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An outbreak of waterborne cryptosporidiosis associated with a public water supply in the UK

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SUMMARY

In November and December 1992, an outbreak of waterborne cryptosporidiosis occurred in Bradford, a city in the North of England. In all 125 cases were involved, the majority of whom lived in part of the city which received its drinking water supply from a single water treatment works. A case control study demonstrated an association between illness and the consumption of tapwater from this source; those drinking large volumes being more likely to have been ill. Treated water from the defined source yielded cryptosporidial oocysts. Heavy rainfall was recorded in the catchment area of the reservoir supplying raw water to the treatment works, immediately prior to the probable time of infection, based on dates of onset of illness.

INTRODUCTION

Cryptosporidiosis is an infection caused by the protozoan *Cryptosporidium* and is characterized by the acute onset of gastroenteritis. A common infection of livestock and humans, domestic pets may also be affected. People are infected by person to person transmission of the organism [1, 2] or from zoonotic sources either directly [1, 3, 4] or indirectly by waterborne transmission from swimming pools [5, 6], surface waters [7] or domestic water supplies [8–13]. Infection following the consumption of raw milk or raw sausages [14] and nosocomial spread have also been reported [15]. The incubation period for human cryptosporidiosis is not accurately known but is probably around 5–7 days and may range from 2 to 14 days or more. Infection may be asymptomatic but when illness results, it is characterized by acute water, offensive diarrhoea associated with cramping abdominal pains. Although the disease is usually self-limiting, immunodeficient individuals may suffer a more severe and prolonged, and occasionally fatal, illness.

The outbreak

On Friday 13 November 1992 the Public Health Department of Bradford Health Authority was informed by a laboratory within the district that seven cases of cryptosporidiosis had been identified in the previous week. Six of these cases lived in the Bingley and Shipley areas of Bradford, a city in the north of England. Enquiries revealed that a further 11 identifications had been made by a second laboratory in the district over the same period and that seven of these cases also lived in the same area.

The water supply

Approximately 50000 people in the Bingley and Shipley areas of the city received their water supply from a single treatment works. Most of the water was supplied from a moorland impounding reservoir through an aqueduct which was built in 1860. A number of minor streams also fed into the water channel along its length. At the treatment works the water was passed through slow sand filters and was chlorinated prior to distribution through the public water supply.

METHODS

Epidemiology

An outbreak control team (OCT) was convened to undertake the investigation and management of the incident. Active case finding was undertaken through general practitioners who were encouraged to request microbiological investigation of individuals with gastrointestinal symptoms. Cases were also ascertained by direct reporting from the two microbiology laboratories in the district. Using a structured questionnaire, information on cases was obtained by environmental health officers and public health physicians either by telephone or by home visit.

A case was defined as an individual who had had cryptosporidial oocysts identified in stool specimens which had been received by the local laboratories on or after 20 October 1992. Cases were classified as household primaries when they were the first person in the household to become ill, as co-primary cases when the onset was within 24 h of the first case and as secondary household cases when the onset of illness was more than 24 h after that of the first household case.

Preliminary analysis of the data confirmed the observation that the majority of cases lived in the distribution area of a single treatment works and had drunk water straight from the tap. On the basis of these observations the OCT decided to proceed to a case control study.

Case control study

A case control study was carried out to test the hypothesis that consumption of unboiled water from the suspected treatment works was associated with the outbreak of cryptosporidiosis and to exclude other potential sources and vehicles of infection.

Questionnnaires

Cases were interviewed using a questionnaire which identified name, age, sex, address (including postcode), clinical features, household contact with people suffering from diarrhoea, and recent foreign travel. Questions also related to a range of exposures based on potential sources of infection identified in previous outbreaks; namely the consumption of foodstuffs, water, contact with animals, and other activities including swimming. Interviews were conducted by telephone or, if that was not possible, a personal interview was undertaken. Individuals were classified as exposed to the suspected water if they lived within the distribution zone of the suspected plant and reported drinking unboiled tap water at home. They were also considered to have been exposed if they had visited the area after 1 October 1992 and reported drinking unboiled tap water.

Data from the questionnaires were analysed using Epi-Info (version 5.01b) following double data entry and cross validation. Mantel-Haenszel and Fisher exact tests were used to test for statistically significant differences in levels of exposure between groups. A χ^2 test was used to test for a dose–response effect in the consumption of unboiled tapwater. Secondary cases were excluded from the study as were cases who reported foreign travel in the 2 weeks prior to onset of the illness.

Controls

Two control groups were defined and matched by age, within 5 years of the case, and sex. Laboratory controls were systematically selected from records held by the two laboratories in the district of individuals submitting faecal specimens from which *Cryptosporidium* oocysts had not been identified. Nomination of controls was sought from each case. These were matched for age and sex and limited to individuals who lived within half a mile of the case.

Microbiological and environmental

Laboratory and local authority records were examined to determine the background incidence of cryptosporidiosis in the locality. Arrangements were made with the two local laboratories to examine all specimens submitted for the presence of oocysts [16], in addition to routine analysis for salmonella, shigella, campylobacter and other bacterial pathogens.

The water company undertook to sample and examine raw, treated, and distributed water and sand from the filter beds at the treatment works. Samples were examined according to procedures defined by the Department of Environment Standing Committee of Analysts manual [17]. Independent analysis of some of the treated water samples was also undertaken. The water company examined the catchment area, including rainfall records, and reviewed the operation of the treatment works, (OCT, unpublished).

RESULTS

Descriptive epidemiology

Between 13 November and 23 December 1992, 125 cases of cryptosporidiosis which met the case definition were identified. Questionnaires were completed for 95 (76%), of whom 52 were female and 41 male (2 not stated). The majority of cases (53) for whom ages were available were children < 15 years, 33 being < 5 (Table 1). Twenty-eight cases were aged from 15 to 44 years, with 9 > 45 years.

Ninety-two cases (97%) reported diarrhoea, while abdominal pain was experienced by 75 (79%), vomiting by 35 (37%), loss of appetite by 63 (66%), and loss of weight by 51 (54%). The date of onset of illness ranged from 15 October to 22 December (Fig. 1). The peak incidence of onset was in the week commencing

Table 1. *Age distribution of cases of cryptosporidiosis*

Age group (yr)	Cases
< 5	33
5–9	13
10–19	12
20–29	13
30–39	8
40–49	2
50+	9
Not stated	5

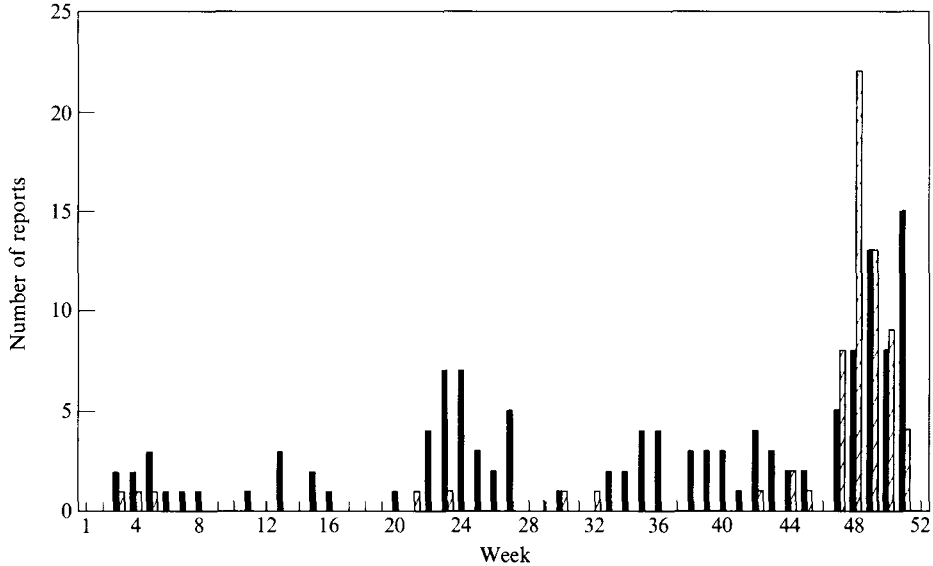

Fig. 1. Reported cases of cryptosporidiosis in the Bradford Metropolitan District. ■, Resident: elsewhere; ▨, resident: suspect zone.

5 November 1992. Eighty-nine cases (94%) had consulted their family doctor about the illness, and nine (10%) were admitted to hospital with a length of stay ranging from 1 to 8 days. Seventy-seven (81%) were household primary cases and 16 (17%) were secondary cases (2% unknown). Twenty-three cases (24%) reported contact with a sick person before they themselves had become ill. Fifty-six cases (59%) lived in an area of the city which received water from a single treatment works.

Eighty-four cases (88%) reported drinking tapwater without prior boiling. Of the foodstuffs investigated, the foods most commonly reported to have been eaten prior to the onset of illness were cooked sausages (70%) and raw vegetables (67%). Only a small proportion of those who became ill had been involved in activities which, in the past, have been associated with human cryptosporidiosis. However, of the 22 who had been swimming prior to their illness, 12 had attended a swimming pool which was supplied by water from the suspected treatment works. Twenty-four children attended day nurseries, but at only one nursery did more than one case attend (three cases). Of the 23 school children, only three

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Table 2. *Exposure frequencies (%) of cases of cryptosporidiosis and laboratory controls*

	Case (n = 35)	Laboratory control (n = 35)	p-Value (Mantel–Haenszel)	Odds ratio
Drank water from suspect supply	28 (80)	8 (23)	< 0·0001	13·5
Glasses of water consumed				
None	9	31	< 0·0001*	
1–2 per day	9	2		
3+ per day	17	2		
Resident in supply zone	24 (69)	2 (6)	< 0·0001†	36·0
Consumed:				
raw milk	0 (0)	2 (6)	0·49†	—
goats milk	0 (0)	0 (0)	1·0	—
sausage	9 (26)	14 (40)	0·21	0·52
cooked meat	20 (57)	21 (60)	0·15	0·38
hamburger	1 (3)	8 (23)	0·09	0·09
raw vegetables	21 (60)	21 (60)	1·0	0·56
Contact with pets	10 (29)	2 (6)	0·03	6·60
Farm visit	3 (9)	1 (3)	0·10	3·19
Went swimming	9 (26)	14 (40)	0·20	0·51

* χ^2 for trend. † Fisher's exact test.

schools were associated with more than one case. The highest number of cases associated with any single school was four.

Case-control study

Thirty-five household primary cases of cryptosporidiosis were entered into the study. A laboratory control was recruited for each case, and a questionnaire was completed. Neighbourhood controls were identified for 20 of the 35 cases; nine cases were unable to nominate a control, three nominated controls were uncontractable, one was unwilling to participate, and another two had recently suffered a bout of diarrhoea and were thus excluded.

Univariate analysis of data, comparing cases with laboratory controls (Table 2) showed that the development of cryptosporidiosis was associated with the consumption of unboiled water from the suspected treatment works (odds ratio = 13·5, 95% CI 3·8–51·7). However, illness was also associated with residence within the supply area (odds ratio = 36·0, 95% CI 6·4–26·7). There was a significant association between the amount of water usually drunk and the likelihood of illness. Contact with young or sick pets in the month prior to the onset of illness was associated with illness, but when this effect was stratified according to area of residence, it was seen only for those resident outside the supply zone.

Analysis comparing cases with neighbourhood controls (Table 3), showed no significant relationship between residence in the supply area and illness. However, the association between the consumption of unboiled tapwater from the suspected treatment works and illness remained (odds ratio = 4·6, 95% CI 0·8–28·5). No other significant associations were demonstrated, however, the differing volumes of consumption between cases and controls were apparently discernable although not at the level of statistical significance.

Table 3. *Exposure frequencies (%) of cases of cryptosporidiosis and neighbourhood controls*

	Case ($n = 20$)	Neighbourhood control ($n = 20$)	p-Value (Mantel–Haenszel)	Odds ratio
Drank water from suspect supply	17 (85)	11 (55)	0·04	4·6
Glasses of water consumed				
None	4 (20)	12 (60)		
1–2 per day	4 (20)	3 (15)	0·07*	
3+ per day	12 (60)	5 (25)		
Resident in supply zone	14 (70)	11 (55)	0·33	1·9
Consumed:				
raw milk	0 (0)	1 (5)	1·0†	—
goats milk	0 (0)	0 (0)	1·0†	—
sausage	6 (30)	9 (45)	0·33†	0·52
cooked meat	10 (50)	13 (65)	0·46†	0·51
hamburger	1 (5)	6 (30)	0·34†	0·22
raw vegetables	12 (60)	16 (80)	0·70	0·60
Contact with pets	7 (35)	2 (10)	0·06	4·85
Farm visit	3 (15)	2 (10)	0·55	1·59
Went swimming	5 (25)	9 (45)	0·23	0·44

* χ^2 for trend. † Fisher's exact test.

Table 4. *Microbiological examination of water samples*

	Date	Volume sampled	Number of oocysts	Concentration (oocysts/l)
Treatment works				
Raw water	30·11	333	4	0·28
Treated water	14·11	785	3	0·05
	14·11	646	3	0·12
	15·11	742	1	0·10
	15·11	767	2	0·18
	18·11	257	1	0·01
Distribution water	16·11	499	2	0·03

Microbiology and environmental

Microbiological examination of treated water at the processing plant and water from the distribution network showed the presence of *cryptosporidium* oocysts at low concentrations during the early stage of the outbreak (Table 4). Oocysts were also identified in raw water samples and sand from the filter beds. The water company reported that one of the slow sand filters at the plant was recommissioned on 27 October 1992. Following heavy rainfall, increased turbidity had been noted in the treated water leaving the plant between 26 October and 29 October 1992. The operation of the treatment works, however, was considered to be normal and to meet the appropriate regulatory standards.

The National Rivers Authority examined the water catchment area and reported no unusual findings and the Ministry of Agriculture, Fisheries and Food reported that there were no known outbreaks of cryptosporidiosis affecting farm animals in the vicinity. Nonetheless, as a precautionary measure, the water company switched to alternative supplies where possible. Although oocysts were not found in the distribution supply an advisory notice to boil water was issued on 15 November and lifted on 20 November on the recommendation of the OCT.

DISCUSSION AND CONCLUSIONS

Conventional treatment of water for human consumption does not provide full protection against waterborne cryptosporidiosis [19]. Because the infective dose of cryptosporidial oocysts, although uncertain, is likely to be small [19] and existing microbiological testing is time-consuming and insensitive, determining the risk from drinking water from any particular supply at a particular point in time is problematic [20].

Some outbreaks of human cryptosporidiosis have been associated with the consumption of contaminated water. Whilst a clear relationship has been shown between drinking water from a public water supply in which oocysts had been detected and subsequent illness, the majority of reported incidents have depended on epidemiological evidence to demonstrate the relationship [8, 10, 11, 18, 19]. However, a number of outbreaks reviewed by a Department of the Environment and Department of Health group of experts [20] and reported subsequently [10] have also been temporally related to major changes in rainfall. There is sufficient evidence to support the view that sudden heavy rain which falls on catchment areas, particularly following a period of drought, and which washes oocysts into the raw water supply may have been a significant factor in a number of outbreaks [10, 19, 20].

In the outbreak reported here, the increase in number of cases of cryptosporidiosis was substantially higher than the normal background incidence of the disease and so represented a true outbreak. The descriptive epidemiology suggested a relationship between illness and residence within the area supplied with water by a particular treatment works. Furthermore, a high proportion of those who were ill reported drinking unboiled tapwater from this supply. This relationship was confirmed by the case control study, which also showed that those drinking larger amounts of this water had a greater chance of being ill.

Two sets of controls were used because the dynamics of transmission of cryptosporidium are complex and there are also many potential confounding risk factors. The association between illness and the consumption of tapwater was demonstrable for each set of controls. Although an increase in the number of adult cases has been noted in some waterborne outbreaks [10], the absence of this feature does not exclude water as the vehicle but may simply reflect differing dynamics, including existing levels of immunity in the exposed population. Whilst consumption of tapwater was the principal determinant of illness in this outbreak, for those cases living outside the drinking water supply zone, contact with animals was also significant. Presumably this latter finding reflects background levels of infection during a period when case ascertainment was at a higher level.

The dates of onset of illness was characteristic of a point source rather than a propagated outbreak. This, together with the knowledge that the usual incubation period for cryptosporidiosis is thought to be 3–14 days, led to the conclusion that the infection was transmitted between 22 and 29 October. During this period three factors were noted. First, there had been heavy rainfall in the catchment area of the reservoir. Secondly, the quality of treated water leaving the plant, as judged by its colour, was reported to have deteriorated (OCT unpublished). Finally, and at the same time as these events, a slow sand filter had been brought back into service following routine maintenance work. The detection of oocysts in low concentrations in treated and distribution supplies of water from the works, and in the sand from one of the filters provided further evidence implicating the water supply as a vehicle of infection.

The findings are consistent with the hypothesis of the OCT (unpublished) that during a period of heavy rain water entering the plant carried a higher microbiological load at a time the slow sand filter had not reached peak efficiency. The relative contribution of each of these factors remains unclear.

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