Epidemiologic Aspects of a Foot-and-Mouth Disease Epidemic in Cattle in Ecuador

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KEY WORDS: foot-and-mouth disease, epidemiology, cattle

ABSTRACT

A case-control study was conducted to identify herd-level risk factors associated with foot-and-mouth disease (FMD) in Ecuador. Case herds were those with presence of cattle with clinical signs of FMD and that tested positive for FMD virus during the epidemic of 2002 (n = 39). Control farms (n = 78) were selected randomly from a list of farms without a history of FMD. All study farms were visited, and managers were interviewed to complete an epidemiologic questionnaire. Feedlot operations, purchase of livestock at markets, and close proximity to markets or slaughter facilities were identified as risk factors for FMD ($P \leq 0.01$). In addition to systematic vaccination of the national herd, we recommend allocation of funds for ring-vaccination of cattle herds in close proximity to markets or slaughter facilities, and to enforce movement of vaccinated-cattle only to help control and prevent new epidemics of FMD.

INTRODUCTION

Foot-and-mouth disease (FMD) is one of the most economically important diseases affecting livestock because it can spread rapidly, impose serious losses to livestock productivity, and, most importantly, lead to severe international restrictions on trade.[1-3] Trade losses represent the largest economic consequence to a country undergoing an FMD outbreak. This is especially true for export-oriented economies. For example, in the event of an FMD outbreak in the United States, US beef and pork exports would stop overnight. Most if not all trading partners would restrict US exports of FMD-affected animals and products. It is estimated that an FMD outbreak would cost USD$12 million/day in lost gross value of trade.[4]

Inadequate animal health infrastructure and trading of livestock through informal markets have made the completion of FMD eradication in Ecuador difficult. In 2002, an epidemic of FMD (virus type O and A) of an unprecedented scale spread throughout the countryside of Ecuador in an uncompromising manner. The epidemic was characterized by widespread dissemination of disease in cattle during February-December 2002. Livestock markets were identified as potential amplifiers of the epidemic and were forced to close. Herds with clinical cases of FMD were placed under quarantine restrictions. The spatial distribution of FMD was characterized by a higher number of cases in the province of Pichincha (North Central Ecuador) (Figure 1).

Veterinary epidemiologic research on FMD has been neglected in Ecuador for many years. An epidemiologic characterization of FMD infected and non-infected farms is fundamental for formulation, implementation, and evaluation of effective control-and-eradication strategies. The purpose of the study reported here was to identify risk factors associated with FMD in cattle farms in the province of Pichincha, Ecuador during the epidemic of 2002.

Figure 1. Map of Ecuador with 21 of 22 provinces (province of Galapagos is not shown) and spatial distribution of farms with presence of cattle with clinical signs of FMD that tested positive for FMD virus in 2002. The province of Pichincha is shown in light grey background.

METHODS

This study was reviewed and approved by the University of Florida-Institutional Animal Care and Use Committee (Training Protocol N038).

Study Area

The study was conducted in the province of Pichincha where the livestock population includes approximately 500,000 cattle and 200,000 pigs (the livestock population in Ecuador includes approximately 4.5 million cattle and 1.5 million pigs). Pichincha is divided by the Andean mountain range into 2 regions: West and East. The Western region is characterized by a subtropical, hot-humid climate; the main types of livestock premises include noncommercial, backyard, dairy farms with less than 10 animals and feedlot operations. This region includes the livestock market of Santo Domingo de los Colorados, Ecuador's largest market, where an average of 3,000 livestock head are sold weekly. The Eastern region is characterized by a high-altitude (3 to 5 km or 2 to 3 miles) with a temperate climate; the main type of livestock premises is noncommercial, backyard, dairy farms with less than 10 animals. Pichincha was selected for this study based on the number of farms with clinical cases of FMD that tested positive for FMD virus, global positioning system data of farms classified as positive for FMD in 2002, availability of veterinary services, and adequate off-road transportation to visit the study farms.

Study Design

The investigation was designed as a case-control study to compare the frequency of investigated risk factors in farms that were classified as positive or negative for FMD during the epidemic of 2002. Case farms were those with presence of cattle with clinical signs of FMD and that tested positive for FMD virus (n = 39); 21 and 18 case farms were located in the Western and Eastern region of Pichincha, respectively. Control farms (n = 78; control:case ratio =

2:1; matched by region) were selected randomly from a list of farms without a history of FMD or vesicular stomatitis and located outside a 10-km radius of any farm that was classified as positive for FMD during 2002. Farms located inside the 10-km radius were not considered for inclusion as controls because, following Ecuador's FMD program guidelines, farms inside the 10-km radius of known infected farms were assumed infected or at high-risk of FMD-infection.

In order to confirm cases, field samples from lesions of suspected cases of FMD in livestock were submitted by field veterinarians to the Ministry of Public Health Laboratory in Quito. Samples were tested for diagnosis of FMD virus and vesicular stomatitis virus by using the complement fixation tube test.[5]

Data Collection

A structured questionnaire was designed, tested, and used for data collection of epidemiologic interest. All farms were visited during June-July 2003, and herd owners or managers were interviewed to complete the questionnaire. For each farm, the following data were collected: herd identification, herd size, geographic location, herd type, presence of pigs on the premises, presence of sheep on the premises, presence of goats on the premises, perimeter fence, pens, chute, own transportation for movement of livestock, cattle feeds inside the premises only, purchase of livestock, distance to closest market, and distance to closest slaughter facility (Table 1). The geographic location of farms, markets, and slaughter facilities was recorded by use of a global positioning system. Using computer records from the National Commission for Eradication of FMD in Ecuador, herd vaccination coverage was estimated as the percentage of the herd vaccinated during 2001 (0% to 100%), the year prior to the epidemic.

Data Analysis

Frequency and distribution of investigated factors were described for case and control farms. Herd vaccination coverage (mean ranks) was compared between case and control farms by using the Mann U Whitney nonparametric test. Conditional logistic regression was used to model the odds of being a case farm as a function of risk factors evaluated in the study.

RESULTS

The first case farm was diagnosed with FMD on 18 February 2002. This farm was identified as a feedlot with 235 cattle (150 bulls, 50 cows, 35 calves), purchased livestock at markets, and was located 11 km from the market of Santo Domingo; examination of vaccination records revealed that 82 animals (35%) were vaccinated against FMD in 2001.

In the univariable analysis, 9 of 14 investigated factors were identified and further analyzed for biological plausibility, magnitude of association, and statistical significance ($P \leq 0.20$) (Table 1). In the multivariable analysis (after adjusting for herd size), feedlot operations, purchase of livestock at markets, and distance from study farm to closest market or to slaughter facility were identified as risk factors for FMD (Table 2).

DISCUSSION

Overall, results from this study support the hypothesis that trade of non-vaccinated cattle and lack of enforcement of animal movement restrictions helped FMD virus move through the Ecuadorian countryside during the epidemic of 2002. In this study, selection of cases was limited to farms with a positive laboratory diagnosis of FMD. It is possible that more farms than those included in this study may have had FMD, but their identification was difficult because funding limitations of the FMD program in Ecuador precluded the investigation of all farms infected or potentially infected with FMD virus during the epidemic, such as farms located near known infected farms. Following Ecuador's FMD program guidelines, farms inside the 10-km radius were assumed infected. Control farms were limited to farms without a history of FMD or vesicular stomatitis and located outside a 10-km

Table 1. Univariable Analysis of Risk Factors Associated With Cattle Farms Affected With FMD.

Variable	Cases n = 39 (%)	Controls n = 78 (%)	Crude OR	95% CI	*P* Value
Herd size					
1-7	8 (21)	20 (26)	1.00	Reference	NA
8-22	8 (21)	23 (29)	0.96	0.29-3.18	0.94
23-51	6 (15)	23 (29)	0.77	0.19-3.04	0.71
≥52	17 (43)	12 (15)	4.02	1.15-14.05	0.02
Herd type					
Dairy	13 (33)	37 (47)	1.00	Reference	NA
Dual purpose	14 (36)	38 (49)	1.43	0.32-6.28	0.63
Feedlot	9 (23)	3 (4)	10.90	1.76-67.59	0.01
Cow-calf	3 (8)	0 (0)	ND	ND	ND
Presence of pigs on premises					
No	23 (59)	30 (38)	1.00	Reference	NA
Yes	16 (41)	48 (62)	0.43	0.19-0.95	0.03
Presence of sheep on premises					
No	37 (95)	62 (79)	1.00	Reference	NA
Yes	2 (5)	16 (21)	0.17	0.03-0.86	0.03
Presence of goats on premises					
No	39 (100)	76 (97)	1.00	Reference	NA
Yes	0 (0)	2 (3)	ND	ND	ND
Own transportation for animal movement					
No	27 (69)	61 (79)	1.00	Reference	NA
Yes	12 (31)	16 (21)	1.71	0.71-4.11	0.23
Perimeter fence					
No	7 (18)	9 (12)	1.00	Reference	NA
Yes	32 (82)	69 (88)	0.56	0.18-1.75	0.32
Corrals					
No	15 (38)	40 (51)	1.00	Reference	NA
Yes	24 (62)	38 (49)	1.75	0.77-3.96	0.17
Chute					
No	19 (49)	53 (68)	1.00	Reference	NA
Yes	20 (51)	25 (32)	2.36	1.04-5.36	0.04
Cattle feeds inside premises only					
Yes	28 (72)	61 (78)	1.00	Reference	NA
No	11 (28)	17 (22)	1.47	0.57-3.79	0.41
Purchase of livestock					
No	20 (51)	56 (72)	1.00	Reference	NA
Yes: farm-to-farm	3 (8)	12 (15)	0.68	0.17-2.68	0.59
Yes: market	15 (41)	10 (13)	4.19	1.62-10.85	< 0.01

Table 1. Univariable Analysis of Risk Factors Associated With Cattle Farms Affected With FMD. *Continued.*

Variable	Cases n = 39 (%)	Controls n = 78 (%)	Crude OR	95% CI	*P* Value
Distance from farm to closest livestock market					
31.92-47.36 km	6 (15)	23 (29)	1.00	Reference	NA
21.61-31.91 km	5 (13)	25 (32)	0.93	0.24-3.50	0.91
12.51-21.60 km	11 (28)	18 (23)	4.86	1.25-18.81	0.02
1.13-12.50 km	17 (44)	12 (15)	14.42	3.22-64.51	< 0.01
Distance from farm to closest slaughter facility					
20.42-44.59 km	3 (8)	26 (33)	1.00	Reference	NA
11.01-20.41 km	13 (33)	17 (22)	7.36	1.80-30.00	< 0.01
7.14-11.00 km	8 (21)	21 (27)	4.84	1.02-22.85	0.04
1.13-7.13 km	15 (38)	14 (18)	13.63	2.94-63.12	< 0.01
Vaccination coverage in cattle herd in 2001					
76%-100%	4 (10)	9 (12)	1.00	Reference	NA
51%-75%	1 (3)	1 (1)	2.23	0.11-44.60	0.59
0%-50%	34 (87)	68 (87)	1.13	0.31-4.08	0.85

OR = odds ratio; 95% CI = 95% confidence interval; NA = not applicable; ND = not determined.

radius of farms with presence of cattle with clinical signs of FMD and that tested positive for FMD virus during the epidemic. It is possible that selection of controls within a 10-km radius could have changed the magnitude of the associations estimated in this study. For example, one can argue that farms located inside the 10-km radius were not infected, and that the criterion for selection of controls might have "pushed" away control farms from livestock markets or slaughter facilities. If a case farm was 8 km from the market and farms were located linearly in one direction along a valley, then the control farm would be at least 18 km away from the market. Therefore, the odds ratio (OR) for this exposure factor would be overestimated. However, if we use the same example and consider the linear distance in the opposite direction (that which begins at the case farm and extends toward the market), we find that the case farm is 8 km away from the market, but the market is only 2 km away from the exclusion radius of 10 km; thus, the distance between the market and a control farm would be 2 km. Therefore, the OR for this exposure factor would be underestimated. While the 10-km radius may have caused artificial inflation in some instances, the epidemiologic analysis revealed that high risk of FMD associated with distance from farm to the closest market or slaughter facility extended beyond 10 km.

The odds of FMD were higher in feedlots. Three explanations may be considered for the observed association between feedlots and high risk of FMD. First, most feedlots in Ecuador are associated with cattle brokers who are in the business of periodically buying and selling cattle; the nature of this activity, characterized by heavy cattle trade, makes this type of operation at a high risk of FMD. Second, cattle brokers often neglect to vaccinate young cattle against FMD because they are offered for sale as soon as an economic incentive develops. Non-vaccinated calves are at high risk of FMD infection, as protective levels of maternal antibodies can last 2-3 months after birth.[6] Third, the lack of biosecurity measures at farms and markets are issues of concern for the overall success of the FMD eradication program in Ecuador. In this study, the fact that dairy farms were identi-

Table 2. Multivariable Analysis for Risk Factors Associated With Cattle Farms Affected With FMD.*

Variable	Adjusted OR	95% CI	*P* Value
Herd type			
Dairy	1.00	Reference	NA
Dual purpose	2.26	0.29-17.07	0.42
Feedlot	45.95	2.16-977.15	0.01
Cow-calf	ND	ND	ND
Purchase of livestock			
No	1.00	Reference	NA
Yes: farm-to-farm	0.64	0.09-4.53	0.65
Yes: market	10.89	1.82-65.03	<0.01
Distance from farm to closest livestock market			
>20 km	1.00	Reference	NA
11-20 km	12.46	1.60-96.70	0.01
≤10 km	39.58	3.89-402.27	<0.01
Distance from farm to closest slaughter facility			
>20 km	1.00	Reference	NA
≤20 km	25.85	1.78-373.72	0.01

*Adjusted for herd size.

fied at low risk of FMD could be explained by a low number of daily animal movements to a herd (direct contact) and indirect contacts (people or vehicles). In contrast to recent studies in the United States[3] and Uruguay,[7] where dairy farms were identified at high-risk of FMD because of greater direct contacts associated with commercial dairy farming, most dairy farms in Pichincha are noncommercial, backyard operations with less than 10 animals.

The odds of FMD were higher in farms with a history of livestock purchase at markets. During the epidemic, the market of Santo Domingo was identified by the National Commission for Eradication of FMD as a high-risk area for FMD infection and spread of infection because of heavy trade of infected or potentially infected livestock and non-vaccinated livestock. The market was closed during 14 June-8 July for cleaning and disinfection. In addition, animal movement restrictions were implemented with the assistance of the national police; admission of non-vaccinated cattle into the market was prohibited. The closure of the market was the right decision to reduce direct and indirect contacts, but too late, as the first case farm of the epidemic was diagnosed on 18 February on a feedlot located 11 km away from the market. Lack of enforcement of animal movement restrictions and local economic forces influenced the delayed decision to call for an immediate halt to animal movements following the confirmed diagnosis of FMD. Livestock markets have been previously identified as high-risk areas for FMD. In a recent study conducted in the United States, the results of an epidemic simulation model identified sale yards as the most important amplifiers of epidemics of FMD, compared to beef, dairy, swine, and goat-sheep herds.[3] Likewise, the movement of FMD-infected livestock to markets proved to be an important factor in the spread of FMD virus during the outbreaks in Great Britain and the Netherlands in 2001.[8-10]

Distance from the study farm to the closest market was associated with FMD. Markets represent a source for adequate direct or indirect contact between susceptible livestock and FMD-infected livestock. In Ecuador, it is not uncommon for producers to move cattle from one market to another in search of better prices. In particular, the market of Santo Domingo offers unique characteristics that favor spread of FMD virus transmission: it is the largest market in the country, and it offers higher prices compared to 5 additional markets in Pichincha. Furthermore, the market opens weekly on Tuesday, and it is a local tradition for producers to arrive with livestock during the weekend before the sale to buy groceries, clothing, equipment, visit relatives, etc. Livestock are kept for 1 to 3 days on leased, small pastures or corrals in premises close to the market before they are moved to the market on Tuesday. This management practice allows for both direct and indirect contact between susceptible livestock and FMD-infected livestock; a similar situation applies to other markets in Pichincha. The fact that an increasing linear trend of risk was associated with a shorter distance between study farms and markets could be explained by a higher probability of adequate direct or indirect contact between susceptible and infected livestock in that geographic area. Herd demographics, herd type, rate of contact between herds and between herds, and markets are important variables that can affect FMD virus transmission.[3,4]

Distance from the study farm to the closest slaughter facility was associated with FMD. Initial assessment of the distance between the study farm and the closest slaughter facility did not reveal a significant linear association with risk of FMD. Consequently, farms were grouped as 1 to 20 km and >20 km on the basis of the frequency distribution of median distance to simplify interpretation of the OR. This study result suggests that slaughter facilities also represent a source for adequate direct or indirect contact between susceptible livestock and FMD-infected livestock in Ecuador. For example, shipment of FMD-infected livestock to a slaughter facility during the epidemic of 2002 could have allowed for virus spread during transportation and at the slaughter facility. In addition, according to local veterinarians and producers, a slaughter facility may also serve occasionally as an informal market where the final destination of infected livestock may not necessarily be slaughter but change of ownership; this practice can lead to FMD virus transmission to susceptible herds located near this high-risk area.

It was difficult to appreciate the merit of vaccination on low risk of FMD because the frequency of vaccination coverage was very low both in case and control farms in 2001. While an important goal of Ecuador's FMD eradication plan is that 100% of the national cattle herd must be adequately vaccinated every year, the national vaccination coverage was 50% in 2000, 65% in 2001, and less than 20% in herds included in this study. The observed, moderate vaccination coverage in the national herd in 2001 and low coverage in the study herds underscore the need of effective vaccination strategies to reduce risk of FMD infection and spread of infection. It seems the national goal of vaccination coverage (100%) is not realistic, and an alternative vaccination approach must be adopted. The fact that markets and slaughter facilities were identified as high-risk areas for FMD suggest that spatial distances between herds and markets and slaughter facilities should be considered for formulation, implementation, and evaluation of control-and-eradication strategies against FMD in Ecuador. In addition to systematic vaccination of the national herd, ring-vaccination of herds in close proximity to markets or slaughter facilities shall be considered as a supplemental vaccination strategy to help control and prevent new epidemics.

ACKNOWLEDGMENTS

We thank Drs. Wandemberg Velastegui, Jaime Viteri, Javier Moncayo, Fernando Paredes, and Luis Brazales for their assistance during data collection on 117 study farms.

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