Giardiasis

Giardia Enteritis,
Lambliasis,
Beaver Fever

Last Updated: December 2012

Importance

Giardiasis, a gastrointestinal disease characterized by acute or chronic diarrhea, is caused by protozoan parasites in the genus *Giardia*. *Giardia duodenalis* is the major species found in mammals, and the only species known to cause illness in humans. This organism is carried in the intestinal tract of many animals and people, with clinical signs developing in some individuals, but many others remaining asymptomatic. In addition to diarrhea, the presence of *G. duodenalis* can result in malabsorption; some studies have implicated this organism in decreased growth in some infected children and possibly decreased productivity in young livestock. Outbreaks are occasionally reported in people, as the result of mass exposure to contaminated water or food, or direct contact with infected individuals (e.g., in child care centers).

People are considered to be the most important reservoir hosts for human giardiasis. The predominant genetic types of *G. duodenalis* usually differ in humans and domesticated animals (livestock and pets), and zoonotic transmission is currently thought to be of minor significance in causing human illness. Nevertheless, there is evidence that certain isolates may sometimes be shared, and some genetic types of *G. duodenalis* (assemblages A and B) should be considered potentially zoonotic.

Etiology

The protozoan genus *Giardia* (Family Giardiidae, order Giardiida) contains at least six species that infect animals and/or humans. In most mammals, giardiasis is caused by *Giardia duodenalis*, which is also called *G. intestinalis*. Both names are in current use, although the validity of the name *G. intestinalis* depends on the interpretation of the International Code of Zoological Nomenclature. Two older names for the organism, *Giardia lamblia* and *Lamblia intestinalis*, are no longer considered to be taxonomically valid. Nevertheless, the term *G. lamblia* can still be found sometimes in the human clinical literature. Additional species in animals include *G. agilis* in amphibians, *G. ardeae* and *G. psittaci* in birds, *G. muris* in rodents and *G. microti* in muskrats and voles. *G. varani*, which infects reptiles, is also thought to be a distinct species. Other species of *Giardia* probably also exist in animals, including fish. None of these species, other than *G. duodenalis*, is known to affect people.

G. duodenalis has been divided into at least 7 genetic assemblages, A through G, which might be distinct enough to be considered species. Assemblages A and B have broad host specificity. Almost all isolates from humans belong to these two assemblages. They also occur in many species of animals. Assemblages C, D, E, F and G appear to have narrow host ranges. Assemblages C and D are found mainly in dogs, assemblage E in artiodactyls, assemblage F in cats and assemblage G in rodents. Proposed species names for the assemblages are *G. canis* for assemblages C and D, *G. bovis* for assemblage E, *G. cati* for assemblage F and *G. simondi* for assemblage G. An additional proposal is to reserve the name *G. duodenalis* for assemblage A, and rename assemblage B *G. enterica*. These names have not yet been accepted, and there are some objections to their validity; however, they may be encountered in some articles. Novel *G. duodenalis* genotypes include a proposed assemblage H, reported in seals and a gull; another isolate from southern brown bandicoots (*Isoodon obesulus*) in Western Australia, and two genotypes of *G. duodenalis* identified in house mice on an island in Australia.

Subassemblages (also called subgroups) have been recognized within some assemblages. Three subassemblages - AI, AII and AIII – have been defined, to date, in assemblage A. Subassemblage AII is usually found in people, while subassemblage AI mainly occurs in livestock and pets. However, this division is not absolute; subassemblage AI has been isolated occasionally from people, and AII from animals. Subassemblage AIII has been detected in hoofed wild animals. As of 2012, it has not been found in humans. It is more difficult to define subassemblages in assemblage B, which is genetically diverse. Two subassemblages, BIII and BIV, were described by allozyme electrophoretic studies, but DNA sequence analyses do not support these 2 groups. Host-specific subassemblages have not yet been identified in assemblages C through G.

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- Diagnosis of Animal Disease and Vaccine Evaluation in the Americas
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Challenges in classifying G. duodenalis into assemblages

Molecular tools (e.g., PCR) are used to classify *G. duodenalis* into assemblages and subassemblages. Most studies use tests based on one or more of 4 genetic loci: SSU rRNA and the triosephosphate isomerase (tpi), glutamate dehydrogenase (gdh) and β-giardin genes. Many studies examine only a single locus, often SSU rRNA. However, the use of a different gene, or even a different set of PCR primers, can occasionally assign the same isolate to a different assemblage.

Multilocus genotyping (MLG) studies use more than one gene to classify the organism. Although this is more accurate than using a single gene, some isolates still cannot be unequivocally assigned to a single assemblage. One possible explanation for this phenomenon is that the individual is infected with two or more organisms that belong to different assemblages. A second possibility is that these samples contain recombinant *Giardia* organisms with sequences from more than one assemblage type. Although *Giardia* species mainly reproduce by asexual means, there is recent evidence that recombination may also occur. PCR of single *Giardia* cysts might be used to distinguish these two possibilities in a sample; however, this technique is still in its infancy.

As a result, it is possible for two studies to assign an isolate to different assemblage types, only one of which may be potentially zoonotic. Furthermore, the interpretation of discrepant results in MLG studies can vary. While some authors assume that the animal is infected with two or more assemblage types (one of which may belong to a zoonotic assemblage), others are more cautious in assigning such isolates.

Zoonotic potential of G. duodenalis in animals

Humans are thought to be the main reservoir for *G. duodenalis* infections in people. Whether infections in animals are zoonotic, and to what extent, is still uncertain and controversial. Cross-transmission studies can be difficult to interpret, and studies examining whether contact with animals is a risk factor for giardiasis have not provided a definitive answer. Genetic analyses that compare *G. duodenalis* isolates from people and animals may shed light on this question. Such studies have found that people are often, though not always, infected with different *G. duodenalis* assemblages or subassemblages than livestock and pets. For example, assemblages A and B, which cause giardiasis in people, can be found in livestock, but assemblage E is usually more common. A few MLG studies have also been published. One reported that 2 of 6 multilocus assemblage A genotypes in *G. duodenalis* databases were potentially zoonotic. One of these 2 genotypes contained a few human isolates, although most were from animals. The other included one isolate from a cat, while the rest were from humans. The remaining 4 genotypes seemed to be limited to either animals or people. Another MLG study found that 3 of 7 assemblage A genotypes had zoonotic potential. Only one study examined assemblage B. It reported that approximately 4-7% of assemblage B isolates were potentially zoonotic. Several recent reviews conclude that zoonotic transmission from domesticated animals is possible but unproven, and likely to be of minor importance compared to person-to-person transmission. However, they also stress that additional well-designed epidemiological studies that use genetic tools, especially MLG, are needed before the extent of zoonotic giardiasis can be fully evaluated. Thus, *G. duodenalis* assemblage A and assemblage B isolates in animals should be considered to be potentially zoonotic at this time. Likewise, assemblage A and B isolates in people may have the ability to infect animals.

In contrast to pets and livestock, assemblage A (and sometimes assemblage B) is common in nonhuman primates, marsupials, marine mammals and terrestrial and aquatic wildlife. The role of wild animals in maintaining and transmitting *G. duodenalis* to people is uncertain. Beavers have been implicated in zoonotic transmission, based on epidemiological investigations of waterborne outbreaks, and reports of giardiasis in hikers and campers. However, this conclusion was based on circumstantial evidence, such as the recovery of *Giardia* cysts from beavers in areas with contaminated water. The possibility that the water was initially contaminated by humans or other animals could not be ruled out. It is possible that people or domesticated animals transmit *G. duodenalis* to wild animals, which may then maintain and/or amplify the organism.

Geographic Distribution

G. duodenalis occurs worldwide, and is particularly common in warm climates.

Transmission and Life Cycle

Giardia spp. have two stages, cysts and trophozoites. The infection is acquired by ingesting cysts, which are excreted in the feces. As few as 10-25 cysts are sufficient to establish an infection in some humans. Some livestock may be infected by as few as 1–10 cysts. *Giardia* cysts can be transmitted directly between hosts, or on various fomites including contaminated water and food. Animals can also be re-infected from their fur when they groom.

Trophozoites are released from the ingested cysts in the small intestine, where the trophozoites then multiply. Many of the dividing trophozoites are carried toward the colon, and encyst along the way, in response to bile salts and other stimuli. Cysts can appear in the feces from 3 days to 3 weeks after infection, depending on the host species. Excretion usually begins around the same time the first symptoms (if any) appear. In both people and animals, infections may last from a few days to several months, and cyst shedding is usually intermittent. Shedding has been reported to increase during the periparturient period in

sheep, goats, pigs and cattle. Most sources consider *Giardia* cysts to be immediately infectious when they are excreted in the feces (although there is evidence that some cysts might become infectious after a maturation period of up to 7 days).

Giardia cysts can survive for long periods in the environment under cool, moist conditions. They are susceptible to desiccation and direct sunlight, and are destroyed more quickly under hot and dry conditions. In various experiments, cyst were shown to survive in tap or lake water for approximately two months at 0-8°C, in tap water for 2 weeks at 20-28°C; and in lake water for 1 month at 17-20°C. Cysts remained viable in river water for nearly 3 months at 0-4°C, and 1 month at 20-28°C, while they survived in seawater for more than 2 months at 4°C. In soil held at 4°C, almost 90% of cysts were still viable after 49 days; however, infectivity was lost within 7 days at 25°C. Cysts also survived for one week in solid cattle manure at 4ºC, and for as long as 18 days in human feces.

Giardia trophozoites may also be found in the feces of some animals or people with diarrhea. These trophozoites survive only briefly in the environment, and are thought to be of little or no epidemiological significance.

Disinfection

G. duodenalis cysts on surfaces are susceptible to 5% sodium hypochlorite at a 1:30 dilution, as well as to some other disinfectants including most quaternary ammonium solutions. In laboratories, 6% H_2O_2 can also be used to disinfect surfaces or decontaminate spills. Leaving disinfectants on contaminated surfaces for 5-20 minutes before rinsing helps ensure inactivation. *Giardia* cysts are susceptible to ultraviolet (UV) light,, as well as to heat (e.g., steam) and desiccation. Freezing reduces the number of cysts, although some may survive.

In water, *G. duodenalis* cysts can be killed by a rolling boil maintained for one minute, or by filtration through an absolute pore size of at least one micron (e.g., a filter that has been National Safety Foundation rated for cyst removal). *Giardia* cysts are relatively resistant to chlorination, particularly if the water is cold, and, the amount of chlorine used routinely in drinking water is not sufficient to kill *G. duodenalis*. Treatment conditions reported to inactivate cysts in 5°C water include 4 mg/L chlorine for 60 minutes, at pH 6-8; 8 mg/L chlorine for 10 minutes, at pH 6 or 7; and 8 mg/L chlorine for 30 minutes, at pH 8. At 25°C, cysts in pH 6 water are inactivated after 10 minutes of exposure to 1.5 mg/L of chlorine. Likewise, the effectiveness of iodination depends on the temperature, pH and turbidity of the water, as well as contact time with the chemical. Ozone and UV light can also inactivate cysts in water.

Composting manure can reduce or eliminate *Giardia* cysts. Cyst numbers and viability were also significantly reduced in slurry waste from cattle held for 90 days.

Giardia trophozoites are killed much more readily than cysts; treatments that inactivate the cysts, as well as milder methods, are expected to be effective.

Infections in Animals

Species Affected

Several species of *Giardia* infect mammals, marsupials, birds, reptiles, amphibians and fish.

Giardia duodenalis in mammals and marsupials

G. duodenalis infections have been reported in many species of domesticated mammals, including cattle, water buffalo, sheep, goats, South American camelids, pigs, horses and other livestock; dogs, cats and ferrets; and small mammals such as chinchillas (*Chinchilla lanigera*), guinea pigs, rats and rabbits. This organism also occurs in wildlife and captive wild animals including terrestrial mammals, freshwater aquatic mammals (e.g., beavers and muskrats), marine mammals (seals, whales, dolphins and porpoises) and a wide variety of marsupials.

Many published studies describe *G. duodenalis* assemblage types found in animals. Given the difficulties in assigning some isolates to an assemblage, it is possible that some organisms (especially those found rarely) were misidentified.

***G. duodenalis* assemblage A** has been reported in domesticated livestock including cattle, water buffalo, farmed bison (*Bison bison*), yaks, sheep, goats, pigs, horses and alpacas; and in companion animals including dogs, cats, pet ferrets and chinchillas. In these species, it is usually (though not always) less common than species-specific assemblage types (e.g., assemblage E in livestock, C and D in dogs, or F in cats). In contrast, assemblage A is the predominant isolate, together with assemblage B, in wild and captive nonhuman primates. It was also the most prevalent genotype in a study of captive and wild Australian marsupials. Assemblage A seems to be common in wild mammals, where it has been documented in a wide variety of species such as beaver, cervids, muskoxen (*Ovibos moschatus*) and marine mammals.

***G. duodenalis* assemblage B** is the predominant isolate, together with assemblage A, in wild and captive nonhuman primates. It can also infect many other species such as cattle, sheep, pigs, horses, dogs, cats, rabbits, guinea pigs, chinchillas, wild and captive mammals and marsupials. However, this assemblage type seems to be uncommon in most mammals. In many studies, it was detected in only 0-2% of the population. On rare occasions, assemblage B is reported to be the most common genotype in a population. For example, one study reported that 92% of the isolates from pooled manure samples on 10 Canadian pig farms belonged to this assemblage. Some studies have reported that assemblage B might occur frequently in beaver, muskrats and seals.

***G. duodenalis* assemblages C and D** are mainly found in dogs and other canids including foxes, wild dogs/dingos, coyotes and wolves, and seem to be adapted to these species. One study reported that assemblages C and D were rare in captive and wild African painted dogs (*Lycaon pictus*), and most isolates belonged to assemblages A and B. Assemblages C and D have also been detected in seals and kangaroos. Rare infections were documented in other domesticated and wild species, including a goat and a few cats.

***G. duodenalis* assemblage E** is usually the predominant type in domesticated, cloven-hoofed species. It has been reported from cattle, yaks, water buffalo, farmed bison, sheep, goats, alpacas and pigs. Assemblage E also occurs in horses. Surprisingly, most studies report that this assemblage type is rare in wild ungulates, although one study from Australia found that it was present in a significant number of the *Giardia*-positive samples from wild deer. Infections have been reported occasionally in other species including wild dogs/dingos and foxes in Australia, as well as a few cats, chinchillas and a wild mouse.

***G. duodenalis* assemblage F** has been detected mainly in cats, and appears to be adapted to this species. It has been reported rarely in a few other species including dogs, pigs and rodents.

***G. duodenalis* assemblage G** is seen mainly in rodents including rats.

***G. duodenalis* assemblage H** has been reported from seals, as well as a gull from the same ecosystem.

Other species of Giardia in mammals

G. muris has been found in rodents, including mice and rats. *G. microti* occurs in voles and muskrats. Possible infections with this organism were reported in mice, a dog, a captive cheetah (*Acinonyx jubatus*) and a captive leopard (*Panthera pardus japonensis*).

Birds

At least two species of *Giardia* seem to be adapted to birds. *G. psittaci* occurs in psittacine birds. *G. ardeae* has been reported from various species of herons and egrets, and a white stork (*Ciconia ciconia*). A closely related organism, which may be a strain of *G. ardae*, was detected in a straw-necked ibis (*Threskiornis spinicollis*). *G. duodenalis* is also reported occasionally in birds, but it is still uncertain whether these birds are infected or acting as paratenic (transport) hosts. In a study of pet birds and zoo birds from 14 orders and 63 species, *G. duodenalis* assemblage A was found only in members of the Psittaciformes. Other studies detected *G. duodenalis* assemblages A and B in wild gulls (*Larus* spp.). There are very few studies of *Giardia* in domesticated poultry. One found *G. duodenalis* in one of 11 domesticated geese (*Anser anser* f. *domestica*), and another reported *G. duodenalis* assemblage B in domesticated ostriches (*Struthio camelus*). The classification of *Giardia* spp. found in some orders of birds (e.g., Charadriiformes, Passeriformes and Piciformes) is still uncertain.

Reptiles and Amphibians

G. agilis occurs in amphibians. A proposed new species, *G. varani*, was reported in reptiles.

Fish

Fish are probably infected with unique species of *Giardia*, but *G. duodenalis* has also been detected. In an Australian survey, *G. duodenalis* assemblages A, B and E were found in cultured fingerlings (barramundi, black bream, mulloway and snapper) at hatcheries, and in wild mullet, as well as in a single minnow from a freshwater environment. Sequences resembling *G. microti* were reported in one cultured barramundi fingerling. The intestines of many fish contained large numbers of *Giardia* trophozoites and cysts, suggesting that they might have been infected rather than acting as transport hosts. In another study, assemblage A was documented in a mako shark (*Isurus paucus*).

Incubation Period

In some experimentally infected animals, clinical signs were reported to occur around the time cyst excretion begins. The prepatent period is 5 to 16 days in dogs and cats. It was reported to be 6 to 21 days in early studies in ruminants, probably due to the method of detection, but more recent research suggests 3 to 10 days.

Clinical Signs

Most infections are asymptomatic, particularly in adult animals. Acute, chronic or intermittent diarrhea or soft stools may be seen in some dogs and cats. The stools are typically light-colored and mucoid. They are often malodorous, and may contain undigested fat, but blood is rare. Vomiting occurs occasionally, but fever is not usually present. Infected animals may also have an unthrifty appearance and occasionally lose weight or fail to gain weight. The diarrhea is self-limited in most immunocompetent dogs and cats.

Giardia is a potential cause of diarrhea and decreased productivity in livestock, especially calves and other young ruminants, but it is still uncertain whether this occurs to any significant extent. Most studies have been done in the field, and are complicated by the possibility of concurrent infections or infestations with other organisms, rapid reinfection with *Giardia* after elimination of the organism, and other factors. Two studies in experimentally infected ruminants suggest that some infections can become symptomatic. Experimentally infected specific pathogen–free (SPF) lambs developed diarrhea, took longer to reach slaughter weight and had lower carcass weight compared to uninfected lambs. Diarrhea, decreased appetite and depression were reported in experimentally infected goats. Diarrhea that does not respond to antibiotic or coccidiostatic treatment, especially in young ruminants, might raise a suspicion of giardiasis. Pasty to fluid feces with a mucoid

appearance would be expected. Alone, *Giardia* does not seem to cause severe or watery diarrhea in ruminants.

Clinical giardiasis appears to be uncommon in horses. In one recent study, the shedding of *Giardia* was correlated with mild diarrhea in young foals.

Giardia spp. infections may also cause diarrhea in some birds. Forms of diarrhea described by various sources include voluminous, aerated "popcorn" feces, soft green stools and mucoid, malodorous diarrhea. Dry, flaky skin, which may progress to pruritus, feather pulling, (especially from the axillae and inner thigh), and alopecia have been attributed to giardiasis in pet birds. Weight loss, depression, decreased feed and water consumption, dehydration and deaths have been documented in some case reports. *Giardia* has not been proven to cause some of these clinical signs in birds, and some cases may have been exacerbated by co-infections.

Communicability

G. duodenalis cysts shed in the feces are infectious. Both symptomatic and asymptomatically infected animals excrete cysts, for days to months. The duration of shedding was found to be at least 100 days in some dairy calves, up to 25 weeks in beef calves and more than 10 weeks in lambs and goats.

Diagnostic Tests

The diagnosis of giardiasis is based on the detection of *Giardia* spp., in conjunction with the clinical presentation and exclusion of other causes. Cysts can also be present in asymptomatic animals, or as an incidental finding in animals with other diseases.

Giardia spp. can be found in feces by direct microscopic examination, using either stained preparations (e.g., Lugol's solution) or unstained wet mounts. An advantage of this method is that it can also detect other parasites that may cause diarrhea. Because they are small and can resemble other fecal components, *Giardia* cysts and trophozoites can sometimes be difficult to identify.

Direct smears or fecal wet mounts can be used to look for trophozoites. Samples should be taken from the surface of the feces, where organisms are more common. The flagellated trophozoite, 9-21 µm long by 5-15 µm wide, has a "tear drop" shape, with two nuclei at the anterior end and tumbling motility. Trophozoites are usually detected only in very fresh samples from animals with diarrhea. Living organisms will probably not be found after several hours or in refrigerated samples.

More often, diagnosis is based on detection of the cysts, which are present in formed stools as well as diarrheic feces. *Giardia* cysts are oval, approximately 8-15 µm long and 7-10 µm wide, with 4 nuclei. Cysts can be concentrated by passive fecal flotation or centrifugal fecal flotation. Zinc sulfate preserves the morphology better than sugar solutions, which can distort the cyst. Shedding can be intermittent; 3 samples from different days are usually recommended to rule out giardiasis with a high probability. In livestock, multiple samples can also be taken from several animals within the same housing facility. Young animals should be sampled, if possible, as they are most likely to excrete cysts.

Direct immunofluorescence, available in veterinary diagnostic laboratories, can be used to visualize the organism. Some researchers consider this test to be the gold standard for the diagnosis of giardiasis in dogs and cats. Morphology and fluorescence can both be examined, reducing the risk of false positives.

Giardiasis can also be diagnosed by detecting antigens in the feces, using various ELISA or rapid solid-phase qualitative immunochromatography assays. These assays have not been validated for all species. Most of the tests are performed by diagnostic laboratories, but at least one in-house ELISA test kit is available in some countries. Antigen shedding may persist for weeks after elimination of the parasite.

PCR assays are performed in some university research and service laboratories, but they are not widely available in commercial diagnostic laboratories. PCR is used mainly to identify *G. duodenalis* assemblage types. Culture of *Giardia* spp. is employed only in research.

There is continuing controversy about the relative merits of the various testing methods, but experts generally agree that a combination of multiple tests on multiple samples is optimal. The Companion Animal Parasite Council currently recommends that, if a direct smear and fecal centrifugal flotation do not detect *Giardia* or are not definitive in symptomatic dogs and cats, a *Giardia* antigen assay should be added. Diagnostic testing is recommended only for pets with clinical signs or when there is a specific zoonotic concern. Routine screening of healthy pets for this organism is not recommended.

Treatment

Pets

In dogs and cats, treatment is usually recommended only to end the clinical signs if the animal is symptomatic. The infection may or may not be eliminated. Commonly used drugs include metronidazole, fenbendazole and a combination product that contains praziquantel, pyrantel and febantel. The latter two products are registered in some countries for use against *G. duodenalis* in dogs, but there is currently no FDA-approved drug for treating animal giardiasis in the U.S. Other drugs have also been used; however, there is limited information about some drugs, and others are no longer recommended for use in dogs and cats, due to the potential for serious side effects (e.g., myelosuppression has been reported with albendazole). Some infections are self-limiting.

Treated animals are often reinfected from the environment (where cysts are widespread) or other animals, or even from the animal's own fur. Bathing the animal is

often recommended on the last day of treatment. It may be helpful to dry the coat with warm air (especially in the perineal region) after the bath. Cleaning and disinfection, as well as a dry environment, can help eliminate cysts from some fomites.

Treatment for subclinically infected pets is controversial. Healthy cats and dogs with normal stools are not considered to present significant health risks for humans. In addition, the infection may persist despite treatment, and animals are readily reinfected from the environment. There are also concerns about side effects from the drugs used to treat giardiasis, For these reasons, most sources do not currently advise routine treatment if the animal is not symptomatic. Treatment may, however, be considered in individual circumstances (e.g., a request from an owner who is immunocompromised). It can be particularly challenging to eradicate *Giardia* from an animal population where it has become established. In this situation, all infected animals in the household or facility must be treated concurrently, and environmental sources of contamination addressed. Disposable litterboxes can be used while cats are being treated, and new litterboxes and scoops purchased once *G. duodenalis* is no longer present.

Livestock

Whether treatment is required or advisable in livestock is unknown. No drug is currently licensed to treat giardiasis in these animals, and while there are some studies in calves, there is little or no information on treatment efficacy in sheep, goats and pigs. One review considered that benzimidazole compounds (e.g., fenbendazole) or paromomycin were currently the most suitable drugs to treat giardiasis in calves and other livestock. Metronidazole and dimetridazole have also been used in calves; however, the nitroimidazoles are no longer approved for use in livestock in some countries. Concurrent cleaning and disinfection of the environment is expected to increase the effectiveness of treatment by reducing the parasite burden. Most treated calves begin shedding cysts again within 2–3 weeks, probably after reinfection from the environment.

Prevention

Prevention is considered to be impractical in livestock, and difficult in most species, because the organisms are so prevalent in the environment. Some measures may, however, reduce exposure or decrease the parasite burden, which might also decrease the potential for clinical signs.

Keeping pets indoors can reduce exposure to *Giardia* sources such as soil, unsafe water and feces from other animals and wildlife. Water treatments similar to those used for humans (e.g., boiling or filtering) can destroy the organism in unsafe water supplies. Indoor housing is expected to favor transmission of *G. duodenalis* between livestock, but housing calves individually and avoidance of crowding are expected to reduce transmission. Rodent control and decreased contact with wild birds might lower the risk of infections in captive birds and other species

Regular cleaning, prompt removal of feces, and frequent changes of bedding materials (where applicable) can limit contamination of animal environments. Hard surfaces can be disinfected or steam cleaned after cleansing, and should be left to dry, as the cysts are susceptible to desiccation. Livestock facilities should be cleaned and dried between introductions of animals. In birds, the use of wire-floors in cages can reduce access to feces. Raised food and water containers in bird cages are less likely to become contaminated by droppings. Ensuring that newborn mammals receive adequate colostrum can help build resistance to disease.

Giardia vaccines were available for dogs and cats at one time. These vaccines were not proven to prevent infections, and were categorized as "generally not recommended" in the 2006 American Animal Hospital Association vaccine guidelines and the American Association of Feline Practitioners vaccine guidelines. They have now been discontinued by the manufacturers. Vaccines are not available for other species.

Widespread screening of healthy pets is not recommended, as infections are common, the organism is difficult to eliminate permanently, and the risk of transmitting the infection to people is thought to be low.

Morbidity and Mortality

Many *Giardia* spp. infections in animals are asymptomatic. Symptomatic infections are not usually life threatening, and are often self-limiting.

Reported prevalence rates for *G. duodenalis* vary widely, depending on the composition of the study population, location and other factors. Although all ages can be infected, both infection and disease occur more often in young animals. Crowding increases the risk of transmission, while frequent cleaning and disinfection can decrease exposure. The sensitivity of the test used for surveillance is also a factor: lower rates are generally reported by surveys that use fecal flotation/ microscopy compared to those using ELISAs.

Dogs and cats

In dogs and cats, animals under the age of 6 months are reported to have the highest infection rates. One study reported that the prevalence was also relatively high in cats between the ages of 6 months and a year. Animals in shelters, breeding facilities, kennels and catteries are more likely to carry *G. duodenalis*, and one study found an increased prevalence among dogs that visit dog parks. Some studies found that this organism was more likely to be present in dogs and cats with diarrhea, while others detected no significant difference in prevalence between animals with diarrheic and normal feces.

A large multi-country European study, performed mainly in dogs with gastrointestinal signs, found that the overall prevalence by antigen-capture ELISA was 25% in all dogs, and 43% in puppies under the age of 6 months. A nationwide U.S. survey of pet dogs, using microscopy, reported that the prevalence was 4% overall, 13% in puppies less than 6 months of age, and less than 1% in dogs more than 3 years of age. Other studies of various healthy and/or symptomatic canine populations reported infection rates of 1% to 36% in Europe, <1% to 16% in the U.S. and Canada, 1% to 37% in South and Central America, <1% to 57% in Asia, and 9% in Australia. Foci with especially high prevalence (e.g., 61-64%) have been reported among dogs in some communities where dogs are allowed to roam and hygiene standards are very low.

A multi-country European study, mainly of cats with gastrointestinal signs, reported a prevalence of 20% by antigen-capture ELISA, while a small number of additional studies from Europe found infection rates of 1% to 37% in various feline populations. Infection rates reported from other countries were <1% to 44% in the U.S., <1% to 4% in Canada, 6% in Brazil, 19% in Chile, 6.5% in Colombia, 0% to 40% in Japan, 1% in Iran and 2% in Australia.

Ferrets and small mammals

There is limited information about *Giardia* spp. in ferrets and small mammals such as rabbits and guinea pigs or other pet rodents. One diagnostic laboratory in Germany found that *Giardia* was present in 13% of fecal samples submitted from ferrets in 2009-2010, compared to 3% in 2002-2004. In another study, 36% of the chinchillas in a Brazilian breeding facility were shedding *Giardia* spp. cysts.

Birds

A limited number of surveys found *Giardia* spp. in 2% to 16% of pet and zoo birds.

Livestock

Feed and management practices affect the prevalence of *G. duodenalis* in livestock. Transmission is expected to be higher in intensive management systems, where young animals are housed together in close contact.

In cattle, published infection rates range from 2% to 57% in various European countries, 9% to 73% in Canada and the U.S., 4% to 50% in Asia (Taiwan, Vietnam and Malaysia), 14% to 58% in Australia, 5% to 49% in New Zealand and 8% to 10% in Uganda. The prevalence is highest in calves under the age of 6 months (however, calves under a month of age are not usually infected). Reported infection rates in sheep were 1-42% in Europe, 25-56% in North America and 9-44% in Australia. In goats, the prevalence was 4-53% in studies from Belgium, Spain, Brazil and Uganda. One Italian study found that 26% of water buffalo were infected. In the published surveys, *G. duodenalis* was found on 10% to 100% of the studied farms. When *Giardia* has been diagnosed on a farm, nearly all animals are expected to be infected at some point in their lives; the cumulative incidence is reported to be 100% in cattle and goats, and nearly 100% in sheep.

Several studies of pigs in Australia, Asia, Europe and North America reported infection rates of < 1% to 31%. In Denmark, *G. duodenalis* was found in 38% of weaners, 3% of piglets and 4% of sows.

Horses

In studies from Italy, Germany, the Czech Republic, Brazil, the U.S. and Canada, the prevalence in horses varied from less than 1% to 37%. Foals were infected more often than adult horses.

Zoo animals

Giardia spp. were detected in 29% of asymptomatic mammals at the zoo of Zagreb, Croatia. The prevalence was 50% among the Artiodactyla, 57% in Carnivora, 40% among primates, and 60% in Rodentia. At the Antwerp Zoo in Belgium, infections were found in 10% of captive wild ruminants under the age of 6 months. *Giardia* spp. were also detected in 13% of captive marsupials in Australia.

Fish

There is very limited information on *Giardia* spp. in fish. In Australia, a PCR-based survey detected *Giardia* spp. in approximately 8% of the cultured fingerlings (barramundi, black bream, mulloway and snapper) from hatcheries; 3% of wild marine fish (all infected fish were mullet); and <1% of wild freshwater fish (a single minnow).

Post Mortem Lesions

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Gross lesions are not usually found, other than evidence of dehydration (especially in birds). Microscopic lesions consist of villous atrophy and cuboidal enterocytes.

Infections in Humans

Incubation Period

The incubation period in humans is 1 to 45 days; in most cases, the symptoms appear in 1-2 weeks.

Clinical Signs

Many human infections with *G. duodenalis* are asymptomatic, with affected individuals either clearing the infection spontaneously or shedding cysts subclinically. Symptomatic cases are characterized by mild to severe gastrointestinal signs. Some patients develop acute or chronic diarrhea, with loose, foul-smelling stools. The feces may have a greasy appearance, but blood is rarely seen. Other gastrointestinal signs may also be present, either with or without diarrhea. They can include abdominal cramps or pain, bloating, flatulence, nausea, anorexia and vomiting. Weight loss or dehydration can result, and fatigue may accompany the illness. Low-grade fever may be seen occasionally at the beginning of the

illness, although some sources report that this is uncommon. Anemia, weight loss and anorexia have been reported as the most prominent signs in some elderly individuals. Most infections are self-limited, and last for a few days to a few weeks; however, cases may occasionally persist for months or even years. In chronic giardiasis, episodes of diarrhea or loose stools can occur continuously, intermittently, sporadically or recurrently. The stools may be normal between bouts of diarrhea. Constipation is also possible. Abdominal discomfort can be continuous in chronic cases, persisting even when diarrhea is absent. Chronic infections may lead to malabsorption syndromes that can include disaccharidase deficiency and vitamin deficiencies, as well as severe weight loss and debilitation. Chronic infections occur in both immunodeficient and immunocompetent individuals.

Clinical giardiasis is reported to be more frequent in patients with immunoglobulin deficiency states, and most of these patients have chronic diarrhea. This population includes people with congenital (genetic) hypogammaglobulinemia, as well as those with acquired conditions associated with protein-calorie malnutrition, lymphoma and other syndromes. The symptoms in HIV-infected individuals appear to be similar to those immunocompetent persons, and *G. duodenalis* infections are often asymptomatic. However, as CD4+ lymphocyte counts decrease and immunosuppression increases, clinical signs are more likely to occur.

Disaccharide intolerance, mainly in the form of lactose deficiency, is the most common complication of giardiasis. It can last for several weeks after the organism is cleared either spontaneously or by treatment. The symptoms resemble those caused by the organism, and may include abdominal cramps, bloating and diarrhea. Deficiencies of fat-soluble vitamins and vitamin B12 are also possible, but less common. A few studies have suggested that *G. duodenalis* infections might cause growth retardation in some populations (e.g., in Bedouin children living in the desert). In contrast, there were no apparent detrimental effects, including gastrointestinal signs or decreased growth, in healthy, well-nourished children in day care facilities. A few studies have suggested that *G. duodenalis* infections might be correlated with an increased incidence of irritable bowel syndrome or other syndromes. Occasional case reports have also attributed extraintestinal signs, including urticaria, pruritus, bronchospasm, reactive arthritis and other allergic signs, to giardiasis. Most sources consider extraintestinal signs to be rare, although one recent survey found that self-reported rashes and ocular, joint and urinary signs were relatively common in symptomatic patients.

Giardiasis is rarely fatal; however, deaths can be caused by extreme dehydration, mainly in infants or malnourished children.

Communicability

G. duodenalis can be transmitted from person to person by fecal contamination. Both symptomatic and asymptomatic individuals can excrete cysts. Cysts are shed in the feces, often intermittently, during the entire period of infection. *G. duodenalis* from people might be able to infect animals.

Diagnostic Tests

Giardiasis can be diagnosed by direct observation of the trophozoites or cysts in the feces. Either stained preparations (e.g., preserved with polyvinyl alcohol or 10% formalin) or unstained wet mounts can be used. Because they are small and can resemble other fecal components, *Giardia* cysts and trophozoites can sometimes be difficult to identify by morphology alone.

Direct smears or fecal wet mounts can be used to look for trophozoites. This stage usually observed only in fresh, watery stools. The flagellated trophozoite is 9-21 µm long by 5-15 µm wide, and has a "tear drop" shape, with two nuclei at the anterior end and tumbling motility. Cysts can be found in formed as well as unformed stools. *G. duodenalis* cysts are approximately 8-15 µm long and 7-10 µm wide, and oval, with four nuclei. Various flotation or sedimentation processes can be used to concentrate the cysts. Repeated sampling may be necessary when there are few organisms. Because shedding occurs intermittently; cysts are more likely to be found if specimens from 3 different days are examined.

If chronic giardiasis is suspected, but repeated stool examinations are negative, the intestinal contents can be examined directly for trophozoites. One technique is the "string test" (Entero-test), in which the patient swallows a gelatin capsule on a string, and the string is later retrieved and examined for trophozoites. Aspiration of duodenal contents has also been used.

Infections can also be diagnosed by enzyme-linked immunosorbent assays (ELISAs) and immuno-chromatographic tests to detect *G. duodenalis* antigens in the feces, as well as by direct-immunofluorescence. Antigen shedding may persist for weeks after elimination of the parasite. Rapid tests such as ELISAs should supplement but not replace routine ova and parasite examination by microscopy, as the latter test can also diagnose other diseases. PCR assays can detect *Giardia* in clinical samples. Genetic characterization of isolates at the assemblage level is usually employed only in epidemiological studies and research.

Serology has been used in epidemiologic investigations and other research. *Giardia* can be cultured *in vitro*, but this technique is used only in research.

Treatment

Giardiasis can be treated with a number of drugs, such as nitroimidazole derivatives, benzimidazole compounds or acridine dyes. Metronidazole or tinidazole are used most often in humans, but other drugs (e.g., furazolidone or paromomycin) may be recommended in some cases. Some drugs are either not available or not recommended in some countries. Supportive care, such as fluid and electrolyte management, may also be necessary. Symptoms can recur for a variety of reasons, such as drug resistant organisms, reinfection or post-*Giardia* lactose intolerance. In some cases, a lactose-free diet may be needed for several months.

Asymptomatic carriers do not usually need treatment, but they may be treated to reduce transmission of the organism. Whether or not treatment is recommended can vary with the situation and risk of reinfection.

Prevention

Drinking water treatment plants reduce the number of *Giardia* using conventional water treatment processes (e.g., filtration), followed by chemical or physical disinfection. Some countries have established regulations for the level of *Giardia* cyst removal in municipal drinking water (e.g., at least 3-log cyst removal or inactivation is required in the U.S.). Chlorination is commonly employed for the disinfection stage, but ozone is used in some plants. Other alternatives being studied include chlorine dioxide and UV irradiation. The use of chemical disinfectants, including chlorine and ozone, is limited by the production of toxic by-products from reactions with compounds in the water.

Because *G. duodenalis* is widespread in the environment, untreated water from lakes, rivers, springs or shallow wells should not be drunk. In countries where the municipal water supply may not be safe (or during an outbreak involving *Giardia*-contaminated drinking water), untreated drinking water or ice should also be avoided. Methods that can be used to treat potentially contaminated water include heating the water to a rolling boil for at least one minute, or filtering the water through a filter that has an absolute pore size of at least one micron (or has been National Safety Foundation rated for cyst removal, e.g., NSF Standard 53 or NSF Standard 58). Chlorination or iodination may also destroy the cysts, but these methods are less reliable and depend on the temperature, pH and turbidity of the water, as well as contact time with the chemical.

Good hygiene, such as hand washing, reduces the risk of acquiring *G. duodenalis*, or transmitting it to others. Prevention efforts should be especially aimed at preventing contact between feces (human or animal) or contaminated items (including soil, untreated water and fomites) and food, potable water or other items that may be ingested or contact the mouth. Fecal contact with skin or mucous membranes should be avoided during sexual activity. People with giardiasis should not swim in recreational water for at least two weeks after the symptoms end.

Both soil and irrigation water can contain *Giardia*, and cysts have been detected on crops. Vegetables and fruits should be washed before eating them. In higher risk situations, they should also be peeled if they will be eaten raw, as washing may not remove all organisms. *G. duodenalis* has been detected in filter-feeding aquatic invertebrates such as clams, mussels, oysters and cockles, which appear to concentrate the organism from the water as they feed; however, the epidemiological significance of this source is still uncertain. In addition, *Giardia* cysts have been found on raw retail meat.

Routine screening of healthy pets is not recommended, as infections are common and the organism is difficult to eliminate permanently. The risk of transmitting the infection to people is also thought to be low. Diagnostic testing is recommended only for pets with clinical signs or when there is a specific zoonotic concern. Environmental modifications, such as restricting access to streams and other surface waters, and providing alternative sources of drinking water can decrease fecal contamination of watersheds by livestock. Composting and other measures can decrease or eliminate *Giardia* cysts in livestock manure.

Morbidity and Mortality

Infections with *G. duodenalis* are very common. Individuals at increased risk include those who drink contaminated drinking water or swallow surface water during recreational activities, children (especially in day care facilities), travelers to regions where human infections are prevalent, men who have sex with men, and contacts of infected individuals. Giardiasis can occur sporadically in individuals, as well as in outbreaks. Many outbreaks have been linked to contaminated water, including unsafe drinking water, recreational water such as ponds, and occasionally other types of water (e.g., contaminated shower water at a camp). Municipal drinking water is occasionally involved, even in developed countries, from deficiencies in water treatment process such as insufficient barriers, and inadequate or poorly operated treatment. Food-related outbreaks have been reported less frequently, and often involve contamination by a food handler. Person-to-person transmission can propagate outbreaks, especially among young children.

Factors such as the level of hygiene, and the availability of clean water and toilets, influence the general risk of infection in an area. Studies from developed countries (mainly conducted in asymptomatic children) have reported overall infection rates of <1% to 6% in various European countries and the U.S., 1% to 7% in Saudi Arabia, 2.5% in South Korea, 2-8% in Australia and 8% in New Zealand. Localized high infection rates have, however, been reported in some groups in these locations, including people living under unhygienic conditions. Infection rates reported in various groups of immunocompromised patients varied from 3% to 14%.

Infections are more prevalent in developing countries. In surveys mainly of children, the infection rate was typically 8-30% in Africa, Asia, South America, Cuba, Mexico and Nicaragua, with a few studies reporting higher or lower rates. Among adults, the prevalence was reported to be 12% in Morocco; 25% among pregnant women in Minatitlan, Mexico; and 5-14% among African refugees and new immigrants to the U.S., the Netherlands and Spain.

Depending on the population, the level of immunity and other factors, approximately 20-40% of *G. duodenalis* infections are estimated to become symptomatic. Although most cases are probably not detected, the incidence of clinical giardiasis (reported cases) was 5.5 to 70 cases per 100,000 population in New Zealand and various developed countries in North America and Europe.

Symptomatic cases in healthy people usually resolve spontaneously within a few weeks. Some studies have reported that assemblage A is more virulent than assemblage B, while other studies found the opposite. It is possible that the virulence of the assemblage depends on the organisms already circulating in the population, and the level of immunity to those organisms. Chronic infections have been reported to occur in less than 4% of patients.

Internet Resources

Centers for Disease Control and Prevention (CDC)
http://www.cdc.gov/parasites/giardia/

Companion Animal Parasite Council
http://www.capcvet.org

Public Health Agency of Canada. Pathogen Safety Data Sheets
http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/index-eng.php

The Merck Manual
http://www.merckmanuals.com/professional/index.html

The Merck Veterinary Manual
http://www.merckvetmanual.com

U.S. FDA Foodborne Pathogenic Microorganisms and Natural Toxins Handbook (Bad Bug Book)
pdf.usaid.gov/pdf_docs/PNADO152.pdf

Acknowledgements

This factsheet was written by Anna Rovid Spickler, DVM, PhD, Veterinary Specialist from the Center for Food Security and Public Health. The U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS) provided funding for this factsheet through a series of cooperative agreements related to the development of resources for initial accreditation training.

The following format can be used to cite this factsheet. Spickler, Anna Rovid. 2012. *Giardiasis*. Retrieved from http://www.cfsph.iastate.edu/DiseaseInfo/factsheets.php.

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