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Animal Disease Surveillance

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Maintaining healthy domestic and wild animal populations involves preventing diseases from occurring and/or controlling their spread. Surveillance is a tool for assessing the health status of a population. Emerging, exotic, and endemic diseases can be studied; however, the strategy employed may vary according to surveillance objectives. This issue of *Large Animal Veterinary Rounds* discusses the principles of disease surveillance in the context of animal health and emerging threats to both animals and humans.

Historically, animal disease surveillance activities encompassed exotic disease preclusion and measuring the effect of indigenous disease control programs.[1] Recently, a third dimension has been added to surveillance to improve detection of emerging diseases. Changing patterns of human behaviour (eg, urban development, food production intensification, and increased movement of biologic life), have accelerated and intensified the emergence and spread of infectious diseases. Spatial mobility has increased more than 1000-fold in 200 years.[2] Movement of animals and plants favour the emergence of infectious disease through many mechanisms, both directly through harbouring the pathogens themselves, or susceptibility to disease and vector immigration, but also indirectly through cultural preferences, customs, behaviours, and technology.[2] Within this shifting environment, unifocal surveillance efforts aimed at specific foreign, indigenous, and zoonotic diseases are deficient in their ability to detect new disease.[1] This has resulted in a surge of activity to improve surveillance systems through better design, new technologies, and improved collaboration among groups. Efforts focused on rapid detection of disease events engage the veterinary practitioner and provide better services to clients through a better understanding of baseline animal health and the trends that affect production.

Definitions

The term "surveillance" was first used during the French Revolution, when it meant "to keep watch over a group of persons thought to be subversive." This term has been extended to animal health programs for defining the process of watching over an animal population to determine whether a specific disease or a group of diseases makes an incursion. The practice attempts to determine the presence/absence of a disease and, if a disease is present, the changes in prevalence and the rate and direction of spread over time.[3] Surveillance involves ongoing efforts to assess the health and disease status of a given population.[3,4]

There are three components of disease surveillance systems:[3]

- a defined disease monitoring system
- a defined level or threshold of disease at which an intervention should take place
- a defined set of interventions that will be undertaken when the threshold is reached.

The interventions applied will vary with the severity of the disease and the public health, environmental, and/or economic consequences. These interventions should always include rapid dissemination of information to those who require this knowledge. Several types of surveillance methods exist, and are classified according to their function and data collection method.[3,5] The method chosen depends on the objectives of the surveillance program.

Passive surveillance

Passive surveillance is defined as a fixed, routine method that typically involves examining clinical cases; it usually relies on veterinarians, meat inspectors, and farmers to report suspicious cases at their discretion (eg, submissions to a diagnostic pathology laboratory).[5] Despite the name, passive surveillance systems require a significant effort to collect and analyze the information that may come from these systems. When compared to active surveillance systems, passive systems are relatively inexpensive because the information is already being collected for some other reason. The general series of subsequent events that must occur before a case

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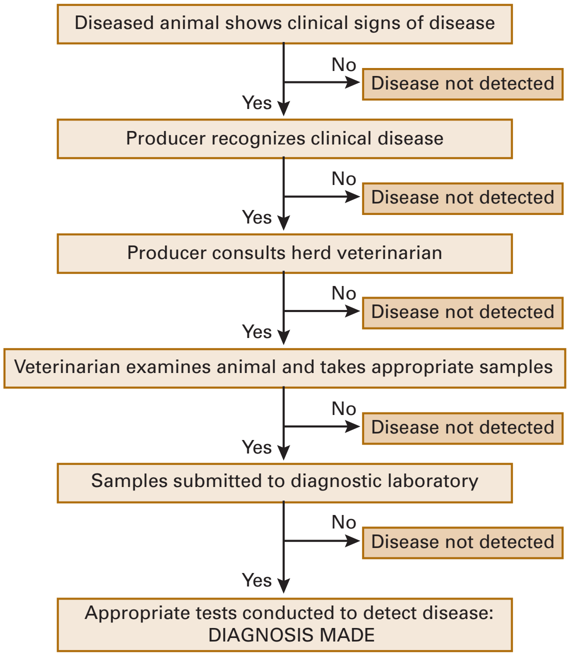
Figure 1: Passive surveillance: Case detection in animals showing clinical disease.



is detected are shown in Figure 1. The greatest disadvantage of passive surveillance systems is that, frequently, the samples collected are not representative of the entire population and information about the population is often lacking. Caution must be exercised in interpreting the results at a general population level.

Passive systems are often used as the first stage in identifying new and emerging diseases. In 2001, the public health authorities and veterinary community of southwestern British Columbia (BC) recognized an increased incidence of human and animal cryptococcosis. The majority of animal cases were initially identified through submissions made by private practitioners to a single private veterinary laboratory that serves BC and Alberta. The laboratory typically diagnosed 4 to 6 animal cases of cryptococcosis per year, but by August 2001, it had already diagnosed 12 cases on Vancouver Island alone.[6] Further testing revealed that a new variant of the fungi had been isolated, *Cryptococcus gattii*, a variant not previously associated with disease in North America.

Stigmatised diseases, mild diseases, diseases with unfavourable cost-benefit ratios, and diseases with nonspecific clinical symptoms, long incubation periods, or low within-herd and between-herd spread often have low case-report levels. These types of conditions are difficult to assess using passive surveillance systems alone. Species of low economic value may also be underrepresented in passive surveillance systems because producers may be reluctant to conduct herd investigations and submit samples for diagnostic pathology.

Active surveillance

Active surveillance involves the purposeful collection of information, often targeting a specific disease. Surveys, sentinel systems, and mass screening methods are examples of active surveillance.[5] This process produces more accurate estimates of disease frequency, such as incidence and prevalence; however, active surveillance processes are often more expensive to implement.

Probability vs nonprobability sampling

Surveillance can also be categorized by the way the observation units are chosen: probability sampling (random) or nonprobability sampling (nonrandom). Examples of nonrandom sampling include targeted and sentinel surveillance. In a disease, such as bovine spongiform encephalopathy (BSE), which is considered rare in Canada, detection in the general population is very difficult and large numbers of animals must be tested in order to detect the disease. Targeting the bovine subpopulation considered at higher risk (ie, the 4Ds: down, diseased, dying, or dead) significantly improves the power to detect the disease and is a more efficient way to spend resources. Under the new classification for BSE in the *Office International des Epizooties* (OIE) Terrestrial Animal Health code, countries must achieve target points for testing based on their BSE-risk classification (Negligible BSE Risk, Controlled BSE Risk, or Undetermined BSE Risk). Individual animals are categorized based on their BSE-risk and assigned point values. Surveillance point values per animal tested are given in Table 1.

The point system recognizes that the prevalence of BSE in clinical suspects is significantly higher than in the general population and there is significant benefit to targeting this high-risk population. Downer animals (casualty slaughter) and those found dead (fallen stock) are the subpopulations with the second and third highest prevalence. The Canadian BSE surveillance program is based on targeting these high-risk subpopulations.

Sentinel surveillance is another form of nonrandom targeted surveillance. In these systems, sentinel units (herds, veterinary clinics, flocks) with known geographic location and immune status are monitored over a specific period of time.[5] Sentinel herd surveillance can take two forms:

- measuring the frequency of an existing disease
- an early warning tool for detecting the first incursion of a disease or a recurrence.

Beneficiaries of information gained from this surveillance strategy may be the population from which the sentinel animals were derived, or other species (eg, humans). Just as canaries were traditionally used in mine shafts as an early warning that toxic gases such as methane and carbon monoxide were at unsafe levels, other species can be used to indicate disease. Waldner and coworkers examined the impact of the oil and gas industry in western Canada using beef cattle operations as sentinels.[7] Beef cattle were presumed to be useful environmental sentinels because they are highly exposed, housed almost exclusively outside, are exposed to airborne environmental contaminants and potentially contaminated surface water sources, and they primarily eat locally-grown forage.[7]

Syndromic surveillance monitors disease trends by grouping clinical diseases into disease syndromes on the basis of clinical features, rather than specific diagnoses.[8] Syndromic surveillance systems identify outbreaks of disease in populations by identifying signals that are defined as a sudden increase in the number of reports of clinical or preclinical surrogates for disease, in real-time data streams. In public health settings, disease surrogates can include clinical syndromes in the classic sense (gastrointestinal, respiratory, neurological, etc.) as defined and reported by emergency room clinicians, telephone calls to medical health support centres, sales of over-the-counter pharmaceuticals to the public for self-medication of specific disease syndromes, or even absenteeism from schools or public services.[9] Data are transferred, often via the internet, from data collection points to a centralized database where automated real-time data analyses for signal detection occurs. Notification of disease control officials is also automated and often occurs by email messages. Since the data are collected prior to the establishment of a firm diagnoses, syndromic systems are considered to be systems having low specificity; as a result, any generalization about the disease status of the population must be made with caution. Syndromic systems have been shown to be very effective at early detection of disease outbreaks in human populations, often identifying disease outbreaks 1- to 2-weeks prior to traditional public health reporting systems.[9] Examples from the animal health field include veterinary practitioner based systems such as the Alberta Veterinary Surveillance Network (Canada), the Veterinary Practitioner Aided Disease Surveillance System (New Zealand), the Rapid Syndromic Validation Project (USA), and the *Émergences système* (France).[10]

Biosurveillance is a new term defined as a process to detect disease in people, plants, or animals, and to monitor the environment for bacteria, viruses, and other biological agents that cause disease.[9] Multiple sources of information are collected, integrated, and analyzed in order to rapidly detect outbreaks and contain the situation as quickly as possible. Individuals working in the field, such as veterinarians, physicians, nurses, environmental officers, and biologists, all provide information critical to early detection of a disease incursion. The challenge comes in providing the technology, training, and desire for individuals on the front lines to enter this information in a timely fashion.

Why perform disease surveillance?

Understanding the amount or distribution of disease

One of the most important reasons for surveillance is to establish baseline information and trends in disease. One problem with attempting to gauge the amount or distribution of disease is that active surveillance efforts often begin once the disease has already occurred and is causing significant problems. As a French scientist accurately stated: “lack of data prevents the field from developing sophisticated models of communicable disease. It’s as if we are trying to study the weather, but collect data only when there is a heat wave or storm.”[11]

In 2005, Canada initiated a national interagency survey for influenza A (AI) viruses in healthy, live, wild ducks.[12] The primary goal of this survey was as an early warning detection system to look for highly pathogenic strains of influenza, specifically H5N1 (Asian strain) in migratory birds. The benefits of this project reached far beyond this objective because laboratory capacity was challenged and improved, and collaborations were established to better prepare the country for responding to a disease emergency. In addition, the detected viruses were characterized and archived for future uses, such as assessing the biosecurity level of Canada’s poultry industry and vaccine production.[12] The most recent study conducted by the Canadian Cooperative Wildlife Health Centre in 2006 found 1429/9659 (14.8%) of birds tested positive for avian influenza. No H7 strains and 5 H5 strains were identified; however, all the isolated strains were considered to be either strains of low pathogenicity or not pathogenic to poultry. This baseline information could prove invaluable in understanding the ecology of avian influenza and determining the origins of future outbreaks. Not only is there more information available about AI through this baseline study, but increased vigilance will increase the likelihood of detecting other significant diseases (eg, Newcastle disease and avian cholera). Therefore, an understanding of the diseases affecting wild waterfowl will improve as an indirect result of avian influenza monitoring. Further, the improved understanding of the amount and distribution of disease will help to appropriately target government/industry spending based on risk.

Table 1: BSE-Surveillance point values for samples collected from animals in the given subpopulation and age category (OIE Terrestrial Code – Surveillance for Bovine Spongiform Encephalopathy: http://www.oie.int/eng/normes/mcode/en_chapitre_3.8.4.htm) Accessed July 23, 2007.

	Surveillance subpopulation			
Age	Routine slaughter	Fallen stock (Found dead)	Casualty slaughter (Downers)	Clinical suspect
>1 year - <2 years	0.01	0.2	0.4	N/A
>2 years - <4 years (young adult)	0.1	0.2	0.4	260
>4 years - <7 years (middle adult)	0.2	0.9	1.6	750
>7 years - <9 years (older adult)	0.1	0.4	0.7	220
>9 years (aged)	0.0	0.1	0.2	45

Surveillance points remain valid for 7 years (the 95th percentile of the incubation period).

Protect public health by rapid detection and prevention of disease

Surveillance activities in animal populations may directly benefit human populations by serving as an early warning of disease. Animals may serve as reservoirs for disease in humans and it is estimated that 62% of emerging human diseases have their origins in animals.[13] Zoonotic diseases that are rapidly detected and rapidly contained in animal populations may prevent the further spread to affect humans. Other diseases, such as vector-borne and environmental diseases affecting both humans and animals, may manifest in animals chronologically earlier than in humans. Avian deaths consistently precede human cases of West Nile Virus (WNV) and can be a useful early warning of WNV activity. In June 1999, as early as 2 months preceding an outbreak of human encephalitis in the Queens borough of New York City, an unusual number of dead and dying crows were found with neurologic illness. Local health officials suspected St. Louis encephalitis (SLE), but a local zoo veterinarian was convinced that it was not SLE and that the two events (human and corvid illnesses) were related. The outbreak was later confirmed to be WNV, the first diagnosis of this disease in North America.[14] Another example of animals as sentinels for human disease is the use of dogs to assess the risk of human *Borrelia burgdorferi* infection (Lyme disease). The behaviour of dogs place them at greater risk of exposure and their close associations with humans make them an appropriate predictor of human exposure.[15-19]

Market access and international trade

Globalization has revolutionized international trade in animals and animal products. During the 1990s, the international community, the World Trade Organization (WTO) and the OIE, made significant progress towards improved fairness and transparency in the conduct of international trade that minimized unjustified impediments, while ensuring safety in the protection of public, animal, and plant health.[20] The "modern rules of the game" require assessment of risk and separation of legitimate from fabricated risk.[20] A country can no longer claim disease-free status with a substandard disease detection system in place. "Absence of evidence" does not constitute "evidence of absence." Countries are now required to demonstrate that they know the diseases they have and that, if required, appropriate measures are in place to control those diseases. If a country can produce substantial evidence to support disease freedom, they may have access to markets not accessible to countries with the disease or who cannot characterize their disease risk. In Canada, surveillance for *Trichinella spiralis* is performed on an ongoing basis to demonstrate that, with the exception of sporadic cases, Canada is free of trichinae in its susceptible domestic populations. Samples are collected in abattoirs and herds are selectively sampled, both randomly and targeted, based on risk (smaller operations, poor management). This testing is essential to satisfy OIE/Animal Health surveillance needs and to maintain market access of Canadian pork products.[21]

Detect emerging diseases

Practicing veterinarians, pathologists, animal health consultants, and diagnostic laboratories comprise the front lines for detecting emerging animal diseases. A producer may identify an unusual combination of clinical symptoms, an increase in morbidity or mortality in a known disease, or a disease that is not responsive to conventional treatment, and decide to call the local veterinarian. The veterinarian my submit samples for diagnostic work-up and/or consult further with specialists. This leads to the identification of a new or emerging disease.

The following excerpts are taken from the BSE Inquiry (UK) as an example of how new diseases are identified:[22]

On 22 December 1984, Mr. David Bee, a local private veterinarian, was called to examine Cow 133, owned by Mr. Peter Stent of Pitsham Farm in Sussex. She had an arched back and had lost weight. Mr. Bee visited the farm on several further occasions over the following months, and continued to see animals showing unusual symptoms. Cow 133 developed a head tremor and a lack of coordination before dying on 11 February 1985. By the end of April 1985, five more cows had died on the farm. Those familiar with the situation coined the phrase 'Stent Farm Syndrome' to describe these cases. A number of samples of body tissue were submitted to the Central Veterinary Laboratory (CVL) for pathological analysis. Various possible ailments were identified, but despite a wide range of tests no definite diagnosis proved possible.

That same year, in April 1985, another private veterinarian, Mr. Colin Whitaker, was called to Plurenden Manor Farm in Kent, to look at a Friesian/Holstein cow that was showing symptoms including a change in behaviour, aggression and a lack of coordination. Over the following year, Mr. Whitaker continued to be called to the farm to treat cattle that had suffered changes in character and behaviour. In particular, the cattle became nervous, aggressive and progressively incoordinated until unable to rise without assistance. Mr. Whitaker consulted Veterinary Officer, Mr. Carl Johnson of the Wye VIC, in November 1986 who referred the brains of three animals to the CVL in November and December 1986. Histopathological examinations of these brains revealed a common novel pathology – 'multifocal spongy transformation of the brain parenchyma' and a degeneration of neurons, principally large neurons, in the brain stem. These 'features were consistent with the clinical neurological signs observed in the animals.' Compared with most other animal disorders, the changes most closely related to scrapie, but there were subtle differences.

Thus, it was the vigilance and curiosity of private veterinarians and multiple submissions from many farms that led to the identification of "bovine scrapie," later identified as BSE.

Analyze effectiveness of disease control/eradication measures and biosecurity programs

Slaughter surveillance is used to evaluate the effectiveness of disease eradication procedures, such as those for bovine tuberculosis. In Canada, 95% of all slaughtered bovine animals move through the federal meat inspection system. Condemnations of cattle due to bovine tuberculosis peaked in 1918 at 58% of condemnations and remained at a relatively high level until 1950. Thereafter, the condemnation rate due to tuberculosis steadily declined, reaching a low point of 2% of condemnations in 1957, associated with the increasing effectiveness of the bovine tuberculosis eradication program.[23] Surveillance for bovine tuberculosis in Canadian cattle and farmed bison continues to be based on routine inspection at slaughter with submission of suspect granulomatous lesions for laboratory examination. This program is supplemented with targeted testing in zones of higher risk.[24]

Early-warning systems

Disease outbreak containment hinges on rapid detection and rapid response. All diseases, new or old, begin in an individual or a population at a single point in time (index case). Further successful transmission is dependent on the agent having access to a susceptible host with sufficient means of contact. As was witnessed in 2003, a highly contagious disease, such as Sudden Acute Respiratory Syndrome (SARS), can spread very quickly across the globe if left unchecked. A single infected individual staying at the Metropole hotel in Kowloon, China infected at least 12 individuals and ultimately resulted in cases in Vietnam, Canada, Singapore, and Hong Kong, with over 800 deaths worldwide. Theoretically, if the index case were detected prior to the occurrence of further transmission and if control measures were instantaneously implemented (quarantine, treatment, slaughter, vaccination), no further disease transmission would have occurred and the disease would have ceased to exist. Even though detection of the index case is often practically impossible, the sooner a disease threat is identified, the more likely the disease can be contained or impeded. SARS has been referred to as the "pandemic that did not occur" and one of the main reasons was due to the early warning sounded by a public health intelligence system developed in Canada, known as GPHIN (Global Public Health Intelligence Network). Users of this system were notified 3 months before the World Health Organization made an official announcement of the new respiratory syndrome in Asia.

Surveillance Systems

The ultimate goal of a veterinary surveillance system is to minimize the negative effects of health-related events in animal populations that affect public health, trade, and animal health and welfare.[25] No single data source is capable of capturing all the information required for surveillance.[10] In fact, surveillance systems are often quite complex and use multiple data sources to formulate the disease picture for a population or geographic region (Figure 2).[26]

A well designed surveillance program should be useful, simple to use, flexible, sensitive, representative, stable, standardized, and have good data quality.[3] The goal of any surveillance program should be to detect disease quickly and accurately with information disseminated and action taken. The objectives must be clearly identified to guide the design of the system. Surveillance programs developed for quickly detecting an emerging disease in a broad range of species will have different requirements than a surveillance program aimed at calculating the prevalence of a specific disease in a population. After a surveillance program has been implemented, it is important to systematically evaluate the effectiveness in detecting the event of interest. The sensitivity of a surveillance program considers the proportion of disease cases detected by the surveillance system.[27] Regular evaluations can help to ensure that monitoring of important diseases are efficient and effective.

Challenges in building good surveillance systems

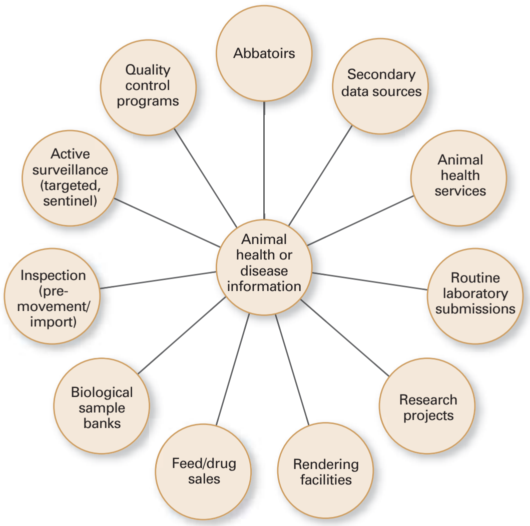
Buy-in and participation

One of the greatest challenges in building good surveillance systems is acquiring both "buy-in" and participation from the essential grass-roots elements of the system. Essential participants are busy individuals and the benefits of the surveillance system are often not immediately apparent. The benefits of the surveillance system may be seen by society or by the industry at large and are not always directly passed on to the participants, who may bear the costs of participating. Buy-in may be improved through increasing awareness of the surveillance program and the reason it is being conducted. Offering information providers incentives, such as regular, timely updates, or financial compensation, can also improve buy-in and participation. For example, financial compensation provided by the Alberta provincial government, above those provided by the federal government, has increased the number of BSE submissions from the province of Alberta in comparison with other provinces.

Data integration and analysis

In some cases, sufficient data are available, but the primary challenge is finding a means of merging data from disparate sources. Many veterinary diagnostic laboratories in Canada regularly collect useful surveillance data; however, without electronic standardization, it can be difficult to retrieve these data in a usable electronic format. It is even more difficult to combine data from a number of laboratories because they may utilize different diagnostic tests or different reporting formats.

Figure 2: Potential data sources for surveillance of animal-health related events (modified)[26]



Confidentiality and data sharing

There are many concerns and questions from information providers about confidentiality and data sharing. Producers may feel threatened by divulging information about their business enterprise and may be reluctant to provide details potentially essential to the success of a surveillance system. It can be very difficult to balance the need for information with the needs of those individuals providing the information; however, ensuring confidentiality is of paramount importance.

Maintaining vigilance

One of the greatest challenges of surveillance is to maintain enthusiasm for this type of vigilance. Funding agencies and industry may be forced to react to the "issue of the day" and funding decisions may result in downsizing or abandonment of programs perceived as "less important." It is difficult to maintain the enthusiasm of funding agencies and industry to demonstrate freedom from disease or to maintain surveillance systems against the threat of emerging diseases.

Disease surveillance and the private practitioner

Private practitioners are the essential "eyes and ears" of many surveillance programs. Frequently, veterinarians are first contacted when an individual producer has concerns and, by servicing multiple operations in an area, they often have valuable insights into changing trends or clusters of endemic disease over populations. Historically, much of this information or insight is left with the practitioner and is not carried forward, simply due to inadequate means of collection, or competing demands for their time. Current changes have resulted in increased interest for improving the collection of this disease information and recent advances in technology have improved the ability to do so. There is also a challenge in convincing veterinarians of the value of this exercise and those given the task of designing surveillance systems must ensure that veterinarians are not only providing valuable information, but are also receiving valuable information of benefit to themselves and their clients in return.

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