Prolonged outbreak of giardiasis with two modes of transmission

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SUMMARY

Large outbreaks of giardiasis caused by person-to-person transmission, or a combination of transmission routes, have not previously been reported. A large, prolonged giardiasis outbreak affected families belonging to a country club in a suburb of Boston, Massachusetts, during June–December 2003. We conducted a retrospective cohort study to determine the source of this outbreak. Giardiasis-compatible illness was experienced by 149 (25%) respondents to a questionnaire, and was laboratory confirmed in 97 (65%) of these cases. Of the 30 primary cases, exposure to the children's pool at the country club was significantly associated with illness (risk ratio 3·3, 95% confidence interval 1·7–6·5). In addition, 105 secondary cases probably resulted from person-to-person spread; 14 cases did not report an onset date. This outbreak illustrates the potential for *Giardia* to spread through multiple modes of transmission, with a common-source outbreak caused by exposure to a contaminated water source resulting in subsequent prolonged propagation through person-to-person transmission in the community. This capacity for a common-source outbreak to continue propagation through secondary person-to-person spread has been reported with *Shigella* and *Cryptosporidium* and may also be a feature of other enteric pathogens having low infectious doses.

INTRODUCTION

Outbreaks of giardiasis linked to drinking water [1] and food handlers [2] have been documented. Large, prolonged outbreaks linked to recreational water, particularly chlorinated sources, are less common [3–5]. Large outbreaks with extensive secondary spread have not been reported.

Giardiasis is an intestinal infection caused by the protozoan parasite *Giardia lamblia* (also known as *G. intestinalis* or *G. duodenalis*). Giardiasis is the most commonly reported protozoal infection in humans [6]. *Giardia* exists in two forms: the trophozoite is responsible for clinical illness, and the cyst for transmission of infection. Transmission of *G. lamblia* is by the faecal–oral route, and can be person-to-person, animal-to-person, foodborne or waterborne. Ingestion of as few as 10–25 cysts can cause illness [7]. After a typical incubation period of 1–2 weeks, symptoms lasting 2–4 weeks can develop, including nausea, vomiting, malaise, flatulence, cramping, diarrhoea, steatorrhoea, and weight loss. However, over 60% of infected individuals may be asymptomatic or have non-specific symptoms [8, 9].

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On 16 September 2003, the Epidemiology Program of the Massachusetts Department of Public Health (MDPH) was notified by a local health department of a laboratory-confirmed case of giardiasis in a town resident. On 30 September, they reported an additional five cases. The dates of onset of the six ill persons were 28 August 2003 to 4 September 2003. Early hypothesis-generating interviews revealed social links between the cases as well as a link to the swimming pools at a local country club. New cases continued to occur for 4 months after the closure of the pools for the season on 5 September 2003.

In response to this reported increase in cases of giardiasis and the association of initial reports with the swimming pools at the country club, as well as with socially linked households, the MDPH and local health department initiated an investigation focusing on these factors. The objectives of this investigation were to determine the source and extent of the outbreak, identify risk factors for illness, and recommend appropriate prevention and control measures.

METHODS

Epidemiological investigation

We conducted a retrospective cohort study of country-club member households. Using a membership list obtained from the country club, questionnaires were mailed to all member households, with follow-up phone interviews conducted as needed. A single questionnaire was used to collect information for all members of a family. The questionnaire captured demographic data for each member of the household, symptoms, which pools they swam in during the course of the summer, frequency of attendance at the pools, and history of hiking or camping. In addition, consumption of food from the poolside snack bar and use of the nappy-changing stations at the country club were captured at the household level. Social relatedness between member households was assessed by asking whether they had children who played together, whether persons from one member household babysat for children from another member household, and whether someone in one member household had contact with an ill member from another member household; we requested the names and addresses of the relevant families. Completed questionnaires were entered into Access 2000 (Microsoft, Redmond, WA, USA) and analysed using SAS 8.0 (SAS Institute, Cary, NC, USA).

Our cohort included only individuals who resided in a member household of the country club as of 1 November 2003. A confirmed case was infection in a person that was laboratory confirmed by a CLIA (Clinical Laboratory Improvement Act of 1988) approved laboratory. Asymptomatic, laboratory-confirmed cases were categorized as confirmed. A probable case was illness in a person who had self-reported diarrhoea without laboratory confirmation or other diagnosis for the illness. A suspect case was illness in a person who had self-reported loss of appetite and cramps and flatulence, but no laboratory confirmation or diarrhoea and no other diagnosis for their illness. Cases were identified through reports of suspected giardiasis to the local health department, laboratory reports of *Giardia* to MDPH, and through self-report of illness on a questionnaire administered by MDPH as part of this investigation.

We created the categories of primary and secondary case to distinguish between cases whose illness was more consistent with an exposure at the country club (primary case) from persons whose illness might be explained by person-to-person spread (secondary case). We defined a secondary case as one with onset of illness on or after 5 October 2003 (i.e. 1 month after closure of the pools at the country club) or with onset of illness during 1 June–4 October 2003, but 7–60 days after the onset of illness in a person from the same or a socially related member household. The remaining cases with onset of illness during 1 June–4 October 2003 were defined as primary cases.

The rationale for the 60-day time-frame for defining secondary cases before 5 October 2003 is illustrated in Figure 1. Given the incubation period of *Giardia* (generally 7–14 days, but up to 30 days) we estimated that a case directly linked to a pool exposure would have become symptomatic no later than 4 October 2003 [10, 11]. Therefore, cases with onset prior to 5 October 2003 could be either primary or secondary cases per our definitions. The 60-day window used to define a secondary case was generated by adding the maximum expected infectious period for *Giardia* (up to 30 days) plus the maximum expected incubation period for *Giardia* (30 days). To evaluate the robustness of this approach, we conducted a sensitivity analysis. In addition to using a 30-day shedding period, this analysis was run using shedding periods of 15 days, 45 days, and 60 days looking for effect on delineating primary and secondary cases.

Risk ratios (RRs) were obtained for primary cases using the Mantel–Haenszel estimates for each of the
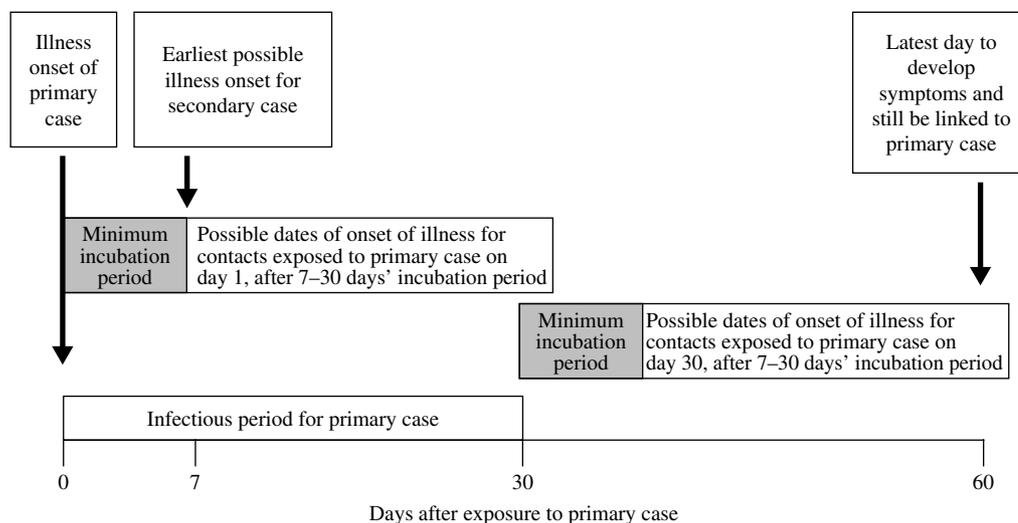
Fig. 1. Rationale for 60-day time-frame for secondary cases with onset of illness before 5 October 2003.

key exposure variables; specifically, pool exposure (adult pool, children's pool), age group [adult *vs.* child (age 0–18 years)], camping/hiking history, and attendance at day care. Two stratified analyses were conducted to assess for confounding and effect modification between groups. Mantel–Haenszel adjusted RRs (RR_{MH}) were obtained for the stratified analyses. These analyses were: children's pool exposure and giardiasis stratified by age group; and age group and giardiasis stratified by children's pool exposure. A dose–response relationship was calculated to further evaluate the role of any significant risk factor.

Environmental investigation

Because this outbreak was reported to MDPH after the closure of the pools at the country club for the season, we relied on multiple routine inspections of the country club conducted by the local health department from 6 June to 29 August 2003. The country club hired an independent firm to conduct an environmental investigation; the investigation took place in March 2004.

Laboratory investigation

No laboratory analyses of environmental samples (i.e. pool water) were possible because the pools had already been drained by the time the outbreak was reported to the MDPH. Local physicians obtained diagnostic stool specimens on suspect cases, and results were reported to the MDPH by routine passive surveillance methods. Laboratory confirmation consisted of visualization of *Giardia* in stool by

microscopy (ova and parasite analysis) or a positive enzyme immunoassay (EIA) for *Giardia* antigens.

RESULTS

Epidemiological investigation

All 498 member households of the country club were mailed a questionnaire; 175 (35%) were completed, representing 584 persons. Of these 584 persons, we identified 149 cases [overall attack rate (AR)=25%]: 30 primary cases, 105 secondary cases, and 14 cases with unknown onset date. Cases with known onset date are depicted in Figure 2. Of the 149 total cases, 97 (65%) were laboratory confirmed, 46 (31%) were probable, and 6 (4%) were suspect.

The epidemic curve (Fig. 2) shows that 39 cases (23 primary) had onset of illness before 5 September 2003 (date of pool closure), 32 cases (seven primary) during 5 September to 4 October, and 64 cases on or after 5 October. All cases with onset on 5 October 2003 or later were, by definition, secondary cases. In the sensitivity analysis, the number of primary and secondary cases did not differ when we varied the presumed shedding periods from 15 to 60 days. Of the 41 secondary cases with onset on or before 5 October 2003, 16 were identified as having only social contacts with an earlier case, seven as having only family contacts, and 18 as having both social and family contacts with an earlier case. This compares to no family contacts and only three social contacts with earlier cases for 451 control individuals.

The median ages for primary and secondary cases were 7 years (n=24, range <1–74 years) and 5 years
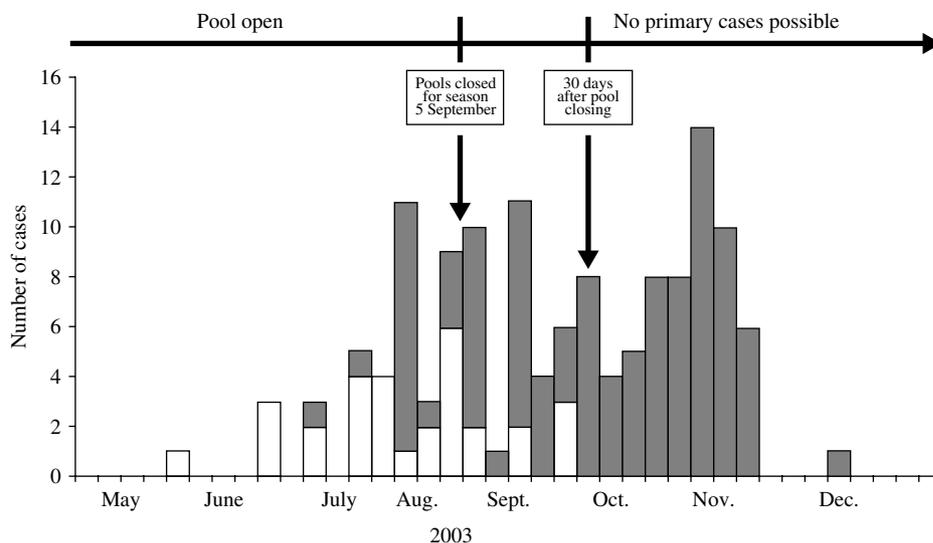
Fig. 2. Epidemic curve of 135 primary (□, $n = 30$) and secondary (■, $n = 105$) cases with known dates of onset.

Table 1. *Symptoms of cases* ($n = 149$)

Symptom	n (%)
Diarrhoea	92 (62)
Foul-smelling stool	83 (56)
Cramps	81 (54)
Flatulence	78 (52)
Loss of appetite	57 (38)
Weight loss	39 (26)
Fever	30 (20)
Asymptomatic	31 (21)

($n = 101$, range <1–64 years) respectively. Fifty per cent of cases occurred in the 0–5 years age group. The proportions of females among primary cases and secondary cases were 46% ($n = 24$) and 51% ($n = 101$) respectively. Of the 97 confirmed cases, 32% were asymptomatic. Table 1 lists the most commonly reported symptoms. The median duration of symptoms for the symptomatic cases ($n = 80$) was 28 days (range 1–139 days, interquartile range 14–53 days). Among the 175 member households completing questionnaires, 65 (37%) reported social relatedness with at least one other member household (median 3). For individuals with illness onset before 5 October 2003, 58% reported either exposure to an ill family member, or social relatedness to another member household with a case.

Among the exposures analysed, children's pool exposure resulted in the highest attack rate (13%), and accounted for about half of the primary cases (Table 2*a*). Persons who went into the children's

pool were at significantly greater risk of illness than those who did not [RR 3·3, 95% confidence interval (CI) 1·7–6·5]. Children were more likely than adults to become ill (RR 1·8, 95% CI 0·9–3·7). Adult pool exposure, camping or hiking, and day-care attendance were not significantly associated with illness. Exposure to food sold at the country club or exposure to nappy-changing stations did not significantly increase a household's risk of having a case.

In the analysis stratified by age, exposure to the children's pool was associated with similar increases in risk of giardiasis for both children (RR 3·3, 95% CI 1·1–9·8) and adults (RR 2·9, 95% CI 0·95–8·7). In the analysis stratified by children's pool exposure, age group itself was not an independent risk factor for disease (RR_{MH} 1·2, 95% CI 0·5–2·5).

We observed a dose–response relationship between children's pool use and risk of illness. Compared with those who did not use the children's pool at all, the RRs for those who used the pool <1 time per week, 1–3 times per week, and ≥4 times per week were 2·8 (95% CI 1·0–7·5), 3·4 (95% CI 1·4–8·3), and 5·1 (95% CI 1·8–14·4) respectively (P value for trend <0·0001).

Environmental investigation

The country club is located in the centre of the Massachusetts town, which has a population of ~27000. It has two pools, an adult and a children's pool, both located outdoors. The pools are situated

Table 2*a*. *Risk factors for illness among primary cases* (*n* = 30)

Exposure	Exposed		Not exposed		RR (95% CI)
	No. ill (%)	Total	No. ill (%)	Total	
Children's pool	16 (13)	124	14 (4)	355	3·3 (1·7–6·5)
Adult pool	12 (5)	225	18 (7)	254	0·8 (0·4–1·5)
Child (*vs.* adult)	16 (9)	184	14 (5)	295	1·8 (0·9–3·7)
Camp/hike	1 (4)	28	29 (6)	455	0·6 (0·1–4·0)
Day care	5 (10)	51	25 (6)	432	1·7 (0·7–4·2)

RR, Risk ratio; CI, confidence interval.
Child, 0–18 years; adult, >18 years.

close to each other, but have separate filtering systems not connected to the municipal water supply. Each pool uses a rapid sand filter and chlorine for disinfection. A single certified pool operator worked for the club during the 2003 season, but he was not available for all hours of pool operation. The club has a snack bar with at least one certified food handler on duty at all times. The men's and women's changing rooms are adjacent to the eating area and contain nappy-changing stations. Hand-washing signs are visible throughout the club.

This community receives drinking water from the Massachusetts Water Resources Authority, which provides treated, unfiltered drinking water to 46 cities and towns in Massachusetts from a surface water source 20 miles from Boston. No increase in cases of giardiasis was reported by these other cities and towns during the outbreak period.

Because the outbreak was reported after the closing of the pools for the season, MDPH and the local health department were unable to conduct an environmental inspection of the facility. However, a review of the country club's records by the town's health inspector raised concerns about record-keeping related to the pools and adequacy of chlorination at times during the summer of 2003. Separately, the private contractor hired by the country club found that incorrect chemicals had been used at times, monitoring of the pools was inadequate, and the equipment did not meet regulatory standards. The contractor concluded that these insufficiencies affected the quality of the water in the pools.

Laboratory investigation

Of the 97 laboratory-confirmed cases of giardiasis, 79 (81%) were confirmed by microscopy and 18 (19%) were confirmed by EIA.

DISCUSSION

The results of this investigation are consistent with a common-source outbreak of giardiasis linked to the children's pool at the country club, with concurrent and subsequent propagation of the outbreak via person-to-person spread in the community.

The initial indications of disease onsets occurring long after closure of the pools at the country club, beyond reasonable incubation periods for *Giardia*, together with close social and family relationships among the cases provided strong evidence for the key role of person-to-person transmission in this outbreak. Continued occurrence of cases over several months among family members and among families with close social relationships provided further support for this key transmission route. However, the common membership of case-families at a local country club made it necessary to evaluate the role of exposure at this country club in the initial stages of the outbreak. An investigation by the local health department and MDPH revealed that there was a faecal accident in mid-July to which the facility may not have responded appropriately.

We investigated whether the source of the outbreak was an exposure at the country club. We could have defined all cases occurring prior to the date of the country club's closure as primary, and all of those occurring after closure of the country club as secondary (person-to-person). However, we constructed our case definitions to allow for secondary cases during the period of time that the country club was open. In addition to exposures through the swimming pools and other facilities at the country club, it was possible that individuals could have been exposed to *Giardia* through person-to-person contact with infectious individuals at the poolside, particularly given the young median age of the cases. Given the evidence for

Table 2b. *Risk factors for illness among secondary cases* (n = 41) *vs. controls*

Exposure	Exposed		Not exposed		RR (95% CI)
	No. ill (%)	Total	No. ill (%)	Total	
Children's pool	31 (22)	140	10 (3)	352	7·8 (3·9–15·5)
Adult pool	30 (12)	242	11 (4)	250	2·8 (1·4–5·5)

RR, Risk ratio; CI, confidence interval.
Child, 0–18 years; adult, >18 years.

person-to-person transmission in the propagation of this outbreak, we did not want secondary cases included in the analysis of risk factors, so we attempted to attribute as many cases to secondary transmission as was reasonable. Our goal was to create a specific case definition for primary cases in order to optimize identification of the culprit exposure. In doing so, we risked reducing our ability to identify a link for primary cases to the country club by misclassifying true primary cases as secondary cases. Any residual misclassification would probably have reduced the observed magnitude of association between country club exposure and illness. Despite sacrificing statistical power by using these case definitions, the children's pool was identified as a significant exposure.

Another potential exposure that we explored was drinking water. As previously noted, the Massachusetts Water Resources Authority provides drinking water to 46 cities and towns in Massachusetts, including the town in which the outbreak occurred. No increase in cases of giardiasis was reported by these other cities and towns during the outbreak period. Additionally, if this had been a drinking water outbreak, the distribution of cases in the affected town would have been expected to be more uniform.

Among primary cases, 53% (16/30) reported swimming in the children's pool (Table 2a). A possible explanation for the 14 primary cases not associated with the children's pool is misclassification on either exposure, case status, or both. Specifically, these cases may have actually been secondary cases, but failed to provide adequate social linkage information (perhaps because of issues of confidentiality). Or, these cases may have failed to provide complete exposure information because the questionnaire was too restrictive (i.e. we did not ask if someone was splashed by pool water or had some other exposure to pool water apart from swimming) or the household member filling out the questionnaire did not learn of use of the children's pool by a family member.

As indicated in Table 2b, secondary cases were significantly more likely than controls to have used the children's pool or the adult pool. If primary cases were misclassified as secondary cases, their inclusion in the analysis of children's pool risk for primary cases would have yielded a higher RR.

A limitation of this study was the low questionnaire response rate. We attempted to obtain additional information about non-responders, but the country club was unable to provide us with further information. Recall bias also played a potential role in our study because the media was involved throughout the investigation, the town is a close-knit community, this was a high-profile outbreak, and our study was retrospective. With the low questionnaire response rate and high-profile nature of the outbreak potentially resulting in proportionally more families with ill members responding, it is possible that we overestimated the attack rate among member families; however, this should not have affected analyses of associations with risk factors.

Outbreaks of giardiasis have previously been linked to exposures to drinking water (including large outbreaks) and recreational water sources. In addition, person-to-person transmission of *Giardia* is well recognized, particularly in day-care and similar settings. Smaller outbreaks of giardiasis potentially linked to chlorinated recreational water have been reported. However, we are unaware of any reported large outbreaks involving person-to-person transmission of *Giardia* or of any large giardiasis outbreaks substantially involving multiple modes of transmission. *Giardia* is considered to be relatively sensitive to chlorination at the levels generally required for recreational water in comparison to *Cryptosporidium*. While the environmental assessment of the pools at this country club was limited because of the timing of disease reports relative to pool closure, there is evidence to suggest that chlorination levels in the pools may not have been adequate at times during the exposure period in question. Thus,

transmission of *Giardia* through the children's pool was possible. The epidemic curve (Fig. 2) is consistent with repeated contamination events in that pool during the summer. No analysis was performed on secondary cases occurring after 4 October. While it is possible that mechanisms other than person-to-person transmission, for example small, point-source outbreaks, may have contributed to these secondary cases, there are no indications of other transmission routes from case reports obtained for these individuals.

This outbreak illustrates the potential for enteric pathogens with low infectious doses to spread through person-to-person transmission following the introduction of the pathogen into a community through a point-source or common-source outbreak involving water, food or other appropriate source. Outbreaks involving multiple modes of transmission have been reported for *Shigella* [12] and *Cryptosporidium* [13]. This investigation demonstrates a similar capacity for *Giardia*; the potential for such multi-mode spread may also exist for pathogens such as norovirus and hepatitis A virus.

This outbreak eventually stopped, possibly due to a vigorous hand-washing campaign, as well as saturation of the potentially exposed population. As a result of this investigation, the country club purchased new equipment, hired a replacement pool operator, and re-wrote their pool protocols. There were three faecal accidents in the pools at the country club during the summer of 2004. In response to each faecal accident, the local board of health was notified and the pools were temporarily closed per the new protocol. In 2004, there were no cases of giardiasis reported in the town. Efforts to prevent future outbreaks in this type of setting need to focus on proper pool maintenance, including close monitoring of disinfection levels and implementing protocols to respond to contamination events. In addition, patron education should address refraining from swimming while ill with gastrointestinal symptoms, use of appropriate swim nappies for young children (or exclusion of children requiring nappies), and appropriate hand washing.

In conclusion, this was a large community outbreak of giardiaisis. The data from this investigation are consistent with the children's pool as a common-source exposure with simultaneous and prolonged, subsequent person-to-person transmission accounting for the majority of cases.

DECLARATION OF INTEREST

None.

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