

Prevalence of heartworm infection in healthy cats in the lower peninsula of Michigan

Tina S. Kalkstein, DVM, DACVIM; Lana Kaiser, MD, DVM; John B. Kaneene, DVM, MPH, PhD

Objective—To determine prevalence of heartworm infection among healthy, client-owned cats in the lower peninsula of Michigan.

Design—Cross-sectional prevalence study.

Animals—1,348 healthy cats examined at private veterinary practices throughout the lower peninsula of Michigan.

Procedure—Sera were tested by use of an ELISA-based antigen test kit to determine infection and 2 commercially available antibody detection kits to determine exposure. A questionnaire was used to collect data to assess risk factors associated with infection.

Results—25 cats had positive results for heartworm antigen, yielding an observed prevalence of 1.9%. Neither antibody test was reliable or provided reproducible results, and neither yielded positive results for more than 20% of the antigen-positive heartworm-infected cats. Multivariate regression indicated that cats from southeastern Michigan and cats ≥ 2 years old had a higher risk of infection.

Conclusions and Clinical Relevance—Results indicated that most (80%) heartworm-infected cats in the lower peninsula of Michigan were from the southeastern part of the state, a pattern that closely paralleled the prevalence of heartworm infection in dogs. Therefore, knowledge of the regional prevalence of heartworm infection in dogs may be useful in assessing the risk of infection in cats. Results also suggested that currently available in-clinic heartworm antibody detection kits have limited utility in the diagnosis of heartworm infection in cats. (*J Am Vet Med Assoc* 2000;217:857–861)

Because heartworm (*Dirofilaria immitis*) infection is difficult to diagnose and potentially fatal in cats,

From the Departments of Small Animal Clinical Sciences (Kalkstein) and the Population Medicine Center (Kaneene), College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824. Dr. Kalkstein's present address is SouthPaws Veterinary Referral Center, 6136 Brandon Ave, Springfield, VA 22150. Dr. Kaiser's present address is Colleges of Nursing & Human Medicine, A110 Life Sciences, Michigan State University, East Lansing, MI 48824.

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Address correspondence to Dr. Kaiser.

the International Feline Heartworm Disease Council advocates the use of chemoprophylaxis for cats at risk of infection.¹ Unfortunately, because it is not known which cats or how many cats are at risk, such a recommendation may not be universally applicable. Knowledge of regional prevalence of heartworm infection in cats could more accurately guide recommendations for heartworm prophylaxis in cats. However, in the absence of such knowledge, perhaps other means of assessing the risk of infection in cats, such as the risk of infection in the local dog population, may be useful.

Heartworms have been found in cats worldwide, with the prevalence thought to reflect that of the local dog population, but at a lower rate. The prevalence of heartworm infection in cats in the United States is estimated on the basis of cases reported to the Veterinary Medical Database, published clinical case reports, and results of surveys to be 5 to 20% of the prevalence of heartworm infection in the local dog population.² Therefore, depending on region and heartworm infection rate in local dogs, the risk of heartworm infection in cats may vary from negligible to substantial.

Establishing an antemortem diagnosis of heartworm infection in cats is difficult, and therefore, the prevalence of infection has traditionally been estimated on the basis of necropsy reports of stray cats.^{3–8} Necropsy reports, however, may underestimate the prevalence for several reasons. First, the lifespan of adult heartworms is shorter in cats (< 2 years) than in dogs (approx 5 years). Second, cats may spontaneously clear heartworm infections; thus, cats that had previously been infected may not be identified at necropsy.⁹ Third, ectopic worms are more common in cats than in dogs^{10–13} and may be overlooked at necropsy if tissues other than the cardiopulmonary vasculature (eg, brain, muscle, subcutaneous tissue) are not evaluated. A 1997 necropsy study of 207 shelter cats in the Detroit area of Michigan reported that adult heartworms were found in only 6 cats,^a suggesting that the prevalence in that area was low or that necropsy studies alone cannot be used to reliably determine prevalence of heartworm infection in cats.

Cats with heartworm infection commonly do not have microfilaremia, have a low worm burden, and have single-sex infections,¹⁴ making diagnosis of heartworm infection in cats difficult. Several diagnostic tests developed for diagnosis of heartworm infection in dogs are not helpful in identifying cats with heartworm infection. For instance, because of the high proportion of single-sex infections in cats and the consequent absence of microfilariae, the microfilarial test is unsuitable for diagnosing heartworm infection in cats.^{13,15} Heartworm antigen detection tests identify circulating

antigens derived from adult female heartworms but are not sensitive enough to reliably identify infections characterized by a low worm burden, infection with male worms alone, or infections of < 5 months duration.¹⁶ The absence of a sensitive and specific diagnostic test for antemortem diagnosis of heartworm infection in cats has hampered efforts to determine the true prevalence of infection.

The purpose of the study reported here was to determine the prevalence of heartworm infection among healthy client-owned cats in the lower peninsula of Michigan. A commercially available antigen detection kit was used to determine which cats were infected, and 2 commercially available antibody detection kits were used to determine which cats had been exposed. The goal was to develop recommendations for use of heartworm prophylaxis in cats.

Materials and Methods

Selection of participants—A mailing was sent to 767 private small animal veterinary practices in the lower peninsula of Michigan to solicit their participation in the study. Participating practices were asked to submit serum samples collected from 20 healthy client-owned cats between July and December 1998. The sample collection period was established on the basis of the known time of heartworm transmission in lower Michigan, estimated to be from May 18 to October 5,¹⁷ and the 50 to 60 days necessary for development of an antibody titer following exposure to *D immitis*. Cats were excluded from the study if they were < 8 months old (ie, if they were too young to have adult heartworm infection), currently receiving heartworm prophylaxis, or exhibiting signs of chronic disease. Cats were considered healthy by participating veterinarians on the basis of history and results of physical examination and clinical assessment. Owners of cats included in the study signed a consent form and filled out a questionnaire.

Sample collection and testing—For cats included in the study, blood samples were collected by the participating practices in serum separator tubes. Samples were centrifuged, and serum was removed, placed in plain evacuated tubes, and stored in the clinic freezer until pick up by student couriers. Samples were stored at -20 F until the end of the enrollment period, at which time they were analyzed in batches. All samples were tested for heartworm antibodies by use of 2 commercially available in-clinic antibody detection kits^{b,c} and for heartworm antigen by use of a commercially available in-clinic antigen detection kit.^d Tests were performed by 1 of the authors (TSK), an experienced licensed veterinary technician, and an assistant.

The antigen detection test was performed in strict accordance with the manufacturer's instructions, using positive and negative control solutions provided with the test kits. Antibody detection tests were performed in strict accordance with the manufacturer's instructions with 1 modification. In an attempt to minimize the number of false-positive results, additional washing time was allotted during the wash step for 1 of the kits,^b as recommended by the manufacturer's technical support staff. To ensure that the tests had been performed properly, internal controls were performed with each antibody test, as per the manufacturer's instructions. Because we attempted to replicate the situation as these tests would be used in private small animal practices, positive and negative control samples were not assayed with the antibody tests, because these are not provided as standard with the test kits.

Risk factors for infection—To identify risk factors asso-

ciated with infection, cat owners completed a questionnaire asking for information on demographics and lifestyle of their cats. Variables of interest included sex (sexually intact male, castrated male, sexually intact female, spayed female), age, housing (indoor only, outdoor only, indoor-outdoor), proximity (within 0.25 mile) to a body of water, type of nearest body of water (stream, creek, pond, lake, river), and where the cat was obtained (breeder, shelter, stray).

Statistical methods—Descriptive statistics were computed for the outcome variable (positive antigen detection kit test results) and for factors that may affect this variable. The observed prevalence of heartworm infection was computed by dividing number of cats for which the antigen detection test yielded a positive result by the total number of cats tested and multiplying by 100.

Cats were considered to have heartworm infection (adult worms) if results of the antigen detection test were positive. Results of the antigen detection test were classified as positive or negative, and multivariable logistic regression was used to evaluate the likelihood of a cat having a positive result, given the presence of various risk factors. For each potential risk factor, the category with the highest number of responses was chosen as the baseline category. The full logistic regression model was used for interpretation, because all variables included in the model were considered to be of biological importance.

Results

Participating practices—One hundred four private veterinary practices responded by the enrollment deadline and registered as participants. Of the 104 practices enrolled, 100 were able to obtain samples for

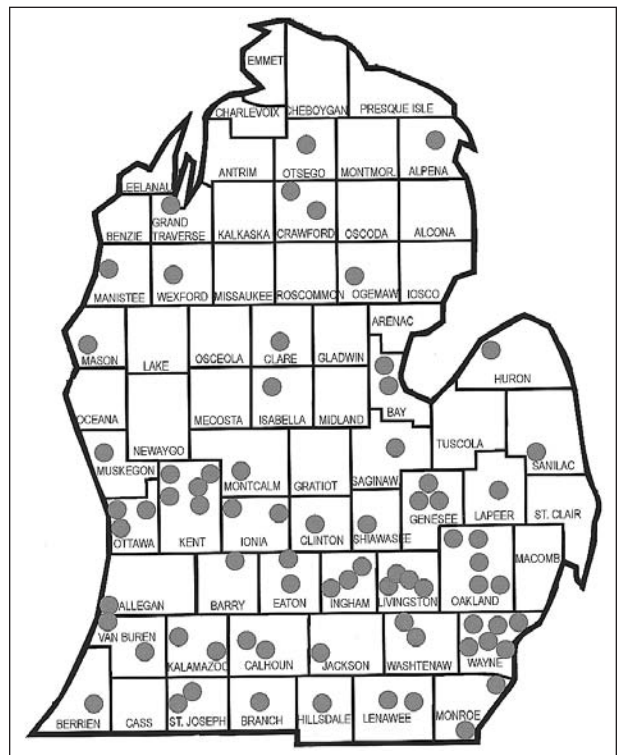


Figure 1—Location of private small animal veterinary practices participating in a study of the prevalence of heartworm infection among healthy client-owned cats in the lower peninsula of Michigan. Practices were located throughout Michigan but tended to cluster in areas of greatest population. Each dot represents the area of the practice, not the number of practices in the area.

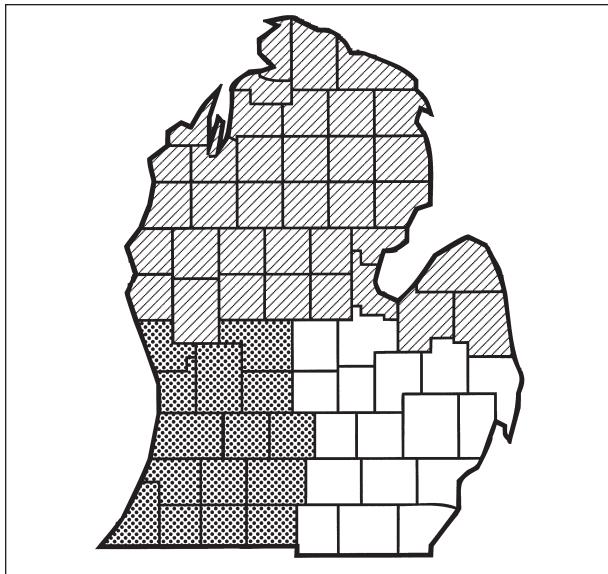


Figure 2—Prevalence of heartworm infection in cats in the lower peninsula of Michigan, by geographic region. Prevalence in northern Michigan (diagonal stripes) = 1.03% (2 antigen-positive cats of 194 tested); prevalence in southwest Michigan (black dots) = 0.60% (2 antigen-positive cats of 333 tested); prevalence in southeast Michigan (white) = 2.56% (21 antigen-positive cats of 194 tested).

the study, and these 100 practices submitted a total of 1,348 serum samples. The number of samples per practice ranged from 1 to 75 (mean, 13.5 samples/practice). Participating practices represented 60% of counties in the lower peninsula (Fig 1).

Antigen and antibody test results—For 25 of the 1,348 samples, results of the antigen detection test were positive (Fig 2). Therefore, the observed prevalence of heartworm infection was 1.9%. Unfortunately, because of the low observed prevalence, low test sensitivity, and high test specificity, it was not possible to calculate real prevalence from the observed prevalence.

All 1,348 samples were tested with 1 of the antibody detection kits,^b and 134 yielded positive results. However, only 5 of the 25 samples positive for heartworm antigen yielded positive results with this test. Only 1,321 samples were tested with the other antibody detection kit^c because of insufficient sample size or insufficient numbers of test kits. Only 17 yielded positive results, and only 4 of the 25 samples positive for heartworm antigens yielded positive results with this test (Table 1).

Only 3 samples yielded positive results for all 3 tests (ie, the antigen detection kit and both antibody detection kits). Two samples yielded positive results for both antibody detection kits but negative results for the antigen detection kit.

Risk factors—Of the 25 infected cats (ie, cats with positive antigen detection test results), 13 were female, and 12 were male. Nine were housed outdoors, and 16 were housed indoors. Most were ≥ 2 years old. Twenty-one of the 25 infected cats were from southeastern Michigan. Logistic regression indicated that the odds

Table 1—Cross-tabulation of results of an antigen detection kit and of 2 antibody detection kits for diagnosis of heartworm infection in cats

Antigen detection kit ^d results (n)	Antibody detection kit ^b results (n = 1,348)		Antibody detection kit results (n = 1,321)*	
	Positive	Negative	Positive	Negative
Positive (25)	5	20	4	21
Negative (1,323)	129	1,194	13	1,283
Total	134	1,214	17	1,304

*Because of insufficient sample volume (n = 17) or insufficient number of test kits (10), tests were performed on only 1,321 samples.

Table 2—Multivariable logistic regression model for risk of heartworm infection among healthy cats in the lower peninsula of Michigan

Variable	Category	Odds ratio	95% CI
Geographic region in Michigan	Southeast	Baseline	NA
	North	0.46	0.20–2.11
	Southwest	0.45	0.21–0.94
Age (year)	< 2	0.12	0.02–0.96
	2–10	Baseline	NA
	> 10	0.79	0.29–2.21
Source	Breeder	1.03	0.28–3.78
	Shelter	0.89	0.24–3.22
	Stray	0.30	0.10–0.92
	Other	Baseline	NA
Sex	Castrated male	Baseline	NA
	Sexually intact male	1.21	0.15–10.03
	Sexually intact female	3.52	0.68–18.31
	Spayed female	0.86	0.36–2.06
Housing	Indoors only	Baseline	NA
	Indoors-outdoors	0.97	0.62–1.52
Nearest body of water	Stream	0.40	0.08–1.91
	Lake	1.31	0.42–4.05
	Pond	1.42	0.53–3.85
	Creek	1.92	0.73–5.04
	Marsh	0.96	0.33–2.78
Shade by the house	Yes	1.08	0.39–3.02
Distance to nearest body of water (miles)	< 1	1.16	0.37–3.65
	1–10	Baseline	NA
	10–20	1.41	0.45–4.44
	> 20	0.75	0.15–3.69

Model was developed on the basis of data for 25 cats with positive antigen test results and 1,323 cats with negative results. Variables in the model were checked for confounding by use of the Mantel-Haenszel χ^2 technique, and variables that were judged to be confounders were controlled in the analysis by use of multivariate logistic regression. The choice of baseline variable does not change the interpretation.

CI = Confidence interval. NA = Not applicable.

of heartworm infection were reduced for cats living in southwestern Michigan, cats < 2 years old, and cats that had been obtained as strays (Table 2).

Discussion

Results of the present study suggested that the minimum prevalence of heartworm infection among healthy client-owned cats in the lower peninsula of Michigan was 1.9%. The heartworm antigen detection test is highly specific (98%) for *D immitis*; therefore, a positive antigen detection test result can confidently be interpreted as diagnostic of heartworm infection.

However, the sensitivity of the antigen detection test in cats is low (79%)¹⁸; therefore, the number of cats infected with adult heartworms may have been underestimated, and the true prevalence of heartworm infection among healthy cats in the lower peninsula of Michigan may be higher. Prevalence of infection is also likely to be higher among cats with clinical signs consistent with heartworm disease, which were not included in the present study. In addition, use of a convenience sample in the present study, rather than randomized case selection, could have led to some degree of selection bias.

We used two commercially available in-clinic antibody detection test kits to assess exposure in the present study. With 1 kit,^b 134 of the 1,348 cats (9.9%) had positive results, whereas with the other,^c only 17 of 1,321 (1.3%) had positive results. In addition, we expected that cats positive for heartworm antigens would also be positive for heartworm antibodies. However, for 20 cats positive for heartworm antigen, results of both antibody detection tests were negative. Therefore, the clinical usefulness of these antibody detection tests for the diagnosis of heartworm infection in cats is not clear.

Immunocompetent cats exposed to heartworm larvae would be expected to develop an antibody response. Because exposure to heartworm larvae is the single most important risk factor for development of adult infection, prevalence of heartworm antibody should be helpful in predicting the maximum number of cats likely to become infected with adult heartworms. This number represents a maximum, because not all cats exposed to heartworm larvae will develop adult infection. In the present study, however, both in-clinic antibody detection tests had poor sensitivity and specificity; therefore, we were unable to confidently assess exposure.

To our knowledge, this was the first study to examine prevalence of heartworm infection among healthy client-owned cats and assess the usefulness of in-house antibody detection tests for diagnosis of heartworm infection in these cats. Other studies have measured seroprevalence among cats with clinical signs suggestive of heartworm infection,¹⁹ compared serologic test results with necropsy findings,²⁰ evaluated serologic test results following experimental infection,¹⁵ or examined prevalence of heartworm infection at necropsy,⁷ making it difficult to compare results of these studies with results of the present study. Nevertheless, results of antibody detection tests in the present study were similar to results obtained by several groups.¹⁸⁻²⁰ For instance, Snyder et al¹⁸ demonstrated that the sensitivity and positive predictive value of the antibody detection tests used in the present study were low and reported that antibody detection test results were negative for some cats positive for heartworm antigen that also had heartworms identified at necropsy. A necropsy study²⁰ of 259 shelter cats in southeast Texas found evidence of heartworm infection in 25 (9.7%) cats. Blood samples collected prior to death from 98 of these cats, including 10 confirmed to have heartworms, were available, and 22 were positive for heartworm antibody. However, results of 1 antibody

detection test were positive for only 5 of the 10 cats with heartworms, and results of another antibody detection test were positive for only 3 of the 10. In a study of 215 cats from 4 southern states that had clinical signs suggestive of heartworm disease,¹⁹ 13 (6%) were positive for heartworm antigen, but only 8 of these 13 had positive results for antibody detection tests performed by 2 reference laboratories. As a whole, results from these studies suggest that results of antibody detection test in cats are difficult to interpret.

A study from Italy²¹ reported that > 95% of cats experimentally or naturally infected with heartworms without clinical signs of disease had heartworm antibody. The diagnosis of heartworm infection was made on the basis of results of echocardiography. Results of this study were very different than results of the present study, and the fact that 44% of the cats in the Italy study²¹ had demonstrable microfilaremia suggests that pathogenesis of heartworm disease in cats in Italy may be very different from the pathogenesis of the disease among cats in North America.

In the present study, cats living in southeastern Michigan and cats ≥ 2 years old appeared to have an increased risk of heartworm infection. All infected cats were ≥ 2 years old. Cats < 2 years old may not have had as many opportunities for exposure to heartworm larvae as older cats, limiting their chances for infection. Cats obtained as strays had a decreased risk of infection, but the meaning of this finding is unclear. Type of housing, sex, and proximity to a body of water were not associated with heartworm infection in this study. Most importantly, living exclusively indoors did not protect cats from heartworm infection. This observation amplifies results of studies by previous investigators. Fox et al²² studied 157 client-owned cats in Tulsa, Oklahoma, and found that 6 (23%) of 26 cats reported to be exclusively indoor cats had evidence of heartworm infection by use of antigen detection, polymerase chain reaction, or immunofluorescence antibody tests. Robertson-Plough et al¹⁹ studied 215 cats from private practices in Florida, South Carolina, Tennessee, and Texas and reported that approximately 20% of their exclusively indoor cats were positive for heartworm antibody, and approximately 12% were positive for heartworm antigen. Thus, even cats that live indoors exclusively should be considered candidates for heartworm prophylaxis in areas where there is a risk of heartworm infection.

Most of the infected cats in the present study were from southeastern Michigan. Based on data obtained from private practices by Merck & Co in 1996 (Fig 3), southeastern Michigan represents a comparatively high-risk area for heartworm infection in dogs as well. This suggests that cats in areas with a high prevalence of heartworm infection in dogs are at risk of developing the infection. Thus, in areas where prevalence of heartworm infection in cats is unknown, information concerning the prevalence of heartworm infection in dogs may be useful in assessing the risk of infection in cats.

As evidenced by the 25 healthy cats positive for heartworm antigen in the present study, cats may harbor heartworms without ill effects. These cats, although infected with heartworms, did not have heartworm disease, because they did not have clinical

