Review Of Sentinel Surveillance Systems With Special Focus on Vector-borne Diseases.

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Abstract

In the past few decades, vector-borne diseases have been spreading into countries previously free of these manifestations. It is imperative for a surveillance method to be tailored to the biology of these agents in order to be able to detect the incursion of a specific disease. Using a sentinel herd system, it is possible to target high-risk areas where disease occurrence is most probable because of the presence of the vector.

Since the 1970's, various countries have been using the sentinel herd strategy for sampling in order to monitor vector-borne disease occurrence. Diseases such as Akabane, Vesicular Stomatitis and Bluetongue disease have been monitored using cattle herds as sentinels in many countries such as Saudi Arabia, Australia, China, Indonesia, Sultanate of Oman and recently in areas of Western Europe. Sentinel systems using other species are also described: birds for West Nile, dogs for Lyme disease, monkeys for Yellow Fever and goats for Rift Valley Fever.

This paper reviews the strengths and weaknesses of sentinel herd surveillance systems in general. In order to determine their efficacy, the following criteria were found to be essential: the choice of sentinel locations, the species and age of the sentinel animal, seasonality of sampling, and diagnostic testing methods. We conclude that due to its specificity in targeting a certain disease, sentinel herd systems have been successful in early detection of spread of the targeted agents. This review is used as a basis for recommendations for the development of future sentinel herd systems for vector-borne diseases.

Key words: Vector-borne disease, sentinel herds, early warning, surveillance

Introduction

In order to maintain a healthy wildlife and domestic livestock population, it is important to control and prevent diseases from occurring and spreading within these groups of animals. Animal disease surveillance programs have been established with the primary aim of preserving a healthy livestock through the control of infectious diseases. Due to the variety of veterinary pathogens circulating worldwide, it is important to have a tailored disease monitoring and surveillance system customized to the dynamics of the agent in question.

By studying disease patterns and their dynamics, various surveillance strategies have been devised and tested. They share the aims of minimizing the effects of a disease upon a population, as well as preventing its spread to surrounding areas either within national borders or even internationally. One of these surveillance strategies is a method based on the establishment of a sentinel herd system. This allows for a targeted, often risk-based surveillance. The term risk-based surveillance involves testing certain animals of a population located where disease is more likely to be introduced or found. This type of targeted surveillance covers a wide range of diseases and conditions such as animal welfare, endemic or exotic, infectious as well as vector-borne diseases. In epidemiological terms, a sentinel herd is defined as a cohort of animals at a pre-determined location, which is monitored over a specified period of time with respect to a specified disease agent (Ward et al., 1995). According to the World Organization for Animal Health (OIE), sentinel units/sites are described as the regular testing and identification of animals whose geographical

location and immune status is known, in order to detect disease occurrence. The data collected can provide information on the local incidence rate or prevalence as well as prove the freedom of infection status of the specific pathogen under investigation.

This review aims to describe the different criteria used in determining the choice of sentinel animals, location and sampling strategies involved for a variety of diseases, as well as determining the factors for assessing the efficacy of sentinel herd systems as a surveillance method. This has been accomplished through the collection of peer-reviewed articles and studying documentation of national surveillance programs. Recommendations for use of sentinel herd surveillance and its success factors, as well as its disadvantages will also be discussed.

Application

Sentinel herd surveillance has been regularly used over the past few decades and has covered a wide variety of diseases and conditions. Studies using sentinel herds have been conducted for parasitic, viral, bacterial and vector-borne diseases as well as for toxicological screening and animal welfare issues. For example in the studies of parasites in deer (Audige et al., 1998), bovine viral diarrhea virus (Waldner and Campbell, 2005), bovine dermatophilosis (Hadrill and Walker, 1994), animal trypanosomiasis (Paling et al., 1987), the effects of air pollution on livestock (Waldner et al., 2001) and studies on cow comfort (Cook et al., 2005), respectively.

Although sentinel herd surveillance has been used for such a broad range of diseases, the basis of creating a sentinel herd as a surveillance tool remains similar in all cases. It consists of two parts: firstly establishing the objective of the surveillance, and secondly deciding upon the specific selection and design criteria needed depending on the nature of the disease/condition in question.

Whether a disease is endemic to a region/country, or if it is still considered as exotic, sentinel herd systems can be tailored specifically to the type of surveillance needed. Sentinel herd surveillance can be divided into two main branches (Figure 1). Firstly, to measure the frequency of an existing disease within different study objectives. In the literature, three main objectives were; 1) monitoring the occurrence or to determine the dynamics of a specific disease, 2) testing a control strategy for a specific disease and, 3) its use as a risk assessment tool. Secondly, sentinel herd surveillance can function as an early warning tool for either; 1) detecting first incursion of a disease or its vector into previously free regions, or 2) actually detect its comeback into that area.

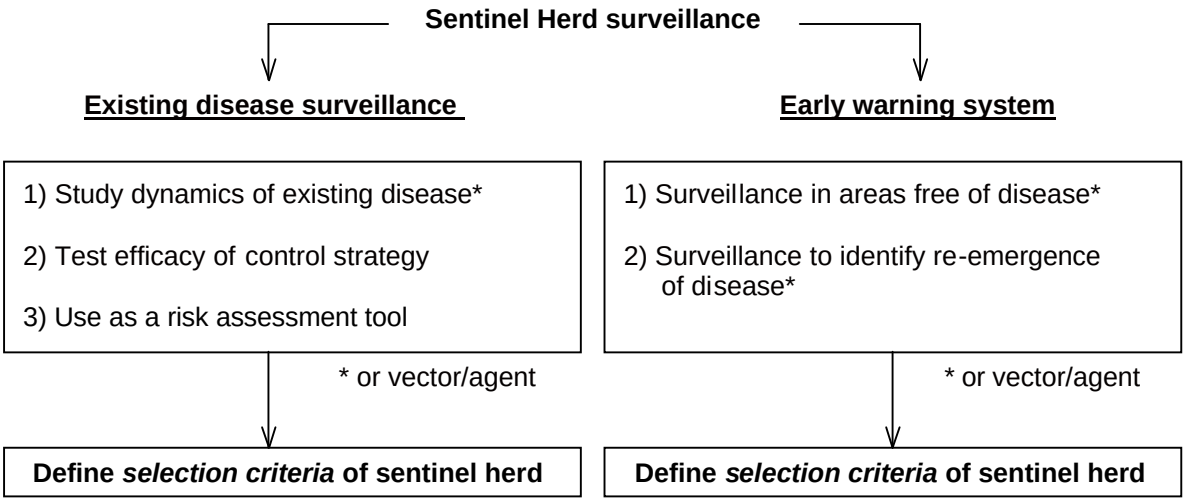

Figure 1 Diagram of sentinel herd surveillance design considering objectives, and subsequent sentinel herd selection

Once the objective of the sentinel herd has been established, design and selection criteria need to be defined in order to fit the disease, condition, vector or agent under investigation. This includes defining the sentinel animal species, the selection of a specific area, characteristic of the herd, and finally determining the type and frequency of testing.

Selecting the sentinel animal species requires epidemiological knowledge of the disease in question. As a minimal rule, the sentinel animal species should be susceptible to the disease/vector and be able to generate a calculable response, preferably more detectable than in other species receptive to the same disease. The choice of location largely depends on the actual purpose of the sentinel surveillance. If the main objective is the surveillance of an existing disease, this would imply choosing a location where the disease is known to circulate. The selection of the herd location or sentinel animal can either be random or non-random depending on the epidemiology of the disease, its presence in the country as well as the surveillance objective. If the disease is present in endemic proportions, the choice of sentinel herd can be random on a national level. Furthermore, the sentinel animal within the herd can also be randomly chosen granted it is susceptible to infection. Selection criteria concerning the age of the sentinel animal vary depending on the aim of the surveillance. If the incidence of the disease is desired, one could designate younger animals as sentinels, since they have only been present for one season on the farm and could rule out previous exposure.

If the goal of the surveillance is to serve as an early warning system, it is important to choose a location considered as a high-risk zone for agent or vector incursion. Vector-borne diseases occur in areas where the vector can establish itself, therefore high-risk zones can be identified depending on climatic and geographic factors as well as actual vector presence determined for example by entomological trapping methods. The selection of sentinel herds in this case is therefore non-random, although the choice of sentinel animal within this herd can eventually be random. The level of potential risk of exposure also needs to be taken into consideration. Exposure risks depend on a variety of factors including production purpose (i.e. exposure-time spent on the farm is different when comparing dairy and beef industries), as well as the type of husbandry management in place (i.e. livestock kept on the same farm compared to livestock which is displaced during the summer months to alpine pastures).

Depending on the seasonality, mode of transmission and severity of the disease, the testing period and diagnostic methods used will differ in each case. Surveillance of an exotic or highly pathogenic disease will need a more frequent sampling timetable, whilst testing for a vector borne disease generally takes place before and/or after the vector season has occurred. This will depend on the epidemiology of the disease. Certain examples of sentinel herd systems obtained through the literature research have been selected in Table 1.

Discussion

It is difficult to obtain specific information from sentinel herd literature using systematic search methods (Rabinowitz et al., 2005). Although the term ‘sentinel herd’ retrieved circa 50 peer reviewed papers on the PUBMED search engine, actual information on selection criteria and specific details on use of sentinels was difficult to specify for certain studies. This is mostly due to the omission of details when describing the design and selection criteria as well as justifications for the use of a sentinel herd. Further searches through national programs and academic institutions was required to find a more comprehensive number of sentinel herd literature sources. The possibility to compare sentinel herd systems with similar objectives was also difficult due to the lack of matching criteria listed in the studies. These problems were mostly overcome through personal communications with the authors who were very helpful by providing information upon request.

Despite the limitations of a sentinel herd surveillance system, it can be a very effective tool for the surveillance of a specific condition or disease category. If the aims of the study are well defined, and the selection criteria have taken in all the specific disease and/or vector characteristics, setting up a sentinel unit as a targeted disease monitoring tool can be very successful. Up to date, sentinel herd surveillance has been used for a variety of purposes such as monitoring for the presence of new or re-emerging diseases, surveying anti-microbial resistance and even as a method to prevent bio-terrorism. It is important to stress however, that the successful use of sentinel herd surveillance depends on the precision of targeting a disease/vector, which inevitably depends on the availability and correct interpretation of epidemiological knowledge.

Critical success factors exist more at the level of infrastructure and the availability of reliable disease and vector information, rather than at the data collection and quality level. Especially concerning vector-borne diseases, the limited links between epidemiological, ecological and entomological data have made it difficult to allow for the full capacity of an early warning system to function at its highest potential. This has been improving in the last decade in large part due to improving technology and the use of satellite imagery in veterinary epidemiology.

In conclusion, the success of sentinel herd surveillance primarily depends on the purpose of the set-up, and more precisely on the actual establishment criteria made regarding location, sentinel species and diagnostic methods. This review has attempted to provide a general overview for the use of sentinel surveillance systems, shown the consequent advantages and disadvantages as well as suggesting possible outlines for creating a sentinel herd.

Table 1 Examples of sentinel herd surveillance programs

Disease, condition	Country	Sentinel animal
Akabane disease	Saudi Arabia	Cattle, sheep and goat
Air pollution	Canada	Cattle
Avian Influenza	France, Holland	Birds
Bluetongue	Australia	Cattle
Bovine dermatophilosis	USA	Cattle
Bovine viral diarrhoea virus	Canada	Cattle
East Coast Fever (Theileria)	Zambia	Cattle
Epizootic Hemorrhagic disease	Sudan	Cattle
Internal parasites	New Zealand	Deer
Livestock comfort	USA	Cattle
Lyme disease	USA	Dog
Rift Valley Fever	Mali, Mauritania	Sheep, goat
St. Louis encephalitis	USA	Chicken
Trypanosomiasis	Burkina Faso	Cattle
Vesicular Stomatitis	USA	Horse
West Nile	USA	Crow
Western equine encephalomyelitis	USA	Chicken
Xenotransplantation	USA	Pig

References

Anonymous (2005) World Organization for Animal Health (OIE), *Weekly disease information and Handistatus II*. www.oie.int

Audige, L.J., Wilson, P.R., Morris, R.S. (1998). A survey of internal parasites and parasite control on North Island deer farms. *New Zealand Veterinary Journal* 46 (6)203-15

Cook, N.B., Bennett, T.B., Nordlund, K.V. (2005). Monitoring indices of cow comfort in free-stall-housed dairy herds. *Journal of Diary Science* 88(11)3876-85.

Hadrill, D.J., Walker, A.R. (1994). Effect of acaricide control of Amblyomma variegatum ticks on bovine dermatophilosis on Nevis. *Tropical Animal Health and Production* 26(1)28-34.

Paling, R.W., Leak, S.G., Katende, J., Kamunya, G., Moloo, S.K. (1987). Epidemiology of animal trypanosomiasis on a cattle ranch in Kilifi, Kenya. *Acta Tropica* 44(1)67-82

Rabinowitz, P., Gordon, Z., Holmes, R., Taylor, B., Wilcox, M., Chudnov, D., Nadkarni, P., Dein, F.J.(2005). Animals as Sentinels of Human Environmental Health Hazards : An Evidence-Based Analysis. *EcoHealth* 2,26-37.

Waldner, C.L., Ribble, C.S., Janzen, E.D., Campbell, J.R. (2001) Associations between total sulfation, hydrogen sulfide deposition, and beef-cattle breeding outcomes in western Canada. *Preventive Veterinary Medicine* 50(1-2)19-33.

Waldner, C.L., and Campbell, J.R. (2005) Use of serologic evaluation for antibodies against bovine viral diarrhea virus for detection of persistently infected calves in beef herds. *American Journal of Veterinary Research* 66(5)825-34.

Ward, M.P., Flanagan, M., Carpenter, T.E., Hird, D.W., Thurmond, M.C., Johnson, S.J., Dashorst, M.E. (1995). Infection of cattle with bluetongue viruses in Queensland, Australia: results of a sentinel herd study,1990-1992. *Veterinary Microbiology* 45(1)35-44

Acknowledgments

The authors would especially like to thank Dr. Audige, Dr. Iverson, Dr. McCluskey and Dr. Mumford for the information they provided in aid of this literature research. This paper was financially supported by the Swiss Federal Veterinary Office.