PEER REVIEWED

Economic Evaluation of Beef Cowherd Screening for Cattle Persistently-infected with Bovine Viral Diarrhea Virus

RL Larson, *DVM, PhD*[1]; **VL Pierce,** *MS, PhD*[1]; **DM Grotelueschen,** *DVM, MS*[2]; **TE Wittum,** *DVM, PhD*[3]
[1]*Commercial Agriculture Beef Focus Team, Outreach and Extension, University of Missouri, Columbia, MO 65211*
[2]*Department of Veterinary and Biomedical Sciences, Panhandle Research and Extension Center, University of Nebraska-Lincoln (Currently veterinary technical services, Pfizer Animal Health), Scottsbluff, NE 69361*
[3]*Department of Veterinary Preventive Medicine, The Ohio State University, Columbus, OH 43210*

Abstract

Bovine viral diarrhea virus (BVDV) infection is responsible for a variety of economically important syndromes in cattle. In order to quantify the economic benefit for removing BVDV persistently infected (PI) animals, a 10-year farm profitability simulation model was used to compare production scenarios with and without PI calves present. Differences in profitability between the scenarios estimates the value of diagnostic testing given expected prevalence in the herd. If the true prevalence of herds with at least one PI animal is 1% (low end of the 95% confidence interval for randomly selected herds), the average annual dollars available for screening is only $0.15. Using a 10-year period, if the whole herd is tested the initial year and the cost of the initial screening is prorated over 10 years, and only replacements are screened in subsequent years, $0.60 is available for costs associated with each animal tested. If, however, the true prevalence of herds with at least one PI animal is 30% (high end of the 95% confidence interval for pre-screened herds), the average annual dollars available for screening is $4.60. In this scenario, $18.40 is available for each animal tested. These figures show that practitioners may not be economically justified to initiate diagnostic screening protocols for PI BVDV cattle for all clients. However, if ranch history raises a suspicion of BVDV PI cattle being present, a screening protocol can be defended based on its likelihood to improve economic return.

Résumé

L'infection causée par le virus de la diarrhée virale bovine (BVD) est responsable d'une multitude de syndromes à répercussion économique chez le bétail. Dans le but de déterminer les avantages économiques d'éliminer les individus infectés de façon persistante par le BVD, une simulation sur la rentabilité au niveau de la ferme pendant une période de 10 ans a été utilisée pour comparer les scénarios de production associés à la présence ou à l'absence d'individus infectés de façon persistante. Les différences entre les deux scénarios au niveau de la rentabilité permettent d'estimer la valeur d'un test diagnostic compte tenu de la valeur attendue de la prévalence dans le troupeau. Si la vraie prévalence des troupeaux avec au moins un individu infecté de façon persistante est de 1% (la borne inférieure de l'intervalle de confiance à 95% de troupeaux pris au hasard), le montant annuel moyen disponible pour le dépistage est de seulement 0.15$. Sur une période de 10 ans, en supposant que tout le troupeau est soumis au test lors de la première année, que le coût du dépistage initial est amorti sur les 10 ans et que seulement les nouveaux animaux sont testés subséquemment, un montant de 0.60$ est disponible pour les frais associés au test de chaque animal. Toutefois, si la vraie prévalence des troupeaux avec au moins un individu atteint de façon persistante est de 30% (la borne supérieure de l'intervalle de confiance à 95% des troupeaux testés au préalable), le montant moyen annuel disponible pour le dépistage est de 4.60$. Dans ce scénario, un montant de 18.40$ est disponible pour chaque animal testé. Ces résultats indiquent qu'il ne serait toujours pas viable économiquement pour les praticiens de développer un système de dépistage diagnostic pour les individus atteints de façon persistante par le virus BVD pour chaque client. Toutefois, si il y a un doute sur la présence d'individus atteints de façon persistante par le virus BVD à la ferme, l'élaboration d'un protocole de dépistage

peut se défendre étant donné l'espérance d'un bénéfice économique.

Introduction

Bovine viral diarrhea virus (BVDV) infection is responsible for a variety of economically important syndromes in beef herds. Quantifying the economic benefit of removing BVDV persistently infected animals from a herd, and hence the value of diagnostic testing to achieve that goal, has not been reported. The purpose of this research is to quantify the economically important factors necessary to establish the value of diagnostic testing.

BVDV infection can cause a complex of disease problems, including respiratory disease, infertility and fetal infection.[2] Fetal infection can lead to early embryonic death, abortion, congenital defects, stunting, or the birth of persistently infected (PI) calves.[2] Persistently infected cattle are the result of *in utero* exposure to the noncytopathic biotype of BVDV prior to the development of a competent fetal immune system at about 125 days of gestation.[5,14,16] Transplacental infection occurs with high efficiency during pregnancy, and if PI fetuses survive to term, they are continually viremic, but immunotolerant to the virus.[7,20] The prevalence of PI animals in the general cattle population has been estimated to range between 0.13% and 2.0%.[4,10,12,22] Differences in reported prevalence may be due to the population tested, the country/continent where the population was located and/or the diagnostic tests utilized.

The presence of calves persistently infected with BVDV in a breeding herd can result in decreased pregnancy percentage compared to herds with no PI calves.[22] Persistently infected calves continuously shed large amounts of virus. Suckling calves are commonly in contact with the breeding herd during early gestation, prior to the time the bovine fetus develops a competent immune system. As a result, PI suckling calves are considered to be the primary source of BVDV infection in breeding herds causing pregnancy loss, pre-weaning mortality and the induction of PI calves in the next generation.[7,16] Horizontal transmission of the virus causing acute infection may be via inhalation or ingestion of infected saliva, oculonasal discharge, urine or feces.[7]

Circulating virus may exist in herds following removal of PI calves although the efficiency of virus transmission is not high.[23] Circulating virus from acute infections of BVDV should be considered if the biosecurity goal is complete elimination of BVDV from the herd. Limited data in dairies suggest BVDV may circulate in an unvaccinated herd for 2-3 years following removal of all PI animals.[23,24,25] The length of time of BVDV circulation in vaccinated beef herds without PI animals has not been reported.

Decreased pregnancy percentage in herds with at least one PI animal in contact with breeding females could be due to ovarian dysfunction,[9,13] failure of fertilization,[8] early embryonic death,[1,11,17] and/or mid-gestation fetal loss[21] in cattle acutely infected with BVDV. Grooms *et al* found that BVDV could be isolated on days six and eight following infection with noncytopathic BVDV in ovarian stromal and macrophage-like cells, and oophoritis was evident from 6 to 60 days post-infection.[9] McGowan *et al* reported that conception rates, determined 20 days after insemination, were lower in heifers intranasally-infected with BVDV nine days before insemination compared to controls (44% vs 70%; p=0.055). In addition, conception rates were numerically lower in heifers exposed to a PI cow-calf pair four days after insemination than in unexposed controls (60% vs 79%; p=0.255).[17] The intranasally-exposed heifers also experienced significant embryo-fetal loss, resulting in a pregnancy percentage, determined 77 days after insemination, significantly lower than controls (33% vs 79%; p=0.018).[17] Rufenacht *et al* found that dairy cows infected with BVDV during the first 45 days of gestation (as indicated by seroconvertion to BVDV during that time frame) had the same conception percentage as cows that either had previous exposure to BVDV (seropositive for BVDV by start of the trial) or that were not exposed to BVDV during gestation (no seroconversion during trial). Similarly, BVD-exposure status did not influence late gestation pregnancy loss (>210 days). However, cows infected with BVDV during mid-gestation (days 46-210) had greater pregnancy loss compared to those that were seropositive prior to breeding or that were not exposed to BVDV during mid-gestation (pregnancy loss of 15.8% vs 6.1%; OR=3.1; p<0.02).[21]

In addition to decreased pregnancy percentage, reproductive efficiency can be decreased due to fatal congenital defects following fetal infection with BVDV between 100 and 150 days of gestation.[7] The teratogenic lesions associated with fetal infection with BVDV include microencephaly, cerebellar hypoplasia, hydranencephaly, hydrocephalus, defective myelination of the spinal cord, cataracts, retinal degeneration, optic neuritis, microphthalmia, thymic aplasia, hypotrichosis, alopecia, brachygnathism, growth retardation and pulmonary hypoplasia.[2]

In a study by Wittum *et al*,[22] nearly 20% of PI calves died preweaning, but overall mortality rates between herds with or without PI calves were not statistically significantly different because of the low prevalence of PI calves within herds. Because of the low prevalence of herds with at least one PI calf in the US (assume 3.9%), one would need to sample 389,199 herds (14,609 with at least one PI calf present and the remainder with no PI calves present) in order to detect a 10% increase in preweaning mortality (5.50%[18] vs 6.05%; includes calves born dead and all calf death loss preweaning).[a]

Given the large sample size needed to detect differences in preweaning mortality, it is not surprising that no study has been published that was able to show a statistically significant difference between herds with and without PI animals present. As a result, a biological difference in preweaning mortality cannot be proved or disproved. For this reason, model-runs both including and excluding a difference in preweaning mortality and weaning weight by presence of PI animals in a herd are reported in this paper.

Calves persistently infected with BVDV can be identified by virus isolation from serum or other tissue, immunohistochemistry staining of viral antigen in skin and other tissue biopsies, antigen-capture enzyme-linked immunosorbent assay (ELISA) and polymerase chain reaction (PCR) methods.[6] Persistently infected animals produce an exceptionally large number of BVDV particles that can be isolated from virtually any tissue sample. Virus isolation is considered to be very specific for BVDV infection, however colostral antibodies may temporarily reduce the amount of free virus in the serum of young calves. Virus isolation may not differentiate between acute infections and PI animals unless positive cattle are retested at a later date (i.e. 2-3 weeks later). In addition, virus isolation methods are labor intensive and take several days to complete. An immunohistochemical test for BVDV infection using skin biopsy samples is available that differentiates between PI animals and acute infections.[19] This test is suitable for herd screening because samples can be taken from cattle of any age, sample collection is simple, the samples are stable for transport and handling, and the test is both sensitive and specific for BVDV PI cattle.[3,19] PCR testing for BVDV infection is more rapid than virus isolation and can detect virus in antigen-antibody complexes. PCR tests are sensitive and have been shown to differentiate between BVDV genotypes. However, a single BVDV positive serum sample tested by PCR does not allow the diagnostician to differentiate between viremia from a postnatal acquired infection and viremia due to being persistently infected. Because PCR tests can identify minute amounts of virus, this test can be used in pooled samples of serum or milk in surveillance programs.

Practitioners are able to categorize US beef herds as high-risk for the presence of BVDV PI animals compared to randomly selected herds.[22] Wittum *et al* identified 48 veterinary practices from five geographically diverse states (Alabama, Nebraska, Nevada, North Dakota and Ohio) that routinely provide veterinary services to commercial beef herds to participate in a BVD PI prevalence study.[22] Using a random-numbers table, 76 herds were randomly selected from client lists for evaluation of BVDV PI prevalence. In addition, these veterinarians were asked to identify client herds in which they suspected BVDV infection based on history and observed clinical signs; these herds were also evaluated for BVDV PI prevalence (52 herds). The prevalence of herds with at least one PI animal in randomly selected herds was 3.9% with a 95% confidence interval (CI) of 1 to 11%, compared to 19.2% of herds with a history of BVDV-compatible syndromes (95% CI of 10 to 33% of herds).[22]

The economic losses from BVDV infection will vary between herds based on the herd immunity and stage of gestation at the time of exposure, the virulence of the BVDV strain and other factors. Determining the value of diagnostic testing depends on identifying the potential performance impact that a diagnosis and corresponding management intervention would have on a herd compared to an expected economic baseline without testing, given expected prevalence in the herd. The economic assessment is then made by quantifying the performance differences as manifested in enterprise analysis and expected changes in farm profitability.

Methods

A 10-year (1991 to 2000) dynamic farm profitability simulation model which generates annual cash flow, balance sheet and income statements was used to compare three production scenarios: 1) herds with no PI calves, 2) herds with at least one PI calf present with a negative effect on pregnancy percentage, but no effect on pre-weaning mortality or weaning weight, and 3) herds with at least one PI calf present with negative effects on pregnancy percentage, pre-weaning mortality and weaning weight. Each scenario incorporates herd performance and economic interactions. Data from Wittum *et al* which estimates the pregnancy percentages and pre-weaning mortality for herds with or without at least one PI calf present were used to model all three scenarios (Table 1).[22] Because the Wittum study involved herds from five geographically diverse states and a fairly large number of herds positive for the presence of at least one PI calf (n=13), we assumed that the

Table 1. Pregnancy percentage and pre-weaning mortality for herds with or without at least one PI calf present.[22]

	At least one PI animal present in herd	
	Positive	Negative
Pregnancy percentage		
Cows	89*	94*
Heifers	93	85
Mortality percentage		
Perinatal	4.6	4.4
Postnatal	2.6	2.8

*$p<0.05$

positive herds represented a cross-section of levels of herd immunity, gestational status and virus virulence combinations present in the US. The Wittum study provides a logical average effect of the presence of PI calves in a US beef herd.

Anecdotal statements claim that the presence of PI calves in a group of suckling calves negatively impacts pre-weaning mortality and weaning weight, however, no citations were found that quantified this impact. For this reason, model-runs both including and excluding a difference in pre-weaning mortality and weaning weight by presence of PI animals in a herd are reported. Increased pre-weaning mortality and decreased weaning weight used in the model are given in Table 2.

Farm economic activity for each scenario was reported as return to fixed costs as determined by subtracting variable costs from income for each year of the evaluation. Herd size was not varied between the scenarios. More heifers needed to be retained in herds with at least one PI calf identified because of decreased pregnancy percentage. Feed and hay costs on a monthly basis over a ten year period (1991 to 2000) were obtained from Missouri Agriculture Statistics Service, Missouri Farm Facts, and the By-products feed listing on the University of Missouri AgEbb electronic bulletin board (http://agebb.missouri.edu/dairy/bull1r.htm). The amount of feed fed to each class of cattle on the farm (mature cows, second calf cows, first calf heifers, developing heifers, bulls, etc.) was determined by meeting NRC requirements. The amount of pregnancy wastage influenced the number of heifers retained for breeding, and the percentage of the herd represented by first calf heifers, second calf cows and mature cows. Some veterinary and management costs on a herd level were also different between scenarios because of the influence of percentage of the herd represented by each class of cattle. Cattle prices for the same period were obtained for Oklahoma City steers, heifers and cull cows from United States Department of Agriculture market reports. Calves were sold each year in November. The average weaning weight for calves sold was assumed to be 550 lb (250 kg) and 500 lb (227.3 kg) for steers and heifers, respectively, in the scenarios with no PI calves present and where the negative effect of the presence of PI calves was limited to pregnancy percentage. In the scenario with at least one PI calf detected and a negative effect on weaning weight of calves sold, the steers were assumed to weigh 547 lb (248.6 kg) and the heifers 498 lb (226.2 kg) (0.5% lower than herds with no PI calves present). Scenarios with higher replacement rates sold fewer heifers at weaning and more open cull cows.

Table 2. Assumptions: Pre-weaning mortality and weaning weights when pre-weaning mortality is 10% higher and weaning weight is 0.5% lower in herds with at least one PI animal.

	Presence of at least one PI animal in the herd	
	Positive	Negative
Pre-weaning mortality	7.92%	7.20%
Weaning weight		
Steers	547 lb (248.6 kg)	550 lb (250.0 kg)
Heifers	498 lb (226.2 kg)	500 lb (227.3 kg)

A 95% confidence interval is used to report the range of values that the data indicate has a 95% probability of containing the true population mean. By using the reported[22] upper and lower cut-offs for the 95% confidence intervals for the presence of at least one PI animal in both randomly selected and PI-suspected herds (Table 3), and multiplying those percentages by the difference in economic return generated by herds with or without PI animals present, the dollars available for diagnostic screening for PI animals can be determined.

Results

The difference in economic return per cow exposed for breeding between herds with or without PI animals by year ranges from $11.29 per cow in 1995 to $19.39 per cow in 1991, assuming the only negative effect of PI calf presence is on pregnancy percentage (Table 4). If the negative effect of PI calves on pre-weaning mortality and weaning weight is included, the economic advantage for herds without PI calves ranges from $14.85 per cow in 1995 to $24.84 per cow in 1991.

The likelihood of finding at least one PI animal in the herd, the negative production effects when PI animals are present, the cost of inputs and the value of animals sold (price cycle) all impact the economic value of annual screening for PI animals in cow-calf herds (Table 5). If the prevalence of herds with at least one PI calf is low (1% to 11%), the dollars available for screening the herd for PI animals would average $0.15 to $1.69 per year multiplied by the number of cows exposed for breeding. However, if the likelihood of finding at least one PI animal in a herd is increased by using history or other tools for pre-screening, and assuming the prevalence is 10 to 30% of herds testing having at least one PI animal, the dollars available for screening is $1.53 to $4.60 per year multiplied by the number of cows exposed for breeding. Regardless of the prevalence of herds with PI calves, more dollars tend to be available in years of high calf sale prices and high profitability compared to years when prices and profitability are low.

Discussion

One procedure for screening herds for PI cattle prior to the start of the breeding season involves ini-

Table 3. Prevalence estimate and 95% Confidence Interval for the presence of at least one PI animal in both randomly selected and BVDV-suspected herds.[22]

	No. Herds Tested	No. Positive Herds	Prevalence Estimate (%)	95% CI (%)
Randomly selected	76	3	3.9	1-11
BVDV suspect	52	10	19.2	10-33
Total herds	128	13		

Multiple positive calves in 10 (77%) of 13 herds
Range of 1 to 13 positive calves in a herd

Table 4. Economic return to fixed costs and difference in economic return between herds with or without PI animals by year and extent of effect on herd productivity.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
	Return to fixed costs per head exposed to breeding									
Without PI	$126.12	$110.49	$122.15	$68.72	-$36.41	-$121.85	$73.27	$73.39	$168.08	$204.24
With PI										
Reproduction loss only	$106.73	$94.18	$106.36	$53.45	-$47.70	-$134.40	$57.90	$59.85	$152.16	$186.36
Reproduction + production loss	$101.28	$88.76	$101.09	$48.66	-$51.25	-$138.17	$53.01	$55.55	$146.95	$180.72
	Difference in return to fixed costs per head exposed to breeding compared to no PI calves present									
Reproduction loss only	$19.39	$16.31	$15.80	$15.26	$11.29	$12.55	$15.37	$13.54	$15.92	$17.88
Reproduction + production loss	$24.84	$21.73	$21.07	$20.06	$14.85	$16.32	$20.26	$17.84	$21.13	$23.52

Table 5. Annual value of testing to remove PI animals from the herd (per cow exposed for breeding).

	Prevalence	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Avg.
Reproduction loss only												
Randomly selected herds	1%	$0.19	$0.16	$0.16	$0.15	$0.11	$0.13	$0.15	$0.14	$0.16	$0.18	**$0.15**
	11%	$2.13	$1.79	$1.74	$1.68	$1.24	$1.38	$1.69	$1.49	$1.75	$1.97	**$1.69**
BVDV suspect herds	10%	$1.94	$1.63	$1.58	$1.53	$1.13	$1.26	$1.54	$1.35	$1.59	$1.79	**$1.53**
	30%	$5.82	$4.89	$4.74	$4.58	$3.39	$3.77	$4.61	$4.06	$4.78	$5.36	**$4.60**
Reproduction + production loss												
Randomly selected herds	1%	$0.25	$0.22	$0.21	$0.20	$0.15	$0.16	$0.20	$0.18	$0.21	$0.24	**$0.20**
	11%	$2.73	$2.39	$2.32	$2.21	$1.63	$1.79	$2.23	$1.96	$2.32	$2.59	**$2.22**
BVDV suspect herds	10%	$2.48	$2.17	$2.11	$2.01	$1.48	$1.63	$2.03	$1.78	$2.11	$2.35	**$2.02**
	30%	$7.45	$6.52	$6.32	$6.02	$4.45	$4.90	$6.08	$5.35	$6.34	$7.06	**$6.05**

tially testing all replacement heifers and bulls, all calves, and all dams without calves due to calf death or failure to calve.[15] In subsequent years, a strategy of vaccination and herd isolation during the breeding season to decrease the risk of exposure to animals acutely infected with BVDV should be implemented. For one or more subsequent years, testing of all calves in a breeding pasture prior to the start of the breeding season may be required to eliminate PI animals from the herd. Once the herd is free of PI calves and cows, only replacement breeding animals need to be tested for persistent infection with BVDV. Therefore the cost of a BVD PI screening program is high in the initial one to three years, and then lower in following years.

The model used in this paper shows that at the low prevalence of herds with at least one PI animal reported for randomly selected herds, the dollars available to remove PI animals may or may not justify diagnostic screening. If the true prevalence of herds with at least one PI animal is 1% (at the low end of the 95% confidence interval),[22] the average annual dollars available for screening is only $0.15. Using a 10-year period, if all calves and dams without calves are tested the initial year, the cost of the initial screening is prorated over 10 years and only replacements (at the rate of 15% of the mature herd) are screened in subsequent years, $0.60 would be available for costs associated with each animal tested. This indicates that the cost of screening exceeds the risk of economic loss. A strategy to implement a BVDV biosecurity program for incoming cattle and to maintain a BVDV vaccination program appears to be a better economic alternative compared to herd screening for PI animals when history does not indicate problems suggestive of BVDV.

If, however, the true prevalence of randomly selected herds with at least one PI animal is 11% (at the high end of the 95% confidence interval),[22] an average of $1.69 per cow annually is available for the cost of screening in the breeding herd. This may justify a strategy where all the calves are screened the initial year and replacements are screened in subsequent years. In such a scenario, if the cost of the initial screening is prorated over 10 years and the herd has a 15% replacement rate, $6.76 would be available for each animal tested. This amount may cover the labor, diagnostic laboratory and consulting fees required to initiate a screening protocol.

The economic conclusion is the same if BVD also affects pre-weaning mortality and weaning weight to a similar extent as in our model, assuming that the cost of initial screening is prorated over 10 years. The dollars available to screen herds for the presence of PI cattle only increases to $0.80 per test if the prevalence of herds with at least one PI calf is 1%. If the prevalence is 11%, the dollars available per animal tested is $8.88.

By pre-screening herds based on a history of BVDV-compatible problems so that the prevalence of herds tested with at least one PI calf increases from 10% to 30%, the economic reward from identifying and removing PI animals is likely to exceed the cost of the presence of PI animals. If the true prevalence of herds with at least one PI animal is 10%, at the low end of the 95% confidence interval reported by Wittum *et al*,[22] the average annual dollars available for screening is $1.53. If all the calves and dams without calves are tested the initial year, the cost of the initial screening is prorated over 10 years and replacements (at the rate of 15% of the mature herd) are screened in subsequent years, $6.12 would be available for each animal tested.

If, however, the true prevalence of herds with at least one PI animal is 30% (at the high end of the 95% confidence interval),[22] an average of $4.60 per cow is available annually to screen the breeding herd. This would probably justify a strategy whereby all calves are screened the initial year and replacements are screened in subsequent years. In such a scenario, if the cost of the initial screening is prorated over 10 years and the herd has a 15% replacement rate, $18.40 would be available for each animal tested.

If BVDV also affects pre-weaning mortality and weaning weight to a similar extent as was used in our model and the same proration of diagnostic test costs is applied, the dollars available to screen herds with a history of BVDV-compatible problems for the presence of PI cattle increases to $8.08 per test if the prevalence of herds with at least one PI calf is 10%. If the prevalence is 30%, the dollars available per test is $24.20.

Wittum *et al* found that among herds where practitioners suspected BVDV-induced syndromes, 19.2% were found to have at least one PI animal present upon screening (95% CI, 10-30%).[22] By using herd history to pre-select herds that are more likely to benefit from a diagnostic screening protocol for BVDV PI animals, veterinarians can provide a diagnostic and consulting service to their clients that is justified economically. In pre-selected herds, the cost of diagnostic testing is less than the risk of BVDV PI cattle and their cost to herd profitability. In contrast, the cost of diagnostic testing is not likely to be recouped if testing all herds in a general population.

The model used in this paper considers the cost of BVD infection to the cowherd to the point of selling the calves at weaning. Insufficient information is available to model the effects of the presence of PI BVD calves on pen or group performance post weaning. One could conjecture that PI BVD calves in a group of stocker or feedlot cattle could increase the morbidity, mortality and potentially decrease the growth and carcass performance of not only the PI calves, but also in-contact penmates. Because of the nature of the model used for this paper, the entire cost of BVD PI cattle to the beef industry is not addressed, and therefore the values reported as costs to cowherds probably underestimates the cost of BVD PI cattle to the beef industry as a whole.

Conclusions

The cost of initiating a BVD PI screening protocol on a farm or ranch is significant. Because of the low prevalence of herds with at least one PI animal, veterinary practitioners may not be economically justified to initiate diagnostic screening protocols for PI BVDV cattle for all their clients. However, if ranch history raises a suspicion of BVDV PI cattle being present in the herd, a protocol to screen the herd can be defended based on its likelihood to improve economic return.

Footnote

[a]α=0.05 β=0.20 The sample size necessary to detect a 10% difference in mortality was calculated using the Epi Info 2000 (Centers for Disease Control, U.S. Dept. of Health & Human Services). This large sample size is based on the assumption of 3.9% prevalence and does not account for diagnostic test accuracy for detection of BVDV.

References

1. Archbald LF, Fulton RW, Seder CL, Al-Bagdadi F, Godke RA: Effect of the bovine viral diarrhea (BVD) virus on preimplantation bovine embryos: a preliminary study. *Therio* 11:81-89, 1979.
2. Baker JC: Bovine viral diarrhea virus: a review. *J Am Vet Med Assoc* 190:1449-1458, 1987.
3. Baszler TV, Evermann JF, Kaylor PS, Byington TC, Dilbeck PM: Diagnosis of naturally occurring bovine viral diarrhea virus infections in ruminants using monoclonal antibody-based immunohistochemistry. *Vet Pathol* 32:609-618, 1995.
4. Bolin SR, McLurkin AW, Cutlip RC, Coria MF: Frequency of persistent bovine viral diarrhea virus infection in selected cattle herds. *Am J Vet Res* 46:2385-2387, 1985.
5. Casaro APE, Kendrick JW, Kennedy PC: Response of the bovine fetus to bovine viral diarrhea-mucosal disease virus. *Am J Vet Res* 32:1543-1562, 1971.
6. Dubovi EJ: Laboratory diagnosis of bovine viral diarrhea virus infections. *Vet Med* 91:867-872, 1996.
7. Duffell SJ, Harkness JW: Bovine virus diarrhea – mucosal disease infection in cattle. *Vet Rec* 117:240-245, 1985.
8. Grahn TC, Fahning ML, Zemjanis R: Nature of early reproductive failure caused by bovine viral diarrhea virus. *J Am Vet Med Assoc* 185:429-432, 1984.
9. Grooms DL, Brock KV, Ward LA: Detection of bovine viral diarrhea virus in the ovaries of cattle acutely infected with bovine viral diarrhea virus. *J Vet Diag Invest* 10:125-129, 1998.
10. Houe H, Baker JC, Maes RK, Wuryastuti H, Wasito R, Ruegg PL, Lloyd JW: Prevalence of cattle persistently infected with bovine viral diarrhea virus in 20 dairy herds in two counties in central Michigan and comparison of prevalence of antibody-positive cattle among herds with different infection and vaccination status. *J Vet Diag Invest* 7:321-326, 1995.
11. Houe H, Myrup Pedersen K, Meyling A: The effect of bovine virus diarrhoea virus infection on conception rate. *Prev Vet Med* 15:117-123, 1993.
12. Howard CJ, Brownlie J, Thomas LH: Prevalence of bovine virus diarrhoea virus viremia in cattle in the UK. *Vet Rec* 119:628-629, 1986.
13. Kafi M, McGowan MR, Jillella D, Davies F, Johnston S, Kirkland PD: The effect of bovine viral diarrhoea virus (BVDV) during follicular development on the superovulatory response of cattle. *Therio* 41:223, 1994.
14. Kahrs RF: Effects of bovine viral diarrhea on the developing fetus. *J Am Vet Med Assoc* 163:877-878, 1973.
15. Kelling CL, Grotelueschen DM, Smith DR, Brodersen BW: Testing and management strategies for effective beef and dairy herd BVDV biosecurity programs. *Bov Pract* 34(1):13-22, 2000.
16. McClurkin AW, Littledike ET, Cutlip RC, Frank GH, Coria MF, Bolin SR: Production of cattle immunotolerant to bovine viral diarrhea virus. *Can J Comp Med* 48:156-161, 1984.
17. McGowan MR, Kirkland PD, Richards SG, Littlejohns IR: Increased reproductive losses in cattle infected with bovine pestivirus around the time of insemination. *Vet Rec* 133:39-43, 1993.
18. National Animal Health Monitoring System, *Part II: Reference of 1997 beef cow-calf health & health management practices.* U.S. Department of Agriculture: Animal and Plant Health Inspection Service: Veterinary Services, July 1997, p 13.
19. Njaa BL, Clark EG, Janzen E, Ellis JA, Haines DM: Diagnosis of persistent bovine viral diarrhea virus infection by immunohistochemical staining of formalin-fixed skin biopsy specimens. *J Vet Diag Invest* 12:393-399, 2000.
20. Roeder PL, Harkness JW: BVD virus infection: prospects for control. *Vet Rec* 118:143-147, 1986.
21. Rufenacht J, Schaller P, Audige L, Knutti B, Kupfer U, Peterhans E: The effect of infection with bovine viral diarrhea virus on the fertility of Swiss dairy cattle. *Therio* 56:199-210, 2001.
22. Wittum TE, Grotelueschen DM, Brock KV, Kvasnicka WG, Floyd JG, Kelling CL, Odde KG: Persistent bovine viral diarrhoea virus infection in U.S. beef herds. *Prev Vet Med* 49:83-94, 2001.