

Article

Giardiasis: A Review of Species, Clinical and Pathological Manifestation and Immunity

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Abstract: *Giardia* are non-invasive intestinal protozoan parasites and are the causative agent of giardiasis. It is widely distributed worldwide, infecting humans, domestic animals such as cats and dog, as well as mammals, fish, and bird clinical signs range from asymptomatic infection to foul-smelling, fatty diarrhea, nausea, bloating, abdominal cramps and weight loss, and chronic exposure to the infection may lead to malabsorption. The *Giardia duodenalis* comprises genetically diverse variants categorized into assemblages A-H. Among these assemblages, assemblages A and B are of particular epidemiological importance due to their capacity to infect humans and animals.

Keywords: Giardiasis, Species, Assemblages A-H, Diagnosis

Introduction

Giardia spp. is a binucleated, flagellated protozoan parasite residing in the intestine, classified within the family Hexamitidae [1]. *Giardia* is a parasite found in domesticated animals, particularly dogs, cats, cattle, and many type of birds and wild mammals, and as well as fish have been recorded as hosts [2]. After ingestion, the infectious cysts are released in the intestinal tract, forming the vegetative stage, where they adhere to the intestinal epithelium and obtain their nourishment from the host. The trophozoite then continue their life cycle by transforming again into cysts that excreted from body with feces, the incubation period usually lasts from one to two weeks [3].

The clinical manifestation of *Giardia* infection vary considerably in both humans and animals, the infection may lead to acute or chronic diarrhea accompanied by nausea, hypersensitivity, and weight loss; however, asymptomatic infection are also known to occur frequently [4], in chronic cases, the disease is distinguished by persistent decreased of appetite, nausea ,fatigue, diarrhea and weight loss. Lactase deficiency following infection is a common complication [5]. Six species

assigned to the genus *Giardia* have been identified, these species have been identified according to morphological and ultrastructural characteristics of their vegetative stages, *Giardia agilis* in amphibians, *Giardia duodenalis* in mammals, *Giardia muris* and *Giardia microti* in rodents, in addition *Giardia ardeae* and *Giardia psittaci* in birds [4]. Molecular analyses revealed that *Giardia duodenalis* is composed of eight genetic assemblage within the *Giardia* complex. Assemblage A and B have been recorded in human as well as in domesticated animals, assemblages C-H are frequently observed in domestic and wild animals and are seldom recorded in humans. [6], assemblage A exhibits subdivision, consisting mainly of two sub-assemblages, AI and AII, which were initially identified based on allozyme study and subsequently confirmed by evolutionary analyses of the A assemblages at the (gdh) locus. Lately, a third sub-assemblages in this assemblages (AIII) has been characterized and is believed to be related to terrestrial hoofed animals [7].

Infection with the *Giardia lamblia* parasite triggers an adaptive cellular and humoral immune response, CD4+ T lymphocytes particularly Th17 and Th1 cells, play a crucial role in regulating this response. Th17 cells contribute to the recruitment of neutrophils and stimulate intestinal epithelial cells to secrete antimicrobial peptides via IL-17 production, while Th1 cells secrete IFN- γ , which activates macrophages and enhances their ability to eliminate the parasite [8].

Life cycle

The *Giardia* parasite in its life cycle includes two phase, trophozoite and the cyst [9], the trophozoite is responsible for the clinical disease in human by attaching to walls of the small [(10), the trophozoite is pear-shaped with a rounded anterior end and a pointed posterior end, it measures approximately 12-15 μ m in length and 5-9 μ m in width [11]. The organism is characterized by morphological symmetry, and the vegetative stage contains eight flagella, a pair of them are located in the front part, two pairs in the middle region ,while a last pair is located at the rear end, which contribute to the movement of the vegetative stage and its transfer from one position to another [12], on other hand, cysts are the infectious stage in nature and responsible for disease transmission. The cyst is oval-shaped, measuring between 10-16 μ m in length and a width of 7-10 μ m, with a wall thickness of approximately 0.3 μ m, the cystic cytoplasm contains remnants of flagella and two pairs of nuclei, which may be situated at one extremity of the cyst or appear as opposite pairs at the other end [13].

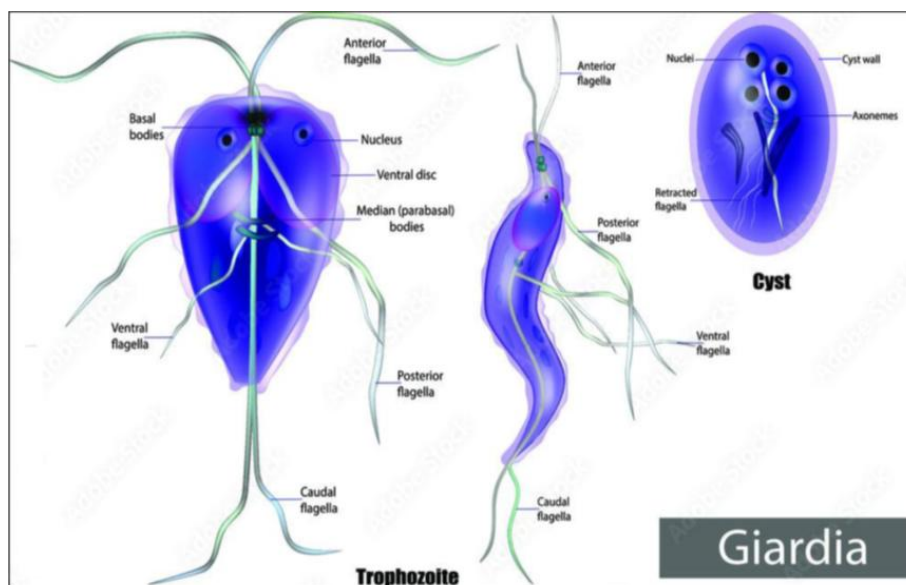


Figure 1. Morphological stages of Trophozoite and Cyst [14]

The process of exiting the cyst and releasing the trophozoite begins due to a reduced pH level in the stomach, exiting the cyst is completed under alkaline condition of the small intestine. The trophozoite adhered to the epithelial layer of the intestinal tract and multiplies in it binary fission, producing huge number of parasites that colonize the duodenum and jejunum [15], the released of bile into the lumen of the small intestine transforms it into a cyst resistant to environmental conditions. These cyst are excreted with feces and has the ability to withstand environmental conditions for several months, being infectious in nature, they contribute to environmental pollution, leading to contamination of food and water sources [16].

Giardia is transmitted via ingestion cysts through contaminated water, and transmission can also occur through uncooked food or fecal-oral contact [17], most cases of giardiasis are transmitted from person to person [18]. Dogs are considered an important factor in the transmission of giardiasis from animals to humans, as dogs in urban areas of developed countries contribute a key role in transmitting the infection from animals to humans [19].

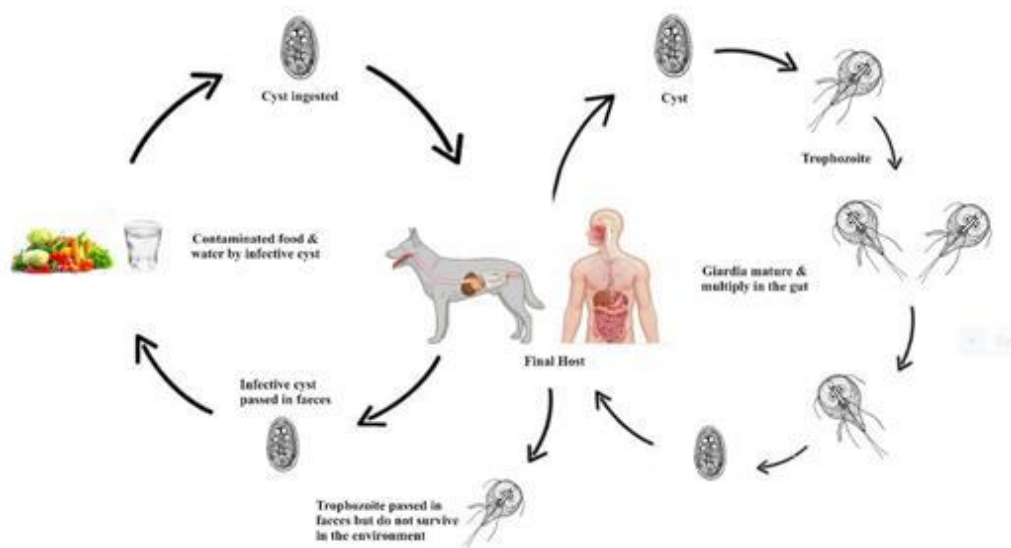


Figure 2. A diagram illustrating the life cycle of Giardia [3]

Species

Currently, six species of the genus *Giardia* have been documented: *G. osittaci*, *G. agilis*, *G. ardeae*, *G. microti*, *G. muris* and *G. duodenalis*, another reptile-isolated, similar in appearance to *G. duodenalis*, except that it lacking the median bodies and possessing a binucleated cyst, has also been reported; therefore, it has been classified as *Giardia varani* [20]. In scientific literature, several names are used to refer to the identical organism, *G. lamblia*, *G. duodenalis* and *G. intestinalis*. The parasite is often referred to as *G. duodenalis* when discussing its infection of livestock, pets and humans. In contrast, the and giardiasis and its pathological effects on humans. [21].

Giardia duodenalis is considered a species capable of infecting human and many other mammals, and it has classified into eight genetically distinct assemblages A-H based on genetic study and the degree of host specificity [22], recently, attention has been paid to infection caused by *Giardia* in animals that can transmit the disease to humans, a clear association has been documented between human giardiasis infections and drinking water and as well as recreational activities [23]. Assemblages A is considered more frequent, as it has been notably documented in livestock includes, sheep, cows, goats, water buffalo, alpacas and pigs, in addition, pets includes dogs, horses and cats [24]. Assemblages A and B are characterized by their ability to infect a broad range of hosts, such as humans, domesticated animals, livestock and wild animals, and are therefore classified as

zoonotic. In contrast, assemblages C and D primarily infect canids, while assemblages E is found in ungulates, both domestic wild. Assemblages F is most commonly found in felines, assemblages G in rodents, and assemblages H is associated with marine animals [25].

The focus of attention regarding the zoonotic susceptibility of *Giardia* is on assemblages A and B, where the pathogen demonstrates infectivity in humans and animals, assemblages A is characterized by variation in its transmissibility between species and has been classified into subtypes ranging from AI to AIV, humans infections are primarily recorded with types AI and AII, while animal infections are recorded with types AI, AIII and AIV [26]. Although *G. lamblia* assemblages continues to be classified and associated with specific hosts to this day, the precise characterization of these assemblages has not yet been definitively established, advances in genotyping studies have shown that host specialization is not as fixed or rigid as previously thought. It is possible that *G. lamblia* strains have undergone evolutionary processes that have enabled them to adapt to hosts belonging to different species, or that early studies lacked a sufficient understanding of the infectivity of these assemblages [27].

Epidemiology

Giardiasis is a common disease worldwide affecting all age group, from children to adults. It is major cause of waterborne and foodborne diarrhea and is associated with spread in childcare institutions and data indicate it is frequently reported among travelers, the disease is more prevalent in developing countries, approximately 200 million of infections diagnosed annually worldwide. In industrialized countries, the spread of asymptomatic giardiasis in children varies between 1% and 8%, while in less developing countries it can reach 8% to 30%. the risk of giardiasis is also higher in individuals with diarrhea due to its higher prevalence group [28,29]. There are multiple risk factors attending daycare centers, their caregivers, residents of closed institution, and travelers to endemic areas, the risk of infection also increases with the consumption or recreational use of contaminated water and individuals with impaired immunity. Diarrhea is considered the most obvious clinical sign in acute cases, occurring in approximately 90% of patients exhibiting symptoms, while about 70-75% experience [5].

Factors affecting the distribution and transmission of the *Giardia* parasite include climate change, and rising temperatures and increased rainfall may lead to disease outbreaks [30], epidemiological surveillance data showed that giardiasis has bimodal age distribution, with the highest incidence rates recorded within the age group of 0-9 years and also within the age group of 45-49 years, with no significant differences in incidence rates between the sexes [31], dogs and cats are among the most important domestic animals for the transmission of giardiasis. The last century saw a significant increase in pet ownership, coinciding with the adoption of stray animals, which often lack proper veterinary care. Furthermore, the growing humanization of pets has led to increased closeness and interaction with humans, potentially facilitating the transmission of zoonotic pathogens [32].

Clinical and pathological manifestation

The clinical symptoms of giardiasis vary from asymptomatic cases to cases with clear clinical signs such as chronic or acute diarrhea occurring simultaneously with nausea and pain in the abdomen [5], the clinical signs of giardiasis vary considerably in animals, ranging from cases that can cause chronic or acute diarrhea, Hypersensitivity, nausea and Wight loss, to asymptomatic infection that commonly occur [4]. *Giardia* is a non-cell-invasive intestinal parasite and is considered the causative agent of giardiasis. Clinically the infection manifests as abdominal pain and nausea, later

progressing to intense watery diarrhea that may lead to dehydration, along with malabsorption and loss of body weight. Chronic infections are marked by repeated short-term or ongoing episodes of diarrhea. In some patients, the infection may resolve within a few weeks, whereas in others it may persist and progress to a chronic condition. The intensity and nature of symptoms vary according to the immune condition of the infected person, in addition to other factors unrelated to immunity that are related to the interaction between the host and the parasite. Nevertheless, the pathophysiological mechanisms underlying these symptoms are still not fully understood [33]. When *Giardia* attaches to the epithelial cells of the intestine, it leads to pathogenesis in the host, which displacement of the normal microflora and an imbalance in the microbial balance, as well as causing injury and stimulating apoptosis, thus creating an anaerobic intestinal environment [34]. The condition manifests with several common signs and symptoms, including bloating, nausea with or without vomiting and general feeling of discomfort. Symptoms to watch for include diarrhea, increased gas, foul smelling stools that tend to float on water, abdominal cramps and pain, and vomiting. Dehydration may develop due to insufficient or lost fluids [35].

Giardiasis may lead to malabsorption and weight loss, signs of infection include loose stools two to five times a day followed by increased fatigue. As for fever, itchy skin, periorbital swelling along with joint swelling and hives, these are less frequent signs. The disease can affect the absorption of essential nutrient includes lactose, fats, vitamin A, vitamin B12, negatively impacting body weight. It's worth noting that some infected individuals experience no noticeable symptoms, and in most cases, recovery occurs within two to six weeks. However, symptoms may temporarily disappear in some cases and then reappear after a few days or week [(36)].

The mechanical interference of the parasite with fat absorption is a major pathogenic mechanism, it adheres to and coats the mucous membrane of the intestinal tract, giving rise to fat malabsorption and the development of steatorrhea, which is frequently observed in chronic infection. Furthermore, inflammation and sensitization of the small intestinal mucosa increase fluid secretion and loss, causing acute or chronic diarrhea [37]. Vegetative stage of the organism capable adhering to the intestinal epithelial lining through their ventral disk, according to research, the organisms can influence the intercellular junction in the small intestinal epithelium, as well as the enzymes of the brush border. This leads to changes in gastrointestinal motility that can be observed infected individuals. Furthermore, the organisms can affect cell through the production of thiol proteinases and lectins, thus increasing permeability and hindering carbohydrate absorption [29]. When livestock are infected with the disease, symptoms often manifest as watery diarrhea accompanied by dehydration, gastroenteritis, loss of appetite, reduced weight gain, and lethargy, and the condition may sometimes end in death [38].

Diagnosis

Stool examination is the most widely used method for diagnosing giardiasis, a smear is prepared from a fecal sample with saline solution or a fixative solution consisting of sodium acetate, acetic acid and formalin, the probability of detecting *Giardia* cysts increases with the number of samples examined [39]. Diagnosis is according to clinical assessment of symptoms and is confirmed through microscopic examination of the parasite stages in a fecal specimen, either the trophozoite or cyst stage, formed fecal samples are usually examined for cysts, while diarrheal stool samples are used to detect trophozoite, as they are more clearly visible in severe cases [40].

Giardiasis can be diagnosed serologically using several tests, including the ELISA test, indirect immunofluorescence assay (IFA), an western blot test. A positive result for *Giardia* antigens indicates a giardiasis infection, if the infected person does not show clinical symptoms, it may indicate that

they are a carrier of the parasite or have chronic infection [41], parasitic antigens are detected in stool samples, whether formalin-preserved or fresh, using several immunological techniques. Among the most prominent of these are enzyme-linked immunosorbent (ELISA), non-enzyme-linked immunochromatographic tests, along with rapid antigen detection tests (RDTs) these methods are characterized by sensitivity comparable to, and sometimes exceeding, that of conventional microscopic examination of stool samples [28].

Studies conducted to date on giardiasis have focused primarily on its molecular characterization in various animals, with the aim of identifying the reservoir host and assessing the risk of zoonotic transmission from animal to humans. With current scientific advancements, it has become possible to determine precise genetic patterns in both animals and humans thanks to the continuous improvement in molecular tools and their application [42]. PCR enables to detect *Giardia* species as well as their genotype, although its diagnostic application are limited it is widely used in research laboratories for subtype in order to diagnose different *Giardia* assemblage and sub-assemblage [39], *Giardia* species have been identified in molecular studies by targeting a number of gene sequences, including: SSu rRNA, *gdh*, *tpi* and β -giardin genes (28).

Immunity

The importance of the mucosa-associated immune system in the gastrointestinal tract lies in maintaining intestinal homeostasis, enabling the precise differentiation between harmful pathogens and beneficial microbes. This system mounts effective immune responses that eliminate pathogens while minimizing damage to body tissue. The first line of defense comprises an integrated system that include various cell type, such as epithelial cell, dendritic cells, goblet cells, macrophages and T cell, in addition to secreted mucins, antimicrobial peptides, IgA, and cytokines, any disruption to one of the components of this system leads to increased susceptibility to infection or inflammation, or to chronic organ dysfunction [43].

Adhesion between the vegetative stage and intestinal epithelial cells stimulates the production of several chemokines and cytokines, whose role are involved in regulating innate immunity and helping to eliminate *G. lamblia*. Dendritic cells also have the ability to recognize and respond effectively to the trophozoite [44], CD4+ T cells contribute significantly to the immune defense mechanisms to resist parasite. Research has shown that they contribute effectively to the immune response against *G. lamblia* by activating immune cells and promoting B cell differentiation, leading to the production of specific antibodies that help fight infection [45], despite the significant of CD4+ T lymphocytes in eliminating *Giardia* parasite in mouse models of parasite, neither IFN- γ nor IL-4, are considered essential agents in the elimination of these parasite (46).

Giardia infection stimulates the production of high level of parasite –specific immunoglobulin A (IgA) with CD4+ T cells playing a pivotal role in promoting this response and regulating the infection pathway. Studies have shown that *Giardia* infection induce significant changes in the mucosal cytokine milieu. In the early stage of infection, a mixed inflammatory response may arise, involving cytokine such as TNF- α , IL-1 β , Th1 and Th17, and accompanied by the production of specific antibodies such as IgA and IgG. As the infection progresses, the immune response pattern often shifts to a regulatory or type-2 biased pattern, characterized by the release of cytokine (IL-5, IL-4 and IL-25), along with increased IL-10 production and an increase in goblet cell numbers. This shift is believed to contribute to parasite survival while providing some protection to the mucosa from damage or excessive inflammation [47].

Control

Completely controlling of *Giardia* poses a significant challenge since the cysts become infectious once shed with feces, increasing the likelihood of reinfection. Therefore, limiting fecal environmental contamination is essential to reducing transmission and preventing recurrence [48], maintaining hands hygiene before preparing meals and eating, as well as after using the restroom, helps reduce the risk of giardiasis. The infection is also common in childcare centers, so children with diarrhea should avoid drinking untreated water such as river, lake, and stream water. Boiling water is an effective way to kill *Giardia*, and chlorination and filtration are also effective methods for removing the parasite from water [49].

Conclusion

There are six documented species of the genus *Giardia*, among these *G. duodenalis* is of great public health importance widespread throughout the world, infecting both humans and animals, *G. duodenalis* are also characterized by genetic diversity, with assemblages A and B possessing the ability to infect both humans and animals, making them an important factor in human-animal transmission.

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