Epidemiology of Gastroenteritis on Cruise Ships, 2001–2004

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Background: The incidence of diarrheal disease among cruise ship passengers declined from 29.2 cases per 100,000 passenger days in 1990 to 16.3 per 100,000 passenger days in 2000. In 2002, the Vessel Sanitation Program of the Centers for Disease Control and Prevention reported 29 outbreaks (3% or more passengers ill) of acute gastroenteritis on cruise ships, an increase from 3 the previous year. This analysis of gastroenteritis on cruise ships, conducted in 2005, details the increase in outbreak incidence rates during 2001 through 2004.

Methods: Using Gastrointestinal Illness Surveillance System data, investigators evaluated incidence rates of gastroenteritis on cruise ships calling on U.S. ports, carrying 13 or more passengers, by cruise length and reporting region during the study period. The investigators also evaluated the association between inspection scores, and gastroenteritis incidence and the frequency of outbreaks in 2001 through 2004.

Results: During the study period, the background and outbreak-associated incidence rates of passengers with acute gastroenteritis per cruise were 25.6 and 85, respectively. Acute gastroenteritis outbreaks per 1000 cruises increased overall from 0.65 in 2001 to 5.46 in 2004; outbreaks increased from 2 in 2001 to a median of 15 per year in 2002–2004. Median ship inspection scores remained relatively constant during the study period (median 95 on a 100-point scale), and were not significantly associated with either gastroenteritis incidence rates (risk ratio, 1.00; 95% confidence interval, 0.98–1.02) or outbreak frequency (Spearman’s coefficient, 0.01, \( p = 0.84 \)).

Conclusions: Despite good performance on environment health sanitation inspections by cruise ships, the expectation of passenger cases of gastroenteritis on an average 7-day cruise increased from two cases during 1990–2000 to three cases during the study period. This increase, likely attributable to noroviruses, highlights the inability of environmental programs to fully predict and prevent risk factors common to person-to-person and fomite spread of disease.

Introduction

From 1990 through 2000, incidence rates of diarrheal disease on cruise ships declined in association with environmental health inspection programs conducted by the Vessel Sanitation Program (VSP), National Center for Environmental Health, Centers for Disease Control and Prevention (CDC).1 Overall incidence of diarrheal disease among passengers declined from 29.2 cases per 100,000 passenger days in 1990 to 16.3 per 100,000 passenger days in 2000. Outbreak-related (outbreak defined as 3% or more of passengers ill) diarrheal disease cases decreased from 4.2 to 3.5 per 100,000 passenger days from 1990–1995 to 1996–2000. This represented a further decline from six outbreak-related illnesses per 100,000 passenger days in 1989–1993.2 However, in 2002, VSP reported 29 outbreaks of acute gastroenteritis on cruise ships, an increase from two outbreaks reported the previous year. Since that time, noroviruses (NoV) (family Caliciviridae) have emerged as a frequent cause of illness at sea and have been associated with multiple modes of transmission of gastroenteritis, recurring shipboard outbreaks linked to multiple strains of calicviruses, spread of NoV from infected ship passengers to persons on land, and illness on consecutive cruises despite aggressive housekeeping measures and environmental

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decontamination. Using routine surveillance data and internal and published outbreak findings, VSP studied the epidemiology of gastroenteritis on cruise ships in an attempt to further detail the increase in outbreaks in 2001–2004.

**Methods**

**Cruise Ship Sanitation Inspections**

The VSP was created in 1975 to assist the cruise ship industry in minimizing the risk for diarrheal disease among passengers and crew on ships sailing into the United States carrying ≥13 passengers. Vessel Sanitation Program environmental health officers (EHOs) of the U.S. Public Health Service conduct twice-annual, routine unannounced inspections of ships with international itineraries that call on U.S. ports according to pre-set criteria, scoring each vessel out of a possible 100. Details of the public health inspection program have been described previously. EHOs enter data collected during inspections directly into the VSP inspection database immediately after inspections. Detailed ship characteristics (e.g., gross registered tonnage, year of construction, fleet size), port codes, inspector codes, and inspection regions also are maintained in the inspection database. Detailed inspection reports, sanitation scores, the VSP Operations Manual and program standards are available at the CDC website (www.cdc.gov/nceh/vsp).

**Gastroenteritis Syndromal Surveillance**

In accordance with U.S. foreign quarantine regulations, ships are required to submit to VSP (24 to 30 hours before arrival) a report of the total (including zero) cases of gastroenteritis among passengers and crew aboard the vessel who present to the designated medical staff. In January 2001, to improve surveillance sensitivity, the case definition (formerly “diarrheal disease” defined as three or more episodes of loose stools within 24 hours) was changed to “acute gastroenteritis” (AGE) (defined as three or more episodes of loose stools within 24 hours, or vomiting plus one additional symptom, including one or more episodes of loose stools, fever, muscle aches, bloody stools, or headache). Previous incidence reports published by VSP originate from diarrheal disease data collected by EHOs during routine ship inspections for the five cruise segments before each ship inspection.

Before 2001, ships reported cases of diarrhea to VSP by telephone or fax. In January 2001, in an effort to improve completeness and timeliness of reporting, the VSP implemented, using the expanded syndromal case definition, an electronic gastrointestinal illness surveillance system (GISS) to collect and respond to mandatory reports of AGE from passenger cruise ships sailing into the United States from foreign ports. Electronic reporting templates, supplied to each cruise line by VSP, are completed by shipboard personnel designated by each cruise line and submitted by electronic mail to VSP with the following data fields: ship name, next U.S. port of call, disembarkation port of call, embarkation and disembarkation dates, total number of passengers on board, total number of crew on board, total cases of AGE among passengers, and total cases of AGE among crew. Reports submitted with missing data are automatically rejected by the VSP server and returned by e-mail accompanied by a notice of receipt of an incomplete submission. Accepted reports are stored in the VSP database, and a confirmation is sent to the cruise ship of a successful GISS report. Confirmation of successful AGE reports for each voyage into the United States from a foreign port is required to be maintained aboard each vessel in accordance with standards described in the VSP Operations Manual, 2000. AGE reports are routinely reviewed by EHOs during inspections and are evaluated for completeness and timeliness of reporting and cross-checked for accuracy with clinical records maintained by each ship. Ships that do not comply with reporting requirements are subject to loss of inspection points during inspections. AGE reports submitted to VSP by phone and fax are entered into the GISS database by VSP staff and represent <0.7% of the raw data stored in the database.

**Outcomes**

The VSP evaluated the outbreak-associated (defined as gastroenteritis among ≥3% of passengers) and non–outbreak-associated (<3% of passengers ill) AGE incidence on cruise ships in 2001–2004. To assess the impact of shipboard environmental sanitation on AGE among passengers, the association between inspection scores and associated AGE incidence and between inspection scores and the frequency of outbreaks was evaluated. Incidence rates were described per 100,000 passenger days in order to minimize the differences between ships in cruise duration and passenger loads. Continuous variables were described using medians, and inter-quartile ranges (e.g., inspection scores, age of ship) and categorical variables (e.g., inspection regions, inspectors, ship size) were described by frequencies and percentile.

**Analysis**

Using the GISS database reports, VSP calculated AGE incidence using the following formula:

$$\frac{\text{(Total reported passenger cases)}}{\text{(total passengers on board x total number of days at sea)}} \times 100,000 \text{ passengers days}$$

Non–outbreak-associated AGE incidence included cruises with <3% of passengers reported ill and excluded contiguous cruises on ships immediately after an outbreak, regardless of the AGE incidence because of the risk for their association with the previous outbreak. The VSP excluded the 6 cruise days following an outbreak to avoid the risk of misclassifying cases. The outbreak-associated incidence was calculated as follows:

$$\frac{\text{(outbreak-associated passenger cases)}}{\text{(total passengers on board x numbers of days at sea exclusively during outbreak cruises)}} \times 100,000 \text{ passenger days}$$

One report per ship per cruise segment (embarkation date to disembarkation date) was included in the analysis. In the event of multiple reports for the same cruise segment, VSP chose the report with the highest number of cases and the associated total passengers reported on board, for each segment.
Data originating from ships not participating in VSP inspections (e.g., ships with domestic itineraries only) or that have failed to submit required AGE reports are not represented in this analysis. The VSP considered an outbreak on a cruise contiguous with a previous outbreak-associated cruise, as part of the same outbreak. Cruise length was calculated in days by subtracting the disembarkation date from the embarkation date. Because of the likelihood of incomplete data associated with cruises lasting >21 days (world cruises and cruises originating in the United States with foreign disembarkation ports), and cruise-associated illnesses manifesting after disembarkation on cruises lasting <3 days (because of average incubation periods of 48 hours), we limited our analysis of AGE to cruises 3 to 21 days in duration. Ships with no inspection scores during the entire study period, test reports, and erroneous reports (e.g., wrong embarkation year or case numbers) were excluded from further analysis.

The VSP performed a univariate analysis of the association between inspection scores and ship and inspection characteristics, including (1) ship age (in days); (2) fleet size (number of vessels in a cruise line’s fleet); (3) ship size (in gross registered tonnage); (4) inspector (10 of 11 who performed inspections during the study period); and (5) inspection region (grouped into seven regions: Northwest [WA, OR, AK]; Hawaiian Islands and Guam; CA; South [all ports on the Gulf of Mexico excluding FL]; Northeast [all states north of and including NC]; Southeast [all Atlantic ports in FL, GA, and SC]; and Caribbean Islands). Tests of association between inspection scores and fleet size, inspection regions, and individual inspectors were performed using a chi-square test. Tests of association between ship age and ship size and inspection scores were performed using correlation coefficients.

A multivariable Poisson regression model was used to test the association between gastroenteritis incidence and ship scores during outbreaks and non-outbreak periods from 2001 to 2004. Confounders were identified as significant by univariate analysis ($p \leq 0.05$) were included in the model with inspection scores, AGE incidence rates, and inspection year. Routine unannounced ship inspections conducted twice in 1 year on the same vessel were considered as independent observations, and each inspection is represented separately in analyses. Reinspections, generally occurring within 45 days of a failed inspection, were treated as dependent events and excluded from these analyses. To test the association between outbreak and non-outbreak AGE incidence and inspection scores, adjusting for ship size, fleet size, ship age, inspectors, and inspection region, VSP fitted a multivariable Poisson regression model. Each inspection score was associated with the incidence rate for the five voyages preceding each inspection. In this model, risk ratios were derived using the backwards stepwise procedure to characterize the association between AGE incidence and inspection score adjusting for inspection year and cruise duration, for each year from 2001 through 2004. Inspection scores were treated as continuous variables in the model. In the regression models, gastroenteritis, fleet size, year of embarkation, and ship size were continuous; inspectors, cruise length, and fleet size were categorical. Because inspections were independent, repeated measures analysis was not performed. Spearman’s correlation coefficients and the Kruskal–Wallis chi-square test were used to measure the association between the frequency of outbreaks per vessel and the median inspection score per vessel. Statistical computations were performed in 2005 using SAS software (SAS Institute Inc., Cary NC, 1997).

**Results**

Among 18,232 cruises identified from the VSP database, 3170 (17%) lasted <3 days, and 165 (1%) lasted >21 days and were excluded from further analyses. An additional 55 (0.3%) cruises of <7 days that immediately followed an outbreak on the same vessel also were excluded because of the risk of misclassifying cases. A total of 14,842 cruises lasted 3 to 21 days and were linked to routine inspections from 2001 through 2004. Of these cruises, 5006 (34%) lasted 3 to 6 days, 7524 (51%) lasted 7 days, 2115 (14%) lasted 8 to 15 days, and 197 (1%) lasted 16 to 21 days. The 14,645 cruises lasting 3 to 15 days represented 184,650,292 (98%) passenger days.

The background (non-outbreak) case incidence during the study period was 3.25 passengers with AGE per cruise (48,206/14,842), or 25.6 non–outbreak-related illnesses per 100,000 passenger days (48,206/1,007,157). This rate increased significantly from 17.4 in 2001 to 28.5 in 2004 (Wald $\chi^2=1305.35$, $p<0.001$) (Figure 1). The outbreak-associated case incidence was 85 passengers with AGE per cruise (6747/79), or 670 outbreak-related illnesses per 100,000 outbreak-associated passenger days (6747/1,007,157). This rate peaked in 2002 at 778 outbreak-related illnesses per 100,000 passenger days (Wald $\chi^2=5.68$, $p<0.0172$).

The combined outbreak and non-outbreak incidence rates of gastroenteritis per 100,000 passenger days among 14,842 cruises were higher on cruises >7 days long than on cruises 3 to 7 days. The combined rate was 27.4 for cruises lasting 3 to 6 days, 26.5 for cruises lasting 7 days, 38.8 for cruises lasting 8 to 15 days, and 48.7 for cruises lasting 16 to 21 days. AGE incidence rates per 100,000 passenger days varied by reporting region; the total incidence rate was highest in the Northwest region (42.2 cases per 100,000 passenger days), and lowest in the Northeast region (17.4 cases per 100,000 passenger days).

Surveillance data indicated 79 cruises associated with outbreaks (Table 1); 71 were considered unique outbreaks; eight were excluded because they were associated with an outbreak on the same ship during the previous contiguous cruise and were associated with either the same or an unidentified pathogen. Among the remaining 71 outbreak-associated cruises, the overall incidence rate was 4.8 outbreaks per 1000 cruises and 3.8 outbreaks per 10,000,000 passenger days. The outbreaks per 1000 cruises increased from 0.65 in 2001 to 6.45 in 2002, and then dropped to 5.73 in 2003 and to 5.46 in 2004. In addition to the outbreaks identified...
from surveillance data, 12 additional outbreak-associated cruises were identified from internal and published reports of epidemiologic investigations. Between 1990 and 2001, annual outbreaks remained less than 10 per year.1

From 2001 through 2004, VSP conducted 1029 sanitation inspections on a total of 200 unique vessels; 25 (2.4%) of the total inspections were reinspections of ships that had failed the previous inspection and were excluded from further analysis because reinspection scores were not considered independent observations. The number of inspections per year ranged from 233 in 2002 to 278 in 2003; the median inspection score for the 1004 inspections was 95, with a range of 54 to 100 throughout the study period; 39 (3.9%) inspections had unacceptable scores (H11021 86). Median inspection scores remained relatively constant throughout the study period with a median of 94.5 (Kruskal–Wallis H9273 2.13, p 0.544). Since 1990, annual inspection scores have steadily increased from a median of 89 in 1990 to 95 in 2004 (Spearman’s coefficient H11005 0.95, p 0.001). The percentage of ships failing inspections also remained constant throughout the study period, ranging from 3.2% in 2003 to 5.1% in 2001 (Cochran–Armitage trend test Z11005 1.10, p 0.314). During the study period, 43 incidents of failed GISS reporting among 18,232 cruises were observed by EHOs in 1029 inspections.

By univariate analysis, vessel size, vessel age, fleet size, and inspector were each significantly associated with sanitation inspection scores; lower scores were associated with smaller ship size, smaller fleet size, and older ship age. Inspection scores did not significantly vary by inspection region (H9273 3.27, p 0.774).

The VSP evaluated the association between sanitation inspection scores and AGE incidence rates using two methods. The first method, using Poisson regression modeling to associate AGE rates on five voyages preceding each inspection with the related inspection score for each ship, resulted in a crude rate ratio of 1.00 (95% confidence interval [CI] = 0.97–1.02). When adjusted for cruise length, ship age, inspectors, fleet size, and embarkation year in the reduced model, inspection scores were not significantly associated with AGE incidence rates (risk ratio [RR] = 1.00; 95% CI = 0.98–0.02). The second method associated the frequency of outbreaks per ship with the median inspection score during the study period. At the aggregate level, VSP found no association between the frequency of AGE

### Table 1. Incidence rates of gastroenteritis among passengers on cruise ships, 2001–2004, Vessel Sanitation Program, Centers for Disease Control and Prevention

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>Total</th>
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<tr>
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<td>28.44</td>
<td>28.54</td>
<td>25.63</td>
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<td>2</td>
<td>25</td>
<td>25</td>
<td>26</td>
<td>79</td>
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<tr>
<td>Passenger cases</td>
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<td>1,806</td>
<td>2,324</td>
<td>6,747</td>
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<td>Cases/100,000 outbreak passenger daysb</td>
<td>626.88</td>
<td>778.59</td>
<td>626.20</td>
<td>613.71</td>
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<td></td>
<td></td>
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<tr>
<td>Passenger days</td>
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<td>46,418,596</td>
<td>51,186,038</td>
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<td>188,070,969</td>
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<tr>
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<td>4,013</td>
<td>4,034</td>
<td>14,842</td>
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<tr>
<td>Cases/100,000 passenger days</td>
<td>17.73</td>
<td>30.94</td>
<td>31.97</td>
<td>32.82</td>
<td>29.22</td>
</tr>
</tbody>
</table>

a From surveillance data only, including cases and passenger days from contiguous cruises with outbreaks, on voyages lasting 3 to 21 days, among ≥3% of passengers.
b Outbreak-associated cases per 100,000 days associated with outbreaks.

![Figure 1. Gastroenteritis incidence among passengers and number of voyages reported by cruise ships to Vessel Sanitation Program, Centers for Disease Control and Prevention, 2001–2004. Outbreak incidence was calculated as outbreak cases divided by passenger days during outbreaks; background incidence was calculated as background cases (non-outbreaks) divided by passenger days during non-outbreaks. Both incidence rates exclude the 6 days following outbreaks. The number of voyages was calculated as distinct cruises lasting between 3 and 21 days in duration as measured by the number of days between embarkation and disembarkation of new cohort of passengers.](image-url)
Diarrheal disease incidence among passengers on cruise ships sailing into the United States declined from 1990 to 2000.

In 2002, the Vessel Sanitation Program of the Centers for Disease Control and Prevention reported 29 outbreaks of acute gastroenteritis on cruise ships, a sharp increase from 2 outbreaks the previous year.

This article reports on the increase in outbreak incidence rates during 2001 through 2004. Despite good performance on environmental health sanitation inspections by cruise ships, passenger cases of gastroenteritis increased compared to the previous study period.

Total incidence rates of AGE were the highest in the Northwest region where cruise ships itineraries are seasonal and generally operate during May through September. Traditionally, the peak NoV incidence in the general population occurs in winter months as demonstrated by increases in outbreaks in closed settings in winter in the United States and in Europe. However, the regional variation noted throughout the study period, associated with cruise ship travel to Alaska during the summer months, is consistent with incidence data from Europe, wherein NoV-related illnesses occurred more frequently on cruise ships in the summer. Furthermore, in the United States from May through December 2002, when the outbreak incidence among cruise ships sailing into the United States during the study period peaked, a previously unidentified circulating strain of genogroup II cluster 4 NoV provisionally named “Farmington Hills strain,” was identified as predominating at sea and on land as the primary pathogen associated with the acute increase in NoV outbreaks and incidence rates that occurred during that year. Similarly, recent epidemiologic trend data from the Netherlands, England, Wales, and Germany show similar patterns of increased numbers of NoV outbreaks in 2002 after detection of a new genogroup II cluster 4 variant. These countries as well as Finland report spring and summer peaks, which preceded the identification of the new NoV variant.

In 2001, the diarrheal disease definition used by VSP expanded to AGE. The effect of this change on surveillance data was not tested, and trends in background incidence rates are difficult to interpret over several study periods. However, the background incidence rate in 2000, using the definition of diarrheal disease alone, was 16.3 cases per 100,000 passenger days. This remained fairly constant into the new study period in 2001 with a background incidence of 17.4 cases per 100,000 passenger days. The increase in background incidence and associated outbreaks occurred between years during which the same surveillance case definition was applied.

The observed increase in AGE incidence attributable to NoV, in the setting of improved environmental health program implementation, highlights the inability of environmental programs to fully predict and prevent risk factors common to the person-to-person and fomite spread of disease. However, the likelihood of contracting gastroenteritis on an average 7-day cruise at sea remains at less than 1%, and available reviews of infirmary data have shown that gastrointestinal illnesses account for less than 10% of all visits by passengers to ships’ infirmaries. Nonetheless, with >10 million passenger embarkations in North American ports in 2004, the challenge for the cruise ship industry is to implement effective strategies to reduce risks for disease while not creating disincentives for passengers to report illness.

The cruise ship industry has cooperated with CDC in implementing rigorous containment strategies, cleaning protocols, and disinfection regimens. Because of the persistence of AGE aboard cruise ships, continued collaboration is essential to serving public health, monitoring the magnitude and extent of the problem, and assisting the cruise industry to continue to responsibly address this problem.
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References


