Risk factors associated with hemorrhagic bowel syndrome in dairy cattle

Roy D. Berghaus, DVM, MS, DACVPM; Brian J. McCluskey, DVM, PhD, DACVPM; Robert J. Callan, DVM, PhD, DACVIM

Objective—To determine risk factors associated with hemorrhagic bowel syndrome (HBS) among dairy cattle in the United States and identify characteristics of HBS in individual cows.

Design—Cross-sectional, population-based survey.

Sample Population—A stratified random sample of 1,013 dairy operations with ≥ 30 cows located in 21 states.

Procedure—Information on management and animal health-related topics was collected with a questionnaire.

Results—HBS was estimated to have been observed on 9.1% of operations during the preceding 5 years and on 5.1% of operations during the preceding 12 months. Factors found in multivariable analysis to be associated with the occurrence of HBS during the preceding 12 months were large herd size, administration of bovine somatotropin, and routine use of milk urea nitrogen concentration to determine ration composition. Use of pasture as part of the lactating cow ration during the growing season was associated with decreased odds of HBS in operations with rolling herd average milk production ≤ 20,000 lb, whereas in operations with higher milk production, use of pasture was not associated with occurrence of HBS. For individual cows with signs consistent with HBS, the third lactation was the median of the parity distribution and the median time between parturition and the onset of clinical signs was 104 days.

Conclusions and Clinical Relevance—Results suggest that management practices implemented to achieve high milk production may increase the risk of developing HBS in dairy cattle. Increased consumption of a high-energy diet seems to be the most plausible common pathway for all of the risk factors that have been described. (*J Am Vet Med Assoc* 2005;226:1700–1706)

RUMINANTS/ SWINE

Hemorrhagic bowel syndrome (HBS), also known as jejunal hemorrhage syndrome, is an acute sporadic enteric disease recognized most frequently in adult dairy cattle. Affected cows have signs of depression and may develop clinical signs consistent with an intestinal obstruction, such as abdominal distension, colic, dehydration, and shock.[1,2] Sudden death is common, with necropsy revealing segmental necrohemorrhagic enteritis of the small intestine and large intraluminal blood clots. Even with prompt medical and surgical intervention, the prognosis is poor, with the case fatality risk for cattle with HBS reported to exceed 85%.[3] Although the cause of HBS is unknown, several investigators have identified *Clostridium perfringens* type A in fecal cultures and tissue samples from affected cattle.[2-4,a] However, because *C perfringens* can be found in the intestinal tracts of healthy animals and is able to proliferate rapidly after death, what role *C perfringens* might have in the pathogenesis of HBS, if any, is unclear.[5] *Aspergillus fumigatus* has also recently been implicated as a possible etiologic agent of HBS.[6]

Despite recent reports[7-9] suggesting that the incidence of HBS may be increasing in the United States and elsewhere, limited information is available about herd- and cow-level risk factors that may be associated with the disease. Potential risk factors that have been suggested include increased milk production and related variables, such as increased consumption of dry matter and soluble carbohydrates; feeding a **total mixed ration (TMR)**; being in the first 100 days after calving; and being in the second or higher lactation.[3,4] Information about HBS was collected as part of the National Animal Health Monitoring System's Dairy 2002 study, and a brief information sheet providing some preliminary information about HBS, including its distribution in the United States by herd size, region, and **rolling herd average (RHA)** milk production during the 5-year period prior to the study, has previously been released.[10] The purposes of the study reported here were to determine risk factors associated with HBS among dairy cattle in the United States and identify characteristics of HBS in individual cows.

Materials and Methods

Data used in the present study were collected as part of the National Animal Health Monitoring System's Dairy 2002 study. Sample selection methodology and numbers of responding and nonresponding operations have been reported previously.[11] Briefly, a stratified random sample of dairy operations in 21 states (California, Colorado, Florida, Idaho, Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New Mexico, New York, Ohio, Pennsylvania, Tennessee, Texas, Vermont, Virginia, Washington, and Wisconsin) representing approximately 85.5% of the milk cows and 82.9% of the operations with milk cows in the United States was selected. A sampling frame was constructed from the National Agricultural Statistics Service's database, with strata formed on the basis of state and herd-size characteristics, from which 3,876 dairy operations were selected for an initial screening. Of those that were screened, 2,461 eligible operations elected to participate in the first phase of the Dairy 2002 study, which included administration of a questionnaire covering general dairy management practices between December 31, 2001, and February 12, 2002. Operations with ≥ 30 dairy cows that completed this first phase of the study were invited to continue to the second phase, which consisted of administration of a second questionnaire between February 25 and April 30, 2002. This

From the Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis, CA 95616 (Berghaus); the Centers for Epidemiology and Animal Health, 2150 Centre Ave, Building B, Mail Stop 2E7, Fort Collins, CO 80526 (McCluskey); and the Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523 (Callan).

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Address correspondence to Dr. Berghaus.

second questionnaire covered additional management and animal health-related topics, including several questions pertaining to HBS. Of the 1,438 operations that were eligible for the second phase of the study, 1,013 participated. The target population for the second phase of the study, on which inferences from the current analysis were based, included all operations with ≥ 30 dairy cows in the 21 states and represented 97.4% of the cows and 74.3% of the operations in those states.

As part of the questionnaire administered during the second phase of the Dairy 2002 study, producers were asked about their familiarity with HBS and were then shown a picture reference card while the following description of the disease was read to them by the attending veterinary medical officer:

> Hemorrhagic bowel syndrome is a highly fatal intestinal disease of milking cows. The frequency of this disease seems to be increasing across the country. Hemorrhagic bowel syndrome is characterized by a sudden onset of bloody feces, with or without intestinal obstruction. Sudden death without prior signs is common. Cows with HBS have a high death rate, approaching 70% to 80%. Both medical and surgical treatments have been relatively unsuccessful. A bloody bowel accompanied by a blood clot that obstructs the intestine may be observed at necropsy. Hemorrhagic bowel syndrome does not appear to be an infectious or contagious disease.

Producers were subsequently asked how many cows with signs consistent with HBS they had observed on their operation within the past 5 years and within the past 12 months. Producers were asked to recall the year in which they had first observed a case of HBS, the month and year of the most recent case, and whether the most recent case had been diagnosed by a veterinarian. Producers reporting a case of HBS in the past 12 months were asked to provide cow-level information for the cow most recently identified with the disease. Information collected included lactation number; breed; recent history of vaccination against *C perfringens*; whether the cow was fed a TMR at the time of illness; and whether the cow had had a displaced abomasum, acidosis, mastitis, metritis, or a retained placenta. Additionally, the number of days between parturition and disease onset was recorded.

Statistical analyses—For herd-level analyses, responses for individual operations were weighted by inverting their probabilities of selection to reflect the population from which they were chosen. Sampling weights were adjusted for nonresponse within each of the strata, and a commercial software package[b] that incorporated algorithms designed for the analysis of complex survey data was used to allow inferences to be made back to the original target population. Univariate descriptive statistics for herd-level characteristics were calculated with the appropriate survey estimators, and bivariate and multivariable logistic regression analyses were performed to evaluate the association of herd-level management factors with having a suspected case of HBS during the previous 12 months. Having 1 or more suspected cases of HBS during the previous 12 months was used as the outcome rather than having a case during the previous 5 years because information collected on management practices was thought to more accurately reflect a 12-month time frame. In selecting the final multivariable model, variables that were of a priori interest, including whether a TMR was fed to lactating cows, RHA milk production, and use of clostridial vaccines, were included regardless of their significance. Likewise, herd size and region were included in all models because of their potential importance as confounders of the relationships between other variables and occurrence of HBS. Other exploratory variables were included as part of a maximum potential model if they had an association ($P \leq 0.15$) with having a suspected case of HBS during the previous 12 months after adjusting for herd size and region. Variables were sequentially removed from the maximum model on the basis of adjusted Wald statistics, providing that their removal did not result in a change of more than 10% to the estimated **odds ratios (ORs)** for other variables that were associated with HBS. After a tentative final model had been reached, each of the discarded variables was evaluated again by attempting to add it back to the final model and 2-way interactions between all significant main effect terms were evaluated.

Sampling weights were not used in calculating descriptive statistics for cow-level information. Characteristics of animals in which the diagnosis had or had not been confirmed by a veterinarian were compared to determine whether there were significant differences between groups. The number of days since parturition at the time of disease onset was compared between cows in which the diagnosis had or had not been confirmed by a veterinarian by use of the Mann-Whitney test, while the remaining categorical variables were analyzed by use of Pearson χ^2 or Fisher exact tests. All analyses were performed as 2-sided tests, with values of $P \leq 0.05$ considered significant.

Results

Univariate herd-level analyses—One hundred seventy-one of the 1,009 (16.9%) producers who completed the portion of the questionnaire pertaining to HBS reported that they had observed at least 1 cow with signs consistent with HBS during the previous 5 years, and 121 (12.0%) reported that they had observed at least 1 cow with signs consistent with HBS during the previous 12 months. After adjustment for characteristics of the survey sample, which differed from the target population by design to ensure that various regions and herd-size categories would be adequately represented, the estimated proportion of operations in the target population with at least 1 cow having signs consistent with HBS during the previous 5 years was 9.1% (SE, 1.1%) and the estimated proportion with at least 1 cow having signs consistent with HBS during the previous 12 months was 5.1% (SE, 0.8%). Estimated proportions of operations with at least 1 cow having signs consistent with HBS during the previous 12 months were 9.6% (SE, 1.8%) for western operations, 4.7% (SE, 1.1%) for midwestern operations, 4.2% (SE, 1.2%) for northeastern operations, and 7.0% (SE, 3.4%) for southeastern operations. As a function of herd size, estimated proportions of operations with at least 1 cow having signs consistent with HBS during the previous 12 months were 3.1% (SE, 0.9%) for operations with < 100 cows, 7.6% (SE, 1.4%) for operations with 100 to 499 cows, and 26.1% (SE, 3.7%) for operations with ≥ 500 cows.

For operations reporting at least 1 cow having signs consistent with HBS during the previous 5 years, the number of cases observed during that time ranged from 1 to 150 (median, 4.0). For operations reporting at least 1 cow having signs consistent with HBS during the previous 12 months, the number of cases observed during that time ranged from 1 to 75 (median, 2.0). When producers were asked about their familiarity with HBS, an estimated 87.8% (SE, 1.3%) had never

heard of the disease, 8.7% (SE, 1.3%) recognized the name, 2.5% (SE, 0.4%) knew some basics, and 1.0% (SE, 0.2%) were fairly knowledgeable.

Holstein cows were the predominant breed (ie, they accounted for > 50% of the herd) on an estimated 92.4% (SE, 1.1%) of operations in the target population. Production-related variables that were evaluated included RHA milk production, frequency of milking, and mean duration of the nonlactating period. Mean RHA for operations in the target population was 18,988 lb (SE, 151 lb), with 33.0% (SE, 2.0%) having RHA milk production ≤ 17,500 lb, 30.9% (SE, 2.0%) having RHA milk production between 17,501 and 20,000 lb, 18.3% (SE, 1.6%) having RHA milk production between 20,001 and 22,500 lb, and 17.7% (SE, 1.4%) having RHA milk production > 22,500 lb. Cows were milked twice a day by 93.6% (SE, 0.8%) of operations and 3 times a day by 5.8% (SE, 0.7%). Mean duration of the nonlactating period in 2001 was 60.8 days (SE, 0.4 days), with 70.6% (SE, 1.8%) of operations having a mean duration ≤ 60 days and 29.4% (SE, 1.8%) having a mean duration of > 60 days.

Because previous reports suggested that HBS may be associated with diet, several factors related to nutrition, including use of pasture during the growing season as part of the ration for lactating cows, whether a TMR was fed, and whether different diets were fed to subgroups of lactating cows, were evaluated. Overall, 52.7% (SE, 2.0%) of operations fed a TMR to lactating cows, and 61.2% (SE, 1.9%) did not rely on pasture for any part of the lactating cow ration. In addition, 59.1% (SE, 2.2%) of operations fed all lactating cows the same ration, whereas 38.2% (SE, 2.2%) fed different rations to lactating cows grouped on the basis of milk production and 2.7% (SE, 0.4%) fed different rations to lactating cows grouped on the basis of other criteria. Producers were also asked about their use of forage testing and **milk urea nitrogen concentration (MUN)** in balancing the rations of lactating cows. Forage tests were used by 82.5% (SE, 1.6%) of operations. In contrast, MUN was used routinely by 9.3% (SE, 1.0%) of operations, only when there was a problem by 13.0% (SE, 1.3%), and never by 77.7% (SE, 1.6%). Probiotics were used as a feed additive for lactating cows by 24.1% (SE, 1.8%) of operations, and cows that had recently calved were routinely treated with propylene glycol or another energy source by 20.2% (SE, 1.7%) of operations. Additional variables that were evaluated included administration of vaccines and use of **bovine somatotropin (bST)**. Clostridial vaccines were normally administered to heifers or cows on 39.4% (SE, 1.9%) of operations, whereas coliform and *Salmonella* vaccines had been administered to most cows during the previous 12 months on 35.8% (SE, 2.0%) and 10.4% (SE, 1.3%) of operations, respectively. Bovine somatotropin was administered to lactating cows on an estimated 22.3% (SE, 1.5%) of operations during the previous 12 months.

Bivariate and multivariable herd-level analyses— Logistic regression was used to evaluate associations between variables examined in the study and having at least 1 cow with signs consistent with HBS during the

Table 1—Results of bivariate logistic regression analysis of potential risk factors associated with having a cow with signs consistent with hemorrhagic bowel syndrome during the preceding 12 months on dairy operations with ≥ 30 cows.

Variable	No. of operations	OR (95% CI)	*P* value
Region	1,005		0.037
Midwest		Referent	
West		2.2 (1.1–4.1)	
Northeast		0.9 (0.4–1.9)	
Southeast		1.5 (0.5–4.8)	
Herd size (lactating and nonlactating cows)	1,005		< 0.001
< 100		Referent	
100–499		2.5 (1.2–5.2)	
≥ 500		10.9 (5.4–22.1)	
Breed composition > 50% Holstein	1,005	3.4 (0.9–12.1)	0.061
RHA milk production > 20,000 lb	1,002	3.3 (1.6–6.7)	0.001
Frequency of milking	1,001		< 0.001
2 times/d		Referent	
3 times/d		4.5 (2.6–8.0)	
Mean duration of nonlactating period > 60 days	1,005	2.6 (1.4–4.7)	0.003
Use pasture as part of the lactating cow ration	1,005	0.16 (0.04–0.68)	0.013
Feed a total mixed ration to lactating cows	1,005	2.9 (1.2–7.2)	0.020
Diet for lactating cows	1,004		0.003
All lactating cows fed same ration		Referent	
Different diets on basis of production		1.4 (0.7–2.7)	
Different diets on basis of other criteria		3.8 (1.8–8.3)	
Use MUN to balance ration	1,004		0.001
Never		Referent	
Only if have a problem		1.7 (0.9–3.1)	
Routinely		4.1 (1.9– 8.6)	
Routinely use clostridial vaccines	955	2.6 (1.4– 5.0)	0.003
Routinely use coliform vaccines	990	4.2 (2.1–8.4)	< 0.001
Routinely use *Salmonella* vaccines	972	3.0 (1.5–6.0)	0.002
Use bST in lactating cows	1,005	4.7 (2.5–9.1)	< 0.001

OR = Odds ratio. CI = Confidence interval. RHA = Rolling herd average. MUN = Milk urea nitrogen concentration. bST = Bovine somatotropin.
P values were based on adjusted Wald statistics.

previous 12 months. In bivariate analyses, having at least 1 cow with signs consistent with HBS during the previous 12 months was significantly associated with being located in the western region of the United States, having a larger herd size, having RHA milk production > 20,000 lb, milking cows 3 times/d, having a mean duration of the nonlactating period of > 60 days, use of pasture as part of the lactating cow ration, feeding a TMR, feeding different diets to lactating cows grouped on the basis of criteria other than production, use of MUN to balance the ration of lactating cows, use of clostridial vaccines, use of coliform vaccines, use of *Salmonella* vaccines, and use of bST (**Table 1**).

After adjustment for herd size and region, feeding a TMR, feeding different diets to lactating cows grouped on the basis of criteria other than production, and use of clostridial vaccines were no longer significantly associated with having at least 1 cow with signs consistent with HBS during the previous 12 months, but having a herd that was predominantly Holstein was significantly ($P = 0.050$) associated.

Exploratory variables removed from the maximum model because they were neither significantly associated with HBS nor important as confounders included having Holsteins as the predominant breed, frequency of milking, mean duration of the nonlactating period, use of coliform vaccines, and use of *Salmonella* vaccines. Region was not significantly associated with occurrence of HBS after adjustment for other variables in the model, but herd size remained significantly associated with occurrence of HBS, with the odds of having at least 1 cow with signs consistent with HBS during the previous 12 months increasing as herd size increased (**Table 2**). The final model included a significant 2-way interaction term between RHA milk production and use of pasture as part of the forage ration. When RHA milk production was ≤ 20,000 lb, operations that used pasture as part of the forage ration were significantly less likely to have had at least 1 cow with signs consistent with HBS during the previous 12 months than were operations that did not use pasture (OR, 0.01; 95% **confidence interval [CI]**, 0.002 to 0.042), whereas when RHA milk production was > 20,000 lb, use of pasture as part of the forage ration was not significantly associated with occurrence of HBS (OR, 0.26; 95% CI, 0.05 to 1.5). Additionally, when pasture was used as part of the forage ration, operations with RHA milk production > 20,000 lb were significantly more likely to have had at least 1 cow with signs consistent with HBS during the previous 12 months than were operations with lower RHA milk production (OR, 37.5; 95% CI, 4.5 to 313), whereas when pasture was not used as part of the forage ration, RHA milk production was not significantly associated with occurrence of HBS (OR, 1.3; 95% CI, 0.5 to 3.5). Operations that routinely used MUN to balance the ration of lactating cows were more likely to have had at least 1 cow with signs consistent with HBS during the previous 12 months, compared with operations that never used MUN, and operations that used bST were more likely to have had at least 1 cow with signs consistent with HBS during the previous 12 months than were operations that did not. Feeding a TMR was not associated with occurrence of HBS in the final multivariable model, nor was use of clostridial vaccines, but these variables were retained because of a priori interest.

Cow-level analyses—For 80 operations, information was provided on the cow most recently identified as having signs consistent with HBS. The third lactation was the median of the parity distribution for affected cows (**Figure 1**), and median time since parturition was 104 days (range, 0 to 444 days; **Figure 2**).

Table 2—Results of multivariable logistic regression analysis of potential risk factors associated with having a cow with signs consistent with hemorrhagic bowel syndrome during the preceding 12 months on dairy operations with ≥ 30 cows.

Variable	Coefficient	SE	OR (95% CI)	*P* value
Region				0.499
Midwest	Referent	Referent	Referent	
West	–0.1756	0.4378	0.8 (0.4–2.0)	
Northeast	0.2591	0.5120	1.3 (0.5–3.5)	
Southeast	0.7819	0.5914	2.2 (0.7–7.0)	
Herd size (lactating and nonlactating cows)				0.027
< 100	Referent	Referent	Referent	
100–499	0.4329	0.3731	1.5 (0.7–3.2)	
≥ 500	1.3959	0.5273	2.2 (1.4–11.4)	
RHA milk production > 20,000 lb	0.2748	0.3628	ND	0.449
Use pasture as part of the lactating cow ration	–4.6925	0.7753	ND	< 0.001
RHA × pasture interaction	3.3492	1.1180	ND	0.003
Use MUN to balance ration				0.026
Never	Referent	Referent	Referent	
Only if have a problem	–0.3224	0.3316	0.7 (0.4–1.4)	
Routinely	0.8984	0.4732	2.5 (1.0–6.2)	
Use bST in lactating cows	0.8439	0.3935	2.3 (1.1–5.0)	0.032
Feed a total mixed ration to lactating cows	0.1233	0.5657	1.1 (0.4–3.4)	0.827
Routinely use clostridial vaccines	0.3991	0.4091	1.5 (0.7–3.3)	0.330
Constant term (intercept)	–3.7546	0.5905	NA	< 0.001

ND = Not determined; OR is not given because it depends on the interacting variable. NA = Not applicable.

Complete information for all variables was provided by 951 (94%) operations.

See Table 1 for remainder of key.

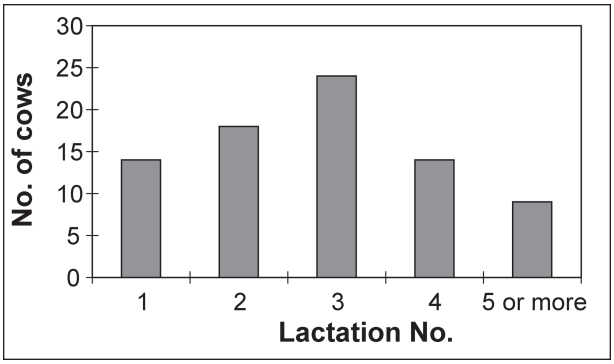

Figure 1—Frequency distribution of lactation number for cows that were identified as the most recent case of hemorrhagic bowel syndrome on 79 dairy operations.

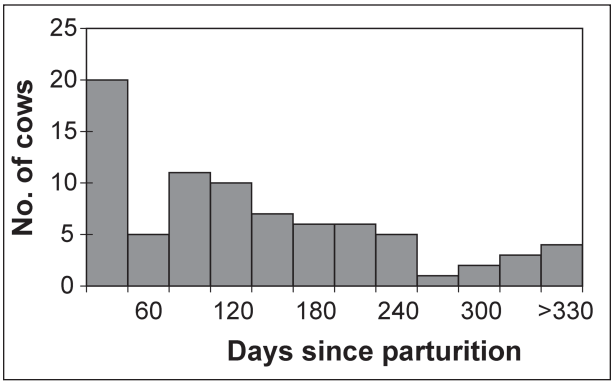

Figure 2—Frequency distribution of the number of days since parturition at the time of disease onset for cows that were identified as the most recent case of hemorrhagic bowel syndrome on 80 dairy operations.

Holsteins accounted for 75 of the 80 (94%) cows. Three (4%) of the remaining cows were Jerseys, 1 (1%) was a Brown Swiss, and 1 was categorized as other. Producers who were able to provide information about vaccination status reported that most (45/77 [58%]) of the cows identified as having HBS had been vaccinated against *C perfringens* during the previous 12 months. Likewise, most (71/80 [89%]) were being fed a TMR at the time of disease onset. Information on specific diseases observed during the lactation in which HBS occurred was provided for variable numbers of animals. Mastitis and metritis were the most commonly observed disorders, occurring in 8 of 76 (11%) and 10 of 74 (14%) cows, respectively. Milk fever and retained placenta were each observed in 5 of 75 (7%) cows. Producers reported that 2 of 78 (3%) cows had had a displaced abomasum earlier in the lactation period and that 3 of 68 (4%) had had acidosis.

A veterinarian had diagnosed HBS in 39 of the 80 (49%) cows for which individual information was collected. No significant differences were identified between cows in which the diagnosis was confirmed by a veterinarian and cows in which it was not.

Discussion

Hemorrhagic bowel syndrome was observed in all regions in the United States included in the present study. Although western operations seemed to have a higher risk of HBS in crude bivariate analyses, there was no significant difference among regions after adjusting for other herd-level characteristics. Herd size was particularly important as a confounder of the effects of region and several other variables. The effect of herd size was likely dependent in part on having a higher number of animals at risk in larger herds, but herd size may also represent other unmeasured characteristics, such as differences in management procedures, dictated by scale of the operations. Having a herd that was predominantly Holstein was associated with risk of HBS after adjustment for herd size and region, but during the final multivariable model selection, this factor was no longer found to be significant. In examining the cow-level information, most of the cows identified with HBS were Holsteins. However, this was not surprising considering the dominance of the breed in the US dairy population, and inferences about breed susceptibility or lack thereof should not be made from results of the study.

A previous study[3] found an association between a standardized herd-level measure of milk production and death losses attributable to HBS in a northern Iowa dairy herd, and the authors suggested that increased intake of dry matter and soluble carbohydrates may be important risk factors for the disease. In the present study, we found that the association between HBS and RHA milk production was dependent on diet and, in particular, with whether lactating cows consumed pasture as part of the forage ration during the growing season. Having RHA milk production > 20,000 lb was associated with an increased risk of HBS on operations that allowed cows to graze on pasture but was not significantly associated with HBS on operations that did not allow lactating cows access to pasture. One possible explanation for this finding is that to achieve a high level of milk production in cows on pasture, the nonpasture portion of the diet would need to be high in energy, whereas cows that were not on pasture could receive an equivalent number of calories without receiving a diet with any particular energy-dense component. The wide CI for the OR comparing RHA milk production in operations that used pasture reflected the relatively small number of operations in the population (6.7%) that had RHA milk production > 20,000 lb and used pasture as part of the ration. To our knowledge, previous studies have not described the absence of pasture in the diet of lactating cows as a risk factor for HBS, but in the present study, operations with RHA milk production ≤ 20,000 lb that used pasture as part of the forage ration had odds of observing HBS that were approximately a hundredth of those for operations with similar milk production that did not use pasture during the growing season. For operations with RHA milk production > 20,000 lb, a significant association between pasture use and occurrence of HBS was not identified, although the point estimate of the OR suggested that even for high-producing operations, use of pasture as part of the forage ration was associated with a decreased risk of HBS. The mechanism by which pasture consumption might be associated with a decreased risk of HBS is unclear, although previous reports[4,10] have suggested that HBS may be less common during the spring and summer, which would be

consistent with the seasonal availability of pasture across most of the United States.

Monitoring MUN has been recommended as an aid in balancing the ration of dairy cows, particularly with respect to protein content of the diet.[12,13] In the present study, operations that routinely used MUN to determine ration composition had a marginally increased risk of having had a case of HBS, compared with operations that never used MUN, whereas operations that used MUN only when there was a perceived problem with the ration were not at increased risk. One possible explanation for this may be that operations that routinely use MUN may make alterations in the ration composition more frequently than do those operations that do not routinely use this measure. Changes to the diet based on fluctuations of MUN may not always be warranted, as previous studies[14,15] have shown that even within the same herd there can be considerable variations in MUN from one test day to the next. Another possibility is that producers who use this measure routinely may have a tendency to be more aggressive in their efforts to feed cows for maximum milk production, compared with their peers who use MUN less frequently. Operations that used bST in lactating cows were also more likely to have had a case of HBS in the previous 12 months than were operations that did not use this product. In the final multivariable model, use of bST was significantly associated with occurrence of HBS even after adjustment for RHA milk production, suggesting that this association may be independent of the effect of bST on herd milk output. This was true regardless of whether RHA milk production was included in the model as a categorical variable or as a continuous covariate. These herd-level findings do not necessarily imply, however, that individual cows receiving bST are at increased risk for developing HBS. Bovine somatotropin has been shown to increase the dry-matter intake of treated cows[16] and provides the greatest increase in milk production when cows are on a relatively high-energy diet.[17] Hence, operations that use bST may have a tendency to feed rations that are more energy-dense, and treated cows on those operations would be expected to consume more feed.

In a previous survey[4] of Minnesota dairy practitioners, feeding a TMR was associated with an increased risk of HBS, compared with feeding a component diet. In the present study, feeding a TMR was also associated with HBS in the crude bivariate analysis, but after adjustment for other herd-level characteristics, this association was not significant. In examining the cow-level data, 89% of the cows were being fed a TMR at the time of disease onset, demonstrating that this is a common practice on operations where HBS has been observed.

The use of clostridial vaccines was of interest in this study because *C perfringens* type A has been suggested as a possible cause of HBS, but in the final multivariable model, vaccination was not significantly associated with occurrence of HBS. In fact, information collected on individual cows showed that most affected cows had been vaccinated against *C perfringens* in the previous 12 months. Although currently available vaccines are directed against *C perfringens* types C and D and may not be expected to provide cross-protection against type A organisms,[5] our data suggest that increasing the use of commercially available 7-way clostridial vaccines in operations where HBS has been observed is not likely to be helpful in preventing additional cases.

Parity has previously been identified as a possible risk factor for HBS. In a previous study,[4] for instance, 16 of 17 cows with HBS were in their second or higher lactation. In the present study, first-parity cows accounted for approximately 18% of the recently identified cases. The distribution of the duration of lactation at the time of HBS onset was consistent with findings in previous studies[2,4] and suggests that cows may be at increased risk during the early lactation period when milk production and feed intake are relatively high. Disease histories for cows with HBS suggested that postparturient reproductive disorders and mastitis were the most commonly observed conditions, but none of the disorders investigated was identified in a substantial proportion of animals.

In conclusion, findings of the present study are consistent with results of previous investigations and suggest that management practices implemented to achieve high levels of milk production may increase the risk for HBS. Increased consumption of a high-energy diet seems to be the most plausible common pathway for all of the risk factors that have been described, although the mechanism by which this may lead to disease is unknown. Current trends in the dairy industry toward larger herd sizes with more intensive nutritional management and less opportunity for cattle to graze on pasture may be responsible for the apparent increase in the occurrence of this disease. Further studies are needed to elucidate the role of specific microbial organisms in the pathogenesis of HBS.

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