

Public Veterinary Medicine: Public Health

Outbreaks of zoonotic enteric disease associated with animal exhibits

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The importance of zoonotic enteric disease transmission at animal exhibit settings has become apparent in recent years, as outbreaks associated with animal exhibits are reported with increasing frequency. Until recently, awareness of direct animal-to-human transmission of enteric pathogens was limited; there had been a few individual case reports.¹⁻³ With recent large outbreaks associated with public animal exhibits, this public health issue has expanded beyond the population of farm families and persons living in close proximity to cattle operations.

The reasons that animal exhibit-associated outbreaks of enteric disease have become more common may include the shift in the human population from rural to urban environments. Patterns of interactions between humans and farm animals have changed from frequent daily activities associated with farm life to less frequent events that are clustered in space and time, such as visits to petting zoo farms and state and county fair exhibits. Annually, more than 125 million people attend agricultural fairs in the United States,⁴ and in a recent survey⁵ of 9,000 US residents, 2% of all respondents reported visiting an exhibit involving animal contact in the last 5 to 7 days. Generalizing those data to the US population suggests that almost 6 million people attend animal exhibits regularly, which is a high risk of exposure.

Despite the high risk of exposure to enteric pathogens associated with attendance at animal exhibits, most visits to petting zoos, open farms, zoologic gardens, and agricultural fairs provide a safe learning experience for the public. However, human enteric pathogens such as *Escherichia coli* O157:H7, *Salmonella enterica*, and *Cryptosporidium parvum* are ubiquitous and can be shed intermittently by apparently healthy animals. Therefore, it is very difficult to

establish a clear-cut strategy for preventing human exposures. The advice of veterinarians is often the first sought by operators of open farms or animal exhibits when a zoonotic disease problem arises. A summary of enteric disease outbreaks associated with animal exhibits, excluding those in which food or water consumed by visitors was the vehicle of infection, is provided in this report. The epizootiology of *E coli* O157:H7, *S enterica*, and *C parvum* is briefly reviewed, and guidelines and recommendations for prevention of exposures are discussed.

Types of Animal Exhibits

Three general categories of animal exhibits are permanent animal exhibits, temporary animal exhibits, and reoccurring animal exhibits. Permanent animal exhibits include petting zoos, children's farms, and animal contact areas of science museums. A wide variety of animal species may be exhibited in all types of exhibits, but those offered for petting and handling often include sheep, goats, and calves. Small commercial dairy farms that are open to the public also often feature contact with young ruminants. These open farms became common during the 1980s in the United Kingdom.⁶ Open farms in the United Kingdom are urban or rural, may be open to the public on a daily basis, or may host a group of children for a period of several days. Contact with animals is often encouraged, and visiting children may feed or bottle-feed young animals and help clean animal pens.⁷

Temporary animal exhibits are those that appear sporadically in shopping malls, at community events, and educational institutions. Some of these animal exhibits may be licensed by the USDA, but many are likely to involve privately owned animals and are not subject to licensing requirements. Reoccurring exhibits include state and county agricultural fairs, at which the public has free access to barns where animals are housed and barriers between animals and the public are minimal. Animals in temporary or reoccurring exhibits are more likely to have been recently transported, and the stress of shipping predisposes them to increase fecal excretion of zoonotic pathogens.⁸ State and county fairs involve the con-

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vergence of animals from diverse locations, a situation that amplifies the probability of infectious disease transmission.

Enteric Zoonotic Disease Outbreaks Associated with Animal Exhibits

Cryptosporidiosis—*Cryptosporidium parvum* is a ubiquitous organism with multiple host species and is capable of surviving for extended time periods in the environment.⁹ In humans, cryptosporidiosis is characterized by profuse, watery diarrhea that is typically self-limiting; the diarrhea is sometimes accompanied by abdominal cramps, nausea, and vomiting, but rarely fever. Infections are most life-threatening for immunocompromised persons.¹⁰ As few as 30 oocysts can cause infection in healthy adults, and oocysts can remain viable in water for 6 months at 20°C (68°F).⁹ Oocysts excreted in feces are immediately infective.¹¹ Evidence for *C parvum* infections in > 150 mammalian species has been reported.⁹ There are 2 main genotypes associated with human infections: 1 is restricted primarily to humans and the other is found in humans and livestock.¹²

Cryptosporidia are commonly detected on North American dairy farms. Data collected via the National Dairy Heifer Evaluation Project indicated that *Cryptosporidium* sp was detectable on more than 90% of farms,¹³ and although the organism is associated with diarrhea in calves, healthy calves can also be shedding

oocysts in their feces.¹³ Young animals are more likely to excrete *Cryptosporidium* oocysts than are adult cattle, and healthy calves will eliminate the infection in a few weeks.¹⁴ Reports^{15,16} of outbreaks of cryptosporidiosis among veterinary students in contact with calves excreting oocysts indicate that direct transmission from cattle can be a source of human cryptosporidiosis. Indirect evidence for this is derived from results of a seroprevalence study¹⁷ in which data for dairy farmers and nonfarmers were compared and from the decrease in human cryptosporidiosis detected in England and Wales during the foot-and-mouth disease epidemic when large numbers of cattle were destroyed.¹⁸

Outbreaks of cryptosporidiosis associated with farm visits have been reported in England, Wales, Ireland, and New Zealand (Table 1). Risk factors for acquiring cryptosporidiosis on farms include contact with young sheep and calves, hand-to-mouth activities in animal contact areas, and inadequate hand-washing facilities.^{20,23,34} The highest risk in 1 farm-associated outbreak was attributed to playing in sand contaminated with farm animal feces.²⁴ As with other enteric pathogens, hand washing before meals was protective against infection.²³

***Escherichia coli* O157:H7 infection**—Most human *E coli* O157:H7 infections are food- or waterborne,³⁸ but direct contact with cattle and the farm environment has also been associated with *E coli* O157:H7

Table 1—Outbreaks of zoonotic diseases associated with animal exhibits, 1990 through 2002

Location	Pathogen	Setting	Year	No. of affected humans	Ref
England	Cryptosporidia	Open farm	1990	11	19
England	Cryptosporidia	Open farm	1992	10	7
England	Cryptosporidia	Open farm	1993	54	7
England	Cryptosporidia	Open farm	1993	33	7
England	Cryptosporidia	Open farm	1994	15	20
England	Cryptosporidia	Open farm	1994	29	20
England	<i>Escherichia coli</i> O157	Open farm	1994	7 (4 with HUS)	21
Wales	<i>E coli</i> O157	Open farm	1995	3 (1 with HUS)	22
Wales	Cryptosporidia	Open farm	1995	31	23
Ireland	Cryptosporidia	Open farm	1995	13	24
Colorado, USA	Salmonellae	Zoo	1996	39	25
England	<i>E coli</i> O157	Open farm	1997	3	26
England	<i>E coli</i> O157	Open farm	1997	12 (2 with HUS)	27
Ontario, Canada	<i>E coli</i> O157	Agricultural fair	1999	159	28
England	<i>E coli</i> O157	Open farm	1999	3	29
Wales	<i>E coli</i> O157	Open farm	1999	24 (3 with HUS)	30
Ohio, USA (Medina County)	<i>E coli</i> O157	Agricultural fair	2000	39	a
Washington State, USA	<i>E coli</i> O157	Petting zoo	2000	5	31
Pennsylvania, USA	<i>E coli</i> O157	Petting zoo	2000	51 (6 with HUS)	32
The Netherlands	<i>E coli</i> O157	Petting zoos	2000	2 (1 with HUS)	33
New Zealand	Cryptosporidia	Open farm	2001	20	34
Ohio, USA (Lorain County)	<i>E coli</i> O157	Agricultural fair	2001	21 (2 with HUS)	35
Ohio, USA (Wyandot County)	<i>E coli</i> O157	Agricultural fair	2001	37 (3 with HUS)	a
Tasmania	Cryptosporidia	Petting zoo	2001	47	36
Wisconsin, USA	<i>E coli</i> O157	Agricultural fair	2001	56 (tentative estimate)	b
Oregon, USA	<i>E coli</i> O157	Agricultural fair	2002	82 (12 with HUS)	c
Australia	Salmonellae	Child care center	2002	7	37
Australia	Salmonellae	Child care center	2002	6	37
Australia	<i>E coli</i> O26	Petting zoo	2002	6	37

HUS = Hemolytic uremic syndrome. Ref = Reference.

infections.¹⁻³ Because of its small infectious dose for humans³⁸ and the severity of disease it causes, *E coli* O157:H7 may be the most important zoonotic agent that has been associated with animal exhibits. Infection with *E coli* O157:H7 causes a spectrum of disease, including self-limiting diarrhea, hemorrhagic colitis, and **hemolytic uremic syndrome (HUS)**. The triad of clinical features that characterize HUS are hemolytic anemia, thrombocytopenia, and renal failure. Infection with *E coli* O157:H7 is the leading cause of acute renal failure in children in the United States.³⁸

Cattle are considered the primary reservoir for *E coli* O157:H7, but the organism has been detected in many animal species that are frequently used in exhibits, notably sheep, goats, horses, dogs, wild birds, and rabbits.^{39,40} Infection in domestic and wild animals is transient and without clinical signs of illness.⁴¹ Prevalence of fecal excretion of *E coli* O157:H7 among commercial cattle is seasonal, peaking in the summer and early fall (agricultural fair time), and is highest in weaned calves.⁴² The causes of these peaks of infection remain undetermined, and their timing is not yet predictable. Results of bacteriologic culture of feces obtained from individual animals may be first positive (ie, growth of the organism detected), then negative, and then positive again when samples are collected at intervals for analysis.⁴² Therefore, this method of testing cannot establish whether an animal or herd is pathogen-free. Among cohoused groups of cattle, the prevalence of fecal excretion of *E coli* O157:H7 within the group may occasionally approach 100%, suggesting efficient transmission from animal to animal or simultaneous transmission from a common source to all animals in the group.⁴³ Efficient transmission of the organism among calves after low dose exposures has been demonstrated experimentally.⁴⁴ *Escherichia coli* O157:H7 can survive in manure and soil for several months.⁴⁵ Animals that are young, recently transported, and stressed are most likely to excrete *E coli* O157:H7.⁴² Data regarding the prevalence of *E coli* O157:H7 infection in exhibition animals are limited. Findings from commercial operations may not accurately represent the situation at exhibits, particularly temporary exhibits that feature young animals primarily. In a study by Jacobson et al,⁴⁶ *E coli* O157:H7 was not detected in animals at a zoo, but the culture methods used were insensitive, compared with those used presently. Results of a recent study³³ conducted in the Netherlands indicated that 2 of 11 petting zoos had animals infected with *E coli* O157:H7. In a study^d of 32 agricultural fairs in the United States, a high prevalence of *E coli* O157:H7 infection was detected in livestock (infection in 13.8% of dairy cattle, 5.9% of beef cattle, and 5.2% of sheep) and in composite samples of trapped flies (7.1%).

The first reported animal exhibit-associated outbreaks of *E coli* O157 infection occurred in the United Kingdom (Table 1). These were associated with visits to open farms and most of the individuals affected were children. Investigations of these outbreaks consistently revealed that hand-washing facilities were inadequate, no information about the potential for zoonoses was provided to visitors, animals were new or overstocked,

and children were allowed direct contact with animals.^{21,22,27} In 1999, a large outbreak occurred in Ontario, Canada, involving 159 probable cases and 7 cases confirmed via bacteriologic culture. Risk of infection was strongly associated with a petting zoo, particularly contact with sheep and goats; risk was also associated with lack of hand washing and eating while in the animal area.²⁸ The following year, 2 more outbreaks associated with direct animal contact at open farms occurred in the United States. The larger of these occurred at a dairy farm in Pennsylvania. At the time of the investigation, 15% of cattle assessed were excreting *E coli* O157:H7 in feces. This outbreak was also characterized by the involvement of a very young group of visitors (most were preschool-aged children), no restrictions on eating or drinking in the animal contact area, and no supervision of animal contact.^{31,32}

From 2000 to 2002, 5 outbreaks of *E coli* O157:H7 infection associated with agricultural county fairs occurred in Ohio, Wisconsin, and Oregon (Table 1). Results from investigations of 3 of them indicated risk factors that were consistent with those identified in previous outbreaks, including contact with animals, hand-to-mouth activities, and less than adequate hand washing. In 2 of the 5 outbreaks, findings indicated a strong likelihood that *E coli* O157:H7 can be transmitted as an airborne pathogen; in both outbreaks, the only common risk factor was exposure to the barns (hand washing and food consumption had no association). The environmental investigations yielded *E coli* O157:H7 isolates from samples of sawdust collected months after the outbreaks and from samples collected from elevated surfaces in the barns. Genomic DNA from these environmental isolates had the same pulsed-field gel electrophoresis pattern as that of the outbreak strain.

Salmonellosis—Nontyphoid *S enterica* infections in humans cause illnesses involving self-limiting diarrhea, sometimes characterized by fever, nausea, abdominal cramps, and bloody diarrhea. Rarely, salmonellae can cause extraintestinal infections. The probability of an infection becoming invasive depends on the immunocompetence of the host and on the serotype of *Salmonella* organisms involved. Most *Salmonella* infections in the United States are foodborne, but there is evidence that environmental exposures may be more important for salmonellosis in children.⁴⁷ As determined for Cryptosporidia and *E coli* O157:H7, oral ingestion is the infection route for *Salmonella* spp. Although *Salmonella* infection is often associated with disease in livestock, many infections do not cause clinical signs; as observed with *E coli* O157:H7, disease is not a reliable marker for infection in animals. There are > 2,000 serotypes of *Salmonella*, some of which are predominantly host-specific, but many (such as *Salmonella* ser Typhimurium) are found in a wide range of host species.⁴⁸ *Salmonella* organisms are ubiquitous in domestic and wildlife populations. The prevalence of *Salmonella* organisms in feces of dairy cattle is high,⁴⁹ even among clinically normal animals. Salmonellae can survive for extended periods in the environment, as can cryptosporidia and *E coli* O157:H7.⁵⁰

The potential of direct zoonotic transmission of *Salmonella* spp is well known but probably best described for reptile-associated salmonellosis in infants and young children.⁵¹ However, only 4 salmonellosis outbreaks associated with public animal exhibits have been reported (Table 1). In 1991, a salmonellosis outbreak in humans in association with an animal exhibit was first reported. At the Pacific Science Center in Seattle, Wash, there was an exhibit of small mammals, baby chicks, and reptiles; children were allowed to handle animals under individual supervision by staff, but there were no hand-washing facilities in the building at the time of the outbreak. Fecal samples from exhibit animals and environmental samples yielded *S Typhimurium*. After depopulation of the exhibit, the environment was sanitized, hand-washing facilities were installed, and children were no longer allowed to handle reptiles. No further cases of salmonellosis developed in association with the exhibit.⁵² A second salmonellosis outbreak in the United States (involving *S Enteritidis*) occurred at the Denver Zoological Gardens in 1996. This was a temporary exhibit of Komodo dragons that were exhibited in a pen surrounded by a 2-foot-high wooden barrier. This barrier was accessible to the public, and bacteriologic culture of samples obtained from it 2 weeks after the exhibit closed yielded *S Enteritidis*. The results of the epidemiologic investigation identified a high risk associated with touching the barrier and the protective effect of hand washing, even after touching the barrier.²⁵

Common features—These 3 human pathogens discussed have certain traits in common. Their exposure route is via ingestion, so the same prevention strategies will be effective for all of them as well as for other zoonotic enteric pathogens that are not reviewed here (eg, *Campylobacter*, *Giardia*, and *Yersinia* spp). They are ubiquitous; *C parvum*, *E coli* O157:H7, and serotypes of *S enterica* are commonly found on most types of livestock operations in North America. These organisms have multiple host species, including wild animal hosts, and can remain viable for a long time (even months) in the environment. For each of these pathogens, disease in animals cannot be used as a marker for infection. The organisms are not candidates for eradication; their ecology is complex and involves many host species, as well as environmental reservoirs. Therefore, test and cull strategies will not be successful.

Each of the outbreaks described above has unique features, but there are also some common patterns. For each pathogen, young children are most susceptible. Hand washing after touching animals or their environment and before eating is protective against infection. Hand-to-mouth activities in animal contact areas increase risk.

Recommendations

Complete prevention of zoonotic transmission at public animal exhibits could only be achieved by complete prevention of any contact between people and animals. This would be not only unfortunate but would also not be feasible. There is a long-standing tra-

dition of agricultural livestock exhibits, and interaction with animals can be an educational and gratifying experience for children. However, as more outbreaks at public animal exhibits occur, liability issues are likely to threaten the future of such exhibits more than any regulatory actions could.

The earliest published recommendations addressing zoonotic transmission at animal exhibits were prepared by the Health and Safety Executive in the United Kingdom⁵³ as a response to the series of outbreaks of cryptosporidiosis and *E coli* O157:H7 infections associated with farm visits (Table 1). In the United States, the CDC published a set of recommendations after 2 outbreaks associated with petting zoos in Pennsylvania and Washington State.³¹ Local government entities have published recommendations as well.^{28,54,55} The American Zoo and Aquarium Association Animal Health Committee has also drafted guidelines for their members.⁵⁶ We have distilled these guidelines and added some additional information with the purpose of presenting recommendations here to minimize the probability of human exposure to enteric pathogens at animal exhibits:

- Signs informing the public about how diseases are transmitted and the importance of hand washing should be posted at every entrance of an animal exhibit.
- Food and drink should never be permitted in animal contact areas.
- Food concessions and animal exhibits should never be located in the same building.
- Adequate hand-washing facilities should be available.
- Animal contact areas should be supervised to prevent hand-to-mouth activities. Children too young to practice adequate hand hygiene should not be allowed contact with animals.
- Animals that are ill should not be included in exhibits.
- The layout of the exhibit should provide hand-washing stations between the animal contact area and food concession areas.
- Animal feces should be removed from the exhibit areas as frequently as possible.
- Fencing and rails in public areas should be cleaned and disinfected daily.
- Buildings used for exhibiting livestock should be adequately ventilated.
- Buildings that have been used previously to exhibit livestock should be thoroughly cleaned and disinfected before being put to any other use.

These recommendations were derived from outbreak investigation findings and current knowledge of the pathogens involved. However, our knowledge is too limited overall to provide precise guidelines where they may be needed. For effective communication with members of the public, the most appropriate type of signage has yet to be determined. Prohibiting food and drink from animal areas is straightforward, but may be difficult to enforce. The minimum distance that should be established between the animal exhibit area and food vendors is not known. It is known that hand

washing with soap and water prevents disease transmission, but providing a sufficient quantity of hand sinks or wash stations for the large numbers of people that attend agricultural fairs is problematic. The Health and Safety Executive of the United Kingdom estimates that if 30 people exit a barn in a period of 15 minutes, 4 hand sinks would be required.⁵³ At large agricultural fairs, however, it is conceivable that 30 people could exit a barn each minute. In that case, according to the Health and Safety Executive calculations, 60 hand sinks would be needed. Waterless hand hygiene preparations have been thoroughly evaluated in health-care settings, and alcohol-based hand gels are effective and well received by health-care workers⁵⁷; however, the efficacy of those preparations has not been rigorously assessed in animal exhibit settings. If a waterless hand hygiene preparation were efficacious at reducing microbial organisms on hands after animal contact, the fair managers could make it available at many sites throughout the exhibit.

The age at which children may safely have contact with animals is not known. It has been recommended that children < 5 years old should not visit farms.⁵⁸ This may seem extreme to some, but there is precedent for the recommendation that vulnerable individuals should not be exposed to situations where the disease risk is otherwise minimal. For example, the CDC and many state authorities recommend that reptiles are not kept as pets in households with infants, young children, and immunocompromised persons.⁵¹ It seems evident that children too young to control their hand-to-mouth actions should not be allowed in animal contact areas.

Evidence from investigations of at least 2 recent livestock fair-associated outbreaks of *E coli* O157:H7 infection suggests an aerosolborne means of transmission.^{35c} The probability of ingestion of this organism either directly or by hand-to-mouth activities from contaminated surfaces is likely to be high in buildings in which most of the particulates are not removed by the ventilation system and bioaerosols are disseminated throughout the building. Therefore, it is possible that adequate ventilation and optimal animal density may be critical to the safety of visitors at livestock exhibits. The Midwest Plan Service located at Iowa State University provides information on ventilation systems and livestock air exchange requirements.⁵⁹ Assessment of ventilation in fair barns should be the subject of research investigations to provide more specific guidelines and remedial methods to improve the health safety of exhibit attendees. In addition to ventilation assessment, management factors that may be associated with environmental contamination in livestock exhibits also need to be identified. Feed and water handling, type of bedding used, and manure handling can all contribute to the pathogen load in a barn.

The problem of animal exhibit-associated outbreaks of zoonotic enteric diseases will continue until appropriate precautions are established and followed by the managers of the exhibition venues. Temporary exhibits, such as state and county livestock fairs, have different challenges than do permanent exhibits. Large

fair operations and petting zoos in urban zoological parks have more resources than do small family farms. To provide guidelines appropriate for the range of animal exhibit types, an expanded knowledge base is needed. With regard to prevention of outbreaks of animal exhibit-associated enteric disease, areas that need to be addressed include appropriate and effective signage and other means to communicate risk to the public, provision of effective hand hygiene alternatives to washing with soap and water, ventilation requirements to reduce or contain airborne bacteria, and correction of management practices that predispose to environmental contamination.

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