

Efficiency of strategies to control BVDV spread within a dairy herd: assessment by simulation

Anne-France Viet, Christine Fourichon*, Henri Seegers

Abstract

At farm level, strategies available to farmers to control infection by the bovine viral-diarrhoea virus (BVDV) rely either on vaccination, or on combined test-and-cull programmes (elimination of persistently infected (PI) animals) with biosecurity actions (prevention of virus introduction and transmission). The objective was to assess ex-ante, using a model, the expected efficiency of strategies to control BVDV spread within a dairy herd without vaccination. A stochastic simulation model was developed representing horizontal and vertical virus transmission in a population structured into groups (defined by age of animals) and with a controlled size (balance between animal entry and exit). Virus transmission from herd's neighbourhood and purchase of PI animals were avoided. A single virus introduction by a heifer carrying a PI foetus was simulated. Four scenarios were studied: (1) no action, (2) prevention of virus transmission between groups of animals in the herd, (3) test-and-cull programme and (4) combination of (2) and (3). Simulation experiments were done for a typical western-France dairy herd. The duration of the virus spread (clearance was obtained when no shedding or PI-carrier animal was present anymore) and its extent (total number of animals newly infected) were compared. Whatever the scenario, very early clearance with no or very limited virus spread occurred in half of the replications or more. When virus spread existed, monitoring herds by the test-and-cull programme enabled to detect it within one year after virus introduction in 87% of the cases if virus transmission between groups was possible, whereas detection was postponed after two years if not (with increased biosecurity in the herd). In the latter situation, the probability for the herd to be already cleared at the time of detection exceeded 75%. The extent of the virus spread over 10 years was moderately reduced by the test-and-cull programme whereas prevention of contacts between groups dramatically limited the number of new infections. Scenarios (2) to (4) reduced persistence of the virus compared to scenario (1). Prevention of contacts mainly increased the probability of clearance within 2 years whereas test-and cull programme reduced the probability of herd infection lasting more than 4 years.

Keywords: bovine viral diarrhoea virus, zoo-sanitary control scheme, test-and-cull, simulation model

1. INTRODUCTION

The bovine viral-diarrhoea virus (BVDV) is widespread in many countries and induces production losses in infected herds (Houe, 1999). Different strategies to control infection by the BVDV within a herd are available to farmers: either protection by vaccination, or strategies combining monitoring, screening and elimination of Persistently Infected (PI) animals with biosecurity actions (prevention of virus introduction into the herd and of transmission between animals in the herd). Strategies without vaccination (zoo-sanitary schemes) are generally preferred in areas where the risk of new introduction of the virus in a herd is lowered by collective control programmes. The efficiency of control measures can be assessed ex-ante using epidemiological models. In the criteria of interest to evaluate the efficiency of a strategy, the ability to eliminate the virus in infected herds can be measured by the probability of clearance, the time to clearance, and the extent of infection. Among the previously published models aiming at studying the BVDV spread (Pasman et al., 1994; Sørensen et al., 1995; Innocent et al., 1997; Cherry et al., 1998; Gunn et al., 2004), two studied BVDV control by elimination of PI animals (Pasman et al., 1994; Cherry et al., 1998). Both were deterministic models and could not represent the variability of expected results. One estimated that the maximum age at which PI new-born calves should be detected and removed to obtain clearance was 11 days of age (Cherry et al., 1998). This is not applicable in field conditions with existing tests. The second concluded that elimination of PI animals was economically unattractive (Pasman et al., 1994). Screening for PI animals was based on individual testing of all animals, and did not consider the availability in dairy herds of bulk-milk testing for antibodies or virus in cows.

The objective of the present study was to investigate, by simulation, the expected effect of applicable zoo-sanitary control schemes in a dairy herd on duration and extent of BVDV infection, in a context of low risk of new infection.

2. MATERIAL AND METHODS

A stochastic simulation model was used (Viet et al., 2004). It consisted of two processes: one modelling the herd dynamics (demography, structure and management) assuming the dairy herd as a multigroup population (semi-Markov process) and the other modelling the transitions between BVDV statuses (Markov process). Animals were assumed to be raised in groups according to their age. Herd size was controlled by sale of female calves and culling, according to birth and death of animals. An individual-based approach was used to take into account individual characteristics influencing the occurrence of events (movements between groups, transitions between BVDV statuses, vertical virus transmission). The transiently infective animals were assumed to be able to transmit the virus to susceptible animals only in the same group whereas the PI animals were assumed to transmit the virus to susceptible animals both within their group and in other groups.

In the modelled herd, actions to avoid virus transmission from herd's neighbourhood were assumed to be in place. PI animals were assumed to be detected before any movement between herds and not to be sold. In such a context, the most probable remaining origin of virus introduction is the purchase of an immune dam carrying a PI foetus which cannot be detected by available tests. The virus introduction was simulated as the purchase of an immune heifer carrying a PI foetus, 20 days before calving. No virus reintroduction over time was simulated. Four scenarios representing four strategies were studied: (1) no other action, (2) prevention of contacts between animals of different groups of age, (3) test-and-cull of PI animals, and (4) combination of (2) and (3). The prevention of contacts between animals was modelled by setting transmission rates between different groups to zero. The test-and-cull programme consisted of monitoring the herd, and, in case of a positive herd result, screening for detecting and eliminating PI animals. Every 6 months, the antibody level in the bulk-milk was measured by an ELISA test. If the percentage inhibition was higher than 60% (corresponding to a prevalence of immune cows higher than 30%; Beaudeau et al., 2001), a virus spread was assumed. Then, screening for PI animals was based on consecutive combined tests for antibody and virus detection, defined per category of animals, in order to mimic existing zoo-sanitary schemes. Specificity of antibody ELISA, antigen ELISA and PCR were set to 0.978, 0.99 and 0.99, and sensibilities to 0.969, 0.97 and 1, respectively (Drew et al., 1999; Sandvik, 1999; Beaudeau et al., 2001).

The initial herd consisted of 38 cows, 13 bred heifers, 18 heifers before breeding, and 3 female calves, all of which were susceptible (all male calves were sold out at 10 days of age). The virus spread was simulated over 10 years. For each strategy, 600 replications were run.

Effects of strategies on virus elimination considered three categories of criteria:

- The interval between virus introduction in the herd and detection of infection from monitoring bulk-milk antibodies.
- The occurrence of and the time to virus clearance.
Clearance was defined as the absence in the herd of any shedding animal or dam carrying a PI foetus. The probabilities of virus persistence within the herd (as opposed to clearance) were represented by Kaplan-Meier curves. The distributions of time to clearance were compared between scenarios, stratifying by time of bulk-milk antibody detection (or level allowing detection in case of strategies with no monitoring). Herds already cleared at the time of bulk-milk antibody detection were excluded from this latter analysis.

- The extent of the infection in the herd

The total number of contaminated animals in the herd during 10 years was calculated for each replication.

3. RESULTS

Monitoring bulk-milk antibodies every 6 months allowed the detection of BVDV infection within one year after virus introduction in most cases when there were contacts between groups of animals of different ages, but could also result in very late detection (Table 1). Detection was postponed after at least 2 years when absence of contacts between groups of animals limited virus transmission within the herd. In case of late detection, the herd was often already cleared from the virus when the seroconversion of the lactating cows was evidenced.

Table 1. Number of replications per interval from virus introduction to detection of bulk-milk antibodies (out of 600 per scenario, after excluding very early clearance) and % of replications with herd not yet cleared at the time of detection

	Time from virus introduction to detection of bulk-milk antibodies - in days					
	190	370	550	730	910	1090
Test-and-cull of persistently infected animals, no increased biosecurity						
Number of replications detected	120	135	25	4	4	4
% not cleared before detection	98.3	96.3	84.0	25.0	0	0
Test-and-cull of persistently infected animals combined with prevention of contacts between groups in the herd						
Number of replications detected	0	0	0	2	178	8
% not cleared before detection	-	-	-	0	24.7	0

Clearance occurred earlier with test-and-cull programme than with do-nothing, and persistence was further reduced by prevention of contacts in the herd, especially in the first two years after virus introduction (Fig. 1). Extent of infection was only slightly reduced by test-and-cull programme, whereas prevention of contacts resulted in a drop in the number of contaminated animals (Fig. 2). Test-and-cull programme reduced time to clearance (Fig. 3 and 4). In herds still infected at time of (possible) detection of antibodies in bulk-milk, the probability of virus persistence lasting more than

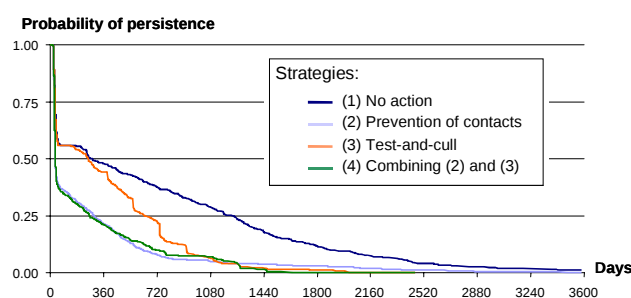


Figure 1. Probability of virus persistence for four strategies (600 replications by strategy)

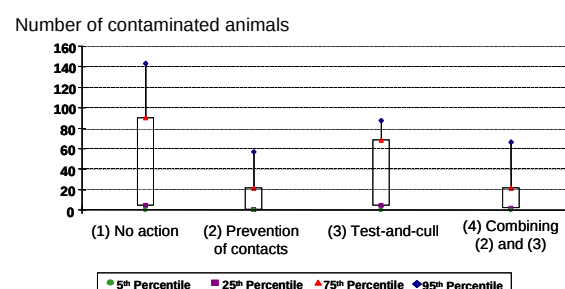


Figure 2. Extent of the infection for four strategies: number of contaminated animals during the simulated 10-year period (600 replications by strategy)

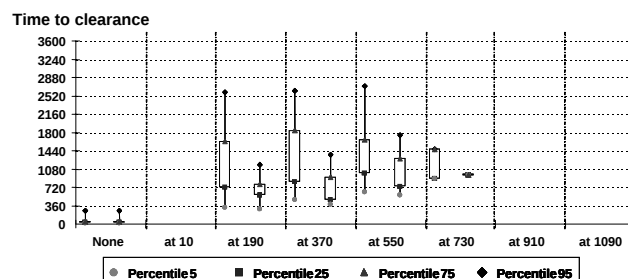


Figure 3. Time to clearance by time of detection of bulk-milk antibodies for test-and-cull (right) vs. no action (left)

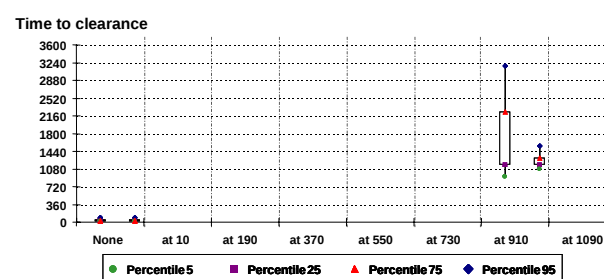


Figure 4. Time to clearance by time of detection of bulk-milk antibodies for prevention of contacts with (right) vs. without (left) test-and-cull

4 years decreased from >25% to <5%. When combined with prevention of contacts, test-and-cull programme reduced time to clearance, but later than three years after virus introduction. In this scenario, because of very early clearance or clearance before virus be detected, only 7% out of 600 replications could benefit from decreased persistence associated with test-and-cull programme.

4. DISCUSSION

After a purchase of a non-PI dam carrying a PI foetus, a zoo-sanitary scheme based on test-and-cull reduces persistence of BVDV in a herd, but this effect may be limited or delayed due to late detection of infection. If late detected, the herd is likely to be free of PI animals at cows' seroconversion. In Bretagne (Western France), PI animals were found in only 28% of seroconverting herds (Joly, unpublished data), suggesting that virus introduction may often have occurred more than one year before. Shortening virus persistence by detecting and eliminating PI animals may in fact be limited to a small proportion of cases, nevertheless at a regional level, benefits from reduced risk of virus introduction in other herds should also be considered.

Prevention of contacts between groups appears to be very efficient in limiting both duration and extent of infection, as compared to test-and-cull. Nevertheless, in many commercial herds, total prevention of contacts (assumed here) may not be possible. BVDV infection in herds where virus transmission between groups is only partly prevented could be further investigated with our model.

Outputs of the simulation model could be used for economic assessment of control strategies. Costs of the test-and-cull programme can be calculated from the number of laboratory analyses, and losses resulting from BVDV can be estimated from number and category of infected animals depending on the strategy.

5. CONCLUSION

Model simulation allows the investigation of how BVDV control strategies interact with herd management and provides relevant data to assess their technical and economic efficiencies in various herd situations. In a context of low risk of virus introduction, zoo-sanitary schemes appear to reduce overall duration of infection, but still have to be evaluated economically.

6. REFERENCES

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