TroCCAP recommendations for the diagnosis, prevention and treatment of parasitic infections in dogs and cats in the tropics

Filipe Dantas-Torres[a,*], Jennifer Ketzis[b], Andrei D. Mihalca[c], Gad Baneth[d], Domenico Otranto[e,f], Gabriela Perez Tort[g], Malaika Watanabe[h], Bui Khanh Linh[i], Tawin Inpankaew[j], Pablo D. Jimenez Castro[k,l], Pablo Borrás[m], Arumugam Sangaran[n], Barend L. Penzhorn[o], Adrian Patalinghug Ybañez[p], Peter Irwin[q], Rebecca J. Traub[r,*]

[a] *Department of Immunology, Aggeu Magalhães Institute, Oswaldo Cruz Foundation (Fiocruz), Recife, Brazil*

[b] *Department of Biomedical Sciences, Ross University School of Veterinary Medicine, St. Kitts, West Indies*

[c] *Department of Parasitology and Parasitic Diseases, University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, Cluj-Napoca, Romania*

[d] *Koret School of Veterinary Medicine, The Hebrew University of Jerusalem, Rehovot, Israel*

[e] *Department of Veterinary Medicine, University of Bari, Valenzano, Italy*

[f] *Department of Pathobiology, Faculty of Veterinary Science, Bu-Ali Sina University, Hamedan, Iran*

[g] *Faculty of Veterinary Sciences, University of Buenos Aires, Buenos Aires, Argentina*

[h] *Faculty of Veterinary Medicine, University Putra Malaysia, Selangor, Malaysia*

[i] *Department of Parasitology, Vietnam National University of Agriculture, Hanoi, Vietnam*

[j] *Faculty of Veterinary Medicine, Kasetsart University, Bangkok, Thailand*

[k] *Department of Infectious Diseases, College of Veterinary Medicine, The University of Georgia, US*

[l] *Grupo de Parasitologia Veterinaria, Universidad Nacional de Colombia, Bogotá, Colombia*

[m] *Centro Nacional de Diagnóstico e Investigación en Endemo-epidemias, Administración Nacional de Laboratorios e Institutos de Salud Dr. Carlos G. Malbrán, Buenos Aires, Argentina*

[n] *Department of Veterinary Parasitology, Madras Veterinary College, Tamil Nadu, India*

[o] *Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, South Africa*

[p] *Institute of Molecular Parasitology and Vector-borne Diseases, College of Veterinary Medicine, Cebu Technological University, Cebu, Philippines*

[q] *Vector and Waterborne Pathogens Research Group, College of Science, Health, Engineering and Education, Murdoch University, Perth, Australia*

[r] *Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Victoria, Australia*

*Corresponding authors: filipe.dantas@cpqam.fiocruz.br (F. Dantas-Torres), troccap@gmail.com (R.J. Traub)

ABSTRACT

The Tropical Council for Companion Animal Parasites Ltd. (TroCCAP) is a not-for-profit organisation whose mission is to independently inform, guide and make best-practice recommendations for the diagnosis, treatment and control of companion animal parasites in the tropics and sub-tropics, with the aim of protecting animal and human health. In line with this primary mission, TroCCAP recently developed guidelines for the diagnosis, treatment and control of feline and canine parasites in the tropics. The development of these guidelines required unique and complex considerations to be addressed, often inapplicable to developed nations. Much of the tropics encompass middle-to-low income countries in which poor standards of environmental hygiene and large populations of stray dogs and cats coexist. In these regions, a range of parasites pose a high risk to companion animals, which ultimately may place their owners at risk of acquiring parasitic zoonoses. These considerations led to the development of unique recommendations with regard, for example, to deworming and endoparasite testing intervals for the control of both global and 'region-specific' parasites in the tropics. Moreover, the 'off-' or 'extra'-label use of drugs for the treatment and control of parasitic infections is common practice in many tropical countries and many generic products lack manufacturers' information on efficacy, safety, and quality control. Recommendations and advice concerning the use of such drugs and protocols are also addressed in these guidelines. The formation of these guidelines is an important first step towards improving the education of veterinarians specifically regarding best-practice for the diagnosis, treatment and control of canine and feline parasites in the tropics.

Keywords: endoparasites; ectoparasites; dog; cat; diagnosis; treatment; prevention.

1. Introduction

Companion animals such as dogs and cats are naturally exposed to a large number of parasites, including ectoparasites (*e.g.*, ticks, fleas, lice, mosquitoes, sand flies, and mites) and endoparasites (*e.g.*, nematodes, cestodes, trematodes, and protozoa) (Dantas-Torres and Otranto, 2014; Maggi and Krämer, 2019). Some of these parasites have apparently adapted to their domestic primary hosts to such a level that they typically cause subclinical infections. Alternatively, some parasites are less well adapted to their hosts (or maybe have adopted a different evolutionary strategy), such that they usually cause disease in dogs, cats, or both. The clinical spectrum of parasitic diseases may range from localized skin lesions to life-threatening systemic disease, as in canine leishmaniosis caused by *Leishmania infantum*, for example (Solano-Gallego et al., 2011). In addition to their veterinary significance, several parasites affecting dogs and cats (*e.g.*, *Ancylostoma* spp., *Toxocara* spp., *Dirofilaria* spp., *Onchocerca lupi*, *Toxoplasma gondii*, *Giardia duodenalis*, *L. infantum*, and *Trypanosoma cruzi*) may also be transmitted to and cause disease in humans (Traub et al., 2004, 2005; Dantas-Torres and Otranto, 2013; Traub, 2013; Dantas-Torres et al., 2019), which makes their prevention and control a priority from a public health perspective as well.

Dogs and cats living in the tropics are disproportionately exposed to the risk of parasitic infections in relation to temperate areas (Irwin and Jefferies, 2004; Rani et al., 2010; Dantas-Torres and Otranto, 2014; Traub et al., 2015; Otranto et al., 2017; Kamani et al., 2019; Maggi and Krämer, 2019). This may be explained partly by the uniqueness of tropical regions in terms of climates, landscapes, and biodiversity. Moreover, much of the tropics encompass middle-to-low income countries in which poor standards of sanitation and environmental hygiene coexist with large populations of stray dogs and cats (Traub et al., 2015; Otranto et al., 2017), further increasing the risk of parasitic infections. In these regions, parasites pose a high threat to companion animals, which in turn place their owners and the public at risk of acquiring parasitic zoonoses (Traub et al., 2005; Dantas-Torres et al., 2012; Dantas-Torres, 2020).

Recognizing the idiosyncrasies of the tropics in terms of climates, landscapes, parasites, animals, and people, a team of scientists established the Tropical Council for Companion Animal Parasites Ltd. (TroCCAP) in 2015 (https://www.troccap.com). TroCCAP is a not-for-profit organisation whose mission is to independently inform, guide and make best-practice recommendations for the diagnosis, treatment and control of companion animal parasites in the tropics, with the ultimate aim of protecting animal and human health (Traub et al., 2015). The organisation is currently comprised of 16 members from different countries who were invited on the basis of their expertise and ability to represent a region (or regions) within the tropics.

In line with its core mission, TroCCAP recently developed guidelines for the diagnosis, treatment and control of feline and canine parasites in the tropics (available in multiple languages at https://www.troccap.com/canine-guidelines and https://www.troccap.com/feline-guidelines). The TroCCAP guidelines were elaborated by the council members on the basis of current literature and clinical experience. The development of these guidelines required peculiar and complex considerations to be addressed that are often inapplicable or not relevant in developed nations (Traub et al., 2015).

These considerations led to the development of unique recommendations with regard, for example, to deworming and endoparasite testing intervals for the control of both global and 'region-specific' parasites in the tropics. Moreover, the 'off'- or 'extra'-label use of drugs for the treatment and control of parasitic infections of dogs and cats is a common practice in many tropical countries and many commonly available generic products lack manufacturers' information on efficacy, safety, and quality control. Wherever available, evidence-based recommendations and advice concerning the use of such drugs and protocols are adopted in these guidelines. The TroCCAP guidelines are considered as the first step towards educating and/or changing veterinarians' knowledge and perceptions regarding the veterinary and zoonotic significance of canine and feline parasites in the tropics, as well as their diagnosis, treatment and control.

In the present article, we address some key issues related to parasites of dogs and cats in the tropics and provide general recommendations for their diagnosis, treatment and prevention, also highlighting some research gaps.

2. Companion animal ownership in the tropics

The tropical zone covers a massive area delimited by the Tropic of Cancer in the north (23.4° N) and the Tropic of Capricorn in the south (23.4° S), with regions spanning from West Asia (including parts of Middle East), South Asia (including India), Southeast Asia, the Pacific Islands, Northern Australia, Central America, and South America, the Caribbean, and Africa. The variable climate types and landscapes encountered in these regions make them suitable for a huge variety of animals and plants. This also reflects in a high diversity of parasites affecting dogs and cats in these regions.

While in North America, the majority of Europe and in Australia and New Zealand, legislation promoting pet ownership assures that most dogs and cats are indeed 'pets' (Traub et al., 2015), the situation in most tropical countries is not quite the same. In addition to massive populations of stray animals, a large proportion of the dog and cat populations in the tropics is free-roaming, with a varied level of dependency on humans (Traub et al., 2015; Otranto et al., 2017). That is, owned and stray dogs roam freely on urban streets or in rural settings. While legislation on pet ownership and stray animal population control may be in place in some countries, these regulations are often not applied or enforced (Otranto et al., 2017). As a result, both owned and unowned animals contaminate the environment with faeces and urine, which are a source of parasite eggs and larvae, capable of infecting other animals and eventually humans (Traub et al., 2015; Dantas-Torres, 2020). Such free-roaming animals may also have uncontrolled access to offal originating from slaughterhouses or traditional animal slaughtering.

The population of pet dogs and cats is increasing year-on-year in several tropical countries; Brazil, the Philippines and India are among the top 10 countries with the largest dog populations in the world (Nag, 2017). As an example of the scale of tropical canine populations, official data from the Brazilian Institute of Geography and Statistics indicate that in Brazil, there are more pet dogs than children 14 years old or younger (*i.e.*, 52.2 million versus 44.9 million) (IBGE, 2015). There are also 22.1 million pet cats in Brazil. According to the same survey, 44.3% of Brazilian families have dogs and 17.7% have cats. Importantly, there is significant inequality in terms of access to veterinary services in most tropical countries. For instance, pets living in urban areas, particularly in high-income cities or districts, have frequent access to veterinary care and therefore are usually vaccinated, dewormed, and protected against ectoparasites. On the other hand, dogs and cats living in poor suburbs or rural areas have limited or virtually no access to veterinary services, being often unprotected against parasites.

3. Parasites of dogs and cats in the tropics

Dogs and cats living in the tropics are at risk of acquiring a very long list of parasites (Irwin and Jefferies, 2004; Rani et al., 2010; Dantas-Torres and Otranto, 2014; Kamani et al., 2019; Maggi and Krämer, 2019). This list of parasites may include unusual species, which are often of unique local interest and/or of minor medico-veterinary significance (Dantas-Torres and Otranto, 2014). Nonetheless, several parasites of dogs and cats are endemic in various tropical regions (Table 1).

The prevalence and incidence of infection by parasites in dogs and cats varies widely within the tropics, but it is generally higher when compared to data from sub-tropical and temperate regions. For instance, the prevalence of *L. infantum* and *Dirofilaria immitis* (heartworm) infection in dogs may be over 70% in highly endemic foci in Latin America (Dantas-Torres, 2009; Simón et al., 2012; Figueredo et al., 2017; Maggi and Krämer, 2019; Dantas-Torres and Otranto, 2020). The annual incidence of some parasites (e.g., *Babesia* spp.) may reach even higher values in high-risk areas (Dantas-Torres et al., 2020a).

In the same way, the prevalence of gastrointestinal helminths may reach remarkably high levels in some dog and cat populations. As an example, the prevalence of *Toxocara canis* in dogs and *Toxocara cati* in cats in Latin America may surpass 50% according to some studies (Dantas-Torres, 2020; López-Osorio et al., 2020). In South and Southeast Asia, the prevalence of egg-shedding *T. canis* infections reach as high as 32.4% and 52% in parts of Malaysia (Ngui et al., 2014) and India (Sudan et al., 2015) and 9.2% in owned dogs in the Philippines (Urgel et al., 2019). As a result, the level of environmental contamination with *Toxocara* spp. in beaches, parks, and squares as well as the seroprevalence in humans are alarmingly high (Corrêa et al., 1995; Paller and Chavez, 2014; Singh et al., 2015; Fontes et al., 2017; Araújo et al., 2018; Dantas-Torres, 2020). The prevalence of hookworms (*Ancylostoma* spp.) in dogs and cats may be even higher than roundworms (*Toxocara* spp.) in many regions (Klimpel et al., 2010; Rodríguez-Vivas et al., 2011; Heukelbach et al., 2012; Ramos et al., 2013; Schar et al., 2014; Traub et al., 2014; Mulinge et al., 2019; Saldanha-Elias et al., 2019).

The high prevalence and diversity of parasites occurring in the tropics is probably a result of a combination of factors. The substantial diversity of biomes results in a wide range of opportunities in terms of climate and landscape for any living creatures, parasites included. It is not by chance that the tropical forests constitute a natural hotspot of biodiversity.

Furthermore, the tropics are home to unique parasite species that occur exclusively or predominantly in this climatic zone. For instance, morphological, biological and molecular studies have indicated that brown dog ticks occurring in the tropics belong to a species that is similar to but different from *Rhipicephalus sanguineus* sensu stricto, which is predominately found in temperate climates (Nava et al., 2018). Moreover, brown dog ticks occurring in the tropics are apparently more competent vectors for some pathogens (*e.g.*, *Ehrlichia canis*) as compared to *R. sanguineus* s.s., which in turn explains partly the higher risk of such infections in the tropics (Moraes-Filho et al., 2015).

Other parasites seem specifically restricted to geographical zones within the tropics. In neotropical regions of Latin America *Lagochilascaris* spp. reside inside nodules most commonly in the neck region or in the oral cavity of dogs and cats (and occasionally humans) (Campos et al., 2017). Similarly, *Gurltia paralysans,* a unique metastrongyloid nematode that causes paralysis in cats is confined to South America (Muñoz et al., 2017). The liver flukes *Clonorchis sinensis* and *Opisthorchis viverrini* are capable of causing anorexia, weight loss, diarrhoea, vomiting, icterus, liver enlargement and occasionally cirrhosis in dogs and cats, and are largely restricted to Asia, whereas *Platynosomum concinnum* is found in Malaysia, Hawaii, West Africa, South America, the Caribbean, and areas surrounding the Gulf of Mexico. This high diversity of unique parasites belonging to different genera or even within a given genus (*e.g.*, *Leishmania* spp. and *Trypanosoma* spp.) has many practical implications for veterinary practitioners with regard to diagnosis, treatment and management of parasitic infections in dogs and cats in the tropics. Just as an example, serological and molecular tests commonly used for diagnosing canine leishmaniosis by *L. infantum* in Europe should be interpreted with caution in tropical regions, including Latin America, where cross reactions with other *Leishmania* spp. and with *Trypanosoma* spp. may occur (Dantas-Torres et al., 2012). For those parasites restricted to unique geographic locations, well-researched and registered treatment options may be limited, leaving little choice than to treat infections using off-label drugs and regimens (Sereerak et al., 2017; Lathroum et al., 2018).

Another important aspect related to parasites infecting dogs and cats in the tropics is that most are widespread and infective loads are high as a result of the suitable climate that offers optimal conditions for the rapid development and survival of environmental stages and vectors. Importantly, there is little or no seasonality for the vectors of some of these parasites, meaning that dogs and cats are at a permanent risk of infection and therefore, as a practical implication, the prevention of some parasitic infections, including vector-borne diseases, should be made during the whole year and not during a specific period or season.

4. Zoonotic parasites in the tropics

4.1. Vector-borne parasitic zoonoses

Many of the parasites infecting dogs and cats in the tropics are agents of zoonotic diseases, including several that are vector-borne. Numerous leishmanial parasites infect dogs, cats, or both (Dantas-Torres, 2009). Among these, *L. infantum* is the most widespread species, being the cause of zoonotic visceral leishmaniasis, a life-threatening illness affecting humans in the Mediterranean Basin, the Middle East, Central Asia, South America, and Central America (Dantas-Torres et al., 2019). Dogs are the main reservoir of *L. infantum* and thus preventing canine infections is of paramount importance to reduce the risk of infection in humans (Otranto and Dantas-Torres, 2013; Miró et al., 2017; Travi et al., 2018; Dantas-Torres et al., 2019).

Another important vector-borne zoonotic protozoan is *T. cruzi*, the agent of Chagas disease. This parasite is also commonly found in dogs and cats in Latin America and there is evidence that these animals may serve as a source of infection to triatomine vectors (Gürtler et al., 2007; Enriquez et al., 2014). Studies suggested that the use of systemic insecticides or deltamethrin-impregnated collars in dogs could curb domestic transmission of *T. cruzi* (Travi, 2019).

Human dirofilariasis is a silent mosquito-borne zoonosis sporadically detected in many areas where this parasite is endemic in dogs and cats. Most human infections are caused by *Dirofilaria repens* and *D. immitis*, and clinically manifest as subcutaneous, subconjunctival or pulmonary nodules. Other extra-pulmonary sites that might be involved include the brain, eyes, and visceral organs. Pulmonary, ocular and subcutaneous infections by *D. immitis* and other wildlife-associated *Dirofilaria* spp. have been described in humans in the Americas (Dantas-Torres and Otranto, 2013). In Asia and the Middle East, human dirofilariasis is more frequently caused by *D. repens*, which dogs harbour mostly sub-clinically. In 2011, a case of ocular dirofilariasis diagnosed in a boy from Pará state, northern Brazil, suggested that a parasite (possibly a cryptic species) morphologically similar to, but genetically different from *D. immitis* may also infect humans in South America (Otranto et al., 2011). So far, this genotype has not been detected in dogs and cats in Brazil; however, this is probably just due to the limited number of studies and with further research it is believed this genotype will be found in dogs or other canids. In 2012, a putatively new species belonging to the genus *Dirofilaria* was described for the first time in the Hong Kong Special Administrative Region, causing cervical lymphadenopathy, subcutaneous masses and subconjunctival nodules in three human patients (To et al., 2012). This nematode, which was genetically related to *D. repens*, was subsequently reported once again in a human patient in Hong Kong Special Administrative Region (Kwok et al., 2016), in an Austrian traveller returning from the Indian subcontinent (Winkler et al., 2017), and dogs, jackals and humans in south India (Pradeep et al., 2019). In Thailand, two additional genotypes from cats were shown to be closely related, but different from the parasite reported in Hong Kong Special Administrative Region and India (Yilmaz et al., 2016, 2019). Altogether, these studies indicate that, in addition to *D. immitis* and *D. repens*, different *Dirofilaria* spp. may be circulating among dogs and cats in the tropics.

In Malaysia, Thailand, India, Sri Lanka and Indonesia, *Brugia malayi* (and to a lesser extent *Brugia pahangi*) is also a mosquito-borne zoonoses, that contribute to lymphatic filariasis in humans, for which dogs and cats may act as reservoirs (Ambily et al., 2011; Al-Abd et al., 2015; Mallawarachchi et al., 2018; Rojanapanus et al., 2019). In 1997, the Global Program for the Elimination of Lymphatic Filariasis was launched by the World Health Assembly to eliminate lymphatic filariasis as a public health problem by the year 2020. In areas where brugian filariosis was highly endemic in cats, for example in Thailand, part of their efforts towards eradication in humans included a One Health approach of mass treating cats with ivermectin to interrupt transmission (Rojanapanus et al., 2019).

Finally, despite the significance of many of the aforementioned diseases, it is worth reflecting on the fact that some of the best-known vector-borne zoonotic infections are not caused by parasites, but by tick-borne bacteria. These include tick-borne human granulocytic anaplasmosis (*Anaplasma phagocytophilum*), human monocytic ehrlichiosis (*Ehrlichia chaffeensis*), and Lyme disease (*Borrelia burgdorferi* sensu lato), which do not typically occur in the tropics as a result of the Holarctic distribution of their vector ticks and are generally restricted to temperate climes. Nonetheless, other tick-borne bacteria are extremely relevant for the tropics, such as *Rickettsia rickettsii* which causes a life-threatening illness in countries such as Argentina, Brazil, Colombia, Costa Rica, Panama, and Mexico (Ortega-Morales et al., 2019).

4.2. Gastrointestinal parasitic zoonoses

There is a plethora of canine and feline gastrointestinal parasites that can be transmitted to humans through different routes, including ingestion of infective stages via contaminated food, water, or both. For instance, dogs and cats are reservoirs of many parasites that are ingested in meat, fish or sea-food (*e.g.*, *Echinococcus* spp., *T. gondii*, *C. sinensis*, *O. viverrini*, *Paragonimus* spp. and *Gnathostoma spinigerum*). Infection may also occur via percutaneous penetration of infective larvae (*e.g.*, hookworms and *Strongyloides stercoralis*). While some parasites are infective immediately upon defaecation (*e.g.*, *G. duodenalis*, *Cryptosporidium* spp. and *Echinococcus* spp.), others require a period of embryonation or development in the environment (*e.g.*, *Toxocara* spp., hookworms, *S. stercoralis*, and *T. gondii*).

The canine and feline hookworms (*Ancylostoma braziliense*, *Ancylostoma ceylanicum*, *Ancylostoma caninum*, *Ancylostoma tubaeforme* and *Uncinaria stenocephala*) are soil-transmitted zoonoses. Not only are they capable of producing morbidity and mortality in dogs and cats, but some are also classified as neglected tropical zoonoses. Each hookworm species differs considerably in its geographical distribution, life cycle, biology, zoonotic potential and pathogenic impacts on both animal and human hosts and response to treatment with anthelmintics. Most noteworthy of the canine and feline hookworms, *A. ceylanicum,* has gained increasing attention as the predominant hookworm of dogs and the second most common hookworm species infecting humans in the Asia Pacific. In parts of the Solomon Islands (Bradbury et al., 2017), Cambodia (Inpankaew et al., 2014), Malaysia (Ngui et al. 2012), and Myanmar (Aung et al., 2017), between 16–50% of hookworm-positive humans are infected with *A. ceylanicum*. Although little is known about the health impacts of this zoonosis on a population scale, growing reports of healthy, well-nourished travellers returning from endemic regions describe markedly increased eosinophil counts and severe clinical signs including abdominal pain, weight loss, fever, diarrhoea, vomiting and anaemia (reviewed by Stracke et al., in press). *Ancylostoma ceylanicum* has also been reported from canines and felines in South Africa (Ngcamphalala et al., 2019) and canines in Tanzania (Merino-Tejedor et al., 2019).

Ancylostoma braziliense is more geographically confined to the 'true tropics' spanning latitudes of up to 15° N and S globally, although the species has been reported infecting dogs and cats as far south as South Africa (Ngcamphalala et al., 2019). Despite the common misconception, *A. braziliense* is the only species of hookworm responsible for causing chronic cutaneous larva migrans ('creeping eruptions') in humans. *Ancylostoma caninum,* the most pathogenic of the canine hookworms, is also zoonotic. Although most infections are asymptomatic, a single immature adult worm residing in the small intestine of humans is capable of eliciting abdominal pain, intestinal bleeding, diarrhoea and weight loss as a result of eosinophilic enteritis and aphthous ileitis (Prociv and Croese, 1990). There is growing evidence suggesting that occasionally, patent, egg-producing infections may also occur in humans (Furtado et al., 2020).

As previously discussed, *T. cati* and *T. canis* also continue to pose a major public health threat in the tropics as a potential cause of human toxocariasis. However, for others such as *S. stercoralis*, the degree to which dogs contribute to human strongyloidiasis may be grossly underestimated on an epidemiological scale owing to inappropriate diagnostic methods employed (see Diagnosis section). However, in limited cases where appropriate diagnostic methods were utilized, 75.9% (22/29) of dogs in rural Cambodia and 4.2% (5/120) in rural Thailand were found carrying two genetically different populations of *Strongyloides* spp., one of which was shared with human isolates within the same area (Jaleta et al., 2017; Sanpool et al., 2019) making this a canine zoonosis of emerging importance.

Another major neglected canine-related zoonotic parasite is *Echinococcus granulosus*. Several tropical countries are hotspots of human hydatid disease, with high prevalence reported in South America (Bolivia, south of Brazil, Peru), Asia (Middle East, India, Bangladesh) and Africa (most countries) (Deplazes et al., 2017). Its occurrence is strongly related to free access of dogs to slaughter offal (poor law reinforcement for slaughterhouses, mass slaughters during religious events and high number of free-roaming dogs) and lack of veterinary services in rural areas with high dog and livestock densities.

As such, diagnosing, treating and preventing parasitic infection in dogs and cats should be a priority for veterinarians and public health workers in the tropics. In the following sections, we provide general recommendations regarding diagnosis, treatment and prevention of parasites of dogs and cats in the tropics.

5. Diagnosis

Given the high diversity of parasites and prevalence of parasitic infections in dogs and cats in tropical regions, regular evaluation of dogs and cats by veterinarians is needed. When feasible, veterinarians in the tropics should perform general testing for gastrointestinal parasites at least every three months in dogs and six months in cats, in addition to annual tests for vector-borne infections.

The ability of veterinarians in the tropics to examine dogs and cats at the frequency desired for an effective parasite monitoring program can be challenging given the economic constraints and limited accessibility to veterinary care in many tropical regions (Otranto, 2015). In addition, many dogs and cats in tropical regions are free-roaming, which might result in low owner compliance in collecting and submitting faecal samples, for example. Several cultural and religious beliefs are also associated with low dog ownership and willingness to handle them (Gray and Young, 2011; Mauti et al., 2017). While these constraints are recognized, veterinarians should be working towards achieving the best-practice level of general parasite screening. These methods are outlined as Standard Operating Procedures within the TroCCAP canine and feline guidelines (https://www.troccap.com/canine-guidelines/standard-operating-procedures/).

5.1. Intestinal parasites

Direct wet saline faecal mounts for general intestinal parasite screening is not recommended owing to notoriously poor sensitivity. For example, wet faecal mounts are commonly used for the observation of motile *G. duodenalis* or *Tritrichomonas blagburni* trophozoites in symptomatic patients (Yao and Köster, 2015), but false-negative results are common. For general parasite screening, faecal samples should be examined using centrifugal floatation with Sheather's sugar solution [specific gravity (SG) ≥ 1.25] or simple floatation with solutions with SG of 1.18 to 1.25. Regardless, the limitations of these methods must be considered given the intermittent shedding of some parasite stages and the sensitivity of the methods for different parasites (Dryden et al., 2006a, 2006b; Ballweber et al., 2014; Otranto, 2015). An awareness of how routine floatation methods can distort some parasitic diagnostic stages and an ability to recognize these distorted stages, as well as clinical signs, can inform decisions regarding the need for additional analysis. For example, thin-walled nematode eggs, protozoan cysts and lungworm larvae may become distorted in certain floatation solutions, making their detection and species identification challenging (Dryden et al., 2006b; Traversa and Guglielmini, 2008). For the detection of *G. duodenalis* cysts, a zinc sulphate (SG 1.18) centrifugal floatation is the simplest and most economical diagnostic method of choice (Dryden et al., 2006b).

Given the variable characteristics of tropical parasites, many will go undetected using standard diagnostic methods such as faecal floatation. For example, heavier trematode eggs require sedimentation methods for isolation. False negative results may also be produced for cyclophyllidean cestodes that shed proglottids as opposed to eggs in faeces (*e.g.*, *Dipylidium caninum* and Taeniidae) as well as for nematodes that shed first-stage larvae in faeces (lungworms and *Strongyloides* spp.). For the latter the Baermann technique is recommended for fresh faeces.

In addition to conventional microscope-based techniques, commercial in-house coproantigen test kits are becoming increasingly utilized for the diagnosis of enteric parasites of dogs. For example, highly sensitive point-of-care ELISAs are widely available for the detection of *G. duodenalis* coproantigens in faeces (*e.g.*, SNAP Giardia Test, IDEXX Laboratories) (Dryden et al., 2006a, 2006b). More recently, coproantigen ELISAs for the detection of excretory/secretory products from intestinal ascarids, hookworms and whipworm were introduced (IDEXX Laboratories, Inc, Westbrook, Maine), with the capability of detecting non-egg-shedding pre-patent or single-sex infections. However, a study demonstrated that these coproantigen assays should be combined with centrifugal flotation and examination by an expert, promoting the detection of more ascarid, hookworm, and whipworm infections (Little et al., 2019). PCR assays for companion animal enteric parasites such as *G. duodenalis*, *Cryptosporidium* spp., *T. gondii* and *T. blagburni* are also commercially offered by many veterinary diagnostic laboratories, but often not accessible or affordable for clients residing in many tropical countries.

5.2. Haemoparasites

Veterinarians in the tropics must be aware of the prevalence and diversity of haemoparasites in their region, their related clinical and clinicopathological signs (*e.g.*, anaemia, thrombocytopenia) and risk factors (*e.g.*, free-roaming pets, lack of effective ectoparasite control). Based on these, general testing can be supplemented with specific diagnostic tests. For some haemoparasitic infections, capillary blood collected via ear-tip or outer lip is recommended over cephalic and jugular veins for blood smears, buffy coat smears and/or a modified Knott's test, in order to increase the sensitivity of detection (Böhm et al., 2006; Păstrav et al., 2018). In this regard, the presence of microfilariae should not be assumed to be *D. immitis*, given the variety of filarial parasites in the tropics, and morphology, immunological tests, and/or PCR should be used for confirmation of the species present.

Point-of-care ELISAs, immunochromatographic assays and/or immunofluorescent antibody tests (IFA) are commercially available for some haemoparasites (e.g., *Babesia* spp. and *Leishmania* spp.) and helminths (e.g., *Dirofilaria* spp.). However, veterinarians should be aware of possible cross-reactivities (Dantas-Torres et al., 2012; Aroch et al., 2015). For many haemoparasites, serological tests may be available in research laboratories (Leony et al., 2019), but not commercially. For instance, there are no commercial antigen or antibody tests for *Hepatozoon* spp., *Rangelia vitalii*, and *T. cruzi* and therefore blood smear evaluation and/or PCR are required for diagnosis (Baneth, 2011; Eiras et al., 2014).

PCR assays are available for many tropical parasites (*e.g.*, *Spirocerca lupi*, *Brugia* spp., *Babesia* spp., *Cytauxzoon* spp., *Hepatozoon* spp., *Leishmania* spp., *R. vitalii*, and *Trypanosoma* spp.), but are not always offered commercially. For haemoparasites, PCR assays can be especially useful in cases of low parasitaemia and for distinguishing closely-related species (*e.g.*, different *Babesia* spp.). While access to PCR assays can be challenging in some tropical regions and cost-prohibitive, as noted earlier, results can inform treatment options to the veterinary practitioner (Baneth, 2018).

6. Prevention and treatment

As discussed earlier, cats and dogs in the tropics are permanently exposed to various parasites, which are often highly prevalent and many zoonotic (Traub et al., 2015; Otranto et al., 2017; Maggi and Krämer, 2019). Therefore, veterinary practitioners should focus on minimizing the risk of parasite transmission and morbidity through recommendations about good nutrition, environmental hygiene, and year-round preventatives for ectoparasites and at least monthly deworming for endoparasites for dogs and cats (Tropical Council for Companion Animal Parasites, 2019a, 2019b). Whenever, monthly deworming is unfeasible, general testing for gastrointestinal parasites at least every three months is advisable.

Similarly, in areas where heartworm is endemic, monthly prophylaxis is recommended for cats and dogs. As with diagnosis, the affordability and access to these preventatives are not uniform within the tropics, nonetheless, these recommendations are best practice given the year-round prevalence of parasites and the generally high prevalence in the tropics.

Prevention of endoparasites should start in puppies and kittens and be supported with proper hygiene and nutrition. Puppies should be dewormed starting at two weeks of age and fortnightly thereafter until eight weeks of age, preferably with a product with activity against adult and immature stages (*e.g.,* moxidectin). At 12 weeks of age, monthly deworming and the use of heartworm preventatives should be implemented. Repeated deworming in adult dogs might be required in cases of heavy burdens. Considering trans-mammary transmission and the pre-patent period of *T. cati* (Overgaauw, 1997), treatment in kittens should commence at 3 weeks of age and fortnightly thereafter until 10 weeks of age. However, in scenarios where queens and their kittens are kept outdoors in potentially contaminated environments, kittens should be treated against hookworms starting at 2 weeks of age and then every 2 weeks until they are at least 10 weeks old (Tropical Council for Companion Animal Parasites, 2019b). Nursing bitches and queens should be treated simultaneously with their litters.

Hygiene around homes is critical when dogs are kept in contained areas or when litter boxes are used for cats. Prompt, daily removal and disposal of faeces is recommended. While collection of faeces from public areas also is recommended, given the number of free-roaming and stray dogs and cats, this is unlikely to be feasible in most low-income countries. Concrete and paved surfaces around homes where dogs are kept and in breeding facilities may be soaked in disinfectants (*e.g.*, 1% sodium hypochlorite solution (bleach), 10% iodine, chloroxylenol or chlorocresol) to kill or at least reduce the viability of protozoan (oo)cysts, helminth eggs and larvae (Oh et al., 2016; El-Dakhly et al., 2018). Disinfection of gravel, loam surfaces or lawns with sodium borate (5 kg/m^2) will kill larvae (Levine, 1969; Bowman, 2014), but will also destroy vegetation. Spraying the ground with brine containing 681 g of salt per gallon of water (180 g/L), using 5.1 L/m^2 of soil, has also been recommended for controlling hookworm larvae (Morgan and Hawkins, 1949).

Proper nutrition may also support the immune system of dogs and cats and help in the prevention of heavy parasite infections. While common practice in many tropical areas, TroCCAP does not support the feeding of raw meat or fish. Hunting by dogs and cats of mammals, birds and reptiles should be discouraged, given the role of these as intermediate or paratenic hosts for many gastrointestinal and lung parasites (Overgaauw, 1997; Otranto et al., 2015).

Given the number of vector-borne diseases transmitted, especially by ticks, products with repellent and fast-killing effects should be used to provide year-round protection (Otranto and Dantas-Torres, 2013). Moreover, since many holometabolic insects like mosquitoes, biting midges, fleas or sand flies almost always transfer the respective pathogens immediately at bite, the use of systemic products without a repellent is not recommended, especially in areas where *L. infantum* for example, is prevalent. In these areas, collars and similar products with repellents that decrease sand fly feeding are recommended (Otranto and Dantas-Torres, 2013; Miró et al., 2017; Dantas-Torres et al., 2020b). For ectoparasites that are common in the tropics, such as fur mites (*e.g.*, *Cheyletiella* spp.), tsetse flies (*Glossina* spp.), and some tick species (*e.g.*, *Amblyomma aureolatum*, *A. oblongoguttatum* and *Ixodes boliviensis*), there are no ectoparasiticides with claims of efficacy on the label. However, it is believed that regular use of ectoparasiticides with claims for fleas, lice and more common tick species (*e.g.*, *R. sanguineus* sensu lato) will provide at least some control with several, albeit limited, studies supporting their use.

When infections are identified, treatments should be tailored to the infections present with preference given to the use of approved drugs and licensed acaricides and insecticides with efficacy, safety, and quality-control data from the manufacturer. However, the availability of endo- and ectoparasiticides can vary from country to country within the tropics and none may have efficacy claims on the label for many tropical zoonotic parasites such as *Brugia* spp., *C. sinensis, Paragonimus* spp. or *Linguatula serrata.* “Off-” or “extra-label” use (*i.e.*, application of active compounds for parasites not named on the label of the product or use at doses or frequencies different than listed on the product label) is often unavoidable in the tropics and veterinary clinicians should be informed whenever possible by the appropriate scientific literature. Efforts by TroCCAP, CVBD® (http://www.cvbd.org) and other organizations to compile recommendations from the literature for treatment of tropical parasites can support veterinarians in such decision-making processes. However, even with these compiled resources, veterinary practitioners should apply a high level of caution when recommending off-label use, closely monitor the dog/cat for any unexpected adverse events and perform follow-up examinations to assess efficacy.

7. Concluding remarks

The tropics are remarkable in many ways, not only in terms of climate and landscapes. Companion animals (and people) living in these regions have their idiosyncrasies with respect to endemic parasitic diseases. Parasites affecting dogs and cats in the tropics are diverse and some species are restricted to or predominately found in this climate zone. As a consequence, the management of parasitic infections of dogs and cats in the tropics demands tailored approaches, which requires region-specific knowledge about the local ecology, together with the animals and the parasites living in these regions. Our intention is that the TroCCAP guidelines will fill a historical gap, by providing veterinary practitioners working in the tropics with up-to-date information about relevant parasites of dogs and cats, while also taking into consideration their zoonotic significance.

These guidelines will not only provide a compilation of treatments for tropical parasites that have been identified in the literature, but also highlight the need for more data on effective and safe prevention and treatment approaches for many tropical parasites. Indeed, there are several knowledge gaps pertaining to research into parasites of dogs and cats in the tropics. For instance, the emergence of macrocyclic lactone resistance in *D. immitis* has been well documented in the United States (Wolstenholme et al., 2015), or the multiple drug resistance to all the most commonly used drug classes in *A. caninum* (Jimenez Castro et al., 2019), have been well documented in the United States, but there is virtually no data about this in tropical countries. This dearth of information has potential implications for the prevention of heartworm in dogs and cats. In the same way, there are currently no data available on the efficacy of the systemic ectoparasiticides for the prevention of infection with common vector-borne parasites including *Babesia vogeli*, *Babesia gibsoni* and *Hepatozoon canis*. Similarly, the diagnosis of *L. infantum* infection may be a difficult task in tropical countries where other *Leishmania* spp. may occur in dogs and cats. Further properly designed research on the sensitivity and specificity of several diagnostic tools is advocated to provide veterinary practitioners with solid information on the best tool to use in each situation. Still regarding *L. infantum*, there are currently several optional tools for the prevention of this zoonotic parasite, including vaccination, but additional large-scale phase III trials should be conducted to assess the preventive efficacy of available vaccines as compared to insecticide-impregnated collars (Dantas-Torres et al., 2020b).

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