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Within herd transmission and evaluation of the performance of clinical and serological diagnosis of foot-and-mouth disease in partially immune cattle herds

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ABSTRACT

The control of foot-and-mouth disease (FMD) in vaccinated populations relies upon surveillance activities such as clinical inspections (CI) and serological monitoring. New evidence to refine current surveillance guidelines has been provided by evaluating (1) the diagnostic performance of CI and serological tests for detection of FMD virus (FMDV) non-structural proteins (NSP), and (2) the within-herd transmission of the virus in partially immune cattle. Data came from 23 affected herds during an epidemic of FMDV type O in Bolivia, in 2007. All cattle ($n = 957$) in these herds were clinically inspected and serum samples were collected one month after the last animal with clinical signs was detected. Samples were tested for the presence of antibodies against NSP using the PANAFTOSA 3ABC-ELISA test and a subset of samples were tested using the enzyme-linked immunoelectrotransfer blot assay (EITB). Data from clinical and serological diagnoses were analysed using a Bayesian model. The sensitivity Se and specificity Sp of the tests, as well as the prevalence and the within-herd reproduction ratio R of FMDV were estimated. In addition, risk factors for infection were identified. The Se of CI, the 3ABC-ELISA and the EITB tests were estimated to be 0.30, 0.88 and 0.96 respectively. The estimated Sp, in the same order, were 0.88, 0.93 and 0.97. The within-herd prevalence of infected animals ranged from 0.04 to 0.91 and R ranged from 1.02 to 2.68. It was observed that cattle coming from areas with high vaccination coverage had a lower risk of becoming infected than home-bred cattle from the affected herds, where vaccination coverage was thought to be low. Although these estimates come from herds kept under specific conditions, they provide a reference for future surveillance design and can inform simulation models for surveillance and control of FMD in similar cattle populations.

1. Introduction

Foot-and-mouth disease (FMD) is a viral disease of cloven-hoofed animals, it can be transmitted rapidly and cause large epidemics [1]. Therefore, FMD is considered as one of the most serious and economically significant diseases of livestock. FMD poses a continuous threat for free countries and constrains access to export markets of livestock and livestock products from endemic countries. To overcome this constraint, some countries, such as those in South America have ongoing eradication programmes based on mass vaccination, movement controls and surveillance. Active surveillance is a very important component of their surveillance system and includes serological surveys to detect FMD virus (FMDV) circulation and/or substantiate its absence. Since most of their cattle population is vaccinated, serological tests that allow the differentiation of infected from vaccinated animals are used for these surveys [2].

The design of serological surveys aimed at the detection of virus circulation requires knowledge of (1) the diagnostic parameters of the tests used and (2) the minimum prevalence (design prevalence) targeted for detection. Reliable estimates of these parameters would improve the efficacy of active surveillance. The Bolivian

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surveillance programme uses an ELISA for the detection of antibodies against FMDV non-structural proteins (NSP) as a screening test and an enzyme linked immune-electrotransfer blot assay (EITB) as a confirmatory test [2,3]. While the ELISA has been extensively validated using experimental and field data [2,4,5], validation of the EITB test has been somewhat limited, in particular with regard to the sensitivity (Se) of the EITB to detect vaccinated and infected animals [2,3,6]. In addition to serological surveys, clinical inspections are an important component of the surveillance programme [7], and, to our knowledge, the Se of clinical inspection in vaccinated and infected animals has not yet been measured.

To validate a diagnostic test, the availability of a reference "perfect" test would be ideal. Under these conditions, the accuracy of other imperfect tests can be readily determined. However, for the diagnosis of FMD no perfect test is available. To evaluate new tests, samples from experimentally infected animals have been used often as "true positive" reference materials [2,4]. Test validation under these conditions might not reflect the field situation. Hence, for a more realistic impression of test accuracy, it is preferable to collect data from the field. Yet, in the absence of a reference test the problem of correctly classifying the true disease status of animals remains. Latent class analysis [8] can help to overcome this limitation and allow the use of field data to evaluate the accuracy of a test [5]. In addition, by using this approach, the "true" prevalence of infection can be inferred and used to further investigate the infection dynamics of FMDV.

After approximately four years of absence of detectable outbreaks of FMD, five outbreaks were detected in January 2007 [9]. One of these outbreaks took place in a closed population, for which information could be gathered of individual inspections and parallel serological testing, thus, offering an opportunity to quantify the accuracy of test methods and the prevalence of FMD in vaccinated herds. This information can be used to optimise current surveillance programmes targeting detection of FMDV circulation in vaccinated populations. The objectives of this study were threefold. (1) To evaluate the diagnostic performance of clinical inspection, the 3ABC-ELISA and the EITB test for the detection of vaccinated infected animals. (2) To quantify the prevalence of infection in the affected herds. (3) To use these prevalence estimates to quantify the within-herd reproduction ratio of FMDV in vaccinated cattle.

2. Methods

2.1. Study population

Data were collected during the last FMD type "O" outbreaks in Bolivia, in January 2007 [9], from one of five reported outbreaks. This outbreak was in a Mennonite colony, and to facilitate control measures the outbreak had been treated as one epidemiological unit. A total of 23 herds (11 dairy and 12 beef cattle herds) containing 957 cattle (dairy = 285, beef = 672) were within this epidemiological unit. Clinical inspection and sampling processes made for data collection are described in Table 1.

Since the year 2000, Bolivia maintains a compulsory vaccination policy and this epidemiological unit was located in an area (municipality of Cabezas, province Cordillera, department of Santa Cruz) where mass vaccination had to be applied twice yearly. Up to the date of the outbreak, it was agreed that for Mennonite colonies that did not agree to have vaccination brigades from the veterinary service (VS) in their colonies, they would purchase the vaccine and perform vaccination themselves. Afterwards, they should report the number of animals vaccinated and the cattle population and demography for each farm within their colonies to the VS, in order to update the VS's population database and receive vaccination certificates for control during animal movements. The last mass vaccination campaign before this outbreak was conducted in July 2006. Following this campaign, a serological survey evaluating the levels of antibodies to structural proteins as correlates of protection [10], was carried out and it indicated a prevalence of protection of 83% (95% confidence intervals (CI): 75–88%) in the province of Cordillera. However, an independent evaluation of vaccination coverage (audit of vaccination certificates) showed a coverage of 63% in the municipality where this colony was located, while the average coverage in other municipalities within the department of Santa Cruz was 85% (unpublished data). Therefore, most (but not all) cattle in this colony were expected to have received one or multiple vaccinations before the outbreak.

A detailed description of the affected herds and an analysis aimed at identifying risk factors that may have had an effect on the probability of animals presenting clinical signs or becoming seropositive is presented as additional material (Supplementary information (SI) 1).

Table 1
Description of the clinical inspection and sampling processes carried out in cattle in one of the outbreaks of foot-and-mouth disease (FMD) in Bolivia 2007[a].

Outbreak timeline	Monitoring activities	Actions taken
Outbreak starts	Start control measures and clinical inspections	Quarantine. No new vaccination in the outbreak zone was made. Number of affected herds = 23 (dairy = 11, beef = 12)
Ongoing	All cattle were clinically inspected Dairy = 285, beef = 672, total = 957 cattle	Cattle clinically positive were ear tagged (identification number) and classified as 'positive' to clinical inspection Follow clinically negative cattle (did not have an ear-tag)
	Clinical inspection (once a week) cattle without ear-tag	Cattle ear tagged if positive
Last animal with clinical signs detected	Clinical inspection (once a week) remaining negative cattle	Follow for the next 2 weeks
Two weeks later	Last clinical inspection of remaining clinically negative animals (no clinical sign detected)	All these animals were ear tagged and classified 'negative' to clinical inspection
Four weeks later	All animals (n = 957) clinically inspected and blood sampled	Blood samples tested for detection of antibodies against FMD Virus non-structural proteins

[a] These is one of five reported outbreaks [9].

2.2. Diagnosis

2.2.1. Clinical diagnosis

Any animal showing lesions (large, small, fresh or old) in the mouth, or on the feet or teats, compatible with FMD, and showing lameness or salivation or having been reported showing