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REVIEW ARTICLE

COVID-19 Vaccine Impact and Future Threats From Other Pandemics

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Abstract: The outbreak of COVID-19 has drawn a new era of global health concerns and brought a different focus to the importance of vaccination. COVID-19 vaccines unleashed unprecedented impacts on public health, the economy, and health systems globally thanks to the relatively fast development, deployment, and distribution. The SARS-CoV-2 virus and sustained mutation to produce Variants of Concern (VoC), making COVID-19 vaccines secure a cause for concern. However, they might complicate some health conditions like thrombocytopenia and myocarditis, among other issues regarding their effectiveness. their risks and consequences, side effects on pregnant women, the elderly, and people with immune diseases. As it focuses on the evaluation of the COVID-19 vaccine in aspects of efficacy and safety, distribution at a global scale, and future threats posed by new emergent pandemics. It remains, as we ponder over the lessons learned, to build up the vaccine foundation, hone the preparedness and effect of COVID-19 vaccines on the public, and address inequities so that in the future pandemic will not evolve into a globally devastating problem.

Keywords: SARS-CoV-2; COVID-19; Vaccines; Pandemic; Variant of Concern; Thrombocytopenia

1. Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, has emerged as the most significant global health crisis of the 21st century. This novel coronavirus has led to unprecedented morbidity and mortality rates, surpassing previous outbreaks in terms of its rapid spread and global impact [1]. The pandemic has not only strained healthcare systems worldwide but has also had far-reaching socioeconomic consequences [2].

Vaccines have played a crucial role in mitigating the severity of COVID-19 and reducing mortality rates. However, it is important to note that while vaccines significantly decrease the risk of severe illness and death, they do not completely prevent the transmission of SARS-CoV-2, particularly its Variants of Concern (VOCs) [3]. This limitation highlights the ongoing need for comprehensive public health measures alongside vaccination efforts. A new challenge that has emerged in the wake of the pandemic is the phenomenon known as "long-COVID" or "post-COVID syndrome." This condition, characterized by persistent symptoms or the development of new health issues after the acute phase of infection, affects a significant proportion of COVID-19 survivors [4]. More than 100 distinct symptoms across various body systems have been associated with long-COVID, ranging from fatigue and cognitive impairment to cardiovascular and respiratory complications [5].

The rapid development and emergency use authorization of several COVID-19 vaccines within a year of the pandemic's onset marked a significant milestone in modern medical history [6]. These vaccines have been instrumental in curbing the spread of the virus and reducing its impact on global health. As of August 2022, over 12.44 billion doses of COVID-19 vaccines have been administered worldwide, representing a monumental achievement in global health efforts [7]. Despite the widespread vaccination campaigns, breakthrough infections remain a concern, particularly with the emergence of new VOCs such as Omicron. Vaccinated individuals can still contract the virus and experience asymptomatic, mild, or moderate COVID-19, although their risk of severe illness is significantly reduced [8]. This reality underscores the importance of continued vigilance and the potential need for updated vaccine formulations to address emerging variants. The relationship between vaccination and long-COVID presents another area of ongoing research. Studies suggest that vaccination may have different effects on individuals who develop long-COVID after breakthrough infections compared to those who had existing long-COVID symptoms prior to vaccination [9]. This association between vaccination, acute COVID-19, and long-COVID highlights the need for continued research and tailored healthcare approaches. Looking ahead, researchers and health organizations emphasize the possibility of more severe disease transmission in the future, potentially from new SARS-CoV-2 variants or other emerging pathogens. [10] This shows the critical importance of developing robust preparedness frameworks that can rapidly respond to future health threats. Such frameworks should incorporate

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lessons learned from the COVID-19 pandemic, including the value of global cooperation, the need for equitable vaccine distribution, and the importance of maintaining flexible and adaptable public health strategies. [11]

2. Impact of COVID-19 Vaccine

2.1. Effectiveness against Virus Strains

COVID-19 vaccines have shown high efficacy in cutting the chances of severe illness, hospitalization, and death. Other strains, such as Delta and Omicron, did away with vaccine effectiveness, and there was the occurrence of breakthrough infections. Booster doses assisted in managing users deteriorating immunity; however, the constant evolution of the virus highlighted the importance of the flexible vaccines [3].

Table 1. Comparison of Major COVID-19 Vaccines

Vaccine	Platform	Efficacy Against Original Strain	Efficacy Against Delta	Efficacy Against Omicron	Dosing Schedule
Pfizer-BioNTech	mRNA	95%	88%	70% (with booster)	2 doses, 21 days apart
Moderna	mRNA	94.1%	76%	75% (with booster)	2 doses, 28 days apart
Johnson & Johnson	Viral Vector	66%	60%	85% (with booster)	Single dose
AstraZeneca	Viral Vector	76%	67%	45-50% (with booster)	2 doses, 4-12 weeks apart
Novavax	Protein Subunit	90.4%	86.3%	60% (with booster)	2 doses, 21 days apart

2.2. Global Distribution and Access

The other difficulty was providing the vaccine equally to those in need across the United States. COVAX made important commitments with vaccine manufacturers and secured large amounts of doses for high-income countries, while giving lower-income countries a hard time procuring vaccines. Other efforts, such as those of COVAX, sought to do so, but obstacles to strong distribution remained. All these differences underlie the need for international cooperation in preparedness for future pandemics.

Table 2. Global COVID-19 Vaccine Distribution by Income Group

Income Group	Population (billions)	Doses Administered (billions)	Doses per 100 people	Fully Vaccinated (%)
High Income	1.2	2.3	184	75%
Upper Middle Income	2.6	5.8	172	76%
Lower Middle Income	3.3	4.0	96	54%
Low Income	0.7	0.3	24	11%

2.3. Safety and Public Perception

The vast majority of those who took the vaccines reported mild symptoms as the main effects, but the reactions like myocarditis and blood clotting dampened the public's confidence. The existing material and social networks were filled with fake news on the COVID-19 vaccine, which influenced a number of people in several areas and districts not to take the jab. This underlined the need for future public health communication and vaccine hesitancy eradication during future vaccination campaigns. [4]

2.4. Economic Recovery and Public Health Systems

Immunization drives made it possible to revive the financial systems and resume normal lives before the COVID-19 crises. But health care organizations were frequently struggling to deliver immunization services, deal with the distribution of vaccines and other personal protective equipment, and tend to patients with COVID-19 illness. The improvement of health systems can be named as one of the lessons learned for future pandemic situations [5].

2.5. Long-term Impacts on Public Health Policies

The COVID-19 vaccination has brought the long-term impacts of mass immunization programs in the history of public health. Pandemic preparedness has now become the part of health care policies in many countries, with a focus on platforms such as vaccine development, which means mRNA technology that can be easily repurposed for other pathogens.[9]

3. Future Pandemic Threats

3.1. Emerging infectious diseases

Social factors include zoonotic diseases, the emergence and spread of antibiotic-resistant bacteria, and climate change. Others are Nipah virus, H5N1 bird flu, SARS, and other coronaviruses, which might become future pandemic threats. Prompt detection, monitoring, and early intervention will be critical in dealing with these threats [6].

3.2. Global Health Inequality

The COVID-19 crisis revealed significant disparities for minorities in terms of exposure to a fairer chance at accessing the vaccine. To provide it, future pandemics may intensify existing societal disparities should they increase the negative effects of such trends without closing the gaps. Improving the health of healthcare systems in the developing nations and equal distribution of good health inventions will help to prevent global health epidemics [7, 8].

3.3. Antimicrobial Resistance (AMR)

AMR is a long-term threat to public health, threatening even the effectiveness of certain drugs and treatments. An epidemic involving antimicrobial-resistant microbes will therefore pose more than questions concerning present-day vaccine development. Research should thus be made towards new drugs and vaccines to tackle the AMR-related pandemics [9].

3.4. Climate Change and Disease Spread

Over time and with changing weather conditions, the area of disease transmission through vectors, including mosquitoes and ticks, is increasing. This shift also puts the onus on the diseases such as malaria, dengue, and Zika virus to switch subdivisions and move toward a prospect of localized septic concrete and extension of the global epidemic [10].

Table 3. Potential Future Pandemic Threats

Threat Category	Examples	Potential Impact	Key Challenges
Emerging Infectious Diseases	Nipah virus, H5N1 bird flu, Novel coronaviruses	High morbidity and mortality, rapid spread	Lack of pre-existing immunity, need for rapid vaccine development
Antimicrobial Resistance	Multi-drug resistant tuberculosis, Carbapenem-resistant Enterobacteriaceae	Reduced treatment options, increased healthcare costs	Overuse of antibiotics, slow development of new antimicrobials
Climate Change-Related Diseases	Dengue fever, Zika virus, Malaria	Expansion of vector habitats, increased transmission	Adaptation of healthcare systems, vector control measures
Zoonotic Diseases	Ebola, Lassa fever, Novel influenza strains	Spillover events, potential for human-to-human transmission	Wildlife conservation, improved surveillance at human-animal interface

The future epidemics, such as COVID-19, will continue to have sharp impacts on the economic and social environment. This may lead to an interconnected dislocation of travel and trade as well as disruption of the supply chain; the most prone would be vulnerable persons. Pandemic experiences from the COVID-19 crisis point to the need for 'Pandemic Insurance,' social protection, and containment measures to reduce these effects.

4. Lessons learnt from the Covid-19 Vaccines

Strengthening Global Vaccine Research and Development: superregional research partnerships, as have been observed during the COVID-19 crisis, have to remain a focus. Having made significant progress in the development of multipurpose platforms to target new diseases, more investment is required to fast-track the response to each new pathogen. Improving existing surveillance networks Early detection and monitoring networks will be important in anticipating future outbreaks and containing them in their

early stages. The WHO, together with other international health organizations, has to work together towards achieving strong reporting systems around the world.

Challenges to the COVID-19 vaccine include issues to do with misinformation that has made the public skeptical about the vaccines. Some of the future considerations for effective communication include information dissonance and mistrust in scientific innovations, which require clear communication channels.

Distribution of Vaccines and Treatments in Pandemics People all over the world needs to get vaccines and treatments for any disease equally during the pandemic time. The systems such as these—COVAX, for instance—should be made better; the low- and middle-income nations require a boost in their participation in accessing crucial medical resources [4].

Healthcare Systems for Future Pandemics Healthcare systems should be made stronger if the next pandemic is to be handled. This entails the development of health facilities, education of human resources in health, and guaranteeing functional health-related commodity chains during calamities.

5. Effect of Covid-19 Vaccination in Different Persons

The COVID-19 vaccine induces neutralizing antibodies and memory cells but may cause adverse events in patients with innate immune diseases, the elderly and pregnant women due to weakened immune system functions and potential abortion, premature birth, or fetal malformation.

5.1. In pregnant women

Previous studies indicate that women infected with SARS-CoV-2 tend to develop conditions like lung injury, diabetes, and cardiovascular diseases compared with non-pregnant women. Nevertheless, later on, other behaviors such as abortion or fetal malformation in women vaccinated against COVID-19 might also be at risk [11, 12]. The research carried out shows that adverse events are more common among pregnant women than in women that are not pregnant, the most common adverse event being pain at the vaccination point. There is, however, an added advantage for the vaccinated pregnant women since they have also been an epidemic shield by producing binding-maximizing and functional non-neutralizing antibodies that can cross the placenta and breast milk and protect the fetus. Because the adverse event rate in the vaccination group is greater than in the placebo group, the COVID-19 vaccine can save both mothers and newborns and minimize the risk of fetal infection after delivery.

5.2. In elderly people

Elderly individuals should be protected from the virus through at least two doses of COVID-19 vaccines, according to studies. While their TB4+ T-cell response is still relevant, their patterns are much worse than in young people. Having a population-based approach is even more effective in order to vaccines lastly, because not all people have fully been vaccinated yet when the vaccine has been available. Vaccination can be sufficient to decrease the spread of the disease, patient hospital admission, and increase the safety of the senior patients [13].

5.3. Human immunodeficiency virus (HIV)-infected persons

SARS-CoV-2 infects HIV-infected patients and autoimmune disease patients since the two groups have a compromised immune system, and they use immune suppressants. The Covid-19 vaccine's effectiveness in systematic individuals is 80%, but breakthrough infection can fail to prevent in patients with progressive AIDS. Immunization should be done and drug dosage altered in a manner that will enable the generation of neutralizing antibodies. [14,15].

5.4. Antibody-dependent enhancement (ADE) of vaccines

ADE refers to a reducing phenomenon whereby the pathogenic impact of virus infections is augmented by sub-neutralizing, or apparently non-neutralizing, antibodies [11, 15]. They can cause it, along with HIV, Ebola, influenza, flaviviruses, and other coronaviruses. COVID-19 vaccines may also result in ADE [16]. From the preclinical data, one can identify a few potential vaccine candidates that possibly cause lung disorders after vaccination, such as formalin-inactivated SARS-CoV various, MVA-vectored vaccines giving SARS-CoV S protein, and S-derived peptide-based vaccines. Finding the way to design a safe anti-antibody-independent COVID-19 vaccine post-vaccination is a paramount concern, as is observing the ADE due to vaccination.

6. Conclusion

The COVID-19 crisis has revealed the effectiveness of vaccines on an individual life as well as the shortcomings of the response system. With the world gradually coming out of a pandemic, it is important to build for the next entering threats by promoting partnerships, promoting dedicated access to vaccines, and proactively building sustainable health systems. Long–COVID symptoms: The effects of the COVID-19 vaccines on the general susceptibility to develop long-term COVID in survivors of COVID-19 also

point to the need to develop flexible vaccines. New generations of multifocal and reemerging pathogens pose potential threats in the forms of epidemic-prone emerging infectious diseases, public health disparities and inequalities, health, and antimicrobial resistance. The above challenges call for improving the healthcare infrastructure and increasing research for new treatments and vaccines. Global warming brings in diseases that cause local outbreaks. Coming outbreaks similar to COVID-19 will have socioeconomic impacts on vulnerable groups of the population. The following areas should be given attention for the next time: vaccines and research, surveillance networks, and combating fake news. There is also a need to enhance the distribution of vaccines, more so to the low- and middle-income countries. Healthcare systems need to be built up to prepare for the subsequent pandemic plans.

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Author's short biography

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Sowmya Gayathri Mylavarapu is enrolled in the B.Pharm program at Narayana Pharmacy College. She demonstrates a strong inclination towards research in pharmacology and pharmacognosy. Sowmya's dedication to these subjects reflects her commitment to expanding her knowledge and skills in pharmaceutical research.