Veterinary Parasitology: Regional Studies and Reports 10 (2017) 139–142

Contents lists available at ScienceDirect

Veterinary Parasitology: Regional Studies and Reports

journal homepage: www.elsevier.com/locate/vprsr

Short Communication

Heterogeneous distribution of *Dirofilaria immitis* in dogs in St. Kitts, West Indies, 2014–2015

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ARTICLE INFO

Keywords:
Dirofilaria immitis
Heartworm
Dogs
Caribbean
Prevalence

ABSTRACT

In the Caribbean region, *Dirofilaria immitis* (heartworm) has been detected on almost all of the islands. While it is assumed to be endemic throughout the region, there is a lack of baseline data from the Leeward Islands (north-east of the Caribbean region). The objective of this study was to estimate the prevalence and the spatial distribution of heartworm disease in dogs on St. Kitts, a small 174 km^2 island which is part of the Leeward Islands. A cross-sectional study was conducted in 2014 with 100 dogs tested using a commercial antigen test. Dogs were from all regions of the island except the southeastern region, which differs socio-economically from the rest of the island. Heartworm was not detected in these 100 dogs.

To complete the survey, in 2015, fifteen dogs from the southeast region were tested, eight of which were positive for heartworm. Prevalence was estimated at 7.0% (95% confidence interval: 4.6–11.6). Data from two other sources were added to complete the report: data from dogs enrolled in a free spay and neuter program and tested against heartworm (164 dogs with 3 positive for heartworm), and the data from positive dogs diagnosed at the Ross University Veterinary Clinic in 2014 and 2015 (3 dogs). Most of the heartworm positive dogs (10/14) lived in a delimited area in the southeast of the island.

These results indicate an overall low prevalence of *Dirofilaria immitis* in St. Kitts, lower than that observed in the other Caribbean islands. Heterogeneity in the spatial distribution of the parasite was observed, with the majority of cases residing in the southeast of the island. Previous spatial models focused on the spread of the parasite over large geographical areas and long distances, but not within a restricted area. Our results indicate the presence of local factors which may have limited spread of the disease over short distances. Further studies are needed to understand this markedly heterogeneous distribution.

1. Introduction

Canine heartworm (*Dirofilaria immitis*) is a vector-borne disease with deleterious consequences in dogs. Adult parasites develop in pulmonary arteria and heart and produce microfilariae (mff), which infect mosquitoes (McCall, 2008). Competent vectors have been identified in different mosquito genera including *Anopheles*, *Aedes*, *Culex*, *Psorphora* and *Mansonia* (Simón and Genchi, 2001). *Aedes trivittatus*, *Aedes sierrensis* and *Culex quinquefascitus* are primary vector species in the U.S. (Wang et al., 2014), versus *Aedes albopictus* and *Culex pipiens* in Europe (Genchi et al., 2009). *Culex quinquefasciatus* and *Aedes taeniorhyncus* were found to be competent vectors in Brazil (Ahid and Lourenço-de-Oliveira, 1999).

To the authors' knowledge no prevalence or case report studies of heartworm in the Leeward Islands have been published. There is a lack of baseline data in this part of the Caribbean region. The present paper aims to document the situation in the island of St. Kitts by evaluating the prevalence and the spatial distribution of *D. immitis* in dogs.

2. Material and methods

This study was conducted in St. Kitts, one of the Leeward Islands in the Caribbean region and part of the Federation of St. Christopher and Nevis (latitude: 17.30° N; longitude: 62.80° W). The island is approximately 174 km^2. Residential areas are primarily along the coast due to the presence of a volcano and mountain range in the center of the island. In general, the vegetation, habitat, temperature and rainfall are similar throughout the coastal regions of the island with the exception

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http://dx.doi.org/10.1016/j.vprsr.2017.10.006
Received 13 July 2017; Received in revised form 21 September 2017; Accepted 16 October 2017
Available online 18 October 2017

of the southeastern peninsular area, which has slightly lower rainfall and more diverse vegetation. No wildlife on the island are known to serve as reservoirs for *D. immitis* with the only wild mammals being mongoose, African green monkeys and deer. The number of dogs on St. Kitts is unknown, although the distribution within the nine parishes (administrative areas of the island) is considered relatively even throughout the island.

Two cross-sectional studies and a review of data from dogs enrolled in the free spay and neuter program offered by the Ross University Veterinary Clinic (RUVC) were used to determine *D. immitis* prevalence.

In 2014 (4th of June to the 26th of July), a cross-sectional ecto- and endo-parasite and tick-borne disease study of dogs was conducted with dogs enrolled from all areas except the southeastern peninsula. Selection of dogs was opportunistic and conducted via door to door visits or central point sites with only dogs 6 months of age and older included. Blood was collected and the heartworm antigen Snap® 4Dx® Plus Test (IDEXX) was performed on 100 dogs. A second cross-sectional study was conducted in 2015 (22nd of July to 3rd of August) in the southeastern region of the island. Fifteen dogs were enrolled and tested as per the 2014 cross-sectional study.

In 2016, a retrospective study of all dogs enrolled in the free spay and neuter program from January 2014 to April 2015 was performed. Data on these dogs (e.g. residential location and results of the Snap® 4Dx® Plus Test routinely administered prior to the spay/neuter) were accessed in Avimark® v2013.1.3.0, the clinical records database used at the RUVC. Dogs ≤ 6 months of age or for which residential location could not be determined were excluded.

To confirm if the results from the cross-sectional studies and the spay/neuter dogs were reflective of the greater population of dogs brought to the RUVC, the Avimark® v2013.1.3.0 database was searched for any dogs (from clients not a part of the spay/neuter program) with positive heartworm results between January 2014 and December 2015.

All data (age, sex, location and test result) were entered in Microsoft Excel® and analysed using R (R Core Team, 2017). Overall prevalence was calculated with data from the two cross-sectional studies. Comparison of proportions by sex, age, breed and residential location were performed on a dataset comprising the two cross-sectional studies and spay/neuter data. Fisher's exact test was used and the threshold of significance was set at 0.05. Spatial occurrences of all sources were mapped with ArcMap 10.3.1®.

All field studies and all record searches were conducted under Ross University School of Veterinary Medicine (RUSVM) Institutional Animal Care and Use Committee and RUSVM Institutional Review Board approvals, respectively. All owners gave consent to the data collection and prior to any blood collection.

3. Results

None of the 100 dogs in the 2014 cross-sectional study were positive for heartworm. Of the 15 dogs tested from the southeastern portion of the island in 2015, 8 were positive for heartworm. Based on these cross-sectional studies with 115 dogs, heartworm prevalence was estimated at 7.0% (95% confidence interval [CI]: 4.6–11.6%). Of the 264 dogs enrolled in the RUVC spay-neuter program, 164 qualified for the analysis. Three were positive for heartworm (1.8%, 95%CI: 0–3.9%). None of the excluded dogs were positive for heartworm. All positive dogs from the study were also mff positive.

The combined prevalence by parish from these data sources are presented in Table 1. Most of the positives cases were found within the southeastern region of the island (Conaree, Half Moon Bay, Frigate Bay, the peninsula and Bird Rock): 9/34 (26.5%) versus 2/245 (0.8%) in the rest of the island (Fisher test; $p < 0.001$) (Fig. 1). The age, sex and breed of the 279 dogs from all data sources are presented in Table 2. The proportion of positive dogs was significantly higher in male dogs ($p = 0.01$). No difference in age or breed was observed between positive and negative dogs.

In the confirmation of the findings, four positive dogs were identified in the Avimark® database. The residency location of one dog could not be determined. Two dogs were from the southeastern region while one dog lived in St John (Fig. 1).

4. Discussion

Our study estimated a prevalence of heartworm in dogs of 7.0% (95% CI: 4.6–11.6%) in St. Kitts in 2014 and 2015. This result indicates a low overall prevalence of *D. immitis* on St. Kitts more comparable to that in the U.S. (0 to 12.5%; Lee et al., 2010) than prevalence on other Caribbean Islands and regions bordering the Caribbean. Prevalence has been reported to range from 6.9 to 63.2% in central and South America (Kozek et al., 1995) reaching 42% in cities on the Gulf Coast of Mexico, 45% in Brazil, 54% in the Bahamas, 63% in Cuba and 74% in Argentina (Alves et al., 1999; Labarthe et al., 1997; Labarthe and Guerrero, 2005; Vezzani et al., 2006, 2011). Prevalence in Grenada was also higher (15.4%) (Chikweto et al., 2014). In island environments outside America, prevalence is usually high (> 30%) as it was reported in Grand Canaria Island (Montoya et al., 1998) or Japan (Suenaga and Kitahara, 1978).

Our study identified a heterogeneous distribution of the parasite. The southeastern portion of the island appears highly endemic (26.5% of tested dogs being positive) compared to the number of cases in other areas of the island (0.8% of dogs tested positive). This highly endemic area is populated by wealthier residents and non-national residents. It was suspected that owners living in this area had more access to heartworm prevention and veterinary care and hence that prevalence would be lower in this area. Specific factors of this unexpected heterogeneous distribution are unknown. Different models were built to study spatial distribution in Europe, the U.S. and South America (Genchi et al., 2005; Vezzani and Carbajo, 2006; Wang et al., 2014). At the continent level, spread of heartworm is driven by two factors: the movement of dogs and the distribution of competent mosquitoes (influenced by temperature and climate). Heartworm distribution studies in the Canary Islands highlighted intra and inter-island specificity in the distribution and a relationship with climate and irrigation (Montoya-Alonso et al., 2016; Simón et al., 2014). These models may help to explain the low prevalence of heartworm in St. Kitts, compared to other Caribbean islands. First *D. immitis* was reported as an invasive species only recently (Thomas et al., 2001) and may have been introduced with movement of dogs from neighbouring islands or North America. Moreover, climate and irrigation in St. Kitts (in the Leeward Island area) is slightly different from the other islands described by Kozek et al. (1995) (eastern and southern Caribbean) and Chikweto et al. (2014) (Winward Island area). However, these models cannot explain the intra-island distribution of heartworm considering the size of St. Kitts (174 km^2).

Several hypotheses can be raised to explain this spatial heterogeneity. First, the mosquito population may also be spatially heterogeneous. Three competent vectors, *Culex quinquefasciatus*, *Aedes taeniorhynchus* and *Aedes aegypti*, were trapped at several locations in St. Kitts; however, their species abundances vary by season and location (Mohammed et al., 2015). For example, *A. taeniorhynchus* was mainly observed in the south of the island and identified sparsely in the rest of the island. Mosquito competency may be different between the species and explain the local distribution of *D. immitis*. As an example in the Canary Islands, while several potential mosquitoes are present, *C. theileri* would be the main vector of *D. immitis* (Morchón et al., 2011). Secondly, the population distribution of cats is different in the southeast. In this area, feral cats live in groups, attracted by the various restaurants and beach bars. The role of cats in the epidemiology of heartworm is still unclear, in high prevalence areas in particular (Montoya-Alonso et al., 2011). They can be exposed to L3, which will develop in rare cases to L5 and even rarer cases to a sufficient number of adult worms to produce microfilaria in blood (Atkins, 2007). A study