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Original article

A comparative analysis of control measures on-board ship against COVID-19 and similar novel viral respiratory disease outbreak: Quarantine ship or disembark suspects?

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ABSTRACT

Background: Management of novel viral respiratory disease outbreak on-board a ship with person-to-person transmission can be a public health challenge because of close proximity of inhabitants due to confined space and air-conditioned environment. It has a potential to be explosive, with high secondary attack rate (SAR) and cause significant morbidity and mortality. This study compares control measures instituted on-board two ships with similar outbreaks and recommends a standardized evidence-based outbreak response against them.
Methods: This is a descriptive study, showing comparative analysis of control measures instituted on-board two ships, a cruise ship in case of COVID-19 and a warship in case of H1N1 influenza, with novel viral respiratory disease outbreak, at different span of time. Data of the date of onset, clinical details, laboratory results, history of travel, history of contact with positive case and control measures initiated were collected, analysed and compared.
Results: Of the two ships compared, one was a cruise ship with 712 COVID-19 cases, with an attack rate (AR) of 19.2% and 13 deaths, and other a warship with 14 cases of H1N1 influenza and an AR of 4.83%. The epidemic curve for both the outbreaks was plotted to study time distribution.
Conclusion: Active surveillance, early self-reporting and immediate disembarkation of the suspects, along with strict compliance of hand hygiene, cough etiquettes and disinfection enhancement, will help in early mitigation of the outbreak. Health education should be undertaken to impart evidence-based knowledge and alleviate fear of the unknown. Vaccination may not be present but if available should only be administered after strict risk–benefit, cost–benefit and effectiveness analysis.

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Introduction

On 07 January 2020, severe acute respiratory syndrome coronavirus2 (SARS-CoV-2) was identified as a causative agent responsible for a viral pneumonia outbreak in Wuhan, China, where the disease was first reported in the month of December 2019.[1] This newly discovered virus, which causes severe acute respiratory disease, is related to the severe acute respiratory syndrome coronavirus and Middle East respiratory syndrome (MERS) coronavirus but distinct from them.[2] Evidence from the outbreak investigations has suggested that infections with SARS-CoV-2 can spread from person to person.[3]

A decade earlier, the global pandemic was caused by the influenza A (H1N1) strain, which was first detected in North America in 2009 (influenza A[H1N1]pdm09). As in the case of coronavirus disease (COVID-19), the World Health Organization (WHO) declared it a Public Health Emergency of International Concern (PHEIC) because of infections' limited scientific knowledge on progression, duration, scope and control measures under various environmental conditions.[4]

Novel viral respiratory diseases, such as COVID-19, H1N1 influenza and so on, because of person-to-person transmission, complex population traffic, confined air-conditioned environment and limited healthcare infrastructure on board can lead to ship becoming an incubator for such infections.[5] An outbreak in such a setting, when secondary attack rate (AR) may be as high as 45%,[6] can be extremely difficult to control and besides disrupting ships operational schedule can lead to high morbidity and mortality on board.[7] There are only two documented research studies for control of H1N1 on board[8,9] and none on the COVID-19 outbreak.

This is a descriptive study, showing comparative analysis of control measures instituted on-board two ships, a cruise ship in case of COVID-19 and a warship in case of H1N1 influenza, to contain a novel respiratory disease, with confirmed person-to-person transmission. The aim of this article is to recommend a standardize outbreak response in case of a viral respiratory disease outbreak in a confined air-conditioned space setting such as a ship or a submarine.

Material and methods

Case definition of COVID-19

A suspected case of COVID-19 is defined as a person with severe acute respiratory infection (fever, cough and requiring admission to hospital) *and* with no other aetiology that fully explains the clinical presentation *and* a history of travel to or residence in China during the 14 day before symptom onset *or* patient with any acute respiratory illness *and* at least one of the followings during the 14 days before symptom onset: (a) contact with a confirmed or probable case of COVID-19 infection or (b) worked in or attended a healthcare facility where patients with confirmed or probable COVID-19 acute respiratory disease were being treated. Probable case was defined as a person for whom testing for 2019-nCoV is inconclusive or is tested positive using a pan-coronavirus assay and without laboratory evidence of other respiratory pathogens. Confirmed case was taken as a person with laboratory confirmation of COVID-19 infection, irrespective of clinical signs and symptoms.[10]

Case definition of H1N1 influenza

A suspected case of H1N1 influenza is defined as a person with acute febrile respiratory illness (fever >100.0 °F) with the onset (a) within 7 days of close contact with a person who is a confirmed case of influenza A (H1N1) 2009 virus infection, or (b) within 7 days of travel to areas where there are one or more confirmed cases or (c) resides in a community where there are one or more confirmed cases of influenza A (H1N1) 2009 cases.[11]

Data collection

Data of the COVID-19 outbreak on board a cruise liner ship was secondary data collected from official releases by the Japanese Ministry of Health, Labour and Welfare and the company which owned the ship. Data on the H1N1 influenza outbreak was also secondary data collected from tertiary care hospitals where the cases were referred for re-evaluation and investigation. Gaps, if any, were filled from the health returns sent to the concerned headquarters by the ship and the hospital.

Data on the date of onset, clinical details, results of laboratory investigations, history of travel and history of contact with positive case and steps taken by the respective ships towards outbreak control, for the two novel viral respiratory diseases, were collected and analysed.

Laboratory investigation

Oropharyngeal swabs were collected and subjected to Reverse Transcription Polymerase Chain Reaction (RT-PCR) for confirmation, as per Centers for Disease Control and Prevention, Atlanta (CDC)/WHO testing guidelines for both the diseases.[12,13]

Data analysis

Cases were classified according to the case definition, proportion of suspected and laboratory confirmed cases, AR and case fatality rate (CFR) of the diseases were calculated. The epidemic curve was drawn to study time distribution of cases.

The ship with the COVID-19 outbreak sailed out on 01 December 2019 as per schedule and touched Hong Kong, China, on 13 Jan 2020. After a symptomatic passenger who disembarked on 25 January at the same port, tested positive for COVID-19 on 1 February, the ship was quarantined off the port of Japan on 04 Feb 2020 for 14 days, till 19 Feb 2020.[14] Active surveillance was continued for 14 days after notification of the last case on-board the ship with the H1N1 influenza outbreak to assess the impact of control measures used on its mitigation.

Results

Ship with COVID-19 outbreak

The cruise liner ship had 2666 guests and 1045 crew members (total = 3711) from varied nationalities when it was quarantined on 04 Feb 2020.[14] Of the total, 712 cases were diagnosed positive on the basis of screening carried out by healthcare professionals on board.[15] The time distribution of cases from the day the ship was quarantined is shown in Table 1.

The AR of COVID-19 during a period of the outbreak was 19.2%. The epidemic curve as shown in Fig. 1 was plotted. Among the positives, 381 (53.5%) were symptomatic and 37 (9.7%) required intensive care unit (ICU) care. There were 13 fatalities due to the disease, and 03 members of the screening team present on board were also found to be subsequently positive for the disease.[16] The CFR of the disease in the present outbreak was 1.8%.

Control measures initiated

Once the ship was put under quarantine, a surveillance system in the form of screening by the designated team was undertaken from time to time. The cases who were symptomatic (fever > 100.4 °F, difficulty breathing, cough, tightness of the chest and so on) were subjected to RT-PCR for confirmation on board, and once confirmed, the individual was disembarked to a shore-based isolation facility. Hand hygiene and cough etiquette were emphasized, and N 95 masks were distributed to both guests and crew members. Social distancing (maintaining distance > 6 feet [1.83 m]) was advocated both when in the cabin and when out, although it was impossible for the crew which was working in a much more space-constrained environment. The guests in windowless cabins were allowed to walk on upper decks in fresh air in batches, for up to 90 min every day.[17]

Ship with H1N1 influenza outbreak

In June 2017, over a 3-week period, 21 patients reported to the sick bay of the ship for treatment. Of these 21 clinically suspected cases, swabs of 14 cases were reported positive for influenza A (H1N1). One of the two confirmed cases notified on 08 June gave history of contact with an H1N1 influenza virus. In this study, he was designated as the index case. The data are summarized in Table 2. In these 14 days, the AR for the disease was 4.83%. The epidemic curve was prepared and is shown in Fig. 2. The CFR of the disease was nil.

Control measures initiated

All the suspected cases were referred to a tertiary care hospital for reevaluation and investigation. Appropriate infection control measures and droplet precautions in the form of disinfection with 5% cresol used every 12 h were emphasized to be adhered to at all times. Health education for frequent hand washing and subsequent use of disposable tissue papers and sanitization of all ladder supports, door handles and railings on board with alcohol-based sanitizers was undertaken. Cough etiquette as per standard guidelines was advised.[18] Active case finding was followed by the health workers on board.

Discussion

The cruise ship with the COVID-19 outbreak did not have HEPA filters which can effectively screen 99% of the particles with a diameter of 3 microns or more and used a heating, ventilation and air-conditioning filtration system,[19] with no facility of isolation on board. Human coronaviruses can persist on inanimate surfaces such as metal, glass or plastic for up to 9 days.[20] In addition, air samples[21] collected from hospitals having patients with MERS coronavirus have been documented to be infectious. With this background, the

Table 1 – Laboratory results of COVID-19 cases.

Date	Tested	Positive new cases	Remarks
01 Feb 2020			Index case diagnosed positive.
04 Feb 2020			Quarantine started.
05 Feb 2020	31	10	
06 Feb 2020	71	10	
07 Feb 2020	171	41	
08 Feb 2020	06	03	
09 Feb 2020	57	06	
10 Feb 2020	103	65	
12 Feb 2020	53	39	
13 Feb 2020	221	44	
15 Feb 2020	217	67	
16 Feb 2020	289	70	
17 Feb 2020	504	99	
18 Feb 2020	681	88	
19 Feb 2020	607	79	
20 Feb 2020	52	13	
16 Mar 2020	648	78	Cumulative figure of tests performed and results after 20 Feb 2020.
Total	3711	712	

COVID-19, novel coronavirus 2019

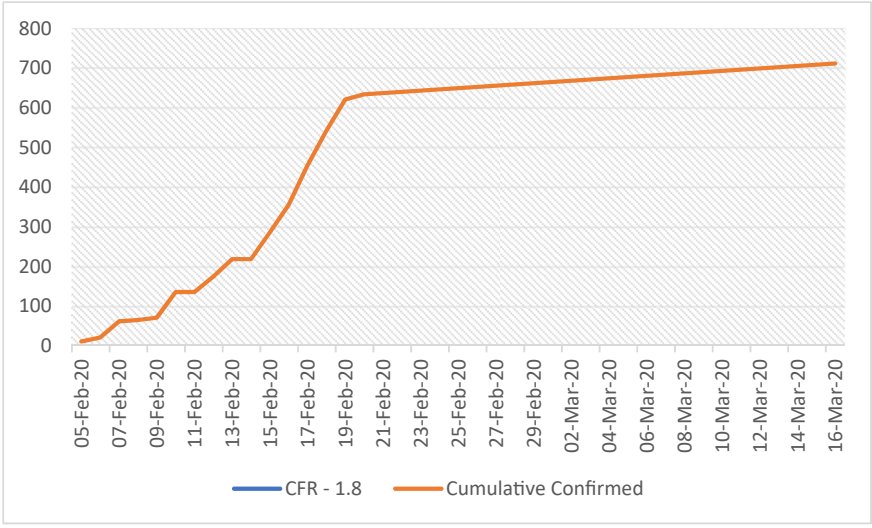

Fig. 1 – Time distribution of cumulative COVID-19 cases. * X-axis = date and Y-axis = number of cases. COVID-19, novel coronavirus 2019.

possibility of airborne transmission of COVID-19 at such an early stage of the outbreak could not be ruled out. Therefore, in a viral disease outbreak with the possibility of person-to-person transmission through air, quarantine on board cannot be a mode of outbreak control response. It will not only club infected cases with non-infected ones but will also increase the secondary AR of the infection because of inhalation of same contaminated air in an air-conditioned environment.

The warship affected by the H1N1 influenza outbreak met the international standards of air conditioning and ventilation as promulgated vide Standard 2–102, Ministry of Defence, the United Kingdom.[22] The ship had no isolation compartment on board. Although the sick bay had a relative negative pressure with respect to ships' ventilation, along with a dedicated air filtration unit, it could not be used for isolation because of it being a single contact point for a person with any morbidity. During the H1N1 influenza outbreak, active surveillance was instituted, and all the suspected cases were disembarked and referred to a shore-based tertiary care hospital for investigation, isolation and treatment. The outbreak was controlled within 14 days, with a low AR of 4.83%. The other study carried out in a similar setting was an influenza A (H3N2) outbreak on board a US Navy ship, and it had documented an AR of 42%.[6] It brings out the critical role of active surveillance in a viral outbreak and in a closed ventilation set-up. Immediate physical segregation of cases including suspected ones from apparently normal, in this case, by referring them to a shore-based facility can bring early end to the outbreak, with significant decrease in AR.

Thirteen deaths were reported amongst the patients who tested positive for COVID-19 on board the cruise ship. Of the patients who were detected positive, 46.5% (331 of 712) of them presented with no symptoms at the time of diagnosis. The CFR was 1.8%. Those aged ≥70 years were most vulnerable, with high CFR of 7.3%.[23] This is consistent with the findings of viral surveillance report by CDC China. It too brought out that the CFR is highest in the group of patients aged ≥70 years, among 44,672 confirmed COVID-19 cases.[24] Nil case fatality was reported on-board warship with the H1N1 outbreak. It was possibly because of multiple factors,

Table 2 – Laboratory results of H1N1 influenza cases.

Date	Tested	Positive new cases	Remarks
02 Jun 2017	02	0	Suspected cases but negative on laboratory confirmation. Active surveillance started
03, 04, 05, 06 and 07 Jun 2017	00	00	
08 Jun 2017	03	02	One case gave positive history of contact with confirmed case. Taken as the index case
09 Jun 2017	01	01	
10 Jun 2017	02	02	
11 Jun 2017	05	04	
12 Jun 2017	02	02	
13 Jun 2017	03	03	
14, 15, 16 & 18 Jun 2017	00	00	
19 Jun 2017	02	00	
20 Jun 2017	01	00	
Total	21	14	

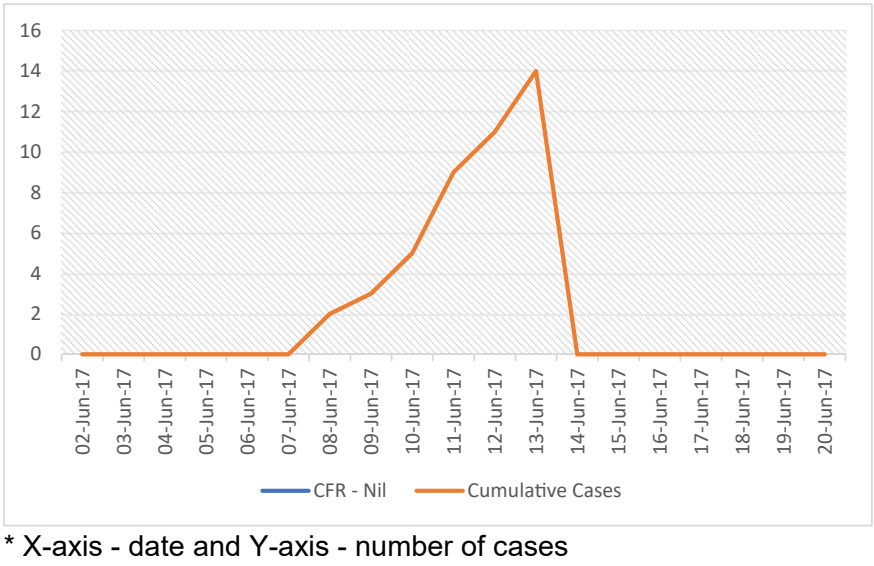

Fig. 2 – Time distribution of cumulative H1N1 Influenza cases. * X-axis = date and Y-axis = number of cases.

important among them include, low CFR of the disease,[25] predominantly young population affected and early control of the outbreak on board.

Extensive preventive sanitation measures were used on board the cruise ship with the COVID-19 outbreak. These included both sanitation measures adopted for the ship and hygiene practices of the individuals on board. Sanitation protocols were increased, and additional 200 hand sanitizer stations were installed. The guests and crew on board were distributed N95 masks liberally, and the crew was additionally provided with personal protective equipment (PPE).[19] Individuals on board were advised to follow strict cough etiquette, maintain social distancing when outside the cabin and follow hand hygiene by frequently washing hands with soap and water or 60–95% alcohol-based hand sanitizers.

Appropriate infection control and droplet precautions were adopted on-board the warship with the H1N1 outbreak. Disinfection once every 12 hours with 5% cresol was carried out, and cleaning of all door handles, ladder supports and railings on board with alcohol-based sanitizers was adhered to at all times.[26] Strict hand washing was followed by all individuals along with the use of disposable tissue papers.[27] Cough etiquette was advised to be followed as per the guidelines.[18] Sanitation measures used on board by both the ships were adequate, exhaustive and in sync with international infection control guidelines in vogue during the respective outbreaks.

Sustained efforts were taken to educate the individuals in both the ships about the sign and symptoms, measures used by the authorities and preventive measures expected in the form of cough etiquettes, hand hygiene and early reporting to control the outbreak. The cruise ship undertook health education by means of ships PA system, release of advisory by experts in the *Public Health*[17] and e-info bulletins of frequently asked Q&A[19] on their website. On-board the warship, health education was carried out by one-to-one counselling during active surveillance, publishing advisories released by health authorities of concerned headquarters as part of ships daily orders which is read by all on board and hoisting designer posters commissioned by the ships' medical team at various notice boards, evenly distributed all over the ship.

The role of immunization against a novel viral infection outbreak on an afloat platform is debatable. Because of very recent nature of the COVID-19 outbreak, no vaccination was available against the disease. Vaccine was available against H1N1 influenza, during the time of its outbreak on-board the warship. In case of the latter, it was decided not to expose predominantly young and healthy population to a vaccine intervention which is not cost-effective,[28] might have strain which is not active against the virus responsible for the outbreak, has questionable benefits and documented although not statistically proven risks.[29] In view of the earlier fact, before undertaking vaccine intervention, if available, as an outbreak prevention strategy, discerning consideration should be given to risk–benefit, cost–benefit and effectiveness analysis.

Conclusion and Recommendation

From the experiences of outbreak control response of two novel viral respiratory diseases on board, the following are recommmended:

1. Active surveillance and disembarkation

Active surveillance, early self-reporting and immediate disembarkation of the suspected cases are the *sine qua non* of outbreak control, in closed air-conditioned environment. It will guide the outbreak to follow an epidemiological pattern of point source epidemic instead of propagated one, thus help bring it to an early end.

2. Do not quarantine the ship

With potential cases on board, the ship should not be quarantined unless absolutely indicated on administrative grounds. It is just impossible to segregate infected from the non-infective in a space constrained, air-conditioned setting, during an outbreak with possible airborne, droplet or a fecal–oral route. All close contacts of confirmed positive cases should be disembarked and quarantined in an appropriate land-based facility.

3. Sanitation and hygiene

Sanitation and hygiene measures both for the ship affected and individuals on board cannot be over-emphasized. Frequency of sanitation protocols should be increased, minimum 12 hourly and all potential contaminated surfaces cleaned with 60–95% alcohol-based sanitizers. Frequent hand washing, cough etiquettes and maintaining social distancing during interactions should be strictly followed.[30] Use of face masks (Surgical/N95) is preferred, but their improper use and disposal can be more harmful than protection it might offer.

4. Health education

It is important to alleviate fear among ships company, which is there with any new unknown illness, and impart correct and evidence-based knowledge of signs and symptoms and preventive measures for self and community protection and most important for early self-reporting of suspected cases.[31]

5. Immunization

Vaccination might not be available, if the outbreak happens on board within a short period of the causative organisms' origin. If the vaccine is available, it should only be administered to the susceptible after evidence-based risk–benefit, cost–benefit and effectiveness analysis.[29] Because of frequent interaction with susceptible cases and increased risk of exposure, healthcare workers on board should be given preference.

6. Health intelligence

Advance intelligence of health hazards including infectious diseases prevailing at the next port of call is absolutely necessary to ensure that the crew avoids disembarking at that port, as part of the preventive strategy. This is certainly a lesson learnt from the cruise ship experience where the ships' passenger had apparently picked up the COVID-19 infection from Hong Kong, China, visit and it led to an outbreak on board.

Disclosure of competing interest

The authors have none to declare.

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