Likely Transmission of Norovirus on an Airplane, October 2008

Hannah L. Kirking,1 Jennifer Cortes,1 Sherry Burrer,1 Aron J. Hall,1 Nicole J. Cohen,1 Harvey Lipman,1 Curi Kim,1 Elizabeth R. Daly,2 and Daniel B. Fishbein1

1Centers for Disease Control and Prevention, Atlanta, Georgia; and 2Department of Health and Human Services, Concord, New Hampshire

Background. On 8 October 2008, members of a tour group experienced diarrhea and vomiting throughout an airplane flight from Boston, Massachusetts, to Los Angeles, California, resulting in an emergency diversion 3 h after takeoff. An investigation was conducted to determine the cause of the outbreak, assess whether transmission occurred on the airplane, and describe risk factors for transmission.

Methods. Passengers and crew were contacted to obtain information about demographics, symptoms, locations on the airplane, and possible risk factors for transmission. Case patients were defined as passengers with vomiting or diarrhea (≥3 loose stools in 24 h) and were asked to submit stool samples for norovirus testing by real-time reverse-transcription polymerase chain reaction.

Results. Thirty-six (88%) of 41 tour group members were interviewed, and 15 (41%) met the case definition (peak date of illness onset, 8 October 2008). Of 106 passengers who were not tour group members, 85 (80%) were interviewed, and 7 (8%) met the case definition after the flight (peak date of illness onset, 10 October 2008). Multivariate logistic regression analysis showed that sitting in an aisle seat (adjusted relative risk, 11.0; 95% confidence interval, 1.4–84.9) and sitting near any tour group member (adjusted relative risk, 7.5; 95% confidence interval, 1.7–33.6) were associated with the development of illness. Norovirus genotype II was detected by reverse-transcription polymerase chain reaction in stool samples from case patients in both groups.

Conclusions. Despite the short duration, transmission of norovirus likely occurred during the flight.

Noroviruses are the leading cause of all gastroenteritis [1], causing an estimated 23 million cases of gastroenteritis annually in the United States [2]. In addition, they are the leading cause of foodborne disease outbreaks [3]. Control of norovirus is complicated by the highly infectious nature of these viruses, which have a median infectious dose of 18 viral particles [4]. In addition, up to 30% of infected people may be asymptomatic but still capable of spreading disease [5]. Recent evidence suggests that norovirus persists in stool beyond the resolution of symptoms [6]. The virus can persist in the environment for weeks [7] and is resistant to many common disinfectants. Because there is substantial strain diversity and no evidence of persistent cross-protective immunity, individuals may have recurrent norovirus infections [8].

Outbreaks of norovirus infections are most commonly propagated person to person by the fecal-oral route, either directly or through food [9], water [10], or environmental contamination [11]. Aerosolization and subsequent ingestion of vomitus [12] may also play a role in transmission. Outbreaks are commonly identified in closed settings, such as nursing homes and hospitals [13, 14], where well-defined populations are in close contact for prolonged periods. For similar reasons, norovirus outbreaks are frequently reported in association with travel on cruise ships, where passengers are in closed settings for extended periods [15–17]. However, relatively little is known about the potential risk for norovirus transmission on aircraft. Only 3 previous reports of norovirus-like illness associated with air travel exist [18–20].

On 8 October 2008, a flight originating from Boston, Massachusetts, and bound for Los Angeles, California, was diverted to Chicago, Illinois, after multiple passengers experienced gastrointestinal illness, including vomiting and diarrhea, during the flight. All ill passen-
ggers were members of a tour company’s New England fall foliage bus tour who were returning home to California. The airline removed the tour group members from the flight and transferred them to a hotel overnight. The remaining passengers flew to Los Angeles that same day on a different airplane. Tour group members returned to Los Angeles on a different flight the following day.

We conducted a preliminary investigation of the 41-member tour group to determine the cause and extent of illness. On the basis of the description of illness, norovirus was highly suspected. Because vomiting and diarrhea reportedly occurred within the aircraft cabin, we sought to determine whether transmission occurred during the flight, the characteristics of the illness among infected persons on the flight who were not tour group members, and the risk factors for transmission.

**METHODS**

This investigation was part of a public health response, and as such institutional review board approval was not required.

**Investigation of tour group passengers.** A telephone survey was designed to characterize the illness among tour group members. The questionnaire included questions on demographics, symptoms experienced from 28 September through 12 October 2008 (before and during the New England bus tour, during the flight, and after the flight), seat location, location on the airplane where illness episodes (ie, diarrhea or vomiting) occurred, and bathroom use while on the airplane. Contact information for all of the travelers was provided by the tour company that organized the trip. Tour group members who were not reached by telephone after 3 attempts or who refused the interview were considered lost to follow-up. Stool samples for laboratory testing were requested from tour group members who met the case definition.

Among tour group members, a probable case was defined as vomiting or diarrhea (≥3 loose stools in 24 h) from 28 September through 12 October 2008. This definition included tour members who did not submit a stool sample and those whose stool sample tested negative for norovirus. A confirmed norovirus case patient was a tour member who met the criteria as a probable case patient and who also had confirmed norovirus by real-time reverse-transcription polymerase chain reaction (RT-PCR) testing of a stool sample.

**Investigation of non–tour group passengers.** We conducted a retrospective cohort investigation of all non–tour group passengers and crew on the diverted flight to assess in-flight transmission and potential risk factors. Tour group members were excluded from this part of the investigation because they were likely exposed before boarding the aircraft. Contact information was obtained from a flight manifest provided by the airline. Efforts were made to contact all passengers who were not part of the tour group and the flight attendants. Pilots were excluded from this investigation. Surveys for children on the flight were completed by a parent.

The questionnaire included questions similar to those used for the tour group: demographic information, symptoms passengers may have experienced during the 1–5 days after the 8 October 2008 flight (9–14 October 2008), seat locations, proximity to ill passengers, lavatory use, and hand hygiene practices. To assess tertiary transmission, the interviewee was also asked whether anyone within his or her family or work environment became ill with vomiting or diarrhea after his or her return. This was asked as an open-ended question, with details of each case recorded individually. Non–tour group members were considered lost to follow-up if they were not reached by telephone after 3 attempts. However, if e-mail addresses were available from the flight manifest, e-mails were also sent in an attempt to establish contact with the passengers of interest.

The case definitions used for non–tour group members in the contact investigation were the same as those for the tour group, except that the period for inclusion was 1–5 days after the flight (9–14 October 2008). Those who met the case definition were asked to submit a stool sample for norovirus testing by RT-PCR.

**Laboratory testing.** Stool samples were collected by local health department staff in the passengers’ respective jurisdictions and submitted to their state public health laboratories for detection of norovirus by RT-PCR. Genetic sequencing was attempted for all samples positive for norovirus by RT-PCR, with an aliquot sent to the Centers for Disease Control and Prevention for confirmation.

**Statistical analyses.** Analysis of the tour group was limited to descriptive epidemiology because resource limitations precluded further investigation of the multiple potential-exposure sources during the tour. Univariate analysis of the non–tour group passenger investigation considered age, sex, bathroom use, hand hygiene, seat location, and proximity to tour group members as possible risk factors. Seat location “near a tour group member” was defined as sitting within 1 row and on the same side of the aisle as or within 1 seat on the opposite side of the aisle from a tour group member. Multivariate logistic regression was performed, initially including those factors found to be significant during the univariate analysis. All analyses were completed using Epi Info, version 3.5 (Centers for Disease Control and Prevention); SAS, version 9.1 (SAS Institute); and StatXact, version 7 (Cytel).

**RESULTS**

**Investigation of tour group passengers.** Thirty-five of the 41 members of the tour group boarded a flight in Boston bound for Los Angeles on 8 October 2008. Of the 6 tour group members who were not on the flight, 2 were hospitalized or unable to fly because of illness (72 and 80 years of age), whereas 4
were not on the flight because of alternate personal travel plans after the tour. Six of the tour group members reported experiencing vomiting or diarrhea during the flight. Five vomited into air sickness bags while in their seats. One had multiple episodes of diarrhea, with at least 1 occurring in the aisle of the first-class section. The soiled aisle was not cleaned until after completion of the flight. Ill tour group members moved throughout the airplane during the flight to use the restrooms and to dispose of air sickness bags after flight attendants refused to touch them. One restroom on the airplane was eventually closed after it became soiled by the ill tour group members. The flight was diverted to Chicago after a flight time of ≈3 h. Four ill passengers were transported to a local hospital emergency department for evaluation, and 2 were hospitalized (76 and 67 years of age).

Of the 41 members of the tour group, 36 (88%) completed the telephone survey. Information on 1 additional tour group member was obtained from a hospitalization medical record. Of the 37 tour group members for whom information was available, 15 (41%) met the case definition. The proportion of case patients who were women (87%) was similar to the proportion of noncase patients who were women (73%) (P = .55). The median age of the case patients (79 years; age range, 23–84 years) was similar to the age of the noncase patients (77 years; age range, 64–87 years) (P = .25). Dates of illness onset ranged from 2 to 10 October, with the peak onset of illness being 8 October, the day of the flight (Figure 1). Two tour group members sought medical care during the tour, 1 in New Hampshire on 7 October and 1 in Massachusetts on 8 October.

Of the 15 tour group members who met the case definition for norovirus infection, 6 submitted stool samples within 2–8 days of symptom onset; all 6 were confirmed to be positive for norovirus genogroup II. Genetic sequencing revealed that all were of the identical GII.4 Minerva strain.

Investigation of non–tour group passengers. Of 106 people eligible for the non–tour group investigation, 101 were ticketed passengers, 2 were infants who sat on their parents’ laps, and 3 were flight attendants. Eighty-five (80%) completed telephone or e-mail surveys.

Seven passengers met the case definition (attack rate, 8%). They reported onset of illness on 10–12 October (peak date of onset, October 10) (Figure 1). The median age of the ill persons was 49 years (age range, 11–73 years). In the univariate analysis, risk factors included age of 65 years or older, sitting in an aisle seat, and sitting near any tour group member (Table 1). A multivariate logistic regression model showed that sitting in an aisle seat (adjusted relative risk, 11.0; 95% confidence interval, 1.4–84.9; P = .004) and sitting near any tour group member (adjusted relative risk, 7.5; 95% confidence interval, 1.7–33.6; P = .006) were statistically significantly associated with illness. Use of a bathroom on the airplane was not statistically significant.

Five passengers submitted stool samples 8–12 days after the onset of symptoms. One of these tested positive by RT-PCR for norovirus genogroup II. However, there was insufficient RNA for genetic sequencing. Figure 2 shows seating locations on the airplane for all passengers who completed a survey.

DISCUSSION

Despite the short flight duration, our investigation indicates that transmission of norovirus likely occurred in flight. This conclusion is supported by our identification of multiple non–tour group passengers with clinically compatible illness occurring within a time frame consistent with exposure in flight on the basis of the mean incubation period of norovirus of 24–48 h [21]. Furthermore, norovirus genogroup II was identified in the stool of both tour group members and 1 of the ill non–tour group passengers. Our findings are generally consistent with those of Widdowson et al [18], who reported probable transmission of norovirus from multiple crew members to 5 passengers during an 8-h transatlantic flight. Similarly, Holmes and Simmons [20] reported that 1 passenger ill with gastroenteritis potentially infected 41 people seated in the adjacent zones on a 12.5-h transpacific flight. Kornylo et al [19] were unable to confirm transmission on a shorter flight (3 h) with asymptomatic but previously ill passengers; the investigators concluded that transmission is more likely on longer flights and on flights with active illness on board.

The risk factors of sitting in an aisle seat and sitting near a tour member suggest that transmission occurred either directly

![Figure 1](cid://image.png)

**Figure 1.** Number of probable and confirmed cases of norovirus among tour group and non–tour group members, by date of onset. A probable case was defined as vomiting or diarrhea (≥3 loose stools in 24 h) without laboratory confirmation. A confirmed case was defined as vomiting or diarrhea (≥3 loose stools in 24 h) with laboratory confirmation of norovirus in stool by real-time reverse-transcription polymerase chain reaction.
from person to person or indirectly via environmental contamination. This finding is consistent with a previous investigation of probable in-flight norovirus transmission that reported lavatory use to be a significant risk factor [18]. Although we did not identify a statistically significant risk of illness associated with use of a lavatory on the airplane, many passengers reported that they used the lavatories early in the flight, before possible contamination by ill tour group members. The observed risk associated with sitting near a tour member regardless of whether they had active illness suggests that asymptomatic viral shedding may have contributed to transmission. In addition, given the localized airflow patterns on the aircraft and the high incidence of vomiting on the flight, aerosolization and subsequent ingestion of viral particles may have played a role as well.

This investigation was subject to at least 3 limitations. First, norovirus illness could be confirmed in only 1 of the 7 non–tour group passengers who met the probable case definition, likely because of the prolonged time lapse (8–12 days) between symptom onset and specimen collection. Second, genetic sequencing of the 1 norovirus-positive specimen from a non–tour group passenger was not possible because of either too small of a viral load or degradation during shipping between laboratories. We were therefore unable to confirm that the same norovirus strain caused illness in both tour group and non–

Figure 2. Seating on plane with transmission of norovirus among passengers, October 2008.
tour group members. Third, our findings may not be generalizable to other flights because the intensity of exposure during this outbreak was much greater than that previously reported.

Given the high incidence of norovirus infection in the general population and the high volume of air travel, it is likely that passengers experience norovirus illness during travel and introduce norovirus into airplane environments. Numerous opportunities exist for transmission on aircraft. Passengers are in close contact with one another in a confined space for hours at a time. Because of passenger volume, inconvenience, and flight procedures, access to lavatories is often limited. Numerous high-contact surfaces, such as armrests, tray tables, and seat controls, may serve as potential norovirus fomites. The shared food and beverage service may also serve as a potential source for transmission through contamination by an ill flight attendant or previous handlers of ready-to-eat foods. Given these potential risks and those demonstrated by our investigation, development of appropriate prevention and control measures must be developed.

The exclusion of ill travelers seems to be the most direct way to prevent norovirus transmission on airplanes. A section within the Code of Federal Regulations states that airlines may refuse boarding to an individual if he or she has a communicable disease that poses a serious health threat to other travelers [22]. The interpretation of this regulation depends on airline staff being aware of ill passengers, the willingness of passengers to voluntarily report illness, and whether airline staff and passengers consider norovirus illness to be a serious health threat.

Despite being widely recommended by both industry and public health officials, the exclusion of ill travelers is challenging to enforce because it relies primarily on self-identification. Sick passengers may be hesitant to refrain from air travel because of financial barriers, inconvenience of changing flight reservations, and the perceived urgency of travel. The adoption of flexible airline policies and procedures for reservation changes, and personal inconvenience. Despite these challenges, the exclusion of ill travelers seems to be the most direct way to prevent norovirus transmission on airplanes. A section within the Code of Federal Regulations states that airlines may refuse boarding to an individual if he or she has a communicable disease that poses a serious health threat to other travelers [22]. The interpretation of this regulation depends on airline staff being aware of ill passengers, the willingness of passengers to voluntarily report illness, and whether airline staff and passengers consider norovirus illness to be a serious health threat.

To reduce the risk of transmission of norovirus and other gastrointestinal pathogens on aircraft, we recommend the development of specific policies and procedures through collaboration between the airline industry and public health authorities. These policies should address reducing financial barriers to delaying air travel because of illness, standardizing aircraft disinfection protocols, and implementing technological solutions to reduce passenger contact with potentially contaminated surfaces. In addition, updating infection control guidelines for airline personnel to include gastrointestinal pathogens, training of cabin crew, and education of the general public might help prevent future norovirus outbreaks associated with air travel. Some of these recommendations may be difficult to implement, and their success will depend on the amount of interest and effort put forth by key stakeholders. Even with great willingness and cooperation from those involved, logistical and financial challenges exist, in addition to time limitations and personal inconvenience. Despite these challenges, it is critical to address the potential burden of norovirus infection associated with air travel, which may be much greater than currently recognized.

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