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Effectiveness of a COVID-19 Preventive Sequestration Strategy: Deployment of the Aircraft Carrier USS Ronald Reagan (CVN-76)

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Brief Report

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Abstract

Objectives: The aim of this study was to develop and evaluate a pre-deployment sequestration (PDS) protocol to prevent severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) cases on board the USS Ronald Reagan (CVN-76).

Methods: The USS Ronald Reagan includes a crew of approximately 3000 Sailors and an embarked Air Wing of 2000 personnel. The PDS was conducted in 3 waves of 14-day strict quarantines during the months of April and May 2020. Sailors were cleared to board the ship with 2 negative reverse transcriptase polymerase chain reaction (rtPCR) tests at days 14 and 16. The ship was sanitized before Wave 1 boarding.

Results: From March 1, 2020, through May 31, 2020, a total of 51 SARS-CoV-2 positive cases were detected. During the 3 waves of PDS, 28 Sailors were found to be positive on exit testing (14, 11, and 3, respectively); no cases were found among the Air Wing. During the first 90 days at sea, no SARS-CoV-2 cases were detected among any of the embarked personnel.

Conclusions: Although resource-intensive, the PDS protocol implemented for USS Ronald Reagan resulted in a coronavirus disease 2019 (COVID-19)-free ship during a global pandemic with unprecedented scope. Elements of this pandemic PDS protocol may be useful in other highly risk-averse environments with no tolerance for COVID-19 infections.

This implementation study describes the pre-deployment sequestration (PDS) strategy for the USS Ronald Reagan (CVN-76), a nuclear-powered U.S. Navy aircraft carrier with a complement of 5000 Sailors and Air Wing personnel. Based in Yokosuka, Japan, one hour south of Tokyo, the ship is currently the U.S. Navy's only forward-deployed aircraft carrier. As the ship prepared for deployment in early 2020, a new disease caused by a novel coronavirus began spreading from China. Very little was initially known about the virus. Human-to-human transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) had just been confirmed on January 21, 2020.[1] Two weeks later, the same day that the United States declared a public health emergency, the *Diamond Princess* cruise ship arrived in the Port of Yokohama with a sick passenger. Within 2 weeks, 691 quarantined passengers were infected on the ship, which was moored approximately 10 miles away from the USS Ronald Reagan. The story captured world headlines and generated controversy regarding the effectiveness of the shipboard public health response.[2] On March 11, the World Health Organization declared a pandemic. By this point in time, the virus had spread throughout China, South Korea had begun aggressive testing to identify cases,[3] and another cruise ship had quarantined passengers off the coast of California. The first worldwide wave of coronavirus disease 2019 (COVID-19) began in late March 2020. Japan first recorded 100 cases in a day on March 27, 2020. The maintenance period for the USS Ronald Reagan was drawing to a close and concerns mounted regarding sending a ship to sea with an infectious respiratory virus in circulation. It was in this setting that the ship's first outbreak of COVID-19 occurred.

Despite aggressive contact tracing, quarantine and isolation, cleaning, and other mitigation measures, new cases continued to be detected among crew members on the densely packed ship. To limit transmission ashore, including between US personnel and the broader Japanese population, heavy restrictions were implemented at the naval base in Yokosuka.

Concurrently, the USS Theodore Roosevelt (CVN-71) was moored in Guam, responding to a widespread outbreak of COVID-19 that made headlines around the world. The challenge of getting the USS Ronald Reagan underway without a similar large outbreak was immense. With over 5000 personnel in total from the ship's company and air wing (collectively called the Carrier Strike Group), the relatively large proportion of asymptomatic cases among a young

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and healthy population, and the ease with which COVID-19 spreads to others in the close confines of a ship, where 6 feet of distance is often impossible, it was determined that halting transmission during a deployed outbreak would be difficult, if not impossible, without pulling into port or otherwise severely impacting operational plans. Simply put, the USS Ronald Reagan needed to be 100% COVID-free before deployment. There was no margin for error. Because a pre-deployment COVID-19 mitigation plan did not yet exist, local U.S. Navy public health officials and operational commanders collaborated to develop a pre-deployment sequestration (PDS) plan. The strategy has proven effective and has potential application for other situations with zero tolerance for infections.

Shipboard isolation and quarantine measures were effectively used by the U.S. Navy during the H1N1 pandemic in 2009 to limit attack rates among the crew to 3-5%.[4,5] However, a unique challenge presented by SARS-CoV-2 is the highly infectious presymptomatic phase exacerbated by a large asymptomatic fraction capable of disease transmission through close contact. A Centers for Disease Control and Prevention (CDC) review of COVID-19 outbreaks on cruise ships found attack rates were approximately 17-20% among crew and passengers. In the first highly publicized outbreak on the *Diamond Princess*, 712 (19.2%) of 3711 passengers and crew tested positive for SARS-CoV-2.[6,7] On the second cruise ship moored off the coast of California, the *Grand Princess*, 21 (46.7%) of the initial 45 passengers who reported respiratory symptoms tested positive for SARS-CoV-2.[6] Following docking in California, the remaining passengers and crew completed a 14-day land-based quarantine and all were offered testing. Of the 469 with test results available, 78 (16.6%) were positive for SARS-CoV-2.[6] These attack rates occurred in a relatively favorable environment where passengers typically had individual or family staterooms, allowing for distancing and physical separation from others. This stands in stark contrast to the densely populated open-bay berthing compartments of a warship.

In April 2020, France's aircraft carrier, the *Charles de Gaulle*, experienced an extensive outbreak affecting 1081 sailors (approximately half of the crew) following a port call before deployment.[8] Although half of all cases were asymptomatic, 24 sailors were admitted to hospital, and 1 sailor was admitted to intensive care. As data emerged from these outbreaks, it became obvious that the standard sick-in-quarters response, however vigorous, was inadequate for shipboard management of COVID-19.

The idea of protective sequestration as a preventive measure during a pandemic has been previously described by Markel et al.[9] During the influenza pandemic of 1918-1920, nonpharmaceutical interventions were effectively used in 6 unique geographic locations in the United States, including a military installation, a mountain town, a rural community, and a college campus. These areas actively protected the population using strict protocols for entering and leaving and a quarantine requirement for visitors. This historical public health success influenced the idea for shipboard PDS described here.

Methods

The PDS plan called for conducting a pre-emptive quarantine of 100% of individuals before boarding the ship for deployment. The ship was cleaned systematically just before Wave 1 personnel came aboard. The PDS was conducted in April and May, with 3 successive waves of 16 days each. Nasopharyngeal swabs were used to collect specimens at days 14 and 16 for polymerase chain reaction (PCR) testing. Only those completing PDS with negative results on both exit tests were allowed to board the ship. The USS Ronald Reagan then was able to get underway with Wave 1 personnel. The ship returned to port to embark Waves 2 and 3 while avoiding all contact with other individuals.

During the PDS, the ship's company and air wing, over 5000 individuals in total, were assigned to rooms in pairs. The decision to put 2 Sailors in each room was due mostly to cost and space constraints, but it was also believed that having a roommate would increase accountability with the PDS process and provide the social support needed to mitigate the potential mental health challenges accompanying strict quarantine.[10,11] Security measures such as tape on the doors and 24-hour monitoring of the premises ensured strict adherence to protocol. To provide for a reasonable quality of life, room service, Internet access, laundry service, and mental health support were available. Meals were dropped off at each room with zero-contact delivery. Close communications between ashore leadership, fleet leadership, medical, logistics, and other stakeholders were paramount to overcoming challenges as they developed.

Any sailor that needed to abort PDS for any reason, such as a medical concern, or because they received a positive test result, was not able to board the ship. For those successfully completing PDS, transit to the ship was by bus with zero contact between the crew and shore-based support personnel. Upon boarding, department heads cohorted the crew into smaller units to limit potential spread of undetected cases. While at sea, attention to hand hygiene, distancing wherever possible, staggered mealtimes, universal masking, port/starboard routing, symptom monitoring, and quarantine drills all enhanced public health preparedness for incident cases. Sick call was modified to reduce the risk of transmission among symptomatic Sailors. COVID-like illness was aggressively evaluated by ship's medical personnel during the deployment and diagnostic testing was performed liberally with PCR-based testing, which was available on the ship throughout the deployment.

Results

During the 3 waves of PDS, 28 Sailors were positive on exit testing (14, 11, and 3, for each respective wave). With a crew of over 3000, the total incidence of COVID-19 was thus approximately 1.5% ($n = 51$ total positive cases detected from March through May). Of note, the air wing personnel, who were stationed in a different part of Japan but also underwent PDS, had zero cases.

Discordant results were present among 22 (78.6%) of the 28 positive cases identified during PDS. Of these, 12 received an initial positive result followed by a negative result upon retest 48 hours later, and 10 had an initial negative result followed by a positive result. Cycle threshold (Ct) values were not available for review. No sailor on board the USS Ronald Reagan was diagnosed with COVID-19 following completion of the PDS, nor through the subsequent 90 days after completion of Wave 3 despite aggressive testing on the ship.

Discussion

This novel strategy was highly effective at a time when understanding of SARS-CoV-2 was still limited and evolving rapidly. At the time of this writing, the PDS process continues for all individuals before embarking a ship for deployment, with the exception of those who are fully vaccinated. Navy policy developed later in

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2020 requires the general principles of PDS, now referred to as restriction of movement-sequester (ROM-S), be followed for all deploying ships.

The strategy has its limitations. It is resource-intensive and requires a high level of collaboration among and between operational and medical leaders. A major hurdle is space for housing. Additionally, the logistics (meals, laundry, testing, and transportation) are daunting. For areas with low community transmission and no known shipboard cases, it may be simpler to conduct PDS on the ship, or allow individuals to conduct it in their place of residence ashore. To attain a high degree of confidence in success, it is also imperative to have enough security to ensure adherence to all measures, by all personnel. A single individual who breaks quarantine and gets exposed could cause the entire plan to fail and lead to a subsequent shipboard outbreak. A single test is reasonable instead of 2, especially with the knowledge we now have about persistent positivity with PCR testing. Because PCR tests do not indicate the degree of infectiousness, a positive test at the end of PDS may exclude some personnel from deployment who are recovered positives and no longer infectious, but are still shedding viral fragments. It is likely that most if not all of our PDS cases with discordant results at the end were persistent positives with an unknown earlier date of infection.

Limitations

This report is subject to several limitations. First, it is a prospective cohort study with no control arm. However, the stringency of the protocols and the detail provided in this report enable subsequent replication of this method for other high-value or high-visibility assets or events, including commercial endeavors such as professional sports playoffs. Second, the evaluation of the effectiveness of the PDS on reducing incident cases at sea relied on symptom reporting and case-finding rather than systematic asymptomatic random sampling of the crew. However, it seems highly unlikely that the ship had any undetected cases aboard for a full 90 days after Wave 3 PDS was completed. The USS Ronald Reagan was provided PCR testing capacity before deployment, enabling onboard testing and results, thus allowing for liberal testing of the crew as determined by the ship's medical staff. Finally, the generalizability of this PDS method may be limited given the current availability of COVID vaccines, a resource not available at the outset of the pandemic in March 2020, to transiently reduce the likelihood of SARS-CoV-2 infection. However, high-value assets with zero-COVID risk tolerance must also consider the ongoing emergence of more-transmissible variants, which can evade vaccine-induced immunity. This may necessitate a COVID-free environment for which this PDS method would remain applicable.

Conclusions

The novel PDS process developed for the USS Ronald Reagan has significant advantages. It is scalable depending on the size of the group and the level of risk acceptance. Most importantly, it is very effective. For high-visibility, high-value assets or missions with low risk tolerance, the plan ensures a high likelihood of success. The general process could be applied to other military units, remote research stations, and other risk-averse missions or commercial endeavors. It could also potentially be used in prisons, nursing homes, or long-term care facilities with a large percentage of high-risk patients.

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