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Review Article

Unveiling the Zoonotic Significance of Toxocariasis in Humans: The Role of *Toxocara canis*

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ABSTRACT

Toxocariasis is a zoonotic disease caused by the parasite *Toxocara canis*, with significant effects on human health. This article provided a comprehensive overview of the importance of complications of *Toxocara canis* infection. The introduction highlighted the relevance of zoonotic diseases and introduced toxocariasis as a specific example. The subsequent sections delved into toxocariasis, covering its transmission, lifecycle, host specificity, and primary sources of human infection. The epidemiology section presented the global prevalence and distribution of toxocariasis at 11.1% (95% CI: 10.6–11.7%), emphasizing high-risk groups and geographical factors contributing to illness. Detailed information was provided regarding the clinical manifestations of toxocariasis, including variations in disease severity and potential complications. Symptoms of visceral toxocariasis include fever, fatigue, coughing, wheezing, or abdominal pain. The diagnostic methods include laboratory methods (serological testing and western blot) and molecular techniques (PCR), and clinical methods (chest X-ray and CT scan). The prevention and control section outlined strategies for prevention, highlighting the significance of public health measures and awareness campaigns. The One Health approach has recognized the interconnections between human health, animal health, and the environment, and highlights the necessity of cooperative actions to prevent the spread of diseases that can be transmitted between animals and humans. Future directions need to highlight ongoing research and advancements, including improved diagnostic tools, targeted therapies, risk assessment, and international collaboration. The conclusion reinforces the importance of understanding and addressing *Toxocara canis* infection on human health. Adopting a One Health approach and implementing effective prevention, diagnosis, and treatment strategies can reduce the burden of toxocariasis, leading to improved health outcomes for humans and animals.

1. Introduction

Zoonotic diseases, which can be passed between animals and humans, pose a significant risk to public health worldwide[1,2]. These diseases can originate from various sources, such as parasites[3-5], bacteria, viruses, and fungi, and effects on human health can range from minor to severe, occasionally leading to widespread outbreaks and epidemics[6,7]. Understanding and addressing zoonotic diseases is crucial for safeguarding human and animal populations.

Toxocariasis is one of the zoonotic diseases caused by the parasitic roundworm *Toxocara canis*[8]. Toxocariasis primarily affects mammals, including dogs, but can also infect humans, making it a significant public health issue[9]. The importance of *Toxocara canis* is due to the ability of *Toxocara canis* to complete its lifecycle in animals and humans[10,11].

Toxocara canis is commonly found in the intestines of infected dogs, and dogs shed their eggs in the environment[12,13]. Soil, water, and other surfaces could be contaminated with eggs and remain infective for an extended period of time[14]. Human infection occurs when individuals accidentally ingest the infective eggs through contaminated hands, objects, or consumption of raw or undercooked food[15]. *Toxocara canis* larvae could migrate inside the human

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body through various organs, including the liver, lungs, and nervous system, causing a range of clinical manifestations[16]. While some infections remain asymptomatic, others can lead to severe symptoms such as fever, respiratory issues, abdominal pain, and organ damage[17]. The disease severity can vary depending on the number of larvae ingested, the host's immune response, and the larvae's migration path.

Raising awareness about the zoonotic significance of toxocariasis is essential due to the global distribution of *Toxocara canis* in dogs and the potential for human infection[17]. Regarding the lifecycle, transmission routes, clinical manifestations, and prevention strategies associated with *Toxocara canis*, the current studies aimed to mitigate the impact of this zoonotic disease on human health[13,18,19].

The following sections of this article delve deeper into the various aspects of toxocariasis, including its epidemiology, clinical manifestations, diagnostic methods, prevention, and the importance of a One Health approach. By understanding toxocariasis and its implications, researchers can take steps toward effective prevention, early diagnosis, and appropriate management of this zoonotic disease.

2. Toxocara canis lifecycle

To comprehend toxocariasis, it is crucial to comprehend its transmission, lifecycle, host specificity, and the primary sources of *Toxocara canis* infection in humans.

2.1. Transmission

Toxocara canis completes its lifecycle in animals (particularly dogs) and humans[20]. The transmission of *Toxocara canis* occurs through the ingestion of infective eggs present in contaminated soil, water, or surfaces[21]. These eggs are shed in the feces of infected animals, typically dogs, which serve as the definitive host for the parasite[22]. After the ingestion of infective eggs by a suitable host, such as humans, the eggs hatch, and the resulting larvae penetrate the intestinal wall. Finally, they migrate through the body via the bloodstream[23].

The larvae can reach various organs within the human body, including the liver, lungs, muscles, and central nervous system[24]. This migration can lead to the development of a range of clinical symptoms and manifestations[25]. In some cases, the larvae may encyst, forming dormant structures known as granulomas, which can remain in the affected tissues for prolonged periods[26].

2.2. Host specificity

Toxocara canis primarily infects canids, including dogs and other related species[27]. However, humans can become accidental hosts through the ingestion of infective eggs[28]. Although humans are not the parasite's intended host, the larvae can still migrate through their tissues, causing various pathological effects like visceral and ocular toxocariasis[29].

2.3. Infection in humans

The most common source of *Toxocara canis* infection in humans is contact with contaminated soil or environments where infected dogs have defecated. Children are particularly vulnerable due to their close interactions with contaminated soil during outdoor activities[30]. Additionally, consuming raw or undercooked meat from infected animals can also be a source of infection[31].

Other potential sources of *Toxocara canis* infection in humans include direct contact with infected dogs, especially puppies, inadequate hygiene practices, and poor sanitation[32]. It is important to note that *Toxocara canis* eggs can persist in the environment for extended periods, contributing to ongoing transmission and the potential for human infection[33].

By understanding the transmission routes, lifecycle, and host specificity of *Toxocara canis*, as well as the primary sources of human infection, researchers can implement adequate preventive measures to reduce the risk of toxocariasis in humans[34]. In the following sections, this article further explores the epidemiology, clinical manifestations, diagnostic methods, and prevention strategies associated with toxocariasis.

3. Epidemiology

To understand the impact of toxocariasis on human health, it is crucial to evaluate its global prevalence and distribution. Additionally, identifying high-risk groups and understanding the geographical factors contributing to infection can help prevention and control strategies.

3.1. Global prevalence and distribution

Toxocariasis is a widespread zoonotic disease affecting both developed and developing countries worldwide[35]. However, the exact prevalence of toxocariasis in humans is challenging due to underreporting, misdiagnosis, and variations in surveillance systems. Nonetheless, studies and surveys conducted in different regions have provided valuable insights into the prevalence rates[36].

Prevalence rates of toxocariasis in humans vary significantly between countries and even within regions of the same country[37]. Regions with poor sanitation, bad hygiene practices, and higher densities of infected dogs tend to have higher prevalence rates[38,39]. In some areas, mainly urban and suburban environments with high populations of stray dogs, the risk of *Toxocara canis* infection is higher[40].

3.2. High-risk groups

Specific populations are considered particularly vulnerable to *Toxocara canis* infection, and recognizing these high-risk groups is essential for targeted prevention and intervention efforts[41]. Children, especially those living in socioeconomically disadvantaged areas or with limited access to healthcare, are at increased risk due to close contact with contaminated environments[42]. Young children frequently participate in activities like playing in sandboxes, parks, or gardens, where they have the potential to encounter *Toxocara canis* eggs present in the soil. Additionally, groups with frequent exposure to contaminated environments, such as veterinary professionals, dog handlers, and individuals working in all agriculture or waste management, may also face an elevated risk of *Toxocara canis* infection[43]. Lack of awareness, inadequate personal protective measures, and limited access to preventive interventions further contribute to their vulnerability[44].

3.3. Geographical factors

Various geographical factors influence the transmission and distribution of toxocariasis. Climatic conditions, including temperature and humidity, play a role in the survival and viability of *Toxocara canis* eggs in the environment[45]. Warmer and more humid regions can provide a favorable environment for the persistence and maturation of infective eggs, thereby increasing the risk of human exposure[46].

Socioeconomic factors, including access to clean water, sanitation facilities, and healthcare services, also impact the prevalence of toxocariasis[47]. Areas with inadequate sanitation infrastructure and limited resources for deworming programs and public health interventions are more likely to experience higher infection rates[48,49].

Moreover, pet ownership behaviors influence the transmission dynamics of *Toxocara canis*. Communities with a higher prevalence of dog ownership, particularly in regions where dogs are not routinely dewormed or where free-roaming dogs are expected, may have an increased risk of *Toxocara canis* infection[50].

Public health authorities can develop targeted interventions, educational campaigns, and preventive strategies by understanding the global prevalence, distribution patterns, high-risk groups, and geographical factors contributing to toxocariasis[51]. These efforts can reduce the burden of toxocariasis in affected populations and minimize the risk of infection transmission. In the subsequent sections, this article explores the clinical manifestations of toxocariasis, diagnostic methods, prevention strategies, and the importance of adopting a One Health approach[52].

4. Clinical manifestations

Toxocariasis, caused by the parasitic roundworm *Toxocara canis*, can lead to diverse clinical symptoms and manifestations in humans. The severity of the disease can vary depending on factors such as the number of larvae ingested, the host's immune response, and the migration route. While some individuals may remain asymptomatic, others may experience mild to severe symptoms.

The clinical manifestations of toxocariasis can involve various organ systems as the larvae migrate through the body. The symptoms can resemble those of other conditions, sometimes making diagnosis challenging. Visceral toxocariasis can manifest with symptoms including fever, abdominal pain, hepatomegaly (enlarged liver), splenomegaly (enlarged spleen), respiratory symptoms, such as cough, wheezing, and dyspnea (difficulty breathing), as well as muscle and joint pain[53,54].

4.1. Ocular toxocariasis

Ocular toxocariasis is characterized by symptoms, such as visual impairment, blurred vision, floaters, and eye pain, along with uveitis (inflammation of the eye structures), retinal granulomas or detachment, and strabismus (misalignment of the eyes).

Neurological toxocariasis presents with symptoms, such as headaches, dizziness, seizures, cognitive and behavioral changes, peripheral neuropathy (numbness, tingling, or weakness in the extremities), and encephalitis or meningitis-like symptoms.

It is important to note that the clinical manifestations of toxocariasis can vary depending on the larval migration pattern and the affected organs. Some individuals may experience a mild and self-limiting course of the disease, while others may develop severe symptoms requiring medical intervention. Complications can also arise in some instances of toxocariasis, further impacting the clinical picture. Potential complications of toxocariasis encompass various aspects. Long-term infection or a heavy larval burden can result in organ damage, particularly affecting the liver and lungs[55,56]. Liver dysfunction, such as hepatitis and cirrhosis, may occur[57], and pulmonary complications like pneumonia and respiratory distress can also arise. Ocular toxocariasis carries the risk of permanent visual impairment or blindness if not promptly diagnosed and treated, with the possibility of retinal detachment leading to irreversible vision loss. In severe cases of neurological toxocariasis, permanent neurological deficits can manifest, including cognitive impairment, epilepsy, and paralysis[58].

It is crucial to recognize the potential complications of toxocariasis and promptly seek medical attention if symptoms arise, especially in high-risk individuals or those with a history of exposure to infected animals or contaminated environments[59].

5. Diagnostic methods

An accurate diagnosis of toxocariasis is essential for appropriate management and treatment. Different laboratory and clinical techniques are employed to diagnose this parasitic infection in humans. These diagnostic approaches aim to identify specific markers or evidence of *Toxocara canis* condition. However, detecting toxocariasis can be challenging due to several factors, including the limitations of available tests and the diverse clinical presentations of the disease.

5.1. Laboratory methods

5.1.1. Serological testing

Enzyme-Linked Immunosorbent Assay (ELISA) is commonly used to detect specific antibodies (IgG, IgM) against Toxocara antigens in the blood[27]. Elevated levels of these antibodies indicate exposure to *Toxocara canis*.

5.1.2. Western Blot

This confirmatory test can be performed to validate positive ELISA results, providing additional specificity[60,61].

5.1.3. Molecular techniques

Molecular techniques such as PCR can detect and amplify Toxocara DNA in various clinical specimens, such as blood, cerebrospinal fluid (CSF), or ocular fluid[62]. PCR offers high sensitivity and specificity, enabling early and accurate diagnosis[63].

5.2. Clinical methods

5.2.1. Imaging techniques

5.2.1. Chest X-ray

In cases of Visceral toxocariasis, a chest X-ray may reveal characteristic findings, such as pulmonary infiltrates or nodules[64].

5.2.2. Computed tomography scan

Computed tomography (CT) scans can provide detailed imaging of affected organs, assisting in identifying granulomas or other abnormalities[65].

5.2.3. Challenges and limitations

There are several challenges and limitations associated with accurately diagnosing toxocariasis due to the nature of the disease and the constraints of available diagnostic methods. Cross-reactivity is a significant challenge, as serological tests like ELISA can produce false-positive results by reacting with antibodies against other parasitic infections. Serological variability among individuals further complicates the reliability of these tests in distinguishing between acute and past infections. Lack of standardization in serological assays for toxocariasis also leads to variations in laboratory results due to differences in test protocols, antigen preparations, and cut-off values. Limited access to molecular testing, such as PCR, in resource-limited settings hampers timely diagnosis. Additionally, the diverse clinical presentations of toxocariasis, which can mimic other diseases, often result in misdiagnosis or delayed diagnosis, particularly in cases with atypical or localized symptoms like ocular or neurological involvement.

6. Prevention and control

Toxocariasis prevention plays a vital role in minimizing the impact of this zoonotic disease on human health. A comprehensive approach involving various strategies can effectively mitigate the risk of infection and transmission. These strategies encompass both individual-level preventive measures and broader public health interventions. Raising awareness about toxocariasis and promoting responsible pet ownership is crucial in prevention and control efforts.

6.1. Individual-level preventive measures

Preventive measures for toxocariasis encompass several key practices. Practicing good personal hygiene, including regular handwashing with soap and water, reduces the risk of ingesting *Toxocara canis* eggs after contact with contaminated environments[66]. Proper food handling, such as thoroughly cooking meat and washing fruits and vegetables, minimizes the chance of ingesting infective eggs present in raw or unwashed produce. Discouraging the habit of geophagy (eating soil) in children, especially in areas with a higher prevalence of Toxocara canis infection, lowers the risk of ingesting contaminated soil[67]. Teaching children about basic hygiene practices, such as not putting dirty hands or objects in their mouths, is an important educational component that aids in the prevention of Toxocara canis infection[28,30].

6.2. Environmental interventions

6.2.1. Pet waste management

Proper disposal of dog feces, especially in public areas, parks, and playgrounds, helps reduce environmental contamination with *Toxocara canis* eggs[68].

6.2.2. Regular deworming of pets

Routine deworming of dogs, especially those in close contact with humans or shared environments is crucial in preventing *Toxocara canis* infection[69]. This includes puppies, as they are more likely to shed infective eggs.

6.2.3. Controlling stray dog populations

Implementing effective stray dog management programs, such as vaccination, sterilization, and deworming campaigns, can help reduce the overall prevalence of *Toxocara canis* in the community[70].

6.2.4. Public health interventions

Public health interventions play a crucial role in addressing toxocariasis. Health education campaigns aimed at the general population and high-risk groups, such as parents, teachers, and healthcare professionals, increase awareness about the disease and emphasize preventive measures, early symptom recognition, and seeking medical attention. Improving sanitation by enhancing access to clean water, proper sanitation facilities, and effective waste management systems helps reduce environmental contamination and the transmission of *Toxocara canis*[71]. Adopting a One Health approach, which acknowledges the interconnectedness of human health, animal health, and the environment, is vital in combating toxocariasis[52]. Collaboration between medical professionals, veterinarians, public health authorities, and policymakers is crucial to develop integrated prevention and control strategies[72].

6.2.5. Responsible pet ownership

Responsible pet ownership involves several key practices. Regular veterinary care, including check-ups, vaccinations, and deworming for pets, particularly dogs, is essential in preventing the transmission of Toxocara canis to humans and other animals. Proper disposal of pet feces is crucial, with prompt and appropriate disposal of dog feces, preferably in designated areas or through sanitary waste disposal methods, effectively reducing environmental contamination. Encouraging the use of leashes for dogs in public areas helps minimize their access to contaminated environments and decreases the risk of environmental contamination.

7. Conclusion

Toxocariasis, caused by the zoonotic parasite *Toxocara canis*, poses a significant threat to human health worldwide. This article explores various aspects of toxocariasis, including its transmission, clinical manifestations, diagnosis, prevention, and future directions for research and control.

Toxocariasis serves as a prime example of the interconnectedness between human and animal health. The disease highlights the importance of adopting a One Health approach that recognizes the interconnectedness of humans, animals, and the environment. By understanding the shared disease pathways and implementing collaborative efforts, it would be possible to effectively mitigate the risks associated with zoonotic infections.

The clinical manifestations of toxocariasis vary widely, ranging from mild symptoms to severe complications. Early recognition of these symptoms is crucial for prompt diagnosis and treatment. However, accurate diagnosis of toxocariasis remains challenging due to limitations in diagnostic methods, including the need for more sensitive and specific tests. Future advancements in diagnostic tools, such as molecular techniques, promise to improve detection accuracy.

Prevention and control strategies are critical in reducing the burden of toxocariasis. Individual-level preventive measures, including personal hygiene and proper food handling, can minimize the risk of infection. Environmental interventions, such as pet waste management and regular deworming of pets, help reduce environmental contamination. Public health interventions, such as health education campaigns and improved sanitation, are essential in raising awareness and implementing effective control measures.

Future research directions offer hope for enhanced prevention, diagnosis, and treatment of toxocariasis. Vaccine development, improved diagnostic tools, targeted therapies, risk assessment, and international collaboration are key focus areas. By investing in these research areas and fostering interdisciplinary collaborations, significantly reducing the impact of toxocariasis on global health is achievable.

Declarations

Competing interest

The authors declare no conflict of interest.

Authors' Contribution

Hassan Borji conceptualized the study. All authors developed The methodology collaboratively, ensuring a comprehensive approach to the investigation. The entire team carried out the formal analysis and investigation, collectively contributing to the data collection and analysis process. All authors participated in the writing of the original draft of the manuscript.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical considerations

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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