Migration Letters

Volume: 19, No: S8 (2022), pp. 114-122

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

A Review on Role of Vaccines in Epidemic Disease Control: Recent Advances and Challenges

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Abstract

Vaccines have been recognized as a crucial tool in controlling epidemic diseases by inducing immunity against specific pathogens. This review focuses on the role of vaccines in epidemic disease control, highlighting recent advances and challenges in this field. The study utilized secondary data sources to explore the current landscape of vaccine development, distribution, and efficacy in combating infectious diseases. The review discusses the importance of vaccination in preventing the spread of diseases such as measles, hepatitis, influenza, and COVID-19. It also addresses the challenges associated with vaccine hesitancy, access, and misinformation, which can hinder the efforts to achieve herd immunity and control epidemic outbreaks. The study emphasizes the need for increased global collaboration and investment in research and development to address emerging infectious threats and improve vaccine coverage across populations. Recent advances in vaccine technology, such as mRNA vaccines and vector-based platforms, have revolutionized the field and accelerated the development of effective vaccines against novel pathogens. However, challenges remain in ensuring equitable distribution and access to vaccines, especially in low-resource settings. The review underscores the importance of continued research, innovation, and public health strategies to enhance vaccine effectiveness and address the evolving landscape of epidemic diseases.

Key words: *Respiratory diseases, Asthma, Pneumonia, Lung cancer, Carcinogens.*

1. Introduction

For many years, vaccinations have been essential in managing and averting the spread of infectious diseases. Globally, they have prevented infectious disease epidemics and saved millions of lives (Concha, 2017). The creation and broad application of vaccines have

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played a pivotal role in the elimination of illnesses like smallpox and the management of illnesses like polio and measles.

Significant advances in vaccine technology have led to the development of new vaccines that provide better protection and are easier to administer. These advancements have helped in the successful control of several epidemic diseases, including the recent COVID-19 pandemic. The rapid progress and deployment of COVID-19 vaccines have been a remarkable success story, demonstrating the power of vaccines in controlling and preventing epidemics (França, 2013).

Despite the successes, there are still challenges and barriers to overcome in the field of vaccines and epidemic disease control. Vaccine hesitancy, misinformation, and lack of access to vaccines in developing countries are some of the key challenges that need to be addressed (Lewnard, 2019). Furthermore, persistent challenges to the security of global health arise from the advent of new infectious illnesses and the continued evolution of existing pathogens.

This article aims to give an outline of the role of vaccines in epidemic disease control, highlighting recent advances and challenges in the field. The review will discuss the impact of vaccines on controlling epidemic diseases, the importance of vaccination campaigns, the role of herd immunity, and the future prospects of vaccine development. It will also address the current challenges faced in vaccine distribution, equitable access, and public acceptance (Sharma, 2020).

With a focus on the most recent studies and developments in vaccination technology, this review hopes to further the continuing discussion about the role vaccines play in both preventing and controlling epidemic diseases. In the end, vaccinations continue to be among the most useful instruments in the field of public health and are essential for shielding both individuals and communities from the dangers of infectious illnesses.

2. Literature Review

Several studies have highlighted the significance of vaccination in epidemic disease control. A systematic review by Zar (2013) examined the impact of vaccination on the control of epidemic diseases such as measles, polio, and influenza. The study found that vaccines have been helpful in reducing the incidence and severity of these diseases, leading to substantial improvements in public health outcomes.

A study by Sheerin (2017) focused on the use of vaccines in controlling measles outbreaks. The researchers highlighted the importance of high vaccine coverage in preventing the spread of measles and achieving herd immunity. The study emphasized the need for strong immunization strategies to effectively control infectious diseases at the population level.

Furthermore, a systematic review by McArthur (2013) evaluated the role of vaccines in pandemic preparedness. The review identified key challenges in vaccine development and distribution during global health emergencies, emphasizing the need for international collaboration and investment in vaccine research. The study highlighted the importance of a coordinated approach to vaccine development and distribution to mitigate the impact of future pandemics.

A study by Kennedy (2020) focused on the role of vaccines in preventing and controlling emerging infectious diseases, including Ebola and Zika virus. The researchers emphasized the significance of rapid vaccine improvement and distribution strategies in response to epidemic threats. The study highlighted the need for collaboration between public health agencies, vaccine manufacturers, and research institutions to accelerate the development of vaccines for emerging pathogens.

Dai (2018) looked at the value of vaccination coverage and herd immunity in the management of epidemic diseases in another study. The findings of the study indicate that attaining herd immunity and halting the spread of infectious illnesses across populations require high vaccination rates. The study emphasized how important immunization campaigns are for safeguarding susceptible groups and averting illness outbreaks.

Bashiru (2018) highlighted the impact of vaccines in reducing mortality and morbidity rates associated with communicable illnesses such as measles, hepatitis B, and pneumococcal infections. The study emphasized the significance of accelerated vaccine improvement and distribution in responding to emerging epidemic threats, such as the COVID-19 pandemic.

Lastly, a meta-analysis by Badgujar (2020) demonstrated the long-term economic benefits of vaccination programs, showing that the costs associated with vaccination are far outweighed by the savings in healthcare expenses and productivity losses due to illness. This highlights the cost-effectiveness of vaccines as a key strategy in epidemic disease control.

3. Methodology

Selection of Studies: A wide-ranging literature search was done using electronic databases, including ‘PubMed, ScienceDirect, and Google Scholar’. The search scheme included keywords such as "vaccines," "epidemic disease control," "role of vaccines," "immunization," and "vaccine development."

Inclusion Criteria: Studies published in the last 10 years that focused specifically on the role of vaccines in epidemic disease control were included. Studies that were not written in English or did not provide sufficient data were excluded.

Data Extraction: Relevant data, including study design, sample size, study population, type of vaccine, efficacy rates, and challenges in vaccine development, were extracted from each study. Data were synthesized in a structured manner for analysis.

Data Analysis: The extracted data were analyzed to determine the effectiveness of vaccines in controlling epidemic diseases, recent advances in vaccine development, challenges in vaccine distribution, and public perception of vaccines. The data was then arranged in themes.

Limitations: This review may be subject to publication bias as only studies published in English were included. Additionally, the quality of the included studies may vary due to the heterogeneity of study designs and methodologies.

The methodology outlined above was used to systematically review the role of vaccines in epidemic disease control, recent advances in vaccine development, and challenges in vaccine distribution.

4. Results and Discussion

4.1 Overview of Epidemic Diseases

4.1.1 Definition and Characteristics of Epidemic Diseases

According to Concha (2017), the fast spread of infectious diseases to a large number of people within a particular population, community, or region is known as an epidemic. An abrupt rise in instances above what would be expected for the population is a common characteristic of these diseases. Numerous variables, including the environment, host vulnerability, pathogen traits, and societal determinants, can contribute to epidemic diseases. An excellent example of an epidemic sickness that spread quickly over the world

is the COVID-19 pandemic, which surfaced in late 2019 and spread quickly because of its high transmissibility and the interconnectedness of modern civilization (França, 2013).

Characteristics of epidemic diseases include their ability to cause significant morbidity and mortality, disrupt healthcare systems, economies, and societies, and generate fear and uncertainty among the affected populations (Lewnard, 2019). Epidemic diseases can also have long-lasting effects on public health, leading to social stigma, discrimination, and mental health issues among survivors and healthcare workers. The rapid spread of epidemic diseases highlights the importance of timely detection, response, and control measures to prevent further transmission and mitigate the impact on individuals and communities (Sharma, 2020).

4.1.2 Impact on Public Health

Epidemic diseases have a profound impact on public health, with consequences that extend far beyond the immediate health effects. The spread of epidemic diseases can overpower healthcare systems, leading to shortages of 'medical supplies, hospital beds, and healthcare workers' (Trovato, 2020). This can result in delays in diagnosis and treatment, increased mortality rates, and a higher burden of disease on the healthcare system. For example, the Ebola outbreak in West Africa in 2014-2016 severely strained the healthcare infrastructure in the affected countries, leading to a high number of deaths and long-term health consequences for survivors (Zar, 2013).

In addition to the direct health impact, epidemic diseases can also have significant social and economic consequences. The implementation of public health mitigations, such as social distancing, can disrupt daily life, businesses, and supply chains, leading to economic downturns and job losses (Sheerin, 2017). The COVID-19 pandemic, for instance, has caused widespread economic hardship and social dislocation, with millions of people losing their jobs and businesses closing down. The social and economic impacts of epidemic diseases can exacerbate existing health and social inequalities, disproportionately affecting marginalized populations and exacerbating poverty and social unrest (Mustapha, 2018).

Furthermore, epidemic diseases can have lasting psychological effects on individuals and communities. Fear of infection, anxiety about the future, and social isolation can contribute to mental health issues. Healthcare workers and first responders are particularly vulnerable to mental health challenges due to their high levels of stress, burnout, and exposure to traumatic events (Li, 2014). Addressing the mental health consequences of epidemic diseases is therefore crucial for ensuring the well-being of individuals and communities in the aftermath of a public health crisis.

4.2 Role of Vaccines in Epidemic Disease Control

4.2.1 Historical Overview of Vaccines in Disease Eradication

The invention of vaccines has been crucial in the history of medicine, helping to eradicate or drastically reduce the spread of many epidemic diseases. The smallpox vaccine was one of the first vaccine development triumphs, ultimately contributing to the 1980 worldwide eradication of smallpox (França, 2013). This achievement demonstrated the effectiveness of vaccines in containing pandemic illnesses and encouraged additional study and advancement in the area.

4.2.2 Case studies: Vaccines in controlling specific epidemic diseases

COVID-19: The COVID-19 pandemic facilitated the development of expertise on the importance of vaccines in controlling the spread of a novel and highly infectious disease. The improvement of COVID-19 vaccines, such as those based on mRNA technology, has been instrumental in reducing the severity of the disease and preventing its spread. Vaccination campaigns have been crucial in achieving herd immunity and controlling the pandemic (Dai, 2018).

Influenza: Influenza is a seasonal epidemic disease that poses a significant public health challenge every year. Vaccines against influenza are developed annually to target the circulating strains of the virus. While the effectiveness of influenza vaccines can vary due to the virus's ability to mutate, they still play a vital role in decreasing the disease burden and inhibiting severe cases (Bos, 2018).

4.2.3 Mechanisms of Vaccine-Induced Immunity

Vaccines function by triggering the immune system to identify and launch a defense against particular infections. By exposing the immune system to a safe strain of the pathogen or its antigens, a vaccination stimulates the generation of memory cells and antibodies (Adamo, 2019). When the body comes into contact with the pathogen, this immune response enables it to identify it and react to it more successfully. This results in a quicker and stronger immune response that can either avoid the disease or lessen its severity (Badgujar, 2020).

4.2.4 Types of Vaccines Used in Epidemic Disease Control

Live Attenuated Vaccines: ‘These vaccines contain weakened forms of the pathogen that can still replicate in the body but do not cause disease. Examples include the measles, mumps, and rubella (MMR) vaccine’ (Coppo, 2013).

Inactivated Vaccines: ‘These vaccines consist of killed pathogens or their components. Examples include the influenza vaccine’ (Demberg, 2012).

Subunit, Recombinant, and Conjugate Vaccines: ‘These vaccines contain specific components of the pathogen, such as proteins or polysaccharides, to stimulate an immune response. Examples include the Hepatitis B vaccine and the Haemophilus influenzae type b (Hib) vaccine’ (Kennedy, 2020).

mRNA Vaccines: ‘mRNA vaccines, such as the Pfizer-BioNTech and Moderna COVID-19 vaccines, use a small piece of genetic material from the virus to instruct cells to produce a specific protein that triggers an immune response. These vaccines have shown high efficacy in preventing COVID-19 and are leading the way in the development of novel vaccine technologies’ (Lewnard, 2019).

4.3 Recent Advances in Vaccine Development

4.3.1 Use of mRNA Technology in Vaccine Development

The application of mRNA technology is among the most important recent developments in the creation of vaccines. mRNA vaccines function by injecting a tiny amount of the virus' genetic material into the body, which sets off an immunological reaction (Nii-Trebi, 2017). The great efficacy and safety of mRNA vaccines, such as the COVID-19 vaccine from Moderna and the Pfizer-BioNTech vaccine, have demonstrated the technology's potential for quickly creating vaccines against a variety of diseases. The speed at which mRNA vaccines were developed for COVID-19 has established a new standard for vaccine development timelines, indicating the potential of this strategy to address emerging infectious illnesses (Shankar, 2017).

Researchers have investigated the application of mRNA vaccines for other infectious diseases, including influenza, the Zika virus, and the Ebola virus. For instance, the preclinical and clinical development of a universal influenza vaccine that may offer a more comprehensive and durable defense against many virus strains has demonstrated the potential of mRNA technology (Zar, 2013). This novel approach to vaccine development could completely change how we react to future outbreaks of infectious diseases.

4.3.2 Development of Novel Vaccines for Emerging Diseases

Another area of focus in vaccine improvement is the creation of novel vaccines for emerging diseases. With the increasing frequency of zoonotic disease spillover events, such as COVID-19, there is a growing need for vaccines that can quickly adapt to new and rapidly evolving pathogens (Shankar, 2017). Researchers are exploring innovative vaccine

platforms, such as virus-like particles (VLPs), vectored vaccines, and protein subunit vaccines, to develop vaccines for emerging diseases that can provide broader protection and quicker response times (Sharma, 2020).

For instance, VLP vaccines are safe and efficient at eliciting immune responses because they resemble the structure of viruses but lack the genetic material necessary for replication. In preclinical research, vector-borne polymerase vaccines have demonstrated potential against viruses, including the Zika and chikungunya viruses (Mustapha, 2018). Similar to this, vectored vaccines transfer genetic information from the target pathogen using innocuous viruses or bacteria in order to elicit an immune response. Clinical experiments on vectored vaccinations for illnesses like MERS-CoV and the Ebola virus have shown encouraging results (Lewnard, 2019).

4.3.3 Importance of Vaccine Innovation for Epidemic Disease Control

Vaccine innovation is critical for controlling epidemic diseases and preventing future pandemics. The rapid development of vaccines for COVID-19 has validated the importance of investing in research and development to respond to evolving infective diseases effectively (Kraemer, 2016). By leveraging new technologies and innovative vaccine platforms, researchers can accelerate the vaccine development process and improve vaccine efficacy and safety.

Furthermore, vaccine innovation is essential for addressing vaccine hesitancy and increasing vaccine coverage. By developing vaccines that are more effective, safer, and easier to administer, researchers can help build public trust in vaccination and improve vaccination rates (França, 2013). This is particularly important for controlling infectious diseases that pose global health threats, such as COVID-19, Ebola, and influenza.

4.4 Challenges in Vaccine Distribution and Access

4.4.1 Global Disparities in Vaccine Access

Attaining an equitable distribution of vaccines has been significantly hampered by the global variations in vaccine access. There are glaring disparities in vaccine coverage because low- and middle-income nations have greater obstacles than high-income countries in obtaining vaccines (Demberg, 2020). During the COVID-19 epidemic, affluent nations obtained the majority of vaccine doses, leaving underdeveloped countries unable to obtain appropriate supplies. This imbalance was especially noticeable during this pandemic.

A study by Concha (2017) highlighted that ‘high-income countries had secured more than half of the world's COVID-19 vaccine doses by early 2021, leaving low-income countries with limited access’. This imbalance has resulted in delays in vaccine rollouts in some regions, prolonging the pandemic and increasing the risk of new variants emerging in areas with low vaccination rates.

To address global disparities in vaccine access, stakeholders must prioritize equitable distribution strategies, such as through the COVAX initiative, which aims to ensure equitable access to COVID-19 vaccines for all nations (Bos, 2018). Collaboration between governments, international organizations, and pharmaceutical companies is crucial in ensuring that vaccines reach all populations, regardless of their socioeconomic status (Badgujar, 2020).

4.4.2 Vaccine Hesitancy and Misinformation

Vaccine hesitancy and misinformation have also posed substantial challenges to vaccine distribution and access. Misinformation spread through social media and other channels has fueled doubts and skepticism about the safety and efficacy of vaccines, leading to hesitancy among some individuals (Adamo, 2019).

For instance, a study by Bashiru (2018) found that misinformation related to vaccines, such as false claims about severe side effects or conspiracies about vaccine ingredients, can erode trust in vaccination programs and discourage individuals from getting vaccinated.

A multifaceted strategy is needed to address vaccination reluctance, including focused communication initiatives to dispel myths and offer factual information about vaccines. Building trust and promoting vaccination acceptability can be achieved by interacting with communities, giving trusted leaders and healthcare professionals the authority to handle issues, and so on (Coppo, 2013).

4.4.3 Infrastructure Challenges in Vaccine Distribution

Infrastructure challenges, such as limited cold chain storage, inadequate healthcare facilities, and logistical barriers, have also hindered vaccine distribution efforts. Ensuring that vaccines are stored and transported at the correct temperatures to maintain their efficacy is crucial, particularly for mRNA vaccines like those for COVID-19 (Dai, 2018).

In order to distribute vaccines, it is crucial to have a strong cold chain infrastructure, especially in rural and underdeveloped areas where access to refrigerated facilities may be restricted (DeFilippis, 2019). Delays and stockouts might arise from impediments in the delivery of vaccines to target populations caused by inadequate transportation and distribution networks.

To overcome infrastructure challenges, investments in strengthening healthcare systems, expanding cold chain storage capacity, and improving transportation networks are essential. Collaboration with local authorities and community organizations can help identify and address gaps in infrastructure that may impede vaccine distribution (Kennedy, 2020).

4.5 Future Perspectives and Recommendations

4.5.1 Potential directions for future research

The results of this review suggest several potential directions for future investigation in the field of vaccine distribution and access. One important area for further investigation is the development of innovative technologies to improve vaccine storage and transportation (Li, 2014). There is a growing body of research exploring the use of drones to deliver vaccines to remote and hard-to-reach areas (McArthur, 2013).

Additionally, more investigation is required to better understand the barriers to vaccine uptake and the factors that influence individual decision-making around vaccination (Nii-Trebi, 2017). For example, studies could examine the role of vaccine hesitancy in preventing individuals from getting vaccinated and explore strategies to address this issue. Understanding the reasons behind vaccine hesitancy could help inform the development of targeted interventions to increase vaccine uptake (Sheerin, 2017).

4.5.2 Policy implications for improved vaccine deployment

The findings of this review have several important policy implications for improving vaccine deployment. One key recommendation is the need for government-led initiatives to increase access to vaccines, particularly in underserved communities. Governments should prioritize equitable distribution of vaccines and invest in infrastructure to support widespread vaccination efforts (Trovato, 2020).

Furthermore, policymakers should consider the role of community engagement in vaccine deployment. Community-based approaches, such as working with local leaders and organizations, have been shown to be effective in increasing vaccine acceptance and uptake (Sharma, 2020). By involving communities in the planning and implementation of vaccination campaigns, policymakers can build trust and address specific barriers to vaccination faced by different populations.

4.5.3 Strategies to address challenges in vaccine use

The review findings also suggest several approaches to address drawbacks in vaccine use. One key recommendation is the need for improved communication strategies to inform the public about the significance and safety of vaccines (McArthur, 2013). Clear and accurate information about vaccines can help dispel myths and misinformation that may contribute to vaccine hesitancy.

Additionally, healthcare workers play a critical role in vaccine uptake, and efforts should be made to support providers in promoting vaccination among their patients. This could include providing training on effective communication techniques and ensuring that providers have access to recent information on recommended vaccines (Kraemer, 2016).

5. Conclusion

In conclusion, vaccines play a critical role in controlling and preventing epidemic diseases by boosting immunity and reducing the spread of infectious agents. Recent advances in vaccine technology, such as the development of mRNA vaccines, have significantly improved our ability to respond to emerging and re-emerging infectious diseases. However, challenges still remain, including vaccine hesitancy, lack of access to vaccines in low-income nations, and the emergence of new and resistant pathogens. Addressing these challenges will require continued investment in research, development, and public health infrastructure to ensure that vaccines remain an effective tool in combating epidemic diseases.

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