Update on the Diagnosis and Management of *Giardia* spp Infections in Dogs and Cats

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Giardia spp are flagellates that are found in the intestinal tract of humans and domestic and wildlife animals, including birds and amphibians, worldwide. The genus *Giardia* contains multiple species, which are for the most part morphologically indistinguishable. Recognized species of this genus are *G. duodenalis*, *G. agilis*, *G. muris*, *G. microti*, *G. ardeae*, and *G. psittaci*. *Giardia duodenalis* (syn. *G. intestinalis* or *G. lamblia*) is the species that infects people, dogs, and cats and is considered a species complex. There are at least 7 distinct assemblages (A-G) based on genetic analyses (Table 1). Host specificity was believed to be minimal, but there have been varying results concerning cross-infection potential of *Giardia* spp. Not all small animal isolates cause disease in human beings. Assemblage A has been found in infected humans and many other mammals including dogs and cats. Assemblage B has been found in infected humans and dogs, but not cats. There are specific genotypes of *Giardia* that commonly infect dogs (assemblages C and D) and cats (assemblage F).[1-3]

There are 2 stages of *Giardia* spp in its life cycle, the trophozoite and the cyst. The teardrop-shaped trophozoite is the active, motile form that is found in the intestinal tract. It is approximately 15 μm long and 8 μm wide (Fig 1). The ellipsoidal-shaped cyst is the environmentally resistant stage mainly responsible for transmission; it is approximately 12 μm long and 7 μm wide (Fig 2). Trophozoites can be found in the feces of dogs or cats with diarrhea, but rarely survive for a significant period outside the host. In contrast, cysts are very resistant and can survive several months outside the host in wet and cold conditions, but are susceptible to desiccation in dry and hot conditions.

Prevalence Rates

Prevalence rates for *Giardia* infection in dogs and cats have varied depending on the population tested, the area studied, the diagnostic method used, and the health status of the animal. The prevalence rates are commonly 5% to 15% in healthy or clinically ill dogs or cats; some examples of prevalence studies are listed in Tables 2 and 3.[4-11]

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1527-3369/06/0604-0171\.00/0
doi:10.1053/j.tcam.2010.07.003

Young animals frequently are more likely than older animals to be positive for *Giardia*. For example, the most recent national survey of *Giardia* infection in pet dogs of the United States that used microscopy after zinc sulfate centrifugation revealed that on average the prevalence rate was 4.0% of 1,199,293 canine fecal samples. The prevalence rates were 13.1% for puppies <6 months of age and <1% for dogs >3 years of age.[7] Which dogs had diarrhea or were normal in that study were unknown. A nationwide survey of *Giardia* infection in dogs and cats with diarrhea in the United States that used a commercially available antigen test (SNAP *Giardia* Test; IDEXX Laboratories, Portland, ME) revealed that 15.6% of 16,064 dogs and 10.3% of 4977 cats were positive.[6] Frequently, *Giardia* detection rates are similar between animals with and without diarrhea. For example, a study in north-central Colorado that used a commercially available immunofluorescence assay (IFA) for *Giardia* cysts and *Cryptosporidium* oocysts (Merifluor *Cryptosporidium/Giardia* direct immunofluorescence assay; Meridian Laboratories, Cincinnati, OH) detected *Giardia* cysts in 5.6% of the dogs with diarrhea and 5.1% of healthy dogs.[8] In cats of the same region, *Giardia* cysts were identified by microscopy after zinc sulfate centrifugation in 3.9% of the cats with diarrhea and 1.9% of healthy cats.[9] Shelter animals often have higher prevalence rates than client-owned animals. For example, *Giardia* antigen was detected in 6.1% and 8.1% of client-owned and shelter cats, respectively, in a study of kittens <1 year of age.[4]

Pathophysiology

Infection of *Giardia* spp in dogs or cats usually is initiated by ingestion of cysts contaminating food or water. After ingestion by the host, excystation, which is triggered by gastric acid and pancreatic enzyme, occurs in the duodenum. The 2 released trophozoites then become mature and freely swim or attach to intestinal epithelium using the ventral disc of the organism. Trophozoites multiply by binary fission in the intestinal tract and then encyst by an unknown mechanism.[12] Although the pathogenesis of *Giardia* infection is not completely understood, studies done in vitro and in vivo revealed that the mechanisms are multifactorial. Because the *Giardia* trophozoites are found on the surface of the intestinal epithelium, the pathogenesis is unlikely a consequence of direct cell damage. The pathogenic mechanisms proposed for *Giardia* spp infections include production of toxins, disruption of normal flora, induction of inflammatory bowel disease, inhibition of normal enterocyte enzymatic function, blunting of

Table 1. Genotypic Groupings on Genetic Analyses of *Giardia duodenalis* and Other Species

Species/Assemblages	Proposed novel nomenclature[1]	Susceptible host
G. duodenalis		
Assemblage A	*G. duodenalis*	Humans and other primates, dogs, cats, livestock, rodents, and other wild mammals
Assemblage B	*G. enterica*	Humans and other primates, dogs, some species of wild mammals
Assemblage C and D	*G. canis*	Dogs and other canids
Assemblage E	*G. bovis*	Cattle and other hoofed livestock
Assemblage F	*G. felis*	Cats
Assemblage G	*G. simondi*	Rats
G. agilis	*G. agilis*	Amphibians
G. muris	*G. muris*	Rodents
G. psittaci	*G. psittaci*	Birds
G. ardeae	*G. ardeae*	Birds
G. microti	*G. microti*	Rodents

microvilli, induction of motility disorders, and indu cti intestinal epithelial cell apoptosis.[12,13] As a result, *Giardia* infection causes diarrhea by a combination of intestinal malabsorption and hypersecretion.

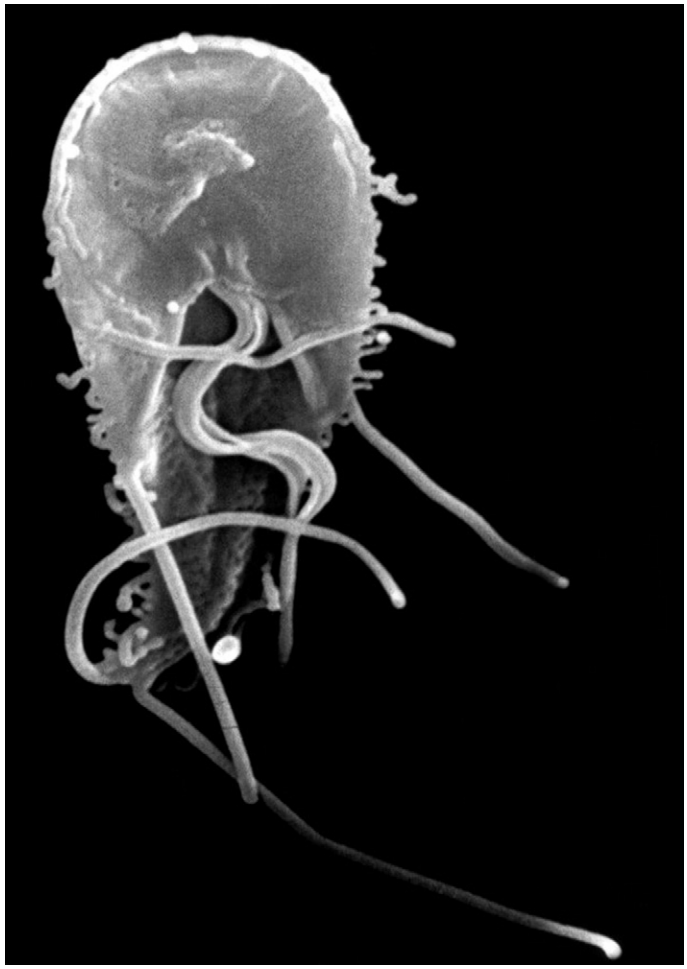

Figure 1. Electron micrograph of a *Giardia* spp. trophozoite. Courtesy of Bayer Animal Health.

Clinical Abnormalities

Giardia infection is common, but the organism is not always an effective primary pathogen because many infected dogs and cats are subclinical carriers (see prevalence section). The clinical signs range from subclinical to slight abdominal discomfort to severe abdominal pain and cramping. When the diarrhea occurs, it is soft to watery, it frequently has mucus on the surface, it can have a strong odor, and steatorrhea may be present.[14-18] Most infected dogs and cats are afebrile. The diarrhea is usually self-limiting in immunocompetent ani-

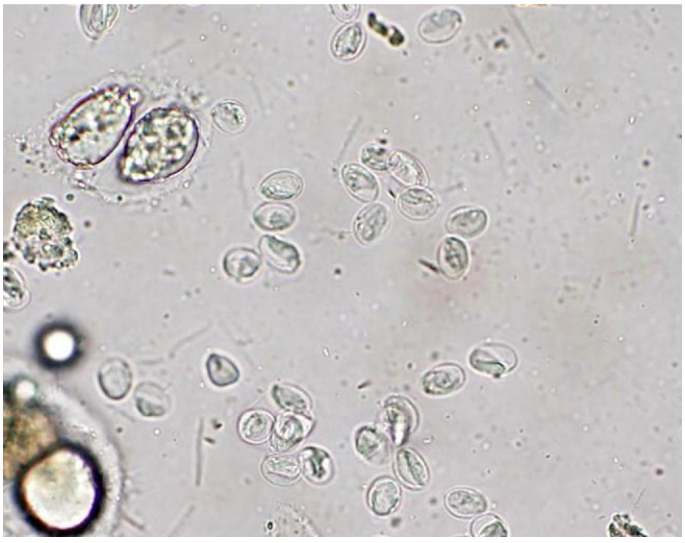

Figure 2. Cysts of *Giardia* spp after sugar centrifugal flotation (400× magnification). Courtesy of Dr. Lora Ballweber, Colorado State University.

Table 2. Prevalence of *Giardia* spp in Dogs in the United States

Location	Diagnostic test	Sample size	Prevalence (%)	Reference
USA*				
National	Antigen	16,064	15.6	6
Northeast	Antigen	3291	19.2	
Midwest	Antigen	5193	15.6	
West	Antigen	3185	15.7	
Southeast	Antigen	4395	12.9	
USA†				
National	Microscopy	1,199,293	4.0	7
Northeast	Microscopy	390,429	3.7	
Midwest	Microscopy	191,840	3.9	
Southeast	Microscopy	307,076	2.3	
West	Microscopy	309,948	6.3	
North-central Colorado‡	IFA	130	5.4	8
Pennsylvania†	Microscopy	6555	3.3	10

*The studied samples were from symptomatic dogs (SNAP *Giardia* Test, IDEXX Laboratories).

†The health status of the dogs was unknown.

‡*Giardia* cysts in 5.6% of the dogs with diarrhea and 5.1% of healthy dogs (Merifluor *Cryptosporidium/Giardia* direct immunofluorescence assay, Meridian Laboratories).

mals. Chronic malabsorption occurs in some animals and so weight loss may be detected. On physical examination, the small intestines may be slightly thickened and the animal can appear unthrifty. Severity of the disease may relate to the interaction of both host and strain factors. Presence of immunosuppressive diseases or coinfections may also potentiate the development of clinical signs of disease.[11,19,20]

Laboratory and Radiographic Abnormalities

Results of a complete blood cell count and serum biochemical panel are usually normal in animals with giardiasis. When abnormalities are detected, changes are not pathognomonic for giardiasis but generally only reflect dehydration and gastrointestinal losses of electrolytes if the diarrhea is severe.

Table 3. Prevalence of Giardia spp in Cats in the United States

Location	Diagnostic test	Sample size	Prevalence (%)	Reference
United States*				
National	Antigen	4977	10.3	6
Northeast	Antigen	1035	11.2	
Midwest	Antigen	1659	10.3	
West	Antigen	977	10.3	
Southeast	Antigen	1306	9.7	
North-central Colorado†	Microscopy	206	2.4	9
Pennsylvania‡	Microscopy	1566	2.3	11
Mississippi and Alabama§	IFA and Microscopy	250	13.6	12

*The studied samples were from cats with diarrhea (SNAP *Giardia* Test, IDEXX Laboratories).

†Zinc sulfate centrifugation; *Giardia* was detected in 3.9% of the cats with diarrhea and 1.9% of healthy cats.

‡The health status of the cats was unknown.

§Twelve of the 34 (35%) cats shedding *Giardia* spp cysts had diarrhea.

Abdominal radiographs can reveal increased air and soft tissue density characteristic of fluid in the intestines.

Diagnostic Tests

The primary diagnostic tests for *Giardia* include direct smear or wet mount examination for trophozoites; microscopic examination for cysts after passive fecal flotation, centrifugal fecal flotation (zinc sulfate or sugar solutions are used most frequently), or IFA; detection of antigens by enzyme-linked immunosorbent assay (ELISA); and amplification of *Giardia* DNA by polymerase chain reaction (PCR) assay. These tests can be used alone or in combination. Identification of *Giardia* trophozoites, cysts, or DNA in fecal samples can be used to prove infection, but as discussed in the prevalence section, positive test results do not always correlate to presence of diarrhea.

It has been reported that young dogs shed an average of 2000 cysts per gram of feces, and the mean cyst count per gram of feces for all infected dogs was 705.8.[21] Another study found that infected dogs shed between 26 and 114,486 cysts per gram of feces.[22] Shedding of *Giardia* cysts by cats may fluctuate from undetectable to concentrations to >1000,000 cysts/gram of feces.[23] Peaks of cyst shedding occur sporadically rather than cyclically, and the duration between any 2 given peaks is generally from 2 to 7 days.[23] Therefore, a single negative test result cannot definitively rule out the *Giardia* infection.

The direct smear or fecal wet mount can be used in the clinic to evaluate for the presence of trophozoites of *Giardia* spp (small bowel diarrhea), *Tritrichomonas fetus* (large bowel diarrhea), and *Pentatrichomonas hominis* (large bowel diarrhea). For a fecal wet mount preparation, a small amount of mucous or feces collected by loop or from the surface of freshly passed diarrhea is mixed with a drop of normal saline solution on a microscope slide, covered with a coverslip, and examined immediately. The surface of the feces or mucus coating the feces should be used because the trophozoites are most common in these areas. The smear is then evaluated for motile organisms by examination at 100× magnification. *Giardia* trophozoites have a "falling leaf" motility pattern in contrast to the rapid, jerky, forward motion of *T. fetus*. Structural characteristics like the concave ventral disc of *Giardia* can be observed at 400×. The application of Lugol's solution, methylene blue, or acid methyl green to the wet mount helps in the visualization of the internal structures of the trophozoites. A refrigerated sample or one examined several hours after collection probably contains no living organisms. Antigen testing or PCR can be used to distinguish between specific organisms if *Giardia* and *T. fetus* cannot be differentiated by morphology.

Fecal flotation with the zinc sulfate centrifugal flotation (specific gravity 1.18) or sugar centrifugal flotation (specific gravity 1.27) are optimal techniques for the demonstration of *Giardia* cysts and are more sensitive for detection of *Giardia* spp cysts than passive flotation (www.capcvet.org).[24,25] Sugar solution is hypertonic and pulls the cytoplasm of the cysts to one side, which makes it appear as a half or quarter moon, and so some parasitologists prefer zinc sulfate. Approximately 2 g of feces is mixed with 10 mL of concentration solution, strained, and added into the 15-mL centrifuge tube. Slowly fill the tube with more solution until a positive meniscus is formed and then place a coverslip. Centrifuge using a swinging rotor at 1500-2000 rpm for 5 minutes. Place the coverslip on a microscope slide and examine for *Giardia* cysts and other parasites at 100×. A drop of Lugol's solution may be added to stain the internal organelle for ease of identification. After concentration in most solutions, the microscope slide should be read within 15 to 20 minutes after being prepared because eventually the cysts will collapse, and identification of *Giardia* cysts will be difficult. However, the time to microscopy is of minimal effect after centrifugation in sugar solution because the solution usually distorts the cyst appearance immediately. If the fecal slides cannot be examined microscopically immediately, storage at 4°C for several days is acceptable, but samples should not be frozen. The feces can be refrigerated, but not frozen, if there is a delay before testing. *Giardia* cysts can be confused with yeast, but *Giardia* should be easily recognized because of its distinct structure and internal organelle. Although sensitivity is <100% when a single sample is evaluated, fecal flotation remains the primary *Giardia* diagnostic test because of the ability of these assays to also identify many other potential parasites. Combination of a fecal flotation with wet mount examination in cases with diarrhea or with a fecal antigen assay will increase sensitivity. In addition, sensitivity of fecal flotation increases to >90% if at least 3 fecal specimens are examined within 5 days.

Multiple ELISAs for detection of *Giardia* antigens in feces are available. Recently, a point-of-care *Giardia* antigen test for use with dog or cat feces (SNAP *Giardia* Test, IDEXX Laboratories) was made available commercially. In a study recently completed in our laboratory, results of this ELISA and IFA were in agreement for 94.4% of the samples (Bachman and Lappin, unpublished data, 2010). *Giardia* antigen assays should be supplemental tests and should not replace fecal flotation and wet mount examination. If either wet mount examination or fecal flotation is positive, a fecal antigen test is not needed except as a confirmation test in questionable samples. False-positive and false-negative rates are estimated to be approximately 2%. Although it is unknown why false-positive reactions occur, it is likely that other fecal antigens are nonspecifically binding to the reagents. False-negative results likely relate to the sensitivity cutoffs of the individual assays. In one study, combination of fecal flotation with one commercially available *Giardia* spp antigen assay had a combined sensitivity of 97.8%.[26]

A fluorescein-labeled monoclonal antibody system is available that contains monoclonal antibodies that react with *Cryptosporidium* spp oocysts and *Giardia* spp cysts (Merifluor *Cryptosporidium/Giardia* direct immunofluorescence assay, Meridian Laboratories) is available in most veterinary diagnostic laboratories. The manufacturer reported the sensitivity and specificity of the test as 100% and 99.8%, respectively, when used with human stool samples. Some *Giardia*

Table 4. Drugs Used for the Treatment of *Giardia* spp Infections in Dogs and Cats

Drug	Species	Dosage
Metronidazole	B	15 to 25 mg/kg, PO, q12 to 24 hour, for 5 to 7 days
Tinidazole	D	44 mg/kg, PO, q24 hour for 6 days
Ipronidazole	D	126 mg/L drinking water, PO, ad libitum for 7 days
Fenbendazole	B	50 mg/kg, PO, q24 hour for 3 days
Albendazole	B	25 mg/kg, PO, q12 hour, for 2 days
Pyrantel, praziquantel, febantel	D	Label dose PO for 3 to 5 days
	C	56 mg/kg (based on the febantel component), PO, q24 hour for 5 days.
Quinacrine	D	9 mg/kg, PO, q24 hour for 6 days
	C	11 mg/kg, PO, q24 hour for 12 days
Furazolidone	C	4 mg/kg, PO, q12 hour for 7 to 10 days

Abbreviations: D, dog; C, cat; B, dog and cat.

researchers consider this assay to be the reference standard for detection of the organism in dog and cat feces.[27] The results of this assay can be superior to those of antigen tests because the test is unlikely to give false-positive test results because the observer can base the diagnosis on the fluorescence as well as the morphology of the organism. The primary disadvantages of the IFA include the need for a fluorescence microscope and additional technician time when compared with *Giardia* antigen assays.

The Companion Animal Parasite Council (www.capcvet.org) recommends the testing of dogs and cats with diarrhea with the combination of direct smear, fecal centrifugal flotation, and *Giardia* antigen assay. If *Cryptosporidium* spp coinfection is suspected, it may be prudent to substitute the IFA for the *Giardia* antigen test in the initial diagnostic workup. In addition, repeat testing performed over several days is also recommended to enhance the sensitivity of the detection if the initial results are negative.

PCR assays can also be used to amplify *Giardia* DNA in feces and are available in some research and service laboratories. The *Giardia* assemblage can also be determined by evaluation of the DNA sequence from the PCR product. Results for *Giardia* assemblage determination can vary based on the gene chosen, and so it is possible that some dog or cat isolates could be genotyped as "potentially zoonotic" by one gene but as "host specific" with another gene.[28] In experiments in our laboratory, *Giardia* PCR fails to amplify DNA from approximately 20% of samples that are positive for *Giardia* cysts or antigens in other assays. This finding likely results from the presence of PCR inhibitors in feces. At this time, PCR testing is only recommended for assessment of the *G. duodenalis* assemblage in cats and dogs, and the use of multilocus genotyping is recommended.[1,29] This service is not widely available commercially but is performed weekly at the Veterinary Diagnostic Laboratory, Colorado State University (http://dLab.colostate.edu/).

Treatment

In the United States, there is no drug that is officially approved for treating giardiasis in dogs and cats, and the use of many drugs for the treatment was extrapolated from use in humans (Table 4).[30-41] The primary goal of *Giardia* treatment is to stop diarrhea. Because healthy pets are not considered significant health risks for immunocompetent people, elimination of infection (which is difficult) is a secondary goal.

Use of metronidazole USP or metronidazole benzoate may be preferentially indicated if clinical findings suggest concurrent *Clostridium perfringens* overgrowth, because this drug is an antibiotic with activity against *Clostridium* spp and is thought to have antiinflammatory properties. In cats, metronidazole benzoate formulated into a tuna suspension was effective, apparently safe, and well tolerated by cats in one experimental study.[15] Care should be taken when using metronidazole and the related drug ronidazole because central nervous system toxicity can occur.[14,42,43] This side effect has occurred both from overdosing the products and from chronic use, which suggests that cumulative neurotoxicity can occur.

If there are clinical findings that suggest concurrent infection with nematodes or cestodes, the use of fenbendazole or the combination of pyrantel/praziquantel/febantel is indicated (Table 4). Many clinicians currently use fenbendazole once daily for 3 to 5 days as initial therapy. Albendazole has been associated with bone marrow suppression in both dogs and cats, so it should no longer be used to treat small animal parasitic diseases.[44] Some clinicians currently recommend use of metronidazole and fenbendazole in combination (www.capcvet.org). Others only resort to combination therapy if there is evidence of a persistent infection that is not cleared by monotherapy. If the first drug fails to control diarrhea and the organism is still detected in feces, a second drug from an alternate class is indicated.

The addition of fiber to the diet may help control clinical signs of giardiasis in some animals by helping with bacterial overgrowth or by inhibiting organism attachment to microvilli. In one study, although *Giardia* infection rates were similar after treatment, dogs treated with silymarin and metronidazole had superior clinical responses for some parameters when compared with dogs treated with metronidazole alone.[45] However, administration of a commercially available probiotic (FortiFlora, Nestle Purina PetCare Company, St. Louis, MO USA) did not lessen *Giardia* infection rates when used alone.[46] In one study, bathing the dog on the last day of treatment was a beneficial adjunct therapy.[37] Immunotherapy with the *Giardia* vaccine lessened cyst shedding and diarrhea in some infected dogs.[47] However, in a controlled study in 16 experimentally infected cats, vaccination as immunotherapy was ineffective with one strain of *Giardia*.[48] Both commercial products have been discontinued in the United States and so this therapeutic option is no longer available.

In dogs and cats with persistent diarrhea and *Giardia* spp infection, a more extensive workup to attempt to diagnose other underlying diseases is indicated if several therapeutic trials fail. In chronic cases, the possibility of underlying disorders such as inflammatory bowel diseases, bacterial overgrowth, coinfection with other organisms like *Cryptosporidium*, *Isospora*, or *Tritrichomonas fetus*, exocrine pancreatic insufficiency, and immunodeficiency should also be considered.[11,19,20] *Giardia* infection does not induce permanent immunity, and so re-infection is likely to occur frequently and can be confused with resistant infection.

Prognosis

Most infected dogs and cats with clinical giardiasis will ultimately have clinical signs of disease resolved with treatment; therefore, the prognosis in both healthy and clinically ill animals is good.

Prevention

The most effective way to prevent *Giardia* infection is to avoid the ingestion of cysts contaminating the environment. These procedures include boiling or filtering of water collected from the environment before drinking. Chlorine disinfection of public drinking water is not completely effective in killing *Giardia* spp. Feces from infected animals should be removed promptly from the environment. The organism can be inactivated on contaminated surfaces by removed fecal contamination by thorough cleaning followed by steam cleaning or disinfecting with quaternary ammonium compounds (1 minute contact time). Paratenic hosts should be controlled. Treatment and bathing of all animals in the same environment could be considered, particularly if repeated diarrhea is occurring. Previously licensed *Giardia* spp vaccines for dogs and cats were classified by American Animal Hospital Association and American Association of Feline Practitioners vaccine guidelines committees as generally not recommended as preventatives, and both products have now been discontinued by the manufacturers.

Zoonotic Considerations

Healthy pets are not considered significant human health risks by the Centers for Disease Control and Prevention (www.cdc.gov/hiv/pubs/brochure/oi_pets.htm), and there is no current recommendation to test healthy dogs or cats for *Giardia* spp infection. However, the detection of the zoonotic assemblages in some dogs and cats and the detection of the same assemblage in dogs and people in the same family have been reported.[49-52] All healthy dogs and cats should be screened for hookworm and roundworm infection once or twice yearly. However, by following this recommendation, some healthy dogs and cats that are harboring *Giardia* cysts will inevitably be detected. Because some *Giardia* spp may be zoonotic, treatment of healthy infected animals should be considered with each owner. Treatment of healthy animals is controversial because all of the drugs can potentially cause side effects, animals with normal stools are not considered human health risks, treatment is unlikely to eliminate infection, and re-infection can occur within days. There is currently no consensus on *Giardia* retesting if the animal is normal. However, if repeat tested is chosen it should be by fecal flotation, not *Giardia* antigen assays, IFA, or fecal PCR assay (www.capcvet.org).

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