Zoonoses Associated with Geohelminthiases

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ABSTRACT

This chapter presents a general and updated overview of the different zoonoses associated with soil-transmitted helminth infections. The topics presented in the chapter are: Angiostrongyliasis; Ascariasis; Capillariasis; Lagochilascariasis; Mammomonogamiasis; Strongyloidiasis; Cutaneous larva migrans. In this context, zoonotic diseases are a major public health problem because animals are the source of human pathogens. The emergence and re-emergence of zoonotic diseases have been attributed to a number of anthropogenic and natural factors, including vector biology, urbanization, climate change, animal migration and trade, travel and tourism, among others. Animals are the origin of a large number of infectious diseases that affect humans. About 60% of newly discovered human infections are zoonotic. Because of this, it is important to consider the areas where we live and the risks of latent diseases in the regions. In addition, it is extremely important to give importance to common wound accidents, because it is better to prevent silent diseases that can be hidden for years through good food and wound asepsis and go to the doctor.

Key words: zoonotic diseases, parasite, helminths, one health, sustainability.

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1. INTRODUCTION

1.1. ANGIOSTRONGYLIASIS

Angiostrongylus (*A.*) *cantonensis* and *A. costaricensis* are the two main roundworm species that cause angiostrongyliasis, also referred as rat lungworm disease. *A. costaricensis* is linked to ingesting raw vegetables contaminated with the parasite's larvae (Rojas et al. 2021). It is the primary cause of angiostrongyliasis and is primarily associated with eating contaminated raw or undercooked snails or slugs, which act as intermediate hosts (Cowie 2017).

A. cantonensis reproduces as adult worms in the pulmonary arteries of rats, where its eggs hatch into larvae in the lungs and are subsequently expelled in the feces. The larvae grow to the infectious stage within the snails after they have consumed the excrement. Rats that eat infected snails continue the cycle by allowing the larvae to enter the brain through circulatory system. (Ringelmann and Heym 1991). Third-stage larvae can inadvertently enter human bodies through the consumption of raw or undercooked infected snails or contaminated product. The larvae migrate to the brain, where they can cause severe, lifelong neurological damage and eosinophilic meningitis. Mild headaches, skin sensitivity, more severe motor disturbances, digestive problems, coma, and even death are among the symptoms. The diagnosis is difficult and depends on a number of factors, including imaging, serological testing, presence in parasite-prone areas, food consumption history, and diagnosis. Treatment is not definitive, and management involves pain relief, spinal taps to decrease intracranial pressure, and corticosteroids to reduce inflammation. Anthelmintics may be used but remain controversial due to the immune reaction to dying worms (Kaplan et al. 2020).

1.1. DISCOVERY AND DISTRIBUTION IN SNAILS

A. cantonensis, first discovered in 1935 in China, was later confirmed to be connected to the disease in Hawaii in 1961. Since then, it has become a global concern, with cases reported in various regions, including the continental USA, where it has been found in snails and rats, notably in Florida and other states. Worldwide, nearly 3,000 cases have been reported, with higher numbers in regions like Thailand, Taiwan, China, and Pacific islands of Southeast Asia, Australia, the Caribbean, and both North and South America (Cowie 2017). Using *Achatina fulica* and *Pomacea canaliculata* as intermediate hosts and *Rattus norvegicus* and *R. rattus* as natural definitive hosts in different regions of the world, this parasite infects a variety of snail species (Hu et al. 2018).

2. ASCARIASIS

Zoonoses are an important public health concern because animals are the source of more than 60% of human pathogens. The emergence and reemergence of zoonotic diseases have been attributed to a number of anthropogenic and natural factors, including vector biology, urbanization, climate change, animal migration and trade, travel and tourism, and others. Animals are the source of a large number of infectious diseases that affect humans. Around 60% of newly discovered human infections are zoonotic, meaning that over 70% of these pathogens originate from wildlife species (Rahman et al. 2020).

Geohelmintiasis, also called soil-transmitted helminthiasis (STH), is a common neglected tropical illness primarily affecting human intestines and caused by parasitic worms. It is a serious public health issue, especially in areas with limited resources and poor hygiene standards. "Geohelmintiasis" refers to the intimate relationship that exists between the spread of these helminths and the infiltration of soil by their infectious stages (WHO 2023).

Beyond causing digestive problems, geohelmintiasis has other negative effects as well. Prolonged and severe infections can cause anemia, stunted growth and development, reduced school attendance and performance, malnourishment, and cognitive decline. These outcomes can prolong a cycle of poverty and lower economic productivity in the impacted communities (WHO 2023).

Humans and pigs are infected with parasitic nematodes called *Ascaris lumbricoides* and *A. suum*, respectively. With 1.2 billion infections worldwide, *A. lumbricoides*, better known as the human roundworm, is one of the most common parasites. The Americas, China, East Asia, and sub-Saharan Africa are the main regions where infections are found. Ascariasis, the related illness brought on by an *A. lumbricoides* infection, accounts for an estimated 10.5 million disability-adjusted life years and adds significantly to the disease burden. Approximately 122 million cases of morbidity with serious health consequences occur each year. Ascariasis is still considered a neglected tropical disease in spite of its effects (Schindler-Piontek et al. 2022). Conversely, *A. suum* is a common parasitic nematode that infects pigs and its high prevalence rates have been found in pig populations. Few swine herds are totally free of *A. suum* infection, although the prevalence of infection varies based on geographic location and farm management techniques. Pigs with porcine ascariasis have poorer health and performance, which lowers feed-to-gain ratios and causes liver condemnation, both of which have a major negative financial impact (Dold and Holland 2011).

Taxonomically speaking, there is little genetic difference between the *Ascaris* species that infect humans and pigs—1.3% in the first internal transcribed spacer (ITS-1) and 3-4% in the mitochondrial genome (mtDNA) sequence, respectively. The two species are morphologically identical. Strong affinities between the two species are indicated by their close phylogenetic relationship (Easton et al. 2020). A recent study on experimental cross-transmission have shown that pigs can contract *A. lumbricoides* infections and vice versa (Tee et al. 2022). Human infections with *A. lumbricoides* were found to contain worms that originated in pigs in non-endemic areas, indicating that pigs may be a possible source of infection for human populations. But molecular epidemiological research in *Ascaris*-endemic areas has revealed little to no cross-infection between host species, indicating constrained gene flow amongst genotypes. Since *A. lumbricoides* and *A. suum* have a major impact on human and pig health, it is imperative to understand their life cycle and characteristics in order to develop effective control and prevention strategies. The feco-oral route is one of the ways that *Ascaris* species transmit disease throughout their life cycle. When consumed, infectious eggs hatch in the small intestine and the larvae move through the mucosa to the proximal colon and caecum. They then shed their L2 cuticle as they pass through the portal blood and arrive at the liver. The larvae then move to the lungs, where they pass through the alveolar space before being ingested and going back into the small intestine. In the small intestine, *A. suum* larvae undergo another molt to become L4 stage larvae. By day 24 after infection, the larvae have reached sexual maturity and have undergone another molt to become L5 stage larvae (Schindler-Piontek et al. 2022).

In both pigs and humans, the hepato-tracheal migration takes place 10–14 days after egg ingestion. Although most adult worms are eliminated from the intestines by the 23rd week of infection in pigs, they can stay there for up to a year. Adult worms are 15–25 cm in length for males and 20–35 cm for females. An estimated 200,000 eggs can be produced daily by female worms, though this number varies depending on the worm load. Embryonated eggs can survive in the soil for up to 15 years before being expelled in feces. The larvae go through two molts within the egg during embryonation (Schindler-Piontek et al. 2022).

As one of the most widespread parasitic infections worldwide, ascariasis is expected to infect 807 million people by 2020. Searching PubMed, Embase, Web of Science, and Google Scholar for studies published between 2010 and 2021 that reported the prevalence of *Ascaris* infection in humans, a systematic review and meta-analysis was developed to estimate the global prevalence of *Ascaris* infection in humans (Holland et al. 2022). The authors identified 1,060 studies, of which 184 met the inclusion criteria, and included studies that reported the prevalence of *Ascaris* infection in humans, whether they were cross-sectional, case-control, or cohort studies. *Ascaris* infection was pooled at a prevalence of 20.2% (95% CI: 18.9-21.5%). Africa had the highest prevalence (33.2%), followed by Latin America (17.7%) and Asia (23.4%). North America (2.9%) and Europe (9.7%) had lower prevalence rates. The most recent estimates of the worldwide prevalence of *Ascaris* infection are given by this study. According to the findings, ascaris infection poses a serious threat to public health, especially in low- and middle-income nations. The geographic distribution and risk factors for giardiasis, amebiasis, and ascariasis in Mexican children were examined by Zavala et al. (2020). The authors create a database of the incidence of these infections in children between the ages of five and nine using publicly available data from Mexico's thirty-two states. Additionally, they gathered information on socioeconomic and environmental variables that might be connected to the prevalence of these infections. While amebiasis was more common in the central states of Mexico, ascariasis was more common in the southern states. The nationwide distribution of giardiasis incidence was more uniform. The authors also discovered a correlation between high rainfall, a low socioeconomic status, and limited access to toilets and piped water. The results of this study indicate that the risk of parasitic infections in children from Mexico varies significantly based on geography and socioeconomic status.

A. lumbricoides has been linked to a number of pathologies in humans, which can result in a range of health issues and complications. Intestinal obstruction, malnutrition, pneumonia, hepatobiliary complications, appendicitis, and allergic reactions are among the illnesses and ailments linked to ascariasis (Dold and Holland 2011).

It is crucial to remember that not everyone who has ascaris will have symptoms or problems. Numerous variables, including the quantity of worms present, the length of the infection, and the person's immune system, can affect the severity of the infection and related illnesses. The prevention and control of ascariasis and its associated complications depend heavily on good hygiene practices, sanitation, and deworming programs. Medications to remove the worms from the body and reduce symptoms are usually used to treat ascariasis (Barbosa et al. 2017).

Here are some ascariasis treatments that are frequently used:

2.1. ANTIHELMINTHIC MEDICATIONS

The main treatment for ascariasis consists of medications created expressly to destroy and eradicate parasitic worms. For ascariasis, the most commonly prescribed anthelminthic drugs are albendazole, mebendazole and ivermectin (Conterno et al. 2020).

2.2. SYMPTOMATIC TREATMENT

Symptoms of ascariasis include nausea, diarrhea, and abdominal pain. These symptoms can be lessened with over-the-counter drugs like antiemetics for nausea and antispasmodics for abdominal pain. Probiotics (Pryshliak et al. 2022) and certain plants (Aschale et al. 2022; Tan et al. 2023) have both been used as treatments to lessen symptoms and reinfection.

2.3. HYGIENE AND SANITATION

To stop the infection from spreading to others and from re-infecting oneself, proper hygiene and sanitation practices are crucial. This entails keeping living spaces clean, washing hands frequently—especially before meals and after using the restroom—and thoroughly cleaning fruits and vegetables before consumption (WHO 2023).

It is crucial to remember that the length and dosage of treatment can be changed based on the patient's age, the severity of their infection, and other variables. For a precise ascariasis diagnosis and suitable treatment regimen, speaking with a medical expert is advised.
Even though deworming programs have been put in place, effective elimination still requires an understanding of transmission dynamics, including zoonotic transmission, and the development of focused treatment plans. Diverse population genetic studies have revealed evidence of human-pig zoonotic transmission. There has been evidence of interbreeding between *A. lumbricoides* and *A. suum*, and genetic variations between the parasites that infect humans and pigs point to a complicated worldwide population expansion (Easton et al. 2020). This emphasizes the necessity of a one-health approach and shows how important it is to take into account both human and pig parasites in the control of human ascariasis. The significance of comprehending and managing the spread of human ascariasis is underscored by the development of a reference-quality *Ascaris* genome and additional genetic analyses that corroborate the interconnectedness of *A. lumbricoides* and *A. suum* populations (Wang 2021).

3. CAPILLARIASIS

Nematodes of the genus *Capillaria* are the source of the zoonotic infection known as capillariasis. Even though the *Capillaria* genus contains 300 species, only a small number of them, including *Capillaria (C.) phillipinensis* and *C. hepatica*, are responsible for most human infections. Due to eating raw or undercooked fish, *C. phillipinensis* causes intestinal capillariasis (Mahendra and Gutama 2024).

3.1. LIFE CYCLE

Capillaria species normally go through several stages in their life cycle, beginning with the adult worm living inside its host's body and laying eggs there. Depending on the species and the site of the infection, these eggs are then expelled from the host through their urine or feces. The eggs develop in the external environment and, after a few weeks, become infectious larvae. The infectious larvae can then enter the host by consuming tainted food or drink or by coming into direct touch with contaminated objects (Harvey et al. 2023; Mahendra and Gutama 2023).
Additionally, depending on the species, the larvae can grow on intermediate hosts. Some *Capillaria* species use specific insects or other invertebrates as intermediate hosts, allowing the larvae to mature before infecting the final host. The life cycle may manifest as either direct or indirect, contingent upon the particular species and the engagement of intermediary hosts (Fig. 1) (Harvey et al. 2023).

3.2. HOST RANGE AND SPECIFICITY

Capillaria species exhibit a broad spectrum of prospective hosts, with distinct species having adapted to infect various categories of animal hosts. Several *Capillaria* species, such as those targeting rodents, demonstrate a predilection for specific host types, while others may parasitize birds, fish, or reptiles. Each species may display either a specific host preference or a more extensive capacity to infect diverse animal species. Some *Capillaria* species are host-specific, whereas others have the capacity to infect several hosts and transmit disease to humans through zoonotic transmission (Santos et al. 2001).

3.3. PATHOGENESIS AND CLINICAL PRESENTATION

Depending on the species involved, the organs affected, and the severity of the infection, the pathogenesis of *Capillaria* infections can differ dramatically. *Capillaria* species infections can be asymptomatic, mild, or severe, resulting in a range of clinical manifestations in varied hosts (Santos et al. 2001).

The most prevalent type of infection in mammals is intestinal capillariasis, which mostly affects the small intestine. Animals with the infection may exhibit signs like diarrhea, weight loss, anorexia, and gastrointestinal pain. Intestinal damage, perforation, and inflammation brought on by severe infections can affect gut health. Depending on the species involved and the organs affected, *Capillaria* infections in birds might present as respiratory or gastrointestinal issues. Coughing, sneezing, nasal discharge, and respiratory distress can all be symptoms of respiratory capillariasis in birds. In contrast, gastrointestinal capillariasis may result in weight loss, diarrhea, and malabsorption. *Capillaria* infections frequently cause inflammation, edema, and epithelial damage in the stomach of fish. The growth rates of infected fish may be slower, their ability to absorb nutrients may be affected, and they may be more vulnerable to other infections (Dubey et al. 2018).

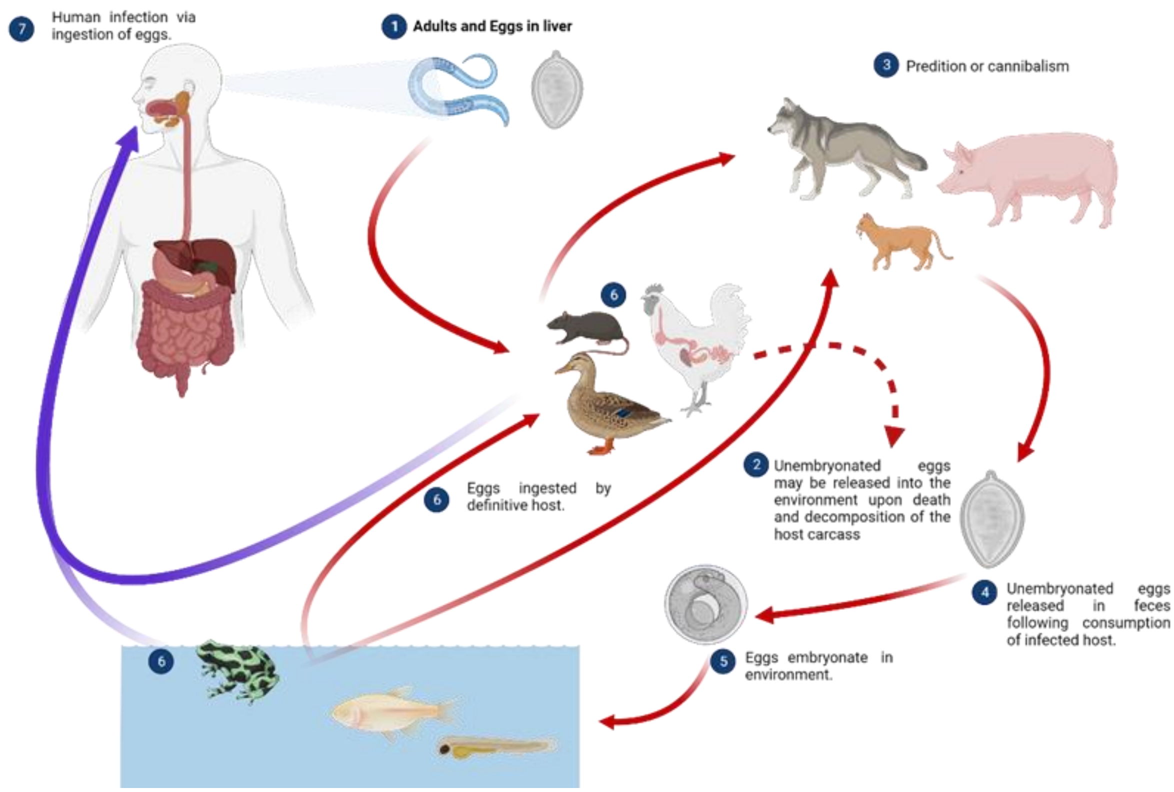

Fig. 1: The life cycle of *Gnathostoma* species. (Source: Centers for Disease Control and Prevention, www.dpd.cdc.gov/dpdx/gnathostomiasis/index.html) 1) Mature nematodes aggregate into a neoplastic mass within the gastrointestinal tract of animals acting as their exclusive hosts, with the subsequent expulsion of their eggs in fecal matter. Within the hepatic parenchyma of the host, adult worms are profoundly entrenched, where they deposit numerous eggs within the surrounding parenchymal tissue. 2,3) The eggs ensnared within the host's hepatic parenchyma persist therein until the expiration of the host organism, or more probable, until it undergoes predation or scavenging. 4) Predatory or scavenging organisms ingest embryonated eggs, thereby facilitating a proficient mechanism for the dissemination of eggs into the surrounding environment. This pathway stands as the predominant environmental route of transmission. 5) Environmental egg development necessitates exposure to air and humid soil for infectious maturation. 6) The continuum persists upon the ingestion of embryonated eggs by a suitable mammalian host. 7) Infectious eggs undergo hatching in the intestinal milieu, liberating larvae at the first developmental stage. Subsequently, these larvae traverse the intestinal wall and migrate through the portal vein, reaching the hepatic parenchyma within a span of 3-4 days. Created with BioRender.com, modified of www.cdc.gov/parasites/

3.4. ZOONOTIC POTENTIAL

Some *Capillaria* species possess zoonotic potential, indicating their capability to infect humans and induce diseases. An exemple is *C. philippinensis*, which instigates intestinal capillariasis in humans, predominantly in Southeast Asia. The transmission of this species occurs through the ingestion of raw or insufficiently cooked fish harboring the infective larvae. In human hosts, intestinal capillariasis can manifest as chronic diarrhea, abdominal pain, malabsorption, and weight loss. Another instance is *Capillaria hepatica*, a parasitic affliction caused by the nematode *C. hepatica*. This parasite predominantly targets the liver in various mammals, encompassing humans, rodents, and certain other animal species. (Frean 2020).

3.5. TRANSMISSION

Rats and mice are the most common rodent hosts for *C. hepatica.* When people unintentionally consume food or water that has parasite eggs in it, they become infected. The eggs, which contaminate the environment, are excreted by infected rodents in their waste. The eggs hatch once they are inside the human body, and the larvae move to the liver where they mature and become adult worms (Santos et al. 2001).

3.6. CONTROL AND PREVENTION

A multifaceted strategy is required to prevent and treat *Capillaria* infections. Maintaining clean and hygienic environments can help to lower the risk of infection in animal husbandry situations. To control *Capillaria* infections in domesticated animals, proper cleanliness, waste management, and routine deworming of animals are crucial. To prevent infections in fish farming, maintaining the quality of water sources is essential. Fish can be identified and isolated if they show symptoms of infection, which will stop the parasite from spreading throughout the population. Public health awareness efforts are essential in informing people about the dangers of consuming raw or undercooked fish as well as other possible infection sources in zoonotic cases involving *Capillaria* species. Additionally, implementing food safety regulations and proper cooking practices can minimize the risk of transmission to humans (Dubey et al. 2018).

4. LAGOCHILASCARIASIS

It is known as a parasitic disease and reports in humans are rare. The helminth responsible for this disease in humans is *Lagochilascaris (L.) minor* (Barbosa et al. 2017; Barreto et al. 2018). Human Lagochilascariasis can also be found in cats and dogs. This disease is considered an emerging zoonosis in America distributed from Mexico to Argentina and the Caribbean islands (Barrera-Pérez et al. 2012; Christello Trindade et al. 2019).

It is a silent and chronic disease, and over the course of years the symptoms may be hidden. The clinical picture of the disease presents itself until the parasite invades the subcutaneous tissues, central nervous system and bone tissues (Solano-Barquero et al. 2022).

L. minor is mainly reported in wild felines, with rare reports in domestic felines. Due to the rarity of disease, the life cycle has not yet been clearly reported (Lanfredi et al. 1998) (Fig. 2).

Although lagochilarscariasis is an uncommon parasitic disease in humans, people must be cautious on probable outbreaks due to the climate change (Quintana de Moura et al. 2012; Solano-Barquero et al. 2022).

5. MAMMOMONOGAMIASIS

Mammomonogamus (a helminth) infection in humans (also known as syngamosis) is quite rare (Castaño et al. 2006; Alves de Almeida et al. 2018). It is produced by the nematode *M. laryngeus*, which parasitize the respiratory tract of some animals like cattle (Echeverry et al. 2011). Infected humans present symptoms like other diseases with respiratory manifestations (Bentivi Pulcherio et al. 2013). One of the main symptoms of the disease is a persistent cough, sometimes causing coughing up blood (Angheben et al. 2009). These symptoms are caused by the parasite settling in the respiratory tract (Nosanchuk et al. 1995; Agosu et al. 2021) (Fig. 3).

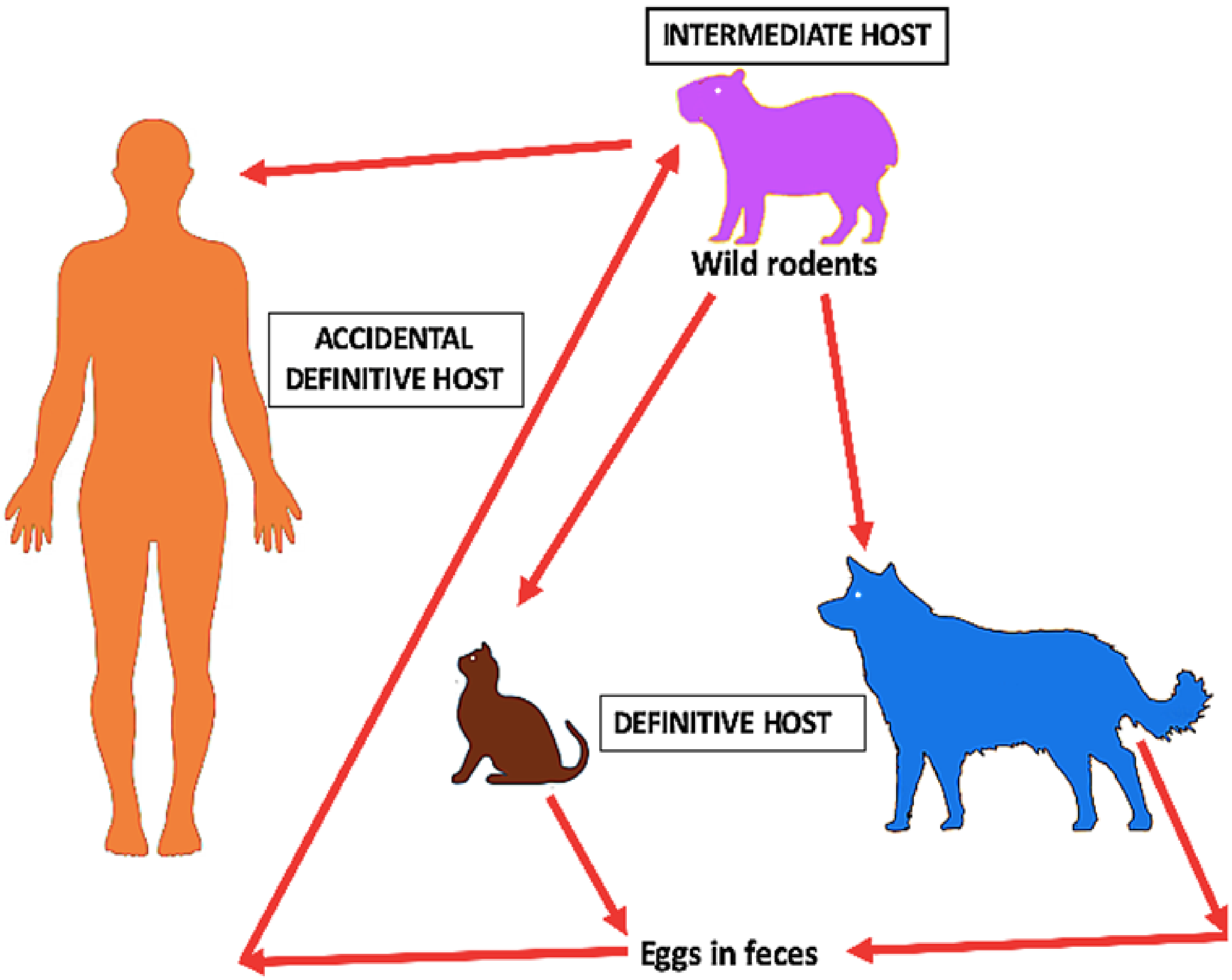

Fig. 2: Probable life cycle of *Lagochilascaris minor*. (Figure made by Carlos Ramón Bautista-Garfias).

The general life cycle of *M. laryngeus* is as follows: humans or cattle ingest Infective eggs or larvae in contaminated food, or water. Then, larvae penetrate intestinal walls into mesenteric veins and migrate to lungs where it develops into adult worms. Adult worms move to tracheolaryngeal region and there attach to mucosal walls. In this region, male and female worms form Y shape, and sexual reproduction occurs. After this, eggs produced and are coughed up and can be reswallowed. Eggs not swallowed are expelled in feces (Fig. 3) (Echeverry et al. 2011).

6. STRONGYLOIDIASIS (*STRONGYLUS* SPP.)

The causative agent of strongyloidiasis is a geohelminth *Strongyloides (S.) stercoralis*. This is a parasite inhabiting the small intestine of the host. The name of this parasite was accepted by Bavay (1876) and was reported by the physician when he observed French soldiers returning from Vietnam with diarrhea and larvae in the feces (Grove 1990).
The life cycles of each species vary in some respects. In the case of *S. stercoralis* the females located in the intestine deposit several eggs in the intestinal epithelium which cause them to develop into larvae and emerge as larvae in the feces (Grove 1980). Due to this variable for the detection of parasite in feces, it is recommended to carry out a wider sampling and on different days (Fernandez-Chavarria 2011).

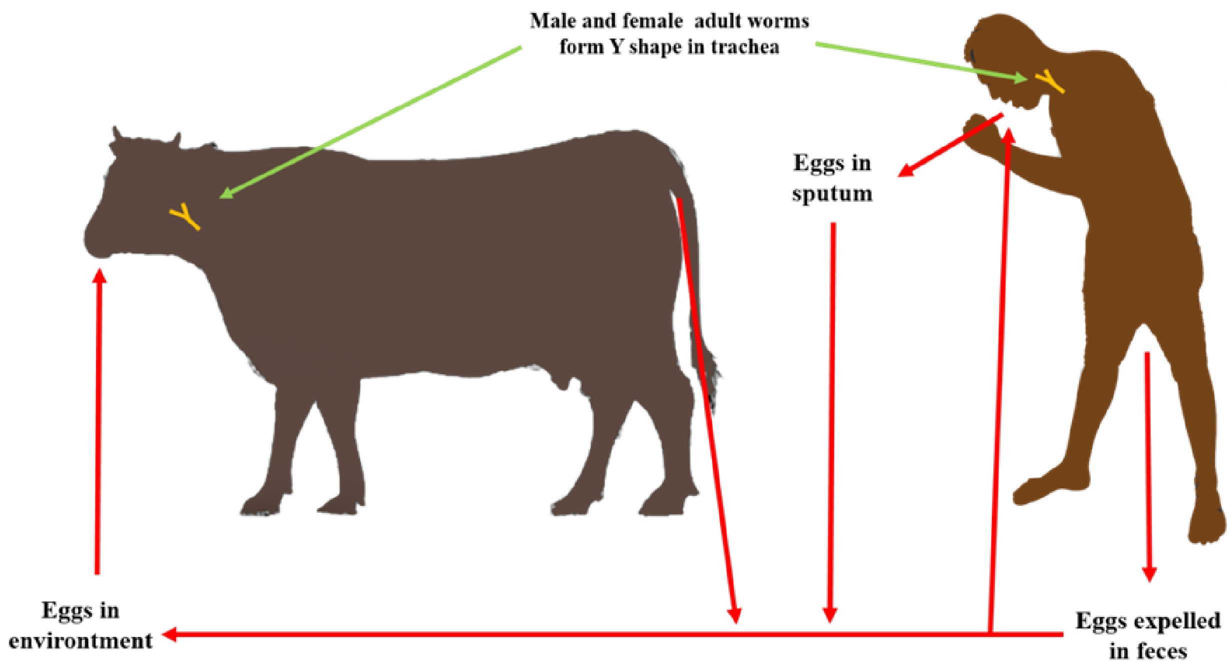

Fig. 3: Life cycle of *Mammomonogamus laryngeus*. (Figure made by Carlos Ramón Bautista-Garfias).

6.1. LIFE CYCLE

In general, the Strongylidae family presents a direct cycle with two phases: exogenous and endogenous. The adult parasites are lodged in the large intestine and the eggs produced by the females are excreted in the feces. Subsequently, the L1 larva hatches from the egg and grows into the infective larva (L3). Infection occurs passively after ingestion of L3 (with a sheath) found in the pasture. There are other types of Strongyloides, but the most common type infecting humans is *S. stercoralis* (Catalogue of Life 2023).

6.2. CLINICAL PICTURE

Once infected, the person starts showing signs and symptoms including intradermal migration of Strongyloides (Larva currens), itchy feet, wheezing, coughing, fever, diarrhea, nausea/vomiting and weight loss. These symptoms may present differently depending on the stage of the disease (Farthing et al. 2018).

6.3. DIAGNOSIS

Tests used for the diagnosis of *S. stercoralis* include the diagnostic techniques by coproparasitological methods, culture of feces on agar plates, the direct method, the modified Ritchie method and the Baerman method. Of these methods, greater sensitivity has been observed in the stool culture tests on agar plates and the Baerman technique (Figueroa 2002; Farthing et al. 2018).

7. CUTANEOUS LARVA MIGRANS

Cutaneous larva migrans (CLM), colloquially known as "creeping eruption" or "sandworm disease," represents a parasitic cutaneous infection induced by the migration of larval stages of certain hookworm species within the epidermal and upper dermal layers. Regions characterized by tropical and subtropical climates, particularly those marked by deficient sanitation and a substantial population of stray dogs and cats, are predisposed to this malady. Individuals inadvertently assume the role of hosts upon exposure to environments contaminated with infectious larvae (Hochedez and Caumes 2007).

Cutaneous Larva Migrans (CLM) stands as the most prevalent dermatological affliction of tropical origin associated with travel. This dermatosis stems from the subcutaneous migration of Ancylostoma larvae. The nomenclature associated with this skin ailment, including "creeping eruption," "creeping verminous dermatitis," "sand worm eruption," and "plumber's itch," contributes to its perplexity. The designation "hookworm-related cutaneous larva migrans" (HrCLM) has been employed to characterize this disorder (Hochedez and Caumes 2007). Specific hookworm species, during their larval stage, precipitate CLM by traversing the epidermis and upper dermal layers, manifesting as a dermatological malady. Principal offenders include larvae of *Ancylostoma (A.) braziliense* and *A. caninum*, predominantly affecting dogs and cats. Additional, albeit less phylogenetically related parasites encompass *Uncinaria (U.) stenocephala*, *Ancylostoma tubaeforme*, *Gnathostoma spinigerum*, certain strains of *Strongyloides stercoralis*, bovine parasites (*Bunostomum phlebotomum*), murine parasites (*Strongyloides myopotami*), and parasites found in wild canids (*S. procyonis*). *Toxocara canis* species are responsible for the onset of ocular and visceral larva migrans (Otamendi et al. 2011). Through the feces of sick animals, these worms discharge eggs into the environment. The larvae become infectious when the eggs hatch in warm, damp soil or sand. The infectious larvae can enter the skin of people who encounter these polluted places and cause CLM (Hochedez and Caumes 2007).

7.1. ETIOLOGICAL AGENT

The major species causing HrCLM are *A. braziliense*, *A. caninum*, or *U. stenocephala*, which are distinguished by slightly elevated and erythematous tracks. They measure roughly as one centimeter. One or more, linear or, more frequently, serpiginous, ramified, and interwoven, may exist. The width of tracks varies from 2 to 4 mm, and the length can vary greatly, sometimes up to many centimeters. Pruritus frequently occurs along with tracks. The larvae puncture the corneal layer of the epidermis when people meet soil contaminated by animal waste. Because humans are incidental hosts that disrupt normal larval development, CLM is self-limiting. However, the creeping eruption could persist for a few months. (Feldmeier et al. 2006).

7.2. EPIDEMIOLOGY

In impoverished communities in tropical and subtropical areas of developing nations, CLM is common, especially in areas with inadequate sanitation and a high population of stray dogs and cats. There have also been reports of autochthonous cases or small outbreaks in temperate countries such as the United States, Germany, France, Great Britain, and New Zealand (Feldmeier et al. 2006). It usually affects visitors and travelers who engage in activities such as walking barefoot on beaches that involve contact with contaminated sand or dirt. The majority of clinical data on this parasitic skin illness comes from observations made by travelers returning from the tropics. Only one study had examined clinical characteristics in individuals living in areas where the disease was endemic (Heukelbach et al. 2004).

7.3. LIFE CYCLE AND PATHOGENESIS

The parasitic hookworm goes through various phases in its life cycle, the first of which is the larvae. Due to their inability to complete their life cycle in humans, these larvae migrate beneath the skin of the host, causing CLM (Freedman et al. 2006).

The small intestine of infected dogs and cats is home to adult hookworms, which cling to the intestinal wall and feed on blood. The eggs laid by the female hookworms are expelled in the feces of the host and number in the millions each day. Through their feces, afflicted animals pass the eggs of *A. braziliense* and *A. caninum* from their bodies. These eggs are extremely tolerant of their surroundings and can remain in the soil for several weeks to months. The hookworm eggs hatch and first-stage larvae (L_1) emerge from the eggs in warm and damp habitats like sandy beaches or soil (Hochedez and Caumes 2007). When people come into contact with sand or dirt that has been polluted with the infectious larvae (L_3), they become unintentional hosts of CLM. The larvae can actively pierce the skin, particularly in places where the skin is thin or injured. Once the infectious larvae have entered the epidermis, they cannot finish their life cycle in people. Instead, they move through the epidermis and higher dermal layers of the skin, resulting in the cutaneous larva migrans rash, which is characterized by a serpiginous or winding rash. The larvae are unable to develop further inside the skin. Instead, they move, producing the recognizable rash and excruciating itching.

Over time, the body's immune response may lead to the elimination of the larvae, and the rash resolves without specific treatment. However, the duration of the infection and resolution of symptoms can vary from weeks to months (Jourdan et al. 2018). As the larvae die or are eliminated by the immune system, the symptoms subside, and the skin gradually heals (Fig. 4). It is essential to note that humans are accidental hosts for these hookworm larvae, and they cannot complete their full life cycle in the human body. The larvae cannot mature into adult worms or reproduce within humans. The infection is generally self-limiting, and the larvae are eventually eliminated by the immune response (Hochedez and Caumes 2007; Jourdan et al. 2018).

7.4. DIAGNOSIS

Clinical features are the primary basis for the diagnosis of CLM. A medical professional will examine the unique appearance of the skin rash, which typically presents as a raised, reddish and elevated lesion that is intensely itchy (Leung et al. 2017). The healthcare professional will work to distinguish CLM from other skin disorders, such as scabies, allergic responses, and other parasite infections, that may have comparable clinical presentations. The form and spread of the rash should be carefully examined to help to differentiate CLM from other skin conditions (Hochedez and Caumes 2007).

7.5. TREATMENT

Treatment for CLM aims to eliminate the hookworm larvae causing the infection, accelerate healing, and alleviate symptoms. CLM typically resolves on its own within weeks to months, as the rash often spontaneously disappears when the larvae either die or are eliminated by the immune system. However, if the rash does not improve or if there is extreme itching or discomfort, medical treatment might be recommended. The use of anthelmintic treatments, which are medicines that can kill parasitic worms, is the main therapy strategy for CLM. Hookworms can be treated with albendazole, an oral drug, along with other parasitic infections (Freedman et al. 2006).

8. TRICHIURIASIS (*TRICHIURIS SUIS*)

Trichocephalosis is caused by *Trichuris* spp or trichocephalus (*T. trichiura*, *T. vulpis* and *T. suis*), a nematode that is in the large intestine and mainly affects children (Carrada-Bravo 2004).
Trichuris is transmitted to humans in different ways including the infection by *Trichuris vulpis* and *Trichuris suis* from dogs and pigs (Nejsum et al. 2020).

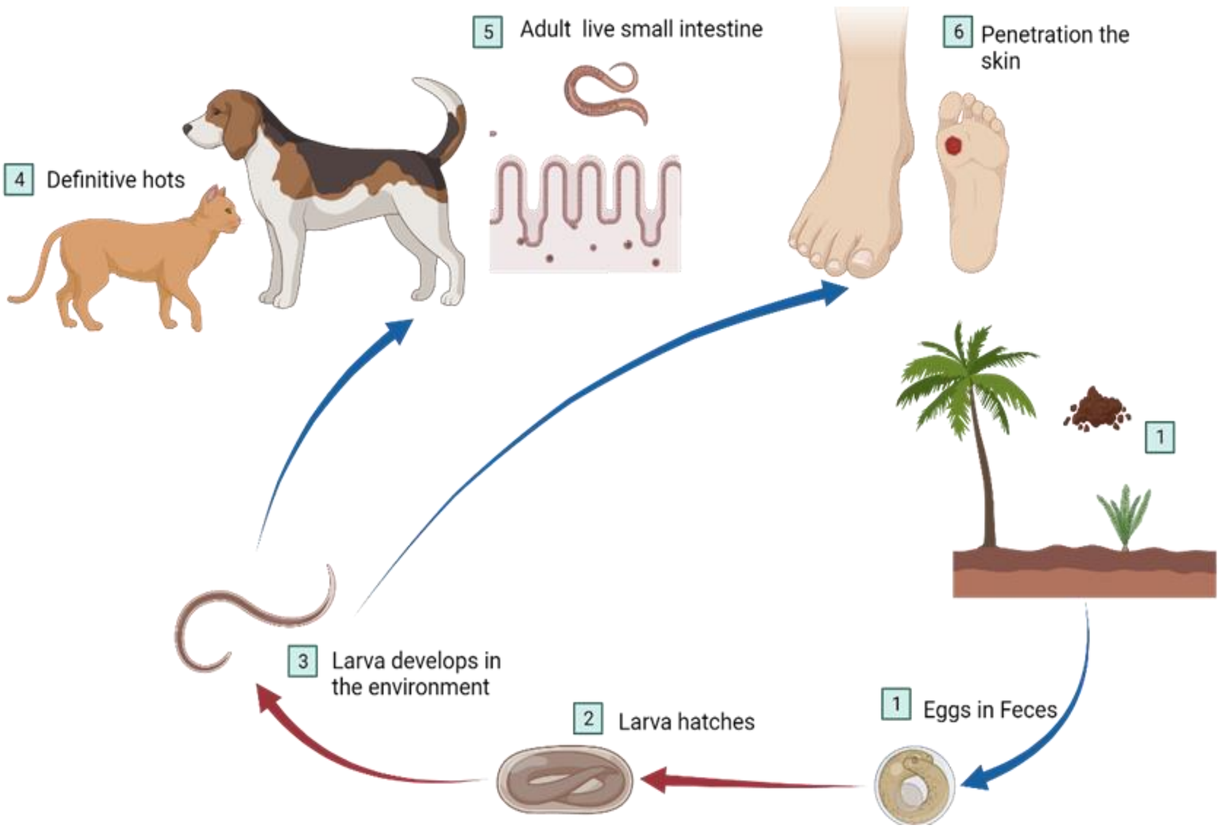

Fig. 4: Cycle in the final host resembling the cycle in the human species quite a bit. Created with BioRender.com, modified of https://www.cdc.gov/dpdx/hookworm/index.html

When it comes to *T. trichiura*, females are found in the mucosa and lay eggs daily. These eggs hatch in feces and the surrounding environment, and only a small percentage of them are able to embryonate until the first larval stage develops in the egg under the right conditions. These eggs contain infectious larvae that, upon ingestion by a new host, settle in the small intestine before moving on to the large intestine, where they eventually mature into adults (Carrado-Bravo 2004; Nejsum et al. 2020). Zoonotic species, such as *Trichuris* spp., can spread through improper treatment of animal feces and environmental contamination. For *T. vulpis* in dogs, the prepatent period lasts 70–90 days, but for *T. suis*, it lasts in 41–45 days.

8.1. CLINICAL PICTURE

Symptoms include inflammation, growth retardation in children, oedema, hemorrhages, anemia, abdominal pain, and occasional diarrhea, and in case of massive infection, appendicitis may occur. However, the absence of symptoms has been observed in several hosts (Bundy 1994).

8.2. DIAGNOSIS

Recently, coproparasitological tests such as flotation technique, Baerman technique and others are of great help to identify *Trichuris* spp. in asymptomatic hosts (Carrada-Bravo 2004). Eggs observed under the microscope have a peculiar lime-shaped form as shown in Fig. 5.

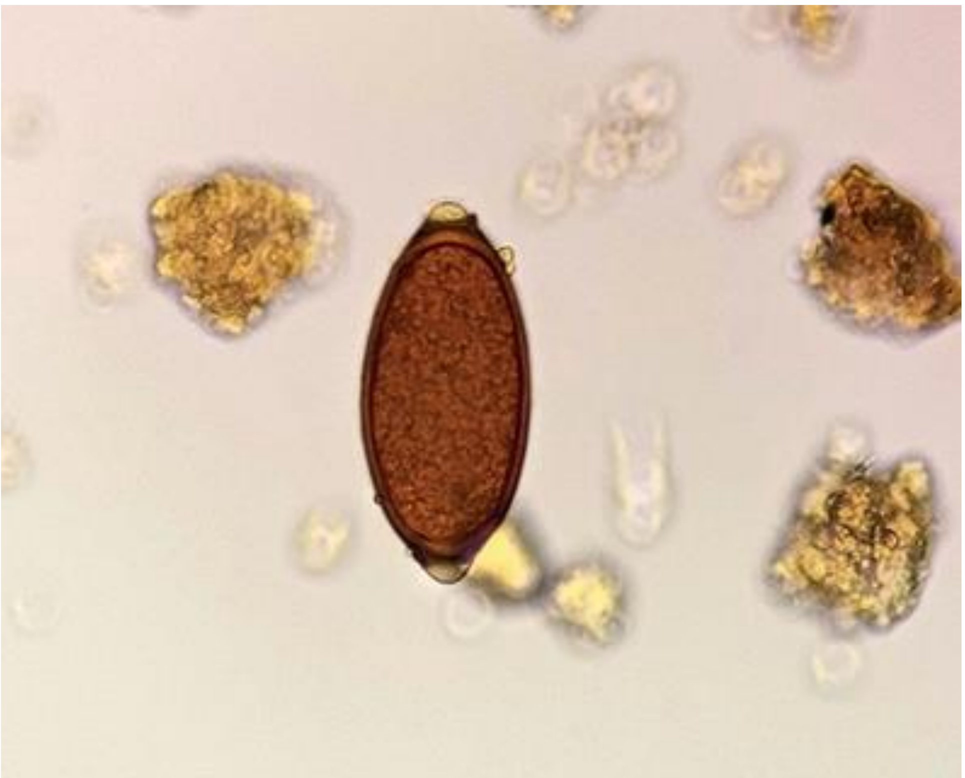

Fig. 5: Egg of *Trichuris trichiura* (Taken from Cauich-Echeverria and Franco-Zetina 2021).

9. CONCLUSION

Zoonotic diseases are a major public health problem because animals are the source of human pathogens. The emergence and re-emergence of zoonotic diseases have been attributed to a number of anthropogenic and natural factors, including vector biology, urbanization, climate change, animal migration and trade, travel and tourism, among others. Animals are the origin of a large number of infectious diseases that affect humans. About 60% of newly discovered human infections are zoonotic. Because of this, it is important to consider the areas where we live and the risks of latent diseases in the regions. In addition, it is extremely important to give importance to common wound accidents, because it is better to prevent silent diseases that can be hidden for years through good food and wound asepsis and go to the doctor.

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