Norovirus outbreak among primary schoolchildren who had played in a recreational water fountain

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Background. A gastroenteritis outbreak was associated with playing in a norovirus-contaminated recreational fountain.

Objective and study design. A retrospective cohort study was performed to estimate the magnitude of the outbreak and identify its source. Epidemiological investigation included standardized questionnaires about sex, age, school, class, risk exposures, and illness characteristics. Stool samples and environmental water samples were analyzed for the presence of bacteria, viruses, and parasites.

Results. Questionnaires were returned for 191 schoolchildren (response rate, 83%) with a mean age of 9.2 years, of whom 47% were ill (diarrhea and/or vomiting). Children were more likely to have been ill if they had played in the recreational fountain (relative risk, 10.4). Norovirus (Birmingham) was detected in 22 (88%) stool specimens from ill children and in 6 (38%) specimens from healthy children. The water sample from the fountain contained a norovirus strain that was identical to the RNA sequence found in stools.

Conclusions. Recreational water may be the source of gastroenteritis outbreaks. Adequate water treatment can prevent these types of outbreak.

In recent years, noroviruses (previously designated as "Norwalk-like viruses" or "small round-structured viruses") have emerged as an important cause of food- and waterborne gastroenteritis outbreaks [1]. Reported waterborne outbreaks caused by norovirus have been associated with private wells, small water systems, and community water systems [2–7]. Recreational surface water, including lakes and swimming pools, has also been associated with norovirus outbreaks [8–10]. However, recreational fountains have so far been associated with gastroenteritis outbreaks caused by Shigella and Cryptosporidium species but not by norovirus [11, 12].

In the present article, we describe the investigation of the first outbreak caused by norovirus among schoolchildren who played in a recreational fountain. On a hot summer day in June 2002, ~200 children in 3 primary schools had their annual preholiday school outing at a playground. Two days later, the principals of the schools informed the Dutch Municipal Health Service that ~100 children had symptoms of vomiting, diarrhea, abdominal pain, and headache. Food was not a probable cause of the illness, because most children had eaten their own homemade lunches. The only common food exposure was commercially packaged ice cream, purchased at the playground by most children. One common source of water exposure was a recreational fountain (figure 1). In addition, some children might have drunk from a water tap close to the fountains and inside the sanitary facility. The inside and outside water taps both contained regular drinking water.

All parents of ill children were given information about hygiene, risk of dehydration, and the application of oral rehydration solution. In addition, a retrospective cohort study was performed to estimate the magnitude of the outbreak among these schoolchildren and to identify its source.

METHODS

Epidemiological investigation. All 3 schools reporting ill schoolchildren had taken part in a visit to a

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playground, featuring a recreational fountain, on 18 June. A retrospective cohort study was conducted among the 231 Dutch children attending the 3 primary schools who had visited the playground that day (referred to below as playground children). Standardized questionnaires were sent to their homes to obtain information about sex, age, school, class, possible risk exposures (playing in or drinking from the fountain, drinking from water taps, or eating ice cream), the onset and nature of symptoms, the duration of illness, contact with a general practitioner or hospital, and prior illness. A primary case was defined as illness in any child or adult who had visited the playground and who had developed diarrhea (≥3 loose stools in any 24-h period) or vomiting (at least 1 episode) or both within 72 h after the visit. An exposed child was defined as a child who had played in the recreational fountain at the playground.

Six weeks after the first questionnaire was sent out, we sent a second questionnaire to all children’s homes to obtain details about family size and possible secondary cases caused by person-to-person transmission. A secondary case was defined as illness in any child or adult—within a family with a playground child—who had not visited the playground and who had experienced diarrhea (≥3 loose stools in any 24-h period), vomiting (at least 1 episode), or both during the 6-week period after the visit. This 6-week period was chosen because the duration of virus shedding can be long and there might be even tertiary waves of cases [13]. We calculated relative risks (RRs) with 95% confidence intervals (CIs) to assess any association between illness and individual exposure factors. The secondary attack rate was calculated as the number of secondary cases divided by the total number of household members, excluding playground children.

Environmental investigation. Two days after the visit, on the day of the notification, the playground was visited so that an environmental assessment could be conducted. Hygiene policies and procedures were reviewed. The recreational fountain covers an area of ∼40 m², in which ∼40 jet spray nozzles squirt water jets whose height varies over time. Children playing in the fountain—frequently in underwear—are completely soaked by the water. The fountain system uses recirculated water that drains from the wet play floor into an underground reservoir. A filter is used for coarse materials like sand, grass, and hair, and part of the water is subjected to sand filtration. The reservoir water is manually chlorinated using hypochlorite tablets, and no continuous water analysis is performed to check chlorination levels. The reservoir is replenished with tap water each day, to compensate for water losses. The nearby water taps provide drinking water.

Environmental samples (100 mL) of the recreational fountain water and the drinking water were obtained for bacterial analysis according to the European recreational and drinking water guidelines, respectively. The water samples were cultured for coliform bacteria, *Escherichia coli*, and *Enterococcus, Salmonella,*
Table 1. Overview of general information per primary school during an outbreak of gastroenteritis.

<table>
<thead>
<tr>
<th>General information</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated no. of schoolchildren on day trip</td>
<td>85</td>
<td>84</td>
<td>62</td>
<td>231</td>
</tr>
<tr>
<td>No. (%) of responding schoolchildren</td>
<td>59 (69)</td>
<td>74 (88)</td>
<td>58 (94)</td>
<td>191 (83)</td>
</tr>
<tr>
<td>No. of households related to responding schoolchildren</td>
<td>56</td>
<td>48</td>
<td>56</td>
<td>160</td>
</tr>
<tr>
<td>Age, mean years (range), of schoolchildren</td>
<td>9.6 (8–11)</td>
<td>8.7 (4–12)</td>
<td>9.4 (8–10)</td>
<td>9.2 (4–12)</td>
</tr>
<tr>
<td>Female, %</td>
<td>51</td>
<td>57</td>
<td>52</td>
<td>53</td>
</tr>
<tr>
<td>Duration of stay at playground, h</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>4.8</td>
</tr>
<tr>
<td>Individual duration of playing in recreational fountain, h</td>
<td>0.5–2</td>
<td>2.5</td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Households responding to second questionnaire, % (no. responding/no. contacted)</td>
<td>64 (36/56)</td>
<td>75 (36/48)</td>
<td>70 (39/56)</td>
<td>69 (111/160)</td>
</tr>
<tr>
<td>No. of persons in family, mean</td>
<td>4.1</td>
<td>3.9</td>
<td>4.1</td>
<td>4.0</td>
</tr>
</tbody>
</table>

and *Campylobacter* species, by standard culture methods. In addition, large volumes (300 L) of drinking and recreational water were concentrated for rotavirus and norovirus detection by polymerase chain reaction (PCR) [14]. Commercially packaged ice cream sold at the playground was also obtained for microbiological investigation but was not examined any further after the cause of the outbreak became clearer. In consultation with the manager of the playground, the recreational fountain and water taps were closed on the day of sampling until further research had clarified the cause of the illness. The water reservoir was emptied and disinfected.

**Laboratory investigation.** Stool specimens were collected 3–6 days after the playground visit and were cultured for *Salmonella*, *Shigella*, and *Campylobacter* species, *Yersinia enterocolitica*, enterohemorrhagic *E. coli* (O157), and *Staphylococcus aureus*, by standard culture methods. A random sample of isolates of *E. coli* was serotyped. Fecal smears were examined by direct microscopy for ova and parasites, including *Cryptosporidium* and *Giardia* species. Fecal examination of a random selection of 11 second samples was performed for *Giardia* species, because it was expected that more positive samples would be detected after 3 weeks if *Giardia* species were the cause of the outbreak. Stool samples were examined for rotavirus and adenovirus by commercially available ELISA kits, and RNA amplification by reverse-transcription (RT) PCR was used to test for astrovirus and caliciviruses (i.e., noroviruses and sapoviruses), as described elsewhere [15], using primers JV12Y/JV13I [16]. The initial results indicated the presence of norovirus genotype Birmingham in some fecal samples. Because it has been found that this genotype is difficult to detect with primers used in routine diagnostic procedures, we used an alternative RT primer and designed a specific primer for the PCR, designated NVp110 [17] and JV12BH (5′-GTT TCA TTA TGA TGC TGA TGA TGC TGA CTA-3′), respectively.

**RESULTS**

**Epidemiological investigation.** Questionnaires were returned for 191 schoolchildren (response rate, 83%) and for 1 parent who had accompanied the children on the school trip (table 1). These data represent 160 different households. The mean age of the children was 9.2 years (SD, 1.5 years; range, 4–12 years), and 53% (102/191) were girls. Symptoms of diarrhea and/or vomiting were present in 47% of the children (90/191). No children had
symptoms of diarrhea and/or vomiting before or during the playground visit. The main symptoms among cases were abdominal pain (89%), nausea (78%), vomiting (75%), diarrhea (70%), headache (70%), and abdominal cramps (49%). Only 8% of the children (7/90) had visited a general practitioner, and none had been admitted to a hospital. The onset of symptoms in most children was 1–2 days after the trip (84%). The mean incubation period was 30 h, with a range of 7 h (18 June) to 72 h (21 June; the see epidemic curve in figure 2). The duration of symptoms was known for 67% of the cases. The remainder still had symptoms at the time of completing the questionnaire. The mean duration for those who had already recovered was 1.7 days (SD, 0.8 days; range, 0.5–5 days). This implies that the estimate for all ill children, including those with illness of longer duration (33%), would be higher (at least 2 days).

There was no relationship between developing illness and drinking from the water taps or consumption of ice cream (table 2). However, schoolchildren were more likely to have become ill if they had played in the recreational fountain (RR, 10.4; 95% CI, 1.5–70.8) or had ingested water from it (RR, 2.0; 95% CI, 1.4–3.0). The question as to whether they had ingested the water could not be answered (“unsure”) by 43 (23%) of the children (7/90) had visited a general practitioner, and none had been admitted to a hospital. The onset of symptoms in most children was 1–2 days after the trip (84%). The mean incubation period was 30 h, with a range of 7 h (18 June) to 72 h (21 June; the see epidemic curve in figure 2). The duration of symptoms was known for 67% of the cases. The remainder still had symptoms at the time of completing the questionnaire. The mean duration for those who had already recovered was 1.7 days (SD, 0.8 days; range, 0.5–5 days). This implies that the estimate for all ill children, including those with illness of longer duration (33%), would be higher (at least 2 days).

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### Environmental investigation

No enterococci or *E. coli* bacteria were detected in the drinking water samples taken at the sanitary facility, in compliance with the European drinking water regulations. The sample taken from the recreational fountain, however, had very high bacterial counts that exceeded the standards of the European recreational water guidelines. Numbers of coliform bacteria exceeded the detection limit of 1000 organisms/mL, and enterococci were found at a rate of 3500 organisms/100 mL, whereas the concentration of *E. coli* bacteria was 7700 organisms/100 mL. No *Salmonella*, *Campylobacter*, or rotaviruses were detected in any of the water samples. The presence of norovirus RNA in the fountain water was ascertained using the primer pair JV12BH/NVp110. The sequence of the PCR product derived from the fountain water was identified as norovirus type Birmingham.

### Microbiological results

Stool specimens were available from 25 children who had fallen ill and 16 children without symptoms of diarrhea and/or vomiting. Two stool samples were available from adults: a teacher and a parent who had accompanied the children on the playground trip. All stool samples were negative for bacterial pathogens. Of the 9 fecal specimens cultured for *E. coli*, all showed possible strains of *E. coli*; a random sample of 7 were serotyped. There was no similarity in serotypes: samples with serotypes O7, O45, O86, O88, O141, and O166, and 1 turned out not to be *E. coli*. This outcome

### Table 2. Univariate analyses of risk factors studied in outbreak of gastroenteritis.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Exposed to risk factor</th>
<th>Not exposed to risk factor</th>
<th>RR (95% CI)</th>
<th>Cases exposed to factor, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drank from fountain</td>
<td>25</td>
<td>15</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>Played in fountain</td>
<td>87</td>
<td>80</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Consumption of water from taps near sanitary facility</td>
<td>18</td>
<td>32</td>
<td>68</td>
<td>64</td>
</tr>
<tr>
<td>Consumption of water from taps near recreational fountain</td>
<td>3</td>
<td>4</td>
<td>78</td>
<td>89</td>
</tr>
<tr>
<td>Commercial ice cream</td>
<td>72</td>
<td>76</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Not exposed to risk factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE.** Data are no. of children, except where noted. CI, confidence interval; RR, relative risk.
does not match a common source outbreak and seems to reflect commensal flora.

No parasites were found, except in 4 feces samples that tested positive for *Giardia lamblia*. As shown in table 3, all 4 of these children had been exposed to the fountain, but only 3 developed any illness. Three weeks after the playground visit, 11 stool specimens (4 from healthy children and 7 from primary cases) showed no new infection with *Giardia* species.

Combined results from all PCRs used showed that norovirus was found in 22 (88%) of the samples from ill children, 6 (37.5%) of the samples from healthy children, and 1 of 2 samples from ill adults. All positive samples from the ill children and 5 of 6 positive samples from healthy children had been taken from children who had played in the fountain. The 1 child who tested positive but who had not been exposed and had not become ill was probably infected by his exposed and ill brother (secondary infection). Eleven random norovirus samples were genotyped, 1 as Mikkeli (healthy child), 9 as Birmingham (1 healthy and 8 ill children), and 1 as both Mikkeli and Birmingham (ill child) (figure 3). The Birmingham strain was identical to the strain identified in the recreational fountain water.

### DISCUSSION

**Norovirus outbreak.** This outbreak in children with a clinical profile of abdominal pain, nausea, vomiting, and diarrhea, with an attack rate of 54%, a mean incubation period of 30 h, a duration of illness of ~2 days, and 39 clear secondary cases, fits in well with norovirus. An identical norovirus strain (Birmingham) was detected in stool specimens from ill persons and in a water sample derived from the fountain. It is very unusual that we were able to detect the causative agent in the water, because the source is usually only identified epidemiologically [18]. The duration of playing in the fountain per school suggests a dose-response relation, because the primary attack rate was significantly higher for the school with the longest visit, compared with the school with the shortest visit. The evidence of the source of this outbreak was provided by the complimentary nature of the epidemiological analytical and microbiological findings and was reinforced by the specific norovirus molecular-sequencing analysis in stool specimens and water samples, which shows the great value of these techniques in discovering new relationships.

**Exposure to recreational fountain.** Recreational fountains are becoming more frequent in traditional playgrounds (and in public parks or town centers), because they are very popular among children. Children like to stand directly over the nozzles (jets), so their entire bodies become soaked (figure 1). Recreational water may be at high risk for contamination by enteric pathogens through overt fecal accidents or the rinsing of contaminated bodies in the water. Operators of recreational fountains should monitor levels of effective chlorine and microbiological water-quality indicators routinely. Public health officials should regularly inspect public recreational fountains about these water-quality procedures. European Union guidelines are based on bacterial indicators (general contamination), but these are not always able to detect contamination by viruses—although, in our outbreak, there was bacterial contamination as well. It is not reasonable to routinely monitor for norovirus, because PCR assays are difficult to perform and interpret. Thus, preventive measures should be taken to reduce the risk of contamination, including adequate chlorination of the water and supervision of the chlorination system, the frequent replacement of the water (especially after hot days with heavy use), and the presence of adequate, clean sanitary facilities. An automatic water-handling system was later installed at the recreational fountain described here that maintains continuous chlorination levels of 1.2 mg/L. Chlorine levels are registered in a journal 3 times/day. Procedures to fill the reservoir with fresh water every 2 days are documented and carried out, and microbiological analysis of water samples is performed by an authorized laboratory every 14 days. Additional measures—which would, however, be more difficult to maintain—include forcing visitors to shower at home or at the fountain area before entering the fountain, excluding patients with di-

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**Table 3.** Positive findings from stool sample analysis (43 stool samples tested) from an outbreak of gastroenteritis.

<table>
<thead>
<tr>
<th>Diagnostic assay</th>
<th>Children exposed to fountain</th>
<th>Ill</th>
<th>Healthy</th>
<th>Ill adults exposed to fountain</th>
<th>Total exposed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norwalk PCR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JV12Y/JV13I</td>
<td>6/25 (24)</td>
<td>0</td>
<td>4/36 (11)</td>
<td>0</td>
<td>10/27 (37)</td>
</tr>
<tr>
<td>JV12BH/NVp110</td>
<td>17/71 (24)</td>
<td>0</td>
<td>2/18 (11)</td>
<td>1/20 (5)</td>
<td>19/51 (37)</td>
</tr>
<tr>
<td>All tests combined</td>
<td>22/92 (24)</td>
<td>0</td>
<td>6/45 (11)</td>
<td>1/20 (24)</td>
<td>1/50 (2)</td>
</tr>
<tr>
<td><em>Giardia</em> species</td>
<td>3/13 (24)</td>
<td>0</td>
<td>1/9 (11)</td>
<td>0</td>
<td>4/11 (37)</td>
</tr>
</tbody>
</table>

**NOTE.** Data are no. positive/no. tested (% positive). PCR, polymerase chain reaction.
Figure 3. Phylogenetic comparison of genogroup I noroviruses detected during 2002 in The Netherlands. Sequences derived from 2 representative fecal samples (EP2002109-21 and EP2002109-37) and the water sample from the fountain (EP2002109-water) in the described outbreak were compared with other sequences, using the unweighted pair-group method with arithmetic mean, after multiple sequence alignment of a 250-nt segment of the polymerase gene. EP2002136, EP2002142, EP2002040, and EP2002026 were sequences of the Birmingham291 genotype from fecal samples from different outbreaks before or after the described outbreak. These sequences are similar to but differ slightly from those from the water outbreak. Nos. in the last column indicate the month of detection.

...arrhea, excluding children wearing diapers, and banning food consumption in the fountain area.

Surveillance and mandatory notification. Studies on gastroenteritis outbreaks are regularly conducted in The Netherlands, as they are in many countries. Interim results from a study of gastroenteritis outbreaks in The Netherlands in 2002 showed that ~53% of 119 microbiologically investigated outbreaks were caused by norovirus, and only 1 outbreak—described in the present report—was waterborne. In the United States, 3%–6% of the norovirus outbreaks have been reported to have originated from water consumption. During the 4-year period from 1997 to 2000, 54 waterborne disease outbreaks of gastroenteritis associated with recreational water were reported in the United States [19, 20]. Five (9%) were caused by norovirus and were associated 3 times with lake-water, once with motel pool water, and once with hot springs in a resort. In the United Kingdom, none of the norovirus outbreaks originated from a water source [21]. Prior outbreak surveillance in England and Wales showed that only 1 of 26 waterborne gastroenteritis outbreaks was caused by norovirus; it originated from recreational water sports on a river [22]. In Ireland, only 1 of 67 gastroenteritis outbreaks studied was waterborne (through water consumption) [23].

This shows that recreational waterborne norovirus outbreaks are reported rarely. These outbreaks go easily unnoticed and are most likely underreported because norovirus outbreaks are so common, with >90% caused through person-to-person transmission, that it is very difficult to motivate local authorities to stay alert and investigate them in order to distinguish the food and waterborne outbreaks in an early stage from the bulk of person-to-person outbreaks. Also, in waterborne outbreaks, affected people often do not know each other and do not visit the same general practitioner or school; therefore, connections are easily missed between the different cases. Furthermore, in The Netherlands, as in most European Union countries, the testing capacity for norovirus is not routinely available in the primary diagnosing laboratories that received stool samples from the diarrheal cases. Norovirus outbreaks often show up as the outbreaks that are unexplained by well-known and routinely tested enteric bacteria, some viruses, and protozoa. Confirmation of the outbreak being caused by norovirus fully depends on these laboratories passing on the stools to the 1 or 2 national laboratories that are able to perform norovirus tests [24]. The large outbreak described in the present report would have probably remained undetected if the primary schools had not reported the cases to the Municipal Health Service. This shows the value of the mandatory notification of gastroenteritis clusters by institutions like primary schools. Outbreak investigations are important in public health to identify the source, implement control measures, and prevent future illness; in ad-
dition, they frequently yield new knowledge that may lead to amended control policies. In the outbreak described, the novel source of norovirus was a recreational fountain.

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**References**