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Review on Hook Worm Infections : Ancylostomiasis

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ABSTRACT

The present review mainly highlighted on hookworm infections and the Ancylostoma species distribution, infection rate, epidemiology, prevalence, pathophysiology, diagnosis and treatments were analyzed. Hook Worms are located in the intestinal tract and/or tissues. Several investigations have reported the interesting phenomenon that the infective larvae of canine hookworm, Ancylostoma canium and other species. The immune response to worm infections also depends upon the location of infestation. Gastrointestinal nematode infections have always been a major animal health problem of domestic animals and/or ruminant livestock. Hosts with nematode infections present a series of pathological effects these changes include tissue damage, alterations in blood constituents, elevation or decrease of enzymatic levels. Hookworm diseases are most common in tropical and subtropical climatic conditions and the infections were observed in both animals and humans. As per the available information globally more than 740 million peoples are infected with hookworm. In sub-Saharan Africa, Asia, approximately 200 million people have been infected with hookworm, 90 million of them were children. The main objective of this review was to identify the prevalence, epidemiology and determinant factors of hookworm infection. Diagnostic methods that differentiate between hookworm species, including molecular methods, need to be developed for widespread use in control programmes to elucidate key features of hookworm epidemiology and control.

Keywords: Hook worm infections, Ancylostomiasis, Prevalence, Epidemiology

I. INTRODUCTION

Hookworms are small (less than 0.5 inches long) parasitic worms that can cause infections in the small intestines. The major species of hookworms associated with infections in humans are Ancylostoma duodenale and Necator americanus. They get their name from the teeth ("hooks") or cutting plates in their mouths by which they attach themselves to the intestinal wall. In areas where hookworm infections are common, improving sanitation can reduce the number of infections. This includes using better sewage-disposal systems and reducing the frequency of outdoor human defecation. The damp tropics and

subtropics are prone to hookworm disease. Many children in underdeveloped countries die as a result of the sickness because it makes them more susceptible to infections that their bodies would ordinarily be able to fend off (Croese *et al.*, 1994; Landmann, 2003; Carroll and Grove, 1986; Anten and Zuidema, 1964).
These infections develop after a person has contact with soil contaminated with human feces. Children are at high risk because they often play barefoot in areas with contaminated soil. In soil, hookworm eggs hatch and form larvae, which then burrow through the skin of a person's foot and crawl into the blood. The blood carries the larvae to the lungs, where they enter into the air sacs. The hookworms then crawl up the breathing tubes to the throat, where they are swallowed. The larvae pass through the stomach and mature into adult worms in the bowel. The worm holds onto the bowel wall with hooks, which cause minor bleeding. Adult hookworms live in the bowel and lay eggs that pass out of the child with the stool.
Intestinal hookworm disease in humans is caused by *Ancylostoma duodenale, A. ceylanicum,* and *Necator americanus.* Classically, *A. duodenale* and *N. americanus* were considered the two primary intestinal hookworm species worldwide, but newer studies show that a parasite infecting animals, *A. ceylanicum*, is also an important emerging parasite infecting humans in some regions. Occasionally larvae of *A. caninum*, normally a parasite of canids, may partially develop in the human intestine and cause eosinophilic enteritis, but this species does not appear to reach reproductive maturity in humans (Chan *et al.*, 1994; de Silva *et al.*, 2003; Hotez, 2009).

Skin-penetrating hookworms from a different species that infects animals can cause cutaneous larva migrans in humans (*A. braziliense, A. caninum, Uncinaria stenocephala*). These parasites, with the exception of *A. caninum*, stop growing once their larvae enter human skin. For more info, see extraintestinal hookworms.

The primary risk factor for contracting the disease is being barefoot on land that has been exposed to hookworm-infected people's excrement. The worm's larvae, or young form, invade the skin. The bloodstream transports the larvae to the lungs, where they enter the airways. The worms are about one-half inch (1 centimeter) long. After traveling up the windpipe, the larvae are swallowed. After the larvae are swallowed, they infect the small intestine. They develop into adult worms and live there for 1 or more years. The worms attach to the intestinal wall and suck blood, which can result in iron deficiency anemia.

The species Ancylostoma duodenale and Necator americanus, which cause ancylostomiasis and necatoriasis, respectively, are two prevalent hookworm infections in humans. People with hookworm infection pass hookworm eggs in their faeces. If these are exposed to the environment, they have the potential to spawn larvae (immature worms) that can pierce the skin. Another way for one type to spread is through tainted food. Walking barefoot in warm climates with insufficient sanitation is one risk factor (Albonico *et al.*, 1994; Crompton, 2000).

The present Nematode parasites, including hookworm, are found in the small intestines of humans, dogs, and cats. There are two primary species of hookworm are Ancylostoma duodenale and Necator americanus. The latter is the main causative factor for hookworm infection (Hotez *et al.*, 2011; Ngui *et al.*, 2012). Here the interesting thing that one of the neglected tropical illnesses mentioned by the WHO is hookworm. Neglected tropical illnesses are the fourth biggest cause of contagious diseases, accounting for 46–57 million years of lost life due to disability (Jeremiah *et al.*, 2012). Hookworm can leave permanent sequel on cognitive performance and growth of children's, hookworm decreases the school performance of children by 20 % (Jeremiah *et al.*, 2012; Fred *et al.*, 2013).

Ancylostoma caninum, *Ancylostoma braziliense*, and *Uncinaria stenocephala* are common hookworm infections in dogs. Cats are commonly infected by *Ancylostoma tubaeforme* and *A. braziliense,* but rarely by *U. stenocephala*. *A. caninum* and *A. tubaeforme* are found most frequently in tropical and subtropical areas; *A. braziliense* in warm coastal areas, Central and South America; and *U. stenocephala* in cooler areas like the northern United States, Canada, and Europe. The prevalence of hookworm infections has changed over the years. In a large study of his 1,213,061 dogs examined at 547 private veterinary clinics in his 44 states in the United States, 4.5% of his samples contained eggs of the Ancyclostoma species. In areas and animals at risk, infection rates can be much higher. For example, in a study in Florida, A. tubeeforme and A. brasiliense was detected in the faeces of 75% and 33% of cats tested, respectively (Cheesbrough, 1998; Gasser *et al.*, 1993; Verweij *et al.*, 2001).

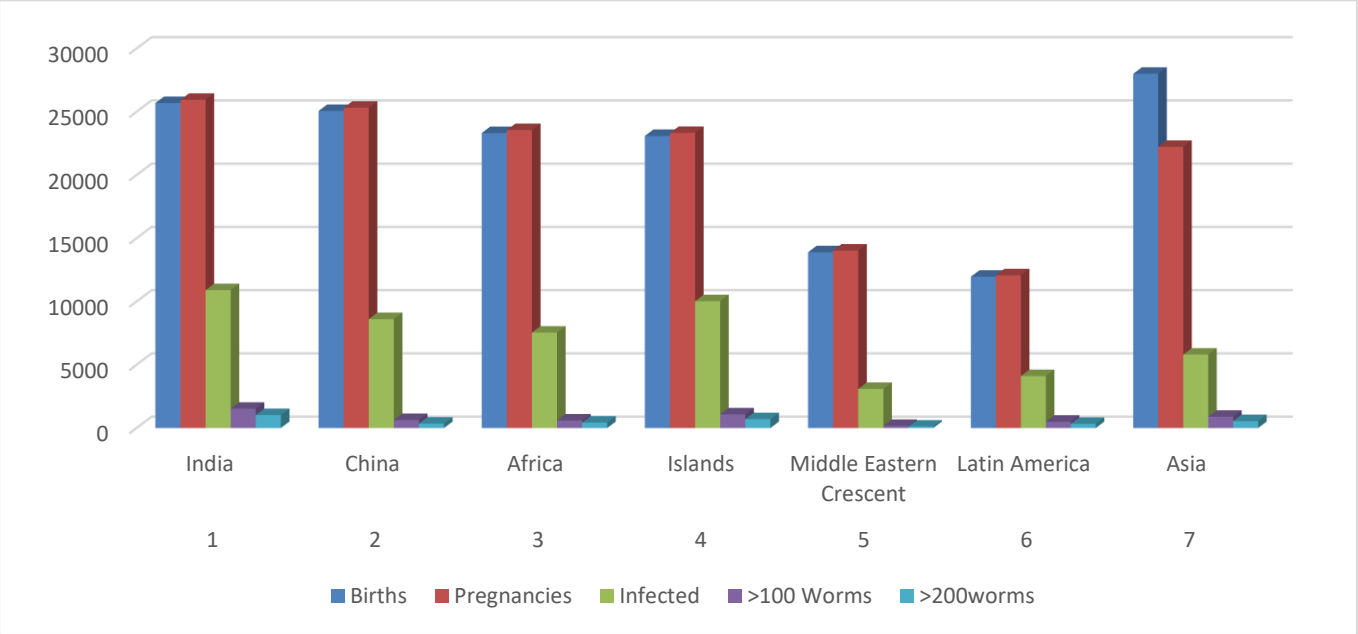
Epidemiology of Ancylostoma

Hookworm is a soil-transmitted helminth (STH) and is one of the most common roundworm of humans. Infection is caused by the nematode parasites Necator americanus and Ancylostoma duodenale. Hookworm infections often occur in areas where human feces are used as fertilizer or where defecation onto soil happens. A. caninum girls are normally 14–sixteen mm (0.55–0.sixty three in) lengthy and 0.five mm (0.02 in) wide, even as the men are smaller at 10–12 mm (0.39–0.forty seven in) in duration and 0.36 mm (0.01 in) in width. Males have a copulatory bursa , which includes spine-like spicules placed on 3 muscular rays that draw close the lady at some point of mating. As with different nematodes, the sperm lack flagella. The copulatory bursa is a completely unique characteristic of Strongylida individuals, as a consequence making it a beneficial method for figuring out individuals of this suborder; it's also used to differentiate individuals inside the suborder because of variations in bursa look among species. The vulva of A. caninum girls is positioned on the boundary of the second one and very last thirds of the frame. A. caninum has an alimentary canal made of an esophagus, intestine, and rectum – the esophagus is tremendously muscular, reflecting its function in pulling intestinal mucosa into the frame whilst it feeds. Esophageal and anal jewelry of A. caninum are the supply of nerve fibres that make bigger for the duration of the frame to innervate sensory organs, consisting of amphids and phasmids (*Animal Diversity Web, 2013; Marquardt,2000; Olsen, 1986*).

The severity of hookworm pathology is directly related to the number of worms a person carries. We found that the intensity of hookworm infection had a sporadic distribution. Although most of the population was infected, only 9% of him had infections >3,000 EPG, putting him at the highest risk of hookworm-related anemia. Predicted numbers infected with hookworm and at risk of morbidity in different regions of world (According to WHO) showed in figure-1.

Related patterns have been reported in other hookworm endemic areas such as Papua New Guinea (Pritchard et al. 1990), West Bengal (Nawalinski et al. 1978) and Zimbabwe (Bradley et al. 1993). The intensity of infection was determined by quantitative counting of oocytes in feces. This is a commonly used indirect measure of worm load. A weakness of this method is that very severe infections may show a partially density-dependent decrease in fertility. Thus, as the parasite load increases, the number of eggs laid per individual nematode decreases (Anderson & Schad 1985). However, a recent study in schoolchildren of Sansavari found that hookworm egg counts reflected parasite load and were indeed strongly linearly associated with anemia and iron deficiency anemia. (Stolzfus et al. 1997).

Figure -1 : Predicted numbers infected with hookworm and at risk of morbidity in different regions of world (According to WHO)



In India, the hookworm prevalence is estimated to be 71 million cases and *A. lumbricoides* contributes 140 million and *T. trichiura* 73 million cases. As per the studies in India, the maximum prevalence is seen in Karnataka (47%) followed by Andhra Pradesh (40%). The prevalence rate in Tamil Nadu is 3.2% whereas in Puducherry, it is 4.8%. The other study done in Vizianagaram, Andhra Pradesh, showed 55.6% STH prevalence and the most common parasite was *Entamoeba* (37.7%) followed by hookworm (8.7%) and the most common age group affected is 8–10 years. Various authors reveals that the information on hook worm in Andhra Pradesh also showed similar prevalence (49%). A recent stusy was done in Vellore the prevalence rates for hookworm (8.4%) was reported by many authors. (Ananthakrishnan *et al.*, 1997; Panda, 2012; Padmaja *et al.*, 2014; Karthikeyan, 2016).

Reports in Karaikal region of Puducherry, the overall prevalence of parasitic infection is found to be 30%, of which 35% was due to hookworm. The overall prevalence of parasitic diseases in Puducherry in 1998 was 67% in slum children aged 1–10 years. In 1987, a hospital-based study done in Puducherry showed the overall parasitic prevalence was 38%. Of these, hookworm constitutes 44% followed by *T. trichiura*, 26% and *A. lumbricoides*, 22%. In a study from Puducherry which was done in school children to find out the prevalence of parasitic infections, the estimated prevalence was 34.56% and the most common infection was *A. lumbricoides* (43.21%) followed by hookworm (28.8%), *T. trichura* (10.87%), and *Hymenolepis nana* (7.68%). It was found that polyparasitism was common among the infected children and out of 28.8% of microscopically positive stool samples for hookworm, 55.5% was positive by stool culture. Another hospital-based study done in Puducherry showed the overall parasitic prevalence of 16%, in which 68% had helminth infection. The most common helminthic infection was due to hookworm (86%) followed by *Strongyloides stercoralis* (6.3%) and *A. lumbricoides* (2.8%) (Rau *et al.*, 1988; Parija and Rao, 1987; Ragunathan *et al.*, 2010; Sunil *et al.*, 2011)

1) Global distribution of hookworm genera and species

Of 1987 unique records identified through the search strategies, 1935 (97·4%) records were excluded following screening, leaving 52 studies to be included in the first systematic review. The studies included approximately

9361 people with hookworm and 6463 people for whom species of hookworm were identified. The most prevalent hookworm species was *N americanus* (pooled proportion 79%, 95% CI 67–89%).

The proportion of people with *Ancylostoma* spp infection was significantly lower (32%, 20–45%). The proportion of people with mixed *N americanus* and *Ancylostoma* spp infections was 5% (1–10%). In studies that identified the species of *Ancylostoma*, a higher proportion of hookworm-infected people had *Ancylostoma ceylanicum* (11%, 3–21%) than *Ancylostoma duodenale* (7%, 0–20%), although these studies were mainly in the Asia-Pacific region (Table-1).

Table-1 Report on Prevalence rate of hook worms in various regions

Sl. No	Provence/ Area/ Region	Caused by	Rate of infection	Reference
1	Darjeeling, Hooghly District, West Bengal, India	*N. americanus*	43%	(Pal *et al.* 2007)[36]
2	Xiulongkan Village, Hainan Province, China	*N. americanus*	60%	(Gandhi *et al.* 2001)
3	Hòa Bình, Northwest Vietnam	*N. americanus*	52%	(Verle *et al.* 2003)[38]
4	Minas Gerais, Brazil	*N. americanus*	63%	(Fleming *et al.* 2006)[39]
5	KwaZulu-Natal, South Africa	*N. americanus*	63%	(Mabaso *et al.* 2004)[40]
6	Lowndes County, Alabama, United States	*N. americanus*	35%	41, 42
7	Asia-Pacific	*Ancylostoma* **sps.**	45%	Archie C A Clements, Kefyalew Addis Alene, 2021
8	Africa	*Ancylostoma* **sps.**	13%	Archie C A Clements, Kefyalew Addis Alene, 2021
9	Americas	*Ancylostoma* **sps.**	15%	Archie C A Clements, Kefyalew Addis Alene, 2021
10	Asia-Pacific Africa Americas	N. americanus Ancylostoma spp. Mixed N. americanus/ Ancylostoma A. duodenale A. ceylanicum	30%	Archie C A Clements, Kefyalew Addis Alene, 2021
11	Karnataka, Andhra Pradesh, Tamilnadu,	*A. lumbricoides*	47% 40% 3.2%	AnathaKrishnan et al., 1997

	Pondicherry		4.8%	
12	Vizianagarm, Andhra Pradesh	Entamoeba	55.6%	Panda, 2012
13	Karikal, Puduchery	Ancylostoma	35%	Karthikeyan,2016
14	Vellore	Ancylostoma	8.4%	AnathaKrishnan et al., 1997; Karthikeyan,2016

It is estimated that over 1.5 billion people worldwide are at risk of contracting acystic and other STHs. Half of the infections occur in the Asia-Pacific region, which has tropical climates, high population density, poor sanitation and poor sanitation. The risk of hookworm infection varies with age, gender, toilet availability, shoe wear, education level, maternal education level, low household income, poor personal hygiene, hand washing, place of residence and water source. (Fred *et al*., 2013; Janice *et al*., 2014).

Incubation period

In general Ancylostoma species migrates within 10 days. Here within 24-48 hours, they develop to first stage larvae (L1) and Latch. Larvae-1, Larvae -2, Larvae-3 stages. During the next week (5 to 10 days) L1 will molt to infections third stage larvae L-3. Three to five weeks after skin penetration the larvae will migrate to the intestinal tract where they will mature into an adult worm. Adult worms may live in the intestine for 1-5 years depending on the species.

The onset of lesions is generally 5–15 days with a range of 0–120 days. Only two previous case reports have documented incubation periods up to 5 months. The cause of variability in incubation period remains unclear; however, it has been postulated that as yet undetermined host factors may play a role. Also, helminth strain differences might be possible. Further investigations are needed to understand this phenomenon (Hochedez, and Caumes, 2007; Archer, 2009; Siriez *et al*., 2010).

Pathophysiology

Acanthosis, a hookworm infection, soil-borne helminth (STH), also known as miner's anemia, tunnel's disease or brickworker's anemia, is predominant in low socioeconomic status countries located in tropical and subtropical regions of the world. The outer surface of helminths contains important molecules of excretory/secretory (ES) products. Hookworm ES products contain a wide range of structurally and functionally diverse molecules, primarily proteins, but also lipids and carbohydrates. These molecules also play important roles in parasite development and survival. These molecules help the parasite survive and evade host immune responses by inhibiting inflammatory responses, promoting effector cell apoptosis, and distorting the immune response phenotype. The biological roles and molecular properties of hookworm ES products are still unclear, despite intensive studies over the years (Peduzzi R, Piffaretti, 1983; Crompton and Whitehead, 1993; Abuzeid *et al*., 2020).

The most serious symptoms of Ancylostoma infection develop during the last phase when the adult worms establish themselves in the human intestine. Using their buccal capsule and teeth, the adult worms attach to the mucosa and rupture capillaries and arterioles to feed, and this results in blood and protein loss.

Human hookworm disease is a common helminth infection worldwide that is predominantly caused by the nematode parasites *Necator*

americanus and *Ancylostoma duodenale*; organisms that play a lesser role include *Ancylostoma ceylanicum, Ancylostoma braziliense*, and *Ancylostoma caninum*. Hookworm infection is acquired through skin exposure to larvae in soil contaminated by human feces. Soil becomes infectious around 5-10 days after contamination and remains so for 3-4 weeks, depending on conditions.

Hookworm infection is generally considered to be asymptomatic, but as Norman Stoll described in 1962, it is an extremely dangerous infection because its damage is "silent and insidious." An individual may experience general symptoms soon after infection. Ground-itch, which is an allergic reaction at the site of parasitic penetration and entry, is common in patients infected with *N. americanus*.Additionally, cough and pneumonitis may result as the larvae begin to break into the alveoli and travel up the trachea. Then once the larvae reach the small intestine of the host and begin to mature, the infected individual will experience diarrhea and other gastrointestinal discomfort (Edward *et al.*, 2006; Stoll, 1962).

Recently, more attention has been paid to other important consequences of hookworm infections that play an important role in public health. It is now widely accepted that children with chronic hookworm infection may experience growth retardation as well as intellectual and cognitive impairment. The disease has been associated with a 1/3 to 1/2 inch long nematode (Ankylostoma duodenalis) in the intestine, primarily through the work of Theodor Bilharz and Griesinger (1854) in Egypt. Symptoms may be related to intestinal inflammation stimulated by feeding hookworms, such as nausea, abdominal pain, and intermittent diarrhea, and progressive anemia with long-term illness. , palpitations, threadlike pulses, cold skin, pale mucous membranes, fatigue and weakness, shortness of breath, and in case of death, dysentery, hemorrhage and edema (Hotez *et al.*, 2005; Hotez *et al.*, 1995). CDC, 2008; Bethony *et al.*, 2006).

Recently, more attention has been given to other important outcomes of hookworm infection that play a large role in public health. It is now widely accepted that children who have chronic hookworm infection can experience growth retardation as well as intellectual and cognitive impairments. Additionally, recent research has focused on the potential of adverse maternal-fetal outcomes when the mother is infected with hookworm during pregnancy. The disease was linked to nematode worms (*Ankylostoma duodenalis*) from one-third to half an inch long in the intestine chiefly through the labours of Theodor Bilharz and Griesinger in Egypt (1854). The symptoms can be linked to inflammation in the gut stimulated by feeding hookworms, such as nausea, abdominal pain and intermittent diarrhea, and to progressive anemia in prolonged disease: capricious appetite, pica/geophagy (or dirt-eating), obstinate constipation followed by diarrhea, palpitations, thready pulse, coldness of the skin, pallor of the mucous membranes, fatigue and weakness, shortness of breath and in cases running a fatal course, dysentery, hemorrhages and edema (Hotez *et al.*, 2005; Hotez *et al.*, 1995; CDC, 2008; Bethony *et al.*, 2006)

An interesting consequence of this in the case of Ancylostoma duodenale infection is translactational transmission of infection: the skin-invasive larvae of this species do not all immediately pass through the lungs and on into the gut, but spread around the body via the circulation, to become dormant inside muscle fibers. In a pregnant woman, after childbirth some or all of these larvae are stimulated to re-enter the circulation (presumably by sudden hormonal changes), then to pass into the mammary glands, so that the newborn baby can receive a large dose of infective larvae through its mother's milk (Hawdon and Hotez, 1996; IDB, 2009; Global Initiative 2008; Pal, 2007 Gandhi *et al.*, 2001).

This accounts for otherwise inexplicable cases of very heavy, even fatal, hookworm infections in children a month or so of age, in places such as China, India and northern Australia. An identical phenomenon is much more commonly seen with *Ancylostoma caninum* infections in dogs, where the newborn pups can even die of hemorrhaging from their intestines caused by massive numbers of feeding hookworms. This also reflects the close evolutionary link between the human and canine parasites, which probably have a common ancestor dating back to when humans and dogs first started living closely together. Filariform larvae is the infective stage of the parasite: infection occurs when larvae in soil penetrate the skin, or when they are ingested through contaminated food and water following skin penetration (Verle *et al.*, 2003; Flemimg *et al.*, 2006; Mabaso *et al.*, 2004; McKenna *et al.*, 2017; Pilkington, 2017).

Diagnosis

Traditional stool tests, such as the Kato-Katz method and formalin-ether enrichment, are the gold standard for diagnosing ancilostoma infection by detecting the presence of eggs and adults. A. duodenale, A. ceylanicum, and N. americanus produce thin-shelled, oval eggs that are readily detected in fresh stool. An enrichment procedure is required to diagnose mild infections. If the stool is not cooled and examined within a few hours, the eggs may hatch and release larvae that must be distinguished from nematode larvae. Her three species of hookworms that infect humans are distinguishable by molecular probes, but the ova are not, and no species-specific diagnosis is made in the clinical laboratory (Hotez, 2005).

Diagnosis depends on microscopic examination of stool showing characteristic parasite eggs, which is not possible in early infection. Limb dragging and anal itching are early signs of infection in most dogs. Eggs are ovoid or oval, 60 x 40 μm in size, colorless, unstained with bile, and have a thin transparent hyaline membrane. When released by worms in the gut, eggs contain unsegmented oocytes. Eggs passed in the faeces have segmented ovules and usually 4 to 8 blastomeres because the ovules develop during passage through the intestine. Eggs of Ancylostoma and Necator (and most other hookworm species) are indistinguishable, so laboratory identification of the genus requires culturing the larvae to allow them to hatch. If a fecal sample is left in a tropical environment for more than a day, the larvae may hatch and the eggs may disappear. In such cases, it is important to distinguish between hookworm and nematode larvae. The latter infection has more serious consequences and requires different management. Larvae of the two hookworm species can also be distinguished microscopically, but this is mainly done for research purposes rather than routinely. Adults are rarely seen (except by endoscopy, surgery, or autopsy), but when found allow definitive identification of the species. Classification can be based on the length of the oral cavity, the space between the oral cavity and the esophagus.

Recent research has focused on developing DNA-based tools for diagnosing infectious diseases, identifying hookworms, and analyzing genetic variation within hookworm populations. Because hookworm eggs are often indistinguishable from those of other parasites, PCR assays may serve as a molecular approach to accurately diagnose hookworms in faeces (Hotez, 2005).

Prevention

The infective larvae develop and survive in an environment of damp dirt, particularly sandy and loamy soil. They cannot survive in clay or muck. The main lines of precaution are those dictated by good hygiene behaviors: Do not defecate in the open, but rather in toilets., Do not use untreated human excreta or raw sewage as fertilizer in agriculture, Do not walk barefoot in known infected areas, Deworm pet dogs and cats. Canine and feline hookworms rarely develop to adulthood in humans. *Ancylostoma caninum*, the common dog hookworm, occasionally develops into an adult to cause eosinophilic

enteritis in people, but their invasive larvae can cause an itchy rash called cutaneous larva migrans, Moxidectin is available in the United States as (imidacloprid + moxidectin) topical solution for dogs and cats. It utilizes moxidectin for control and prevention of roundworms, hookworms, heartworms, and whipworms.

Treatment

The drugs are usually taken once by him to treat an infection. Wear shoes when walking outdoors, especially where there may be feces on the ground. Drink clean water, wash food clean, cook properly, and practice good hand washing. A. duodenale, A. ceylanicum, and N. americanus produce thin-shelled, oval eggs that are readily detected in fresh stool. An enrichment procedure is required to diagnose mild infections. If the stool is not cooled and examined within a few hours, the eggs may hatch and release larvae that must be distinguished from nematode larvae. Her three species of hookworms that infect humans are distinguishable by molecular probes, but the ova are not, and no species-specific diagnosis is made in the clinical laboratory. Eosinophilia is common in people infected with hookworm (Albonico *et al.*, 1994; Crompton, 2000). . During the pre-infectious stage (ie, 5-9 weeks from larval infestation to appearance of eggs in stool), eosinophilia may be the only laboratory abnormality. Hookworm prevalence is an important aspect in the differential diagnosis of eosinophilia in immigrants or travelers returning from endemic areas with poor sanitation. One cause of eosinophilic gastroenteritis is human infection with the canine hookworm Ancylostoma caninum. Gastrointestinal pain, nausea, vomiting, diarrhea, and bowel obstruction are common, most often with eosinophilia and leukocytosis. Egg cells are not produced, but adult worms may be seen during endoscopy. Patients respond to standard therapy with mebendazole 100 mg twice daily for 3 days.

Anthelmintic drugs

The most common treatments for hookworms are benzimidazoles, especially albendazole and mebendazole. BZA kills adult worms by binding to nematode β-tubulin and subsequently inhibiting microtubule polymerization within the parasite. Levamisole and pyrantel pamoate can be used in certain situations. A review found that single-dose treatment efficacy for hookworm infections was 72% with albendazole, 15% with mebendazole, and 31% with pyrantel pamoate. This supports previous claims that albendazole is much more effective than mebendazole against hookworm infections (Hotez, 2005). It is also worth noting that the World Health Organization recommends anthelmintic treatment for women in the first trimester of pregnancy. It is also recommended to be administered at the same time. This should continue until hemoglobin levels return to normal. This can take up to 3 months. In the 1910s, common hookworm treatments included thymol, 2-naphthol, chloroform, gasoline, and eucalyptus oil. In the 1940s, in the fasting state he used 3–4 cc of tetrachlorethylene, followed by his treatment of choice with 30–45 g of sodium sulfate. Tetrachlorethylene is reported to have an 80% cure rate for Necator infections, but a 25% cure rate for Ancylostoma infections and often causes mild poisoning in patients.

Discussion

Hookworm infections in dogs, cats and other animals typically come from a different species than the one that infects humans. Animal hookworms can sometimes penetrate a person's skin, but they don't mature or lay eggs inside a human host. Animal hookworms can cause a rash as they move under the skin. This itchy rash, called *cutaneous larva migrans*, shows up as a thin, raised red line that spreads across the skin (*Bravata*, 2001). Hookworm-infected people with *N. americanus* and Ancylostoma spp infections, finding a lower proportion of *N. americanus* and a higher proportion of Ancylostoma spp. infections in

the Asia-Pacific region relative to Africa and Latin America. Lower proportions of people were infected with *Ancylostoma* spp. and mixed infections in the 2000s and 2010s compared to the 1990s.

Various reports in children only had significantly higher rates of *A. duodenale* infection and lower rates of *A. ceylanicum* infection than studies in adults (all age groups). Interestingly, in multivariate models, the proportions of people infected with various hookworm genera and species were not statistically different between tropical and non-tropical regions. A meta-analysis of severe anemia found no difference in the risk of severe anemia among infections (and co-infections) caused by hookworm species (Verle *et al.*, 2003; Flemimg *et al.*, 2006; Mabaso *et al.*, 2004; McKenna *et al.*, 2017; Pilkington, 2017).

In previous reports for the deworming program of community dogs in Thailand, an oral dose of 10 mg/kg BW of pyrantel pamoate and the subcutaneous injection of 0.2–0.4 mg/kg BW ivermectin have been regularly administered for deworming; however, the efficacy of these regimens against *A. ceylanicum* in dogs remains unclear. Currently, many commercial drugs against *A. ceylanicum* infection in dogs have been tested at the laboratory level and exhibited greater than 99% efficacy within 3–7 days, including a combination of 15 mg/kg BW of febantel and 14.4 mg/kg BW of pyrantel embonate (Drontal Plus, Bayer Animal health), a spot-on of 2.5 mg/kg BW moxidectin (Advocate®, Bayer Animal health), and 0.5 mg/kg BW milbemycin oxime (NexGard Spectra®, Boehringer Ingelheim) (Taweethavonsawat *et al.*, 2010; Taweethavonsawat *et al.*, 2010; Tielemans *et al.*, 2017).

Ancylostoma caninum infection can be acquired by vertical (transmammary) infection, percutaneous penetration, or ingestion from infective 3rd instar larvae or paratheneal hosts. In adult dogs that have acquired some immunity, infected larvae do not develop directly into adult dogs, but instead migrate to somatic tissues such as the kidneys and skeletal muscle, where they undergo prolonged quiescence. These arrested larvae are most commonly reactivated by hormones of pregnancy and lactation, and the larvae infect nursing puppies in the milk of bitches. Hookworm infections can be seen in dogs of all ages. However, puppies and young pets are more likely to show clinical signs such as anemia, weakness, melena, anorexia, weight loss and poor growth. As with most parasites, clinical symptoms are exacerbated by malnutrition, stress, or complications.

Hookworm is classified into four different syndromes that depend on the animal's age, route of infection, or general health. In hyperacute ankylosing anastomosis, nursing puppies die of severe anemia at about 2-3 weeks of age. It has no clinical signs due to overwhelming hookworm infection via the mammary route. Acute ankylosis affects slightly older or weaned puppies, which survive long enough to develop signs of melena and severe anemia. Again, transmammary transmission is the usual route. The remaining two categories of ankylosing anastomosis occur in adult dogs that are repeatedly exposed to the L3 phase or continuously reinfected with larvae activated from the arrested somatic cell pool. Decompensated ankylosis occurs when malnutrition or comorbidities prevent animals from coping with hookworm infestations through immunological or general defense mechanisms (Taweethavonsawat *et al.*, 2010; Taweethavonsawat *et al.*, 2010). In contrast, no clinical signs are seen in dogs with *compensated* ancylostomosis, which is a term used to describe recurrent infections that are partially controlled, but not eliminated, by host mechanisms. Compensated ancylostomosis is typically recognized when fecal examinations after repeated treatments document the incessant reappearance of hookworm eggs. Diagnostic methods that differentiate between hookworm species, including molecular methods, need to be developed for widespread use in control programmes to elucidate key features of hookworm epidemiology and control.

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II. REFERENCES

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