THE EPIDEMIOLOGY OF A CASE OF RACCOON ROUNDWORM INFECTION

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ABSTRACT: The epidemiologic investigation of a recent case of cerebrospinal nematodiasis caused by the common raccoon intestinal roundworm (*Baylisascaris procyonis*) in an 11-month old child from Monterey County, California revealed a remarkable series of circumstances which led to the child's infection. Human infection results from the inadvertent ingestion of eggs which are passed in large numbers (millions of eggs/day) in the feces of infected raccoons. Groups of raccoons typically defecate in common areas called latrines where the environmentally resistant *B. procyonis* eggs accumulate. Once infective-stage eggs are ingested, the immature larvae hatch and begin to migrate extensively and aggressively in tissues, frequently invading the spinal cord and brain. The one acre property where the child lived had extensive evidence of raccoon activity including 21 latrine sites. Fecal samples collected from the latrines and soil samples on the property were examined using concentration/flotation methods. All samples contained numerous embryonated *B. procyonis* eggs in both immature and fully infective larva stages. Unprecedented numbers of raccoons were observed living in the area and surrounding community. Further examination of the raccoon feces revealed that the raccoons using the latrines were eating corn and animal offal-based pet food provided by some residents in the area. Necropsies performed on 11 raccoons trapped on the property in connection with this investigation revealed that all (100%) were infected with *B. procyonis*. The patient's behavioral history, large number of latrine sites, and the wide dispersal of raccoon feces observed on site indicated that the likelihood of exposure to infective *B. procyonis* eggs was extraordinarily high.

KEY WORDS: raccoons, larva migrans, baylisascariasis, raccoon roundworm, latrines, cerebrospinal nematodiasis, *Baylisascaris procyonis*, neural larva migrans, zoonotic helminths, public health

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INTRODUCTION

In the Fall of 1998, an 11-month old boy from Pacific Grove, California was diagnosed with severe, irreversible brain damage and partial blindness due to infection with the intestinal roundworm parasite of raccoons, *Baylisascaris procyonis*. Human disease caused *B. procyonis* is among the most severe of all known helminthic zoonoses, often resulting in permanent neurologic damage, blindness, or death. This child's infection has typical clinical features and outcome, but the circumstances which led to the infection are interwoven with extraordinary epidemiologic circumstances. This case underscores the need for increased awareness of this parasite.

B. procyonis biologically and morphologically resembles the intestinal roundworm (*Toxocara canis*) of dogs (Averbeck et. al. 1995). Like other ascarids, *B. procyonis* has a typical direct (i.e., no obligatory intermediate host) life cycle. Female worms in the small intestine of raccoons collectively produce millions of eggs per day which are shed in the feces of infected raccoons. Depending on environmental conditions, the eggs become fully infective (containing a larvae) in about two to four weeks. Like all ascarid eggs, the eggs of *B. procyonis* are very resistant to degradation in the environment. Young raccoons become infected by ingesting the eggs during feeding and grooming activities. Once ingested by the raccoon, the eggs hatch in the intestinal tract and undergo a series of developmental stages, finally becoming sexually mature adult worms which copulate and thus complete the life cycle of the parasite. The parasite causes no disease in its natural host unless there is an unusually heavy infestation in juveniles. Because a large variety of other species of mammals and birds can become infected with *B. procyonis* (suffering severe neurologic damage as a result), adult raccoons can also become infected by ingesting the larvae-containing flesh of affected animals (Kazacos and Boyce 1990). Humans become infected with *B. procyonis* just as these other animals do, by becoming intermediate hosts following inadvertent ingestion of larvae-containing eggs.

If infective-stage eggs are ingested by non-raccoon hosts, the eggs hatch in the intestinal tract releasing the immature larvae which, instead of developing into adults as they do in raccoons, begin to migrate extensively through body tissues causing visceral larva migrans (VLM) producing damage directly and by an intense inflammatory reaction along the tract of migration. Unlike the larvae of other helminths that cause VLM, the larvae of *B. procyonis* exhibit very aggressive tissue migration behavior and continue to grow and molt during their migration, growing up to 2 mm long, and do not readily die (Kazacos and Boyce 1990). The larvae of *B. procyonis* have a noted tendency to invade the eye (causing ocular larva migrans; OLM), spinal cord, and brain (causing neural larva migrans; NLM) of humans resulting in permanent neurologic damage, blindness, or death. The severity of disease caused by infection with the raccoon roundworm, especially in very young children, who are most likely to become infected, cannot be over emphasized. Also of concern are reports of patent *B. procyonis* infections in dogs which could greatly amplify the likelihood of human exposure to this parasite (Greve and O'Brien 1989).

Of great importance to understanding the transmission of *B. procyonis* to other hosts is their behavior which

typically includes group defecation in common areas called latrines. Typically, raccoon latrines are found off the ground in downed timber, rocky outcroppings, and tree cavities (Page et al. 1998). Significantly, during the Pacific Grove case investigation, numerous latrines were found directly on the ground, on lawns, at the bases of trees, along and on tops of fences, on roofs, and on stored firewood. This finding suggested a large population of raccoons in the area, which was supported by the frequent observation of dozens of raccoons resting and moving about in trees and on the ground in the community. A substantial risk factor for human infection with *B. procyonis* is the presence of raccoon latrines around areas of human habitation. Both actively used and abandoned latrines become focal accumulations of large numbers of the environmentally resistant eggs which remain viable and thus infective for years. The eggs also possess a sticky surface coating that makes them adherent to objects they come into contact with, including human hands, toys, garden tools, and the like. The eggs can be inactivated only by incineration or soaking with volatile solvents such as mixtures of xylene and acetone.

METHODS

In order to document exposure to *B. procyonis*, a field epidemiologic investigation was conducted at the residence where the patient lived with his parents in Pacific Grove. A thorough inspection of the property, including buildings, was conducted. The relationship of the house to the surrounding property and an adjacent vacant wood lot (where the child sometimes played) was recorded, as were the locations of latrine sites. Fecal samples were collected from all latrine sites, seven surface soil samples were collected from areas where the infected child frequently played or had been seen placing rocks in his mouth. Eleven raccoons were trapped on the property, humanely euthanized with carbon dioxide gas, and necropsied.

Fresh and desiccated fecal samples collected from all latrine sites on the property were examined for *B. procyonis* eggs using a modified zinc sulfate flotation procedure (Sloss et al. 1994). *B. procyonis* eggs were identified based on their size and other morphologic characteristics (Averbeck et al. 1995). Soil samples were also collected from each of the latrine sites and from seven other specific sites known to be frequented by the patient. At each location, a sample of surface soil was collected from an area approximately 1 meter in diameter and 20 mm deep. Each sample was later mixed well and 30 gm specimens from each was examined for *B. procyonis* eggs using a modified detergent wash, filtration, centrifugation, and Sheather's sugar-flotation procedure (Kazacos 1983).

RESULTS

Residence and Latrine Sites

The patient and his family resided in a one-story house situated on a one-half acre lot in a suburban setting. Immediately adjacent to the property was a similarly sized partially wooded, but otherwise vacant, lot. The parents reported numerous problems with raccoons on their property, and raccoons were found to be a common nuisance throughout the community. A thorough inspection of the property and the adjoining vacant lot revealed extensive evidence of raccoon activity and fecal contamination including 21 latrine sites, most of which were located directly on the ground. Large numbers (up to 30 at one time) of raccoons were frequently seen moving about in the vicinity of the property and in the numerous pine trees found in the area.

Fecal and Soil Sample Analysis and Post-mortem Examinations

All fecal samples collected from the 21 latrine sites found on the property contained numerous *B. procyonis* eggs in both embryonated and fully infective larva stages, as did the soil samples collected in the vicinity of the latrines. One latrine site in the adjacent vacant lot contained three freshly expelled *B. procyonis* adults. Four of the seven (57%) soil samples, including one from a sand play area near the child's swing set, were positive for *B. procyonis* eggs. All 11 raccoons necropsied had adult *B. procyonis* in their small intestines. Of note was that eight of these raccoons (73%) were positive for *B. procyonis* by pre-necropsy fecal examination (feces obtained by abdominal squeeze), but at necropsy all 11 were found to be infected indicating that eggs can be shed intermittently by infected animals. Examination of the feces found in latrines revealed that the raccoons were consuming a corn-based high protein pet food diet, an observation corroborated during necropsy where all the raccoons had abnormally high body fat deposition.

Observation of Raccoon Activity Elsewhere in the Community

In Pacific Grove, and elsewhere on the Monterey peninsula, numerous latrines are located directly on the ground, on roofs, in attics, on steps and fences—an indication of the presence of large numbers of raccoons. In the city of Pacific Grove, 27 other raccoon latrine sites were sampled and 12 (44%) were positive for infective-stage *B. procyonis* eggs. Unprecedented numbers of raccoons were observed living in the area and surrounding community. Some residents of the community were found to be providing large amounts of pet food to raccoons and other wildlife in the area.

DISCUSSION

All animals can harbor zoonotic pathogens but the case of raccoons is unusual. Few other species of wildlife have the propensity to live freely in such close association with humans. Fortunately, human infections with *B. procyonis* are rare. The case described in this paper is the second reported case of baylisascariasis in California, the first occurring in 1992 in San Leandro involving another young infant male (Rowley et al. 2000). Approximately 11 cases of NLM (three of which were fatal), caused by this parasite have been documented in the United States, virtually all of them in very young children. A number of non-fatal cases of *B. procyonis* OLM have been reported (Kazacos 1997). The prevalence of sub-clinical cases is unknown, but are likely. Because there is no widely available definitive diagnostic test for humans infected with this parasite in routine use, many cases are initially mis-diagnosed by physicians which contributes to the severity of the disease

as the larvae continue to migrate unimpeded in body tissues. Most cases are diagnosed only after there has been extensive central nervous system damage.

Latrine sites are frequently implicated as the source of human infections. In this particular case, the patient's behavioral history, large number of latrine sites, and the wide dispersal of raccoon feces observed on site indicates that the likelihood of human exposure to infective *B. procyonis* eggs was extraordinarily high. Moreover, raccoon latrines have been implicated in epizootic transmission of *B. procyonis* to a wide variety of small wild mammals and birds causing significant reductions in local populations of these animals (Kazacos and Boyce 1990; Page et al. 1999). In the United States, the prevalence of *B. procyonis* infection in raccoons ranges from 0 to 85% depending on geographical area sampled (Kazacos and Boyce 1990). In an area of Northern California, 57.7% of raccoons sampled were infected with *B. procyonis* (Park et al. 1998). This prevalence rate is similar to that found in the limited sample examined in Pacific Grove case. These data suggest strongly that in any area where raccoons are found, the probability of infection with *B. procyonis* is likely, and any raccoon should be considered infected unless proven otherwise. Under no circumstances should raccoons be purposefully (or inadvertently) fed or otherwise encouraged to take up residence near areas of human habitation.

Infections in humans are difficult to confirm and often diagnosis is arrived at by exclusion of other known cases of VLM. Results obtained from CBC and CSF examinations are usually consistent with a parasitic infection, but are non-specific. Examination of tissue biopsies can be helpful, but removing tissue where the larvae actually are is problemmatic. Ocular examinations revealing retinal lesions, larva tracks, or migrating larvae themselves are often the first clue to a helminthic cause for clinical signs in a patient. An ELISA test is available in one research laboratory, but is not in routine use. It was used in the case of the child from Pacific Grove to help confirm the diagnosis. There is no effective cure for human infection. Symptomatic treatment with steroids and antihelminthic agents are usually employed, but the efficacy of this is controversial. In communities where raccoons co-exist with humans, preventing human exposure to *B. procyonis* eggs is of utmost importance.

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