

# Raccoon Roundworm (*Baylisascaris procyonis*): Are You at Risk?

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**Abstract:** Zoo veterinary technicians, wildlife rehabilitators, parents, and pediatricians are becoming increasingly concerned about the raccoon roundworm, *Baylisascaris procyonis*, due to the recent rise in the number of human cases of neural larva migrans. The worm is classified under Phylum Nematelminthes, Class Nematoda, member of the Family Ascaridae, and Superfamily Ascaridoidea, which represents intestinal worms with direct life cycles. This roundworm is common in raccoons throughout the US where prevalence in some populations has grown to greater than 80 percent. *B. procyonis* may exhibit no clinical or pathological signs in raccoons where the larvae develop to adult worms in the small bowel. However, when aberrant hosts become infected with *B. procyonis*, the larvae migrate throughout the liver, brain, spinal cord, and other organs causing severe central nervous system disorders and other tissue damage which eventually results in death. Parasitic infection is difficult to detect in aberrant hosts. Even if infection with *B. procyonis* is suspected, there is no proven effective therapy or existing vaccine. There are two main categories of humans that are at risk for this disease: those who accidentally come in contact with raccoon feces in their neighborhoods and those who work directly with raccoons. Fortunately, preventive measures including discouraging raccoons' visitation near homes by removing food and shelter sources and implementation of proper cleaning methods for raccoon enclosures can decrease risk to these groups.

**Keywords:** raccoon roundworm, nematode, *Baylisascaris procyonis*, neural larva migrans, wildlife parasites, raccoon care, urban wildlife

## INTRODUCTION

The raccoon roundworm, *Baylisascaris procyonis*, is classified under Phylum Nematelminthes (the roundworms) and Class Nematoda. It is a member of Family Ascaridae and Superfamily Ascaridoidea, which represents intestinal worms with direct life cycles. Adult worms measure 15–20 cm (6–8 in) in length and 1 cm (0.4 in) in width, are tan–white in color, cylindrical, and tapered at both ends. *B. procyonis* biologically and morphologically resembles the intestinal roundworm (*Toxocara canis*) of dogs. The egg itself is a typical ascarid egg, although smaller than a *Toxocara canis* egg,

with a thick pitted shell and a large, dark zygote that almost completely fills the shell.

*B. procyonis* is an endoparasitic nematode whose primary host is the raccoon, *Procyon lotor*. It is common in raccoons, where prevalence levels in some US populations may be greater than 80 percent (Gompper et al 2005). However, except for extreme worm burdens, the impact on the primary host is relatively minor, so raccoons may be asymptomatic and infections may not be suspected. There is also evidence that dogs can acquire patent *B. procyonis* infections after scavenging paratenic, or intermediate, hosts (Bowman et al 2003; Ching et al 2000; Murray and Kazacos 2004). Although clinical or pathological signs are usually not observed in raccoons, heavy infections can lead to intestinal obstruction. A rupture of the intestinal tract can occur due to the large number of parasites present.

Raccoons can become infected in one of two ways. Young raccoons become infected by ingesting the eggs during feeding and grooming activities. Many other species of mammals and birds can become infected through ingestion of the parasite, which often causes severe central nervous system (CNS) disease. Adult raccoons then become infected by ingesting the larva-containing flesh of these affected animals. Humans can also become aberrant hosts following inadvertent ingestion of eggs, usually from soil, water, or fomite sources (Murray 2002; Murray and Kazacos 2004).

When raccoons ingest infective (i.e., containing second-stage larvae) eggs, the larvae hatch, enter the wall of the small intestine, and subsequently develop to adult worms in the small bowel. Adult raccoons infected with *B. procyonis* can shed millions of unembryonated eggs in feces each day. These eggs can mature to infective larvae in as little as two weeks. Once infective, eggs can remain viable in the environment for years, even during harsh winters or in dry conditions, and they are resistant to most typical decontamination methods (Wise et al 2005).

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A principal concern regarding *B. procyonis* is transmission to accidental hosts, which can include humans. As stated above, eggs ingested by raccoons hatch and grow to adult stages in the intestinal tracts of the raccoon, but those ingested by aberrant (abnormal) and paratenic (substitute intermediate) hosts immediately hatch into active larvae that migrate in the tissues and organs of the host. This larval migration may then produce extensive tissue damage leading to various clinical diseases, behavioral abnormalities, and possibly death (Gompper et al 2005). Infected raccoons have been found throughout the US, mainly in the Midwest, Northeast, middle Atlantic and West Coast. Infection is rarely diagnosed in humans: fewer than 25 cases have been diagnosed and reported in the US as of 2003. However, it is believed that many cases are mistakenly diagnosed or go undiagnosed. Cases have been reported in OR, CA, MN, IL, MI, NY, and PA. Five of the infected persons died (CDC 2004).

The epidemiology of *Baylisascaris* infection in humans is linked to the defecation habits of raccoons. Presumably for communication or territorial reasons, individuals and groups of raccoons habitually defecate in focal areas called *latrines*, where large amounts of feces and *B. procyonis* eggs accumulate. Raccoon latrines are found directly on the tops of fences, on roofs, decks, and stored firewood, and in outbuildings, attics, and various other locations. Homeowners are often unaware that there are latrines on roofs or hidden elsewhere on their property, thus increasing their risk of exposure to raccoon feces (Murray and Kazacos 2004).

### **PREVALENCE OF *B. PROCYONIS***

Research projects were conducted on the prevalence of *B. procyonis* within human communities in three northern CA communities (Roussere et al 2003) and in a forested region of lower New York (Gompper and Wright 2005). A raccoon's natural tendency is to defecate in latrine situations, thereby concentrating the eggs in specific areas. This tendency is one of the major factors leading to the high potential for infection. The potential for infection at latrine sites in CA communities was determined by actually recording the density and distribution of raccoon latrines and the prevalence of eggs at private residences. Fecal samples were collected from 215 latrines with the finding that 44 to 53 percent of the latrines contained *B. procyonis* eggs and 16 to 32 percent contained infective eggs. Among the properties surveyed, 28 to 49 percent harbored at least one latrine that was positive for *B. procyonis* eggs. Latrine densities were higher in these

communities than any previously reported, leading the researchers to conclude that the presence of *B. procyonis* eggs in raccoon latrines were common, widespread, and closely associated with human habitation (Roussere et al 2003).

In the state of New York, the prevalence of *B. procyonis* was assessed over a four-year period in a population of raccoons in a southern forested region of the state (Gompper and Wright 2005). Prevalence ranged from zero percent (undetected) to 21 percent, which was relatively low compared to values reported in other studies from the Northeast. What was even more interesting about this study was that during year three, a subset of the raccoon population was experimentally manipulated through altered resource distribution, similar to what would be found in human communities (e.g., trash deposits, pet food sources, supplemental wildlife feeding stations), to enhance the contact between individual raccoons. Within the manipulated subpopulation, prevalence of *B. procyonis* increased to 54 percent, which was significantly greater than in a similar subpopulation studied where raccoons did not experience increased intraspecific contact. These observations suggest that altered resource distributions that directly influence raccoon behavior may indirectly play a role in the ecology of *B. procyonis* (Gompper and Wright 2005). Since humans, especially rural ones, contain landscapes with highly clumped human-based resources, contact rates of raccoons increase (as demonstrated by this study), resulting in a higher percentage of *B. procyonis* in the population as compared to natural settings where raccoons are more dispersed.

### **HEALTH CONCERNS**

So why is there a growing health concern about raccoon roundworm? Increasing prevalence among human communities as described is one reason. Another reason is the lethal manner by which raccoon roundworms manifest themselves in aberrant or paratenic hosts. After infective eggs are swallowed, they hatch into larvae that migrate extensively through the liver, brain, spinal cord, and other organs. Migration of large numbers of larvae in animals such as mice, woodchucks, squirrels, rabbits, and birds, may cause liver, lung, brain, and spinal cord damage. Larvae may also cause eye disorders by migrating through ocular tissues.

An infected animal will initially exhibit a head tilt and an inability to walk and/or climb properly due to damage caused to the brain and spinal cord by the larvae. As the clinical illness progresses, the animal may lose fear of humans, circle, roll, fall over, lie on its

side and paddle its feet, become recumbent, comatose, and finally die (MDNR 2005). In humans, *B. procyonis* larvae have a tendency to invade the eyes, spinal cord, and brain, causing inflammatory reactions and tissue damage. The result can be blindness, neurological damage, and even death (Stephenson 2002). *B. procyonis* infection of humans typically results in fatal disease or severe sequelae. Clinical manifestations include eosinophilic encephalitis (inflammation of the brain with high percentage of eosinophils), ocular disease, and eosinophilic cardiac pseudotumors (cardiac myofibroblastic tumors with high percentage of eosinophils). Elevated peripheral cerebrospinal fluid eosinophilia can be detected in cases of meningoencephalitis (infection/inflammation of the meninges and the brain) (Sorvillo et al 2002). Furthermore, to date no case of human neurological disease caused by *B. procyonis* has been successfully treated (Wise et al 2005).

### DIAGNOSIS

Diagnosis of *B. procyonis* in raccoons is fortunately fairly easy due to the relatively large size of the egg (80 x 70 µm [0.08 x 0.07 mm]) and the worm (12–23 cm) [4.7–9.1 in]. In raccoons, infection with *B. procyonis* can be confirmed by recovering and identifying the adult worms (postmortem examination) or by fecal flotation (live animal) to identify their eggs in the feces. Occasionally, sub-adult worms are passed in feces or vomit. However, since humans and other animals are dead-end hosts for *B. procyonis*, which evolved to complete its life cycle in raccoon intestines exclusively, no eggs, larvae, or adult worms will be found in human or any other aberrant hosts' stool specimens. Results obtained from complete blood count and cerebrospinal fluid examinations in humans are usually consistent with a parasitic infection but may not be profound. In cases of ocular larva migrans (OLM), ophthalmologic examinations revealing chorioretinal lesions, larval tracks, or migrating larvae can support a diagnosis of *B. procyonis*. However, the *gold standard* for diagnosis is a postmortem tissue biopsy (particularly of the brain, heart, lungs, and eyes) that demonstrates *B. procyonis* larvae in the tissue (Murray 2002). If no other diagnosis is evident, it can be assumed *B. procyonis* is probably the culprit in an individual who 1) is showing signs of OLM, visceral larva migrans (VLM) and/or neural larva migrans (NLM), 2) possesses other clinical signs (e.g., meningoencephalitis, diffuse unilateral subacute neuroretinitis, pseudotumor, and/or positive radiological tests results for white matter disease), and 3) has had a recent history of working with or around raccoons (Sorvillo et al 2002).

### TREATMENT

Raccoons can be successfully treated with several different drugs destructive to adult worms such as the anthelmintics piperazine, fenbendazole, pyrantel pamoate, and levamisole; and organophosphates such as dichlorvos. Treatment of migrating larvae in the human body can be done, but tissue damage caused by the larvae is usually irreparable, especially in the case of nervous tissue (Kazacos et al 2001, Garrison 1996). Laser surgery has been successfully performed to kill larvae present in the retina of the eye, but the damage caused by the migrating larvae is irreversible. Treatment with steroids in paratenic or aberrant hosts is mainly supportive and is designed to decrease the inflammatory response (MDNR 2005).

Human infections are hard to treat because the larvae continue to migrate unimpeded in body tissues and positive diagnosis is often not made until late in the course of the disease. However, various anthelmintic agents have been employed for treatment in humans. Currently the drug of choice is albendazole because it has been shown to have good distribution into the brain and CNS, especially when used in conjunction with dexamethasone. Experimental *B. procyonis* infections in mice have demonstrated that albendazole and another anthelmintic, diethylcarbamazine, were of prophylactic value in preventing CNS disease when administered one to ten days post infection. Furthermore, in several cases in which children were observed ingesting raccoon feces, the prompt administration of albendazole is thought to have prevented development of clinical symptoms of *B. procyonis*. In light of these facts, the current recommendation is that whenever infection with *B. procyonis* is suspected, treatment should be started immediately while diagnostic tests and field investigations to document a source of exposure are carried out (Murray 2002).

### ROUNDWORM—A BIOTERRORISM AGENT?

In an era of increasing concern about bioterrorism, the characteristics of *B. procyonis* larvae have been thought by several researchers to make a feasible bioterrorist agent (Sorvillo et al 2002). The organism is ubiquitous in raccoon populations and is therefore easy to acquire. Enormous numbers of eggs can be readily obtained in latrine areas, and these eggs can survive in an infectious form for prolonged periods of time. Moreover, the organism causes a severe, frequently fatal infection in humans, and no effective therapy or vaccine exists. In fact, a similar agent, *Ascaris suum*, a roundworm of pigs, was used to intentionally infect four university students in New England

who required hospitalization after eating a meal contaminated with a massive dose of *A. suum* ova.

Alternatively, bioterrorists could employ post-treatment contamination or targeting of smaller systems (Sorvillo et al 2002). Although the eggs of *B. procyonis* are relatively large and readily removed by standard water filtration methods, there is still risk to these smaller systems.

## PREVENTION

The above information about raccoon roundworm infection prompts the question: *Are you at risk?* There are specific human populations that are at higher risk for this disease and that fall into two main categories: individuals accidentally infected by contact with raccoon feces, and individuals in direct contact with raccoons. Of the accident groups, children (especially toddlers) and people of any age who are developmentally disabled are at high risk because they may come in contact with raccoon feces in a playground, a sandbox, or along a trail, and inadvertently pick it up and bring infected fecal matter into their mouths. Hunters, trappers, wildlife rehabilitators, zoo veterinary technicians, animal control officers, taxidermists, and people who keep raccoons as pets (illegal in most areas) are also high risk.

Fortunately, preventive measures can decrease the risk for these groups. Individuals can take preventive measures such as: preventing raccoon access to trash containers or other food sources, closing off access to attics and basements, keeping sandboxes covered when not in use, removing fish ponds and other water sources, cleaning up known latrine areas, removing bird feeders used by raccoons, and clearing yard brush to prevent denning and discourage raccoon visitation near homes and communities. Not keeping raccoons as pets is also highly recommended (Murray and Kazacos 2004). There is evidence that dogs can acquire patent *B. procyonis* infections after scavenging paratenic hosts and raccoon roundworm can be passed in a dog's feces (Kazacos 2006). Regular parasite control in pets may serve as a means to reduce human exposure (Ching et al 2000).

Since *B. procyonis* has been shown to cause a larva migrans producing severe or fatal neurological disease in over fifty species of birds and mammals (Ching et al 2000), it is imperative that those who handle raccoons in zoos and rehabilitation centers are knowledgeable about control of the parasite in order to decrease transmission to collection animals and other wildlife. Increased awareness by physicians, especially pediatricians, nurse practitioners, and others is essential in public education efforts. Veterinarians are important

resources for information on larva migrans and other zoonotic diseases (Murray and Kazacos 2004, Samuel et al 2001). For individuals who work with raccoons as part of their occupation, removing raccoon feces from raccoon enclosures often, and then burning, burying, or taking the waste immediately to a landfill, is a major preventive measure. Prompt cleaning of cages to remove and destroy feces before the eggs become infectious (about 30 days after shedding) can reduce the risk of transmission. Heat is the best method of killing *B. procyonis* eggs. Boiling water, a propane flame torch, steam cleaner, autoclave, or other means of heat can be used for small or large areas of contaminated soil or concrete, metal cages, enclosures, holding pens, and contaminated tools and utensils. Using gloves and a face mask when working around raccoons, washing hands immediately after handling, and decontaminating surfaces with a propane torch, boiling water, or boiling Lysol<sup>®</sup> (Reckitt Benckiser, Berks, England) are other necessary measures that should be employed as standard operating procedures for any enterprise where contact with raccoons occurs. Separate cages and frequent fecal parasite exams are also recommended for raccoons in possession. Newly admitted raccoons should be quarantined until appropriate anthelmintic treatment is completed and fecal parasite examinations are negative. In rehabilitation circumstances, release of raccoons, not treated for *B. procyonis*, away from parks and suburban areas and into remote areas should result in a decreased risk of infection to the public and wildlife (Ching et al 2000, Samuel et al 2001).

## CONCLUSION

*Baylisascaris procyonis*, a ubiquitous roundworm of raccoons, is increasingly being recognized as a human health concern. Raccoons have adapted to living within human communities where food sources exist. This behavior can lead to high infection rates of other raccoons, domestic animals, and humans. Raccoons' natural tendency to defecate in latrine situations in places such as lawns, bases of trees, roofs, outbuildings, stored firewood, and playgrounds concentrates the fecal egg source and increases the opportunity for humans to become exposed to the parasite. The eggs of *B. procyonis* are also highly resistant to typical decontamination methods and can remain viable for years even under severe environmental conditions. Those who work with raccoons as part of their occupation are also in danger of contracting the disease, especially if effective disinfecting and waste removal strategies are not practiced. Fortunately, prevention measures which focus on discouraging raccoon visitation in or around

homes, and adequate sanitation methods with caged raccoons, can greatly decrease human exposure to the disease. Public education about the disease, how it is contracted and how to prevent it, will also be necessary in those areas of the country where raccoons live. Furthermore, proven prevention measures that are simple to put into practice exist for those who work with raccoons; these measures can halt the spread of the parasite to other raccoons and caretakers in their facilities. Humans have chosen to live in rural areas where raccoons once roamed freely. It is not surprising that raccoons, intelligent and adaptable, have learned to live among people and thrive. Raccoons are not the *bad guys*; they simply carry a parasite that has evolved to utilize them as a host and that also, unfortunately, can be of great zoonotic concern. The *bad guy* is not using common-sense prevention methods to stop the spread of *B. procyonis*, that has become more prevalent due to human propensity to have food sources and potential den sites readily available to these animals. Through discontinuing these practices and implementing preventive measures, humans can become a proactive force in stopping the spread of raccoon roundworm. When raccoons are encouraged to remain wild, they can be appreciated for the intelligent, interesting, and adaptable creatures they are.

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