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Surveillance of Vector-Borne Diseases in California

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ABSTRACT: Public health surveillance is defined as the ongoing systematic collection, analysis, interpretation, and dissemination of health data. Public health surveillance is a dynamic process because it represents information for action. Action taken may in turn affect how and what further surveillance is performed. Surveillance data is collected from a variety of different sources including disease reporting, laboratory reporting, sentinel systems, and surveys. The Vector-Borne Disease Section of the California Department of Health Services performs surveillance primarily for diseases that are carried by rodents, ticks, mosquitoes, and fleas. Surveillance for these diseases is often multifaceted, involving the monitoring of human and animal diseases, monitoring vector populations, and monitoring for infections in these vectors. Information gained from surveillance of vector-borne diseases is used to guide control or prevention measures. Examples of the surveillance systems for West Nile virus, plague, and Lyme disease are presented.

KEY WORDS: Lyme disease, plague, public health, surveillance, vector-borne disease, West Nile virus

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INTRODUCTION

The Vector-Borne Disease Section (VBDS) in the California Department of Health Services (CDHS) has the mission to "protect the health and well-being of Californians from insect- and vertebrate- transmitted diseases and injurious pests" (Fritz 2005). The primary health issues of concern include diseases transmitted by mosquitoes (e.g., West Nile virus), fleas (e.g., plague), ticks (e.g., Lyme disease), and rodents (e.g., hantavirus). Other health issues of concern include Africanized honeybees, head lice, red imported fire ants, yellow jackets, kissing bugs, flies, and spiders. An important mission of VBDS is to perform surveillance for these various agents and diseases. Surveillance for vector-borne diseases is not necessarily confined to VBDS, since other sections of CDHS and local agencies are also involved in order to evaluate disease occurrence in humans and evaluate health events at the local level. The purpose of this presentation is to give a brief overview of public health surveillance and how it pertains to vector-borne diseases in California. Specific examples of surveillance strategies for West Nile virus, plague, and Lyme disease in California are discussed.

PUBLIC HEALTH SURVEILLANCE

Public health surveillance has been traditionally defined as, "the ongoing systematic collection, analysis, interpretation, and dissemination of health data" (Declich and Carter 1994). Two key concepts in public health surveillance are that disease is being monitored in populations (not individuals), and that the information gained from surveillance is intended for public health action (Thacker *et al*. 1989). Examples of public health action include planning, implementing and evaluating disease investigation, control and prevention, assessing public health status, defining public health priorities, evaluating programs, and using the information to stimulate research.

There are many data sources for public health surveillance. The sources specific to vector-borne diseases include notifiable diseases, laboratory specimens, sentinel surveillance systems, and surveys.

Notifiable Diseases

Notifiable diseases are also called reportable diseases. These include diseases that in general are highly communicable, cause high morbidity and/or mortality, or whose occurrence importantly impacts society. Reportable diseases are listed in Title 17 of the California Code of Regulations. Health care providers are required by law to report an occurrence or suspected occurrence of a reportable disease to their local health department. The local health department in turn submits reports to CDHS, who then reports the information to the Centers for Disease Control and Prevention (CDC). Vector-borne reportable diseases in California include West Nile virus, dengue fever, plague, Lyme disease, relapsing fever, Rocky Mountain spotted fever, babesiosis, Q-fever, hantavirus, and tularemia. Information on reportable diseases may be acquired either by passive or active surveillance. Passive surveillance means that the health-care provider or a laboratory must initiate the reporting process following regulation guidelines. All vector-borne diseases are reported via passive surveillance. In contrast, active surveillance is initiated by the health department. Active surveillance may be used for monitoring disease trends where reporting timeliness is important. There are no vector-borne diseases in humans for which active surveillance is performed, however, and an example of active surveillance performed by CDHS is the active flu surveillance program. In this program, CDHS contacts certain physicians and health care agencies on a weekly basis to gather reports of new flu cases. This helps monitor for unusual patterns in the flu season. Though active surveillance for human cases is not performed for most vector-borne diseases, local agencies' activities

collecting information on the presence of West Nile virus in mosquitoes and chickens could be considered active surveillance. Active surveillance is more costly than passive surveillance.

All reportable diseases are associated with a surveillance case definition that describes the case clinically and sometimes the laboratory test results needed to make sure it is a case. For most of the diseases that are reportable throughout the country, the surveillance case definition is developed by the Council for State and Territorial Epidemiologists (CSTE) to standardize reporting across the country. The purpose of a common surveillance case definition is to allow valid comparison in disease incidence over time (e.g., from one year to the next) and space (from one county to another, or between states). The case definition is designed to capture as many true cases as possible; in a few instances, true cases may not meet the definition while non-cases actually satisfy the definition and are included in the case count. It is not necessary to capture all cases for effective surveillance as long as the "reporting fraction" (the number of reported cases meeting the case definition divided by the theoretical actual number of cases) remains constant, because it is the trends of disease occurrence that are used in public health decision-making (Declich and Carter 1994).

Laboratory Reportable Diseases

Another source of surveillance information comes from laboratories. When a disease is laboratory reportable, all positive laboratory tests are forwarded to the local health department in which the patient resides. The local health department then follows up with the physician who ordered the test to determine if the case meets surveillance criteria. Laboratory reporting may be mandated for certain diseases when timely notification is important for intervention for public health, or if passive reporting is deemed insufficient for monitoring disease trends. West Nile virus is laboratory reportable because it is primarily a laboratory diagnosis, and timely information on human cases is important to disseminate to local health agencies and vector control agencies who may act to prevent further cases. Lyme disease was recently made laboratory reportable, to increase contact with physicians who suspect the disease, in order to better monitor trends in Lyme disease occurrence.

Sentinel Surveillance

Sentinel surveillance actively monitors risk of disease by gathering information from specific medical providers, hospitals, or monitoring key events. In vector-borne diseases, sentinel surveillance implies the monitoring of events or detection of disease-agents in animals or arthropods key to the disease agent cycle. Specific examples that will be discussed in more detail include detecting West Nile virus (WNV) in mosquitoes, or documenting rodent die-offs in plague-endemic areas. Sentinel surveillance plays a critical role in assessing risk of vector-borne diseases.

Surveys

Surveys are occasionally used in surveillance methods for vector-borne diseases. An unusual disease occurrence may prompt a follow-up investigation of close family or neighbors to assess if anyone else is ill or may become ill. A survey may be a simple questionnaire or may also include sample collection, such as blood, to test for exposure to an agent. Surveys may also help identify behaviors or conditions that may put people more at risk for certain diseases.

Disease Surveillance in California for Select Vector-Borne Diseases

West Nile Virus

West Nile virus (WNV) is an arbovirus transmitted by mosquitoes and is maintained in nature in a mosquito-bird cycle. People and other mammals become infected when they are bitten by an infected mosquito. The wide range of animals that can be infected with WNV allows for a multi-element surveillance approach.

The State of California Department of Health Services' "California Mosquito-Borne Disease Surveillance and Response Plan" takes current surveillance information and translates it into a semi-quantitative transmission risk score that can be used by local agencies to plan response activities (http://www.dhs.ca.gov/ps/dcdc/disb/disbindex.htm) (CDHS 2006). Weather conditions, human cases, horse cases, wild bird mortality, mosquito species, mosquito abundance, mosquito infection prevalence, sentinel chicken seroconversion, and proximity of virus activity to human-populated areas are the elements that feed into the surveillance and response plan. Different risk tables are used for West Nile virus, western equine encephalitis virus, and Saint Louis encephalitis virus, since these disease-causing agents have different ecologies that impact how the diseases are monitored.

One reason for the multi-focal approach to WNV surveillance is that certain elements provide better information in some environments than others. For example, public reporting of dead birds is useful primarily in urban areas where people are more likely to see and report a bird, while monitoring seroconversion of strategically placed chicken flocks (where mosquitoes are likely to be found) is useful for following virus activity in rural areas.

Similarly, following WNV-caused equine morbidity and mortality is also useful for monitoring virus transmission in rural areas since, in general, horses do not travel much. Veterinarians are interested in WNV activity in equines because a vaccine is available for horses that can prevent or modify the disease outcome. Knowledge of virus activity helps them tailor their prevention messages. Monitoring equine WNV infections can have the additional benefit to serve as public health education tool, because their general appeal to the public helps bring attention to the seriousness of WNV infection.

Mosquito vectors are monitored in WNV surveillance. The larval or pupal mosquito is monitored for abundance, developmental stage, source size, and control effectiveness. The presence of adult mosquitoes is a key factor to evaluate risk of disease transmission. Monitoring adult mosquitoes also helps evaluate effectiveness of larval control efforts. Finally, testing adults for presence of WNV offers early detection of virus activity.

For most reportable diseases, only human cases are reported to CDHS and then forwarded on to CDC. However, unique to arbovirus (WNV, western equine encephalitis virus, St. Louis encephalitis virus) surveillance is that all surveillance elements (human, bird, mammal, and mosquito data) are reported to the CDC via a reporting system specifically designed to monitor arbovirus activity. This system is called ArboNET. Because WNV is a new disease to North America, public health officials across the country have needed to watch its emergence in order to plan for its arrival in their area. As a result, national surveillance indicators are posted weekly online (http://diseasemaps.usgs.gov/). Local health officials in California also need timely data dissemination to plan control activities. In California, detailed local surveillance data is also disseminated weekly online (http://www.westnile.ca.gov). Data dissemination has also been important to satisfy the intense public interest in WNV.

Plague

Plague is a disease caused by the bacteria *Yersinia pestis* and is transmitted by the bite of an infected flea or inhalation of the bacteria from an infected individual or animal. Old world rats (*Rattus norvegicus* or *R. rattus*) are the traditional reservoirs for this bacterium, resulting in the scourge known as the "Black Death" that ravaged Europe from the 14th through 17th centuries. One of the first examples of disease surveillance followed by public health action occurred in the 14th century, when ships that arrived in Venice were inspected by public health guardians and excluded from port if any infected people were found on board (Declich and Carter 1994). Plague continues to garner notoriety because it has been classified as a "Category A" potential biological weapon by the Working Group on Civilian Biodefense.

Plague was first detected in California in 1900, likely introduced from infected rats off of ships arriving from Asia into various California seaports (Smith *et al*. 2006). Local wildlife, most commonly deer mice (*Peromyscus* spp.), meadow voles (*Microtus* spp.), and some species of woodrats (*Neotoma* spp.), are efficient reservoirs and their fleas are effective vectors. Susceptible or amplifying rodent species in California such as ground squirrels (*Spermophilus* spp.) and chipmunks (*Tamias* spp.), can succumb to plague when infected, resulting in an increase of infective fleas in the environment and potentially an elevated risk of transmission to humans (Smith *et al*. 2006). Wild carnivores such as coyotes can develop antibody titers in response to infection and can be useful as sentinel animals.

Plague is now well established within California in a variety of rodent-flea associations and can be found in many foothill and mountainous regions in California. Plague activity cycles yearly in epizootic conditions (resulting in death of reservoir species due to plague) and enzootic conditions (where the reservoir species is resistant to plague but can be a source of infection to fleas). Human epidemics of plague are rare to non-existent in California, and people are most often infected through contact with infected fleas or through occupational exposure, for example, veterinarians who may encounter an infected cat. Between 1927 and 2004, 57 human plague cases were detected in California (Smith *et al*. 2006).

In addition to detection of human cases, plague surveillance involves proactively evaluating the risk of plague transmission in order to prevent human exposure. In general, human risk of plague in endemic areas is low, except when epizootics occur. Thus, since the 1930s, surveillance and control of plague has been an important cornerstone of vector-control activities (Smith *et al*. 2006).

Risk assessment for plague activity involves evaluation of historical plague activity at a site, presence of susceptible rodent species and reservoir species, potential of human exposure, and determination of the existence of epizootic conditions. To evaluate epizootic conditions, population densities of known plague amplifying species are measured by looking for signs of rodent burrow abandonment and live-trapping rodents. Sera from trapped rodents, wild carnivores, or dead rodent carcasses are tested for *Yersinia pestis*. Importantly, the abundance of known vector fleas is also measured using a "flea index", which is the average number of fleas recovered per rodent host. Information gained from these surveillance activities is immediately put into action. Depending on the findings, warning signs may be posted alerting people to the general risk of plague, insecticides may be applied to burrows to decrease flea abundance or in epizootic conditions, or campgrounds additionally may be closed to the public to prevent imminent human exposure.

Lyme Disease

Lyme disease is a tick-borne disease caused by the bacteria, *Borrelia burgdorferi*. It is transmitted to humans by the bite of an infected western black-legged tick (*Ixodes pacificus*), either by the adult or the earlier life stage called the nymph. In nature, it is maintained in small rodents such as woodrats (*Neotoma fuscipes*), deer mice (*Peromyscus maniculatus*), or western gray squirrels (*Sciurus griseus*) (Brown *et al*. 2006). Lyme disease was first detected in California in a human from Sonoma County in 1975 (Lane and Lavoie 1988).

Lyme disease became a reportable condition in 1989, and since that time over 1,500 cases have been reported to CDHS, with about 100 cases reported each year (Fritz 2005). The highest incidence (number of cases per 100,000 population) occurs in the northwestern part of the state, specifically Mendocino, Humboldt, and Trinity Counties (10-year incidences are 6.9, 7.9, and 19.2, respectively) (Fritz 2006). Lyme disease has traditionally been passively reported by physicians to CDHS and, like many passively reported diseases, it is quite likely underreported. In order to assess if underreporting may bias the understanding of disease occurrence in California, Lyme disease was made laboratory-reportable in 2005. Positive laboratory tests will now be reported to local health jurisdictions that will follow up with the ordering physician to evaluate if the positive laboratory test represents a true case of Lyme disease, following surveillance case definition guidelines. It is too early to evaluate if this anticipated change in the reporting

fraction will affect the understanding of Lyme disease trends in California.

In addition to human case surveillance, surveillance for *B. burgdorferi* in western black-legged ticks is performed by CDHS and other local vector agencies in California. Ticks are "flagged" from vegetation where they "quest," waiting to attach to a host. A large white cloth is dragged over the vegetation and the ticks are collected off the cloth and tested for the presence of *B. burgdorferi*. Knowledge of *B. burgdorferi* prevalence in ticks helps physician assess prior probability of exposure, a key point for appropriate diagnostic test interpretation (the higher the probability that a person was exposed to the agent, the higher the probability that a positive test result is truly positive). CDHS tests western black-legged ticks (adults and nymphs) from throughout California. CDHS test results, along with test results from other collaborating agencies, are made available on our website for both physician and public use (http://www.dhs.ca.gov/ps/dcdc/disb/pdf/Detection%20of%20the%20Lyme%20Disease%20Agent%20in%20California%20Ticks%202005.pdf).

CONCLUSION

Data on vector-borne diseases in California are summarized yearly and made publicly available via an annual report (Fritz 2005). Publication of these data helps ensure the continuation of the "Information Loop of Public Health Surveillance", whereby data are collected, analyzed, summarized and distributed so that disease occurrence can be monitored and appropriate public health action taken.

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