EMERGING PARASITES OF PUBLIC HEALTH SIGNIFICANCE

Rhonda D. Pinckney, MS, DVM, PhD
St. George’s University, School of Veterinary Medicine
Grenada, West Indies
E-mail: RPinckney@SGU.EDU

ABSTRACT
Zoonoses are defined as infectious diseases naturally transmitted from vertebrate animals to humans. Both domestic and wild animal species can act as vectors for the spread of a large variety of zoonotic viruses, bacteria and parasites. The route of transmission to humans is dependent on the pathogen. Of particular concern are the zoonotic parasites. In Atlanta, Georgia, USA, the Centers for Disease Control and Prevention (CDC) provides a list of parasitic diseases on their website (www.cdc.gov). Many of the parasitic diseases that appear on this list are zoonotic and are considered to be to be emerging pathogens of public health significance. This paper provides an overview of the most important emerging parasitic zoonoses with particular attention to those present in the Caribbean and South America. The author is currently involved in several studies on the Caribbean island of Grenada on zoonotic parasites of both domestic and wild animals and information from these studies are included as examples. This study also includes information on some non-zoonotic free-amoeba and microsporidia because of their emerging significance in the area of public health.

KEY WORDS: Public Health, Geohelminths, Toxocara, Ancylostoma, Trematoda, Microsporidia.

Toxocara species are common parasites of dogs and cats worldwide. Newborns are infected transplacentally in the case of T. canis, or through the transmammary route for T. cati. Toxocara canis and, to a lesser degree, T. cati are recognized causative agents of human toxocariasis. A third agent, Baylisascaris procyonis (the raccoon roundworm), has lately been establishing patent infections in dogs more commonly. Manifestations of human toxocariasis include visceral larva migrans, ocular larva migrans, and neural larva migrans. In the United
States, 14% of the population is infected with *Toxocara* species (Lee and Bowman, 2008). Children ingesting embryonated eggs in the dog’s feces and contaminating the soil is the primary means of transmission (Neil, 2008). This is due to poor hygiene habits, the consumption of dirt (pica) and play in infected soil. In children, the seroprevalence of *Toxocara* exposure has been estimated to be 4% to 31% in developed countries and may increase to 86% in tropical regions, where environmental conditions favor the transmission of geohelminths (Good, 2004; Thompson *et al*., 2001. *Toxocara* infection which manifests with non-specific clinical symptoms and no progression to visceral larva migrans (VLM) or ocular larva migrans (OLM) is referred to as covert toxocarosis (CT). Patients that suffer from CT often present with a broad range of symptoms including abdominal pain, sleep disturbances, hepatomegaly, cough and headache. The vague symptoms of CT in children can result in misdiagnosis by physicians. CT can be recognized through the presence of abdominal pain, headache in combination with respiratory problems, eosinophilia and a positive toxocaral antibody titer (Neil, 2008). *Toxocara canis* infection is usually self-limiting, with treatment only necessary if symptoms are severe. The use of corticosteroids and thiabendazole is recommended for severely symptomatic cases. Albendazole, and mebendazole have also been recommended (Markell *et al*., 1999).

Hookworms are parasitic blood feeding nematodes that infect humans and a variety of different animals, including dogs and cats. *Ancylostoma duodenale* and *Necator americanus* are the two primary non-zoonotic species that cause hookworm infection in humans. The three species of particular zoonotic importance are *Ancylostoma caninum*, *Ancylostoma ceylanicum* and *Ancylostoma braziliensis*. Prevention of hookworm infection in dogs is very difficult due to the large reservoir of larvae in somatic tissues (“leaky larvae syndrome”) and larvae found in contaminated soil. Free-roaming dogs often have unrestricted access to places of popular human habitation, such as beaches and parks. When infected dogs defecate in soil of human interaction zones, there is an increased risk that humans may become infected by a canine hookworm larvae. Depending on the species of hookworm, zoonotic transmission may result in completion of the hookworm life cycle in the human host or the larvae may become arrested and begin to wander within its human host.

*Ancylostoma ceylanicum* has the ability to complete its life cycle in humans. Infection with *A. ceylanicum* in humans is very mild, with a minimal amount of eggs shed in the feces.
Symptoms may also include gastrointestinal problems and anemia. *Ancylostoma caninum* larvae are able to develop into pre-adults, but are not able to mature sexually in the human host. Symptoms typically include pruritic lesions in the area where larvae penetration occurred and short subcutaneous migratory tracts (i.e., “creeping eruption” or “plummer’s itch”). Due to vague clinical symptoms and lack of eggs in the stool, *A. caninum* infection in humans is often difficult to diagnose. There is often a positive association between eosinophilia and/or IgE antibodies for hookworm antigens in the human and dog ownership. These associations strongly suggest that zoonotic disease transmission has occurred.

*Ancylostoma braziliense* hookworms cannot complete their life cycle in humans. Arrested juvenile larvae migrate throughout the host’s skin, unable to pierce the basement membrane, in the process causing small “creeping eruption” tracts. This is known as cutaneous larva migrans (CLM). Thin, pruritic red tracts appear around the area of skin penetration by *A. braziliense* larvae. Initial symptoms of CLM begin one hour after skin penetration occurs, resulting in papules and the development of pruritus (Overgaauw and Knapen, 2000). Skin eruptions appear within one week after cutaneous penetration by the parasite and may last for months. Larvae migrate through the tissue until they die and are reabsorbed by the host. CLM may result in increased eosinophilia and erythema due to the presence of larvae in the tissues. CLM is not restricted to *A. braziliense*, as other species of hookworm including *A. caninum*, *A. ceylanicum*, *G. pingeium*, *U. stenocephala*, *B. phlebotomum*, *N. americanus* and *A. duodenale* have all been shown to cause some form of CLM in humans (Gourgiotou, 2001).

Treatment of CLM and other zoonotic hookworm infections include albendazole, oral thiabendazole, topical thiabendazole and various hydrocortisone creams. Oral chemotherapy is the preferred form of treatment when multiple CLM lesions are present, or when the infecting hookworm is from a human (non-zoonotic) species of hookworm (Gourgioutou, 2001).

Currently there is no vaccine to prevent hookworm infection. Prevention is primarily through avoidance of areas that may contain infective larvae and the improvement of public health. Hookworm infection is often tied to a variety of social and economic problems, such as improper sanitation and lack of proper footwear (Neil, 2008). Given that dogs and cats can be continually re-infected throughout life, and given the potentially debilitating nature of the zoonosis, it is important to perform regular fecal exams and anthelmintic treatment in both
young and adult companion animals. Without the incorporation of education programs aimed at pet owners regarding strategic deworming protocols and the necessity to remove pet feces from the environment, zoonotic transmission and human disease will continue to occur.

*Dirofilaria immitis* is the heartworm of dogs in the United States and is transmitted to them, other animals and occasionally humans by mosquitoes. Most human infections with this parasite are subclinical and usually reported as “incidental findings” (i.e., calcified lesions in the skin, lungs or other tissues).

A study was conducted on the island of Grenada, West Indies to evaluate the prevalence of intestinal parasites and heartworm disease in owned dogs (Coomansingh, 2008). Fecal analysis utilizing zinc sulfate flotation and heartworm diagnoses were analyzed by a commercially available ELISA antigen test. A modified Knott’s test was used to confirm the presence of *D. immitis* microfilariae in the blood. The overall prevalence of gastrointestinal parasitic infection found in this study was 62.4% (106/170). Of the 106 positive fecal samples which were obtained from the study animals, 83% (88) of the dogs were found to be positive for one species of intestinal helminth, while multiple infections consisting of two or more species occurred in 17% (18). The most frequently observed parasite was *Ancylostoma* species (58%), followed by *Dipylidium caninum* (6%), *Toxocara canis* (4%), *Trichuris vulpis* (4%) and *S. stercoralis* (3%). The overall prevalence of *D. immitis* was 25.3% (45 of 178).

When comparison was made between the ages of the dogs and parasite prevalence, *Ancylostoma* species was the most prevalent in all age groups. *Toxocara canis* was not found in any dogs over 24 months, while *D. caninum* was not found in any dogs less than 6 months of age (Coomansingh, 2008).

The Grenadian government has recognized the public health implications of free-roaming dogs and environmental contamination with feces. Tourism is one of the main sources of revenue for Grenadians. Dog fecal contamination of beaches and soil presents a public health concern due to zoonotic parasites in dog feces. Another dog-associated concern for public health in Grenada is the frequent observation of dogs tipping over garbage (Fielding et al., 2005). When no food is available, roaming dogs often resort to tipping over exposed garbage bins which is unsightly and attracts rodents. It is currently unknown how much garbage bin waste supports the roaming population, due to communal dog feeding practices (Neil, 2008).
An on-going study in Grenada examines the free-roaming population of dogs that visit Grand Anse beach (Neil, 2008). The Grand Anse area is one of the most populated areas on the south-western coast of Grenada. This area and its beach (length 2.2 km, 1.36 miles) is also a popular vacation spot for Grenadians and visitors. Tourists visit Grand Anse due its pristine beach and the lavish hotels that line the beach, while souvenir sellers walk the beach in search of buyers. Many restaurants are located in close proximity to Grand Anse beach. Free-roaming dogs visit Grand Anse beach for food. Grand Anse beach provides both a great source of potential meals in garbage, human handouts while open water drains provide drinking water. These food sources are enough to support a small population of stray free-roaming dogs which live on the beach and a larger population of privately owned free-roaming dogs that visit the beach (Neil, 2008).

The ecology of a beach plays a critical role in determining if parasite transmission can occur and is a major focus of this study on Grand Anse beach. Various parasitic species can be found on a beach at a given time. They occur in all zones of the beach and extend for several meters into the sand, with many species not being limited by oxygen availability (Brown and McLachlan, 1990). The hypothesis will be tested by measuring several variables such as dog ecology on the beach, dog fecal analysis, temperature of the sand at different times of the day and during different seasons, rainfall and air temperature. This baseline data should provide relevant information on whether public health interventions with regard to dogs on Grand Anse beach are necessary.

The Grenadian government has recently begun to enforce a dog licensing law. This law requires that dogs which are unlicensed and non-vaccinated be collected and humanely euthanized. A follow-up study will evaluate the extent to which there is a prevalence of parasites in these dogs.

Hurricane Ivan devastated Grenada in September 2004. Standing water and trash attracted many free roaming dogs, rats and mosquitoes to urban and rural dwellings. During 2005, 238 rats (Rattus norvegicus) were trapped in Grenada for evaluation of zoonotic protozoa (Dubey et al., 2006) and for gastrointestinal and visceral parasites. Lung samples are being evaluated for the prevalence of Angiostrongylus cantonensis. Adult worms of A. cantonensis live in the pulmonary arteries of rats. The eggs hatch, yielding first-stage larvae, in the terminal branches of arteries. The first-stage larvae migrate to the pharynx, are
swallowed and passed in the feces. They penetrate, or are ingested by, an intermediate host (snails or slugs). After two molts, the larvae reach the infective (third) stage. Humans become infected through ingestion of food containing third-stage (infective) larvae. Food items may include uncooked or undercooked snails or slugs, infected paratenic or transport hosts (i.e., crabs, freshwater shrimp), and raw vegetables contaminated with snails or slugs. Humans are incidental hosts. Passage of larvae in humans has never been documented. However, human infection with larvae of *A. cantonensis* is one of the main causes of eosinophilic meningitis worldwide. Eosinophilic meningitis (EM) is a distinct clinical entity that may have infectious and noninfectious causes (Slom and Johnson, 2003). Most cases of eosinophilic meningitis have been reported from Southeast Asia and the Pacific Basin, although the infection is spreading to many other areas of the world including Africa and the Caribbean. A recent outbreak of *A. cantonensis*-associated EM among US travelers to Jamaica (West Indies) and subsequent parasitological surveys of local snails and rats confirm earlier case reports and engender a wider appreciation of the Caribbean islands as a new region for endemic *A. cantonensis* infections (Slom and Johnson, 2003). Clinically, eosinophilia is not always present in the cerebrospinal fluid or in the peripheral blood during the initial manifestations of *A. cantonensis*-associated EM, which include headache and cutaneous sensory alterations. Effective management of patients involves careful attention to the control of intracranial pressure. Steroid therapy without specific anthelmintic treatment is a safe and effective control of headache of adult patients with *A. cantonensis*-associated EM. A clinical case report was documented in a 27-year-old female German patient exhibiting severe headache and wandering paresthesias one week after returning from a holiday in the Dominican Republic (Rau et al., 2006). Cerebrospinal fluid (CSF) revealed an eosinophilic pleocytosis. In the acute phase of the disease, antibodies against nematodes were found in CSF, without corresponding antibody-reactivity in serum. During the course of the illness the nematode antibodies in CSF increased and antibody-reactivity in serum was observed. Successful treatment was achieved with a combination of oral albendazole and corticosteroids given for 4 weeks.

Rats and other rodents are also definitive hosts for other zoonotic parasites. *Panstrongylus costaricensis* (Morera and Céspedes, 1971) Ubelaker, 1986 (Nematoda: Angiostrongylidae) is a parasite of the mesenteric arteries of the cotton rat, *Sigmodon hispidus*, and other rodents in north central, and South America. It is also the causative agent
of abdominal angiostrongylia in humans in Costa Rica (Morera and Céspedes, 1971), Honduras (Sierra and Morera, 1973), Mexico (Carrada-Bravo, 1980), Nicaragua (Duarte et al., 1991), Brazil (Rambo et al., 1997), Guatemala (Kramer et al., 1998), Columbia (Rodriguez, 2000), and in islands of the Caribbean such as Martinique (Jeandel et al., 1988) and Guadeloupe (Juminer et al., 1992). In an outbreak of human abdominal angiostrongylia in Guatemala, mint leaves were implicated as the likely vehicle of infection (Kramer et al., 1998). *Panstrongylus (=Angiostrongylus) costaricensis* was first reported in the United States from cotton rats *S. hispidus*, in Texas in 1979. Miller and colleagues (2006) report the findings of *P. costaricensis* in a siamang monkey (*Hylobates syndactylus*) from the Miami MetroZoo, in two Ma’s night monkeys (*Aotus nancymaae*) from the DuMond Conservancy located at Monkey Jungle in Miami, in four raccoons (*Procyon lotor*) trapped near the MetroZoo, and in an opossum (*Didelphis virginiana*) trapped at the MetroZoo. These are the first reports of *P. costaricensis* from the four species mentioned above. All of the primates were zoo-born, and the raccoons and opossum were native, indicating that this parasite is now endemic in these 2 sites.

Gnathostomosis is a foodborne zoonotic disease caused by several species of nematode *Gnathostoma*. Adult parasites of *G. spinigerum* are found in the stomach of dogs and cats. Domestic and wild pigs are the definitive host of *G. hispidum*. Feces containing ova reach the water (i.e., when domestic parasitized animals live at the shore of a lagoon). Free-swimming first-stage larvae are formed, which are ingested by the minute copepod crustacean *Cyclops*, and become second-stage larvae. Freshwater fish or frogs eating *Cyclops* are the second intermediate hosts. Larvae develop to the third stage (L3) in the fish or amphibian muscles. Consumption of infected fish, frogs or paratenic hosts (e.g., birds) by cats, dogs or other mammals result in development of adults in the gut (Rojas-Molina *et al*., 1999). Humans acquire the infection by consuming raw or undercooked freshwater fish. When a larva is ingested by a human host, no further development occurs, but the larva migrates through subcutaneous tissue and internal organs where it produces migratory swelling in the skin and other symptoms depending on the site or organ affected. In most cases, symptoms are not serious; however, if the parasite migrates to vital organs of the host, it can cause severe illness or even death (Rusnak *et al*., 1993; Yoshimura, 1998).
With the highest prevalence in Southeast Asia, gnathostomosis is now an emerging public health problem in Peru, Ecuador, and, since 1970, in Mexico (Pelaez and Perez-Reyes, 1970). Acapulco (estimated population 890,000), a resort on the southern Pacific coast, is the major Mexican city where gnathostomosis cases have been reported (Ogata et al., 1998). Inability to interrupt the parasite’s life cycle and lack of effective medical treatment make preventive measures critical in controlling the disease. Therefore, travelers to disease-endemic areas must be warned of the possibility of acquiring gnathostomosis and be instructed to avoid ingesting any form of raw fish. To protect the general population in disease-endemic areas, public campaigns should be implemented and encouraged against eating or selling raw or poorly cooked freshwater fish, especially in the form of sashimi or “ceviche” (a spicy lime-marinated fish salad of South American origin now very popular in Mexico) (Rojas-Molina et al., 1999).

With the increased consumption of fish worldwide and the decline of captured fish stocks has continued to expand in the United States (Pote, 2008). Fish-borne zoonotic trematodes (FZTs), including liver and intestinal flukes, are significant public health problems worldwide, especially in Asian countries (WHO, 1995, 2004; Chai et al., 2005; Keiser and Utzinger, 2005; Tesana, 2005; Yoshida, 2005). The number of people currently infected with FZTs was recently estimated by the World Health Organization (WHO) to exceed 18 million; however, the number of people at risk worldwide is more than 500 million (WHO, 2004). Recent figures suggest that about 1.5 million people in Korea, 6 million people in China, and over 5 million in Thailand are infected with liver flukes (Clonorchis sinensis or Opisthorchis viverrini) (Chai et al., 2005; Tesana, 2005; Yoshida, 2005). Information on the status of FZTs in Vietnamese fish is critical because of the importance of aquaculture to the economy and national nutritional needs. Freshwater fish production in Vietnam has increased 9.3-fold, from 41,750 tons in 1962 to 390,000 tons in 2005 (Keiser and Utzinger, 2005). The prevalence of FZT metacercariae was investigated in fish farmed by rural households in Nghe An Province, located in northern Vietnam. Results demonstrate that intestinal flukes are common in farmed fish in this area, suggesting that reservoir hosts such as dogs, cats, and pigs are more important in sustaining the life cycles of these flukes in fish farms than human hosts. This has implications for the effectiveness of control programs focused mainly on treatment of humans (Chi et al., 2008). Elsewhere in Vietnam, however, the habit of consuming improperly cooked
fish is widespread and may be increasing (De et al., 2003; Chai et al., 2005); therefore, fish transported to other parts of Vietnam for consumption may pose a greater threat, emphasizing the need to control these parasites in food for human use (Chi et al., 2008).

Some non-zoonotic free-living amoebas are also emerging parasites with public health significance. *Acanthamoeba* is a microscopic, free-living amoeba that is relatively common in the environment. This amoeba has been isolated from water (including natural and treated water in pools or hot tubs), soil, air (in association with cooling towers, heating, ventilation and air conditioner [HVAC] systems), sewage systems, and drinking water systems (shower heads, taps). Most people exposed to *Acanthamoeba* will not get sick. However, *Acanthamoeba* is capable of causing several infections in humans.

*Acanthamoeba* keratitis (AK) is a local infection of the eye that typically occurs in healthy persons and can result in permanent visual impairment or blindness. AK is a rare disease and information about incidence is limited because AK cases are not required to be reported to the Centers for Disease Control and Prevention (CDC). In general, an estimate of one to two cases of AK per million contact lens users occur each year in the United States, based on an analysis of cases identified during an outbreak of AK during 1985-1987 (http://www.cdc.gov/ncidod/dpd/parasites/acanthamoeba/index.htm). With an estimated 30 million people in the United States wearing soft contact lenses, this would equate to approximately 30 to 60 cases of AK per year.

As of June 25, 2007, the CDC had received reports from public health authorities and ophthalmologists in 37 US states and Puerto Rico identifying 221 people with AK, of whom 158 became ill on or after January 1, 2005 and tested positive for *Acanthamoeba* by cultures taken from corneal specimens. The U.S. Food and Drug Administration is alerting health care professionals and their patients who wear soft contact lens about a voluntary recall of Complete ® Moisture Plus Multi-purpose Contact Lens Solution™ manufactured by Advanced Medical Optics of Santa Ana, CA (USA). The link between the solution and AK infection was identified as a result of an investigation by the CDC. Of the 76 patients for whom clinical data were available on June 25, 2007, medical therapy for AK was unsuccessful for 20 (26%). These 20 people were required or expected to undergo corneal transplantation. Of the 102 people with AK included in the preliminary analysis on June 25, 2007, 79 (77%)
wore soft contact lenses, 10 (10%) wore rigid lenses, 1 (1%) wore hybrid lenses, and 12 (12%) reported no contact lens use.

Granulomatous Amebic Encephalitis (GAE) is a serious infection of the brain and spinal cord that typically occurs in persons with a compromised immune system. A disseminated infection can affect the skin, sinuses, lungs, and other organs independently or in combination. It is also more common in persons with a compromised immune system (CDC, 2008).

The non-taxonomic term, “microsporidia” applies to an interesting group of pathogens in the phylum Microspora. Although their taxonomic classification as protozoa or fungi is controversial, these parasites are always intracellular and are characterized by a unique polar tube organelle that facilitates host cell invasion. While most microsporidia species are found in invertebrates, in the past 25 years, at least 12 new species have been identified in mammalian hosts. *Encephalitozoon cuniculi* is commonly found in rabbit and rodent hosts as well as domestic dogs, goats, Scandinavian fur foxes and humans. Genotype 1 has been reported to occur in rabbits and humans. Most cases in the host are asymptomatic; however, fatalities have been reported in immunocompromised hosts. The infective spores are shed in the urine and are extremely resistant to environmental conditions. Direct contact by ingestion and transplacental transmission have also been reported. Microsporidia can cause a systemic “encephalitis-nephritis” disease (Snowden, K.F., 2008).

*Encephalitozoon hellem* was first identified in 1991 (Didier, 1991) in immunocompromised humans causing ocular and respiratory disease. The organism has also been identified in at least 11 bird species, and is now usually considered an avian parasite. While low pathogenicity occurs in the bird, infections in humans may become systemic in immunocompromised individuals.

*Encephalitozoon intestinalis* is the second most frequently identified human pathogen (Snowden, 2008) and has been reported in HIV positive patients, 20% of AIDS patients, children and travelers with diarrhea. There is one report of a Koala bear dying in a zoo after contact with a tourist (Snowden, 2008).

*Enterocytozoon bieneusi* has been reported in HIV positive individuals, chemotherapy (cancer) patients and other immunocompromised hosts, children and travelers with diarrhea.
Domestic and wild pigs, calves, goats, llama, muskrat, dogs and cats have also been reported to have *E. bieneusi* infections.

While these four microsporidian species should be considered potential zoonotic pathogens, the importance of animal to human transmission has not been established. Asymptomatic microsporidian infections in animals are increasingly recognized. Microscopic or serologic diagnostic testing for these organisms is not widely available in the veterinary setting. That no ideal animal models have been established and a lack of isolates in tissue culture complicates research endeavors. There are few therapeutic options for treating these parasite infections. Increased awareness and documentation are needed to further understand these emerging pathogens (Snowden, 2008).

In conclusion, there is not enough time to present all of the emerging zoonotic parasites of public health significance. Client education is necessary to inform the public of the ways in which parasitic infections can be acquired through the consumption of infected food products or direct contact through the skin or other tissues. The prompt removal of feces from domestic owned animals and the incorporation of strategic deworming and vaccination programs will improve public health strategies. Law enforcement of government policy regarding the necessity of licensing dogs will assist in the prevention of many of the more important zoonotic parasitic diseases. The eradication of parasitic diseases is a monumental task that can only be accomplished through client education with the cooperation of government and law enforcing agencies.
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