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A Critical Appraisal on Transmission, Epidemiology and Control of Toxoplasmosis: A Major Protozoan Zoonosis

Mahendra Pal[1,*], Carl H.D. Steinmetz[2], Nidhish Bhardwaj[3], Sonia de Avila Botton[4]

[1]Narayan Consultancy on Veterinary Public Health and Microbiology, Anand, Gujarat, India.
[2]Expats and Immigrants B.V., Amsterdam, The Netherlands.
[3]CII-Food and Agriculture Centre of Excellence, Andhra Association Building, New Delhi, India.
[4]Federal University of Santa Maria (UFSM), Postgraduate Program in Pharmaceutical Sciences (PPGCF) and Veterinary Medicine (PPGMV), Centre for Rural Sciences, Department of Preventive Veterinary Medicine. One Health Laboratory, Brazil.

Abstract

Toxoplasmosis is an emerging and re-emerging zoonotic disease caused by *Toxoplasma gondii*, which is one of the most prevalent parasites in the world. Globally, one third of human population suffer from toxoplasmosis. The disease is usually transmitted by eating infected meat that has been improperly cooked or baked, exposure to the feces of sick cats, or from mother to child during pregnancy. Transmission can also occur by ingestion of unpasteurized milk and contaminated water with the protozoa. *Toxoplasma gondii* oocysts or tissue cysts inadvertently enter the human body through food or water Transmission from mother to fetus can also occur congenitally. Transmission can also occur through organ transplantation or hematopoietic stem cell transplantation. Individuals infected with *Toxoplasma gondii* often remain unaware of their infection. Yet, a minority of individuals may exhibit flu-like manifestations such as body aches, swollen lymph nodes, headaches, fever, fatigue, confusion, lack of coordination, and seizures. Diagnosis of toxoplasmosis in humans is made by biological, serologic, histologic, or molecular techniques, or a combination of these techniques. Treatment is recommended only for people with serious health problems. This includes people with HIV, as the disease is most severe when a person's immune system is compromised. Infection with *Toxoplasma gondii* can be prevented by avoiding drinking contaminated water and wearing gloves when gardening, as soil or sand may contain cat feces containing *Toxoplasma gondii*.

Keywords

Cat, Meat, Protozoa, Public health, *Toxoplasma gondii*, Water, Zoonosis

1. Introduction

Zoonoses, which are primarily animal diseases, are transmitted through various routes, including direct contact,

ingestion, inhalation, animal bite etc. [1]. Many countries around the world report suffering from protozoan zoonoses, such as amoebiasis, babesiosis, cryptosporidiosis, giardiasis, leishmaniasis, sarcocystosis, simian malaria, toxoplasmosis, and trypanosomiasis [2]. These zoonoses cause morbidity and mortality in susceptible individuals [2]. Toxoplasmosis is a major life-threatening parasitic zoonosis, that is reported in developing and developed nations and is caused by *Toxoplasma gondii*, a facultatively heterogeneous, polygenic protozoan that has developed distinct modes of transmission within and between host species [3]. The infection is common in humans, and it is estimated that approximately one-third of the world's population suffers from the disease [4].

Toxoplasma gondii infection may be subclinical or clinical. Geographic variations exist in the seroprevalence of *T. gondii* antibodies in the human population. HIV infection does not affect *T. gondii* seropositivity, and there is no difference in the rate of toxoplasmosis infection between AIDS patients with and without cats [5]. However, most infections are subclinical, and the disease only becomes "apparent" in congenitally acquired infections and in patients with significant immunodeficiency, such as acquired immunodeficiency syndrome (AIDS) [6]. Sometimes the patient presents with a more severe clinical picture, especially if the immune system is compromised. Severe eye infections, pneumonia, and meningitis may occur. In 10 percent of European HIV-infected patients, Toxoplasma infection causes brain abscesses and encephalitis. While *Toxoplasma gondii* typically results in mild symptoms among healthy individuals, toxoplasmosis poses a prevalent opportunistic infection with significant mortality rates in immunocompromised individuals, often attributed to the reactivation of the infection in the central nervous system. However, following dispersal, the parasite develops into semi-dormant cysts that form inside neurons and muscle cells, where they remain within the infected host for the duration of their lives. Control of infection in the central nervous system, a compartment of immune privilege, relies on modified immune responses aimed at balancing infection control while limiting potential damage from inflammation [7]. Congenital infection in children can only occur if a woman has a primary infection during pregnancy. Congenital infection occurs when a fetus is infected intrauterine. This can have serious consequences, especially if the infection occurs during the first 3 months of pregnancy. An adequate immune response does not occur and the infection is not controlled. In addition, there are rare case reports of people being infected through blood transfusions or organ transplants [2] [8]. This article discusses toxoplasmosis as an important protozoan zoonosis that occurs worldwide.

2. Review

2.1 Life Cycle of Protozoa

Toxoplasma gondii can infect a wide range of hosts and many different host cells [9, 10]. Intermediate hosts can be any warm-blooded animal, including most livestock, and humans. Final hosts are members of the Felidae family, such as domestic cats [11, 12]. In intermediate hosts, *T. gondii* undergoes two phases of asexual development [13]. In the first phase, tachyzoites (or endozoites) multiply at a high rate through repeated endodyogeny (daughter cells consuming the parent cell) in different types of host cells. The tachyzoites of the last generation initiate the second stage of development, which results in the formation of tissue cysts. Inside the tissue cyst, bradyzoites (also known as cystozoites) reproduce slowly through a process called endodyogeny [14]. Tissue cysts are attracted to neural and muscular tissues and are found primarily in the central nervous system (CNS), eye, skeletal and cardiac muscles. They are also found, to a lesser extent, in visceral organs such as the lungs, liver, and kidneys [15]. Tissue cysts represent the final stage of the life cycle in the intermediate host and are immediately infectious. In some intermediate hosts, tissue cysts can persist for life [16]. The mechanism for this persistence is unknown. However, many researchers believe that tissue cysts periodically degrade, after which bradyzoites transform into tachyzoites, which re-enter host cells and transform into bradyzoites within new tissue cysts [11, 17]. When taken up by a definitive host, the bradyzoites initiate an asexual proliferation phase, this time consisting of initial multiplication by endodyogeny followed by repeated endopolygeny in small intestinal epithelial cells [18]. The final stages of this asexual multiplication initiate the sexual phase of the life cycle. Gamogony and oocyst formation also occur in the small intestinal epithelium. Unpopulated oocysts are released into the intestinal lumen and enter the environment through feces. Sporogony occurs outside the host and results in the development of infectious oocysts. *T. gondii* has three infectious phases in its life cycle., namely tachyzoites, bradyzoites in tissue cysts, and sporozoites in sporulated oocysts [16]. All three stages are infective to intermediate and final hosts, which can acquire *T. gondii* infection primarily by one of the following routes: (A) horizontally by oral ingestion of infective oocysts from the

environment, (B) horizontally by oral ingestion of tissue cysts in raw or undercooked meat or primary offal (viscera) of intermediate hosts, or (C) vertically by transplacental transmission of tachyzoites [19]. In addition, in several hosts, tachyzoites can be transmitted to offspring through maternal milk [20, 21]. There is also evidence that the housefly and cockroaches can transfer infectious oocysts from cat feces to human and animal feed [2].

2.1.1 Animal to human transmission

Cats are a key factor in the transmission of toxoplasmosis. Infection occurs when they ingest infected rodents, birds, or other small animals. The parasite is then passed into the cat's feces in the form of microscopic oocysts. Kittens and adult cats have the potential to release large quantities of oocysts in their feces for a period of up to three weeks post-infection. Adult cats are less likely to release *Toxoplasma* if they have had a previous infection. A *Toxoplasma*-infected cat that sheds the parasite in its feces will contaminate the litter box. If the cat is allowed outside, it may also contaminate the soil or water in the area.

People can be infected by:

- Accidental consumption of oocysts can occur when cleaning a cat's litter box if the cat has expelled Toxoplasma in its feces.
- Accidental consumption of oocysts may happen when handling or eating anything that has been exposed to cat feces containing Toxoplasma.
- Accidental swallowing of oocysts can occur through contact with contaminated soil, such as not washing hands after gardening or consuming unwashed fruits or vegetables from a garden.
- Drinking water contaminated with *Toxoplasma* parasite [2, 22].

2.1.2 Mother-to-child (congenital) transmission

If a woman contracts *Toxoplasma* infection during or just before pregnancy, she can transmit the infection to her fetus, leading to congenital infection. The woman may have no symptoms, but the consequences for the unborn child can be severe, including diseases of the nervous system and eyes.

2.1.3 Rare instances of transmission

Organ transplant recipients are at risk of acquiring infection if they receive an organ from a donor who is positive for *Toxoplasma*. Rarely, people can also become infected by receiving infected blood through a transfusion. Laboratory workers who handle infected blood can also become infected through accidental inoculation.

2.2 Epidemiology

It is estimated that approximately 11% of the population aged 6 and older in the United States has been infected with Toxoplasma. In various places around the world, more than 60% of some populations have been found to be infected with *Toxoplasma.* Infection rates tend to be highest in regions characterized by hot, humid climates and lower altitudes, as these environments are conducive to the survival of oocysts [22].

An older source gives higher estimates, specifically: the seroprevalence of *T. gondii* in the United States is approximately 15%, and rates of exposure to *T. gondii* in HIV patients are similar to those in the general population [23]. In patients with AIDS who are positive for *T. gondii* antibodies, the risk of developing toxoplasmosis is approximately 30% if prophylactic or antiretroviral medication is not started [24, 25].

A more recent study (2020) reported the following results on *T. gondii* seroprevalence: The combined global seroprevalence of *T. gondii* was estimated to be 35% (95% CI: 32-38%) in domestic cats and 59% (95% CI: 56-63%) in wild felids, as determined by a random-effects model. Seroprevalence was higher in Australia and Africa, where *T. gondii* seropositivity in domestic cats was 52% (95% CI: 15-89%) and 51% (95% CI: 20-81%), respectively. The lowest seroprevalence was estimated to be 27% (95% CI: 24-30%) in Asia. Seroprevalence rates for *T. gondii* in wild felids were found to be 74% (95% CI: 62-83%) in Africa, 67% (95% CI: 23-111%) in Asia, 67% (95% CI: 58-75%) in Europe, and 66% (95% CI: 41-91%) in South America [26].

The development of toxoplasmosis in immunocompromised patients does not appear to vary by region; however, the prevalence of immunocompromised patients is higher in some countries due to HIV/AIDS infection, organ transplantation, and the prescription of immunomodulatory drugs [27, 28].

2.2.1 Importance of cats in the epidemiology of infections with Toxoplasma gondii

In cats, *T. gondii* infections are usually asymptomatic; vertical transmission, such as from mother to child, is rare.

In contrast, latent *T. gondii* infections are common in domestic and wild cats worldwide [29, 30]. At least 17 species of wild cats have been reported to shed *T. gondii* oocysts, including European and African wild cats, pallas cat, bobcat, leopard cat, amur leopard cat, iriomote cat, ocelot, geoffroy's cat, pampas cat, jaguarundi, puma, leopard, jaguar, tiger, lion, and cheetah. In domestic cats, antibodies to *T. gondii* have been detected in up to 74% of the adult cat population, depending on the type of diet and whether the cats are kept indoors or outdoors [31, 32].

In addition, there are serologic test data indicating *T. gondii* infection in sheep and goats. A total of 1078 goat and 882 sheep blood samples were collected from 17 of 21 provinces and the capital of Mongolia. Overall, the seroprevalence of *T. gondii* in the goat and sheep samples was 32% and 34.8%, respectively [33, 34]. Free-ranging domestic cats pose a significant risk to environmental contamination and the infection of food animals, largely due to their abundant populations and frequent intrusion into natural and agricultural areas [35]. *Toxoplasma gondii* infection is caused by eating raw, undercooked, or fried meat containing *T. gondii* cysts. Consumption of contaminated water, milk, and other foods containing oocysts from cat feces can also cause infection [36].

2.2.2 Mortality and Morbidity Rates

The routine use of cotrimoxazole prophylaxis, both in the United States and internationally, has probably significantly reduced the incidence of CNS toxoplasmosis [37]. Cotrimoxazole has beneficial effects against *Pneumocystis jiroveci* pneumonia (PJP), malaria, cerebral toxoplasmosis, and non-typhoidal salmonellosis. Although toxoplasmosis has been well studied in women of childbearing age because of its adverse effects on the fetus, no difference in prevalence between the sexes has been reported [38]. The prevalence of toxoplasmosis is correlated with the specific disease burden in certain countries, accounting for 23% of the variability in disease burden in Europe [38]. Furthermore, no differences in seroprevalence have been observed between age groups; with the exception of *T. gondii* chorioretinitis, older individuals are more likely to have clinically evident reactivation of *T. gondii* infection. Congenitally acquired *T. gondii* chorioretinitis is more likely to recur in individuals older than 40 years [39, 40].

Toxoplasma retinochoroiditis (TRC) is likely the most prevalent cause of infectious retinochoroiditis globally. One-quarter of patients with a history of Toxoplasma retinochoroiditis report visual acuity worse than 20/200 in at least one eye. Patients may be infected in utero or by ingestion of the parasite [41].

2.2.3 Infection in the Immunocompetent Host

Eighty to ninety percent of *T. gondii* infections in immunocompetent hosts are asymptomatic. When acute infection is symptomatic, symptoms usually include symmetric lymphadenopathy, fever, and a nonspecific rash. The vast majority of infections are benign and resolve within a few weeks. The infection due to *T. gondii* is reported in immunocompetent as well as in immunocompromised patients [42].

Chorioretinitis, or ocular toxoplasmosis, is a relatively common manifestation of *T. gondii* infection. Ocular toxoplasmosis occurs when cysts in or near the retina become active and produce tachyzoites. Focal necrotizing retinitis is the characteristic lesion, but retinal scarring from previous reactivation is often present. Ocular toxoplasmosis is usually associated with ocular pain and decreased visual acuity. In adults who contracted the disease at a young age, both eyes are usually affected. Adults with acute infection usually have unilateral ocular disease [43, 44].

2.2.4 Congenital Infection

Approximately 10-20% of pregnant women infected with *T. gondii* develop symptoms. The most common signs of infection are fever and malaise. If the mother contracts the infection before becoming pregnant, the risk of infecting the fetus is virtually nonexistent as long as her immune system stays healthy. However, if the mother is infected during pregnancy, there is a risk of fetal infection. The transplacental infection rate is estimated to be 50% for untreated mothers and 25% for treated mothers [45, 46].

In a cohort study spanning 12 years, maternal *T. gondii* antibody screening revealed an incidence of congenital *T. gondii* infection of 1.5% (7/469) among Japanese women who tested positive for *T. gondii* HA/IgG and additionally tested positive or equivocal for *T. gondii* IgM. One hundred four (22.2%) women with low IgG avidity were considered to have had primary *T. gondii* infection during the first trimester. The incidence of congenital *T. gondii* infection in Japanese who acquired primary infection during pregnancy was calculated to be 6.7% (7/104). None of the women with a high or borderline IgG avidity index had a positive PCR test for *T. gondii* DNA in amniotic fluid or neonatal blood [47].

The rate of fetal infection increases with each trimester of pregnancy: 10-25% of infections occur in the first trimester, 30% in the second trimester, and 50% in the third trimester [48]. Clinical features of congenital *T. gondii*

infection include chorioretinitis, blindness, seizures, microcephaly, anemia, and encephalitis. Infections acquired during the third trimester are usually subclinical, with clinical disease occurring later in life. Seventy-five percent of infants born with a congenital infection of *T. gondii* show no symptoms, 14% had chorioretinitis, and 9% of infants had *T. gondii* enter the CNS through the blood-brain barrier (BBN) [45] [49] [50]. Lower birth weight and an earlier delivery have been linked to latent Toxoplasmosis. Among women with latent Toxoplasmosis, the odds of an early delivery were 1.7, and low birth weight was 1.9 times more common than in women who tested negative for *T.gondii* [51].

2.2.5 Infection in Immunocompromised Patients

Often, toxoplasmosis in immunocompromised patients is a consequence of latent infection and reactivation [52]. It has been proposed that *Toxoplasma gondii* is a significant opportunistic pathogen in patients with compromised immune systems. [5]. In patients with AIDS, *T. gondii* tissue cysts can reactivate at CD4 T lymphocyte counts below 200 cells/μ L, and clinical disease becomes more likely at counts below 100 cells/μ L. On the other hand, individuals with CD4 counts below 100 cells/μL who test positive for T. gondii IgG antibodies face a 30% risk of developing reactivation disease if prophylaxis is not administered or immune function is not adequately restored [25, 5]. Toxoplasmic pneumonitis, myocarditis, and disseminated toxoplasmosis are often diagnosed in addition to CNS toxoplasmosis in immunocompromised patients [53].

2.3 Prevention and Control of the Disease in Humans

Preventive measures can significantly reduce the risk of infection with *T. gondii*, but cannot always prevent infection [29]. To prevent horizontal, food-borne transmission of *T. gondii* to humans, meat and other edible parts of animals should not be eaten raw or undercooked/overcooked, i.e. thoroughly cooked (70°C) before eating [1]. While freezing by itself may not guarantee that all tissue cysts are rendered non-infectious, freezing meat at -12°C or below before cooking can help lower the risk of infection. In addition, meat should not be tasted during seasoning or cooking, and pregnant women who are not immunocompromised should follow this rule of conduct [54]. Furthermore, high standards of kitchen hygiene are essential to prevent the risk of horizontal transmission of *T. gondii* to humans via tissue cysts [55]. In a case-control study in Norway, infrequent washing of kitchen knives after preparing raw meat was associated with an increased risk of primary infection during pregnancy. Both tissue cysts and tachyzoites are killed by water, so hands and all utensils used to prepare raw meat or other animal foods should be washed thoroughly with hot water and soap [56, 57]. Implementing awareness and cost-effective screening programs for pregnant women can alleviate the emotional and financial burden of this condition [58]. It is important to impart health education to women, butchers, pig breeders, pet handlers, and others about the reservoir of infection, mode of transmission, and hazards of eating raw or uncooked meat [2]. In addition, pregnant women are advised not to clean cat litter box [2].

3. Conclusion

Toxoplasma gondii is a zoonotic agent of major public health concern. For this reason, several organizations, including the World Health Organization, have repeatedly recommended that we collect accurate epidemiological data on this parasite. Because tachyzoites can survive outside the host for only a short time, It is generally believed that postnatal human infections result from the ingestion of one of two persistent stages of *T. gondii*, tissue cysts in the flesh or viscera of many animals, and oocysts shed into the environment by domestic and feral cats. Their specific role in the epidemiology of *T. gondii* infection is still not well understood. Consumption of undercooked or grilled meat has been shown to be the primary risk factor for primary infection or seropositivity in humans in several recent case-control studies.

Waterborne transmission of oocysts to humans may be of greater epidemiologic importance than previously thought. Whether the risk of infection with *T. gondii* from oocysts shed by domestic cats in their owners' homes can be significantly reduced by preventive measures is currently unknown. The same is true for measures related to drinking water quality control. Contagious *T. gondii* oocysts from the environment may be present in this drinking water. Therefore, the human toxoplasmosis outbreak in Vancouver has prompted research on the oocyst stage of the parasite, and methods are being developed to facilitate its detection in drinking water. It is hoped that future epidemiologic studies of *T. gondii* will consider the role of oocysts as a potential source of human infection. There

is also a need for methods to control them in the environment.

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References

[1] Pal, M. (2005). Importance of zoonoses in public health. Indian Journal of Animal Sciences,75: 586-591.

[2] Pal, M. (2007). Zoonoses. 2nd Edition. Satyam Publishers, Jaipur, India.

[3] Ibrahim, A.M. and Abakar, A.D. (2015). Human toxoplasmosis in the Sudan: A review. European Academic Research, 3(6): 6890-6904.

[4] Montoya, J.G. and Liesenfeld, O. (2004). Toxoplasmosis. The Lancet, 363: 1965-1976.

[5] Wang, Z.D., Liu, H.H., Ma, Z.X., Ma, H.Y., Li, Z.Y., Yang, Z.B., Zhu, X.Q., Xu, B., Wei, F. and Liu, Q. (2017). Toxoplasma gondii infection in immunocompromised patients: a systematic review and meta-analysis. Frontiers in Microbiology, 8: 389.

[6] McAuley, J.B. (2014). Congenital toxoplasmosis. Journal of the Pediatric Infectious Diseases Society, 3(1): S30-S35.

[7] Matta, S.K., Rinkenberger, N., Dunay, I.R. et al. (2021). Toxoplasma gondii infection and its implications within the central nervous system. Nat Review of Microbiology, 19**:** 467-480.

[8] Hussain, M.A., Stitt, V., Szabo, E.A. and Nelan, B. (2017). Toxoplasma gondii in the food supply. Pathogens, 6 (2): 21.

[9] Dubremetz, J.F. and Lebrun, M. (2012). Virulence factors of Toxoplasma gondii. Microbes and Infection, 14(15): 1403-1410.

[10] Muralikrishna, P., Sunil, B., Savita, R.K., Archana, S.N., Sudharsan, M., Bharathi, S.V., and Drishya, P. (2017). Toxoplasmosis-The Public Health significance. International Journal of Science, Environment and Technology, 6 (5): 2752-2758.

[11] Frenkel, J.K. (2000). Biology of Toxoplasma gondii. In: Ambroise-Thomas P, Peterse E, editors. Congenital toxoplasmosis: scientific background, clinical management and control. Paris: Springer-Verlag, Pp. 9-25.

[12] Foroutan, M., Dalvand, S., Daryani, A., Ahmadpour, E., Majidiani, H., Khademvatan, S. and Abbasi, E. (2018). Rolling up the pieces of a puzzle: a systematic review and meta-analysis of the prevalence of toxoplasmosis in Iran. Alexandria Journal of Medicine, 54 (3): 189-196.

[13] Hehl, A.B., Basso, W.U., Lippuner, C., Ramakrishnan, C., Okoniewski, M., Walker, R.A., Grigg, M.E., Smith, N.C., and Deplazes, P. (2015). Asexual expansion of Toxoplasma gondii merozoites is distinct from tachyzoites and entails expression of non-overlapping gene families to attach, invade, and replicate within feline enterocytes. BMC Genomics, 16(1): 1-16.

[14] Dubey, J.P. (2007). The life cycle of Toxoplasma gondii. Toxoplasma Molecular and Cellular Biology. Norfolk, UK: Horizon Bioscience, 1: 3-16.

[15] Maenz, M., Schlüter, D., Liesenfeld, O., Schares, G., Gross, U., and Pleyer, U. (2014). Ocular toxoplasmosis past, present and new aspects of an old disease. Progress in Retinal and Eye Research, 39: 77-106.

[16] Tenter, A.M. (2009). Toxoplasma gondii in animals used for human consumption. Memórias do Instituto Oswaldo Cruz, 104 (2): 364-369.

[17] Tu, V., Yakubu, R. and Weiss, L.M. (2018). Observations on bradyzoite biology. Microbes and Infection, 20(10): 466-476.

[18] Abdel-Rahman, M.A. (2017). Toxoplasmosis in man and animals. Journal of Chemistry Environmental Health, 3 (2): 54-73.

[19] Dubey, J.P. (2020). The history and life cycle of Toxoplasma gondii. In Toxoplasma gondii. Academic Press, Amsterdam, Netherlands. Pp. 1-19.

[20] Tenter, A.M., Heckeroth, A.R. and Weiss, L.M. (2000). Toxoplasma gondii: from animals to humans. International journal for parasitology, 30(13): 1217-1258.

[21] Zhou, P., Chen, Z., Li, H.L., Zheng, H., He, S., Lin, R.Q., and Zhu, X.Q. (2011). Toxoplasma gondii infection in humans in China. Parasites and Vectors, 4(1): 1-9.

[22] CDC (Center for Disease Control and Prevention). (2024). Epidemiology and risk factors. https://www.cdc.gov/parasites/toxoplasmosis/epi.html.

[23] Daryani, A., Sarvi, S., Aarabi, M., Mizani, A., Ahmadpour, E., Shokri, A., Rahimi, M.T., and Sharif, M. (2014). Seroprevalence of Toxoplasma gondii in the Iranian general population: a systematic review and metaanalysis. Acta Tropica, 137: 185-194.

[24] Pereira-Chioccola, V. L., Vidal, J. E. and Su, C. (2009). Toxoplasma gondii infection and cerebral toxoplasmosis in HIV-infected patients. Future Microbiology, 4(10): 1363-1379.

[25] Kodym, P., Malý, M., Beran, O., Jilich, D., Rozsypal, H., Machala, L. and Holub, M. (2015). Incidence, immunological and clinical characteristics of reactivation of latent Toxoplasma gondii infection in HIV-infected patients. Epidemiology and Infection, 143(3): 600-607.

[26] Montazeri M, Mikaeili Galeh T, Moosazadeh M, Sarvi S, Dodangeh S, Javidnia J, Sharif M, Daryani A. (2020). The global serological prevalence of Toxoplasma gondii in felids during the last five decades (1967-2017): a systematic review and meta-analysis. Parasit Vectors. 17;13(1):82.

[27] Foerster, B.R., Thurnher, M.M., Malani, P.N., Petrou, M., Carets-Zumelzu, F.and Sundgren, P.C. (2007). Intracranial infections: clinical and imaging characteristics. Acta Radiologica, 48(8): 875-893.

[28] Ahuja, J. and Kanne, J.P. (2014). Thoracic infections in immunocompromised patients. Radiologic Clinics, 52(1): 121-136.

[29] Elsheikha, H.M. (2008). Congenital toxoplasmosis: priorities for further health promotion action. Public Health, 122 (4): 335-353.

[30] Pal, M., Alem, B., Gari, G. and Tuli, G. (2014). Toxoplasmosis in animals and humans, its diagnosis, epidemiology and control. International Journal of Livestock Research, 4 (2): 1-10.

[31] Opsteegh, M., Haveman, R., Swart, A.N., Mensink-Beerepoot, M.E., Hofhuis, A., Langelaar, M. F.M. and Van der Giessen, J.W. (2012). Seroprevalence and risk factors for Toxoplasma gondii infection in domestic cats in The Netherlands. Preventive Veterinary Medicine, 104(4): 317-326.

[32] Baneth, G., Thamsborg, S.M., Otranto, D., Guillot, J., Blaga, R., Deplazes, P.and Solano-Gallego, L. (2016). Major parasitic zoonoses associated with dogs and cats in Europe. Journal of Comparative Pathology, 155(1): 54-74.

[33] Dubey, J.P. (2009). History of the discovery of the life cycle of Toxoplasma gondii. International Journal for Parasitology, 39(8): 877-882.

[34] Pagmadulam, B., Myagmarsuren, P., Fereig, R.M., Igarashi, M., Yokoyama, N., Battsetseg, B. and Nishikawa, Y. (2018). Seroprevalence of Toxoplasma gondii and Neospora caninum infections in cattle in Mongolia. Veterinary Parasitology: Regional Studies and Reports, 14: 11-17.

[35] Wilson, A.G., Lapen, D.R., Provencher, J.F., Wilson, S. (2024) The role of species ecology in predicting Toxoplasma gondii prevalence in wild and domesticated mammals globally. PLoS Pathog, 20(1): e1011908.

[36] Warschkau, D., Seeber, F. (2023). Advances towards the complete in vitro life cycle of Toxoplasma gondii. Fac Review, 13; 121.

[37] Pitter, C., Kahn, J. G., Marseille, E., Lule, J. R., McFarland, D. A., Ekwaru, J. P. Bunnell, R., Coutinho, A. and Mermin, J. (2007). Cost-effectiveness of cotrimoxazole prophylaxis among persons with HIV in Uganda. JAIDS Journal of Acquired Immune Deficiency Syndromes, 44 (3): 336-343.

[38] Flegr, J., Prandota, J., Sovičková, M., and Israili, Z. H. (2014). Toxoplasmosis–a global threat. Correlation of latent toxoplasmosis with specific disease burden in a set of 88 countries. PloS One, 9 (3): e90203.

[39] Dubey, J.P. and Jones, J.L. (2008). Toxoplasma gondii infection in humans and animals in the United States. International Journal for Parasitology, 38(11): 1257-1278.

[40] Stanić, Ž., and Fureš, R. (2020). Toxoplasmosis: a global zoonosis. Veterinaria, 69 (1): 31-42.

[41] Stokkermans TJ, Havens SJ. (2023). Toxoplasma retinochoroiditis. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing.

[42] Pal, M., Berhanu, G., Steinmetz, C.H.D., Durglishilvi, N. (2021). Toxoplasmosis: An emerging and re-emerging zoonosis of global public health concern. American Journal of Infectious Disease and Microbiology, 9: 32-38.

[43] Mathew, S. (2018). Seroprevalence of IgG Toxoplasma in HIV Infected Patients. Journal of Evolution of Medical and Dental Sciences, 7(9): 1148-1152.

[44] Smith, J.R., Ashander, L.M., Arruda, S.L., Cordeiro, C.A., Lie, S., Rochet, E., Belfort, R., and Furtado, J.M., (2021). Pathogenesis of ocular toxoplasmosis. Progress in Retinal and Eye Research, pp.100882.

[45] Sepúlveda-Arias, J.C., Gómez-Marin, J.E., Bobić, B., Naranjo-Galvis, C.A., and Djurković-Djaković, O. (2014). Toxoplasmosis as a travel risk. Travel Medicine and Infectious Disease, 12(6): 592-601.

[46] Frenkel, L.D., Gomez, F., and Sabahi, F. (2018). The pathogenesis of microcephaly resulting from congenital infections: why is my baby's head so small? European Journal of Clinical Microbiology and Infectious Diseases, 37(2): 209-226.

[47] Yamada, Hideto, Tanimura, Kenji, Deguchi, Mashashi, Tairaku, Sinya, Morizane, Mayumi, Uchida, Akiko, Ebina, Yasuhiko and Nishikawa, Akira. (2019). A cohort study of maternal screening for congetinal Toxoplasma gondii infection: 12 years' experience.

Journal of Infection and Chemotherapy, 25 (6): 427-430.

[48] Rorman, E., Zamir, C.S., Rilkis, I.and Ben-David, H. (2006). Congenital toxoplasmosis-prenatal aspects of Toxoplasma gondii infection. Reproductive Toxicology, 21(4): 458-472.

[49] Moncada, P.A. and Montoya, J.G. (2012). Toxoplasmosis in the fetus and newborn: an update on prevalence, diagnosis and treatment. Expert Review of Anti-infective Therapy, 10 (7): 815-828.

[50] Fallahi, S., Rostami, A., Shiadeh, M. N., Behniafar, H. and Paktinat, S. (2018). An updated literature review on maternal-fetal and reproductive disorders of Toxoplasma gondii infection. Journal of Gynecology Obstetrics and Human Reproduction, 47(3): 133-140.

[51] Hurt, K., Kodym, P., Stejskal, D., Zikan, M., Mojhova, M., Rakovic, J. (2022). Toxoplasmosis impact on prematurity and low birth weight. PLoS ONE, 17(1):

[52] Khurana, S. and Batra, N. (2016). Toxoplasmosis in organ transplant recipients: Evaluation, implication, and prevention. Tropical Parasitology, 6(2): 123.

[53] Montoya, J.G. (2002). Laboratory diagnosis of Toxoplasma gondii infection and toxoplasmosis. Journal of Infectious Diseases, 185 (1): S73-S82.

[54] Liu, Q., Wang, Z.D., Huang, S.Y. and Zhu, X.Q. (2015). Diagnosis of toxoplasmosis and typing of Toxoplasma gondii. Parasites and Vectors, 8(1): 292.

[55] Dong, H., Su, R., Lu, Y., Wang, M., Liu, J., Jian, F. and Yang, Y. (2018). Prevalence, risk factors, and genotypes of Toxoplasma gondii in food animals and humans (2000-2017) from China. Frontiers in Microbiology, 9: 2108.

[56] Kijlstra, A. and Jongert, E. (2008). Control of the risk of human toxoplasmosis transmitted by meat. International Journal for Parasitology, 38(12): 1359-1370.

[57] Aguirre, A.A., Longcore, T., Barbieri, M., Dabritz, H., Hill, D., Klein, P.N., Lepczyk, C., Lilly, E.L., McLeod, R., Milcarsky, J. and Murphy, C.E. (2019). The one health approach to toxoplasmosis: epidemiology, control, and prevention strategies. EcoHealth, 16 (2): 378-390.

[58] Deganich, M.; Boudreaux, C.; Benmerzouga, I. (2023). Toxoplasmosis Infection during pregnancy. Tropical Medicine and Infectius Diseases, 8: 3.