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Research paper

Dingoes (*Canis dingo* Meyer, 1793) continue to be an important reservoir host of *Dirofilaria immitis* in low density housing areas in Australia

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ABSTRACT

Heartworm (*Dirofilaria immitis*) is a parasitic nematode responsible for canine and feline cardiopulmonary dirofilariasis and human zoonotic filariosis in both tropical and temperate regions throughout the world. Importantly, this study in the Wet Tropics of Far North Queensland found *D. immitis* remains at high prevalence (72.7%) in wild dingoes in low density housing areas in Australia. This prevalence is equivalent to the highest levels seen in wild dogs in Australia and represents an ongoing risk to domestic dogs, cats and humans. In contrast, in higher density residential areas prevalence was significantly lower (16.7%, $p = 0.001$). It is possible that chemotherapeutic heartworm (HW) prevention in domestic dogs in these higher density housing areas is helping to control infection in the resident dingo population. Five dingoes killed in council control operations around Atherton, a non-endemic HW region in the Wet Tropics, were all negative for HW likely due to the colder climate of the region restricting transmission of the disease. This survey highlights the importance of dingoes as reservoir hosts of HW disease and that the subsequent risk of infection to companion animals and humans depends on local factors such as housing density, possibly linked to chemotherapeutic HW control in domestic dogs and climate. Our findings show that veterinary clinicians need to ensure that pet owners are aware of HW disease and do not become complacent about HW chemoprohylaxis in areas which support dingo populations.

1. Introduction

Very little is known about the epidemiology of heartworm (HW) disease caused by the filarial nematode, *Dirofilaria immitis*, within wild and rural domestic dog (or human) populations. Concerns have been raised that wild canids constitute an important on-going reservoir for HW and other parasitic diseases that may be transmissible to domestic dogs and humans (Polley, 2005). Reports of canids that act as reservoirs for HW infection include jackals, foxes and wolves in Serbia (Penezić et al., 2014) coyotes in California (Sacks, 1998), the red fox in Australia (Marks and Bloomfield, 1998; Mulley and Starr, 1984) and the dingo in the dry tropics of northern Australia (Brown and Copeman, 2003; Starr and Mulley, 1988).

D. immitis is a serious and potentially life-threatening parasite of canines and felines. It is responsible for canine cardiopulmonary dirofilariasis, otherwise known as HW disease, in both tropical and temperate regions throughout the world. *D. immitis* infections are widespread in those regions of Australia where the climate is suitable for mosquito vectors of the genera *Aedes*, *Culex* and *Anopheles* (Welch et al., 1979).

Human infections are also possible. Many reported cases are asymptomatic but pulmonary infection may cause radiological coin lesions of the lung (Rena et al., 2002; Ro et al., 1989; Theis, 2005). This can result in radiological misdiagnosis of a primary or metastatic lung tumour, leading to invasive procedures to achieve a definitive diagnosis (Lee et al., 2010; Theis, 2005). Ocular diro-

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filariasis caused by *D. immitis* has also been reported in Australia (Moorhouse, 1978).

Historically, the presence of this nematode in domestic dogs and dingoes (or wild dogs) is well documented in Australia (Brown and Copeman, 2003; Carlisle and Atwell, 1984; Coman, 1972; Dunsmore and Shaw, 1990; Kelly, 1977; Starr and Mulley, 1988). However, there is a marked lack of recent literature on current distribution and prevalence, with most surveys dating back to the 1970s and 1980s. Previously, the prevalence of HW was reported to have been as high as 77% in domestic dogs from Townsville, a growing city of several hundred thousand people located in the dry tropics region of north Queensland (Aubrey and Copeman, 1972), but this decreased to about 15% in adult pound dogs in 2001 (Brown and Copeman, 2003). This decline is thought to have been due to the widespread use of effective prophylaxis in domestic dogs with macrocyclic lactones first used in Australia in 1994 (Brown and Copeman, 2003; Holm-Martin and Atwell, 2004). However, a subsequent high prevalence of 75% in Townsville in 2003 contradicts this explanation (Brown and Copeman, 2003) and highlights the need for a greater understanding of the epidemiology of HW.

Very high prevalences of *D. immitis* infections have been reported in domestic dogs from far north Queensland Aboriginal communities on the western side of Cape York Peninsula, with 88% and 90% in Kowanyama and Aurukun, respectively (Welch et al., 1979). A correspondingly high prevalence of anti-*D. immitis* antibodies and relatively elevated antibody titres were seen in the human population (Welch and Dobson, 1974). These communities have limited or no access to veterinary care and minimal management of domestic dog health.

Little is known about the transmission of HW from dingoes to domestic dogs and potentially humans. The availability of standing water used by mosqutio vectors is thought to be the most important risk factor and is influenced by temperature and rainfall (Carlisle, 1969). Previous studies have found that heartworm infection is most common in domestic dogs living in areas close to permanent bodies of water, where mosquito populations are high (Welch et al., 1979). However, the abundance of a pathogen in a reservoir host is known to vary with population-specific factors such as demography and behaviour (Carlisle, 1969).

Canine HW infection can be effectively prevented by chemoprophylactic treatment of animals (Boreham and Atwell, 1983). Over the past two decades successful programs have been available to domestic dogs resulting in reduced reports of infection. A recent study on HW infection in dog shelters across South Australia, New South Wales and Queensland reported prevalences ranging from 0 to 2.2% (Mitchell, 2012).

Therefore, in order to better predict the current and potential on-going threat of HW infection it is important to understand its epidemiology in wild canids. The first step in assessing the potential HW threat posed by dingoes to both domestic dogs and humans is to establish prevalence in wild populations under a range of ecological conditions. This study presents the results of the first survey for *D. immitis* in dingoes in the Wet Tropics of Far North Queensland, Australia; a potential high-risk region where the combination of high rainfall, humidity and temperature are favourable to increased mosquito populations. These results are compared with those found for other dingo populations previously surveyed in locations in northern Queensland.

2. Materials and methods

Australia's largest land predator, the dingo (*Canis dingo* Meyer, 1793) is distributed widely in all states of Australia with the exception of Tasmania. European settlement has led to hybridisation of dingoes and domestic dogs and this has resulted in fewer genetically pure bred wild dingoes in many areas (Ritchie et al., 2012; Woodall et al., 1996). We have chosen to use the term dingo for all animals referred to in this study as all resembled dingoes morphologically, including features such as a larger palatal width, longer rostrum, shorter skull height and wider top ridge of skull when compared with domestic dogs (Crowther et al., 2014; Newsome et al., 1980).

2.1. Study area and collection of specimens

The study was conducted in two sections of the Wet Tropics World Heritage Area in north-eastern Queensland, Australia: the Cairns coastal region and Atherton Tablelands, a mid-elevation plateau (600–900 m). Cairns has a tropical climate with strongly seasonal rainfall of approximately 2000 mm annually. Mean monthly temperatures range from 20 °C to 29 °C. Eleven dingoes were trapped in the Cairns coastal region between October 2010 and May 2013. These animals were trapped in natural forested areas, often bordering cane farms, away from houses and will be referred to as 'wild' dingoes for the purposes of this study. Five millilitres of whole blood were collected from the jugular vein of each animal and stored in tubes containing EDTA anti-coagulant under refrigeration. As these 11 dingoes were then fitted with collars and enlisted in a GPS tracking study, necropsies were not performed.

Seventeen dingo carcasses ranging in age from seven months to greater than five years were supplied for necropsy by Cairns Regional Council animal control officers and local landholders. These dogs were killed during control programs, in or adjacent to, agricultural farming land and/or the outer suburbs of northern and southern Cairns and Atherton from 2007 onwards and will be referred to as 'urban fringe' dingoes for this study. No dingoes were specifically killed for this study. All protocols were reviewed and approved by James Cook University Animal Ethics Committee (Approval no. A1546).

2.2. Necropsy for adult D. immitis

At necropsy, the heart and lungs were excised and right ventricle and pulmonary arteries were examined without magnification for pathology and the presence of adult *D. immitis.* Other organs were also examined for evidence of ectopic migration of adult HW. Further details such as age, sex and body condition score of the animals were recorded.

2.3. Detection of adult D. immitis antigen

Blood samples from trapped animals were tested for circulating antigen, as per manufacturers instructions, using a commercial ELISA SNAP test kit for heartworm (IDEXX Laboratories Inc., Rydalmere, NSW.): sensitivity 84% and specificity 97% (Atkins, 2003).

2.4. Blood smears

Thin blood smears from the 11 wild dingoes were also stained with Diff Quik and examined under a light microscope to further test for the presence of microfilariae. *D. immitus* microfilariae were identified morphologically and distinguished from *Acanthocheilonema* (syn. *Dipetalonema*) *reconditum*, a filarial parasite of the subcutaneous tissues and fascia of canids, according to existing descriptions (Kelly, 1973; Sawyer et al., 1963). *Dirofilaria repens* is not known to occur in Australia (Stringfellow et al., 2002).