Zoonoses Associated with Petting Farms and Open Zoos

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ABSTRACT

The popularity of open farms and petting zoos has increased markedly over the last 5 years, with most children in developed countries now having the opportunity to visit such a facility at some stage in their childhood, either through school or family visits. The open access policy of these establishments allows visitors to be in direct contact with animals such as sheep (lambs), goats, cats (kittens), dogs (puppies), and birds and to have the opportunity to feed such animals. This contact may lead to the transmission of microbial pathogens from animals to humans, e.g., \textit{Escherichia coli} O157:H7, resulting in human disease. This review outlines the causal organisms associated with such zoonoses, a description of previous outbreaks at farms and zoos, as well as infection control measures to help prevent such zoonotic infections. Key Words: Zoonosis—\textit{Campylobacter}—\textit{Salmonella}—\textit{E. coli} O157—\textit{Yersinia}—\textit{Arcobacter}—\textit{Shigella}—Antibiotic resistance—Petting farms—Open farms—Exotic species.

INTRODUCTION

O VER THE LAST DECADE, there has been a significant rise in the popularity of open farms and petting zoos in the United Kingdom. Visitors have access to animals such as goats, sheep, lambs, rabbits, kittens, and puppies, which makes these attractions particularly popular among children. This close association, promoted through activities such as feeding and handling the animals, has led to reports of zoonotic transmission of several mainly gastrointestinal infections, including \textit{Escherichia coli} O157:H7 (Heuvelink et al., 2002). In addition, several zoos and recreational theme parks have introduced petting farms and other areas of open public contact with animals.

The World Health Organization (www.who.int/en) defines the term zoonosis as “a disease and/or infection that can naturally transmit between vertebrate animals and man.” Zoonosis and zoonoses are terms that encompass a variety of diseases including toxoplasmosis and avian influenza, as well as a range of causative agents such as bacteria and viruses, to unconventional agents such as prions. Zoonoses are not defined to a specific area but rather a global occurrence.

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MODES OF TRANSMISSION

Woolhouse (2002) considers there to be three major routes of zoonotic transmission:

1. **Direct contact** refers to being in close proximity to an animal with the zoonotic agent. In May 1994, a 41-year-old male farmer who had close contact with cattle, developed a scaly nonpustular lesion on the left cheek (Maslen 2000). The Mycology Reference Laboratory of the Microbiological Diagnostic Unit at The University of Melbourne, Victoria, Australia, identified the causative agent as *Trichophyton verrucosum*. This fungus produces lesions on cattle and tinea of humans (cattle ringworm). It is recognized as a common cause of ringworm in humans of rural areas and is contracted directly from cattle.

2. **Indirect contact** refers to transmission routes that have an affiliation with the infecting animal, such as food or an environmental reservoir. In a case report, an 8-year-old girl on admission to hospital was febrile, had a rapid heart rate, an increased breathing rate, and normal blood pressure (Sauret and Vilissova 2002). She had previously complained of abdominal pain, sore throat, fever, and weight loss. A bone marrow biopsy indicated brucellosis; this was confirmed with positive blood cultures showing gram-negative rods that were serum agglutination positive for *Bacillus melitensis* (Sauret and Vilissova 2002). A review of her history showed she was born in Iraq and later moved to Syria with her parents and three siblings, where they lived on a farm. While living there she had consumed unpasteurized goat’s milk.

3. **Vector-borne contact** refers to the transmission of the causative agent by a third party. West Nile fever is caused by a virus belonging to the genus *Flavivirus* of the family *Flaviviridae* (Solomon et al. 2003). It is responsible for causing flu-like symptoms, such as pain behind the eyes, backache, a feeling of discomfort, fever, headache, joint and muscle pain. Those infected may also display anorexia, diarrhea, a cough, nausea, sore throat, and vomiting. West Nile virus (WNV) is normally maintained in a bird-mosquito cycle; however, human infections occur by the virus being transmitted by bites from infected mosquitoes of the genus *Culex* (Gould and Fikrig 2004). To the best of our knowledge, there has not been a case of human West Nile fever originating from a positive infected animal, although the potential for animal infection in zoos has been described previously, particularly among birds (D’Agostino and Isaza 2004).

It should be noted that the mode of transmission by the majority of pathogens may incorporate more than one category.

STUDIES ON THE DIVERSITY OF ZOONOTIC AGENTS FOUND IN ZOO ANIMALS

There are relatively few studies describing the carriage of zoonotic pathogens in open farm or zoo animal populations.

Luechtelfeld et al. (1981) tested 619 fecal specimens from healthy and sick animals within the Denver zoo in an attempt to identify any animal reservoir for *Campylobacter fetus* subspecies *jejuni*. The organism was obtained in samples from birds, felids, hooved animals, primates, red panda, and a reptile.

In March 1998, fecal samples were taken from 100 macaroni penguins, 40 black-browed albatrosses, and 100 gray-headed albatrosses, which were all too young to leave the nest, and 206 Antarctic fur seal pups from Bird Island, South Georgia (Broman et al. 2000). The samples were tested for the presence of *Campylobacter jejuni* subspecies *jejuni*. Three isolates were identified, all originating from the macaroni penguins.

In February 2002, 233 fecal samples were taken from eight bird species found within six penguin colonies along the Antarctic Peninsula (Bonnedahl et al. 2005). Each sample was tested for the presence of *Campylobacter*, *Salmonella*, and *Yersinia* species; none was found.

Between 2002 and 2003, 274 fecal samples were collected from 100 mammals and 29 reptiles to determine the presence of *Cryptosporid-
ium (Alves et al. 2005). Cryptosporidium oocysts were found in a black wildebeest, a Prairie bison, and an Indian star tortoise.

One aural, nasal, oral, rectal, and pharyngeal swab, coat hair, and fecal sample were collected from each participating dog used for visitations at hospitals within Ontario (Lefebvre et al. 2006). Samples were cultured for 18 specific pathogens of bacterial, fungal, and parasitic origin. Zoonotic agents were found in 80% of the animals, with Clostridium difficile being isolated the most. An extended-spectrum beta-lactamase (ESBL) producing Escherichia coli was isolated from one dog, an extended-spectrum cephalosporinase Escherichia coli from three dogs, Pasteurella multocida or Pasteurella canis from 29 dogs, and Salmonella from three dogs. Malassezia pachydermatis, a yeast, was isolated from eight aural swabs, two dogs had Toxocara canis and one had Ancylostoma caninum. This study showed that visitation dogs may be a potential risk to patients, especially those who are immunocompromised, and are a new concern for infection control.

In 2003, the British media brought to society’s attention that pets including the domesticated cat, dog, and rabbit were found to be colonized with methicillin-resistant Staphylococcus aureus, or MRSA, as it is more commonly known. This has been confirmed in a study by O’Mahony et al. (2005). Currently, scientists are examining the link of transmission of MRSA from animals to humans, but it is possible that transmission may be from humans to animals, or even both, as was observed by Weese et al. (2006).

### OCCURRENCES OF ZOONOTIC INFECTIONS

**Infections by bacteria**

E. coli O157:H7 infection from a petting zoo in Florida. Following 22 reports to Florida health officials in March 2005, a total of 63 people were identified as being infected with E. coli O157:H7, 17 of whom were hospitalized (CDC, 2005). Attending fairs and festivals was determined as the source of infection. At three of the implicated events, there was one common farm exhibit that offered interaction with the animals. Some of the environmental sampling of the exhibit grounds, and of human and animal stools, yielded E. coli O157:H7.

E. coli O157:H7 infection from an Arizona zoo. Two unrelated children were hospitalized with an E. coli O157:H7 infection in July 2005, after visiting a zoo that contained a petting area (CDC, 2005). Of the 25 fecal samples from animals within the petting zoo, 15 yielded E. coli O157:H7. As a result, zoo officials closed the petting zoo and an adjacent play area.

Salmonella typhimurium in a Dutch farm. In January 2001, on a farm in IJsselstein, The Netherlands, that housed 80 dairy cows and 250 pigs in separate sheds, a farmer observed that a pig from one of the pig pens had died suddenly (Hendriksen et al. 2004). Another pig from the same compartment was very weak and was passing yellowish diarrhea; all other pigs were not showing any similar signs. The farmer had noticed that diarrhea had occurred in several of the other pig pens. Twenty days later, calves from the same farm were displaying diarrhea and fever, two of which had symptoms of pneumonia. At one stage, the farmer’s son became ill with diarrhea and fever. Samples from both animals and child yielded Salmonella. The primary source was thought to be the pigs, as the calves were a day old when the
pig died. Carriage to the calves may have occurred by the farmer, who took care of animals in different areas without changing clothes, or by other members of the family or visitors transmitting contaminated pig feces to the calves on dirty boots or clothes. The pigs or the calves could have infected the son, as he had access to all areas. It was suspected that the calves were the most likely source of infection to the son, as his rabbits were housed in the calves’ stable. Another theory is that the farmer transmitted the infection to his son due to inadequate hand washing, wearing inadequately disinfected footwear, or wearing work clothes indoors.

**Shigellosis in a Vienna zoo.** During February 2004, a Barbary macaque developed bloody diarrhea with a further three becoming ill; all died despite prompt antibiotic therapy and quarantine measures (Lederer et al. 2005). Furthermore, two orangutans developed bloody diarrhea and both died within 24 hours of showing symptoms. Despite taking precautions, an animal keeper drafted in to clean the cages of the two deceased orangutans, also developed bloody diarrhea and was hospitalized for 4 days. Samples from the macaque, orangutans, and animal keeper all yielded *Shigella flexneri*.

**Infections by parasites**

**Cryptosporidiosis at a veterinary teaching hospital and a northern Colorado farm.** At the beginning of March 1987 on a farm in northern Colorado, nearly all the beef calves showed a diarrheal illness (Reif et al. 1989). Four calves were admitted to an isolation unit at a veterinary teaching hospital. The cause of the diarrheal illness was found to be *Cryptosporidium*, which was present in both animals in the isolation unit and those tested on the farm. A female veterinary student who cared for, sampled, and treated the calves had symptoms of watery diarrhea, abdominal cramps, nausea, fever, headache, vomiting, and flatulence a week after initial contact. After parasitological examination of her stool, she was found to have cryptosporidiosis. Several additional students and faculty members also complained of gastrointestinal symptoms over the next 2 weeks.

**Cryptosporidiosis at an educational farm.** In April 1995, a group of 43 children between 8 and 11 years old and four adults stayed for a week at an educational farm in Pembrokeshire (Evans and Gardner 1996). They took part in activities which included handling, feeding, and cleaning horses, calves, and lambs; feeding and milking goats; as well as feeding poultry and collecting their eggs. A few days after returning from the farm, 27 children and the four adults displayed diarrhea, abdominal pain, or vomiting. *Cryptosporidium* oocysts were observed in fecal samples from six children and one adult when microscopically examined using a modified Ziehl-Neelsen stain. As a preventative measure, children washed their hands under adult supervision after each activity, and boots and outdoor clothing were removed when the group returned to their accommodation. Hand washing should have occurred again at the accommodation, but it was identified that this was not always supervised.

**Infections by viruses**

**Monkeypox virus transmitted by prairie dogs.** A 3-year-old girl was admitted to a central Wisconsin hospital with cellulitis and fever after being bitten by a pet prairie dog (Reed et al. 2004). Using electron microscopy, an orthopoxvirus was observed from cell culture supernatants from the prairie dog and one of the child’s parents who later became ill. Polymerase chain reaction (PCR) of the hemagglutinin gene of the orthopoxvirus, followed by restriction fragment length polymorphism (RFLP) analysis, resulted in a sequence that matched the hemagglutinin gene from monkeypox virus.

**Transmission of sealpox virus to human.** Following a superficial abrasion caused by a bite from a captive young gray seal, a marine mammal research technician developed a lesion on the back of his right hand (Clark et al. 2005). A biopsy was taken from the lesion for histological and electron microscopic analysis, with the
rest being surgically removed for mycobacterial culture. Histological findings were in keeping with orf, a skin disease caused by viruses of the Poxviridae family. Electron microscopy observed parapox virions and mycobacterial culture was negative. Viral DNA was amplified via PCR and sequenced and was found to have homology (98%) with the sealpox virus.

**Zoonoses That May Be Transmitted by Handling Infected Animals**

Several zoonotic infections have been described as potentially being transmitted from infected animals to their handler(s). Between 1994 and 1996, three elephants from an exotic animal farm in Illinois died of pulmonary disease due to *Mycobacterium tuberculosis*. In October 1996, a fourth living elephant was culture-positive for *M. tuberculosis*. Twenty-two handlers at the farm were screened for tuberculosis (TB); 11 had positive reactions to intradermal injection with purified protein derivative. One had smear-negative, culture-positive active TB. DNA fingerprint comparison by IS6110 and TBN12 typing showed that the isolates from the four elephants and the handler with active TB were the same strain. This investigation indicates transmission of *M. tuberculosis* between humans and elephants (Payeur et al. 2002).

On September 3, 1999, *Morbidity and Mortality Weekly Report* (MMWR) detailed that on August 27 of that year, a black bear cub, approximately 5–6 months old, died after several hours of acute central nervous system symptoms; preliminary test results available on August 28 indicated the bear had rabies (CDC, 1999). The bear was part of the Swenson’s Wild Midwest Exotic Petting Zoo in Clermont, Iowa (northeastern Iowa). At the petting zoo, visitors fed, wrestled, and may have been nipped by the bear. The bear also was taken to a barnwarming at the Tharp barn in Holy Cross, Iowa (eastern Iowa), where it reportedly nipped people.

During the 28 days before its death, an estimated 400 people from 10 states (Arizona, California, Florida, Illinois, Iowa, Minnesota, New Mexico, New York, Ohio, and Wisconsin) and Australia had contact with the bear cub, at either the petting zoo or the barnwarming, during which time the bear may have transmitted the rabies virus.

In addition, a study by Juncker-Voss et al. (2004) which examined antibodies against zoonotic agents among 60 employees of the Zoological Garten of Vienna found that 97% of them had antibodies to one zoonotic agent, including Hantavirus type Puumala (3%), Hantavirus type Hantaan and Borna disease virus (all negative), *Bartonella henselae* (65%), *Borrelia burgdorferi* (10%), *Leptospira interrogans* serovar copenhageni and serovar icterohaemorrhagiae, as well as *Chlamydia psittaci* (2% each). The antibody responses to *Brucella* spp., *Coxiella burnetii*, and *Francisella tularensis* were all negative, whereas the antibody responses to the parasitic zoonotic agents *Toxoplasma gondii* and *Toxocara* spp. were 53% and 21%, respectively.

**Factors Attributing to Emerging and Reemerging Zoonoses**

**Bacterial zoonoses**

The occurrences of emerging and reemerging bacterial zoonoses have been shown to be attributed to several factors. *Campylobacter* and *Salmonella* foodborne infections have increased due to the construction of large-scale industrial food processing factories and the numerous fast food restaurants, as well as changes in our dietary habits (Blancou et al. 2005). Currently adopted breeding methods of domestic animals and the increase in animal population densities due to intensive farming have favored some zoonotic pathogens (Blancou et al. 2005, Daszak et al. 2001). Even our interest in exotic pets can result in the emergence of new infections. In 2002, a large number of prairie dogs died at an exotic pet facility in Texas, where it was believed that infected wild prairie dogs were supplied to the facility and spread the disease via cannibalism, due to being in a confined space (Peterson and Schriefer 2005). The causative agent was *Francisella tularensis*, a very infectious bacterium with some strains requiring less than ten organisms to cause infection in humans (Ellis et al. 2002).

Various outdoor activities may result in increased animal contact, and the same may oc-
cur if the human or animal population is displaced or translocated, leading to the possibility of infection (Blancou et al. 2005).

Weakening of the immune system by either medication or infection and the existence of multidrug-resistant organisms due to excessive use or misuse of drugs in both human and veterinary medicines also may lead to an increase in zoonotic occurrences (Blancou et al. 2005).

**Viral zoonoses**

The occurrences of viral zoonoses have been shown to be attributed to several factors. Human intervention once again could prove to be a powerful destructive influence. An Australian research team showed that they could modify a vaccinia virus to express interleukin 4 (IL-4), which suppresses the hosts antiviral cell mediated immune response (Sharma et al. 1996). This has the potential of being used as a bioterrorist weapon.

Entering wildlife habitats that are normally untouched by humans, not only increases the chances of interacting with wild animals, but may also expose us to harmful zoonotic infections. Ebola has been responsible for several outbreaks that have occurred in places such as Gabon, Sudan and Zaire. As the disease affects both humans and primates, it is unlikely that primates are the reservoir (Mwanatambwe et al. 2001), however evidence indicates that bats may be potential carriers (Monath 1999).

The ability of some viruses to be genetically diverse from those within the same species can be so great that the virus may become lethal. The best example is the influenza virus; a negative stranded RNA virus whose genome is divided into eight segments. This virus can undergo two types of genetic change: antigenic drift which is the gradual accumulation of minor mutations including the addition, subtraction or substitution of nucleotides. The second genetic change is antigenic shift, a dramatic change due to the re-assortment of the virus segmented genome with another genome of a different antigenic type. Spanish influenza is an example of antigenic drift that resulted in twenty million deaths in 1918 and has been suggested to have originated from birds (Ludwig et al. 2003).

The cause of a hantavirus outbreak in the USA in 1993 was thought to be caused by environmental changes brought about by El Niño–Southern Oscillation (ENSO); where the interaction of the ocean and the atmosphere have a combined effect on climate (Ludwig et al. 2003). It is believed this caused an increase yield of vegetative growth, which in turn allowed for a rise in the rodent population, resulting in an outbreak in the Four Corners region of southwest USA (Ludwig et al. 2003).

How we care and manage animals may have an influence on zoonotic infections. In 1999 the Bukit Pelandok area in the Negri Sembilan state of Malaysia, was subject to an outbreak of viral encephalitis among pig-farmers (Chua et al. 1999). It resulted in over two hundred people becoming infected, of which twenty eight died. Chua et al. (1999) looked at the first three fatal cases seen at their hospital, where nucleotide sequence studies showed the virus to be the Nipah virus.

With the demand for organs exceeding supply, one considered solution is the use of animal organs for transplantation, better known as xenotransplantation. Not only does this procedure face ethical concerns and organ rejection issues, but there is the possibility that the immunosuppressed patient will be introduced to porcine endogenous retroviruses (PERVs), allowing the virus to adjust and infect humans (Ludwig et al. 2003).

**REDUCING THE RISK OF ZOONOSIS**

In order for any preventative or controlling strategy to be effectively put in place, it first requires the zoonosis to be recognized. Recognition most likely does not occur until the disease or infection has presented itself within the human population, even though an animal may have been the first to show any symptoms (Chomel 2003).

Recently, Hori et al. (2006) have presented a zoonosis control program at a zoo. The control program is divided into two components: (1) a routine disease prevention activity, and (2) action planning for a crisis, whereby zoo workers, an operating officer, an occupational physician, and a veterinarian from the zoo cooperate with infection control professionals from the local community.
To identify the emergence of any zoonosis outbreak requires an adequate surveillance program. This may be simple for a local outbreak such as *E. coli*. If a zoonosis is identified, the next step for its prevention or control is to understand the epidemiology; what are the main risk factors and what animals are potential reservoirs. The process of surveillance, recognition, and understanding of the zoonosis requires the collaboration of people from several disciplines (Chomel 2003), including veterinarians or medical staff, who will most likely be the first to observe any outbreaks depending on the source. Scientists including microbiologists, virologists, or mycologists may be needed for identification and/or determining the life cycle and molecular biologists for epidemiological studies. This collaboration cannot be fully implemented unless all the data obtained are collated in such a way that the information on the zoonosis and preventive measures is accurately distributed and appropriate education is in place so that those most likely to encounter these will recognize them.

Most recently, Heuvelink et al. (2007) from The Netherlands have published their findings of hygienic status of 132 petting farms, 91 care farms, and 84 farmyard campsites. This study identified a number of points for hygiene improvement, including informing visitors about hygiene and handwashing, and providing handwashing facilities, a footwear cleaning facility, a specifically designated area where visitors can eat that is strictly separated from the animals, and an isolation ward with distinct clothing and boots. These workers have prepared a Code of Hygienic Practices, which is available at www.vwa.nl.

At the majority of traditional zoos, visitors have limited access to the animals, mainly for health and safety reasons, therefore the risk of zoonotic transmission of pathogens is limited. However, owners and those responsible for open zoos and farms, where access and contact with animals are greatest, should carefully develop a risk assessment and control strategy, to eliminate or minimize the risk of zoonotic transmission of microbial pathogens from animal to the visiting public, farm workers, and veterinarians. Such risk/control programs should have the commitment and support of senior management within such institutes, and the programs should be reviewed regularly, as well as when an alteration of the stocking arrangements takes place or where there is additional interaction with the public.

Those who provide public access to animals should inform visitors about the risk of transmission from animals to humans and possible prevention strategies, as suggested by the Centers for Disease Control and Prevention (CDC, 2001). Food and beverages should be prepared, served, and consumed in separate areas from where humans and animals interact and where animals cannot enter. Activities such as eating and drinking, smoking, or anything that involves the hand interacting with the mouth should be avoided in interaction areas. Children younger than 5 years old, the elderly, pregnant women, and immunocompromised individuals should take extra care, as they are at a higher risk of being infected. Washing facilities (running water, soap, and disposable towels) should be available in both the interacting and animal-free areas and in sufficient quantities to cope with the amount of visitors. Signs should be displayed to highlight the need to wash hands before eating or leaving the interaction area.

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