Companion Animals as Sentinels for Public Health

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The concept of using animals as sentinels for danger is not new. From the domestication of dogs to protect and warn of impending danger to the introduction of canaries in coal mines, people have used animals to protect health. While archeologists continue to debate about when dogs were domesticated, their use early on as an early warning system for invading animals or people is generally accepted. Dogs served not only as a warning system to allow extra time to prepare for attack, but also as protectors themselves who joined in the defense against invaders.

In the past century, miners used companion birds as sentinels for environmental hazards in the deep shafts of coal mines. With their rapid heart rates, canaries are more susceptible than humans to the effects of carbon monoxide poisoning or depletion of oxygen. These characteristics made canaries good sentinels for dangerous air quality. If a canary dropped from its perch in the cage, miners quickly exited the area in search of better air. This early warning spared the lives of miners. As for the canaries, they often could be resuscitated and returned to sentinel service another day. Today the phrase “a canary in a coal mine” remains a popular expression for a small misfortune as a harbinger of a much larger disaster.

SENTINEL-ANIMAL SURVEILLANCE

Disease surveillance refers to an active system of collection, analysis, and interpretation of data on health-related conditions. The dissemination of these data is necessary for the planning and implementation of useful public health actions. Sentinel-animal surveillance involves collecting data on disease occurrence in animal populations, which can be used for identification of disease outbreaks, for testing effectiveness

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of preventive medicine or intervention programs, or for hypothesis testing involving the epidemiology of pathogen. Use of sentinels also provides information on changes in the incidence of a disease over time, geographic spread of disease, and risk factors of specific diseases or syndromes in reference to a specific target population.

Animal sentinels for disease surveillance may be individuals or populations of animals that exhibit particular characteristics. First, the animal must be susceptible to the disease of interest. Sentinels should be just as likely, if not more likely, to be affected by the disease than the target species. Increased susceptibility may allow for early detection, which in turn allows for rapid implementation of disease-control and prevention strategies to avoid or minimize spread of disease in the target species. Second, the animal must generate a measurable clinical or immunologic disease response. Clinical signs of disease should be recognizable in the sentinel, but do not need to be identical to clinical signs of disease in the target species. Immunologic responses should be rapid and easily measured. In routine sampling, points at which seroconversion occurs provide temporal data for assessment of transmission risk. Beyond these two traits, sentinels ideally should pose little risk of zoonotic transmission to people handling the animals and should not contribute to the amplification and spread of the agent as a reservoir. Animal species vary greatly in approaching these ideal characteristics.

Animals can serve as incidental or intentional (or experimental) sentinels for disease. Incidental animal sentinels are not purposefully placed in a situation where disease may occur specifically for the purpose of detection. For instance, animals using the same tap water as their owners serve as incidental sentinels for water-borne illness. Meanwhile, animals sharing a common household environment with their owners serve as incidental sentinels for household environmental contaminants. Conversely, intentional animal sentinels are purposefully placed in areas of potential risk to determine presence of disease. In some instances, intentional sentinels may be selected for their immunologic naïveté to the disease of concern, such as unvaccinated or specific-pathogen–free animals. In other instances, intentional sentinels may immunocompetent animals undergoing routine monitoring for clinical signs or immunologic evidence of disease.

Animal-sentinel systems can range from simple to complex. An example of a simple animal-sentinel system is the classic canary in a coal mine. Pathology laboratory reports of findings on submitted necropsies are also examples of simple animal-sentinel systems. More complex systems may combine incidental and intentionally placed animals, multiple species of sentinels, and advanced diagnostics, such as DNA sequencing and databasing of phylogenetic information. Geographic Information Systems mapping and instantaneous global communications have made complex systems of animal sentinels useful on a larger scale.

ANIMAL SENTINELS IN PRODUCTION SETTINGS

In animal-production settings, unvaccinated or immunologically naïve animals are intentionally cominled with the vaccinated population as a means of detecting circulating pathogens within the population. For example, swine veterinarians use unvaccinated pigs to monitor for evidence of remaining circulating porcine reproductive and respiratory syndrome virus (PRRSV) following an outbreak within a production facility. Following a PRRSV outbreak, vaccination of the population is implemented in conjunction with other control measures, such as test and cull or herd closure. Once infection is believed to be controlled, seronegative sentinel animals are placed within the population of vaccinated animals. Serum samples are collected from these
sentinels at predetermined intervals and tested to detect seroconversion to PRRSV, which would indicate ongoing disease transmission within the population. In worst-case scenarios, the sentinels succumb to PRRSV and confirmation of infection occurs upon necropsy. No matter whether the sentinel survives or dies, the animal provides information about the risk to other members of the population and allows for disease-control and -prevention strategies to be maintained or altered as needed.

Sentinel animals in production settings can also serve as components of more complex public health surveillance efforts. Recent emergence of highly pathogenic avian influenza (HPAI) H5N1 has prompted global efforts to map and predict geographic spread of the disease. Poultry serve as important sentinels for HPAI incursion and spread and have been used to describe the ecology of HPAI outbreaks throughout the world. Despite the important role poultry play in HPAI detection, they do possess undesirable characteristics for HPAI sentinels. Poultry are a reservoir species for both low-pathogen avian influenza (LPAI) and HPAI and demonstrate a high risk for zoonotic transmission to animal handlers. Waterfowl in the wild or used in production settings are also naturally susceptible to HPAI infection and have sentinel use, but are more likely to reflect nonlocal disease transmission, either through migration or contact with migrating birds, and are more susceptible to virus mutation than poultry are. Similar to waterfowl, domestic production pigs are susceptible to HPAI and can demonstrate serologic responses to infection, making them another potential production-animal sentinel. However, as with poultry and waterfowl, pigs have the potential to serve as HPAI reservoirs and may pose a risk for zoonotic transmission to animal handlers. Due to the close association between production animals and people, these species rarely serve as intentional sentinels for zoonotic disease. However, they often serve as incidental sentinels for zoonotic disease in public health surveillance.

WILDLIFE SENTINEL SETTINGS

Wildlife serve as classic sentinels for environmental human health risks, as they share the same air, water, and land resources with people. Biological processes of many wildlife species often react to environmental toxins with clinical and pathologic signs that parallel the effects in people. Monitoring wildlife in situ provides integrated data on the type, amount, and bioavailability of contaminants and the clinical effects of exposure. Disease monitoring in wildlife species has permitted the exploration of increases in the incidence of disease syndromes, such as metabolic, endocrine, or reproductive diseases. The resulting findings have generated hypotheses about potential toxins and assisted with the identification of environmental contaminants that pose a risk to human health. For example, examinations of free-living birds (including bald eagles, gulls, terns, and tree swallows), mammals (including mink, river otters, and beluga whales), fish (including walleye, bullheads, and suckers), and amphibians (including snapping turtles and mudpuppies) over multiple decades have revealed numerous human health hazards, such as the contamination of the Great Lakes–St. Lawrence basin of the United States and Canada with dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), and dioxin.

COMPANION-ANIMAL SENTINEL SETTINGS

Through interactions with individual patients, veterinarians monitor the health of the animal populations the practices serve. Many diseases seen daily in veterinary practices have the potential to affect the health of animal owners, clinic employees, and community members.
Cats and dogs have been identified as potential sentinels for numerous diseases that also affect people. Companion animals are effective sentinels, as they share a common environment with their owners. In intimate contact with members of the human family, companion animals often eat similar foods, share the same beds, and serve as travel companions, making their disease risk similar to that of their owners. Thus, the health of the companion animal often mirrors the health of or suggests the health risks to humans in the same household. The following examples highlight just a few specific situations where companion animals can serve as sentinels for both animal and human health.

**Feed Contamination**

Recently, dogs and cats became incidental sentinels for possible contamination in the United States food supply. In March 2007, pet food manufacturer Menu Foods began the first of many recalls of pet food products following increased reports by veterinarians of dogs and cats with renal failure. Other pet food companies soon followed suit, recalling millions of pounds of cat and dog food containing melamine-contaminated wheat gluten that had been imported from China. Unfortunately, many pigs and chickens destined for human consumption were exposed to contaminated feed before the source of contamination could be identified and pulled from the animal food supply. While there were no reports of human illness associated this incident, the massive public attention to the untimely illness and death of pets has led to increased monitoring of imported food supplies for both pets and people.

**Infectious Diseases**

Many bacteria, viruses, parasites, and fungi infect both companion animals and people. Differences in infectious dose, severity of clinical signs, and immunologic response to infection can lead to detection of some diseases in companion animals before detection in their owners, an important characteristic of a good sentinel. Companion animals are less than ideal as intentional sentinels when they pose a risk of zoonotic transmission or when they serve as a reservoir species for the pathogen. Even so, companion animals remain valuable incidental sentinels.

**Cat scratch disease**

Since the identification of *Bartonella henselae*, the etiologic agent of cat scratch disease (CSD), in the early 1990s, cats have served as the only population for CSD surveillance, primarily through serosurveillance. Recent studies have indicated that dogs can be naturally infected with at least six species of *Bartonella*, including *B. henselae*, and may also function as sentinels, as all *Bartonella* spp identified in sick dogs are also pathogenic or potentially pathogenic in humans. Unlike cats, which rarely exhibit clinical disease following bartonella infection, dogs develop a wide range of clinical abnormalities very similar to those observed following bartonella infection in people. For example, infection with *B. vinsonii* subspecies *berkoffii*, produces endocarditis with similar lesions in both dogs and people. Due to similarities between clinical signs in canine and human bartonella spp infection, the canine species may be a good sentinel species for CSD and other potential bartonella infections of humans. One caveat is the potential risk of transmission between infected dogs and people.

**Rocky Mountain spotted fever**

The spotted fever group diseases represent over a dozen species of *Rickettsia*, several of which have importance as globally re-emerging diseases. Rocky Mountain spotted fever, caused by *Rickettsia rickettsii*, is an important tick-borne disease of both dogs and people in North, Central, and South America. Reports in North and
South America have demonstrated parallels in human and canine infection within households and across geographic areas. Close contact between dogs and tick habitats makes them a sensitive indicator of the environmental presence of infected vectors and useful as sentinels for other household members or others in the same geographic location. Because dogs infected with Rocky Mountain spotted fever do not present a direct transmission risk to people, they have potential usefulness as both intentional and incidental animal sentinels, although theoretically they could transfer infected ticks to the peridomestic environment.

**Leishmaniasis**

Leishmaniasis, a vector-borne disease of worldwide concern, is transmitted by the bite of infected female phlebotamine sandflies and manifests as either a cutaneous or visceral form. The World Health Organization indicates that nearly 350 million people are at risk of leishmaniasis in 88 countries around the world. While most human cases of leishmaniasis in the United States can be traced to exposures outside North America, a few cases of domestically acquired cutaneous leishmaniasis have been reported in Texas. Companion animals, including dogs, cats, and horses, are also susceptible to leishmaniasis. In endemic regions of Columbia and Panama, dogs have been used as sentinels for detection of leishmania spp transmission. For nonendemic regions, clinical diagnosis of canine leishmaniasis or evidence of seroconversion to *Leishmania* spp may indicate an isolated imported case or expansion of endemic regions due to an extended vector range or introduction of the parasite into a new vector or reservoir species. Evidence of an outbreak of canine visceral leishmaniasis in a New York kennel in 1999 prompted an investigation of the epidemiology of *Leishmania* spp in North America. While no evidence of human infection was found in the 3-year study, infected dogs were identified in 18 states and two Canadian provinces. Evidence of newly infected dogs during each year of the study indicated the occurrence of ongoing disease transmission. Clear evidence of clinical illness or seroconversion in infected dogs, their potential for exposure to the sandfly vector, and the absence of direct transmission from dogs to humans are desirable sentinel characteristics in dogs. However, dogs can serve as a reservoir for *Leishmania* spp, which limits their use as intentional sentinels for disease surveillance.

**Trypanosomiasis**

*Trypanosoma cruzi* represents another important public health concern where companion animals may be effectively used as sentinels across the American continents. American trypanosomiasis, or Chagas disease, is a vector-borne disease transmitted during the simultaneous feeding and defecation on hosts by blood-sucking members of the family Reduviidae. Chagas disease affects many animal species, including cats, dogs, mice, and rats. Most human cases of Chagas disease in North America are traced to exposure in endemic regions of Mexico, Central America, and South America, but cases of transmission in the United States have also been documented. *T cruzi* is considered to be endemic in eastern, southern, and southwestern regions of the United States with opossums and raccoons serving as natural reservoirs. Serologic evidence of exposure to *T cruzi* has been found in hounds from the southeastern and central United States as well as the Canadian province of Ontario. As with leishmaniasis, dogs can exhibit clinical or serologic signs of *trypanosoma cruzi* infection without the risk of direct disease transmission to humans. Therefore, dogs may serve as valuable sentinels for Chagas disease in nonendemic areas to monitor geographic spread of the disease as well as the effectiveness of vector control programs and other preventive measures. However, as a main reservoir species for *T cruzi* in
endemic regions, dogs may be limited for service only as incidental sentinels for disease surveillance.

**Environmental Contaminants**

While companion animals share the same air, water, and housing as their owners, they tend to be free of many lifestyle factors that can confound associations with true risk factors. Lifestyle factors often associated with chronic disease in people include tobacco use, alcohol and caffeine consumption, poor diet, insufficient physical inactivity, and low social class. The physiologically compressed life span of companion animals also makes them valuable sentinels for many diseases where lengthy latency periods associated with the human life span preclude early detection of many hazardous environmental conditions.

**Lead poisoning**

Lead exposure in people and animals has well-known and well-documented detrimental clinical effects. Identical biological mechanisms of toxicity in both people and animals, including companion animals, have allowed for the successful use of dogs as animal models for toxicologic studies of lead exposure. The use of companion animals as sentinels for environmental lead contamination has also been successful in determining human health risk for plumbism. For example, both dogs and cats suffering from plumbism have led to the discovery and successful treatment of nonclinical lead toxicity in children living in the same household.

Environmental lead exposure beyond the household environment can also be determined through serologic surveillance of blood-lead concentrations in both cats and dogs. A study of pets and their owners living near a secondary lead smelter in Illinois found that when a dog or cat in a household had a high blood-lead concentration, there was a significant increase in the likelihood of finding a person in the same household with a high blood-lead concentration. In Uruguay, similar findings were reported following investigation of the "La Teja" neighborhood, where people settled into an area of abandoned lead-handling factories. While blood-lead concentrations were significantly higher in dogs than in children, correlation between high blood-lead concentrations in dogs and children was evident.

While both dogs and cats share similar household environmental exposures with their owners, dogs exhibit behavioral traits more in common with children. Like children, dogs explore the environment low to the ground and may eat or chew objects they discover. These behavior similarities between dogs and children make dogs the better choice for incidental animal-sentinel surveillance related to lead exposure.

**Organochlorines**

Dioxins, a group of several hundred similar chemical compounds, have been linked to increased risk of cancer development, adverse reproductive effects, and developmental abnormalities in both people and animals. While wildlife species have been key animal sentinels for determining the environmental risk of dioxins for human and animal health, the use of companion animals as sentinels for environmental dioxins is not as well defined. In an investigation of the health effects of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the most toxic of the dioxin compounds, on pets in Missouri, researchers were unable to confirm the usefulness of either cats or dogs as potential animal sentinels. However, researchers relied on owner-reported illness to determine if pets were likely suffering from TCDD toxicity. TCDD exposure was assumed based on owner’s exposure risk rather than serum or tissue testing. Along with small sample size and lack of typical reported signs of toxicity, the investigators...
reported their results as inconclusive. Conversely, a study of environmental exposure of dogs to PCB, another common dioxin compound, found them to be a potentially useful animal sentinel for environmental PCB exposure. In this study, serum PCB levels in dogs from known areas of contamination in Monroe County, Indiana, were significantly higher than levels in control dogs from noncontaminated areas in Atlanta, Georgia. Interestingly there was no association between being an outdoor dog and having higher serum PCB levels, as would be expected if soil exposure to PCBs significantly contributed to exposure. Unfortunately neither the PCB nor the TCDD studies were able to correlate outcomes in companion animals with their owners, as outcomes in the owners were not measured. Until those studies are completed, the usefulness of companion animals as sentinels for environmental dioxin risk in people will remain inconclusive.

Organochlorine pesticides such as DDT, its active metabolite DDE (dichlorodiphenylchloroethylene), and lindane have also been implicated in numerous health risks ranging from neurologic symptoms to adverse reproductive effects to cancer development. Dogs living near Superfund sites in North Carolina had a significantly higher micronucleus frequency, a biomarker for DNA damage, than did dogs from nearby noncontaminated areas. While not all measured biomarkers differed between the exposed and control dogs, this study suggests that dogs may be useful sentinels when carefully chosen biomarkers are used. However, as with the dioxins, correlations between human and animal health risk have not been determined for the organochlorine pesticides, and extrapolations based on available data should be done with caution.

**Industrial chemicals**

Between May 1 and August 31, 2006, a community in Georgia was exposed to propyl mercaptan, an offensive smelling chemical used to scent odorless toxic chemicals, following the accidental release of propyl mercaptan from a nonhazardous waste-treatment facility. During the initial investigation, a community survey was conducted that included a section for owner-reported signs of illness in pets. Follow-up on the 36 pets with reported illnesses determined that only 6 animals were seen by a veterinarian. Of the 8 sick pets reported to have died during the study period, only 1 had a necropsy performed, with findings consistent with gastric torsion. The lack of veterinary confirmation of disease and cause of death and reliance on owner-reported clinical signs made it difficult to evaluate dogs as sentinels for environmental contamination of propyl mercaptan during this event. Using data from veterinary hospitals, the National Companion Animal Surveillance Program conducted a second study on pets as sentinels during the same event. This retrospective syndromic surveillance study found indications of changes in respiratory, gastrointestinal, and eye inflammation syndromes concurrent with the chemical exposure. These syndromes paralleled reports of clinical complaints by people in the affected community, but showed no conclusive and consistent evidence of adverse health effects. The results of this study support the need for further studies on the use of companion animals as sentinels following chemical accidents and for the development and evaluation of methods for using pet medical records for the detection of environmental health hazards.

**Bioterrorism and Chemical Terrorism**

Since the terrorist attacks on September 11, 2001, there is an increased awareness of potential biological, chemical and radiological threats, which has led to increased efforts for early detection of terrorist attacks. Animal-sentinel surveillance has been proposed as an early detection warning system for terrorist attacks. If companion-animal species develop rapid clinical signs of illness, identification of an attack can be made before
detection of disease in people. This rapid detection may allow for early interventions designed to decrease the impact of the attack on both animal and human health.

The CDC has categorized biological agents into three categories, depending on how easily they can be spread, the severity of illness they might cause, and the likelihood of deaths that might result. Category A agents are considered the highest risk and category C agents are those that are considered emerging threats for disease. Listed biological agents that can cause clinical disease in companion animals include anthrax, brucellosis, plague, and tularemia. Vector-borne diseases, such as some species of *Rickettsia*, may also have potential as effective bioterrorism agents. In addition, numerous chemical agents have been identified as potential terrorist weapons. Neurologic gases, heavy metals (e.g., mercury and lead), cyanide compounds, pesticides, dioxin, and PCBs are all identified by the CDC as chemical agents that may be used by terrorists.

A single case of lead toxicity in a dog or tularemia in two cats from the same household are not likely to lead a veterinarian to suspect bioterrorism. However, a veterinarian is in a good position to see larger trends that might be a tip off of a terrorist attack. By tracking the incidence of disease in an individual practice, a veterinarian can recognize unusual increases in the incidence of specific disease or disease syndromes. Companion animals also have the potential to become sensitive animal sentinels for bioterrorism or chemical terrorism attacks as a part of a larger syndromic surveillance system.

**SUMMARY**

Animal-sentinel surveillance is a key component of public health risk assessment. To be effective sentinels, animals must be susceptible to the disease of interest and create a measurable response to the disease. Ideally, animal sentinels do not pose a threat of direct disease transmission to people or serve as an amplifying host or reservoir for the disease. While many species serve as animal sentinels, companion animals have an especially valuable role as sentinels because of their unique place in people’s lives, with exposure to similar household and recreational risk factors as those for the people who own them. Incidents of food contamination, infectious disease, environmental contamination, and even bioterrorism or chemical terrorism events may be detected in dogs and cats before disease is detected in people. In any of these events, communication between veterinarians and public health officials can facilitate rapid detection of disease and implementation of disease-control and prevention strategies to ultimately minimize detrimental health effects in both people and animals.

**REFERENCES**


