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An outbreak of gastroenteritis on a passenger cruise ship

By MARY C. O'MAHONY, N. D. NOAH, B. EVANS, D. HARPER,
PHLS Communicable Disease Surveillance Centre, Colindale, London

B. ROWE,
PHLS Central Public Health Laboratory, Colindale, London

J. A. LOWES, A. PEARSON,
Public Health Laboratory, Southampton

AND B. GOODE
Port Health Authority, Southampton

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SUMMARY

In an outbreak of gastroenteritis on board a cruise ship 251 passengers and 51 crew were affected and consulted the ship's surgeon during a 14-day period. There was a significant association between consumption of cabin tap water and reported illness in passengers. Enterotoxigenic *Escherichia coli* were isolated from passengers and crew and coliforms were found in the main water storage tank. Contamination of inadequately chlorinated water by sewage was the most likely source of infection.

A low level of reported illness and late recognition of the outbreak delayed investigation of what was probably the latest in a series of outbreaks of gastrointestinal illness on board this ship. There is a need for a national surveillance programme which would monitor the extent of illness on board passenger cruise ships as well as a standard approach to the action taken when levels of reported illness rise above a defined level.

INTRODUCTION

Outbreaks of gastroenteritis aboard cruise ships, although infrequent, are of public health importance for a number of reasons: ships are a closed environment in which infection may easily spread and may be also difficult to control; many passengers are elderly and thus at more risk of serious morbidity or even mortality; the ships' water supply is replenished in different ports with variable standards of hygiene; passengers frequently take trips ashore to ports where infection may be acquired and then spread aboard ship.

Several outbreaks in cruise ships sailing from ports in the United Kingdom have been reported in which water was suspected as the vehicle of infection although this was not confirmed. We report an outbreak of enterotoxigenic *Escherichia coli*

(ETEC) gastroenteritis on board ship in which there was both epidemiological and microbiological evidence implicating the water supply.

THE OUTBREAK

On a Wednesday in September 1984, the Public Health Laboratory Service Communicable Disease Surveillance Centre (CDSC) was informed that 230 out of a total of 1682 passengers and 40 out of 790 crew members of a ship on a fortnight's pleasure cruise to the Mediterranean had reported to the ship's surgeon with diarrhoea over the previous 12 days. No one was hospitalized. Faecal specimens taken during the cruise and tested in a Mediterranean city had not revealed intestinal pathogens. The 'normal/average' rate for gastrointestinal illness on a 14-day cruise with similar passengers and crew was less than 20 passengers and 6 crew ($< 2\%$).

Epidemiological investigation

The ship was boarded in the Mediterranean on the 10th day of the cruise and pilot interviews of 20 passengers and crew were conducted. Many of the passengers who saw the ship's surgeon became ill between day 3 and day 8. There appeared to be no common meal or activity associated with illness and it was decided to conduct a cohort study using a self-administered questionnaire. This sought information on symptoms, general food preferences of 89 separate food items, trips ashore and leisure activities aboard ship. The questionnaire was distributed to all passengers and crew who had reported to the ship's surgeon. A more detailed case-control study was undertaken which looked at specific menu preferences over a 3-day period in the 83 passengers who presented to the ship's surgeon with an illness commencing during the peak of the outbreak, namely days 4 and 5. The limited time available did not allow random selection of controls. Thus the spouse of a case, or the nearest adult(s) on the passenger list if a couple were both ill or if the case was a person travelling alone were selected. In addition, the general questionnaire was sent to all remaining passengers and crew so that the level of unreported illness could be ascertained.

Other investigations

The galley was visited and inspected and current food handling practices were reviewed. Water and sewage treatments were investigated and faecal specimens were obtained from passengers reporting to the ship's surgeon in the last week of the cruise and from symptomatic food handlers. Samples of stored food and water were also collected for examination.

RESULTS

Epidemiological

A total of 1408 (83%) of the general questionnaires were completed by passengers. These questionnaires contained 181 (72%) which were returned from the final total of 251 passengers who reported to the ship's surgeon and 182 from

their controls. As only 12 questionnaires were returned from crew members reporting to the surgeon, they were not included in the analysis.

A case was defined as someone suffering from diarrhoea or loose bowel motions and abdominal pain. A 20% random sample (200) of passengers who were not categorized as cases or controls showed that 102 of them were ill at some time during the cruise giving an overall attack rate of 51%, or an estimated total of 858 ill passengers.

Case control study

Of the 181 cases in the case control study 82 were males and 99 were females. Although 182 controls completed the questionnaire, 96 (53%) fulfilled the case definition and 27 others suffered from one or more gastrointestional symptoms. They were, therefore, excluded from the control group and an additional 75 randomly selected controls from the 20% sample of passengers who were symptomless, were added to the group, making a total of 134 controls. Of the 83 passengers whose symptoms commenced on days 4 and 5, 53 (63%) returned a questionnaire. Fifty-four controls responded, but as 32 of these also fulfilled the case definition, the remaining 22 controls were used.

Of the 181 cases, 22 (12%) were aged 0–30 years, 93 (51%) 31–60 years and 65 (36%) above 61 years; 1 was age unknown. Sixty-seven (50%) of the controls were males and the age distribution of controls was similar to cases.

The most frequent symptoms were loose stools reported in 169 (93%), diarrhoea in 163 (90%) and abdominal pain in 126 (70%) cases. Although nausea occurred in 90 (50%) cases, vomiting was rare and was reported by fewer than 20%. The mean duration of symptoms was 5 days with a range of 1–15 days. Cases occurred thoughout the fortnight but the peak was on the 4th and 5th days of the cruise (see Fig. 1).

Food preference tables for food consumed were examined in relation to cases and controls using the χ^2 test for two by two contingency tables. Food preference tables for food consumed occasionally and/or frequently in cases and controls showed significant differences in food preference rates for tap water, fruit juices, yoghurt, sauces, prawn cocktail and eating in Limassol (Tables 1 and 2). However, the food preference rates were higher in controls for all food items except tap water, suggesting that only drinking tap water was associated with the development of symptoms.

Environmental health investigation

Food was carried by container lorries from the United Kingdom to each port of call but fresh water, fish and vegetables were purchased locally. A dock strike in England meant that supplies of milk and cream (both UHT), ice-cream and cheese were taken on board in Spain. This milk and cheese were initially served on the cruise but the milk was discontinued on day 5 when passengers and crew complained of an unusual taste. The ice-cream was not served. Water was chlorinated manually on board as it was pumped from shore and chlorinated further before distribution through the ship. During the cruise, the chlorine level was kept at 0·6 p.p.m. in the tanks until day 9 of the cruise (Fig. 1) when it was

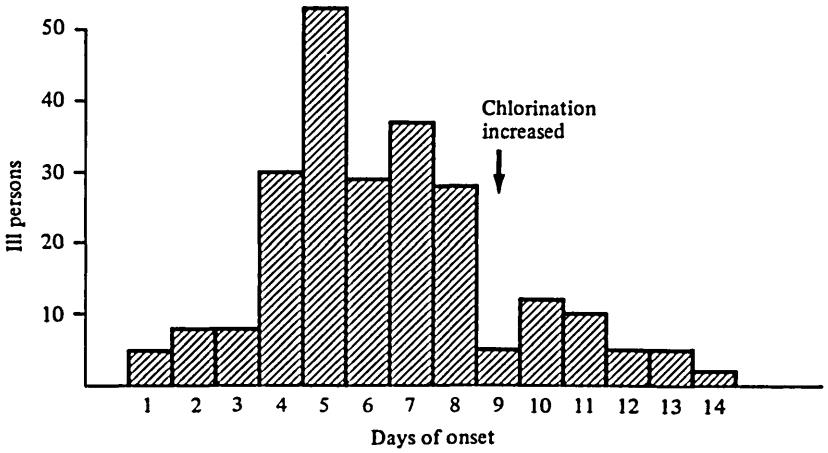

Fig. 1. Outbreak of gastroenteritis on board ship.

increased to 1 p.p.m. due to the high level of reported illness. Chlorination readings were taken by the ship's dispenser and a member of the engineering staff.

Microbiological investigation

In the last 5 days of the cruise 22 faecal samples were obtained from passengers and 13 from crew who were ill. Microbiological testing revealed the presence of ETEC in 13 passengers and 6 crew. Several serogroups of ETEC were involved but *Eschevichia coli* 027H7 were present in 5 passengers and 3 crew. In addition four passengers were found to be excreting small round virus particles and one passenger to be excreting salmonella.

The only food poisoning organism found in food was *Bacillus cereus*, which was isolated from a sample of Bombay Duck. Non-enterotoxigenic *E. coli* were present in the sample of Spanish cheese. No coliforms were found in the water.

When the ship was boarded only 3 days before the end of the cruise, the water chlorine level had already been increased but further water and stool samples were taken after the two following cruises. During the first of these, 94 passengers and 28 crew reported to the ship's surgeon with similar symptoms. At the end of this cruise one water sample taken from the main water tank (tank 15) showed a total coliform count of 200 per 100 ml and a faecal coliform count of 190 per 100 ml. *E. coli* of five different serotypes were present but these were not ETEC. Faecal samples from 19 passengers with diarrhoea were examined and ETEC were found in 4; 3 of these were *E. coli* 0148H28 and 1 was *E. coli* 06H16. *E. coli* 027H7 was not found. No bacterial pathogens, including ETEC, were isolated from 8 crew members who were ill and from 11 crew controls.

On the next cruise, the last of the UK season, 85 passengers and 22 crew developed gastroenteritis. This pattern of illness suggested a continuing source of infection and as the main water tank was found to have an unacceptable coliform count and to contain *E. coli*, it was believed that the ship's water system should be investigated further. Faecal samples from 21 affected passengers were examined

Table 1. *Food preferences, cases and controls*

Food activity	Ill			Not ill			*P* value
	Yes	No	%	Yes	No	%	
Drank water							
Table water	157	22	85	117	13	90	NSD
Tap water	132	45	75	78	52	60	0·01
Ice	142	34	81	104	25	81	NSD
Tap+table	166	13	93	120	11	92	NSD
Tap+table+ice	175	5	97	129	2	98	NSD
Milk	127	43	75	93	26	78	NSD
Ate							
Cream	23	137	14	25	88	22	NSD
Cereal	98	72	58	74	44	63	NSD
Ice cream (1)	73	95	43	58	71	45	NSD
Ice cream (2)	144	34	81	108	24	82	NSD
Any ice cream	154	25	86	114	18	86	NSD
Prawn cocktail	80	79	50	90	47	66	0·01
Fruit in cabin	22	150	13	28	96	23	0·04
Yoghurt	5	155	3	12	98	11	0·02
Sauce	13	154	8	20	101	17	0·03
Went to Limassol	145	36	80	121	13	90	0·02
Ate in Limassol	134	47	74	106	28	79	NSD
Use of sea water swimming pool	62	116	35	50	80	37	NSD

NSD, No significant difference.

Table 2. *Three-day menus*

Food	Ill			Not ill			*P* value
	Ate	Did not eat	%	Ate	Did not eat	%	
Lunch day 1							
Chops	13	38	25	13	9	61	0·014
Courgettes	8	43	15	11	11	50	0·007
Lunch day 2							
Grill	15	35	30	13	9	61	0·039
Potatoes	18	33	35	14	8	64	0·047
Dinner day 3							
Sardines	2	49	4	6	16	27	0·015
Cheese	6	45	12	10	12	45	0·005
Biscuits	3	48	6	6	16	27	0·04

and 2 had ETEC. Twenty crew members with diarrhoea were studied and ETEC were not found.

Investigation by water engineer

An investigation of the ship's water and sewage systems was carried out by a water engineer while the ship was sailing for its annual refit. This revealed one major and four minor problem areas which could have affected the quality of the

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water supply aboard ship. The manual chlorination system on bunkering water, aided by the transfer of water from one tank to another, resulted in variable chlorination levels, with some tank water being superchlorinated to 2 p.p.m. and others hypochlorinated. Moreover, the chlorine readings of tap water taken by the dispenser and the engineers on board ship showed discrepancies. Until day 9 chlorine levels in taps tested by the dispenser were less than 1 p.p.m. Then, when the chlorine levels were increased, the level of illness decreased, although the engineers' testing of tap water from the sun deck tap showed that they were still less than 1 p.p.m at this time. On day 11 of the cruise, the water was chlorinated still further and levels of 2 p.p.m. were recorded. These high levels of chlorination were continued for the two subsequent cruises.

The minor areas were: a loose inspection cover with a poor seal on tank 15 over which bilge water flowed; sewage and water pumps which if ineffective could lead to sewage-contained bilge water touching the fresh water pumps; galley water from the butcher's shop collected in a tank which allowed it to overflow, which then mixed with the bilge water close to the water pumps. In addition, when the ship went into dry dock, a leak in tank 15 was found, caused by loose rivets in the base of the tank.

DISCUSSION

In previous outbreaks of ETEC infection affecting passengers aboard cruise ships, no vehicle of transmission was detected (Dannenberg, Yashuk & Feldman, 1982; Hobbs *et al.* 1976). In one outbreak with a similarly high attack rate (Lumish *et al.* 1980), crabmeat cocktail was suspected to be the vehicle but water was also considered to be a possible source of spread: it was only considered unlikely because residual free chlorine was found in the water distribution system but the high attack rate of illness in both passengers and crew, and the appearance of new cases over several days suggests water rather than a single food item. In another outbreak (Snyder *et al.* 1984) eating at cold buffets, but not drinking water or iced drinks, was significantly associated with illness. Although our investigation provided epidemiological and microbiological evidence which implicated the water supply as the vehicle of infection, the difficulties of investigation made it necessary for samples of food and water to be taken over three consecutive cruises before evidence was convincing.

The evidence implicating the water supply, particularly that from tank 15, as the source of the infection was as follows. Each peak of the outbreak coincided with the use of tank 15 and there was also a suggestion that illness followed the taking of water on board. The epidemic curve of three successive cruises indicated several episodes of different illnesses or continued contamination of a widely distributed vehicle of infection. The questionnaire survey revealed a strong association between drinking tap water and the development of illness. Although the method used for the identification of controls introduced a potential bias because they were likely to have had similar life styles to the cases, more than half of them were ill and were replaced by random controls from the general passenger list which may have reduced the original bias.

Faecal samples taken from affected passengers revealed several serogroups of ETEC and one water sample taken from tank 15 had a high coliform count which implied a sewage contaminated water supply. Furthermore, the discrepancies in recorded chlorination levels between the ship's engineer and dispenser probably did not ensure that all water was adequately chlorinated. Until day 11 chlorination levels of the drinking water supply recorded by the dispenser were below 0·7 p.p.m. Following this date the levels were increased and at the same time fewer passengers and crew reported to the ship's surgeon.

Since water was the most likely vehicle of infection it is possible that contamination may have been due to poor quality water bunkered from the ports visited or it may have occurred on board or it may have been due to a combination of these. Moreover the manual chlorination method used did not ensure that all water was adequately treated. The report from the water engineer showed that the fresh water supply in tank 15 could become contaminated on board. Bilge water could seep through the inspection cover of the tank. Contaminated sea water could also enter through the loose plates which would happen whenever there was a pressure difference between the tank and the sea water, most likely when the ship approached port and at a time when the sea water was most likely to be polluted.

Following these findings, the chlorination procedure was made the responsibility of the ship's engineer and the drinking water levels kept at 0·6 p.p.m. free residual chlorine from taps at the furthest point from the chlorination system and at a minimum of one other tap selected daily at random in the ship.

It was advised that automatic proportional chlorination pumps be installed as soon as possible. The damaged water tanks and inefficient sewage pipes were repaired and the overflow pipe from the butcher's shop was resited.

It was agreed that the level of illness should be monitored in the subsequent cruises by reporting levels of gastrointestinal illness affecting 3 % of those on board as well as by routinely informing the British Port Health Authorities of the level of reported illness at the end of each cruise. In the 2 months following the repair and review of the water systems, the reported illness dropped to the pre-outbreak levels of less than 2 %.

Ships based in the United Kingdom report the number of ill passengers each time they enter port and on docking an environmental inspection is carried out by the Port Health Authorities. If the level of reported illness is above normal, a report may be radioed ashore and the vessel boarded for inspection while at sea. Although each Port Authority monitors its own shipping traffic there are no national data available, nor agreed procedures dealing with a predetermined level of reported illness aboard ships. Illness aboard cruise liners has always been recognized as a very real threat but attention is increasingly directed to ferry traffic because of the large number of passengers on each sailing and their rapid dispersal. This outbreak indicates the need for a national surveillance scheme which would monitor the extent of illness on board cruise ships and which would agree a standard approach to the action to be taken when levels of illness rise above a defined acceptable level.

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