewed to the left. The phase of BRDC during which affected calves were identified and treated might have had an effect on rectal temperature. Calves experimentally infected with *Mannheimia haemolytica* were pyrectic for only 1 to 3 days after the challenge inoculation before becoming normothermic.[14–17] Thus, calves with BRDC identified during the later stages of the disease may not always be pyrectic.

The pattern for the association of the interaction between rectal temperature and number of days in the feedlot at the time of BRDC diagnosis with the probability that a calf would be classified as DNF (probability of DNF) was interesting. The probability that a calf DNF remained fairly constant until rectal temperature increased to > 40.6°C, at which point the probability that a calf DNF increased for all categories of the number of days in the feedlot. The probability that a calf DNF was greatest for calves in which BRDC was diagnosed when the animals were between 10 and 20 days in the feedlot and lowest for calves in which BRDC was diagnosed when the animals were > 40 days in the feedlot. In general, the probability that a calf DNF increased as the number of days in the feedlot at which calves were first treated for BRDC decreased. These results may help feedlot veterinarians and managers forecast the economically important outcome of cohort mortality risk on the basis of the proportion of calves treated for BRDC and the rectal temperatures of those calves at the time of first BRDC treatment.[18–20]

Although the interaction between rectal temperature and sex was significantly associated with the probability that a calf DNF, the probability that a calf DNF did not differ significantly between male and female calves within any rectal temperature category. Similar to number of days in the feedlot at the time of BRDC diagnosis, the probability that a calf DNF remained relatively constant until rectal temperature increased to > 40.6°C, at which point it increased for both male and female calves. Results of another study[21] indicate that sex has no significant effect on the overall mortality rate of feedlot cattle; however, cattle that were culled prematurely because of chronic disease were not included in that analysis.

The effect of the interaction between rectal temperature and quarter of year during which calves arrived at the feedlot on the probability that a calf DNF was unexpected. We hypothesized that calves that entered the feedlot during the summer months (quarter 3) would have a low probability of being classified as DNF because high ambient temperatures could increase rectal temperatures of calves and lead to more healthy calves being treated for BRDC on the basis of pyrexia than during the other seasons. Seasonal adjustments to the rectal temperature cutoff used to diagnose BRDC in field settings have been suggested to account for the effect of high ambient temperature on rectal temperature.[6,14] The rectal temperatures of healthy calves can be increased from the reference range during periods of extreme heat, and calves with heat stress frequently have clinical signs that mimic those of BRDC.[6,14] Healthy calves with heat stress that are treated for BRDC solely on the basis of results of clinical observations should respond well to treatment and finish the production cycle with their cohort because they never had the disease.[6,14] For most of the rectal temperature categories, the probability that a calf DNF was greatest for calves that entered the feedlot during quarter 4 (October through December). This finding was most likely associated with standard management practices in which most beef calves are weaned and transported to feedlots (ie, stressors that put them at risk for BRDC) during quarter 4.

The negative relationship between body weight at feedlot arrival and probability that a calf DNF in the present study was consistent with results of another study.[7] In the present study, calves with a body weight ≤ 226 kg at feedlot arrival had a probability of 7.5% of being classified as DNF, which is greater than the probability of not finishing the observation period (1% to 5%) for similar calves in other studies.[22,23] However, in those other studies,[22,23] calves were monitored for only 63 days after feedlot arrival and only calves that died were included in the probability of not finishing the observation period, whereas in the present study, calves were monitored throughout the entire feeding period and the probability that a calf DNF included calves that died as well as those that were euthanized or culled prematurely. The case-fatality rate for BRDC in feedlot calves typically ranges between 5% and 10% and may be influenced by the type of calves evaluated.[10] In general, compared with calves with a low body weight (≤ 226 kg) at feedlot arrival, calves with a higher body weight at feedlot arrival are less susceptible to BRDC and spend less time in the feedlot (ie, reach finished or slaughter weight more quickly).

The accuracy of the final multivariable general linear model of the present study for predicting the probability that a calf would be classified as DNF was low on the basis of the area under the ROC curve (0.646). Management of health outcomes is an important component to improve profitability and manage economic risk in feedlot settings.[24,25] On the basis of the findings of this study, a multivariable model that included sex, body weight at feedlot arrival, quarter of year at feedlot arrival, number of days in the feedlot at the time of BRDC diagnosis, and rectal temperature at first BRDC treatment did not accurately predict whether an individual calf was going to be classified as DNF.

The economic tradeoff between sensitivity and specificity for BRDC diagnosis of calves in feedlot settings may not be equal because a false-negative classification does not incur the same costs as a false-positive classification in terms of calf performance, frequency of misclassification, and true disease status.[18] Management decisions for calves with BRDC might be altered on the basis of rectal temperature at initial BRDC treatment to maximize overall net returns. For example, a false-positive diagnosis of BRDC could result in healthy calves that were unnecessarily treated but that would have finished the production cycle with their cohort and would not have died or been culled prematurely. Conversely, a false-negative diagnosis of BRDC could result in BRDC-affected calves not being appropriately identified and treated, which in the long term could result in additional treatment and feed costs for those calves, when the most economically sound decision would have been to cull those calves early in the disease process. Although the economic tradeoff value for BRDC diagnostic sensitivity and specificity is unknown, the curvilinear line for sensitivity versus 1 – specificity (ROC curve; Figure 6) created on the basis of the results of the mixed general linear model was relatively flat; thus, improvement of the predictive ability of the model for identifying calves that will be classified as DNF is limited. This limitation in improvement might be a consequence of the case-definition of BRDC used in field settings, which has a low estimated sensitivity and specificity.[3] Another reason for the relatively flat relationship between sensitivity and specificity might be a result of the syndromic nature of BRDC and the fact that the multiple etiologic agents of BRDC cause a variety of pathophysiologic changes in affected calves in field settings. Additional studies are necessary to evaluate how variables such as sex, body weight at feedlot arrival, and number of days in a feedlot and rectal temperature at BRDC diagnosis affect the predicted outcome for BRDC-affected calves and to determine the most accurate method for identification of cattle with BRDC in a field setting.

In the present study, the probability of a calf being classified as DNF was relatively stable until rectal temperature at initial BRDC treatment was > 40.6°C for most of the covariates assessed (sex, number of days in the feedlot at the time of BRDC diagnosis, and quarter of year of feedlot arrival), at which point it began to increase as rectal temperature increased. An explanation for these results is that rectal temperatures > 40.6°C were indicative of severe BRDC or that the diagnostic specificity for BRDC increased as rectal temperature increased. Conversely, the case-fatality risk for calves with a high rectal temperature (> 40.6°C) might be a more typical response in truly ill calves, and the relative decrease in case-fatality risk at lower rectal temperatures is related to diagnostic inaccuracy or decreased specificity that results in healthy calves being misclassified as affected with BRDC (ie, false-positive results).

The probability that a calf DNF did not differ significantly among rectal temperature thresholds (39.4°C, 39.7°C, or 40.0°C) commonly used for BRDC diagnosis. Case definition and treatment protocols for BRDC can be influenced by rectal temperature; however, the present study did not identify a specific rectal temperature threshold that could be used to clearly delineate which cattle with BRDC will be classified as DNF. The data analyzed in this study were obtained from multiple feedlots across all seasons and many years, and care should be taken when extrapolating these findings to a situation in which the BRDC treatment protocol differs on the basis of a preexisting rectal temperature threshold. The ROC curve developed for the model of this study indicated that, even when all variables were included, rectal temperature at time of first treatment for BRDC had a low prognostic value for determining which calves would be classified as DNF.

The analysis of data collected in field settings generally results in high external validity of the findings; however, a potential limitation of the data obtained for the present study was that they were collected retrospectively from multiple production systems. The data management process included steps to ensure data validity, and potential recall bias was minimized owing to the electronic nature of the data management systems. Each operation used its own standard case definition to identify calves with BRDC, and although differences in case definition contributed to outcome variability, the collection of data from multiple feedlots that used representative standard industry practices should have provided good external validity of the study findings. Several significant interactions between cattle demographics and arrival characteristics were identified in this study, and extrapolation of these findings to specific cattle populations should be performed with caution.

Results of the present study provided some information about the probability that feedlot calves with BRDC will finish the production cycle with their unaffected cohorts; however, we were not able to identify a rectal temperature that could be used as a cutoff threshold on which BRDC treatment decisions can be made. All calves included in this study were identified and treated for BRDC, and the findings indicated that rectal temperature of feedlot calves at time of initial BRDC treatment alone is not an accurate prognostic indicator for treatment outcome.

a. SAS, version 9.3, SAS Institute Inc, Cary, NC.

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From this month's *AJVR*

Effect of ambient temperature on viral replication and serum antibody titers following administration of a commercial intranasal modified-live infectious bovine rhinotracheitis-parainfluenza-3 virus vaccine to beef cattle housed in high– and moderate–ambient temperature environments

Gretchen P. Grissett et al

Objective—To evaluate the effect of ambient temperature on viral replication and serum antibody titers following administration of an intranasal modified-live infectious bovine rhinotracheitis (IBR)-parainfluenza-3 (PI3) virus vaccine to beef calves housed in high– (> 32°C) and moderate– (21°C) ambient temperature environments.

Animals—28 calves (mean weight, 206.8 kg).

Procedures—Calves were randomly allocated to 4 treatment groups (housed outdoors during high ambient temperature with [HAT; n = 10] or without [HAC; 4] vaccination or housed indoors in a moderate ambient temperature with [MAT; 10] or without [MAC; 4] vaccination). Rectal and nasal mucosal temperatures were recorded every 2 hours from 8 AM to 8 PM on days 0 (vaccination) and 1. Nasal swab specimens were obtained on days 0 through 7 for virus isolation. Serum samples were collected on days 0, 7, 14, and 28 for determination of antibody titers.

Results—Mean rectal temperature did not differ among the treatment groups. Mean nasal temperature for the HAT group was significantly higher than that for the MAT group at 6, 24, 30, 32, and 38 hours after vaccination. Viable IBR virus was isolated from all vaccinated calves on days 1 through 6. Two weeks after vaccination, vaccinated calves had anti-IBR antibody titers that were significantly greater than those for unvaccinated calves. Mean anti-IBR antibody titers did not differ significantly between the HAT and MAT groups.

Conclusions and Clinical Relevance—Results indicated that, following vaccination with an intranasal modified-live IBR-PI3 virus vaccine, IBR viral replication and serum antibody titers did not differ significantly between calves housed in high– and moderate–ambient temperature environments. (*Am J Vet Res* 2014;75:1076–1082)

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