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Prevalence and risk factors for *Giardia* spp. infection in a large national sample of pet dogs visiting veterinary hospitals in the United States (2003–2009)

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ABSTRACT

Estimates of the prevalence of intestinal infection of dogs with *Giardia* spp. in the United States vary widely. Risk factors for infection in a large sample of dogs over an extended period of time have not been well characterized. A national, electronic database of medical records was used to estimate the prevalence and identify risk factors for *Giardia* spp. infection among dogs visiting Banfield Pet Hospital™ located in 43 states in the United States. The overall prevalence of *Giardia* spp. Infection was 0.44% (95% CI: 0.43–0.45%) in approximately 2.5 million owned dogs who had a fecal flotation test performed from January 2003 to December 2009. A steady decrease in annual prevalence was observed, from a high of 0.61% in 2003 to 0.27% in 2009. Seasonal increases in prevalence were noted during the winter and summer months. *Giardia* spp. prevalence was highest in the Mountain region, especially Colorado (2.63%; 95% CI: 2.53–2.73%), and in puppies ≤0.5 year of age (0.63%; 95% CI: 0.61–0.64%). It was lowest for dogs of mixed breeding compared with pure breeds. Infection risk was 25–30% greater in sexually intact dogs compared to spayed and neutered dogs.

1. Introduction

Giardia species (spp.) are enteric protozoa that infect a wide range of mammalian hosts including domestic animals, wildlife, and humans. The total number of *Giardia* spp. infecting animals is unclear because the taxonomy of *Giardia* spp. has undergone regular revisions based on new molecular findings. The more common *Giardia* spp. include *G. lamblia* in mammals, *G. muris* in mice and *G. psittaci* in birds (Thompson et al., 2000). Only *Giardia lamblia* (also known as *G. duodenalis*, *G. intestinalis*) has been recovered from both humans and dogs (Thompson, 2004). Some *G. lamblia* subspecies are regarded as potentially zoonotic (Ballweber et al., 2010). However, available evidence suggests that zoonotic transmission of *Giardia spp.* is rare (Hunter and Thompson, 2005).

Giardiasis is a common enteric infection in dogs with risk factors including geographic location, poor hygiene, young age, breed, and a dog's spay/neuter status (Blagburn et al., 1996; Tupler et al., 2012). A study conducted more than 20 years ago found a higher prevalence in the fall and winter months compared with the spring and summer months and among intact dogs when compared to dogs spayed and neutered (Kirkpatrick, 1988). In recent studies, *Giardia* spp. prevalence was highest in dogs from the Northeast and the West regions in the United States, and lowest in the South region (Little et al., 2009; Carlin et al., 2006).

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Puppies, one year of age or less, were reported to be at a higher risk compared to older dogs (Little et al., 2009). In countries other than the United States, higher prevalence has been associated with dogs from breeding kennels (Mundim et al., 2007), purebred dogs (Fontanarrosa et al., 2006), and selected breeds (Rottweiler) (Upjohn et al., 2010).

In the United States, *Giardia* spp. prevalence has varied widely from 0.62% in a national survey of 6458 dogs residing in animal shelters (Blagburn et al., 1996) to 36% of 117 healthy puppies (Hahn et al., 1988). Another study found up to 100% of puppies housed in pet stores to be infected (Stehr-Green et al., 1987). The wide variation in prevalence is likely dependent on the population studied, hygiene conditions, the presence or absence of gastrointestinal signs in dogs tested, and the accuracy of the diagnostic technique used. The sensitivity of diagnostic methods is also influenced by the intermittent nature of the shedding of cysts (Dryden et al., 2006).

Previous *Giardia* prevalence studies from the United States have generally included owned dogs visiting university teaching hospitals or dogs housed in shelters, with a bias towards dogs showing with gastrointestinal problems. Therefore, the objectives of the present study were to evaluate the prevalence of *Giardia spp.* infection in pet dogs across the United States that visited private veterinary hospitals for any reason over a relatively long period of time and to characterize risk factors for a positive fecal flotation test in these dogs.

2. Materials and methods

2.1. Diagnostic method

Methods of fecal collection, processing, and examination, were described elsewhere (De Santis et al., 2006). In summary, fecal samples were collected from pet dogs during routine visits to Banfield Pet Hospital™. Fecal flotation with 1.18 SG zinc sulfate ($ZnSO_4$) solution[1] was used without centrifugation to detect *Giardia* spp. cysts in the stool; individual *Giardia* spp. were not differentiated. Samples were first examined microscopically at 10X magnification and subsequently examined at 40× magnification for diagnostic confirmation and measurement of cysts by a trained individual.

2.2. Data management

Electronic medical records from all hospitals were downloaded weekly and stored in a data warehouse using proprietary software[2]. The study population included all dogs visiting Banfield hospitals during the study period with fecal flotation test examined for *Giardia* infection, thus it included dogs showing gastrointestinal symptoms as well as asymptomatic dogs examined for wellness and preventive reasons. Each dog had a unique patient identifier (PetId) consisting of the hospital code, pet number, and visit number. Data for the dogs' age, breed, owner state of residence, date of the hospital visit, and positive/negative results of a fecal flotation test for *Giardia* spp. from January 1, 2003 to December 31, 2009 were extracted and stored in electronic data sets. Data regarding clinical signs or chief complaint were not collected or analyzed as part of this study. If a dog had multiple fecal tests performed, during the study period, only the first test result was used. The state where the hospital was located was considered as the pet owners' state of residence if the owner's address was missing or did not match a standard postal coding format for states or military posts. States were classified into the nine geographic regions used by the Centers for Disease Control and Prevention (CDC) for disease reporting and surveillance. Dog breeds were placed into one of eight groups following the American Kennel Club (AKC) classification scheme (American Kennel Club, 2012) or coded as mixed breed or "other". The "other" breed group included dogs of breeds not recognized by the AKC or not designated as "mixed" or "mixed breed" in the patient record. Age was grouped as: ≤0.5 years, >0.5–2.0 years, >2.0–5.0 years, and >5.0 years of age. Gender and neuter status were recorded as intact female, spayed female, intact male, and neutered male. Month and year of the each dog's visit were also extracted from the records.

2.3. Statistical analysis

The number and proportion of positive fecal tests with 95% binomial confidence interval (95% CI) were calculated. A multivariable mixed logistic regression model was used to estimate the odds ratio (OR) for the risk of *Giardia* spp. infection with adjustment for geographic region, breed, gender, neuter status, age, and year and month of the fecal test. The variable "Hospital" was included in the regression model as a random effect. The group with the lowest OR for each potential risk factor was the reference group. Interactions between region and month and between age and gender were also included in the model. Due to the large size of the dataset, univariate screening for significant variables was not considered necessary. Therefore, all potential risk factors were simultaneously included in a multivariate model. All calculations were conducted using Stata 11.2[3]. A p-value ≤0.05 was considered statistically significant. ArcGIS 10[4] was used to produce prevalence maps.

3. Results

A total of 2,468,359 dogs visiting 777 Banfield hospitals in 43 states from January 1, 2003 through December 2009 had a fecal flotation test, of which 10,843 [0.44% (95%CI = 0.43–0.45)] were positive for *Giardia* spp. The average prevalence of *Giardia* spp. positive tests declined by year from a high in 2003 (0.61%, 95%CI = 0.58–0.64) to a low in 2009 (0.27%, 95%CI = 0.26–0.29) (Fig. 1). Slight seasonal increases were noted yearly during the winter (January and February) and summer (July and August) months (Fig. 2).

[1] Ovasol, Vedco Inc., Saint Joseph, MO, USA.
[2] PetWare®, Banfield, The Pet Hospital, Portland, OR, USA.
[3] StataCorp, College Station, TX, USA.
[4] ESRI, Redlands, CA, USA.