ARTICLE

Communitywide Outbreak of Cryptosporidiosis in Rural Missouri Associated With Attendance at Child Care Centers

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Objective: To determine risk factors for infection during a cryptosporidiosis outbreak in a rural Missouri community.

Design: Community-based case-control study.

Setting: Madison County, Missouri.

Participants: Case patients had laboratory-confirmed *Cryptosporidium* infection. Controls were randomly selected from the community.

Interventions: Pool water and municipal tap water were analyzed for *Cryptosporidium* oocysts. Univariate and multivariable logistic regression analyses were performed to evaluate potential risk factors.

Outcome Measures: Risk factors for cryptosporidiosis infection.

Results: In total, 56 case patients (median age, 7.0 years) who developed cryptosporidiosis from July 27 to August 30, 2005, and 76 controls (median age, 8.4 years) participated in this study. The main risk factors for cryptosporidiosis were attending child care center A or B (adjusted odds ratio, 42.11; 95% confidence interval, 4.88-363.57) and using a water park (adjusted odds ratio, 6.02; 95% confidence interval, 1.25-29.01). A pool-based case-control study indicated that the highest risk for infection was associated with eating at the pool (adjusted odds ratio, 7.26; 95% confidence interval, 2.57-20.48). The epidemiologic curve for cases without child care exposure peaked 4 days later than that for the child care–associated cases. Samples of water from the city water plant and the water park tested negative for *Cryptosporidium* oocysts.

Conclusions: Children attending child care center A or B were the likely sources of this cryptosporidiosis outbreak. Recreational pool water probably served as a vehicle for disease transmission in the community. Early recognition of first cases of cryptosporidiosis by health care providers (ie, pediatricians and family physicians) caring for children could play an important role in limiting community outbreaks.

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CRYPTOSPORIDIUM SPECIES are intestinal protozoan parasites of domestic and wild animals and are increasingly recognized as human pathogens.[1] Cryptosporidiosis is an endemic disease with a global distribution, but it can also occur in localized outbreaks. The 2 most important species are *Cryptosporidium hominis* (previously known as *Cryptosporidium parvum* genotype 1), infecting only humans; and *C parvum* (previously known as *C parvum* genotype 2), infecting humans and animals.[2] *Cryptosporidium* oocysts are transmitted by a fecal-oral route. Infection can be acquired from touching contaminated surfaces, pets, and farm animals; drinking contaminated surface or recreational water; and eating contaminated food.[3] Person-to-person transmission can occur among household members, sex partners, and children attending child care centers and through nosocomial infections. Infected patients can be asymptomatic or can experience watery diarrhea that is self-limited among immunocompetent persons. The seroprevalence for *Cryptosporidium* is high worldwide, indicating that exposure to this pathogen occurs commonly.[4] Clinical laboratories do not routinely screen stool samples for *Cryptosporidium* from patients with diarrhea, unless the physician specifically requests this test[5]; therefore, cryptosporidiosis might be more common than reported.

In the United States, cryptosporidiosis outbreaks associated with treated recreational water are well documented. For example, from January 1, 1991, to December 31, 2000, *Cryptosporidium* was identified as a causal agent in 37.7% of reported

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recreational water–associated outbreaks of gastroenteritis of known and suspected infectious cause.[6] This pathogen is highly transmissible in swimming pools because it is extremely resistant to chlorine, has small oocysts that can penetrate conventional pool filters, and has a low infectious dose; also, an infected person can shed many oocysts in the stool for a prolonged period.[7] Outbreaks of cryptosporidiosis associated with child care attendance are well documented.[8,9] Persons who come in contact with young children with diarrhea also have been shown to be at increased risk for cryptosporidiosis.[10]

Despite existing knowledge of cryptosporidiosis transmission, often the exact mode of transmission during an outbreak is difficult to establish.[11] The importance of certain risk factors for acquiring infection during outbreaks, such as child care center attendance, remains unclear. From July 27 to August 30, 2005, an outbreak of cryptosporidiosis occurred in Madison County, Missouri. We conducted an epidemiologic investigation of the outbreak to identify the potential source and the risk factors for the infection.

METHODS

Madison County is a predominantly rural area with a population of 12 151; the population of Fredericktown, Missouri, where the outbreak occurred, is 3928. Fredericktown's municipal water is supplied from a nearby reservoir and undergoes treatment at the municipal water treatment plant before distribution. Fredericktown Memorial Pool is the only public swimming pool. A total of 8 licensed child care facilities are located in Madison County, 7 of which are located in Fredericktown. Staff of child care facilities in Fredericktown often take children to the pool during the summer as part of their summer recreational activities. Two of the larger child care centers took the children at least twice a week to the pool during the summer of 2005. Children and families also visited a popular water park in a neighboring county.

On August 8, 2005, a local physician informed the Madison County Health Department of a case of cryptosporidiosis in a child; the case was believed to be linked to a local area swimming pool. On initial epidemiologic investigation, more cases of diarrheal illness among attendees of swimming pools were discovered, including attendees of another swimming pool in the same area. The Madison County Health Department and the Missouri Department of Health and Senior Services conducted an investigation of the outbreak. Based on findings of the investigation, preventive measures were implemented and the spread of the disease in the community was limited.

CASE-CONTROL STUDY

We conducted a community-based case-control study and a swimming pool–based case-control study. The community-based study included all case patients and controls and was designed to identify the source of the outbreak and to evaluate risk factors for *Cryptosporidium* infection in the community. Only laboratory-confirmed cryptosporidiosis cases were included in the study. A case was defined as a Madison County resident who had diarrhea, vomiting, or abdominal cramps, with onset from July 27 to August 30, 2005, and a stool specimen that tested positive for *Cryptosporidium*.

Case patients were identified through the state public health laboratory reports of *Cryptosporidium*-positive stool samples, active surveillance by the local health authorities, and physician reports. A control was a Madison County resident without any symptoms of gastrointestinal illness from July 27 to August 30, 2005. Controls were selected by systematic random sampling of students of the only school in the community and their families, using a database compiled by the school containing the information of students and their families. Controls were comparable to case patients in age distribution and residential neighborhood. To eliminate the possibility of including controls with a mild or subclinical illness, no controls were taken from households with known gastrointestinal illnesses.

A trained public health professional administered a telephone interview by using a standard questionnaire. Questions were asked about known risk exposures during the 2 weeks (representing the maximum incubation period) before the disease onset for the case patients or between July 27 and August 23, 2005, for the controls. The interviewer also collected information about the illness, sociodemographic characteristics, food consumption, travel history, child care center attendance, swimming pools visited, activities at the pool, sources of drinking water, and exposure to pets and farm animals. Case patients 13 years or older were interviewed directly; for case patients 12 years or younger, parents or guardians were interviewed as a proxy. All telephone interviews were conducted between August 15 and September 1, 2005.

The pool-based study was conducted to evaluate the risk for cryptosporidiosis associated with activities at the pool among those case patients and controls who attended either the town pool or the water park during the study period.

LABORATORY INVESTIGATION

The local public health authority encouraged persons with acute gastrointestinal illness to submit stool specimens for testing. The state public health laboratory tested stool samples for *Cryptosporidium* by using a direct fluorescent assay kit (MeriFluor *Cryptosporidium/Giardia* direct fluorescent assay kit; Meridian Bioscience, Inc, Cincinnati, Ohio).

ENVIRONMENTAL INVESTIGATION

The Madison County Health Department, with assistance from the Missouri Department of Natural Resources and the Centers for Disease Control and Prevention, conducted an environmental investigation to determine the sources of the cryptosporidiosis outbreak in the community. The investigation included testing of municipal drinking water, testing water from the swimming pool, and site visits to the water park and the town pool. During the visit to swimming facilities, information was collected about water chlorination, pH levels, filter-backwash records, pool maintenance, and fecal accidents. The local water treatment facility, which supplies drinking water to the community, was inspected, and water quality records and procedures were reviewed. The samples of municipal tap water and the water park water were tested for *Cryptosporidium* and *Giardia* by using US Environmental Protection Agency method 1623, which includes filtration, immunomagnetic separation, and immunofluorescence assay microscopy.[12]

STATISTICAL ANALYSIS

Sociodemographic characteristics, possible exposures to *Cryptosporidium*, pool activities, and other potential risk factors were compared between cases and controls by using the χ^2 test or the Fisher exact test.[13] Logistic regression was used to estimate crude and adjusted odds ratios and their associated 95% confidence intervals for the risk of *Cryptosporidium* infection in relation to potential risk factors. Variables that had some association with the illness ($P \leq .20$) in univariate analyses were included in the initial multivariable model. The least significant variable was removed 1 at a time until all variables remaining in the model were statistically significant ($P \leq .05$). The final model included child care attendance, swimming pools visited, and age. In analyzing the data from the pool-based study, we included the same variables as previously described, except that we replaced the variable "pool visited" with variables measuring behaviors and activities in and around the pool. A multivariable logistic regression model was constructed in a similar manner. The final model for the swimming pool–based study included child care attendance, eating at the pool, and age. The variables of the logistic regression models were estimated by using the maximum likelihood method; their statistical significance was assessed using the Wald statistic.[14] All statistical analyses were performed using SAS statistical software, version 9.1 (SAS Institute Inc, Cary, North Carolina).[15]

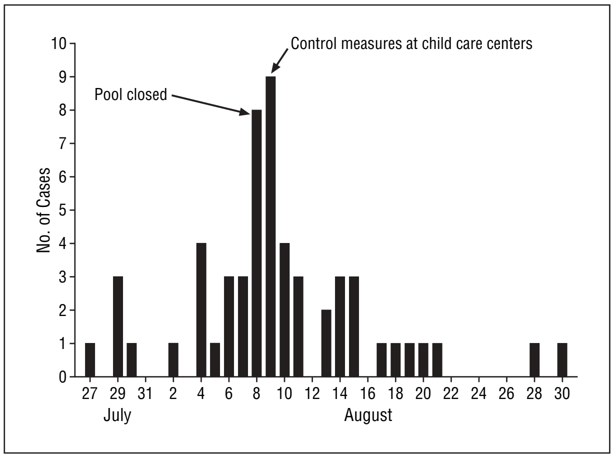

Figure 1. Epidemiologic curve for the 56 cryptosporidiosis cases in Madison County, Missouri, from July 27 to August 30, 2005.

RESULTS

From July 27 to August 30, 2005, 56 laboratory-confirmed cases of cryptosporidiosis were identified in Madison County. The epidemiologic curve of these cases indicated that transmission in the community occurred from the end of July through mid-August and significantly declined after the closure of the swimming pool (**Figure 1**). The median age was 7.0 years (range, 1.0-

Table 1. Distributions of Risk Factors for Cryptosporidiosis Among Case Patients and Controls, Madison County, Missouri, 2005

Characteristic	Cases (n = 56)[a]	Controls (n = 76)[a]	*P* Value[b]	Crude OR (95% CI)
Age, y				
≤6	25 (45)	14 (18)	<.01	4.17 (1.63-10.67)
>6-9	19 (34)	34 (45)		1.30 (0.54-3.14)
≥10	12 (21)	28 (37)		1 [Reference]
Sex				
Female	22 (39)	33 (43)	.63	1 [Reference]
Male	34 (61)	43 (57)		1.19 (0.59-2.39)
Child care center attended				
Center A or B	20 (36)	1 (1)	<.01	46.92 (5.98-368.22)
Other child care center	10 (18)	14 (18)		1.68 (0.66-4.26)
None	26 (46)	61 (80)		1 [Reference]
Animal exposure during 2 wk before onset				
Puppies	28 (50)	10 (13)	<.01	1.75 (0.46-6.62)
Other animals	20 (36)	61 (80)		0.21 (0.06-0.70)
None	8 (14)	5 (7)		1 [Reference]
Type of drinking water				
Municipal tap water				
Yes	38 (68)	16 (21)	<.01	7.92 (3.61-17.38)
No	18 (32)	60 (79)		1 [Reference]
Private well				
Yes	23 (41)	52 (68)	<.01	0.32 (0.16-0.66)
No	33 (59)	24 (32)		1 [Reference]
Recreational water exposure				
Town pool and water park	17 (30)	4 (5)	<.01	11.20 (3.08-40.76)
Only town pool	22 (39)	39 (51)		1.49 (0.62-3.55)
Only water park	6 (11)	4 (5)		3.96 (0.93-16.74)
Neither town pool nor water park	11 (20)	29 (38)		1 [Reference]
Activities at the pool[c]				
Eating				
Yes	31 (69)	12 (26)	<.01	6.46 (2.60-16.05)
No	14 (31)	35 (74)		1 [Reference]
Using restrooms while at pool				
Yes	33 (73)	21 (45)	<.01	3.40 (1.42-8.17)
No	12 (27)	26 (55)		1 [Reference]

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Data are given as number (percentage) of each group. Percentages may not total 100 because of rounding and are based on the total for each category.
[b] Obtained from the χ^2 test or the Fisher exact test.
[c] Restricted to 45 case patients and 47 controls who had visited the town pool or water park.

Table 2. Adjusted Data for Cryptosporidiosis From a Community-Based and a Swimming Pool–Based Case-Control Study, Madison County, Missouri, 2005

Variable	Adjusted OR (95% CI)
Community-Based Case-Control Study Data	
Child care center attendance	
Center A or B	42.11 (4.88-363.57)
Other child care center	1.24 (0.40-3.84)
None	1 [Reference]
Recreational water exposure	
Town pool and water park	10.60 (2.53-44.38)
Only town pool	1.24 (0.45-3.45)
Only water park	6.02 (1.25-29.01)
Neither town pool nor water park	1 [Reference]
Age, y	
≤6	1.59 (0.47-5.33)
>6-9	0.73 (0.27-2.03)
≥10	1 [Reference]
Swimming Pool–Based Case-Control Study Data	
Any child care center attended	
Yes	3.16 (1.06-9.42)
No	1 [Reference]
Eating at the pool	
Yes	7.26 (2.57-20.48)
No	1 [Reference]
Age, y	
≤6	3.04 (0.75-12.38)
>6-9	1.33 (0.37-4.73)
≥10	1 [Reference]

Abbreviations: CI, confidence interval; OR, odds ratio.

37.0 years) for the case patients and 8.4 years (range, 2 months to 20 years) for the controls. Nearly all of the case patients had diarrhea (53 patients [95%]); other symptoms frequently experienced by the case patients included abdominal cramps (47 patients [84%]), fatigue (43 patients [77%]), and nausea (35 patients [62%]). Less frequent symptoms included vomiting (26 patients [46%]), headache (26 patients [46%]), fever (21 patients [38%]), chills (14 patients [25%]), body aches (10 patients [18%]), and bloody diarrhea (5 patients [9%]). Of the 34 case patients (61%) who sought health care, half were treated with nitazoxanide (Alinia; Romark Laboratories, LC, Tampa, Florida). One case patient was hospitalized; no one died.

Case patients were more likely than controls to have been 6 years or younger, to have attended child care center A or B, to have visited the water park, or to have drunk municipal tap water. For the 45 case patients and the 47 controls who had exposure to the town pool or the water park, being a case patient was associated with diving into the water, eating at the pool, and using the restrooms (**Table 1**).

Multivariable analysis for the community-based study revealed that attending child care center A or B and using the water park were significantly associated with the risk for cryptosporidiosis (**Table 2**). In the multivariable analysis of the swimming pool–based study, the effect of having attended child care centers remained significant; having eaten at the pool was also a significant risk factor (Table 2). When the epidemiologic curve for the child care–associated cases (**Figure 2**) was compared with that for cases with no child care center association (**Figure 3**), the latter group of cases peaked 4 days later than the former group of cases.

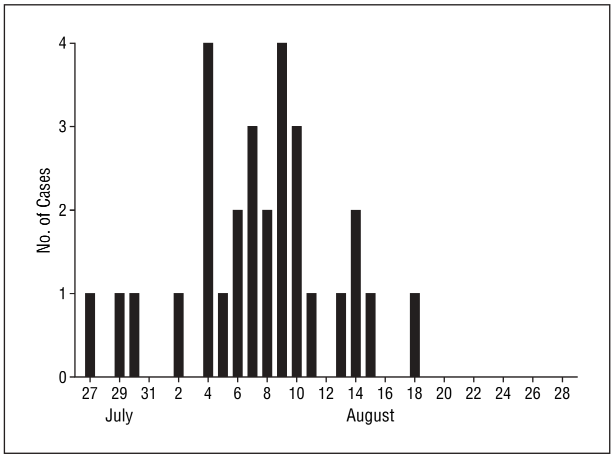

Figure 2. Epidemiologic curve for cases with child care–associated exposure, Madison County, Missouri, from July 27 to August 28, 2005.

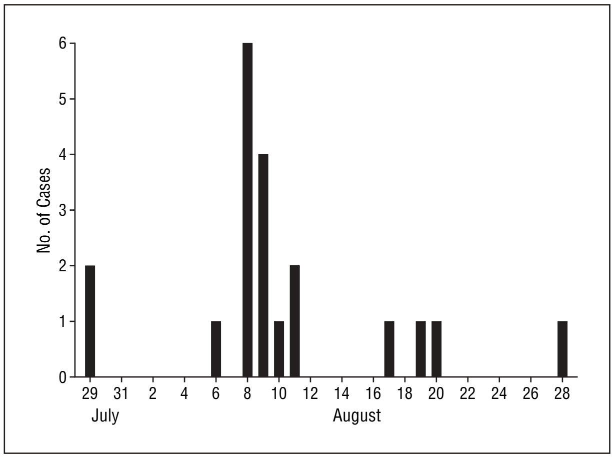

Figure 3. Epidemiologic curve for cases without child care–associated exposure, Madison County, Missouri, from July 29 to August 28, 2005.

Staff attending the pool did not report any pool maintenance problems during the time preceding the outbreak. Before the outbreak, a single fecal accident was reported by the pool staff to the Madison County Health Department. Proper measures for pool disinfection were implemented by the pool staff after the incident. Samples of water from the city water plant collected on August 15, 2005, tested negative for *Cryptosporidium* and *Giardia*. Based on the preliminary findings of this investigation, the town pool and the water park were hyperchlorinated and outbreak control measures were implemented at all child care centers. The town pool was closed on August 8, 2005. Samples of the water at the water park collected after the hyperchlorination tested negative for *Cryptosporidium* and *Giardia*.

COMMENT

This epidemiologic investigation demonstrates that child care center A or B was the likely source of the cryptosporidiosis outbreak in this rural Missouri community. This conclusion was reached based on the results from the univariate and multivariable analyses of the case-control study and the comparison of the epidemiologic curves of the child care–associated cases with the curves of the cases having no child care association. The outbreak was likely to have been propagated in the community through the swimming pool water after the ill child care attendees contaminated the recreational water. Lending further support to this conclusion was the fact that, after the implementation of control measures at the pool, water park, and child care centers, the outbreak was soon terminated.

Cryptosporidiosis was identified as primarily a disease among children during a population-based laboratory surveillance of *Cryptosporidium* infection in a Canadian health region; the median age of outbreak-related patients was substantially lower than that of non–outbreak-related patients in that study.[16] Other studies have found that having contact with young children with diarrhea[17] and attending a child care center[18] were risk factors for acquiring cryptosporidiosis in recreational water-associated outbreaks. Also, helping a child younger than 5 years to use the toilet was associated with cryptosporidiosis in sporadic cases; hence, asymptomatic carriage of *C hominis* was thought to be common among young children.[19] Our investigation revealed that child care attendees infected with *Cryptosporidium* might be the source of a communitywide outbreak. Our findings underscore the importance of mandating exclusion of children with diarrheal illness from attending child care while symptomatic. Previously described risk factors for cryptosporidiosis (eg, drinking contaminated water, contact with young animals, or eating contaminated food)[20] were not statistically significant risk factors during this outbreak. Our finding that eating at the pool was a significant risk factor for cryptosporidiosis among pool attendees is consistent with the fecal-oral route of transmission for this disease.

At least 2 limitations should be considered in interpreting our results. First, our environmental investigation did not detect *Cryptosporidium* oocysts in the water park water. The negative results might be because testing was conducted after the pool had been hyperchlorinated. Intrinsic limitations of US Environmental Protection Agency method 1623 (eg, sensitivity and accuracy) might also have contributed to the negative results.[21] This method has been validated for testing surface water but might not be suitable for testing water from swimming pools. Second, we did not conduct genotyping of the *Cryptosporidium* identified in the stool specimens; therefore, we were unable to establish whether a single genotype of *Cryptosporidium* was responsible for this outbreak and whether the organism causing the outbreak was a human genotype or another species of *Cryptosporidium*.

To detect communitywide outbreaks of cryptosporidiosis in a timely manner, physicians should be aware of this disease and specifically request *Cryptosporidium* testing of fecal specimens. Physicians often assume incorrectly that diagnostic laboratories routinely test for *Cryptosporidium* when a stool test for ova and parasites is requested. For example, in a survey of Connecticut physicians, a third of the physicians assumed *Cryptosporidium* testing was included in a standard ova and parasite examination; 75% of gastroenterologists, general or family practitioners, internists, and pediatricians never or rarely ordered testing for *Cryptosporidium*, even when their patients had symptoms consistent with cryptosporidiosis.[22]

Early recognition is crucial for implementing public health measures to limit the extent of communicable disease outbreaks. During this outbreak, the first laboratory-confirmed case came to the attention of public health officials 12 days after the first confirmed case patient had experienced symptoms. If the earliest cryptosporidiosis cases had been detected among the child care attendees in a timelier manner, control measures could have been implemented earlier and the spread of infection in the community might have been prevented. Therefore, health care providers caring for children (ie, pediatricians and family physicians) can play a crucial role in limiting the spread of cryptosporidiosis outbreaks in the community by identifying the disease early and reporting it to public health officials in a timely manner.

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