

SARS-CoV-2 Infections among Crew Members Onboard Passenger-Voyaging Cruise Ships during a Period of Delta Variant Predominance-United States, June-October 2021

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Abstract

Objective: Following suspension of cruising due to the COVID-19 pandemic, passenger voyaging operations resumed in June 2021 when cruise lines, with assistance from the Centers for Disease Control and Prevention (CDC), implemented protocols to manage COVID-19. We describe demographic characteristics, time since vaccination and living and working conditions of crew members testing positive for SARS-CoV-2 following resumption of passenger operations in the US during a period of Delta variant predominance.

Methods: Ships sailing under CDC's framework for conditional sailing order reported SARS-CoV-2 test results, vaccination rates and hospitalizations/medical evacuations due to SARS-CoV-2 infection to CDC daily. Ships experiencing large outbreaks (≥ 20 SARS-CoV-2-positive cases among crew/passengers within 14 days) submitted additional case data (e.g. demographics, vaccination history, living/working quarters and numbers of crew members who were close contacts of cases).

Results: During June-October 2021, 1,079 SARS-CoV-2 positive crew members were reported to CDC; 402 cases from large outbreaks had case level data and were included in this analysis. All cases completed a primary vaccine series before they were infected. Median number of days from last vaccination to infection was 76 days (Interquartile Range (IQR): 53-98). Most crew received the Janssen vaccine ($n=302$; 76%) and Janssen recipients had lower median number of days from last vaccination to infection than recipients of vaccines from other manufacturers (75 days (IQR: 55-87) vs. 86 days (IQR: 46-125; $p=0.03$)). No hospitalizations or medical evacuations for SARS-CoV-2 were reported; 263 cases (65%) were asymptomatic at time of testing. Forty percent of cases shared either a cabin or restroom with another crew member at time of diagnosis.

Conclusion: SARS-CoV-2 infections were reported among vaccinated crew member's onboard passenger voyaging ships although severe illness was rare. Enhancements to existing COVID-19 mitigation measures and facilitating booster vaccination, ensuring vaccinations are up to date, may reduce the risk of infections in such congregate settings.

Keywords: COVID-19; CDC; Vaccination; Janssen vaccine; Medical evacuations

Introduction

Cruise ships are residential congregate settings with high risk of transmission of SARS-CoV-2 due to frequent contact and shared spaces among passengers and crew [1]. In March 2020, outbreaks of SARS-CoV-2 on cruise ships resulted in an unprecedented suspension of cruising in the US under the Centers for Disease Control and prevention (CDC) No Sail Order (NSO) [2,3]. In June 2021, passenger operations resumed in US waters as part of a phased approach after cruise lines, in partnership with CDC, implemented the framework for Conditional Sailing Order (CSO) which allowed cruise lines to offer voyages under a comprehensive set of regulations [4,5]. Cruise ships choosing to enter US waters were required to follow guidance aimed at reducing the introduction and spread of SARS-CoV-2 on board cruise ships to align with national health and safety protocols.

In 2020 COVID-19 outbreaks on cruise ships resulted in hundreds of confirmed cases among passengers and crew, including fatalities [6]. In the first five months of 2021, during the pandemic's pre-Delta variant period, SARS-CoV-2 crew attack rates and severe disease associated with COVID-19 decreased on cruise ships. This decrease in

disease prevalence among crew occurred at a time of increased vaccine availability, implementation of CSO interventions and additional efforts from the cruise industry to manage outbreaks [7,8].

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An investigation of four delta variant period COVID-19 outbreaks occurring onboard passenger voyaging cruises participating in the CSO reported attack rates among crew ranging from 6.0% to 11.1%. Similarly, a Delta variant outbreak among a 98% vaccinated crew aboard a US Navy ship after a port visit in Iceland resulted in a 6% attack rate.

Reducing the risk of infection among crew is essential to the continuation of safe cruise travel. Crew members remain onboard for months at a time, have limited access to health care beyond what is available on the ship and may work in conditions that could increase their risk of exposure [9]. Currently, there is a lack of published data about which crew members are more likely to become infected despite following vaccination recommendations. In this report, we use case data to describe the demographic characteristics, vaccination history, living and working quarters and numbers of crew members who were close contacts of NAAT or antigen positive crew members following the resumption of passenger operations in the US during the period of Delta variant predominance.

Materials and Methods

Setting

Under the CSO, cruise ships were defined as commercial, non-cargo, passenger carrying vessels subject to the jurisdiction of the United States with the capacity to carry ≥ 250 individuals (passengers and crew) and an itinerary anticipating, at a minimum, an overnight stay onboard or a twenty four (24) hour stay onboard for either passengers or crew. Participating cruise lines were required to follow CDC Technical guidance developed specifically for cruise ships including:

- Onboard surveillance to identify passengers and crew with COVID-19 and COVID-19 Like Illness (CLI).
- Implementation of vaccination strategies.
- Training all crew on COVID-19 prevention, mitigation and response activities.
- Onboard isolation and quarantine.
- COVID-19 diagnostic and screening testing following CDC technical instructions.
- Onboard medical staffing.
- Procedures for the disembarkation of passengers who test positive for SARS-CoV-2.

Study design

Cruise ship healthcare personnel or contracted services conducted specimen collection and SARS-CoV-2 testing with NAAT or antigen tests. The CSO required crew members are tested every two weeks and before disembarkation. SARS-CoV-2 testing was also performed at the ship's medical center for close contacts of NAAT or antigen positive crew members or crew members who reported at least one of the following symptoms of CLI: Fever, cough, difficulty breathing, shortness of breath, new olfactory disorder, or new taste disorder; or at least two or more of the following symptoms: Sore throat, nasal congestion, runny nose (rhinorrhea), chills, rigors, muscle or body aches (myalgia's), headache, fatigue, vomiting or diarrhea. Close contacts were defined as crew members who were less than 6 feet away from an infected crew member for a total of 15 minutes or more over a 24 hours period based on the infectious period of the case (*i.e.* starting 2 days before the case had any symptoms (or for crew

members without symptoms, 2 days before the positive specimen collection date). However, testing protocols varied by ship and SARS-CoV-2 testing beyond the minimum requirement was sometimes conducted at the cruise ships' discretion. Embarkation testing results were not included in this analysis, as crew who tested positive upon embarkation were isolated on board for 10 days [10].

Cruise ship personnel reported SARS-CoV-2 test results, vaccination rates and crew members requiring hospitalization or medical evacuation in aggregate daily using the Enhanced Data Collection during COVID-19 pandemic (EDC) form, CDC's online COVID-19 surveillance instrument for cruise ships. Ships with large outbreaks (≥ 20 SARS-CoV-2 positive cases among crew or passengers identified in a 14 days period) required healthcare personnel onboard to collect additional case information such as demographics, symptoms, vaccination history, living/working quarters and the number of close contacts of NAAT or antigen positive crew members). Crew and passengers were considered as having completed a primary vaccine series two weeks after they received the second dose of a two dose mRNA series or two weeks after the received one dose of a single dose vaccine.

Data analysis

This analysis was limited to crew members with available case data who tested NAAT or antigen positive for COVID-19. Comparable data was not available for crew members who were not tested or tested negative. Descriptive statistics of demographic characteristics, vaccination history, living/working conditions and numbers of crew members who were in close contact with one or more cases were calculated for SARS-CoV-2 positive crew members who were part of large outbreaks. The number of days since last vaccination was calculated along with the number of close contacts identified. The Kruskal Wallis test was used to test for statistical differences [11]. Statistical significance was determined at $p < 0.05$. Data management and analyses were conducted using R (version 3.6.3; The R Foundation), SAS (version 9.4; SAS Institute, Cary, North Carolina) and Microsoft Excel.

Results

Between June and October 2021, a total of 1,079 cases of crew members who tested NAAT or antigen positive for COVID-19 were reported to CDC by 98 cruise ships operating under the CSO. An estimated daily average of 52,466 crew members was onboard passenger voyaging ships during the same period and 86% had completed a primary vaccine series. Crew members with partial or missing data for vaccination history were excluded from this analysis ($n=26$). Additional case data was available for 402 (37%) crew members who tested NAAT or antigen positive for COVID-19 who were also part of a large outbreak. All cases with additional information had completed a primary vaccine series prior to their SARS-CoV-2 infection. Demographic characteristics, vaccination history and illness severity of SARS-CoV-2 positive crew members with additional case report data from crew members who were part of a large outbreak are presented in Table 1. The median age was 37 years (Interquartile Range (IQR):31-43). Most crew were from the Western Pacific global region ($n=180$; 45%) followed by Southeast Asia ($n=133$; 33%), the Americas ($n=46$; 11%), Europe ($n=36$; 9%) and Africa ($n=7$; 2%). Median number of days from last vaccination until SARS-CoV-2 infection and days from ship embarkation until infection was 76 (IQR: 53-98) and 57 (IQR: 49-78), respectively.

Most NAAT or antigen positive crew with additional case data (n=302; 76%) received the Janssen vaccine followed by Pfizer-BioTech (n=48; 12%), AstraZeneca (n=24; 6%), Sinovac-CoronaVac (n=22; 5%), Moderna (n=4; 1%) and Covishield (n=2; 0.5%). Median number of days from last vaccination until infection were highest among crew members who were part of a large outbreak who received the AstraZeneca (115 days (IQR: 61-131)) and Sinovac-CoronaVac (87 days (IQR: 42-126)) vaccines (Figure 1). The median number of days from last vaccination until infection for AstraZeneca recipients

was statistically higher than Janssen vaccine recipients (75 days (IQR: 55-87); p=<0.01)). Janssen vaccine recipients also had lower median days from last vaccination until infection compared to a composite measure of crew who received vaccines from other manufacturers (86 days (IQR: 46-125; p=0.03)) (Figure 2). Thirty five percent (n=139) of infected crew reported symptoms and 27% (n=108) sought medical attention from the ship clinician. No COVID-19 related onboard hospitalizations, medical evacuations or deaths were reported.

	Crew n (%)
Age in years, median (IQR)	37 (31-43)*
Age group, in years	
18-29	83 (21)
30-39	169 (42)
40-49	111 (28)
≥ 50	34 (8)
Missing	5 (1)
Global region of permanent residence	
Western Pacific	180 (45)
Southeast Asia	133 (33)
Americas	46 (11)
Europe	36 (9)
Africa	7 (2)
Vaccine manufacturer of primary series	
Janssen (Johnson and Johnson)	302 (76)
Pfizer-BioNTech	48 (12)
AstraZeneca	24 (6)
Sinovac-CoronaVac	22 (5)
Moderna	4 (1)
Covishield	2 (0.5)
No. of days from last vaccination to positive SARS-CoV-2 test result	
Median (IQR)	76 (53-98)*
No. of days from ship embarkation to positive SARS-CoV-2 test result	
Median (IQR)	57 (49-78)*
Presence of symptoms on day of positive SARS-CoV-2 test result[†]	
Yes	139 (35)
No	263 (65)
Risk factors for severe COVID-19[‡]	
Yes	10 (2)
No	281 (70)

Missing	111 (28)
Sought medical attention from ship clinician (i.e. medical center or in-cabin clinician visit)	
Yes	108 (27)
No	264 (66)
Missing	30 (7)
Note: IQR: Interquartile Range	
*Crew members were considered as having completed a primary vaccine series two weeks after they received the second dose of a two dose m-RNA series or two weeks after the received one dose of a single dose vaccine. Vaccine manufacturers were identical for the primary series and the last vaccine received for 401 (99%) crew members. Ships with ≥ 20 SARS-CoV-2 positive cases among crew or passengers identified in a 14 days period were defined as having large outbreaks.	
†Crew member reported at least one or more of the following symptoms of COVID-19 like illness: Fever, cough, difficulty breathing, shortness of breath, new olfactory disorder or new taste disorder; or at least two or more of the following symptoms: Sore throat, nasal congestion, runny nose (rhinorrhea), chills, rigors, muscle or body aches (myalgia's), headache, fatigue, vomiting or diarrhea.	
‡Includes adult aged 65 years and older, pregnant or recently pregnant people or people with co-morbid medical conditions (Underlying medical conditions associated with higher risk for severe COVID-19: Information for healthcare professionals (CDC).	

Table 1: Demographic characteristics, COVID-19 vaccination history and illness severity among crew members who tested NAAT or antigen positive for SARS-CoV-2 and were part of a large SARS-CoV-2 outbreak* United States, June-October 2021 (N=402).

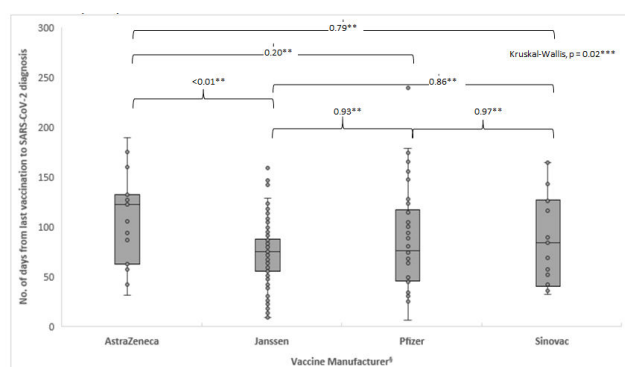


Figure 1: Number of days from most recent vaccination to SARS-CoV-2 diagnosis by vaccine manufacturer among crew members who tested NAAT or antigen positive and were part of a large outbreak* United States, June-October 2021 (N=402).

*Crew members were considered as having completed a primary vaccine series two weeks after they received the second dose of a two dose mRNA series or two weeks after the received one dose of a single dose vaccine. Ships with ≥ 20 SARS-CoV-2 positive cases among crew or passengers identified in a 14 days period were defined as having large outbreaks.

§Covishield (n=2) and Moderna (n=4) vaccine recipients not shown due to small sample size.

**P-values for pairwise comparisons tested using Wilcoxon rank sum test.

***P-values for overall comparisons tested using Kruskal-Wallis test.

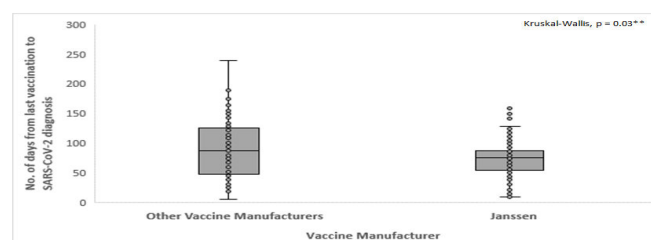


Figure 2: Number of days from last vaccination to SARS-CoV-2 diagnosis among crew who tested NAAT or antigen positive, were part of a large SARS-CoV-2 outbreak* and received the Janssen vaccine versus other vaccine manufacturers United States, June-October 2021 (N=402).

*Crew members were considered as having completed a primary vaccine series two weeks after they received the second dose of a two dose mRNA series or two weeks after the received one dose of a single dose vaccine. Ships with ≥ 20 SARS-CoV-2 positive cases among crew or passengers identified in a 14 days period were defined as having large outbreaks.

**P-values for overall comparisons tested using Kruskal-Wallis test.

More than 40% of crew members who were part of a large outbreak who tested positive either shared a cabin or a restroom with another crew member at their time of diagnosis. The highest proportion of infected crew (37%; n=148) worked in the restaurant department followed by 29% (n=114) working in housekeeping related occupations. Forty two percent (n=167) of cases reported one or more close contacts among other crew members within two days before the case had any symptoms or before the positive specimen collection and 24% (n=95) reported 3 or more close contacts (Table 2). There were no significant differences in average numbers of close contacts identified for each infected crew member by infected crew occupation (p=1.00).

	Crew n (%)
Shared cabin at time of diagnosis	
Yes	161 (40)
No	180 (45)
Missing	61 (15)
Shared restroom at time of diagnosis[§]	
Yes	168 (42)
No	155 (39)
Missing	79 (20)
Working quarters	
Restaurant	148 (37)
Housekeeping	114 (29)
Other technical staff [†]	33 (8)
Entertainment	31 (8)
Casino	24 (6)
Bar	14 (4)
Shops/Spa	13 (3)
Guest services	11 (3)
Deck	8 (2)
Medical	4 (1)
Number of close contacts	
0	44 (11)
1-2	167 (42)
3 or more	95 (24)
Missing	96 (24)
<p>Note: [†]Close contacts were defined as crew members who were less than 6 feet away from an infected crew member for a total of 15 minutes or more over a 24 hour period based on the infectious period of the case (<i>i.e.</i> starting 2 days before the case had any symptoms (or, for crew members without symptoms, 2 days before the positive specimen collection date).[§] Shared restrooms varied by ship and may or may not have been located within sleeping quarters. Ships with ≥ 20 SARS-CoV-2 positive cases among crew or passengers identified in a 14 days period were defined as having large outbreaks.</p>	
<p>[†]e.g. administrative, engine room/engineering and information technology.</p>	

Table 2: Shared spaces, working quarters and numbers of close contacts of crew members who tested NAAT or antigen positive for SARS-CoV-2 and were part of a large SARS-CoV-2 outbreak* United States, June-October 2021 (N=402).

Discussion

This is the first description of SARS-CoV-2 infections among cruise ship crew members during the Delta period since passenger voyaging operations resumed in June 2021; it demonstrates the continued risk of SARS-CoV-2 infection in these congregate settings despite high vaccination coverage and implementation of other COVID-19 mitigation measures. Crew members onboard cruise ships live and work in spaces with high population density and have frequent close contact with other crew or passengers, which likely increase

their risk of exposure to the SARS-CoV-2 virus. Data for this investigation was reported daily to the CDC from a total of 98 cruise ships with a daily average of 52,466 crew members on board operating under the CSO and to our knowledge, represents the largest sample available of crew members who tested positive for SARS-CoV-2 and who developed breakthrough infections after passenger voyaging resumed.

Resumption of passenger voyaging cruising under US jurisdiction occurred during the emergence of the SARS-CoV-2 Delta variant, prior to the availability of booster vaccinations [12,13]. The Delta

variant's higher transmissibility and increased ability to evade immune protection compared to wild type could partially explain outbreaks among crew members despite vaccination requirements and protocols to manage COVID-19. Our study estimated the prevalence of SARS-CoV-2 infection to be 2.1% of approximately 52,000 crew members, which is a reliable indicator of asymptomatic and symptomatic infection during this time period given that participating ships conducted prospective, active SARS-CoV-2 surveillance. In comparison, prevalence rates among crew members reported from other cruise ship outbreaks investigations occurring during a period of Delta variant predominance were much higher (ranging from 6.0% to 11.1%) than those reported in this investigation. This difference is likely due to our inclusion of all cases reported onboard cruise ships sailing under the CSO rather than only from ships experiencing SARS-CoV-2 outbreaks. Our study did not examine vaccine effectiveness among crew members; however, our findings support published descriptions of waning vaccine effectiveness over time since vaccination. In our analysis, 75% of cases were reported more than 50 days after the crew member's last vaccination and none of the cases required hospitalizations or medical evacuations. Crew members generally received the Janssen vaccine most likely because it requires a single dose; however, study findings indicate that Janssen vaccine recipients, of which $n=25/302$ (8.3%) became infected within 30 days of completion of primary series of vaccine, had significantly fewer days from last vaccination until infection compared to crew who received vaccines from other manufacturers. In addition, only three of the six vaccines listed were approved for use in the US during the time of this study. This is likely because most infected crew with additional case data were from Western Pacific or Southeast Asian global regions. Crew members should remain up to date with their vaccines, which includes additional doses for individuals who are immunocompromised, and booster doses as recommended by CDC and WHO guidance. Studies have shown that people who are up to date with their vaccines are less likely to experience severe illness.

Cruise ship crew members live in close quarters, often with regular interaction with other crew and passengers, putting them at risk of exposure to the SARS-CoV-2 virus. In our investigation, restaurant and housekeeping positions were the most frequently reported occupations among cases and more than 40% of crew members who tested positive were sharing a closed space with another crew member at the time of diagnosis. These positions are typically the largest departments on cruise ships, although the composition of crew members varies by cruise line. Although we cannot say that those working in these areas are at higher risk because we cannot calculate attack rates by working quarters, our results identified a high number of cases in these positions which suggests enhancing mitigation measures for crew members working in these positions may reduce numbers of infections among vaccinated crew members. The CDC developed specific strategies over the course of the pandemic to assist the cruise industry with mitigating the spread of COVID-19. Crew members should be instructed on how to properly wear a well-fitting mask when outside of individual cabins and always use respiratory/hand hygiene. Additional strategies include modified meal service to facilitate physical distancing (e.g. reconfigure dining room seating, stagger mealtimes, encourage in-cabin dining), increasing ventilation particularly in crew smoking areas and placing messaging in high visibility areas that encourages hand hygiene to help stop the spread of infectious diseases.

Conclusion

This investigation was subject to several limitations. First, the conclusions from this sample of crew members who tested positive for SARS-CoV-2 may not be generalizable to all crew members operating on passenger voyaging cruise ships. In addition, case data was collected by cruise ship clinicians and was subject to the disclosure of symptoms by the crew member being tested or evaluation in a medical center. Data were not collected from crew members who did not test positive for SARS-CoV-2 and detailed case report data was available for only 37% of all reported cases during the investigation and only from cases who were part of a large outbreak, which may not represent characteristics found among sporadic cases among the crew. Second, although we compared time from last vaccination to infection by the type of vaccine received by crew members, this study did not evaluate vaccine effectiveness and did not adjust for other risk factors for SARS-CoV-2 infection, such as age, presence of underlying medical conditions and race/ethnicity. In addition, some sample sizes from among the 6 vaccines listed were small and underpowered to detect significant differences. Finally, cases reported here occurred during Delta variant predominance (in US). Available data may be biased towards ships with outbreaks of SARS-CoV-2 because those ships provided detailed case data to the CDC. Additional mitigations measures might be necessary to control other variants with increased transmissibility, such as Omicron. Furthermore, future variants or sub variants may require different mitigation strategies and preventative measures to prevent transmission and severe outcomes. Cruise lines should continue to monitor the frequency and severity of cases so that resources can be allocated appropriately.

In conclusion, working on cruise ships still poses a risk of infection despite the implementation of COVID-19 mitigation strategies. Continuous prevention and mitigation efforts are needed to protect the health and safety of crew onboard and should account for shared spaces and specific working conditions that may increase the risk of exposure to the SARS-CoV-2 virus.

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