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Perspective

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Managing passenger flows for seaborne transportation during COVID-19 pandemic

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The attempts to curb the coronavirus disease 2019 (COVID-19) pandemic have led many nations to set social distancing and mobility restrictions, which have greatly affected our daily lives and exposed several weaknesses in our society. Travel and transportation are vital to the welfare of society as it guarantees the availability of food and medicine. Furthermore, mobility restrictions have impacted negatively on industries, individuals and work possibilities both at national and international level. The cruise industry, including ship owners and the shipbuilding supply chain, cruise and ferry operators, and passenger ports, is one of the hardest hit. The news coverage regarding the COVID-19 outbreak on the Diamond Princess cruise ship, amongst other outbreaks onboard vessels, has given a blow to the reputation of the cruise industry in general, as the spreading from one single individual resulted in several hundred infected passengers.[1] The pandemic has drained revenue streams and plummeted passenger numbers, and COVID-19 outbreaks on ships have resulted in a sharp value decrease for the cruise ship owners.[2] Consequently, there is an urgent need to develop strategies to limit the spread of pathogens onboard cruise ships and ferries. To this end, we propose a rethink of seaborne passenger transportation by rapidly implementing healthy travel concepts that include integrating healthcare technology, introducing behavioural and service production changes to avoid viruses from spreading during the voyage. Furthermore, in order to ensure passenger health, cruise and ferry operators will most likely have to develop new types of service concepts regarding food, hosting and recreation as many of the current core services create an ideal environment for pathogens to spread.[3] Although the ongoing COVID-19 pandemic will likely affect the cruise industry much more than, for example, the global financial crisis of 2008–09 or the negative publicity from the loss of the Costa Concordia in 2012, the proactive approach to ensuring safe travel can lead to overcoming difficulties in this challenging situation, too.[1–4]

This perspective presents a model of macro-passenger flows based on a combination of both new and rather well-known countermeasures that considers how pathogens spread on ships and in terminals. In contrast to the detailed, zero-risk view of countermeasures that is predominant in the literature and currently implemented by central authorities, macro-passenger flows comprise the broader actions taken to combat pathogens in a more applicable near zero-risk approach. We advocate a holistic perspective on how to mitigate pandemic outbreaks that includes the behavioural (e.g. social distancing), procedural (e.g. different boarding time) and technical (e.g. testing procedures) actions against infectious agents. This involves identifying bottlenecks, transmission hotspots, changing boarding and transportation procedures, and calculating which countermeasures are the most cost efficient, that is, those with the lowest price per protection.

Several studies demonstrate how restrictions in mobility, social distancing, use of face masks, hand washing and general hygiene significantly reduce the transmission potential of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[1–7] However, less is known about how to combine these different countermeasures in a practical and cost-efficient way in real-life scenarios and near zero-risk contexts. The case of the Diamond Princess, where one infected passenger spreads the virus to

697 people who were potentially in contact with an additional 627 386 individuals, has demonstrated that improved procedures are needed to limit the spread of contagious diseases.[1,8] Some of the biggest difficulties were in implementing large-scale quarantine and obtaining medical support during the voyage and hospitalization after disembarking the passengers.[2] In order to practically minimize the risk of an infected passenger boarding a ship, we suggest different terminal procedures depending on the number of passengers. The number of COVID-19-infected individuals within the population varies, but many studies estimate that the infected portion of a population during a pandemic is around 1–2%.[5] One of the challenges in identifying COVID-19-infected individuals is that some do not manifest any symptoms; a meta-study estimated that asymptomatic individuals make up around 17% of the SARS-CoV-2-positive population and that the pre-symptomatic proportion is around 63%.[9] Therefore, several layers of precautions are needed to identify possible COVID-19-infected passengers, as relying solely on measuring temperature or only looking for other symptoms to indicate possible COVID-19 is insufficient. On the other hand, even with the most sophisticated reverse transcriptase polymerase chain reaction testing (RT-PCR) equipped with ∼90% sensitivity, there will always be a risk of false negatives rendering the detection of COVID-19 difficult.[10] Therefore, we advocate for a holistic and practical near zero-risk implementation strategies as shown in Figure 1 (recommended boarding procedures and recommended onboard procedures).

Based on recent COVID-19 publications and discussions with health sector professionals and marine industry stakeholders, we recommend different boarding procedures depending on the size of the ship, as illustrated in Figure 1a. Simply put, the bigger the ship and the longer the duration of the voyage, the more precautions and procedures are necessary to ensure that infection does not spread among the passengers.

For smaller ships, the near zero risk is achieved by decreasing the maximal numbers of passengers, implementing health questionnaire before boarding combined with symptom and temperature measurement at check-in (Figure 1a). For example, if there are up to 800 passengers boarding, then the calculated number of disease carriers is 8–16 (with 1–2% infected population). The number of symptomatic disease carriers can initially be narrowed down by a self-diagnostic questionnaire, where the passengers are asked if they have COVID-19 symptoms the evening before boarding. If answered affirmatively, the passenger needs to test negative in order to travel. This procedure would reduce the number of potential disease carriers arriving at the terminal to ∼5.04–10.08 if the passengers comply with the instructions. At check-in, passengers should be given both temperature and symptoms check, possibly in combination with rapid tests, which would further narrow down the number of disease carriers to 0.86–1.71, depending on the COVID-19 carrying population, which also dictates the relevant safety procedures.

For bigger ships carrying up to 2400 passengers, a tracking system is needed in addition to the above-mentioned procedures, giving around 74% efficacy if >60% of the passengers comply with the instructions. The tracking system, such as a mobile application that tracks the vicinity of other users, is shown during boarding and demonstrates that a passenger has not been exposed to the pathogen. To enter the biggest ships with 6000 passengers, the travellers need to either have a negative RT-PCR test 1–2 days before boarding or proof of vaccination against a specific disease to achieve near zero-risk travel.

During boarding, it is advisable to spread out the arrival times at the terminal so that there are no >60% of the maximum passenger capacity at any given time, reducing the numbers of transmittable passengers arriving simultaneously to the terminal.[5,11] Dividing passengers into smaller groups can be accomplished by boarding (and devising terminal arrival) in intervals. According to a passenger movement simulation done for the St Peters terminal, it is obvious that the most crowded place is the queue line and the vicinity of the check-in area.[11] Therefore, we suggest having separate queues across several check-in stations, with a 2 m distance between each passenger, and handing out complementary hand sanitizers and face masks at the beginning of each queue. Passenger flows should also be organized so that encounters between the departing and arriving passengers are avoided. Also, staffs that are in contact with passengers inside the cabins while cleaning should be avoided to minimize potential cross-transmissions between staff and passengers. Furthermore, it is advisable to have separate gangways to the ship for the elderly and other high-risk groups in order to reduce their risk of contracting possible diseases during boarding.

Then, based on the transmission risk onboard and the epidemiological situation at the departure and the destination, we suggest different modes of operation: normal condition, elevated risk or outbreak mode, which would also be communicated to the passengers with the simple ‘traffic light’ modes of green, yellow or red. To pursue such an operation, we recommend having several levels of procedures to mitigate the risk of spreading contagious diseases inside the vessel that can be adjusted according to the transmission risk, as illustrated in Figure 1b. The first level of protection is to introduce social distancing of individuals by reducing both mobility and the number of passengers by at least 20% in order to decrease the transmission risk by 10%.[12] Then, by blocking all three main transmission routes (aerosols and direct or indirect contact) at the same time, the risk of spreading the disease is greatly reduced, depicted as an adjusted basic reproduction number (R0; Figure 1b). These procedures would incorporate face masks, hand sanitizers, and additional disinfection and antimicrobial coatings of surfaces that are often in contact with passengers.[1–12] A third level of risk mitigation would be to inform passengers that, when feeling sick, they could take a self-diagnostic test online where healthcare professionals would estimate the situation and possible administer a COVID-19 test in order to determine whether quarantine is required. The fourth level implemented during an outbreak demands a 60% decrease in mobility to control the spread throughout the ship, where the nightlife, buffet and shopping malls would be closed for keeping human contact at minimal.

For the second part of our ‘toolbox’, we proposed the use of a price per protection by usage (P/PU) calculation, where the price of an item is divided by the protection in percentage divided per usage. The following example illustrates the reasoning: for a disposable 1 euro face mask, the P/PU would be around 0.56–0.7, whereas for a 10 euro hand sanitizer that can be used by 100 passengers, the P/PU would be 0.0735, or an antimicrobial coating for 1000 euros could greatly reduce the risk of contracting infectious diseases for potentially over 10 000 passengers (P/PU = 0.1). Thus, the hand sanitizer and antimicrobial coating would provide more cost-efficient prevention as part

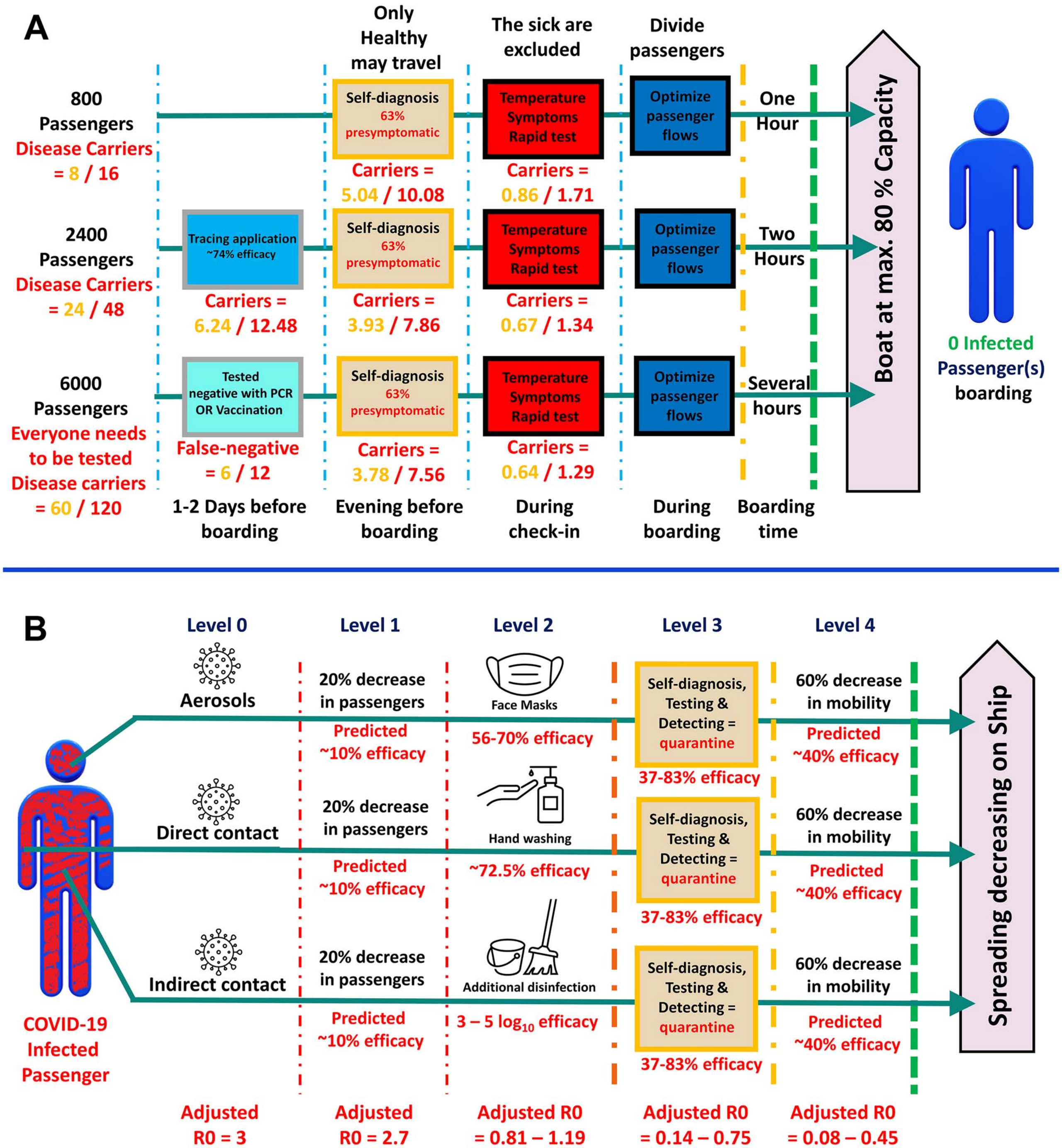

Figure 1. (a) Illustration of different boarding procedures based on passenger numbers; (b) illustration of different levels of procedures to decrease the reproductive number (R0) of COVID-19 during seaborne transportations.

of an acute first line of defense against contagious diseases both now and in the future.

In Figure 1b, the first level of procedures starts by decreasing mobility of passengers, and the second level relies on additional safety measures such as face masks, increased hand hygiene and additional disinfection. The third level relies on online self-diagnostics combined provided by healthcare professionals combined with rapid tests and quarantine. The fourth level represents a lockdown where the mobility of staff and passengers are minimized.

In our procedures, we are considering both the practical, theoretical and cost-efficient mitigation strategies in combating COVID-19 for achieving a near zero-risk strategy where the most important implementation is to improve the boarding procedures so that no one sick board the ship and to have stand-by proceeding for the crew to quickly respond to the different risk levels during the voyage by changing passenger behaviour and mode of operation. However, it is crucial to consider the characteristics of different types of ships and terminals combined with the movements, activities and uses of protective measures by passengers and crew members during the voyage as well as the specific characteristics of the infectious agent that could all influence the transmission dynamics of the specific setup. These factors are likely to affect the pathogen-spreading dynamics that dictate the most efficient mitigation procedures at each specific risk level. Nevertheless, 'the toolbox' of the procedures described in this study represents a holistic approach in mitigating current and future pandemic threats during seaborne passenger transportation. Combined with calculating a price per protection of each specific countermeasure, this toolbox can serve as a practical means to 'restart' the cruise industry with a pragmatical near zero-risk approach.

Authors' Contributions

Conceptualization, investigation and writing—original draft preparation: E.N., J. Spohr, M.H., J.L., A.T., J. Sjöblom, F.K., J.E.E., K.W.; writing—review and editing—and visualization: E.N., J. Spohr, M.H., J.L.; supervision: M.H., J.E.E., K.W.; project administration: J. Spohr; funding acquisition: J. Spohr, M.H., J.E.E., K.W.

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Conflict of Interest

None declared.

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