Producer survey of herd-level risk factors for nursing beef calf respiratory disease

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Objective—To identify herd-level risk factors for bovine respiratory disease (BRD) in nursing beef calves.

Design—Population-based cross-sectional survey.

Sample—2,600 US cow-calf producers in 3 Eastern and 3 Plains states.

Procedures—The associations of herd characteristics with BRD detection in calves and cumulative BRD treatment incidence were determined.

Results—459 (17.7%) surveys were returned and met the inclusion criteria; 48% and 52% of these surveys were completed by producers in Plains and Eastern states, respectively. Mean (95% confidence interval) number of animals in herds in Plains and Eastern states were 102 (77 to 126) and 48 (40 to 56), respectively. Bovine respiratory disease had been detected in ≥ 1 calf in 21% of operations; ≥ 1 calf was treated for BRD and ≥ 1 calf died because of BRD in 89.2% and 46.4% of operations in which calf BRD was detected, respectively. Detection of BRD in calves was significantly associated with large herd size, detection of BRD in cows, and diarrhea in calves. Calving season length was associated with BRD in calves in Plains states but not Eastern states. Cumulative incidence of BRD treatment was negatively associated with large herd size and examination of cows to detect pregnancy and positively associated with calving during the winter, introduction of calves from an outside source, offering supplemental feed to calves, and use of an estrous cycle synchronization program for cows.

Conclusions and Clinical Relevance—Results of this study indicated factors associated with calf BRD risk; modification of these factors could potentially decrease the incidence of BRD in nursing calves. (*J Am Vet Med Assoc* 2013;243:538–547)

Bovine respiratory disease is the most common cause of death for all production classes of cattle and calves in the United States; animal deaths attributable to that disease cost producers > $643 million in 2010.[1] Results of National Animal Health Monitoring Systems surveys indicate BRD is the most common cause of death for US feedlot cattle,[2] weaned dairy heifers,[3] and nursing beef calves ≥ 3 weeks old.[4] Thus, BRD has a substantial effect on the health and welfare of cattle and the profitability of cattle operations.

Abbreviations

BRD	Bovine respiratory disease
CI	Confidence interval
ZINB	Zero-inflated negative binomial

Bovine respiratory disease is caused by multiple factors. Management practices have a role in the development of BRD in feedlot cattle and dairy calves.[5–9] Modification of management procedures and use of methods intended to improve immunity and limit

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pathogen exposure of animals can be effective for decreasing the spread of respiratory disease among feedlot cattle.[5,7,10] Thus, knowledge of management-related risk factors for BRD may be useful for improving the health and productivity of cattle of certain production classes. Although a large amount of information is known about the management practices that increase BRD risk for feedlot cattle and dairy calves, little information is published regarding the management-related BRD risk factors for nursing calves in cow-calf operations. This lack of information is important because respiratory disease is the most common cause of death for calves that are ≥ 3 weeks old in US cow-calf operations.[4] Death is attributable to BRD for 16% of calves on cow-calf operations that are born alive and subsequently die.[11]

The epidemiological characteristics of respiratory disease in nursing calves in North American cow-calf herds have not been thoroughly determined. Authors of 2 reports[12,13] determined epidemiological characteristics of respiratory disease in nursing calves in a herd at the USDA Agricultural Research Service Meat Animal Research Center. Results of these studies indicated the annual incidence of BRD in preweaned calves in that herd was 3% to 24% during a 20-year period (mean, 11%). The annual mortality rate for calves with BRD in that herd was 7% to 17% during that period (mean, 13%). Results of those studies indicated preweaned calves with BRD weighed 7.7 kg (16.9 lb) less at the time of birth versus such calves without BRD. During some years of those studies, the incidence of BRD in preweaned calves was higher than the incidence of BRD in calves after weaning and transfer to a feedlot. Although the findings of those studies were determined for animals in only 1 large herd, they suggest that BRD has substantial effects on nursing beef calves.

The objective of the study reported here was to determine herd-level risk factors for BRD in nursing beef calves by use of a population-based, cross-sectional survey of cow-calf producers in 2 US calf-producing regions. The goal of the study was to identify risk factors for BRD in nursing beef calves.

Materials and Methods

Sample—Beef operations from 3 Eastern states (Florida, Georgia, and West Virginia) and 3 Plains states (Iowa, Kansas, and Nebraska) were selected for participation in the study. The survey was conducted in collaboration with the USDA National Agriculture Statistics Service. For each region (Eastern and Plains states), beef operations were stratified by state and herd size. Questionnaires were mailed to 1,300 beef operations in each of the 2 regions (total number of questionnaires, 2,600). Operations were selected by use of computer-generated random numbers; stratum-specific (ie, for each combination of state and herd size category) sample sizes were determined via proportional allocation on the basis of the most recent stratum population estimates of the USDA National Agriculture Statistics Service during July 2011. The target population consisted of beef cow-calf operations that had ≥ 1 beef cow at the time of their most recent contact with the National Agriculture Statistics Service; dairy and feedlot operations were excluded from the study. Selected operations received a questionnaire with a postage-paid return envelope via mail during the first week of August 2011. A postcard reminder was sent 2 weeks after the initial mailing, and a second copy of the questionnaire was mailed to operations that had not responded within 4 weeks after the initial mailing.

Questionnaire development—A preliminary version of the questionnaire was developed by one of the investigators (ARW) and was subsequently reviewed by the other investigators. After the investigators determined the structure of the questionnaire and wording of questions by consensus, a preliminary version of the survey was pretested by personnel of 2 to 6 cow-calf operations in each state included in the study. Revisions to the questionnaire were subsequently made on the basis of the responses and comments provided by personnel of the operations that completed the preliminary version. Operations for testing of the preliminary version of the questionnaire were selected by convenience; consequently, responses to those questionnaires were not included in analysis of data. The final version of the questionnaire had questions in 5 sections: respiratory disease, calf diarrhea, use of vaccines, calving season management, and overall herd management. Respondents were directed to restrict their responses to a single production group of calves born at their operation during the 2010 calendar year; a production group was defined as calves born in a single calving season to a group of cows that were managed in a similar manner. Surveys were completed by personnel of operations that participated in the study. The following description of respiratory disease was provided for personnel completing the survey: "Calves with respiratory disease (also called 'pneumonia' or 'BRD') are less active and less interested in eating than normal calves. They may cough and have a snotty nose, and have a fever. Their breathing may be faster than normal or harder than normal, and they may breathe with an open mouth. Calves with respiratory disease may get better on their own, they may die, or they may survive but lose weight and look sick for weeks or months (become chronic)."

Statistical analysis—Data were evaluated to detect errors by means of range and logic checks. Responses for each operation were statistically weighted by inverting probabilities of selection, and sampling weights for each stratum (ie, each combination of state and herd size category) were subsequently adjusted for nonresponse to allow inferences to be made for the original target population. A commercial software package[a] that incorporated algorithms designed for the analysis of complex survey data was used to determine appropriate population estimates. Standard errors for all parameters were calculated with linearized variance estimators.

Logistic regression of survey data was used to evaluate the association of herd characteristics with the herd-level probability of detecting respiratory disease in any nursing beef calf. Multivariable model selection was performed with a maximum main-effects model that included all predictor variables that were associated with calf BRD ($P < 0.10$) in the univariable analysis. Variables were removed from the multivariable model in a stepwise fashion on the basis of the level of significance until only those variables with a value of $P < 0.05$ remained in the model. Region and herd size were retained in all models

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regardless of the *P* value because they were considered to be of theoretical importance as confounding variables. After determination of a preliminary main-effects model, the significance of previously removed variables was reevaluated in that model; all possible 2-way interactions including the variable region were evaluated. The goodness of fit of the final logistic regression model was evaluated via the *F*-adjusted mean residual test.[14] Data were evaluated to detect outlier values and influential observations via examination of plots of the predicted probabilities versus delta χ^2, delta-deviance, and delta β statistics determined with an unweighted version of the final logistic model.

A survey ZINB model was used to evaluate the association of herd characteristics with the number of calves in each herd that were treated for BRD. The ZINB model consisted of 2 components (binary logistic and negative binomial components) that allowed zero counts to be predicted via 2 distinct processes.[15,16] This model was considered to be theoretically appropriate for analysis of data in the present study because many herds did not have calves that were treated for BRD because BRD had not been detected in calves or calves with BRD did not require treatment. The same variables that were included in the best-fitting logistic model for the prediction of the herd-level detection of BRD in calves were included in the binary inflation portion of the ZINB model.

Model selection for the negative binomial portion of the ZINB model was performed with the same method performed for logistic regression model selection. The number of live calves born in each herd was included as an exposure variable to account for differences in the size of the population at risk for BRD. Consequently, the exponentiated coefficients determined from the negative binomial portion of the ZINB model were interpreted as the relative cumulative incidence (ie, relative risk) of treatment of calves for BRD in herds with the specified characteristics. For example, a relative risk of 2.0 for a particular characteristic indicated that the proportion of calves treated for BRD in herds with that characteristic was twice as high as the proportion of calves treated for BRD in herds without that characteristic. The exponentiated coefficients determined with the logistic portion of the ZINB model were interpreted as the relative odds (ie, OR) of detecting no calves with BRD in herds with the specified characteristics. Because the logistic portion of the ZINB model predicted the absence of BRD in calves rather than the presence of that disease in calves, the interpretation of coefficients for the logistic portion of the ZINB model was opposite in direction to that for the logistic regression model that was used to predict the probability that BRD would be detected in calves. A likelihood-ratio test of the null hypothesis (that the dispersion parameter $\alpha = 0$) was used to assess the fit of the ZINB model relative to a zero-inflated Poisson model, and the Vuong test was used to assess the fit of the ZINB model relative to a standard negative binomial model.[17] All testing was conducted with an assumed 2-sided alternative hypothesis, and values of $P < 0.05$ were considered significant.

Results

Survey response—Questionnaires were returned by 873 of the 2,600 (33.6%) operations to which they were distributed. Of the 873 operations that returned a questionnaire, 463 (53.0%) indicated that 1 or more beef calves had been born at the facility during 2010 (this response indicated questionnaire data were eligible for inclusion in the study). Of those 463 operations, 224 (48.4%) were in Plains states (87 [18.8%] in Iowa, 74 [16.0%] in Kansas, and 63 [13.6%] in Nebraska) and 239 (51.6%) were in Eastern states (66 [14.3%] in Florida, 104 [22.5%] in Georgia, and 69 [14.9%] in West Virginia); of those operations, 136 (29.4%) had 1 to 19 animals, 133 (28.7%) had 20 to 49 animals, 81 (17.5%) had 50 to 99 animals, 57 (12.3%) had 100 to 199 animals, 25 (5.4%) had ≥ 200 animals, and 31 (6.7%) did not provide herd size information. Of those 463 cow-calf operations, 459 (99.1%) provided information regarding respiratory disease in nursing beef calves. Data analyses were performed for these 459 questionnaires.

Characteristics and vaccination practices of operations—Herd size characteristics of operations and information regarding the percentage of operations that vaccinated calves against respiratory diseases were summarized **(Tables 1 and 2)**. Operations in Plains states had a significantly higher number of cows, calves born, and calves weaned versus operations in Eastern states. A significantly higher number of operations in Plains states vaccinated nursing calves, replacement heifers, and adult cows against respiratory diseases versus operations in Eastern states. For herds in which nursing calves were vaccinated against respiratory disease pathogens, 12.1% of calves were first vaccinated when they were < 30 days old, 54.8% of calves were vaccinated when they were 30 to 120 days old, 21.5% of calves were vaccinated when they were 121 to 180 days old, and 11.7% of calves were vaccinated when they were > 180 days old. Vaccines had been administered by a veterinarian or a person working under a veterinarian's direction for 29.9% of operations that vaccinated animals against respiratory diseases; vaccines had been administered by the producer or a person working under the direction of that person for 74.6% of such operations. On some operations, vaccines had been administered by both a veterinarian and by the producer. Vaccines were administered SC or IM for 93.1% of operations and intranasally for 16.7% of operations that vaccinated animals against respiratory tract pathogens. A booster vaccination was administered to calves prior to weaning in 39.5% of operations in which animals were vaccinated against respiratory disease pathogens.

Respiratory disease—The estimated percentage of cow-calf herds with ≥ 1 nursing beef calf with signs of respiratory disease was 21.1% (95% CI, 17.1% to 25.0%). Among operations that had calves with respiratory disease, ≥ 1 calf was treated for BRD in 89.2% (95% CI, 83.3% to 95.2%) and ≥ 1 calf died because of BRD in 46.4% (95% CI, 35.1% to 57.8%). The mean number of calves treated for BRD in herds that detected calves with that disease was 8.0 (95% CI, 5.9 to 10.1), and the mean number of calves that died because of BRD in such herds was 1.2 (95% CI, 0.7 to 1.8). Of operations in which BRD was detected, 36.1% detected BRD in calves < 30 days old, 61.5% detected BRD in calves 30 to 120 days old, 28.7% detected BRD in calves 121 to 180 days old, and 11.3% detected BRD in calves > 180 days old. One or more adult cows or replacement

Table 1—Herd characteristics of Plains and Eastern states beef cow-calf operations that responded to a survey for identification of risk factors for BRD in nursing calves born during 2010.

Variable	No. of operations responding	Mean (95% CI) No. of animals	*P* value*
No. of cows in herd			< 0.001
Plains states	212	102 (77–126)	
Eastern states	220	48 (40–56)	
No. of calves born in herd			< 0.001
Plains states	212	95 (72–118)	
Eastern states	218	37 (30–44)	
No. of calves weaned in herd			< 0.001
Plains states	209	94 (71–118)	
Eastern states	218	37 (30–43)	

*Determined with a design-based *t* test.

Plains states include Iowa, Kansas, and Nebraska. Eastern states include Florida, Georgia, and West Virginia. The number of operations responding to the survey varied among variables because of question nonresponses.

Table 2—Use of vaccines against respiratory tract pathogens in Plains and Eastern states beef cow-calf operations that had ≥ 1 calf born during 2010 and responded to a survey for identification of risk factors for BRD in nursing calves.

Type of animal receiving vaccines	No. of operations responding	Percentage (95% CI) of herds that vaccinated	*P* value*
Nursing calves			< 0.001
Plains states	210	52.2 (45.9–58.4)	
Eastern states	219	15.0 (10.1–20.0)	
Replacement heifers			< 0.001
Plains states	180	55.6 (48.8–62.5)	
Eastern states	197	19.8 (14.3–25.3)	
Adult cows			< 0.001
Plains states	202	47.5 (40.8–54.2)	
Eastern states	208	17.2 (12.2–22.2)	

*Determined with a design-based Pearson χ^2 test.

See Table 1 for remainder of key.

heifers were treated for BRD in 6.1% (95% CI, 3.6% to 8.6%) of herds, and ≥ 1 adult cow or replacement heifer died because of BRD in 2.7% (95% CI, 0.9% to 4.4%) of herds.

Of operations in which calves were treated for BRD, antimicrobial drugs were administered via an injectable route (ie, IV, IM, or SC) in 100%, antimicrobial drugs were administered via an oral route in 10.5%, and antimicrobial drugs were administered in feed in 8.5%. Of operations in which calves were treated for BRD, treatment recommendations were made by a veterinarian in 63.5%, by a person other than a veterinarian in 7.6%, and by operation personnel in 48.0%.

Risk factors for BRD in nursing calves—Herd characteristics that had an association (*P* < 0.10) with detection of BRD in calves in univariable analyses were summarized (**Table 3**). Twenty-one of 35 variables evaluated had an association with BRD in calves in univariable analyses, although many of those variables were strongly related to the number of animals in a herd, which was also a predictor variable for detection of BRD in calves. Consequently, variables that were associated with detection of BRD in calves in the univariable analysis should be interpreted cautiously because those variables were likely confounded by differences in numbers of animals among herds and possibly by other herd characteristics.

The results of the multivariable logistic regression analysis were summarized (**Table 4**). In the multivariable model, detection of BRD in calves was associated with the number of animals in a herd, detection of respiratory disease in cows, detection of diarrhea in calves, and duration of the calving season in Plains herds but not Eastern herds. Compared with operations that had 1 to 49 cows, the odds of detecting BRD in calves were similar for operations that had 50 to 99 cows (OR, 1.1) but were approximately 4 to 5 times as great for operations with ≥ 100 cows. The odds of detecting BRD in calves were 4.1 times as great for operations in which cows had been treated for respiratory disease versus operations in which cows had not been treated for respiratory disease and 8.4 times as great for operations in which diarrhea had been detected in nursing calves versus operations in which diarrhea had not been detected in nursing calves. Significant interaction was detected between the variables region and duration of the calving season. For operations in Plains states, the odds of detecting BRD in calves was significantly (*P* = 0.002) lower for herds in which calves were born during a period < 3 months versus herds in which calves were born during a period ≥ 3 months (OR, 0.15; 95% CI, 0.05 to 0.49). For operations in Eastern states, no significant (*P* = 0.290) association was identified between detection of BRD in calves and a calving season < 3 months (OR, 1.9; 95% CI, 0.58 to 6.0). The reason for the difference between regions regarding the effect of calving season length on detection of BRD in calves could not be determined; however, a significantly (*P* < 0.001) lower percentage of herds in Eastern states had a calving season < 3 months versus herds in Plains states (10.1% and 25.6%, respectively). Also, the percentage of herds with a calving season < 3 months that had a herd size ≤ 10 cows was significantly (*P* < 0.001) higher for Eastern states versus Plains states (47.8% and 12.4%, respectively). Therefore, a short calving season for herds in Eastern states may have been attributable to smaller herd sizes, compared with herds in Plains states, where it may be more likely to reflect a decision by producers to limit the length of the breeding season. Also, the potential benefit of a short calving season may have been low for very small herds, in which few animals may have been at risk for BRD. Results of an

Table 3—Variables determined in univariable analyses to have an association ($P < 0.10$) with detection of respiratory disease in nursing beef calves during 2010 in cow-calf operations that had ≥ 1 calf born during that year and responded to a survey for identification of risk factors for BRD in nursing calves.

Variable	No. of operations responding	Percentage (95% CI) of operations in which BRD was detected in nursing calves	*P* value*
Region			< 0.001
Plains states	220	27.1 (21.1–33.0)	
Eastern states	239	11.6 (7.6–15.6)	
No. of cows in herd			< 0.001
1–49	269	10.8 (6.7–14.9)	
50–99	79	24.9 (14.6–35.1)	
100–199	56	44.3 (30.5–58.0)	
≥ 200	25	56.0 (36.4–75.5)	
Treatment of ≥ 1 cow for respiratory disease			< 0.001
No	403	20.1 (16.0–24.3)	
Yes	23	57.2 (36.3–78.2)	
Detection of diarrhea in ≥ 1 calf			< 0.001
No	290	8.0 (4.4–11.6)	
Yes	142	46.5 (37.7–55.2)	
Administration of vaccines against respiratory tract pathogens to calves before weaning			< 0.001
No	287	16.3 (11.5–21.1)	
Yes	141	31.9 (23.9–39.8)	
Administration of vaccines against respiratory tract pathogens to cows or replacement heifers			< 0.001
No or don't know	249	11.8 (7.2–16.3)	
Yes	160	34.9 (27.5–42.3)	
No. of months during which calves were born in 2010			0.009
< 3	77	11.0 (3.8–18.1)	
≥ 3	336	25.0 (20.2–29.9)	
> 50% of cows or heifers gave birth in confinement			0.002
No	318	17.2 (12.9–21.6)	
Yes	113	31.9 (22.8–41.0)	
No. of times/d cows were examined during the calving season			< 0.001
< 1	91	13.9 (6.5–21.3)	
1–2	194	16.5 (10.8–22.3)	
> 2	143	32.5 (24.2–40.8)	
≥ 1 cow or heifer required assistance during calving			< 0.001
No	245	10.0 (5.9–14.0)	
Yes	184	34.7 (27.5–41.9)	
≥ 1 calf did not receive adequate passive transfer of maternally derived antibodies			< 0.001
No	313	14.4 (10.1–18.8)	
Yes	117	38.3 (29.0–47.5)	
A bottle or tube was used to feed colostrum to ≥ 1 calf			< 0.001
No	300	13.1 (9.0–17.1)	
Yes	130	38.3 (29.4–47.2)	
Topical treatment of umbilicus of calves ≤ 3 days after birth			0.098
No	385	20.6 (16.3–24.9)	
Yes	47	31.9 (17.9–45.9)	
Castration of calves before weaning			0.004
No	171	13.4 (7.6–19.1)	
Yes	264	26.3 (20.8–31.8)	
Calves assigned a unique identification prior to weaning			< 0.001
No	187	12.4 (7.0–17.8)	
Yes	243	27.8 (21.9–33.7)	
Introduction of cattle (of any type) to the operation from outside sources during 2010			< 0.001
No	167	9.9 (5.2–14.6)	
Yes	270	27.9 (22.2–33.6)	
Cow-calf pairs physically separated into groups on the basis of calf age			0.001
No	394	19.2 (15.0–23.4)	
Yes	42	42.4 (27.0–59.9)	
Use of estrous cycle synchronization program for cows or heifers			0.001
No	416	19.1 (15.1–23.1)	
Yes	36	42.8 (25.9–59.7)	
Examination of cows or heifers to determine pregnancy status			0.003
No	326	16.6 (12.1–21.2)	
Yes	125	30.2 (22.0–38.4)	
Herd was moved > 1 mile via ambulation at any time prior to weaning of calves			0.001
No	400	18.0 (14.0–22.1)	
Yes	48	39.5 (24.8–54.1)	
Cows and calves gathered to avoid flies			< 0.001
No	200	9.2 (5.1–13.4)	
Yes	242	29.8 (23.7–35.9)	

See Tables 1 and 2 for key.

Table 4—Results of multivariable logistic regression for the prediction of respiratory disease in nursing calves born in 2010 in 380 cow-calf operations that provided complete survey information for all variables.

Variable	Regression coefficient (SE)	OR (95% CI)	*P* value
No. of cows in herd			0.001
1–49	Referent	Referent	NA
50–99	0.072 (0.432)	1.1 (0.46–2.5)	0.869
100–199	1.41 (0.453)	4.1 (1.7–10)	0.002
≥ 200	1.62 (0.616)	5.0 (1.5–17)	0.009
Region			
Plains states	Referent	Referent	NA
Eastern states	–0.418 (0.352)	NR	0.236
Treatment of ≥ 1 cow for respiratory disease			
No	Referent	Referent	NA
Yes	1.40 (0.595)	4.1 (1.3–13)	0.019
Detection of diarrhea in ≥ 1 calf			
No	Referent	Referent	NA
Yes	2.13 (0.368)	8.4 (4.1–17)	< 0.001
No. of months during which calves were born in 2010			
≥ 3	Referent	Referent	NA
< 3	–1.91 (0.602)	NR	0.002
Region × No. of months during which calves were born (Eastern region × < 3 mo)	2.54 (0.861)	NR	0.003
Constant	–2.57 (0.407)	NA	< 0.001

Odds ratios for region and no. of months during which calves were born were not reported in the table because there was a significant interaction between these variables. Odds ratios for the interaction are reported in the text.

NA = Not applicable. NR = Not reported.

See Table 1 for remainder of key.

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overall goodness-of-fit test indicated that the final logistic regression model provided a good fit for data ($P = 0.927$).

A ZINB model was used to identify herd characteristics associated with the proportion of calves that were treated for BRD in herds that had animals with that disease (**Tables 5 and 6**). Because the logistic portion of the ZINB model predicted the absence rather than the presence of BRD in calves, the coefficients for the logistic portion of the ZINB model were opposite in direction to those of the logistic regression model (Table 4), but the substantive conclusions regarding herd-level detection of BRD in calves were similar. On the basis of results of the negative binomial portion of the model for herds in which BRD was detected in calves, the cumulative incidence of treatment of calves for BRD was associated with herd size, calving during winter and early spring months (January through April), introduction of calves into an operation from an outside source, providing calves with supplemental food (eg, creep feed), use of a estrous cycle synchronization program for cows or heifers, and not examining cows to detect pregnancy. The cumulative incidence of treatment of calves for BRD in herds with 1 to 49 cows was not significantly different from that for herds with 50 to 99 or 100 to 199 cows, but the incidence of treatment was significantly lower (relative risk, 0.55) for herds with ≥ 200 cows. The cumulative incidence of treatment of calves for BRD was 1.6 times as high for herds in which > 50% of calves were born between January and April and 2.6 times as high for herds in which calves were introduced from an outside source versus other herds without those characteristics. Likewise, the cumulative incidence of treatment of calves for BRD was 1.7 times as high for herds in which calves were provided with supplemental food that was not accessible to cows and 1.6 times as high for herds in which an estrous cycle synchronization program was used as part of the breeding program versus herds without those characteristics. The cumulative treatment incidence was significantly lower (relative risk, 0.62) for herds in which cows or heifers had been checked for pregnancy versus other herds. No significant ($P = 0.555$) difference was detected between Eastern and Plains regions regarding cumulative incidence of treatment of calves for BRD, but the variable region was retained in the negative binomial portion of the ZINB model so that the other estimates would be adjusted for the influence of that variable because it may have been a confounding factor.

Data for 1 operation in which all (100%) calves were treated for BRD were excluded from the ZINB model because it was assumed that this constituted mass treatment, which may not have been representative of the true proportion of calves in the operation that had developed clinical respiratory disease. The highest cumulative incidence of treatment of calves for BRD for any other herd was 35.8%. The estimated value of the dispersion parameter for the final ZINB model was $\alpha = 0.248$ (SE, 0.059). Results of a likelihood-ratio test of the null hypothesis that the dispersion parameter $\alpha = 0$ indicated that the ZINB model had a significantly ($P < 0.001$) better fit for data versus a comparable zero-inflated Poisson model. Results of a Vuong test for comparison of the final ZINB model with a standard

Table 5—Results of the negative binomial portion of a multivariable ZINB analysis for the prediction of respiratory disease in nursing calves born in 2010 in 364 cow-calf operations that provided complete survey information for all variables.

Variable	Regression coefficient (SE)	Relative risk (95% CI)	*P* value
No. of cows in herd			0.003
1–49	Referent	Referent	NA
50–99	0.292 (0.331)	1.3 (0.70–2.6)	0.377
100–199	–0.414 (0.277)	0.66 (0.38–1.1)	0.136
≥ 200	–0.591 (0.284)	0.55 (0.32–0.97)	0.038
Region			
Plains states	Referent	Referent	NA
Eastern states	–0.144 (0.243)	0.87 (0.54–1.4)	0.555
> 50% of calves born during January through April			
No	Referent	Referent	NA
Yes	0.466 (0.198)	1.6 (1.1–2.4)	0.019
≥ 1 calf introduced to the operation from an outside source during 2010			
No	Referent	Referent	NA
Yes	0.940 (0.386)	2.6 (1.2–5.5)	0.016
Nursing calves fed supplemental feed (eg, creep feed)			
No	Referent	Referent	NA
Yes	0.508 (0.187)	1.7 (1.1–2.4)	0.007
Use of estrous cycle synchronization program for cows or heifers			
No	Referent	Referent	NA
Yes	0.498 (0.186)	1.6 (1.1–2.4)	0.008
Examination of cows or heifers to determine pregnancy status			
No	Referent	Referent	NA
Yes	–0.478 (0.220)	0.62 (0.40–0.96)	0.031
Constant	–2.96 (0.251)	NA	< 0.001
ln of No. of calves born	1.00	NA	NA

*The negative binomial portion of the ZINB model predicted the cumulative incidence of BRD treatment of calves in herds with animals that had respiratory disease.

See Tables 1 and 4 for remainder of key.

Table 6— Results of the logistic portion of a multivariable ZINB analysis for the prediction of respiratory disease in nursing calves born in 2010 in 364 cow-calf operations that provided complete survey information for all variables.

Variable	Regression coefficient (SE)	OR (95% CI)	*P* value
No. of cows in herd			0.007
1–49	Referent	Referent	NA
50–99	0.179 (0.507)	1.2 (0.44–3.2)	0.725
100–199	–1.33 (0.544)	0.27 (0.09–0.77)	0.015
≥ 200	–1.43 (0.707)	0.24 (0.06–0.96)	0.043
Region			
Plain states	Referent	Referent	NA
Eastern states	0.844 (0.419)	NR	0.045
≥ 1 cow treated for respiratory disease			
No	Referent	Referent	NA
Yes	–1.35 (0.635)	0.26 (0.07–0.90)	0.034
Detection of diarrhea in ≥ 1 calf			
No	Referent	Referent	NA
Yes	–2.18 (0.427)	0.11 (0.05–0.26)	< 0.001
No. of months during which calves were born in 2010			
≥ 3	Referent	Referent	NA
< 3	1.90 (0.621)	NR	0.002
Region × No. of months during which calves were born (Eastern region × < 3 mo)	–2.66 (1.12)	NR	0.018
Constant	2.39 (0.478)	NA	< 0.001

The logistic portion of ZINB model predicted the probability that an operation would have no calves with respiratory disease.

See Tables 1 and 4 for key.

negative binomial model indicated a value of $z = 5.40$ ($P < 0.001$), indicating that the zero-inflated model was strongly preferred.

Discussion

Results of the present study in which cow-calf producers in 2 major US calf-producing regions were surveyed indicated associations between certain management practices and the development of BRD in nursing calves and increased incidence of treatment of calves for BRD. These results should be interpreted with consideration of the limitations of mailed surveys, including potential bias attributable to a low response rate and the possibility that producers may have misclassified some calves regarding BRD status. The overall survey response rate in this study (34%) was a typical response rate for a mailed survey[18]; however, only 53% of the respondents had calves that were born during 2010, which was a criterion for inclusion. Moreover, because surveys were completed by producers in only 6 states, results may not have been representative of risk factors for BRD in calves in other states or countries. However, a large number of operations were included in this study, and the findings regarding risk factors for BRD in calves may be useful for the design of future studies for development of evidence-based strategies to control BRD in calves.

The high proportion of respondents (47%) in this study without calves born during 2010 was surprising. This finding may have been partly attributable to the shorter amount of time required to complete the survey for producers without calves compared to producers with calves. Producers without calves only had to check 1 box on the questionnaire indicating that they did not have any calves born during 2010, whereas producers who had calves born during 2010 had to complete the entire questionnaire. Consequently, producers with no calves may have been more likely to return their questionnaires. Also, approximately 57% of the respondents who indicated that they did not have any calves born during 2010 had an estimated herd size of 1 to 19 animals in the National Agriculture Statistics Service database (data not shown). Many of the operations in this herd size category may have been small-scale or hobby producers that had gone out of business after their most recent National Agriculture Statistics Service contact.

The responses of producers surveyed in the present study were similar to those of respondents of other surveys regarding animal health and management in cow-calf operations. Twenty-one percent of respondents to the survey of the present study indicated BRD had been detected in ≥ 1 calf in their operation during 2010; similarly, results of a mailed survey of producers in Québec indicated 16% of respondents with < 40 cows had detected BRD in calves, versus 36% of respondents with ≥ 40 cows.[19] The difference in the percentage of operations in the Plains and Eastern regions in the present study in which vaccines against respiratory diseases were administered to animals was similar to findings of another study[4] in that 91% of producers in the central region of the United States administered such vaccines to cows or calves and 60% of producers in the southeast region administered such vaccines to cows or calves. Results of that other study[4] indicated personnel in 13% to 33% of operations administered vaccines against respiratory pathogens to calves when they were 22 days old to the time of weaning; this finding was similar to the percentage of producers in the Eastern region in the present study that administered such vaccines to nursing calves (15%) but was lower than the percentage of producers in the Plains region that administered such vaccines to nursing calves (52%). In addition, most operations in that other study[4] and the present study indicated that information regarding the use of antimicrobial drugs for treatment of respiratory diseases of unweaned calves was obtained from veterinarians (66% and 64% of operations, respectively).

Few studies have been conducted to identify herd-level risk factors for BRD in nursing calves. Results of a survey of cow-calf producers in Québec indicated that herd size, duration of calving season, and geographic region in that province are herd-level factors associated with development of BRD in preweaned calves.[19] Results of a seroepidemiologic study[20] conducted in Québec indicated that herds in which cows are vaccinated against viruses that cause respiratory diseases have lower rates of BRD infection in preweaned calves versus herds in which cows do not receive such vaccines. Results of the present study indicated that factors associated with detection of BRD in calves included herd size, detection of diarrhea in calves in the herd, treatment of cows for respiratory disease, and, for operations in the Plains region but not for operations in the Eastern region, calving season duration. Risk factors associated with the cumulative incidence of treatment of calves for BRD included introducing calves from outside sources, feeding of creep feed to nursing calves, use of an estrous cycle synchronization program for cows or replacement heifers, and having > 50% of calves born between January and April. Factors significantly but negatively associated with the incidence of treatment of calves for BRD included examination of cows or replacement heifers to detect pregnancy and a large number of cattle in the herd. Thus, although operations with a large number of cattle were more likely to have calves with BRD versus operations with a small number of cattle, a smaller proportion of calves was treated for BRD in large herds versus small herds. This finding may have been attributable to the possibility that a producer with a large number of calves may have more opportunities to identify animals with respiratory disease versus a producer with a small number of calves. However, perhaps BRD of severity sufficient to warrant treatment is relatively uncommon in a larger population. Alternately, it may be that in larger herds, producers are not able to treat all calves that they judge to need treatment because of logistical limitations. Results of the multivariable analysis in the present study indicated that administration of vaccines against respiratory diseases to calves or cows and replacement heifers did not have a significant positive or negative association with the detection of BRD in calves. Use of the results of the present study for determination of conclusions regarding the effectiveness of vaccination of animals would not be ap-

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propriate, however, because the cross-sectional design of this study did not allow us to distinguish between herds in which vaccines were administered purely for prevention of disease and those in which vaccines were administered because of a perceived BRD problem in the herd.

Investigators of a recent study[21] also identified factors associated with development of BRD in nursing calves in cow-calf operations by means of a survey of cow-calf herds. Results of that study[21] indicated that introduction of steers from outside sources, proportion of breeds of animals in a herd, number of visits to the herd by nonoperation personnel, administration of antimicrobial drugs in feed to prevent BRD in calves, and status of the herd as the primary source of income for the producer were associated with the percentage of calves treated for BRD. Those results were similar to results of the present study in that management practices that could allow introduction of pathogens new to the herd were associated with development of BRD in calves. Other factors associated with BRD in calves identified in that study[21] were not associated with BRD in calves in the present study; this difference in findings may have been attributable to differences between the studies regarding the states in which respondents were located or definitions of calf BRD used in the 2 studies. However, although not all findings of that study[21] and the present study were similar, herd characteristics that were associated with development of BRD in calves in the studies may be related. For example, results of the other study[21] did not indicate herd size to be significantly associated with BRD in preweaned calves; however, status of the herd as the primary source of income for the producer was associated with BRD in preweaned calves, and number of animals in the herd was associated with status of the herd as the primary source of income for the producer.

Although the management practices that we found to be associated with development of BRD in calves or cumulative BRD treatment incidence cannot be assumed to be causative, some of them may be. Further research is warranted to evaluate whether modification of management practices associated with these risk factors can decrease BRD in calves. For example, diarrhea was determined to be strongly associated with BRD in calves in this study. Results of other studies[6,9] indicate that diarrhea is associated with development of respiratory disease in dairy calves; this finding may be attributable to negative metabolic or immunologic effects of diarrhea, which decrease the ability of calves to resist development of respiratory tract infection. Alternately, this finding may have been indicative of increased susceptibility of calves to disease because of suboptimal passive transfer of maternally derived antibodies, frequent opportunities for contact with infectious agents, or other factors. Control of diarrhea in calves in operations in which that disease is a substantial problem might lead to decreased incidence of respiratory disease. The relationship between estrous cycle synchronization and development of BRD in calves identified in this study has been anecdotally reported; thus, the finding that estrous cycle synchronization was significantly associated with cumulative incidence of treatment of calves for BRD was interesting. This finding may have been attributable to the possibility that gathering cow-calf pairs together for administration of the treatments required for estrous cycle synchronization of cows increased opportunities for transmission of infectious respiratory pathogens from cows to calves or among calves. Modifications of calf-handling practices during estrous cycle synchronization of cows or efforts to increase the strength of immunity of calves to disease before such treatments of cows could help decrease the incidence of respiratory disease in herds in which estrous cycle synchronization of cows is performed. Likewise, creep feeding of calves may increase opportunities for transmission of infectious respiratory pathogens among calves. Alternately, estrous cycle synchronization and creep feeding of calves may not increase the risk of BRD for calves; instead, those management practices may increase the number of opportunities for producers to observe calves and detect signs of BRD. Introducing calves to a herd from outside sources may increase the risk of BRD for calves through introduction of respiratory or other pathogens that are new to the herd; this management practice is a biosecurity risk and should be discouraged for operations with a high incidence of BRD in nursing calves. The most important conclusions determined from the results of this and other studies may be that management practices that increase the number of opportunities for introduction of pathogens new to a herd and practices that increase opportunities for transmission of infectious agents among cows and calves should be evaluated in future efforts to develop evidence-based practices for control of BRD in nursing calves in cow-calf operations.

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