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Quantitative Analysis of Historical Foot-and-Mouth Disease Data: Identifying Return-Associated Characteristics

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Abstract

"Foot-and-mouth disease (FMD)" is extremely transmittable and has financial ramifications, it continues to be a major problem for cattle populations globally. This study analyzes historical FMD data quantitatively in-depth to identify trends, patterns and risk factors related to outbreaks. A subset of animals at the farms that housed adult dairy cattle (Farm A) and juvenile-yearling steers and heifers (Farm B) showed clinical signs of FMD, even though the cattle in these herds had received immunizations. The mature dairy cows at Farm B went extinct far faster than the younger animals at Farm A, with a mean extinction period for the carrier state of 15 months. Each month, the percentage of carrier animals will decrease by 0.02 percent. There was a temporary decline in sero-prevalence against FMDV non-structural proteins, but this was followed by a brief increase following multiple vaccinations. These results offer fresh perspectives on the host and viral elements connected to the FMDV carrier condition in the wild. The results are relevant to field veterinarians working on FMD response and control initiatives as well as government regulatory bodies.

Keywords: Persistence, Carrier, Virus, Immunizations, Veterinarians, Foot and Mouth Disease (FMD)

INTRODUCTION

The biggest illnesses afflicting cattle, FMD (foot-and-mouth disease), is cited as having a large financial impact. These effects differ depending on whether the illness is endemic or has been introduced to an area where FMD is not common (1). One of the most infectious illnesses that affect wild animals and animals with cloven hooves, such as sheep, cattle, goats and pigs, is foot-and-mouth disease (FMD). The FMD virus, known as FMDV, includes members of the family Picornaviridae and genus Aphthovirus (2). The estimated dispersion rate (EDR) is one metric used to forecast outbreak trends. The average number of herds or locations that each sick herd brings a disease agent is known as the disease's dissemination rate (3). Many animals with cloven hooves are prone to FMDV infection, which has a detrimental effect on the profitability of the cattle business. Animals with FMDV infection exhibit vesicles surrounding their mouths, noses, mammary glands and feet as lesions. The ability of FMD to spread to one or more additional species and its persistent infection in ruminant species make the disease difficult to treat (4). Models that forecast pathogen spread and evaluate the possible efficacy of control measures can improve preparedness for infectious disease outbreaks. The validity of these models hinges on the clarification of crucial epidemiological factors about the disease, coupled with a profound comprehension of the dynamics of illness transmission in vulnerable groups and the impact of intervention tactics on impeding disease dissemination (5). Illness mapping and qualitative risk assessment have shown to be beneficial in circumstances when data is limited, which is prevalent in developing nations and lacks quantitative data on potential risk variables, such as the distribution of farms, livestock and animals, among other things (6). Treating new and trans-boundary infectious diseases like FMD and Ebola hemorrhagic fever requires a thorough understanding of the transmission network modeling of infectious disease epidemics, a topic of active research. Numerous dynamic models have been created that reconstruct the network of individuals infected during epidemics using genetic and epidemiological data (7). The infectious diseases pose a major threat to international trade, financial stability and food security in many nations. Trans-boundary animal diseases

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(TADs) can spread to countries where they are not present and their control or management necessitates collaboration among multiple nations (8). Enteroviruses, including coxsackievirus-A16 (CoxA16), enterovirus 71 (EV71) and others are the cause of this illness. Usually, fecal–oral or direct contact with an infected individual or their possessions is how the virus spreads. Typical signs of HFMD include mouth pain, maculopapular rash, oral mucosal ulcers and blisters that emerge on the hands, feet, as well as buttocks (9). Many animals with cloven hooves are susceptible to FMD, one of the most contagious animal illnesses. Rich nations increased research and funding on FMD in the early 20th century and by the century's conclusion, they had the disease under control (10).

The study (11) provides quantitative proof of livestock transportation's ability to anticipate FMD epidemics. Using this method could assist decision-makers in creating plans for FMD prevention and control. A quantitative research was conducted to determine the probability of FMD viral release from five of the biggest commercial bull studs that contaminated frozen processed semen. More recent statistics are included in the technique, which was modified to better reflect the US production system (12). The monthly frequency of FMD outbreaks was estimated and predicted in the study using a range of time-series modeling techniques. Error trend seasonality (ETS), Trend and Seasonal components (TBATS), ARMA errors and hybrid approaches (13). The study's (14) two mathematical models are specially designed for confined and unconfined situations in Namibia to provide a thorough analysis of FMD. Important compartments in the models employed show the complicated interactions of animal populations, including the possibility of FMD in them, recuperation, concealed exposure and contagiousness. The study (15) provides an analysis of the genetic characteristics of the CV-A16 strains that were isolated from Indian patients suffering from hand, foot and mouth disease (HFMD). The 55 clinical samples were subjected to reverse transcription PCR (RT-PCR) and isolated CV-A16 using cell culture. All seven isolates were used to do a comprehensive genomic study of the CV-A16 strain. Bioinformatics techniques were used to generate a phylogenetic tree following the analysis of the sequences. The research (16) provided insight into the optimal timing and location for applying control measures to prevent and control food-borne illness. When creating risk-defined regional management plans, the current livestock production including rural livestock, livestock commerce between provinces and uncontrolled animal movements in border regions should be taken into account. The findings (17) suggest that various strategies are needed in different regions to contain an FMD outbreak. Less stringent control methods were sufficient in an area with a low farm density to contain the generally moderate outbreaks. The study (18) asserts that there is no chance of FMDV entering the FMD-free area created by bone-in cattle, swine, goats, or sheep, without immunization under specific circumstances, such as serological testing. Compared to the existing situation of forbidding the introduction, the incoming danger might even be smaller if lawful trade was permitted. The livelihoods of herders have been adversely affected by the FMD outbreaks and existing management methods, which is likely to decrease stakeholder advocacy. There were discovered several tactics that might be used to lessen the adverse consequences of the current control program (19). FMD is a danger to livestock populations and agricultural industries around the world due to its recurring recurrence. There is a knowledge vacuum on the precise traits and triggers of future FMD epidemics, despite intensive attempts to manage and control the disease. This research challenge uses quantitative analysis of historical FMD data to identify characteristics is linked to returns in an attempt to identify trends and variables that could be related to the disease's gradual recurrence. The inability to understand the mechanisms underlying FMD recurrence poses a challenge to the development of targeted preventative medicines. Conducting a thorough quantitative examination of the parameters associated with returns is necessary to improve our capacity to predict, contain and manage future outbreaks of FMD.

MATERIALS AND METHODS

The quantitative analysis of historical FMD data to identify characteristics linked to returns is covered in this section. A quantitative technique is used to extract relevant insights from the analysis of historical data on FMD with an emphasis on return-associated factors.

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Dataset

Twelve crossbred cows were chosen for two groups based on factors such as age, parity and number of days in milk. With a mean of 67.6 months, the age varied from 35.1 to 101.2 months and the parity varied from one to three. There was a range of 64 to 180 days in milk. A licensed veterinarian performed a general health examination prior to the experiment's start, ruling out subclinical mastitis in the chosen cows (20).

Clinical Setting for Hand, Foot and Mouth Disease Cases

The clinical severity at admission determines the five separate stages into which HFMD cases are classified: Stage 1 comprises people who have a fever, herpangina, isolated exanthem and eruptions on their hands, feet, lips and buttocks. Acute flaccid paralysis, aseptic meningitis and encephalitis are a few instances of stage 2 central nervous system (CNS) involvement. Clinical symptoms include sucking weakness, headaches, lethargy, limb tremors, nausea, agitation, nuchal rigidity and a high tolerance for shock. People with dysregulation of the autonomic nerve system (ANS) are classified as stage 3. Hypertension, cold extremities, excessive perspiration and resting tachycardia are examples of clinical symptoms. People in stage 5 are those whose heart and brain functions have improved, while neurological after effects might occasionally linger. Individuals in stage 4 are characterized by bradycardia or tachycardia, hypotension, tachypnea, cyanosis, coughing up pink, frothy, or even bloody sputum, a history of recurrent seizures and profound unconsciousness. Patients in stages 2 through 5 are regarded as critical cases.

Experiment on animals

A trivalent inactivated FMDV vaccine was administered to animals at both farms twice a year to protect them against FMD before the outbreak began. The most recent vaccination occurred three to four days before the outbreaks started. An earlier multiplex Polymerase Chain Reaction (PCR) investigation has shown a correlation between FMDV serotype O and the outbreaks observed here. More information about the clinical, antigenic and genomic characteristics of the FMDV isolates from the farms under examination has been published. In April 2020, around seven months after the outbreaks began; sample collection for the previously mentioned study began. The selection of study animals was contingent upon animal availability and operational logistical considerations. Among the clinically afflicted animals, vesiculoerosive stomatitis, pododermatitis, fever and in-appetence were among the signs of FMD. Samples were taken from Farms A and B's 6 adult cows and 6 young cattle, respectively. Every animal provided samples of its serum and oropharyngeal fluid. Throughout the sample period, which began at the beginning of the outbreak and ended at the beginning of the sampling, no additional clinical cases were reported.

RESULTS AND DISCUSSION

6 out of the 12 cows were tested positive for FMDV and samples of oropharyngeal fluid were found to contain viral RNA. All the other animals that were part of the analysis were assumed to have contracted the disease at the time of the outbreak, even though it was discovered through later samplings that the remaining animals were carriers. Every member of the carrier state perished before the study's conclusion, with an average extinction length of 15 months for the carrier state on both farms. The extinction times for Farms A and B were, on average, 14.5 and 15.6 months and, on the median, 12 and 9 months. Table (1) and Figure (1) present the number of cases of HFMD from 2018 to 2022.

Table (1). Number of cases of HDMD from 2018 to 2022
(Source: Author)

Years	Cases
2018	1500
2019	3000
2020	1000
2021	2000
2022	6500

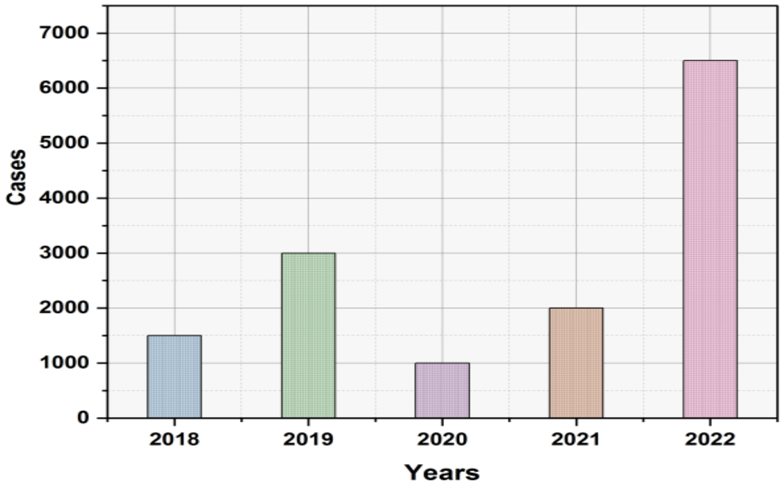

Figure (1). Cases of HDMD between 2018 and 2022
(Source: Author)

The extinction rates of Farm B were higher than those of Farm A. The extinction rates of animals with clinical indicators throughout the outbreak did not show a significant difference when compared to animals with no symptoms. The percentage of carrier animals was found to be declining at a rate of 0.07 each month. Around 14 months and 11 months, respectively, 45% and 49% of the carriers were able to resist infection; at these months, the proportion of carrier animals reduced considerably. More field and experimental research is required to evaluate the biological mechanisms that underlie these events and investigate the differences in FMDV carrier state durations among age groups. The results of this study regarding the extinction trend differ with those of an earlier meta-analysis, results showed a consistent decline in the percentage of positive animals housed in labs. The study's total rate was comparable to the 0.11 monthly rates found in the earlier research. There is no known cause for this abrupt decline in carrier prevalence; there are a few areas where field-based and experimental research could diverge. Several contributing factors could account for the animals at Farm A having lower titers following vaccination and illness. The initial four to five months of protection from the inactivated FMDV vaccines that are developed in India are anticipated to be improved with successive shots. Cattle from Farm B are believed to be better protected than those from Farm A since they are older and have received booster doses for a longer period of time. Farm A's younger animals not have received as many vaccinations as Farm B's, making them less protected. Table (2) and Figure (2) illustrate the survival probability of the FMDV carrier stage in animals.

Table (2). Survival Probability of FMDV carrier stage in animals
(Source: Author)

Months	Farm A	Farm B
5	1.2	1.2
9	0.7	0.9
12	0.8	0.5
16	0.6	0.5
17	0.3	0.4
18	0.1	0.3

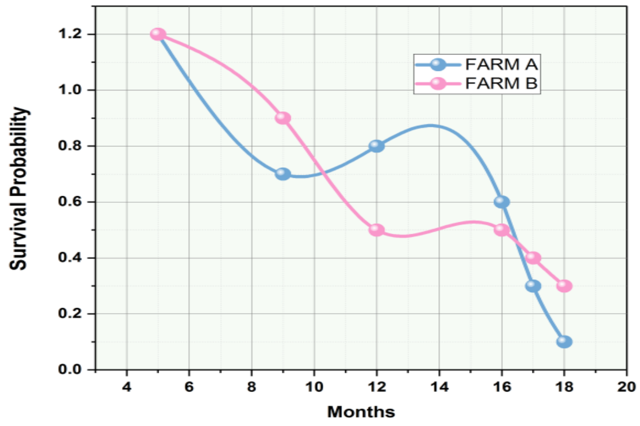

Figure (2). Animals' chances of surviving the FMDV carrier stage
(Source: Author)

Table (3) and Figure (3) show the number of FMDV vaccination doses administered between 2018 and 2022.

Table (3). Number of FMDV vaccine doses administered in 2018 to 2022
(Source: Author)

Years	Doses
2018	5000
2019	5200
2020	7600
2021	8200
2022	9600

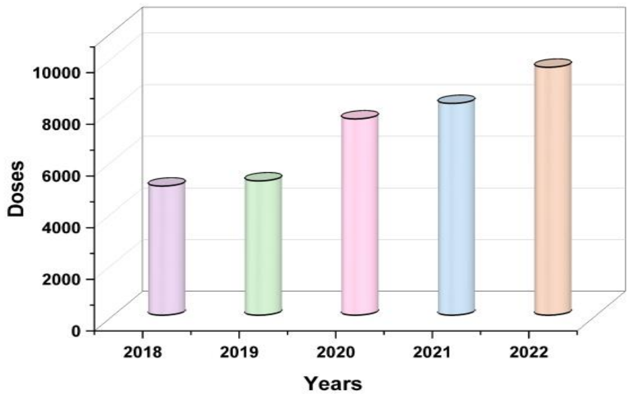

Figure (3). Number of doses of the FMDV vaccination given between 2018 and 2022
(Source: Author)

DISCUSSION

Effective control of infectious disease outbreaks involves identifying affected individuals and minimizing risks that could otherwise result in widespread infection. In the event of no epidemic, data-driven mathematical models that predict the rate of disease transmission and the outcomes of control measures might facilitate planning and preparation. Such modeling's ultimate objective is to direct and evaluate the effectiveness of control tactics to reduce the effects of disease, measured as economic loss, morbidity, or other pertinent metrics.

The findings presented here offer fresh perspectives on the length of time an FMDV carrier state lasts as well as the serological traits of immunized Indian cattle in their native environment. Government organizations, field veterinarians and modelers developing procedures for the management of food-borne illnesses will find considerable use in these data, which are unique in the literature. In particular, it is crucial to understand how long it takes for FMDV to eradicate itself from carrier animals during an epidemic.

To improve FMD control in India and other endemic locations, more epidemiological and experimental research is required to clarify the mechanisms underlying the findings provided here.

CONCLUSION

In this study, the quantitative examination of historical FMD data offers important new understandings of the dynamics of the illness and possible patterns of recurrence. This study attempted to identify patterns as well as variables linked to the recurrence of FMD outbreaks using data-driven methodologies and strict statistical techniques. The quantitative study helps to manage and prevent FMD by elucidating parameters related to returns. By reducing the impact of FMD on livestock and agricultural economies, specific measures can be developed with the help of the insights gathered from this study. Future studies in this domain will lead to a more comprehensive and proactive strategy for treating FMD and reducing its effects on livestock coupled with the world's food security.

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