

Contaminated drinking water in one town manifesting as an outbreak of cryptosporidiosis in another

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SUMMARY

In early 1992 we identified an outbreak of cryptosporidiosis in Oregon and sought to identify and control its source. We used a series of studies to identify risk factors for illness: (i) a case-control study among employees of a long-term-care facility (LTCF); (ii) a matched case-control study of the general community; (iii) a cohort study of wedding attendees; and (iv) a cross-sectional survey of the general community. Drinking Talent water was associated with illness in the LTCF (OR = 22.7, 95% CI = 2.7–1009.0), and in the community (matched OR = 9.5, 95% CI 2.3–84.1). Drinking Talent water was associated with illness only among non-Talent residents who attended the wedding ($P < 0.001$) and in the community (RR = 6.5, 95% CI 3.3–12.9). The outbreak was caused by contaminated municipal water from Talent in the absence of a discernible outbreak among Talent residents, suggesting persons exposed to contaminated water may develop immunity to cryptosporidiosis.

INTRODUCTION

While only first identified as a human pathogen in 1976 [1, 2], *Cryptosporidium parvum* is now a well recognized cause of diarrhoeal illness [3–7]. Person-to-person [8] and animal-to-person [9–11] transmission have been well-documented, and sporadic cases of disease have been associated with consumption of untreated surface water [12]. Several large outbreaks linked to consumption of contaminated municipal water systems have been reported [13–17]. There is mounting evidence from volunteer studies that persons acquire protective immunity to cryptosporidiosis [18, 19]. However, the impact that immunity has on the recognition and control of community-

wide outbreaks remains unclear. In 1992, an unusual combination of events transpired in southern Oregon that allowed us to investigate this phenomenon.

For several years, the two hospital-based laboratories in Medford (population 42 000) routinely tested faecal specimens for *Cryptosporidium*, and furthermore reported all *Cryptosporidium* identifications to the local health department, although at the time reporting was not required. The number of reported cases noticeably increased during the first 4 months of 1992. An initial investigation of the cases with most recent onsets (in March and April) failed to reveal common exposures to untreated water, swimming pools, farm animals, children in day-care centres, or persons with diarrhoea. All but one patient, however (23/24), reported drinking Medford municipal water in the 2 weeks before onset of symptoms [20].

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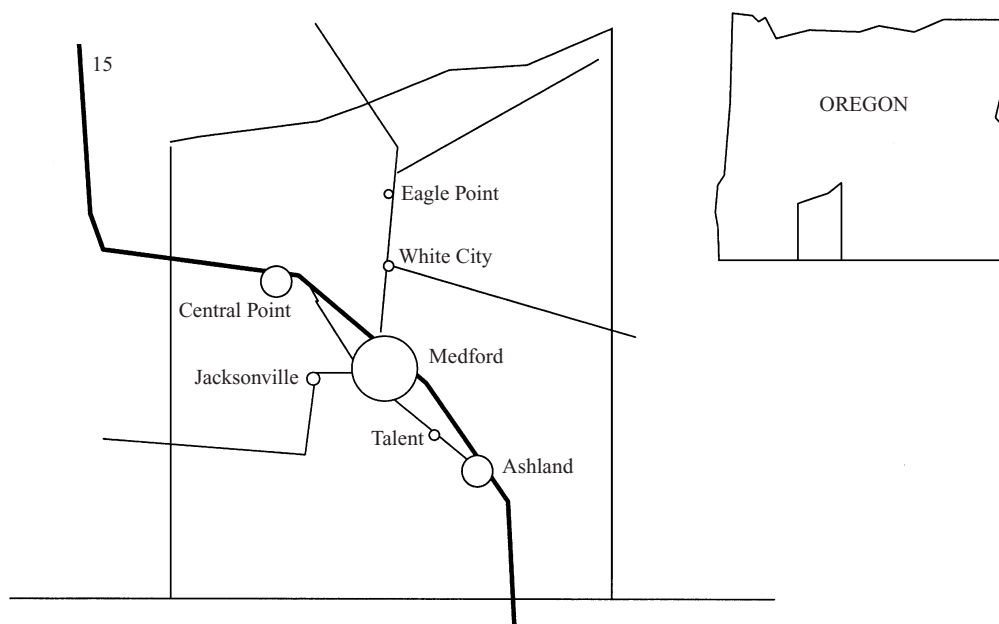


Fig. 1. Jackson County, Oregon, United States of America.

The Medford Water Commission (MWC) supplied water to households in Medford and most Jackson County municipalities, comprising approximately 80 000 persons (Fig. 1). Two other municipal water works independently supply the towns of Ashland (population 17 300) and Talent (population 2800). From autumn to the end of spring (encompassing the outbreak period), MWC water derived solely from a mountain spring, and was chlorinated, but not filtered. At the time, MWC water was not routinely tested for the presence of *Cryptosporidium* oocysts. However, the increased case counts and preliminary investigation raised the possibility of waterborne transmission, and MWC water was assayed for the presence of *Cryptosporidium* oocysts. On 1 May, oocysts were detected at low levels in all three MWC samples taken on 26 April, including one at the spring box. As a result, public health and water works officials advised MWC customers to boil their water until an alternative source that was normally used only as a summer supplement could be brought on-line in lieu of the spring water. (The alternative was surface water from the Rogue River, which was treated at a modern coagulation and filtration plant.) Anecdotal reports indicate that while a large proportion of the population began to boil their water, others switched to bottled water or filled containers from other municipal sources, including taps in Ashland and Talent.

This prompt public health action proved unsuccessful at stemming the outbreak; indeed, things soon

became worse. Within a week, a renewed wave of case reports began to come in, including discrete clusters from a Medford long-term-care facility (LTCF) and following a wedding in Talent, as well as apparently unrelated cases throughout the county. Here we report our response to these reports and the light they shed on the hypothesis that protective immunity develops after exposure.

METHODS

Investigation of the long-term-care facility outbreak

The LTCF, located in Medford, employed 390 staff and cared for 800 residents. Infection control staff at the facility reported that many employees and residents had developed acute diarrhoea, and *Cryptosporidium* oocysts were identified in the stools of 9 of 25 people with diarrhoea tested. We conducted an unmatched case-control study among employees to determine the cause of the outbreak in late May. We excluded all residents of the LTCF as many had dementia or other psychiatric diagnoses. For the study, we defined case-patients as employees identified through sick call or the facility's acute care log book who reported diarrhoea lasting ≥ 3 days after 8 May. (More than 3 days was chosen to maximize the likelihood of excluding conditions other than cryptosporidiosis.) A random sample of potential controls was drawn from a list of employees. We excluded persons who reported diarrhoeal illness during May.

Investigation of 'sporadic' community case-patients

To determine risk factors associated with community-acquired cryptosporidiosis, we conducted a matched case-control study. Case-patients were defined as persons residing in Jackson County who had stool-confirmed cryptosporidiosis identified by Medford laboratories from March through May 1992. Case-patients who were not the first person to become ill in their household were excluded. Case-patients that were part of recognized clusters (e.g. at the LTCF) were also excluded. Controls were systematically identified and matched to case-patients by street of residence (using a reverse telephone directory) and age (within 10 years for case-patients aged > 25 years, within 5 years if aged 10–24 years, and within 3 years if aged < 10 years). Potential controls who reported diarrhoeal illness in the previous 2 weeks were excluded. Case-patients were asked about municipal water consumption during the 2 weeks before onset of illness. Controls matched to case-patients who became ill before the Medford boil-water order were asked about consumption of municipal water during the 2 weeks before the Medford boil-water order; controls matched to later case-patients who were ill after the Medford boil-water order about consumption of municipal water during the 2 weeks before the interview.

WEDDING OUTBREAK

In late May, an outbreak of diarrhoeal illness was reported among persons who attended a wedding reception on 16 May in Talent, a small town 20 km south of Medford. *Cryptosporidium* oocysts were identified in stool specimens collected from two attendees. In a retrospective cohort study we interviewed all reception attendees about illness and consumption of foods and beverages at the reception. Case-patients were defined as those who developed a diarrhoeal illness lasting ≥ 3 days, with onset during 18–31 May.

COMMUNITY DIARRHOEA PREVALENCE SURVEY

To determine the prevalence of cryptosporidiosis-like illness (CLI) among residents of Medford and Talent, in mid-May we conducted a telephone survey of Medford and Talent households systematically selected from the county telephone book. We asked an adult in each household about the duration of any

diarrhoeal illness for household members in the previous 10 weeks (since 1 March) and about sources of drinking water. CLI was defined as diarrhoea lasting ≥ 4 days after 1 March. We used this more stringent criterion to maximize the specificity of the case-definition, since (unlike the specific cluster samples reported on here), no laboratory-confirmed cases were identified in the telephone survey.

ENVIRONMENTAL STUDY

Talent has two package filtration water treatment plants on independent surface sources. We reviewed plant records for turbidity and other characteristics. Raw and treated water samples were assayed for *Cryptosporidium*.

Statistical methods

In the case-control study at the LTCF, crude odds ratios (ORs) and confidence intervals (CIs) were calculated to compare proportions. For the community case-control study, matched ORs and CIs were calculated to compare proportions. For the retrospective cohort study among wedding guests, a χ^2 test for trend was used to compare proportions. For the community prevalence survey, relative risk and 95% CI limits were calculated with an allowance for the clustered sample design where household was the sampling unit [21]. Differences were considered statistically significant where the CI did not include 1.0. For continuous data, differences in distributions were compared by using the Kruskal–Wallis test.

RESULTS

Long-term-care facility outbreak

Infection control staff at the LTCF reported that 40 of the 390 employees and 200 of the 800 residents had recent onset diarrhoea. For the case-control study of staff, we interviewed 26 case-patients and 32 controls, who were of similar distribution by age, sex, and place of residence. Illness was not associated with eating at the cafeteria or any other nearby facility, but was strongly associated with drinking water that had been trucked to the facility from the nearby town of Talent in response to the boil-water alert (OR = 22.7, 95% CI = 2.7–1009.0) (Table 1). This water had been delivered by hose into large containers in the kitchen and then ladled into smaller dispensers that were distributed about the facility. The truck had been

Table 1. *Characteristics of case-patients and controls, long-term-care facility, Medford, May 1992*

Characteristic	Case-patient (%)	Controls (%)	OR (95% CI)
Total	26 (100)	32 (100)	
Mean age (years)*	44	47	
Sex			
Male	16 (62)	15 (47)	1.8 (0.6–6.0)
Female	10 (38)	17 (53)	Referent
Place of residence			
Medford	11 (42)	12 (38)	Referent
Talent	0 (0)	2 (6)	0.0 (0.0–6.8)
Other	15 (58)	18 (56)	0.9 (0.3–3.0)
Ate at cafeteria	13 (50)	10 (31)	2.2 (0.7–7.4)
Drank carried-in water	11 (42)	1 (3)	22.7 (2.7–1009.0)

* Kruskal–Wallis test, $P = 0.14$.

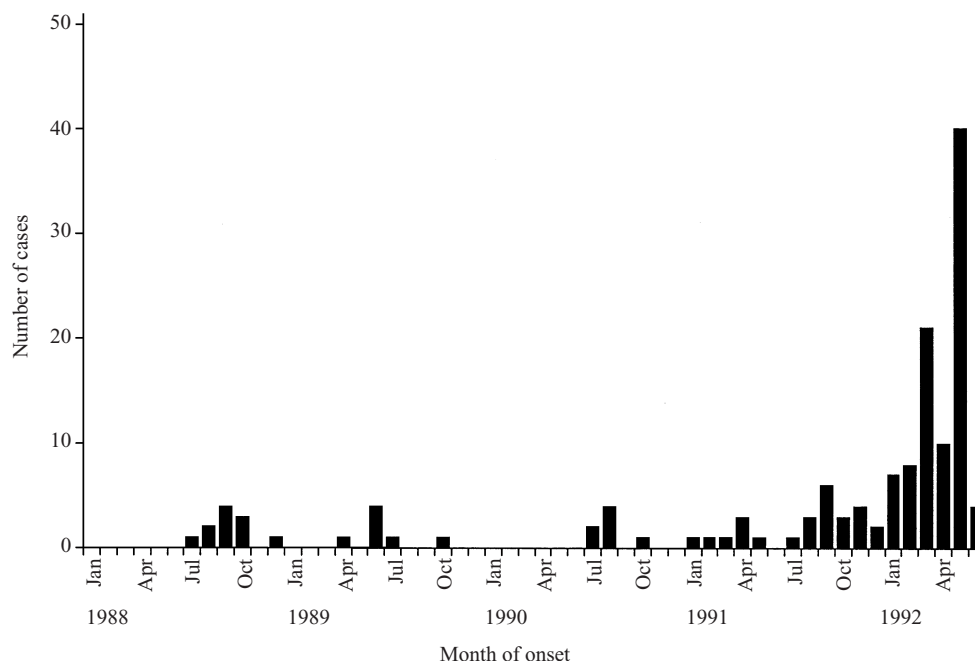


Fig. 2. Reported case-patients with cryptosporidiosis, Jackson County, by month of onset, January 1988 to June 1992.

filled at a potable water fire hydrant in Talent. No source of contamination from the truck was identified. On interview, the driver stated that he often carried MWC water, but in response to the boil-water order, he flushed the tank several times with bleach before filling it with Talent water.

Community matched case-control study

Fifty primary community case-patients were reported between March and mid-May 1992 (Fig. 2). Forty-four (88%) lived in the Medford area, 4 (8%) lived in

Ashland and 2 lived in Talent. Their mean age was 28 years (range: 1–86); 23 (46%) were male. Twenty-three (46%) reported drinking Talent water in the 2 weeks before onset, compared with 6 (12%) controls (matched OR = 9.5, 95% CI = 2.3–84.1).

Wedding outbreak

Fifty-eight persons attended the wedding reception in Talent. Their mean age was 29 years (range: < 1–84 years); 26 (46%) were male. Twenty-five persons (43%) reported onset of diarrhoea within

Table 2. Reported diarrhoeal illness ≥ 4 days duration among persons in community prevalence survey, Jackson County, March–May 1992, by water consumption

City water exposure	Persons	Diarrhoea ≥ 4 days	No diarrhoea ≥ 4 days	Relative risk (95% CI)
Total	521	50 (10)	471 (90)	
Medford resident				
No Talent water	245	25 (10)	220 (90)	Referent
Talent water	6	4 (67)	2 (33)	6.5 (3.3–12.9)
Talent resident				
No Talent water	77	5 (6)	72 (94)	Referent
Talent water	193	16 (8)	177 (92)	1.3 (0.5–3.4)

Table 3. Summary of epidemiological studies of cryptosporidiosis Jackson County, March–May 1992

Setting	Study design	Case definition	Risk of illness associated with Talent water*
Long-term-care facility	Case-control study	Diarrhoea ≥ 3 days	22.7 (OR)
Jackson County	Matched case-control study	Stool-confirmed	9.5 (OR)
Talent Wedding	Retrospective cohort study	Diarrhoea ≥ 3 days	Incalculable
Jackson County	Cross-sectional survey	Diarrhoea ≥ 4 days	6.5 (RR – Medford residents) 1.3 (RR – Talent residents)

* OR, odds ratio; RR, relative risk.

2 weeks of the wedding, including 13 (22%) who reported symptoms lasting ≥ 3 days. The median incubation period was 6 days (range: 4–8 days). Case-patients were no more likely than other attendees to report consuming any food or beverage at the wedding reception, but everyone drank Talent water at the reception or within the previous 24 h. Diarrhoea lasting at least 3 days was most common among attendees who lived outside Jackson County [7/11 (64%)], less common among persons who lived elsewhere in Jackson County [6/30 (20%)], and not reported among the Talent residents who attended (0/17) (χ^2 test for trend = 14.4, $P < 0.001$).

Community diarrhoea prevalence survey

We surveyed 101 Medford and 101 Talent households comprising 521 persons about water source and their history of diarrhoea between March and May 1992. The mean age of household members was 40 years (range: < 1–99 years); 245 (47%) were male. Among Medford residents, those who reported drinking Talent water in the previous 10 weeks were significantly more likely to report CLI than those who did not (RR = 6.5, 95% CI = 3.3–12.9). Among Talent residents, those who reported drinking Talent water in

the previous 10 weeks were no more likely to report CLI than those who did not drink Talent water (RR = 1.3, 95% CI = 0.5–3.4) (Table 2). Results of these investigations are summarized in Table 3.

Environmental study

Talent water is supplied from two treatment plants served by two creeks. According to state drinking water engineers, Bear Creek (the major source) is considered a relatively low-quality source, with much of its flow deriving from effluent from an upstream sewage treatment plant, supplemented with agricultural run-off. Turbidity levels at the Bear Creek Treatment plant exceeded 1.0 nephelometric turbidity units (NTU) on 32/61 days in April and May, with spot readings over 2.0 NTU on some occasions. No *Cryptosporidium* oocysts were detected in untreated or treated water collected from Bear Creek in May, although algae and other particulate matter of the same size and shape as *Cryptosporidium* were present.

The intervention

On 22 May, Talent residents were advised to boil water before consumption, while engineers corrected

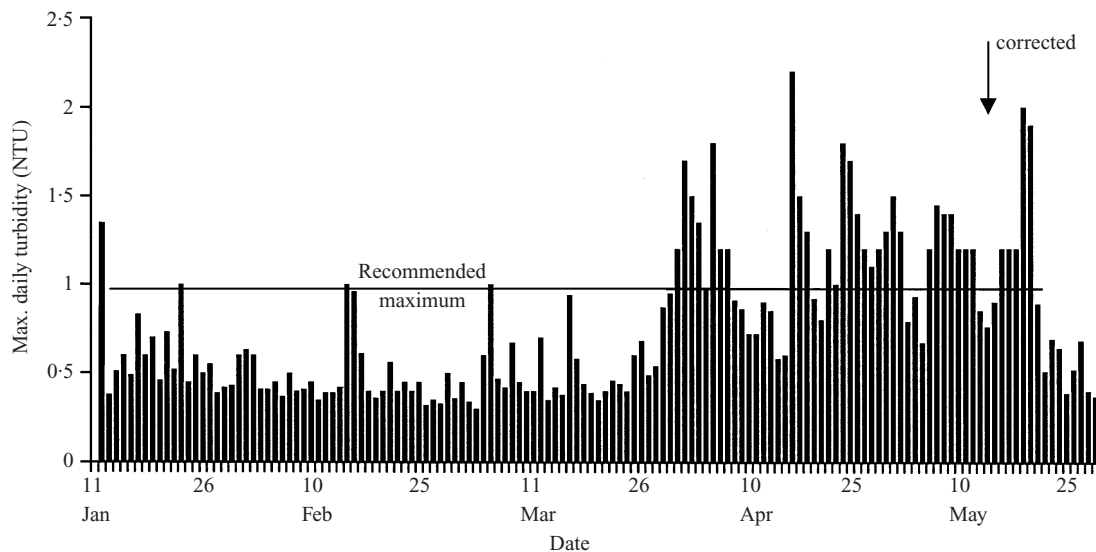


Fig. 3. Treated water turbidity, Bear Creek Plant, Talent, January–May 1992.

several operational deficiencies at the Bear Creek plant [22]. Turbidity levels soon dropped markedly (Fig. 3), and the outbreak subsided.

DISCUSSION

The incidence of cryptosporidiosis began to increase in Jackson County as early as December 1991 (Fig. 2). While the role that Medford water played in the early months of the outbreak remains controversial, evidence indicates that most if not all of the later cases stemmed from consumption of Talent water. Talent water was consumed by many Jackson County residents after the initial (Medford) boil-water notice, including some who were supplied by the water truck that went to the LTCF. It is clear, however, that the truck was merely the innocent conveyor of water that was contaminated in the distribution system. Although *Cryptosporidium* was never detected in Talent water; contamination may have been intermittent, and the large number of similarly sized particles in the sample would have markedly reduced the sensitivity of the tests.

The wedding investigation and the community surveys indicate that Talent residents were less likely in April and May to report clinical illness compatible with cryptosporidiosis than other persons who drank Talent water. The most plausible explanation is a relative immunity among Talent residents.

Volunteer studies indicate that prior exposures to *Cryptosporidium* oocysts provide some protection

from reinfection [18, 19]. Varying degrees of protective immunity may develop among persons exposed to many other protozoa, including *Giardia lamblia* [23] and *Plasmodium* spp. Immunocompetent persons spontaneously clear cryptosporidiosis infections [3], while immunodeficient patients can have persistent and clinically severe infections [24]. Asymptomatic *Cryptosporidium* infections are probably common [25, 26].

These were not controlled experiments. Recall bias may have affected the community diarrhoea prevalence survey because the interviews were conducted after the MWC boil-water order was issued. These interviews took place before any suspicions about Talent water were bruited, however. Because the investigation did not begin until April, we excluded cases from December 1991 to February 1992 on the assumption that it would be fruitless to interview case-patients about incidental water consumption that long ago. Thus, we are unable to assess what proportion of earlier case-patients may have consumed Talent water. Similarly, we cannot determine when or how regularly Talent water was contaminated. Thus, we cannot speculate on how soon after infection protective immunity develops, or for how long it may persist.

Absent specific laboratory findings, misclassification of persons with respect to infection status is a potential problem with any infection, such as cryptosporidiosis, that lacks a pathognomonic clinical presentation. We varied our case definitions in the several settings to optimize sensitivity and specificity.

This epidemic was detected only because of the universal screening and voluntary reporting policies of local laboratories. Mandatory reporting of cryptosporidiosis was initiated state-wide in 1994, although by 1997 only 17% (7/41) of laboratories in Oregon that did stool examinations for ova and parasites reported that they routinely looked for *Cryptosporidium* infections (Oregon Health Division, unpublished data). In the absence of both widespread screening and centralized reporting, even large outbreaks can easily escape detection.

Results of the community matched case-control study indicate that perhaps up to 46% of cryptosporidiosis cases could be accounted for by direct consumption of Talent water. This proportion is similar to that attributable to other point source outbreaks [27]. While *Cryptosporidium* oocysts were detected in MWC water collected in late April, and its consumption was thought to have played some role in the early part of this outbreak, the epidemiological data more strongly points to consumption of Talent water as a major source of infection, at least in the later part of the outbreak. Nonetheless, consumption of MWC water may have accounted for some cases [20]. Many of the remaining cases are likely attributable to person-to-person spread of this highly infectious organism.

If persons with previous or ongoing exposure to *Cryptosporidium* develop protective immunity, contamination of community water sources may not necessarily manifest as explosive outbreaks among residents. In other words, dramatic rates of community-wide disease may not be the inevitable result of ongoing water supply contamination. Rather, such problems may manifest primarily among community visitors or immunocompromised residents. Where contamination is identified in a community water supply, travellers to that community, especially those from nearby towns, should be advised to avoid consuming the water.

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