Pilot implementation of a newly developed bovine leukemia virus control program on 11 Alberta dairy farms

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ABSTRACT

We developed a custom bovine leukemia virus (BLV) control program for the Alberta dairy industry, consisting of a risk assessment and a comprehensive list of best management practices (BMP) aimed at prevention of BLV transmission between cattle. This control program was implemented on 11 farms for approximately 1 yr. Blood samples were collected from all cattle ≥ 12 mo old, and serum was tested with a commercial ELISA. Risk assessments were performed on each farm, risk-connected on-farm management was identified, and management changes expected to prevent transmission of BLV between cattle were suggested by the first author and agreed upon with each farmer. Throughout the following year, all participating farmers were visited multiple times to identify and overcome barriers to implementation and to monitor progress. After approximately 1 yr of implementing BLV control, all cattle ≥ 12 mo old on farm with a negative or no previous test result were sampled, and the within-herd prevalence was determined. The median number of cattle on farm that were ≥ 12 mo was 195 (range 110–524). The initial prevalence averaged 39% (13–66%). On average, 5 BMP (3–7) were suggested to each farmer. On average, 4 BMP (1–7) were implemented. At the second sampling, the average within-herd prevalence of all animals that tested positive (including the previous sampling) was 36% (12–62%). Eight farms reduced their within-herd BLV prevalence, within-herd prevalence stayed constant on 1 farm, and it increased on 1 farm. The remaining farm terminated their participation before the second sampling. The number of seroconversions per farm ranged from 3 to 109, highlighting the success of some producers to minimize new infections. The

risk assessment was proven to be a valuable tool to identify flaws in on-farm management, although risk assessment score was unrelated to the within-herd BLV prevalence. Finally, it appeared that implementation of BMP aimed at prevention of BLV transmission between cattle could reduce within-herd BLV prevalence when farmers committed to their implementation.

Key words: bovine leukemia virus, control, on-farm control program

INTRODUCTION

Infectious animal diseases have always posed a risk to food animal productivity because they decrease production and negatively affect farm profitability and animal welfare (Bartlett et al., 2014; Wolf et al., 2014; Santman-Berends et al., 2015). Therefore, various disease control and pathogen eradication strategies have been applied in agriculture, whereby farmers strive to improve the health and well-being of their herds (Leach et al., 2010b; Nielsen, 2011). For several diseases (e.g., bovine spongiform encephalopathy and brucellosis), mandatory disease control or eradication programs were initiated by the federal government in Canada (Canadian Food Inspection Agency, 2018). Additionally, for some other diseases, voluntary disease control programs were established and supported by the industry (e.g., Johne's disease and lameness). By providing information on the disease, as well as discussing farm-specific best management practices (BMP) that can limit pathogen transmission, farmers were enabled to control these diseases on farm. Additionally, by using risk assessments in collaboration with the farm veterinarian, control programs can be tailored to specific farm situations. This approach has been successful, for example, for farms participating in Johne's disease control (Sorge et al., 2011; Wolf et al., 2015; Solano Quesada, 2016).

Bovine leukemia virus (BLV), the causative agent of a production-limiting bovine disease, is common in North American dairy herds (herd prevalence $\sim 90\%$; LaDronka et al., 2018; Kuczewski et al., 2019). It can

Received July 8, 2020.

Accepted November 3, 2020.

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impair milk production, reduce cow longevity, decrease responses to vaccines, and lead to development of enzootic bovine leukosis. Because BLV is a retrovirus, infection with this virus is lifelong (Goff, 2013); therefore, reduction in BLV prevalence among and within herds is only possible by replacing BLV infected cattle. Following identification of BLV-positive cattle, there are 3 common options for BLV control: culling, segregation, or management of infected cattle (Rodríguez et al., 2011; Bartlett et al., 2014). Culling or segregation programs have been used to successfully eradicate BLV from many European countries, as well as from dairy herds in New Zealand and Australia (European Commission, 2003; Voges, 2012; Dairy Australia Limited, 2015). These programs were mandatory; the entire cattle population was regularly tested, positive cattle were eliminated or physically segregated, and a monitoring program was initiated (EFSA AHAW Panel, 2015). However, thus far in Canada, no mandatory or voluntary BLV control program has successfully been implemented on a large scale. Currently, it is up to the farmer to decide to control BLV and which strategy to pursue once infected cattle are identified. Nonetheless, culling or segregation strategies are often either not feasible or logistically challenging (Huijps et al., 2009), as the mean within-herd prevalence is relatively high at approximately 40% in Alberta, Canada (Kuczewski et al., 2019). Therefore, Canadian farmers often prefer to implement management practices that reduce BLV transmission, and thereby within-herd prevalence [Cindy Adams (Department of Veterinary Clinical and Diagnostic Sciences Faculty of Veterinary Medicine, University of Calgary, Canada, and Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Canada), Frank van der Meer, and Alessa Kuczewski (both Department of Ecosystem and Public Health, Faculty of Veterinary Medicine, University of Calgary, Canada), unpublished data]. To assist the Canadian dairy industry to decrease BLV prevalence within and across herds, we developed a voluntary BLV control program based on a risk assessment and BMP identification. The goal of this project was to design and evaluate the use of a BLV risk assessment tool and associated on-farm BLV control measures by implementing them on a limited number of Alberta dairy farms. Identification of potential shortcomings and their corrections before large-scale roll out was considered imperative before the control program could be introduced to farmers on a larger scale. Additionally, the effectiveness of BLV control after 1 yr was evaluated by measuring within-herd prevalence and seroconversions.

MATERIALS AND METHODS

Risk Assessment

We based the approach for BLV control in Alberta on a risk assessment, thereby identifying management practices on farm that could allow transmission of BLV between cattle, followed by the implementation of mitigation strategies. The risk assessment tool was designed to be used in combination with BLV laboratory test results that identified BLV-positive cattle and provided within-herd prevalence estimates. Additionally, testing was intended to be repeated on a regular basis (e.g., once per year) to enable modification of BMP in response to changes in on-farm management or BLV prevalence. By testing all cattle ≥ 12 mo of age, the age group with the highest increase in seropositive individuals could be identified (Erskine et al., 2012). In this way, the management period with the highest infection rate could be determined, and control efforts could be focused on the identified age group (e.g., by focusing on the most relevant part of the risk assessment only). Consequently, the risk assessment was divided into 4 sections of attention as follows: (1) general biosecurity measures applicable to the entire operation that could facilitate introduction of BLV into the herd (e.g., cattle purchases), (2) adult cows (>2 yr old), (3) heifers (≤ 2 yr old), and (4) calves (≤ 9 mo old).

A list of possible transmission routes was established. Next, management practices potentially causing BLV transmission were identified, listed according to animal management groups (i.e., biosecurity, cows, heifers, and calves), and used to design detailed questions for the risk assessment. The answers consisted of a comprehensive list of alternatives for the performance of a certain practice (e.g., various ways of dehorning). Every answer was given a weighted value (5–25, in increments of 5), with an increase in value indicating a higher risk for BLV transmission. Any practice considered to have a negligible risk for transmission was assigned 0. Where possible, literature was used to assign levels of risk; otherwise, expert opinion was used. Literature regarding BLV transmission risk and control was thoroughly evaluated, and findings were summarized [Alessa Kuczewski, Frank van der Meer (both of Department of Ecosystem and Public Health, University of Calgary, Canada), Karin Orsel, Herman W. Barkema (both of Department of Production Animal Health, University of Calgary, Canada), Steve Mason (Agromedia International Inc., Calgary, Canada), and Ron Erskine (Large Animal Clinical Sciences, College of Veterinary Medicine, Michigan State University, East Lansing),

unpublished data]. Experts were the authors as well as other veterinarians and extension officers with extensive practical and research experience in on-farm BLV control. Ultimately, the biosecurity section consisted of 3 subcategories, and the maximum score was 55. Adult cow management had 10 subcategories and a maximum score of 145. Next was the heifer category with 11 subcategories and a maximum score of 170. Finally, the calf management category consisted of 9 subcategories and a maximum score of 155 (see Supplemental File S1, <https://doi.org/10.3168/jds.2020-19251>). By using the risk assessment with participating farmers, its design and applicability to dairy farm management were meant to be evaluated.

Recruitment

The control program implementation was part of a larger BLV-focused study that gathered data on BLV control as well as motivational factors. Therefore, multiple interviews with farmers were conducted during the pilot (Figure 1). A list of farmers potentially interested in participating in BLV-focused research was created by inviting farmers to provide their contact information between March 2016 and November 2017 at various dairy farmer-focused events (e.g., Western Canadian Dairy Seminar; WCDS, Red Deer, AB, Canada) and publications (e.g., Alberta Milk Milking Times; Alberta Milk, Edmonton, AB, Canada). In total, 42 farmers provided contact information. These farmers were sent an email with a short outline of the pilot and an invitation to respond if they were interested in participating. In addition to their responses, inclusion criteria for the pilot were that the farm had to be located within a 4-h driving distance from Calgary and be within Alberta. Farmers that matched the criteria were contacted by the first author in the order of their response until 11 farmers were recruited. During a phone call, an outline of the pilot was discussed and all potential farmers were given a chance to ask questions, as well as to consent to participation. All contacted farmers consented, and the first meeting on farm was scheduled.

This pilot was approved by the Conjoint Faculties Research Ethics Board (CFREB) of the University of Calgary (REB16-0224) and by the Veterinary Sciences Animal Care Committee of the University of Calgary (VSACC AC17-0242).

Pilot Implementation

The pilot consisted of 7 steps (Figure 1). (1) All farms were first visited in January and February of

Figure 1. Overview and timeline for interviews and samplings.

2018, and a risk assessment as well as an interview were conducted. (2) During a second visit between February and April of 2018, blood samples were collected, with test results communicated to the farmers as soon as they were available. (3) Between February and May of 2018, test results were discussed during a phone conversation with each farmer individually and recommendations for farm-specific BMP were provided. During the same phone call, another short interview was conducted. (4 and 5) Approximately 3 and 6 mo after recommending BMP, all participating farmers were visited to evaluate BMP implementation, whereby reasons for implementing, or not implementing, certain BMP were discussed. (6) At approximately 13 mo after the first sampling, a second sampling was performed and a second risk assessment conducted, enabling a thorough comparison of on-farm management practices between first and last samplings. Once laboratory test results for the second samples were available, they were communicated to the farmers. (7) Finally, a last phone interview was conducted between April and June of 2019 to assess farmers' experiences during the pilot. All steps were conducted by the first author.

Sampling and Testing. Blood samples were collected by venipuncture of coccygeal vessels and collected in 10-mL serum tubes (Vacutainer, BD, Franklin Lakes, NJ). Within 48 h after sampling, all samples were centrifuged ($1,500 \times g$, 13 min, 7°C), and serum was separated and stored at -20°C. All samples were tested for BLV antibodies (IDEXX Leukosis Serum X2 Ab Test; IDEXX, Westbrook, ME), as this assay has a high sensitivity and specificity (Kuczewski et al., 2018). All female cattle ≥ 12 mo, as well as breeding bulls that could be safely handled, were sampled. At approximately 13 mo, blood samples were obtained from cattle not previously tested (calves < 12 mo at the first sampling and additions to the herd) or with a negative test result at the first sampling. Animals that had tested positive prior were not retested (Kuczewski et al., 2018). The age of 12 mo was chosen to avoid detection of maternal antibodies, but still enable a comprehensive overview of infection risk of youngstock (Johnson et al., 1987; Gutiérrez et al., 2011; Erskine et al., 2012).

Recommendation of BMP. Specific BMP based on risk assessment and laboratory test results per age group were discussed during a phone conversation by the first author with each farmer. Based on the findings of the risk assessment, each farmer was provided with a comprehensive list of all possible BMP that could reduce the spread of BLV on farm and had not been implemented yet. This list was followed by an evaluation of the importance of each BMP and a possible prioritization based on the test results. Following this phone conversation, farmers were provided with a list

of these recommendations, as well as an explanation and rationale via email at the farmer's request. Even though a prioritization was provided, the decision was left with the farmer if and when a specific BMP would be implemented. This was deemed important to better understand farmers' decision processes and involved motivational factors concerning on-farm BLV control (manuscripts in preparation).

RESULTS

Participants

In total, 11 farms participated. One farmer withdrew from the pilot after 6 mo for personal reasons. This farm's numbers are included when available for the respective data point (no information on the second sampling, seroconversions, or change in prevalence). The median number of cattle on farm that were > 12 mo was 195 (range 110–524). On average, daily milk production per animal was 38.4 kg (range 34–44 kg). Two farms had tiestalls for the milking herd, whereas 9 milking herds were housed in freestalls. Within the freestalls, 3 farms used automated milking systems, whereas 5 farms used conventional milking parlors. Three farmers stated that they had not implemented any measures with the sole purpose to control BLV before the start of the pilot; the remaining 8 farmers had already implemented some BLV control measures (e.g., single-use of needles) at the start of the pilot. All participating farmers indicated that they were able to implement at least 1 new BMP and provide feedback about this process on commercial farms.

Pilot Implementation

The pilot started in January of 2018 and was completed in June of 2019. The median score of the first risk assessment was 270 (155–315; maximum score possible: 525). At the first sampling, the mean within-herd prevalence was 39% (13–66%). Based on individual test results (Table 1) and risk assessments (Tables 2, 3, and 4), various BMP were recommended (Table 5). On average, 5 BMP (3–7) were suggested to each farmer. All farms implemented at least 1 BMP, and on average 4 BMP (1–7) were implemented. At the second sampling, the mean within-herd prevalence (new and old infections combined) was 36% (12–62%; Table 4). All but 2 farms decreased the within-herd prevalence (Table 5). On 1 farm, the within-herd prevalence remained constant, whereas on another farm, within-herd prevalence increased within the examined timeframe. On all farms, seroconversions were detected between first and second samplings (Table 1). The median for seroconversions

Table 1. Overview sampling and ELISA results¹

Farm ID	No. animals I ²	No. missing samples I ³	Prevalence I ²	Prevalence 2+ I ²	No. animals II ⁴	No. missing samples ⁵ II ⁴	Prevalence II ⁴	Prevalence 2+ II ⁴	No. seroconversions ⁵
1	517	2	26	34	543	11	40	51	109
2	167	1 ⁶	64	80	162	1	52	62	11
3	176	2	29	37	192	0	29	24	3
4	110	0	45	53	101	0	37	46	3
5	195	0	13	13	209	0	12	12	3
6	457	0	29	36	447	5	27	28	14
7	429	1	29	39	— ⁷	—	— ⁷	— ⁷	— ⁷
8	209	0	48	64	256	1	41	57	27
9	162	0	43	66	155	0	43	55	17
10	183	0	66	78	198	1	58	69	7
11	524	4	21	27	570	4	17	21	14
Average	195 ⁸		39	50	203.5 ⁸		36	44	21

¹Animals on farms participating in a bovine leukemia virus control program pilot study were sampled twice in an approximately 13-mo timespan. Based on sampling results, within-herd prevalences and seroconversions were calculated.

²Result at first sampling (number of animals present on farm, within-herd prevalence, within-herd prevalence of animals 2 yr of age and older).

³Number of animals that were missed on sampling days.

⁴Result at second sampling (number of animals present on farm, within-herd prevalence, within-herd prevalence of animals 2 yr of age and older).

⁵Number of seroconversions from first to second sampling. Only animals were included that had test results from both samplings.

⁶Animal had anatomically deformed tail and sampling from coccygeal vein was not possible. This animal was tested by milk.

⁷Farmer withdrew from pilot for personal reasons before second sampling.

⁸Median.

was 12.5 cattle (3–109 per farm). The median score of the second risk assessment was 142.5 (80–305; Table 4).

Evaluation of Risk Assessment and Recommendation of BMP

Overall risk assessment score was not related to the within-herd prevalence (data not shown). All farmers completed all parts of the risk assessment, thereby

facilitating evaluation of the included questions as well as the design of the risk assessment (Tables 2 and 3). Detailed questions provided insights into specific management practices without overlooking small but important flaws in on-farm management. For example, some farmers changed needles after every use for most applications, but did not change them for others (e.g., administration of local anesthetics for dehorning, or administration of oxytocin in the milking parlor). Some

Table 2. Overview of risk assessment (RA) scores, recommendations, and implementations by farm¹

Farm ID	Score RA I ²	Score RA II ³	No. recommendations ⁴	No. implementations ⁵
1	275	180	5	2
2	155	120	4	5
3	315	305	7	3
4	270	200	4	4
5	200	80	6	7
6	305	245	3	1
7	280	NA ⁶	6	1
8	165	105	5	5
9	160	100	5	5
10	195	140	6	4
11	295	145	6	7
Median	270	142.5	5	4

¹Farmers participating in a bovine leukemia virus control program pilot study completed a RA, were provided with recommendations for best management practices (BMP), and could chose how many BMP would be implemented.

²Total score of first RA.

³Total score of second RA.

⁴Number of recommendations made by first author to control bovine leukemia virus (BLV) on farm.

⁵Number of measures implemented by participating farmers to control BLV on farm.

⁶NA = not available; farmer withdrew from pilot before RA could be completed.

Table 3. Overview of risk assessment scores by risk assessment category

Item	Farm 1		Farm 2		Farm 3		Farm 4		Farm 5		Farm 6		Farm 7		Farm 8		Farm 9		Farm 10		Farm 11	
	Max. score ¹	I ²	II ²	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	
Category																						
Biosecurity	55	45	45	35	35	35	35	55	55	0	35	35	55	NA ³	35	35	25	25	55	55	55	45
Adult cows	145	90	55	50	45	100	85	60	25	75	100	55	105	NA	75	50	75	40	55	35	80	45
Heifers	170	90	65	45	25	110	110	55	70	45	105	80	65	NA	50	15	55	20	50	35	100	45
Calves	155	50	15	25	15	70	75	100	50	80	40	65	75	55	NA	5	5	5	15	35	15	60
Total sum	525	275	180	155	120	315	305	270	200	200	80	305	245	280	NA	165	105	160	100	195	140	295

¹Maximum score possible for category in risk assessment.²Scores for first (I) and second (II) risk assessment.³NA = not available.

farmers had already implemented some BMP before the onset of the pilot (e.g., use of milk and colostrum pasteurizer or dehorning methods) in the highest risk age group in their herd (e.g., ~40% heifers infected) or in general (e.g., changing needles). Similarly, financial or structural restrictions (e.g., space limitations in the milk house) did not always allow the farmer to implement the BMP in the identified highest risk age group or in the most optimal way. Consequently, other sections of the risk assessment were used or management practices were adjusted accordingly. For example, some farmers could not purchase a colostrum pasteurizer due to financial constraints. To prevent transmission of BLV from dams to calves, freezing and thawing colostrum from negative dams was considered the next-best option (Kanno et al., 2014). A detailed overview of recommended BMP by farm is shown (Table 5).

DISCUSSION

The goal of this pilot was to evaluate and improve a newly designed BLV risk assessment and potential on-farm BLV control measures to identify and address potential shortcomings, thereby increasing chances of successful implementation on a larger group of farms. Although a sample size of 11 farms was insufficient to reach statistical power, it facilitated close monitoring of all participating farms, permitting a thorough examination of the risk assessment and BMP, making set goals achievable. However, selection bias may have been introduced due to the voluntary recruitment process and the possibility of increased interest in BLV control from participating farmers as opposed to nonparticipating farmers. Even though true generalizability cannot be achieved, participating farmers were close to the Alberta average for several characteristics including average number of milking cows in the herd (153 in pilot vs. 131 in Alberta), average daily milk production per cow (38 kg/d for pilot vs. 38.5 kg/d for Alberta), and average BLV within-herd prevalence (39.2% for pilot, first sampling vs. 39.5% for Alberta; CanWest DHI, 2019).

The risk assessment was designed to be combined with laboratory testing to allow for the focus of recommended BMP on the age group with the highest risk of BLV transmission. This could be achieved by testing the entire herd or, alternatively, by testing only a subset of the adult herd as described in Erskine et al. (2012). In addition, knowing each individual animal's BLV status is helpful for implementing specific BMP (e.g., freezing colostrum from ELISA test-negative dams). Although farmers may be reluctant to invest in laboratory testing due to financial constraints (Leach et al., 2010a; Sorge et al., 2010), they might value implementation of BLV control strategies. In the latter case, specific age groups

identified through laboratory testing might not be the focus of the risk assessment, but all age groups could be considered.

The risk assessment was designed based on available literature on BLV transmission. During the evaluation, we observed that suboptimal management practices could go unnoticed if only the results of the highest risk age group was taken into account. Importantly, financial consequences of the BMP were not taken into account, which might have directed the farmer's decision-making process toward the BMP implementation. During the pilot, some questions were removed from some sections (e.g., the use of hormones in prebreeding heifers), as they were not relevant. Additionally, the rating system was optimized. Initially, all questions were assigned a specific value, whereas groups of questions (e.g., needles) were assigned a value in the final version. Overall, the risk assessment was deemed valuable in identifying on-farm management that could allow the transmission of BLV. One concern brought forward by some farmers was the time-commitment for the risk assessment (up to 90 min). However, it was possible to

perform the risk assessment in approximately 20 min, if the questions were answered concisely.

Additionally, participating farmers were offered a choice of BMP whenever possible as opposed to other studies (e.g., 3 distinct recommendations; Wolf et al., 2014). The farmer decided how many and which BMP they wanted to implement and when implementation should occur. It was considered valuable to leave these decisions with farmers to better understand motivators and barriers influencing farmers' decision-making processes. Moreover, by allowing the farmer to decide which BMP would be implemented and how, mutual trust was increased, thereby encouraging openness from the farmer. As a consequence, there was more confidence in the reports on implementation of BMP, and farmers were more likely to give honest answers even if such responses were not the social norm (Braun and Clarke, 2013).

As mentioned above, within-herd prevalence and risk assessment score were unrelated. This was expected and could be explained by the farm's management, interval since initial BLV infection, and nature and duration of

Table 4. Risk assessment (RA) scores and prevalence

Year	Biosecurity ¹	Calves ²	Heifers ³		Cows ⁴		Total ⁵	
	RA score	RA score	RA score	Prevalence (%)	RA score	Prevalence (%)	RA score	Prevalence (%)
Year 1								
1	45	50	90	17.5	90	38.3	275	25.9
2	35	25	45	36.8	50	95.0	155	64.2
3	35	70	110	19.2	100	43.1	315	29.0
4	55	100	55	30.2	60	59.6	270	45.5
5	0	80	45	9.4	75	17.2	200	13.3
6	35	65	105	16.8	100	41.3	305	28.9
7	55	55	65	12.8	105	50.0	280	28.9
8	35	5	50	25.6	75	76.1	165	47.8
9	25	5	55	22.9	75	80.7	160	43.2
10	55	35	50	52.7	55	79.3	195	66.1
11	55	60	100	9.6	80	32.3	295	21.0
Year 2								
1	45	15	65	24.1	55	57.1	180	40.0
2	35	15	25	30.1	45	68.7	120	52
3	35	75	110	26.5	85	32.0	305	28.6
4	55	50	70	19.6	25	50.9	200	36.6
5	0	40	15	14.2	25	8.3	80	11.5
6	35	75	80	17.3	55	37.0	245	26.8
7								
8	35	5	15	21.5	50	72.4	105	41.0
9	25	15	20	25.0	40	65.7	100	42.6
10	55	15	35	37.8	35	78.0	140	58.1
11	45	10	45	7.5	45	27.0	145	17.0
Maximum possible ⁶	55	155	170		145		525	

¹Score for biosecurity section in RA.

²Score for calves section in RA.

³Score for heifers section in RA and prevalence for cattle 1–2 yr old based on ELISA testing.

⁴Score for cows section in RA and prevalence for cattle older than 2 yr based on ELISA testing.

⁵Total risk assessment score and within-herd prevalence.

⁶Maximum possible score in RA for each section and entire RA.

Table 5. Overview of within-age group prevalence, recommended, and implemented best management practices (BMP)

Prevalence at first sampling (%)										Prevalence change, year 2 vs. year 1 (%)	Reasoning	Recommendations ²	Comments	BMP implemented ²
ID ¹	By age group (yr)					Total								
	1	2	3	4	≥ 5									
1	5.5	28.4	34.7	28.1	48.8	25.9	+14.1	Low prevalence in youngstock, increase in prevalence with age; reuse of needles, very good youngstock management	Needles, disinfection, hoof trimmer, vet gloves, AI gloves			Needles, change gloves between animal groups on farm		
2	24.4	50.0	93.0	100.0	95.0	64.2	-12.2	High prevalence in youngstock, prevalence increased mostly from 1- to 2-yr-old and 2- to 3-yr-old animals (breeding age, positive effect of BMP implemented 2-3 yr ago)	Test additions (ELISA), reduce overstocking, hoof trimmer, vet gloves, AI gloves, bull, colostrum	Financial restrictions; bull breeding only	Retesting animals (ELISA), hoof trimmer, disinfection, vet gloves (examines negative animals first), freeze colostrum			
3	11.3	27.5	50.0	35.0	38.9	29.0	-0.4	Low prevalence in youngstock, increase in prevalence for older animals; high risk colostrum management	IV needles, disinfection, hoof trimmer, vet gloves, AI gloves, bull, colostrum			IV needles, disinfection, colostrum (no pooling)		
4	24.1	37.5	50.0	50.0	76.2	45.5	-8.9	High prevalence in youngstock, increase in prevalence in adult herd; high risk dehorning management	Needle for L/A, hoof trimmer, vet gloves, AI gloves, dehorne	Application for financial support for colostrum pasteurizer		Needle for L/A, hoof knives, vet gloves, AI gloves, dehorne		
5	15.1	2.3	11.8	5.9	32.3	13.3	-1.8	Comparatively high prevalence in youngstock; increase in prevalence with age	Needles, hoof trimmer, vet gloves, AI gloves, bull, tags, colostrum	Mistake in dehorning caused high prevalence in youngstock		Needles, hoof trimmer, disinfection, vet gloves, AI gloves, tags, colostrum		
6	5.6	26.4	30.4	44.4	59.3	28.9	-2.1	Low prevalence in youngstock, increasing prevalence with age; no change of needles in milking parlor, recent change in BMP	Needles (Oxy), hoof trimmer, bull			Bull (ELISA before purchase)		
7	11.0	15.9	38.0	49.2	58.4	28.9	NA ³	Low prevalence in youngstock, increase in prevalence with age; no change of needles in milking parlor, high risk colostrum management	Needles (Oxy), syringes, hoof trimmer, vet gloves, AI gloves, colostrum			Needles (Oxy)		
8	12.3	42.3	60.5	90.0	85.3	47.8	-6.8	Low prevalence in youngstock, sudden increase in prevalence from 1- to 2-yr-old animals (breeding age); many BMP already implemented 2-3 yr ago	Disinfection, hoof knives, vet gloves, bull, tags	Bull breeding only		Hoof knives, disinfection, vet gloves, tags		

Continued

Table 5 (Continued). Overview of within-age group prevalence, recommended, and implemented best management practices (BMP)

ID ¹	Prevalence at first sampling (%)						Prevalence change, year 2 vs. year 1 (%)	Reasoning	Recommendations ²	Comments	BMP implemented ²
	By age group (yr)										
	1	2	3	4	≥ 5	Total					
9	7.8	46.3	69.2	81.8	95.0	43.2	−0.6	Low prevalence in youngstock, sudden increase in prevalence with age; many BMP already implemented 2–3 yr ago	Test additions (ELISA), reduce overstocking, syringes, disinfection, hoof trimmer, vet gloves	Bull breeding only	Syringes, disinfection, hoof knives, vet gloves, tags
10	34.7	73.8	70.4	79.2	85.4	66.1	−8.0	High prevalence in youngstock, sudden increase in prevalence from 1- to 2-yr-old animals; recent implementation of BMP for youngstock	Test additions (ELISA), needles (ET), disinfection, hoof knives, vet gloves, AI gloves, bull calves		Needles (ET), disinfection (some equipment), hoof knives, vet gloves
11	6.1	14.0	11.6	33.3	47.0	21.0	−4.0	Low prevalence in youngstock, increase in prevalence with age	Needles, disinfection, hoof knives, vet gloves, AI gloves, bull, colostrum	Eager to control BLV	Needles, syringes, disinfection, gloves, bull, tags, colostrum

¹Farm ID.

²Explanation of recommended and implemented BMP. Test additions: laboratory test animals before purchase and introduction into the herd, purchase only BLV test-negative animals. Reduce overstocking; reduce overstocking in pens. Needles, local anesthetics (LA), oxytocin (Oxy), embryo transfer (ET), intravenous treatment (IV): do not reuse needles (sometimes needles were not reused except for local anesthetics during dehorning LA, Oxy in the milking parlor, Oxy i.v. treatments, i.v. embryo transfer (ET). Syringes: do not reuse syringes. Disinfection: disinfect commonly used equipment (e.g., drench guns, calving chains, pill guns). Hoof trimmer: ask hoof trimmer to disinfect hand knives between animals. Vet gloves: ask veterinarian to change gloves between animals or to examine laboratory test-negative animals before test positive ones. AI gloves: do not reuse gloves for AI. Bull: purchase only laboratory test-negative bulls; try to breed test positive cows with different bulls than laboratory test-negative cows. Tag: use colored ear tags to identify laboratory test-positive animals in the herd. Pasteurizer: pasteurize colostrum and milk before feeding it to calves. Colostrum: implement safe colostrum management (i.e., pasteurize and freeze colostrum from negative dams or use powdered colostrum). Dehorner: implement safe dehorning methods (i.e., hot dehorning or caustic paste). Bull calves: implement BMP for bull calves as well, if they will be sold as breeding bulls.

³NA = data not available, as farm terminated pilot before the second sampling.

BLV control. For example, 1 farm had a high within-herd BLV prevalence, as well as numerous enzootic bovine leukosis cases, and had already implemented BLV control measures approximately 6 mo before the first risk assessment, resulting in a low risk assessment score. However, effects of these control measures were not yet reflected in the within-herd prevalence. Similarly, for herds with a low prevalence and a high risk assessment score, BLV control was not a priority at the start of the pilot implementation. These herds were either closed herds or recently established herds founded with BLV-free youngstock. However, without effective BLV control, within-herd prevalence would have likely increased in the following years. Alternatively, the relative weightings assigned to various risk assessment questions may not have been appropriate, which would result in a poor correlation.

It is important to note that the goal of this pilot was not to maximize the reduction of within-herd BLV prevalence within 1 yr. It was considered more important to allow the farmers to decide when and which BMP were implemented to better understand which BMP were easy to implement, which BMP were met with challenges, and to better understand farmers' motivators and barriers [Frank van der Meer, Alessa Kuczewski (both of Department of Ecosystem and Public Health, Faculty of Veterinary Medicine, University of Calgary, Canada), Karin Orsel (Department of Production Animal Health, University of Calgary, Canada), and Cindy Adams (Department of Veterinary Clinical and Diagnostic Sciences, Faculty of Veterinary Medicine, University of Calgary, Canada, and Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Canada), unpublished data]. Additionally, monitoring on-farm BLV control as well as the within-herd prevalence for 5 to 10 yr would result in a better assessment of true effects of management optimization through BMP implementation on BLV prevalence than just 1 yr. However, after 1 yr of BLV control, 8 farmers were able to reduce their herd's prevalence. While this could be due to natural fluctuation, it might be a true reduction in within-herd prevalence and an effect that could be enhanced if BLV control was consistently applied and sustained for longer intervals (Johnson et al., 1985; DiGiacomo et al., 1987). Nonetheless, 1 farm's prevalence remained constant over the examined time frame. This farm relied on natural breeding, making new infections likely (Benitez et al., 2019). Additionally, this farm decreased its herd size. The number of BLV test-negative as well as BLV test-positive animals decreased, keeping the proportions equal, which makes it difficult to assess de-

velopment of BLV prevalence. Another farm's within-herd prevalence increased when comparing the results of the first to the second year. This was likely caused by a delay in implementation of some BMP. Needles were reused multiple times for multiple animals at the beginning of the pilot. Implementing single-use needles was delayed, and convincing all employees took time (during which needles were reused), and thus likely caused BLV transmission (Bartlett et al., 2014). Additionally, a large number of untested cattle were purchased and introduced into this herd, creating additional sources of infection.

At least 3 cattle on each participating farm seroconverted. Perhaps these cows became infected during the pilot or they were infected before the first sampling and subsequently seroconverted (Klintevall et al., 1997; Nagy et al., 2007); however, it was not possible to distinguish between these 2 scenarios within the scope of this pilot. Even though at least some cattle seroconverted in every participating herd, most farms were able to decrease within-herd prevalence. Consequently, the seroconversion rate was lower than the rate of BLV-positive animals leaving the operation. This was consistent with other studies that reported BLV-positive cattle were more likely to be culled or die than BLV test-negative animals (Bartlett et al., 2013; Nekouei et al., 2016). If new infections can be prevented or minimized, this would result in a net reduction of infected animals. Nevertheless, because farmers knew each animal's status, it is possible that BLV-positive animals were culled more readily than BLV test-negative animals. However, it was beyond the scope of this pilot to investigate farmers' culling decisions.

During this pilot, all herd veterinarians were informed about the study. Although no herd veterinarians actively participated in the performance of the risk assessment, they were involved by the farmers in the implementation of some BMP (e.g., single-use of rectal examination gloves). This pilot was performed with the herd veterinarian in mind. The risk assessment was designed to provide herd veterinarians with a structured approach to on-farm BLV control. Herd veterinarians could use the risk assessment during regular herd health visits, combine the findings with test results, and thereby assist farmers with the implementation of BLV BMP. The risk assessment could then be used on a regular basis to assess the success of on-farm BLV control and ensure long-term commitment of the farmers. To provide as many veterinarians with access to the risk assessment as possible, organizations such as Alberta Milk (Edmonton, AB) could be involved in its distribution.

CONCLUSIONS

The risk assessment was proven to be a useful tool to identify management practices that promote transmission of BLV. By collaborating with participating farmers, it was possible to identify at least 1 BMP, or a variation thereof, that could be implemented on farm. One year of on-farm BLV control reduced BLV prevalence on most farms. Therefore, even though long-term studies are needed to better understand the effect of management on BLV prevalence, this study provided indications that managing BLV-positive cattle with a producer-supported control program would be an option for successful on-farm BLV control.

ACKNOWLEDGMENTS

This study was funded by Alberta Milk (Edmonton, AB, Canada) and the Alberta Livestock and Meat Agency/Alberta Agriculture and Forestry (Edmonton, AB, Canada). The authors are grateful for the participation and support of the dairy farmers and their assistance in this study, as well as for the help of John Kastelic (Department of Production Animal Health, University of Calgary, Canada) in editing the manuscript. Finally, the authors thank all graduate and undergraduate students that assisted in the sampling efforts. The authors have not stated any conflicts of interest.

REFERENCES

- Bartlett, P. C., B. Norby, T. M. Byrem, A. Parmelee, J. T. Ledergerber, and R. J. Erskine. 2013. Bovine leukemia virus and cow longevity in Michigan dairy herds. *J. Dairy Sci.* 96:1591–1597. <https://doi.org/10.3168/jds.2012-5930>.
- Bartlett, P. C., L. M. Sordillo, T. M. Byrem, B. Norby, D. L. Grooms, C. L. Swenson, J. Zalucha, and R. J. Erskine. 2014. Options for the control of bovine leukemia virus in dairy cattle. *J. Am. Vet. Med. Assoc.* 244:914–922. <https://doi.org/10.2460/javma.244.8.914>.
- Benitez, O. J., J. N. Roberts, B. Norby, P. C. Bartlett, S. N. Takeshima, S. Watanuki, Y. Aida, and D. L. Grooms. 2019. Breeding bulls as a potential source of bovine leukemia virus transmission in beef herds. *J. Am. Vet. Med. Assoc.* 254:1335–1340. <https://doi.org/10.2460/javma.254.11.1335>.
- Braun, V., and V. Clarke. 2013. Successfull qualitative research - A practical guide for beginners. First ed. M. Carmichael, ed. SAGE Publications Ltd., London, UK.
- Canadian Food Inspection Agency. 2018. Reportable Diseases. Accessed Jul. 22, 2019. <https://www.inspection.gc.ca/animals/terrestrial-animals/diseases/reportable/eng/1303768471142/1303768544412>.
- CanWest DHI. 2019. Western Progress Report 2018. Accessed Jul. 9, 2019. <http://www.canwestdhi.com/flipwest18/mobile/index.html#p=26>.
- Dairy Australia Limited. 2015. Page 47 in Annual Report 2014–15. Dairy Australia Limited, Melbourne, Australia.
- DiGiacomo, R. F., S. G. Hopkins, R. L. Darlington, and J. F. Evermann. 1987. Control of bovine leukosis virus in a dairy herd by a change in dehorning. *Can. J. Vet. Res.* 51:542–544.
- EFSA AHAW Panel. 2015. Scientific opinion on enzootic bovine leukosis. *EFSA J.* 13:4188. <http://dx.doi.org/doi:10.2903/j.efsa.2015.4188>.
- Erskine, R. J., P. C. Bartlett, T. M. Byrem, C. L. Render, C. Febvay, and J. T. Houseman. 2012. Using a herd profile to determine age-specific prevalence of bovine leukemia virus in Michigan dairy herds. *Vet. Med. Int.* 2012:350374. <https://doi.org/10.1155/2012/350374>.
- European Commission. 2003. 2003/467/EC: Commission Decision of 23 June 2003 establishing the official tuberculosis, brucellosis, and enzootic-bovine-leukosis-free status of certain Member States and regions of Member States as regards bovine herds (Text with EEA relevance) (notified under document number C(2003) 1925).
- Goff, S. P. 2013. Chapter 47, Retroviridae. Pages 1424–1473 in *Fields Virology*. 6th ed. B. N. Fields, D. M. Knipe, and P. M. Howley, ed. Wolters Kluwer Health/Lippincott Williams & Wilkins, Philadelphia, PA.
- Gutiérrez, G., I. Alvarez, R. Politzki, M. Lomonaco, M. J. Dus Santos, F. Rondelli, N. Fondevila, and K. Trono. 2011. Natural progression of bovine leukemia virus infection in Argentinean dairy cattle. *Vet. Microbiol.* 151:255–263. <https://doi.org/10.1016/j.vetmic.2011.03.035>.
- Huijps, K., H. Hogeveen, T. J. G. M. Lam, and R. B. M. Huirne. 2009. Preferences of cost factors for mastitis management among Dutch dairy farmers using adaptive conjoint analysis. *Prev. Vet. Med.* 92:351–359. <https://doi.org/10.1016/j.prevetmed.2009.08.024>.
- Johnson, R., C. D. Gibson, and J. B. Kaneene. 1985. Bovine leukemia virus - A herd-based control strategy. *Prev. Vet. Med.* 3:339–349. [https://doi.org/10.1016/0167-5877\(85\)90011-X](https://doi.org/10.1016/0167-5877(85)90011-X).
- Johnson, R., J. B. Kaneene, and S. M. Anderson. 1987. Bovine leukemia virus - Duration of BLV colostral antibodies in calves from commercial dairy herds. *Prev. Vet. Med.* 4:371–376. [https://doi.org/10.1016/0167-5877\(87\)90023-7](https://doi.org/10.1016/0167-5877(87)90023-7).
- Kanno, T., R. Ishihara, S. Hatama, Y. Oue, H. Edamatsu, Y. Konno, S. Tachibana, and K. Murakami. 2014. Effect of freezing treatment on colostrum to prevent the transmission of bovine leukemia virus. *J. Vet. Med. Sci.* 76:255–257. <https://doi.org/10.1292/jvms.13-0253>.
- Klintevall, K., L. Fuxler, and C. Fossum. 1997. Bovine leukemia virus: Early reflections in blood after an experimental infection of calves. *Comp. Immunol. Microbiol. Infect. Dis.* 20:119–130. [https://doi.org/10.1016/S0147-9571\(96\)00043-4](https://doi.org/10.1016/S0147-9571(96)00043-4).
- Kuczewski, A., H. Hogeveen, K. Orsel, R. Wolf, J. Thompson, E. Spackman, and F. van der Meer. 2019. Economic evaluation of 4 bovine leukemia virus control strategies for Alberta dairy farms. *J. Dairy Sci.* 102:2578–2592. <https://doi.org/10.3168/jds.2018-15341>.
- Kuczewski, A., K. Orsel, H. W. Barkema, D. F. Kelton, W. A. Hutchins, and F. van der Meer. 2018. Short communication: Evaluation of 5 different ELISA for the detection of bovine leukemia virus antibodies. *J. Dairy Sci.* 101:2433–2437. <https://doi.org/10.3168/jds.2017-13626>.
- LaDronka, R. M., S. Ainsworth, M. J. Wilkins, B. Norby, T. M. Byrem, and P. C. Bartlett. 2018. Prevalence of bovine leukemia virus antibodies in US dairy cattle. *Vet. Med. Int.* 2018:5831278. <https://doi.org/10.1155/2018/5831278>.
- Leach, K. A., H. R. Whay, C. M. Maggs, Z. E. Barker, E. S. Paul, A. K. Bell, and D. C. Main. 2010a. Working towards a reduction in cattle lameness: 1. Understanding barriers to lameness control on dairy farms. *Res. Vet. Sci.* 89:311–317. <https://doi.org/10.1016/j.rvsc.2010.02.014>.
- Leach, K. A., H. R. Whay, C. M. Maggs, Z. E. Barker, E. S. Paul, A. K. Bell, and D. C. Main. 2010b. Working towards a reduction in cattle lameness: 2. Understanding dairy farmers' motivations. *Res. Vet. Sci.* 89:318–323. <https://doi.org/10.1016/j.rvsc.2010.02.017>.
- Nagy, D. W., J. W. Tyler, and S. B. Kleiboeker. 2007. Timing of seroconversion and acquisition of positive polymerase chain reaction assay results in calves experimentally infected with bovine leukemia virus. *Am. J. Vet. Res.* 68:72–75. <https://doi.org/10.2460/ajvr.68.1.72>.
- Nekouei, O., J. VanLeeuwen, H. Stryhn, D. Kelton, and G. Keefe. 2016. Lifetime effects of infection with bovine leukemia virus on

- longevity and milk production of dairy cows. *Prev. Vet. Med.* 133:1–9. <https://doi.org/10.1016/j.prevetmed.2016.09.011>.
- Nielsen, S. S. 2011. Dairy farmers' reasons for participation in the Danish control programme on bovine paratuberculosis. *Prev. Vet. Med.* 98:279–283. <https://doi.org/10.1016/j.prevetmed.2010.12.005>.
- Rodríguez, S. M., A. Florins, N. Gillet, A. de Brogniez, M. T. Sanchez-Alcaraz, M. Boxus, F. Boulanger, G. Gutierrez, K. Trono, I. Alvarez, L. Vagnoni, and L. Willems. 2011. Preventive and therapeutic strategies for bovine leukemia virus: Lessons for HTLV. *Viruses* 3:1210–1248. <https://doi.org/10.3390/v3071210>.
- Santman-Berends, I. M. G. A., M. H. Mars, L. Van Duijn, and G. van Schaik. 2015. Evaluation of the epidemiological and economic consequences of control scenarios for bovine viral diarrhoea virus in dairy herds. *J. Dairy Sci.* 98:7699–7716. <https://doi.org/10.3168/jds.2014-9255>.
- Solano Quesada, L. 2016. Detection, prevention and control of lameness and foot lesions in Canadian dairy herds. PhD thesis. Department of Production Animal Health, University of Calgary, Calgary, AB, Canada.
- Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick, and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. *J. Dairy Sci.* 93:1491–1499. <https://doi.org/10.3168/jds.2009-2447>.
- Sorge, U. S., K. Lissemore, A. Godkin, J. Jansen, S. Hendrick, S. Wells, and D. F. Kelton. 2011. Changes in management practices and apparent prevalence on Canadian dairy farms participating in a voluntary risk assessment-based Johne's disease control program. *J. Dairy Sci.* 94:5227–5237. <https://doi.org/10.3168/jds.2010-3869>.
- Voges, H. 2012. New Zealand dairy enzootic bovine leukosis (EBL) control scheme. *Surveillance* 39:41–41.
- Wolf, R., H. W. Barkema, J. De Buck, and K. Orsel. 2015. Factors affecting management changes on farms participating in a Johne's disease control program. *J. Dairy Sci.* 98:7784–7796. <https://doi.org/10.3168/jds.2015-9610>.
- Wolf, R., F. Clement, H. W. Barkema, and K. Orsel. 2014. Economic evaluation of participation in a voluntary Johne's disease prevention and control program from a farmer's perspective—The Alberta Johne's Disease Initiative. *J. Dairy Sci.* 97:2822–2834. <https://doi.org/10.3168/jds.2013-7454>.

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