SVOA Microbiology

ISSN: 2634-534X

ScienceVolks Open Access

Research

Giardiasis in the Southwest Region of the United States: Causes and Preventive Measures

Jeriah Boyd[1] and Shazia Tabassum Hakim[1]*

[1] *Hakim's Lab., School of STEM, Diné College, Tuba City, AZ, USA.*

***Corresponding Author:** Shazia Tabassum Hakim, Hakim's Lab., School of STEM, Diné College, Tuba City, AZ, USA.*

DOI: https://doi.org/10.58624/SVOAMB.2023.04.031

***Received:** September 01, 2023* ***Published:** September 21, 2023*

Abstract

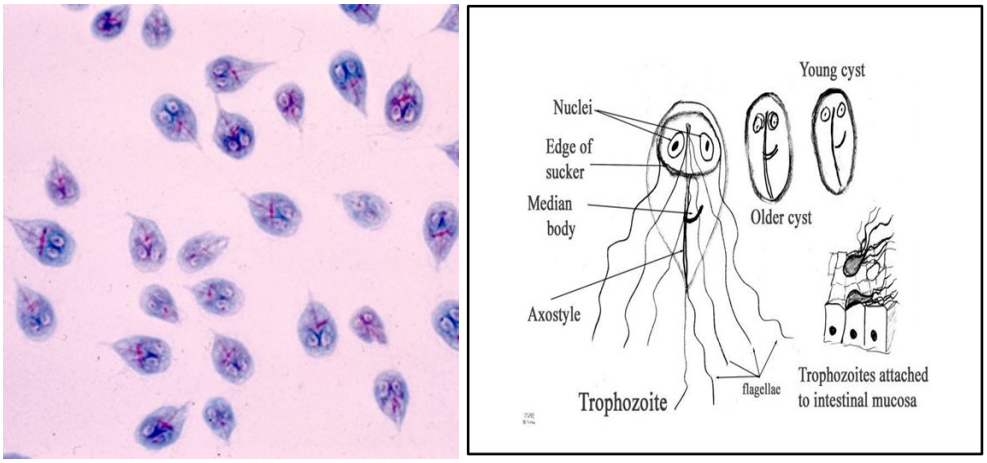
Giardia is a protozoan parasite of the small intestine, and a leading cause of diarrheal diseases worldwide in a variety of animals, as well as humans. Despite the decrease, *Giardiasis* remains the most commonly reported intestinal parasitic infection principally in the Southwestern region of the United States. The parasite is typically transmitted by fecal-oral route and may be transmitted by direct intake or indirectly from contaminated food or water. Symptomatic *Giardiasis* is often treated to reduce the duration of symptoms, to prevent future complications, and to minimize transmission of the parasite to other hosts. The clinical image of *Giardiasis* is mixed, with high variability in severity of clinical disease which can become chronic or be followed by post-infectious sequelae. At present, treatment options include nitroimidazoles derivatives; especially metronidazole, which has been the mainstay of treatment for decades and is still widely used. The Navajo Nation located in the Southwestern region of the United States has suffered from the scarcity of water expediting Navajo populations to use water resources such as underground water, river streams, lakes and surface water as their main source of accessibility. The lack of adequate domestic and municipal water has led several Navajo families to become ill with waterborne infectious diseases like *Giardiasis*. More recently, molecular methods have become amateur in diagnosis for testing patient samples as well as water samples for *Giardiasis*. Through direct immunofluorescent staining and other methods that detect intact organisms have improved the detection of *Giardia* trophozoites or cysts. An understanding of clinical and molecular variability of organisms is important for effective treatment and the response of remedies that are commonly used. The molecular classification of bacteria and viruses isolated from Indigenous patients might have their own specification that can be correlated with isolates from water samples collected from the same localities. This correlation could help us in source tracking and finding solutions for the communities who are already at risk due to the lack of infrastructure and resources. In this review of literature, the causes and preventive measures of *Giardiasis* are covered to potentially help understand the importance behind this parasitic disease, more specifically on the Navajo Nation of the Southwest of the US.

***Keywords:** Giardiasis, Parasitic disease, Infection.*

Introduction

Giardiasis is an intestinal infection caused by *Giardia* species mainly *Giardia duodenalis, Giardia intestinalis* and *Giardia lamblia* that usually spreads through contaminated soil, food, and water, or sometimes it could be through person-to-person contact (Dunn N, 2023). *Giardiasis* is also known as a *Giardia* infection. *Giardiasis* is a self-limiting illness characterized by diarrhea, abdominal cramps, bloating, weight loss and malabsorption and results from the ingestion of *Giardia* cysts through the consumption of fecally contaminated food or water or through person-to-person or via animal-to-person transmission (Painter et al, 2015). Primarily it is a tiny parasite (protozoan) called *Giardia* that is the cause of diarrheal disease which is found worldwide particularly in places where people do not have access to clean drinking water, a common cause of waterborne illness (Benson et al, 2022). Upon endoscopy *Giardia* can be seen as characteristic pear or sickle-shaped, binucleate trophozoites either attached to the small intestinal enterocytes or, most frequently, in the intervillous spaces (Zylberberg et al, 2017).

Figures



Giardiasis is an uncommon cause of iron deficiency anemia and zinc deficiency and can lead to post-infectious syndromes such as irritable bowel syndrome, functional dyspepsia, and chronic fatigue syndrome months to years after the parasite had been eliminated (Leung et al, 2019).

Giardiasis is commonly known to be in areas with poor sanitation and unsafe water primarily transmitted through ingestion of food or water contaminated with human waste from infected individuals (Hajare et al, 2022). The infectious cysts can survive for months in the environment, explaining why the infection is closely associated with unsafe water. While *Giardiasis* is generally known to be caused from contaminated food or water, participation in backpacking, camping, swimming, having close contact with animal species, and certain sexual practices could also increase the risk for *Giardiasis*. Microbial contamination is typically not visible with naked eyes except the physical characteristics like color, odor, turbidity, or change in taste in water, or food, and hard surfaced areas, therefore, it is difficult for people to realize the transmission of this parasite from the water or food resources that apparently look fresh and clean like spring water or raw vegetables washed with contaminated water. Symptoms of *Giardiasis* usually start 1-3 weeks after a person has been exposed, which will last for 2-6 weeks (about 1 and a half months) and include diarrhea, gas, greasy stool that floats, stomach or abdominal cramps, nausea, dehydration, and weight loss (Benson et al, 2022). The clinical manifestations can range from asymptomatic, to acute or chronic diarrheal disease. The pathophysiological consequences of *Giardia* infection are multifactorial, and involve both host and parasite factors, as well as immunological and non-immunological mucosal processes (Halliez & Buret, 2013). *Giardia* infections may also have detrimental effects on nutritional status, growth status, and weight loss while keeping the body from absorbing nutrients it needs, like fat, lactose, vitamin A, and vitamin B12. A person may receive *Giardia* cyst by touching contaminated surfaces, drink water from an untreated source, swallow a parasite while swimming, eat uncooked food or during travel to countries where it's most common (Benson et al, 2022).

Giardia infections are self-limited in duration; however, some people may experience a recurrence of symptoms or develop long-term complications. Although this varies from person to person, *Giardia* may become chronic with long-lasting fatigue and abdominal symptoms. There are also many *Giardiasis* risk factors upon diagnosis such as close contacts, poor sanitation, and consumption of untreated water from springs, lakes, or rivers. Most people who procure *Giardiasis* typically get better without treatment, however, if it seems to be getting severe, the best treatment is medication such as metronidazole, nitazoxanide, tinidazole, and nitroimidazoles. Even after *Giardiasis* has gone away, there could still be complications especially in infants and children. The clinical diagnosis of *Giardiasis* can be difficult since most symptoms are nonspecific and resemble those of several other gastrointestinal infection (Faubert, 2000). These complications consist of dehydration, failure of physical growth, and becoming or staying lactose intolerant (Painter et al, 2015). Many patients endure symptoms long before they receive a diagnosis. *Giardiasis* can cause chronic mucosal inflammation and nodular lymphoid hyperplasia in the duodenum, mesenteric lymphadenopathy and, rarely, retroperitoneal lymphadenopathy (Leung et al, 2019).

Rural and tribal communities are particularly vulnerable to environmental contamination due to lack of public infrastructure, insufficient medical facilities, and low socioeconomic status in most indigenous communities where majority of community members live without electricity and running water. Access to safe drinking water for persons residing within the Navajo Nation can be limited (Grytdal et al, 2018). Under these circumstances, most people rely on water resources that could potentially have parasites such as *Giardia species*.

To help provide better healthy options, the Navajo Tribal Utility Authority (NTUA) and Navajo Nation Department of Water Resources (NDWR) provide watering points at several locations within the communities that include public water taps at trading posts, chapter houses, schools, and border towns, in order that regulated water may be hauled for human consumption (Grytdal et al, 2018). But still there are places where people do not have any other option than hauling water from unregulated water resources. In most cases, many patients remain asymptomatic, disease remain unnoticed and hence results in long-term consequences of *Giardiasis*. These long-term consequences consist of arthritis, allergies, muscular complications, nutritional consequences, failure to thrive, stunting, impaired cognitive function, chronic fatigue syndrome, and cancer (Halliez & Buret, 2013).

The importance of waterborne and foodborne illnesses caused by the parasitic *Giardiasis* is extremely important in the Navajo Nation because most people are asymptomatic leading them to be diagnosed later than anticipated. The Navajo Nation, located in the American Southwest, is the largest contiguous Native American Nation and has over a 100-year legacy of rock mining (Credo et al, 2019). Mining in the four corners region has been ongoing for the past 100 years containing an abundance of natural resources, including coal, copper, uranium, and vanadium, and has left a legacy of environmental contamination, affecting groundwater and soil. Credo (2019), mentions that along with water contamination on the Navajo Nation of elemental contaminants in unregulated water *Giardiasis*, is just as important. As a consequence of environmental contamination on the Navajo land, the Navajo population has been highly affected by health conditions like cancers and infections like *Giardiasis, and Helicobacter pylorii* can be considered to be a core reason of gastric or peptic ulcers that can lead to cancers. *Giardiasis* included in the World Health Organizations (WHO) neglected diseases initiative owing to its burden and association with poverty (Leung et al, 2019). The rate of poverty on the Navajo Nation has been high since the early 1900s with lack of resources and availability of opportunities that support our concern regarding prevalence of *Giardiasis* among Navajo communities.

Gastric cancer is a worldwide concern, particularly for Indigenous populations who face greater disparities in healthcare. Indigenous populations encounter high rates of food shortage, exposure to harmful environmental agents, structural racism in the built environment and compromised healthcare quality as an effect on colonialism (Cordova-Marks et al, 2022). As cancer is the second leading cause of disease and death for the Navajo people, stomach cancer or infections are also a part of this rate (Cordova-Marks et al, 2022). As of recently, the Supreme Court ruled against the Navajo Nation to fully have access to develop a plan to secure the needed water, and potentially build pipelines, pumps, wells, or other water infrastructure to either facilitate better access to water on the reservation or to transport off-reservation water onto the reservation (599 U.S. 2023). Under these circumstances on the Navajo reservation, the Navajo population use needed water from various resources such as groundwater, rivers streams, lakes, and springs within the reservation.

Foodborne illness associated with *Giardiasis* can also be related or connected to the contamination through livestock, in which cattle feces were the likely source of contamination. Some possible sources of contamination include direct contamination by infected farm workers or food handlers and indirect contamination by oocyst- or cyst-contaminated water used in irrigation, washing, or processing foods. Contaminated foods, such as fresh produce and shellfish have been the most common cause of foodborne illness. An increasing number of food-related outbreaks of *Giardia* have been documented, with causes ranging from unknown transmission to food handlers across the United States, more specifically in the southwestern region. (Budu-Amoako et al, 2011). In addition to *Giardia* among foodborne infections caused by direct ingestion, there are many other foodborne illnesses that are caused by the presence of microbial toxins in food. For example, toxins produced by *Staphylococcus aureus, Bacillus cereus,* and *Clostridium perfringens* require different treatment depending on the consequences they produce. Illnesses that involve primarily diarrhea or vomiting for example, cholera may require only adequate hydration, while antibiotics are usually not recommended for most foodborne illnesses.

Methods

There is a variety amount of research methodologies that have been applied to the species of *Giardiasis* in the Southwest region on the United States. The most common methods that have been used are cross-sectional studies, biopsies, human case data, clinical trials and treatments, both in humans and animals. In the Southwest region of the United States, during 2009-2010, *Giardiasis* rates appeared to be increasing with a total number of 40,000 reported cases for both years combined in the United States including the southwest region states (Painter et al, 2015). Most cases occur in the summer months and early autumn in these Southwestern regions. The national *Giardiasis* surveillance for 2009-2010 were analyzed using SAS v.9.3 which is a software that were used to calculate rate by year, age, and sex. During 2009-2010, the number of *Giardiasis* cases increased 1.9%, however, when a patient's sex was missing or unknown, they were excluded; potentially lowering the rates but not the amount of people who were getting sick from *Giardiasis* (Painter et al, 2015). Many of these cases reported were in the states of California, Arizona, Colorado and Nevada.

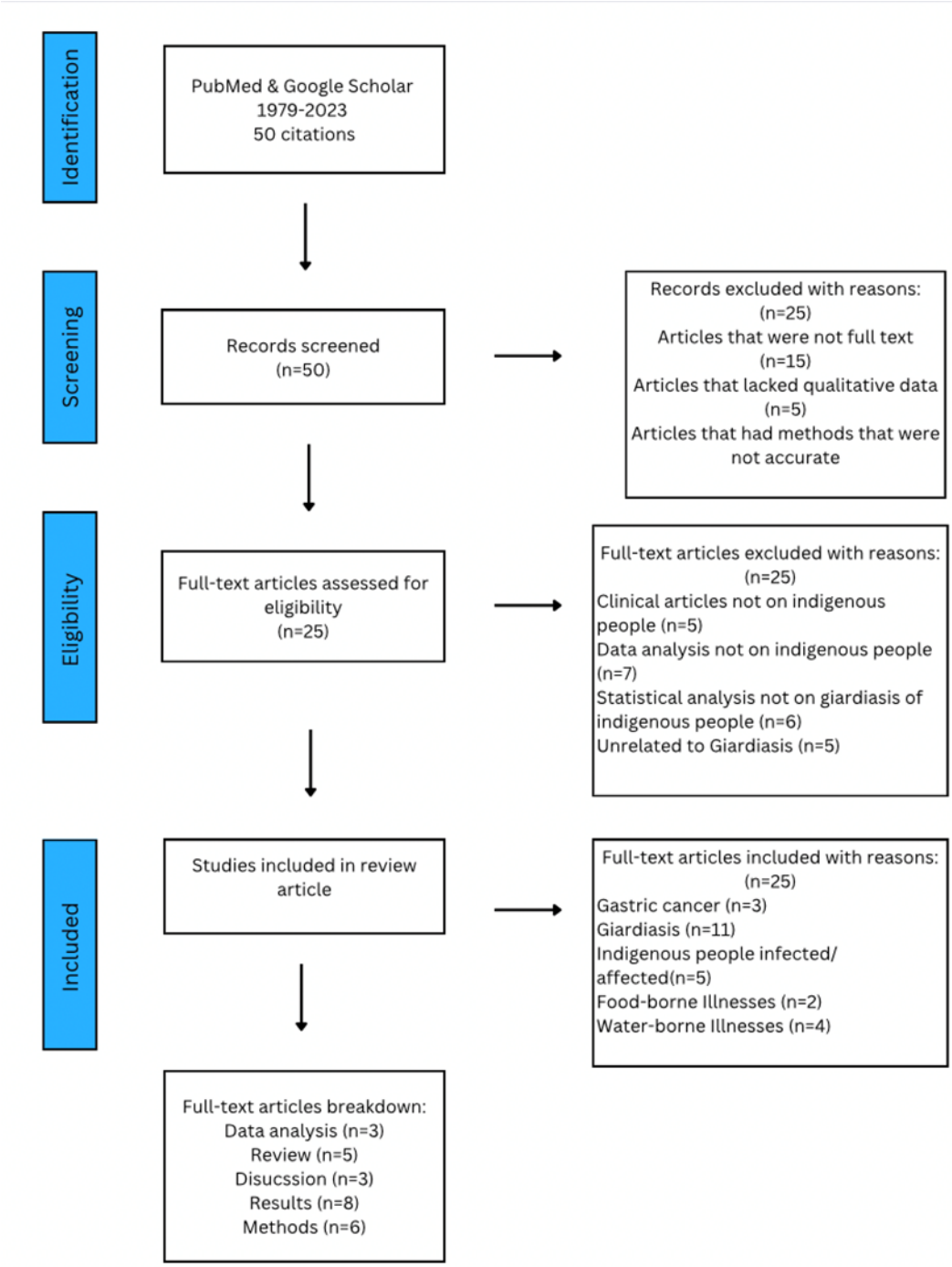


Figure 1. *Systematic literature review, PubMed & Google Scholar from 1979-2023.*

The first patient retaining *Giardia* trophozoites in the gastric mucosa was observed in December 1988, where gastric biopsies specimens were routinely evaluated for the presence of this parasite (Doglioni et al, 1992) When *Giardia* was identified, all cases in this trial were also morphologically investigated for *Helicobacter pylori* infection. According to Cordova-Marks (2022), various infections are the main cause of gastric cancer within indigenous populations elevating the risks of becoming infected. Among indigenous populations, *H. pylori* infections are seen at greater prevalence for the non -cardia subtype of gastric cancer compared to cardia subtypes. The most common testing method to detect the parasite *Giardia* is collecting stool by direct identification of cysts or trophozoites in the feces. Cysts are typically seen in wet mount preparations, while trophozoites are seen in permanent mounts. Although these are the common testing methods on the Navajo reservation or in the state of Arizona, worldwide methods of testing for the parasite *Giardia* varies widely. Lauren classification is the most applied and accepted histological classification of gastric cancer that pathologists and physicians use today (Sanjeevaiah et al, 2018).

Overall by state, in the US, *Giardiasis* rates were lowest in Arizona and highest rates had been in Vermont which is not a part of the Southwestern United States. Data was displayed by age distribution, with most reported cases occurring in young children with a smaller amount in middle-aged adults; however, rates were higher in males than females in almost all age groups. The methods in this article consisted of case definition, reporting and data analysis (Painter et al, 2015). By region, the rates of reported *Giardiasis* cases per 100,000 population ranged from 4.8 in the Southwest to 9.4 in the Northwest in 2011 and 4.6 in the Southwest and South to 8.5 in the Northwest in 2012. The rural community within the Navajo Nation also faces foodborne illnesses because of lack of electricity and facilities to keep the food and produce fresh and consumable for more than few days.

Other methods to diagnose Giardiasis include cell culture, amino acid analysis, intestinal epithelial cell (IEC) growth measures, 3-(4,5dimethlthiazol-2-yl)-2,5-diphenyl-2-tetrazolium bromide (MTT) assay, gene expression analysis, and polyamine measurements (Stadelmann et al, 2012). This method is prompt to further investigate additional roles of arginine during pathogen infections as a model using the parasite *Giardia* that actively consumes arginine as the main energy source and secretes an arginine-consuming enzyme. Reagents and cell culture detect *Giardia* trophozoites by being diluted in high-glucose, non-essential amino acids, and streptomycin with an incubation performed at 37°C (Stadelmann et al, 2012). To maintain epithelial integrity and homeostasis, a balance between epithelial cell proliferation, differentiation, migration and death is needed. Intestinal pathogens are known to affect this homeostasis in various ways in order to reduce arginine consumption such as *Giardia*. It is important to consider that *Giardiasis* is a multifactorial disease that is characterized by involving contributions from both, host and parasite.

Recent studies reveal 5-nitromidazole refractory infections occur in 50% of cases making it known that the prevalence of treatment refractory of *Giardiasis* is increasing (Mørch et al, 2020). The cysts are instantly infectious once they are passed out through feces, with the potential to remain infectious for several months as they can withstand unfavorable environmental conditions. Upon ingestion by a host, cysts are activated during passage of acidic surroundings in the stomach and undergo excystation in the duodenum. This results in the release of proliferating trophozoites, establishing an intestinal infection. Potential factors associated with *Giardia* infection, as well as the genotypes of *Giardia* among different indigenous groups in the American southwest comes with a preference towards evaluating the connection of *Giardia* infection in indigenous groups with the socioeconomic status in these rural areas. In fact, indigenous communities have long experienced lower health statuses compared to other Americans. Lower life expectancy and the disproportionate disease burden exist perhaps because of inadequate education, disproportionate poverty, discrimination in the delivery of health services, and cultural differences.

With reference to water quality and availability on the Navajo Nation, methods that have been consistently used are pilot case-control study to assess associations between acute gastroenteritis, water availability, use patterns, and quality (Grytdal et al, 2018). In this specific method of pilot case-control study, water sample collection and laboratory testing were conducted. These water samples that were collected were tested for coliforms, viruses and protozoa in windmills, wells, lakes, or unregulated water resources, considering the fact that in some areas, these resources can become contaminated by pollutant chemicals or pathogenic organisms, leading to significant illnesses such as *Giardiasis* (Rogan et al, 2009). There was also contamination of chemicals mostly nitrate, volatile organic compounds, inorganic compounds, sodium chloride, lead, arsenic, radon, fluoride, uranium, methyl tertiary butyl ether, and perchlorate. After testing water samples, Navajo families were notified for their safety of consumption by Grytdal et al., 2018.

Virus and *Giardia* monitoring of reclaimed wastewater that can be used for irrigation has also been initiated as a means for controlling the public's exposure to these pathogens (Rose et al, 1989). In the state of Arizona, there are livestock almost everywhere especially on the Navajo Nation, where all animals are dependent on ground water in order to survive, also Navajo families use these resources as their own especially those who do not have access to running water. Irrigation in Arizona is widely used for crops, animals, resources and access to running water for families across Arizona. There had been 11 facilities that were treated and tested to detect *Giardia* by Rose et al, (1989) Treatment facilities must produce wastewater with no detectable *Giardia* cysts and one virus plaque forming unit per 40 liters (about 10.57 gal) for unrestricted use while 125pfu is allowed. According to Rose et al. 1989, some elders who live on the Navajo Nation do not know what *Giardia* is leading them or their animals to become sick with *Giardiasis*, an intestinal infection. Most people do not know what comes from the underground water leaving them hospitalized with mild to severe symptoms. The methods and results had been based on filtration to monitors facilities so that there were no detectable viruses, bacteria and most importantly, *Giardia*. In the results of them all, *Giardia* was detected in 29 to 50% samples, making it a conclusion that plants would need to upgrade their infrastructure and treatment strategy in order to meet standards for unrestricted irrigation.

Results

Giardiasis in the Southwestern region of the United States is much more common than any other infection of waterborne and foodborne illnesses. Outbreak investigations play a significant role in revealing risk factors or sources of infection for disease hosts. The application of molecular and biochemical methods has improved both the taxonomy and our understanding of zoonosis, and epidemiology of the diseases caused by these parasites (Budu-Amoako et al, 2011). The taxonomy of *Giardia* has largely been resolved with the advent of molecular tools which have shown that the observations of early taxonomists were correct. Whereas, epidemiological evidence supports humans, or cohabitating livestock, as the source of infection through environmental contamination, either directly or indirectly via domestic hosts (Thompson 2016). These results correlate on the Southwest region of the US where taxonomists confirmed that water resources particularly unregulated water resources have been contaminated with microorganisms (bacteria, virus, or protozoa) from livestock and appropriate preventive measures should be taken in those suspected areas where unregulated water resources are only source of water for local communities.

As mentioned previously, many Navajo families do not have access to regulated piped water and/or electricity leaving them with option to use unregulated water resources for their routine household chores. By using these unregulated resources, there is a 40% chance that every household can be exposed to the parasite *Giardia*. These clinical and demographic findings may aid medical practitioners in the assessment and testing of patients' symptoms compatible with this infection (Zylberberg et al, 2017). Most households do not have access to filtering their water, leaving it more significant for them to become infected. Statistics show that because of these conditions on indigenous lands, 30% of individuals have a family member who has been diagnosed with a gastrointestinal malignancy, higher than what is reported in other populations (Nolen 2019). Although the main treatment of the *Giardia* parasite is metronidazole and nitroimidazoles, the long-term side effects can be just as harmful as being untreated by the parasite.

Among all jurisdictions that reported cases of *Giardiasis,* in the Southwestern United States number of cases has declined. However, it remains the major cause of diarrheal disease and gastric cancer worldwide. (Yoder et al, 2012). Meticulous hygiene with soap and water is the most important preventative measure as well as avoiding contaminated food or water, and cleaning and disinfection regularly. Also, prompt diagnosis and treatment can prevent further spread. For example, in a U.S study of insurance claim data, one half of *Giardiasis* patients require three or more clinical visits a year after the initial diagnosis of gastrointestinal symptoms (Conners et al, 2021). In these waterborne *Giardiasis* rates, it was seen that person-to-person transmission was found to be relatively infrequent and swimming in unchlorinated pools, domestic animal exposure, or out of state foreign travel had not been associated with *Giardia* infections.

To protect against transmission, all surface water should receive chemical pretreatment, preferably with sedimentation, and filtration in addition to disinfection. The parasite spreads by ingestion of mature cysts via fecally contaminated soil, surface, water and food. Direct transmission from person-to-person through oral-fecal route occurs for example, in schools, chapter houses between children and elderly as a result of poor hygiene practices or workers with children are also at risk of infection (Dixon, 2021). In the case of waterborne transmission, a multiple barrier approach, including limiting access of people and animals to watersheds and reservoirs, and treatment using flocculation, filtration and disinfection, is necessary to minimize the risk. Since foodborne transmission is often associated with the consumption of fresh produce, several control measures can be taken during pre- and post-harvest, as well as at the food storage, food handler/consumer level to minimize the risk of contamination, or for removing or inactivating parasites.

In terms of treatment solutions, secondary and tertiary drug options and combinations of these drugs are available, however, there is a need for better health care facilities, rapid diagnostic facilities and locally trained culturally rich health care workforce that can create a better level of understanding among local communities and provide prompt treatment. In some other cases, resistance to common anti-giardial drugs has increased in recent years, the search for new molecular targets for anti-giardial drugs is urgently needed that can be supported by developing better research facilities in the local communities. In low-prevalence settings, treatment of confirmed cases of *Giardiasis* is always recommended to cure symptoms and shorten the course of the disease. Moreover, effective treatment may reduce the risk of post-infectious complications and limit the spread of infection. (Lalle & Hanevik, 2018).

Discussion & Conclusion

Although *Giardiasis* is a sporadic illness, outbreaks from daycare centers to waterborne and foodborne outbreaks are the most common in the Southwest region of the United States. Strategies for minimizing contamination of food and water sources with *Giardia* for destroying any contaminating oocyst or cyst require a multi sectoral approach.

Water is life, which means water should be used safely by families, however, regular testing is recommended by all relevant authorities especially in all indigenous and underserved communities. Ecological studies could potentially characterize contributions of private wells, septic systems, land application of bio-solids, and agricultural operations in *Giardiasis* transmission. In most studies particularly on the Navajo Nation, almost every other household has one or more aesthetic water quality problems, such as water being off-color, or having bad taste or smell.

Water on the Navajo reservation has already been scarce, however, there have been demonstrated similarities in drinking water contaminants across the Navajo Nation, the American Southwest as well as the United States; they have additionally demonstrated for other potential contaminants that may pose measurable health effects in those exposed. According to these studies, the parasite *Giardia* may be present in most water resources, especially those that livestock use. The preventions of giardiasis in any area of the world should be crucial for reducing the risk of *Giardia* infection. Research has shown that conventional drinking water treatment facilities, as well as other methods can help in lowering the concentrations of *Giardia* cysts.

It is recommended that water treatment facilities regularly test water samples for the presence of *Giardia* cysts and other contaminants. Continued study of the role of *Giardia* in chronic diarrhea and malnutrition in developing and remote regions will help focus strategies to improve growth and nutrition. The prevalence and insistence related to control planning for eradicating the parasite especially clean the source of drinking water still restricted, therefore, further future research on the mechanism of resistance to infection and strategy for good control measure should be taken to eradicate the Giardiasis infection are required. The prevalence and insistence related to control planning for eradication of the parasite especially clean the source of drinking water still restricted, therefore, further research on the mechanism of resistance to infection and strategies for good control measure to eradicate the giardia infection are vital.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Benson, S. (2022). *Giardiasis (giardia infection): Symptoms, causes, treatment*. WebMD. https://www.webmd.com/digestive-disorders/giardiasis-overview
2. Budu-Amoako, E., Greenwood, S. J., Dixon, B. R., Barkema, H. W., & Mcclure, J. T. (2011, November 1). *Foodborne illness associated with cryptosporidium and giardia from livestock*. Journal of Food Protection. https://www.sciencedirect.com/science/article/pii/S0362028X2212853X
3. Conners, E. E., Miller, A. D., Balachandran, N., Robinson, B. M., & Benedict, K. M. (2021). Giardiasis outbreaks — United States, 2012–2017. *MMWR. Morbidity and Mortality Weekly Report*, *70*(9), 304–307. https://doi.org/10.15585/mmwr.mm7009a2
4. Cordova-Marks, F. M., Carson, W. O., Monetathchi, A., Little, A., & Erdrich, J. (2022). Native and indigenous populations and gastric cancer: A Worldwide Review. *International Journal of Environmental Research and Public Health*, *19*(9), 5437. https://doi.org/10.3390/ijerph19095437
5. Credo, J., Torkelson, J., Rock, T., & Ingram, J. C. (2019). Quantification of elemental contaminants in unregulated water across western Navajo Nation. *International Journal of Environmental Research and Public Health*, *16*(15), 2727. https://doi.org/10.3390/ijerph16152727
6. Dixon, B. R. (2021). Giardia duodenalis in humans and animals – transmission and disease. *Research in Veterinary Science*, *135*, 283–289. https://doi.org/10.1016/j.rvsc.2020.09.034
7. Doglioni, C., De Boni, M., Cielo, R., Laurino, L., Pelosio, P., Braidotti, P., & Viale, G. (1992). Gastric giardiasis. *Journal of Clinical Pathology*, *45*(11), 964–967. https://doi.org/10.1136/jcp.45.11.964
8. Dunn, N., & Juergens, A. L. (2022). *Giardiasis - statpearls - NCBI bookshelf*. Giardiasis. https://www.ncbi.nlm.nih.gov/books/NBK513239/
9. Faubert, G. (2000). Immune response to *giardia duodenalis*. *Clinical Microbiology Reviews*, *13*(1), 35–54. https://doi.org/10.1128/cmr.13.1.35
10. Grytdal, S. P., Weatherholtz, R., Esposito, D. H., Campbell, J., Reid, R., Gregoricus, N., Schneeberger, C., Lusk, T. S., Xiao, L., Garrett, N., Bopp, C., Hammitt, L. L., Vinjé, J., Hill, V. R., O'Brien, K. L., & Hall, A. J. (2018). Water quality, availability, and acute gastroenteritis on the Navajo Nation – a pilot case-control study. *Journal of Water and Health*, *16*(6), 1018–1028. https://doi.org/10.2166/wh.2018.007
11. Hajare, S. T., Chekol, Y., & Chauhan, N. M. (2022). Assessment of prevalence of Giardia Lamblia infection and its associated factors among government elementary school children from Sidama Zone, SNNPR, Ethiopia. *PLOS ONE*, *17*(3). https://doi.org/10.1371/journal.pone.0264812

12. Halliez, M. C. (2013). Extra-intestinal and long term consequences of giardia duodenalis infections. *World Journal of Gastroenterology*, *19*(47), 8974. https://doi.org/10.3748/wjg.v19.i47.8974

13. Lalle, M., & Hanevik, K. (2018). Treatment-refractory giardiasis: Challenges and solutions. *Infection and Drug Resistance*, *Volume 11*, 1921–1933. https://doi.org/10.2147/idr.s141468

14. Leung, A. K. C., Leung, A. A. M., Wong, A. H. C., Sergi, C. M., & Kam, J. K. M. (2019). Giardiasis: An overview. *Recent Patents on Inflammation & Allergy Drug Discovery*, *13*(2), 134–143. https://doi.org/10.2174/1872213x13666190618124901

15. Mørch, K., & Hanevik, K. (2020). Giardiasis treatment: An update with a focus on refractory disease. *Current Opinion in Infectious Diseases*, *33*(5), 355–364. https://doi.org/10.1097/qco.0000000000000668

16. Nolen, L. D., Vindigni, S. M., & Parsonnet, J. (2020). Combating gastric cancer in Alaska native people: An expert and community symposium. *Gastroenterology*, *158*(5), 1197–1201. https://doi.org/10.1053/j.gastro.2019.11.299

17. Painter , J. E., Gargano, J. W., Collier, S. A., & Yoder, J. S. (2015). *Giardiasis surveillance - United States, 2011–2012*. Centers for Disease Control and Prevention. https://www.cdc.gov/mmwr/preview/mmwrhtml/ss6403a2.htm

18. Rogan, W. J., & Brady, M. T. (2009). Drinking water from private wells and risks to children. *Pediatrics*, *123*(6). https://doi.org/10.1542/peds.2009-0752

19. Rose, J. B., De Leon, R., & Gerba, C. P. (1989). Giardia and virus monitoring of sewage effluent in the state of Arizona. *Water Science and Technology*, *21*(3), 43–47. https://doi.org/10.2166/wst.1989.0076

20. Sanjeevaiah, A., Cheedella, N., Hester, C., & Porembka, M. R. (2018). Gastric cancer: Recent molecular classification advances, racial disparity, and management implications. *Journal of Oncology Practice*, *14*(4), 217–224. https://doi.org/10.1200/jop.17.00025

21. Stadelmann, B., Merino, M. C., Persson, L., & Svärd, S. G. (2012). Arginine consumption by the intestinal parasite giardia intestinalis reduces proliferation of intestinal epithelial cells. *PLoS ONE*, *7*(9). https://doi.org/10.1371/journal.pone.0045325

22. Supreme Court of the United States. (2022). https://www.supremecourt.gov/opinions/22pdf/21-1484_aplc.pdf

23. Thompson, R. C. A., & Ash, A. (2016). Molecular epidemiology of Giardia and Cryptosporidium infections. *Infection, Genetics and Evolution*, *40*, 315–323. https://doi.org/10.1016/j.meegid.2015.09.028

24. Yoder, J. S., Gargano, J. W., Wallace, R. M., & Beach, M. J. (2012). *Giardiasis surveillance - United States, 2009–2010*. Centers for Disease Control and Prevention. https://www.cdc.gov/mmwr/preview/mmwrhtml/ss6105a2.htm

25. Zylberberg, H. M., Green, P. H., Turner, K. O., Genta, R. M., & Lebwohl, B. (2017). Prevalence and predictors of giardia in the United States. *Digestive Diseases and Sciences*, *62*(2), 432–440. https://doi.org/10.1007/s10620-016-4447-0

Citation: Boyd J, Hakim ST. Giardiasis in the Southwest Region of the United States: Causes and Preventive Measures. *SVOA Microbiology 2023,* 4:2, 48-55.