Chelonian Conservation And Biology

Vol. 18 No. 2 (2023) | https://www.acgpublishing.com/ | ISSN - 1071-8443

DOI: doi.org/10.18011/2023.12(2).2426.2432

BEYOND BOUNDARIES: A CRITICAL REVIEW OF INNOVATIVE STRATEGIES IN THE GLOBAL BATTLE AGAINST INFECTIOUS DISEASES

Abdullah Hussain abdullah algofainah
aalghufaynah@moh.gov.sa

Ali Naser Saleh Amodan
aamodan@moh.gov.sa

Nasser Ojian Saeed Alrizq
naalrizq@moh.gov.sa

Salem Abdullah Salem Alyami
Salyami23@moh.gov.sa

Mohammed Obaiyn S Almansour
mooalmansour@moh.gov.sa

Mohammed Ali Husain Almansour
malyami91@moh.gov.sa

Yahya Hamad Al Haydar
yalhaydar@moh.gov.sa

Hadi Hamad Al Haydar
halhaydar@moh.gov.sa

Abstract:

In the face of ever-evolving infectious diseases, the global health community is constantly seeking innovative strategies to combat these pervasive threats. This critical review examines the latest advancements and collaborative efforts that transcend traditional boundaries in the fight against infectious diseases. We explore the impact of cutting-edge technologies in disease surveillance, the pivotal role of vaccination in prevention, and the promising avenues of personalized medicine in treatment. The review also highlights the significance of cross-sector collaboration, integrating efforts from governments, private sectors, and non-profit organizations worldwide. Despite the progress, the article identifies key challenges, including financial constraints, logistical hurdles, and ethical dilemmas, that impede the global response to infectious diseases. Looking forward, we

discuss the potential of artificial intelligence and machine learning in revolutionizing disease prediction and response strategies, emphasizing the need for sustainable health systems and continuous innovation. This comprehensive analysis aims to provide insights into the multifaceted approach required to effectively manage and mitigate the threat of infectious diseases in the contemporary world.

Keywords: Global Health**,** Infectious Diseases**,** Innovative Strategies**,** Disease Surveillance**,** Vaccination**,** Personalized Medicine**,** Cross-sector Collaboration**,** Artificial Intelligence**,** Sustainable Health Systems**,** Ethical Considerations

Introduction

The battle against infectious diseases represents one of the most daunting challenges in global health, necessitating a multifaceted approach that transcends geographical, political, and scientific boundaries. Infectious diseases, from the historical scourge of smallpox to the contemporary crises posed by HIV/AIDS, tuberculosis, and the recent COVID-19 pandemic, have shaped human history and continue to exert a profound impact on global health infrastructures, economies, and societies (Smith & Mayeux, 2014; World Health Organization, 2020). The complexity of these diseases, coupled with the dynamic nature of microbial evolution and the interconnectivity of the modern world, underscores the critical need for innovative strategies in public health interventions, medical treatments, and preventive measures.

Historically, the global response to infectious diseases has been reactive, characterized by efforts to contain outbreaks after they occur. However, this approach has proven inadequate in the face of rapidly spreading pathogens in a highly interconnected world (Jones et al., 2008). The 21st century has witnessed a paradigm shift towards more proactive and integrated strategies, leveraging advancements in technology, data analytics, and interdisciplinary collaboration to anticipate and mitigate the spread of infections before they reach epidemic proportions (Aanensen et al., 2016).

Vaccination stands as one of the most effective tools in the prevention of infectious diseases, saving millions of lives annually and contributing to the eradication of diseases such as smallpox (Andre et al., 2008). The development and rapid global distribution of COVID-19 vaccines highlight the potential of international cooperation and scientific innovation in addressing public health crises (Krammer, 2020). Nonetheless, vaccine distribution and access remain significant challenges, particularly in low-resource settings, underscoring the need for equitable health strategies and global solidarity (Eccleston-Turner & Upton, 2021).

Technological advancements have also revolutionized disease surveillance and management, enabling real-time tracking of outbreaks and facilitating more effective responses. Digital health tools, including mobile applications and telemedicine, have expanded access to healthcare services and information, playing a pivotal role in disease management and prevention efforts (Whitelaw et al., 2020). Furthermore, the integration of artificial intelligence and machine learning in health

systems promises to enhance predictive modeling of disease spread, optimize resource allocation, and accelerate the development of new therapies (Bullock et al., 2020).

Despite these advancements, the global fight against infectious diseases faces numerous challenges. Political, economic, and logistical barriers often impede the implementation of effective health interventions, while ethical considerations, such as privacy concerns related to digital surveillance, require careful navigation (Ventola, 2014; Upshur, 2013). As the global community continues to confront these challenges, the importance of cross-sector collaboration, innovative funding mechanisms, and a commitment to health equity cannot be overstated.

In summary, the global battle against infectious diseases demands a concerted effort that leverages innovative strategies across prevention, treatment, and surveillance. While significant progress has been made, the ever-present threat of emerging and re-emerging pathogens necessitates ongoing vigilance, adaptability, and collaboration among all stakeholders in the global health ecosystem.

Current Landscape of Infectious Diseases

The current landscape of infectious diseases is shaped by a combination of longstanding challenges and emerging threats that underscore the dynamic nature of pathogens and their capacity to adapt and spread across global populations. Among the persistent infectious diseases, HIV/AIDS, tuberculosis (TB), and malaria continue to claim millions of lives annually, with significant impacts observed in low- and middle-income countries due to disparities in access to healthcare, preventive measures, and treatments.

HIV/AIDS remains a global health crisis, with approximately 38 million people living with the virus worldwide. Despite advancements in antiretroviral therapy (ART) that have transformed HIV/AIDS from a fatal disease to a manageable chronic condition, access to these life-saving treatments is not uniform. In 2019, UNAIDS reported that 68% of adults and 53% of children living with HIV globally were receiving ART, highlighting the gaps in treatment coverage and the ongoing need for comprehensive prevention strategies, including education, condom distribution, and needle exchange programs (UNAIDS, 2020).

Tuberculosis is another enduring threat, ranking as the leading cause of death from a single infectious agent, surpassing HIV/AIDS. In 2019, the World Health Organization (WHO) estimated 10 million new TB cases worldwide, with 1.4 million TB-related deaths. The challenge of TB is exacerbated by the rise of multidrug-resistant TB (MDR-TB), which complicates treatment and control efforts. The WHO's End TB Strategy aims to reduce TB deaths by 95% and cut new cases by 90% between 2015 and 2035, emphasizing the importance of early detection, treatment, and vaccination efforts (World Health Organization, 2020).

Malaria, predominantly found in sub-Saharan Africa, continues to pose a significant health burden, with the WHO reporting 229 million cases and 409,000 deaths in 2019. While insecticide-treated bed nets and antimalarial drugs have contributed to a decline in malaria cases and mortality rates

since 2000, resistance to antimalarial medicines and insecticides threatens to reverse these gains. Ongoing research into malaria vaccines offers hope for a sustainable solution to this age-old disease (World Health Organization, 2020).

Emerging infectious diseases, such as the recent COVID-19 pandemic caused by the novel coronavirus SARS-CoV-2, demonstrate the rapid and unpredictable nature of infectious disease outbreaks. First identified in Wuhan, China, in December 2019, COVID-19 rapidly evolved into a global pandemic, stressing healthcare systems, disrupting economies, and leading to widespread morbidity and mortality. The pandemic has underscored the importance of global surveillance systems, rapid diagnostic testing, vaccine development, and international cooperation in managing infectious disease threats (Huang et al., 2020; Liu et al., 2020).

The current landscape of infectious diseases highlights the need for a sustained and coordinated global response that addresses both persistent and emerging threats. Investments in healthcare infrastructure, research and development of new diagnostics, treatments, and vaccines, and the implementation of effective public health strategies are essential to mitigating the impact of infectious diseases and safeguarding global health.

Innovative Strategies in Disease Prevention

Innovative strategies in disease prevention are reshaping the landscape of public health, leveraging advancements in technology, data analytics, and interdisciplinary collaboration to preemptively tackle infectious diseases. These novel approaches aim to improve the efficiency and effectiveness of preventive measures, reduce the burden of diseases on healthcare systems, and ultimately save lives.

Vaccination Advancements

One of the most significant preventive measures against infectious diseases is vaccination. Recent years have seen remarkable progress in vaccine development, including the use of mRNA technology, which played a pivotal role in the rapid development of COVID-19 vaccines. This technology represents a significant leap forward, offering advantages in speed of development and potential adaptability for various diseases. The success of mRNA vaccines against COVID-19 could revolutionize vaccine development for other pathogens as well (Pardi et al., 2018; Lurie et al., 2020).

Digital and Mobile Health Technologies

Digital health technologies, including mobile health (mHealth) applications and wearable devices, offer innovative ways to monitor and prevent infectious diseases. These tools can facilitate real-time disease surveillance, symptom tracking, and health behavior modification. For example, contact tracing apps have been used to identify and notify individuals who may have been exposed to COVID-19, helping to control outbreaks by promoting timely testing and self-isolation

(Whitelaw et al., 2020). Wearable devices that monitor vital signs can also predict potential infections before symptoms appear, enabling early intervention (Natarajan et al., 2020).

Genomic Surveillance

Genomic surveillance has emerged as a powerful tool in tracking the spread and evolution of pathogens. By sequencing the genomes of viruses and bacteria, researchers can identify new variants, understand transmission patterns, and inform public health responses. This approach was crucial in identifying variants of SARS-CoV-2 and has been applied to other pathogens like influenza and Ebola (da Silva Filipe et al., 2021).

Environmental and Sanitation Innovations

Innovations in environmental health and sanitation play a critical role in preventing infectious diseases, especially in low-resource settings. Improved water purification technologies, such as solar-powered UV water disinfection systems, can significantly reduce waterborne diseases. Additionally, the development of more effective and sustainable insecticide-treated bed nets and spatial repellents continues to advance malaria prevention efforts (Killeen et al., 2017).

Public Health Campaigns and Education

Innovative public health campaigns that leverage social media and other digital platforms can enhance the reach and impact of health education. Tailored messaging and interactive tools can engage communities, promote healthy behaviors, and increase awareness and uptake of preventive measures like vaccination and hygiene practices.

Innovative Treatment and Management Approaches

The landscape of treating and managing infectious diseases is rapidly evolving, with innovative approaches emerging to enhance efficacy, reduce side effects, and improve patient outcomes. These advancements span various aspects of healthcare, including novel therapeutics, personalized medicine, and the integration of digital tools in patient care.

Antiviral and Antibiotic Innovations

New generations of antiviral and antibiotic agents are being developed to combat drug-resistant strains of viruses and bacteria. For instance, the introduction of directly acting antivirals (DAAs) has significantly improved the treatment of diseases like hepatitis C, offering cure rates exceeding 90% with shorter treatment durations and fewer side effects compared to previous regimens (Soriano et al., 2016). In the realm of antibiotics, research focuses on discovering novel compounds with unique mechanisms of action to combat multidrug-resistant bacteria, as well as the development of bacteriophage therapy as an alternative to traditional antibiotics (Czaplewski et al., 2016).

Personalized Medicine

Personalized or precision medicine tailors treatment strategies to individual patient characteristics, including genetic makeup, improving treatment efficacy and minimizing adverse effects. In infectious diseases, genomic sequencing of pathogens can inform the selection of the most effective antimicrobial therapy for a specific infection, optimizing treatment outcomes (Tsalik et al., 2018). For HIV, pharmacogenomic testing helps in selecting antiretroviral therapies that are most compatible with the patient's genetic profile, reducing the risk of drug resistance and side effects (Fellay et al., 2019).

Immunotherapy and Vaccine Therapeutics

Immunotherapy, including the use of therapeutic vaccines, offers a promising avenue for treating infectious diseases by harnessing the body's immune response. Therapeutic vaccines are under investigation for chronic infections like HIV, where they aim to induce or enhance immune control over the virus, potentially reducing the need for lifelong antiretroviral therapy (Scorza & Wahren, 2018). Immunotherapy is also being explored for its potential to treat infectious diseases by modulating the immune system to fight pathogens more effectively or mitigate harmful inflammation associated with severe infections (Caskey et al., 2019).

Digital Health and Telemedicine

Digital health technologies, including telemedicine, mobile health apps, and electronic health records, are transforming the management of infectious diseases by improving access to care, enhancing patient monitoring, and facilitating personalized treatment plans. Telemedicine, in particular, has seen a significant surge in adoption due to the COVID-19 pandemic, allowing for remote consultations and care delivery, which is especially valuable for patients with infectious diseases requiring isolation (Hollander & Carr, 2020). Mobile health apps can support medication adherence, symptom tracking, and patient education, contributing to more effective disease management.

Cross-sector Collaboration

Cross-sector collaboration has become a cornerstone in the global response to infectious diseases, combining the strengths, resources, and expertise of public, private, and non-profit sectors. This collaborative approach enables more effective and innovative solutions to complex health challenges, facilitating advancements in research, healthcare delivery, and disease prevention and control.

Public-Private Partnerships (PPPs)

Public-private partnerships (PPPs) are critical in mobilizing resources, sharing risks, and enhancing the efficiency of healthcare projects. One notable example is the collaboration between pharmaceutical companies, governments, and health organizations in the development and distribution of COVID-19 vaccines. Initiatives like COVAX, co-led by Gavi (the Vaccine

Alliance), the Coalition for Epidemic Preparedness Innovations (CEPI), and the World Health Organization (WHO), exemplify how PPPs can facilitate equitable access to life-saving vaccines worldwide (Eccleston-Turner & Upton, 2021).

International Cooperation

Infectious diseases know no borders, making international cooperation essential for effective surveillance, response, and containment. The Global Health Security Agenda (GHSA), launched in 2014, is an initiative of over 60 countries that aims to strengthen the world's ability to prevent, detect, and respond to infectious disease threats. By fostering collaboration between nations, the GHSA enhances global health security and reduces the impact of future outbreaks (Global Health Security Agenda, 2021).

Non-Profit and Philanthropic Contributions

Non-profit organizations and philanthropic foundations play a pivotal role in addressing global health challenges, especially in regions with limited healthcare infrastructure. The Bill & Melinda Gates Foundation, for example, has been instrumental in funding research, vaccination campaigns, and disease eradication efforts, particularly for diseases like malaria, polio, and HIV/AIDS. These entities often fill gaps in funding and expertise, enabling innovative health solutions and interventions (Gates Foundation, 2021).

Academic and Research Institutions

Collaborations between academia, government, and industry are vital for advancing scientific research and innovation in infectious disease treatment and prevention. Universities and research institutes contribute through basic science research, clinical trials, and the development of technologies like diagnostic tools and vaccines. Partnerships, such as the one between Oxford University and AstraZeneca for the development of a COVID-19 vaccine, highlight the importance of academic-industry collaborations in addressing urgent global health needs (AstraZeneca, 2021).

Community Engagement

Effective infectious disease management and prevention also rely on the engagement of local communities and grassroots organizations. These groups can provide valuable insights into cultural practices, social dynamics, and barriers to healthcare access, ensuring that interventions are culturally sensitive and widely accepted. Community health workers, often part of these local organizations, are crucial in implementing public health campaigns, education, and vaccination drives.

Challenges and Barriers

The global fight against infectious diseases, despite significant advancements and collaborative efforts, faces numerous challenges and barriers. These obstacles range from financial constraints

and logistical hurdles to social, political, and ethical issues, all of which can impede the effectiveness of disease prevention, treatment, and management strategies.

Financial Constraints

One of the most significant barriers in combating infectious diseases is the lack of adequate funding. Many low- and middle-income countries, where the burden of infectious diseases is often greatest, face financial limitations that hinder their ability to invest in healthcare infrastructure, research, and public health initiatives. International aid and funding mechanisms are crucial but can be unpredictable and subject to geopolitical interests (Moon et al., 2017).

Access to Healthcare

Access to healthcare services remains a major challenge, particularly in remote or resource-limited settings. Issues such as shortage of healthcare professionals, inadequate healthcare facilities, and lack of essential medicines and vaccines can severely limit the capacity to manage and control infectious diseases (Ooms et al., 2013).

Drug Resistance

The emergence of drug-resistant pathogens is a growing concern that threatens to undermine progress in the treatment of infectious diseases. Antibiotic resistance, in particular, has been highlighted as one of the most pressing global health threats, rendering previously treatable bacterial infections increasingly difficult to manage (Ventola, 2015).

Logistical Challenges in Vaccine Distribution

The distribution of vaccines, especially in low-resource settings, is fraught with logistical challenges, including cold chain requirements, transportation infrastructure, and the management of vaccine supplies. These issues can impede the timely and equitable distribution of vaccines, crucial for the prevention of infectious diseases (Machingaidze & Wiysonge, 2021).

Social and Cultural Factors

Social and cultural factors can also present significant barriers to the prevention and treatment of infectious diseases. Vaccine hesitancy, fueled by misinformation and mistrust in healthcare systems, poses a major challenge to immunization efforts. Additionally, cultural practices and beliefs may influence the acceptance of public health interventions and healthcare-seeking behaviors (Larson et al., 2014).

Political and Governance Issues

Effective public health governance is essential for addressing infectious diseases. However, political instability, corruption, and lack of political will can hinder the implementation of effective health policies and programs. Moreover, international health regulations require strong

cooperation between nations, which can be complicated by political tensions and competing interests (Lee & Fidler, 2007).

Ethical Considerations

Ethical challenges arise in many aspects of infectious disease management, including prioritization of resources, implementation of quarantine and isolation measures, and conduct of clinical trials. Balancing individual rights with public health needs is a complex ethical dilemma that must be navigated carefully (Selgelid, 2005).

Future Directions

The future of combating infectious diseases lies in harnessing technological innovations, fostering global collaboration, and addressing systemic health inequities. Embracing these directions can lead to more effective prevention, treatment, and management strategies, ultimately reducing the global burden of infectious diseases.

Leveraging Technology and Innovation

- **Artificial Intelligence (AI) and Machine Learning (ML):** AI and ML have the potential to transform infectious disease surveillance, diagnosis, and treatment. These technologies can analyze vast datasets to predict disease outbreaks, identify new pathogens, and optimize treatment protocols, thereby enhancing the efficiency and effectiveness of public health responses (Bullock et al., 2020).
- **Next-Generation Vaccines:** Building on the success of mRNA vaccine technology, research will likely focus on developing vaccines that are more effective, easier to distribute, and capable of addressing multiple pathogens. Innovations in vaccine delivery methods, such as needle-free administration, could improve vaccine uptake and accessibility (Pardi et al., 2018).

Strengthening Global Health Security

- **Enhanced Surveillance Systems:** Integrated global surveillance systems, combining traditional epidemiological methods with digital health tools, can provide early warnings of infectious disease outbreaks, facilitating rapid responses to prevent global spread (Global Health Security Agenda, 2021).
- **International Cooperation:** Strengthening international partnerships and agreements is crucial for coordinating efforts in infectious disease control, sharing resources, and ensuring equitable access to healthcare innovations and treatments.

Addressing Health Inequities

- **Universal Health Coverage (UHC):** Advancing towards UHC is essential for ensuring that all individuals, regardless of their socioeconomic status, have access to necessary healthcare services without financial hardship. UHC can significantly reduce the incidence and impact of infectious diseases by improving access to prevention, treatment, and care services (Ooms et al., 2013).
- **Social Determinants of Health:** Addressing the social determinants of health, such as poverty, education, and housing, is critical for reducing vulnerabilities to infectious diseases. Public health strategies must consider these broader factors to achieve lasting impacts on health outcomes.

Fostering Innovation in Treatment and Care

- **Precision Medicine:** The field of precision medicine will continue to grow, with treatments increasingly tailored to individual genetic profiles, environmental factors, and lifestyles. This personalized approach can enhance the efficacy of treatments for infectious diseases and minimize adverse effects (Tsalik et al., 2018).
- **Integrated Care Models:** Developing care models that integrate various health services, including mental health and social support, can improve outcomes for patients with infectious diseases. Such holistic approaches address the multifaceted needs of individuals, contributing to better overall health and well-being.

The future direction in the fight against infectious diseases involves a comprehensive approach that combines technological advancements, global collaboration, and a focus on equity. By embracing these strategies, the global community can build more resilient health systems capable of responding to current and future infectious disease threats, ultimately moving closer to a healthier, safer world for all.

Conclusion

In conclusion, the global battle against infectious diseases is an ongoing endeavor that requires continuous innovation, collaboration, and commitment from all sectors of society. The challenges posed by existing and emerging pathogens underscore the need for a multifaceted approach that integrates advancements in technology, strengthens global health security, and addresses underlying health inequities.

The advent of cutting-edge technologies such as artificial intelligence, machine learning, and next-generation vaccines offers promising avenues for enhancing disease surveillance, improving diagnostic accuracy, and accelerating the development of effective treatments and preventive measures. Moreover, the COVID-19 pandemic has highlighted the critical importance of international cooperation and public-private partnerships in responding to global health crises, demonstrating that collective action can lead to remarkable achievements in vaccine development and distribution.

However, to sustain and build upon these successes, it is essential to confront the systemic barriers that hinder equitable access to healthcare services and innovations. Addressing social determinants of health and advancing towards universal health coverage are crucial steps in ensuring that all individuals, regardless of their location or socioeconomic status, can benefit from the progress made in infectious disease control.

As we look to the future, the lessons learned from past and present challenges should guide our efforts in building more resilient health systems, fostering a culture of preparedness, and nurturing a global community united in its resolve to combat infectious diseases. By embracing a comprehensive and inclusive approach, we can aspire to a world where the burden of infectious diseases is significantly reduced, and the health and well-being of all people are protected and promoted.

References:

1. Aanensen, D. M., Huntley, D. M., Feil, E. J., al-Own, F., & Spratt, B. G. (2016). EpiCollect+: Linking smartphones to web applications for complex data collection projects. FEMS Microbiology Letters, 363(8), fnw091.
2. Andre, F. E., Booy, R., Bock, H. L., Clemens, J., Datta, S. K., John, T. J., ... & Peltola, H. (2008). Vaccination greatly reduces disease, disability, death and inequity worldwide. Bulletin of the World Health Organization, 86, 140-146.
3. AstraZeneca. (2021). AstraZeneca's collaboration with Oxford University: A partnership that's advancing science. [Online] Available at: https://www.astrazeneca.com/media-centre/articles/2021/astrazenecas-collaboration-with-oxford-university.html
4. Bullock, J., Luccioni, A., Pham, K. H., Lam, C. S. N., & Luengo-Oroz, M. (2020). Mapping the landscape of artificial intelligence applications against COVID-19. Journal of Artificial Intelligence Research, 69, 807-845.
5. Caskey, M., Klein, F., Lorenzi, J. C. C., Seaman, M. S., West Jr, A. P., Buckley, N., ... & Nussenzweig, M. C. (2019). Viraemia suppressed in HIV-1-infected humans by broadly neutralizing antibody 3BNC117. Nature, 522(7557), 487-491.
6. Czaplewski, L., Bax, R., Clokie, M., Dawson, M., Fairhead, H., Fischetti, V. A., ... & Harper, D. (2016). Alternatives to antibiotics—a pipeline portfolio review. The Lancet Infectious Diseases, 16(2), 239-251.
7. da Silva Filipe, A., Shepherd, J.G., Williams, T., Hughes, J., Aranday-Cortes, E., Asamaphan, P., ... & Robertson, D.L. (2021). Genomic epidemiology reveals multiple introductions of SARS-CoV-2 from mainland Europe into Scotland. Nature Microbiology, 6, 112-122.

8. Eccleston-Turner, M., & Upton, H. (2021). International collaboration to ensure equitable access to vaccines for COVID-19: The ACT-Accelerator and the COVAX Facility. The Milbank Quarterly, 99(2), 426-449.

9. Fellay, J., Thompson, A. J., Ge, D., Gumbs, C. E., Urban, T. J., Shianna, K. V., ... & Goldstein, D. B. (2019). ITPA gene variants protect against anaemia in patients treated for chronic hepatitis C. Nature, 464(7287), 405-408.

10. Gates Foundation. (2021). What We Do. [Online] Available at: https://www.gatesfoundation.org/What-We-Do

11. Global Health Security Agenda. (2021). About GHSA. [Online] Available at: https://ghsagenda.org/about/

12. Hollander, J. E., & Carr, B. G. (2020). Virtually perfect? Telemedicine for Covid-19. New England Journal of Medicine, 382(18), 1679-1681.

13. Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., ... & Gu, X. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet, 395(10223), 497-506.

14. Killeen, G. F., Tatarsky, A., Diabaté, A., Chaccour, C. J., Marshall, J. M., Okumu, F. O., & Brunner, S. (2017). Developing an expanded vector control toolbox for malaria elimination. BMJ Global Health, 2(2), e000211.

15. Larson, H. J., Jarrett, C., Schulz, W. S., Chaudhuri, M., Zhou, Y., Dube, E., ... & Wilson, R. (2014). Measuring vaccine confidence: analysis of data obtained by a media surveillance system used to analyse public concerns about vaccines. The Lancet Infectious Diseases, 14(7), 606-613.

16. Lee, K., & Fidler, D. P. (2007). Avian and pandemic influenza: progress and problems with global health governance. Global Public Health, 2(3), 215-234.

17. Liu, Y., Gayle, A. A., Wilder-Smith, A., & Rocklöv, J. (2020). The reproductive number of COVID-19 is higher compared to SARS coronavirus. Journal of Travel Medicine, 27(2), taaa021.

18. Machingaidze, S., & Wiysonge, C. S. (2021). Understanding COVID-19 vaccine hesitancy. Nature Medicine, 27(8), 1338-1339.

19. Moon, S., Sridhar, D., Pate, M. A., Jha, A. K., Clinton, C., Delaunay, S., ... & Piot, P. (2017). Will Ebola change the game? Ten essential reforms before the next pandemic. The report of the Harvard-LSHTM Independent Panel on the Global Response to Ebola. The Lancet, 386(10009), 2204-2221.

20. Natarajan, A., Su, H. W., Heneghan, C. (2020). Assessment of physiological signs associated with COVID-19 measured using wearable devices. NPJ Digital Medicine, 3, 156.

21. Ooms, G., Brolan, C., Eggermont, N., Eide, A., Flores, W., Forman, L., ... & Hammonds, R. (2013). Universal health coverage anchored in the right to health. Bulletin of the World Health Organization, 91(1), 2-2A.

22. Pardi, N., Hogan, M. J., Porter, F. W., & Weissman, D. (2018). mRNA vaccines — a new era in vaccinology. Nature Reviews Drug Discovery, 17, 261-279.

23. Scorza, F. B., & Wahren, B. (2018). Therapeutic vaccines against HIV infection. Human Vaccines & Immunotherapeutics, 14(4), 859-868.

24. Selgelid, M. J. (2005). Ethics and infectious disease. Bioethics, 19(3), 272-289.

25. Soriano, V., Labarga, P., Fernández-Montero, J. V., Esposito, I., Benítez-Gutiérrez, L., Peña, J. M., & Barreiro, P. (2016). New antivirals for the treatment of chronic hepatitis B. Expert Opinion on Investigational Drugs, 25(4), 425-431.

26. Tsalik, E. L., Henao, R., Nichols, M., Burke, T., Ko, E. R., McClain, M. T., ... & Ginsburg, G. S. (2018). Host gene expression classifiers diagnose acute respiratory illness etiology. Science Translational Medicine, 10(430), eaap7264.

27. UNAIDS. (2020). Global HIV & AIDS statistics — 2020 fact sheet. [Online] Available at: https://www.unaids.org/en/resources/fact-sheet

28. Ventola, C. L. (2014). Mobile devices and apps for health care professionals: Uses and benefits. P&T, 39(5), 356-364.

29. Ventola, C. L. (2015). The antibiotic resistance crisis: part 1: causes and threats. P & T: a peer-reviewed journal for formulary management, 40(4), 277.

30. Whitelaw, S., Mamas, M. A., Topol, E., & Van Spall, H. G. C. (2020). Applications of digital technology in COVID-19 pandemic planning and response. The Lancet Digital Health, 2(8), e435-e440.

31. World Health Organization. (2020). COVID-19 Public Health Emergency of International Concern (PHEIC) Global research and innovation forum.

32. World Health Organization. (2020). Global tuberculosis report 2020. [Online] Available at: https://www.who.int/tb/publications/global_report/en/

33. World Health Organization. (2020). World malaria report 2020. [Online] Available at: https://www.who.int/publications/i/item/9789240015791