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Swimming-associated haemorrhagic colitis due to *Escherichia coli* O157:H7 infection: evidence of prolonged contamination of a fresh water lake*

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SUMMARY

We describe an *Escherichia coli* O157:H7 outbreak associated with a fresh water lake at a county park. Campers were surveyed for diarrhoeal illness within 10 days of their visit, and a case-control study of day visitors was conducted. A confirmed case was a symptomatic person with a stool culture positive for *E. coli* O157:H7 and a probable case was a person with bloody diarrhoea. Clinical isolates of *E. coli* O157 were subtyped by pulsed field gel electrophoresis (PFGE). In the camper survey, 12 (38%) of 32 swimmers had a diarrhoeal illness (relative risk [RR] = 12·4; 95% confidence interval [CI] = 1·7–89·7). For the case-control study, the 12 cases were more likely than controls to have purposefully ingested lake water (odds ratio [OR] = 6·9, 95% CI = 0·9–55·8). The PFGE patterns of six clinical isolates were indistinguishable. This report further demonstrates that contaminated fresh-water lakes can be the source of community outbreaks of *E. coli* O157:H7.

INTRODUCTION

Escherichia coli O157:H7 is increasingly recognized as a cause of sporadic and epidemic gastrointestinal disease. Most outbreaks have been traced to the consumption of undercooked ground beef [1–3]. However, other foods [4, 5] and drinking water [6] have also been implicated. Three recent reports have demonstrated transmission through swimming water, including an extended outbreak at a fresh water lake [7–9].

In July 1993, New York State (NYS) mandated the reporting of *E. coli* O157:H7 infections to local health departments. On 25 July 1994, a hospital in northern Dutchess County reported two children with bloody diarrhoea and a local laboratory reported that stool cultures from two other symptomatic children were positive for *E. coli* O157:H7. Initial interviews of the four patients did not reveal any common food exposures. However, all had swum at a county park on 17 July 1994. The Dutchess County Department of Health suspected that transmission had occurred through swimming water and ordered the park closed

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on 25 July. We conducted an investigation to determine the extent of the outbreak and to identify the source of infection.

BACKGROUND

The outbreak occurred at a multi-use park in northern Dutchess County (population 260000). The park was open Wednesdays–Sundays from May to October and on summer weekend days often had more than 1000 visitors. The park has 40 overnight camping sites, three pavilions for large picnic groups, several baseball fields, a small lake for rowing and fishing, and a larger lake for swimming. The swimming lake is approximately 5 acres in area with an average depth of 1·5 metres. The lake is fed by rainwater and a small stream. Food was not sold at the park.

METHODS

To determine risk factors for illness among persons who visited the park, we surveyed groups that had camped at the park in the period 13–24 July, conducted a case-control study and conducted an environmental investigation.

Survey of campers

To quickly assess whether the park was the source of infection, we surveyed persons by telephone who had registered to camp at the park in the period 13–24 July. Persons were asked when they had been at the park, how many adults and children had been in their party, where they bought their food, and whether persons in their party had either drunk potable water from the park of swum in the lake, and whether any had diarrhoeal illness ($\geqslant 3$ loose stools within 24 h) within 10 days of their visit. Specific information on dates of swimming was not obtained for individual members of these groups.

Case-control study

For this study, we defined a confirmed case-patient as a symptomatic person with a stool culture positive for *E. coli* O157:H7. A probable case-patient was defined as a person with bloody diarrhoea and illness onset within 10 days of visiting the park. Case-patients were identified through routine laboratory and physician reports and then by active surveillance of area hospitals and large paediatric practices after the outbreak was recognized. Clinical laboratories in the county were informed of the outbreak and asked to test all bloody stools for the presence of *E. coli* O157:H7. Health departments in neighbouring counties were also asked to question persons with *E. coli* O157:H7 infection about visits to the park.

Controls were selected from day visitors to the park in the period 17–24 July. The park recorded the licence plate number and number of occupants of over 400 vehicles entering the park during this period. We obtained the names and addresses of owners of vehicles registered in New York State ($> 99\%$ of vehicles). Owners of vehicles with three or more occupants (vehicles likely to have at least one child) were randomly selected and telephoned between 1 August and 12 August. Because all case-patients were under age 14, we randomly selected a well person under age 14 from each vehicle until we enrolled three controls per case in three age groups (age < 5 years, aged 5–9 years, age 10–14 years). Cases and controls (or a parent for children under 10 years) completed a formal questionnaire about swimming and water consumption at the park, what they had eaten the day of the visit, where they usually bought groceries, and what restaurants they had eaten at in the period 10–20 July.

Environmental investigation

On 26 July, sanitarians from the Dutchess County Department of Health reviewed all park operations. Park supervisors and life guards were interviewed and campsites and picnic areas were inspected. We conducted fluorescein dye tests of the septic systems at the beach bathhouse and park headquarters to test for cross-connections between the septic system and the lake. Approximately 250 g of disodium fluorescein dye (Bruce Color and Chemical Co., Tranquility, NJ) was flushed down toilets at park headquarters and bathhouse. For the next 7 days, the lake and area above the septic systems were visually inspected for the presence of characteristic green dye.

The Dutchess County Department of Health routinely collected swimming water samples for coliform analysis at 2-week intervals from all county bathing beaches. If any one sample exceeded 2400 faecal coliforms/100 ml water, additional samples were collected to assess the bacteriological quality of the water, as required by the NYS sanitary code [10].

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Sanitarians reviewed previous water quality tests and collected potable and lake water samples in the period 26 July–1 August for bacteriologic testing using standard membrane filter methods [11] and performed qualitative tests for *E. coli* (Colilert, Index Corporation, Westbrook, ME) on lake water samples. Additional water samples were collected and tested for the presence of *E. coli* O157:H7 by filtering followed by inoculation into trypticase soy broth, overnight incubation, and plating onto sorbitol-MacConkey agar [12].

Laboratory procedures

Microbiologic identification

Isolates of *E. coli* O157:H7 were obtained from area laboratories and their identity was confirmed by conventional biochemical methods at the New York State Laboratory (Wadsworth Center) [13].

Subtyping of E. coli O157:H7

Isolates of *E. coli* O157:H7 from Dutchess County residents were tested for the presence of shiga-like toxins. Park-associated isolates of *E. coli* O157:H7 were compared by pulsed field gel electrophoresis (PFGE) with a sample of other isolates submitted to the Wadsworth Center in 1994. Cellular DNA was digested with *SpeI* and restriction: fragment-length polymorphisms (RFLPs) were analysed using methods previously described [14].

Statistical analysis

Survey data were entered and analysed using Epi Info software, version 6.0 [15]. Mantel–Haenszel odds ratios (OR) and Taylor series 95% confidence intervals (CI) were computed. In the analysis of the case-control study, swimming water exposure variables were analysed individually and in combination.

RESULTS

Descriptive epidemiology

We identified 6 confirmed and 6 probable cases of *E. coli* O157:H7 infection in persons who had visited the park in the period 17–24 July (Fig. 1). All of the case-patients had visited the park in this period (Fig. 2), all were under 14 years of age (median age 7 years; range 1–13) and 7 were female. The median incubation period from the date of park visit to onset of symptoms was 4·5 days (range, 1–10 days). All 12 case-patients had bloody diarrhoea, 11 (92%) experienced abdominal cramps, and 10 (83%) had fever. All but 1 case-patient had seen a physician, but 5 probable case-patients did not have a stool culture. Five children were hospitalized and two developed the haemolytic-uraemic syndrome (both were confirmed cases). No deaths occurred and no secondary cases were identified. One other Dutchess County child who had not visited the park had *E. coli* O157:H7 infection during the period of the outbreak. No additional information could be obtained from this patient.

Camper survey

We were able to contact leaders of 30 camping parties, representing 117 (27%) of 437 persons camping at the park between 13 July and 24 July. Groups at the park the week of 13–17 July were compared to groups visiting 20–24 July. Of persons camping 20–24 July, 13 (20%) of 65 became ill with diarrhoeal illness within 10 days of visiting the park, compared with 4 (8%) of 52 persons camping 13–17 July (relative risk [RR] = 2·6, 95% confidence interval [CI] = 0·9–75·0). Among the groups who camped between 20 July and 24 July, 12 (38%) of 32 swimmers became ill, compared with 1 (3%) of 33 persons who did not swim (RR = 12·4; 95%CI = 1·7–89·7). One person reported bloody diarrhoea and two persons saw their physician. There were no confirmed cases of *E. coli* O157:H7 infection in this group. None of the persons contacted in the camper survey was included in the case-control study.

Case-control study

Of 55 persons under 14 years of age contacted to participate as controls in this study, 9 (16%) persons were excluded because they developed diarrhoeal illness within 10 days of visiting the park. Twelve case-patients were compared with 36 day-visitor controls. Cases and controls were frequency matched by age and were similar in sex and date on which they visited the park. All of the case-patients and 35 (97%) of 36 controls swam in the lake (Table 1). Only two of the case-patients reported drinking from any of the potable water sources at the park. Case-patients were more likely than controls to have accidentally swallowed lake water or drunk lake water on purpose,

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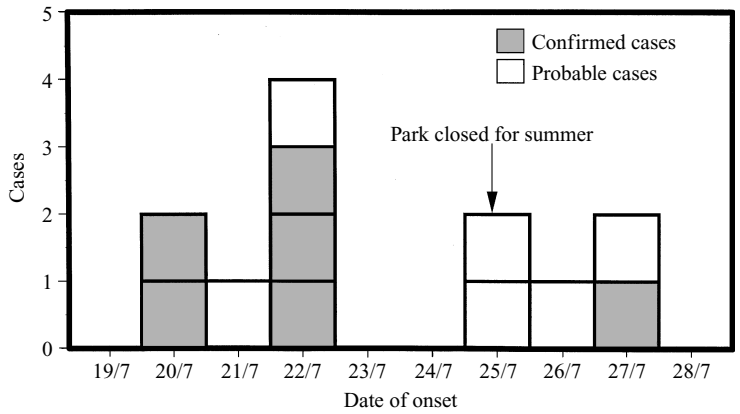

Fig. 1. Confirmed and probable cases, *E. coli* O157:H7 infection among swimmers, by date of onset, 19–28 July 1994, Dutchess County, New York.

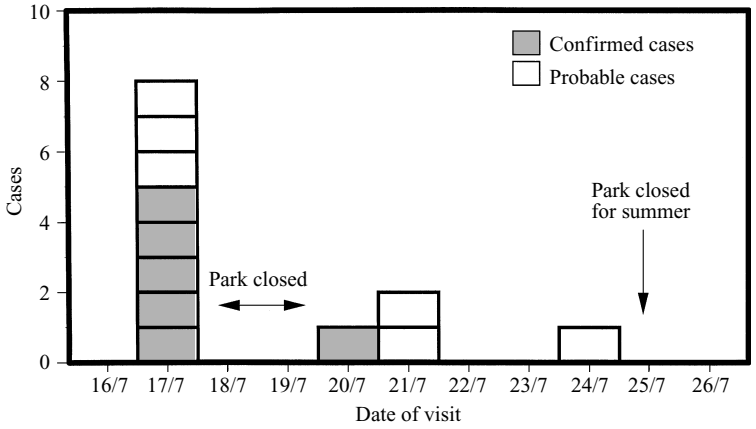

Fig. 2. Confirmed and probable cases, *E. coli* O157:H7 infection, by dates of park visit, 16–26 July 1994, Dutchess County, New York.

Table 1. *Risk factors for haemorrhagic colitis, case-control study, Dutchess County, New York, 1994*

Variable	Case-patients ($n = 12$)	Controls ($n = 36$)	Odds ratio	95% CI
Swam in lake	12/12	35/36	Undef.	0·1–inf.
Swam with head under water	8/12	25/35	0·8	0·2–4·1
Drank potable water	2/10	3/31	1·9	0·2–17·0
Swallowed lake water*	7/10	14/29	2·5	0·4–15·5
Drank lake water on purpose*	4/10	3/34	6·9	0.9–55·8

* The questions were phrased, 'Did you (your child) swallow water while swimming in the lake', and, 'Did you (your child) drink water on purpose from the lake'.

although this association was not statistically significant. No association was observed between case status and time spent in the water or swimming with one's head under water (data not shown). None of the case-patients had eaten in the same restaurant between 10 July and 20 July, and only one case-patient had eaten undercooked (pink) ground beef within 10 days of becoming ill. Only two case-patients shopped at the same market.

Environmental investigation

Dutchess County sanitarians had conducted biweekly inspections of the park through the summer. The

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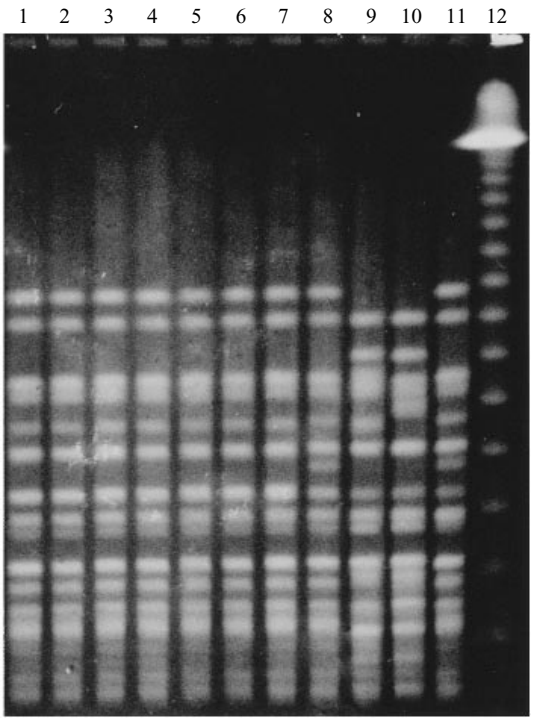

Fig. 3. Subtyping of *E. coli* O157:H7 isolates by pulsed-field gel electrophoresis. Isolates from six outbreak cases (lanes 1–6), another Dutchess county resident (lane 7), and four sporadic New York State cases are shown. Lambda phage markers (48·5 concatemers) are shown in lane 12.

beach, pond and campgrounds were clean, well maintained, and in compliance with sanitary regulations. Toilets and showers were in a bathhouse 20 metres from the beach. Lifeguards did not notice anything unusual during the weekend of 17 July, but several lifeguards recalled removing human faeces from the lake at various times that summer. There was no livestock within the park's watershed, although there were deer and other wild animals in the park. In the period 10–17 July there was only trace precipitation in Dutchess County.

At 2-week intervals, from 3 May until 12 July 1994, 1-litre samples of lake water were collected and tested for total coliforms. Except for one date (28 June) these samples met New York State standards for swimming water. After the park was closed on 25 July, extensive testing of the pond and potable water was conducted. No coliforms were isolated from public potable water in the park. Of 40 1-litre samples taken from various places in the swimming lake between 27 July and 1 August, none exceeded 600 cfu/100 ml for total coliforms or 70 cfu/100 ml for faecal coliforms (NYS standards for single samples of swimming water require total coliforms to be < 2400 cfu/100 ml and faecal coliforms to be < 200 cfu/100 ml). Five 1-litre water samples collected in August tested at the Wadsworth Center and were negative for *E. coli* O157:H7. Fluorescein dye tests done on the bathhouse and park headquarters septic systems showed no cross-connections between the septic systems and the lake.

Bacterial subtyping

E. coli O157:H7 isolates from 7 Dutchess County residents, including 6 case-patients, were confirmed by serotyping. Shiga-like toxin type I and II activity was found in 5 isolates; the other 2 isolates had Shiga-like toxin type II activity. Eleven isolates of *E. coli* O157:H7 were subtyped by PFGE. Isolates from the 6 case-patients and the 1 Dutchess County resident who did not visit the park had indistinguishable PFGE patterns (Fig. 3).

DISCUSSION

We investigated an outbreak of bloody diarrhoea associated with swimming in a lake. The only common exposure among case-patients was swimming at the park between 17 July and 24 July. Among campers in the park the week of 20–24 July, illness was strongly associated with swimming, and among day visitors to the park, case-patients were more likely than controls to have ingested lake water while swimming. Food was not sold in the park, nor did any of the case-patients eat in the same restaurant during the 10 days before the outbreak. There was no evidence of contamination of potable water or leakage from septic systems at the park, and the lack of rain prior to the outbreak made surface runoff an unlikely source of contamination. Furthermore, there are no cows or other farm animals kept within the lake watershed, although deer and other small mammals are present. We cannot determine whether the lake was contaminated once or repeatedly during the week that cases were exposed, although PFGE analysis of faecal isolates supports a single source of infection. None of the known-case-patients returned to the lake after they became symptomatic, and so could not have been a source of repeated contamination. It is possible that one or more swimmers became ill early in the week and then returned to the lake later in the week. No additional cases of *E. coli* O157:H7 infection were

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reported from Dutchess or neighbouring counties after the lake was closed.

Although only 12 persons met a case definition, many persons contacted during the camper survey and case-control investigation reported having non-bloody diarrhoea following their visit to the park. To avoid a misclassification bias, we chose a specific case definition and did not include these persons in the case-control study. Nevertheless, the high rate of diarrhoeal illness suggests a larger outbreak than reflected by confirmed and probable cases. In other outbreaks of gastroenteritis caused by *E. coli* O157:H7 infection, rates of non-bloody diarrhoea have varied from zero to 69% of cases [16]. We believe as many as 15% of children who had visited the park during the outbreak had milder gastrointestinal illness. A high incidence of mild disease might be explained either by a low concentration of *E. coli* O157:H7 in the contaminated water and/or by small amounts of water ingested by swimmers.

Our findings are limited by several methodological weaknesses. In the camper survey, we did not collect person-specific information on dates people swam. Furthermore, members of both camper groups (those in the park 13–17 July and those in the park 20–24 July) were potentially exposed to contaminated lake water because the first confirmed case was exposed on 17 July. However, exposure of both groups to potentially contaminated water would only tend to reduce the strength of the association between swimming and illness. In the case control study, there was a potential for recall bias as well as misclassification bias due to parents inaccurately reporting on their child's exposure. These weaknesses are inherent in outbreak investigations, particularly when the exposure (putting lake water in one's mouth) may be viewed as innocuous. We were also unable to isolate *E. coli* O157:H7 from the environment. Although there were no other bacterial pathogens identified in any of the stool samples submitted by the cases, viral pathogens were not tested for, and it is possible that some of the illness reported by campers was due to viral gastroenteritis. Nevertheless, the association between exposure to lake water and illness in two studies, the identification of a single strain in all cases, and the lack of any other common exposure make the lake the likely route of transmission.

Many viral, bacterial and parasitic pathogens have been implicated in recreational water outbreaks [17–20]. In the period 1991–2 11 outbreaks of gastroenteritis associated with recreational water use were reported to the Centers for Disease Control and Prevention, of which 6 (55%) were due to *Giardia* or *cryptosporidium* [21]. In many of these outbreaks, the most likely source of contamination was other swimmers. Various behaviours, including putting one's head underwater, having water in one's mouth, or swallowing water have all been shown to increase the risk of illness [7, 17].

Are current standards for monitoring fresh water lakes adequate to prevent illness among swimmers? NYS requires that bathing beaches be free of sewage and untreated sewage discharge, and that the watershed for the beach meets basic sanitary conditions. A local health authority may require the beach to monitor bacteriologic water quality, although the regulations call for measuring indicator organisms (total or faecal coliforms) that have been shown to correlate poorly with rates of gastroenteritis in swimmers [22, 23]. Most studies of gastrointestinal illness among swimmers have been done either in marine water or in large lakes with sewage outlets or commercial boating. The value of monitoring small lakes for faecal contamination from septic systems or swimmers has not been studied. Furthermore, current methods for collecting and testing recreational water may be insensitive to low concentrations of pathogens such as *E. coli* O157:H7. As is the case in many bacterial waterborne outbreaks, we were unable to recover the pathogen from the environment [24].

When is it safe to reopen fresh water lakes after evidence of faecal contamination? Many factors, including water temperature, dilutional effect, currents and amount of organic matter may affect the survival and growth of bacteria in lakes. Under laboratory conditions, *E. coli* O157:H7 has been shown to survive for up to 35 days at 5 °C and 20 °C [6] and shigella has been shown to survive in water for > 100 days [25]. Because the infectious dose of *E. coli* O157:H7 may be very small [26], recreational water that meets current standards for indicator organisms may still have a sufficient density of pathogens to cause disease. Therefore, it may not be possible to determine when the risk of disease is sufficiently low to allow the beach to reopen. In this outbreak, total coliform levels on scheduled testing dates fell within acceptable levels. It is not shown whether more frequent testing would have identified faecal contamination, although in the only other previously published outbreak of swimming-associated *E. coli* O157:H7 infection, transmission occurred over a 3-week period during which time enterococcus counts (a

more specific indicator of human faecal contamination) were mostly within Environmental Protection Agency standards [7].

Because routine monitoring of recreational water may not detect faecal contamination by swimmers, the Dutchess County Department of Health is promoting proper hygiene for swimmers using the lake. Pamphlets and posted signs will warn against drinking lake water and ask that persons suffering from gastrointestinal disease or infants with dirty diapers not go in the lake. Changing tables have been installed in men's and women's locker rooms to encourage parents to change their children's diapers away from the beach.

Prompt reporting through routine disease surveillance and the recognition of a common exposure among the first case-patients led to the identification of the outbreak. Had local health officials not recognized this common link between initial case-patients, the lake might have remained open and more people might have become ill. Physicians and laboratories should promptly report cases of *E. coli* O157 infection to their local health department. Physicians and local health officials should consider exposure to recreational fresh water as a possible vehicle for enteric pathogens, including *E. coli* O157:H7.

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