Uttar Pradesh Journal of Zoology

Volume 45, Issue 20, Page 90-108, 2024; Article no.UPJOZ.4236
ISSN: 0256-971X (P)

The Nematodes Menace: A Review of Parasitic Species, Transmission Dynamics and Preventive Measures

K. Amala [a*], K. Swathi [b], M. Krishnaveni [c], R.Shyamala Gowri [d], R.Premalatha [e] and Suresh Malakondaiah [f]

[a] Department of Microbiology, Sacred Heart College (Autonomous), Tirupattur – 635601, Tamil Nadu, India.
[b] Department of Microbiology, St.Francis College For Women, Begumpet, Hyderabad, Telangana 500016, Tamil Nadu, India.
[c] Department of Biochemistry, Nadar Saraswathi College of Arts and Science, Theni – 625 531, Tamil Nadu, India.
[d] Department of Microbiology, Nadar Saraswathi College of Arts and Science, Theni – 625 531, Tamil Nadu, India
[e] Department of Microbiology, School of Biological Sciences, CMS College of Science and Commerce (Autonomous), Coimbatore – 632002, Tamil Nadu, India.
[f] Centre for Materials Engineering and Regenerative Medicine, Bharath Institute of Higher Education and Research, Selaiyur, Chennai-6000073, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i204568

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4236

Review Article

Received: 10/08/2024
Accepted: 17/10/2024
Published: 25/10/2024

**Corresponding author: Email: amalak87@gmail.com;*

Cite as: *Amala, K., K. Swathi, M. Krishnaveni, R.Shyamala Gowri, R.Premalatha, and Suresh Malakondaiah. 2024. "The Nematodes Menace: A Review of Parasitic Species, Transmission Dynamics and Preventive Measures". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (20):90-108. https://doi.org/10.56557/upjoz/2024/v45i204568.*

ABSTRACT

This review offers a detailed examination of nematodes, directing specifically on gastrointestinal (GI) nematodes and their consequences for human health. Nematodes, commonly known as roundworms, demonstrate a highly heterogenous groups of multicellular organisms and are responsible for various diseases in humans, particularly in resource-limited settings. The paper explores different types of GI nematodes, their characteristics, symptoms, and transmission pathways, highlighting the significant impacts these parasites can have, such as malnutrition, anemia, and cognitive impairments. Additionally, the manuscript emphasizes the importance of prevention and control strategies, including proper sanitation, personal hygiene, and public awareness, in minimizing the spread of these infections. It discusses the role of anthelmintic medications as a vital part of treatment, while also advocating for a comprehensive approach that incorporates improved living conditions, access to clean water, and health education for effective long-term management of GI nematode infections. Ultimately, this work highlights the necessity for coordinated public health initiatives and ongoing research to alleviate the burdens of GI nematodes and improve health outcomes in at-risk populations.

Keywords: Parasitology; Helminth; Nematodes; GI tract; human health.

1. INTRODUCTION

Parasitic infections are a significant global health issue, it causes more illness and increased mortality rate than other virulent diseases, particularly in developing countries. Every year, worldwide millions of people are affected by parasitic diseases, with the greatest impact observed in countries characterized by hot, humid climates and poor hygiene standards (Ghorbani, 2023). Parasites are divided into two main groups: (a) protozoa, single-celled organisms and (b) helminths, multi-celled organisms including cestodes, trematodes, and nematodes (Stepek *et al.,* 2006). Nematodes, generally termed as roundworms, represent among the most varied and numerous classes of multicellular organisms on the earth. These organisms inhabit diverse environments, ranging from soil and freshwater to marine ecosystems. While there are estimates of over 25,000 identified nematode species, the true number could be much higher, potentially surpassing 100,000, given that many species have yet to be formally described.

2. NEMATODES

Nematodes, commonly referred to as roundworms, are a diverse group of parasitic worms that significantly impact human health worldwide. Characterized by their elongated, cylindrical bodies, these organisms include various species that cause infections through

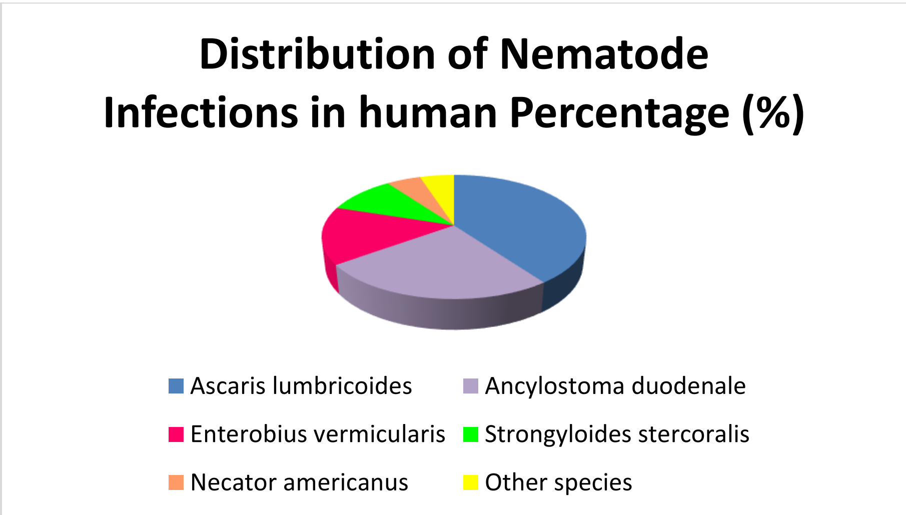

Fig. 1. Distribution of Nematode Infections in human

contaminated food, water, or soil. Notable human nematodes, such as *Enterobius vermicularis, Ascaris lumbricoides*, *Ancylostoma duodenale*, and *Trichuris trichiura*, are among the most prevalent parasites, particularly in regions with inadequate sanitation and hygiene standards (Salim *et al.,* 2021). Infections from these nematodes can result in numerous clinical symptoms, from mild gastrointestinal disturbances to extreme complications like malnutrition and anemia, particularly in vulnerable populations such as children. Many individuals may remain asymptomatic, enabling these infections to persist within communities. Understanding the epidemiology, transmission dynamics, and health consequences of human nematodes is essential for developing effective control strategies and improving global health outcomes (Chan (1997).

3. TYPES OF NEMATODES

3.1 Intestinal Nematodes

Intestinal nematodes are a significant group of parasitic worms that infect the gastrointestinal tract of humans, leading to a variety of health issues, particularly in tropical and subtropical regions, common species include *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm), and hookworms (*Necator americanus* and *Ancylostoma duodenale*). These parasites are transmitted by ingesting eggs in contaminated food or water or through skin contact with contaminated soil. (Ziegalbauer *et al.,* 2012).

Infection with intestinal nematodes often results in a range of symptoms, from mild gastrointestinal discomfort to severe conditions like malnutrition, anemia, and impaired physical and cognitive development in children. The prevalence of these parasites poses a significant public health challenge, particularly in impoverished communities with inadequate sanitation and hygiene practices.

3.2 Tissue Nematodes

Tissue nematodes represent a diverse group of parasitic worms that impact and cause diseases in humans and other animals, residing primarily in tissues such as muscle, skin, and lymphatic systems. Notable examples include *Brugia malayi, Wuchereria bancrofti*, *Brugia timori* and *Onchocerca volvulus*, that cause lymphatic filariasis and onchocerciasis, respectively. These nematodes are predominantly found in tropical and subtropical regions, where environmental conditions favor their transmission through vectors, particularly mosquitoes. The impact of tissue nematodes on public health is profound, as they can lead to debilitating conditions like elephantiasis and river blindness. These diseases not only result in considerable morbidity and mortality but also have extensive socio-economic consequences, disrupting livelihoods and burdening healthcare systems in endemic regions.

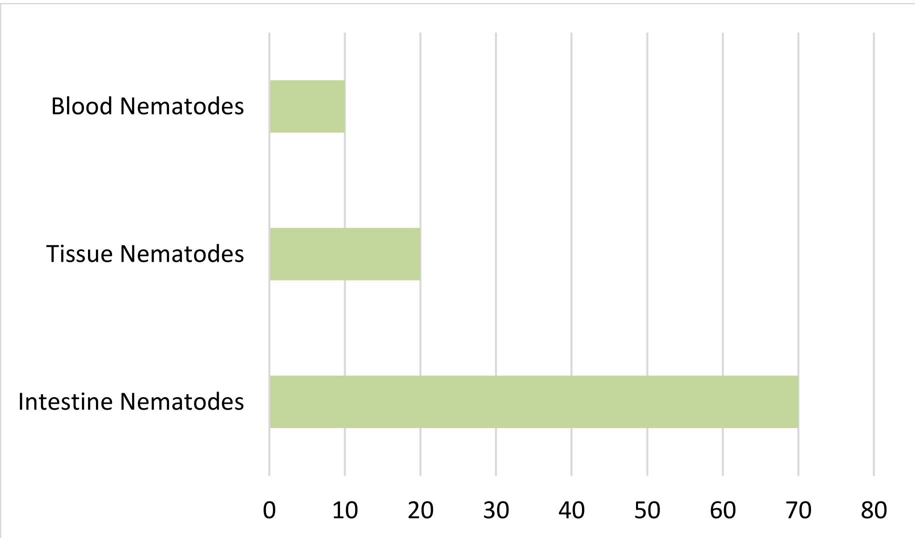

Fig. 2. Distribution of Nematodes by Primary Location in the Host (%)

3.3 Filarial Nematodes

Lymphatic filariasis (LF) is a mosquito-transmitted neglected tropical disease (NTD) caused by filarial nematodes, including *Brugia malayi*, *Brugia timori*, and *Wuchereria bancrofti*. It persists as an endemic health issue in 72 countries, placing over 860 million people at risk or already affected by the infection (WHO, 2021).

Filarial nematodes are a distinct group of parasites that primarily colonize in the lymphatic and subcutaneous tissues of humans, causing various health problems. Prominent species that cause lymphatic filariasis include *Brugia timori, Wuchereria bancrofti* and *Brugia malayi*, as well as *Onchocerca volvulus*, which leads to onchocerciasis, generally termed as river blindness. These nematodes are Spread to humans through bites from infected mosquitoes, resulting in a high prevalence in tropical and subtropical regions. Infections caused by filarial worms can lead to chronic and debilitating conditions, such as severe swelling (elephantiasis) and vision impairment. In addition to their detrimental effects on individual health, these diseases impose significant social and economic challenges On communities experiencing the effects, impacting productivity and access to essential resources. These parasites are conveyed to humans via the bites of infected mosquitoes. They can lead to chronic and debilitating diseases such as lymphatic filariasis and onchocerciasis, impacting millions of individuals in tropical and subtropical regions.

4. ASCARIS LUMBRICOIDES (ASCARIASIS)

Ascaris lumbricoides can infect people by ingesting microscopic eggs found in infected food, soil and water typically in areas with poor sanitation. Ascaris lumbricoides is responsible for ascariasis, a widespread roundworm infection commonly seen in children, particularly in developing countries with inadequate sanitation and hygiene. The infection is transmitted through contaminated soil and affects the small intestine (Tietze *et al.,* 1991; Wu and Jones 2000; Dongjain *et al.,* 2018). Female worms, which are larger in size than male worms, range from 15 to 35 cm in length and can release around 200,000 eggs/ day. Ultimately, *A.lumbricoides* eggs can exist in three different forms such as unfertilized, fertilized corticated and fertilized decorticated (WHO, 2019).

These parasitic eggs are excreted in human excrement and, once ingested, breakout in the intestines. The larvae subsequently move through the bloodstream then they migrate to the lungs, where they undergo maturation. The infected person may cough up the larvae, which are subsequently swallowed again, allowing them to return to the intestines and grow into adult worms. The life cycle of this parasite can span 2 to 3 years (Dold and Holland 2011 and Barid *et al.,* 1986). This cycle often occurs without immediate symptoms, allowing the infection to go unnoticed for long periods, sometimes years, especially in mild cases. Many individuals may remain asymptomatic until the worm load becomes significant, causing symptoms or complications like abdominal pain, respiratory issues, or digestive disturbances. (Tietze and Tietze 1991).

The Mini-FLOTAC technique method has demonstrated (Cringoli *et al.,* 2017) reliability in diagnosing *Ascaris lumbricoides* and other soil-transmitted helminths (STHs) (Benjamin-Chung *et al.,* 2015; Barda *et al.,* 2014; Lim *et al.,* 2018; Lamberton and Jourdan, 2015).

The fertilized corticated eggs of *Ascaris lumbricoides* are round, measuring 45–75 μm in diameter, consist thick outer shell and mamillated layer. In some cases, the outer layer is absent and resulting in fertilized decorticated eggs (Ash and Orihel, 2007). This characters of polumorphism can sometimes leads to the misidentifications of non-parasitic elements of *Ascaris lumbricoides* eggs (Colmer-Hamood, 2001; Speich *et al.,* 2015; WHO, 2016; Benjamin-Chung *et al.,* 2020).

The ability of the parasite to evade early detection and the widespread presence of its eggs in unsanitary environments contribute to its persistence and global prevalence, especially in developing countries. An adult *Ascaris* worm can live in the human intestine for several years often without causing noticeable symptoms until the infestation becomes significant. When the infection is severe, it can lead to various symptoms such as abdominal pain, loss of appetite, nausea, vomiting, shortness of breath, diarrhea, coughing with bloody mucus, wheezing, and fever. If left untreated, ascariasis can result in serious complications, including bowel obstruction, pancreatitis, and infection of the biliary tract or gallbladder. In rare cases, the worms may cause aspiration pneumonia, leading to chest discomfort. For treatment, the antiparasitic medications mebendazole and albendazole are commonly prescribed to expel the worms. In some instances, piperazine is used to paralyze the worms' muscles, making them easier to eliminate from the body (Harhay *et al.,* 2010 and Canterno *et al.,* 2020).

In Lahore, a study on *Ascaris lumbricoides* was conducted from November 2010 to October 2012, focusing on contaminated fecal samples from schoolchildren in urban areas. A total of 3,600 samples were collected across six different locations, with 32 samples (0.88%) testing positive for *Ascaris lumbricoides* eggs (Ali et al., 2020).

5. WUCHERERIA BANCROFTI (FILARIASIS)

Infection with lymphatic filariasis is often asymptomatic, but it can also lead to cause clinical symptoms which cause effective morbidity and in rare case mortality. The disease associated with morbidity include lymphangitis and lymphedema, majorly affecting the extremities. Furthermore, the conditions of filariasis cause secondary infections and dermatiditis, which may worsen the patient's overall health status (WHO, 2021).

Wuchereria bancrofti is a significant parasitic worm and the primary causative agent of lymphatic filariasis, more commonly known as elephantiasis. This disease is characterized by a nocturnal periodicity affecting the lymphatic system, leading to the development of inguinal or axillary lymphadenopathy in humans. This parasitic disease is common in tropical and subtropical regions, presenting a significant public health challenge. The transmission of *W. bancrofti* occurs through the bites of infected mosquitoes, particularly those of the *Culex*, *Aedes*, and *Anopheles* genera respectively, in Pacific and in Asia. When an infected mosquito bites a human, it injects larvae into the bloodstream, where they travel to the lymphatic system (Taylor *et al.,* 2010 and Plaisier *et al.,* 2000).

When a mosquito bites a human, it injects juvenile larvae into the bloodstream, which then migrate to the nearest lymph nodes to develop into adult worms. Once sexually mature, the adult worms reside in the lymphatic vessels and release thousands of sheathed microfilariae into the bloodstream. This circulation allows the microfilariae to be ingested by mosquitoes when they bite an infected individual, perpetuating the transmission cycle. If left untreated, the disease can progress to chronic lymphatic filariasis, which is associated with tropical eosinophilia and may manifest with asthmatic symptoms. The adult worms can live for several years in the lymphatic system, producing millions of microfilariae that continue to circulate in the bloodstream, sustaining the cycle of infection (Nutman and Kumaraswami, 2001). Two additional worms, *Brugia timori* and *Brugia malayi* also lead to lymphatic filariasis. However, *Wuchereria bancrofti* leads to approximately 90% of all cases of this disease. While many individuals infected with *W. bancrofti* remain asymptomatic, severe cases can lead to a range of debilitating symptoms. The most notable of these is the swelling of limbs, genitals, and breasts caused by lymphatic obstruction, which can significantly affect a person's quality of life. Chronic infections can result in complications such as lymphedema, where fluid accumulates in tissues, and hydrocele, which is the swelling of the scrotum due to fluid accumulation. These conditions can lead to social stigma and psychological distress for those affected (Kwan-Lim, 1990).

Diagnosis of lymphatic filariasis typically involves blood tests that detect the presence of microfilariae or clinical evaluations based on the patient's symptoms. Due to the periodicity of microfilariae in the bloodstream, blood samples are often taken at night when levels are highest. Symptoms of the disease may manifest as fever, skin exfoliation, discomfort in the testicular or inguinal regions, leg elephantiasis, and swelling of the arms, scrotum, vulva, and mammary glands (Nutman, 2001). The treatment for lymphatic filariasis primarily involves antiparasitic medications, including diethylcarbamazine (DEC), ivermectin, or albendazole. These medications aim to eliminate both adult worms and microfilariae from the body. Additionally, supportive care is often required to manage symptoms and prevent complications associated with the disease.

Preventive measures play a crucial role in controlling lymphatic filariasis. Efforts focus on mosquito control strategies, such as the use of insecticide-treated bed nets, environmental management to reduce mosquito breeding sites, and community-based mass drug dosage programs to reduce the impact of infection in endemic areas. Education and awareness campaigns are also essential to inform communities about the disease and promote practices that minimize transmission. It is estimated that over 31 million people in India are infected with microfilariae (Gaur *et al.,* 2007). Currently, the diagnosis of lymphatic filariasis involves various methods, including ELISA and PCR tests, as well as microscopic examination of blood smears to identify active infections. Ultrasonography is a quick method for detecting viable microfilarial worms by the sounds generated by moving adult worms, while X-ray techniques can identify dead worms (Laurence, 1989).

The preferred medications for treatment are diethylcarbamazine, albendazole, and ivermectin. Combination therapy using two of these drugs has proven more effective than any single medication. In 2015, William Campbell and Omura Satoshi received the Nobel Prize in Physiology or Medicine for their discovery of ivermectin, which has greatly decreased the global incidence of filariasis. Moreover, *Mansonella streptocerca*, a filarial worm transmitted by arthropods, causes subcutaneous filariasis in humans in the rainforests of Africa. Other filarial worms, such as *Loa loa* and *Onchocerca volvulus*, are responsible for diseases like They are responsible for African eye worm and river blindness, respectively. Diethylcarbamazine (DEC) has proven effective against both the microfilarial and adult stages of *M. streptocerca*. (Ta–Tang *et al.,* 2018; Pion *et al.,* 2019).

6. ANCYLOSTOMA DUADENALE (ANCYLOSTOMIASIS)

Ancylostoma duodenale is a prevalent, soil-transmitted hookworm that primarily affects humans in regions with warm, moist climates, including parts of Africa, Asia, and South America. This intestinal parasite, often associated with dogs and cats, causes a disease known as “ancylostomiasis” in humans. It is recognized as one of the most common zoonotic diseases and is classified among the most overlooked tropical diseases globally. The condition is also referred to as miner’s anemia, tunnel disease, and brickman’s anemia, Egyptian chlorosis, and old-world hookworm infection (Albonjco *et al.,* 1998). The life cycle starts when the worms eggs shed in the excrement of infected individuals hatch into larvae in the soil, which then develop into infective third-stage larvae capable of penetrating human skin, typically through direct contact with contaminated soil. This transmission often occurs in areas with poor sanitation and hygiene practices (Ashton *et al.,* 1998; Hoff *et al.,* 2008; Caliskan *et al.,* 2016). The disease is typically caused by infective larvae found in soil contaminated by dog and cat excrement. These penetrating larvae can enter humans through exposed skin, particularly when walking barefoot. Often, they only cause “cutaneous larva migrans,” A condition marked by itching and serpentine, snake-like patterns on the skin as the hookworms do not reach adulthood. However, in some cases, the larvae can enter the bloodstream and migrate to the lungs. When a person coughs up the larvae, they are swallowed again into the intestine, where they develop and reproduce. These worms are dioecious, with females capable of laying between 10,000 and 30,000 eggs daily, which are excreted in feces. The eggs subsequently develop into infective third-stage larvae within 5 to 10 days (Ronquillo *et al.,* 2019).

Clinical symptoms of ancylostomiasis can include abdominal pain, nausea, and vomiting, as well as more severe effects like iron deficiency anemia due to blood loss from the intestines (Changhua *et al.,* 1999 and Beigal *et al.,* 2000) Ancylostomiasis can lead to gastrointestinal bleeding, and chronic heavy infections may result in iron deficiency anemia. Symptoms may include paleness, shortness of breath, fatigue, rapid heartbeat, tiredness, and swelling in the extremities. In some cases, the infection can result in Löffler's syndrome, marked by coughing, wheezing, elevated eosinophils, coughing up blood, cramp-like abdominal pain, gas, diarrhoea, and weight loss. *Ancylostoma duodenale* infection typically presents as iron deficiency anaemia in tropical and subtropical region, through haemorrhage due to heavy infestation is rare (Tan *et al.,* 2017).

The most effective treatment is mebendazole, which typically requires only a single dose to eliminate the worms. Diagnosis often involves confirmed by identifying hookworm eggs in stool samples through microscopic examination. Preventive measures focus on improving sanitation, promoting the use of footwear To stay away from skin contact with contaminated soil, and educating communities about hygiene practices to reduce transmission risks. Understanding the epidemiology, transmission, and prevention of A. duodenale is crucial in combating this neglected tropical disease. Another hookworm, *Necator americanus*, commonly known as the “new world hookworm,” also causes a zoonotic disease in humans called necatoriasis. Its mode of infection is similar to that of *Ancylostoma duodenale* (Peduzzi *et al.,* 1983).

Ancylostoma duodenale and *Necator americanus* are key hookworms infecting humans. *Ancylostoma duodenal*, a soil-transmitted nematode that enter through the open wounded skin. The infection can cause iron deficiency anemia (IDA), fatigue and blood loss of up to 250ml/day in serious cases, associated with pregnant women particularly affected with *Ancylostoma duodenal* (Priti Karadbhajne1 *et al.,* 2012).

7. STRONGYLOIDES STERCORALIS (STRONGYLOIDIASIS)

The zoonotic intestinal pin-threadworm *Strongyloides stercoralis* leads to strongyloidiasis in humans. This parasite is commonly present in mammals such as cats and dogs and thrives in environments where fecal contamination of soil and water occurs. Infection happens when humans come into contact with contaminated soil, allowing larvae to enter the body. These larvae enter into lungs via the bloodstream, and when expelled through coughing, they are re-swallowed into the intestine, where they develop into adult female worms. after molting twice. Notably, only female worms reach reproductive maturity, producing eggs parthenogenetically (Ericsson *et al.,* 2001).

Common symptoms include localized itching with red rashes at the site of larval penetration, tracheal irritation leading to symptoms may include a dry cough, constipation, abdominal pain, and loss of appetite. In chronic cases, individuals might experience arthritis, arrhythmia, duodenal obstruction, nephritic syndrome, and recurrent asthma. Life-threatening complications, such as hyper infection syndrome and disseminated strongyloidiasis, can arise in immunocompromised individuals. Hyper infection syndrome is characterized by extensive larval proliferation, which can result in systemic sepsis and failure of multiple organs; however, it is often diagnosed late due to symptom overlap with classical strongyloidiasis (Czeresnia *et al.,* 2022). Autoinfection is another characteristic of strongyloidiasis, allowing the infection to persist indefinitely if untreated. Immunocompromised patients are particularly vulnerable, with hyper infective syndrome showing a death rate around 90%. Patients on high doses of corticosteroids are at increased risk for accelerated autoinfection, leading to larvae invading various organs. Repeated autoinfection can cause hives, particularly on the thighs and buttocks, with rashes rapidly advancing at a rate of up to 10 cm per hour (Keiser and Nutman, 2004). A specific form of larva migrans syndrome affecting the skin associated with *S. stercoralis* has also been recorded. Additionally, malnutrition may lead to peritoneal ascites and swollen belly syndrome in infants and children. Chronic strongyloidiasis has been linked to gastric and colorectal adenocarcinoma (Johnston *et al.,* 2005; Olsen *et al.,* 2009). Diagnosis typically involves examining stool samples for the parasite through direct fecal smears and culture agar plates, with serodiagnosis conducted via ELISA. Ivermectin is currently the first-line treatment for strongyloidiasis (Segarra-Newnham, 2007; Bounfrate *et al.,* 2013; Krolewiecki and Nutman, 2019; Bounfrate *et al.,* 2013).

Autoinfections are also seen in strongyloidiasis. It is understood that infections can persist in the human body for an indefinite period if not treated promptly. Likewise, an immunocompromised patient who becomes infected may develop hyperinfective syndrome, also known as disseminated strongyloidiasis. This condition is highly lethal, with a mortality rate approaching 90%. Patients receiving high doses of corticosteroids may experience accelerated autoinfection, allowing migratory larvae to invade various organs in the body. (Igra-Siegman *et al.,* 1981; Marcos *et al.,* 2008; Arthur and Shelley, 1958). Stool samples are analyzed to detect the parasite using direct fecal smears and culture agar plates. Serodiagnosis is also performed through ELISA. Currently, ivermectin is the preferred medication for physicians treating strongyloidiasis.

8. ENTEROBIUS VERMICULARIS (ENTEROBIASIS)

Enterobius vermicularis, commonly known as the pinworm, threadworm, or seat worm, is a prevalent parasitic nematode found in the human intestine. It causes enterobiasis, also referred to as pinworm infection or oxyuriasis, and is particularly common among children worldwide. The eggs are typically laid around the anus, leading to intense anal itching, which plays a significant role in the transmission of the infection. This nocturnal itching often disrupts sleep in affected children, making nights particularly uncomfortable (Cook, 1994).

The life cycle of *E. vermicularis* takes approximately 4 to 8 weeks to complete. Transmission occurs via the ingestion of eggs, these hatch into larvae in the duodenum, where they quickly develop and migrate to the small intestine and colon, mating in the ileum. After molting twice, they mature into adults. Male worms typically die after mating and are expelled in the stool, while gravid females attach to the ileum, cecum, appendix, or ascending colon. Once full of eggs, the female migrates to the anus to deposit her eggs before dying (Jong *et al.,* 2003; Rajendran *et al.,* 2015). In addition to anal itching, other clinical symptoms of *E. vermicularis* infection include Symptoms include disturbed sleep, restlessness, irritability, loss of appetite, abdominal pain, diarrhoea, emotional instability, and bedwetting. Untreated chronic infections can result in vulvar and vaginal inflammation, as well as urogenital infections, since the parasites may migrate to the uterine cavity, fallopian tubes, peritoneal cavity, and appendix surface, carrying bacteria and other pathogens. (Aziz Kadir, and Amin, 2011). Young girls with urinary tract infections (UTIs) have also been found to have concurrent pinworm infections, and cases of pelvic masses due to *E. vermicularis* infestation in the fallopian tubes have been reported.

Diagnosis mainly involves identifying eggs or light-yellow adult pinworms. An adhesive tape test placed around the anal area can also detect the presence of eggs. The preferred treatments for pinworm elimination include benzimidazole, albendazole, and mebendazole, which inhibit microtubule function and cause glycogen depletion in the parasites, effectively starving them. Pyrantel pamoate is another option that kills adult worms by inducing neuromuscular blockage (Vermund, Wilson, 2000). Other options include piperazine and pyrantel pamoate, which cause paralysis and induce oxygen deprivation in pinworms, respectively. Because these medications primarily target adult worms, long-term treatment at regular intervals is often required to achieve the best outcomes. (Dong *et al.,* 2010).

9. TRICHURIS TRICHIURA (TRICHURIASIS)

Trichuris trichiura, also known as whipworm, is the third greatest prevalent nematode affecting humans. This prominent intestinal parasite is responsible for inducing trichuriasis, characterized by its whip-like shape. Humans serve as the primary host for this parasite. The eggs of *T. trichiura* are released into the soil via human feces, particularly in areas where untreated feces are utilized as fertilizer might lead to significant contamination of vegetables, food, and potable water. Children who play in such contaminated soil are particularly susceptible to infection (Stephenson *et al.,* 2000).

More than 70 species of genus *Trichuris* have been identified. While these species are generally specific to their hosts, instances of cross-host transmission have been observed, including between humans and pigs, humans and dogs, and humans and non-human primates (Hawash, 2016; Areekul *et al.,* 2010; Cavallero, 2015).

Once ingested, the eggs hatch in the small intestine, and the larvae mature into dioecious adult worms that inhabit the human colon, where they can live for about a year (Bundy *et al.,* 1989). While most infected individuals remain asymptomatic, heavy infections can lead to clinical manifestations such as abdominal pain, nocturnal diarrhea, blood in the fecal, Decreased appetite, weight reduction, rectal prolapse, and anemia. In children, severe cases may lead to trichuriasis dysentery syndrome (TDS), which presents with mucoid diarrhea, rectal bleeding, and rectal prolapse (Ok *et al.,* 2009). Diagnosis of *T. trichiura* infection typically involves a stool test to identify the characteristic whipworm eggs. The Kato-Katz thick smear method is commonly employed for egg detection, while colonoscopy can be used to visualize adult worms. Effective treatment options include mebendazole, albendazole, and ivermectin, which have been shown to achieve a high clearance rate for the infection (Stephenson *et al.,* 2001).

10. TRICHINELLA SPIRALIS (TRICHINOSIS)

Another name of *Trichinella spiralis,* also known as *Trichinia spiralis*, is a well-known parasitic nematode responsible for the disease trichinosis in humans. This parasite is predominantly associated with domestic pigs, particularly in several Eastern European and Asian countries. It is important to differentiate *T. spiralis* from *Taenia solium*, as they are distinct organisms. *T. spiralis* is the smallest nematode that infects humans globally and holds the title of the largest intracellular parasite (Campbell, 2012).

Pigs become infected by consuming raw meat containing encysted larvae. Once ingested, the cysts are released in the stomach through the action of protein-digesting enzymes such as pepsin and hydrochloric acid. The larvae then migrate to the small intestine, where they mature into adult worms. Female worms are notably larger than their male counterparts, often being twice their size. After mating, females produce new larvae that migrate to the striated muscles, where they encyst again. Unlike soil-transmitted parasites, *T. spiralis* does not lay eggs, and adult worms do not survive long outside of a host (Murrell and Pozio, 2000). Humans contract *T. spiralis* through the consumption of undercooked or raw pork containing these cysts. Similar to pigs, the cysts are released in the stomach upon digestion, allowing the larvae to migrate to the small intestine where they mature and reproduce (Taratuto, and Venturiello, 1997). The new larvae then enter the lymphatic system and bloodstream, spreading throughout various organs, including the Heart muscle, lymphatic nodes, and cornea, kidneys, and Musculo-skeletal system. However, it is primarily the larvae that migrate to the skeletal muscles that survive, forming cysts known as nurse cells (Mitreva, and Jasmer, 2006).

Symptoms of trichinosis typically manifest within 12 hours of consuming infected pork, initially presenting as nausea, vomiting, abdominal pain, and diarrhea. If left untreated, additional symptoms may appear 5 to 7 days post-ingestion, including facial edema (especially around the eyes), fever, splinter hemorrhages, and skin rashes. By the tenth day, further complications can arise, such as severe muscle edema and soreness (myalgia), weakness (asthenia), lung edema leading to difficulty breathing, pneumonia, and disturbances in pulse and blood pressure. In rare cases, more severe neurological complications, such as meningitis and encephalitis, may develop (Pozio *et al.,* 2009).

Diagnosis of trichinosis typically involves identifying larvae in muscle tissue, often through muscle biopsy. Testing of meat samples can also aid in diagnosis. Additionally, immunological tests such as ELISA are available for detection. Treatment options include mebendazole, albendazole, and thiabendazole. Currently, there are no vaccines available for preventing trichinosis, highlighting the importance of proper cooking methods for pork to mitigate infection risk (Dordevic, *et al.,* 1991 and Yao *et al.,* 2001).

11. DOG AND CAT NEMATODS

Nematodes, commonly known as roundworms, represent a diverse group of parasitic worms that can infect domestic animals, particularly dogs and cats, leading to a range of health complications. These parasites thrive in various environments and are primarily transmitted through contaminated soil, feces, or intermediate hosts. In canines, species such as *Toxocara canis* and *Ancylostoma caninum* can cause significant gastrointestinal disturbances, anemia, and developmental issues in young animals. Similarly, *Toxocara cati* can infect felines and poses zoonotic risks to humans, especially children, potentially resulting in conditions like visceral larva migrans.

To mitigate these health risks, regular veterinary care, including fecal examinations and preventive deworming protocols, is crucial. Understanding the life cycles and transmission pathways of these nematodes is essential for effective management and control, ensuring the health and well-being of both pets and their human caregivers. By implementing appropriate preventive measures, the incidence of nematode infections can be significantly reduced, promoting a healthier environment for all.

12. TOXOCARA CANIS (TOXOCARIASIS)

Toxocara canis is a parasitic roundworm primarily found in dogs, responsible for causing toxocariasis in humans. This zoonotic infection occurs when humans, especially children, accidentally ingest the parasite's eggs through contaminated soil or surfaces exposed to dog feces. Once ingested, the larvae migrate through various tissues without developing into adult worms, potentially leading to conditions such as visceral larva migrans (VLM) and ocular larva migrans (OLM) (Nicoletti, 2013). Symptoms of VLM may include fever, coughing, abdominal pain, hepatomegaly, and respiratory issues, while OLM can result in vision problems, including blurred vision and even blindness. Diagnosis typically involves a clinical assessment of symptoms, serology tests to detect specific antibodies against *Toxocara canis*, and evaluating eosinophil counts in the blood. Imaging studies may also be used to assess ocular involvement. Preventative measures include regular deworming of pets and practicing good hygiene to reduce the risk of exposure to contaminated environments (Hamilton, *et al.,* 2014).

13. TOXOCARA CATI (TOXOCARIASIS)

Toxocara cati is a parasitic roundworm primarily found in cats, responsible for the zoonotic infection known as toxocariasis in humans. This infection typically occurs when individuals, especially children, accidentally ingest the eggs of the parasite through contaminated soil, surfaces, or unwashed fruits and vegetables (Fisher, 2003). Upon entering the human body, the larvae migrate through various tissues, leading to conditions such as visceral larva migrans (VLM) and ocular larva migrans (OLM). Symptoms of VLM may include fever, cough, abdominal pain, and liver enlargement, while OLM can cause significant eye issues, including blurred vision and potential blindness. Diagnosis often involves serological tests to detect antibodies against *Toxocara cati* and may be complemented by imaging studies for ocular manifestations. Preventative strategies focus on regular deworming of cats and maintaining proper hygiene to reduce exposure to contaminated environments (Nicoletti, 2013).

The study examined the molecular prevalence of *Toxocara canis* and *T. cati* in stray dogs and cats in Bangkok, Thailand, collecting 1,000 fecal samples (500 from each). *T. canis* was found in 5.4% of stray dogs, primarily in Bang Khen district, while *T. cati* was detected in 0.6% of stray cats in Lat Krabang district. These results indicate a significant public health risk from zoonotic parasites, especially *T. canis* (Maciag *et al.,* 2022).

Stray or neglected dogs and cats often have poor health due to various helminths diseases, posing a significant risk for zoonotic infections. Environmental contamination with helminth eggs or protozoan cysts is highly associated with the prevalence of intestinal parasitic infections in these animals (Overgaauw *et al.,* 2013).

14. FISH NEMATODS

14.1 *Anisakis simplex* (Anisakiasis)

Anisakis simplex is a parasitic roundworm commonly found in marine fish and seafood, causing the zoonotic infection known as anisakiasis in humans. Infection occurs when individuals consume raw or inadequately cooked fish harbouring the parasite's larvae. Once ingested, the larvae can invade the stomach or intestinal wall, resulting in symptoms such as intense abdominal pain, nausea, vomiting, and diarrhoea (Arizono *et al.,* 2012). Additionally, some individuals may experience allergic reactions. Diagnosis often involves endoscopy to detect the larvae or imaging techniques to assess related inflammation. Preventive measures include thoroughly cooking fish to eliminate any potential larvae and freezing fish at designated temperatures to kill the parasite (Sakanari and Mckerrow, 1989).

14.2 *Capillaria philippinensis* (Capillarisis)

Capillaria philippinensis, the causative agent of capillariasis, is primarily transmitted to humans through the ingestion of undercooked or raw freshwater fish that harbour the infective larvae of the parasite. The life cycle of this nematode is complex and involves definitive hosts, mainly fish-eating birds, where adult worms reside in the intestinal tract. In these birds, the worms lay eggs that are expelled into the environment through feces (Lu et al., 2006). Once released into freshwater ecosystems, these eggs can become embryonated and develop into infective larvae. The larvae are then ingested by fish, particularly species commonly found in tropical and subtropical regions. Humans typically acquire the infection by consuming contaminated fish that have not been properly cooked, as the cooking process is essential for killing the larvae (Watten *et al.,* 1972).

In the human host, the ingested larvae mature in the intestine, leading to infection and the potential development of symptoms. Capillariasis can cause a range of gastrointestinal issues, including abdominal pain, diarrhoea, and malnutrition, particularly in areas where consumption of raw or undercooked fish is common. The transmission cycle highlights the importance of proper cooking practices and hygiene to prevent infection and mitigate the risk associated with consuming contaminated seafood (Khalifa *et al.,* 2020).

14.3 *Gnathostoma spinigerum* (Ganthostomiasis)

Gnathostoma spinigerum is a parasitic nematode that causes gnathostomiasis, an infection linked to the consumption of undercooked or raw freshwater fish, eels, and amphibians. This parasite is endemic in several regions, especially Southeast Asia, Latin America, and parts of Africa, where local culinary practices often involve raw aquatic animals (Tapchaisri *et al.,* 1991). The life cycle of *Gnathostoma spinigerum* starts with eggs excreted by definitive hosts, typically carnivorous mammals like cats and dogs, hatching in freshwater. This releases first-stage larvae, which can be ingested by intermediate hosts such as fish and eels, where they develop into second-stage larvae. Humans become infected when they consume inadequately cooked infected fish, allowing the larvae to migrate through the intestinal wall and into various tissues.

Initial symptoms of gnathostomiasis may include gastrointestinal issues, such as abdominal pain and nausea, along with cutaneous manifestations like itchy, migratory skin lesions. In more severe cases, systemic symptoms can develop, including fever and muscle pain, particularly if larvae invade critical organs (Nawa, and Nakamura-Uchiyama, 2004). Diagnosis usually involves serological tests to detect specific antibodies, imaging techniques to locate migrating larvae, and tissue biopsies to confirm their presence. Treatment typically includes antiparasitic medications that can help relieve symptoms and lower the risk of complications.

14.4 Raccoon Nematodes

Raccoon nematodes, primarily from the genus Baylisascaris, are parasitic roundworms commonly found in raccoons (Procyon lotor), posing potential health risks to other animals and humans. The most notable species, *Baylisascaris procyonis*, is particularly widespread in North America. These nematodes reside in the intestines of raccoons, where they mature into adult worms and release eggs into the raccoon's feces. In areas with high raccoon populations, these eggs can contaminate the environment, especially soil, leading to accidental ingestion by other animals or humans. The life cycle of *Baylisascaris procyonis* involves various potential hosts, including rodents and other mammals, which can experience severe neurological or visceral diseases upon infection with the larval form of the parasite. In humans, accidental ingestion of the eggs can result in baylisascariasis, a serious condition that may cause neurological damage or organ dysfunction. Understanding the implications of raccoon nematodes for both animal and human health is crucial, particularly in urban and suburban settings where raccoon populations are increasing. Implementing preventive measures, such as maintaining proper sanitation and managing wildlife, can help reduce the risks associated with these parasitic nematodes.

14.5 *Baylisascaris procyonis* (Baylisascariasis)

Baylisascaris procyonis is a parasitic roundworm predominantly found in raccoons (Procyon lotor), where it resides and matures in the intestines. This parasite is noteworthy for its ability to cause baylisascariasis, a severe zoonotic infection that can affect various hosts, including humans. The life cycle of *Baylisascaris procyonis* begins when adult females release eggs in raccoon feces, which can contaminate soil and surfaces in areas frequented by these animals (Gavin *et al.,* 2005). Humans may become infected by accidentally ingesting the eggs, often through contact with contaminated soil, water, or surfaces. Once ingested, the eggs hatch in the intestines, releasing larvae that can migrate to different tissues and organs, including the brain and eyes.

This migration can lead to severe neurological damage, vision impairment, and, in some cases, may be fatal. Symptoms of baylisascariasis can include fever, lethargy, respiratory distress, and neurological issues such as seizures or behavioral changes (Sorvillo, et al., 2002). Diagnosing baylisascariasis can be difficult due to the nonspecific nature of the symptoms and the need for a background of exposure to raccoon faecal excrement. Confirmatory tests may include serological assays or identify larvae in tissue samples. Preventive measures are essential, especially in areas with significant raccoon populations, and include maintaining proper sanitation, avoiding contact with raccoon faces, and educating the public about the associated risks of raccoon habitats.

15. CONSEQUENCES OF GASTROINTESTINAL TRACT INFECTIONS

In cases of heavy infections caused by gastrointestinal nematodes, the predominant symptoms typically include gastrointestinal disturbances such as diarrhea and abdominal pain. In the case of *Ascaris lumbricoides*, intestinal obstruction may also occur (Gonzalez & Javier de la Cabada 1987; Kucik *et al.,* 2004).

16. ANEMIA

Anemia is a major predominant gastrointestinal nematode infection, particularly those caused by hookworms, although heavy infections of *Trichuris trichiura* have also been associated with iron-deficiency anemia (Gilgen *et al.,* 2001). Most instances of hookworm-induced anemia are found among rural populations in developing countries, where individuals rely on agricultural work as their primary source of income (Gilles 1968; Clinch & Stephens 2000).. This anemia reduces their physical capacity to engage in work, resulting in poor nutrition and a heightened risk of hookworm infection, thereby creating a vicious cycle (Crompton 1986). The severity of anemia is affected by the infection's intensity, the particular species of nematode involved (with *Ancylostoma duodenale* resulting in significantly greater blood loss than *Necator americanus*), as well as the host's nutritional status and iron intake (Albonico *et al.,* 1998).

Pregnant women with hookworm infections have a higher risk of developing severe iron-deficiency anemia than their non-pregnant counterparts, primarily due to the greater iron demands during pregnancy. This worsening anemia can contribute to maternal mortality and increase the risks for the fetus, including premature birth (Dreyfuss *et al.,* 2000). As a result, hookworms are a major contributor to the global prevalence of anemia, particularly among malnourished pregnant women in developing countries (Bundy *et al.,* 1995).

17. MAL NUTRITION

Livestock infected with gastrointestinal (GI) nematodes exhibit varying abilities to cope with these infections, depending on their nutritional status (Coop & Kyriazakis, 2001). This is also true for humans, particularly in endemic regions characterized by poverty, poor sanitation, and inadequate hygiene, leading to malnutrition and iron deficiency anemia. Such infections are particularly harmful to malnourished children (Stephenson *et al.,* 2000), worsening their nutritional status and reducing appetite, thereby impacting their physical, cognitive, and social development (Crompton, 1986; Dossa *et al.,* 2001).

GI nematodes damage the intestinal lining, hindering nutrient absorption and causing stunted growth. (Stephenson, 1999), which can decrease adult productivity in developing countries (Guyatt, 2000). Nevertheless, treatments like a single dose of albendazole can significantly improve growth rates, weight, physical fitness, and appetite in infected children (Stephenson *et al.,* 1993).

Moderate to heavy infections of *Trichuris trichiura* or hookworms in schoolchildren are linked to poor attendance and reduced cognitive function, with effects correlating to malnutrition and infection severity. Thankfully, cognitive impairments can be reversed with anthelmintic treatment, suggesting that better nutrition and lower infection rates can enhance educational outcomes (Nokes *et al.,* 1992a,b; Simeon *et al.,* 1995).

18. SECONDARY INFECTIONS

Nematodes can cause secondary infections that result in serious health complications, largely due to their immunosuppressive effects on the host's immune system (Stürchler 1987). These parasites often induce a Th2 immune response, which dampens the Th1 response vital for fighting off other infections. This shift in immune response increases susceptibility to secondary infections, particularly in individuals with underlying conditions like tuberculosis (TB) or human immunodeficiency virus (HIV), where the presence of nematodes can hasten disease progression. Additionally, co-infection with nematodes and other pathogens may worsen symptoms and complicate treatment efforts (Gonzalez & Javier de la Cabada 1987). The gastrointestinal issues and malabsorption linked to nematode infections can also lead to malnutrition, further compromising the immune system and increasing the risk of various infections (Jain *et al.,* 1994; Milder *et al.,* 1981; Schneider & Rogers 1997;). Ultimately, the interaction between nematode infections and secondary infections presents a significant public health challenge, particularly in endemic regions, underscoring the need for effective treatment strategies that address both types of infections to enhance overall health outcomes. (Gilles 1968; Bwibo 1971; Fisher *et al.,* 1993; Tsai *et al.,* 2002; Keiser & Nutman 2004).

19. CONTROL OF GI TRACT NEMATODS

Effective control of nematode infections in humans and animals is crucial for public health and agricultural productivity. Several strategies can be employed to manage these parasites.

20. MASS DRUG ADMINISTRATION

The primary strategy for controlling human gastrointestinal (GI) nematode infections involves administering one of four anthelmintic drugs recommended by the World Health Organization (WHO): albendazole, mebendazole, levamisole, and pyrantel. Each drug targets specific major GI nematodes and falls into two main categories: group 1 (benzimidazoles: albendazole and mebendazole) and group 2 (imidazothiazoles/ tetrahydropyrimidines: levamisole and pyrantel). A third class, macrocyclic lactones (group 3; e.g., ivermectin), is effective against certain GI nematodes but requires multiple doses and has variable efficacy across species, with no single drug achieving 100% effectiveness against all nematodes.

For example, albendazole has proven effective in reducing infections from *Ascaris*, hookworms, and *Trichuris* in school-aged children, leading to significant improvements in growth, weight, physical fitness, cognition, and nutrition (Stephenson *et al.,* 1993). However, its efficacy varies by species, with reported cure rates of 95% for *Ascaris*, 78% for hookworms, and only 48% for *Trichuris* (Horton, 2000). Treating *Strongyloides stercoralis* is more challenging, as the commonly used anthelmintics like mebendazole and pyrantel exhibit low efficacy, while thiabendazole is the most effective option. However, it is associated with side effects in about 50% of cases, including nausea, dizziness, weakness, loss of appetite, vomiting, and headaches.

Albendazole and ivermectin are more effective with fewer side effects, with ivermectin recently approved for strongyloidiasis in France, Australia, and the USA. Benzimidazoles inhibit β-tubulin polymerization, disrupting glucose uptake in parasites. Imidazothiazoles and tetrahydropyrimidines stimulate nicotinic acetylcholine receptors, causing paralysis through overstimulation (Cook 1986; Sturchler 1987; Schneider & Rogers 1997). Macrocyclic lactones induce flaccid paralysis by opening glutamate-gated chloride channels. Heterocyclic ethyleneamines, like piperazine, inhibit neuromuscular transmission via GABA receptor stimulation, targeting *A. lumbricoides* and *E. vermicularis*. While generally safe with minor gastrointestinal side effects, these anthelmintics are not recommended for pregnant women, especially during the first trimester ((Rang *et al.,* 2003).

Though albendazole and ivermectin have seen greater effectiveness with fewer side effects - and ivermectin has recently been approved for use in France, Australia, and the USA for strongyloidiasis - it is still considered standard treatment Benzimidazoles are broad-spectrum drugs that inhibit the polymerization of free β-tubulin, disrupting microtubule-dependent glucose uptake in the parasites. The imidazothiazoles/tetrahydropyrimidines stimulate nicotinic acetylcholine receptors, leading to overstimulation and paralysis of the worms, which are then expelled through intestinal peristalsis. Macrocyclic lactones function by opening glutamate-gated chloride channels, resulting in flaccid paralysis due to disrupted neurotransmission. There is also a fourth class of anthelmintics, heterocyclic ethyleneamines, with piperazine being the most well-known member, used exclusively against A. lumbricoides and Enterobius vermicularis. Piperazine works by inhibiting neuromuscular transmission through GABA receptor stimulation, causing paralysis and subsequent removal by peristalsis These anthelmintics are generally safe and have few minor gastrointestinal side effects, but none are recommended for pregnant women, particularly during the first trimester. Although these drugs can be administered as single doses, their efficacy is enhanced with repeated treatments.

21. VECTOR CONTROL

Nematodes, particularly those responsible for zoonotic diseases, often rely on specific vectors for transmission to their hosts. Mosquitoes, such as those from the *Anopheles*, *Aedes*, and *Culex* genera, are crucial vectors for lymphatic filariasis (*Wuchereria bancrofti* and *Brugia malayi*) and onchocerciasis (*Onchocerca volvulus*). Blackflies (*Simulium* species) are similarly significant in the transmission of onchocerciasis, while fleas (*Ctenocephalides* species) can act as vectors for some nematodes and tapeworms. Sandflies, including *Phlebotomus* and *Lutzomyia* species, transmit *Dirofilaria immitis*, the canine heartworm, which can also infect humans. Ticks, particularly those from the *Ixodes* genus, are another vector that can transmit certain nematodes in specific regions. Rodents may also serve as intermediate hosts for nematodes like *Baylisascaris procyonis*, which primarily affects raccoons but poses risks to other animals and humans. Understanding the roles of these vectors is essential for developing targeted control strategies to mitigate the transmission of nematode infections and reduce the associated health risks.

22. SANITATION AND HYGIENE PRACTICE

The gastrointestinal (GI) nematodes were transmitted into human through GI tract, except *Enterobius vermicularis*, can be effectively prevented through the proper disposal of human excrement in latrines, as humans are the only hosts for these parasites (Cook, 1994; Kucik *et al.,* 2004). Proper sanitation is crucial, given that the infective stages exit solely through human faces. Maintaining good personal hygiene and cleanliness is essential for preventing infections, particularly with *E. vermicularis*. (Gonzalez & Javier de la Cabada, 1987).

Dogs can act as reservoirs for zoonotic parasites, especially in areas with inadequate sanitation. In Northeastern India, viable eggs of *Trichuris trichiura* and *Ascaris lumbricoides* were found in the feces of pet dogs, indicating they may transmit these infections by ingesting infected human feces (Traub *et al.,* 2002). Additionally, direct contact with infected dogs, whose coats may carry *Toxocara canis* eggs, also contributes to transmission (Wolfe & Wright, 2003). Thus, improving hygiene practices is vital for reducing the spread of these parasites.

Public health education is a crucial component of integrated control programs, particularly to discourage geophagy, which is associated with increased infection rates of *T. trichiura, A. lumbricoides* and *T. canis* (Glickman *et al.,* 1999 and Geissler *et al.,* 1998). Control efforts should target school-aged children, who are most vulnerable to infection, while also addressing older community members to effectively manage hookworm infections (Bundy *et al.,* 1988). While current anthelmintics can significantly lower parasite burdens, an integrated approach encompassing improved sanitation, hygiene practices, health education, and nutritional status, combined with the strategic administration of anthelmintics, is essential for the effective control of GI nematode infections. This comprehensive strategy will prolong the efficacy of existing anthelmintic treatments and help delay reinfection.

23. CONCLUSION

In conclusion, this manuscript provides a thorough overview of nematodes, with a particular emphasis on gastrointestinal (GI) nematodes and their effects on human health. We have discussed various types of nematodes, detailing their unique characteristics, symptoms, and modes of transmission. The detrimental impacts of GI nematodes, including malnutrition, anemia, and impaired cognitive function, are especially severe in vulnerable groups, such as children and individuals living in poverty. To effectively prevent and control these parasitic infections, it is essential to implement strategies that enhance sanitation, promote personal hygiene, and educate communities about zoonotic transmission risks. Additionally, the targeted use of anthelmintic medications can significantly decrease worm burdens and related health issues. However, a comprehensive approach that integrates health education, improved living conditions, and access to clean water is vital for achieving lasting success. Ultimately, addressing the challenges associated with GI nematodes requires a concerted effort involving public health initiatives, community involvement, and continued research to create innovative control measures. By adopting these strategies, we can significantly reduce the prevalence of nematode infections and enhance health outcomes for affected populations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Albonico, M., Crompton, D. W. T., & Savioli, L. (1999). Control strategies for human intestinal nematode infections. *Advances in Parasitology, 42,* 277–341.

Albonico, M., Stoltzfus, R. J., Savioli, L., Tielsch, J. M., Chwaya, H. M., Ercole, E., & Cancrini, G. (1998). Epidemiological evidence for a differential effect of hookworm species, *Ancylostoma duodenale* or *Necator americanus*, on iron status of children. *International Journal of Epidemiology, 27*(3), 530-537.

Ali, S. A., Niaz, S., Aguilar-Marcelino, L., Ali, W., Ali, M., Khan, A., & Amaro-Estrada, I. (2020). Prevalence of *Ascaris lumbricoides* in contaminated faecal samples of children residing in urban areas of Lahore, Pakistan. *Scientific Reports*, 10(1), 21815.

Areekul, P., Putaporntip, C., Pattanawong, U., Sitthicharoenchai, P., & Jongwutiwes, S. (2010). *Trichuris vulpis* and *T. trichiura* infections among schoolchildren of a rural community in northwestern Thailand: The possible role of dogs in disease transmission. *Asian Biomedicine*, 4, 49–60.

Arizono, N., Yamada, M., Tegoshi, T., & Yoshikawa, M. (2012). *Anisakis simplex* sensu stricto and *Anisakis pegreffii*: Biological characteristics and pathogenetic potential in human anisakiasis. *Foodborne Pathogens and Disease, 9*(6), 517-521.

Arthur, R. P., & Shelley, W. B. (1958). Larva currens; a distinctive variant of cutaneous larva migrans due to *Strongyloides stercoralis*. *AMA Archives of Dermatology, 78*(2), 186-190.

Ashton, F., Schad, G., & Li, J. (1999). Chemo and thermosensory neurons: Structure and function in animal parasitic nematodes. *Veterinary Parasitology, 84,* 297-316.

Aziz Kadir, M. A., & Amin, O. M. (2011). Prevalence of enterobiasis (*Enterobius vermicularis*) and its impact on children in Kalar/Sulaimania-Iraq. *Tikrit Medical Journal, 17*(2).

Barda, B., Cajal, P., Villagran, E., Cimino, R., Juarez, M., Krolewiecki, A., Rinaldi, L., Cringoli, G., Burioni, R., & Albonico, M. (2014). Mini-FLOTAC, Kato-Katz and McMaster: Three methods, one goal; highlights from north Argentina. *Parasites & Vectors, 7,* 271.

Barid, J. K., Mistrey, M., Pimsler, M., & Connor, D. H. (1986). Fatal human ascariasis following secondary massive infection. *The American Journal of Tropical Medicine and Hygiene, 35*(2), 314-318.

Beigal, Y., Greenburg, Z., & Ostfeld, I. (2000). Letting the patient off the hook. *The New England Journal of Medicine, 342*(22), 1658-1661.

Benjamin-Chung, J., Pilotte, N., Ercumen, A., Grant, J. R., Maasch, J. R., Gonzalez, A. M., ... & Colford Jr, J. M. (2020). Comparison of multi-parallel qPCR and double-slide Kato-Katz for detection of soil-transmitted helminth infection among children in rural Bangladesh. *PLoS Neglected Tropical Diseases, 14*(4), e0008087.

Bounfrate, D., Requena, M. A., Angheben, A., Munoj, J., & Bisoffi, Z. (2013). Severe strongyloidiasis: A systematic review of case reports. *BMC Infectious Diseases, 13,* 78.

Bundy, D. A. P., & Cooper, E. S. (1989). Trichuris and trichuriasis in humans. *Advances in Parasitology, 28,* 107-173.

Bundy, D. A. P., Kan, S. P., & Rose, R. (1988). Age-related prevalence, intensity and frequency distribution of gastrointestinal helminth infection in urban slum children from Kuala Lumpur, Malaysia. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 82,* 289–294.

Bwibo, N. O. (1971). Clinical significance of *Strongyloides* in African children. *Journal of Tropical Medicine and Hygiene, 74,* 79–81.

Caliskan, E., Uslu, E., Turan, H., Baskan, E., & Kilic, N. (2016). Cutaneous larva migrans: Report of three cases from the western Black Sea region, Turkey. *Turkish Microbiological Bulletin, 50*(1), 165-169.

Campbell, W. (Ed.). (2012). *Trichinella and trichinosis*. Springer Science & Business Media.

Canterno, L. O., Turchi, M. D., Correa, I., & Monteiro, R. A. (2020). Anthelminthic drugs for treating ascariasis. *The Cochrane Database of Systematic Reviews, 4,* CD010599.

Cavallero, S., et al. (2015). Genetic heterogeneity and phylogeny of *Trichuris* spp. from captive non-human primates based on ribosomal DNA sequence data. *Infection, Genetics and Evolution*, 34, 450–456.

Chan, M.-S. (1997). The global burden of intestinal nematode infections – fifty years on. *Parasitol. Today, 13,* 438–443.

Changhua, L., Xiaorong, Z., Dongchuan, Q., Shuhua, X., & Hotez, P. (1999). Epidemiology of human hookworm infections among adult villagers in Hejiang and Santai Counties, Sichuan Province, China. *Acta Tropica, 73,* 243-249.

Colmer-Hamood, J. A. (2001). Fecal microscopy: Artifacts mimicking ova and parasites. *Laboratory Medicine, 32,* 80–84.

Cook, G. C. (1994). *Enterobius vermicularis* infection. *Gut, 35*(9), 1159.

Coop, R. L., & Kyriazakis, I. (2001). Influence of host nutrition on the development and consequences of nematode parasitism in ruminants. *Trends in Parasitology, 17*(7), 325-330.

Cringoli, G., Rinaldi, L., Maurelli, M. P., & Utzinger, J. (2010). FLOTAC: New multivalent techniques for qualitative and quantitative copromicroscopic diagnosis of parasites in animals and humans. *Nature Protocols, 5,* 503–515. https://doi.org/10.1038/nprot.2009.235

Crompton, D. W. T. (1986). Nutritional aspects of infection. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 80,* 697–705.

Czeresnia, J. M., & Weiss, L. M. (2022). *Strongyloides stercoralis*. *Lung, 200*(2), 141-148.

Dold, C., & Holland, C. V. (2011). Ascaris and ascariasis. *Microbes and Infection, 13*(7), 632-637.

Dong, H. K., Hyun, M. S., Joo, Y. K., Min, K. C., Mee, K. P., & Hak, S. Y. (2010). Parents' knowledge about enterobiasis might be one of the most important risk factors for enterobiasis in children. *Korean Journal of Parasitology, 48*(2), 121-126.

Dongjain, Y., Ya, Y., Yingjian, W., Yu, Y., & Yibiao, Z. (2018). Prevalence and risk factors of *Ascaris lumbricoides*, *Trichuris trichiura*, and *Cryptosporidium* infections in elementary school children in Southwestern China: A school-based cross-sectional study. *International Journal of Environmental Research and Public Health, 15*(9), 1809.

Dordevic, M. (1991). Detection of *Trichinella* by various methods in Yugoslavia. *Southeast Asian Journal of Tropical Medicine and Public Health, 22,* 326-328.

Dossa, R. A. M., Ategbo, E. A. D., de Koning, F. L. H. A., Van Raaij, J. M. A., & Hautvast, J. G. A. J. (2001). Impact of iron supplementation and deworming on growth performance in preschool Beninese children. *European Journal of Clinical Nutrition, 55,* 223–228.

Ericsson, C. D., Steffen, R., Siddiqui, A. A., & Berk, S. L. (2001). Diagnosis of *Strongyloides stercoralis* infection. *Clinical Infectious Diseases, 33*(7), 1040-1047.

Fisher, D., McCarry, F., & Currie, B. (1993). Strongyloidiasis in the Northern Territory: Under-recognised and under-treated? *Medical Journal of Australia*, 159, 88–90.

Fisher, M. (2003). *Toxocara cati*: An underestimated zoonotic agent. *Trends in Parasitology*, 19(4), 167–170.

Gaur, R. L., Dixit, S., Sahoo, M. K., Khanna, M., Singh, S., & Murthy, P. K. (2007). Anti-filarial activity of novel formulations of albendazole against experimental *Brugia* filariasis. *Parasitology*, 134(4), 537–544.

Gavin, P. J., Kazacos, K. R., & Shulman, S. T. (2005). Baylisascariasis. *Clinical Microbiology Reviews*, 18(4), 703–718.

Geissler, P. W., Mwaniki, D., Thiong'o, F., & Friis, H. (1998). Geophagy as a risk factor for geohelminth infections: A longitudinal study of Kenyan primary schoolchildren. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 92, 7–11.

Ghorbani, A. (2023). An overview of the science of parasitology simply for the general public. *International Journal of Medical Parasitology and Epidemiology Sciences*, 4(1), 12-18.

Gilles, H. M. (1968). Gastrointestinal helminthiasis. *BMJ*, 2, 475–477.

Glickman, L. T., Camara, A. O., Glickman, N. W., & McCabe, G. P. (1999). Nematode intestinal parasites of children in rural Guinea, Africa: Prevalence and relationship to geophagia. *International Journal of Epidemiology*, 28, 169–174.

Gonzalez, S., & Javier de la Cabada, F. (1987). Parasitic infections of the colon and rectum. *Baillière's Clinical Gastroenterology*, 1, 447–467.

Guyatt, H. (2000). Do intestinal nematodes affect productivity in adulthood? *Parasitol. Today*, 16, 153–158.

Hamilton, C. M., Yoshida, A., Pinelli, E., & Holland, C. V. (2014). Toxocariasis. In *Helminth infections and their impact on global public health* (pp. 425–460).

Harhay, M. O., Horten, J., & Olliaro, P. L. (2010). Epidemiology and control of human gastrointestinal parasites in children. *Expert Review of Anti-infective Therapy*, 8(2), 219–234.

Hawash, M. B. (2016). Whipworms in humans and pigs: Origins and demography. *Parasites & Vectors*, 9, 37.

Hoff, N. P., Mota, R., Groffik, A., & Hengge, U. R. (2008). Cutaneous larva migrans. *Hautarzt*, 59(8), 622–626.

Horton, J. (2000). Albendazole: A review of anthelmintic efficacy and safety in humans. *Parasitology*, 121, S113–S132.

Igra-Siegman, Y., Kapila, R., Sen, P., Kaminski, Z. C., & Louria, D. B. (1981). Syndrome of hyperinfection with *Strongyloides stercoralis*. *Reviews of Infectious Diseases*, 3(3), 397–407.

Jain, A. K., Agarwal, S. K., & EL-Sadr, W. (1994). *Streptococcus bovis* bacteremia and meningitis associated with *Strongyloides stercoralis* colitis in a patient infected with human immunodeficiency virus. *Clinical Infectious Diseases*, 18, 253–254.

Johnston, F. H., Morris, P. S., Speare, R., McCarthy, J., Currie, B., Ewald, D., Page, W., & Dempsey, K. (2005). Strongyloidiasis: A review of the evidence for Australian practitioners. *The Australian Journal of Rural Health*, 13(4), 247–254.

Jong, de, M. D., Baan, J., Lommerse, E., & Van, G. T. (2003). Severe diarrhoea and eosinophilic colitis attributed to pinworms, *Enterobius vermicularis*. *Nederlands Tijdschrift voor Geneeskunde*, 147, 813–815.

Karadbhajne, P., Tambekar, A., Gaidhane, A., Syed, Z. Q., & Gaidhane, S. (2021). A case report on *Ancylostoma duodenale* infection in pregnant woman. *Bioscience Biotechnology Research Communications, 14,* 100-103.

Keiser, P. B., & Nutman, T. B. (2004). *Strongyloides stercoralis* in the immunocompromised population. *Clinical Microbiology Reviews*, 17, 208–217.

Khalifa, M. M., Abdel-Rahman, S. M., Bakir, H. Y., Othman, R. A., & El-Mokhtar, M. A. (2020). Comparison of the diagnostic performance of microscopic examination, Copro-ELISA, and Copro-PCR in the diagnosis of *Capillaria philippinensis* infections. *PLOS ONE*, 15(6), e0234746.

Krolewiecki, A., & Nutman, T. B. (2019). Strongyloidiasis: A neglected tropical disease. *Infectious Disease Clinics of North America*, 33(1), 135–151.

Kucik, C. J., Martin, G. L., & Sortor, B. V. (2004). Common intestinal parasites. *American Family Physician*, 69, 1161–1168.

Kwan-Lim, G. E., Forsyth, K. P., & Maizels, R. M. (1990). Filarial-specific IgG4 response correlates with active *Wuchereria bancrofti* infection. *Journal of Immunology*, 145(12), 4298–4305.

Lamberton, P. H. L., & Jourdan, P. M. (2015). Human ascariasis: Diagnostics update. *Current Tropical Medicine Reports, 2,* 189–200. https://doi.org/10.1007/s40475-015-0064-9

Laurence, B. R. (1989). The global dispersal of bancroftian filariasis. *Parasitology Today*, 5(8), 260–264.

Lim, M. D., Brooker, S. J., Belizario Jr, V. Y., Gay-Andrieu, F., Gilleard, J., Levecke, B., ... & Annecy STH diagnostic experts group. (2018). Diagnostic tools for soil-transmitted helminths control and elimination programs: A pathway for diagnostic product development.

Lu, L. H., Lin, M. R., Choi, W. M., Hwang, K. P., Hsu, Y. H., Bair, M. J., ... & Chung, W. C. (2006). Human intestinal capillariasis (*Capillaria philippinensis*) in Taiwan. *American Journal of Tropical Medicine and Hygiene*, 74(5), 810–813.

Maciag, L., Morgan, E. R., & Holland, C. (2022). Toxocara: Time to let *cati* ‘out of the bag’. *Trends in Parasitology*, 38(4), 280-289.

Marcos, L. A., Terashima, A., Dupont, H. L., & Gotuzzo, E. (2008). Strongyloides hyperinfection syndrome: An emerging global infectious disease. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 102(4), 314–318.

Milder, J. E., Walzer, P. D., Kilgore, G., Rutherford, I., & Klein, M. (1981). Clinical features of *Strongyloides stercoralis* infection in an endemic area of the United States. *Gastroenterology*, 80, 1481–1488.

Mitreva, M., & Jasmer, D. P. (2006). Biology and genome of *Trichinella spiralis*.

Murrell, K. D., & Pozio, E. (2000). Trichinellosis: The zoonosis that won’t go quietly. *International Journal for Parasitology*, *30*, 1339-1349.

Nawa, Y., & Nakamura-Uchiyama, F. (2004). An overview of gnathostomiasis in the world. *Southeast Asian Journal of Tropical Medicine and Public Health*, *35*(Suppl 1), 87-91.

Nicoletti, A. (2013). Toxocariasis. In *Handbook of Clinical Neurology* (Vol. 114, pp. 217-228).

Nokes, C., Grantham-McGregor, S. M., Sawyer, A. W., Cooper, E. S., & Bundy, D. A. P. (1992). Parasitic helminth infection and cognitive function in school children. *Proceedings of the Royal Society of London B*, *247*, 77–81.

Nokes, C., Grantham-McGregor, S. M., Sawyer, A. W., Cooper, E. S., Robinson, B. A., & Bundy, D. A. P. (1992). Moderate to heavy infections of *Trichuris trichiura* affect cognitive function in Jamaican school children. *Parasitology*, *104*, 539–547.

Nutman, T. B., & Kumaraswami, V. (2001). Regulation of the immune response in lymphatic filariasis: Perspectives on acute and chronic infection with *Wuchereria bancrofti* in South India. *Parasite Immunology*, *23*(7), 389-399.

Ok, K. S., Kim, Y. S., Song, J. H., Lee, J. H., Ryu, S. H., Lee, J. H., ... & Lee, H. K. (2009).

Trichuris trichiura infection diagnosed by colonoscopy: Case reports and review of literature. *The Korean Journal of Parasitology*, *47*(3), 275.

Olsen, A., Van LL, Marti, H., Polderman, T., & Magnussen, P. (2009). Strongyloidasis – the most neglected tropical disease. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *103*(10), 967-972.

Overgaauw, P. A., & van Knapen, F. (2013). Veterinary and public health aspects of *Toxocara* spp. *Veterinary Parasitology*, 193, 398–403.

Peduzzi, R., & Piffaretti, J. C. (1983). *Ancylostoma duodenale* and the Saint Gothard anemia. *British Medical Journal*, *287*(6409), 1942-1945.

Pion, S. D., Tchatchueng, M. J. B., & Chesnais, C. B. (2019). Effect of a single standard dose (150-200 µg/kg) of ivermectin on *Loa loa* microfilaremia: Systematic review and meta-analysis. *Open Forum Infectious Diseases*, *6*, ofz019.

Plaisier, A. P., Stolk, W. A., Van Oortmarssen, G. J., & Habbema, J. D. F. (2000). Effectiveness of annual ivermectin treatment for *Wuchereria bancrofti* infection. *Parasitology Today*, *16*(7), 298-302.

Pozio, E., Rinaldi, L., Marucci, G., Musella, V., Galati, F., Cringoli, G., ... & La Rosa, G. (2009). Hosts and habitats of *Trichinella spiralis* and *Trichinella britovi* in Europe. *International Journal for Parasitology*, *39*(1), 71-79.

Rajendran, S., Carmody, E., Murphy, M., & Barry, B. (2015). Enterobius granulomas as a cause of abdominal pain. *BMJ Case Reports*, *2015*, bcr2015210464.

Rang, H. P., Dale, M. M., Ritter, J. M., & Moore, P. K. (2003). Chapter 49: Anthelmintic drugs. In H. P. Rang, M. M. Dale, J. M. Ritter, & P. K. Moore (Eds.), *Pharmacology* (5th ed., pp. 687–692). London: Churchill Livingstone.

Ronquillo, A. C., Puelles, L. B., Espinoza, L. P., Sánchez, V. A., & Luis Pinto Valdivia, J. (2019). *Ancylostoma duodenale* as a cause of upper gastrointestinal bleeding: A case report. *Brazilian Journal of Infectious Diseases*, *23*(6), 471-473.

Sakanari, J. A., & Mckerrow, J. H. (1989). Anisakiasis. *Clinical Microbiology Reviews*, *2*(3), 278-284.

Salim, M., Masroor, M. S., & Parween, S. (2021). An overview on human helminthic parasitology I. Nematodes, the roundworms. *International Journal of Medical Research*, *7*(5), 161-166.

Schneider, J. H., & Rogers, A. I. (1997). Strongyloidiasis: The protean parasitic infection. *Postgraduate Medicine*, *102*, 177–184.

Segarra-Newnham, M. (2007). Manifestations, diagnosis, and treatment of *Strongyloides stercoralis* infection. *Annals of Pharmacotherapy*, *41*(12), 1992-2001.

Simeon, D. T., Grantham-McGregor, S. M., Callender, J. E., & Wong, M. S. (1995). Treatment of *Trichuris trichiura* infections improves growth, spelling scores, and school attendance in some children. *Journal of Nutrition*, *125*, 1875–1883.

Sorvillo, F., Ash, L. R., Berlin, O. G. W., Yatabe, J., Degiorgio, C., & Morse, S. A. (2002). *Baylisascaris procyonis*: An emerging helminthic zoonosis. *Emerging Infectious Diseases*, *8*(4), 355.

Speich, B., Ali, S. M., Ame, S. M., Albonico, M., Utzinger, J., & Keiser, J. (2015). Quality control in the diagnosis of *Trichuris trichiura* and *Ascaris lumbricoides* using the Kato-Katz technique: Experience from three randomised controlled trials. *Parasites & Vectors, 8,* 82.

Stepek, G., Buttle, D. J., Duce, I. R., & Behnke, J. M. (2006). Human gastrointestinal nematode infections: Are new control methods required? *International Journal of Experimental Pathology*, *87*(5), 325-341.

Stephensen, C. B. (1999). Burden of infection on growth failure. *Journal of Nutrition*, *129*, 534S–538S.

Stephenson, L. S., Holland, C. V., & Cooper, E. S. (2001). The public health significance of *Trichuris trichiura*. *Parasitology*, *121*, 73-95.

Stephenson, L. S., Latham, M. C., Adams, E. J., Kinoti, S. N., & Pertet, A. (1993). Physical fitness, growth, and appetite of Kenyan school boys with hookworm, *Trichuris trichiura*, and *Ascaris lumbricoides* infections are improved four months after a single dose of albendazole. *Journal of Nutrition*, *123*, 1036–1046.

Stürchler, D. (1987). Parasitic diseases of the small intestinal tract. *Baillière's Clinical Gastroenterology, 1,* 397–424.

Tan, X., Cheng, M., Zhang, J., et al. (2017). Hookworm infection caused acute intestinal bleeding diagnosed by capsule: A case report and literature review. *Korean Journal of Parasitology, 55*(4), 417-420.

Tapchaisri, P., Nopparatana, C., Chaicumpa, W., & Setasuban, P. (1991). Specific antigen of *Gnathostoma spinigerum* for immunodiagnosis of human gnathostomiasis. *International Journal for Parasitology, 21*(3), 315-319.

Taratuto, A. L., & Venturiello, S. M. (1997). Trichinosis. *Brain Pathology, 7*(1), 663-672.

Ta–Tang, T. H., Crainy, J. L., Post, R. J., Luj, S. L., & Rubio, J. M. (2018). Mansonellosis: Current perspectives. *Research and Reports in Tropical Medicine, 9,* 9-24.

Taylor, M. J., Hoerauf, A., & Bockarie, M. (2010). Lymphatic filariasis and onchocerciasis. *Lancet, 376*(9747), 1175-1185.

Tietze, P. E., & Tietze, P. H. (1991). The roundworm, *Ascaris lumbricoides*. *Primary Care: Clinics in Office Practice, 18*(1), 25-41.

Traub, R. J., Robertson, I. D., Irwin, P. J., Mencke, N., & Thompson, R. C. A. A. (2005). Canine gastrointestinal parasitic zoonoses in India. *Trends in Parasitology, 21,* 42–48.

Tsai, H.-C., Lee, S. S.-J., Liu, Y.-C., et al. (2002). Clinical manifestations of strongyloidiasis in southern Taiwan. *Journal of Microbiology, Immunology and Infection, 35,* 29–36.

Vermund, S. H., & Wilson, C. M. (2000). Pinworm (*Enterobius vermicularis*). In *Seminars in Pediatric Infectious Diseases* (Vol. 11, No. 4, pp. 252-256). WB Saunders.

Watten, R. H., Beckner, W. M., Cross, J. H., Gunning, J. J., & Jarimillo, J. (1972). Clinical studies of *Capillariasis philippinensis*. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 66*(6), 828-834.

Wolfe, A., & Wright, I. P. (2003). Human toxocariasis and direct contact with dogs. *Veterinary Record, 152,* 419–422.

World Health Organization. (2016). *Diagnostic errors: Technical series on safer primary care*. Geneva, Switzerland: World Health Organization.

World Health Organization. (2019). Bench aids for the diagnosis of intestinal parasites. Geneva, Switzerland: World Health Organization.

World Health Organization. (2021). Global programme to eliminate lymphatic filariasis: Progress report, 2020. Available at: https://www.who.int/publications-detail-redirect/who-wer9641-497-508.

World Health Organization. (2022). Lymphatic filariasis. Available at: https://www.who.int/news-room/fact-sheets/detail/lymphatic-filariasis.

Wu, M. L., & Jones, V. A. (2000). *Ascaris lumbricoides*. *Archives of Pathology & Laboratory Medicine, 124*(1), 174-175.

Yao, C., & Jasmey, D. P. (2001). *Trichinella spiralis* infected muscle cells: High levels of RNA polymerase II in nuclear speckle domains and depletion by mebendazole treatment. *Infection and Immunity, 69,* 4065-4071.

Ziegalbauer, K., Speich, B., Mausezahl, D., Bos, R., Keiser, J., & Utzinger, J. (2012). Effect of sanitation on soil-transmitted helminth infection: Systematic review and meta-analysis. *PLoS Medicine, 9*(1), e1001162.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

© Copyright (2024): Author(s). The licensee is the journal publisher. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/4236