PEER REVIEWED

Integrated BVD Control Plans for Beef Operations

Daniel L. Grooms[1], *DVM, PhD;* **M. Daniel Givens**[2], *DVM, PhD;* **Michael W. Sanderson**[3], *DVM, MS;* **Bradley J. White**[3], *DVM, MS;* **Dale M. Grotelueschen**[4], *DVM, MS;* **David R. Smith**[5], *DVM, PhD*
[1]*Department of Large Animal Clinical Sciences, Michigan State University, East Lansing, MI 48824*
[2]*Departments of Pathobiology & Clinical Sciences, Auburn University, Auburn, AL 36849*
[3]*Department of Clinical Sciences, Kansas State University, Manhattan, KS 66506*
[4]*Pfizer Animal Health, Beef Cattle Veterinary Operations, Gering, NE 69341*
[5]*Department of Veterinary and Biomedical Sciences, University of Nebraska-Lincoln, Lincoln, NE 68583*
Corresponding author: Dr. Daniel L. Grooms, Michigan State University, College of Veterinary Medicine, A100 VTH, East Lansing, MI 48824, Tel: (517) 432-1494, Fax: (517) 432-1042, Email: groomsd@cvm.msu.edu

Abstract

Infection of cattle with bovine viral diarrhea virus (BVDV) can result in a wide assortment of disease manifestations. Diseases related to BVDV cause economic losses to cattle producers throughout the world due to decreased performance, loss of milk production, reproductive wastage, and increased risk of morbidity and mortality. There are three broad types of BVDV infection: acute, fetal, and persistent. It is persistent infection that is predominantly responsible for perpetuating the virus in cattle populations, and animals persistently infected with BVDV are an important target for control of transmission. The approach to BVDV control must be multidimensional, with consideration for all tools at our disposal including strategic management of the production system, diagnostic investigation, and vaccination. Decisions regarding BVDV control should factor into consideration the strategy's potential to decrease risk for transmission and its cost. Producers must first know with reasonable certainty if the virus is circulating in the herd. If the virus is found in the herd, then the appropriate actions are those that minimize the harmful effects of infection or work to eliminate the virus. If the virus is not present in the herd, then the appropriate actions are those that keep the herd free of BVDV and minimize losses should the virus be introduced. Recently, a new website was created to consolidate BVDV information in a single location on the internet: **www.bvdinfo.org**.

Keywords: bovine viral diarrhea virus, BVDV, disease control, biosecurity, persistent infection, PI

Résumé

L'infection des bovins avec le virus de la diarrhée virale bovine (BVDV) peut se manifester par plusieurs types de maladies. Les maladies associées au BVDV causent des pertes économiques aux producteurs bovins partout dans le monde car l'infection entraîne une moins bonne performance, des pertes au niveau de la production laitière et de la reproduction et un accroissement de la morbidité et de la mortalité. Il existe trois grands types d'infection au BVDV : aiguë, fœtale et persistante. L'immunotolérance, qui est associée à l'infection persistante, est responsable en grande partie de la propagation du virus dans les populations bovines et les animaux immunotolérants au BVDV sont donc une cible importante dans le contrôle de la transmission. Le contrôle du BVDV doit comporter plusieurs facettes et prendre en compte tous les outils disponibles incluant la gestion stratégique des systèmes de production, l'évaluation diagnostique et la vaccination. Les décisions sur le contrôle du BVDV devraient considérer le potentiel de la stratégie à réduire le risque de transmission et son coût. Les producteurs doivent en premier lieu savoir avec assez de certitude si le virus est présent dans le troupeau. Si le virus est présent dans le troupeau, il serait pertinent de minimiser les effets néfastes de l'infection ou bien de tenter d'éradiquer le virus. Si le virus n'est pas présent dans le troupeau, il serait pertinent d'empêcher le virus de s'y installer et de minimiser les pertes si le virus devait apparaitre. Un site web a été créé récemment afin de présenter dans un seul site internet l'information disponible sur le BVDV www.bvdinfo.org.

Introduction

More than 60 years ago an enteric disease of cattle was described in North America that was characterized by outbreaks of diarrhea and erosive lesions of the digestive tract.[17] The disease was called bovine viral diarrhea, or BVD, and the virus causing BVD was named bovine viral diarrhea virus (BVDV). Diseases in cattle resulting from infection with BVDV cause economic losses throughout the world, stemming from decreased performance, loss of milk production, reproductive wastage,

and increased risk of morbidity and mortality. Due to increasing realization of BVDV's serious impact, efforts to control this virus have been steadily increasing. As we learn more about BVDV, there is also an increasing realization that successfully controlling BVDV requires a management program that involves multiple components and is customized to fit the goals and capabilities of each producer. By developing a complete program, the risk of BVDV-associated losses can be significantly reduced.

Clinical Outcomes Associated with BVDV

Infection with BVDV can result in a wide assortment of clinical manifestations ranging from subclinical conditions to death. The clinical outcome after infection is complex and depends on a number of factors. Host factors that influence the clinical outcome include pregnancy status, gestational age of the fetus at time of infection, immune status (passive or active from natural exposure or vaccination), and the concurrent level of environmental stress at the time of infection. In addition, genetic diversity, antigenic variation, and differences in virulence among BVDV isolates may account for variations in clinical response to infection.

BVDV infections fall into three broad types: acute infection, fetal infection, and persistent infection (PI). Acute BVDV infection is often defined as infection that occurs in cattle that are not PI. Acute BVDV infection has also been referred to as "primary BVDV" and "transient BVDV" infections. Most acute BVDV infections are subclinical in nature, resulting only in mild fever and the development of antibodies. These infections often go undetected. More severe acute BVDV infections may include clinical signs of fever, depression, decreased appetite, eye and nasal discharge, oral ulcers, diarrhea, and death. Some strains of BVDV can also lead to platelet dysfunction, resulting in a bleeding syndrome. More importantly, acute infections can cause transient impairment of the immune system, thereby allowing for secondary infections to occur. This is the most important role of BVDV in the bovine respiratory disease complex ("shipping fever") in feedlots. Immunosuppression can also be important in the cow-calf setting, especially in neonates where concurrent BVDV infections have been associated with neonatal diarrhea outbreaks.[2,3]

Fetal infection occurs when a pregnant dam becomes acutely infected with BVDV or when a PI dam becomes pregnant. The result of the fetal infection depends on the virulence of the virus and the stage of gestation when infection occurs. Untoward outcomes of fetal infection include embryonic death, abortion, congenital defects, and the development of PI with BVDV.[6] Persistent infection with BVDV occurs when the fetus is exposed to virus between days 50 and 125 of gestation and survives. It is important to note that fetal infection during this window of gestation is the only known way of creating PI cattle. The calf is born a lifelong carrier of the virus and is referred to as being persistently infected, or PI. Persistently infected cattle have virus in every organ system and tissue, and shed large amounts of virus in all excretions and secretions as long as they are alive. Although PI calves can live a normal life and survive well into adulthood, most are unthrifty and end up being culled or dying before they become adults. There is no cure for PI; once a PI, always a PI, and therefore always a potential source of virus transmission.

How BVDV is Transmitted

Because PIs shed large amounts of virus their entire lives, they are considered the major source of BVDV transmission both within and between herds. Acutely infected cattle are also an important source of BVDV transmission, but the amount of virus shed is considerably lower and the length of shedding is limited. Inhalation or ingestion of virus is the most common mode of infection. The most efficient mode of transmission is direct contact with body fluids from PI cattle. Virus has been isolated from nasal swabs, aerosols, saliva, urine, feces, semen, and uterine fluids from PI cattle. Other species can become infected with BVDV and potentially serve as a source of transmission including sheep, camelids (i.e. llamas and alpacas),[15] and cervidae (i.e. deer and elk).[18] Less efficient, but important ways of transmitting BVDV include contamination of clothing, boots, and equipment including needles and nose tongs,[7] contaminated injectables,[16] and rectal sleeves.[10]

Why Control BVDV – Importance

First, BVDV causes significant losses to the cattle industry. Second, we as an industry have excellent tools, some relatively new, to greatly improve control of BVDV. Third, by using planned approaches using these tools for BVDV control and working together as an industry, we can utilize these tools to control this virus and thereby increase our ability to sustain cattle businesses and compete in domestic and foreign markets.

Production and economic losses related to BVDV span all aspects of the beef and dairy industries in North America. From a beef herd perspective, costs of PI presence have been estimated to range from $14.85 to $24.84 per year, per cow exposed to a bull in a published 10-year farm profitability model.[11] A recent study in high-risk cattle in a starter feedlot found fatality losses of $5.26, performance losses of $88.26, and costs of PI exposure in feedlot cattle ranging from $41.84 to $93.52 per animal.[8] Production and economic losses can be significant.[8,11,24]

Losses of productivity, including economic costs, extend throughout all phases of production in cattle enterprises. Pregnancy rates of cow herds with PI calves present have been measured at 5% lower than cow herds with no PI calves present.[24] Immunosuppressive effects of the virus affect animals acutely diseased with the virus. This potentiates losses from secondary infections, including bovine respiratory disease, especially in feedlots, increased risk for neonatal calf diarrhea, and other infectious diseases of cattle.[5,14,19] Control by individual operations at the cow/calf level can impact all sectors of beef production.

Cattle persistently infected with BVDV are defective individuals who adversely affect other cattle. Control strategies, especially prevention, reduce the prevalence of PI animals in cattle populations, thus decreasing their effects, costs, and risks to individual animal owners as well as the industry as a whole. It is possible that large numbers of the cattle population become exposed during their lifetime, even though PI animals are relatively rare.[12] In a recent study, a 0.4% prevalence rate of PI calves resulted in exposure to 62% of the animals in the starter feedlot population.[8] Several European countries are engaged in BVDV eradication efforts with some very near completion. It is possible that international markets in the future may favor cattle from populations where BVDV is eradicated.

Management decisions related to rising priority for BVDV control can be made using program approaches that embrace biosecurity and biocontainment principles.[22] Factors influencing selection of specific strategies include past BVDV related losses, risk for future BVDV related losses, risk tolerance, and others.

Relatively new resources, including diagnostic tests, improved vaccines, and better developed strategies for disease prevention, are key for improved BVDV control and even eradication, if chosen. Excellent tests utilizing immunohistochemistry (IHC), enzyme-linked immunosorbent assay (ELISA), and polymerase chain reaction (PCR) technologies have become readily available to the industry.[13] Vaccine development has focused on prevention of birth of PI calves, and vaccines with data and labeling related to PI prevention (fetal protection) are available. Testing alone does not eliminate all risk for BVDV infection, and vaccination alone will not prevent birth of all PI calves in the event exposure occurs. Therefore, it is critical that control strategies utilize these resources in a planned, systematic manner to achieve production and health related goals.

Components of a BVDV Control Program

Since the initial discovery of BVDV, intense research has led to a firm understanding of the virus and associated disease. Despite many unanswered questions, our current knowledge is such that successful BVDV control programs have been developed. It is clear that BVDV control needs to be multidimensional and cannot rely on one thing, such as vaccination. Therefore, BVDV control needs to be a comprehensive, programmed approach. This approach starts with first understanding the virus, its associated clinical presentations, and how it might affect an operation's productivity or ability to market animals. With this understanding, producers are better able to analyze risk and make more informed decisions. Second, it involves setting goals related to BVDV control. Thirdly, it involves using the tools currently available for BVDV control to meet those goals.

Importance of Setting Goals

The first step in a BVDV control program is to identify the final goal for the operation. Setting a reasonable target is necessary to ensure program success in both the short and long term. Initial goals may range from eliminating BVDV from a herd with an existing problem to keeping the virus from entering a herd that is currently BVDV free. Achieving these two goals may require very different diagnostic testing, vaccination, and biosecurity plans. Therefore, goals should be determined using information about the herd BVDV status, current management practices, and likelihood of future introduction of the virus (based on animal movement and biosecurity practices). If the herd BVDV status is unknown, a testing strategy to determine the presence of the virus can help optimize the control program.

Due to the nature of the disease, production targets should be based on long-term consequences of the proposed control program. When uncontrolled, the virus can persist for long periods of time in breeding herds due to the production of PI animals. Even after a control program is initiated, elimination of the virus may take until after the next breeding season. Keeping BVDV out of a negative herd is also a constant challenge; therefore, the goals of the control program should be for the herd's long-term health.

The final step in goal setting is to determine how success will be measured. Objective criteria such as performance measures, reproductive rates, number of health problems, or number of BVDV positive animals can all be used to gauge the changes the control program has made in the herd. Accurate records throughout the process can help provide information on the long-term viability of the control program.

Tools Available for Controlling BVDV

Tools available for controlling BVDV include a multitude of diagnostic tests for detecting both acute and persistent infections, vaccines available in a variety

of combinations with other important disease-causing pathogens, and biosecurity practices.

Diagnostic tests - A firm understanding of the disease is required to select the appropriate diagnostic tests, strategies, and samples and to make sound interpretations of the results. BVDV diagnostics are used for essentially two reasons. The first is to identify if BVDV is the cause of or part of a clinical problem that has been identified. A variety of diagnostic assays are available for identifying virus in blood samples taken from sick animals or tissue samples taken at necropsy.[21] The most common assays used to detect BVDV in clinically affected animals include virus isolation, fluorescent antibody assays, and PCR. In addition, detection of an immune response to BVDV (antibody titers) can be useful in situations where previous information about an animal's immune status is available. The second use of BVDV diagnostic assays, and the most important use in a BVDV control program, is for the identification of PI cattle.

Cattle PI with BVDV continuously shed large amounts of virus and serve as the major mechanism to spread the virus in the cattle population. By identifying and eliminating PIs, the risk of BVDV transmission is reduced significantly. Persistently infected cattle can be identified by detecting virus in either blood or tissue samples. Again, a variety of assays have been developed that can be used to detect PIs. The most commonly used sample for identifying PIs is skin. A small notch of skin, often taken from the ear, can be submitted to diagnostic labs where different tests can be used to detect virus. Any animal testing positive should be isolated and retested in three weeks before being classified as PI. Tests most commonly used for screening for PI cattle include IHC, antigen capture ELISA, and PCR. With the development and refinement of new technologies, such as pooled PCR, the cost of screening large numbers of animals has been reduced significantly, making it increasingly practical for producers to routinely include PI testing in their BVDV control program. A summary of currently available tests can be found in Table 1.

Vaccines - Although no vaccine is 100% efficacious, judicious use of BVDV vaccines is a sound management practice to reduce risks associated with BVDV infections.[9] Vaccination has a role in preventing acute infections that under some circumstances can result in severe disease. Under stressful conditions, cattle are more susceptible to BVDV and suffer more severe consequences. Therefore, in stressed cattle, such as calves entering a feedlot, it is beneficial to induce immunity to BVDV through immunization before onset of the stressful event(s). For reproductive herds, BVDV vaccines should be used to reduce the risk of fetal infection, including those resulting in PIs. Vaccines for BVDV should be applied in a manner that provides a high level of immunity to the dam just before breeding and throughout gestation. The ideal time to vaccinate breeding females is prior to the breeding season. Both killed and modified-live BVDV vaccines are available; both have been shown to be safe when used according to the manufacturer's label. Attributes of these vaccines are summarized in Table 2. In general, MLV vaccines are believed to be more effective and should be incorporated into vaccine programs at appropriate times. Vaccines that contain modified live, non-cytopathic BVDV should be used with caution in breeding herds as they have the potential of causing PIs. Because of their ability to stimulate greater breadth of immunity against the diverse strains of BVDV that may be encountered in the field, vaccines containing both type 1 and type 2 strains of BVDV are recommended.[4] Vaccines are manufactured in a variety of combinations to facilitate incorporation into many different management schemes.

Biosecurity - BVDV control programs need to adapt management practices to prevent or limit the introduction of BVDV into a herd. Biosecurity measures are most important for the breeding herd, but should not be overlooked in fed cattle situations. The goal of biosecurity is to greatly reduce, not necessarily eliminate, the risk of BVDV being introduced into a farm by identifying risks, understanding their importance, and then managing those risks that are most important to BVDV control.

The most common means by which BVDV is introduced to a herd is through addition of outside cattle. New herd additions may be infected acutely or PI with BVDV. Newly purchased cattle should be screened for presence of the virus and preferably isolated from the rest of the herd until test results are available. This is especially important when purchasing young stock, i.e. replacement heifers or bulls, as the prevalence of PI cattle is highest in younger animals. An important point to remember is that newly acquired pregnant cattle may test negative for BVDV, but the unborn fetus may be a PI (recall that an acute BVDV infection between days 50 and 125 of gestation can result in development of a PI fetus). Therefore, a comprehensive program should not only test dams, but also test all newborn calves.

Producers that exhibit cattle are at high risk of bringing BVDV back to their herd. Show cattle should be isolated upon return to the farm for three to four weeks. Similarly, other contact with cattle of unknown background should be considered a risk, including sharing of bulls or fence line contact with neighboring cattle.

Semen from acutely infected or PI bulls can be contaminated with BVDV and serve as a source of virus introduction into a farm. Bulls used in the commercial production of semen for artificial insemination are

screened routinely. However, bulls collected privately often are not screened for BVDV.

BVDV is not very stable outside of cattle and is susceptible to common disinfectants. However, virus has been isolated from manure up to three weeks at temperatures slightly above freezing (41°F; 5°C).[1] Thus, precautions should be taken to prevent potential BVDV contaminated objects (boots, vehicles, equipment) from entering a livestock premise.

Other ruminant species, both domestic (i.e. sheep) and wild (i.e. white-tail deer), can become infected with BVDV and potentially serve as a source of transmission.[18] With increasing evidence that wildlife can serve as a reservoir of many economically important diseases, management strategies to limit wildlife interaction with cattle should be considered.

Table 1. Summary of BVDV diagnostic tests and their uses.*

Diagnostic test	Relative cost	Specimen	Used for	Notes
Polymerase chain reaction (PCR)	Low to high	Serum, whole blood, tissue	Identifying persistently infected (PI) animals and acute infections	Rapid and sensitive. Can detect acute infections and vaccine virus within limited time frames post exposure.
Polymerase chain reaction (PCR)	Low to high	Skin - usually taken from ear	Identifying PIs	Skin samples can be pooled to reduce costs. Number per pool depends on laboratory. Rapid results.
Immunohistochemistry (IHC) of skin	Low	Skin - usually taken from ear	Identifying PIs	Fresh or formalin-fixed samples. Work closely with laboratory to provide preferred sample.
Antigen-capture ELISA (ACE)	Low	Serum or skin	Identifying PIs	Rapid results. Serum testing may be inhibited by passive immunity, thus not recommended for young calves.
Virus isolation	Moderate to high	Serum, whole blood, tissue samples – spleen, lung, small intestine (ileum), thymus	Identifying acute or persistent infections	Gold standard test for detecting BVDV; however, expensive, takes a long time to conduct, and requires specialized labs.
Virus neutralization or antibody ELISA	Low	Serum	Identification of virus exposure – NOT useful for detecting PIs	Detects immune response (titer) to BVDV.

Reason for testing	Suggested diagnostic test
Diagnosis of acute infection including: • sick animals • dead animal • abortion	• Virus isolation from tissues, serum or whole blood • PCR from tissue, serum or whole blood
Detection of PIs in calves younger than four months of age	• PCR on pooled skin samples • Skin IHC • Skin ELISA
Detection of PIs in calves older than four months of age	• PCR on pooled skin samples • Skin IHC • Skin ELISA • Blood ELISA

*Table adapted from Larson *et al*, *Bov Pract* 39:96-100, 2005.

BVDV Risk Analysis and Control

Beef cattle production is in many ways a risky business. One of the risks is disease introduction and the resultant loss of return. Risks are defined by a probability of occurrence and a magnitude of loss associated with that occurrence. The magnitude of loss is termed the impact. We can try to decrease the probability that an unwanted risk happens, or decrease the impact if it does. So for BVDV control, there is a probability that BVDV will be introduced to the herd; there is the cost of disease if it is introduced, thus the impact. There are also costs associated with attempts to decrease the probability or impact. So there are costs associated with control and costs associated with an outbreak. Risk analysis is a method to simulate the consequences of different strategies, in our case different prevention strategies, in terms of their use in controlling long-term economic risk.

The goal, then, is to identify the most appropriate strategy, which is a combination of how much that strategy decreases the risk and how much it costs. It is an interplay of both the biology (how can the risk and impact of disease be changed) and how much does it cost to get that change in risk. One way to look at it from a biosecurity and biocontainment standpoint is that we are attempting to decrease the probability of an outbreak and the magnitude should one occur. That is really a function of risk management in biosecurity and biocontainment.

Risk analysis is a way to identify the most cost-effective management to control the risk from a particular issue. Practices that are effective and economical need to be critically examined. A quantitative risk analysis approach is an attempt to rigorously evaluate which things pay and which things don't. A recently developed risk analysis model was designed to assess BVDV risk and identify optimal management strategies.[20,23]

Specifically related to BVDV, the risk for introduction into the herd occurs each year, dependent upon a ranch's management practices. There is always some risk of introducing BVDV to the herd. The actual occurrence of disease is an occasional event for most herds, but risk varies according to how the herd is managed and their import profiles. If a prevention plan is established, those costs add up every year. The ranch will pay for the prevention plan every year to control risk from the occasional outbreak. So how does one balance annual costs of prevention against occasional losses and at the same time account for the complexity of the biological system and the effectiveness and cost of prevention? One way to do that is by a risk analysis process. It is necessary to capture an appropriate amount of that complex biology, tie it together with economics, and present it in a way that is helpful in making production decisions for producers and practitioners.

The probability that an individual imported heifer is PI is low, but, multiplied by 50 imported bred heifers per year, one could expect about 20% of the time to purchase one PI heifer out of those 50. Over multiple years the probability of importing at least one PI into the herd becomes high. These heifers are pregnant, therefore there are two animals for each import, a heifer and a fetus. If 50 bred heifers are purchased every year, the probability of getting at least one PI fetus is about 25%. If 50 bred heifers are imported every year for 10 years, the probability of importing one or more PI BVD heifers or fetuses into the herd is over 95%. By participating in the fairly risky practice of importing pregnant heifers, the likelihood of importing at least one PI is high.

The likelihood of getting a PI if we import 50 pregnant heifers every year is high – but what effect will that have on productivity and profitability? Does the impact justify investing in a risk-prevention program? It is also necessary to consider how effective the risk prevention program would need to be to make it cost effective. It

Table 2. Attributes of BVDV vaccines.

Vaccine type	Advantages	Disadvantages	Notes
Killed	• Safe in all classes of cattle	• Shorter duration of immunity • Require two doses initially • May require frequent boosters	• Individual doses of killed vaccine can be aseptically removed from bottles over time.
Modified-live (MLV) or attenuated	• Rapid response • Can induce immunity with a single dose • Broader protection • Longer duration of immunity • Better efficacy for fetal protection	• Can cause abortion • Immunosuppression	• MLV vaccines must be reconstituted just prior to use and then must be used within two hours.

has to save more than it costs. Simulation can calculate the average cost of disease over 10 years and compare it to the average cost of prevention. The goal is to project over the long run how risk and interventions affect profitability and determine the most economical risk management strategies.

Following are some example herds. In all these cases we are assuming the herd does not currently include any PI cattle.

Example Herd One

The first example herd has 300 head and imports 50 pregnant replacement heifers annually for the whole 10-year run of the model. They also buy three yearling bulls every year, and from calving to weaning they are in a private pasture sharing fence line with another herd. They have over a 95% probability of introducing BVDV into the herd over 10 years if they do nothing to prevent it. The question for this herd is what biosecurity is cost-effective. Should they test and if so, who; should they vaccinate; or should they do both? The biggest risks for this herd are the import of pregnant heifers, each carrying a fetus that could be a PI, and the three yearling bulls. They bring in 103 imports each year that could introduce BVDV to the herd (heifers plus fetuses). There is also some risk from fence line exposure to the neighboring herd. The import risk is best controlled by testing the imports, including the calves of the pregnant imports following birth, and keeping them separate from the resident herd until the testing is completed. The fence line exposure is best handled by maintaining vaccination of the breeding herd to maintain high immunity against possible exposure.

Example Herd Two

The second example is a 300-head herd importing 50 non-pregnant heifers. They still import three yearling bulls and share a fence line with another herd. They have about a 70% probability of introducing BVDV into the herd over 10 years if they do nothing to prevent it. Here the risks are similar, but fewer animals are imported – specifically, there are not fetuses included in the imports so the overall risk is lower. Because herd two is managed differently than herd one, the basic level of risk is lower. Testing the imports, keeping them separate from the resident herd until testing is completed, and vaccinating the breeding herd to maintain high immunity against possible exposure, are again the best ways of controlling the risk of loss from BVDV.

Example Herd Three

Example herd three raises their own replacement heifers, imports three yearling bulls every year, and shares a fence line with another herd during the breeding season. They have about a 40% probability of introducing BVDV into the herd over 10 years if they do nothing to prevent it. They import only three animals each year and have fence line risk. Interestingly in this scenario, there are some biosecurity plans that are worse than doing nothing (the cost of the risk prevention program is more than the program can return). For example, testing the whole calf crop every year is likely to cost more over 10 years than taking chances with doing nothing. Recall this is a herd that does not have BVDV, and our sole concern is keeping it out. Equally effective strategies are to vaccinate the breeding herd or vaccinate and test imports (the three yearling bulls).

Example Herd Four

Example herd four is a 300-head herd that raises its own replacement heifers, imports three yearling bulls per year, has contact with the neighboring herds, and imports 100 stocker cattle every spring that share a fence line with the breeding herd during breeding season. This herd has risk similar to herd three except for the stockers. This herd has about a 91% probability of introducing BVDV into the herd over 10 years if they do nothing to prevent it. The majority of their risk comes from the fence line contact with the stockers. Control of this risk is most economically achieved by vaccinating the breeding herd and testing the stockers before contact with the cows. Alternately, if pastures can be managed so that the stockers and the breeding herd do not have fence line contact during the breeding season, risk can be controlled without the expense of testing.

The right BVDV risk management plan is specific to the management practices and disease status of the herd. The right plan is best determined in consultation with a veterinarian that understands BVDV, the management practices and limitations of the ranch, and the economic ramifications of recommended decisions. The risk model used to produce the results discussed here is available online at *www.bovineinfo.org* under the "Software Tools" link, and then "Cow-Calf BVD Risk Analysis Model".

Putting it all Together - Simple Targeted BVD Control

The productivity of any farm is impacted more by implementing sustainable disease control programs than by simple possession of information by the decision makers. Thus, each producer is encouraged to determine if BVDV is circulating in their herd. Methods to answer this question vary in cost and reliability (Figure 1). If BVDV is detected in the herd, producers are encouraged to implement appropriate protocols to minimize the negative impact of infection or eliminate circulating virus on the farm (Figure 1). If BVDV is not present in the herd, producers are encouraged to implement

Figure 1. Is BVDV circulating in the herd?

Methods to answer the question:

Lowest Cost & Least Reliable ↑ ↓ Highest Cost & Most Reliable

1.	Observe for clinical signs of disease.
2.	Observe for clinical signs of disease. Submit samples from all aborted and underweight calves for BVDV testing.
3+2.	Submit blood samples for antibody detection from unvaccinated sentinel animals that are ≥ 7 months of age and have experienced close contact with all other animals in the herd at least one month prior to sampling.
4+2.	Submit ear notches from young calves for validated pooled PCR testing.
5+2.	Submit ear notches from young calves for individual testing (ELISA or IHC).
6+2.	Submit ear notches from young calves, non-calving females and bulls for individual testing (ELISA or IHC).

Answer: BVDV is circulating in the herd.

Objective 1: Minimize the negative impact of infection = biocontainment.

1.	Prevent direct commingling of untested, young calves with groups of pregnant females other than their lactating dams.
2.	Prevent fence line contact of untested, young calves with groups of pregnant females other than their lactating dams.
3.	Prevent contact of imported pregnant females (< 150 days of gestation) with other animals in the herd.

Objective 2: Eliminate circulating virus from the herd = biocontainment.

Higher Cost & More Reliable

1.		Before breeding cows, submit ear notches from *previously untested* young calves, non-calving females, and bulls for individual testing (ELISA or IHC).
	a.	Submit ear notches from *previously untested* dams of all calves that tested positive.
	b.	**Remove all PI animals from the herd.**
		1. If pregnant animals are present in the herd when the last PI animal is removed, submit ear notches from all calves born within the next 12 months. Remove any positive calves from the herd. Continue testing newly born calves until 12 months elapse with no positive calves born.

Follow-up: Consider re-evaluation of question on a scheduled basis and consider vaccination to minimize the negative impact of infection (See Figure 2). Consider options to keep herd free of BVDV (outlined below).

Answer: BVDV is NOT circulating in the herd.

Objective: Keep the herd free of BVDV = biosecurity.

Least Restrictive & Least Reliable ↑ ↓ Most Restrictive & Most Reliable

1.		Observe for clinical signs of disease in imported animals before adding to the herd. Submit samples from all aborted, sick, dying and underweight calves for BVDV testing.
2.		Prevent fence line contact of imported stocker calves with pregnant females. Import bulls, pregnant replacement heifers, and non-pregnant replacement heifers into the herd only after a negative BVDV test.
3.		Import stocker calves, bulls, pregnant replacement heifers, and non-pregnant replacement heifers into the herd only after a negative BVDV test.
4.		Import stocker calves, bulls and non-pregnant replacement heifers into the herd only after a negative BVDV test and 21-day quarantine.
	a.	Pregnant replacement heifers can only be imported if they are quarantined during pregnancy and the resulting calf is tested negative by ear notch IHC or ELISA before addition to the herd.
5.		Import bulls and non-pregnant replacement heifers into the herd only after a negative BVDV test and 21-day quarantine.
6.		Only import semen cryopreserved under guidelines established by Certified Semen Services (CSS) and embryos washed according to International Embryo Transfer Society (IETS) guidelines.

Follow-up: Consider re-evaluation of question on a scheduled basis and consider vaccination of susceptible animals to ensure that BVDV does not amplify and cause significant disease if introduced into the herd (See Figure 2).

appropriate protocols to keep their herd free of BVDV (Figure 1). Producers are encouraged to consult with their veterinarian to determine the most appropriate schedule to re-evaluate the presence or absence of BVDV on the farm and reassess the most biologically appropriate and cost-effective control measures.

Selection of vaccination protocols for each farm should be based on (a) risk of disease introduction, (b) reliability of protection afforded by the vaccination protocol, (c) cost of vaccine, (d) cost of vaccine administration, (e) safety of the vaccination protocol, (f) ease with which vaccination protocols are integrated with other management procedures, (g) any temporally associated transfer of animal ownership, and (h) effectiveness of communicating the value of prior immunization. While understanding the reliability of protection afforded by vaccination protocols is critical (Figure 2), other listed factors should be carefully considered in selecting a protocol which can be implemented correctly and sustained on specific farms. In conclusion, appropriate management practices and vaccination protocols should be selected specifically for each farm to maximize animal health and profitability in the face of unique disease risk.

BVDV Resources

A large amount of information has been produced regarding BVDV disease, diagnosis, prevention, and control methods. This virus affects primarily cattle, and the impact of the disease varies based on the production and management situation. Some literature describing general information, such as the virus and diagnostic methods, can be transferred between production situations; however, biosecurity and control programs are usually specific for management systems. Finding the

Figure 2. How can vaccination for BVDV be used most effectively to minimize the negative impact of disease on a farm?

Vaccination of calves to prevent subsequent disease:

Least Reliable	1	Vaccination prior to four months of age with a single dose of killed virus administered to healthy calves that nursed adequate colostrum. **NOT RECOMMENDED**
	2	Vaccination after four months of age with a single dose of killed virus immediately before weaning, transport, and commingling. **NOT RECOMMENDED**
	3	Vaccination prior to four months of age with a single dose of modified-live virus administered to healthy calves that nursed adequate colostrum.
	4	Vaccination after four months of age with two doses of killed virus two to four weeks apart on the farm of origin with the second dose immediately before weaning, transport, and commingling.
	5	Vaccination after four months of age with a single dose of modified-live virus immediately before weaning, transport, and commingling.
	6	Vaccination after four months of age with two doses of killed virus four weeks apart on the farm of origin with the second dose at least two weeks before weaning, transport, and commingling.
	7	Vaccination after four months of age with a single dose of modified-live virus at least two weeks before weaning, transport, and commingling.
	8	Vaccination after four months of age with two doses of modified-live virus four weeks apart on the farm of origin with the second dose immediately before weaning, transport, and commingling.
Most Reliable	9	Vaccination after four months of age with two doses of modified-live virus four weeks apart on the farm of origin with the second dose at least two weeks before weaning, transport, and commingling.

Vaccination of developing heifers to prevent reproductive losses:

Least Reliable	1	Vaccination of heifers prior to breeding with a single dose of killed virus. **NOT RECOMMENDED**
	2	Vaccination of heifers with two doses of killed virus with the second dose at least 30 days before initial breeding.
	3	Vaccination of heifers with a single dose of modified-live virus at least 30 days before initial breeding.
Most Reliable	4	Vaccination of heifers with two doses of modified-live virus with the second dose at least 30 days before initial breeding.

(Figure 2 continued)

Annual revaccination of cows to prevent reproductive losses:

		Protocol #	Revaccination with a single dose of: Vaccine: Modified-live	Vaccine: Killed	Timing: Prior to breeding	Timing: Post-breeding*	After initial vaccination of heifers with: Vaccine: Modified-live	Vaccine: Killed	Doses: 1 dose	Doses: 2 doses
Least Reliable	∅	1	None					√	√	
	∅	2		√	Either			√	√	
	∅	3	None					√		√
		4	None				√		√	
		5	None				√			√
		6		√		√		√		√
		7		√	√			√		√
		8		√		√	√		√	
	§	9	√			√	√		√	
		10		√		√	√			√
	§	11	√			√	√			√
Most Reliable		12	√		√		√		√	
		13	√		√		√			√

*Post-breeding vaccination is less protective for the early fetus than vaccination prior to breeding.

∅ = Not recommended.

§ = Follow specific label directions.

Vaccination of bulls to prevent amplification and spread of virus:

Least Reliable	1	Vaccination of bulls each year prior to breeding with a single dose of killed virus. **NOT RECOMMENDED**
	2	Vaccination of bulls with two doses of killed virus with the second dose at least 30 days before initial breeding, without annual revaccination.
	3	Vaccination of bulls with a single dose of cytopathic, modified-live virus at least 30 days before initial breeding, without annual revaccination.
	4	Vaccination of bulls with two doses of cytopathic, modified-live virus with the second dose at least 30 days before initial breeding, without annual revaccination.
	5	Vaccination of bulls with two doses of killed virus with the second dose at least 30 days before initial breeding, and annual revaccination with a single dose of killed virus prior to breeding.
	6	Vaccination of bulls with a single dose of cytopathic, modified-live virus at least 30 days before initial breeding, and annual revaccination with a single dose of modified-live virus prior to breeding.
Most Reliable	7	Vaccination of bulls with two doses of cytopathic, modified-live virus with the second dose at least 30 days before initial breeding, and annual revaccination with a single dose of modified-live virus prior to breeding.

*****All vaccines should be used according to label directions. Please note that the least reliable vaccination protocols do not follow label directions. These inappropriate protocols provide no significant protection against disease.*****

right information for the correct situation is critical to implementing a successful control or elimination program.

Recently, a new website was created to consolidate BVDV information in a single location on the internet: **www.bvdinfo.org**. The goal of this website is to provide a clearinghouse for BVDV information. Members from two national committees (National Cattlemen's Beef Association BVD Working Group and Academy of Veterinary Consultants ad hoc BVD Committee) have contributed to the design and content on the site. The site contains a section for peer-reviewed manuscripts (divided by topic), non-peer reviewed articles, articles from *Bovine Veterinarian*, and links to external sites with pertinent information. The site also houses software tools that help make decisions associated with

BVDV testing or control programs. Finally, the site contains information from national BVD committees, including current position statements and schedules for upcoming meetings. This website will provide one stop for collecting valuable BVDV information to help keep producers, veterinarians, and researchers up to date on the latest information.

Conclusions

BVDV can have a significant effect on all aspects of cattle production. Research has furthered our understanding of the virus, helped develop new diagnostic tools, and refine management strategies. Cattle producers now have multiple tools to help in developing a BVDV control program. Successful control and prevention programs integrate multiple tools and do not rely on just one strategy. Successful integrated BVDV control programs will ultimately improve productivity, performance, health, welfare, and ultimately economic return.

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