Ancylostoma caninum: A Focus on this Zoonosis and its Significance for Public Health

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Abstract

The hematophagous nematodes *Ancylostoma* spp. primarily inhabit the intestines of dogs and cats. They use their buccal capsule to feed on blood and tissue, causing anemia and iron deficiency, among other clinical signs. *Ancylostoma caninum, A. braziliense*, and *A. ceylanicum,* the most common of these nematodes, are widely distributed throughout the world and cause zoonotic diseases. Although diagnostic tests are available for animals and humans, these infections are often underdiagnosed because they are typically asymptomatic. Prevention and control measures include hygiene and proper handling of pets. Given the difficulties in diagnosis, very variable prevalence rates have been reported, so it is important to assess where the infection may pose a greater risk to human and animal health.

Keywords: *Ancylostoma*, Zoonosis, Hookworms, Dogs

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Introduction

Hookworm infection is one of the most neglected and important tropical diseases, affecting approximately 576–740 million people worldwide (Chang et al., 2020). Human infections occur primarily in countries with low socioeconomic status in tropical and subtropical regions, where environmental conditions such as temperature, humidity, and soil type combine with poverty and inadequate sanitation infrastructure to create an environment conducive to their development (Stracke et al., 2020; Servián et al., 2022). In these countries, infections are mainly caused by *Ancylostoma duodenale* and *Necator americanus*. On the other hand, infections with *A. caninum* are rarely reported (Acha and Szyfres, 2003), since humans are accidental hosts in which the parasite cannot continue its biological cycle.

Domestic animals play an important role in the transmission of parasitic diseases, most commonly affecting children, the elderly, and immuno-compromised persons. To prevent transmission, caretakers of these animals should practice good hygiene after contact with them (Lima et al., 2010; Silva et al., 2021). Hookworm disease in dogs and cats is caused primarily by *A. caninum, A. braziliense,* and *A. ceylanicum*, all of which pose a zoonotic risk. Most human infections with animal-transmitted hookworms result in clinical symptoms due to migrating larvae LMC (cutaneous larva migrans) (George et al., 2015). Hookworm-infected animals can develop bloody diarrhea, lethargy, anorexia, and anemia (Bhatt et al., 2019; Firdaus et al., 2024). Therefore, the prevention and diagnosis of these parasitoses in both humans and companion animals are important. This chapter aims to provide a comprehensive approach to *A. caninum* zoonoses, raise awareness of their impact on public health, and provide practical tools for their prevention and control.

Etiology

Ancylostoma spp. including *A. braziliense, A. caninum,* and *A. tubaeforme* are nematodes of the superfamily Ancylostomatoidea that are important in veterinary medicine. Adult parasites are reddish-gray and hook-shaped. The male of *A. caninum* measures 11–13 mm and the female 14–20 mm. The female is capable of lying between 7000 and 28,000 eggs per day (Taylor et al., 2016; Giraldo et al., 2009).

A. caninum is a hematophagous parasite that colonizes the small intestine of dogs, cats, and other wild carnivores (Giraldo et al., 2009). Transmission of *A. caninum* in dogs occurs percutaneously (larval stage) or by ingestion of food, water, or feces contaminated with *A. caninum* eggs, and in puppies by the lactogenic route. When the parasite enters through the skin, it travels through the blood vessels or lymphatic ducts to the heart and lungs; from the lungs, it can ascend through the bronchi to the pharynx, pass into the esophagus, and then into the intestines, where it develops into the adult stage. Because of this larval journey, the dog may present with dermatitis, rash, cough, eosinophilic pneumonia, bronchopneumonia, diarrhea or constipation, eosinophilic enteritis, and the presence of mucus with blood in the feces (Coello et al., 2017). The parasites attach to the intestinal mucosa of the definitive host with their buccal capsule to feed on blood and

tissue, causing iron deficiency anemia (initially with normocytic, normochromic anemia, then hypochromic microcytic anemia) (Coello et al., 2017), enteritis, hypoalbuminemia, hematochezia, and melena (Balk et al., 2023).

Epidemiology

A. caninum has a broad global distribution. Although its prevalence is higher in tropical and subtropical climates, this is not limiting, and there are reports of its presence in different latitudes of Europe, Asia, Africa, and the Americas (Acha and Szyfres, 2003); several studies have even estimated its prevalence in different places, but it should be noted that it is difficult to establish prevalence values for two main reasons. The first is that it is not a notifiable disease, so the data on its findings are mainly limited to studies aimed at its search; that is, its search in many scientific articles is not always carried out according to a planned epidemiological design, so the result may be biased and could explain to some extent the large variations in the frequencies found, ranging from < 10 to > 60%. The second reason is that the infection is often asymptomatic, and regardless of its presence, routine deworming of companion animals is recommended, creating cycles of infection and elimination throughout the animal's life. Some studies in Mexico and other places are shown in Table 1, where enormous variations in the incidence of this parasitosis can be observed.

Table 1: Prevalence of *Ancylostoma caninum* in dogs from different locations in Mexico and elsewhere.

Location	Prevalence	Reference
Mexico		
Toluca, State of Mexico	9.2	Lara-Reyes et al. (2021)
Gómez Palacio, Durango	12	Aguillón-Gutierrez et al. (2021)
Puerto Escondido, Oaxaca	17.88	Vélez-Hernández et al. (2014)
Tulancingo, Hidalgo	50	Olave- Leyva et al. (2019)
Escárcega, Campeche	52.2	Encalada-Mena et al. (2011)
Other countries		
Argentina	60.7	Alegre et al. (2023)
Colombia	22–65	Salgado & Martínez (2023)
Chile	41.9	Quilodrán-González et al. (2018)
Venezuela	45.9	Cazorla & Morales (2013)
Ecuador	11.29	Coello et al. (2017)

In dogs, the risk of acquiring this parasitosis may be related to environmental factors, both physical and social. Among the latter, free-roaming has been found to increase the risk of infection. Age is also important, especially in young animals (Lara-Reyes et al., 2021; Olave-Leyva et al., 2019). Canine infection is more common in areas of high marginalization, as the lack of public services such as paving and drainage may facilitate its persistence. In addition, the practice of allowing animals to roam freely and the presence of stray dogs (Aguillón-Gutiérrez et al., 2021; Vélez-Hernandez et al., 2014) contaminate soil and water (Quilodrán-Gonzalez et al., 2018).

Human infection with *A. caninum*, although rare compared to *A. ceylanicum*, appears to be more common than previously thought, particularly in Australia (Acha and Szyfres, 2003). Humans are accidental hosts in which the parasite cannot continue its life cycle. Infection occurs through bare-skin contact with infective larvae, especially when working with contaminated soil, walking barefoot, or unprotected exposure to soil (Salgado and Martinez 2023).

Impact on Public Health

A widely accepted concept of zoonoses was proposed by the Joint FAO/WHO Expert Committee on Zoonoses (1969), which defined them as "all those diseases which are naturally transmitted from vertebrate animals to man and vice versa" (WHO, 2020), however, that some parasitic infestations do not exactly fit this definition, as they are not necessarily transmitted between vertebrates, but some agents may persist in inanimate environments and reservoirs (non-animal or inert medium) from which they can circumstantially affect humans (Jaramillo, 2024). Thus, zoonoses are classified according to different criteria that can be used to develop prevention, control, and even eradication strategies. One of these classifications is based on the evolutionary cycle of the pathogen and includes saprozoonoses, where the etiologic agent requires an inert reservoir in addition to the animal reservoir (Schwabe, 1968).

Hookworm disease is a parasitic zoonosis with a cosmopolitan distribution. It is considered one of the most common soil-transmitted helminthiases (saprozoonoses). Dogs are the main reservoir due to their role as companion animals and the close contact this entails, in addition to the environmental contamination caused by these populations through feces contaminated with parasite eggs (Peña et al., 2017).

Fig. 1 helps to understand the possible transmission mechanisms of the hookworm disease, as well as the vulnerable points in the elements involved in establishing effective contact between the parasite and a susceptible host.

Dogs or cats infected with adult parasites contaminate the environment (soil, gardens, and parks) with eggs in feces. The risk is further increased by the presence of stray dogs (even if they are owned) and the lack of collection of feces on public property (Peña et al., 2017; Castillo-Cuenca et al., 2016).

Clinical Manifestations in Humans

Once the parasite completes its life cycle in the definitive host (usually dogs), non-embryonic *A. caninum* eggs are excreted with the feces and end up in sand or warm, moist soil (Vargas-Álvarez & Acuña-Bolaños, 2019; Shrestha et al., 2024). There, if conditions are favorable, including a temperature of 25–30 °C, shade, and good oxygenation (Vargas-Álvarez & Acuña-Bolaños, 2019), in addition to the

presence of bacteria as a food source (Brenner & Patel, 2003) and a pH of 4.6–9.4, the eggs hatch after 48 hours of transition to the embryonic stage (Coello et al., 2024). The embryos then develop into the rhabditiform larval stages (L1 and L2) and progress to the third stage, the filariform larva (L3). After two months, the filariform larvae become infective (Vargas-Álvarez & Acuña-Bolaños, 2019).

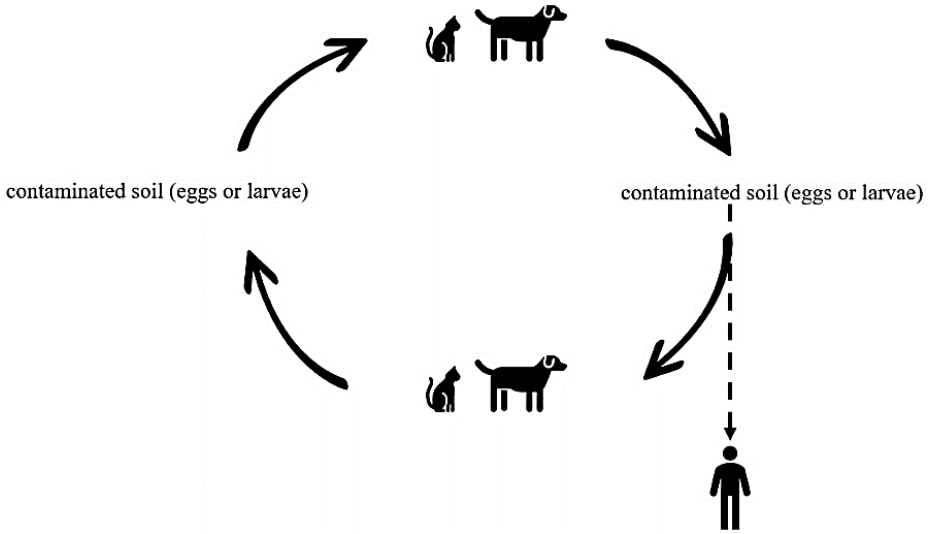

Fig. 1: Transmission cycle of hookworm disease. Source: Adapted from Acha and Szyfres (2003), and Schwabe (1968).

The L3 stage is capable of penetrating the skin through direct contact with the ground while the human host is barefoot or lying down (Kwon et al., 2003; Upendra et al., 2013; Dam Larsen et al., 2023; Coello et al., 2024). The nematode enters the skin after locating a lesion, through pilosebaceous follicles and sweat glands, or even through intact skin (Brenner & Patel, 2003; Campos-Muñoz et al., 2007; Vargas Álvarez & Acuña Bolaños, 2019). The infective larvae produce hyaluronidases and proteases, enzymes involved in molting, tissue invasion, and destruction, as well as mucosal degradation and as a hemolytic factor (Brenner & Patel, 2003; Cárdenas-Perea et al., 2013; Tekely et al., 2013; Siddalingappa et al., 2015; Shrestha et al., 2024).

Since the parasite does not produce collagenase, it is believed that it cannot cross the basal membrane of the dermis, so in most cases, it is limited to migrating in the epidermis (Brenner & Patel,2003; Shrestha et al., 2024), usually between the stratum germinativum and the stratum corneum (Kwon et al., 2003), causing a localized skin lesion in the form of a serpiginous linear rash (Campos-Muñoz et al., 2007; Siddalingappa et al., 2015; Carrasquer-Pirla & Clemos-Matamoros, 2017). A slightly raised brownish or reddish tortuous track is observed, which is the pathognomonic sign of larva migrans (Kacprzak & Silny., 2004; Rygula et al., 2023).

The lesion is more common in areas commonly exposed to contaminated soil, such as the feet and hands (Kwon et al., 2003; Campos-Muñoz et al., 2007; Siddalingappa et al., 2015; Vargas Álvarez & Acuña Bolaños, 2019; Kuna et al., 2023), as well as the gluteal region in young children (Brenner & Patel, 2003; Shrestha et al., 2024). Similarly, although less frequently, it can occur in the anterior abdominal wall, breasts, perineum, and penile shaft (Siddalingappa et al., 2015; Shrestha et al., 2024).

Initially, the entry lesion resembles a bite. After approximately 14 hours (Cardenas-Perea et al., 2013), an erythematous and pruritic papule develops (Tekely et al., 2013; Vargas Álvarez & Acuña Bolaños, 2019; Quintana et al., 2023; Shrestha et al., 2024). The incubation period of *A. caninum* larva migrans varies depending on host conditions; an average of 1–6 days has been reported (Kwon et al., 2003; Campos-Muñoz et al., 2007; Quintana et al., 2023), but symptoms of infection may appear 10–15 days after exposure (Kuna et al., 2023). The earliest part of the lesion dries and crusts and may leave transient changes in skin color after healing (Rygula et al., 2023; Shrestha et al., 2024).

The presence of the larvae causes intense pruritus, resulting in a serpiginous lesion that grows 1–3 cm per day (Kwon et al., 2003; Kacprzak et al., 2004; Siddalingappa et al., 2015) and can reach up to 20 cm in length and a few millimeters in width (Brenner & Patel, 2003). The lesion may be single or multiple in cases of extensive infestation (Tekely et al., 2013; Adam et al., 2023; Cardenas-Perea et al., 2013; Siddalingappa et al., 2015). These changes may be accompanied by vesicles, papules, and desquamation (creeping verminous dermatitis) as the worm changes direction (Kacprzak et al., 2004; Vargas Álvarez & Acuña Bolaños, 2019). Similarly, histamine release is increased by scratching due to intense itching, which exacerbates the risk of secondary bacterial infection from skin ulcers (Kuna et al., 2023; Calvopina et al., 2024; Osman et al., 2024; Shrestha et al., 2024). Finally, it is also associated with febrile illness in immunocompromised individuals, such as children or HIV patients (Upendra et al., 2013).

Most cases are self-limiting because humans are incidental hosts, meaning the larva cannot complete its biological cycle and dies after 2–6 weeks (Campos-Muñoz et al., 2007; Carrasquer-Pirla & Clemos-Matamoros, 2017; Kuna et al., 2023; Shrestha et al., 2024). Treatment may be complemented by anthelmintic therapy to alleviate symptoms and reduce the risk of bacterial infection (Quintana et al., 2023; Calvopina et al., 2024; Shrestha et al., 2024).

In some cases, secondary clinical manifestations may occur due to the patient's condition, including:

- Hookworm folliculitis is caused by inflammation of the hair follicles.
- Diffuse multifocal papulovesicular eruption.
- Migratory urticaria (Shrestha et al., 2024).

In even rarer cases, it can reach the visceral larva migrans stage after entering the circulation, causing Löffler syndrome, characterized by asthma, pulmonary infiltrates, eosinophilia, fever, erythema multiforme, and occasionally urticaria (Siddalingappa et al., 2015).

Diagnosis

Hookworms, especially *A. caninum* and *A. ceylanicum,* are zoonotic parasites of public health importance due to their ability to survive. Recent studies, such as that of Nath et al. (2023), have demonstrated the presence of hookworm larvae and eggs in soils using coproparasitoscopic and molecular techniques (Ferreira et al., 2024).

Diagnosis in Animals

Animals infected with hookworms may present with bloody diarrhea, lethargy, anorexia, and anemia (Bhatt et al., 2019; Firdaus et al., 2024). These clinical signs guide the veterinarian in the initial diagnosis.

Once diagnostic suspicion is established, fecal samples should be collected directly from the rectum or the floor after defecation, taking the part that is not in contact with the floor to minimize the likelihood of contamination (Segura et al., 2023). Sample quality affects egg detection, so fresh or 5% formalin-preserved feces gives better results than frozen or 10% formalin-preserved samples (Cringoli et al., 2011).

A variety of coproparasitoscopic techniques have been employed, but no gold standard has been established due to the variable sensitivity of the tests (Restrepo-Vonschiller et al., 2013). The most common diagnostic techniques are listed in Table 2.

Table 2: Diagnostic coproparasitoscopic methods used in veterinary medicine.

Beaver direct smear	It has low sensitivity for helminth diagnosis (Restrepo-Vonschiller et al., 2013).
Flotation methods	Willis' and centrifugation-flotation techniques are more effective than Hoffman's and Faust's, while Sheather's offers high precision (Táparo et al., 2006; Mandarino-Pereira et al., 2010; Rezende et al., 2015; Rodríguez Vivas, 2015; De-La-Rosa-Arana & Tapia-Romero, 2018; Ferreira et al., 2024).
Mini-FLOTAC and FLOTAC	These techniques are reliable and highly sensitive. Mini-FLOTAC is particularly useful because it does not require centrifugation, which simplifies the process (Cringoli et al., 2011; Maurelli et al., 2014).
Concentration or sedimentation techniques	The ether-formalin method is useful when the number of organisms in feces is low, as their specific gravity is higher than that of the solution (De-La-Rosa-Arana & Tapia-Romero, 2018; Khurana & Sethi, 2017).

Traditional methods cannot distinguish between *Ancylostoma* species due to the low morphological specificity of eggs. In addition, the absence of eggs in feces does not rule out infection, as it can take up to five weeks for eggs to be detected (Bhatt et al., 2019).

Recently, molecular techniques have improved the sensitivity and diagnostic accuracy in detecting nematode infections, overcoming the limitations of traditional techniques. The most widely used techniques include semi-nested PCR-RFLP, qPCR, and multiplex qPCR, which allow accurate species identification (Nath et al., 2023; Stracke et al., 2020). However, these highly effective tools are not accessible in endemic areas.

Diagnosis in Humans

The diagnosis of cutaneous larva migrans (CLM) is based on physical examination and a history of travel to tropical areas. Initially, there is an insect bite lesion that evolves into a pruritic papule, and in the following days, the typical creeping verminous dermatitis develops (Vargas Álvarez & Acuña Bolaños, 2019). The physician should consider the diagnosis of CLM in patients who do not respond to treatment with antihistamines or corticosteroids, even if they have no history of exposure (Osman et al., 2024).

While clinical observation is sufficient to make the diagnosis, in some cases it may be supported by additional tests (Table 3).

Table 3: Laboratory tests for diagnosing larva migrans in humans.

Hemogram	It may show eosinophilia, but this is present in less than 40% of cases (Adam et al., 2023; Kwon et al., 2003).
Serologic tests	They are of limited use because of cross-reactivity with other helminths (Kwon et al., 2003).
Coproparasitoscopic tests	Stool examination will not show eggs or adult parasites because the human presents only the larval form on the skin.
Biopsy	It shows larvae in the epidermis and spongiotic dermatitis, eosinophilic and neutrophilic infiltrate within the canal through which the larvae have traveled (Kuna et al., 2023; Kwon et al., 2003).
Kato-Katz thick smear	It has low sensitivity for hookworm detection and does not allow species differentiation (Stracke et al., 2020).
Optical coherence tomography	It is a useful diagnostic approach, but its availability is limited.

It is important to differentiate CLM from erythema chronicum migrans (Lyme disease), urticaria, scabies, myiasis, fungal infections, herpes zoster, and other inflammatory dermatoses (Kuna et al., 2023; Osman et al., 2024; Ryguła et al., 2023).

Prevention and Control

The following are the most important measures to prevent and control hookworm disease for pet owners, veterinarians, animal shelters, and other healthcare professionals who come into contact with dogs:

- Practice good personal hygiene, especially washing hands after touching animals, handling animal feces, and handling utensils such as food and water dishes. Bathe pets regularly to remove parasite eggs, proglottids, or larvae that may remain on the coat or other areas of the skin. Keep kennel floors and play areas dry and clean. Earth-covered areas can be disinfected with sodium borate at a rate of 0.5 kg/m^2. It is also recommended that 1% sodium hypochlorite be used to clean these areas (Moriello, 2015).
- Composting is ideal for eliminating fecal matter and reducing the environmental pollution. Temperatures of 45–55 °C are reached during the process, which destroys the vast majority of viruses and bacteria in the composted feedstock, but the effectiveness of inactivating

cestodes and other larval stages of parasites has not been fully demonstrated (Roman et al., 2013; Azim et al., 2018).

- Female dogs should be dewormed before breeding and during pregnancy. If not done earlier, the dam and puppies can be dewormed. It is important to maintain good control of parasitic diseases through regular laboratory testing. The use of deworming schedules for our pets and ourselves is a good aid. Broad-spectrum drugs are available for the prevention of helminthiasis, including ivermectin, mebendazole, albendazole, and pyrantel. Their use should be alternated to prevent reinfection and to avoid parasite resistance to commercial anthelmintics (Raza et al., 2018). The use of parasiticidal fungal chlamydospores, such as *Mucor circinelloides* (ovicidal) and *Duddingtonia flagrans* (larvicidal) using handmade edible jellies, is being investigated to avoid overuse and misuse of anthelmintics and thus avoid parasite resistance. Reductions in parasite loads of several parasites, including third instar *A. caninum*, have been reported with this approach (Hernández et al., 2018; Viña et al., 2022).
- With regard to vaccination, the immune response to hookworm infection in patients in epidemic and non-epidemic areas is being studied, as well as the immunological mechanisms of protection, including those based on humoral antibody-dependent cellular responses, especially to allergens. To this end, protein subunits or proteins are used for vaccine development in both humans and dogs (Schneider et al., 2011; Shalash et al., 2021).
- Children who play with dogs should keep their nails trimmed, wash their hands, and not walk barefoot.

Conclusions

Based on the knowledge of the risk factors, prevention and control measures are based on health promotion activities through education on responsible pet ownership at the individual and community levels. In this way, environmental contamination by parasite eggs and larvae is reduced through environmental sanitation, proper sanitary disposal of excreta, and educational strategies to raise awareness of the zoonotic impact of this parasitosis. Another primary prevention measure, the deworming of companion animals, should not be overlooked (Peña et al., 2017; Castillo-Cuenca. 2016).

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