Cryptosporidiosis Outbreak Associated With a Single Hotel

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Abstract We investigated a gastrointestinal illness cluster among persons who attended a baseball tournament (>200 teams) during July 2015. We interviewed representatives of 19 teams; illness was reported among only the 9 (47%) teams that stayed at Hotel A ($p < .01$). We identified 55 primary cases. A case-control study demonstrated that pool exposure at Hotel A was significantly associated with illness (odds ratio: 7.3; 95% confidence interval: 3.6, 15.2). Eight out of nine (89%) stool specimens tested were positive for *Cryptosporidium*, with *C. hominis* IfA12G1 subtype identified in two specimens. The environmental health assessment detected a low free available chlorine level, and pool water tested positive for *E. coli* and total coliforms. A possible diarrheal contamination event, substantial hotel pool use, and use of cyanuric acid might have contributed to this outbreak and magnitude. Aquatic facilities practicing proper operation and maintenance (e.g., following the Centers for Disease Control and Prevention's Model Aquatic Health Code) can protect the public's health.

Introduction

Cryptosporidium is a protozoan parasite that can cause gastrointestinal illness in humans and animals (Heymann, 2008). This parasite is transmitted by the fecal–oral route, with infection occurring after the ingestion of highly infective, immediately infectious oocysts through contact with an infected person or animal and through contaminated water or food (Chappell et al., 2006). The average incubation period is 7 days (range: 4–28 days); symptoms of acute, watery diarrhea can last up to 4 weeks. Among immunocompetent persons, cryptosporidiosis typically causes a self-limited diarrheal disease; however, it can cause chronic disease and even life-threatening malabsorption in the immunocompromised (Davies & Chalmers, 2009; Heymann, 2008; Hunter et al., 2004).

Cryptosporidiosis is a nationally notifiable disease, with approximately 8,000–9,000 cases reported in the U.S. annually (Painter, Hlavsa, Collier, Xiao, & Yoder, 2015). Nearly 30 species of *Cryptosporidium* are known; however, *C. parvum* and *C. hominis* account for more than 90% of human cases. *C. parvum* is predominantly found in the mammalian intestinal tract and is transmitted zoonotically, whereas *C. hominis* primarily infects the human intestinal tract (Bouzid, Hunter, Chalmers, & Tyler, 2013; Xiao, Fayer, Ryan, & Upton, 2004). *Cryptosporidium* has emerged as the predominant cause of recreational water-associated outbreaks in the U.S. and worldwide (Baldursson & Karanis, 2011; Hlavsa et al., 2015; Hopkins, Hague, Hudgin, Ross, & Moore, 2013; Mayne et al., 2011; Widerström et al., 2014).

On July 30, 2015, the Shelby County Health Department (Memphis, Tennessee) received reports of gastrointestinal illness among persons who had traveled to Tennessee to participate in a multistate baseball tournament (>200 teams) held in Southaven, Mississippi (<15 miles from Memphis, Tennessee). The Tennessee Department of Health and Shelby County Health Department, in cooperation with local and state health departments in Alabama, Florida, and Georgia, performed a joint investigation.

Methods

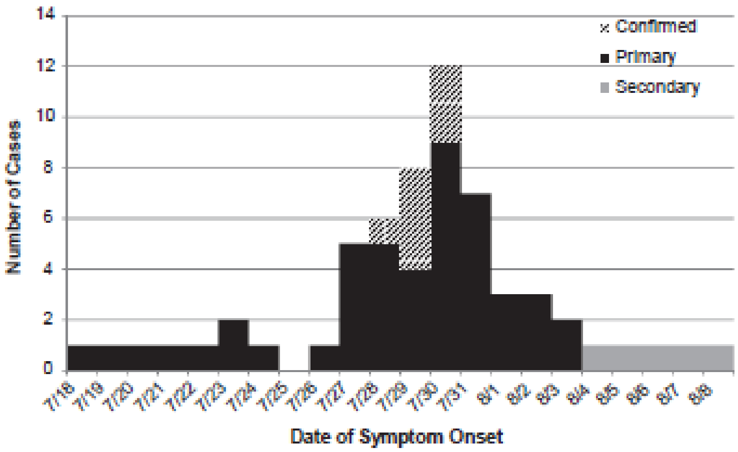
Epidemiologic and Laboratory Investigation

Initial reports of illness were only from persons affiliated with the baseball tournament, so standardized telephone interviews were conducted with a convenience sample of 19 participating teams to determine illness scope.

Through speaking with the baseball teams, it became evident that illness was reported only among the teams whose players and family members stayed at a single hotel (Hotel A); therefore, we decided to focus our investigation on Hotel A. A questionnaire was developed in order to identify additional cases at the hotel and to serve as the primary data collection tool for the case

FIGURE 1

Epidemic Curve of Cryptosporidiosis Associated With Hotel A, July 18–August 8, 2015 (n = 60)



control study. We identified potential cases by using player and family rosters obtained from team coaches or managers. Hotel A provided guest registration data to identify additional persons who were ill and potential control subjects.

We defined a primary case as vomiting or diarrhea (≥3 stools in 24 hours) among guests who stayed at Hotel A with symptom onset dates July 15–August 3, 2015. These dates represent approximately one incubation period before and two incubation periods after the exposure period of interest. A secondary case was a person with vomiting or diarrhea, with symptom onset on or after August 4, 2015, and a household contact of a primary case. Control subjects had stayed at Hotel A during the same time frame and had no gastrointestinal illness.

Guests at the hotel during July 2015 were invited to complete a standardized questionnaire, which was available online during August 7–17, 2015. Invitations to the online questionnaire were sent to 326 households, and 156 (48%) households responded. Information including demographics, illness, and sick contacts, as well as food, water, and other potential exposures was requested for each member of the household. Heads of household could complete surveys concerning multiple household members. A convenience subset of households received a follow-up open-ended, semistructured telephone interview to ascertain additional details about their experience, including pool conditions, communication with hotel management, and observed pool maintenance.

Data were analyzed by using Epi Info 7.1.5.2, and odds ratios (*OR*) with corresponding 95% confidence intervals (*CIs*) were calculated for selected exposures. Pearson's chi-squared test was used to measure associations between categorical case status and individual exposure variables. Nonresponses were excluded from analysis; percentages, *OR*, and *CI* calculations were based on respondents who answered each question. All p-values were two-sided and considered statistically significant if < .05.

Stool specimens were requested from persons who were ill, and tested for *Cryptosporidium* and bacterial and viral pathogens by standard methods. Stool specimens positive for *Cryptosporidium* were sent to the Centers for Disease Control and Prevention (CDC) for species identification and molecular subtyping by polymerase chain reaction amplification and subsequent bidirectional sequencing of the 18S rRNA gene and 90 kDa glycoprotein gene (gp60) (Alves et al., 2003; Xiao, 2010).

Environmental Health Investigation

An environmental health assessment of the pool at Hotel A was performed on August 5, 2015. We collected a small volume, "grab" water sample of approximately 10 L of water from the pool's sand filter and tested for *Cryptosporidium* and *Giardia* (U.S. Environmental Protection Agency, 2005). We analyzed one 100 mL water sample directly from the pool for *E. coli* and total coliforms (Eaton, 2005).

Results

Epidemiologic and Laboratory Investigation

Illness was reported only among all nine teams that stayed at Hotel A (p < .01). There were 55 primary cases (including 8 with laboratory confirmation), and 5 secondary cases of cryptosporidiosis identified (Figure 1). Illness onset dates of 55 primary case-patients ranged from July 17 to August 3, 2015. Median age was 11 years (range: 3–65 years); 42 (76%) were male. Illness onset dates of 5 secondary case-patients ranged from August 4 to August 8, 2015. Median age was 30 years (range: 12–41 years) and 4 (80%) were female.

Among all 60 patients, 59 (98%) reported diarrhea, 44 (73%) abdominal cramps, 43 (72%) nausea, 41 (68%) fatigue, and 26 (43%) vomiting. Less than one third of patients (19 out of 60) reported having fever (32%). More than one third of patients (21 out of 60) sought medical care (35%), and one required hospitalization (3%). The median illness duration was 5 days (range: 2–21 days).

Data were collected on 250 persons (55 primary cases, 5 secondary cases, and 190 control subjects). In bivariate analysis, which excluded secondary cases, the only risk factor significantly associated with illness was swimming in the pool at Hotel A (n = 44/55; *OR*: 7.3; 95% *CI*: 3.5, 15.2) (Table 1).

Analysis of swimming exposure by date revealed the most significant risk associated with illness to be on July 23 (n = 25/55; *OR*: 11.3; 95% *CI*: 5.2, 24.6). Additional survey questions were asked about specific pool activities (swallowing water, diving, swimming with head underwater, and playing pool games) and observations (diapered infants or animals observed in the pool) among swimmers at the pool; however, none was significantly associated with illness. Eating breakfast or dinner at Hotel A, using the hotel refrigerator or ice machine, eating at nearby restaurants, eating a group meal prepared with outside food, and eating at the concession stand at the tournament were not significantly associated with illness.

Of nine stool specimens tested, eight (89%) were positive for *Cryptosporidium* and negative for bacterial and viral pathogens. Of six *Cryptosporidium* specimens sent to the CDC CryptoNet laboratory, two (33%) were typeable and identified as *C. hominis* IfA12G1 subtype.

Among those who responded, 34 out of 48 (71%) of case-patients and 26 out of 67 (39%) of control subjects felt that the pool water appeared dirty or unclean at any time ($p < .01$). Furthermore, 5 of 48 (10%) persons who were ill reported swimming for multiple days while ill with diarrhea (i.e., could have potentially contaminated the pool). One of the persons who was ill reported swimming with diarrhea daily at the hotel pool from July 17 to July 22; two of the persons who were ill reported swimming with diarrhea between July 23 and July 25.

Moreover, 15 of 57 (26%) of case-patients and 62 of 180 (34%) of control subjects reported knowledge that recreational water could be contaminated and make people sick. And 28 of 44 (64%) of case-patients and 36 of 66 (55%) of control subjects who responded reported swallowing pool water either accidentally or intentionally while swimming, though the difference between groups was not significant.

The follow-up interviews with case-patients and their families revealed numerous anecdotes about Hotel A's pool during the outbreak period. Multiple families reported cloudy pool water. Some guests not associated with the baseball tournament noted that the hotel seemed crowded and the pool area was often congested. Multiple persons noted that a supply of clean towels was unavailable, and piles of dirty towels were observed near the pool.

TABLE 1

Bivariate Analysis of Select Exposures Associated With Cryptosporidiosis Outbreak, July 18–August 10, 2015

Exposure	Case-Patients (*n* = 55)		Control Subjects (*n* = 190)		*OR*	95% *CI*
	#	%	#	%		
Swimming (all dates)	44	80	67	36	7.3	3.5, 15.2
Swimming July 18	4	7	11	6	1.3	0.4, 4.2
Swimming July 19	2	4	12	6	0.6	0.1, 2.6
Swimming July 20	2	4	10	5	0.7	0.1, 3.2
Swimming July 21	2	4	9	5	0.8	0.2, 3.6
Swimming July 22	8	15	8	4	3.9	1.4, 10.9
Swimming July 23	25	45	13	7	11.3	5.2, 24.6
Swimming July 24	27	49	20	11	8.2	4.1, 16.6
Swimming July 25	33	60	39	21	5.8	3.0, 11.1
Swimming July 26	24	44	39	21	3.0	1.6, 5.7
Swimming July 27	21	38	25	13	4.1	2.0, 8.1
Swimming July 28	15	27	9	5	7.5	3.1, 18.4
Swimming July 29	2	4	3	2	2.4	0.4, 14.4
Hotel breakfast (all days)	45	85	138	73	2.0	0.9, 4.6
Hotel dinner (all days)	17	32	45	24	1.5	0.8, 2.9
Hotel refrigerator	48	89	161	86	1.3	0.5, 3.4
Hotel ice machine	36	65	97	52	1.8	0.9, 3.3
Any restaurant	50	94	165	89	2.0	0.6, 7.1
Outside food	23	45	59	33	1.7	0.9, 3.2
Tournament concessions	11	22	37	20	1.1	0.5, 2.3

OR = odds ratio; *CI* = confidence interval.
Note. The nonresponse rate per question range was 0%–5.24%; average nonresponse rate was 0.9%.

Environmental Health Investigation

Hotel A's swimming pool was located outdoors and enclosed by an approximately 4-foot tall fence. The pool was filled with water from the public supply with a sand filtration system. The chemical feed equipment was located within the pool area and enclosed by its own 5-foot fence with a secure entrance. Pool chemicals were stored in this subarea and in direct sunlight. The pool was disinfected with chlorine (calcium hypochlorite tablets) and stabilized with cyanuric acid to minimize depletion of free available chlorine (FAC) by the sun's ultraviolet light. No signage was present within the pool area addressing maximum bather load or standard pool etiquette and hygiene measures. The hotel allowed pets in the pool area.

The pool was reportedly checked 3 times daily by employees to ensure no warning lights in the automatic monitoring system indicated an imbalance or low level of pool chemicals. Water sample testing results were reportedly transmitted to a third-party company for remote monitoring by telephone line; however, after further investigation, the telephone line was found to be unconnected, and no information had been transmitted for an indeterminate time period. Employees responsible for pool maintenance were not required to hold any specific certifications and they did not routinely log chemical levels or other monitoring information.

During assessment, the pool water had a pH of 7.2, and both total and FAC levels of 0.5 ppm (Table 2). Oxidation–reduction potential measured by the water chemistry monitor was 528 mV. Pool water tested positive for *E. coli* (20 most probable number [MPN]/100 mL) and total coliforms (365 MPN/100 mL); however, neither *Cryptosporidium* nor *Giardia* was detected in the water sample collected from the pressure release valve of the pool's sand filter. Of

TABLE 2

Comparison of Results From Water Testing Conducted During Environmental Health Assessment of Pool at Hotel A to the Model Aquatic Health Code (MAHC) Recommendations

Test	Pool Result, Hotel A	MAHC Recommendations	MAHC Code
pH	7.2	7.2–7.8	5.7.3.4.1
Free available chlorine	0.5 ppm	1–3 ppm	5.7.3.1.1.2
Oxidation–reduction potential	528 mV	600–900 mV	4.7.3.3.4.6.2 4.7.3.3.4.6.3
E. coli	20 MPN/100 mL	—	—

ppm = parts per million; MPN = most probable number.

note, large volume, filtered water samples were not possible to collected, which may be preferable for detection of *Cryptosporidium* as the oocysts occur in low numbers in aquatic environments (Kaucner & Stinear, 1998). Based on these test results, the Shelby County Bureau of Environmental Health Services issued a health directive closing the pool at Hotel A on August 11, 2015. The pool remained closed until September 5, 2015, when it completed the required remediation procedures and was allowed to reopen under the guidance of local environmental health officials.

Discussion

A cryptosporidiosis outbreak identified among participants in a multistate baseball tournament was traced to a hotel swimming pool. Epidemiologic investigation determined that the risk factor most strongly associated with illness was swimming in the pool on July 23, 2015. No direct epidemiologic link with the baseball tournament was identified. Secondary transmission within households, a phenomenon that has been noted in published material, was reported (Ichinohe et al., 2005; Johansen et al., 2015). Molecular subtyping demonstrated *C. hominis* IfA12G1, a species and subtype that is primarily transmitted among humans and circulating in the U.S. since at least 2013 (D. Roellig, personal communication, September 2015). To prevent future outbreaks of this extremely chlorine-tolerant parasite, key stakeholders (e.g., swimmers, operators of pools and other treated recreational water venues, and public health officials) need to be engaged to understand risks, implement control and prevention measures, and participate in ongoing education.

A definitive determination of when each primary case-patient became infected cannot be made because persons swam during multiple days. *Cryptosporidium* oocysts are extremely chlorine tolerant and transmission could have occurred during multiple days. Although the majority of infectious pathogens are inactivated within minutes in treated recreational water with 1 part per million (ppm) FAC, *Cryptosporidium* oocysts are infectious immediately upon excretion and can survive for more than 10 days (Shields, Hill, Arrowood, & Beach, 2008).

After a diarrheal incident (i.e., a high-risk *Cryptosporidium* contamination event) or a treated recreational water-associated outbreak suspected to be caused by *Cryptosporidium*, CDC recommends 1) closing the involved venue to swimmers, 2) raising FAC levels to inactivate 99.9% *Cryptosporidium* oocysts (i.e., hyperchlorination), and 3) backwashing the filter thoroughly (CDC, 2016a). Hyperchlorination will achieve the concentration time inactivation value of 15, 300 mg-min/L (e.g., 20 ppm FAC for 12.75 hours or 10 ppm for 25.5 hours), which will inactivate *Cryptosporidium*. Of note, cyanuric acid prolongs the inactivation time of infectious pathogens, with inactivation times increasing with higher cyanuric levels. For example, at 20 ppm FAC, raising the cyanuric acid level from 16 ppm to 48 ppm decreases effectiveness of inactivation from 26.3 hours (99.9% inactivation) to 63.8 hours (90% inactivation) (Murphy et al., 2015).

Our investigation identified five case-patients who swam while ill with diarrhea, three during or just before the time period with the highest odds of infection. Swimmers who are ill can introduce 10^7–10^8 *Cryptosporidium* oocysts into the water with a single diarrheal contamination incident, and fewer than 10 oocysts can cause infection (Chappell et al., 2006; Goodgame, Genta, White, & Chappell, 1993; Okhuysen, Chappell, Crabb, Sterling, & DuPont, 1999). These characteristics, combined with evidence that children can unintentionally ingest as much as 150 mL of water during 45 minutes or more of swimming, are favorable conditions for the transmission of infectious pathogens (Dufour, Evans, Behymer, & Cantú, 2006).

The reported unhealthy swimming behaviors, which facilitate the transmission of infectious pathogens, underscore the need to educate the public (i.e., the primary source of *Cryptosporidium* contamination of treated recreational water) regarding healthy swimming practices. Healthy swimming messages include not swimming with diarrhea, not swallowing water while swimming, washing with soap and water before swimming, and keeping animals out of the pool area. Healthy swimming education campaigns can help the public understand potential risks associated with use of treated recreational water venues and their role in helping to keep themselves and others healthy (CDC, 2012; McClain, Bernhardt, & Beach, 2005), potentially decreasing the incidence of recreational water-associated illness outbreaks. In addition, to facilitate understanding of risks and to promote adoption of healthy swimming behaviors, healthy swimming education campaigns can dispel commonly held mistaken beliefs (e.g., chlorine instantly inactivates all infectious pathogens or waterborne disease occurs only outside the U.S.).

Cryptosporidium is the leading etiology of reported recreational water-associated illness outbreaks because of the number of outbreaks it has caused since 1988 (Sorvillo, Lieb, Kerndt, & Ash, 1994). This statistic calls for a better understanding of *Cryptosporidium* transmission. *Cryptosporidium* species are morphologically indistinguishable by traditional diagnostic tests; thus, molecular typing is needed to distinguish species and subtypes. To improve the ability to understand U.S. cryptosporidiosis epidemiology, CDC has established CryptoNet, a molecular-based surveillance program (CDC, 2015).

CryptoNet confirms outbreaks and types *Cryptosporidium* specimens from sporadic cases; however, the goal of CryptoNet is to molecular type *Cryptosporidium* specimens for every case reported to the National Notifiable Diseases Surveillance System and to integrate molecular typing data with traditional epidemiologic data. Communication between the Tennessee Department of Health and CDC CryptoNet laboratory during this outbreak investigation provided important context for this cluster within the national framework. Identifying *C. hominis* indicates transmission was limited to humans (i.e., no animal source). The specific subtype detected in this outbreak, IfA12G1, is the most common subtype currently associated with recreational water-associated illness outbreaks in the U.S. (D. Roellig, written communication, September 2015).

During 2011–2012, approximately 20% of all outbreaks associated with treated recreational water venues were in a hotel setting (Hlavsa et al., 2015). In addition, analysis of data collected during routine inspections conducted in 15 state and local jurisdictions during 2008 found the percentage of inspections resulting in immediate closure or in identifying particular violations (e.g., disinfectant level violations) to be among the highest for hotel and motel pools (CDC, 2010).

Although our environmental health assessment identified numerous points for potential intervention at Hotel A, none of the findings explicitly contributed to this cryptosporidiosis outbreak except possibly the use of cyanuric acid. The inadequate FAC level is less important for transmission of this extremely chlorine-tolerant parasite, but it is important for the transmission of chlorine-susceptible infectious pathogens (e.g., *Campylobacter*, or Shiga toxin-producing *E. coli*) and provides further evidence of overall poor pool maintenance.

Findings of our environmental health assessment indicate that operators of Hotel A's pool needed training. Studies have demonstrated that pools staffed by certified operators have improved water quality, which prevents transmission of chlorine-susceptible infectious pathogens (Buss et al., 2009; Johnston & Kinzinger, 2007); however, only 24 states and the District of Columbia require operator training to some degree (S. Wichmann, written communication, November 2015).

This variation among state and local codes for treated public recreational water venues is not limited to operator training requirements and cuts across every aspect of the design, construction, operation, and maintenance of public treated recreational water venues. In 2005, federal, state, and local public health officials and representatives of the aquatics sector met to address the increasing incidence of reported recreational water-associated illness outbreaks. Meeting attendees deemed variations in state and local codes across the U.S. to be a key barrier to preventing these outbreaks. Consequently, the Council of State and Territorial Epidemiologists requested CDC spearhead development of national guidance to prevent illness and injury associated with public treated recreational water venues.

During 2007–2014, CDC and the New York State Department of Health led a multistakeholder (public health, aquatics sector, and academic researchers) effort to develop a science-based and best practices-based model code, which addressed design, construction, operation, and maintenance of public venues. The first edition of the Model Aquatic Health Code (MAHC) was released in August 2014 and the revised second edition was released in July 2016 (CDC, 2016b). Multiple MAHC recommendations could improve overall operation and maintenance of Hotel A's pool.

MAHC calls for hotels like Hotel A to have an "on-site responsible supervisor," who is in charge of water treatment operations when a "qualified operator" is not present. MAHC defines responsibilities of the "on-site responsible supervisor" and includes knowledge of when to close the venue to swimmers (e.g., when FAC level is inadequate or the water is so cloudy the venue bottom is not visible). MAHC also calls for FAC levels to be 1 ppm when cyanuric acid is not used and 2.0 ppm when cyanuric acid is used. Table 2 summarizes water quality findings of the hotel pool environmental health assessment and compares them with MAHC guidance. Additionally, MAHC also calls for keeping pool chemicals away from direct sunlight, temperature extremes, and high humidity to prevent pool chemical-associated health events. Chemical storage spaces should be completely enclosed to prevent unauthorized access; signage should be posted addressing hours of operation, theoretical peak occupancy, and hygiene standards; and no animals should be allowed in the pool area except for service animals.

Some limitations to our investigation were noted. The response rate for our questionnaire was 48%, which might have impacted our ability to capture all cases. Our case definition was intentionally broad with regards to clinical symptoms, so cases of gastrointestinal illness other than cryptosporidiosis might have been included in our analysis. Given the significant *ORs*, laboratory confirmation, and biologic plausibility of the spread of *C. hominis*, we feel confident in our findings despite any potential misclassification bias. Lastly, we did not collect measurements of cyanuric acid levels during this outbreak; however, including them might have provided additional information regarding risk for delayed pathogen inactivation.

Conclusions

An outbreak caused by *C. hominis* among participants in a multistate baseball tournament was traced to the swimming pool of Hotel A. We found that a possible contamination event, substantial hotel pool use, and the use of cyanuric acid might have contributed to this outbreak and its magnitude. Aquatic facilities practicing proper operation and maintenance (e.g., following CDC's MAHC) can protect the public's health.

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