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Feline toxoplasmosis: Advances in diagnostic techniques and zoonotic threats to pregnant women- a review

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Abstract

Toxoplasma gondii is a globally prevalent protozoan parasite, with felids serving as its definitive hosts. Although infection in cats is usually asymptomatic, the shedding of oocysts in feces poses a significant zoonotic risk. Human infection occurs primarily through ingestion of sporulated oocysts from contaminated soil, water, or cat litter, consumption of undercooked meat containing tissue cysts, or congenital transmission during pregnancy. Pregnant women are particularly vulnerable, as primary infection can result in fetal transmission, leading to congenital toxoplasmosis with severe neurological and ocular consequences, including hydrocephalus and chorioretinitis. In immunocompetent individuals, infection is often asymptomatic or mild, whereas immunocompromised patients may experience life-threatening complications, such as encephalitis or ocular toxoplasmosis. Recent advances in molecular diagnostics, including PCR and droplet digital PCR, along with serological assays and imaging techniques, have improved detection and clinical management of *T. gondii* infection. Preventive strategies, focusing on litter box hygiene, safe food handling, handwashing, and public education, are critical in minimizing zoonotic transmission. Understanding the lifecycle of *T. gondii*, its environmental persistence, and transmission routes underscores the importance of mitigating exposure, particularly among high-risk groups. Enhanced awareness and targeted interventions are essential to reduce the public health impact of this hidden zoonotic threat.

Keywords: Cat, Toxoplasma, Pregnancy, Zoonotic risk, Diagnostic Techniques

Introduction

Toxoplasma gondii is a protozoan parasite that infects warm-blooded animals, including humans. It has an estimated seroprevalence of 60 million infected people in the United States alone. Felids, particularly domestic and wild cats, are the definitive hosts of *T. gondii*, where the sexual phase of its lifecycle occurs. While feline infection is often asymptomatic, the shedding of oocysts presents a significant zoonotic risk. Humans can acquire *T. gondii* infection through ingestion of oocysts, undercooked meat containing tissue cysts, or through congenital transmission during pregnancy. Despite the relatively low risk of direct transmission from cats to humans, environmental contamination and exposure are the primary mechanisms for human infection.

This article reviews the lifecycle of *T. gondii*, the primary routes of transmission to humans, the clinical consequences of infection, and public health considerations for managing zoonotic risks associated with feline toxoplasmosis.

Lifecycle and Transmission

Toxoplasma gondii exists in three main forms: tachyzoites, bradyzoites, and sporozoites (within oocysts). Cats acquire the parasite by ingesting infected prey or raw meat containing tissue cysts. After ingestion, *T. gondii* undergoes sexual reproduction in the cat's intestine, producing oocysts that are excreted in the feces (Frenkel *et al.*, 1995). These oocysts sporulate in the environment within 1–5 days and can remain infectious for over a year (Dubey, 2009). Humans typically become infected with *T. gondii* via one of the following routes:

1. **Ingestion of oocysts:** Contaminated soil, water, food, or cat litter can serve as sources of infection, particularly when oocysts are ingested accidentally (Aspinall *et al.*, 2002) ^[1].
2. **Consumption of undercooked meat:** Tissue cysts of *T. gondii* are found primarily in the muscle tissues of infected intermediate hosts such as pigs, goats, and lamb.
3. **Congenital transmission:** Pregnant women who acquire the infection for the first time can transmit the parasite to their fetus, leading to congenital toxoplasmosis.
4. **Rare transmission through organ transplantation or blood transfusion:** While uncommon, *T. gondii* can also be transmitted via infected organs or blood products.

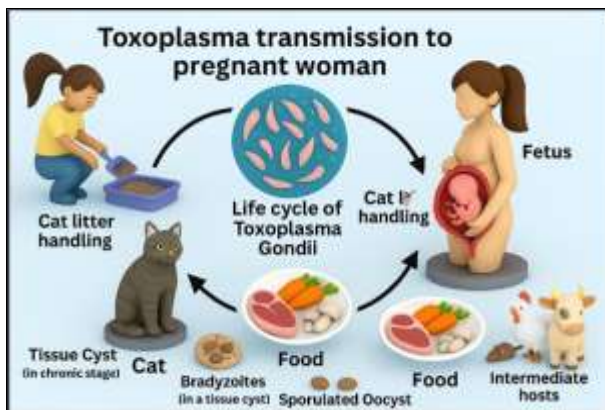


Fig 1: Lifecycle and transmission routes of *Toxoplasma gondii* to pregnant women

Cats serve as the definitive hosts, shedding unsporulated oocysts in their feces. These oocysts become sporulated in the environment and contaminate soil, water, and food. Intermediate hosts (such as cattle, poultry, and rodents) ingest oocysts, leading to the formation of tissue cysts (bradyzoites) in their muscles.

Clinical Manifestations in Humans

In immunocompetent individuals, toxoplasmosis is typically asymptomatic or results in mild flu-like symptoms. However, in immunocompromised patients, such as those with HIV/AIDS or individuals undergoing immunosuppressive therapy, *T. gondii* can cause life-threatening complications, particularly encephalitis. Ocular toxoplasmosis, which involves infection of the retina, can lead to vision impairment and blindness, especially in patients with weakened immune systems.

Congenital toxoplasmosis remains a significant concern for pregnant women. If a woman contracts the infection during pregnancy, the parasite can be transmitted to the fetus, leading to severe neurological and ocular damage, including hydrocephalus and chorioretinitis (Poirier *et al.*, 2019). The severity of congenital toxoplasmosis depends on the timing of maternal infection, with early gestational infections resulting in more severe outcomes.

Clinical Manifestations in Felines

Felines are the definitive hosts of *T. gondii* and may shed millions of oocysts in their feces, especially during the initial stages of infection (Frenkel *et al.*, 1995). Despite the potential for widespread oocyst shedding, most infected cats show no clinical signs. Clinical signs may occur in immunocompromised cats or those with underlying diseases, and symptoms can include fever, lethargy, respiratory distress, and, less commonly, neurological abnormalities ().

Studies suggest that stress, such as that induced by disease or corticosteroid treatment, may increase the likelihood of symptomatic infection.

Epidemiology of Toxoplasmosis

The prevalence of *T. gondii* antibodies in cats varies depending on several factors, including geographic location, hunting habits, and diet. Studies have reported prevalence rates ranging from 14% to 100%, with higher rates observed in areas where cats are allowed to roam freely outdoors and hunt (Dubey, 2009) ^[3]. In the United States, the prevalence of *T. gondii* antibodies in cats is estimated to be between 20% and 30%, with outdoor cats being at higher risk due to their exposure to infected prey.

In humans, the prevalence of *T. gondii* infection is influenced by dietary practices, hygiene, and geographic location. In regions where undercooked meat is commonly consumed, seroprevalence is higher, and serological surveys have indicated that the overall prevalence in the U.S. population is around 22%. The highest risk groups for acquiring *T. gondii* include pregnant women and immunocompromised individuals, particularly those undergoing chemotherapy or organ transplantation.

Recent Advances in Diagnostic Techniques

In recent years, significant advances in the diagnosis of *T. gondii* infection have improved our ability to detect the parasite with greater accuracy and speed. These developments are crucial for better clinical management, early detection, and surveillance of the parasite in both felines and humans.

Molecular Diagnostics

1. **Polymerase Chain Reaction (PCR):** PCR has become the gold standard for diagnosing *T. gondii* infections, particularly in humans and animals with ocular or neurological symptoms. PCR-based methods can detect the presence of parasite DNA in blood, cerebrospinal fluid (CSF), and ocular fluids (Cerva *et al.*, 2020) ^[2]. The sensitivity and specificity of PCR assays have significantly improved with the development of quantitative PCR techniques, which allow for the detection of very low parasite loads (Sauer *et al.*, 2021) ^[5].
2. **Droplet Digital PCR (ddPCR):** A more recent advance, ddPCR offers ultra-sensitive detection of *T. gondii* DNA in complex clinical samples, even in cases of low parasitic load (Wu *et al.*, 2022) ^[6]. This method allows for absolute quantification of *T. gondii* DNA, making it particularly useful for monitoring parasite levels in immunocompromised patients.
3. **Serological Methods**
 - **Enzyme-Linked Immunosorbent Assay (ELISA):** ELISA remains the most widely used serological test for diagnosing *T. gondii* infection. It detects antibodies (IgG, IgM) against the parasite, helping determine whether an infection is acute or chronic (Aspinall *et al.*, 2022) ^[1]. Newer, automated ELISA systems have increased throughput and accuracy in clinical settings.
 - **Immunoblotting:** This technique is used to detect specific *T. gondii* antigens in serum samples and is useful for confirming results obtained from ELISA (Liu *et al.*, 2020) ^[4]. It has high specificity and can help differentiate between *T. gondii* and other similar infections.

Advanced Imaging Techniques

- **Ocular Imaging:** For cases of ocular toxoplasmosis, advanced imaging techniques such as Optical Coherence Tomography (OCT) are increasingly used to visualize retinal lesions caused by *T. gondii* (Sauer *et al.*, 2021) [5]. OCT allows for non-invasive, high-resolution imaging, aiding in the diagnosis and monitoring of retinal infections.
- **Magnetic Resonance Imaging (MRI):** In cases of cerebral toxoplasmosis, MRI is highly effective at detecting lesions caused by *T. gondii* in the brain. MRI findings, when correlated with PCR and serological results, provide a comprehensive diagnostic approach for neurologically symptomatic patients (Aspinall *et al.*, 2022) [1].

Point-of-Care Diagnostics

Recent efforts have focused on developing rapid, point-of-care diagnostic tests for *T. gondii*. Lateral flow assays and portable PCR devices have been developed for use in both veterinary and human medicine (Yun *et al.*, 2020) [7]. These tests offer fast, affordable, and accurate detection of *T. gondii* infection, particularly in resource-limited settings.

Preventive Measures

Although direct transmission from cats to humans is unlikely, preventive strategies focus on reducing environmental contamination and minimizing exposure to oocysts. Key measures include:

1. **Litter box hygiene:** Regular cleaning of litter boxes is crucial to reduce the risk of oocyst transmission. Cleaning should be done daily to prevent oocysts from sporulating, as they can become infectious within 1–5 days after excretion (Dubey, 2009) [3].
2. **Safe food handling:** Avoiding the consumption of undercooked meat, particularly pork, lamb, and venison, significantly reduces the risk of acquiring tissue cysts.
3. **Hand hygiene:** Thorough handwashing after handling cats, cleaning litter boxes, or gardening can reduce the risk of accidental ingestion of oocysts.
4. **Public education:** Educating high-risk populations, especially pregnant women and immunocompromised individuals, about the risks of toxoplasmosis and safe practices is crucial for prevention.

Conclusion

Feline toxoplasmosis is a complex zoonotic infection with significant public health implications. While cats are essential to the lifecycle of *T. gondii*, human infection is most commonly acquired through environmental contamination and dietary factors. Recent advances in diagnostic techniques, including molecular assays, point-of-care tests, and advanced imaging methods, offer new opportunities for early detection and better clinical management. Preventive measures, including proper hygiene, food safety, and public education, are crucial in reducing the zoonotic risks associated with *T. gondii*. Further research into vaccine development and improved diagnostic techniques is needed to better control this parasitic infection.

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