Recurring Norovirus Transmission on an Airplane

Craig N. Thornley,1 Nicola A. Emslie,2 Tim W. Sprott,2 Gail E. Greening,3 and Jackie P. Rapana1

1Auckland Regional Public Health Service, Auckland District Health Board, Auckland, New Zealand; 2Air New Zealand Medical Unit, Air New Zealand, Auckland, New Zealand; and 3Environmental Health Food Group, Institute of Environmental Science and Research, Porirua, New Zealand

(See the Editorial Commentary by Lopman, on pages 521-22.)

Background. Previously reported outbreaks of norovirus gastroenteritis associated with aircraft have been limited to transmission during a single flight sector. During October 2009, an outbreak of diarrhea and vomiting occurred among different groups of flight attendants who had worked on separate flight sectors on the same airplane. We investigated the cause of the outbreak and whether the illnesses were attributable to work on the airplane.

Methods. Information was obtained from flight attendants on demographic characteristics, symptoms, and possible transmission risk factors. Case patients were defined as flight attendants with diarrhea or vomiting, 51 hours after the end of their first flight sector on the airplane during 13–18 October 2009. Stool samples were tested for norovirus RNA.

Results. A passenger had vomited on the Boeing 777-200 airplane on the 13 October flight sector. Sixty-three (82%) of 77 flight attendants who worked on the airplane during 13–18 October provided information, and 27 (43%) met the case definition. The attack rate among flight attendants decreased significantly over successive flight sectors from 13 October onward (P < .001). Working as a supervisor was independently associated with development of illness (adjusted odds ratio, 5.8; 95% confidence interval, 1.3–25.6). Norovirus genotype GI.6 was detected in stool samples from 2 case patients who worked on different flight sectors.

Conclusions. Sustained transmission of norovirus is likely to have occurred because of exposures on this airplane during successive flight sectors. Airlines should make provision for adequate disinfection of airplanes with use of products effective against norovirus and other common infectious agents after vomiting has occurred.

Norovirus is considered to be the most frequent cause of gastroenteritis in developed countries [1, 2] with a recently estimated community incidence of 4.5 cases per 100 person-years [3]. Although transmission of norovirus is ultimately through oral ingestion of virus shed by infected individuals in feces [4] or vomit [5], several features of the virus facilitate its spread [6]: the virus is shed before and after illness, persists in the environment, exhibits considerable strain diversity, is genetically labile, and requires only a low infectious dose.

Outbreaks of norovirus gastroenteritis not related to contaminated food or water have occurred in many different settings, including cruise ships [7], hotels [8], public venues [9], nursing homes [10], and hospitals [11]. Features of these settings that may predispose to norovirus transmission are large numbers of individuals, close personal contact, and shared sanitation facilities. These features are also present in airplane cabins; however, despite the global volume of air travel, relatively few norovirus outbreaks on airplanes have been reported [12–16]. Of those that have, all involved a single flight sector, defined as the period from an airplane’s departure from one airport to arrival at the next airport.

On 18 October 2009, an airline medical team became aware that multiple flight attendants working in different teams had become unwell with gastroenteritis since 14 October. All these teams had worked on a single airplane over successive flight sectors. The airline medical
staff notified the disease investigation team at Auckland Regional Public Health Service on 19 October, and an outbreak investigation commenced.

METHODS

This was a public health investigation to control a disease outbreak and, therefore, did not require approval by an institutional review board. Information was obtained from airline records on flight origins, departures, and flight times for the implicated airplane. Crew supervisors for each flight sector were asked whether any incidents had occurred on the airplane that could be associated with the outbreak. Contact details for flight attendants who worked on the implicated airplane were retrieved from the airline personnel database. Case finding among passengers was not attempted because of the practical difficulties inherent in tracing internationally dispersed individuals without comprehensive contact details.

A questionnaire was developed that included questions on flight attendants’ activities onboard the airplane (work areas, work role, site where meals were eaten, bathroom(s) used, and use of crew rest bunks), presence of illness before boarding the airplane, contact with others with illness, illness experienced (onset time, symptoms, duration of illness, and medical attendance), and flight sectors worked subsequent to their first flight sector on the implicated airplane. Flight attendant work roles were categorized as either crew supervisors or general flight attendants. Flight attendants either self-completed questionnaires or were interviewed by telephone. Times of events were adjusted to New Zealand Standard Time. Information on food served was sought for initial flight sectors but not for subsequent flights after the multisector nature of the outbreak became apparent, because catering on the aircraft was conducted by different companies in different countries. Flight attendants were not asked whether others in their households had become sick after their illness.

Case patients were defined as flight attendants with an acute illness characterized by diarrhea (≥3 loose stools in a 24-hour period) or vomiting with onset <51 hours after the end of their first flight sector on the airplane commencing during 13–18 October 2009. Patients who had onset of illness >50 hours after the end of their first flight sector and who had been in contact with colleagues with illness after the flight sector were considered to be secondary cases.

Attack rates were calculated for the entire cohort and separately for each flight sector. Each case’s incubation period was calculated as the interval from the time of the midway point in the flight sector (half-way between the departure and arrival times) to the onset of symptoms. Relative risk was calculated for all questionnaire items. Multivariate logistic regression was performed for exposures that were found to be statistically significant during the univariate analysis and that denoted work locations or practices on the airplane. All results are presented including 95% confidence intervals (CIs).

Patients with gastroenteritis were requested to submit a stool specimen for analysis.

Specimens were collected 7 days after the vomiting incident from interior surfaces of the airplane with use of dry sterile cotton swabs moistened with sterile water. Swab samples collected from frequently touched surfaces on the airplane, including water filter taps, galley door handles and surfaces, toilet surfaces, and flush buttons, were submitted for testing. Samples were also obtained from the airplane’s potable water supply.

All submitted specimens were tested for RNA of norovirus genogroups I and II (GI and GII) with use of real-time polymerase chain reaction (RT-PCR) conducted according to published methods [17]. Norovirus strains were further characterized using genetic sequencing [18, 19]. Genetic sequences were analyzed using BioNumerics, version 4.6 (Applied Maths) and were identified by comparison with reference norovirus sequences from the Centers for Disease Control and Prevention, Calicinet database, and the Foodborne Viruses in Europe database. Fecal specimens were also tested for bacterial causes of gastroenteritis, and a water sample was tested for fecal coliforms and norovirus.

Data were entered and stored in an Excel spreadsheet (Microsoft). All data and statistical analyses were performed using Epi Info, version 3.5.1 (Centers for Disease Control and Prevention).

RESULTS

The implicated airplane was a Boeing 777-200 with 26 business class seats, 278 economy seats, 10 flight attendants at full complement, 10 restrooms in 4 stations, and 2 galley areas. The ventilation system exchanged air in the cabin 20 times per minute, with circulated air passed through high-efficiency particulate air filters. The airplane was used for 9 flight sectors during 13–18 October 2009. Eight sectors were international flights with durations from 10 hours 50 minutes through 13 hours 40 minutes; the remaining sector was a domestic flight with duration of 1 hour 20 minutes. A total of 77 flight attendants worked on the airplane during the 6-day period. Of these, 66 worked only 1 flight sector on the airplane. Each of the remaining 11 flight attendants worked 2 flight sectors on the airplane: 10 were part of a crew that collectively worked 2 consecutive flight sectors on the airplane (flight sectors 6 and 7), and 1 worked on both flight sectors 2 and 8.

Interviews with supervisors indicated no gastrointestinal illness in flight attendants who had worked on the aircraft before 13 October. The supervisor for the 13 October flight reported that an unidentified male passenger seated in the economy section of the airplane had vomited and soiled carpet next to his
seat. This was cleaned during the flight by one of the flight attendants. Waste from the clean-up was deposited in a waste disposal unit in a passenger restroom at the rear of the aircraft. No other episodes of vomiting in the airplane cabin were known to the supervisors for flight sectors during 14–18 October. In addition to illness in flight attendants, reports were received by the airline of gastrointestinal illness in 5 passengers, all of whom had traveled on the 13 October flight sector.

**Epidemiologic Investigation**

Sixty-three (81.8%) of the 77 flight attendants returned questionnaires. The median age of flight attendants was 39.5 years (range, 22–64 years), and 60.9% were female. Twenty-nine flight attendants developed gastrointestinal illness after their flight sectors; 2 developed illness 52 hours and 63 hours after their flights on the airplane and were exposed to symptomatic colleagues during their incubation periods; thus, they were conservatively classified to be secondary cases. The remaining 27 flight attendants meeting the case definition developed illness <51 hours after flight sectors commencing during 13–18 October (Figure 1). The attack rate was therefore 42.9% (95% CI, 30.5%–56.0%). There was a decreasing trend in the proportion of flight attendants who developed gastroenteritis after exposure to the airplane on successive flight sectors from 13 October onwards ($\chi^2$ test for trend, 14.6; $P < .001$). All flight attendants who developed illness had worked with at least one other colleague on the same flight sector who also became unwell: a median of 9.5 hours (range, 1–39 hours) occurred from the onset of symptoms of the first case to that of each subsequent case in their respective flight sector crew group. The median incubation time was 30.5 hours (range, 7–50 hours). The median duration of illness was 57 hours (range, 12–157 hours). The most common symptom experienced was diarrhea (89%), followed by nausea (82%), abdominal pain (70%), fever (67%), and vomiting (56%). No case patients required hospitalization, and none worked on the implicated airplane while symptomatic or during the 48-hour period after resolution of symptoms.

In the univariate analysis, risk factors included age ≥40 years, working on the airplane on flight sectors commencing during 13–14 October, working as a crew supervisor, having meals in the aft galley, or working in the airplane economy section (Table 1). A multivariate logistic regression model showed that working as a crew supervisor was statistically significantly associated with illness (adjusted odds ratio, 5.8; 95% CI, 1.3–25.6; $P = .02$).

**Microbiologic Investigation**

Two patients submitted fecal specimens for analysis. Bacterial pathogens were not identified. Norovirus GI.6 was identified in both specimens, and isolates were indistinguishable in the region analyzed. The 2 patients had worked on different flights 2 days apart (sectors 3 and 6) (Figure 1) and had no recent contact with one another. All swab specimens collected from the airplane interior tested negative for norovirus. Water analysis was negative for norovirus and bacterial contamination.

**Outbreak Control**

After identification of the outbreak and collection of environmental specimens, the airplane was intensively decontaminated. Access to the airplane was restricted, and personal protective equipment was worn. The airplane cabin surfaces were disinfected with a 0.2% parachlorometaxylenol disinfectant (EnviroTru; EnviroSystems). Particular cleaning attention was given to toilet

---

**Figure 1.** Number of cases of acute gastroenteritis in flight attendants, by date of symptom onset, who worked on a single airplane on any of 9 consecutive flight sectors during 13–18 October 2009. Arrows indicate start and end times of each flight sector. A case was defined as any instance of vomiting or diarrhea in a flight attendant that occurred ≤50 hours after the end of the flight sector worked by the flight attendant on the airplane. Attack rates for each flight sector were calculated using the number of participating flight attendants from that sector as the denominator.
and galley areas. Carpets, seat covers, and curtains were removed and replaced in the 3 complete rows fore and aft of the site where vomiting had occurred. Carpet in other areas of the airplane was steam-cleaned. Restroom faucets throughout the aircraft were removed and replaced.

**DISCUSSION**

During this gastroenteritis outbreak, separate groups of flight attendants who worked on the same airplane on consecutive flights over a 6-day period were infected with norovirus. Findings from our investigation suggest that flight attendants were infected through their work on the airplane, with transmission recurring over multiple flight sectors. First, all patients, other than the 2 likely secondary cases, developed symptoms in the range of the norovirus incubation period [20] after work on the airplane. Second, 2 case patients were found to be infected with norovirus GI.6 with indistinguishable genetic sequences, and the only link between the 2 during their respective incubation periods was to have worked on the same airplane during separate flight sectors 45 hours apart. Third, there was an apparent dose-response relationship, whereby attack rates on earlier flight sectors were higher than those on later sectors. Last, analysis of risk factors suggests that staff exposed to particular sections of the airplane had greater risk of illness.

Alternative explanations for this outbreak are less likely. Opportunities for person-to-person spread between flight attendants in settings outside the airplane were rare, because different groups of crew were widely dispersed internationally and had little if any contact with other crew groups. In particular, the second case patient with a norovirus-positive stool sample was traveling internationally throughout his incubation period and had no possible exposure to the first norovirus-positive case patient during this period. Because GI.6 is an infrequently identified norovirus strain in New Zealand, present in only 11 of 1206 outbreaks confirmed as being attributable to norovirus during 2002–2009 (Gail Greening, personal communication), unrelated infection in these 2 flight attendants from separate sources in the community would be an improbable coincidence. Foodborne spread would not account for this outbreak, because different catering facilities in different countries supplied the food for the various flights.

Both the start of the outbreak and the highest attack rate occurred among flight attendants who worked on the 13 October flight sector, suggesting that the vomiting incident that occurred on this sector may have had a role in later disease transmission. Transmission to flight attendants on the 13 October flight sector may have occurred through direct contact with vomit or virus aerosolized by vomiting [21] or indirectly by contact with contaminated fomites [8]. Similarly, outbreaks of norovirus gastroenteritis involving air passengers exposed during a single flight sector to sick individuals vomiting [15] or defecating [16] in the airplane cabin have implicated a combination of direct and indirect transmission mechanisms. In the outbreak described here, flight attendants working on flight sectors after 13 October were not directly exposed to the vomiting incident; instead, indirect transmission through exposure to persistently contaminated fomites would have been more probable. Norwalk virus has been detected on surfaces up to 7 days after experimental inoculation [22], and in one instance, transmission may have occurred 12 days after contamination, albeit with close exposure to contaminated material [23]. Outbreaks resulting...
from contact with contaminated surfaces occurring days after the contamination incident have been reported in other contexts [9]; however, to our knowledge, this has not been previously reported in an airplane cabin environment. Norovirus was not detected in swab samples taken from surfaces and fittings in the airplane cabin, although this may have been because our testing was undertaken 7 days after the suspected initial contamination episode.

Infected flight attendants, whether symptomatic or asymptomatic, may have been an ongoing source of contamination of the airplane cabin or of person-to-person transmission to colleagues during their flight sectors. The contribution of this source would have been modest at best; for all but 11 flight attendants, the interval between first and last contact with the airplane was shorter than the minimum period before norovirus shedding commences after exposure [20, 24]. The 11 attendants who worked multiple flight sectors (and, therefore, had longer intervals between first and last contact with the airplane) did not return to the airplane until flight sectors 7 and 8, late in the course of the outbreak.

Working or having meals in the economy section was associated with illness in univariate analysis, and in multivariate analysis, flight attendants in supervisory roles were more likely to develop gastroenteritis than were others. Supervisors tend to move more widely through the airplane cabin rather than staying in one section and may have, therefore, increased their exposure to virus present on airplane surfaces. Norovirus can be spread on hands from one surface to another [25]; thus, flight attendants with exposure to a wider range of surfaces may have had increased opportunities for infection.

The investigation had several limitations. Questionnaire completion for some flight attendants did not occur for several weeks after the flight sectors, and their recollections of exposures on the airplane may have been imperfect, potentially reducing the size of relative risk for some exposures. We did not obtain questionnaires for all flight attendants, particularly those who worked on later flight sectors. A diagnosis was only confirmed in 2 individuals; however, the characteristics of the illness in other individuals met the revised Kaplan criteria [26], supporting our assumption that norovirus was the overall etiologic agent. The scale of transmission from exposures on the airplane may have been overestimated if some flight attendants classified as case patients had, in fact, become ill through secondary transmission from their colleagues after the end of their flight sectors. This may have exaggerated the attack rates in particular flight sector groups but not the overall number of flight sector groups affected; any misclassification is likely to have been small, because the intervals between the onset of illness times for the first and last cases from any single flight sector crew group did not exceed the estimated mean serial interval for norovirus infection [27].

Passengers were not investigated because of logistical difficulties in locating and contacting travelers after disembarkation; however, the airline did receive a limited number of complaints of gastrointestinal illness from passengers who traveled on the 13 October flight sector. The actual number of affected passengers may have been substantial; an investigation after vomiting in an airplane cabin found that 34% of passengers traveling during the same flight sector as the sick person and seated in cabin sections proximal to the site of vomiting developed illness [15]. In the outbreak presented here, the airline may have received few complaints, because passengers did not readily attribute their illness to their air travel several days earlier.

Norovirus outbreaks pose significant management challenges in any context [28]; however, these are compounded by concerns specific to aircraft. Disinfectants must be consistent with those recommended by the airline operator’s engineering department [29], because some standard virucidal disinfectants may be hazardous to aircraft materials [30]. International ground handling standards [31] exist for cleaning airplane cabins between flight sectors. Hard surfaces in the passenger cabin of the airplane implicated in this outbreak had been routinely cleaned with an alkylamine product, compounds of which may have limited efficacy against murine norovirus [32]. Cleaning surfaces with nonvirucidal detergent can facilitate virus transfer [25], inadvertently distributing contamination more widely. Parachlorometaxylenol was used to disinfect the cabin of this airplane after detection of the outbreak, because this has efficacy against feline calicivirus [33] and is approved for use in aircraft. Subsequent to this outbreak, the affected airline installed kits containing personal protective equipment, disposable scoops, biohazard bags, and parachlorometaxylenol disinfectant spray bottles on all airplanes in the fleet, and crew were instructed on safe cleaning after incidents involving vomiting or diarrhea.

We recommend that consideration be given by public health agencies in collaboration with the airline industry to develop and implement policies for preventing norovirus transmission associated with air travel. These should include policies enabling ill passengers to delay travel without incurring financial hardship, for managing sick workers, for training flight attendants on the risks and management of vomiting and diarrheal incidents onboard aircraft, and for ensuring routine onboard availability of appropriate cleaning equipment, including aircraft-approved virucidal disinfectants.

Acknowledgments

We thank the flight attendants and the flight service managers, for assisting with this investigation; Joanne Hewitt, for virology work on specimens collected; Diane Stephenson, for graphic design work for the manuscript; and Air New Zealand, LTD, for demonstrating support for the investigation and for making key staff available to assist.
**Financial support.** All authors were funded by the organizations to which they are affiliated. Norovirus identification was performed with funding from the New Zealand Ministry of Health (G.G.), as part of an ongoing contract with the Institute of Environmental Science and Research to carry out infectious disease surveillance.

**Potential conflicts of interest.** All authors: No reported conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed in the Acknowledgments section.

**References**