

Infectious Risks on Different Types of Ships with Reference to the COVID-19 Pandemic

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Due to nature of their profession, seafarers visit many ports in different parts of the world and are thus exposed to various infectious diseases. And yet, chronic non-communicable diseases, malignant illnesses and accidents have lately become an important cause of death among the seafarers. Although before the COVID-19 pandemic outbreak the communicable disease outbreaks were becoming less common, their share in seafarer morbidity remains significant. The aim of this research is to determine the most common infectious risks/contagious diseases on ships. The Medline and Scopus databases have been searched using the following key words: seafarers, infectious diseases, morbidity, mortality. The information sources include relevant literature, as well as national and international regulations on preventive measures against infectious diseases. At the global level no national or international surveillance systems exist on infectious disease occurrences on ships. There are only a few exceptions. However, based on some available individual and group research, conclusions may be drawn concerning the most

important diseases in seafarer pathology. Of communicable/infectious diseases on ships, the most important ones are the acute respiratory illnesses, including the COVID-19 disease, followed by food poisoning/acute gastroenteritis, vector-borne diseases and HIV as the most common sexually transmitted disease in the past 20 years. Estimating the threat from infectious diseases in seafarers depends on the type and trade of vessels. For COVID 19 and other respiratory infections, as well as food poisoning, risks are higher on cruise ships and passenger ships than on cargo ships. For better understanding of the issue, we need internationally co-ordinated studies and well organised surveillance systems.

1. INTRODUCTION

Seafaring has always been a dangerous occupation, with infections and accidents being important health hazards (Hansen et al., 2019; Hansen et al., 2005; Hansen et al., 2002).

It is known that ships can make a suitable environment for respiratory and gastrointestinal pathogens, which can spread easily among travelers and crew members on board. With a few exceptions, no national or international surveillance systems exist on infectious disease occurrences on ships, including ships under Croatian flag. However, there have been partial research and projects but these are “marked” by local characteristics. The pathology of seafarers (illnesses, disorders, accidents) is not completely identical for all countries or areas, since every community has its own epidemiological, social, cultural, economic and other determinants. Risk factors for illness and injury can be supposed with an understanding of the socio-demographic distribution of the full at-risk seafarer population (Hansen et al., 2019; Lefkowitz, 2013).

KEY WORDS

- ~ Seafarers
- ~ Infectious diseases
- ~ Morbidity
- ~ Mortality

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Research into the causes of accidents, reasons for hospitalization (Hansen et al., 2005; Hansen et al., 2002) and mortality (Roberts et al., 2002; Borch et al., 2012) as well as the health reasons behind repatriation (Abaya et al., 2015) has shown that cardiovascular diseases, followed by malignancies and accidents, are among the leading causes of pathology in seafarers. The significance of communicable diseases in the morbidity of seafarers varies between studies, which are scarce due to the fact that an international surveillance system cannot be easily established. In a retrospective study based on incidents recorded in medical log-books from merchant ships under the German flag during period 2002-2008, Schlaich and others (2009) found that nearly one-fourth of the visits to the ship's infirmary were caused by communicable diseases, mainly gastrointestinal and respiratory infections. According to a research by Hansen et al. the accident rate/10,000 days is the highest in roll on roll off ships (2.85), followed by passenger ships at 2.63 and gas tankers with a rate of 0.86 (Hansen et al., 2002).

As a rule, there are no physicians on board cargo ships, where medical care is usually provided by the second mate or the shipmaster, neither of whom are health professionals (Schlaich et al., 2009; Mulic et al., 2015). According to the International Health Regulations (IHR, 2005) and Handbook for management of public health events on board ships, shipmasters are required to notify Port Health Authorities about any cases of illness suspected of a disease of an infective aetiology or evidence of a public health risk on ship (WHO, 2016). These documents are the international legal instruments that define measures for preventing the international spread of infectious diseases, with the purpose and scope "to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade". The IHR also outline the criteria to determine whether or not a particular event constitutes a "public health emergency of international concern" (WHO, 2016).

There are a lot of national and international legal acts and recommendations referring to preventive measures on ships: The European Manual for Hygiene Standards and Communicable Disease Surveillance on Passenger Ships; Vessel Sanitation Program (VSP, USA); The VSP 2018 Construction Guidelines (USA); Guide to Ship sanitation (World Health Organisation, WHO). Others include regulations issued by Croatia's Ministry of the Sea, Transport and Infrastructure, 2016; European Commission Directorate General for Health and Food Safety, 2016; CDC, 2020; VSP, 2018, WHO 2011.

Since Croatia has ratified all relevant maritime conventions, national provisions are in line with international regulations. Aware of the importance of prevention, public health workers, ship owners and seafarers take comprehensive preventive healthcare measures on all types of vessels. Particular attention

has been paid to cruise ships that have large agglomerations of passengers with quite different health conditions and countries of origin present in a limited space. Before COVID 19 pandemic started, the demand for cruising worldwide increased from 1.8 million passengers in 1980 to 26.75 million in 2017, at an annual growth rate of 7.5%, while the annual growth rate for land-based tourism was 4.9 % in the same (1980-2017) period (Peručić D, 2019).

Considering the global character of cruising tourism, many organizations and corporations have united in their fight against communicable diseases on cruise ships. Cruise Lines International Association (CLIA), is the world's largest cruise association, dedicated to the promotion and growth of the cruise industry. More than 15,000 travel agencies and agents are currently affiliated with CLIA all over the world (Peručić D, 2019). Nothing has been left to chance and cruise ships are built in line with the regulations, considering what might seem as the slightest detail that could lead to mistakes in e.g. food handling. The responsibility of each ship operator is to apply all preventative and practicable measures to ensure that no sources of infection and contamination are present on board, including the water system or food supplies. It is important that these standards are upheld on board ships and at ports, in terms of the safety of the food served, from the source of supply ashore to distribution on board ships. Food safety plans (FSPs) are required to manage the process of providing safe food. Typically, the FSP is based around hazard analysis and critical control point (HACCP) methodology, as it is on land (Dahl, 2018; Zhang et al. 2016). Risks, accidents, morbidity and mortality on board should be considered depending on the vessel type (cargo, passenger, cruise, and military), her crew and passengers (Roberts et al. 2016; Lefkovitz et al. 2018; Marimoutou et al., 2017; Carter T et al., 2014). Among cruise line passengers, gastrointestinal and respiratory infections have shown to be significant disease causes.

2. MATERIALS AND METHODS

The Medline and Scopus databases have been searched for the purpose of this study and other available sources included national and international regulations on preventive measures against infectious diseases. In total, we studied 55 published papers and documents.

2.1. Passenger Ship

Vessels carrying more than 12 passengers are considered to be passenger ships. The term "passenger ship" is a term covering many aspects. Passenger ships are merchant ships generally employed for the transportation of passengers or voyagers (Marine Insight, 2020).

A cruise ship is a passenger ship that is built with the intention of providing passengers with the pleasure of a journey and facilities for entertainment aboard, rather than the transport of persons from one seaport to another. It is equipped for a multi-day stay of passengers and must provide food, drinks and accommodation. Throughout its journey, a foreign vessel on a cruise calls at in seaports of several interesting destinations and in different countries.

From the epidemiological point of view, cruise ships represent "semi-enclosed communities". The reason is that, even though the cabins and shared living areas are designed in line with international standards, a large agglomeration of people with various health, cultural and other backgrounds share a limited space and are exposed to close contacts.

Infection among crew members may lead to transmission on sequential cruises on the same vessel because crew members may continue working and living onboard the ship from one cruise to the next. Sometimes, but not often, crew members from one ship may serve on board multiple different ships for subsequent voyages, increasing the potential for infective diseases transmission (Hadjichristodoulou et al., 2011; Middaugh et al., 2020; Rooney et al., 2004; American College of Emergency Physicians, 2020).

On cruise ships a large number of passengers from many countries, of all ages, many with other diseases (co-morbidities), come in contact with a large multi-national crew over a relatively short period of time. All of these present risk factors for the spreading of various infections, primarily respiratory (Schlaich et al., 2009; Dahl, 2018; Zhang et al., 2016). Cruise passengers consume high-risk food in common spaces on board and have access to local food markets and restaurants in ports, which can be risky for gastrointestinal infections (Schlaich et al., 2009; Dahl, 2018; Zhang et al., 2016, Marimoutou et al., 2017). That is reason why, in recent years, the operators/cruise ship owners have started not recommending or even banning the consumption of food and drinks in ports during the cruise.

Medical facilities can vary widely depending on cruise ship size, itinerary, cruise length and type of passengers, their age, life and health characteristics. Medical consultation with a physician and well-equipped medical facilities and enhanced systems of disease surveillance are also available on some cruise ships (Mulic et al., 2015; American College of Emergency Physicians, 2020; Dahl, 2020).

However, risks exposure of cruise passengers depends on the destination. Itineraries of cruises play an important role, since the endemicity of diseases differs around the world, and cruise ship port calls may include countries where vector-borne diseases are endemic such as malaria (American College of Emergency Physicians, 2020; Korzeniewski, 2017).

2.2. Cargo Ship

A cargo ship is a ship with one or more decks, having the possibility to carry a variety of commodities in different forms and to accommodate bulk materials such as grain (Hadjichristodoulou et al., 2011). There are thousands of cargo ships sailing the world's seas at all times as most of the global trade is carried by sea and handled by ports worldwide. Shipping is considered to be the best mode of transportation of traded goods, due to very safe handling of delicate materials and affordable pricing. On cargo ships, a multicultural crew of 25 (on average) live in a common, small space for months. In general, there is a lack of opportunity for merchant seafarers to visit local food markets or restaurants or for person-to-person contact in port cities, which is why they are spared the risk of food-borne or waterborne disease (Schlaich et al., 2009).

From the epidemiological point of view, due to the above, merchant ships are considered semi-closed communities (Roberts et al., 2016; Leftkowitz et al., 2018; Marimoutou et al., 2017). No routine disease surveillance is in place and food hygiene is highly variable. The transferability of study results from cruise line to merchant seafaring is limited (Schlaich et al., 2009). Cargo ships often carry dangerous goods including explosives, liquid gases and different chemicals (Hansen et al. 2002, Roberts et al. 2002, Roberts et al. 2016) and expose fewer people to potential health hazards when compared to modern passenger ships. Crew members of cargo ships have been at the risk of accidents following an explosion or cargo spill. However, the risk of infectious diseases among the crew on cargo ships has been less than in cruise ship crews.

The average cruise ship carries 3,000 passengers and 1,500 crew members (Peručić, 2019). In terms of their market share, international shipping accounts for the transportation of more than 80 % of global trade to peoples and communities all over the world. Cruise ships participate with less than 1 % in the world maritime community.

Another important difference is that cargo ships may sail for a long period of time without a doctor on board. Still, in case of health emergency during navigation, the possibilities include telemedicine services, presence on board of crew members trained and qualified to provide medical assistance having obtained the "Medical Care", as required by the international convention STCW 1978/1995 in its updated version in Manila in 2010, as well as the possibility of ground transport by helicopter for the most urgent cases.

Ferry voyages are shorter and may include frequent stops to ports where medical consultation can be arranged ashore. On merchant ships, especially those with a small crew, if a large proportion of crew fall ill and are unable to perform their duties, the safety of sailing might be affected (Mulic et al, 2015; Marine Insight, 2019, American College of Emergency Physicians, 2020).

3. FOOD-BORNE DISEASES/ACUTE GASTROENTERITIS ON SHIPS

A gastrointestinal infection such as acute gastroenteritis is the most frequent disease and outbreaks among travellers have been a problem on cruise ships ever since they appeared on the maritime market. With time, its pathology has changed: in the beginning it was “traveller's diarrhoea at sea” caused mostly by bacteria such as *E. coli* (Daniels et al., 2000). However, fewer outbreaks are nowadays caused by bacteria than by viruses (CDC, 2020), probably due to far better diagnostics of viral infections today. Furthermore, the low occurrence of such diseases in the past was only the tip of the iceberg in terms of infectious diseases.

In their article, Rooney et al. present data on 50 outbreaks on passenger ships, which were caused or transmitted through food (Rooney et al., 2004). They provide a detailed description of the failures in food preparation that are identical to those taking place on land such as inadequate temperature control, infected food handler, contaminated raw food, cross-contamination, inadequate heat treatment and other factors such as lack of a sufficient number of toilet facilities for the galley crew. Relatively often (in 58.53 % or 24 of 41 outbreaks of bacterial food poisoning), no main factor contributing to the outbreak was identified. In this research, of the 50 outbreaks described, only 4 were caused by norovirus (Rooney et al., 2004).

Since acute gastroenteritis can pose a serious problem on cruise ships and lead to financial losses, food handling procedures

have been prescribed in detail. Thus, for example, if an animal food such as beef, poultry, pork, lamb, eggs, milk, fish or shellfish that is raw, undercooked, or not otherwise processed to eliminate pathogens, is offered in a ready-to-eat form or as a raw ingredient in another ready-to-eat food, the consumer must be informed by menu advisories, placards, or other easily visible written means of the significantly increased risk to certain especially vulnerable consumers eating such foods in raw or undercooked form. The advisory must be located at the outlets where these types of food are served (VSP, 2018).

With time, norovirus has turned into a more common cause of gastrointestinal infection outbreaks on cruise ships. Furthermore, it is the leading cause of both outbreaks and sporadic cases of acute gastroenteritis in children and adults worldwide (Mans, 2019). Research into the outbreaks has shown that the majority of transmissions take place through direct contact with persons carrying the virus, water, aerosols, contaminated food, and due to environmental contamination. Some characteristics of norovirus that facilitate outbreaks are a low infective dose, easy transmissibility between persons, prolonged shedding of viruses, short-term immunity, and the organism's ability to survive routine cleaning procedures and disinfections. On international cruise ships porting in the United States from 2010 through 2019, 5-16 outbreaks of norovirus infections occurred each year (see Table 1).

Table 1.

Reported outbreaks of gastrointestinal illness on international cruise ships during the 2010 – 2019* period.

Year	Total number of outbreaks	Norovirus as causative agent		Enterotoxigenic <i>E. coli</i> (ETEC)		Unknown causative agent	
		N	%	N	%	N	%
2019	10	8	80.00	-	-	2	20.00
2018	11	5	45.45	1	9.09	4	36.36
2017	11	9	81.81	-	-	1	9.09
2016	13	11	84.61	1	7.69	1	7.69
2015	12	12	100.00	-	-	-	-
2014	9	8	88.88	-	-	1	11.11
2013	9	8	88.88	1	11.11	-	-
2012	16	16	100.00	-	-	-	-
2011	14	10	71.43	2	14.28	2	14.28
2010	14	8	57.15	-	-	6	42.85
Total	119	95	79.83	5	4.20	17	14.29

*Published data from *Vessel Sanitation Program, Outbreak Updates for International Cruise Ships*, CDC

In published data, there is no information on the total number of passengers or the length of the voyage, making the rate calculation impossible.

Systematic implementation of preventive measures, in ship design as well as through constant sanitary supervision, has gradually led to a trend of reducing the number of people infected by acute gastroenteritis and the share of bacterial infections (*E. Coli*, *Shigella sp*, *Salmonella sp*). The rate of acute gastroenteritis illness on cruise ships has decreased over time, as has the number and severity of outbreaks by year, except for 2012 when a new strain of norovirus emerged (CDC, 2020; Cramer et al., 2003; Cramer et al., 2006).

In a study by Mouchotouri V. A. et al. (2017), the overall incidence rate of acute gastroenteritis was 2.81 cases per 10,000 traveller-days, while the attack rate was 19.37 cases per 10,000 travellers. As we can see in Table 1, norovirus is the main causative agent (95/119; 79.8 %) of outbreaks of gastrointestinal infections on international cruise ships, which are included in VSP, during the 2010 – 2019 period. Five outbreaks (4.20 %) were caused by Enterotoxigenic *E. coli*. One (0.84 %) outbreak was caused by rotavirus and one (0.84 %) by *C. perfringens* enterotoxin. Unfortunately, data about case counts (passengers and crew) are not available in this report. During this period, causative agents were not proven in 17 outbreaks (14.29 %).

Companies in the USA and EU ensure that cruise ship chefs follow the HACCP system – Hazard Analysis Critical Control Point – which research has shown is a viable food safety operation system. By rigorously following the procedure, chefs on board can identify chemical, physical and biological threats at any step of the flow of food – from delivery and storage to cooking and service (European Commission Directorate General for Health And Food Safety, 2016, CDC, 2020; VSP 2018; Mouchtouri et al., 2017, Mouchtouri et al., 2010).

The management of acute gastroenteritis, prevention and control procedures arising with outbreaks of acute gastroenteritis, present an enormous challenge to all relevant parties within the cruise industry (Ministry of the Sea, Transport and Infrastructure, Croatia, 2016; Mouchtouri et al., 2017; Mouchtouri et al., 2010; Tardivel et al., 2020). In the process of disease investigation, timely collection of food and water samples and medical specimens is crucial. Surveillance plans define what materials are collected and how, and these plans must be periodically reviewed to make sure they are on hand and ready to use if needed (WHO, 2016; Ministry of the Sea, Transport and Infrastructure, Croatia, 2016; WHO, 2011; Mouchtouri et al., 2017, Mouchtouri et al., 2010; Tardivel et al., 2020).

4. ACUTE RESPIRATORY ILLNESS

Acute respiratory illnesses are a common occurrence on cruise ships. The flu and other vaccinated preventable diseases

are the most common, but pneumonia outbreaks caused by *Mycoplasma pneumoniae* (Sliman et al., 2009) and *Legionella pneumophilla* (Kura et al., 2006) have also been described. *Mycoplasma pneumoniae* is commonly associated with acute respiratory disease and pneumonia outbreaks among civilians, usually children and young adults, and has been identified in pneumonia outbreaks among crowded military recruit populations (Sliman et al., 2009). In several reports, Legionnaires' disease has been linked to passenger ship cruises. Cases of legionellosis associated with cruisers are probably not all recorded. Among cruiser passengers can be immunocompromised persons and advanced age are risk factors for the disease, which is why it is necessary to pay close attention to the hygiene of water supply systems, air-conditioning machines, and especially spas on any cruise ship where elderly people are likely to be passengers (European Commission Directorate General for Health and Food Safety, 2016; Kura et al., 2006)

5. COVID 19

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. Cruise passengers are at increased risk of person-to-person spread of infectious diseases, including COVID-19, and outbreaks of COVID-19 have been reported on cruise ships (Dahl, 2020, Moriarty et al., 2020; Brewster et al., 2020; Russell et al. 2020; U.S. Department of Health and Human Services, 2020; Yamagishi et al., 2020).

The COVID 19 pandemic have not affected just cruise ships. There are problems on merchant ships as well, where in times of a pandemic it has proven incredibly difficult to facilitate crew changes or replacements. This has led to many seafarers remaining on board ship long after their end of contract date and in many cases for more than the maximum period of 11 months allowed by the Maritime Labour Convention 2006. At the start of the COVID-19 pandemic, an estimated 200,000 seafarers remained stuck on board due to difficulties in traffic and repatriation (U.S. Department of Health and Human Services, 2020; Maritime Insight, 2020).

Due to the COVID-19 pandemic, measures were introduced to prohibit the entry of ships on international cruises, which had a direct impact on a decrease in the number of foreign vessels on cruise in Croatian seaports in 2020. In the period between January and June 2020, the number of foreign vessels on cruise in Croatian seaports dropped by 88.9 % as compared to the same period of 2019 (Croatian Bureau of Statistics).

For periodically hired seafarers who spend several months on board, departures and returns were made more difficult during the COVID-19 pandemic by the strict preventive measures including mandatory tests and quarantines prior to embarking (IMHA, 2020).

The risk of COVID-19 on cruise ships is very high, which is reason why the CDC recommends that all people, especially those at an increased risk of severe illness, avoid travel on cruise ships, including river cruises, worldwide (U.S. Department of Health and Human Services, 2020; Maritime Insight, 2020).

6. VECTOR-BORNE DISEASES

Malaria is a significant public health problem at a global level. According to the WHO, 91 countries reported an estimated 228 million cases of malaria and 405,000 deaths in 2018 worldwide. The remarkable geographical distribution of malaria causes travellers and sailors to be particularly exposed to this disease. In fact, a category of people particularly at risk is that of seafarers, especially those embarked on commercial ships that take long journeys around the world, for relatively long periods of time, and without a physician on board in malaria risk areas (Korzeniewski 2017, Tan et al., 2020).

Italian researchers conducted the first comprehensive study on the occurrence of malaria among seafarers. According to their results, a reduction in the number of cases of malaria among seafarers was noted over the years of study, confirming the fact that reducing the cases of infection by this disease is an achievable goal (Pallotta et al., 2019).

Every year Croatia records several imported malaria cases, mainly through seafarers (Mulic, 2012). Seafarers need to be trained on how to protect themselves by taking prophylactic medication and other non-specific preventive measures.

The zika virus was first identified in 1947 in Uganda. In the Western hemisphere, in 2015 it was identified for the first time, with large outbreaks in Brazil. The virus then spread throughout much of the Americas, with 48 countries and territories reporting local transmission. In 2016, large outbreaks occurred in the Caribbean, and limited local transmission was identified in the parts of Florida and Texas. Since then, the number of reported Zika virus disease cases in the Americas has declined in all regions, though there have been occasional increases in reporting from some countries.

The zika infection for most people is mild but little is yet known about the complications of the disease. The highest health risk appears to be to women who are pregnant or planning to become pregnant, as the virus may be linked to an increase in babies born with microcephaly in Brazil. For now, no vaccine or any preventive drug is available. However, several types of vaccines against this infection are at different stages of development (Staples et al., 2020).

Yellow fever is a vaccine preventable disease. According to the IHR, all seafarers have to be vaccinated before embarking. A safe and effective yellow fever vaccine has been available for more than 80 years. The vaccine is a live, weakened form of the virus given in one dose (Gershman et al., 2020).

7. SEXUALLY TRANSMITTED INFECTIONS

Sexually transmitted infections (STIs) are a significant public health problem in some part of the world. Travelling to different countries around the world makes seafarers vulnerable to sexually transmitted diseases such as HIV/ AIDS and other STIs like gonorrhoea and syphilis. AIDS is a major concern because it results in serious consequences for both professional and personal life. In recent days, seafarers no longer fit the stereotype of having a woman in every port but, owing to long term isolation, lack of leisure and recreational facilities and the availability of a strong sex industry in almost every port of call, seafarers are easily susceptible to unsafe sexual activities which makes them victims of STIs. Research of Pougnet et al. showed that, at the beginning of the 21st century, attention was mainly focused on the human immunodeficiency virus (HIV), and that there has been a lot of misunderstanding and ignorance about STIs among seafarers: 28.3 % of them believe that a healthy-looking person could not be HIV-positive (Pougnet et al., 2020; Mulic et al., 2010).

According to some research, STIs do not pose a significant problem on cruise or merchant navy ships (Schlaich et al., 2009). A study by Thomas et al. indicates that female workers on cruise ships have a greater tendency of changing sex partners while on board than men (Thomas et al., 2013). It seems that cruise ship workers represent a potentially important group for understanding and combating the spread of sexually transmitted infections. Migrant workers in general, and seafarers in particular, have long been acknowledged to be both vulnerable to sexually transmitted infections and they are an important factor of sexually diseases spread in different, especially domicile populations (Gershman et al., 2020; Pougnet et al., 2020; Mulic et al., 2010; Thomas et al., 2013).

8. CONCLUSION

The threat from infectious diseases in seafarers depends on the type and trade of ships. For COVID 19 and other respiratory infections, as well as food poisoning, higher risks exist on cruise ships and passenger ships than on cargo ships.

Estimating the threat of infectious diseases in seafarers requires well-designed and transnational co-ordinated studies, and/or integration in the routine country's surveillance system of communicable diseases.

According to the available data, acute respiratory infections and acute gastroenteritis are the most common problems on cruise ships. Although significant effort has been invested into preventing acute gastroenteritis, cruise ships still record outbreaks. The main problem on board cargo ships are cardiovascular and malignant illnesses; a number of conducted studies show that communicable diseases account for about 25 % of the pathology and are the third most common disease

on cargo ships. Despite high technology and other civilizational achievements, seafarers are still at risk of a wide range of infectious diseases. These may either result from person-to-person transmission of infectious agents or through food, water or insects onboard ships or in ports, as well as from pre-existing conditions. It seems that the only effective solution could be continuous education.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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