Outbreaks of Enteric Disease Associated with Animal Contact: Not Just a Foodborne Problem Anymore

Nicole Steinmuller,[1] Linda Demma,[1,2] Jeff B. Bender,[3] Millicent Eidson,[4] and Frederick J. Angulo[1]

[1]Enteric Diseases Epidemiology Branch, Centers for Disease Control and Prevention, and [2]Atlanta Research and Education Foundation, Atlanta, Georgia; [3]University of Minnesota, St. Paul; and [4]New York State Department of Health, Albany

In the past 10 years, an increasing number of outbreaks of enteric disease associated with animals in public settings, such as fairs and petting zoos, have been reported. Fifty-five of these outbreaks that occurred in the United States during 1991–2005 are reviewed in this article. Lessons learned from these outbreaks and recommendations for prevention are also discussed. Physicians should be aware of this important public health problem and play an active role in prevention of human illness associated with animals in public settings.

Many venues encourage or permit the public to come in contact with animals. These settings include county or state fairs, petting zoos, visitor farms, educational exhibits at schools, wildlife photography opportunities, animal swap meets, pet stores, zoologic institutions, circuses, carnivals, and livestock-birthing exhibits. Although benefits of human-animal contact exist, outbreaks of enteric disease can occur in these settings. Pathogens that are often associated with foodborne outbreaks, including Shiga toxin–producing *Escherichia coli* O157:H7 and *Salmonella*, *Campylobacter,* and *Cryptosporidium* species, have also been linked to outbreaks of infection associated with animals in public settings [1–7]. Cattle, sheep, and goats are common sources of infection; however, poultry [8, 9], rodents [10], and other domestic and wild animals are potential sources as well.

In this article, we describe reported enteric disease outbreaks associated with animals in public settings in the United States during the period 1991–2005, discuss factors associated with human illness, and provide recommendations aimed at preventing disease transmission. The number of recent outbreaks associated with animals in public settings underscores the importance of physician awareness about the risks of exposure from animals in public settings and the role of the physician in the prevention of human illness associated with animals in public settings.

RESERVOIRS FOR PATHOGENS AND MECHANISMS OF TRANSMISSION

Both ill and healthy-appearing animals found in public settings can harbor enteric pathogens in their intestinal tracts and shed these pathogens in their feces. Removing ill animals, although important, is therefore not sufficient to prevent disease transmission and environmental contamination. Studies have shown that shedding is often intermittent and is more common during the summer and fall [11, 12]. Shedding of pathogens can contaminate the environment, and these pathogens can remain in the environment for long periods of time [12, 13]. Screening for fecal shedding of pathogens with laboratory tests and treatment with antimicrobials will not eliminate the risk of transmission, because shedding is intermittent, and reinfection from the contaminated environment often occurs.

The primary mode of transmission of enteric pathogens is the fecal-oral route. Transmission of pathogens from animals to humans can occur through a variety of mechanisms. Because animal fur, hair, skin, and saliva can become contaminated with fecal organisms [14], direct transmission can occur through petting, touching, and feeding animals in these settings. Indirect transmission has also been documented in outbreak settings, with illness being associated with contact with contaminated clothing or shoes, animal bedding, flooring, barriers, and other environmental surfaces [1, 4, 5, 15]. Because pathogens can survive for long periods of time in the environment [6, 15], transmission can occur from a contaminated environment long

Received 23 May 2006; accepted 19 August 2006; electronically published 8 November 2006.

Reprints or correspondence: Dr. Linda Demma, Enteric Diseases Epidemiology Branch, Centers for Disease Control and Prevention, Mailstop D63, Atlanta, GA 30333 (ldemma@cdc.gov).

Clinical Infectious Diseases 2006; 43:1596–602

1058-4838/2006/4312-0012$15.00

after animals have been removed. Transmission can also occur through contaminated or inadequately maintained drinking water and sewage/manure disposal systems [16, 17].

CLINICAL MANIFESTATIONS

E. coli O157, *Salmonella, Cryptosporidium,* and *Campylobacter* infections are the most common human infections attributed to animal exposure in public settings. The most common clinical manifestations of *E. coli* O157 infection include diarrhea that may be bloody, abdominal cramping, and abdominal tenderness that develop 2–8 days after exposure. Vomiting occurs in 30%–60% of cases, and fever (usually low grade) is documented in only 30% of cases. Most patients recover within 7 days without receipt of antibiotics or specific treatment [18]. Patients with *E. coli* O157 infection—particularly children aged <5 years—are at risk of developing hemolytic uremic syndrome, a triad of hemolytic anemia, thrombocytopenia, and renal insufficiency. Approximately 8% of culture-confirmed cases of *E. coli* O157 infection progress to hemolytic uremic syndrome [19]. The mortality rate for hemolytic uremic syndrome is 3%–5% [18].

The clinical manifestations of salmonellosis are sudden onset of headache, fever, abdominal pain, diarrhea, nausea, and sometimes vomiting, and the manifestations develop 8–36 h after exposure. The illness usually lasts 4–7 days, and most persons recover without receiving treatment, although it may take several months before bowel habits return to normal. Infection that begins as acute enterocolitis may develop into septicemia or localized infections. Deaths are uncommon and are reported predominately among young and very old persons or among those who are debilitated or immunosuppressed [20].

The clinical manifestations of *Cryptosporidium* infection include frequent, nonbloody, watery diarrhea; abdominal cramps; and fatigue. Fever and vomiting are common among children. Cryptosporidiosis is usually self-limited, lasting 1–20 days [20].

Campylobacter infection can cause diarrhea, cramping, abdominal pain, and fever that develop 2–5 days after exposure, with a typical duration of 1 week. The diarrhea may be bloody and can be accompanied by nausea and vomiting. Some persons may develop complications, such as reactive arthritis, Guillain-Barré syndrome, or meningitis [20].

DESCRIPTION OF OUTBREAKS OF ENTERIC DISEASE, 1991–2005

National surveillance does not exist for outbreaks of enteric disease associated with animals in public settings. The National Association of State Public Health Veterinarians (NASPHV) conducted a literature review and a survey of state veterinarians to collect information on outbreaks from the period 1990–2000 [21] and kept an informal summary of outbreaks from 2000 to present. Outbreaks were also identified through the national Shiga toxin–producing *E. coli* outbreak database at the Centers for Disease Control and Prevention (CDC; Atlanta, GA), a compilation of reported outbreaks of Shiga toxin–producing *E. coli* infection that occurred in the United States during 1982–2004, including outbreaks of nonfoodborne infection. These materials and recent review articles [22, 23] provided an initial list of outbreaks.

This initial list of outbreaks of enteric disease associated with animals in public settings was distributed to all State Public Health Veterinarians through NASPHV in December 2005. The veterinarians were asked to update the list with further information about additional outbreaks that occurred in their state and to provide reports from outbreak investigations conducted by state health departments.

In this review, we attempted to include only those outbreaks that occurred in public settings, such as a petting zoos, fairs, or visitor farms. Differentiation between public and private settings was difficult and was not possible for all outbreaks. Outbreaks of enteric disease associated with animal contact that occurred in home settings, such as cases that involved the handling of pet rodents [10], reptiles, and chickens [8, 9], were not included in our review. However, these outbreaks demonstrate other important animal sources of enteric disease.

Fifty-five enteric disease outbreaks associated with animals in public settings were reported in the United States during the period 1991–2005. The annual number of reported outbreaks has increased substantially in recent years (figure 1). A listing of reported outbreaks since 2000 is in table 1. Most of the reported outbreaks were caused by *E. coli* O157 or *Salmonella* species (table 2). Other pathogens associated with these outbreaks include *Campylobacter, Cryptosporidium,* and *Giardia* species. A total of 1175 cases were associated with the 55 reported outbreaks (median, 6 cases per outbreak; mean, 21.4 cases per outbreak). Information about hospitalizations was obtained for 35 of the 55 outbreaks, with 163 hospitalizations

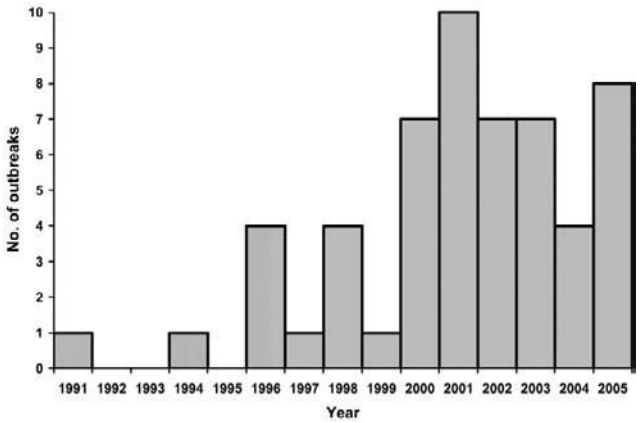

Figure 1. Number of reported outbreaks of enteric disease associated with animals in public settings in the United States, by year, 1991–2005.

Table 1. Reported outbreaks of enteric disease associated with animal contact in public settings in the United States, 2000–2005.

Year	State	Pathogen	No. of ill persons				Suspected or confirmed vehicle/animal	Reference(s) or source
			All ill persons	Culture-confirmed infection	Hospitalized	HUS		
2000	MN	*Escherichia coli* O157	2	2	2	2	Calves	CDC[a]
2000	MN	Multiple pathogens[b]	59	13	1	…	Calves	[4, 18]
2000	OH	*Salmonella enterica* serotype Typhimurium	18	14	…	…	Unknown	[22]
2000	OH	*E. coli* O157	22	22	10	…	Food and beverages	[2, 23]
2000	PA	*E. coli* O157	51	15	16	8	Cattle/calves	[1, 22]
2000	SD	*E. coli* O157	2	…	…	…	Unknown	CDC[a]
2000	WA	*E. coli* O157	5	5	3	1	Rabbits, chicken, goats, calf	[1, 22]
2001	MN	*S.* Typhimurium	40	26	4	…	Owl pellets	CDC[a]
2001	HI	*E. coli* O157	3	3	0	0	Unknown	CDC[a]
2001	MI	*S. enterica* serotype Newport	4	4	1	…	Dairy cattle, raw milk	CDC[a]
2001	MI	*S.* Newport	2	2	0	…	Ill equine	CDC[a]
2001	MN	Multiple pathogens[c]	25	14	2	0	Calves	[4]
2001	OH	*E. coli* O157	91	23	6	2	Environmental contamination	[15, 23]
2001	OH	*E. coli* O157	88	27	…	3	Cattle/calves, rabbits	[23]
2001	PA	*E. coli* O157	12	…	…	…	Calves	CDC[a]
2001	WI	*E. coli* O157	55	21	6	1	Cattle/ environmental contamination	CDC[a]
2001	WI	*E. coli* O157	34	16	6	0	Environmental contamination	CDC[a]
2002	CA	*E. coli* O157	4	…	…	…	Unknown	CDC[a]
2002	MN	*Campylobacter* species	3	3	1	…	Chickens, pigs	CDC[a]
2002	MN	*Campylobacter* species	9	2	…	…	Turkeys	CDC[a]
2002	MN	Multiple pathogens[d]	5	5	3	…	Dairy calves	CDC[a]
2002	MI	*S.* Newport	6	6	0	0	Cattle	CDC[a]
2002	OR	*E. coli* O157	82	72	22	12	Goats, chickens	[23]
2002	VA	*E. coli* O157	3	3	2	2	Unknown (likely cows)	CDC[a]
2003	CO	*S.* Newport	3	3	…	…	Ill calf	CDC[a]
2003	MI	*S. enterica* serotype Enteritidis	17	3	1	0	Wallaby	CDC[a]
2003	MN	*E. coli* O157	5	5	2	1	Calves, sheep, goat	CDC[a]
2003	MN	*Cryptosporidium* species	31	7	0	…	Calves	[7]
2003	MN	*Cryptosporidium* species	37	7	…	…	Calves	[7]
2003	TX	*E. coli* O157	25	7	19	…	Unknown (likely livestock)	[6]
2003	VT	*E. coli* O157	6	1	1	1	Goat	CDC[a]
2004	CA	*E. coli* O157	3	…	…	…	Steer	CDC[a]
2004	MI	*S.* Newport	6	6	0	…	Diary cattle	CDC[a]
2004	NC	*E. coli* O157	108	45	20	15	Goats, sheep	[5]
2004	SD	*E. coli* O157	4	…	…	…	Cattle	CDC[a]
2005	AZ	*E. coli* O157	2	2	2	0	Goats, pigs, cow	[5]
2005	CA	*E. coli* O157	9	6	1	1	Unknown	CDC[a]
2005	CA	*E. coli* O157	4	4	0	0	Unknown	CDC[a]
2005	FL	*E. coli* O157	63	20	17	7	Cow, goat, sheep	[5]
2005	MI	*S.* Typhimurium	3	3	0	…	Unknown	CDC[a]

(continued)

Table 1. ***(Continued.)***

Year	State	Pathogen	No. of ill persons				Suspected or confirmed vehicle/animal	Reference(s) or source
			All ill persons	Culture-confirmed infection	Hospitalized	HUS		
2005	MI	*Campylobacter* species	1	1	0	…	Calves, cow, sheep	CDC[a]
2005	WI	*S.* Typhimurium	19	16	4	…	Pigs, environmental contamination	CDC[a]
2005	WY	*Cryptosporidium* species	2	…	0	…	Unknown	CDC[a]

NOTE. CDC, Centers for Disease Control and Prevention; HUS, hemolytic uremic syndrome.

[a] Unpublished data.
[b] *Cryptosporidium parvum* (9 cases), non-O157 Shiga toxin–producing *E. coli* (2), and *S.* Typhimurium and *Campylobacter jejuni* (1 each).
[c] *C. parvum* (8 cases), *E. coli* O157:H7 (4), and non-O157 Shiga toxin–producing *E. coli* (5).
[d] *C. jejuni* (3 cases) and *C. parvum* (2).

reported (median, 2 hospitalizations per outbreak; mean, 4.7 hospitalizations per outbreak). Information about cases of hemolytic uremic syndrome was obtained for 17 of the 32 outbreaks of *E. coli* O157 infection, with 56 cases of hemolytic uremic syndrome reported (median, 1 case of hemolytic uremic syndrome cases per outbreak of *E. coli* O157 infection; mean, 3.3 cases of hemolytic uremic syndrome cases per outbreak of *E. coli* O157 infection).

LESSONS LEARNED

Risk Factors

Direct contact. Investigations conducted during numerous outbreaks of enteric disease have reported an association between illness and direct contact with animals. Case-control studies of outbreaks of *E. coli* O157 infections at a Pennsylvania dairy farm in 2000, an Ohio county fair in 2001, the North Carolina State Fair in 2004, and Florida petting zoos in 2005 found that ill persons were more likely to have had direct contact with animals (CDC, unpublished data) [1, 2, 5]. At the North Carolina State Fair, a petting zoo held 100 goats and sheep in an open area where visitors could have extensive contact with these animals; ill persons were more likely to have visited this petting zoo and for longer amounts of time, compared with persons who were not ill [5]. In the Florida petting zoos, direct contact, such as touching, feeding, or being licked by an animal, were associated with illness (CDC, unpublished data) [5].

Indirect contact. Disease transmission has also been associated with indirect contact with animals. In the Pennsylvania dairy farm outbreak, illness was associated with markers of human hand-mouth activities, such as nail biting and purchasing food or drink from an outdoor concession at the farm [1, 2]. In the investigation of the outbreak of *E. coli* O157 infection at the Ohio county fair, illness among visitors was associated with eating or drinking a beverage in a contaminated barn and with handling sawdust [15].

In the North Carolina State Fair outbreak, illness among children aged <6 years was associated with touching or stepping on manure, falling or sitting on the ground, use of a pacifier or spill-proof cup, and sucking one's thumb while in the petting zoo [5]. In the Florida petting zoo outbreak, illness was associated with eating while or after visiting the zoo; having soiled hands, clothes, or shoes; sitting or playing on the ground near animals; stepping on manure; touching ground sawdust or shavings; and milking a fake cow outside the petting zoo (CDC, unpublished data) [5].

Environmental contamination. Contact with pathogens in animals' environments can result in disease. Investigations conducted in some outbreaks revealed an association between acquisition of illness and contact with the animals' environment. In the outbreak of *E. coli* O157 infection at an Ohio county fair, ill persons were more likely to have visited a large barn on the fairgrounds that held animal shows and a dance during the fair period. Cultures of sawdust and environmental swabs from the doorways, rails, and bleachers yielded *E. coli* O157. Patient and environmental isolates were found to be indistinguishable by PFGE [15].

Disease transmission was associated with contact with the animal environment in an investigation of an outbreak of *Salmonella enterica* serotype Enteritidis infection in 1996 at a Komodo dragon exhibit at a zoo in Colorado. No ill persons reported touching the Komodo dragons, but ill persons were more likely to have touched the wooden barrier surrounding the dragon pen. Environmental samples from the barriers yielded *S.* Enteritidis; isolates obtained from ill persons, a Komodo dragon, and the barriers were found to be indistinguishable by PFGE [3]. In the Pennsylvania dairy farm outbreak, illness was associated with contact with the animal environment, and *E. coli* O157 was isolated from environmental swabs of a railing surface. Isolates recovered from ill persons, cattle, and the railing surface were found to be indistinguishable by PFGE [1, 2]. Both the North Carolina state fair and Florida petting zoo outbreaks of *E. coli* O157 infection demonstrated extensive environmental contamination of the petting zoo exhibit grounds with environmental isolates matching isolates recovered from ill persons [5].

Table 2. Reported outbreaks of enteric disease associated with animal contact in public settings in the United States, by pathogen, 1991–2005.

Pathogen	No. (%) of outbreaks
Campylobacter species	3 (5.5)
Cryptosporidium species	4 (7.0)
Escherichia coli O157	32 (58.0)
Giardia species	1 (2.0)
Multiple pathogens	3 (5.5)
Salmonella species	12 (22.0)
All outbreaks	55 (100.0)

Pathogens can survive in the environment for weeks to months. Environmental samples from the contaminated barn in the Ohio county fair outbreak yielded the outbreak strain of *E. coli* O157 42 weeks after the outbreak [15]. After an outbreak of *E. coli* O157 infection at an agricultural fair in Texas in 2003, the outbreak strain was isolated from environmental samples of the fairgrounds 46 days after the end of the fair [6]. These investigations demonstrate that steps must be taken to limit environmental contamination.

Protective Factors

Hand hygiene. Hand washing can prevent disease transmission associated with animal contact. This was demonstrated in the Colorado zoo outbreak of *S.* Enteriditis infection, in which washing hands after visiting the lizards was highly protective against illness [3]. In outbreaks at a Minnesota children's farm day camp in 2000 and 2001, washing hands with soap after touching a calf and washing hands before going home was associated with a lower rate of illness [4]. In the Florida petting zoo outbreak investigation, use of running water to wash hands, creating lather with soap while washing hands, and washing hands before eating or drinking were found to protect against illness and disease transmission (CDC, unpublished data) [5].

Changes in hand-washing facilities had an impact on the course of an outbreak of *E. coli* O157 infection at a Washington dairy farm in 2000. In the beginning of the outbreak, visitors were advised to bring antibacterial wipes and use a communal rinse basin present at the farm to wash hands. No signs were posted instructing visitors to wash hands after touching animals. During the outbreak, interventions included distribution of instructional materials and installation of hand-washing stations that provided soap and running water. No further illnesses were reported after these interventions were instituted [1].

Outbreak investigations indicate that certain hand hygiene practices, however, can increase the risk of illness. In the Florida petting zoo outbreak, drying hands on clothes and using antimicrobial wipes before eating and drinking was associated with an increased risk of illness (CDC, unpublished data) [5], suggesting that washing hands with soap and water and drying hands with paper towels are necessary for preventing illness. The use of hand sanitizer gels in animal contact venues remains controversial. In the Florida petting zoo outbreak, having hand gel available was associated with a lower risk of disease (CDC, unpublished data) [5], whereas, in the North Carolina State Fair outbreak, alcohol-based hand sanitizer use was not found to be protective against illness [5].

Other protective factors. In addition to good hand-washing practices, immunity may have a role in protection against disease transmission and illness. The investigation of the Ohio county fair outbreak associated with the contaminated barn demonstrated that ill persons were less likely to own farm animals, suggesting that prior animal contact could lead to acquired immunity and protection against illness (CDC, unpublished data) [15]. Education has also been shown to be a protective factor in disease transmission in these settings. For example, in North Carolina, reported awareness of disease risk from contact with livestock was shown to be protective [5], and in Florida, awareness of the dangers of visiting petting zoos also appeared to protect against illness (CDC, unpublished data) [5]. These findings emphasize the importance of education in prevention of illness and disease in these settings.

NATIONAL RECOMMENDATIONS

NASPHV established recommendations to prevent disease outbreaks associated with animals in public settings in September 2003. Each year, NASPHV and the CDC have updated these recommendations and disseminated them through public health, agricultural, and university extension agencies. The lessons learned from previous outbreaks, including the identified risk factors and preventative factors for illness and disease transmission, are used to formulate and update these recommendations. The current recommendations consist of 5 sections: (1) recommendations for local, state, and federal agencies; (2) recommendations for education; (3) recommendations for managing public and animal contact; (4) recommendations for animal care and management; and (5) additional recommendations, including those for high-risk populations [24].

Local, state, and federal agencies conduct outbreak detection, investigation, and response. Thorough epidemiological investigations of all outbreaks of infection involving contact with animals in public settings should be conducted and reported to the state public health departments and the CDC. Documentation of indirect and direct animal exposure should be included on outbreak investigation and case report forms. Standardized laboratory protocols should be established for obtaining and testing human, animal, and environmental samples.

Physicians can help local, state, and federal agencies improve disease surveillance and outbreak investigation. Physicians should be aware of the diseases associated with animals in

public settings and request cultures for enteric pathogens in stool specimens obtained from patients who present with diarrheal illness—in particular, patients with a recent history of animal exposure. Patients with laboratory-confirmed infections should be questioned about specific exposures to animals and their environment, or public settings where animals are present. Table 3 provides a list of questions physicians can use to obtain information about animal exposure. Laboratory-confirmed cases should be reported to the local or state health department, with information about animal exposure that occurred during the 7 days before the onset of illness.

Local, state, and federal agencies should disseminate recommendations for prevention of disease transmission to all animal venue operators, and educate and train these operators about disease risks associated with animal exposure and risk-reduction measures to prevent disease outbreaks. Animal venue operators should be held responsible for implementation of these measures in public settings where animals are present. Animal venue operators should also be held responsible for educating visitors about these disease risks and risk-reduction measures.

Physicians can play an important role in this education by ensuring that their adult patients and parents of pediatric patients are educated about the risks associated with attending venues where animals are present and about measures to reduce risk, such as hand washing and avoidance of direct and indirect contact with animals, when possible. Populations at high risk for serious infection include young children (i.e., those aged <5 years), older adults, and persons who are cognitively impaired, pregnant, or immunocompromised. Persons in these high-risk groups should take heightened precautions, such as thorough and frequent hand washing and avoidance of contact with animals and their environment, at all animal exhibits.

Parents need to supervise young children closely in animal contact settings to discourage hand-to-mouth activities and contact with manure and soiled bedding. Very young children should be carried by an adult through animals' areas or have animal contact only over a barrier to avoid being knocked down. Hand washing should be supervised and should occur when hands become soiled in animals' areas, when exiting animals' areas, and before eating or drinking in non–animal areas at these venues.

CONCLUSIONS

An increased number of outbreaks of enteric disease associated with animals in public settings, such as fairs and petting zoos, have been reported over the past 10 years in the United States. The most common enteric pathogens that cause illness in this setting include *E. coli* O157 and *Salmonella* species. Outbreaks have caused preventable illnesses, hospitalizations, and complications of these infections, such as hemolytic uremic syndrome, in many persons. It is unclear whether the increase in outbreaks is associated with improved surveillance or with environmental factors that result in higher rates of human exposure and illness. However, it has been determined that disease transmission is associated with direct and indirect contact with animals and their environment and that it can be prevented by hand washing and educating the population about the risks associated with attending animal venues. Physicians should educate patients about these risks and aid in surveillance of these outbreaks through collection and culturing of stool samples and reporting of cases to health departments. Through improved education and surveillance, outbreaks of disease associated with animals in public settings could be prevented in the future.

Table 3. List of questions to obtain information about animal exposure from patients who present with diarrheal illness or from patients with culture-confirmed infection due to enteric pathogens.

Do you live or work on a farm? If yes, what animals are present on the farm (cattle, sheep, goats, chickens, pigs, or other)?
Did you have any contact with animal manure in the 7 days before illness? If yes, during what kind of activity did you have this contact (farming, gardening, caring for animals, or other)?
Did you visit a farm, fair, or petting zoo in which there were animals present in the 7 days before illness?
Where (city, state)?
When (dates)?
What animals were present (cattle, chicks/ducklings, sheep, reptiles, goats, rodents, chicken, birds, pigs, horses, or other)?
Did you have direct contact with any of these animals?
If yes, what type of contact did you have with these animals (petting, feeding, licking [by animal], or other)?
If yes, what type of animals did you have direct contact with (cattle, chicks/ducklings, sheep, reptiles, goats, rodents, chickens, birds, pigs, or horses)?

NOTE. Adapted from [25].

Acknowledgments

We thank all members of the NASPHV and their respective state public health departments. In addition, we thank all NASPHV Compendium committee members and consultants. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the funding agencies.

Financial support. National Center for Infectious Diseases and CDC; N.S. was funded by Pfizer Public Health Group through the CDC Foundation as a CDC Experience Fellow.

Potential conflicts of interest. All authors: no conflicts.

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