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A systematic review of financial and economic assessments of bovine viral diarrhea virus (BVDV) prevention and mitigation activities worldwide

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ABSTRACT

Infection with bovine viral diarrhea virus (BVDV) results in major economic losses either directly through decreased productive performance in cattle herds or indirectly, such as through expenses for control programs. The aim of this systematic review was to review financial and/or economic assessment studies of prevention and/or mitigation activities of BVDV at national, regional and farm level worldwide. Once all predefined criteria had been met, 35 articles were included for this systematic review. Studies were analyzed with particular focus on the type of financially and/or economically-assessed prevention and/or mitigation activities. Due to the wide range of possible prevention and/or mitigation activities, these activities were grouped into five categories: i) control and/or eradication programs, ii) monitoring or surveillance, iii) prevention, iv) vaccination and v) individual culling, control and testing strategies. Additionally, the studies were analyzed according to economically-related variables such as efficiency, costs or benefits of prevention and/or mitigation activities, the applied financial and/or economic and statistical methods, the payers of prevention and/or mitigation activities, the assessed production systems, and the countries for which such evaluations are available.

Financial and/or economic assessments performed in Europe were dominated by those from the United Kingdom, which assessed mostly vaccination strategies, and Norway which primarily carried out assessments in the area of control and eradication programs; whereas among non-European countries the United States carried out the majority of financial and/or economic assessments in the area of individual culling, control and testing. More than half of all studies provided an efficiency calculation of prevention and/or mitigation activities and demonstrated whether the inherent costs of implemented activities were or were not justified. The dairy sector was three times more likely to be assessed by the countries than beef production systems. In addition, the dairy sector was approximately eight times more likely to be assessed economically with respect to prevention and/or mitigation activities than calf and youngstock production systems. Furthermore, the private sector was identified as the primary payer of prevention and/or mitigation activities.

This systematic review demonstrated a lack of studies relating to efficiency calculations, in particular at national and regional level, and the specific production systems. Thus, we confirmed the need for more well-designed studies in animal health economics in order to demonstrate that the implementation and inherent costs of BVDV prevention and/or mitigation activities are justified.

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1. Introduction

Bovine viral diarrhea virus (BVDV) is a *Pestivirus* related to both the causative agent of classical swine fever (CSF) and border disease virus (BDV), which was first described in New York in 1946 by Olafson and Rickard (1947). BVDV exists in most cattle-producing countries worldwide (Truyers et al., 2010). Infection leads to substantial costs to the private-public sector through decreased reproductive performance as direct losses, and increased control efforts as indirect losses (Otte and Chilonda, 2000). The direct losses of bovine viral diarrhea infection, such as reduced milk yield, respiratory disorders, congenital defects, growth retardation, extended calving intervals, reduced first service conception, and increased mortality of animals due to immunosuppression (Houe, 1999), can all justify the implementation of programs to prevent or mitigate the disease (Moennig et al., 2005). Prevention activities may comprise biosecurity measures aiming to prevent transmission of infection between infected and uninfected herds, i.e. by avoiding contact with PI animals (movement restrictions) and/or vaccination and/or testing of cattle before movement (Houe et al., 2006). Mitigation activities may include surveillance and intervention measures (Howe et al., 2012). Surveillance measures intend to detect the presence or demonstrate the absence of the disease (Howe et al., 2012). Intervention measures such as control or eradication programs aim at reducing disease prevalence, but differ in the degree of disease reduction (Houe et al., 2006). Control measures aim to reduce disease prevalence to a relatively low level, while the purpose of eradication is to provide a continued absence of the disease (Andrews and Langmuir, 1963; Houe et al., 2006) by testing and removal of infected cattle. The relationship between prevention, surveillance and interventions measures and avoided production losses should be considered simultaneously from an economic point of view (Howe et al., 2012). High investments in prevention activities at the farm level can lead to minor costs incurred for mitigation of the disease at the national level or vice versa. With respect to BVDV, the eradication of persistently infected (PI) animals is the primary goal of mitigation programs (Lanyon and Reichel, 2013). PI animals were infected *in utero* prior to 120 days' gestation and subsequently their immune systems fail to recognize the BVD virus as a non-self antigen (Tizard, 2009). As such, they excrete large amounts of virus, but are unable to develop specific antibodies to BVDV. PI animals are, therefore, essential in transmitting infection (Houe, 1999) and are often considered to be the primary source of BVDV introduction to a cattle herd (Niskanen et al., 2002; Smith et al., 2014; Burgstaller et al., 2016). In contrast, transiently infected (TI) cattle show mild clinical signs and shed small amounts of virus particles for a period of approximately 14 days (Brownlie et al., 1987).

It is clear that mitigation activities for nonregulated animal diseases, such as BVDV in the European Union, can vary substantially between countries (Heffernan et al., 2009) and even within a single country, if no national form of coordination exists (Geraghty et al., 2014). The degree of variation in mitigation activities depends on the perceived importance of the disease by policy makers (Heffernan et al., 2009), the geographical level at which mitigation activities are implemented (Lindberg et al., 2006; such as national, regional or farm level) and/or whether compulsory or voluntary regulations exist; all of which have an influence on the costs and benefits of the implemented measures.

The lack of economic data relating to the prevention and/or mitigation activities of animal diseases has been discussed in many veterinary studies (Drewe et al., 2012; Pinior et al., 2015a,b). As yet, no global review exists that provides information on the availability of financial and/or economic assessments with regard to BVDV prevention and/or mitigation. Thus, the aim of this systematic review was to review financial and/or economic assessment studies of prevention and/or mitigation activities of BVDV at national, regional and farm level. Studies were analyzed with particular focus on the type of financially and/or economically-assessed prevention and/or mitigation activities and financial and economic variables such as the efficiency, costs or benefits of these prevention and/or mitigation activities, the applied financial and/or economic and statistical assessment methods, the payers of prevention and/or mitigation activities, the assessed production systems, and the countries for which such assessments are available.

Table 1
Terms used for the systematic search of scientific studies.

Section	Search terms BVDV AND
Prevention and/or mitigation activities	control program/me* OR eradication*OR intervention* OR mitigation* OR surveillance* OR freedom from disease*OR biosecurity* OR Scandinavian strategy[a]
Financial and/or economic	financial impact* OR cost analysis* OR cost benefit* OR economics* OR economic models* OR expenses* OR production losses* OR disease losses

Due to the high number of studies available, the search terms "control program/me", "diseases losses" and "production losses" were set in quotation marks to ensure that the search engine returned only items where these combinations of terms were adjacent to each other.

[a] The term "Scandinavian strategy" refers to the assessment of the BVDV status of herds by monitoring BVDV herd health using serological diagnostic methods, on clearance of the virus from the herd (Lindberg and Alenius, 1999) and livestock movement controls.

2. Material and methods

In order to identify studies focusing on the economics of BVDV prevention and/or mitigation activities at national, regional or farm level, an extensive literature search with no restriction on the date of study publication was performed between December 2014 and January 2015 using the following scientific online databases: PubMed (from 1879 until present), ISI Web of Science (from 1900 until present) and Scopus (from 1960 until present). The restricted number of search terms used for this systematic review was applied to all databases and are described in Table 1. No restrictions were made with respect to article language. Depending on the original article language, multilingual authors (CF, MT, MD, SH), as well as professional translators such as from the Department of East Asian Studies, University of Vienna, assisted in the translation of a variety of articles.

In the systematic review presented here, the term "prevention and/or mitigation" referred to the following activities as described by Lindberg and Houe (2005): "prevention (biosecurity) measures, vaccination, monitoring and/or surveillance, testing and/or virus elimination measures e.g. within the context of control and/or eradication programs, and the subsidization of these activities e.g. compensation payments to the farmer for the elimination of PI animals" at national, regional and farm level. Our systematic review comprises financial and/or economic assessments of BVDV prevention and/or mitigation activities. Financial assessments focused on private entities (farm or organization level) and investigated (Otte and Chilonda, 2000), e.g. the changes of cash flows (inflow and/or outflow), repayments, income statements, balance sheet, financial returns to the private sector regarding the implementation of BVDV prevention and/or mitigation activities, whereas economic assessments determine e.g. whether investments in the prevention and/or mitigation activities are justified to a society (national level) as a whole (Otte and Chilonda, 2000).

Different financial and economic assessment methods exist, which can inform decision makers about the efficiency, costs or benefits of prevention and/or mitigation activities. Methods

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