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Risk-based testing of imported animals: A case study for bovine tuberculosis in The Netherlands

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ABSTRACT

In intra-EU trade, the health status of animals is warranted by issuing a health certificate after clinical inspection in the exporting country. This certificate cannot provide guarantee of absence of infection, especially not for diseases with a long incubation period and no overt clinical signs such as bovine tuberculosis (bTB). The Netherlands are officially free from bTB since 1999. However, frequent reintroductions occurred in the past 15 years through importation of infected cattle. Additional testing (AT) of imported cattle could enhance the probability of detecting an imported bTB infection in an early stage. The goal of this study was to evaluate the effectiveness of risk-based AT for bTB in cattle imported into The Netherlands.

A generic stochastic import risk model was developed that simulates introduction of infection into an importing country through importation of live animals. Main output parameters are the number of infected animals that is imported (N_{inf}), the number of infected animals that is detected by testing (N_{det}), and the economic losses incurred by importing infected animals (loss). The model was parameterized for bTB. Model calculations were optimized to either maximize N_{det} or to minimize loss.

Model results indicate that the risk of bTB introduction into The Netherlands is very high. For the current situation in which Dutch health checks on imported cattle are limited to a clinical inspection of a random sample of 5–10% of imported animals, the calculated annual N_{inf} = 99 (median value). Random AT of 8% of all imported cattle results in N_{det} = 7 (median value), while the median N_{det} = 75 if the sampling strategy for AT is optimized to maximize N_{det}. However, in the latter scenario, loss is more than twice as large as in the current situation, because only calves are tested for which cost of detection is higher than the expected gain of preventing a possible outbreak. When optimizing the sampling strategy for AT to minimize loss, only breeding and production cattle are selected for AT resulting in N_{det} = 1 (median value). Loss is; however, reduced by 75% if compared to the current situation.

We conclude that the effectiveness of AT can greatly be improved by risk-based sampling. The optimal sampling strategy for risk-based AT for bTB is highly dependent on the objective of AT. If economic losses are to be contained, AT should focus on breeding and production cattle originating from high-risk countries.

1. Introduction

The importation of live animals is a major introduction route for infectious animal diseases into regions free of disease. The Netherlands import millions of livestock each year. In 2012, for example, approximately 2.8 million livestock (pigs and ruminants) and 376 million poultry (CBS, 2014) were imported, almost all of which originated from European Union (EU) member states. In the case of intra-EU trade, the health status of imported animals is warranted by issuing a health certificate after clinical inspection of the animals in the exporting country. Additional inspection or testing by the importing country is only allowed when done randomly, i.e., no distinction is to be made between animals based on exporting country, because that would detract from the equal treatment of all member states. This certificate can; however, not provide guarantee of absence of infection, since infected animals might go unnoticed because they either do not show overt clinical signs or they are still incubating the disease.

Abbreviations: bTB, bovine tuberculosis; AT, additional testing.

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This is especially a problem for infections that have a long incubation period and that do not show overt clinical signs such as bovine tuberculosis (bTB), a chronic bacterial disease of animals and humans that is caused by *Mycobacterium bovis* (OIE, 2014a). In many countries, bTB is a major infectious disease among cattle, but also in other domesticated animals and certain wildlife populations.

The majority of EU member states is officially free from bTB (CEC, 2003). This status is obtained if for a period of ≥6 years <0.1% of the cattle herds in the country are infected (CEC, 1964, 1998). The Netherlands are officially free from bTB since 1999, but the infection was frequently reintroduced in the past 15 years by importation of infected cattle (Spierenburg et al., 2014). These cattle not only originated from EU member states that are not officially tuberculosis-free (non-OTF), but also from EU member states that are officially tuberculosis-free (OTF) (Table 1) (CEC, 2003). Two of the bTB-infections that were detected in this period could not be traced with certainty, although importation of an infected bovine was the most likely source. Apart from that, no domestic bTB-infections were detected in cattle in The Netherlands in the past 15 years.

Reintroduction of bTB brings about economic losses for the Dutch livestock sector, especially if detection is late and the infection has spread to other farms. It is impossible to completely prevent the introduction of bTB in the case of intra-EU trade. Cattle originating from non-OTF member states or non-OTF regions of member states are required to originate from a bTB-free herd and are tested before export if older than six weeks (CEC, 1964). Cattle coming from OTF member states are only clinically inspected before export. Given its extremely low sensitivity to detect a bTB infection in cattle, clinical inspection is not likely to detect animals that are infected with *M. bovis*. Additional testing (AT) of cattle imported from both OTF and non-OTF EU member states could greatly enhance the probability of detecting a bTB infection in an early stage. It would be advantageous if AT could be risk-based, i.e., only those cattle that are estimated to have a relatively high probability of being infected are tested, because diagnostic testing of all imported cattle would entail a high cost and will result in many false-positive diagnostic test results.

The goal of this study was to evaluate the effectiveness of risk-based AT for bTB in cattle imported into The Netherlands. For this purpose, we developed a generic import risk model that was used to simulate the risk of bTB introduction into The Netherlands through importation of cattle from EU member states and to evaluate the effectiveness of testing of imported animals. Model calculations were optimized to either maximize the number of bTB-infected cattle detected by AT or to minimize the economic consequences of importing bTB-infected cattle.

2. Material and methods

A stochastic import risk model was developed in Excel (Microsoft Office 2010) and @Risk 5.7.1 (Palisade Corporation, 2010) that simulates introduction of infection into an importing country through importation of live animals. An outline of the model is given in Fig. 1. Main output parameters of the model are (1) the number of infected animals that is imported (N_{inf}), (2) the number of infected animals that is detected by AT (N_{det}), and (3) the economic losses incurred by importing infected animals (loss).

In the default calculations, a random sample of the imported animals is tested with one test or a combination of tests. Model calculations can be optimized to maximize N_{det} or to minimize loss (target cells in Fig. 1). The decision parameter for optimization is the percentage of animals tested from each group of imported animals ($AT_{perc_{ij}}$, adjustable cell in Fig. 1). The constrained parameter for optimization is the total number of animals sampled (SS, constrained cell in Fig. 1), and thus indirectly the cost of testing.

The model was parameterized for the introduction of bTB into The Netherlands. All EU member states (27 in 2012) but The Netherlands were included in the model as possible countries of origin. Cattle imports were divided into three groups: breeding cattle (age >2 years), production cattle (age between 2 months and 2 years), and calves (age <2 months), assuming that different import risks are associated with these groups because of differences in destination farm and expected life span. Model calculations were performed separately for each EU member state ($i = 1, 2, ..., 26$) and each cattle group ($j = 1–3$) and results are summed where appropriate.

Although two tests are currently approved in the EU for diagnosis of bTB in cattle, viz the in vivo intradermal tuberculin test (skin test) and the in vitro γ-interferon assay (γ-IFN) (De la Rua-Domenech et al., 2006), we only performed model calculations for the skin test, because the γ-IFN is not economically feasible for testing imported cattle for bTB. On the European continent, the cervical single intradermal test (SIT) is most frequently applied; whereas, the UK and Ireland use the single intradermal comparative cervical tuberculin (SICCT) test (De la Rua-Domenech et al., 2006). In the latter both bovine tuberculin and avian tuberculin are injected and the interpretation of the test is based on the difference in reaction to both tuberculins. In our calculations we assumed that The Netherlands would use the SICCT test for AT, because it results in less false positive reactors that might be infected with, e.g., *Mycobacterium avium* spp. paratuberculosis. Full response to the skin test is only obtained 3–6 weeks post-infection (De la Rua-Domenech et al., 2006; OIE, 2014a). Therefore, delaying AT to six weeks after importation was assumed to reduce the probability of missing recent bTB infections.

Table 1
Bovine tuberculosis outbreaks in The Netherlands since 1999.

Year	Originating country	Herd type	Primary infected herds	Secondary infected herds
1999	Unknown	Dairy cattle	1	9
2002	Germany	Veal calves	1	–
2002	Ireland	Dairy cattle	1	–
2007	United Kingdom	Veal calves	1	–
2007	Belgium	Dairy cattle	1	–
2008	United Kingdom	Veal calves	6	–
2010	Poland	Veal calves	1	–
2010	Ireland	Veal calves	2	–
2010	Unknown	Dairy cattle	1	2
2011	Ireland	Veal calves	4	–
2012	Belgium	Suckling cattle	1	–
2013	Germany	Veal calves	3	–