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Evaluation of the benefit of emergency vaccination in a foot-and-mouth disease free country with low livestock density

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ABSTRACT

Foot-and-mouth disease (FMD) is highly contagious and one of the most economically devastating diseases of cloven-hoofed animals. Scientific-based preparedness about how to best control the disease in a previously FMD-free country is therefore essential for veterinary services. The present study used a spatial, stochastic epidemic simulation model to compare the effectiveness of emergency vaccination with conventional (non-vaccination) control measures in Switzerland, a low-livestock density country. Model results revealed that emergency vaccination with a radius of 3 km or 10 km around infected premises (IP) did not significantly reduce either the cumulative herd incidence or epidemic duration if started in a small epidemic situation where the number of IPs is still low. However, in a situation where the epidemic has become extensive, both the cumulative herd incidence and epidemic duration are reduced significantly if vaccination were implemented with a radius of 10 km around IPs. The effect of different levels of conventional strategy measures was also explored for the non-vaccination strategy. It was found that a lower compliance level of farmers for movement restrictions and delayed culling of IPs significantly increased both the cumulative IP incidence and epidemic duration. Contingency management should therefore focus mainly on improving conventional strategies, by increasing disease awareness and communication with stakeholders and preparedness of culling teams in countries with a livestock structure similar to Switzerland; however, emergency vaccination should be considered if there are reasons to believe that the epidemic may become extensive, such as when disease detection has been delayed and many IPs are discovered at the beginning of the epidemic.

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1. Introduction

Foot-and-mouth disease (FMD) is a viral disease of cloven-hoofed animals that occurs worldwide in many countries (World Organisation for Animal Health, 2010). The agent, FMD virus (FMDV) of the family *Picornaviridae*, genus *Aphthovirus*, is highly contagious and spreads rapidly within a naïve population. The high level of global trade

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of animals and animal products poses a persistent threat for disease-free countries (Herholz et al., 2008; Bruckner, 2011), which would suffer severe production and economic losses in the agricultural sector if FMD were introduced (Thompson et al., 2002).

The current policy to control FMD in the European Union (EU) and European Free Trade Association (EFTA) countries is culling susceptible animals in infected premises (IPs), epidemiological surveillance and movement restriction within protection (3 km around IPs) and surveillance (10 km around IPs) zones (EU legislation 2003/85/EC). Additional measures, such as pre-emptive culling or emergency vaccination, are foreseen in the legislation under specific conditions, e.g. to reduce the risk to other member states due to the geographical situation or important epidemiological contacts. For example, during the FMD epidemic in the United Kingdom (UK) in 2001, pre-emptive culling was used and supported by different simulation model results (Keeling et al., 2001; Ferguson et al., 2001a,b). However, large-scale culling was questioned, mainly by the veterinary community but also the public, and remains controversial (Kitching et al., 2005; Mansley et al., 2011). Although emergency vaccination has recently only been used once in Europe, during the FMD epidemic in The Netherlands in 2001 (Pluimers, 2004), it is widely discussed as a viable control measure (Hutber et al., 2011) and the EU recommends maintenance of vaccine and diagnostic banks to enable a rapid vaccine delivery during an epidemic (European Commission, 2010). Concern about long-term international trade restrictions after vaccination resulted in the management decision to cull vaccinated animals after the epidemic in The Netherlands. The vaccination-to-live policy potentially avoids culling vaccinated animals; however, substantial economic losses to the livestock sector can be expected in countries using the vaccination-to-live strategy due to the restrictions within the vaccination zones (EU legislation 2003/85/EC) and an extended waiting period of at least 6 months after the last case or vaccination for the recovery of free status (according to OIE standards, World Organisation for Animal Health, 2011). However, a recently published study found that the number of undetected infected animals for vaccination-to-live was not higher than for pre-emptive culling strategies after adequate final screening (Backer et al., 2012a), which supports the choice of the vaccination-to-live strategy.

Epidemic models have been used to quantify benefits of alternative FMD-control strategies, such as pre-emptive culling or emergency vaccination (Kitching et al., 2005; Hutber et al., 2011; Stevenson et al., 2013) both for the 2001 FMD outbreak in the UK (Ferguson et al., 2001a,b; Keeling et al., 2001, 2003; Hutber et al., 2006; Tildesley et al., 2006) as well as other venues (Bates et al., 2003a,c; Schoenbaum and Terry, 2003; LeMenach et al., 2005; Ward et al., 2009; Traulsen et al., 2011; Carpenter et al., 2011; Backer et al., 2012b). Most of these studies revealed a benefit of vaccination or pre-emptive culling in reducing either the epidemic or the economic impact or both, although non-beneficial vaccination in respect to the epidemic size has also been reported (Hagerman et al., 2012). Furthermore, two studies reported that in sparsely livestock-populated areas, pre-emptive culling or vaccination were not necessary to control FMD epidemics (Tomassen et al., 2002; Backer et al., 2012b).

Beyond the decision of whether or not to vaccinate if FMD were to enter a previously FMD-free country, policy makers are faced with several questions regarding the efficient implementation of vaccination, which should be answered prior to an outbreak. If a vaccination-to-live strategy were used, what species should be vaccinated? How large should the vaccination zones be? How do actions, such as reduced farmer compliance to movement restrictions or delayed culling, affect these decisions? Outbreak exercises, based on scientific evidence and practical field training, as recently conducted in Switzerland in 2011 (Anonymous, 2011), are indispensable in order to address FMD contingency planning strategies.

The present study was mandated by the Swiss Federal Veterinary Office to assist it in preparing an emergency FMDV-(serotype O) vaccination contingency plan for Switzerland, a country with small herd sizes and low livestock density. We used the Davis Animal Disease Simulation (DADS) model, which was developed to simulate FMD spread and control in California (Bates et al., 2003b; Pineda-Krch et al., 2010; Carpenter et al., 2011) and recently used to simulate the spread and control of classical swine fever in Switzerland (Durr et al., 2013). In the present study, we examined two alternative control strategies, conventional (non-vaccination) and emergency vaccination-to-live in addition to the conventional strategy. For the conventional strategy, we evaluated the effect of animal density in the region of the index premises, the level of farmers' compliance to movement restrictions and the delay of culling animals on the cumulative number of IPs and epidemic duration. For the vaccination strategy, we evaluated scenarios with different vaccination target species, vaccination zone sizes and epidemic situations. The results can be informative for FMD contingency planning in Switzerland as well as other FMD-free countries with livestock demographics similar to those of Switzerland.

2. Methods

2.1. Premises data

Switzerland has a mean livestock (cattle, sheep, goats, pigs) density of 90 per km^2 and a mean premises density of 1.3 per km^2 ranging up to 3.4 for the most dense canton (political unit of Switzerland, Fig. 1) (Swiss Federal Office for Statistics, 2011). Premises location and herd size data were available due to mandatory registration in the Swiss agriculture information system (Anonymous, 2013). Geographic and demographic information for 52,180 premises were incorporated into the model. Premise type-specific parameter values can be defined in the model and we distinguished between six premises types according to species (more than 5 animals per species) kept: dairy premises keeping only dairy cattle (n = 19,456; mean number of animals per premises = 29), beef premises keeping beef cattle, fattening calves and/or mother cows (3677; 26), small ruminant premises keeping only small ruminants (4167; 56), pig premises keeping only pigs (1244; 364), mixed

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