A web-based system for near real-time surveillance and space-time cluster analysis of foot-and-mouth disease and other animal diseases ☆

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ABSTRACT

Considerable attention has been given lately to the need for global systems for animal disease surveillance that support real-time assessment of changing temporal-spatial risks. Until recently, however, prospects for development of such systems have been limited by the lack of informatics tools and an overarching collaboration framework to enable real-time data capturing, sharing, analysis, and related decision-making. In this paper, we present some of the tools of the FMD BioPortal System (www.fmd.ucdavis.edu/bioportal), which is a web-based system that facilitates near real-time information sharing, visualization, and advanced space-time cluster analysis for foot-and-mouth disease (FMD). Using this system, FMD information that is collected and maintained at various data acquisition and management sites around the world can be submitted to a data repository using various mutually agreed upon Extensible Markup Language (XML) formats, including Health Level Seven (HL7). FMD BioPortal makes available a set of advanced space-time cluster analysis techniques, including scan statistic-based methods and machine learning-based clustering methods. These techniques are aimed at identifying local clusters of disease cases in relation to the background risk. Data and analysis results can be displayed using a novel visualization environment, which supports multiple views including GIS, timeline, and periodical patterns. All FMD BioPortal functionalities are accessible through the Web and data confidentiality can be secured through user access control and computer network security techniques such as Secure Sockets Layer (SSL). FMD BioPortal is currently operational with limited data routinely collected by the Office International des Epizooties, the GenBank, the FMD World Reference Laboratory in Pirbright, and by the FMD Laboratory at the University of California in Davis. Here we describe technical attributes and capabilities of FMD BioPortal and illustrate its functionality by analyzing and displaying information from a simulated FMD epidemic in California.

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1. Introduction

Foot-and-mouth disease (FMD) is a highly infectious disease of cloven-hoofed mammals caused by a virus of the family *Picornaviridae*, which is generally referred to as the FMD virus (FMDV). FMD is considered to be one of the most infectious diseases of livestock. The disease is spread by

transmission of virus through direct contact between animals and by indirect contact with fomites containing infectious virus particles, such as contaminated vehicles, feed, or clothing of livestock personnel. Airborne spread of the virus is also possible. FMD imposes severe and far-reaching economic consequences for countries that acquire the disease. Economic impact of FMD is associated with direct costs due to decrease in the productive performance of infected animals and indirect costs derived from disease prevention and control activities, and from international restrictions of exports from infected countries and regions. For example, it has been estimated that the cost of the FMD epidemic that the United Kingdom experienced in 2001 was more than USD 15 billion, including compensation paid to farmers, cost for cleaning and disinfecting, support for businesses impacted by the outbreak, legal claims, decline in tourism, and mental health assistance (UK National Audit Office, 2002).

To eliminate or decrease the social and economic impact of FMD, countries develop programs to control and eventually eradicate the disease or to prevent FMDV incursions into the country. Programs for control and prevention of FMD generally apply strategies of diagnostic screening, movement restrictions, quarantine, and in some cases, vaccination and strategic culling of susceptible animals. Increasingly, there is a recognized need for countries and agencies to have regional and global situational awareness of FMD and to be able to anticipate new incursions of FMD, or of new FMDV strains, or an increase in the risk of an FMD incursion, so that appropriate measures can be taken in advance to prevent or mitigate disease and its impact. One of the strategies for early detection of and response to FMD is that of surveillance, both at a national and at a global level, that would aim to seek out specific information about FMD, risks of FMD, and the FMD virus that is needed by the international community and by individual countries in planning and preparing FMD programs.

In veterinary medicine, surveillance has been defined as "an active, ongoing, formal, and systematic process aimed at early detection of a specific disease or agent in a population or at early prediction of elevated risk of a population acquiring an infectious disease, with a pre-specified action that would follow detection of the disease, agent, or elevated risk" (Thurmond, 2003). An effective surveillance system has the ability to collect and process information rapidly, minimizing the time between collection of information and communication of findings to decision makers and stakeholders, who can then act to control or prevent the spread of disease. One general goal of surveillance is to identify new or emerging risks, including those that could be characterized by temporal and spatial clusters of disease. Other goals include development of optimal systems or strategies for sampling, collection of data and information, and performing data analysis. The primary objective is to maximize early virus detection or early detection of an elevated risk (temporal sensitivity), while minimizing false alarms.

A fundamental element of surveillance is how well the system can provide information rapidly in order to allow necessary planning and preparation for control and prevention to begin immediately. For this reason it is critical for a surveillance system to be able to provide information and results of analysis of the information to those who are responsible for planning and implementing programs to prevent and control FMD in approximate real-time, also commonly referred to as near real-time in informatics technology. One of the greatest problems facing development of surveillance systems, however, is that data collection, analysis and communication of the results for real-time, or near real-time decision-making, is limited by the lack of real-time information systems that utilize informatics and communication tools. Currently, systems do not exist that allow routing of data among and between laboratories, field veterinarians, farmers, and decision makers.

In this paper we describe some of the technological capabilities of a new near real-time surveillance information system, referred to as the FMD BioPortal, which is currently operational for global FMD surveillance. FMD BioPortal is aimed at providing real-time information, analysis, and visualization of FMD surveillance-type data. The objective of this paper is to describe key features of the FMD BioPortal, including design and functionality of tools and methods for visualization and analysis of georeferenced data. It is also an objective of this paper to discuss concepts and considerations for global FMD surveillance function and operation, which hopefully will encourage advancement in formalizing international surveillance efforts for FMD and for other animal diseases.

2. Methods

2.1. Current version of FMD BioPortal

The current version of FMD BioPortal (FMD Bioportal 2.0) was developed as a collaborative effort of the Institute for Animal Health (the FMD World Reference Laboratory) at Pirbright, England, the Artificial Intelligence Laboratory at the University of Arizona, and the FMD Laboratory at the University of California, Davis. Version 1.0 was made operational in January, 2007 (see: http://fmd.ucdavis.edu/bioportal/). The initial goal was to create a web-based system that would make available via the web and in near real-time those non-sensitive FMD-related data that are of interest to governments, agencies, researchers, and academic institutions. A primary objective was to be able to apply to the data basic search and analytic tools, including graphic and tabular presentation of the data and cluster analysis, and to be able to download selected records. Generally, data represent results of laboratory testing of submissions from OIE-member countries with ongoing programs to control and eradicate FMD. Data available include the outbreak location and time of onset, information about the host or host species, and the serotype of the virus involved in the outbreak. The data send command is initiated at the source of the data and directed to the FMD Lab at UC Davis, which is a process commonly referred to as 'pushing' in informatics technology (Finin et al., 1997). There is a 3-to-6 months delay in acquisition of data to provide countries time to address changes in their FMD