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ORIGINAL ARTICLE

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## Influenza Outbreaks Among Passengers and Crew on Two Cruise Ships: A Recent Account of Preparedness and Response to an Ever-Present Challenge

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**Background.** During spring 2014, two large influenza outbreaks occurred among cruise ship passengers and crew on trans-hemispheric itineraries.

**Methods.** Passenger and crew information for both ships was obtained from components of the ship medical records. Data included demographics, diagnosis of influenza-like illness (ILI) or acute respiratory illness (ARI), illness onset date, passenger cabin number, crew occupation, influenza vaccination history, and rapid influenza diagnostic test (RIDT) result, if performed.

**Results.** In total, 3.7% of passengers and 3.1% of crew on Ship A had medically attended acute respiratory illness (MAARI). On Ship B, 6.2% of passengers and 4.7% of crew had MAARI. In both outbreaks, passengers reported illness prior to the ship's departure. Influenza activity was low in the places of origin of the majority of passengers and both ships' ports of call. The median age of affected passengers on both ships was 70 years. Diagnostic testing revealed three different co-circulating influenza viruses [influenza A(H1N1)pdm09, influenza A(H3N2), and influenza B] on Ship A and one circulating influenza virus (influenza B) on Ship B. Both ships voluntarily reported the outbreaks to the Centers for Disease Control and Prevention (CDC) and implemented outbreak response plans including isolation of sick individuals and antiviral treatment and prophylaxis.

**Conclusions.** Influenza activity can become widespread during cruise ship outbreaks and can occur outside of traditional influenza seasons. Comprehensive outbreak prevention and control plans, including prompt antiviral treatment and prophylaxis, may mitigate the impact of influenza outbreaks on cruise ships.

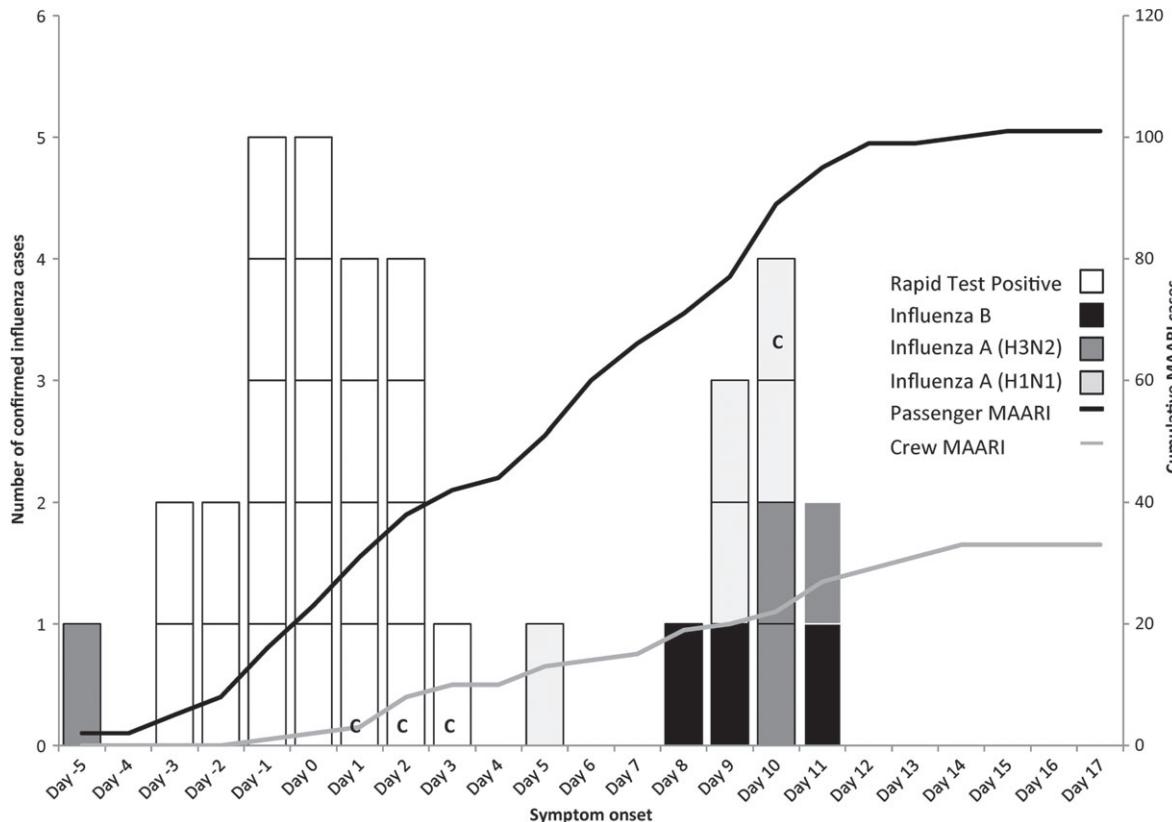
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Respiratory illness accounts for up to 29% of recorded illnesses on cruise ships,<sup>1</sup> and cruise ship influenza outbreaks have been previously reported worldwide.<sup>2–5</sup> Although influenza seasonality typically corresponds to winter months in temperate areas of the Northern and Southern Hemispheres,<sup>6</sup> cruise ship destinations can include tropical areas where influenza activity lacks well-defined seasonality.<sup>6,7</sup> Additionally, cruise ship environments, which often accommodate many travelers in partially enclosed settings, may facilitate influenza transmission.

Between March 15 and April 5, 2014, two cruise ships reported large outbreaks of medically attended acute respiratory illness (MAARI) among passengers and crew to the Centers for Disease Control and Prevention (CDC). MAARI includes cases of influenza-like illness (ILI) [defined as temperature of  $\geq 100^{\circ}\text{F}$  ( $\geq 37.8^{\circ}\text{C}$ )], oral or equivalent, and cough and/or sore throat, without a known cause other than influenza; and acute respiratory illness (ARI) (defined as cough and/or sore throat, without a known cause other than influenza). Both cruises originated in South America and terminated in Los Angeles, USA, following 17-day itineraries, which included eight ports of call at destinations in Chile, Peru, Costa Rica, Nicaragua, and Mexico. Low levels of influenza activity were reported in those areas during both voyages.<sup>8,9</sup> As a result of the illnesses among passengers and crew, both ships activated their respiratory illness outbreak response plans.

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**Figure 1** Epidemic curve of confirmed influenza cases and cases of medically attended acute respiratory illness (MAARI) among passengers and crew on Ship A, March 15 to April 1, 2014. Medically attended acute respiratory illness includes cases of influenza-like illness and acute respiratory illness. Day 0 corresponds to March 15, 2014, which was the day of departure for Ship A. C corresponds to a confirmed case of influenza in a crew member.

## Methods

Passenger and crew information for both ships was obtained from components of the ship medical records released to the CDC Los Angeles Quarantine Station. Data included demographics, diagnosis of ILI or ARI, illness onset date, passenger cabin number, crew occupation, influenza vaccination history, and rapid influenza diagnostic test (RIDT) result, if performed. For a subset of persons with MAARI, influenza testing was conducted using the CDC Human Influenza Real-Time Reverse-Transcription Polymerase Chain Reaction (rRT-PCR) assay or Luminex xTAG multiplex respiratory viral panel (Luminex Corporation, Toronto, Canada). Laboratory-confirmed influenza was defined as a positive RIDT result or a positive rRT-PCR test, if performed.

Both ships used questionnaires to identify passengers with respiratory illness symptoms upon embarkation and voluntarily reported ILI outbreaks to CDC using established methods.<sup>10</sup> CDC defines a maritime ILI outbreak as exceeding a threshold of 1.38 cases per 1,000 traveler-days. Initial rapid influenza diagnostic testing for passengers and crew members was ordered independently at the discretion of the cruise ship's medical staff.

CDC was consulted for outbreak prevention and control recommendations; cruise ship staff were responsible for implementing prevention and control measures.

## Results

Ship A traveled from March 15 to April 1, 2014. Ship A entered service in the early 2000s and carried 2,595 passengers and 1,057 crew during the current voyage. Illness onset for the first case of laboratory-confirmed influenza during this voyage occurred in a passenger from the UK 5 days before the ship's departure date (Day 0) (Figure 1). Nine additional laboratory-confirmed influenza cases occurred in passengers who reported having symptoms prior to Day 0. The cumulative passenger ILI rate (2.70) exceeded the outbreak threshold on Day 0. In total, Ship A identified 97/2,595 (3.7%) passengers with MAARI (Table 1). The country of origin with the highest proportion of affected passengers (46/97, 47.0%) was the United States. The median age of passengers with MAARI was 70 years (range 6–89 years); 33/95 (34.7%) had comorbid risk factors for influenza complications; 22/97 (22.7%) reported sharing a cabin with another ill

**Table 1** Cases of medically attended acute respiratory illness\* (MAARI) and characteristics of confirmed influenza cases among passengers on Ships A and B

	Ship A: n (%)	Ship B: n (%)
Passengers	2,595	2,987
MAARI (n/passengers)	97 (3.7)	187 (6.2)
Age (median, range) (n = MAARI)	70 (6–89)	70 (29–91)
Male (n/MAARI)	38/97 (39.2)	80/186 (43.0)
Comorbid risk factor† (n/MAARI)	33/95 (34.7)	Data unavailable
Shared cabin with ill passenger (n/MAARI)	22/97 (22.7)	60/187 (32.1)
Received influenza vaccination (n/MAARI)	65/97 (67.0)	154/186 (82.8)
Passengers tested (n/MAARI)	54/97 (55.7)	45/187 (24.1)
Laboratory-confirmed influenza (n/tested)	31/54 (57.4)	10/45 (22.2)

\*Medically attended acute respiratory illness includes cases of influenza-like illness and acute respiratory illness.

†Comorbid risk factors include persons with chronic pulmonary conditions (including asthma); cardiovascular disease (except hypertension alone); renal, hepatic, or hematologic (including sickle cell) disease; metabolic disorders (including diabetes mellitus); or neurologic and neurodevelopment conditions [including disorders of the brain, spinal cord, peripheral nerve, and muscle, such as cerebral palsy, epilepsy (seizure disorders), stroke, intellectual disability (mental retardation), moderate to severe developmental delay, muscular dystrophy, or spinal cord injury]; persons with immunosuppression, including that caused by medications or by human immunodeficiency virus infection.

passenger, and 65/97 (67.0%) reported having received an influenza vaccination. Of 54 passengers tested, 31 (57.0%) had laboratory-confirmed influenza (20 by RIDT and 11 by rRT-PCR). Illness onset for the first laboratory-confirmed case among the crew occurred on the day after the ship's departure date (Day 1) (Figure 1), and the cumulative crew ILI rate (1.89) exceeded the outbreak threshold on Day 2. Of 1,057 crew members, 33 (3.1%) had MAARI (Table 2). The majority of crew members with MAARI (57.6%) had occupations in food service. Overall crew influenza vaccination coverage on Ship A was 90%, and 31/33 (93.9%) crew with MAARI reported receipt of influenza vaccination. Of the crew tested, four (40%) had laboratory-confirmed influenza (three by RIDT and one by rRT-PCR). Overall, rRT-PCR testing performed by CDC revealed three different co-circulating influenza viruses among passengers and crew (five influenza A(H1N1)pdm09, four influenza A(H3N2), and three influenza B viruses).

Ship B traveled from March 20 to April 5, 2014. Ship B entered service in the mid-2000s and carried 2,987 passengers and 1,157 crew during the current voyage. Two passengers from the United States and Australia with laboratory-confirmed influenza reported symptoms on Day 0; however, additional passengers and crew also reported having respiratory symptoms before departure (Figure 2). The cumulative passenger ILI rate (2.00) exceeded the outbreak threshold on

**Table 2** Cases of medically attended acute respiratory illness\* (MAARI) and characteristics of confirmed influenza cases among crew on Ships A and B

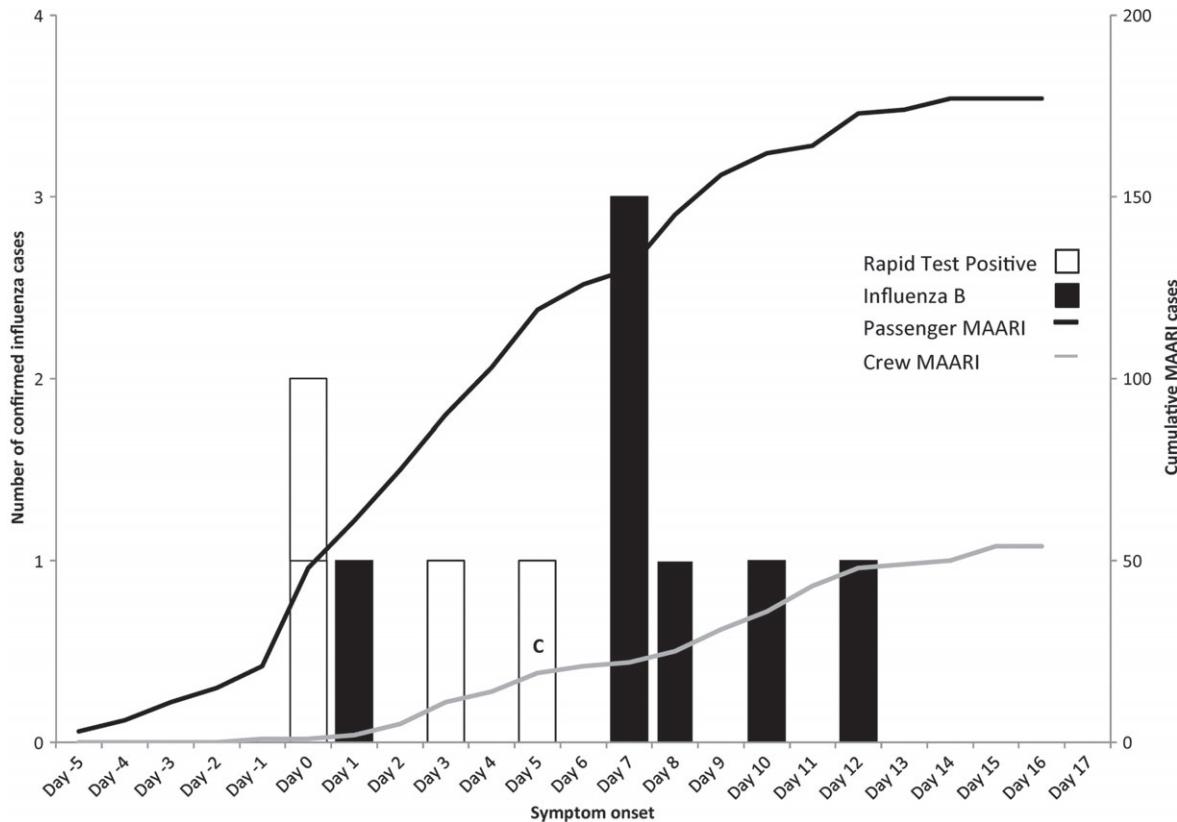
	Ship A: n (%)	Ship B: n (%)
Crew	1,057	1,157
MAARI (n/crew)	33 (3.1)	54 (4.7)
Age (median, range) (n = MAARI)	33 (23–49)	31.5 (22–61)
Male (n/MAARI)	22/33 (66.7)	37/54 (68.5)
Comorbid risk factor† (n/MAARI)	0/33 (0)	Data unavailable
Received influenza vaccination (n/MAARI)	31/33 (93.9)	54/54 (100)
Occupation category (n/MAARI)		
Food service	19/33 (57.6)	21/54 (38.9)
Entertainment	4/33 (12.1)	6/54 (11.1)
Accommodation	2/33 (6.1)	10/54 (18.5)
Other	8/33 (24.2)	17/54 (31.5)
Crew tested (n/MAARI)	10/33 (30.3)	6/54 (11.1)
Laboratory-confirmed influenza (n/tested)	4/10 (40.0)	1/6 (16.7)

\*Medically attended acute respiratory illness includes case of influenza-like illness and acute respiratory illness.

†Comorbid risk factors include persons with chronic pulmonary conditions (including asthma); cardiovascular disease (except hypertension alone); renal, hepatic, or hematologic (including sickle cell) disease; metabolic disorders (including diabetes mellitus); or neurologic and neurodevelopment conditions [including disorders of the brain, spinal cord, peripheral nerve, and muscle, such as cerebral palsy, epilepsy (seizure disorders), stroke, intellectual disability (mental retardation), moderate to severe developmental delay, muscular dystrophy, or spinal cord injury]; persons with immunosuppression, including that caused by medications or by human immunodeficiency virus infection.

Day 0. In total, Ship B identified 187/2,987 (6.2%) passengers with MAARI (Table 1). The highest proportion of affected passengers (108/187, 58.0%) was from the United States. The median age of passengers with MAARI was 70 years (range 29–91 years); 60 (32.1%) reported sharing a cabin with another ill passenger, and 154 (82.8%) reported receipt of influenza vaccination. Of 45 passengers tested, 10 (22.0%) had laboratory-confirmed influenza (seven by rRT-PCR and three by RIDT). Ship B identified 54/1,157 (4.7%) crew with MAARI (Table 2) and the cumulative crew ILI rate never exceeded the outbreak threshold. The majority of the affected crew (38.9%) had occupations in food service. Overall crew influenza vaccination coverage on Ship B was 95.5%; all crew with MAARI reported receipt of influenza vaccination. Of six crew tested, one (17.0%) was positive by RIDT. The Los Angeles County Public Health Laboratory identified seven influenza B viruses among passengers using the Luminex xTAG multiplex respiratory viral panel.

Outbreak control measures on both ships included active surveillance for MAARI in crew and passengers to identify incident cases, isolation of passengers and crew with MAARI, empiric antiviral treatment for confirmed and suspected cases of influenza, chemoprophylaxis of all close case contacts (eg, sharing a room with a



**Figure 2** Epidemic curve of confirmed influenza cases and cases of medically attended acute respiratory illness (MAARI) among passengers and crew on Ship B, March 20 to April 5, 2014. Medically attended acute respiratory illness includes cases of influenza-like illness and acute respiratory illness, Day 0 corresponds to March 20, 2014, which was the day of departure for Ship A, C corresponds to a confirmed case of influenza in a crew member.

symptomatic individual), and other nonpharmaceutical measures such as improved hand hygiene.

## Discussion

We report two large influenza outbreaks among passengers and crew on cruise ships with similar itineraries during spring 2014. The proportion of persons with MAARI on Ship A (3.5%) and Ship B (5.8%) suggests that widespread influenza activity occurred during each voyage, prompting voluntary reporting. These outbreaks highlight the usefulness of respiratory disease surveillance and several issues important to influenza preparedness and response activities on cruise ships.

Although cruise ships destined for the United States are required to report novel or reemergent influenza viruses with pandemic potential among passengers or crew to CDC under the Foreign Quarantine Regulations (42 CFR Part 71), reporting of seasonal influenza is not required.<sup>7</sup> Since respiratory disease outbreaks on cruises may be frequent,<sup>1,7,11</sup> CDC has developed a cruise ship ILI surveillance mechanism in conjunction with cruise ships to augment reporting.<sup>7</sup> Unlike CDC's Vessel Sanitation Program,<sup>12</sup> which requires

reporting of gastrointestinal illness in cruise ships carrying 13 or more passengers and with a foreign itinerary with US ports,<sup>12</sup> reporting of suspected or confirmed outbreaks of seasonal influenza on cruise ships is voluntary.<sup>13</sup> Per CDC's ILI guidance, surveillance for influenza on cruise ships involves recording all ILI cases or confirmed cases of influenza among passengers and crew on reporting logs and calculating ILI thresholds.<sup>7,13</sup> If a cruise ship voluntarily reports an outbreak, CDC can provide guidance on prevention and control measures. Similarly, in Europe, the European Union SHIPSAN TRAINET Project has developed a similar set of maritime influenza outbreak prevention and response guidelines, which includes logging cases of ILI as part of routine surveillance as well as plans for treatment and chemoprophylaxis in the event of an outbreak.<sup>14</sup> The Maritime Declaration of Health, a component of the World Health Organization's 2005 International Health Regulations, is another mechanism by which cruise ships can report illnesses to health authorities in countries of disembarkation.<sup>15</sup> As occurred in our two outbreaks, routine ILI surveillance enabled cruise ship medical staff to detect their ongoing influenza outbreaks quickly and to report the outbreaks to CDC, which allowed a collaborative

approach to rapidly implementing outbreak response activities.

Both outbreaks occurred during periods of low influenza activity in areas included in the ships' trans-hemispheric journeys<sup>8,9</sup> suggesting that maritime cruises may be vulnerable to influenza outbreaks outside of the traditional influenza seasons of the countries in their itineraries.<sup>16</sup> Influenza outbreaks on cruise ships have previously been reported as occurring during and outside of traditional influenza seasons.<sup>2,17</sup> Furthermore, since cruise ships frequently carry passengers from many different countries,<sup>5</sup> it may be prudent to consider their influenza "season" to be year-round, regardless of the itinerary. The outbreaks described in this report are similar to previous cruise ship outbreaks in that both were large and one involved multiple co-circulating strains of influenza.<sup>2</sup> These findings underscore how cruise ship environments can facilitate influenza outbreaks that may not occur in other travel settings. First, cruise ships can facilitate respiratory virus transmission because passengers and crew are in close contact for extended periods of time in partially enclosed areas.<sup>4,14</sup> Second, because travel includes frequent layovers at ports of call where new crew and passengers can board, cruise ships allow introduction of new susceptible persons (and perhaps new infected persons as well) into this enclosed environment at multiple points during their voyages.

Influenza outbreaks on cruise ships can resemble outbreaks in long-term care facilities (LTCFs)—in both settings, outbreaks can be extensive and involve high-risk populations. Similar to LTCFs, cruise ships often carry passengers at increased risk for influenza complications—persons aged  $\geq 65$  and with medical comorbidities.<sup>2</sup> Therefore, cruise ship outbreak response strategies should reflect the multifaceted nature of outbreak management plans in LTCFs and communities.<sup>5,18</sup> The primary components of outbreak management on cruise ships involve surveillance, case identification, and treatment and response measures. Routine ILI surveillance can identify potential cases of respiratory illness among passengers and crew. Diagnostic testing is challenging in a cruise ship setting and often relies on point-of-care platforms, such as RIDTs, which both Ship A and Ship B employed.<sup>19</sup> Although RIDTs have poor sensitivity,<sup>20</sup> which may produce false-negative results, the finding of positive RIDT results in the setting of multiple cases of ILI within a 72-hour period is likely indicative of an influenza outbreak in a cruise ship setting, which necessitates prompt response.<sup>13,18</sup> After cruise ship outbreaks are identified, recommended control measures include isolation of ill persons, antiviral treatment of confirmed and suspected cases, and chemoprophylaxis of high-risk contacts<sup>13</sup>—recommendations similar to guidance for influenza outbreak management in LTCFs.<sup>5,18</sup> Prompt influenza antiviral treatment can prevent complications among hospitalized and high-risk ambulatory patients with influenza.<sup>21,22</sup> Additionally,

antiviral chemoprophylaxis can limit transmission to noninfected individuals; it is used in LTCFs to prevent ongoing transmission during influenza outbreaks, and the same reasoning can apply for cruise ship outbreaks.<sup>18</sup>

Prevention and control of influenza outbreaks during maritime travel can involve complexities not commonly seen in other settings. For example, identifying illnesses may prove challenging if some passengers withhold symptoms because they fear travel may be curtailed or denied. Although both ships in this report used questionnaires to identify ill passengers at embarkation, 17 confirmed influenza cases with symptom onset prior to or on the day of departure were later identified, only after passengers eventually sought care for their illnesses. Cruise ship staff should strongly encourage passengers who elect to travel while ill, or who become ill *en route*, to report symptoms promptly so that they may receive appropriate medical treatment and that, if appropriate, the ship's outbreak response plan may be employed to mitigate illness among other passengers and crew. Additionally, cruise ship influenza outbreaks have been shown to be prolonged if newly susceptible passengers join the cruise ship at different destinations at ports along the itinerary.<sup>17</sup> Since we do not know if new passengers or crew embarked along the itinerary for either ship in this report, we are unable to assess whether this mechanism contributed to either of the outbreaks we describe.

Our findings are limited because we were unable to interview all passengers and crew; thus, both outbreaks we describe represent only medically attended illnesses. Previous studies have shown that self-administered passenger surveys often identify additional cases.<sup>5</sup> Therefore, both outbreaks may have been larger than suggested by our data. Additionally, our findings do not include data from previous or subsequent cruises for either ship, so we were unable to evaluate events not reported during their current voyages. Finally, we were unable to evaluate the implementation of our active surveillance or treatment recommendations during the outbreaks.

The potential impact of influenza outbreaks on cruise ships is large as >70 million passenger-days of travel are booked annually on North American cruises.<sup>23</sup> Often isolated from land-based medical assistance, cruise ships may need to rely on staff and supplies on hand for outbreak control during their voyages. As part of an overall prevention plan, cruise ship medical staff should vaccinate crew members prior to departure and anticipate surges in demand for medical care that an outbreak may precipitate. This includes ensuring that antiviral medication supplies are sufficient to control outbreaks involving large numbers of persons. Passengers should also be encouraged to seek medical consultation prior to travel to determine specific medical care needs and to receive an annual influenza vaccination. Collaboration between public health and cruise ship medical staff to create response strategies may also help overcome the

challenges in managing influenza outbreaks during maritime travel.

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### Disclaimer

The opinions expressed by the authors contributing to this journal do not necessarily reflect the opinions of the Centers for Disease Control and Prevention or the institutions with which the authors are affiliated.

### Declaration of Interests

There are no financial conflicts of interest among any of the authors.

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