agriculture

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Application of Surveillance Principles in the Progressive Control Pathway for Global Control of Foot-and-Mouth Disease

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Abstract: Progressive control pathways provide a stepwise, measurable approach to disease control. Documenting program progress, assessing intervention efforts, and the achievement of interim outcomes depend on the capability of a surveillance system to provide useful information. We demonstrate a practical surveillance approach that progresses from measuring broad disease epidemiology and risk factors to specifically evaluating intervention options and documenting low disease prevalence. The process focusses on aligning components with disease program outcomes using foot-and-mouth disease as an example.

Keywords: surveillance; surveillance system; progressive control pathway; foot-and-mouth disease; global strategy

Citation: Metwally, S.; Wagner, B.; Salman, M.; Drewe, J.A.; Ferrari, G.; McLaws, M.; Gonzales, J.L. Application of Surveillance Principles in the Progressive Control Pathway for Global Control of Foot-and-Mouth Disease. *Agriculture* **2023**, *13*, 994. https://doi.org/10.3390/agriculture13050994

Academic Editor: Nicole Kemper

Received: 31 March 2023
Revised: 13 April 2023
Accepted: 20 April 2023
Published: 30 April 2023

1. Introduction

Foot-and-mouth disease (FMD) is a transboundary animal disease affecting cloven-hoofed animals in Asia, Africa, and the Middle East and sporadically in northern South America. The Food and Agriculture Organization (FAO) and the World Organisation for Animal Health (WOAH) developed a 15-year global control strategy in 2012 to reduce the burden of FMD in endemic and to maintain the status of FMD-free countries [1].

The Progressive Control Pathway for Foot-and-Mouth Disease (PCP-FMD) is used as the main tool for the implementation of component 1 of the global strategy [2]. The PCP-FMD was developed by FAO and the European Commission for the Control of Foot-and-Mouth Disease (EuFMD) and further endorsed by WOAH. The PCP-FMD is a risk and evidence-based framework guiding endemic countries to progressively improve the management of FMD risks and reduce disease impacts and viral circulation. Although similar progressive control pathways have been developed for other diseases (e.g., peste des petits ruminants: PPR [3]), the PCP-FMD serves as an established example for progressive control processes. The reason for framing efforts to prevent and control diseases such as FMD and PPR into a progressive pathway was to provide intermediate objectives toward achieving WOAH freedom status that could be measured against established indicators, especially for countries where such diseases are endemic.

The collection of reliable surveillance data is critical for documenting progress and guiding decision processes that drive the PCP-FMD and other transboundary animal disease (TAD) programs. Animal health surveillance can be defined as *the systematic, continuous, or repeated measurement, collection, collation, analysis, interpretation, and timely dissemination of animal-health-related data from defined populations, for the purposes of taking action*

to control disease [definition adapted from [4]. Collection, analysis, and reporting of animal health data for effective control or eradication depend on a reliable integrated surveillance system. In all stages of the PCP-FMD, surveillance planning and implementation are linked with progressive prevention and control activities for TADs.

The aim of this paper is to emphasize the importance of a surveillance system as part of implementing the progressive disease control pathway (PCP) approach to disease control, using the PCP-FMD as a model. The intention is to demonstrate the application of building a link between PCP outcomes and surveillance system design. This paper focuses on linking outcomes and surveillance design in the first PCP-FMD stage with some discussion of changes in a surveillance system with changing PCP-FMD outcomes in later stages.

This paper is a summary of a full FAO guiding document entitled 'Practical Surveillance Guidelines for the Progressive Control of Foot and Mouth Disease and Other Transboundary Animal Diseases' that describes in more detail the surveillance systems in the first three stages of the PCP-FMD [5].

2. Importance of a Surveillance System in a Progressive Control Pathway

The role of a surveillance system in the attainment of disease control strategic and operational goals is extremely important [6]. Without a well-designed, practical, and effective surveillance system, it is difficult to achieve and document disease control progress.

A surveillance system must accomplish three primary objectives in the context of a PCP. Firstly, information generated from surveillance activities should allow countries to design and critically evaluate current prevention and control efforts by providing both baseline and updated information to measure progress over time and to identify and assess disease risks. Secondly, as control progresses, the surveillance system must be able to provide consolidated data and information to both domestic and international groups to substantiate movement along the pathway. The need for a practical approach suggests an evolving purpose of surveillance, starting with the goal of identifying information gaps and developing hypotheses on disease maintenance in the initial stages to assessing the disease control interventions in later stages. Thirdly, the system must be flexible to accommodate disease program progress and changes in disease status.

Surveillance systems are composed of specific activities used to investigate one or more pathogens in a target population [7,8]. Within surveillance systems, several components may need to be implemented to meet the individual needs of national or targeted populations, taking into account the ecology of the diseases under consideration and geopolitical considerations.

Each PCP stage is well delineated and flows from one stage to the next. Similarly, the surveillance goals and activities must be well defined and strategically managed to align with prevention and control measures and, specifically, provide scientific support for PCP outcomes. There are important overarching surveillance concepts to consider for this alignment. First, most surveillance components within the surveillance system are important in all PCP stages. Some of these consistently utilized surveillance components may be modified to address new surveillance goals but, in some instances, some components may be largely unchanged over time. Secondly, the design of surveillance should receive practical consideration given that the primary goal of surveillance is to provide useful information in the disease management decision process. Flexibility is important since circumstances that drive the design of surveillance vary greatly depending on the existing situation in the country and change over time. The need for a practical approach suggests a focus on balancing the value of high-quality information with precision (sample size and confidence associated with estimates). In the preliminary PCP stages, the added value of collected information, even with limited sample size or confidence, should be considered. As progress in eradicating PCP is attained, the need for precise evaluation of prevention and control measures may suggest the need for more complex and resource-intensive surveillance activities.

3. Surveillance Modality in Achieving the PCP-FMD Stage 1 Outcomes (An Example)

The purpose of PCP-FMD Stage 1 is to understand the ecology and epidemiology of FMD to develop an approach to reducing the disease impact. During Stage 1, surveillance activities are implemented to systematically collect and analyze all relevant baseline information.

Surveillance should generate information to support the defined PCP-FMD outcomes. Nine outcomes are defined in PCP-FMD Stage 1 to guide countries in completing the stage [2]. Three of the nine outcomes depend directly on surveillance results (Table 1). For example, the first outcome of PCP-FMD Stage 1, understanding the distribution of FMD in the country, depends heavily on information obtained from implemented surveillance components, including outbreak patterns, serosurveys, and participatory surveillance. Survey components can provide information to support more than a single outcome.

Table 1. The relationship of PCP-FMD Stage 1 outcomes with surveillance.

PCP-FMD Stage 1 Outcome	Surveillance Relationship with PCP Outcome
The distribution of FMD in the country is well described and understood.	Collation of FMD outbreak reporting from all regions/areas in the country through farmer disease reporting/passive surveillance Representative surveys (e.g., serological survey to assess seroprevalence to FMD virus in different husbandry and/or production systems, non-structural protein (NSP) survey) Participatory epidemiologic studies
The most common circulating strains of FMDV have been identified.	Outbreak investigation and sample collection from different production sectors for diagnostic analysis Samples shipped regularly to a WOAH/FAO Reference Centre for virus characterization
Important risk hotspots for FMD transmission and FMD impact are identified and a 'working hypothesis' of how FMD virus circulates in the country has been developed.	Representative survey Outbreak investigations Participatory surveillance

3.1. Surveillance Components Required to Understand the Disease Distribution

3.1.1. Compile Existing Information

PCP-FMD Stage 1 should begin with compiling and summarizing all available (historical) surveillance information, focusing on the previous 5 years. Important information includes temporal and spatial outbreak data, clinical or laboratory confirmation of cases, and identification of circulating serotypes and important viral strains. This task is also referred to as a situation analysis. The information is analyzed to identify and describe the risks contributing to the introduction and spread of disease and applied to develop a strategy to mitigate those risks and improve disease control.

3.1.2. Passive Disease Surveillance

Passive disease surveillance (farmer reporting) should be assessed and strengthened during this stage. As a pre-condition, FMD should be a notifiable disease within the national legislation. Passive surveillance has several advantages at this stage of disease control:

- Provides continuous, complete coverage of the population;
- Lower cost than active surveillance options;
- Farmers are well placed to detect disease in their animals because they observe them more frequently than animal health professionals such as veterinarians or para-veterinarians/community animal health workers;
- Most effective when clinical signs are obvious, as is the case with FMD, especially in large ruminants.

The main disadvantage of passive surveillance is that it may lead to an inaccurate picture of the disease distribution. This inaccuracy could be due to under or unspecific reporting, which may be uneven across the country and in different livestock sectors, leading to a biased result. Under-reporting can occur for many reasons, including a lack of awareness and incentives, or barriers such as inconvenience, stigma, and punitive control measures. Unspecific reporting can occur when other endemic diseases with similarly clinical signs are present. During PCP-FMD Stage 1, these issues should be identified, and efforts made to mitigate them. A case definition should be developed and widely disseminated. Reporting of suspected cases should be encouraged through awareness-raising activities, streamlining communication, and removing barriers.

3.1.3. Representative Serological Survey

A national serosurvey is useful to establish an indication of virus distribution that can act as a baseline for future monitoring programs. Serosurveys can assess the prevalence of animals with antibodies for FMDV. Antibodies are an indicator of past infection or vaccination [9]. Therefore, previous infection (either subclinical or mild infection) can be detected in animals [10]. During PCP-FMD Stage 1, there likely will not be substantial changes to disease control interventions. Consequently, there may not be a need for more than one national survey while a country is in this stage. In PCP-FMD Stage 2, an additional representative survey may be needed to assess the effectiveness of control measures.

The survey should also collect information on risk factors. Common risk factors include vaccination status, age, exposure to common grazing, animal movement, and markets.

3.1.4. Participatory Surveillance

Participatory surveillance is an active surveillance component in which specifically trained veterinary staff search for a disease syndrome to explore local knowledge about a disease [11,12]. This component improves the understanding of the disease situation and/or detect outbreaks.

Participatory surveillance involves conducting group interviews with livestock keepers at the village or community level, together with observation of flocks/herds, examination of clinical cases, and investigation of any suspected cases of the disease of interest. It can also be carried out at livestock markets or other places where livestock keepers come together. This surveillance approach is a very powerful tool for investigating the spread of diseases in a population and can also be used to detect active outbreaks.

3.2. Surveillance Component to Identify the Most Common Circulating Strains of FMDV

In FMD, there is no cross-protection between serotypes (or even some strains within serotypes); therefore, it is crucial to know which serotypes and strains are circulating to inform vaccine selection.

Outbreak Investigations

Suspect cases identified during passive or active surveillance should be examined under the outbreak investigation component to provide information on the distribution of serotypes. With the goal of identifying circulating strains, the priority should be collecting samples from outbreaks where it is more difficult to infer the likely serotype, which may occur when there is an outbreak in a new geographical area or a suspected novel serotype or strain that might be evidenced by unusual clinical signs.

Outbreak investigation can be utilized for much more than confirming the diagnosis, including identifying the source, spread tracing, identifying risk factors, measuring the impact of FMD, and assessing control measures.

3.3. Surveillance Components to Identify Important Risk Hotspots for FMD

Risk hotspots are points in animal production with a high risk for FMD entry or spread. These hotspots can be geographical areas or areas at risk due to farmers' behavior

or management practices. Successful completion of this outcome relies on information from surveillance activities that support other outcomes of PCP Stage 1 (i.e., representative surveys, outbreak investigations, and participatory surveillance). The geographic distribution of seropositive epidemiological units, as revealed by a serologic survey, and infected epidemiological units identified by passive surveillance and outbreak investigations directly contribute to identifying important geographic risk hotspots using spatial analysis techniques [13].

A representative survey based on clinical signs can also be used to identify hotspots and contribute to the understanding of animal or other associated movements linked with virus circulation. A representative survey can also provide information that helps identify behavior or husbandry risk factors and how they are distributed in the population. Surveillance information, including variables such as the age of the animal, its vaccination status, the presence of clinical signs, animal trading patterns, and husbandry system information, can be statistically compared to assess risk characteristics [14].

4. Modifying the Surveillance System to Meet Changing PCP Goals in Later Stages

The goals of PCP-FMD after Stage 1 reflect progress in disease control activities and lead to the identification of outcomes that require additional evidence from surveillance systems. Stage 2 focuses on assessing implemented disease control activities while Stage 3 addresses compiling evidence for the progressive reduction in both the number of outbreaks and virus circulation in at least one zone of the country [2]. Details on surveillance system approaches can be found in the practical guidelines document [5]. Herein, we provide a brief example of the modification of a component to address changing information requirements.

The purpose of outbreak investigations in Stage 1 is to provide information on circulating viral strains, trace-related activities, and better understand the distribution of clinical disease, including hotspots. However, in Stage 2, outbreak investigations, also termed disease investigations, are aimed at developing a better understanding of the dynamics of the outbreaks and informing intervention effectiveness. The selection of outbreaks to be investigated may become more dependent on targeting herds in a control program or herds in specific geographic regions. The methodological approach would also need to be modified to gather information about the frequency of the outbreak occurrences and the status of outbreaks, which necessitates enumeration of outbreaks considered to be active.

In Stage 3, outbreak investigations are enhanced further to assist in rapid detection and response as well as contributing information on progressively reduced disease prevalence. Fewer disease outbreaks, with a concomitant reduction in clinical signs, occur at this stage. More attention is paid to responding quickly to detected outbreaks and conducting periodic, active herd-level clinical inspections following a specific protocol.

5. Summary

Surveillance is essential to support successful, sustained animal disease interventions for the purposes of prevention and control. The use of a surveillance system to support a PCP necessitates the alignment of the pathway outcomes with surveillance system components. Initially, broad sources of information are sought to determine the disease epidemiology. However, as the disease control program progresses, there is a critical need to modify the surveillance system to provide the information necessary to understand the effectiveness of control efforts and to document the decreasing prevalence of disease.

Author Contributions: All authors contributed equally in building the guidelines which is summarized in this paper. All authors have read and agreed to the published version of the manuscript.

Funding: FAO conducted this work through a trust fund provided by the Defense Threat Reduction Agency, USA.

Institutional Review Board Statement: The views expressed in this publication are those of the author(s) and do not necessarily reflect the views or policies of the Food and Agriculture Organization of the United Nations.

Informed Consent Statement: The authors are in agreement with the presented contents of this paper.

Data Availability Statement: The guidelines referred to in this paper will be available when published in the FAO website.

Acknowledgments: The project or effort depicted was or is sponsored by the United States Department of Defense, Defense Threat Reduction Agency. The content of the information does not necessarily reflect the position or the policy of the Federal Government of the United States, and no official endorsement should be inferred; We would also like to acknowledge the United States DoD DTRA Cooperative Threat Reduction Program's support of project HDTRA1-19-1-0037 "Global Framework for the Progressive Control of Transboundary Animal Diseases".

Conflicts of Interest: No conflict of interest related to this work by all authors.

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