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Antimicrobial drug use and reason for treatment in 203 western Canadian cow–calf herds during calving season

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ABSTRACT

Investigators examined antimicrobial drug use practices and reason for treatment as part of a large on-farm observational study of cow–calf herds from western Canada. Reason for treatment and antimicrobial drug use (AMU) were described using data collected during the calving season (January 1 to June 30, 2002). The study included 28,573 calves and 36,634 cows and heifers from 203 beef herds. All herds had more than 50 cows. Individual animal treatment records and a herd-level standardized questionnaire were collected from every herd. During the period of January 1 to June 30, 2002 at least one treatment was reported in 14% (95% CI, 11–17) of calves and 2.7% (95% CI, 2.2–3.4) of cows and heifers from these herds. The median percent of calves reported as treated per farm was 6.5% (range 0–100%) while the median percent of cows and heifers reported as treated was 0.9% (range 0–15%). Antimicrobial drugs used during the calving season were primarily for disease treatment rather than prevention or growth promotion. Diarrhea was the primary reason for treating calves and metritis was the primary reason for treating cows. Parenteral antimicrobial drugs were the most common formulation used in both calves and cows. The most commonly used antimicrobial drugs in these herds were tetracyclines, sulphonamides, and florfenicol. This study provides baseline estimates of the frequency of antimicrobial drug exposure, the types of drugs used, and diseases treated in these cow–calf herds. The challenges identified in collecting these data can be used to improve the design of future on-farm studies.

1. Introduction

The treatment of infectious disease in food producing animals is an essential component of veterinary medicine. Antimicrobial drug therapy is an important tool available to producers and veterinarians and is necessary to ensure that animal health and welfare are maintained. In addition to therapeutic use, antimicrobial drugs are also used to prevent disease, for growth promotion, and to increase production efficiency.

While a few studies have provided some insight to more intensive livestock production units such as hog farms (Dunlop et al., 1998; Rajic et al., 2006), there is no information about antimicrobial drug use (AMU) in western Canadian cow–calf herds. Based on farm cash receipts the beef industry is the largest livestock commodity in Canada (Anon., 2006a). The provinces of Alberta and Saskatchewan contain more than 65% of the beef cow, breeding heifer, and calf populations in Canada (Anon., 2006b). A better understanding of AMU patterns in this population is essential to develop a baseline and determine

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the need for future monitoring in the Canadian cow–calf industry.

As part of a large on-farm observational study of factors affecting the productivity of cow–calf herds, an opportunity was available to examine AMU during calving season. The objectives of this study were to describe the frequency of treatment with any antimicrobial drug in beef calves and cows, common reasons for AMU, the types of antimicrobial drugs used, and risk factors for treatment in western Canadian cow–calf herds during the calving season.

2. Materials and methods

2.1. Background and overview of study herds

The herds included in this study were concurrently enrolled in a comprehensive investigation of risk factors affecting the productivity and health of cow–calf herds in western Canada. The baseline study collected data from the spring of 2001 through the end of calving in 2002. The investigation of antimicrobial drug use practices was undertaken to maximize the industry benefit from this unique opportunity for on-farm access to individual animal data from a large number of cow–calf herds. The design of the baseline health and productivity study, including sample size calculations and herd selection criteria, have been described in detail elsewhere (Waldner, 2008). A brief overview of the herd selection criteria is provided here.

Mixed and large animal practitioners from the western provinces of Saskatchewan, Alberta and British Columbia were asked to participate in the study. Sixty-one veterinary clinics referred 485 producers who indicated some level of interest in learning more about the study (Waldner, 2008). Study personnel initially contacted this group by phone to provide background information about the project. If, after the call, the producer was still interested, study personnel visited the farm to collect some baseline information on herd size and management to ensure that selection criteria were met. Herds were eligible for enrollment based on completeness of animal identification, existing calving records, presence of animal handling facilities, use of pregnancy diagnosis and bull evaluation, and a relationship with a local veterinary clinic. Herds of less than 50 animals, greater than 250 animals, and herds not using a winter/spring calving season were excluded.

Of those initially contacted 417 herd owners provided basic demographic data. From this group, 212 herds that best fit the selection criteria and that agreed to participate after learning more about the study were enrolled. Characteristics of participating and non-participating herds were compared (Waldner, 2008). Producers that were not enrolled in the study were more likely to have <50 or >300 cows, less likely to use pregnancy diagnosis and bull breeding soundness exams, and were less likely to have complete calving records (Waldner, 2008). Participants were more likely than non-participants to be 36–50 years old and less likely to be older than 65 (Waldner, 2008).

Five producers changed their minds before the start of the study and data collection began in 207 herds in the spring of 2001 (Waldner, 2008). Two herds then withdrew form the study in the fall of 2001, and two more were lost in the winter of 2002 leaving 203 herds providing data for the 2002 calving season (Waldner, 2008).

Participating herds were visited regularly by one of six veterinarians contracted by the health and productivity study to collect samples and data and to monitor the quality and consistency of on-farm records. The individual animal treatment records from January 1 to June 30, 2002 were summarized for 203 study herds. Treatment data for spring-born calves were investigated separately from that of cows and replacement heifers in the breeding herd. In the first step of the analysis only calf treatment data were considered. The analysis was restricted to information collected for calves born alive between January 1 and May 31, 2002. Potential risk factors for treatment were summarized for calves and their dams meeting these inclusion criteria (Table 1). The second step of the analysis included treatment data reported for all cows, bred heifers, and yearling heifers present in the herd on January 1, 2002. Cows and bred heifers with stillborn calves, non-pregnant cows and heifers were included in the total number of animals available for investigation. Any cows or heifers purchased after January 1, 2002 were not included. Variables considered as potential risk factors for treatment were summarized for cows and heifers (Table 2).

Available calving records for each animal included dam identification, calf identification, date of calving, single or twin birth, sex of the calf, the type of assistance provided to the dam, any post-calving problems, and calving outcome (born alive, stillbirth and died later). If the calf died, the date of death was reported. Other data recorded for each herd included the ecological region in which the herd was located, the veterinary clinic servicing the herd, vaccination status for infectious bovine rhinotrachietis (IBR) and bovine viral diarrhea virus (BVDV), and vaccination status for neonatal diarrhea (coronavirus, rotavirus and *Escherichia coli*). Dam body condition (BCS) was scored (9-point scale) at the time of pregnancy diagnosis and again before or during the early part of the calving season.

2.2. Farm and animal information

Records from 203 herds across Alberta (146), Saskatchewan (53), and northern British Columbia (4) were included in this study. On January 1, 2002, herd size ranged from 53 to 481 mature, breeding females, with a median herd size of 154. Of the 203 included in the study, 169 herds (83%) had between 100 and 400 mature, breeding females.

2.2.1. Calf population

The 28,573 calves born alive from January 1 and May 31, 2002 were included in the study. This period captured 98% of all calves born alive in these herds and provided a minimum one-month observation period for the youngest calves included in these data. The majority of calves were born in March and April (64%). Most calves born alive were unassisted; 4.4% of live births were twins (Table 1). About half of the dams were vaccinated for BVDV and IBR prior to breeding in 2001, while about one third of the dams

Table 1
Summary of animal[a] and herd[b] level variables examined as potential risk factors for calf treatment during the 2002 calving season.

Variable examined as a potential risk factor	Percent (number) of cows with attribute	Percent (number) of herds with at least one cow with attribute
Ecoregion		
1. Aspen Parkland	26 (7516)	26 (53)
2. Boreal Transition	11 (3047)	11 (22)
3. Fescue Grassland	13 (3773)	12 (25)
4. Mixed Grassland	15 (4202)	14 (29)
5. Moist Mixed Grassland	13 (3566)	13 (26)
6. Northern Continental Divide	4.2 (1193)	3.9 (8)
7. Peace Lowland	9.5 (2710)	12 (25)
8. Western Alberta Upland	4.7 (1338)	3.9 (8)
9. Western Boreal	4.3 (1228)	3.5 (7)
Vaccinated for BVD/IBR prebreeding 2001		
1. Live vaccine	42 (11,896)	42 (85)
2. Inactivated vaccine	16 (4491)	17 (35)
3. No vaccine	4 (1177)	3.5 (7)
4. Not reported	39 (11,009)	37 (76)
Heifers vaccinated for diarrhea (*E. coli*) precalving 2002[c]	39 (1828/4748)	35 (65/184)
Cows vaccinated for diarrheas (*E. coli*) precalving 2002[d]	33 (7737/23,825)	32 (65/203)
Heifers vaccinated for diarrhea (viral) precalving 2002[c]	38 (1785/4748)	34 (63/184)
Cows vaccinated for diarrhea (viral) precalving 2002[d]	32 (7518/23,825)	31 (63/203)
BCS pre-calving <5 (9-point scale)[e]	5.7 (1636)	70 (142)
BCS at pregnancy testing <5 (9-point scale)[e]	8.3 (2357)	83 (168)
Cow born on farm and not purchased	67 (18,997)	92 (187)
Twin births	4.4 (1256)	88 (178)
Calf gender		
1. Male	51. (14,526)	100 (203)
2. Female	47. (13,416)	100 (203)
3. Not recorded	2.2 (631)	56 (113)
No cow problem other than dystocia	99 (28,242)	100 (203)
Prolapse	0.2 (50)	21 (43)
Retained fetal membrane (RFM)	1.0 (275)	40 (82)
Metritis	<0.1 (6)	2.5 (5)
Calving assistance reported		
1. No assistance	92 (26,291)	100 (203)
2. Easy pull	4.9 (1395)	87 (177)
3. Hard pull	1.7 (474)	68 (138)
4. Malpresentation	1.0 (285)	55 (111)
5. Caesarean section surgery	0.5 (128)	34 (69)
Calving month		
1. January 2002	8.0 (2271)	48 (98)
2. February 2002	21 (6115)	75 (152)
3. March 2002	39 (11,109)	97 (197)
4. April 2002	25 (7176)	96 (195)
5. May 2002	6.7 (1902)	81 (165)
Predominant breed type		
1. British	43 (12,353)	83 (168)
2. Continental	48 (13,692)	79 (160)
3. Cross	7.9 (2270)	32 (64)
4. No record	0.9 (258)	17 (34)
Age category		
1. Yearling heifer (born 2002)	0.1 (32)	10 (21)
2. 2 year old heifer (born 2000)	17 (4748)	91 (184)
3. 3 year old heifer (born 1999)	16 (4497)	97 (196)
4. Mature cow (born 1993 to 1998)	53 (15,206)	100 (203)
5. Old cow (born 1991 or earlier)	12 (3300)	94 (191)
6. No record of age	2.8 (790)	21 (42)

[a] Total number of calves enrolled, $n = 28{,}573$.
[b] Total number of herds enrolled, $N = 203$.
[c] These data pertain to bred heifers that had a live calf between January 1st and May 31st, 2002.
[d] These data pertain to bred cows that had a live calf between January 1st and May 31st, 2002.
[e] BCS, body condition score.

Table 2
Summary of animal[a] and herd[b] level variables examined as potential risk factors for cow or heifer treatment during the 2002 calving season. Denominators are provided in instances where data are only applicable to a sub-set of animals.

Variable examined as a potential risk factor	Percent (number) of cows with attribute	Percent (number) of herds with at least one cow with attribute
Ecoregion		
1. Aspen Parkland	25 (9086)	26 (53)
2. Boreal Transition	11 (3838)	11 (22)
3. Fescue Grassland	13 (4884)	12 (25)
4. Mixed Grassland	14 (5283)	14 (29)
5. Moist Mixed Grassland	13 (4822)	13 (26)
6. Northern Continental Divide	4.5 (1648)	3.9 (8)
7. Peace Lowland	10 (3720)	12 (25)
8. Western Alberta Upland	4.6 (1668)	3.9 (8)
9. Western Boreal	4.6 (1685)	3.5 (7)
Vaccinated for BVDV/IBR prebreeding 2001		
1. Live vaccine	16 (5772)	17 (35)
2. Inactivated vaccine	42 (15,317)	42 (85)
3. No vaccine	38 (14,033)	37 (76)
4. Not reported	4.1 (1512)	3.5 (7)
Heifers vaccinated for diarrhea (*E. coli*) precalving 2002[c]	34 (1749/5207)	35 (65/185)
Cows vaccinated for diarrhea (*E. coli*) precalving 2002[c]	35 (9092/26,040)	34 (70/203)
Heifers vaccinated for diarrhea (viral) precalving 2002[c]	38 (1969/5207)	35 (65/185)
Cows vaccinated for diarrhea (viral) precalving 2002[c]	29 (7518/26,040)	31 (63/203)
BCS pre-calving <5 (9-point scale)[d]	6.0 (1740/29,173)	72 (146)
BCS at pregnancy testing <5 (9-point scale)[c]	8.4 (3063/36,464)	77 (157)
Cow born on farm not purchased	52 (18,997)	92 (187)
No cow problem post-partum	99 (30,901/31,247)	100 (203)
Prolapse	0.2 (57/31,247)	21 (43)
Retained fetal membrane	0.9 (281/31,247)	40 (82)
Metritis	0.0 (8/31,247)	2.5 (5)
Calving assistance reported		
1. No assistance[c,e]	94 (29,337/31,247)	100 (203)
2. Easy pull[c,e]	4.4 (1392/31,247)	87 (177)
3. Hard pull[c,e]	1.7 (538/31,247)	68 (138)
4. Malpresentation[c,e]	1.2 (367/31,247)	55 (111)
5. Caesarian section surgery[c,e]	0.5 (151/31,247)	34 (69)
Predominant breed type		
1. British	43 (15,755)	83 (170)
2. Continental	47 (17,075)	80 (163)
3. Cross	9.4 (3424)	36 (73)
4. No record	1.0 (380)	16 (34)
Age category		
1. Yearling heifer (born 2001)	15 (5387)	84 (171)
2. 2-year old heifer (born 2000)	14 (5207)	91 (185)
3. 3-year old cow (born 1999)	13 (4837)	96 (195)
4. Mature cow (born 1993 to 1998)	45 (16,364)	100 (202)
5. Old cow (born 1991 or earlier)	10 (3648)	96 (194)
6. No record of age	3.3 (1191)	22 (45)

[a] Total number of cows and heifers enrolled, $n = 36,634$.
[b] Total number of herds enrolled, $N = 203$.
[c] Data pertains to all adult females in the herd as of January 1, 2002, except for the attributes that are specific to bred cows and heifers.
[d] Not all cows had BCS (body condition scores) these data represent cows with body condition scores.
[e] Calving information includes stillbirths, abortions and live calves.

received some type of vaccination to prevent neonatal calf bacterial or viral diarrhea (Table 1). Most dams had a BCS of 5 or higher on a 9-point scale at pregnancy testing and again at calving (Table 1).

2.2.2. Cow and heifer population

There were 36,634 cows and heifers reported in study herds on January 1, 2002 (5387 yearling replacement heifers and 31,247 cows and bred heifers expected to calve in the spring of 2002). This number included all cows and heifers that had calves born alive from January 1 to May 31, 2002 (dams of calves described above), cows and heifers that had abortions or stillborn calves during this period, and non-pregnant cows and heifers. The majority of cows were between 4 and 10 years of age (Table 2). Dystocia was reported in <10% of cows/heifers, and <1% of cows/heifers had post-partum complications such as retained placentas, prolapses, or metritis (Table 2).

2.3. Antimicrobial drug use data collection

Data on AMU were collected using individual treatment records as well as a herd level questionnaire and these data were summarized for the period of January 1 to June 30,

2002. The data used in this study were limited to this time frame for two reasons. First, in western Canadian herds that have cows calving in the winter and early spring-months cows are often confined for ease of monitoring and feeding. Confinement also simplifies identification and treatment of sick animals and the recording of these treatments. In contrast, during the summer and fall months cattle are generally turned out into large pastures where routine observation and identification of sick animals is more difficult and treatment records are more sporadic. The second reason for collecting data during this period is that the majority of treatments in cow–calf herds occur during the calving season. Calving during the winter and spring often exposes young animals to severe weather extremes. Close confinement during this period increases the risk of disease transmission. By restricting the analysis to the period between January and June the investigators captured the most accurate treatment records available for these herds during the time frame when the majority of treatment episodes were expected to occur.

Producers reported individual animal treatments in a record book originally designed for the primary health and productivity study. Treatment type was reported as a coded pick list: injectable antimicrobial, oral antimicrobial, oral and injectable antimicrobial, fluids, and other. Coded lists were also provided to standardize the responses for class of animal, reason for treatment, and type of treatment. A notes section allowed producers to write in any comments. Where completed by the producers, the notes section was used by investigators to help further classify diagnoses or treatments.

Producers could report more than one reason for, or type of treatment for, each treatment episode. The producer was asked to record each treatment occurrence; however, animals reported as treated more than once for the same diagnosis within a 7-day period were classified as having one treatment event for the purpose of analysis.

Treatment data were summarized in two ways. First, to provide an estimate of treatment intensity per herd for the period of January 1 to June 30, 2002, a count of total treatment events per herd was determined. This was calculated separately for the calves and then for the cows and heifers. The treatment intensity was reported as the number of treatment events per every 100 animals at risk during the 6-month period. Second, risk of treatment was described using the cumulative incidence for the period of January 1 to June 30, 2002 for calves and then for the cows and heifers. This was calculated as the number of animals that were reported as ever having been treated as a percentage of the number of animals per herd at risk of treatment at any time during the study period.

A herd-level questionnaire was developed to identify the types of antimicrobial drugs most commonly used on each cow–calf farm. This was done because the individual animal records did not consistently include information on the type of antimicrobial drug used for treatment. Herd owners were asked about the frequency of use for sulphonamides, tetracylcines/oxytetracyclines, trimethoprim/sulphadiazine, and penicillins. Antimicrobials that did not fall into these broad categories were classified as "other". Producers were asked to report separately the number of treatments for both cows and calves for each drug category listed above. The number of treatments for each category was coded as follows: l–3 animals treated, 4–10 animals treated, and greater than 10 animals treated.

The quality of the treatment records were assessed at the end of the study. The veterinarians responsible for data collection and entry were asked for a subjective, comparative assessment of the quality of the data. They classified the data for each herd into one of the following categories: excellent, good or satisfactory, and less than satisfactory. Herd owner compliance in completing treatment records was also evaluated by considering the relative frequency of calf mortality in the herds that did not report any treatments. Inventory and post-mortem examination data that were available from the baseline productivity study were used to verify calf mortality records. The plausibility of no reported treatments was assessed when compared to the percent calf death loss in each herd.

2.4. Statistical analysis

All data were entered into a customized database (Microsoft® Office Access 2000, Microsoft Corporation). Descriptive analyses were completed and variables were recoded as necessary for statistical modeling using commercially available software (SPSS 11.0 for Windows, SPSS Inc., Chicago, Illinois).

Factors affecting the occurrence of treatment, a class variable with two levels (treated or not treated), were examined in calves as well as cows and heifers using mixed models with a binomial distribution and logit link function. The calculations were performed using penalized quasi-likelihood estimates (2nd order PQL) (MLwiN version 2.0, Centre for Multilevel Modelling, Institute of Education, London, UK). The strength of the association between outcome and exposure was reported as an odds ratio (OR) with 95% confidence intervals.

A null model (intercept only) was created for each outcome variable. Random intercepts were examined to assess degree of clustering for treatments reported within herd, veterinary clinic, and ecological region (ecoregion). Ecoregion is a geographical delineation characterized by regional ecological factors such as vegetation, soil, climate, water and fauna (Wiken, 1986). Within-herd clustering was accounted for as a random intercept in all models. Veterinary clinic and ecoregion where not included as random intercepts in any model as neither explained a substantial part of the variation. Models were checked for the presence of extra-binomial variation, but extra-binomial parameters in the range of 0.9–1.0 were reset at 1.0 (binomial variation).

Data from the null models were used to estimate the intra-class (i.e., intra-herd) correlation coefficient (ICC or ρ) to measure clustering of each outcome within herd (Dohoo et al., 2003). The null models were also used to generate population-average estimates of the risk of calf treatment and cow and heifer treatment (Dohoo et al., 2003).

The unconditional associations between each of the potential risk factors (Table 1 for calves and Table 2 for cows and heifers) and the odds of treatment were examined. All potentially important risk factors ($P \leq 0.25$) were identified and a final model was then developed using backwards stepwise elimination.

Any potential risk factors where $P < 0.05$ or that acted as important confounders (removal of the potential risk factor from the model changes the effect estimate for the exposure by ≥20%) were retained in the final model. After establishing the main effects model, biologically reasonable (Dohoo et al., 2003) first order interaction terms were tested if two or more variables ($P < 0.05$) were retained in the final model. The adequacy of all models was evaluated using plots of residuals to check that all assumptions had been met as appropriate.

Associations between calf treatment and mortality in each herd were investigated using generalized estimating equations (SAS v.8.2 for Windows (PROC GENMOD); SAS Institute, Cary, North Carolina, USA). The number of calves with any treatment (numerator) as a proportion of the total number of calves in the herd (denominator) was the outcome of interest. The predictor variable, percent calf mortality for the herd, was categorized into quartiles (<2%, 2–5.9%, 6–14.9% and >15% mortality). The model specifications included a binomial distribution, logit link function, repeated statement with subject equal to herd, and an exchangeable correlation structure.

3. Results

3.1. Individual animal records of treatment and diagnosis

3.1.1. Individual calf treatment records

Herd owners reported treating 14% (95% CI, 11–17%) of calves with an antimicrobial drug at least once between January 1 and June 30, 2002. The median age of calves at the time of their first treatment was 11 (range 0–141) days of age and 59% (2171/3702) of calves were first treated between birth and 14 days of age. The median percentage of calves treated at least once on each farm was 6.5% (range 0–100%). The median number of treatment events per farm was 6.8 (range 0–104) for every 100 calves at risk from January 1 to June 30, 2002.

The most commonly recorded antimicrobial drug formulation used in calves was injection (Table 3). Parenteral antimicrobial drugs were used in 56 (28%) herds on <1% of the calves, in 70 (34%) herds on 1–5% of the calves, in 56 (28%) herds on 5–15% of the calves, and in 23 (11%) herds on >15% of the calves. Four herd owners treated 50–80% of the calves and three herd owners treated all of their calves at least once. The maximum number of times a calf was treated with parenteral antimicrobial drugs was 14 (median, 1; range 0–14).

The second most commonly reported protocol for calves included treatment with both oral and parenteral antimicrobial drugs (Table 3). Oral and parenteral antimicrobial drugs were used together on <1% of the calves in 130 (64%) herds, on 1–5% of the calves in 40 (20%) herds, on 5–15% of the calves in 23 (11%) herds, and on >15% of the calves in 10 (4.9%) herds (maximum, 42%).

Oral formulations were used alone as an antimicrobial treatment in <2% of calves (Table 3). One hundred and forty-four (71%) herd owners treated <1% of their calves with oral antimicrobial drugs, 40 (20%) treated 1–5% of the calves, 13 (6.4%) treated 5–15% of the calves, and 6 (2.9%) treated between 15 and 51% of their calves with oral antimicrobial drugs.

3.1.2. Individual calf records of diagnoses

Diarrhea was the most commonly reported reason for treatment in calves (Table 4). The percentage of calves treated for diarrhea per farm ranged from 0 to 89% (median, 4.3%). Within these 203 herds, 145 (71%) producers treated 0 to 5% of their calves for diarrhea, 20 (9.9%) treated 5–10%, 25 (12%) treated 10–20%, and 13 (6.4%) producers treated >20% of their calves for diarrhea.

The next most common reason for treatment was pneumonia (Table 4). The frequency of calf treatments for pneumonia per farm ranged from 0 to 52% (median, 2.0). One hundred and twenty-six (62%) producers treated ≤1% of their calves for pneumonia, 51 (25%) treated 1–5% of their calves, 20 (9.9%) treated 5–15% of their calves, and 6 (2.9%) treated >15% of their calves for pneumonia.

Treatment and prevention of omphalitis (navel infection) made up the third most common recorded reason for treatment (Table 4). Four producers treated between 65 and 100% of their calves prophylactically for omphalitis.

3.1.3. Individual cow treatment records

Between January 1 and June 30, 2002, 2.7% (95% CI, 2.2–3.4%) of the cows and heifers were treated at least once. The median percent of cows and heifers ever treated per farm was 0.9% (range 0–15%). Since almost all cows and heifers that were treated were only treated once during the period of January 1st to June 30th, the number of treatment

Table 3
Administration routes for antimicrobial drugs used in calves[a] and in cows/heifers[b] at the animal and herd[c] level between January 1 and June 30, 2002[d].

Treatment	Percent (number) of calves	Percent (number) herds reporting calf treatment	Percent (number) of cows/heifers	Percent (number) herds reporting cow/heifer treatment
Injectable antimicrobials	8.4 (2400)	80 (162)	1.8 (658)	61 (123)
Oral and injectable antimicrobials	3.0 (852)	46 (93)	<0.1 (6)	2.5 (5)
Oral antimicrobials	1.8 (512)	39 (80)	<0.1 (3)	1.0 (2)
Other treatment[e]	0.6 (173)	30 (61)	0.3 (91)	23 (46)
Fluids	0.4 (123)	27 (54)	<0.1 (1)	0.5 (1)

[a] Total number of calves enrolled, n = 28,753.
[b] Total number of cows enrolled, n = 36,634.
[c] Total number of herds enrolled, N = 203.
[d] Any individual animal may have been treated with more than one type of treatment.
[e] Other treatment includes; treatment with mineral oil, vitamin injections, etc.

Table 4
Top 10 diagnoses recorded for antimicrobial drug treatment from January 1 to June 30, 2002 summarized at the individual calf[a] and herd[b] level[c].

Diagnosis	Percent (number) of calves affected	Percent (number) of herds with at least one animal affected[d]
Diarrhea	5.8 (1648)	64 (129)
Pneumonia	2.2 (625)	51 (103)
Prophylactic treatment for navel infections	1.9 (529)	2.0 (4)
Not recorded	1.2 (355)	33 (67)
Omphalitis	1.1 (300)	43 (87)
Fever, depression, not doing well	0.5 (139)	22 (44)
Coccidiosis	0.4 (114)	17 (35)
Prophylactic treatment at castration	0.2 (45)	1.5 (3)
Weak	0.1 (25)	6.9 (14)
Interdigital necrobacillosis	0.1 (27)	9.9 (20)

[a] Total number of calves enrolled, $n = 28{,}573$.
[b] Total number of herds enrolled, $N = 203$.
[c] Individual calves may have more than one diagnoses.
[d] Corresponds to the percent (number) of herds with at least one case of the diagnosis.

events per 100 cows and heifers at risk was also 0.9 (range 0–15).

The most commonly reported treatments in cows and replacement heifers were with parenteral antimicrobial drugs (Table 3). Very few cows or heifers were reported to receive either oral antimicrobial drugs or oral and parenteral antimicrobial drugs together (Table 3). Oral treatments were only given in 2 (1.0%) herds and to <3% of the cows in these herds; whereas, oral and parenteral treatments were given in 5 (2.5%) herds to <1% of cows. One hundred and eleven (55%) producers treated <1% of their cows with parenteral antimicrobial drugs, 69 (34%) treated 1–5% of their cows, and 23 (11%) producers treated >5% of their cows with parenteral antimicrobial drugs.

Treatments other than antimicrobial drugs were more commonly reported for cows and heifers than for calves (Table 3). Treatments categorized as "other" were given on 46 (23%) herds to 0.2–5% of the cows. Other treatments included non-antimicrobial treatments such as mineral oil or other products for gastrointestinal disorders.

Table 5
Top 10 diagnoses made from antimicrobial drug treatment form January 1 to June 30, 2002 summarized at the individual cow/heifer[a] and herd[b] level[c].

Diagnoses	Percent (number) of cows/heifers affected	Percent (number) of herds with at least one animal affected[e]
Metritis	0.4 (145)	26 (52)
Interdigital necrobacillosis	0.4 (140)	25 (51)
Retained placenta	0.3 (93)	18 (37)
Not recorded	0.2 (81)	22 (45)
Mastitis	0.1 (41)	14 (28)
Extraction/C-section	0.1 (30)	9.4 (19)
Gastrointestinal[d]	0.1 (30)	10 (21)
Fever/depression/ not doing well	0.1 (25)	8.4 (17)
Prolapse	0.1 (26)	9.9 (20)
Pneumonia	0.1 (27)	8.9 (18)

[a] Total number of cows enrolled, $n = 36{,}634$.
[b] Total number of herds enrolled, $N = 203$.
[c] Individual animals may have had more than one diagnoses.
[d] Gastrointestinal includes hardware and perotinits.
[e] Corresponds to the percent (number) of herds with at least one case of the diagnosis.

3.1.4. Individual cow records of diagnoses

Table 5 summarizes the primary reasons for treatment of cows and heifers. Metritis was diagnosed in 1–2% of the animals with calving records in 9 (4.4%) herds, and in >2% of the animals in 12 (5.9%) herds. One hundred seventy-four (86%) herd owners treated <1% of their cows and heifers and 29 (14%) treated 1–5% of their cows and heifers for interdigital necrobacillosis (footrot). Retained placentas were diagnosed and treated in <1% of the animals with calving records in 173 (85%) herds, in 1–2% of the animals in 20 (9.8%) herds, and in >2% of the animals in 10 (4.9%) herds.

3.2. Antimicrobial drug use

The most commonly reported antimicrobial drugs used are summarized for calves in Table 6, for cows and heifers in Table 7, and for all herds in Table 8.

Ionophores were used in the feed supplied to cows or heifers in 29% (58/203) of herds. Reason for use was not specified.

Enrofloxacin was reported as used on 287 calves in 8 herds. One herd reported treating 172 of 191 (90%) calves with a combination of enrofloxacin and sulbactam-ampicillin. For all calves treated with enrofloxacin, the recorded reason for treatment was diarrhea. Florfenicol was listed specifically in the notes section for the treatment records of 92 calves on 17 farms. Of these 92 calves, 41 (45%) were treated for diarrhea, 31 (34%) for omphalitis, 5 (5.5%) for pneumonia, 1 (1.1%) for arthritis, and 14 (15%) for other reasons.

3.3. Effect of herd, veterinary clinic, ecoregion, and other risk factors on reported treatment practices for calves and cows

Neither the location of the herd by ecoregion or differences in recommendations among referring veterinary clinics explained a substantial part of the variation in reported treatment practices for either calves or cows. However, treatment practices were clustered within herd (calf treatment, $\rho = 0.21$; cow treatment, $\rho = 0.20$).

Calf gender, assistance at parturition, and the percent of cows and heifers treated in the herd were unconditionally

Table 6
Percent (number) of herds[a] recording various antimicrobial drug treatments used in calves from January 1 to June 30, 2002.

Treatment	Never used, percent (number)	Used 1–3 times, percent (number)	Used 4–10 times, percent (number)	Used >10 times, percent (number)	Herds ever used, percent (number)
Calf oral sulphonamides	49 (100)	12 (24)	17 (35)	22 (44)	51 (103)
Calf injectable sulphonamides	72 (146)	8.9 (18)	8.4 (17)	11 (22)	28 (57)
Calf florfenicol	59 (119)	9.9 (20)	16 (33)	15 (31)	42 (84)
Calf LA[b] oxytetracycline	63 (127)	11 (22)	13 (27)	13 (27)	37 (76)
Calf SA[c] oxytetracyline	99 (201)	0.5 (1)	0.5 (1)	0.0 (0)	1.0 (2)
Calf tetracycline bolus	100 (202)	0.5 (1)	0.0 (0)	0.0 (0)	0.5 (1)
Calf tilmicosin	79 (161)	10 (21)	4.9 (10)	5.4 (11)	21 (42)
Calf SA[c] Penicillin	87 (177)	4.4 (9)	5.4 (11)	3.0 (6)	13 (26)
Calf LA[b] penicillin	93 (189)	3.4 (7)	0.5 (1)	3.0 (6)	6.9 (14)
Calf sulbactam-ampicillin injectable	92 (187)	3.9 (8)	0.5 (1)	3.4 (7)	7.9 (16)
Calf ceftiofur	92 (187)	2.0 (4)	3.0 (6)	3.0 (6)	7.9 (16)
Calf amprolium hydrochloride oral	98 (199)	0.5 (1)	1.0 (2)	0.5 (1)	2.0 (4)
Calf gentamicin injectable	99 (201)	1.0 (2)	0.0 (0)	0.0 (0)	1.0 (2)
Calf ampicillin trihydrate injectable	99 (201)	1.0 (2)	0.0 (0)	0.0 (0)	1.0 (2)
Calf enrofloxacin tablets oral	100 (202)	0.5 (1)	0.0 (0)	0.0 (0)	0.5 (1)
Calf cephalexin oral	100 (202)	0.0 (0)	0.5 (1)	0.0 (0)	0.5 (1)
Calf erythromycin	100 (202)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Calf other	95 (193)	4.9 (10)	0.0 (0)	0.0 (0)	4.9 (10)
Calf unknown other	98 (198)	1.0 (2)	0.5 (1)	1.0 (2)	2.5 (5)

[a] Total number of herds enrolled, $N = 203$.
[b] LA = long acting.
[c] SA = short acting.

Table 7
Percent (number) of herds[a] recording various antimicrobial drug treatments used in cows/heifers from January 1 to June 1, 2002.

Treatment	Never used, percent (number)	Used 1–3 times, percent (number)	Used 4–10 times, percent (number)	Used >10 times, percent (number)	Herds ever used, percent (number)
Cow oxytetrcycline LA[b]	48 (98)	23 (46)	19 (38)	10.0 (21)	52 (105)
Cow oxytetetrcycline SA[c]	97 (197)	2.0 (4)	1.0 (2)	0.0 (0)	3.0 (6)
Cow tetracycline bolus	98 (199)	1.0 (2)	1.0 (2)	0.0 (0)	2.0 (4)
Cow LA[b] penicillin	79 (160)	13 (26)	5.4 (11)	3.0 (6)	21 (43)
Cow SA[c] penicillin	89 (180)	6.9 (14)	3.0 (6)	1.5 (3)	11 (23)
Cow tilmicosin	92 (187)	7.4 (15)	0.5 (1)	0.0 (0)	7.9 (16)
Cow trimethoprim/sulphadiazine	95 (192)	4.9 (10)	0.0 (0)	0.5 (1)	5.4 (11)
Cow oral sulphonamides	97 (197)	2.5 (5)	0.5 (1)	0.0 (0)	3.0 (6)
Cow florfenicol	96 (194)	3.9 (8)	0.5 (1)	0.0 (0)	4.4 (9)
Cow sulbactam-ampicillin injectable	97 (197)	0.5 (1)	0.0 (0)	2.5 (5)	3.0 (6)
Cow ceftiofur	99 (200)	1.5 (3)	0.0 (0)	0.0 (0)	1.5 (3)
Cow spectinomycin hydrochloride	100 (202)	0.5 (1)	0.0 (0)	0.0 (0)	0.5 (1)
Cow dihydrostreptomycin	100 (202)	0.5 (1)	0.0 (0)	0.0 (0)	0.5 (1)
Cow amprolium hydrochloride oral	100 (202)	0.5 (1)	0.0 (0)	0.0 (0)	0.5 (1)
Cow novobiocin/penicillin G intramammary	98 (199)	1.0 (2)	0.5 (1)	0.5 (1)	2.0 (4)
Cow cephapirin sodium intramammary	99 (200)	1.0 (2)	0.0 (0)	0.5 (1)	1.5 (3)

[a] Total number of herds enrolled, $N = 203$.
[b] LA = long acting.
[c] SA = short acting.

Table 8
Percent (number) of herds[a] that reported using certain antimicrobial drugs at least once in beef cows or calves on the farm during the period of January 1 to June 30, 2002.

Treatment	Used at least once, percent (number)	No use, percent (number)
Oxytetracycline/tetracycline	61 (123)	39 (80)
Sulphonamide	59 (120)	41 (83)
Florfenicol	43 (88)	57 (115)
Penicillin	38 (77)	62 (126)
Tilmicosin	27 (54)	73 (149)
Sulbactam-ampicillin injectable	9.9 (20)	90 (183)
Ceftiofur	8.9 (18)	91 (185)
Enrofloxacin	0.5 (1)	100 (202)

[a] Total number of herds enrolled, $N = 203$.

associated with the odds of a calf having been reported as treated by the herd owner. After accounting for other variables in the model, female calves were less likely to be treated than male calves (OR, 0.8; 95% CI, 0.7–0.9). Calves for which manipulation or traction was applied during calving were 1.5 (95% CI, 1.3–1.7) times more likely to be reported as treated than calves that were not assisted. The odds of calf treatment also increased 1.2 (95% CI, 1.1–1.3) times for every percent increase in cow treatment reported for the herd.

Yearling heifers were one fifth (OR, 0.2; 95% CI, 0.2–0.3) as likely to be treated as all other breeding females. Other risk factors, including breed, vaccination status and body condition score, did not significantly contribute to the odds of a cow or heifer being treated.

Calving-related factors were examined only for mature females with calving records in 2002. After accounting for other risk factors, cows or bred heifers were more likely to be treated if they were assisted at the time of calving or if they experienced post-calving problems such as prolapse, retained fetal membranes or metritis. Cows or bred heifers for which manipulation/traction or caesarian sections were reported at calving were respectively 2.1 (95% CI, 1.7–2.7) and 15 (95% CI, 8.8–24) times more likely to be treated than cows and bred heifers that did not require assistance at calving. Cows or bred heifers with post-calving problems such a prolapse, retained fetal membranes or metritis were respectively 57 (95% CI, 29–110), 109 (95% CI, 78–153) and 312 (95% CI, 50–1941) times more likely to be treated than cows or bred heifers that did not have these conditions.

3.4. Assessment of the quality of treatment records

The study-employed veterinarians responsible for collection and entry of all herd data subjectively rated 39% of the herd treatment records as excellent, 41% as good or satisfactory, and 20% as less than satisfactory. Herd owner compliance in recording these data was also investigated by comparing herd calf mortality and treatment rates in the 28 (14%) herds that had no reported treatments. Of these herds, 4 had no calf mortality, 10 had <2% calf mortality, 8 had 2–5% calf mortality, 4 had 5–10% calf mortality and 2 had >10% calf mortality. The risk of calf mortality was not associated with the proportion of calves treated in all study herds ($P = 0.6$).

4. Discussion

The extent of under reporting of antimicrobial drug use was difficult to estimate using the data available from this study. Based on the crude subjective and comparative assessment of the quality of the data, at least 20% of the herds had less than satisfactory treatment records. When combined with information on the calf mortality and the proportion of herds reporting no treatments there is further evidence that there was under reporting of AMU by some study herds. For example, it is unlikely that herds with greater than 5% calf death losses would have no calf treatments. While under reporting was a potential limitation of this study, complete and accurate farm-based antimicrobial drug use records are difficult to obtain from extensively managed livestock operations. Complete recording of use information is demanding for producers especially during busy times where farm labor resources are limited.

Another limitation of the study was the lack of consistent reporting for individual animals detailing which antimicrobial drugs were used to treat specific conditions and the dose used. While investigators attempted to collect information on the types and relative amounts of drugs used in each herd, these data were potentially subject to recall bias since the questionnaire was administered at the end of the calving season and relied on producer accounts of the number of animals treated with each class of antimicrobial. Future studies should focus on working with producers to prospectively report the amount and type of each antimicrobial used to more accurately assess antimicrobial drug exposure. While the baseline health and productivity study provided a unique opportunity to collect information about on-farm treatment practices, the data collection tools were not specifically designed to measure the amount and frequency of individual antimicrobial drugs used in these herds. A producer-friendly data collection instrument designed for the purpose of capturing detailed information on both the type and amount of antimicrobial drug used and the class of animal treated would be necessary to more exactly measure antimicrobial drug exposure.

Despite the limitations, this study does provide the first available documentation of the proportion of calves and proportion of cows and heifers treated during the calving season and the types of conditions most often treated in western Canadian herds. The study also provides some initial information about antimicrobial drug use practices in these herds which can be used to design future studies of extra-label drug use, prophylactic treatment, and the importance of managing dystocia in reducing treatment of cows or calves.

The relatively small proportion of treated animals is consistent with the finding that the primary reasons reported for antimicrobial drug use in cow–calf operations were for individual therapeutic use rather than prophylaxis, metaphylaxis, or growth promotion. In contrast, between 75 and 90% of all dairy cattle receive prophylactic antimicrobial drugs to prevent mastitis (Sischo et al., 1993; USDA, 2003). Depending upon the size of the feedlot, the type of cattle placed and bovine respiratory disease risk designation, anywhere between 16–19% of feedlot cattle in the United States (USDA, 1999) and 20–50% of feedlot animals in Canada receive prophylactic injectable antimicrobial drugs on arrival for the control of bovine respiratory disease (Radostits, 2001; personal communication with Calvin Booker, Feedlot Health Management Services Ltd., February 22, 2007).

There are few available antimicrobial drug use studies for cow–calf herds (Bair and McEwen, 2001; Powell and Powell, 2001; Sayah et al., 2005). Powell and Powell (2001) and Sayah et al. (2005) both gathered information via questionnaires while Bair and McEwen (2001) had access to treatment records. The previously reported studies had substantially fewer cattle and herds enrolled than the present study. Also, the reporting structure of the previous three studies did not differentiate between drug use in cow–calf herds and drug use in feedlots limiting direct comparisons to the present study.

Extra-label drug use was reported in some cow–calf herds in the current study. The most commonly reported antimicrobial drugs used in these herds were tetracyclines, sulphonamides, and florfenicol. In Canada, florfenicol is labeled for bovine respiratory disease and for the treatment of interdigital phlegmon (Compendium of Veterinary Products, 2003), but the individual animal treatment notes indicate that it was also used in an extra-label manner in calves for diarrhea and omphalitis. Extra-label use of fluoroquinolones and cephalosporins were also reported. Powell and Powell (2001) also reported off label use of enrofloxacin in their survey of Ontario beef producers. At the time of these studies, enrofloxacin was not readily obtainable by cattle producers because in 2002 there was only a small animal formulation available in Canada. Since the time of this study, a cattle formulation has been approved for use in Canada for the treatment of bovine respiratory disease (Compendium of Veterinary Products, 2003). Follow up studies are needed to see how antimicrobial drug use patterns might change following the release of new products.

In addition to describing use patterns, this study identified factors associated with the reported frequency of calf treatment. Calves that were assisted during birth were more likely to be reported as treated. Sanderson and Dargatz (2000) also reported that increasing incidence of dystocia in a herd was associated with increased morbidity. Another potentially related finding was that female calves were less likely to be treated than male calves. This could be because male calves are often larger than females (Bellows et al., 1987). Larger calves are more likely to experience delayed parturition, increased fetal stress, and reduced vigor; potentially negatively affecting passive transfer and calf health. Calves were also more likely to be treated in herds where more cows or heifers were treated. This finding might reflect an increased likelihood of exposure to disease on these farms because of management or other factors, or it may reflect an increased tendency of these producers to administer and report treatment.

Yearling heifers were less likely to be treated than cows. Risk factors for cow or bred heifer treatment included assistance at calving and post-calving problems such as a prolapse, retained fetal membranes, and metritis. Because cows and bred heifers were more likely to be treated if there was assistance at calving, further investigation is needed into whether producers are providing treatment prophylactically because of the intervention or it they are treating an observed morbidity, either related to parturition or for some other reason. This distinction is not clear from the available data.

Calves were more likely to be reported as treated than cows or heifers in this study and the primary reason reported for calf treatment was diarrhea. Diarrhea was also the most commonly reported illness in beef calves in the United States (USDA, 1997) and in a survey of beef producers in Ontario (Powell and Powell, 2001). In the current study the primary reported reason for treatment of cows or bred heifers was metritis followed closely by interdigital necrobacillosis; whereas, in the United States infectious keratoconjunctivitis and interdigital necrobacillosis were listed as the two primary disease conditions reported among breeding females (USDA, 1997). The current study only looked at treatment from January to June; whereas, the National Animal Health Monitor System (NAHMS) study questions spanned the entire year. Infectious bovine keratoconjunctivitis (IKC) is more common in the summer months. Although there was a difference in the primary reasons for cow and heifer treatment between western Canada and the United States, both studies did report a relatively low occurrence of disease and treatment in breeding females.

Because herds were enrolled in the larger productivity study based on their ability to provide the required data, these herds probably represent some of the more progressive, commercially viable, and intensively managed herds in western Canada. Antimicrobial drug use may be different in very large cow–calf herds or the small herds present on some mixed or hobby farms. Data from this study can be applied to typical commercially viable cow–calf farms in Canada with 50 to about 300 cows which would represent the core of the industry in western Canada.

These data demonstrate that antimicrobial drug use on cow–calf farms, during the calving season, is primarily for treatment of disease and that on most farms few animals are exposed to antimicrobial drug therapy. Researchers can use data collected in this study for baseline estimates of antimicrobial drug exposure and the types of diseases treated in this population. They can also learn from the challenges identified in collecting these data to improve future study designs. The risk factors identified by this work can be used by industry to develop strategies to optimize the use of antimicrobial drugs in these herds.

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