Mini-Review: Potential Interactions and Immunomodulatory Effects of Marine Virus Exposure on SARS-CoV-2 Infection Outcomes in Coastal Populations

Abstract

The COVID-19 pandemic has underscored the complexity of viral co-infections and their impact on human health. While much attention has been given to terrestrial pathogens,Marine viruses play an important role in marine ecosystems and biological cycles, and their study can provide us with new insights into environmental science and biotechnology.marine viruses—particularly those infecting marine mammals and plankton—remain underexplored in the context of co-infections with SARS-CoV-2. This mini-review examines the potential interactions between marine viruses and SARS-CoV-2, focusing on immunomodulatory effects, ecological considerations, and public health implications for coastal populations. We discuss the role of marine viruses in shaping immune responses, their potential to exacerbate or mitigate COVID-19 severity, and the challenges in diagnosing and managing such co-infections. The review highlights the need for interdisciplinary research to understand the broader ecological and health impacts of marine virus exposure in the era of COVID-19.

Keyword: Immune system, Marine, Virus, SARS-CoV-2, Infection, Coastal Populations

Introduction

The COVID-19 pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has highlighted the complexity of viral infections and the profound influence of co-infections on disease severity and progression. While the majority of research has focused on co-infections involving terrestrial viruses such as influenza, respiratory syncytial virus, or other coronaviruses, little attention has been given to the potential role of marine viruses in modulating SARS-CoV-2 infections. Marine viruses are the most abundant biological entities in aquatic environments, with estimates suggesting that they outnumber all cellular organisms in the ocean by at least an order of magnitude. These viruses play pivotal ecological roles, influencing microbial community composition, biogeochemical cycles, and the health of marine animals, including mammals that share physiological and immunological similarities with humans.

Coastal populations are uniquely positioned at the interface of human and marine ecosystems, where frequent interactions with marine environments can result in exposure to diverse viral communities. Marine viruses, including those infecting plankton, fish, and marine mammals, may interact with human hosts either directly through contact with

seawater, seafood consumption, or aerosols, or indirectly by modulating environmental microbial communities that influence pathogen dynamics. Given the immunological crosstalk between environmental viral exposures and human immune responses, there is a plausible hypothesis that marine viruses could impact SARS-CoV-2 infection outcomes, either by priming the immune system for enhanced antiviral responses or by exacerbating inflammatory pathways that contribute to severe COVID-19 manifestations.

Furthermore, emerging evidence indicates that SARS-CoV-2 can infect non-human mammals, including domesticated animals and wildlife, raising concerns about potential cross-species viral interactions in marine mammals. Co-infections in these animal reservoirs may not only affect animal health but also influence viral evolution and the risk of zoonotic spillover. Understanding these complex interactions requires an interdisciplinary approach, integrating marine biology, virology, immunology, and public health perspectives. This review aims to explore the potential intersections between marine virus exposure and COVID-19, highlighting immunomodulatory effects, ecological considerations, and public health implications for coastal populations.

Marine Viruses and Their Ecological Roles

Marine viruses are highly diverse, including DNA and RNA viruses that infect bacteria (bacteriophages), algae, invertebrates, fish, and marine mammals. These viruses are critical drivers of ecological balance in oceans, regulating microbial populations, controlling algal blooms, and influencing nutrient cycling through cell lysis. For instance, viral lysis of plankton releases organic matter that fuels microbial food webs, a process known as the viral shunt. Marine viruses also play a role in horizontal gene transfer among microorganisms, contributing to the evolution of microbial communities and the emergence of novel traits.

In terms of human health relevance, marine viruses may indirectly impact humans through environmental exposure in coastal regions, seafood consumption, or interactions with marine mammals, which can act as reservoirs for viruses with zoonotic potential. Marine mammal viruses, such as cetacean morbilliviruses and influenza-like viruses, share structural and functional characteristics with human pathogens, raising the possibility that co-exposure with SARS-CoV-2 could influence viral replication dynamics and immune responses. Understanding the ecological roles of these viruses helps contextualize potential human health risks and underscores the importance of monitoring viral populations in marine environments.

Potential Interactions with SARS-CoV-2

1. Environmental Co-Exposure: Coastal populations are often exposed to seawater aerosols, seafood, and marine wildlife. If marine viruses or viral particles interact with human mucosal surfaces, they could influence susceptibility to SARS-CoV-2 infection by modulating local innate immunity.

2. Cross-Species Transmission: Some marine mammals express receptors compatible with SARS-CoV-2 entry, such as ACE2 analogs, suggesting that these animals could be co-infected. Such co-infections might affect viral shedding patterns, viral evolution, or even the emergence of recombinant variants, although this remains speculative.
3. Immune Priming or Dysregulation: Chronic or repeated exposure to marine viruses could prime antiviral innate immunity through mechanisms such as interferon signaling or toll-like receptor activation. Conversely, simultaneous viral exposures might exacerbate inflammatory responses, potentially worsening COVID-19 outcomes in co-exposed individuals.
4. Indirect Effects via Microbiome Modulation: Marine viruses can influence bacterial and planktonic communities that enter human food chains or coastal waters. Alterations in microbiomes could indirectly affect human susceptibility to SARS-CoV-2 or modulate systemic immune responses.

Immunomodulatory Effects and Co-Infection Dynamics

- Innate Immunity: Exposure to marine viruses can stimulate pattern recognition receptors (PRRs) such as Toll-like receptors (TLRs) and RIG-I-like receptors, enhancing interferon-mediated antiviral responses. This could potentially limit SARS-CoV-2 replication in early infection.
- Adaptive Immunity: Persistent or repeated marine viral exposures might affect B-cell and T-cell memory pools, modulating adaptive immune responses during SARS-CoV-2 infection. Cross-reactive epitopes are unlikely but could theoretically influence immune recognition.
- Cytokine Regulation: Marine viral infections may induce cytokine responses that either enhance antiviral defenses or contribute to inflammatory pathology. In individuals infected with SARS-CoV-2, pre-existing immune activation from marine viral exposure could exacerbate cytokine storms, increasing the risk of severe disease outcomes.
- Microbiome-Immune Interactions: Marine viruses modulate bacterial communities in coastal environments. Altered microbiota in humans due to dietary or environmental exposure may affect systemic immunity and inflammatory responses during COVID-19.

Challenges in Diagnosis and Management

5. Limited Diagnostic Tools: Most marine viruses are not routinely screened in human clinical settings. Molecular assays and serological tests for marine viral infections are scarce, making it difficult to identify co-infections.
6. Symptom Overlap: Many viral infections, including potential zoonoses from marine environments, produce non-specific symptoms that overlap with COVID-19 manifestations, complicating clinical interpretation and management.
7. Environmental Transmission: Marine viruses may reach humans indirectly through seafood consumption, recreational water activities, or aerosols from seawater.

Identifying environmental sources of viral exposure requires interdisciplinary approaches combining virology, marine ecology, and environmental monitoring.

8. Therapeutic Considerations: Co-infections could modify the host immune response, potentially affecting the efficacy of antivirals, vaccines, or immunomodulatory therapies for COVID-19. Understanding these interactions is crucial for optimizing treatment strategies in coastal populations.

Future Perspectives

- Epidemiological Studies: Longitudinal monitoring of coastal populations for marine virus exposure and COVID-19 outcomes to assess potential correlations.
- Immunological Research: Characterization of immune responses induced by marine viruses and their impact on SARS-CoV-2 infection severity.
- Zoonotic Surveillance: Screening marine mammals and other aquatic animals for SARS-CoV-2 and co-infecting viruses to evaluate cross-species transmission risks.
- Environmental Virology: Mapping the distribution of marine viruses in coastal waters and seafood to identify potential sources of human exposure.
- Integrated Public Health Strategies: Developing guidelines for safe seafood consumption, recreational water activities, and wastewater management to mitigate co-infection risks.

Conclusion

Marine viruses represent a largely unexplored factor in the landscape of COVID-19 co-infections. Coastal populations may face unique risks due to frequent interactions with marine environments and potential exposure to marine viral communities. While direct evidence of co-infection with SARS-CoV-2 remains limited, the ecological, immunological, and zoonotic implications underscore the need for interdisciplinary research. Enhanced surveillance, improved diagnostics, and public health interventions are essential to understand and mitigate potential risks associated with marine virus exposure in the context of COVID-19.

Table 1: Selected Marine Viruses and Potential Implications for SARS-CoV-2 Co-Infection

Marine Virus Type	Host Range	Transmission to Humans	Potential Interaction with SARS-CoV-2	References
Cetacean morbillivirus	Dolphins, whales	Direct contact, aerosols (rare)	Potential co-infection in marine	3,4

			mammals; immune modulation in hosts	
Influenza A viruses (marine-associated strains)	Seals, seabirds	Zoonotic (contact, aerosols)	Co-exposure may modulate antiviral responses; surveillance relevance	5
Bacteriophages (marine)	Marine bacteria	Indirect via food chain/microbiome	Microbiome-mediated immune effects that could influence COVID-19 severity	1
Algal (phytoplankton) viruses	Plankton	Indirect/environmental	Ecosystem-level effects on microbial communities; indirect human impacts	2
Marine aerosolized microbes/viruses (sea-spray)	Mixed environmental	Inhalation during coastal aerosol exposure	Potential mucosal immune priming or irritation affecting susceptibility	9,10

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