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Review Article

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Review on the Epidemiology and Public Health Importance of Giardiasis

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Abstract

Giardia is a protozoan parasite of mammals including humans. It is one of the most common parasitic infections having a worldwide distribution. Giardia parasites have a wide host range, including mammals, birds and amphibians. Amongst the species of Giardia, G. duodenalis (syn, G. intestinalis/lamblia) has the broadest host range and is the species with the greatest public and animal health significances in terms of gastrointestinal disease. Humans have been reported to have G. duodenalis Assemblages A-II or B, and these assemblages are considered to be of broad host ranges, and thus potentially zoonotic due to infect both human and other domestic and wild animals. Aquatic mammals, is commonly infected with Giardia, there is little evidence to implicate such infections as the original contaminating source in waterborne outbreaks. Giardia lamblia infections have a wide clinical spectrum ranging from asymptomatic carriage to long-lasting diarrhea with malabsorption. So far, it remains unclear whether asymptomatic human infections relate to the carriage of "nonpathogenic" strains, or whether the host is able to maintain parasite numbers at a subclinical level without complete clearance of the infection. There are four main cycles of transmission that have been proposed to maintain host-specific and zoonotic assemblages of Giardia in mammalian hosts: human, livestock, dog/cat and wildlife cycles. Water is an essential factor in the transmission of giardiasis in men that is why this is the commonest human waterborne disease. Future studies by animal and public health experts should focus on genetic characterization of the parasite so as to elucidate the zoonotic importance of Giardia. More extensive research is necessary among humans, animals and water sources with regard to Giardia carriership. The obtained isolates should be genotyped in order to investigate the sources of contamination and to undertake efficient measures for reduction of infection rates in both animals and people.

Keywords: Assemblages, Giardiasis, Public Health Importance, Zoonotic Significance

1. Introduction

Giardia is a ubiquitous intestinal flagellated protozoan parasite of mammals that cause giardiasis and are common in various hosts including humans, nonhuman primates, domestic and wild animals, with high frequency in dairy calves [1,2]. Giardiasis is one of the most common parasitic infections having a worldwide distribution and occurring both in developed and developing nations. In Africa, Asia and Latin America about more than 200 million giardiasis cases have been estimated to occur annually Prevalence's of giardiasis in humans are generally lower in developed countries with 0.4 7.5% reported for developed countries and 8 30% for developing countries [3,4].

Currently, genus Giardia has six Giardia species that are accepted by most researchers on the basis of their morphological and ultrastructural characteristics of their trophozoites and/or cysts and host range. This comprises *G. agilis* in amphibians, *G. ardeae* and *G. psittaci* in birds, *G microti* and *G. muris* in rodents, and *G.*

duodenalis in mammals [5]. Amongst these six currently accepted species of Giardia, *G. duodenalis* (syn. *Intestinalis/lamblia*) has the broadest host range and is the species with the greatest public and animal health significances in terms of gastrointestinal disease. *G. duodenalis* is detected frequently in many mammals and is one of the most common intestinal parasites in pets like dogs and in livestock [4,6,7].

There are eight recognized genotype groups or assemblages of *G. duodenalis*, named A H [8]. Among them, assemblages A and B have been identified in both humans and animals whereas the remaining six assemblages (C–H) infect non-human hosts and have marked host specificity (narrow host range) [9]. Dogs (Canis familiarise) are infected primarily with assemblages C and D, cats (*Felis catus*) with Assemblage F, cloven hoofed animals with assemblage E, rats with assemblage G and assemblage H infects marine animals [10].

However, several animal species, including dogs and cats, have also been reported to carry assemblages A or B. These assemblages are considered to be of broad host specificity, and thus potentially zoonotic [7]. Humans have been reported to have *G. duodenalis* assemblages A-II or B, later reports show infections with assemblage A-I. However, no infections with assemblages C or D (dog specific) and F (cat specific) have ever been reported in people [11].

Data from molecular studies have proved that productive animals, pets and wild animals were carriers of zoonotic and host-specific G. duodenalis genotypes. Giardia is considered zoonotic agents that transmitted either directly by the fecal oral route or through water. The consumption of water from unreliable sources is a considerable risk with regard to infection with Giardia [12].

It is well documented that in developing countries, infections are associated with poor sanitary conditions, poor water quality and overcrowding [13]. whereas in industrialized countries cases are usually associated with international travel and immigration [14,15]. Populations at increased risk of autochthonous infection include small children in day care centers [16], men who have sex with men and persons in custodial institutions [14,17,18].

Giardiasis is continuously causing an infection of millions of peoples throughout the world and it is one of particular importance in developing countries and socio economically disadvantaged area. Therefore, current and up to date information on the epidemiological status of Giardiasis is an important in order to design appropriate control and prevention strategies so as to reduce the risk infection and safer guard public health. Therefore, objective of this paper is

- To overview the current epidemiology and public health implications of Giardiasis.

2. Literature Review

2.1 Historical Background of Giardia

Giardia was first discovered by Antoine van Leeuwenhoek over 300 years ago and since then, six Giardia species have been described [19]. Two hundred years later, in 1859, the organism was described in greater detail by Vilem Lambl, a Czech physician that gives his name to the parasite, when observing the stools of children with diarrhea. However, he believed that the protozoa were a commensal microbe not responsible for the diarrhea. Curiously, this concept remains for a long time in the mind of many physicians, even on the twenty centuries. In 1888, Blanchard suggested the name lamblia intestinalis to the parasite described by Vilem Lambl. Later it was modified to G. duodenalis by Stiles in 1902. Subsequently, Kofoid and Christiansen proposed the names G. lamblia in 1915 and G. ienter in 1920.

2.2 Taxonomy And Nomenclature Of Giardia

The nomenclature for Giardia is confusing and, although the modern genetic analysis tools helped in this organization, there is still lack of clarity [11]. Previously the systematic nomenclature was based on host specificity and light microscopy characteristics. According to this nomenclature, Giardia is flagellated protozoan parasites that belong to the Phylum Protozoa, Subphylum Sarcomastigophora, Superclass Mastigophora, Class Zoomastigophora, Order Diplomonadida, and Family Hexamitidae The family Hexamitidae is characterized by flagellated protozoa with diploid nuclei, a unique attachment organelle called the ventral disc, and absence of mitochondria and peroxisomes [20].

The newest systematic, however, is based on genetic, structural and biochemical data, and places Giardia in the phylum Metamonada, Subphylum Trichozoa, Superclass Eopharyngia, Class Trepomonadea, Subclass Diploza, Order Giardiia and Family Giardiidae [16].

2.2.1 Giardia Species

Currently, six G iardia spp. are accepted by most researchers on the basis of the morphological and ultra-structural characteristics of their trophozoites and/or cysts and host range: *G. duodenalis* in mammals, *G. muris* and *G. microti* in rodents, *G. psittaci* and *G. ardeae* in birds, and *G. agilis* in amphibians [5,21]. Amongst the six currently accepted species of Giardia, *G.duodenalis* (syn. *Intestinalis/lamblia*) has the broadest host range and is the species with the greatest public and animal health significance in terms of gastrointestinal disease. *G. duodenalis* is detected frequently in many mammals and is one of the most common intestinal parasites in pets like dogs and in livestock [4]. Remain five species are host specific and have not been found to infect humans.

Species	Hosts	Trophozoite morphology	Trophozoite dimensions, µm
G. duodenalis	Man, domestic and wild mammals	Piriform trophozoite with claw shaped median bodies	12–15/6–8
G. agilis	Amphibians	Long, narrow trophozoite with club-shaped median bodies	20–30/4–5
G. muris	Rodents	Rounded trophozoite with small round median bodies	9–12/5–7
G. ardeae	Birds	Rounded trophozoite with prominent ventral disc notch and rudimentary caudal flagellum. Oval to claw-shaped median bodies	~10/~6.5
G. psittaci	Birds	Piriform trophozoite with no ventrolateral flange and claw-shaped median bodies	~14/~6
G.microti	Rodents, voles and muskrats	Similar to *G. duodenalis*	_____

Table 1: Species of giardia and typical hosts. From Adam, 2001

2.2.2 Giardia Duodenalis Assemblages

Following the great advances on the Giardia molecular typing, the main observation is that G. duodenalis is not a uniform species but a species complex comprising a variety of genetically and phenotypically (yet morphologically similar) differing assemblages (Monis and Thompson, 2003; Thompson, 2004). So, *G. duodenalis* has been classified into at least eight assemblages from A to H, based on substantial sequence differences identified in the gdh, tpi and bg genes [21]. Two of the assemblages, A and B, have zoonotic potential [22]. However, the remaining assemblages (C to H) appear to be host specific [19]. This is because assemblages C and D have been identified in dogs and cats, assemblage E in cattle, sheep, goats and pigs, assemblage F in cats, and assemblage G in rats [23,24].

Sub genotyping techniques have further classified assemblage A into two genetic groups, A-I and A-II, [25]. Type A-II is exclusive to humans, while type A-I occurs in humans, dogs, rodents, and other animals but not cattle [26,27]. More difficult to define sub assemblages in assemblage B, which is genetically diverse. Two sub assemblages, BIII and BIV, were described by alloenzyme electrophoretic apparatus, but DNA sequence analyses do not support these two groups [28].

Also, based on the genetic differences among the *G. duodenalis* complex, some authors propose to classify these assemblages into six different species [29]. In this way, for assemblage A, it was proposed the name *G. duodenalis*, for assemblage B, *G. enterica,* for assemblage C, *G. canis*, for assemblage E, *G. bovis*, for assemblage F, *G. catis* and for assemblage G, *G. simondi.* However, the proposed new species names have not yet been validated by the International Code for Zoological Nomenclature [30].

Genotype/assemblage	Host range
Zoonotic/A	Humans, livestock, cats, dogs, beavers, guina pig, slow loris
Zoonotic/B	Humans, slow loris, chinchillas, dogs, beavers, rats, siamang
Dog/C, D	Dog
Livestock/E	Cattle, sheep, pig
Cat/F	Cat
Rat/G	Domestic rats, wild rodents

Table 2: Genotypes of Giardia duodenalis groups. Taken from Thompson, 200

2.3 Biology of Giardia

2.3.1 General Morphology

Giardia has two distinct morphological forms: the trophozoite (replicative stage) and the cyst (environmentally resistant and infective stage). Trophozoites are 9-20 µm by 5-15µm, pear-shaped body with a broadly rounded anterior end, bi-nucleate cells, with four pairs of flagella, curved median bodies and a ventral adhesive "sucking" disc (cytostome) [30,31].

Cysts are 8-18 µm by 7-10 µm ovoid, with two or four nuclei, non-motile and metabolically dormant [32]. Environmentally stable cysts are passed out in the faeces, often in large numbers.

It is interesting to note that unlike other eukaryotes, Giardia lacks common eukaryotic subcellular compartments such as mitochondria, peroxisomes, and a traditional golgi apparatus [33].

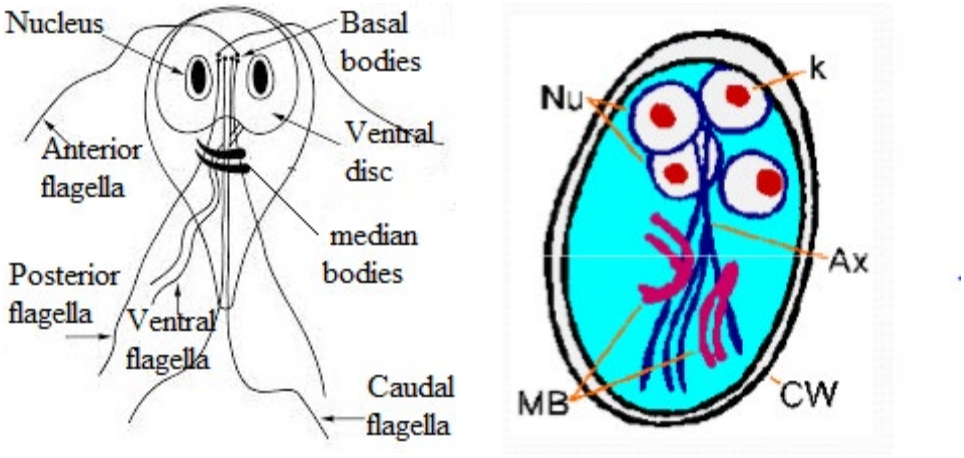

Figure 1: Trophozoite and cyst of g. duodenalis respectively (adapted from faubert, 2000).

2.3.2 Life Cycle of Giardia

The life cycle of *G. duodena*lis is direct, simple, and contains only 2 stages, the trophozoite, the vegetative form found in the intestine, and the cyst, the environmentally resistant form that causes infection upon ingestion [34,35]. Infection with Giardia occurs after a susceptible host ingests an infective dose of viable cysts. Once the cysts are ingested, trophozoites are released from the cysts via excystation, which is triggered by exposure to the alkaline environment in the upper small intestine, as well as gastric acid and pepsin [36].

One cyst will produce four trophozoite as two rounds of cytokinesis occur without immediate DNA replication [37]. The trophozoites then attach to the enterocytes of the mucosal surface in the lumen of the small intestine by using a suction disc located on their ventral surface. Negative pressure at the host-parasite interface created by flagelar movement is believed to facilitate this attachment [38]. Trophozoites are non-invasive and remain in the lumen of the small intestine either attached to the intestinal wall or freely motile, and multiply asexually via longitudinal binary fission.

Although trophozoites mainly reproduce asexually, there is evidence for sexual recombination among Giardia [39]. It has been suggested that there are infrequent combinatory events between different isolates and allelic sequence heterozygosity, particularly associated with G. duodenalis Assemblage B.

As trophozoites, together with the faecal mass, pass through the small intestine, they encyst and are excreted with the faeces. Encystation may be initiated by the presence of bile salts and depletion of cholesterol [40,41]. The implication of encystation is a reduction in adhesion, metabolism and multiplication of the trophozoite which results in disassembly of the ventral disc, internalization of flagella, and encasement in a protective cyst wall.

Encystation is crucial to the survival of the parasite in adverse environmental conditions, and its transmission to susceptible hosts The prepatent period, before cysts appear in the faeces, is generally three to 10 days. Cyst shedding may be continuous over several days and weeks although it is often intermittent, particularly in the chronic phase of infection Cysts do not require maturation after shedding and are immediately infectious to a susceptible host once they are shed into the environment [42]. Cysts are also able to survive for prolonged periods in non-arid environments due to the filamentous structure of their cell wall However, cysts will not survive desiccation or exposure to multiple freeze-thaw fracture cycles.

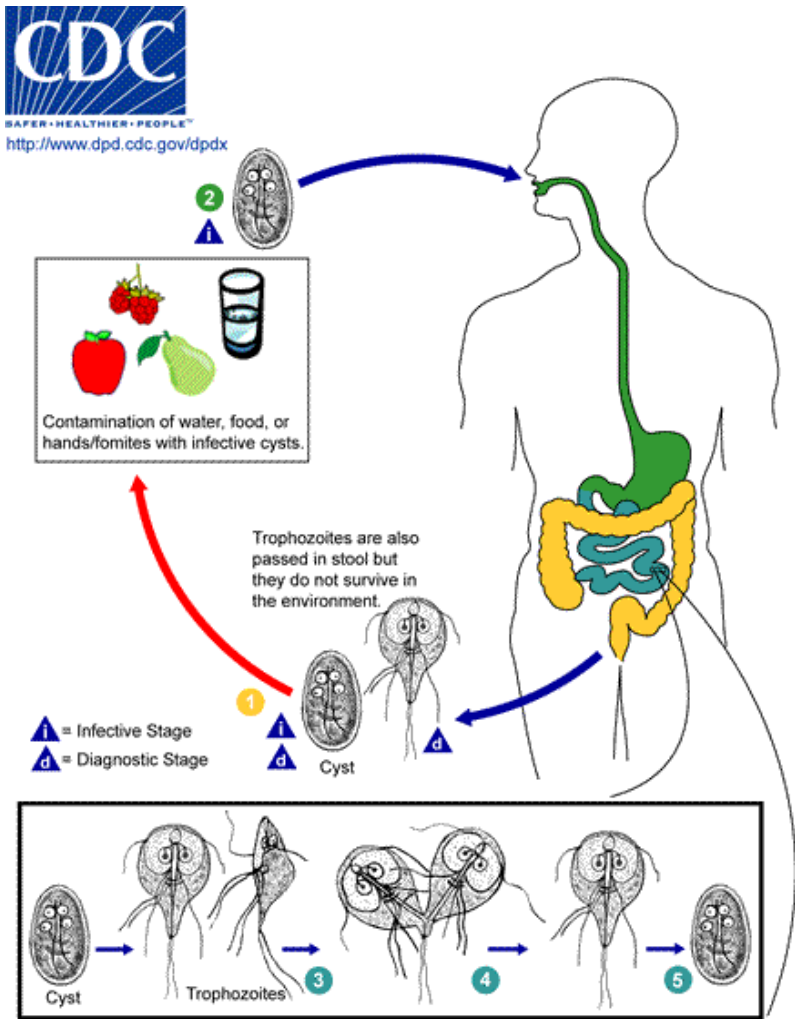

Figure 2: Life Cycles Of Giardia Duodenalis. From CDC 2004 (Www.Cdc.Gov)

2.4 Epidemiology of Giardiasis

2.4.1 Geographical Distribution

G. duodenalis has a world-wide distribution, particularly common in warm climates [43,44]. Giardiasis has a global distribution and places a considerable burden on public health systems worldwide due to the high prevalence and disease burden of the infection, its ability to cause large waterborne outbreaks and its effects on growth and cognitive function in children Therefore, it was included in the World Health Organization's (WHO) neglected disease initiative in 2004 [45]. Although Giardia is the most commonly identified intestinal parasite of humans, it remains highly under-reported [46]. As such, the quality and availability of data concerning infection with Giardia varies from country to country, even in industrialized nations [47].

Various factors such as sensitivity and specificity of a diagnostic test used, number of animals tested, the area studied, number of farms, the health status of the animal, and whether only a one-off faecal sample was examined, considering the intermittent nature of cyst excretion, have contributed to differences in prevalence of Giardia globally [48].

2.4.2 Host Range

Giardia parasites have a wide host range, including mammals, birds and amphibians. Amongst the species of Giardia, *G. duodenalis* (syn. Intestinalis/lamblia) has the broadest host range and is the species with the greatest public and animal health significance in terms of gastrointestinal disease Giardia duodenalis is found in animals, both livestock and companion animals Most of these animals harbor unique *G. duodenalis* assemblages, although some were also found to harbor assemblages A and B, where relies the zoonotic potential of *G. duodenalis.*

According to worldwide observations, majority of cattle, sheep and pigs are infected with the assemblage E of *G. duodenalis*, although a significant number of cattle are also infected with assemblage A. In the opposite, assemblage B is rarely found in cattle and other assemblages (C, D, F or G) were never found in these

animals. There is no age associated differences in the prevalence of assemblages A and E in cattle. In sheep, assemblage E is much more dominant than A, and assemblage B is rarely detected [49]. In pigs, the pattern of assemblage A and E prevalence is similar to that of cattle and sheep Although the studies are quite limited, only assemblages A and B were detected in horses [50].

Regarding the companion animals, for instance dogs, they are infected by a broader range of G. duodenalis assemblages: dogs were found to be infected with assemblages A, B, C and D Cats are also infected with assemblage A and also assemblage F: this assemblage is cat-specific and is found more frequently than assemblage A.

Little information is available on the prevalence of G. duodenalis assemblages affecting wildlife. Some studies showed the presence of assemblage A and E in wild corvids, and only assemblage A in white-tailed deer in the USA moose and reindeer fallow deer and fox and kangaroos [51,52,53] Assemblages B, C and D are found in other wild mammals, such as assemblage B in beavers or assemblage B, C and D in coyotes [54].

G. duodenalis is the only species infecting humans, particularly the established assemblages A and B Both assemblages A and B are also able to infect animals, which imply that the zoonotic transmission plays an important role in the epidemiology of human giardiasis and From Xiao and Fayer, 2008 varies considerably from country to country with assemblage B appearing to be more common overall. However, the number of molecular epidemiological studies concerning giardiasis in humans is smaller and, until now, do not evidence clear geographic or socioeconomic differences in the distribution of assemblage A and B.

2.4.3 Risk Factors

Factors that may be associated with risk of infection with Giardia can be narrowed down to demographic and management factors [54]. Demographic factors may include age distribution of animals sampled, size of the farm, geographic location, herd size, and other species of animals present on the farm.

Calves aged over nine days were found to be more likely to be infected with Giardia when compared with those less than four days [55]. The dairy calves as young as two days of age were harboring the parasite [56]. However, the burden of infection is low in dairy cattle above six months of age (Becher et al., 2004). The high occurrence of Giardia in young animals could be due to the slow development of specific immunity by the host against the parasite [57]. As a result, young animals can be considered to be a source of infection for susceptible hosts. Adult animals are also a potential source of Giardia especially for neonates as a pre-parturient rise cyst excretion in cattle, sheep, goats and pigs [58]. High levels of infection of calves with the parasite on farms located in areas with poorly drained soils and it may increase the retention of moisture which in turn prolongs survival of the cysts in the environment [59,60].

Management factors include general management (type of flooring, calf housing, and frequency and method of cleaning) separation of the dam from the calf and administration of colostrum, and direct contact with infected animals. Generally, intensive management has favor transmission of Giardia cysts The animals reared indoors especially under group housing are more likely to be infected with the parasite than those housed outside [61].

The calves in contact with the dam had higher odds of infection with the parasite than those that separated from the dam [62]. The periparturient rise in Giardia cyst excretion has attributed to the reduced immunity as a result of hormonal alterations during late gestation and early lactation The cattle housed on a concrete floor are more at risk for Giardia duodenalis infection than those housed on slatted ones Furthermore, keeping calves in pens on sand floors is associated with an increased risk of infection with Giardia Concomitant infections with other pathogens such as rotavirus and Cryptosporidium are also a risk factor for infection of calves with Giardia [63].

Seasonality through its influence on management practices of dairy farms such as calving is also contributing to the possibility cattle becoming infected with the parasite Cattles are at higher risk of infection with Giardia in summer than in winter [64]. Cattle shed fewer cysts in winter (November through March) and spring (April through June) than in summer (July through October) Giardia infections propagate within herds by close contact of cattle due to confinement in winter, and access to contaminated water and pasture in summer while spring is characterized by a low number of calves as the calving season began in late summer.

In human Susceptibility is universal, however those at higher risk include: Travelers to/recent immigrants from countries where giardiasis is common, People in childcare settings, men who have sex with men, persons in care institutions, patients who have had previous gastric surgery and/or reduced gastric acidity, and backpackers, hikers or campers or others who drink untreated water (e.g., river water) [65].

Persons with immunodeficiency (e.g., HIV or AIDS) can experience a more serious and prolonged illness or may be more difficult to treat Children younger than five years of age and pregnant women, may have severe illness characterized by weight loss and require hospitalization. Breast milk can be protective and even cytotoxic against Giardia Adults between the ages of 31 to 40 years are at a higher risk for infection with Giardia due to increased risk activities Males also have a greater risk of infection compared to females, due to sexual practices such as anal or oral-anal sex [66].

2.4.4 Mode of Transmission

There are four main cycles of transmission that have been proposed to maintain host-specific and zoonotic assemblages of Giardia in

mammalian hosts: human, livestock, dog/cat and wildlife cycles [67].

Human to human transmission of Giardia can occur either directly in settings where hygiene levels may be compromised like in day care centers or indirectly through the accidental ingestion of cysts in contaminated water or food [68,69]. Through this transmission, assemblages A and B can be maintained within the human cycle. However, some studies have shown that zoo anthroponotic (reverse zoonotic) transmission is occurring, and is a vital factor in understanding the epidemiology of Giardia infections [70].

For the livestock cycle, Giardia has been reported in both dairy and beef cattle Within the livestock cycle, transmission is common among infected calves and chronically infected adults. However, transmission of the parasite is particularly high amongst dairy calves [71]. While the livestock cycle ensures maintenance of assemblage E, studies have revealed that a small proportion of cattle in a herd may harbor genetic groupings of Giardia with zoonotic potential.

The dog and cat cycles ensure maintenance of assemblage's C/D and F respectively [72]. However, zoonotic transmission of Giardia between humans and dogs in the same household has been reported from communities in tea growing areas of India In a Brazilian study, zoonotic assemblage A1 was isolated from dogs and children in the same locality suggesting the existence of a zoonotic cycle of the parasite in that community [73].

Furthermore, a study in Thailand revealed that dogs were a potential source of Giardia infections for humans, and also responsible for maintenance of the parasite within the canine cycle of transmission Intensive contact between large numbers of dogs sharing the same shelter can favor the transmission of dog specific assemblages of Giardia as they are able to out-compete other assemblages It has also been suggested that household dogs are likely to harbor zoonotic assemblage A as the dog to dog transmission of Giardia is less frequent in such settings [74].

For the wildlife cycle, animals like beavers and deer have been reported to harbor infections with zoonotic genotypes of Giardia [75]. In Italy, water buffaloes (Bubalus bubals) were found to harbor both host specific and zoonotic genotypes of Giardia However, the parasite was found to be rare in indigenous wildlife species in Australia Transmission of Giardia cysts between wildlife and domestic animals may occur where there is common sharing of pastures especially in such situations as human encroachment of wildlife habitats [76,77]. Further, it has been suggested that Giardia likely spills from domestic cycles into wildlife hosts, and following infection, the wildlife populations serve as reservoir hosts for subsequent infection of domestic animals and humans.

While assemblage A and to some extent, B can infect livestock, companion animals and wildlife, there is lack of clear evidence on the frequency of transmission of these assemblages between different hosts [78]. This has left a gap in full understanding of the epidemiology of Giardia infections.

2.5 Clinical Manifestation of Giardiasis

2.5.1 Pathogenesis

Although the pathogenesis of Giardia is not completely understood, an intricate pathophysiological process is initiated by infection with the parasite resulting in variable clinical signs of abdominal pain, diarrhea and weight loss [79]. Studies have also revealed that the pathogenesis of Giardia infections in cattle is similar to that in laboratory animals and humans.

Pathogenesis results from interaction between parasite products (e.g. serine and cysteine proteinases) that break the epithelial barrier and host inflammatory and immunological responses A rise in numbers of intraepithelial lymphocytes increases in epithelial permeability and activation of T lymphocytes has been observed in Giardia infections [80,81]. Trophozoite toxins and T-cell activation initiate a diffuse shortening of brush border microvilli and decreased activity of the small intestinal brush border enzymes, particularly lipase proteases and disaccharidases The diffuse microvillus shortening leads to a decrease in overall absorptive area in the small intestine and an impaired uptake of water, electrolytes, and nutrients The combined effect of this decreased resorption and the brush border enzyme deficiencies results in malabsorptive diarrhea Steatorrhea and mucous diarrhea which has been described in Giardia infected hosts may be due to the reduced activity of lipase and increased production of mucin by goblet cells.

Giardia induces enterocyte apoptosis, associated with disruption of cytoskeletal and tight junction proteins in a strain-dependent manner. As a result, enterocyte brush border is damaged; the epithelial permeability is increased, resulting in inflammation and gastrointestinal troubles Apoptosis and severity of disease are determined by strain dependent virulent factors of the parasite as well as by physiological and immunological status of the host It is established that the increased intestinal permeability could also result from increased luminal antigens. This could provoke the appearance of allergic reactions a complication, often observed in humans infected with Giardia [82].

2.5.2 Clinical Features of Giardiasis in Animals

Giardia infections in domestic animals are often asymptomatic. However, in calves, giardiasis can cause diarrhoea that does not respond to treatment with antibiotic or anti-coccidia drugs [83]. Infection may also result in numerous diarrhoea episodes which in turn adversely affects production and results in economic loses for farmers. In young animals, especially below six months of age, the excretion of watery faeces with a mucoid appearance may be an indication of infection with the parasite. In lambs and goat kids, giardiasis was found to have a negative effect on feed efficiency, rate of weight gain and time to slaughter in both experimental and

natural infections [84].

Severity of the disease is dependent on factors like the developmental, nutritional and immunity of the host as well as virulence factors of the parasite Although gross intestinal lesions are rarely observed, microscopic lesions consisting of villous atrophy and cuboidal enterocytes may be reported.

2.5.3 Clinical Symptoms in Humans

In humans, clinical manifestations vary, ranging from absence of symptoms to acute or chronic infection depending on factors such as age and health of the infected host as well as infective dose and genetic background of the parasite [85]. In acute phase, common symptoms of giardiasis include abdominal pain, fatty diarrhea, flatulence, bloating and weight loss (10-20%), with less frequent symptoms including nausea, vomiting and fever Similarly, in a recent epidemiological and clinical description of giardiasis cases conducted in Waterloo, Canada, the most common symptoms reported were diarrhea (84%) and abdominal bloating (68%), with fatigue symptoms increasing with age.

In malnourished hosts, especially children, the infection can become chronic and result in intense diarrhea and weight loss, and can have detrimental effects on nutritional status, cognitive function, growth and development Chronic infections are usually associated with intermittent or recurrent fatty diarrhea, lactase deficiency and vitamin deficiencies, as well as fatigue and irritable bowel syndrome (IBS)-like symptoms.

2.6 Public Health Importance of Giardiasis

Giardiasis has a global distribution and places a considerable burden on public health systems worldwide due to the high prevalence and disease burden of the infection, its ability to cause large waterborne outbreaks, its effects on growth and cognitive function in children and its zoonotic potential Therefore, it was included in the World Health Organization's (WHO) neglected disease initiative in 2004.

2.6.1 Incidence and Burden of Disease

G. lamblia has been consistently reported as one of the most common pathogens worldwide Due to high endemicity among humans, and domestic and wildlife animals, it is considered of public health and veterinary health importance Symptomatic infections have been reported by millions in Asia, Africa, and Latin America by the World Health Organization, which have estimated that it causes 183 million (confidence interval of 95%, 130–262 million) cases of giardiasis.

Although Giardia is the most commonly identified intestinal parasite of humans, it remains highly under reported As such, the quality and availability of data concerning infection with Giardia varies from country to country, even in industrialized nations Worldwide, the incidence of Giardiasis has been estimated in 2.8 × 108 cases per year However, several epidemiological studies have reported that such rates could be significantly underestimated, with giardiasis prevalence rates ranging from 10 to 20% of the general population, from 10 to 50% in developing countries, and from 2 to 5% in developed countries This could be explained by the large fraction of asymptomatic carriers, which regardless of the absence of symptoms also contribute to the transmission of the diseases[86].

Giardiasis is generally a self-limiting clinical illness characterized by watery diarrhea, abdominal cramps, bloating, weight loss, and malabsorption However, asymptomatic infections occur more frequently than symptomatic ones.

Giardiasis is a ubiquitous disease so it occurred across broad epidemiological contexts and with a broad range of distributions. On one side, in most developed countries Giardia is mostly reported as a rare disease affecting travelers Furthermore, in the countries such as the Unites States, where Giardia is continually under surveillance, Giardia has higher incidences (incidence rate ratios, 1.2–1.5) in countries with higher private well reliance compared to countries with lower well reliance On the other side, in most developing countries, Giardia has been associated with poor health hygiene, poor toilet training, overcrowding, and low socioeconomic status.

In productive animals Giardia infection may also result in numerous diarrhea episodes which in turn adversely affect production and result in economic loses for farmers. In younger calves, especially below 6 months of age, the excretion of watery faces with a mucoid appearance may be the only indication of infection with the parasite. Chronic cases of giardiasis in calves may impact negatively on performance which may be result in reduced weight gain, impaired feed efficiency and decreased carcass weight and result in economic loses for farmers [87].

2.6.2 Zoonotic Potential of Giardiasis

The zoonotic transmission of G. duodenalis has attracted much debate. A number of animal species have been implicated as potential reservoirs, including livestock, pets and aquatic animals Although the World Health Organization has considered G. duodenalis to have a zoonotic potential direct evidence has been lacking. However, two distinct genotypes of G. duodenalis, A and B, found in cattle which are also isolated from humans and other animals are proposed to be zoonotic [88,89].

Although molecular evidence in some studies have revealed that cattle are normally infected with the non-zoonotic livestock assemblage E, molecular evidence of the zoonotic transmission of G. duodenalis has been demonstrated among dairy farm workers in India [90]. In the study conducted in India, it was revealed that besides the livestock-specific assemblage E zoonotic assemblage. A was identified in a number of dairy calves Further, assemblage. A1 found in humans and cattle showed a 100% homology with each other. As a result of such studies, the zoonotic potential of

Giardia is no longer in doubt. However, there is limited data on the frequency of zoonotic transmission [71].

2.6.3 Outbreaks

The majority of outbreaks involving Giardia are waterborne, as Giardia is particularly suited for this route of transmission due to the following characteristics: cysts are shed in high numbers cyst persistence in the aquatic environment is high, cysts are very small which allows them to be easily re-suspended in water systems, cysts are resistant to chemical disinfectants, such as chlorine and cysts are highly infective [13,60]. Worldwide, there have been 154 documented waterborne giardiasis outbreaks between 1954 and 2011 [91].

Although the majority of the reported waterborne giardiasis outbreaks involve contaminated drinking water, approximately 10% of the outbreaks involve recreational water exposure In general, the number of individuals infected in recreational outbreaks is lower than the number of individuals involved in drinking water outbreaks [92].

Giardiasis outbreaks are more common after heavy precipitation, snowmelt or extreme weather events During extreme weather events, heavy snowmelt or precipitation, water treatment plants may be overwhelmed, resulting in cross-contamination between sewage and drinking-water pipes, sewage overflow or bypass into local waterways.

2.7 Diagnosis of Giardiasis

There are several methods used in the diagnosis of giardiasis, and these are categorized broadly into microscopy, immunological and molecular methods [93,94].

2.7.1 Microscopic Examination

Microscopy is considered to be the 'gold standard' for laboratory diagnosis of G. lamblia against which all other methods are evaluate because of its high specificity and sensitivity [95]. The procedure involves staining of slide preparations, which allows the morphological features of the pathogens to be clearly seen on the slide [53]. The motile, piriform trophozoites may be seen in saline smears of watery faces. They can be distinguished from trichomonas which have a single rather than double nucleus, an undulating membrane, and no concave ventral surface.

To aid identification, the cysts can be stained with iodine or trichrome [48]. As Giardia cysts are excreted intermittently, itis recommended that several faucal examinations (e.g. three samples collected over three to five days) should be performed of giardiasis is suspected [61]. Apart from using microscopy for screening, permanently stained prepared slides can be useful for demonstration and teaching purposes. Microscopy is used widely at many hospitals in developing because its application is comparatively affordable. The other methods have rather been used in most cases for epidemiological studies or research purposes than routine diagnosis at the hospitals and clinics [97].

2.7.2 Serology

Immunological methods, which depend on antigens of the parasites present in stool samples for detection of infection are faster, and more sensitive especially in cases where infection or parasite dosage is very low. Several immunofluorescence assay (IFA) and enzyme-linked immunosorbent assay (ELISA) test kits are commercially available for the detection of Giardia antigen in faucal specimens [96].

One of the highly conserved cyst antigens detected by most ELISA is the cyst wall protein 1 (CWP-1) which is normally secreted in large amounts by encysting trophozoites [98]. Some coproantigen detection ELISA has a higher diagnostic sensitivity than IFA because ELISA is capable of detecting both encysting trophozoites and cysts compared to IFA which only detects cysts [99]. Both ELISA and IFA have been found to be more sensitive and specific than microscopic examination for the diagnosis of infection [5]. Immunochromatography uses monoclonal antibodies directed against cyst wall proteins, and a commercial test for use in dogs is available [54]. However, the laboratory-based immunofluorescence and ELISA assays are still reported to be more sensitive than the immunochromatographic assays for the clinical diagnosis of Giardia.

2.7.3 Molecular Techniques

The recent application of molecular tools in the detection of Giardia in stool samples has not only improved upon diagnosis of these parasites but also helped to determine sources of infection through genotyping and sub-genotyping procedures [100,95]. An emerging diagnostic technique, loop mediated isothermal amplification (LAMP) has been used to detect Giardia in faucal and environmental samples [101-104]. It has been revealed that LAMP is highly selective, does not require a thermocycler and is not affected by presence of inhibitors [91].

The PCR assays are based on the amplification of a gene fragment with primers that bind to deoxyribonucleic acid (DNA) sequences that are conserved in all G. duodenalis assemblages [30]. Polymerase Chain Reaction enables identification of Giardia to species level and hence assessing the zoonotic potential of the parasite [105-108].

Amplification of DNA in PCR are done by targeting specific genetic markers (loci). Several genetic markers which differ in their information content and the nature of the DNA fragment selected for detecting and characterizing Giardia are used including triosephosphate isomerase (TPI) gene, glutamate dehydrogenase (GDH), beta-Giardin (β- Giardin), elongation factor 1α (EF-1α) and G. lamblia open reading frame C4 (GLORF-C4) and 16S ribosomal DNA [14,87].

In determining the zoonotic potential of G. lamblia, used a two-

step nested PCR protocol to amplify triosephosphate isomerase (TPI) gene. According to the authors, TPI gene was chosen because of the high heterogeneity displayed by Giardia sp. at the TPI locus. They observed from their study that the TPI gene is a good phylogenetic marker for analysis of the molecular evolutionary and taxonomic relationship of G. lamblia parasites. Although many researchers have used either TPI, β-giardin or GDH in their studies to successfully genotype G. lamblia [27,49,57]. some authors are of the view that, the use of only one genetic marker produces information that has limited discriminatory power, in terms of genotyping. In view of this, the use of multi-loci analysis has been suggested for genotyping these parasites [109-112].

Although PCR assays are very costly for diagnostic laboratory use, they are more sensitive and specific than microscopy and immunological assays [113-115]. To address the limitations of molecular methods in determining the viability and infectivity of Giardia cysts, a new integrated culture assay (Electrophysiological analysis of cell culture reverse transcription polymerase chain reaction) was evaluated and found to be a rapid and cost-effective method for assessing infectivity of Giardia cysts from environmental samples [116-118].

There is evidence that, based on the type of diagnostic tool used, the results obtained from screening stool samples for G. lamblia may differ significantly from one another or may agree without significant difference [103,90]. To determine prevalence accurately therefore, it will be very useful if each sample is tested by more than one diagnostic method.

2.8 Treatment and Prevention/Control

2.8.1 Treatment in Animals

At the moment, there is no drug permitted for the treatment of Giardia infections in ruminants Through previous studies, benzimidazoles like albendazole, mebendazole and fenbendazole have been found to be effective in reducing the excretion of Giardia cysts by infected calves In vitro studies revealed that these anthelmintic were much more effective than metronidazole, tinidazole and quinacrine against Giardia trophozoites However, other studies showed that the dose of 20mg/kg daily for three days in calves for anti-giardia treatment was much higher than that for anthelmintic treatment (10mg/kg once).

It has been suggested that benzimidazoles inhibit the polymerization of tubulin to microtubules, which are a major component of flagella, median body and ventral disc, resulting in distortion of trophozoite morphology and inhibition of its attachment to the intestinal mucosa [7]. The benzimidazoles were found to have a wide safety margin compared to the nitro-imidazole's which were mutagenic and teratogenic in food animals Furthermore, fenbendazole and albendazole (5-20 mg/kg/day for 3 days) have been reported to significantly lower the peak and duration of cyst excretion [54].

Treatment of dairy calves which are infected with Giardia with oral fenbendazole at 5mg/kg body weight once daily for three days have a clinical benefit as it reduced the number of days calves have a diarrhea [65]. Furthermore, there is an environmental benefit as the number of cysts shed by calves significantly reduced due to treatment of infected calves with fenbendazole Paromomycin (50-75 mg/kg per os, for 5 days) was also found to be highly efficacious and safe against an experimental Giardia infection in calves However, re-infection is common where frequency of transmission is high and cattle are exposed to a contaminated environment.

Daily administration of drugs like paromomycin and fenbendazole may be a long-term solution to the control of giardiasis in ruminants [58]. However, this kind of treatment regimen is impractical as it does not make economic sense, and there is a risk for the parasite to develop resistance to the drugs. As calves are unable to mount an effective immune response against Giardia, infections may be reduced by access to colostrum There is scanty data available on the effectiveness of treatment against giardiasis in pigs, sheep and goats [119].

2.8.2 In Human

Many giardiasis patients do not require treatment as their infection spontaneously resolves, however, chronic infections do require treatment. Currently, there are several drugs that can be used to treat Giardia infection in human inhibitors of nucleic acid synthesis such as metronidazole, tinidazole and ornidazole are the first line of drugs employed in giardiasis treatment. In severe cases, these drugs are coupled with supportive treatment including fluid and electrolyte replacement [15.31]. Metronidazole is the most common treatment; however, it can have severe side effects such as central nervous system toxicity and pancreatitis Tinidazole is gaining in popularity as it requires fewer doses than metronidazole and achieves similar efficacy with fewer and less severe side effects Alternatives to these medications include paromomycin [11,67] and furazolidone [86].

2.8.3 Prevention/Control

In animals; there is no developed prevention strategy of giardiasis. However, as Giardia cysts are a source of infection for animals on most farms, discarding faces promptly from pens, frequent change of bedding, regular cleaning and disinfection of pens can help reduce environmental contamination Furthermore, it has been revealed that storage of cattle slurry for three months greatly reduces the number and viability of Giardia cysts and this can reduce contamination of surface water by run-off from manure contaminated fields [99]. It has been speculated that ammonia present in urine within the slurry may reduce cyst survival and infectivity. Strips of vegetation have also been suggested to be an effective buffer against cyst contamination of surface water by run-off from manure contaminated dairy calf areas [120].

Some chemical disinfectants have been found to be effective in inactivating Giardia cysts in water although their effectiveness is dependent on such factors as the chemical and its concentration, temperature, pH, and the contact time The study also demonstrated that Giardia cysts were completely inactivated by heating water to 70°C for 10 minutes. Furthermore, the cysts can be inactivated by use of quaternary ammonium compounds and using boiling water in cleaning of the pens.

Despite attempts to come up with an efficacious vaccine, there is no Giardia vaccine available for use in ruminants [106]. A study conducted in.

2.9 Status of Giardiasis in Ethiopia

According to 1996 Federal Ministry of Health of Ethiopia reported that more than half a million out patients visited hospital/clinic due to intestinal protozoan parasitic infections. However, this may be an underestimate, as most of the health institutions lack appropriate diagnostic methods to detect parasites with small detection limits. Among the common intestinal protozoan parasites Giardia lamblia is most widely distributed in Ethiopia.

The studies conducted in different parts of Ethiopia indicate that 7-9 age groups have significant association with prevalence of intestinal protozoan parasites. Prevalence of giardiasis among asymptomatic children less than 14 years old was higher than adult children. This is because, younger people have lower resistance to intestinal protozoan infections as compared to adults since many of the defense systems are not fully developed in children. In addition to this, children are more exposed to overcrowded conditions (schools, nurseries, playgrounds etc.).

The prevalence of parasitic G. intestinali is different in study area of the country due to different factors. The prevalence G .dodunalis is (8.4%) in south wollo reported by Haji Mamo (2016), 4.3% in Awuramba reported by Yihinew (2011), 6.7% in Babile town Eastern Ethiopia reported by Tadesse (2005), 6.6% in Teda Health center North Gondar, 4.9% in Gorgora and chuahit health center North Gondar reported by Abate et al. (2013), 69.4% prevalence among Delgi schoolchildren North Gondar reported by Ayalew et al. (2011), 16.9 in selected primary school children in Wukro town Tigray Region North Ethiopia reported by Eleni et al. (2014), 11.8% among primary school children in Motta town reported by Mulusew (2014).

Although the children had not shown signs and symptoms of the diseases, the prevalence was higher than the earlier reports from Addis Ababa and Jimma in symptomatic children with rates of 5.6% and 3.3% . respectively. The prevalence of giardia infection is higher in patients those that came from rural area than that of urban area. This because of the knowledge, attitude and practice gap between the two communities. This was similar with a study at Wollega university students' in 2015; the students from rural areas have higher prevalence than their counterparts. That is why communities from rural areas are engaged in dirty environments and they usually use river or springs which are not treated well. This further increases the risk of significantly high parasite prevalence of the infection by the parasites [121].

3. Conclusion and Recommendations

Giardiasis is caused by infection with the enteric pathogenic intestinal flagellate, G. Intestinalis (syn. Glanbia, G. duodenale). The incidence is estimated at 200 million clinical cases per year. The prevalence of giardiasis is very high in low income countries where the living standard of the society is very low. G. duodenalis is frequently encountered in domestic animals, mostly productive species, dogs and cats. Numerous wild mammalian and bird species are also hosting of Giardia. Infected hosts shed cysts that are resistant in the environment and allow the parasite to be transmitted to another host either directly or indirectly through environmental contamination.

There are four main cycles of transmission that have been proposed to maintain host-specific and zoonotic assemblages of Giardia in mammalian hosts: human, livestock, dog/cat and wildlife cycles Water is an essential factor in the transmission of giardiasis in men that is why this is the commonest human waterborne disease [122].

The zoonotic potential of Giardia is beyond any doubt. Productive, companion and wild animal species are carriers of specific and zoonotic genotypes. Aquatic animals could contribute to increase in zoonotic Giardia genotypes that could contaminate waters.

Depending on above conclusion the following recommendations are forwarded: -

- Future studies by animal and public health experts should focus on genetic characterization of the parasite so as to elucidate the zoonotic importance of Giardia.
- More extensive research is necessary among humans, animals and water sources with regard to Giardia carriership.
- The obtained isolates should be genotyped in order to investigate the sources of contamination and to undertake efficient measures for reduction of infection rates in both animals and people.
- Educate a society about a disease, source of infection, mechanisms of transmission and control and prevention ways
- An integrated approach involving discarding faeces promptly from calf pens, frequent change of bedding, regular cleaning using boiling water and subsequent disinfection of calf pens with quaternary ammonium compounds should be used on dairy farms.
- Farmers should be encouraged to alternate between use of fenbendazole and albendazole when deworming the calves as the drugs tend to significantly lower the peak and duration of cyst excretion.
- Always wash hands thoroughly with soap and running water after: using the toilet, handling animals, changing nappies, other exposure to faecal matter, working in the garden; and

before preparing food and drinks.

- Avoid consuming unboiled tap water and uncooked foods when travelling in countries where the water supply may be unsafe.
- Do not drink untreated water from rivers or lakes. Boiling water from these sources will kill Giardia and other parasites. Water purification tablets may kill Giardia, but may not kill other parasites.
- Treating diseased pet animals and avoid close contact with them.

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