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Improving beef calf health: frequency of disease syndromes, uptake of management practices following calving, and potential for antimicrobial use reduction in western Canadian herds

Cheryl Waldner,[†,1] Barbara Wilhelm,[‡] M. Claire Windeyer,[||] Sarah Parker,[†] and John Campbell[†]

[†]Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 5B4, Canada
[‡]Big Sky Health Analytics, Vermilion, Alberta, T9X 2B3, Canada
[||]Department of Production Animal Health, University of Calgary Faculty of Veterinary Medicine, Calgary, Alberta, T3R 1J3, Canada
[1]Corresponding author: Cheryl.Waldner@usask.ca

ABSTRACT

Bovine respiratory disease (BRD), calf diarrhea (CD), and navel infections are the most commonly reported diseases of western Canadian beef calves. The objectives of this study were to estimate the frequency of treatment for these diseases for specific age cohorts and identify potential opportunities for reducing antimicrobial use. Producers representing 89 western Canadian cow-calf herds completed a survey describing calfhood diseases and management. The most common reason for calf treatment before weaning was BRD (4.9%), and BRD treatment was described in 51% of reporting herds before 2 months of age. Calf diarrhea (2.9%) and navel infection (2.0%) were the second and third most common reasons for treatment. Most calves were treated for CD between 6 days and 1 month of age. Almost one in five herds reported routinely administering antimicrobials at birth. Calving heifers and cows together were all associated with an increased treatment risk for BRD in calves from birth to 2 months (OR 3.55, 95%CI 2.13–5.94, $P < 0.0001$), CD from 1 month to weaning (OR 3.94, 95%CI 1.29–12.0, $P = 0.02$), and navel infection (OR 4.55, 95%CI 1.78–11.6, $P = 0.002$). Failure to sort cow-calf pairs out of the calving area was also associated with an increased treatment risk for BRD from 4 months to weaning (OR 4.89, 95%CI 1.96–12.2, $P = 0.0006$) and CD from 24 h to 5 days (OR 2.82, 95%CI 1.03–7.75, $P = 0.04$), and not using the Sandhills system was associated with an increased treatment risk for navel infection (OR 4.55, 95%CI 1.78–11.6, $P = 0.002$). Other potentially modifiable factors associated with an increased risk of BRD in calves from birth to 2 months were winter feeding and calving in one area ($P < 0.0001$), heifers calving in a higher density area ($P = 0.01$), and an increasing number of times cow-calf pairs were gathered before turn out to summer pasture ($P = 0.0005$). The purchase of any cows during the calving or prebreeding period was associated with an increased risk of BRD from birth to 2 months ($P < 0.0001$) and from 2 to 4 months ($P < 0.0001$). A history of respiratory bacterin vaccines administered to the dams was associated with a decreased risk of BRD in calves from 4 months to weaning ($P = 0.01$). Cows calving in a higher density area was associated with an increased risk of CD from 1 month to weaning ($P = 0.02$). These practices present opportunities for investigation of approaches to disease management that could support the judicious use of antimicrobials.

Key words: antimicrobial use, beef calves, bovine respiratory disease, calf diarrhea, disease management, navel infection

INTRODUCTION

Common calfhood diseases such as bovine respiratory disease (BRD), neonatal calf diarrhea (CD), and navel infection present challenges for the beef industry due to animal morbidity and mortality leading to major expenses for both pharmaceutical treatments and labor requirements (Jim, 2009; Blakebrough-Hall et al., 2020; White and Larson, 2020), in addition to lost gain and herd productivity (Gow et al., 2005; Gifford et al., 2012; Foote et al., 2017). Potential loss of sales at an industry level, driven by factors such as consumer perception related to treatment for these diseases, are more difficult to estimate but could be substantial. For example, a recent consumer survey reported that 50% of respondents considered meat labeled to indicate no antimicrobials had been used to be healthier (Newman et al., 2020). Understanding the frequency of important calfhood diseases, as well as the current uptake of management procedures to mitigate them, is vital to informing risk-based and cost-effective disease control strategies for the beef industry that protect animal welfare and promote antimicrobial stewardship.

Farm-level disease benchmarking and concurrent assessment of herd management practices uptake are reported periodically in the United States by the National Animal Health Monitoring System (NAHMS) (United States Department of Agriculture (USDA), 2020). Recently, a Canadian review compiled beef management practices and their uptake across regions (Beef Cattle Research Council, 2019) and another study reported on frequency and risk factors for antimicrobial use (AMU) in cow-calf herds (Waldner et al., 2019a, Waldner et al., 2019b). However, studies examining the frequency of calfhood diseases in cow-calf herds and risk factors for these diseases are more limited (Gow et al., 2005; Smith et al., 2008; Waldner et al., 2013; Woolums et al., 2013; Elghafghuf et al., 2014; Woolums et al., 2018). In particular, details on the

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timing of the diseases and period specific risk factors have not been reported. There is evidence that risk factors for death in calves born alive vary based on calf age and timing during the calving season (Smith et al., 2008; Elghafghuf et al., 2014).

Previous work has identified that BRD and CD are the two most common reasons for AMU (Smith et al., 2008; Waldner et al., 2013; Waldner et al., 2019a) in addition to important reasons for preweaning calf death loss in western Canada (Waldner et al., 2010). Antimicrobials are indicated for treating calves with BRD. However, by identifying factors characterizing herds with the highest risk of BRD, veterinarians could more efficiently target prevention strategies, such as vaccination and other management interventions, and reduce the need for antimicrobial use (Woolums et al., 2013; Woolums et al., 2018). While these same risk factors can also be examined for CD (Gow et al., 2005; Waldner et al., 2013), there is a further opportunity to target AMU to the calves with CD that are most likely to benefit. In addition, given the expected importance of viruses and protozoa in calves with CD greater than 1 week of age (Waldner et al., 2013), we can better understand how and when other ancillary therapies are being used.

After BRD and CD, navel infection is the next most common reason for treatment and antimicrobial use in western Canadian cow-calf herds (Gow and Waldner, 2009; Waldner et al., 2013; Waldner et al., 2019a). In addition to the use of antimicrobials for treatment of affected calves, long-acting antimicrobials have been used at birth in some high-risk herds to prevent navel infection (Gow and Waldner, 2009). However, the overall proportion of herds using antimicrobials for disease prevention in calves before weaning was small and decreased between 2010 and 2014 (Waldner et al., 2013; Waldner et al., 2019a).

The first objective of this study was to describe the timing and frequency of treatment for BRD, CD, and navel infection in pre-weaning calves in selected western cow-calf herds. The second objective was to report the uptake of management practices after calving and prior to breeding season across the study herds and their association with disease frequency. The final objective was to identify opportunities to reduce AMU in western Canadian beef calf production.

MATERIALS AND METHODS

Herd Recruitment and Data Collection

One hundred and five herds were recruited in 2014–2015 for a multi-year surveillance initiative from the western Canada. The relative frequency of herds recruited from Alberta, Saskatchewan, and Manitoba was determined from the proportion of cow-calf herds located in each province in the 2011 Census of Agriculture, as well as the targeted geographic distribution of moderate (i.e. 100–300 cow-calf pairs) and large sized herds (i.e., >300 cow-calf pairs).

Researchers identified veterinarians with beef cow-calf clients in each region, who then contacted clients with a minimum of 100 cows, reporting pregnancy testing and maintenance of at least basic calving and production records. Interested producers, who met these inclusion criteria, received a consent form and baseline survey. This observational study was approved by the University of Saskatchewan Animal Research Ethics Board (#20140003) and the University of Saskatchewan Behavioral Research Ethics Board (#14-07).

Survey Design

The survey described in this study captured several broad areas describing the participating herds, their calfhood disease profiles, and their management practices including demographics, management of herds during and after breeding season, calving season practices, frequency, and timing of treatment of calves prior to weaning for common syndromes (i.e., BRD, CD, and navel infection), questions about AMU relative to alternative treatments for CD, and previously reported risk factors for calf disease including BRD. This survey was sent to 100 producers on December 20, 2017. Surveys were returned between January and May 2018. A copy of the survey is available from the corresponding author upon request.

Data Entry and Statistical analysis

Survey responses were recorded in a commercial spreadsheet software program (Excel, Microsoft Corp., Mississauga, Ontario, Canada) and checked for accuracy. Summarized outcomes of interest included metrics of reported treatments for calfhood disease and herd-level frequency and timing of treatment for selected diseases (e.g., number of calves per herd treated for CD from 24 h to 5 days).

Potential predictors investigated included herd management practices during as well as after calving and breeding seasons. Potential risk factors for each outcome model were excluded if they occurred after the event of interest, or so far prior to the event of interest that a biological connection was not reasonable. Potential confounders considered in all models included herd size and the month the herd started calving.

Generalized estimating equations employing a binomial distribution and a logit link function were used to compare the occurrence of disease treatments in herds exposed and unexposed to potential predictors captured by the survey while accounting for clustering within herd (SAS for Windows version 9.4, SAS Institute Inc., Cary, N.C.). The outcome for each of the models was the number of treatment outcomes of interest (numerator) and the total number of calves at risk (denominator) (e.g., number of calves per herd treated for CD from 24 h to 5 days/total calves born alive).

All variables for which $P < 0.20$ in univariable analysis were considered for inclusion in multivariable models, using a backward stepwise selection process. Variables were removed from the multivariable model if $P > 0.05$ and if not confounding. A variable was considered confounding if it was not an intervening variable and if its removal from the model changed another coefficient of interest by > 20%. Interactions were not evaluated given the relatively small size of the dataset and convergence challenges for some lower frequency outcomes.

RESULTS

Description of Study Population

Of 100 participants receiving the survey, 89 responded, of whom 87 reported calving and treatment records. Of the 87 herds with treatment records, 82 reported separate records for cows and heifers, 1 herd had no heifers, and 4 did not have separate records for cows and heifers. Within the responding herds, 88% (78/89) had individual animal calving records, 78% (69/89) had individual animal

Table 1. Percentages of calves alive at 24 h that were observed ill, treated for disease, or died from 24 h to weaning on cow-calf operations in western Canada (n = 87)

Disease reported:		Mean	SD	Median	75th	95th
Bovine respiratory disease						
24 h to 2 months	Observed illness	3.6	9.3	0.2	2.3	19
	Treated	3.9	12	0.2	2.2	19
	Dead	0.3	1.1	0.0	0.2	2.0
2 months to 4 months	Observed illness	0.6	1.5	0.0	0.4	3.0
	Treated	0.5	1.5	0.0	0.3	3.0
	Dead	0.1	0.5	0.0	0.0	0.7
4 months to weaning	Observed illness	0.5	1.9	0.0	0.0	2.7
	Treated	0.5	1.9	0.0	0.0	1.4
	Dead	0.1	0.3	0.0	0.0	0.6
24 h to weaning	Observed illness	4.7	10	1.0	4.8	25
	Treated	4.9	13	0.9	4.7	25
	Dead	0.5	1.4	0.0	0.5	2.3
Calf diarrhea						
24 h to 5 days	Observed illness	0.6	1.3	0.0	0.2	3.0
	Treated	0.6	1.3	0.0	0.2	2.8
	Dead	0.1	0.3	0.0	0.0	0.7
6 days to 1 month	Observed illness	2.2	6.0	0.0	1.9	8.0
	Treated	2.1	6.0	0.0	1.7	8.0
	Dead	0.4	2.0	0.0	0.2	1.2
1 month to weaning	Observed illness	0.3	1.0	0.0	0.0	2.4
	Treated	0.3	1.0	0.0	0.0	2.3
	Dead	0.1	0.3	0.0	0.0	0.5
24 h to weaning	Observed illness	3.0	6.3	1.1	3.7	9.7
	Treated	2.9	6.3	0.9	3.2	9.5
	Dead	0.5	2.0	0.0	0.4	2.0
Navel infection						
24 h to weaning	Observed illness	2.0	4.8	0.5	1.3	12
	Treated	2.0	4.8	0.5	1.3	12
	Dead	0.1	0.4	0.0	0.0	0.6

treatment records, and 83% (74/89) kept either individual-, group-, or herd-level treatment records. Treatment and mortality records were not consistently provided separately for cows and heifers, and as such, combined values are reported. Participants were from Alberta (54%, 48/89), Saskatchewan (27%, 24/89), and Manitoba (19%, 17/89). Most reported having commercial cattle (74%, 66/89) with one quarter reporting selling some seed stock or purebred animals (26%, 23/89).

Descriptive Summary of Pre-weaning Mortality, Morbidity, and Treatment for Selected Calf diseases

Herd size and calf mortality The median (5th, 95th percentile) number of cows at calving time within these herds was 185 (89, 684), and the median number of first calf heifers at calving time was 42 (12,173). The median number of calves alive at 24 h was 220 (102, 812), and the mean was 318 (SD 313). The median percentage of calves reported dead between 24 h and weaning was 2.5% (0%, 6.5%) and the mean was 3.0% (SD 2.6%). Most calves died between 24 h and 1 month (median 1.4%, 0%, 4.3%; mean 1.8%, SD 2.2%). Less than half of herds reported mortality of at least 1 calf due to BRD (38%, 33/87), CD (36%, 31/87), and navel infection (21%, 18/87).

Morbidity and treatment Bovine respiratory disease was the most commonly observed reason for treatment, with 4.9% of calves treated before weaning (Table 1). Most calves were observed sick and treated before 2 months (Table 1). A similar but smaller proportion of calves were observed sick and treated between 2 and 4 months and between 4 months and weaning. At a herd level, 51% (44/86) of herds reported treating ≥1 case of BRD in calves from birth to 2 months, 31% (26/84) reported treating ≥1 calf for BRD from 2 to 4 months, and 26% (21/82) reported treating ≥1 calf from 4 months to weaning. Overall, 66% (57/87) of responding herds reported treating ≥1 calf for BRD between birth and weaning.

Calf diarrhea was the second most commonly reported reason for calf treatment within herds but accounted for a similar proportion of calf deaths as BRD (Table 1). Most calves were treated for CD from 6 days to 1 month. However, for about one in five calves, treatment for CD occurred before 6 days with a smaller proportion treated after 1 month and before weaning. At a herd level, 63%

of herds (55/87) reported treating ≥1 calf for CD between birth and weaning.

Treatment for navel infection was slightly less common than CD and resulted in lower reported mortality (Table 1). At a herd level, 57% of herds (50/87) reported treating ≥1 calf for navel infection.

Mass antimicrobial use Almost 1 in 5 producers (17/89, 19%) reported AMU at or near birth to prevent disease; 10 reported using injection, 4 oral administration, and 3 did not elaborate. Nine herds (10%), including 3 who also reported AMU at or near the time of birth, specifically reported treating calves to prevent protozoal disease (i.e., coccidiosis). In addition, 7% (6/89) of producers reported mass treatment with antibiotics to prevent or treat calf BRD. Three of six herds reported mass-treating calves once in the preceding 3 years, and three reported mass-treating every year. Two of these herds reported mass treating BRD before weaning as well as for prevention at birth.

Anti-inflammatory drug usage One in five producers (20%, 18/89) reported always using anti-inflammatory drugs when treating sick calves, 62% (55/89) reported using them occasionally, and 18% (16/89) reported never using anti-inflammatory drugs. While not all producers provided reasons for use, the most commonly reported indications for usage were pain (14), dystocia and injuries (9), BRD (7), navel or joint infection (3), branding and castration (2), CD (2), and fever (2).

Antimicrobial use relative to alternative therapies for CD Most study herds treated ≥1 calf for CD (65%, 58/89). Of the 58 herds treating ≥1 calf for CD; 81% (47/58) used oral electrolytes, 78% (45/58) used oral antibiotics, 72% (42/58) used injectable antibiotics, 50% (29/58) used anti-inflammatory drugs (16 meloxicam, 4 flunixin, 4 dexamethasone), 22% (13/58) used intravenous fluids, 7% (4/58) used bismuth subsalicylate, and 3% (2/58) used amprolium.

The two most common reasons reported for treating CD with oral electrolytes were the extent of dehydration (i.e., had sunken eyes, skin tent, or tacky gums) (84%, 49/58) and severity of diarrhea (79%, 46/58). The reasons for using antibiotics to treat a calf with CD, were if the calf appeared lethargic and dull (83%, 48/58) or dehydrated (79%, 46/58).

Description of Management Practices Potentially Impacting Calf Health

Calving season management High-density confined calving areas were used by 47% (42/89) of herds for cows and 64% (57/89) for heifers. Frequent night checks during calving were common [61% (54/89) for cows, 76% (68/89) for heifers]. Most producers (64%, 57/89) described bedding cow-calf pairs routinely during the calving season with 26% (23/89) reporting providing bedding less frequently (e.g., as needed for extreme weather) and the remainder (10%, 9/89) reported that bedding was not required. Cows and pregnant heifers were managed together through the winter-feeding period and remained together through the calving season in 30% (27/89) of herds. Body condition scoring was used in 19% (17/89) of herds.

Animals calved in the same area where they over-wintered in 17% (15/89) of herds. Animals were sorted out of a winter-feeding area into the calving area based on appearance (e.g., closeness to calving) in 29% (26/89) of herds. Animals remained in a single calving area until or near the end of calving season in 37% (33/89) of herds.

Calf processing near birth A majority of producers processed most or all of their calves within 24–48 h of birth (76%, 68/89), and only 9% (8/89) reported that they did not process any calves at or shortly after birth. After tagging (90%, 81/89), the next most common activities were castration (60%, 53/89), selenium and vitamin E injections (47%, 24/89), vitamin A and D injections (38%, 34/89), and vaccinations (33%, 29/89). Nineteen (21%) producers reported using intranasal vaccines for BRD, 10 (11%) administered ≥1 type of injectable vaccine, and 6 (7%) reported providing oral vaccines for CD.

Cow-calf pairs were sorted out of the calving area to nursery pastures in 70% (62/89) of herds. Timing varied with half of herds moving pairs at or within 24 h, 75% (46/62) within 4 days, and 95% (59/62) within 15 days of birth. Pairs remained where they calved and animals yet to calve were moved to clean pastures at intervals throughout the calving season (i.e., the Sandhills system) in 7% (6/89) of herds.

Calves gathered for spring processing Most herds gathered cow-calf pairs at least once for processing between calving and movement to summer pasture (94%, 84/89), and half gathered pairs for processing at least twice before weaning. Almost all herds (93%, 83/89) vaccinated calves during these activities. Other spring processing procedures included: castration (47%, 42/89), branding (46%, 41/89), hormone implanting (38%, 34/89), dehorning (33%, 30/89), providing anti-inflammatory drugs (26%, 23/89), artificial insemination (14%, 12/89), and estrus synchronization (8%, 7/89).

Other potential risk factors for BRD Most herds (91%, 81/89) had vaccinated cows for viral BRD pathogens in the previous year. However, only 29% (26/89) had vaccinated cows with BRD bacterial vaccines. Almost one third (26/89) of producers reported clinical cases of BRD in cows in the past year, but only 9% (8/89) of herds treated ≥2 cows. Most herds also vaccinated their calves for BRD between birth and movement to summer pasture (61%, 54/89). In contrast with the cow herd, BRD bacterial vaccines were widely used in calves before summer turnout with 60% (53/89) of respondents indicating vaccination at either: birth (3/89), spring processing (37/89), or some other time (13/89).

Other previously documented risk factors for calfhood BRD (Woolums et al., 2013; Woolums et al., 2018; Wennekamp et al., 2021) included: diagnosis of bovine viral diarrhea virus (BVDV) within the herd (2%, 2/89), creep feeding before weaning (27%, 24/89), purchasing cows or calves during the calving season (10%, 9/89), use of reproductive technologies to manage breeding such estrus synchronization (8%, 7/89) and artificial insemination (13%, 12/89), use of communal pastures (26%, 23/89), and the number of breeding groups (median 5, range 2–25).

Management Practices Associated with Treatment for Bovine Respiratory Disease

Calves <4 months of age from herds starting to calve either before March or after were more likely to be treated for BRD as compared to those from herds starting to calve in March (Table 2).

Table 2. Factors associated with the proportion of beef calves treated for bovine respiratory disease (BRD) from birth to weaning

Management factors retained in final multivariable models	Odds ratio[1]	95% CI low[1]	95% CI high[1]	*P* value
Calves from birth to 2 months				
Month calving started				
December to February	10.5	2.87	38.1	0.0004
March (referent)				
April to May	6.68	1.53	29.2	0.01
Winter feeding and calving in one area				
Yes	6.00	2.43	14.8	<0.0001
No (referent)				
Cows and Heifers calve together				
Yes	3.55	2.13	5.94	<0.0001
No (referent)				
Heifer calving area density:				
Higher	3.22	1.28	8.11	0.01
Lower (referent)				
Calves are tagged by 2 days of age				
Yes	18.5	2.24	153	0.007
No (referent)				
Calves are vaccinated with respiratory vaccine before summer pasture				
At or near birth	4.42	1.51	13.0	0.007
After 1 week and before summer pasture	1.78	0.94	3.38	0.08
No vaccine (referent)				
Any cows or calves purchased during calving or prebreeding period				
Yes	3.50	2.06	5.93	<0.0001
No (referent)				
Number of times pairs are gathered before pasture (range 0–5)	2.17	1.40	3.37	0.0005
Pairs are separated for artificial insemination				
Yes	2.30	0.86	6.11	0.10
No (referent)				
Calves from 2 to 4 months				
Month calving started				
December to February	8.51	3.27	22.2	0.0001
March (referent)				
April to May	3.26	1.18	8.98	0.02
Calves are vaccinated with respiratory vaccine before summer pasture				
At or near birth	8.55	4.72	15.5	0.0001
After 1 week and before summer pasture	2.99	1.62	5.53	0.0005
No vaccine (referent)				
Number of breeding management groups				
≥5 (median)	1.91	0.79	4.63	0.15
<5 (referent)				
Any cows or calves purchased during calving or prebreeding period				
Yes	4.11	2.23	7.59	0.0001
No (referent)				
Commercial producer				
Some seedstock sold	1.94	1.11	3.39	0.02
Commercial production only (referent)				
Province in which herd is located:				
1 Saskatchewan	3.49	0.96	12.7	0.06
2 Alberta	8.98	2.79	28.9	0.0002
3 Manitoba (referent)				

Table 2. Continued

Management factors retained in final multivariable models	Odds ratio[1]	95% CI low[1]	95% CI high[1]	*P* value
Calves 4 months to weaning				
Respiratory bacterins administered to dams				
No	8.07	1.64	39.7	0.01
Yes (referent)				
Calves are vaccinated with respiratory vaccine before summer pasture				
At or near birth	5.93	0.23	155	0.29
After 1 week and before summer pasture	39.9	7.07	225	0.0001
No vaccine (referent)				
Pairs sorted out of the calving area to a clean nursery pasture(s) after calving:				
No	4.89	1.96	12.2	0.0006
Yes (referent)				
Calves castrated at spring processing				
Yes	14.9	3.77	59.0	0.0001
No (referent)				

[1]95% CI low = 95% confidence interval (lower); 95% CI high = 95% confidence interval (higher);
Odds ratios derived from multivariable models account for clustering by herd where the cumulative incidence for each herd was summarized by a numerator (count of cases) and denominator (number of calves at risk).

Winter feeding and then calving animals in a single area, calving cows and heifers together, and calving heifers in areas with relatively higher animal density were each associated with treatment for BRD in calves <2 months (Table 2).

The more often pairs were separated before movement to summer pasture, the more likely calves <2 months were to be treated for BRD (Table 2). Similarly, separating cow-calf pairs for artificial insemination was associated with a trend towards increased BRD treatment in calves <2 months in the multivariable model (Table 2). If not adjusted for the number of times the calves were separated, the association was significant (OR 2.92, 95%CI 1.03–8.28, $P = 0.04$).

Calves <2 months and between 2 and 4 months were more likely to be treated for BRD from herds that purchased any cows or calves during calving or the period before breeding (Table 2).

Calves <2 months from herds that either tagged or vaccinated for BRD within 2 days of birth were more likely to be treated for BRD. Similarly, calves were also more likely to be treated for BRD from 2 to 4 months if they were vaccinated at birth, and from 4 months to weaning if they were vaccinated for BRD between 1 week and summer pasture turnout (Table 2). However, vaccinating the dam with a BRD bacterial vaccine within the last year reduced the occurrence of BRD in calves >4 months (Table 2).

Sorting cow-calf pairs out of the calving area and into nursery pastures after calving was associated with a decreased risk of BRD from 4 months to weaning (Table 2).

Castrating calves at spring processing was associated with an increased risk of BRD in calves >4 months (Table 2).

Risk factors identified as significant in the multivariable models for treatment for BRD are summarized in Table 5.

Management Practices Associated with Treatment for Calf Diarrhea

Sorting cow-calf pairs into a nursery area shortly after calving was associated with decreased CD treatment in calves <6 days, but a smaller increased frequency of CD treatment in calves 6 days to 1 month (Table 3). The only other factor associated with decreased CD in calves <6 days, was the use of body condition score for herd management.

Reporting more frequent night-time calving checks was associated with increased CD treatment in calves 6 days to 1 month (Table 3). Tagging or administering vitamin A and D to calves within 2 days of birth were each associated with the increased likelihood of CD treatment in calves from 6 days to 1 month, and administering any vaccine to calves within 2 days was associated with increased reports of CD treatment from 1 month to weaning (Table 3).

Calving cows in higher density areas was associated with an increased likelihood of CD in calves >1 month, as was calving cows and heifers together. Herds that started calving in March were less likely to report treating CD in calves >1 month than either herds starting to calve before or after March (Table 3).

Risk factors identified as significant in the multivariable models for treatment for CD are summarized in Table 5.

Management Practices Associated with Treatment for Navel Infection

Factors associated with increased likelihood of treating calves for navel infection in these herds included: reporting more frequent night checks, reporting more frequent bedding during calving season, not calving cows and heifers separately, and not using the Sandhills calving system (Table 4).

Risk factors identified as significant in the multivariable models for navel infection are summarized in Table 5.

DISCUSSION

Consistent with recent western Canadian surveys (Pearson et al., 2019; Waldner et al., 2019a), BRD was identified as the most frequently diagnosed clinical illness before weaning, closely followed by CD, and finally by navel infection. This survey differed from most other recent reports in that the

Table 3. Factors associated with the proportion of beef calves treated for calf diarrhea (CD) from birth to weaning

Management factors retained in final multivariable models	Odds Ratio[1]	95% CI low[1]	95% CI high[1]	*P* value
Calves aged 24 h to 5 days				
Herd owner uses body condition scoring				
No	6.75	2.15	21.2	0.001
Yes (referent)				
Pairs sorted to clean nursery pasture after calving				
No	2.82	1.03	7.75	0.04
Yes (referent)				
Calves aged 6 days to 1 month				
Calving season checks of cows:				
Frequent with night checks	2.42	1.29	4.53	0.006
Infrequent with no night checks (referent)				
Calves tagged by 2 days				
Yes	16.7	3.03	100	0.001
No (referent)				
Calves receive vitamin AD by 2 days				
Yes	2.63	1.19	5.88	0.02
No (referent)				
Pairs sorted to clean nursery pasture after calving				
Yes	1.82	1.08	3.13	0.03
No (referent)				
Calves aged 1 month to weaning				
Month calving started				
December to February	9.98	1.23	80.8	0.03
March (referent)				
April to May	14.8	1.57	139	0.02
Cows' calving area density				
High	3.20	1.20	8.52	0.02
Low (referent)				
Cows and Heifers calve together				
Yes	3.94	1.29	12.0	0.02
No (referent)				
Calves vaccinated by 2 days				
Yes	4.58	1.48	14.2	0.008
No (referent)				
Province in which herd is located:				
1 Saskatchewan	16.6	1.58	177	0.02
2 Alberta	14.8	1.46	151	0.02
3 Manitoba (Referent)				

[1] 95% CI low = 95% confidence interval (lower); 95% CI high = 95% confidence interval (higher).
Odds ratios derived from multivariable models account for clustering by herd where the cumulative incidence for each herd was summarized by a numerator (count of cases) and denominator (number of calves at risk).

age of the calf at the time of diagnosis was also requested, allowing a more targeted examination of the temporal relationship with potential risk factors for disease. This study also differed from typical cross-sectional surveys in that the participants were part of a longitudinal network where relevant herd management information on specific risk factors could be linked from previous surveys in the same herd. The only other identified report examining the timing of diagnosis was limited to CD outbreaks and data collected in 2010 (Waldner et al., 2013). The NAHMS study of American cattle herds used a less detailed description of calf ages, categorizing calves <3 weeks or older (USDA, 2020).

The overall frequency of diseases likely to result in AMU was relatively low in these herds, consistent with a previous report describing AMU in this cohort (Waldner et al. 2019a). Seventy-five percent of herds treated less than 4.7% of their calves for BRD and 3.2% or less of their calves for CD between birth and weaning. These findings are supported by previous reports in western Canada based on both survey data (Waldner et al. 2013) and individual animal treatment records (Gow and Waldner, 2009). While there are opportunities to identify opportunities to enhance the judicious use of antimicrobials, the AMU in most herds was limited to a small proportion of animals.

Table 4. Factors associated with the proportion of beef calves treated for navel infection from birth to weaning

Management factors retained in final multivariable models	Odds ratio[1]	95% CI low[1]	95% CI high[1]	*P* value
Calving season checks of heifers:				
Frequent with night checks	3.58	1.38	9.32	0.009
Infrequent with no night checks (Referent)				
Calving season bedding provided				
Yes	13.2	1.79	96.8	0.01
Yes infrequent	4.23	0.53	33.8	0.17
No, not necessary (referent)				
Cows and heifers calve together				
Yes	4.55	1.78	11.6	0.002
No (referent)				
Sandhills calving system[2]				
No	3.89	1.00	15.2	0.05
Yes (referent)				

[1] 95% CI low = 95% confidence interval (lower); 95% CI high = 95% confidence interval (higher).
Odds ratios derived from multivariable models account for clustering by herd where the cumulative incidence for each herd was summarized by a numerator (count of cases) and denominator (number of calves at risk).
[2] Sandhills system: pairs remained where they calved and animals yet to calve were moved to clean pastures at intervals throughout the calving season.

In the present study, the highest risk of BRD was identified in calves <2 months and the highest risk of CD between 6 days and 1 month. In the 2010 study (Waldner et al., 2013), 60% of producers reporting CD outbreaks described the age of onset as between 1 and 4 weeks. Given the etiology of navel infection, there was no attempt to break it down by the age of diagnosis. However, that information could have been useful as calves identified early will be more responsive to treatment and less likely to have severe complications.

The use of bacterial BRD vaccines in calves was associated with an increase in the reported frequency of BRD. Most calves were vaccinated at spring processing, and as most BRD cases were seen before 2 months of age, a benefit during this time frame was not expected. The most likely explanation is that herds with a history of BRD were also more likely to use BRD vaccines in their calves before summer pasture. While longitudinal data were available for these herds, there was no specific information on prior BRD occurrence, making it impossible to test this hypothesis. Similarly, herds with early BRD would also be expected to vaccinate earlier.

In a previous study, this same group of producers reported that having a problem with BRD in the past was the primary reason for using BRD vaccines (Waldner et al., 2019c). Most producers in the previous study vaccinated preweaning calves at least once for BVDV, infectious bovine rhinotracheitis, parainfluenza type 3, and bovine respiratory syncytial virus and once for *Mannheimia haemolytica*. Most of these calves were also vaccinated before summer pasture turnout or at birth.

Controlled trials will be required to better understand the benefits of calf vaccination in managing early BRD (Erickson et al., 2020; Erickson et al., 2021). However, there was a substantial decrease in BRD in calves >4 months in herds that had vaccinated their dams with a BRD bacterial vaccine in the last year. A study in Quebec beef herds found that the risk of respiratory disease in calves was negatively associated with the serological status of the cow (Ganaba et al., 1995). The importance of dam vaccination to reduce BRD risk in calves after weaning and in the feedlot has also been previously reported (Perrett et al., 2018).

In the present study, several, often correlated risk factors were associated with a higher risk of BRD in calves <2 months that related to calving early, winter feeding and calving in the same area, calving heifers and cows together, and calving heifers in high-density facilities. Early calving was also associated with an increased risk of BRD in calves from 2 to 4 months. These management practices contribute to increased potential for contact between cows and heifers and greater animal density during calving increasing the potential for spread of BRD pathogens from cows to calves (Woolums et al., 2013; Woolums et al., 2018).

There was also an unexpected association between calving later than March and an increased risk of BRD for calves <4 months as well as CD in calves >1 month in the present study. There were, however, two very large snowstorms in April and in May of 2017 in Alberta and some areas of Saskatchewan where many of these herds were located. Weather-related stress has previously been reported as an important risk factor for preweaning calf mortality in a study using detailed meteorological records linked to calf-specific birth dates (Elghafghuf et al., 2014). Consistent with this interpretation, calves from Alberta and Saskatchewan were at higher risk of BRD from 2 to 4 months and from CD >1 month in the present study. In calves >1 month, CD was more also common in herds calving cows in higher-density facilities.

Calving cows and heifers together was associated with a consistently increased risk of BRD in calves <2 months, CD in calves >1 month, and navel infection. The lack of separate winter-feeding areas and calving areas was also a clearly associated risk factor for BRD in calves from birth to 2 months with a very high odds ratio. The risk of CD in calves 6 days to 1 month was associated with frequent night-time checks, which is typical of herds that calve early and manage more intensively. Similarly, the risk of navel infection was also higher in herds not calving cows and calves separately, more frequent night-time checks, and more frequent bedding during calving season.

Table 5. Summary of risk factors associated with bovine respiratory disease, calf diarrhea, and navel infection in calves from birth to weaning from 89 western Canadian cow-calf operations calving in the spring of 2017

	Bovine respiratory disease (BRD)			Calf diarrhea (CD)			Navel infection
	<2 months	2 - 4 months	> 4 months	5 days	6 days - 1 month	>1 month	birth to weaning
<u>Increased exposure and disease risk associated with:</u>							
Contamination of calving area and mixing of cows and heifers							
• Winter feeding and calving in one area	↑↑↑[1]						
• Cows and heifers calve together	↑↑					↑↑	↑↑
• Using high density calving area (pens or barns vs pasture)	↑↑ (Heifers)					↑↑ (Cows)	
• Failure to sort pairs out of the calving area to a clean nursery pasture(s) after calving or use Sandhill's system			↑↑	↑↑	↓		↑↑
More intensively managed herds and herds calving earlier							
• Calving started in December to February or April to May vs March [2]	↑↑↑	↑↑↑				↑↑↑	
• Calving season checks of cows: More frequent checks vs. less frequent checks					↑↑ (Cows)		↑↑ (Heifers)
• Calving season bedding provided							↑↑↑↑
• Calves are tagged by 2 days of age	↑↑↑↑				↑↑↑↑		
• Calves receive vitamin AD by 2 days					↑↑		
• Calves given respiratory vaccine at or near birth	↑↑	↑↑↑				↑↑↑	
Increased gathering and exposure mixing within herd							
• Calves given respiratory vaccine after 1 week and before summer pasture		↑↑	↑↑↑↑				
• Calves castrated at spring processing			↑↑↑↑				
• Number of times pairs gathered before pasture	↑↑						
Exposure from outside the herd							
• Any cows or calves purchased during calving or prebreeding period	↑↑	↑↑					
Immunity from dam							
• Respiratory bacterins NOT administered to dams			↑↑↑				
• Herd owner does NOT use body condition scoring				↑↑↑			

[1]↑ OR < 2, ↑↑OR >= 2 and < 5, ↑↑↑OR >=5 and < 10, ↑↑↑↑OR >10.
[2]December to February were colder than March. April and May had spring snow storms resulting in calf mortalities in much of this region severe enough to be reported in the media.

The capacity to change some of these management practices can be limited by labor, facilities, and cost. Examples examined in the current study included calving in the same area cows were wintered, cows and heifers calved together, and density of housing heifers during calving to facilitate regular checking. The last example might be the most difficult of these factors to alter, especially for early calving herds where supervision is required to minimize losses due to dystocia or cold ambient temperatures.

Two commonly recommended management practices in the face of infectious disease outbreaks in cow-calf herds include sorting cow-calf pairs into a clean nursery area shortly after calving and the Sandhills system where pairs remain where they calve and animals yet to calve are moved to clean pastures at intervals throughout the calving season. The value of moving cow-calf pairs into a nursery area has previously been reported in a multilevel analysis of individual and herd risk factors for calf mortality in western Canada (Elghafghuf et al., 2014). In the current study, moving cow-calf pairs was reported to happen within 4 days of birth in 75% of herds and almost all herds by 15 days. Sorting cow-calf pairs into clean pastures was much more common (70%) than periodically moving the cows yet to calve (7%). This is likely a reflection of the limited options for appropriate access to shelter and water in winter calving herds. It is often easier to manage cow-calf pairs than calving cows at greater distances away from central facilities, especially in colder weather.

Moving cow-calf pairs to nursery pastures was associated with a decreased risk of BRD in calves greater than 4 months and CD in calves less than 6 days. The use of the Sandhills system was associated with a decreased risk of navel infection. However, movement of cow-calf pairs to a nursery pasture was associated with a modest (OR<2) increased risk of CD in calves from 6 days to 1 month. This could be a reflection of increased handling stress or potential stress associated with mixing and re-mixing cow-calf pairs. Additional information on how many different nursery pastures were used and the potential for mixing calf cohorts of different ages and associated pathogen exposure was not available from this survey but might influence the success of such programs.

Other management practices requiring early handling of cow-calf pairs such as tagging were associated with increased risk of BRD in calves <2 months and CD in calves 6 days to 1 month. Vitamin A injections near birth were also associated with increased CD risk in calves from 6 days to 1 month and vaccinating calves <2 days was associated with an increased risk of CD in calves >1 month. This might suggest that handling very young calves could unintentionally interrupt adequate colostrum intake or perhaps these practices are simply associated with exposure risks linked to more intensive management. Regardless, the strength of the associations between tagging and disease risk were some of the highest reported and suggest the need for further study.

Other notable findings included the positive association between higher frequency of gathering of pairs before summer pasture as well as specifically gathering and separating cow-calf pairs for artificial insemination and an increased risk of calf diseases. During spring processing activities, calves and cows are potentially crowded for sorting and handling, calves can be stressed by separation from their dams, and calves of different ages and different management cohorts could potentially be mixed. The association between calf and cow handling events and BRD in calves has been demonstrated in other observational studies of cow-calf herds in North America (Woolums et al., 2013; Woolums et al., 2018).

While the adoption of preferred management practices such as vaccination, castration, implanting, artificial insemination, and dehorning before the summer grazing season can have tangible benefits to herd health and productivity, seeking opportunities to minimize animal stress, confinement, and exposure to new management groups and among calves of different ages should be a focus where possible. Approximately a quarter of producers reported using anti-inflammatories for pain control during spring processing. While assessing this practice was not a primary focus of this study, pain control and minimizing stress following any painful procedure does have the potential to reduce the impact on the immune system and risk of subsequent illness (Coetzee et al., 2012).

Finally, calves from herds where cows, calves, or cow-calf pairs were purchased during the calving period were more likely to be treated for BRD. This is consistent with another recent report describing an association between the occurrence of BRD outbreaks and the purchase of cows and bulls and a previous survey of risk factors for BRD from the United States (Woolums et al., 2018; Wennekamp et al., 2021). Unlike the recent Canadian paper (Wennekamp et al., 2021), the use of community pastures was not associated with either BRD or CD risk for calves in the herds within the present study.

While BRD and navel infection in young calves almost always require antimicrobials, the etiologic agents and resulting treatments for CD are more complicated. In this study, CD most commonly occurred in calves aged 6 days to 1 month. The primary etiologic agents for CD in calves of this age are viral with some exceptions where protozoa such as cryptosporidia can be identified (Ngeleka et al., 2019). While more than one type of pathogen is often isolated from these calves, viruses and protozoa were commonly identified (Berber et al., 2021, Wei et al. 2021). Bacteria such as *Salmonella sp* have been reported, but are much less common (Gow et al., 2005, Ngeleka et al., 2019). Although the most reported treatment for CD was oral electrolytes, both oral and injectable antibiotics were almost as commonly used.

In a previous study in this group of herds (Waldner et al., 2019a), the most common antimicrobials reported for treating CD were oral sulfamethazines, sulfadoxine/trimethoprim, and florfenicol. Both sulfamethazine boluses and injectable sulfadoxine/trimethoprim have label claims for the treatment of CD. However, the label claim is for specifically treating colibacillosis and salmonella, and colibacillosis is most common in calves less than 1 week of age. Sulfonamides are also often used for treating coccidiosis in calves, which is common in calves up to 6 months of age. Florfenicol is indicated for the treatment of BRD for which CD was identified as a risk factor.

When faced with a sick and valuable calf, the decision not to treat it with antibiotics can be difficult. In the present study, producers reported very similar criteria for using antibiotics and using oral electrolytes when making treatment decisions. However, antimicrobials are not recommended for the treatment of calves with a normal appetite and no evidence of fever (Constable, 2004) but have been recommended for the treatment of bacteremia resulting from CD and coliform overgrowth in the small intestine (Smith et al., 2008). Thus, guiding producers to more strategically select calves with CD that require antibiotic treatment does present a potential opportunity for reduction in AMU and presents an opportunity for developing targeted educational materials. Previous studies have evaluated the potential to reduce AMU for CD in dairy calves (Gomez et al., 2021). The change in Canadian regulations in December 2018 whereby all medically important antimicrobials must be purchased with a prescription should also the increase veterinary guidance of AMU (Health Canada, 2021). A European study suggested regulatory guideline was a potential predictor of AMU for CD treatment (Eibl et al., 2021).

Another potential opportunity to reduce AMU identified by this study was the use of preventive antimicrobials near the time of birth. In contrast with two previous western Canadian studies reporting less prophylactic or preventive use of antimicrobials than for the current study (Gow and Waldner, 2009; Waldner et al., 2013), almost 20% of producers used antibiotics at or near birth to prevent disease, with another six producers reporting mass treating most of their calves to prevent or treat BRD. The effectiveness of prophylactic AMU at birth is unclear and should be re-evaluated as part of efforts to enhance antimicrobial stewardship.

There are several important limitations to this type of cross-sectional survey study. While mail surveys are prone to recall bias, >80% of participants maintained herd treatment records, most of which were for individual animals. Cross-sectional observational studies are also limited by the difficulty in detangling temporal associations. Collecting risk period-specific treatment data for BRD and CD provided an opportunity to more carefully match the timing of risk factor outcome relationships examined in this study as did consider data from previous surveys in the same herds.

The highly correlated nature of many of the management factors examined also complicated the analysis and interpretation of the results. Many of the factors considered were proxies for the degree of crowding and contamination and the potential for pathogen transmission from heifers to calves and among calves of different ages. Finally given the number of herds enrolled in the study and the relatively low frequency of many of the outcomes of interest, the power of the study to detect factors associated with productivity was limited. Further given these were primarily moderate-sized herds with active veterinary relationships, caution is necessary for extrapolating the results to herds that are substantially smaller or larger, and that is less likely to use a veterinarian and the management practices typical of these herds.

In conclusion, a number of risk factors were identified that could be leveraged to potentially reduce the risk of BRD, CD, and navel infection in these herds as well as the need for AMU. Table 5 provides an overall summary of these findings. However, this summary needs to be interpreted with care given the design of the study and that many of the factors identified can be surrogates for more proximate latent and difficult measure risk factors. For example, tagging calves is unlikely to be a true risk factor for disease. However, the additional stress and disruption from handling cow-calf pairs near the time of birth might be in some herds.

Most identified factors contributed to the increasing risk of calf exposure to pathogens from other cows, calves, or the environment, such as calving cows and heifers together, and early, intensive calving. There was also evidence of the importance of managing BRD risks associated with mixing calves during spring processing and the introduction of purchased cows and calves. Vaccination of the cow herd was associated with a decreased risk of BRD in calves >4 months. Management practices to reduce animal density and exposure of young calves to contagious and environmental pathogens should be encouraged to improve calf health and survival. Sorting cow-calf pairs out of the calving area shortly after calving was associated with a decreased risk of BRD >4 months, CD from 6 days to 1 month, and use of the Sandhills system with a decreased risk of navel infection. Herd-level disease management strategies present opportunities to improve animal health and reduce AMU and associated treatment costs for the Canadian beef industry.

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Conflict of interest statement

The authors declare no known conflicts of interest.

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