PEER REVIEWED

Bovine Viral Diarrhea Virus (BVDV) Status in Cow-calf Herds and Associations with Biosecurity and Production Practices among Montana Beef Producers

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Abstract

Bovine viral diarrhea virus (BVDV) manifests in several clinical syndromes. Cattle persistently infected (PI) with BVDV are lifelong shedders and the primary reservoir of the virus in the herd. The Montana BVD-PI Herd Biosecurity Program assists Montana beef producers with BVDV education, detection, and prevention. A survey was conducted to determine associations among specific biosecurity and management practices and herd BVDV status. Of the 585 beef herds enrolled in the program from 2006-2009, 6.5% (n = 38) detected ≥ 1 PI animal. Among these positive herds, the within-herd PI prevalence ranged from 0.12% to 20.0%. Among the respondent herds with known BVDV status (n = 230), 4.3% (n = 10) were previously diagnosed with ≥ 1 PI animal. Herds that annually vaccinated home-grown heifers and bulls prior to introduction to the resident herd displayed a significantly reduced risk of being BVDV positive ($P < 0.10$). Producers with high self-perceived BVDV knowledge were more likely ($P < 0.10$) to annually vaccinate the resident herd for BVDV, less likely ($P < 0.10$) to participate in communal grazing practices from breeding to weaning, but more likely ($P < 0.10$) to transport pregnant heifers off-site with subsequent reintroduction to the resident herd. These data suggest that although beef producers in Montana engage in management practices potentially increasing the risk of BVDV introduction, educated producers have taken steps to mitigate that risk.

Keywords: cow-calf, BVDV, persistent infection, biosecurity

Résumé

Le virus de la diarrhée virale bovine (BVDV) fait partie de plusieurs syndromes cliniques. Les bovins immunotolérants au BVDV sont des excréteurs à vie et représentent le réservoir primaire du virus dans le troupeau. Le programme BVD-PI de biosécurité au niveau du troupeau du Montana assiste les producteurs bovins du Montana au niveau de l'éducation, de la détection et de la prévention. Une enquête a été menée afin de déterminer l'association entre des pratiques de biosécurité et de régie particulières et le statut du virus au niveau du troupeau. On retrouvait au moins un animal immunotolérant dans 6.5% (n = 38) des 585 troupeaux de boucherie faisant partie du programme entre 2006 et 2009. Parmi ces troupeaux positifs, la prévalence intra-troupeau d'animaux immunotolérants variait entre 0.1% et 20%. Parmi les troupeaux avec un statut BVDV connu et pour lesquels on avait des réponses, 4.3% (n = 10) avait déjà rapporté dans le passé au moins un animal immunotolérant. Le risque que le BVDV soit présent diminuait significativement ($P < 0.10$) dans les troupeaux où l'on vaccinait annuellement les taures produites à même l'élevage et les taureaux avant leur introduction dans le troupeau résident. Les producteurs qui se jugeaient plus au fait de la problématique du BVDV avaient plus de chances ($P < 0.10$) de vacciner annuellement le troupeau résident contre le BVDV, avaient moins de chances ($P < 0.10$) d'envoyer les animaux dans des pâturages communautaires entre la période de reproduction et le sevrage, et enfin plus de chances ($P < 0.10$) de déplacer les taures en gestation de la ferme avant leur réintroduction dans le troupeau résident.

Ces données suggèrent que même si les producteurs de bovins de boucherie du Montana utilisent des modes de régie qui peuvent potentiellement accroître les risques d'introduction du BVDV, les propriétaires plus au fait font des efforts afin de réduire ce risque.

Introduction

Bovine viral diarrhea virus (BVDV) has long been recognized as a pathogen that manifests in a variety of clinical syndromes.[1,3,15,20] The viral reservoir, cattle persistently infected (PI) with the virus, are created by *in utero* infection occurring during days 45-125 of gestation and are thereby lifelong shedders of BVDV.[22] Therefore, the creation of PI cattle in both beef and dairy production systems can be attributed to the maternal segments of each respective industry.

Numerous management tools have been implemented to minimize production losses attributed to PI cattle among herd and pen mates. Currently, several testing modalities are commercially available for identification of individual PI cattle.[5,16-21] Additionally, vaccination programs are considered an important component of most BVDV control programs within the United States, and are intended to elevate herd immunity to reduce risk of fetal infection.[2,6,7,14] Prevention of BVDV introduction into a beef herd is also an important attribute of BVDV control programs. Biosecurity has previously been defined as efforts to prevent the introduction of pathogens or toxins that have the potential to damage the health of a herd of cattle or the safety of a food product.[25] Therefore, biosecurity programs focus on minimizing the risk of pathogen exposure by implementing specific cattle management and procurement practices.[27]

The Montana BVD-PI Herd Biosecurity Project was created in 2006 as a segment of the Montana Beef Quality Assurance program. The overarching goal of this program is to reduce the risk of introducing BVDV into Montana beef herds by providing cow-calf producers with BVDV education, BVDV herd risk assessment, testing protocols to screen herds for PI cattle, and strategies to optimize herd biosecurity and management.[23] Data compiled from this project provide a unique opportunity to estimate the relationship among common management practices and herd BVDV status. These findings can potentially be implemented into current BVDV preventative and control programs in order to modify and/or strengthen current recommendations.

The objective of this study was threefold: 1) describe the herd and within-herd prevalence of BVDV among program participants in Montana, 2) survey the participating owners and managers to estimate the distribution of specific management practices of beef cow-calf producers in Montana during the three years prior to their individual involvement in the program, and 3) determine if significant associations are present among management practices of cow-calf herds and herd BVDV status or with the individual producer's perceived knowledge of BVDV.

Materials and Methods

Sample population – Implemented in 2006, the Montana BVD-PI Herd Biosecurity Project is a voluntary program open to all beef producers within the state of Montana. Sample collection materials as well as BVDV testing recommendations were provided by program coordinators (i.e. extension specialists within the Montana Beef Quality Assurance program); however, ultimately, the total number of cattle as well as the classes of cattle tested was determined by the producer. Individual animal diagnosis was performed by a previously described technique[18,19] currently offered by a private commercial laboratory.[a] Individual animal results were communicated to both the producer and the project coordinators. Test results and management considerations were then discussed among the herd owner, project coordinators, and the herd veterinarian to determine the optimal management protocol given the herd BVDV status.

The sample population in this study included all past and active participants of the Montana BVD-PI Herd Biosecurity Project since its inception in 2006 and extending through 2009. The authors were supplied with individual herd information consisting of herd size, classes of cattle tested for BVDV, and annual BVDV test results, thereby providing the means to classify herds as either of BVDV positive or negative status while subsequently determining the within-herd BVDV prevalence among participating herds. All herds were subsequently surveyed to evaluate objectives 2 and 3. Due to the variability in the number of years that participants had engaged in the program (i.e one to three years), the herd BVDV status was determined based upon diagnostic test outcomes collected during the first year of participation.

Survey instrument – The survey consisted of six open and seven nominal scalar (closed) questions designed to capture information regarding various cow-calf herd management practices. The questions were designed to determine herd size (one question), replacement female/male procurement and management practices (three questions), BVDV vaccination implementation and timing of administration (two questions), procurement and management of stocker cattle in relation to the resident herd (two questions), communal grazing practices of the resident herd (two questions), the practice of transporting cattle off-site followed by reintroduction to the resident herd (two questions), and individual understanding of BVDV and its effect on production systems (one question). Each question was asked with regard to three years prior to entry into the program in order to obtain an idea of the production and biosecurity practices that were in place before herd BVDV status was known. To maintain anonymity but yet provide identification, each participant was randomly assigned a unique number, produced by a commercial software package,[b] and merged onto their respective survey. This survey was approved by the Kansas State University Committee for Research Involving Human Subjects Institutional Review Board. A copy of the four-page survey may be obtained from the authors upon request.

Survey implementation – In order to contact the program participants, home addresses of herd owners were obtained from the Montana State University Beef Quality Assurance program previously collected upon individual enrollment in the program. Upon receipt of the survey, each respondent (i.e. herd owner) was requested to return the completed survey within 30 days of receipt. All surveys were returned to the co-author (CP; in Montana) and subsequently delivered to Kansas for data entry and analysis. No follow-up was performed among non-responders and no incentive was provided for completing the survey.

Statistical analysis – The experimental unit was the herd throughout all analyses, and the case definition of a positive herd was a herd previously diagnosed with one or more PI animal (yes or no) during its tenure in the Montana BVD-PI program. Potential associations were evaluated between survey responses (independent variables) and both herd BVDV status and herd self-assessment of BVDV knowledge (dependent variables). Data were entered into a commercial software package[b] and descriptive statistics were calculated. Independent categorical variables displaying sparse data within individual levels were collapsed with adjacent categories (when appropriate) to provide sufficient numbers of observation among levels. Linearity between the remaining continuous independent variables and dependent variables was assessed by categorizing the continuous variable by quartiles or natural breaks in the data and analyzed by commercial software;[c] continuous independent variables failing to demonstrate linearity remained as categorical variables. Evidence of correlation was assessed by correlation matrices (continuous responses) as well as contingency tables (categorical responses). Correlation of ≥ 0.4 (continuous variables) or a significant association among two (categorical) variables ($P < 0.05$) were considered potentially collinear. Among all models, each independent variable was assessed for association with the dependent variable by bivariable models using a screening P-value (≤ 0.25).[d] A forward step-wise model building procedure was then implemented to determine a final multivariable model; an alpha level of 0.10 was used for inclusion. Potential confounders were analyzed by measuring the change in the coefficient of the covariate of interest; a numerical modification of the coefficient by ≥ 20% (when the potential confounder was added to the model) suggested that significant confounding was present. Confounding variables were retained in the model regardless of statistical significance. All biologically plausible two-way interactions were also assessed following determination of main effects.

Results

Description of Project Participants

From 2006 through 2009, 585 beef herds voluntarily enrolled in the Montana BVD-PI Herd Biosecurity Project. The number of herds joining the program (for the first time) on an annual basis was 49 (8.4%) in 2006, 411 (70.3%) in 2007, 92 (15.7%) in 2008, and 33 (5.6%) in 2009. These participating herds represent 5.2% of the beef herds in the state of Montana.[29] Among the herds participating in the program, 38 were determined to possess ≥ 1 PI animal; thus, a herd BVDV prevalence of 6.5% (90% Confidence Interval [90% CI]; 4.5%, 8.5%). The within-herd prevalence among these 38 positive herds ranged from 0.12% to 20.0%, with a median value of 0.75% (Figure 1). Although not statistically evaluated, clustering of PI cattle among individual herds was evident, as 68.4% (n = 26) of BVDV positive herds detected > 1 PI animal at the time of testing.

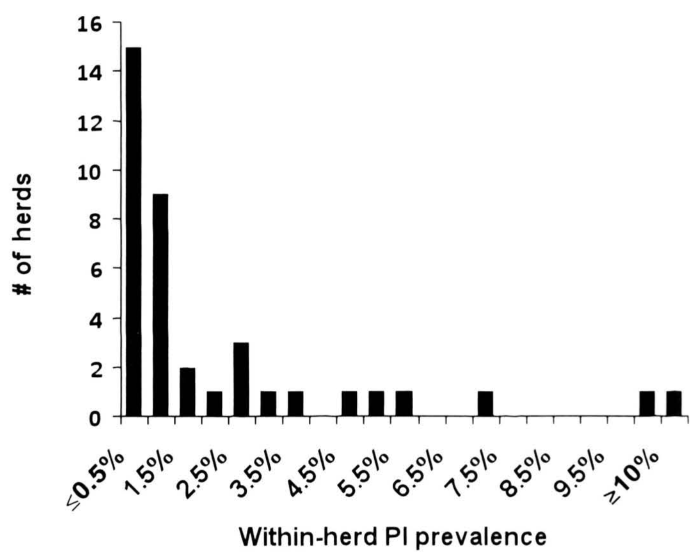

Figure 1. Within-herd prevalence of PI cattle among all BVDV-positive herds (n = 38) voluntarily enrolled in the Montana BVD-PI Biosecurity Program from 2006 to 2009.

Survey Outcomes in the Present Study

Of the 585 herds enrolled in the program from 2006 to 2009, diagnostic results were available for 563 herds that were subsequently contacted to participate in the survey. Of these, 230 herds completed and returned the aforementioned survey (40.9% response). Respondents included 95.7% (n = 220) BVDV test-negative herds and 4.3% (n = 10, 90% CI; 2.1%, 6.5%) BVDV-positive herds.

Herd size – The distribution of herd size among the survey respondent population is summarized in Table 1. Upon analysis, this variable was categorized by quartiles.

Replacement female/male procurement and management practices – Producers were asked to provide the number of purchased heifers, yearling bulls, pregnant heifers, pregnant cows, as well as heifers and bulls, born on the farm but raised off-site, that were subsequently reintroduced to the resident herd (Table 1). After preliminary analysis, data were dichotomized to indicate that producers either did or did not engage in procuring the above classes of cattle (Table 2). Among the respondents to this question, 82.5% (n = 198/230) stated that they annually imported one or more of the aforementioned classes of cattle to the resident herd.

Among producers indicating importation of cattle, 33.8% (n = 86/198) stated that they annually introduced

Table 1. Descriptive statistics of continuous variables among the respondent population (n = 230) that provided answers to the following questions.

Survey question	No. of respondent herds	Mean	Median	S.D.*	Minimum observation	Maximum observation
Herd size	229	323	200	399	3	3000
Cattle (purchased or home-grown) raised off-site and introduced to resident herd						
heifers	213	6.4	0	40.3	0	500
yearling bulls	223	3.0	2	4.8	0	40
pregnant heifers	215	6.0	0	25.8	0	300
pregnant cows	211	8.0	0	30.0	0	250
home-raised heifers and bulls	212	30.0	0	60.0	0	375
Number of days that purchased cattle are quarantined prior to introduction to resident herd						
heifers	22	19.0	10	27.0	0	90
yearling bulls	129	19.0	7	27.0	0	180
pregnant heifers	45	16.0	10	20.0	0	90
pregnant cows	44	12.0	10	14.0	0	60
Number of neighboring herds allowed fence line contact with resident herd (breeding to weaning)	222	3.5	3	2.5	0	15
Number of neighboring herds that shared pasture with resident herd (breeding to weaning)	225	0.6	0	1.5	0	10
Number of days that home-raised cattle, transported off-site, are quarantined prior to introduction to resident herd						
heifers (breeding)	27	39.4	0	79.3	0	365
heifers (exhibition)	14	2.5	0	5.2	0	14
pregnant heifers	28	13.0	0	38.3	0	180
pregnant cows	45	8.2	0	24.6	0	125
bulls	55	13.9	0	41.8	0	250

*S.D. = standard deviation of the mean.

Table 2. Descriptive statistics of categorical variables among the respondent population (n = 230) that provided answers to the following survey questions.

Survey question	Number of respondents (herds)	Did the herd engage in the management practice?	
		Yes (%)	No (%)
Replacement cattle leased, purchased, or raised off-site and introduced to resident herd			
heifers	213	11.3%	88.7%
yearling bulls	223	66.1%	33.9%
pregnant heifers	215	21.3%	78.7%
pregnant cows	211	19.1%	80.9%
home-raised heifers and bulls	212	43.0%	57.0%
Transporting cattle off-site with subsequent reintroduction to resident herd			
heifers (for breeding)	218	10.6%	89.4%
heifers (for exhibition)	214	5.6%	94.4%
pregnant heifers	219	11.0%	89.0%
pregnant cows	221	15.4%	84.6%
bulls	222	19.4%	80.6%

pregnant females (heifers and/or cows) to the herd. Among these herds that import pregnant cattle, 91.9% (n = 79) disclosed the method of procurement of pregnant heifers and/or cows. Of these individuals, 19.0% (n = 15), 57.0% (n = 45), and 24.1% (n = 19) indicated they procured pregnant females outside of the resident herd by means of auction markets, private treaty, or both methods, respectively.

Respondents who imported cattle were asked to state the length of time (if any) that each of the above classes of cattle (excluding home-raised heifers and bulls) were quarantined from the resident herd prior to introduction (Table 1). Given the low number of responses, the distributions of the given data, and previous research estimating the length of transient infection of BVDV,[4,12,13] the above data was subsequently dichotomized and analyzed to have (or have not) quarantined cattle from the resident herd more than 14 days prior to introduction. Open heifers, yearling bulls, pregnant heifers, and pregnant cows were isolated for greater than 14 days prior to introduction to the resident herd in only 31.9% (n = 7/22), 39.5% (n = 51/129), 35.6% (n = 16/45), and 36.4% (n = 16/44) of respondent herds, respectively.

BVDV vaccination and timing of administration – Among the respondents to this question, 88.3% (n = 190/215), 85.1% (n = 86/101), and 76.9% (n = 90/117) indicated that BVDV vaccine was annually administered to the cattle within the resident herd, replacement heifers/bulls (born on the farm but raised off-site), and leased/purchased replacement cattle, respectively, during the three years prior to enrollment in the program. Among the entire respondent population (n = 230), 49.2% (n = 91), 30.8% (n = 57), and 20.0% (n = 37) indicated that BVDV vaccine was administered prior to breeding, at pregnancy diagnosis, or at both timepoints, respectively.

Procurement and management of stocker cattle – Program participants were asked if stocker cattle were purchased during any of the three years prior to enrolling in the program. Among those that responded to this question (n = 220), 10% (n = 22) indicated that they had purchased stocker cattle during this time frame. Among these 22 herds who purchased stocker cattle, 72.7% (n = 16) indicated that the stocker cattle shared a pasture or had fence line contact with the resident herd at some time point from breeding to weaning (i.e. were in contact with pregnant cattle).

Communal grazing practices – Descriptive statistics for respondents who allowed fence-line access and pasture-sharing among neighboring herds and the resident herd anytime during the breeding season through the weaning period are displayed in Table 1. Due to the low number of respondents indicating that pasture sharing did occur, no further analysis was performed on these data. Among respondents who indicated that fence-line access to neighboring herds did occur, data were categorized based upon fence-line exposure to 0 - 2, 3, 4, and > 4 herds. Among respondents in the first (n = 84), second (n = 55), third (n = 30), and fourth (n = 53) categories, 15.6% (n = 13), 22.8% (n = 13), 35.3% (n = 11), and 37.3% (n = 20) indicated, respectively, that exposure to pregnant cattle within the resident herd occurred due to fence-line contact with neighboring herds.

Transporting cattle off-site and reintroduction to the resident herd – The number of respondents to this question regarding the various classes of cattle allowed to leave the premise and subsequently return to the resident herd is located in Table 2.

Participant understanding of BVDV – Among the respondents to a question regarding their understanding of BVDV (n = 217), 73.0% (n = 159) perceived themselves to be "fairly knowledgeable" in regard to BVDV, 26.1% (n = 57) "knew some basics", and 0.9% (n = 1) "recognized the name, BVDV". Due to the small number of responses in category three, this last level was not included in further analyses.

Association of Survey Outcomes and Herd BVDV Status

Upon multi-variate analysis, herd BVDV status was associated ($P < 0.10$) with the practice of annually vaccinating home-grown heifers and bulls (raised off-site) that are subsequently introduced to the resident herd (odds ratio (OR) = 0.16; 90% CI: 0.04 - 0.28). Therefore, herds that annually vaccinated this class of cattle prior to introduction to the resident herd displayed approximately an 85% reduction in the risk of being BVDV positive. All remaining survey outcomes were not significantly associated ($P > 0.10$) with herd BVDV status.

Association of Perceived Understanding of BVDV and Herd Biosecurity Practices

A multivariate model consisting of all herd management practices was then analyzed with regard to perceived knowledge of BVDV (i.e. producers that perceived themselves as "fairly knowledgeable" or "know some basics" about BVDV). Only covariates included in the model are discussed; therefore, reported data reflect model-adjusted estimates. Herd size was observed to be significantly associated ($P < 0.10$) with producer knowledge of BVDV. Upon further analysis, this difference was observed to be driven predominately when comparing the fourth quartile (herd with greater than 375 cows) to the bottom three quartiles. These findings suggest that producers of herd sizes greater than 375 cows were significantly more likely ($P < 0.10$) to perceive themselves as "fairly knowledgeable" with regard to BVDV (OR = 1.9; 90% CI: 1.2 - 2.5).

Annual BVDV vaccine administered to the resident herd was significantly associated ($P < 0.10$) with perceived knowledge of BVDV (OR = 2.7; 90% CI: 2.1 - 3.3). Therefore, herd owners that annually vaccinate the resident herd for BVDV are 2.7 times more likely to perceive themselves as "fairly knowledgeable" in regard to BVDV.

Communal grazing practices from breeding to weaning were significantly associated ($P < 0.10$) with perceived knowledge of BVDV (OR = 0.45; 90% CI: 0.25 - 0.65). Therefore, program participants who engage in communal grazing are 55% less likely to perceive themselves as "fairly knowledgeable" with regard to BVDV.

The practice of transporting pregnant heifers off-site and subsequently reintroducing them to the resident herd was also significantly associated ($P < 0.10$) with being "fairly knowledgeable" with regard to BVDV (OR = 14.7; 90% CI: 3.7 - 25.7). This suggests that producers who engage in this activity were 14.7 times more likely to perceive themselves as being relatively educated with regard to BVDV.

Discussion

Herds in the Montana BVD-PI Herd Biosecurity Program had a BVDV herd prevalence of 6.5%. This finding is similar to previous studies that have determined herd BVDV prevalence among US beef herds as well as those in western Canada.[30-32] However, to our knowledge, this is the first report providing herd prevalence data specifically for the state of Montana. Therefore, these findings from the present study suggest that only a small percentage of beef herds in the state of Montana are BVDV positive. The clustering of PI cattle within individual farms was not controlled for in this analysis solely due to the lack of data addressing the presence of more than one PI animal when compared to farms with only one PI animal. Further work is needed to determine if a "dose effect" is present with regard to the number of PI animals housed within individual production systems. However, given the distribution of within-herd PI prevalence, these data suggest that approximately 65% of BVDV-positive herds possess more than one PI animal; therefore (although statistically not evaluated), PI cattle appear to be clustered in a small percentage of herds as outlined elsewhere.[32]

Although the findings from this study highlight specific management practices implemented by participating herds, BVDV herd status was not shown to be associated with management practices traditionally recognized as factors that may influence the probability of introducing BVDV to the resident herd.[20] Given that the BVDV herd prevalence in the present study (6.5%) is low, these outcomes may be attributed to loss of statistical power, thereby elevating risk of type II errors.

Despite the lack of statistical association with herd BVDV status, the findings from the present study suggest that a large proportion of the participating herds engage in management practices previously described as having the potential to elevate the risk of disease introduction.[25,26,28] Based on modeling import risk, Smith *et al* reported that importation of pregnant beef heifers was a significant risk factor regarding the introduction of BVDV to resident herds when evaluated within a stochastic model.[27] In the present study, approximately 34% of respondents indicated that pregnant females had been previously brought into the herd within three years of enrolling in the program. Although importing cattle into the resident herd increases the risk of disease introduction, implementation of adequate quarantine procedures (i.e. housing cattle for a sufficient duration of time within pastures/pens that are isolated from the resident herd) may help reduce the probability of this occurrence by allowing time for transient infections to wane, vaccines to be administered and take effect, and for diagnostic tests to be performed.

In addition to exposing the resident herd to outside sources of cattle, 25.5% of respondent herds in the present study indicated that they participated in communal grazing activities. This estimate closely parallels survey data in a previous report regarding western US beef producers' participation in some variety of communal grazing (24%).[25] This practice is common among states in the western US and is necessary in providing adequate levels of forage to cow herds during the grazing months. Therefore, communal grazing is not likely to be curtailed solely due to its effect on the risk of BVDV introduction. However, the obvious hazard of communal grazing is attributed to the commingling among multiple herds, thereby increasing the risk of disease transmission. Instituting biosecurity measures such as herd testing protocols for BVDV (prior to commingling), quarantine protocols prior to reintroduction, and vaccinating incoming cattle prior to introduction/reintroduction (described below) may reduce the risk of introducing economically devastating disease syndromes to the resident herd.

In the present study, annually administering BVDV vaccine to home-grown heifers and bulls (raised off-site) prior to reintroduction to the resident herd significantly reduced the risk of positive herd BVDV status. Among pregnant females, the introduction of BVDV to the herd may be attributed to the production of PI calves. Pre-breeding administration of BVDV vaccine to heifers should not be viewed as the sole element of BVDV prevention; however, prior research has shown significant reduction in fetal infection and subsequent PI calf production among vaccinated heifers when compared to unvaccinated controls.[6-10,14,24]

In the present study, owners of larger herds (> 375 cows) were significantly more likely to perceive themselves as "fairly knowledgeable" with regard to BVDV. Potential reasons for this finding could be that the cow-calf enterprise of larger producers is their primary source of income; therefore, these individuals may be more likely to be familiar with BVDV due to greater exposure to their herd veterinarian and a greater interest in the beef industry as compared to smaller producers. Alternatively, simply due to sheer numbers, larger herds may be more likely to have previously experienced actual clinical effects associated with BVDV than smaller herds, subsequently forcing them to be highly aware of BVDV.

In addition to herd size, the data in the present study suggest that producers who understand BVDV may avoid certain management practices that potentially increase the risk of disease introduction. Beef producers in the present study who considered themselves "fairly knowledgeable" in regard to BVDV were more likely to institute annual BVDV vaccine programs within the resident herd and avoid communal grazing during the time frame of breeding to weaning. This suggests that prior BVDV education (coming from numerous potential sources such as firsthand experience with BVDV, experiences of other producers, veterinarian consultation, as well as state and national organizations) has improved client understanding and compliance with BVDV control protocols. These findings contradict a previous study (performed in a different country) that observed a poor association between producer knowledge and compliance with BVDV control programs.[11]

Conversely, in the present study, producers indicating a high level of BVDV knowledge were significantly more likely to transport pregnant heifers off-site while subsequently reintroducing them to the resident herd at a later time. Without proper precaution, this practice may be hazardous due to the unknown PI status of the unborn fetus upon return. These findings suggest that either beef producers don't recognize this practice as being a potential biosecurity risk, or other constraints such as pasture management, breeding/calving supervision, labor allocation, or forage availability forces herds to adopt this practice in order to optimize herd production. One preventative measure aimed to potentially reduce the risk of BVDV introduction by this practice would be to segregate pregnant heifers upon return to the resident herd until both the heifer and calf are confirmed free of BVDV. This final variable signifies that continued education is needed at the herd level in order to reduce the risk of BVDV introduction.

In spite of the aforementioned findings, sources of bias were likely present in this study. Non-response bias may have been introduced as herds previously diagnosed as being BVDV positive may have been less likely to participate in the present study. Despite a lack of statistical significance when comparing the proportion of non-response among BVDV-positive herds (73.9%, 95% CI; 59.0%, 88.4%) and BVDV-negative herds (59.6%, 95% CI; 55.5%, 63.7%) the low number of BVDV-positive herds suggests that non-response further reduces the statistical power when attempting to detect a significant difference in production parameters among positive and negative herds. Further analyses (although not statistically significant) comparing the aforementioned BVDV herd prevalence estimate for the respondent population (4.3%; 95% CI, 1.7% - 7.0%) and that of the non-respondent population (8.4%; 95% CI, 5.4% - 11.4%) may again be due to low numbers of BVDV-positive herds. Therefore, it is likely that non-response bias may have altered the estimates in the current study and subsequently reduced the statistical power while increasing the risk of type II error.

Recall bias may have impacted this study as participants were asked if certain management practices were being utilized three years prior to volunteering in the Montana BVD-PI program. Therefore, given the year this program was founded (2006), it is likely that some participants may be unable to specifically remember how long a management practice has been employed or when it began, thereby potentially affecting the accuracy of individual responses.

Survey respondents did not consist of a random sample as the study population consisted of herds that voluntarily participated in the Montana BVD-PI program. Nonetheless, geographical distribution of BVDV-positive herds (data not shown) displayed a relatively uniform distribution throughout the state of Montana; therefore, it is likely that the survey responses of positive herds in the present study would be typical of other positive herds. However, geographic location was not evaluated in this study; therefore, further work is needed to elucidate this question.

Likewise, herd BVDV status was determined *a priori* of the present study. However, closer inspection of diagnostic records indicated that a small number of herds failed to test the calf population and tested only replacement cattle or the mature cows (i.e. failing to test the subpopulation [i.e. calves] at greatest risk of housing PI cattle). Therefore, the present herd and within-herd prevalence estimates may be slightly underestimated. Lastly, due to the cross-sectional nature of this study, we are unable to determine if reverse causation was present due to the inability of determining if the modeled fixed effects (e.g. BVDV vaccination of home-raised replacement heifers) occurred before or after the modeled response variables (e.g. herd BVDV status).

Conclusions

The present data suggests that a small percentage of beef herds in Montana are infected with BVDV. However, among those positive herds, the within-herd distribution of PI cattle is large, thereby suggesting that PI animals are indeed clustered at the level of the farm. These data also provide evidence that many beef producers in Montana currently engage in management practices that may elevate the risk of eventual disease introduction. Veterinarians and beef producers must constantly assess their production practices and determine if a biosecurity risk is present. However, instituting any biosecurity program must be determined to be of economic benefit to the producer based upon the prevalence of the disease and the individual producer's risk aversion to the pathogen. Continued persistence among veterinarians, academic institutions, extension services, and state and national organizations is necessary to maintain and improve producer education to optimize BVDV control and prevention.

Endnotes

[a]Animal Profiling International, Inc., Portland, OR
[b]Microsoft Excel®, 2007, Redmond, WA
[c]Proc GLM, SAS (version 9.1), Cary, NC
[d]Proc Logistic, SAS (version 9.1), Cary, NC

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