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Cruise Ship Travel and the Spread of COVID-19 – Australia as a Case Study

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Abstract

Introduction: Cruise ship linked COVID-19 outbreaks have been identified as a potential source of community transmission of COVID-19 in Australia and worldwide. The risk factors and potential mitigation around COVID-19 infections on cruise ships and communities is a research gap.

Methods: A correlation and regression analyses for risk factors for COVID-19 attack rates oncruise ships worldwide with reported COVID-19 from January 1, 2020 to May 11, 2020 were performed, with a more detailed analysis done for Australia. Geospatial emerging hot spot analysis during key time periods was used to assess temporal trends in spatial clustering of COVID-19 cases related to two cruise ship events in NSW, Australia.

Results: For 36 cruise ships with global COVID-19 cases, available cabins had a moderate inverse correlation with the attack rate (-0.4154; 95% CI [-0.0002, -0.00003], $P<0.0118$). The number of cabins, the number of decks with cabins, and passenger-to-space ratio were significantly associated with attack rate, however, the duration at sea was not. By May 2020, cruise ship passengers made up 14.9% of COVID-19 cases in Australia and 27% of the COVID-19 related deaths. Emerging hot spots of community transmission in Sydney occurred during 1-2 incubation periods of two cruise ship events.

Conclusion: Mitigation of risk on cruise ships should focus on spatial design and reducing crowding, including rapid surveillance and on-board testing. To mitigate this risk during the era of COVID-19, all passengers disembarking an infected ship should be quarantined for at least the 14-day window period and tested for COVID-19, regardless of symptoms. Vaccination should be a pre-requisite for travel of any kind once available.

Keywords: COVID-19, Travel, Contact Tracing, Public Health, Spatial Analysis, Infection Control

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Introduction

In 2019, 30 million passengers travelled via cruise ships worldwide.[1] Cruise ships serve as a reservoir for infectious diseases and transmission is facilitated by the presence of large numbers of individuals in close proximity to each. Infectious disease outbreaks on cruise ships globally have been frequently reported. The incubation period and the subsequent period of maximum infectivity of many infectious diseases fall within the average cruise period of 6 days.[1] During the 2009 Influenza pandemic, over 1970 passengers and over 730 crew members were infected on board.[2] The role of international cruise ship travel in the global transmission of Influenza viruses highlights the importance of maintaining adequate surveillance and rapid responses to emerging infectious diseases.[3] The impact of cruise ship travel on the rapid transmission of COVID-19, both nationally and globally, has not yet been fully investigated.

On December 31, 2019, China reported a cluster of pneumonia cases in Wuhan, Hubei province. On January 7, 2020, a novel coronavirus (COVID-19) was identified as the causative pathogen. The genomic characterization of COVID-19 and the development of methods to detect the virus in clinical samples was urgently investigated.[4-8] Although extraordinary prevention and control measures were implemented by the Chinese government,[9] the outbreak of COVID-19 was not contained, and the disease rapidly spread to other countries. On January 31, 2020, the World Health Organization (WHO) recognized the epidemic as a public

health emergency of international concern. Large, sustained local transmission was established in many countries such as Italy, Iran, South Korea, Japan, and the United Kingdom, with the number of confirmed cases rapidly exceeding or approaching 10 000 in these and several other nations.[10] On March 11, 2020, the WHO declared the COVID-19 outbreak a pandemic.[11] As of May 13, 2020, over four million cases of COVID-19 have been confirmed worldwide, causing more than 250 000 deaths.[12]

The first case of COVID-19 was reported in Australia on January 25, 2020; a male having arrived in Melbourne on an international flight from Wuhan, China. By February 15, 2020, fifteen COVID-19 cases were notified with all cases having reported a travel history to China. On February 14, 2020, New South Wales (NSW) Health began assisting Australian Government Agencies in assessing cruise ship passengers who had been in China 14-days prior to COVID-19 outbreak as part of routine practice.[13] On February 16, 2020, NSW Health began conducting risk assessments on each cruise ship arriving in Sydney.[14] Australian passengers on the stricken ship, The Diamond Princess, docked in Yokohama, Japan, were evacuated on February 17.[15]

By March 1, 2020, COVID-19 had spread to five states (namely NSW, Victoria, Queensland, Western Australia, and South Australia) and had reached a total of 29 cases, with Australia reporting its first COVID-19 related death in WA. On March 19, 2020 and as case numbers soared into the thousands, the Australian government imposed further restrictions on international travel, along with tighter social restrictions. Despite these precautions, cruise ships continued to arrive in Australian waters during March 2020, with disembarked passengers travelling nationwide or internationally in some instances. It has now been reported that cruise ships such as the Ruby Princess, Diamond Princess, Ovation of the Seas, Voyager of the Seas, Artania, and the Celebrity Solstice have had passengers who have tested positive for COVID-19 nationwide.[16] Passengers on the Ruby Princess cruise ship, which was assessed and determined low risk by the NSW Health, were allowed to disembark, despite passengers having influenza-like symptoms (with a large proportion of positive Influenza tests) as no COVID-19 cases were reported.[17] The Ruby Princess has now been linked to the largest number of COVID-19 positive passengers, with over 350 cases reported nationwide and a linked outbreak of 114 cases in Tasmania.[17,18]

A detailed analysis of the cumulative effect of cruise ship travel on nationwide COVID-19 cases is crucial for the review of effective control strategies for international travel considering pandemic preparedness going forward. This study aims to assess the impact of cruise ship travel on the overall transmission of COVID-19 in Australia. Here, we report the results of a descriptive, exploratory analysis of all COVID-19 cases linked to cruise ship travel from January 25, 2020 through April 30, 2020.

Methods

Study Design

We conducted a three-part observational study of cruise ships and COVID-19. Firstly, a correlation analysis of cruise ships with COVID-19 globally to May 11th; secondly, a study of reported COVID-19 cases nationwide in Australia as of the end of April 30, 2020; and thirdly, a geospatial hot-spot analysis. For the correlation analysis, univariate analyses were performed on attack rate for the number of cabins, the number of decks with cabins, duration at sea, and the passenger-to-space ratio.[19] These similar variables were tested against attack rate with the use of Pearson's correlation coefficient analysis.[19] For the Australian study, a comprehensive line list was created by using publicly available, real-time data on laboratory-confirmed COVID-19 patients nationwide. The data was used to assess trends in the epidemiology of COVID-19 nationwide. For the geospatial hot-spot analysis, space-time cubes associated with a 14-day temporal window were created for emerging hot spot analysis, using a distance interval of 5 km and a time step interval of one day. Hot spots are categorized as new hot spots, persistent hot spots, consecutive hot spots, intensifying hot spots, and sporadic hot spots based on definitions in ArcGIS 10.7's guideline.[20]

The data generated from this study were cleaned prior to analysis and presented using descriptive statistics after analysis with Stata IC version 16.1.[21]

COVID-19 on Global Cruise Ships

A correlation analysis for risk factors for infection attack rate (number of cases divided by total passengers) on all cruise ships which had reported cases of COVID-19 on board was performed from January 1, 2020 to May 11, 2020. A database of publicly available data for a total of 43 cruise ships with reported COVID-19 infected passengers during the study period were created. Data were sourced from news reports and cruise ship alerts.[19,22] Cruise ship layout, design, COVID-19 passenger cases, deaths, total passengers on board, and the number of crew for each ship was analyzed. Univariate and multivariate analyses were performed on attack rate for the number of cabins, number of decks with cabins, duration at sea, and the passenger-to-space ratio.[21] These similar variables were tested against attack rate with the use of Pearson's correlation coefficient analysis.[21] Variables with statistically significant results were selected for multi-variant linear regression analysis. Due to missing passenger information, seven ships were excluded from the analysis. This affected the case-per-passenger ratio used for univariate analysis.

COVID-19 Related to Cruise Ships in Australia

A comprehensive line list was created by using publicly available, real-time data on laboratory-confirmed COVID-19 patients nationwide obtained from the Australian Government Department of Health (DOH),[16] individual state/territory Health Department,[23-30] and official reports from the WHO.[31] Positive cases were assigned a state case number and characteristics of each case were recorded where possible. Data such as the date of confirmation, basic demographics, cruise ship/travel history, location, cluster information, and mortality were recorded. No personable identifying information was recorded. Data were updated daily and any additional data from reliable online reports were included.

News reports were reviewed to obtain additional information. Analysis and reporting were based on the STROBE guidelines for epidemiological studies.[32]

Australian confirmed cases were those with a diagnosis based on positive viral nucleic acid test results on throat swab samples between January 20, 2020 and April 30, 2020. The date of COVID-19 confirmation was recorded as a proxy for the onset date. Demographic and location data were summarized using descriptive statistics. Transmission data were categorized based on whether the patient had travelled overseas, been on a cruise ship, been in contact with an identified case, or been a local case without any confirmed epidemiological linkage. Cases whose contact tracing was still being performed at the time of analysis were marked as under investigation. Australian cases linked to cruise ships were monitored and the details of the cruise ship (cruise ship name, passenger or crew member, and state or territory) were recorded in the line list. The epidemic curve was constructed by date of confirmation, and the key dates relating to government control measures. Key dates relating to cruise ship data were over-laid to aid interpretation. Case fatality rates (CFRs) were calculated as the total number of deaths (numerator) divided by the total number of cases (denominator), expressed as a percentage.[33]

Spatial-Temporal Analysis

Emerging hot spot analysis was carried out to assess statistically significant temporal trends in spatial clustering of all COVID-19 cases in NSW, Australia, being the most affected state by cruise ship outbreaks. The Australian policy has been to test only symptomatic people on cruise ships. Given the evidence of high rates of asymptomatic infection on cruise ships,[34,35] a Spatio-temporal analysis was performed to examine whether hot spots of transmission emerged within 1-2 incubation periods (2-4 weeks) of significant events such as the Diamond Princess evacuation on 21/2/2020 and the Ruby Princess landing on 13/3/2020. The analysis timeline is divided into the following time points: date of the first available case with geospatial data (January 22, 2020), date of arrival of passengers from Diamond Princess cruise ship (February 21, 2020), date of disembarkation from Ruby Princess cruise ship (March 19, 2020), 14-day post-disembarkation (April 2, 2020) and 21-day post-disembarkation (April 9, 2020).

Results

Global Cruise Ship Data

There were 50 cruise ships with reported COVID-19 cases at sea between February 5, 2020, and May 11, 2020, with demographic data available for 43 of these ships only.[19,36] Of those, seven were excluded from the univariate analysis, due to the unavailability of passenger information. The analysis of 36 cruise ships with COVID-19 cases reported on board globally, revealed an attack rate of 8.66% (0.03% to 75.12%). The number of available cabins has a moderate inverse correlation with the attack rate (-0.4154; 95% CI –[0.0002, -0.00003], $P<0.012$); as the number of available cabins per ship increases, the attack rate decreases, as seen in Table 1. In addition, there was a fair inverse correlation of decks with cabins (-0.3832; 95% CI [-0.0579, -0.0050], $P<0.021$); the more spread out the cabins are throughout various decks, the lower attack rate occurs. Lastly, there was a moderate positive correlation with passenger-to-space ratio (0.5133, 95% CI [0.0084, 0.0327], $P<0.002$). As the passenger-to-space ratio increases, i.e. the ship becomes more crowded, the attack rate increases.

Table 1. Correlation Coefficient of Attack Rate: Univariate Analysis (N = 36)

Variable	Correlation Coefficient	95% CI	*P* Value
Number of cabins	-0.4154	-0.0002 to -0.00003	0.012*
Number of decks with cabins	-0.3832	-0.0579 to -0.0050	0.021*
Duration at sea	0.2086	-0.0011 to 0.0043	0.236
Passenger-to-space ratio	0.5133	0.0084 to 0.0327	0.002*

* Statistically significant.

A multivariate linear regression was conducted to assess the potential effect of an enclosed space (i.e. number of cabins per ship and decks with cabins) and cruise duration on the attack rate (Table 2). All variables except cruise duration predicted attack rate ratio. A second multivariate linear regression was performed to analyze the potential effect that the enclosed space with space ratio has on the attack rate. These variables statistically predicted a significant attack rate. The number of cabins and the decks with cabins was statistically significant separately; however, when included together, the correlation between attack rates became less significant.

Australian Analysis

On April 30, 2020, a total of 6753 confirmed COVID-19 cases were recorded nationwide as reported by the Australian DOH.[16] A total of 71 deaths were recorded with an overall CFR of 1.05%. Figure 1 shows the epidemic curve peaking on March 27, 2020, with key dates for travel, disease control, and cruise ship events marked. The two-week period from March 6 and April 09, 2020 saw a decrease in COVID-19 reported cases.

Of the 6753 cases, 63.6% were linked to overseas travel, with 26% of the cases linked to a known positive case and 0.3% were still under investigation.[16] Local, unlinked transmission in the community amounted to 10% of the reported cases.[16] As a total, cruise ship passengers made up 14.9% of COVID-19 cases nationwide and contributed to 27% of the deaths occurring in Australia as a result of COVID-19, as shown in Table 3 and Figure 2. A total of 693 (23%) of the cases in NSW alone were passengers of cruise ships. Queensland (QLD) had 4 COVID-19 cases linked to cruise ships, all fatal. Western Australia (WA), another state heavily impacted by cruise ship cases, had a CFR of 4.9%, with 75% of the recorded deaths in WA linked to cruise ship passengers. The Ruby Princess cruise ship contributed to 665 cases nationwide, with 548 of those cases seen in NSW and was linked to 9 deaths.

Between February 20 and March 1, over 60% of cases reported nationwide were cruise ship passengers. The DNC refers to Daily New Cases. An increase in unlinked DNC began 2 incubation periods after the Diamond Princess evacuees arrived, as shown in Figure 3. From March 19 (the docking

Table 2. A Multivariate Linear Regression Of Effects on Attack Rate (N=36)

Regression 1: Cruise Ships duration at sea, number of cabins, and number of decks prediction for cruise ship attack rate			
Overall	Adjusted R^2=0.2007	*P* =0.0210	
Factor	**Regression Coefficient**	**95% CI**	***P* Value**
Duration at Sea	0.00233	0.00233 to 0.00123	0.068
Number of Cabins	-0.00008	-0.00008 to 0.00006	0.189
Number of Decks with Cabins	-0.02158	-0.02157 to 0.01688	0.211
Regression 2: Cruise Ships passenger-to-space ratio, number of cabins, and number of decks prediction for cruise ship attack rate			
Overall	Adjusted R^2=0.3862	*P* =0.0004	
Factor	**Regression Coefficient**	**95% CI**	***P* Value**
Passenger-to-space ratio	0.01895	0.00770 to 0.03020	0.002
Number of cabins	-0.00006	-0.00017 to 0.00004	0.265
Number of decks with cabins	-0.02196	-0.05141 to 0.00749	0.138

date of the Ruby Princess) there was a steady increase in the number of cruise ship reported COVID-19 cases beyond the 14-day window period. Around 25% of COVID-19 cases reported during April 2020 nationwide had cruise ship linkage. An increase in unlinked local transmission was seen during the second incubation period of the Diamond Princess. A steady rate of cases with an unlinked transmission was seen during both the first and second incubation period of the Ruby Princess. During 1-2 incubation periods of both the Diamond and Ruby Princes, cases due to local linked transmission increased.

A total of ten cruise ships have had at least one confirmed case within Australia and this can be seen in Table 4. While demographics could not be obtained for all cruise ships, the overall proportion of Australian passengers aboard these cruise ships was 22.51% (n = 10 142). Additionally, of the total COVID-19 cases of the ten cruise ships (n = 1908), 50.16% (n = 957) were Australian, which is 14.17% of the total confirmed cases in Australia. The CFR varied per ship of Australian passengers but was estimated to be 1.36% (n = 26) in total for the ten ships.

Spatial-Temporal Analysis, New South Wales

Figure 4 shows notable hot spots during the four-week window following the landing of the evacuation flight carrying Australians from the Diamond Princess cruise ship (February 21, 2020). Consecutive hot spots and some new hot spots were identified in Metropolitan Sydney (NSW) during

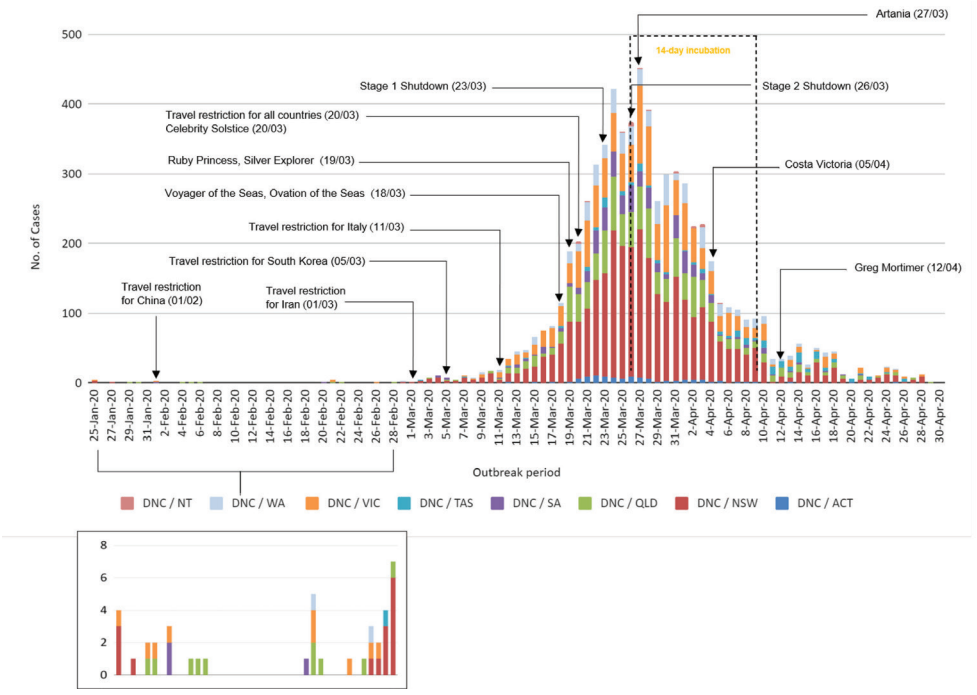

Figure 1. Epidemic Curve of COVID-19 in Australia from January 25, 2020 Through April 30, 2020 (n=6,753). The inset depicts a close-up view of the cases reported from January 25, 2020 to March 3· 2020 when the total daily count remained below 10. Total cases are stacked to represent total daily cases per state territory. DNC refers to Daily New Cases.

Table 3. Analysis of Confirmed COVID-19 Cases Linked to Cruise Ships Per State Territory, in Australia as of April 30th, 2020 (n=1004)

	Confirmed Cruise Ship Cases, No. (%)	Cruise Ship Deaths, No. *(%)	Case Fatality Rate (%)
New South Wales	693 (23)	9 (21.4)	1.30
South Australia	125 (28.5)	2 (50)	1.60
Tasmania	24 (11.7)	3 (23.1)	12.50
Western Australia	124 (22.5)	6 (75)	4.90
Victoria	11 (0.8)	0 (0)	0.00
Queensland	4 (0.4)	4 (66.7)	100.00
Australian Capital Territory	21 (19.3)	2 (66.7)	9.50
Northern Territory	2 (7.1)	0 (0)	0.00
Nationwide Total	1004 (14.9%)	26 (27.7%)	0.39

% deaths are expressed as a percentage of total deaths per state territory.

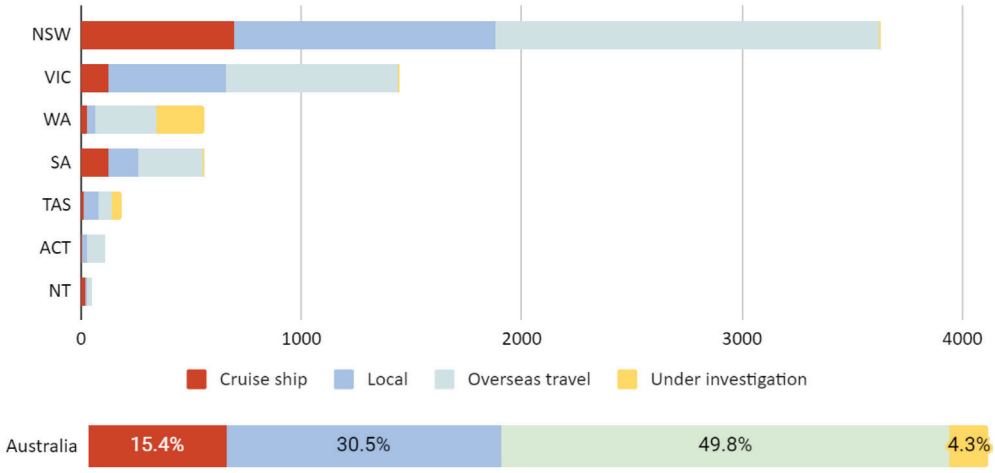

Figure 2. Total Cruise Ship Cases Per State Territory Expressed as a Percent of Total Cases in Australia as of April 30, 2020.

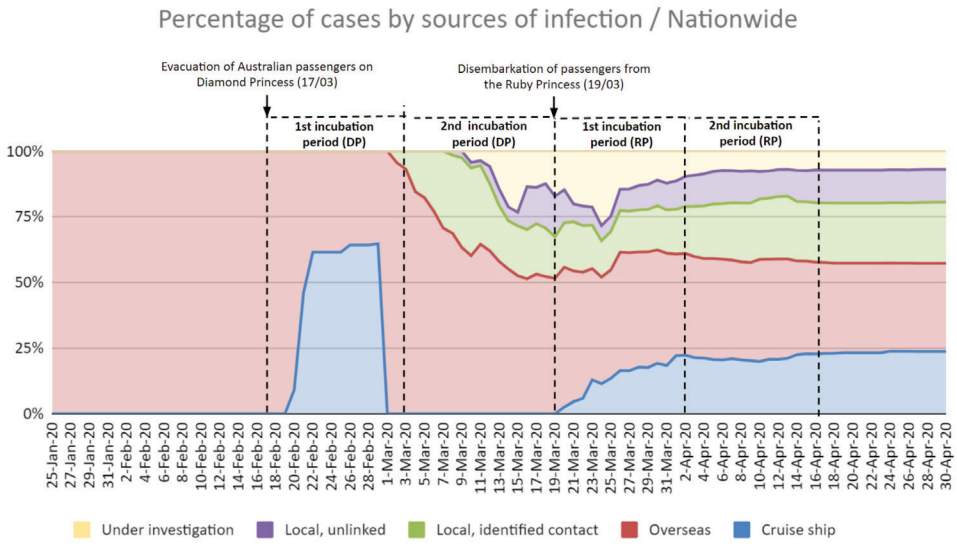

Figure. COVID-19 Cases Directly Linked to Cruise Ship Passengers Nationwide From January 25, to April 30, 2020. DP refers to the Diamond Princess, RP refers to the Ruby Princess.

this period.

Figures 5a-b show the change in clustering patterns following the disembarkation of passengers from the Ruby Princess cruise ship on March 19, 2020. Compared to the analysis period prior to March 19, the analysis period inclusive of 14-day post-disembarkation (up to April 2, 2020) shows an increase in quantity, number, and coverage of consecutive hot spots in Metropolitan Sydney, with new consecutive hot

Table 4. Epidemiological Analysis of Confirmed COVID-19 Cases Linked to Specific Cruise Ships (n=1908) in Australia as of April 30th, 2020

Cruise ship name	Date of Arrival[a]	Total Passengers (N)	Australian Passengers		Total Cruise COVID-19 Cases		Deaths		CFR (%)
			No.	%[b]	No.	%	No.	%	
Diamond Princess	20/02	3200	180	5.6	712	22.3	1	0.03	0.14
Ruby Princess	19/03	2700	1747	64.7	753	27.9	17	0.63	2.26
Ovation of the Seas	18/03	4800	*	*	98	2.0	1	0.02	1.02
Voyager of the Seas	7/03 & 18/03	3100	*	*	45	1.5	1	0.03	2.22
Celebrity Solstice	20/03	3400	*	*	17	0.5	1	0.03	5.88
Artania	27/03	1250	0	0.0	81	5.7	4	0.32	4.94
Costa Victoria	05/04	2310	250	10.8	15	0.6	0	0.00	0.00
Silver Explorer	19/03	465	16	3.4	4	0.9	0	0.00	0.00
Greg Mortimer	12/04	217	90	41.5	128	59.0	0	0.00	0.00
Celebrity Eclipse	*	3420	*	*	67	2.0	1	0.03	1.49
Total		24862	2283	9.2	1908	7.7	26	0.10	1.36

* Information not available.

[a] For cruise ships that docked at Australian ports, the date of arrival refers to the date of disembarkation of passengers from the cruise ship. For cruise ships that docked outside Australia, the date of arrival refers to the arrival date of returning flights carrying Australian evacuees.

[b] All percentages are expressed as a percentage.

Source data adapted from Cruise Mapper.[19]

spots observed in Newcastle and Central Coast. Figure 5c shows the trend of the clusters within three weeks after the disembarkation date (March 19 to April 9, 2020). While the clusters in regional NSW had subsided by May 20, 2020, clusters in metropolitan Sydney continued to persist and intensify beyond this date.

Discussion

The cruise industry attracts many international travelers and is rapidly growing. Around one-third of cruise passengers are senior citizens, who are the highest risk group for COVID-19.[37]

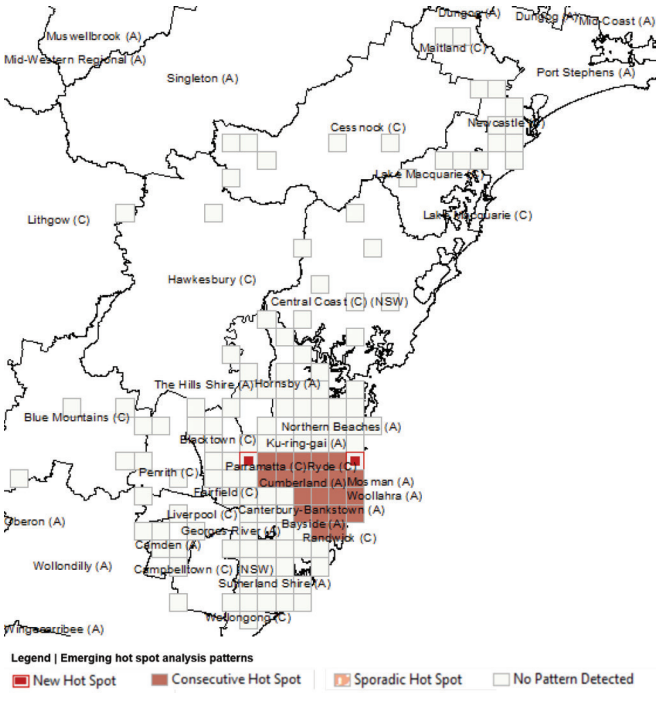

Figure 4. Trends in Spatial Clusters of COVID-19 Cases in New South Wales Within 14 Days of the Arrival of Australian Evacuees From Diamond Princess Cruise Ship (February 21 to March 19, 2020).

Cruise ships are at risk for outbreaks of respiratory infections, and the COVID-19 pandemic has severely affected the industry.[3]

In Australia, cruise ship cases were responsible for almost 15% of all cases and 26.6% of total COVID-19 related deaths have occurred nationwide up to May 2020. In the worst affected State, NSW, cruise ship cases were almost a quarter of all cases. During the (H1N1) pandemic of 2009, of over 1970 passengers and more than 730 crew members, less than 7% were infected with influenza on a cruise ship docked in Sydney in May 2009.[2] In contrast, the infection rate with COVID-19 on the Diamond Princess was 17% or higher.[38]

Although cruise passengers underwent a mandatory quarantine period upon arriving in Australia, not all were tested for COVID-19. Testing was only done for symptomatic passengers. Asymptomatic and presymptomatic transmission of COVID-19 has been reported, as well as high rates of asymptomatically infected people on cruise ships.[34,39,40] Failure to test all passengers may result in undetected chains of community transmission. The emergence of hot spots in Sydney within 1-2 incubation periods following the arrival of cruise ship passengers from the Diamond and Ruby Princess, raises the question of whether asymptomatic or mildly symptomatic infected passengers could have been the source of local clusters. Moreover, the appearance of hot spots in geographically dispersed locations such as Inner Sydney, Newcastle, and Central Coast during the 14-day window period was consistent with the travelling pattern of Ruby Princess passengers, who disembarked in Circular Quay, Sydney and spread out to return to their respective homes via public transport. By this stage, international air travel bans were in place, and from March 28, 2020,[41] arriving travelers were required to quarantine in hotels, thus air travel was a less likely source of undetected transmissions. In addition, two Ruby Princess passengers were identified as the source of infection for a hospital cluster in Tasmania that was linked to 11 deaths and the infection of 73 health care workers, and

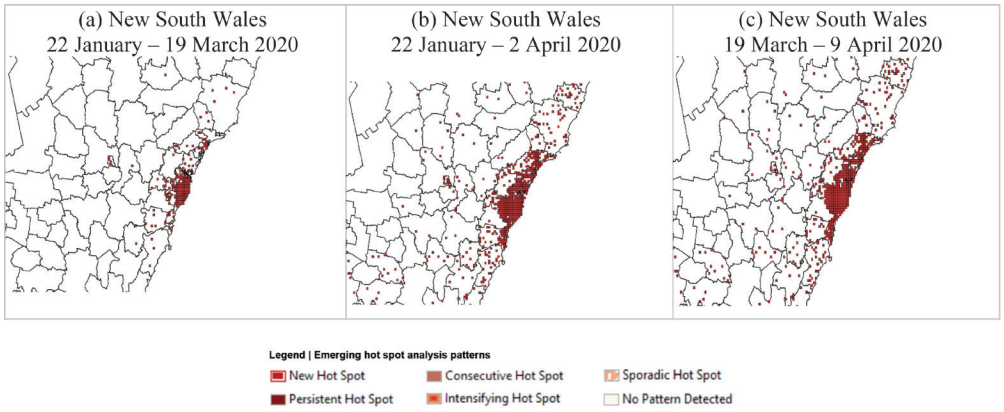

Figure 5. Trends in Spatial Clusters of All COVID-19 Cases in New South Wales Before, Within 14 Days, and Within 21 Days After the Disembarkation of Passengers From the Ruby Princess Cruise Ship (March 19, 2020).

the closure of a hospital.[18,42] There is insufficient geospatial data to analyze the impact of both Diamond Princess and Ruby Princess passengers on emerging clusters in Tasmania, although it is likely that a temporal-spatial pattern like that of NSW may be observed.

COVID-19 is unlike any respiratory illness the human population has been faced with. As the epidemiology of COVID-19 on cruise ships is unclear, the findings of this study confirm that a high rate of transmission may occur on a cruise ship and can spill over into community transmission if not managed well. A ship with hundreds of infected passengers docking in a port could pose both a substantial burden on the health system of the receiving country[43] and pose a risk of community transmission if proper quarantine and complete testing of all passengers and crew, regardless of symptoms, is not done. On the Diamond Princess, on initial testing of 619 infected people, more than half were asymptomatic.[38] It was estimated that the reproductive number R_o on board the Diamond Princess reached 11 at the peak of the outbreak, but declined to levels below 1 after the quarantine was implemented, showing the onboard quarantine measures were effective.[44] Without these measures, almost everyone on board may have become infected. Despite the lessons of the Diamond Princess in February 2020, cruise ships continued to operate after the disease was declared a pandemic by the WHO. Finally, on March 14, 2020, all international cruising ceased as cruise ships were issued a no-sail order by the Centre for Disease Control and Prevention (CDC).[45] Several cruise ships faced the plight of being denied entry at multiple ports, despite having sick people on board,[46] raising human rights issues and the obligations of countries to assist ships in distress. It is possible that crew, who are on board much longer than passengers may also prolong transmission from one set of passengers to another onboard these vessels.[47,48]

We identified spatial factors related to cabins that may influence risk, but the duration of cruises was not associated with risk. Inverse correlations between enclosed areas on board and COVID-19 cases suggest modifiable design features on cruise ships should be reviewed. One study of the Diamond Princess showed that transmission was most intense within cabins and in passengers rather than crew.[44] This points to better management of within-cabin risks of infection. During an outbreak on a ship, mask use and social distancing could help reduce transmission.[49] We did not have data to examine ventilation in cabins, but a modifiable factor to existing cruise ship designs would be the ventilation of cabins and indoor spaces. Accumulation of respiratory aerosols may pose a risk in indoor spaces and can be reduced markedly by ventilation with fresh air (open windows) or air purifiers.[50]

Until we have an effective COVID-19 vaccine, risk management strategies are needed if there is to be a resumption of cruising. Cruise ships will need to establish enhanced surveillance for febrile respiratory illness together with onboard rapid diagnostic testing of COVID-19 amongst other respiratory illnesses such as influenza when resuming operations in the future. Other strategies may include geographic limitation of cruises to regions with good control of COVID-19, upgraded cleaning protocols, changes to crew rostering, use of masks during outbreaks, and spatial modifications to ships. Buffet meals may need to be reviewed, given the potential for fecal-oral transmission.[51] Receiving countries should test all passengers if a confirmed case is on board and should test for COVID-19 if an influenza-like illness is present. As seen with the Ruby Princess, where febrile passengers (some who had tested positive for COVID-19 and some who had tested negative for COVID-19) were allowed to disembark before test results were known, the presence of confirmed influenza on board does not exclude COVID-19, and a highly precautionary approach to screening and quarantine should be taken by receiving countries. Clear contingency plans for isolation of ill passengers and quarantine of contacts will need to be in place, as well as international agreements for the management of epidemics in international waters and in foreign jurisdictions, given cruise ships carry international passengers and crew. There are also human rights implications of denial of entry for sick passengers aboard a ship.

Conclusion

This study identified some spatial and design features of cruises that could be modified to mitigate the risk of respiratory outbreaks. Cruise ships made a significant contribution to

the burden of COVID-19 in Australia, with some indirect evidence of contributing to community transmission. To mitigate this risk during the era of COVID-19, all passengers disembarking an infected or potentially infected ship should be quarantined for at least the 14- day window period and be tested for COVID-19, regardless of symptoms. When a vaccine is available, vaccination should be a pre-requisite for travel of any kind.

Authors' Contributions

All authors contributed equally to this study.

Conflict of Interest Disclosures

The lead author certifies that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. CR MacIntyre consulted for Royal Caribbean Cruises in April 2020 for less than one month.

Ethical Approval

The data were sourced in de-identified from published media reports and public government press releases. Ethical approval was not required for this study.

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Research Highlights

What Is Already Known?

Cruise ships are at risk for infectious disease outbreaks, and transmission is facilitated by the presence of large numbers of individuals in close proximity to each other. Infectious disease outbreaks on cruise ships have been frequently reported and COVID-19 outbreaks on multiple cruise ships have occurred in 2020.

What This Study Adds?

This study highlights the fact that cruise ship outbreaks contributed to the burden of COVID-19 in Australia, with indirect evidence of contributing to geographically clustered community transmission. This research suggests that to mitigate this risk during the era of COVID-19, all passengers disembarking an infected or potentially infected ship should be quarantined for at least the 14-day incubation period and be tested for COVID-19, regardless of symptoms (because of the high incidence of asymptomatic infection). Testing for SARS-COV-2 should be done for any outbreak of febrile respiratory illness during the pandemic. When a vaccine is available, vaccination should be a pre-requisite for travel of any kind.

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