Outbreak Management and Implications of a Nosocomial Norovirus Outbreak

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Background. Noroviruses are enterically transmitted and are a frequent cause of gastroenteritis, affecting 23 million people annually in the United States. We describe a norovirus outbreak and its control in a tertiary care hospital during February–May 2004.

Methods. Patients and health care workers met the case definition if they had new onset of vomiting and/or diarrhea during the outbreak period. Selected stool samples were tested for norovirus RNA. We also determined outbreak costs, including the estimated lost revenue associated with unit closures, sick leave, and cleaning expenses.

Results. We identified 355 cases that affected 90 patients and 265 health care workers and that were clustered in the coronary care unit and psychiatry units. Attack rates were 5.3% (7 of 133) for patients and 29.9% (29 of 97) for health care workers in the coronary care unit and 16.7% (39 of 233) for patients and 38.0% (76 of 200) for health care workers in the psychiatry units. Thirteen affected health care workers (4.9%) required emergency department visits or hospitalization. Detected noroviruses had 98%–99% sequence identity with representatives of a new genogroup II.4 variant that emerged during 2002–2004 in the United States (e.g., Farmington Hills and other strains) and Europe. Aggressive infection-control measures, including closure of units and thorough disinfection using sodium hypochlorite, were required to terminate the outbreak. Costs associated with this outbreak were estimated to be $657,644.

Conclusions. The significant disruption of patient care and cost of this single nosocomial outbreak support aggressive efforts to prevent transmission of noroviruses in health care settings.

Noroviruses, formerly known as the “Norwalk-like viruses,” are an important cause of gastroenteritis worldwide, with an estimated 23 million cases annually in the United States [1, 2]. The association of noroviruses with gastroenteritis outbreaks in health care facilities is well documented [3, 4]. Nosocomial outbreaks caused by noroviruses are particularly difficult to control because of their stability in the environment and efficient transmission by person-to-person contact, exposure to contaminated fomites, or inhalation of infectious particles from vomitus aerosols [4–8]. Recent data from England demonstrate that norovirus outbreaks result in significant cost to health care institutions [9].

Noroviruses are classified into genogroups, which are further subdivided into genotypes or genoclusters [10]. Genogroups GI and GII account for most human outbreaks, although the rarer GIV noroviruses infrequently infect humans [11–14]. During 2002, there was a sharp increase in reports of norovirus-associated outbreaks worldwide [15–17]. Most of these outbreaks occurred in long-term care facilities, schools, and restaurants and were caused by a previously unrecognized variant of the GII, genotype 4 (GII.4) norovirus, the prototype strain of which was collected in Farmington Hills, MI [18, 19]. Among reported norovirus outbreaks in the United States, 45% were associated with this new GII.4 variant [16, 20].

In early 2004, the Maryland Department of Health and Mental Hygiene (Baltimore, MD) became aware of outbreaks of norovirus within the city of Baltimore. A total of 24 norovirus outbreaks were reported through
out Maryland from February through June 2004 (L. Edwards, personal communication). This report describes the epidemiologic and virologic characteristics of 1 such outbreak in a tertiary care hospital and provides cost analysis of the outbreak. We also detail our prevention and control measures, which we believe terminated the outbreak within the institution.

METHODS

Setting. Johns Hopkins Hospital (JHH) is a 946-bed tertiary care hospital in Baltimore, Maryland, serving as a referral center for the Mid-Atlantic region. The coronary care unit (CCU) is a 25-bed unit consisting of 10 critical-care and 15 intermediate-care beds in private rooms. The cardiac surgery intensive care unit (CICU) is a 16-bed critical-care unit where postoperative cardiac patients are treated. Tests for adult patients throughout the hospital are performed in the echocardiogram laboratory, which is located close to the CCU. Echocardiogram technicians perform studies in the CCU on a daily basis. The psychiatry units are located in a building that is separate from but connected to the CCU.

Outbreak investigation. JHH Hospital Epidemiology and Infection Control (HEIC) was notified on 13 February 2004 of 2 CCU HCWs who had acute gastroenteritis. Because community and hospital outbreaks due to noroviruses had already been recognized in the Baltimore region, an outbreak investigation was initiated.

A case was defined as occurring in a JHH patient or HCW with new onset of vomiting or diarrhea from January through May 2004. Vomiting was defined as any episode of emesis, and diarrhea was defined as ≥2 loose stools in a 24-h period or an unexplained increase in the number of bowel movements. This definition was purposefully broad in an attempt to capture all cases and was similar to that used in other investigations [15, 16, 21].

Active surveillance was initiated in the hospital on 13 February 2004. Nurse managers were instructed to screen all patients and staff for any symptoms of gastrointestinal illness. HEIC infection control professionals also performed case-finding with daily rounds in all units and emergency departments. For each potential patient, a standard questionnaire recorded information about type, onset, and duration of symptoms, exposure to ill persons, and, for HCWs, whether they reported to work while sick. All potential patients were interviewed by HEIC staff during or after the outbreak to verify accuracy of the recorded information.

Microbiologic methods. Stool samples from patients were sent to the Maryland Department of Health and Mental Hygiene and the National Institutes of Health laboratories to identify the outbreak agent and to determine its nucleotide sequence. Both laboratories performed RNA extraction, reverse transcription, and PCR for noroviruses, as previously described [18, 22]. Nucleotide sequences (GenBank accession no. DQ658413) were determined at the National Institutes of Health from overlapping PCR-amplified cDNA for the complete genome, except the 5′ terminus, which was 5′ RACE System (Invitrogen) amplified. Nucleotide sequences were compared with those of other noroviruses using BioEdit and ClustalX software [23].

Economic analysis. The economic analysis focused on institutional costs of the outbreak. All census and cost information were from the JHH Casemix administrative database (JHH Department of Casemix Information Management). The financial impact associated with the outbreak was calculated by including estimated total lost revenue associated with closure of units to new admissions, attributable sick leave and overtime salary, cost of replacing supplies, and cleaning expenses. The analysis was limited to the CICU, psychiatry units, and echocardiogram laboratory, where nosocomial transmission was strongly suspected. For each cardiac and psychiatry unit, the estimated lost revenue was calculated by multiplying estimated total patient-days lost by median daily revenue with interquartile ranges (IQRs). Outbreak periods were defined as 9–26 February 2004 (weeks 6–8) for the cardiac units and 16 February–23 April 2004 (weeks 7–16) for psychiatric units. Cases occurred throughout the hospital, but the economic analysis only included the units where admissions were limited.

Data analysis and statistical analysis. Survey data were entered and stored in an Excel spreadsheet (Microsoft). All data and statistical analyses were performed using Stata software, version 8 (Stata) [24].

RESULTS

Description of the outbreak. From 7 January through 1 May 2004 (weeks 1–17), 265 HCWs and 90 patients met the case definition (figure 1). A bimodal distribution of cases occurred primarily in the psychiatry wards. Although infected HCWs and patients were identified throughout the hospital, most were clustered in several locations, including the CCU, echocardiogram laboratory, and psychiatric wards. Nosocomial transmission was suspected in these locations because of the clustering of cases. The other infected HCWs and patients were identified throughout the hospital, including in the pediatric, adult medicine, psychiatry, emergency, oncology, surgery, and radiology departments.

On average, HCWs were younger than patients, with mean ages (±SD) of 36.2 ± 10.4 years and 45.5 ± 23.4 years, respectively (table 1). Of the affected HCWs, 83.8% were female, and 47.8% of the patients were female. By definition, all infected HCWs and patients had diarrhea or vomiting, but nausea and abdominal cramps were common symptoms among both HCWs and patients. Nearly 50% of HCWs reported fever (42.2%), chills (39.2%), or myalgia (55.7%). Symptoms lasted
for a mean duration (± SD) of 3.2 ± 1.4 days and 3.7 ± 3.2 days for HCWs and patients, respectively. Thirteen (4.9%) of the 265 HCWs required emergency department visits (n = 9) or hospitalization (n = 4) for intravenous hydration.

**CCU.** On 13 February 2004 (week 6), >20 cases were identified among HCWs, with multiple potential sources and modes of spread (figure 1). One of the first infected HCWs to be identified vomited in the CCU bathroom, which was shared by the entire staff. Another early infected HCW vomited into one of the trash baskets in the unit. Part of this HCW’s job included filing paperwork in all of the patient charts. Food was frequently brought into the staff lounge for communal consumption. In addition, a patient was transferred from an outside hospital to the CCU with gastrointestinal symptoms on 9 February 2004.

Overall, CCU attack rates were 5.3% (7 of 133) for patients and 29.9% (29 of 97) for HCWs. The epidemic curve was consistent with a single-exposure outbreak involving person-to-person transmission. After 26 February 2004 (week 8), no additional cases were observed in the CCU. A total of 456 h of sick leave were used during February.

**Echocardiogram laboratory.** Nine (75%) of 12 members of the echocardiogram staff met the case definition for gastroenteritis within a similar time frame as the outbreak in the CCU. Six of the 9 affected staff members became ill within 1 week after the CCU staff became ill. Because of staffing shortages and concern for nosocomial transmission from HCWs to patients, 148 tests were not performed in the appropriate time frame, although all were completed at a later date. Employees used a total of 138 h of sick leave and 18.5 h of overtime.

**Psychiatry units.** Cases were initially identified in February (week 6), temporarily subsided, and resumed in mid-March (week 11), possibly representing 2 distinct outbreaks from 2 separate sources (figure 1).

During mid-March (week 11), 1 HCW and 4 patients with gastrointestinal symptoms were reported to HEIC. The HCW had symptoms prior to the patients and may have transmitted the infection in the unit. Despite implementing routine infection-control measures, including contact isolation for ill patients and use of hand hygiene, more cases occurred. Seventeen additional cases were identified during subsequent weeks, with the last cases being noted on 22 April and 23 April (week 16) in HCWs and patients, respectively. Attack rates were 16.7% (39 of 233) for patients and 38.0% (76 of 200) for HCWs. In the psychiatry units, HCWs used 2029 h of sick leave or overtime during the outbreak period.

**Molecular typing.** Maryland Department of Health and Mental Hygiene detected noroviruses in 2 of the 10 tested samples. Both viruses had ORF1 "region B" nucleotide sequences identical to that of the GII.4 Farmington Hills strain collected in Michigan in 2002 (R. Myers, personal communication) [3]. One of 6 additional stool specimens, which was analyzed independently at the National Institutes of Health, contained a norovirus. Complete genome analysis confirmed that the outbreak strain, designated MD-2004, belonged to genogroup II.4. The MD-2004 nucleotide sequence is 98%–99% identical to those of the Farmington Hills strain and other new-variant norovirus GII.4 viruses that circulated in the United States and Europe during 2002–2004 but is distinct (93% identical) from that of GII.4 strain MD-145, the predominant Maryland norovirus during 1987–1988 [18].

**Termination of the outbreak.** Multiple infection-control measures were implemented throughout the hospital to prevent additional transmission as soon as the outbreak was identified on 13 February 2004. HCWs were educated about the symptoms of norovirus gastroenteritis, appropriate cleaning measures, and isolation protocols for symptomatic patients. Symptomatic HCWs were instructed not to report to work and furloughed for 72 h after their last symptoms. Initial interventions included reinforcement of standard precautions and contact isolation of patients with gastrointestinal symptoms. Patients were placed in private rooms or were cohorted together.

In the emergency department, all patients with gastrointestinal symptoms were cohorted in a designated section to minimize nosocomial transmission.

Frequent hand hygiene with either soap and water or alcohol-based hand gel was heavily emphasized. Because the outbreak affected the entire city, HCWs practicing in other institutions were not allowed to care for patients at JHH. At a nearby

### Table 1. Demographic characteristics and symptoms of gastroenteritis in health care workers (HCWs) and patients.

<table>
<thead>
<tr>
<th>Variable</th>
<th>HCWs (n = 265)</th>
<th>Patients (n = 90)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean years ± SD</td>
<td>36.2 ± 10.4</td>
<td>45.5 ± 23.4</td>
</tr>
<tr>
<td>Duration of symptoms, mean days ± SD</td>
<td>3.2 ± 1.4</td>
<td>3.7 ± 3.2</td>
</tr>
<tr>
<td>Female sex</td>
<td>83.8</td>
<td>47.8</td>
</tr>
<tr>
<td>Symptom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td>89.7</td>
<td>93.1</td>
</tr>
<tr>
<td>Vomiting</td>
<td>63.6</td>
<td>52.0</td>
</tr>
<tr>
<td>Nausea</td>
<td>88.1</td>
<td>56.8</td>
</tr>
<tr>
<td>Abdominal cramping</td>
<td>78.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Bloody stools</td>
<td>2.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Fever</td>
<td>42.2</td>
<td>32.4</td>
</tr>
<tr>
<td>Headache</td>
<td>58.0</td>
<td>29.4</td>
</tr>
<tr>
<td>Diaphoresis</td>
<td>32.9</td>
<td>18.5</td>
</tr>
<tr>
<td>Chills</td>
<td>59.2</td>
<td>24.2</td>
</tr>
<tr>
<td>Myalgia</td>
<td>55.7</td>
<td>28.6</td>
</tr>
</tbody>
</table>

**NOTE.** Data are percentage of subjects, unless otherwise indicated. All of the HCWs and patients characterized in this table met the case definition for the norovirus outbreak. SD, standard deviation.
hospital, a gastroenteritis outbreak involving staff and patients had been identified, and their emergency department was closed to new patients. Nurse managers and infection-control professionals screened patients and HCWs and reinforced infection-control practices during daily surveillance rounds. All visitors were screened for gastrointestinal symptoms by nurse managers, and if symptoms were present, they were not allowed to visit patients in the units for 72 h. In addition, group meals, such as potlucks and catered conferences, and any shared food among HCWs were prohibited.

To control environmental contamination, aggressive cleaning measures were implemented using 1:50 dilution of sodium hypochlorite (i.e., bleach). Instructions were distributed to environmental-service personnel, detailing what needed to be cleaned and how often (table 2).

When additional cases occurred despite the above measures, further actions were taken on 16 February. Visitors were prohibited completely, unless there were extenuating circumstances approved by HEIC. Nurses on the affected floors were cohorted; 1 group cared for symptomatic patients, and the second group cared for patients without symptoms for the duration of the outbreak. Gowns and gloves to enter rooms were universally implemented in affected units until there were no additional cases.

In several units, new admissions were stopped because of staffing shortages and the potential risk of nosocomial transmission to patients. Because of concerns of environmental contamination with identification of new cases, despite implemented infection-control measures, the CCU was closed for 24 h on 17 February 2004 while extensive cleaning occurred, with remaining patients temporarily transferred to other floors. All disposable supplies, including medical supplies in the patient rooms and utility closet, were discarded. Any items with fabric surfaces, including furniture and curtains, that could not be properly disinfected were discarded. All surfaces were wiped with sodium hypochlorite twice by 2 consecutive cleaning crews. Within 24 h, the CCU was reopened. No additional infected HCWs were identified among HCWs after cleaning, although there were 2 additional patients, 1 of whom had gastrointestinal symptoms at admission.

Control of the outbreak in the psychiatric units presented unique challenges because of the emphasis on group activities. When cases increased in the psychiatric units, despite furloughing of HCWs and isolation of symptomatic patients, further measures were taken on 21 March. Group therapy sessions were suspended, and patients with gastroenteritis were confined to their rooms, which anecdotally delayed therapy or set back therapeutic progress for some patients. Treatment outside of the affected units was limited to that deemed medically essential. For example, patients received electroconvulsive therapy at the end of the day and were transported with contact precautions.

**Economic analysis.** On examination of the daily census, the CICU experienced a sharp decrease in the number of patients following the suspension of new admissions and closure of the CCU on 17 February (data not shown). Because of this strong association between the CCU and the CICU census, the CICU was included in the analysis, despite only 5 cases in HCWs.

The estimated total lost revenue attributable to the outbreak was $418,370. The CCU and CICU lost $147,507 (IQR, $86,351–$257,737) and $158,620 (IQR, $116,520–$229,614), respectively.

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**Table 2. Cleaning instructions.**

<table>
<thead>
<tr>
<th>Cleaning frequency, location or surface</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every shift High-touch surfaces</td>
<td>Doorknobs, light switches, tables, counter tops, computer keyboards, etc.</td>
</tr>
<tr>
<td>Bathrooms</td>
<td>Give special attention to toilets and fixtures</td>
</tr>
<tr>
<td>Every 24 h Patient room</td>
<td>Include walls, windows, beds, chairs, and ledges; rooms of patients with vomiting and/or diarrhea should be cleaned last</td>
</tr>
<tr>
<td>Floors</td>
<td>Replace cleaning solutions and mop head used to clean floors every 3 rooms</td>
</tr>
<tr>
<td>At discharge Patient rooms Floors</td>
<td>Discard any contents and then clean before restocking with new supplies</td>
</tr>
<tr>
<td>Patient dressers and over-bed tables</td>
<td>Replace curtains if soiled or contaminated</td>
</tr>
</tbody>
</table>

**NOTE.** Primary disinfectant should be bleach solution (1:50 dilution). Bleach may be supplemented with quaternary ammonium compounds.

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**Table 3. Economic impact of norovirus outbreak, 2004.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cost, US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost revenue</td>
<td></td>
</tr>
<tr>
<td>CCU</td>
<td>147,507</td>
</tr>
<tr>
<td>CICU</td>
<td>158,620</td>
</tr>
<tr>
<td>Psychiatry</td>
<td>112,242</td>
</tr>
<tr>
<td>Additional costs</td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td>96,961</td>
</tr>
<tr>
<td>Replacement of supplies</td>
<td>53,075</td>
</tr>
<tr>
<td>Sick leave and overtime</td>
<td>89,239</td>
</tr>
<tr>
<td>Total</td>
<td>657,644</td>
</tr>
</tbody>
</table>

**NOTE.** CCU, coronary care unit; CICU, cardiac surgery intensive care unit.
respectively. Three inpatient psychiatry units, designated in the analysis as A, B, and C, lost $69,536 (IQR, $44,198–$118,034), $26,060 (IQR, $15,486–$43,560), and $16,646 (IQR, $11,412–$26,646), respectively. In addition, these units (i.e., cardiology and psychiatry units) incurred 2623 h of sick leave and overtime as a result of this outbreak, totaling $89,239. Cleaning expenses for the hospital were $96,961, and replacement medical and unit supplies were an additional $53,075. The total estimate of economic impact of this outbreak on the hospital was $657,644 (table 3).

DISCUSSION

Gastroenteritis outbreaks due to noroviruses have a significant impact worldwide, particularly on hospitals, long-term care facilities, schools, and restaurants [4]. In this report, we describe a norovirus outbreak in a tertiary care hospital. Although this outbreak primarily affected HCWs, psychiatric patients had a significantly higher attack rate than those in the CCU (19% vs. 5%). This difference could have been because of greater opportunity for transmission among psychiatric patients, who were encouraged to participate in group activities, compared with cardiac patients in private rooms. We believe that HCWs were affected at a higher attack rate because of the rapid patient isolation and increased risk of exposure to the pathogen through environmental contamination, patients, and other HCWs. The female predominance and younger age in HCW patients, compared with the other patients, are reflective of the demographic characteristics of the HCWs.

The norovirus strain associated with this outbreak, MD-2004, is nearly identical in nucleotide sequence to those of the Farmington Hills strain and other new-variant GII.4 strains from 2002–2004, when the number of norovirus outbreaks in the United States and Europe markedly increased. Another recent gastroenteritis outbreak in a US psychiatric ward was also
associated with a new-variant GII.4 norovirus [25]. Other reports similarly documented a worldwide increase in gastroenteritis outbreaks in 2004 that were caused by GII.4 strains that were hypothesized to be more stable and virulent than earlier GII.4 strains [9, 17, 22].

The impact of norovirus outbreaks in health care settings is significant. First, although norovirus disease is often described as mild and self-limited, the JHH outbreak led to new illness among already hospitalized patients and to intravenous hydration for nearly 5% of HCWs with gastroenteritis. Second, the costs attributable to this outbreak were conservatively estimated to be $657,644 in our 946-bed hospital. A cost analysis for nosocomial gastroenteritis in the United Kingdom had estimated the impact to be US$1.01 million per 1000 beds, which was similarly based on revenue lost from closure to new admissions and staff absences [9]. Our analysis focused on the cardiac and psychiatric units, where clusters of infections were identified, although we were estimating the financial impact on the institution. The estimate is an underestimate; opportunity costs for increased duration of hospitalization were not included, because we could not accurately determine attributable days due to the outbreak.

The need for aggressive management of norovirus gastroenteritis is evident from the large numbers of HCWs affected by this outbreak, the impact on patients, and the disruption of patient care. Noroviruses have been detected on surfaces, such as carpet (after cleaning), elevator buttons, bed rails, and dining room tabletops [22, 26, 27]. Termination of the outbreak in the CCU occurred only after the unit was temporarily closed for extensive environmental decontamination with sodium hypochlorite (i.e., bleach), patients and HCWs were screened for gastroenteritis, ill HCWs were furloughed, and other aggressive infection-control measures were implemented. Bleach is the disinfectant of choice based on its performance against feline calicivirus, a surrogate of norovirus (formerly Norwalk-like viruses), compared with quaternary ammonium compounds, detergents, or alcohol [4–8]. The recommended concentration is 1000 ppm or 1:50 dilution with water. Environmental decontamination beyond standard practices was deemed necessary to assure that surfaces were sufficiently decontaminated.

There are several limitations to our investigation. Similar to previously reported gastroenteritis outbreaks, the case definition relied on symptoms alone. Stool specimens from 16 hospitalized patients (17.9%) were tested for noroviruses; 3 specimens had results positive for norovirus. Prior studies have defined a norovirus outbreak on the basis of ≥2 samples demonstrating the presence of noroviruses among a cohort of symptomatic people with an epidemiologic link. In this case, we believe the common epidemiologic link was exposure to the hospital. Samples from HCWs identified as patients were not obtained because of the difficulty of reporting to the occupational health care unit while ill and the concern for nosocomial transmission if symptomatic HCWs reported to the occupational health care clinic.

It is in the best interest of institutions to act early, because these outbreaks can be explosive and can rapidly disrupt services. Norovirus outbreaks also represent significant morbidity to staff and patients, as well as financial costs to institutions. Further research should focus on developing effective strategies for prevention, containment, and termination of norovirus outbreaks. Prompt implementation of infection-control policies in hospitals when norovirus is first identified in the community could potentially prevent nosocomial outbreaks.

Acknowledgments

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