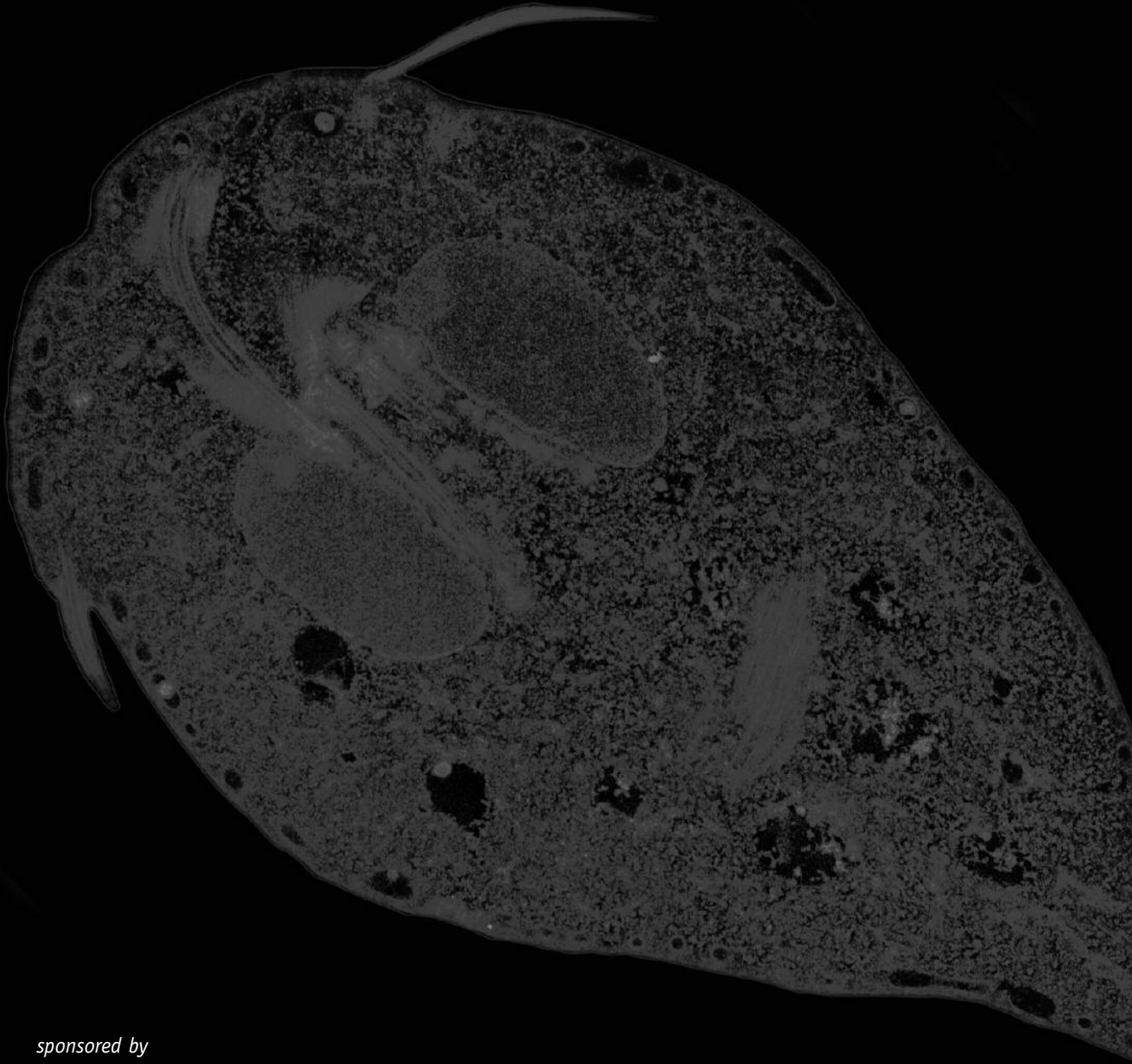




Results of a National Study

Prevalence of *Giardia* in Symptomatic Dogs and Cats in the United States



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Prevalence of *Giardia* in Symptomatic Dogs and Cats in the United States*

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CLINICAL RELEVANCE

The national prevalence of *Giardia* infection in dogs and cats presenting to clinics with gastrointestinal signs was examined using the IDEXX SNAP *Giardia* Test (IDEXX Laboratories).¹ Veterinary practices across the United States were asked to use the test on fecal samples from cats and dogs identified as having diarrhea and/or vomiting. Results from 16,114 dogs and 4,978 cats were submitted. Analysis of the data showed a *Giardia* prevalence of 15.6% among tested dogs and 10.8% among tested cats. The results of this study show that *Giardia* is a common enteric agent among dogs and cats with gastrointestinal signs.

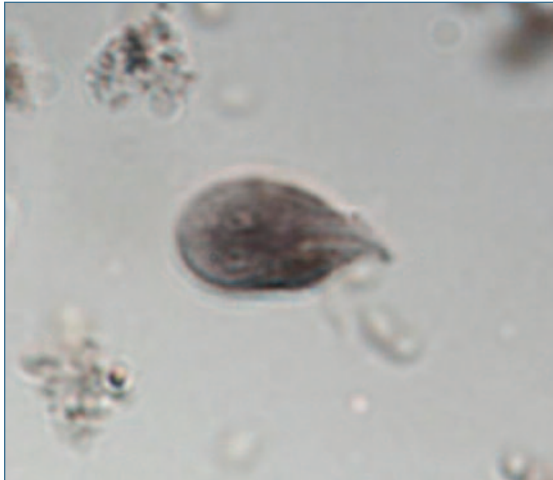
INTRODUCTION

Correct diagnosis of giardiasis is a challenge for many veterinary clinics because the protozoan cysts are small and are shed intermittently, and staff members are often suboptimally trained to identify these elusive bodies. In addition, the motile trophozoite stage is typically found only in fresh unformed or liquid stools. Sugar flotation solutions often preclude accurate diagnosis of *Giardia* because the high specific gravity of these solutions distorts the *Giardia* cysts.² To increase cyst recovery, many laboratories use zinc sulfate as their flotation medium²; however, the problem of cyst identification persists among the inexperienced. Some studies³⁻⁵ have explored *Giardia* prevalence based on flotation techniques and microscopic analysis of recovered cysts, but because of inherent problems with the assays and the varying expertise of differ-

ent laboratories, concern exists that infections may be underdiagnosed. The SNAP *Giardia* Test (IDEXX Laboratories, Westbrook, ME) offers the advantages of being accurate and easy to use while providing a consistent methodology that removes technical bias.²

Using the SNAP Test as the diagnostic method, we undertook an investigation of the prevalence of *Giardia* spp among a convenience sample of a large subset of dogs and cats in the United States. The objective of our study was to determine the prevalence of *Giardia* spp in dogs and cats presenting to US clinics with clinical signs of gastrointestinal (GI) disease; study parameters defined GI signs as vomiting and/or diarrhea. Broadly speaking, the study sought to determine the prevalence of an enteric pathogen using a type of diagnostic test that has

*Some of the information presented here originally appeared in Carlin EP, Bowman DD, Scarlett JM, et al: Prevalence of *Giardia* in symptomatic dogs and cats throughout the United States as determined by the IDEXX SNAP *Giardia* Test. *Vet Ther* 7(3):199-206, 2006.



▲ **Figure 1.** *Giardia trophozoite.*



▲ **Figure 2.** *Giardia cyst.*

demonstrated substantial utility for the identification of other organisms.

***Giardia*: Biology and Clinical Features**

Protozoan parasites within the genus *Giardia* have a long history within veterinary medicine. Most species that infect domestic animals were initially described as separate species in the 1920s: *Giardia caprae* (Nieshulz, 1923) from sheep and goats; *Giardia bovis* (Fantham, 1921) from cattle; *Giardia equi* (Fantham, 1921) from horses; *Giardia canis* (Hegner, 1922) from dogs; and *Giardia felis* (Hegner, 1924) from cats (synonym, *Giardia cati* [Deschiens, 1925]). During the first 50 years that these agents were known to infect animals, it was difficult to assess their effects because of the many other gastrointestinal agents co-inhabiting these hosts. As the prevalence of other enteric agents declines, the effects of *Giardia* infection alone are becoming better understood.

The two most commonly seen stages of *Giardia* are the trophozoite and the cyst. The actively motile and dividing stage, the trophozoite (Figure 1), is usually found only in unformed or liquid feces.⁶ It is teardrop shaped, bilaterally symmetrical, and flattened dorsoventrally. Trophozoites typically measure about $15 \times 10 \times 3 \mu\text{m}$. Prominent features observed via light microscopy are four pairs of flagella, two nuclei, two axonemes, and median bodies (aggregates of microtubules and other proteins). On the ventral aspect is a sucking disc; this feature allows for trophozoite attachment to the small intestinal mucosa. The cyst (Figure 2), which is the

transmission stage, is commonly present in formed feces and in animals without clinical signs. It is an ellipsoidal body measuring approximately $10 \times 7 \mu\text{m}$. When mature, it contains four nuclei (representing two potential trophozoites). Most infections in which cysts are passed are asymptomatic.⁷

The life cycle of all *Giardia* species is direct.⁶ Cysts are ingested by a host via feces or in fecal-contaminated food or water. Excystation occurs in the duodenum after the cysts have been exposed to gastric acid and pancreatic enzymes. The newly excysted cell, termed the *excystoite*, actually divides twice to form four trophozoites containing two diploid nuclei each; the nuclei contain several copies of five chromosomes.^{8,9} The trophozoites, whose metabolism is anaerobic, attach most often at the basal aspect of the brush border of the proximal small intestine and absorb nutrients through the cell membrane.⁶ Trophozoites multiply by simple binary fission to produce the very large numbers that are present in a typical infection. At some point, some trophozoites encyst for the purpose of transmission because the unprotected trophozoites are incapable of causing infection and die if released into the environment.^{6,10} The exact location of encystation is unknown,⁷ but it probably occurs in the ileum or colon.⁶ Cysts are the stage usually passed in feces, but occasionally trophozoites are passed, especially in hypermotile guts that expel them before they have the opportunity to encyst. The cysts passed in the feces are available for ingestion by a new host or by the same host via a process known as autoinfection. The prepatent

period in animals that have been experimentally infected has been determined to be somewhere between 5 to 10 days for dogs and up to 16 days for cats.¹¹

Infected animals may develop severe enteritis with subsequent diarrhea and dehydration. Pathology and clinical signs result from both the direct action of the parasite and the body's response to it.⁶ When signs occur, they are related to maldigestion and malabsorption. Studies of pathogenesis in animals are limited, and most of our assumptions are deduced from knowledge of human infections.⁷ Proposed mechanisms include epithelial cell apoptosis, barrier dysfunction,

Because signs are nonspecific, detection of Giardia in an animal's feces is necessary for accurate diagnosis.

transport dysfunction, inhibition of lipases and disaccharidases, and physical disruption of the microvillar glycocalyx (which contains the disaccharidases).^{6,12} The host's inflammatory response results in villar and microvillar blunting, which decreases the surface area available for absorption.¹³ Impaired active transport and accelerated exfoliation also contribute. Clinical signs that result from these microscopic changes include malodorous diarrhea, steatorrhea, and weight loss or failure to gain weight. Appetite may be normal. The organism is unlikely to be the sole cause of diarrhea and does not in itself typically cause vomiting.^{6,7} Diagnostic differentials should include other causes of maldigestion and malabsorption, such as exocrine pancreatic insufficiency, inflammatory bowel disease, and lymphangiectasia.^{6,14} Because signs are nonspecific, detection of the organism in an animal's feces is necessary for accurate diagnosis.

Is *Giardia* Zoonotic? Implications for Treatment

Giardiasis in animals has received increased attention in recent years, partly because *Giardia* infections do cause disease in people, and numerous human giardiasis outbreaks have been associated with drinking and recreational water.¹⁵⁻¹⁸ Giardiasis became a nationally report-

able disease in humans in 2002.¹⁵ *Giardia intestinalis* (also known as *Giardia duodenalis* and *Giardia lamblia*) is the most commonly reported intestinal parasite of humans and is a frequent cause of disease, particularly in the young.^{19,20} A recent Centers for Disease Control and Prevention (CDC) report on giardiasis in the United States described data for 1998 to 2002, with 19,708 to 24,226 cases reported per year during that time period.¹⁵ Reported cases were greatest among young people, in more northern states, and during the summer months. The actual number of cases was believed to be much higher, anywhere from 424,120 to 2,120,600 cases in 2002, equating to a possible annual incidence of 0.15% to 0.73%.

The taxonomy of the genus *Giardia* is complicated. Traditionally, species designations were assigned mainly based on the host species.⁶ Classification was also based on morphologic characteristics²¹ (e.g., cell shape, morphometrics of cysts and trophozoites). Then, from the 1960s through the 1980s, a tendency arose to lump the different species of *Giardia* occurring in mammals (other than mice) as *G. duodenalis*, as redescribed by Filice in 1952.²² More recently, molecular methods have indicated that distinct groups of *Giardia* organisms (called assemblages) infect certain groups of hosts.^{21,23-26} The most commonly applied assemblage clusters place assemblages A/B in people, assemblages C/D in dogs, assemblage E in hoofed stock, assemblage F in cats, and assemblage G in rats; mice are host to their own recognized species, *Giardia muris*.

The species-specific assemblages suggest that the potential zoonotic threat from these organisms is low. We now know that typically, people get *Giardia* A/B from other people, dogs get *Giardia* C/D from other dogs, cats get *Giardia* F from other cats, and cattle get *Giardia* E from other hoofed stock. Thus, for the most part, people get human giardiasis, dogs get canine giardiasis, and cats get feline giardiasis, and the risk of zoonotic infection is now thought to be much lower than when all species were lumped simply under the same name *G. duodenalis*.

The practical question is whether to treat nonclinical animals to prevent zoonotic infections. There have been cases under certain circumstances in which the human assemblage has been found in dogs.²⁵ *G. duodenalis* assemblage A has been recovered from humans and dogs living within the same locality.²⁵⁻²⁷ In an urban setting in

Japan, a mix of human- and dog-specific assemblages were recovered from dogs in breeding kennels and households.²⁸ In contrast, a study of an Australian aboriginal community found dogs to harbor purely dog-specific assemblages.²⁹ Questions clearly linger regarding the amount of crossover that actually occurs between these different assemblages and their hosts under conditions that allow transmission. In addition, the general public is aware of human giardiasis as a disease entity, and clients may refuse to accept an explanation of it being nonzoonotic. Thus, the simple response to the question of treatment is to treat the infected animals and thereby remove any potential risk for both humans and other animals.

For the prevention of canine infection, an available vaccine has worked well in some clinical trials³⁰ but has not been accepted as highly efficacious in the field by many veterinarians. Published reports on its lack of efficacy in shelters³¹ and as a potential therapeutic in canine carriers³² have limited its usage.

There are no drugs labeled for the treatment of giardiasis in dogs and cats.^{33,34} Medications that have been used off-label include the benzamidozoles, metronidazole, and quinacrine. Therapeutic data for cats are limited, although furazolidone has been tried successfully.¹¹ Fenbendazole has been shown to be effective in dogs.^{35,36} Treatment with Drontal Plus (Bayer Animal Health; fenbendazole in the prodrug form febantel, plus praziquantel and pyrantel pamoate) has also been found to be efficacious.³⁷ Quinacrine and metronidazole have also been shown to be effective³⁸; however, quinacrine is not available in the United States. Treatment may be less efficacious in animals with hypermotile diarrhea because the drug may require a prolonged presence around the trophozoites, which may be difficult with increased GI transit time. One limiting factor in treatment is the possibility of side effects, including bone marrow suppression with albendazole, vomiting with fenbendazole, neurologic abnormalities with metronidazole, and fever and lethargy with quinacrine.^{33,38} Although side effects may be uncommon with these drugs at proper dosages, their effects should be weighed against the value of treatment in a nonclinical animal. Current drug recommendations from the Companion Animal Parasite Council (CAPC) for dogs are fenbendazole plus or minus metronidazole and either or both of these drugs for cats.³⁴ CAPC does not recommend albendazole in either species for safety reasons.

Diagnosis and the SNAP *Giardia* Test Kit

Proper diagnosis of giardiasis can be a challenge. Even among those who routinely perform fecal analyses, recognition of the cysts is difficult at best if they have not been appropriately trained (cysts are much smaller than helminth eggs and are rather transparent). Although living trophozoites are relatively easy to observe under a microscope, they are fragile and can decompose rapidly, cease their movements, and then become much harder to find. In a recent study comparing the diagnostic efficacy of sugar flotation, zinc sulfate flotation, and the SNAP *Giardia* Test (Figure 3) in the hands of practicing veterinarians,² only six of 27 participants could identify *Giardia* cysts using flotation techniques on a known positive sample. On the other hand, all 27 participants were able to correctly diagnose the samples using the SNAP *Giardia* Test.²

Similar to other SNAP tests, this diagnostic test is ELISA based and uses antibody reagents specific for the detection of soluble cyst wall antigens from *Giardia*. A fresh fecal sample is collected on a reagent swab that also houses a conjugate-bound antibody solution. The feces and conjugate are mixed within the reagent swab. If *Giardia* antigen is present, the conjugate-bound antibody binds with it. The fecal-reagent solution is then placed on the test device, which contains a membrane coated with secondary antibody; as the solution flows over the membrane, the conjugated antigen is bound by the secondary

In a recent study, only six of 27 participants could identify *Giardia* cysts using flotation techniques on a known positive sample.

antibody. After depression of one end of the device and an audible “snap,” two waves of suspensions flow: a wash that removes unbound material, followed by a substrate solution; if the substrate solution encounters the conjugated antibody, a blue color is generated that denotes a positive sample.

The cyst wall of *Giardia* spp is formed by the exocytosis of cyst wall antigens in the form of filamentous proteins over the surface of the



▲ **Figure 3.** All 27 participants in a recent study were able to accurately identify known positive samples using the SNAP Giardia Test Kit shown here.

trophozoite, including the sucking disc.³⁹ In vitro, the encysting trophozoites detach, round up, and become enclosed in the filamentous network. Near the end of encystment, some cysts have a “tailed” appearance because of the flagella that have not been fully retracted into the developing cyst. The proteins that make up the cyst wall have various designations, and the antigen that is used in most detection assays is known as cyst

Overall Giardia prevalence was 15.6% for dogs and 10.3% for cats.

wall protein 1.⁴⁰ It is suspected that this antigen is not species specific and that cross-reactions between species or assemblages occur, but each test system should be verified using the feces of animals under investigation.

MATERIALS AND METHODS

An invitation letter was mailed to 21,788 veterinary clinics that are part of the IDEXX mailing list (two mailings: one in 2004 and one in 2005) requesting that veterinarians evaluate all canine and feline patients presenting with clinical signs of GI disease (vomiting and/or diarrhea) for *Giardia* infection using the SNAP Giardia Test. In return, the clinics received a rebate on the cost of the test for each data point submitted. Data were submitted on standard forms, indicating the species, clinical signs, test date, and test results for each animal.

The data were entered into an Excel spreadsheet (Microsoft, Redmond, WA) and analyzed with the statistical package Statistix (Analytical Software, Tallahassee, FL).

Prevalence estimates were obtained by dividing the number of positive samples by the number of samples submitted. Estimates were categorized by species, clinic, state, and geographic region; regions were Northeast, Southeast, Midwest, and West (including Alaska and Hawaii) as characterized by Blagburn et al.³ Statistical comparisons were made between species and among regions using the chi-square test of

independence, with $P < .001$ considered significant. Geographic estimates were plotted and displayed using the software package MapViewer (Golden Software, Golden, CO).

RESULTS

A total of 21,041 test results were reported: 941 clinics submitted results for 16,064 dogs, and 871 clinics submitted results for 4,977 cats. Most of the canine samples tested came from some of the most populated states in the country, including California, Texas, and Florida; New York, however, which ranks tenth in state population,⁴¹ supplied the most results (Figure 4). Supplied cat data predominantly came from many of the same states as the dog data, with New York again being the top contributor of samples (Figure 5).

Overall prevalence for dogs was 15.6%. Regional sample numbers and prevalence values for dogs showed highest prevalence in the Northeast at 19.2%, although the most samples were collected from the Midwest (Figures 6 and 7; Table 1).

Except in terms of Midwest versus West, prevalence calculations in all regions were significantly different from one another. The Northeast had the highest percentage of positive canine tests of any region. The state with the highest prevalence was New Hampshire, at 30.6% (37 of 121). Other states ranking among those with the highest rates were Connecticut (30.2%; 91 of 301) and New Jersey (27.7%; 94 of 340) in the Northeast and Idaho (26.8%; 11 of 41) and Nevada (25%; eight of 32) in the West.

Overall prevalence for cats was 10.3%. There was a significant difference in the overall

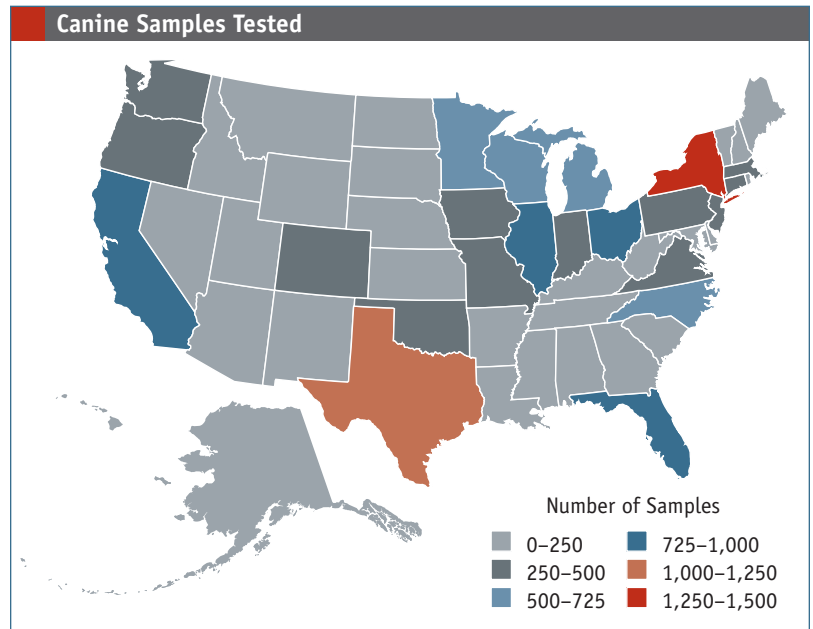
prevalence (15.6% versus 10.3%) between the two species tested ($P < .001$). Regional sample numbers and prevalence values for cats demonstrated that the region with the highest prevalence was the Northeast at 11.2%; the Midwest submitted the most samples (Figures 8 and 9; Table 2).

Although the Northeast again ranked highest in prevalence, regional differences were not significant for cats. Tennessee had the highest prevalence of *Giardia*-infected cats at 24.7% (18 of 73), followed more distantly by five states (Maine, Nebraska, New Jersey, Oklahoma, and Vermont) in multiple regions with values in the 16% to 20% range.

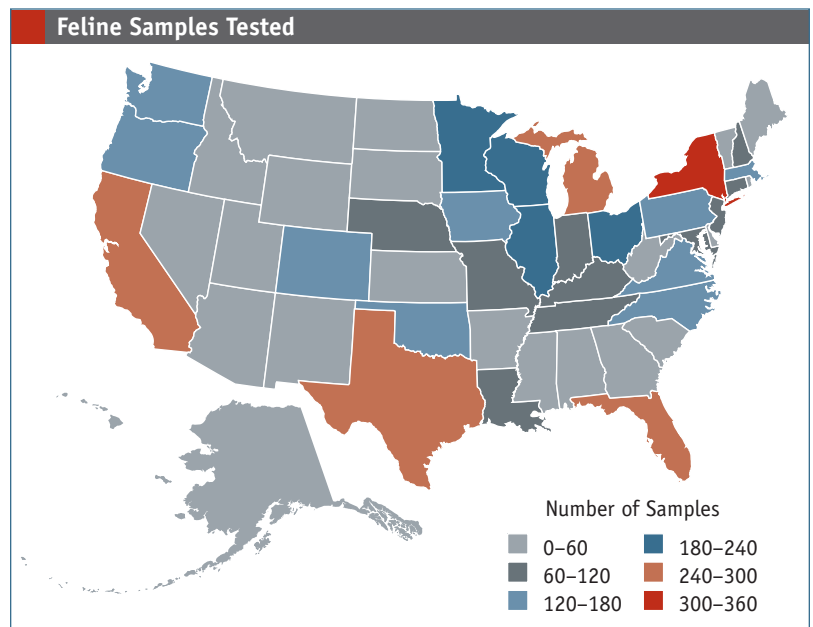
DISCUSSION

Based on the IDEXX SNAP Test, *Giardia* is common in dogs and cats presenting with GI disease as defined by the presence of vomiting and/or diarrhea. The only previous national survey for canine *Giardia* found an overall prevalence of 0.62% in shelter dogs based on centrifugal sucrose flotation, and the authors of that study believed that this number substantially underestimated the true prevalence because sucrose solution is considered an insensitive diagnostic.³ A recent study⁴ in pet cats in Banfield hospitals found an overall prevalence of 0.58% based on zinc fecal flotation or direct smear. The much higher percentages we found may be partially related to the fact that only symptomatic dogs and cats were examined but also because the SNAP Test is likely to be more sensitive than flotation methods in most practice situations.² The test produces few false-negative or false-positive results. Compared with ELISA microplate results, the sensitivity of the SNAP Test is 92% and specificity is 99.8%.⁴²

Other sources of bias are possible. For example, the age of animals sampled or the severity of their disease may have varied across participating clinics, potentially influencing the prevalence estimates. Also, the responding clinics may have been motivated to participate because

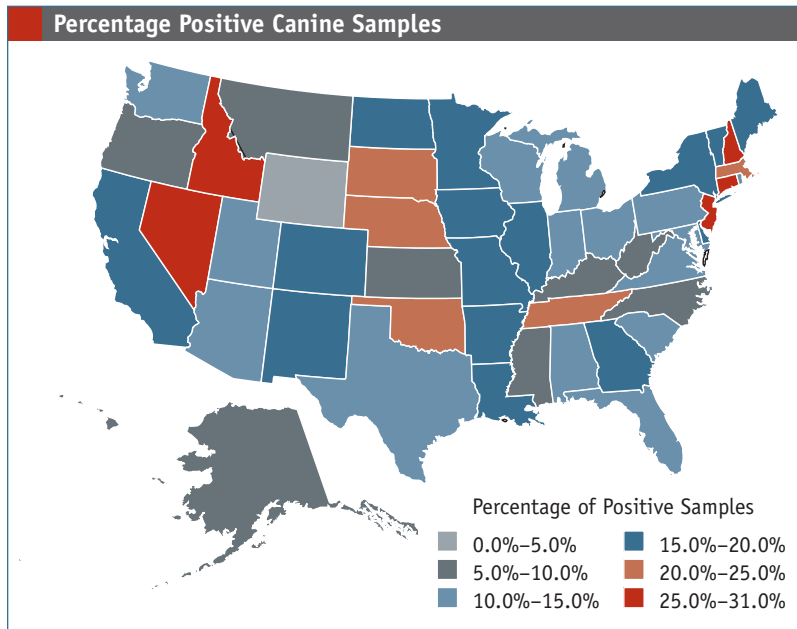


▲ **Figure 4.** Number of canine fecal IDEXX SNAP *Giardia* Test results submitted from each state.

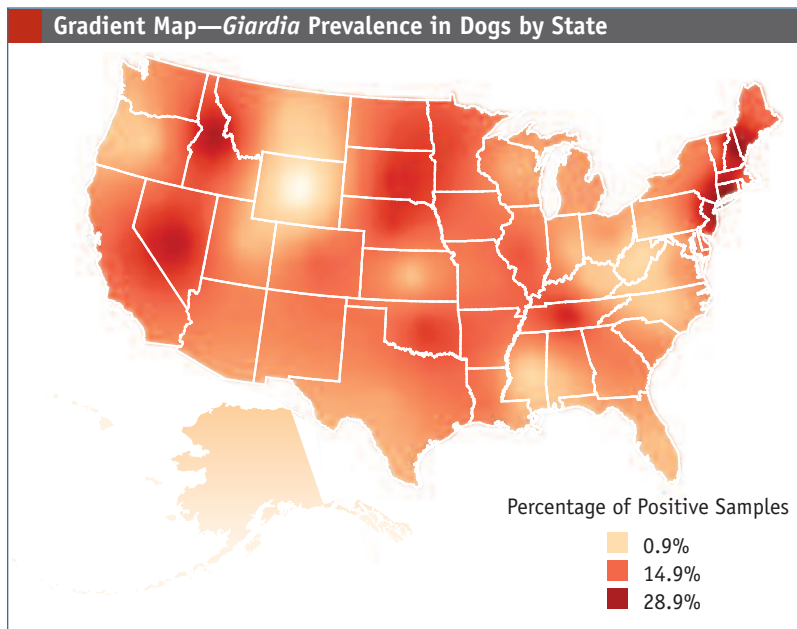


▲ **Figure 5.** Number of feline fecal IDEXX SNAP *Giardia* Test results submitted from each state.

they had previously identified (or suspected) a high rate of *Giardia* among animals presenting to them (potentially leading to biased prevalence estimates). As is true of all epidemiologic studies, the results require replication by other investigators, in other populations, and so on.



▲ **Figure 6.** Percentage of canine fecal samples from each state testing positive for *Giardia* using the IDEXX SNAP *Giardia* Test.



▲ **Figure 7.** Gradient map by state of percentage of canine fecal samples from each state testing positive for *Giardia* using the IDEXX SNAP *Giardia* Test.

As the maps show, *Giardia* infection is most common in dogs in New England and the western Midwest. Among cats, infection also predominates in New England and the western Midwest, as well as some of the south-central states, such as Oklahoma, Arkansas, Mississippi, and Tennessee (although the differences were not significant). Causative reasons for differences in prevalence were not studied here. An epidemiologic study in people indicates that giardiasis is geographically widespread but may show a northern proclivity.¹⁵ Our study showed the highest prevalences in the Northeast for dogs and cats compared with other regions of the United States (although the difference was not significant for cats). Care must be taken to not overinterpret these similarities because data collection methods among studies differ and much of the human data have been the result of passive surveillance. Prevalence among a particular animal species is also presumably correlated to the population density of that species. Any geographic similarities between animal and human prevalence may be attributed to the fact that *Giardia* cysts of any species thrive best in wet environments. One study in central New York State found *Giardia* spp in 7.3% of cats less than 1 year of age⁴³; 2.4% of cats (GI symptomatic and asymptomatic) in north-central Colorado were infected in another investigation.⁴⁴ The CDC study of giardiasis in people also demonstrated marked seasonality, with the highest incidence during the summer. Seasonality was not

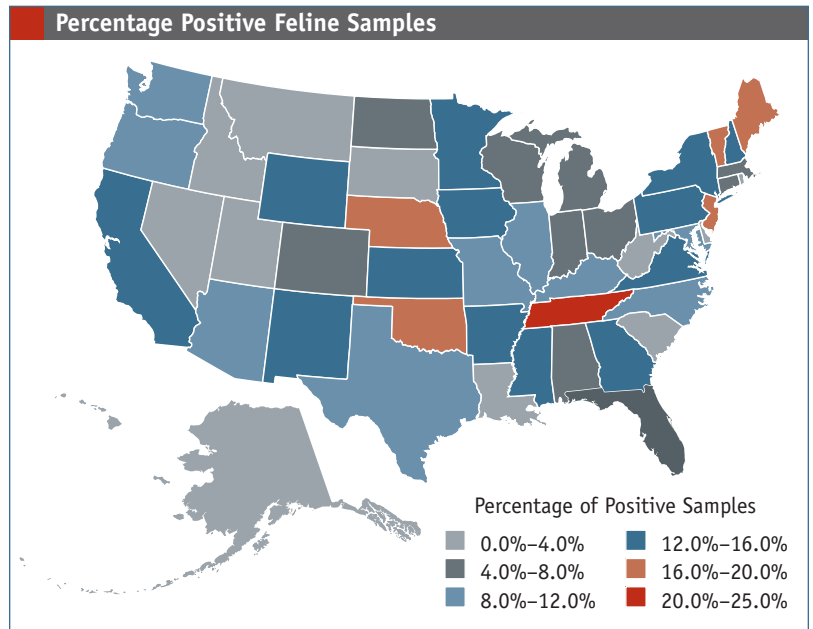
TABLE 1. Prevalence of *Giardia* spp in Dogs by Region of the United States

Region	Total Sample	Percentage Positive	Region	Total Sample	Percentage Positive
Northeast	3,291	19.2%	West	3,185	15.7%
Midwest	5,193	15.6%	Southeast	4,395	12.9%

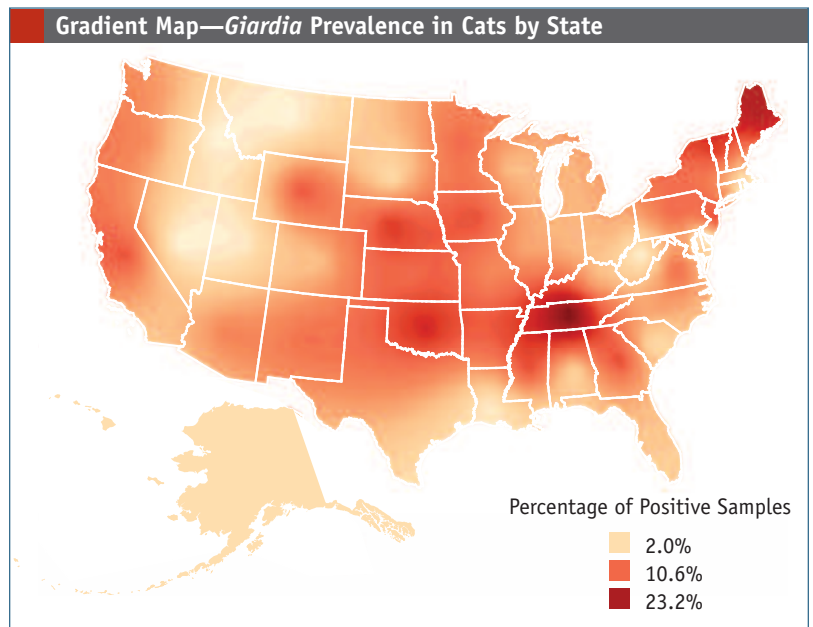
considered in the study reported here.

This study looked at prevalence of *Giardia* among dogs and cats with signs referable to GI disease among animals presented to veterinary clinics. The results pertain only to animals similar to those sampled, and the study did not examine whether *Giardia* was the cause of the signs or simply an incidental finding. Infection in adult dogs and cats is usually asymptomatic, with immature animals being more susceptible to disease.⁶ Acute diarrhea, when seen, tends to occur in very young dogs and cats; in older animals, diarrhea may be acute, intermittent, or chronic.⁷ Clinical disease in cats is particularly uncommon. Some human data suggest that although infection may be either clinical or subclinical, ostensibly asymptomatic children may have stunted growth rates,⁴⁵⁻⁴⁷ although not all research supports this hypothesis.⁴⁸ The role of giardiasis in nutrient deprivation and its contribution to co-infective states offer an important area of further research in both people and nonhuman animals. Correlation of our results with specific clinical signs in dogs and cats would allow for improved understanding of what clinical role *Giardia* may play.

No attempt was made during data collection in this study to correlate the SNAP *Giardia* Test results with those of other fecal analyses, but this presents a welcome research opportunity. Because of limitations associated with flotation techniques and intermittent agent shedding,^{49,50} it is suggested that the SNAP *Giardia*



▲ **Figure 8.** Percentage of feline fecal samples from each state testing positive for *Giardia* using the IDEXX SNAP *Giardia* Test.



▲ **Figure 9.** Gradient map by state of percentage of feline fecal samples from each state testing positive for *Giardia* using the IDEXX SNAP *Giardia* Test.

TABLE 2. Prevalence of *Giardia* spp in Cats by Region of the United States

Region	Total Sample	Percentage Positive	Region	Total Sample	Percentage Positive
Northeast	1,035	11.2%	West	977	10.3%
Midwest	1,659	10.3%	Southeast	1,306	9.7%

Test would be beneficial in many practices. The test may also be useful in shelters, where the prevalence of *Giardia* may be equivalent to or substantially higher than that in the general population.^{5,51}

CONCLUSION

Because of its ease of use and interpretation, the IDEXX SNAP *Giardia* test has allowed for a relative easy clinic survey on a national level. The results of the test are reproducible because of the minimal staff training required to use the device correctly. Prevalence among dogs and cats with GI signs was high at 15.6% and 10.3%, respec-

Given the difficulties of diagnosing *Giardia* using traditional in-clinic techniques, veterinarians should consider *Giardia* in any dog or cat presenting with GI signs.

tively. The population studied represents the ostensibly “owned and well-cared-for” population of dogs and cats with GI signs; many other populations exist, including pets that do not receive adequate veterinary care, shelter animals, and feral animals. These populations may have different prevalence rates. Furthermore, additional sampling of a similar pet cohort presenting without GI signs would offer an interesting comparison.

This study is relevant to veterinarians attempting to diagnose (or rule out) *Giardia* in pet dogs and cats presenting to their clinics. Given the difficulties of diagnosing *Giardia* using traditional in-clinic techniques, veterinarians should consider *Giardia* in any dog or cat presenting with GI signs and prioritize it based on such factors as age, history, and geographic locale. The issue of differential regional prevalence is being further examined with an additional data set from these and other clinics.

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