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A Norwalk-like virus waterborne community outbreak in a Swedish village during peak holiday season

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SUMMARY

An outbreak of gastroenteritis due to Norwalk-like virus (NLV) affecting approximately 500 people occurred in a Swedish ski resort during February–March 2002. Epidemiological investigations were performed on cohorts of schoolchildren, permanent residents and skiers visiting the area. Attack rates were respectively 39·7, 29·9 and 38·5%. Drinking un-boiled water originating from one of the three communal water systems was a significant risk factor for all groups. For schoolchildren, the risk of illness increased with increasing amount of water consumed. Nine of 12 stool samples of patients analysed tested positive for NLV. The water tested negative for indicator bacteria and results of NLV tests were inconclusive. In the absence of microbiological findings, the environmental authorities were reluctant to act based on the epidemiological analysis alone, and intervention was delayed until mid-April, following the discovery of a crack in a sewage pipe 10 m from the well.

INTRODUCTION

Norwalk-like viruses (NLV) have been recognized as a leading cause of acute, non bacterial gastroenteritis worldwide [1]. The viruses are transmitted by the faecal–oral route from person to person, and also by contaminated food and water [2]. Several waterborne NLV outbreaks have been described previously [3–5].

A problem in confirming the source of viral waterborne outbreaks is the technical difficulty in detecting viruses in patients [6], and especially in the water vehicle [7]. Because of this latter difficulty, investigators have usually relied on the detection of viruses from patient samples and 'indicator bacteria' in the water and the establishment of statistical association with the consumption of the water vehicle.

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In Sweden, waterborne outbreaks involving different pathogens have been reported with relative frequency [8–10]. The present paper describes a large NLV water-borne outbreak which was investigated using epidemiological methods in the absence of microbiological confirmation in the water vehicle and makes the case for a more vigorous intervention as soon as epidemiological findings are available in order to prevent further cases.

The outbreak

During the last week of February 2002 (designated 'winter sports break' in Sweden) the Dalarna Office for Infectious Disease Control was informed by a district health centre clinician of several cases of gastroenteritis among guests of a hotel situated in a village in the County of Dalarna (west of Sweden). The area was in peak tourist season during this period, with many visitors from Sweden and abroad. Precautionary recommendations were given advising residents and visitors to boil the water.

In spite of these recommendations, additional cases were found among residents as well as visitors to the area. A school (60 pupils), located in the village, had remained closed for holidays during the winter sports break, and several schoolchildren were also affected soon after returning to school. All schoolchildren live in a nearby village and travel to the school by bus. Visitor cases identified included several members of a group of skiers from Southern Sweden who had arrived to participate in the 1-day long Vasa cross-country ski competition ('Vasalopp') during 1–3 March.

Initially, NLV was confirmed in stool samples from four hotel guests. Given the high number of cases scattered across the area, the drinking water was the suspected vehicle of infection. An epidemiological investigation was conducted with the aim of determining the magnitude of the event, describing the disease in the different age groups and determining the source in order to control the outbreak.

MATERIALS AND METHODS

The study area

Transtrand, with a population of 605 residents, is located in the Western mountain range of Sweden. Within the village there are two hotels and several guesthouses, which provide accommodation to visiting winter sports fans.

Once a year, thousands of skiers gather in the area to participate in the Vasalopp. Most of them stay overnight in Transtrand and other nearby villages. The village has a food shop, a school and a petrol station, and is served by three different community water supplies (A, B, C). In addition there are a number of households with a private well. The school and the two hotels are served by water supply A.

Epidemiological studies

The Swedish Institute for Infectious Disease Control and the Dalarna County Office for Communicable Disease Control carried out a cohort study among the 60 schoolchildren (age range 10–13 years). This was followed by a second cohort study with the 605 permanent residents in the village. A third cohort study was performed with the 107 skiers belonging to the above-mentioned ski group.

Information for the school survey was collected by telephone. Schoolchildren were asked directly about exposure to food and water during the first 2 days after returning to school (5–6 March). Given that the school gym had been used as temporary accommodation for some visitor cases, the questionnaire also gathered information about participation in the class of gymnastics. For the population survey, questionnaires were mailed to all 214 households in the village. Heads of family were asked to provide information about water consumption, illness in any family members and number of guests lodged during the period 16 February to 19 March. The environmental office provided data on the type of water supply for each address. Information for the ski group study was collected by a questionnaire mailed to all 107 skiers.

A case was defined as a person who developed either diarrhoea (equal to or greater than three loose stools per day) or vomiting or abdominal pain plus one of: muscle pain, fever, and headache between 5 and 9 March (schoolchildren group), between 16 February and 19 March (resident group) and between 2 and 6 March (ski group). In view of the shape of the epidemic curve of resident cases, these were further divided into 'early cases' (with disease onset in February) and 'late cases' (with onset in March).

Dose–response model

After having established that consumption of one type of community water (A) was associated with illness and that there was a dose response among schoolchildren, the ED_{50} (effective dose 50%) was calculated from a logistic regression model for the water consumption data for schoolchildren. The exposure was the average amount of water drunk per day (5–6 March) and the outcome was 'being a case'.

Temporal spread of cases in the household

The transmission within the households was described by studying the temporal spread of the dates of onset of symptoms in both types of households (those with community water A and those with water source other than A). For households containing two or more cases, these were classified into primary (with the earliest date of onset) and non-primary (all subsequent cases). The number of days between disease onset in the primary case and non-primary cases (time lag) was calculated and compared between both types of households. In households with co-primary cases, only one of them was chosen as primary case.

Statistical methods

Exposure-specific attack rates and relative risks (RR) with Taylor 95% confidence intervals (CI) were calculated using Epi-Info 6.04 (Centre for Disease Control, Atlanta/World Health Organisation, Geneva).

A Mann–Whitney test was used to compare time lags from index cases. All reported *P* values are two-sided and calculated by Fisher's exact method. The software used was SAS version 8 (SAS Institute, Cary, USA).

Microbiological studies

Stool samples obtained from schoolchildren and visitors were tested for NLV by electron microscopy (EM) and RT–PCR. Water samples obtained from the school were tested for *Escherichia coli* and other indicator bacteria (cultures) as well as NLV (RT–PCR).

RESULTS

Epidemiological studies

Survey responses

Information was gathered for 58 schoolchildren (response = 96·7%). In the resident study, a total of 165/214 (77%) heads of family returned completed questionnaires. The questionnaire from one household was very incomplete and therefore rejected. In addition two families had been away for longer than 1 week during the study period and were therefore excluded from the study. This left us with 162 families and 387 individuals (64% of population) in our study. Ninety-six of 107 (89·7%) ski participants returned completed questionnaires.

Descriptive study

There were 23, 115 and 37 cases among schoolchildren, residents and skiers, respectively. The ARs were 39·7% for schoolchildren (42·8% and 35·3% for girls and boys respectively); 29·7% for residents (30·5% and 28·9% for females and males, respectively) and 38·5% for skiers (55·5% and 36·8% for females and males, respectively). The epidemic curve showed a clear peak for the residents, with most cases occurring during the last week of February, but the curve drops abruptly in March. All pupils became sick within 2 days after returning to school (Fig. 1). The majority (93·7%) of cases from the ski group became sick within 3 days after arriving at the village.

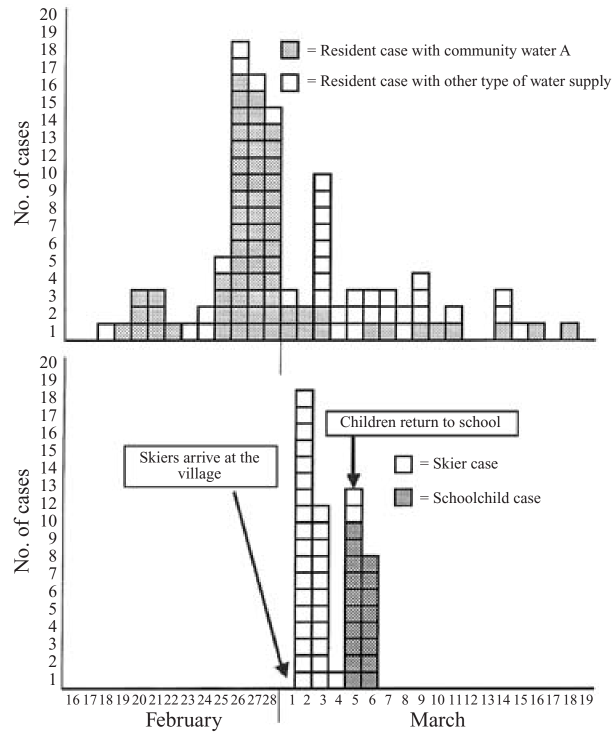

Fig. 1. Date of onset of cases of gastroenteritis among residents ($n = 106$) (top panel), schoolchildren ($n = 18$) and skiers ($n = 32$). Transtrand NLV waterborne outbreak, Sweden, February–March 2002.

Symptoms

Symptoms among schoolchildren included vomiting (91%), stomach pain (86%), diarrhoea (83%), headache (65%), fever (56%), and muscle/body pain (22%). Symptoms among resident cases included diarrhoea (74%), vomiting (70%), abdominal pain (54%), headache (35%), muscle/body pain (29%), and fever (26%). Among the residents there was a marked variation in the distribution of symptoms among by age group (Table 1). There was a trend of decreasing frequency of vomiting with increasing age. Headache was more prevalent among the 10–39 year-old group (54–60%) and lowest among the 50–59 year-old group (10%), whereas abdominal pain was reported most frequently by the 20–39 year-old group (69–80%) and least frequently by the 40–49 and over 70 year-old group (38% in each). Symptoms in the ski group were similar to those found in the 20–59 age resident groups (data not shown).

Analytical study

Among schoolchildren, ARs were higher among those who drank water from the school (RR = 2·6; 95% CI = 1·0–6·5). Other exposures like eating food items

Table 1. *Distribution of symptoms among resident cases by age agroup (n = 113). Transtrand NLV waterborne outbreak, Sweden, February–March 2002*

Age group (years)	No. people	Diarrhoea (%)	Vomiting (%)	Abdominal pain (%)	Headache (%)	Muscle/body pain (%)	Fever (%)
0–9	18	67	94	44	17	6	39
10–19	13	54	92	54	54	31	23
20–29	16	75	88	69	56	31	31
30–39	15	100	67	80	60	40	13
40–49	16	63	56	38	19	38	25
50–59	10	70	50	50	10	10	10
60–69	16	81	56	56	31	44	31
Over 69	8	88	37	38	25	25	25
Total	112	74	70	54	35	29	26

Table 2. *Attack rates according to food, drink and other school exposures for schoolchildren (n = 53). Transtrand NLV waterborne outbreak, Sweden, February–March 2002*

	Exposed			Not exposed					
Exposures	Cases	Total	AR	Cases	Total	AR	RR	95% CI	% cases exposed
Water	18	33	52·3	4	19	17·6	2·6*	1·0–6·5	81·2
Milk	19	46	41·3	3	5	60·0	0·5	0·0–4·0	86·4
Gymnastics 5 March	23	48		0	3	0	NC†	—	100
Shower 5 March	20	41	48·8	3	10	30·0	1·6	0·6–4·8	86·9
Lunch 5 March									
Fish	21	43	48·8	0	5	0	NC	—	100
Potatoes	20	44	45·5	1	3	33·3	1·4	0·3–7·0	95·2
Raw vegetables	6	16	37·5	14	30	46·7	0·8	0·4–1·7	30
Dessert	5	11	45·5	15	36	41·7	1·1	0·5–2·3	25
Lunch 6 March									
Rice	20	43	46·5	2	5	40·0	1·2	0·4–3·6	90·1
Bread	21	45	46·7	1	4	25·0	1·9	0·3–10·5	95·4
Ham	11	23	47·8	11	26	42·3	1·1	0·6–2·1	50
Sausage	10	19	52·6	12	29	41·4	1·3	0·7–2·3	45·5
Whey cheese	5	9	55·5	16	38	42·1	1·3	0·7–2·6	23·8

* Statistically significant 95% confidence level.
† NC, not calculated.

served in the school canteen, having a shower at the school or having attended the class of gymnastics were not associated with the development of illness (Table 2).

Persons living in a household connected to community water A had higher ARs than those with other water supplies. The ARs were higher among people living in households with 3 and 4 persons (Table 3). Stratification of household size by type of water supply revealed that all households of 5–7 persons had their own well (data not shown). A logistic regression model fitted with the variables 'having community water supply A', 'living in a household of 3' and 'living in a household of 4' showed that only community water supply A and living in a household of 4 were significant independent risk factors (adjusted odds ratios, OR = 16·7; 95% CI = 9·6–30·1 and OR = 2·4; 95% CI = 1·3–4·6, respectively).

For the ski group, the AR for those staying in a guesthouse served by water supply A was 57·5% (23/40), compared to 25·5% (14/55) for those staying in a guesthouse served by other water systems (RR = 2·3; 95% CI = 1·3–3·8).

Dose–response

For schoolchildren, the probablity of illness increased with the amount of water consumed at the school (χ^2 for linear trend = 8·6; P = 0·003), but not for residents

Table 3. *Attack rates according to sex, age, household size and type of water among residents (n=387). Transtrand NLV waterborne outbreak, Sweden, February–March 2002*

	Case	Total	AR (%)	RR	95% CI
Sex					
Female	58	188	30·8	1·1	0·8–1·5
Male	54	187	28·9	Ref	—
Age (years)					
0–19	32	100	32	1·5	0·7–3·1
20–49	47	134	35·1	1·6	0·8–3·3
50–69	26	92	28·3	1·3	0·6–2·8
70–89	7	33	21·1	Ref	—
Household size					
1	11	43	25·6	Ref	—
2	25	100	25·0	1·0	0·5–1·8
3	31	75	41·3	1·6	0·9–2·9
4	37	99	37·4	1·5	0·8–2·6
5–7	11	68	16·2	0·6	0·3–1·3
Source of domestic water					
Comm water A	74	101	73·3	6·4*	3·9–10·7
Comm water B	18	88	20·4	1·8	0·9–3·4
Comm water C	4	31	12·9	1·1	0·4–3·2
Other type	5	41	12·2	1·1	0·4–2·8
Own well	14	123	11·4	Ref	—

* Statistically significant 99% confidence level.

living in households served by water supply A (water drank at home) (χ^2 for linear trend = 1·7; P = 0·2) nor for the skiers (χ^2 for linear trend = 0·29; P = 0·6). The ED_{50} (effective dose 50%) for schoolchildren was 1·25 glasses; 95% CI = 0·6–1·9, equivalent to 250 ml; 95% CI = 116–380 ml (Fig. 2).

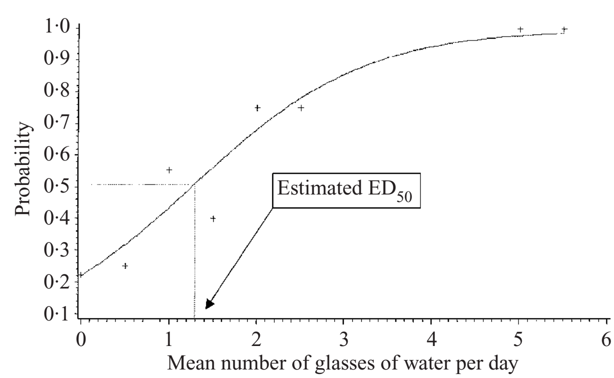

Fig. 2. Dose–response for the average number of glasses of water drunk per day among schoolchildren at the school. Outcome = probability of being a case (n = 50). Transtrand NLV waterborne outbreak, Sweden, February–March 2002.

Risk factors for early and late cases

Table 4 shows the ARs by type of water supply (water system A compared to water systems other than A) for early and late cases. The RR for illness for those having water supply A decreased from 17·4 (95% CI = 9·0–33·9) for early cases down to 3·2 (95% CI = 1·8–5·6) for late cases. Having community water supply A explained 86% of early cases but only 34·1% of late cases. No dose response was found for early or late cases analysed separately (data not shown).

Temporal spread of cases in the household

For households connected to water supply A, the median time lag between non-primary and primary cases was 1 day (interquartile range = 0–4). For households with water supply other than A the median value of the time lag was 6 days (interquartile range = 2–7). In these households, only 2/14 (14%) non-primary cases had occurred within 1 day after onset in their respective primary cases. We concluded that non-primary cases from households served by community water supply A occurred earlier after primary cases compared to those served by other water supplies (P = 0·006).

Estimation of the magnitude of the outbreak

The questionnaire for the residents also inquired about lodgers during the outbreak period. For visitors

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Table 4. *Attack rates for early and late resident cases by type of water supply. Transtrand NLV waterborne outbreak, Sweden, February–March 2002*

Type of water	Cases	Total*	AR	RR	95% CI	% cases exposed
	Early cases					
Comm water A	56	101	55·4	17·4	9·0–33·9†	86·1
Water other than A	9	283	3·5	Ref	—	13·9
Total	65	384	16·9			100
	Late cases					
Comm water A	14	45	31·1	3·2	1·8–5·6§	34·1
Water other than A	27	277	9·7	Ref	—	65·8
Total	41	322	12·7			

* All study population with known date of onset.
† Statistically significant 99% confidence level.
‡ Late cases plus non-cases.
§ Statistically significant 95% confidence level.

to the area an AR similar to that of the ski group (38%) was assumed. From these responses, together with the assumed incidence in non-responders, it could be estimated that 500 people were ill in the outbreak. This is a conservative estimate, since it assumes that the non-respondents did not lodge any guests and does not take into account visitors staying in the two local hotels, for which there are no available data.

Microbiological studies

Nine of 12 faecal samples analysed tested positive for NLV by EM and RT–PCR. In addition, water samples tested negative for coliforms, *E. coli*, sulphite-reducing clostridia, faecal streptococci, heterotrophic bacteria and *E. coli* phages. RT–PCR tests for NLV in the water were inconclusive.

DISCUSSION

The present study describes a large NLV waterborne outbreak associated with the consumption of communal drinking water that may have affected over 500 people. The epidemiological findings, the laboratory analysis of the faecal samples and the later discovery of a technical failure in the sewage pipe, are all factors which are consistent with a NLV waterborne outbreak. The epidemiological study of the outbreak was facilitated by the fact that the village was served by independent water distribution systems and ARs for different water sources could be compared. The similar (high) attack rates in all age groups is also typical of a community waterborne aetiology. In spite of the lack of microbiological findings in the water vehicle, the outbreak can be categorized as 'strongly associated with water' according to the classification devised by Tillett et al. [11].

No other exposures were suspected to confound this association (i.e. closeness to the village centre), since households served by the different water supplies were part of the same urban area (with the possible exception of those with a well, which were few and tended to live further away from the centre).

Recall biases are common in the investigation of waterborne outbreaks [12]. In the resident group we cannot rule out some biased responses leading to a better dose-response relationship as a result of the boil notice in the village, which was posted as early as the first week of March. And yet, no dose–response relationship was found in this group. Conversely we did not suspect a recall bias in the schoolchildren group. They did not reside in the area and we could confirm that the school managers were unaware of the boil water notice. Indeed, un-boiled tap water was available for the children at the school. Moreover, questions about water consumption were buried among other food exposures.

Four school cases replied that they had not drunk tap water. We investigated this further and found out that these students had attended a lesson of 'home economics' where they had been learning to dilute syrup to prepare refreshments using tap water.

The high ARs among those exposed to water from system A (73·3% in the population cohort) is consistent with ARs found in experimental studies, where 68% of exposed volunteers were found to develop illness [13]. In our study, 26·7% of the population did not develop illness, in spite of having consumed presumably contaminated tap water. It has been shown that for NLV infections some people seem to show a natural resistance to the disease, even after direct challenge [14].

A dose–response was detected among the school group, but not among any of the other two groups served by communal water A, in spite of their larger sizes. This discrepancy may be partly explained by the fact that only 63% of the children drank water from the school, whereas in the resident cohort all but five people answered positively that they had drunk un-boiled water from home. Given that the contaminated water was available at home for a longer period, it is conceivable that they also drank a much larger total amount compared to the schoolchildren. Likewise, it is also conceivable that the ski group drank water from different sources and in larger quantities as a result of their physical exercise. Skiers who drank from the area reported drinking a median of eight glasses of un-boiled water (=1·6 litres) per day.

In most Swedish households, unlike in other European countries, drinking tap water is considered to be safe. It is estimated that about 96% of Swedes drink regularly tap water from their household [15]. Information about households that switched to drinking bottled water or that paid heed to the water boil notice was regrettably not gathered, and questions were only asked about consumption of un-boiled water.

An interesting but explainable finding was that cases of households served by water system A tended to fall sick within a shorter period compared to those living in households with other water supplies, reflecting differences in the availability of the infectious source. It is likely that people living in households served by non-contaminated water had the opportunity to become infected through drinking water through visits to friends, relatives or by working in-places which may have been connected to water supply A, as well as through person-to-person transmission.

Although most members of individual households became sick almost simultaneously, not all households served by water supply A were affected necessarily on the same days. A possible explanation may be that the contaminated water reached different households at different times, probably reflecting low contamination levels in the water. One may hypothesize that only marginal increases in the contamination may have been sufficient to trigger sickness in a given household. These low levels of contamination may also explain the negative bacteriological and virological results in the water samples. At the time of writing this article, techniques for detecting viruses in environmental samples are still in an early stage of development. Only few papers have reported the successful detection of NLV in water [4, 16].

The analysis performed dividing cases into early and late shows that water system A remained a risk factor throughout, suggesting that the water was contaminated over a prolonged period of time, and is consistent with anecdotal evidence of visitors to the area falling sick well until the end of March. Our study shows that among village residents, the water-borne route of transmission may have been more important during the first period (February) whereas person-to-person transmission may have become more important in the second period (March) of the outbreak.

The relatively large sample size of the populations surveyed allowed the study of the clinical differences across age groups. A high frequency of vomiting among cases has been used as a rudimentary indication to suggest NLV as the aetiology of an outbreak of gastrointestinal disease. In our study, vomiting was more prevalent in younger age groups, a finding consistent with previous studies [17]. However this proportion drops to levels of below 40% among the oldest age group. One of the explanations for this low frequency may be a low sample size in this age group (eight individuals). A frequency of vomiting over 50%, one of the four Kaplan criteria [18], is commonly used for recognizing NLV outbreaks in the field. Hedberg and Osterholm [2] suggested that the increased frequency of vomiting in relation to fever may be a better criterion for distinguishing outbreaks caused by NLV from those caused by bacteria. In our study this ratio ranged from 5·1 in the 30–39 year-old age group to just about 1·5 in the over 70 year-old age group.

The described outbreak highlights a problem that is all too common in viral food- or waterborne outbreaks, namely a strong statistical association that implicates the vehicle of infection (in this case the water), but a lack of success by the laboratory in detecting the pathogen in the suspected vehicle. Most routine laboratory testing of water relies on the detection of 'indicator bacteria' as a proxy for 'sewage contamination'. It has been shown, however, that these indicators do not have an unequivocal correlation with the presence of enteric viruses in ground water [7].

The apparent potability of the water, when 'indicator bacteria' are absent, creates an additional difficulty in persuading environmental authorities of the convenience of carrying out a more vigorous public health intervention (i.e. chlorination of the communal water supply). We believe that at least one-third of the cases, including disease in schoolchildren, could have been prevented if preventive recommendations at the early stages of the investigation had been more thoroughly followed. The boil water notice, issued during the first week of March was not sufficiently adopted, as demonstrated by the subsequent occurrence of cases among schoolchildren, skiers and visitors. The effective conveyance of this preventive message to the visitors was indeed hampered by their high turnover, but sporadic cases in the community also occurred since then. The water was not chlorinated until mid-April, when videofilming of a sewage pipe by the environmental authorities revealed a sizeable crack located 10 m from one of the wells supplying water to water system A. Until then, the authorities had opposed to chlorination of the water due to lack of conviction of the waterborne nature of the outbreak and the general reluctance of the population to regular chemical treatment of the water supplies.

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