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Monitoring and surveillance of vaccine research aimed at predicting the emergence of new and re-emerging infectious diseases: A case of addressing natural hazards in the field of health

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Abstract

Monitoring and surveillance refer to the activities of collecting, analyzing, and evaluating information about a specific subject. Monitoring means continuously tracking the status of a phenomenon and gathering information to identify changes and trends. Surveillance involves assessing the collected data and analyzing the impacts and effectiveness of programs. These two tools are vital for management and performance improvement in various fields. Vaccines play a key role in controlling emerging and re-emerging infectious diseases that arise due to environmental changes and viral mutations. Vaccines stimulate the immune system to produce antibodies, making the body resistant to these diseases. In the case of emerging diseases, vaccines have been rapidly developed to control outbreaks. Additionally, public vaccination reduces infection and mortality rates and strengthens herd immunity. Effective production and distribution of vaccines improve public health and socio-economic conditions. By utilizing monitoring and surveillance in vaccine studies, the likelihood of outbreaks caused by infectious agents can be predicted. Up-to-date information helps researchers enhance their capabilities in designing and producing effective vaccines. Consequently, investment in this field not only contributes to public health but also strengthens countries' ability to manage health crises. The aim of this study is to determine the role of analyzing and evaluating information obtained from monitoring and surveillance of research centers in the field of vaccines to predict the emergence of new and re-emerging infectious diseases.

Keywords: Surveillance, Monitoring, Vaccines, Emerging and re-emerging, Infectious diseases.

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Introduction

Emerging and re-emerging infectious diseases are recognized as serious threats to public health and national security. These diseases arise from new infectious agents or from the return of previously controlled diseases, and their spread is considered one of the major public health challenges of the twenty-first century[1]. Emerging diseases refer to diseases that have recently appeared in human populations or have increased significantly. These diseases are usually caused by new infectious agents, environmental changes, genetic mutations, and changes in human behaviors[2,3]. On the other hand, re-emerging diseases refer to diseases that return to high levels of prevalence after a period of decline or control. These diseases may result from factors such as microbial resistance, climate change, and social instability[3]. Environmental hazards, including climate change, pollution, and social instability, play a significant role in the spread of these diseases. For example, climate change can create new habitats for infectious agents and increase human contact with these agents. In addition, social and economic instability can reduce access to healthcare services and consequently increase the risk of disease outbreaks[4]. In this regard, surveillance and monitoring are considered key tools in public health management.

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Surveillance refers to the continuous tracking of the status of a particular phenomenon or issue and involves the regular and systematic collection of data and information. This activity helps identify existing changes and trends. Monitoring, on the other hand, refers to the evaluation and analysis of the collected data and helps researchers and decision-makers determine whether the established objectives have been achieved[5,6]. By using surveillance and monitoring of vaccine-related studies at the global level, it is possible to gain insight into the spread of emerging and re-emerging diseases. This process includes collecting and analyzing data related to disease outbreaks, genetic changes in viruses and bacteria, and epidemiological behaviors. Up-to-date information helps researchers strengthen their capabilities in designing and producing effective vaccines. Moreover, continuous surveillance and precise monitoring of information can help identify new patterns in disease spread and evaluate the impacts of existing vaccines on different populations. The aim of this study is to determine the role of analyzing and evaluating information obtained from the surveillance and monitoring of research conducted by research centers in the field of vaccines in order to predict the spread of emerging and re-emerging infectious diseases. This study examines how data related to disease outbreaks, genetic changes of infectious agents, and epidemiological patterns are collected and analyzed. By using advanced data analysis methods, this research helps identify new trends and patterns in disease spread and enables researchers and decision-makers to respond to health threats in a timely and effective manner. It also evaluates the impacts of existing vaccines on different populations and identifies the health needs of communities. Ultimately, the results of this study can contribute to the development of preventive strategies and the improvement of health responses to emerging and re-emerging infectious diseases, thereby helping to maintain public health at the global level.

Emerging and Re-emerging Infectious Diseases

Emerging and re-emerging infectious diseases are recognized as serious threats to global public health. These diseases may arise from new infectious agents or from the return of previously controlled diseases, and their spread is increasing due to environmental, social, and economic changes. Emerging diseases refer to diseases that have recently appeared in human populations or have increased significantly. These diseases are usually caused by new infectious agents, changes in human behaviors, or genetic mutations. On the other hand, re-emerging diseases refer to diseases that return to high levels of prevalence after a period of decline or control. These diseases may result from factors such as microbial resistance, climate change, and social instability[7,8] (Figure 1).

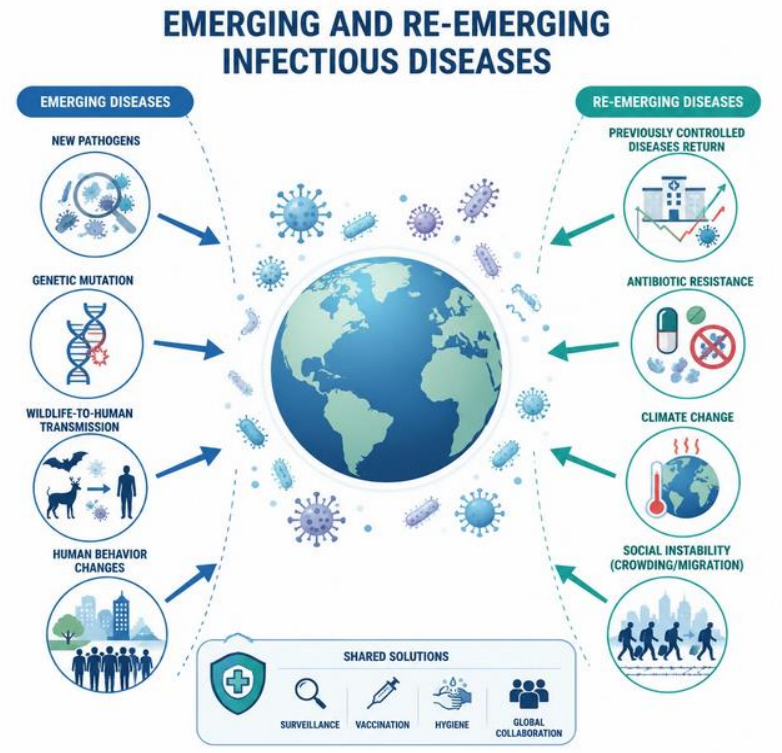


Figure 1. Conceptual illustration of emerging and re-emerging infectious diseases and the key factors contributing to their spread, including new infectious agents, genetic mutations, climate change, microbial resistance, and social instability, which collectively pose significant threats to global public health.

Factors Influencing the Spread of These Diseases

Multiple factors contribute to the spread of emerging and re-emerging diseases. Climate change can create new habitats for infectious agents and increase human contact with these agents. In addition, social and economic instability can reduce access to healthcare services and consequently increase the risk of disease outbreaks. Other factors include changes in lifestyle patterns, migration, and increased international travel, all of which can contribute to the more rapid spread of diseases[9].

Examples of Emerging and Re-emerging Infectious Diseases

Examples of emerging diseases include COVID-19, Zika fever, Nipah, and Ebola, which have recently spread in human populations and have had significant impacts on public health. In addition, diseases such as tuberculosis, SARS (Severe Acute Respiratory Syndrome), Lyme disease, dengue fever, measles, and malaria—recognized as re-emerging diseases—have returned to high levels of prevalence after a period of decline and have created serious challenges for health systems[10] (Figure 2).

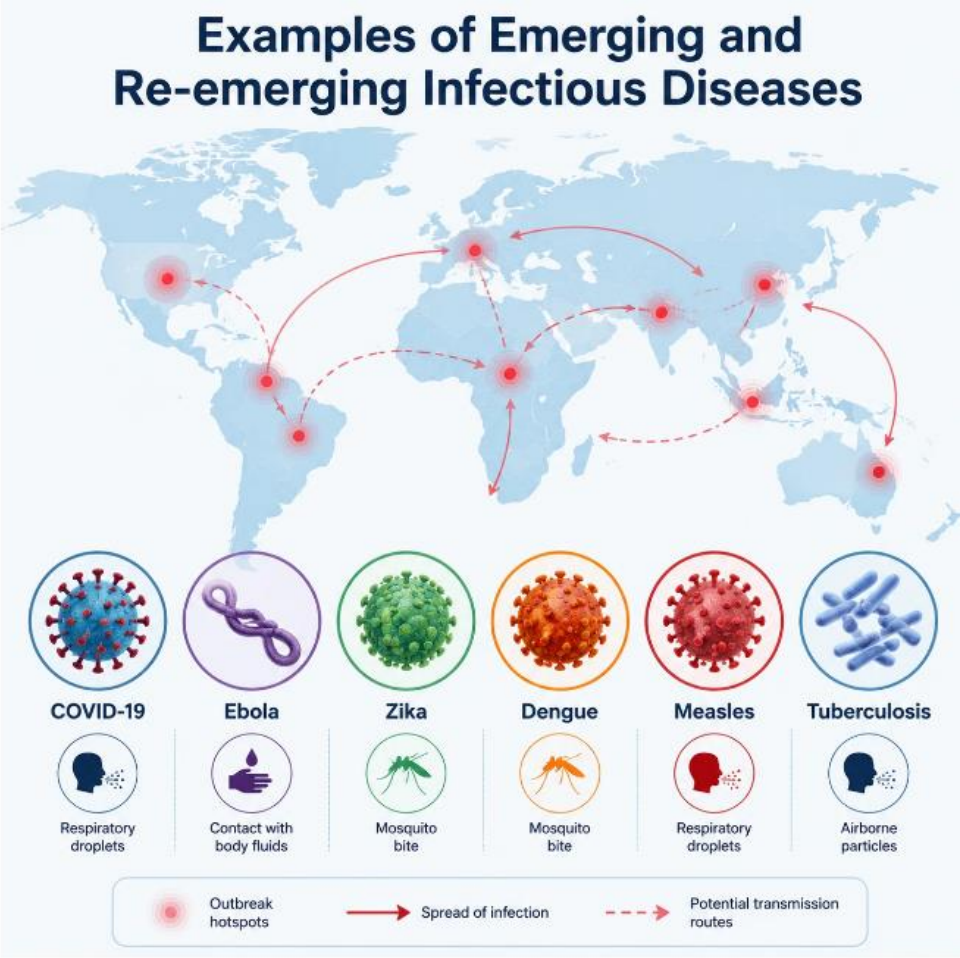


Figure 2. Examples of emerging and re-emerging infectious diseases, including COVID-19, Zika, Nipah, and Ebola as emerging diseases, and tuberculosis, SARS, Lyme disease, dengue fever, measles, and malaria as re-emerging diseases that continue to pose significant challenges to global public health.

Prediction of Disease Outbreaks

Predicting the spread of infectious diseases is recognized as a key tool in public health management and in planning responses to epidemics and pandemics. This process involves the use of data and models to identify patterns of disease spread and to predict future trends.

Methods for Predicting the Spread of Infectious Diseases

Various methods are used to predict the spread of infectious diseases. One of these approaches involves the use of mathematical and epidemiological models, which help analyze disease behavior and forecast their spread. These models usually include variables such as transmission rate, recovery rate, and mortality rate. In

addition, the use of historical data and previous outbreak patterns can help identify future trends. Furthermore, machine learning and artificial intelligence methods are increasingly being used to predict disease outbreaks[11].

History and Development of Vaccines

The history of vaccines dates back to the eighteenth century, when Edward Jenner, an English physician, developed the first vaccine to prevent smallpox. He inoculated individuals with the weakened cowpox virus and observed that these individuals became immune to human smallpox. This discovery not only laid the foundation for the science of vaccination but also led to a global reduction in the spread of smallpox[12]. In the nineteenth and early twentieth centuries, with scientific and technological advances, new vaccines were developed for various diseases. Vaccines against tetanus, diphtheria, and pertussis were among those that significantly reduced the prevalence of these diseases. With the development of vaccines against polio and measles in the following decades, the incidence of these diseases declined dramatically, and many countries moved closer to the goal of eradicating them[12]. In recent decades, the development of vaccines has accelerated due to advances in biotechnology and genetics. Recombinant vaccines and mRNA vaccines, such as COVID-19 vaccines, are examples of these advances that were rapidly developed and brought to market[13].

The Impact of Vaccines on Controlling Infectious Diseases

The relationship between vaccine discovery and the prevalence of diseases is very clear. Whenever a vaccine for a disease is developed and widely used, the incidence of that disease decreases significantly. For example, polio vaccines have led to a substantial reduction in the prevalence of this disease in many countries and, in some regions, have resulted in its complete eradication. Similarly, measles and rubella vaccines have significantly reduced mortality caused by these diseases. These positive impacts highlight the importance of vaccination in maintaining public health and preventing the spread of infectious diseases[14] **(**Figure 3).

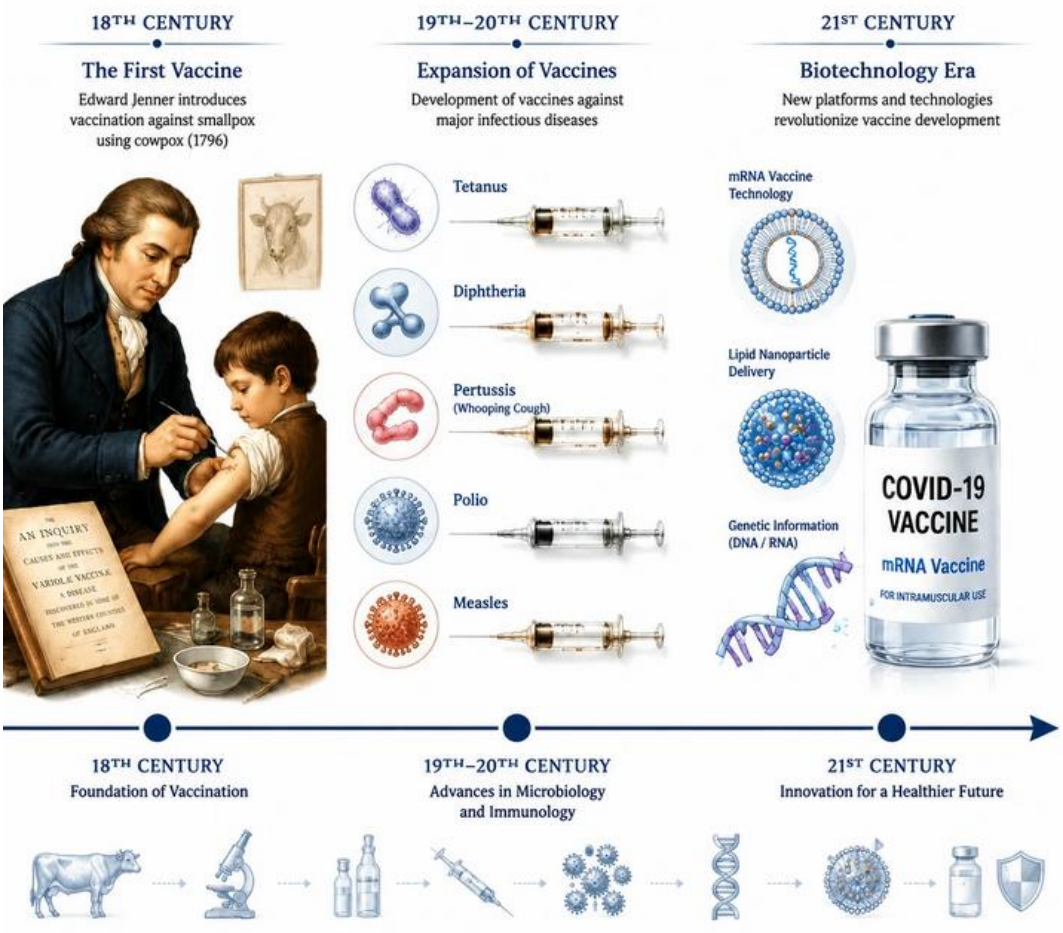


Figure 3. Illustration of the history and development of vaccines, showing the progression from Edward Jenner's early smallpox vaccination to modern vaccine technologies such as mRNA platforms, highlighting the major milestones in vaccine science and their role in controlling infectious diseases.

The Role of Emerging Technologies in the Development of Future Vaccines

Emerging technologies play a very important role in the development of future vaccines and can help accelerate the process of vaccine research and production. One of the key technologies is messenger RNA (mRNA) technology. This technology has enabled the production of mRNA-based vaccines that can be designed rapidly and with high precision against viruses. These types of vaccines allow researchers to respond quickly to genetic changes in viruses and develop new vaccines in a short period of time[15]. Novel technologies in the field of nanoparticles also contribute to the development of effective vaccines. Nanoparticles can function as vaccine carriers and help improve the safety and efficacy of vaccines. These technologies can increase vaccine stability and reduce their side effects. Biotechnology technologies also play an important role in the production of modern vaccines. They enable researchers to artificially produce specific proteins that can be used as antigens in vaccines. This can facilitate the development of new vaccines against both infectious and non-infectious diseases[16]. In addition, digital technologies and data mining are also influential in the vaccine development process. By using big data analysis and computational modeling, researchers can make accurate predictions about pathogen behavior and the body's immune responses. This information can help accelerate the design and testing of vaccines[17]. Emerging technologies also help improve vaccine manufacturing and distribution processes. The use of automation and robotics technologies in production lines can increase the speed and accuracy of vaccine manufacturing. Furthermore, supply chain technologies can improve vaccine distribution and ensure that proper storage conditions are maintained.

Challenges and Opportunities in Vaccine Production and Distribution

The evaluation of vaccines from the production stage to distribution is a critical aspect of public health management and ensuring the safety and effectiveness of vaccines. This process involves several key stages. Initially, research phases and clinical trials are conducted, including preclinical tests on animals and three phases of clinical trials on humans. During these stages, the safety and effectiveness of the vaccine are assessed, and data related to side effects are collected. After vaccine approval, production begins, and quality control at this stage is extremely important. Various tests are carried out to ensure the purity, safety, and effectiveness of the vaccine[18]. Effective vaccine distribution requires careful planning, including determining distribution points, managing the supply chain, and ensuring proper storage of vaccines at specific temperatures. In addition, training healthcare personnel and raising public awareness about the importance of vaccination are also important aspects. After vaccine distribution, its impact on reducing disease prevalence and potential side effects within the target population is evaluated. These assessments help health authorities make better decisions regarding public vaccination programs and update strategies when necessary[19] (Figure 4).

Challenges in Vaccine Importation

The importation of vaccines, particularly in developing countries, faces numerous challenges that can negatively affect public health and community safety. These challenges include legal and economic limitations, as well as the presence of counterfeit vaccines. One of the main challenges in vaccine importation is legal and regulatory restrictions. Many countries require specific permits for importing vaccines, which may delay the importation process. These permits usually involve safety and efficacy evaluations of vaccines by health and pharmaceutical authorities. In some cases, these procedures can be time-consuming and complex, leading to delays in vaccine supply[20]. In addition, economic constraints can also create challenges. Developing countries often face financial limitations in purchasing vaccines. The high price of vaccines and the costs associated with transportation and storage can restrict access to vaccines. This issue can become particularly critical in situations where immediate access to vaccines is needed to respond to epidemics[21]. Another challenge is the presence of counterfeit vaccines, which are recognized as a serious threat to public health. Counterfeit vaccines usually lack the necessary quality and safety standards and can cause serious adverse effects in individuals who receive them. These vaccines are typically distributed in unregulated markets without proper oversight and can easily reach consumers. The presence of counterfeit vaccines can reduce public trust in vaccines and vaccination programs. This issue may contribute to the spread of diseases and epidemics and undermine public health efforts. Therefore, addressing this challenge requires strict monitoring and strengthening quality control systems within vaccine supply chains[22-24].

Global Surveillance and Monitoring of Vaccine Research

Monitoring and surveillance of studies conducted in the field of vaccines around the world and in sensitive research centers allow us to understand the importance and priority of various diseases. This process not only involves collecting and analyzing data related to emerging diseases and vaccines under development but also helps identify patterns of disease spread and public health needs. Vaccines studied in global research centers are usually based on identified needs or formal requests for research. These needs are typically determined through the analysis of epidemiological data and the identification of emerging diseases. For example, if a new disease begins to spread in a specific region, research centers respond quickly and initiate the research and development of effective vaccines based on this need. This situation acts as a warning that these diseases may spread more widely in the future. Therefore, accurate surveillance and monitoring of such studies can help prevent being caught off guard by emerging diseases and ensure preparedness to respond to them. Reputable research institutions and global health organizations such as the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) continuously monitor and analyze data related to emerging diseases and existing vaccines. These centers also include research institutes in various countries and sensitive military research facilities that pay particular attention to this field in order to maintain preparedness against biological threats. Using information obtained from clinical trials, monitoring adverse effects, and evaluating vaccine effectiveness, these centers can identify new trends. Various tools, such as scientific and medical databases (e.g., PubMed and ClinicalTrials.gov), are used to collect information about vaccines under development and clinical studies. In addition, analyzing safety and efficacy data from clinical trials and post-marketing reports helps identify effective vaccines. Using the collected information for precise planning and for selecting vaccines that should receive further study and investment is highly important. For instance, with the emergence of new diseases, research centers can rapidly develop effective vaccines by analyzing data and identifying patterns of disease spread, thereby preventing unexpected outbreaks of emerging diseases.



Figure 4. Schematic illustration of the key stages and challenges in vaccine production and distribution, including research and clinical trials, large-scale manufacturing with quality control, cold-chain supply systems, global distribution to healthcare centers, vaccination of populations, and post-distribution monitoring of vaccine effectiveness and safety.

Operational Steps for Surveillance and Monitoring

To conduct surveillance and monitoring of vaccine-related studies at the global level, the first step is to identify research centers and international health organizations. This includes identifying and compiling a list of reputable research institutions and leading universities involved in vaccine research. The next step involves collecting information from global databases. After that, global trends in disease outbreaks and vaccine development should be analyzed. Examining data on vaccine safety and effectiveness is also highly important. Establishing international collaboration networks and organizing international conferences and workshops can help share findings and experiences related to vaccines and disease outbreaks. Developing predictive models to forecast disease outbreak trends and assess the impact of vaccines is another key step. Finally, regular reports on the findings obtained from vaccine surveillance and monitoring should be directly communicated to policymakers so that they can make more informed decisions regarding public health and vaccination programs.

Developing a Research Roadmap for Scientists Based on Surveillance and Monitoring Data

To design an effective research roadmap in the field of vaccines, particularly in response to emerging and re-emerging infectious diseases, the first step is to identify research priorities. This process begins with analyzing data and conducting surveillance and monitoring of vaccine research. Identifying emerging and re-emerging diseases, related pathogens, and the health needs of communities are among the key aspects that should be considered at this stage. Consulting with public health experts, epidemiologists, and vaccine researchers can also help gather expert opinions regarding research priorities. After identifying priorities, designing a research program becomes essential. This program should include the development of clear research protocols for each vaccine, outlining the stages of testing and the evaluation of safety and effectiveness. In addition, the required resources—including financial resources, human resources, and the necessary infrastructure for conducting research—should be determined. Establishing international collaborations is another key component of this roadmap. Building networks with international research institutions and universities can facilitate the exchange of knowledge and experience. Collaboration with global health organizations can also help researchers benefit from their expertise and gain access to the most up-to-date information. Training and capacity building for researchers should also be incorporated into this roadmap. Organizing workshops and training programs related to vaccine research and strengthening researchers' scientific and technical skills are among the important measures that should be implemented. Continuous monitoring and evaluation of research progress and its impact on public health is another important stage. Establishing a monitoring and evaluation system to track these developments and using research outcomes to continuously improve the research roadmap are essential. Finally, planning for rapid response to disease outbreaks and the development of new vaccines during health crises should be included in the roadmap. Developing rapid response strategies and ensuring the supply chain for raw materials and vaccine production so that effective action can be taken during emergencies is highly important. By following these steps, a roadmap can be designed that guides researchers toward effective vaccine research and helps prevent being caught unprepared during outbreaks of emerging and re-emerging infectious diseases. (Figure 5).

Conclusion

Given the continuous emergence of new diseases and the health threats associated with them, careful surveillance and monitoring of vaccine status and related research are recognized as key strategies for the prevention and control of these diseases. By monitoring and evaluating vaccine research worldwide—particularly in sensitive and military research centers—it is possible to anticipate vaccine production priorities and predict the potential spread of emerging and re-emerging diseases. These centers conduct precise studies based on clearly identified needs and do not operate without structured planning. Their approaches can serve as useful models, and by analyzing available data, it is possible to predict potential disease outbreaks and support the development of effective vaccines. In today's world, due to rapid environmental changes, evolving lifestyles, and increased international interactions, emerging diseases can spread quickly and pose serious threats to public health. Therefore, establishing effective surveillance and monitoring systems to enable early identification of such diseases and to evaluate the status of vaccines is considered essential.

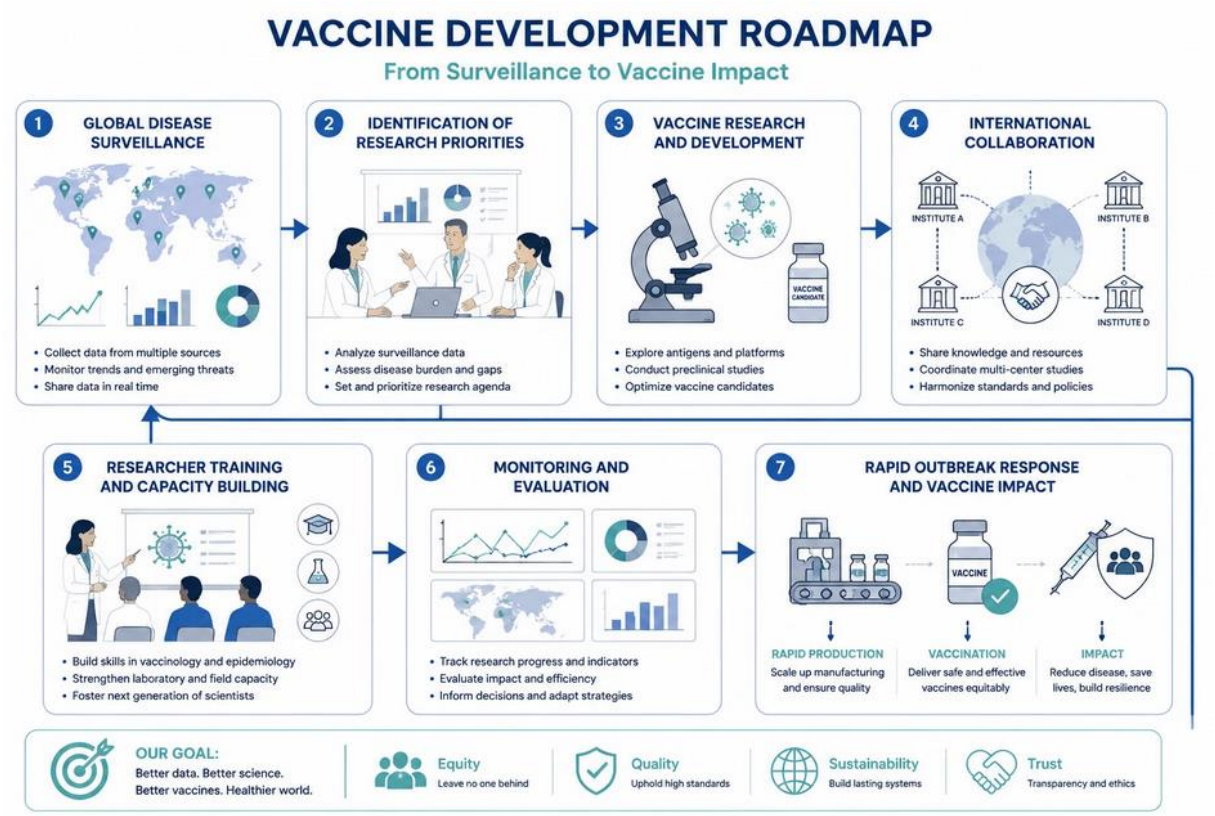


Figure 5. Schematic diagram illustrating the development of a vaccine research roadmap based on surveillance and monitoring data, including identification of research priorities, vaccine research and development, international collaboration, researcher training and capacity building, continuous monitoring and evaluation, and rapid response strategies for emerging and re-emerging infectious disease outbreaks.

Highlights

What Is Already Known?

Existing evidence shows that emerging and re-emerging infectious diseases are increasing due to environmental, social, and global factors. Vaccines play a crucial role in controlling these diseases. Advances in surveillance systems, epidemiological monitoring, and modern technologies such as biotechnology and mRNA platforms have improved the ability to detect outbreaks and accelerate vaccine research and development.

What Does This Study Add?

This study highlights the importance of integrating surveillance and monitoring data to guide vaccine research priorities. It proposes a structured research roadmap that supports international collaboration, capacity building, and rapid response strategies, helping scientists and health authorities better prepare for emerging and re-emerging infectious disease outbreaks and improve vaccine development efforts.

Authors' Contributions

All authors contributed equally to the writing of this article.

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Conflicts of Interest Disclosures

There is no conflict of interest.

Consent For Publication

Not applicable.

Ethics approval

Not applicable.

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The extent of AI use

Artificial intelligence tools, including ChatGPT, were used to design the figures included in this study.

Reference

1. Wang WH, Thitithanyanont A, Urbina AN, Wang SF. Emerging and Re-Emerging Diseases. Pathogens. 2021 Jun 30;10(7):827. doi: 10.3390/pathogens10070827.
2. Koren O, Bukari KN. (Re)Emerging disease and conflict risk in Africa, 1997-2019. Nat Hum Behav. 2024 Aug;8(8):1506-1513. doi: 10.1038/s41562-024-01929-1.
3. Biswas S, Khuntia HK, Bal M, Pati S, Ranjit M. Emerging and re-emerging diseases: A narrative review. One Health Bulletin. 2023 Nov 1;3(1):20. doi:10.4103/2773-0344.389607
4. Hakim MS, Wang W, Goeijenbier M, Saxena SK. Viral emerging and re-emerging diseases: basic understanding and future intervention strategies. Frontiers in Microbiology. 2024 Mar 15;15:1395742. doi: 10.3389/fmicb.2024.1395742.
5. Biswas S, Khuntia HK, Bal M, Pati S, Ranjit M. Emerging and re-emerging diseases: A narrative review. One Health Bulletin. 2023 Nov 1;3(1):20. doi: 10.4103/2773-0344.389607.
6. Naga NG, Taha RM, Hamed EA, Nawar EA, Jaheen HO, Mobarak AA, Radwan YM, Faramawy AG, Arayes MA. The silent microbial shift: climate change amplifies pathogen evolution, microbiome dysbiosis, and antimicrobial resistance. Trop Dis Travel Med Vaccines. 2025 Nov 13;11(1):43. doi:10.1186/s40794-025-00275-y.
7. Shen Y, Liu Y, Krafft T, Wang Q. Progress and challenges in infectious disease surveillance and early warning. Medicine Plus. 2025 Mar 1;2(1):100071. doi:10.1016/j.medp.2025.100071.
8. Ingelbeen B, van Kleef E, Mbala P, Danis K, Macicame I, Hens N, Cleynen E, van der Sande MAB. Embedding risk monitoring in infectious disease surveillance for timely and effective outbreak prevention and control. BMJ global health. 2025 Feb 17;10(2):e016870. doi: 10.1136/bmjgh-2024-016870.
9. Goswami S, Das R, Mukherjee M, Samanta P, Adhikari MD. Introduction to Emerging and Re-Emerging Infectious Diseases (EID-REID). InEmerging and Re-Emerging Viral Diseases 2025 Jul 21 (pp. 1-17). CRC Press. doi:10.1201/9781032721811-1.
10. Mishra SK, Kalathiya U, Padariya M, Georrge JJ. Role of Bioinformatics in Emerging and Re-Emerging Infectious Diseases: A Drug and Vaccine Development Prospective. InEmerging and Re-Emerging Viral Diseases 2025 (pp. 266-274). CRC Press. doi: 10.3389/fphar.2025.1547131.
11. Zhang T, Liu J. Impact of climate change on infectious disease transmission: a CiteSpace-and VOSviewer-based visualization of enteric, respiratory and vector-borne infectious disease studies. Frontiers in Climate. 2025 Nov 19;7:1703904. doi: 10.3389/fclim.2025.1703904.
12. Wang WH, Thitithanyanont A, Urbina AN, Wang SF. Emerging and re-emerging diseases. Pathogens. 2021 Jun 30;10(7):827. doi: 10.3390/pathogens10070827.
13. Hu WH, Sun HM, Wei YY, Hao YT. Global infectious disease early warning models: An updated review and lessons from the COVID-19 pandemic. Infectious Disease Modelling. 2025 Jun 1;10(2):410-22. doi:10.1016/j.idm.2024.12.001.
14. Montero DA, Vidal RM, Velasco J, Carreño LJ, Torres JP, Benachi O MA, Tovar-Rosero YY, Oñate AA, O'Ryan M. Two centuries of vaccination: historical and conceptual approach and future perspectives. Frontiers in public health. 2024 Jan 9;11:1326154. doi: 10.3389/fpubh.2023.1326154.
15. Al Fayez N, Nassar MS, Alshehri AA, Alnefaie MK, Almughem FA, Alshehri BY, Alawad AO, Tawfik EA. Recent advancement in mRNA vaccine development and applications. Pharmaceutics. 2023 Jul 18;15(7):1972. doi: 10.3390/pharmaceutics15071972.
16. Rodrigues C, Plotkin SA. Impact of vaccines; health, economic and social perspectives. Frontiers in microbiology. 2020 Jul 14;11:550510. doi: 10.3389/fmicb.2020.01526.
17. Paczkowska A, Hoffmann K, Andrzejczak A, Pucek WF, Kopciuch D, Bryl W, Nowakowska E, Kus K. The Application of mRNA Technology for Vaccine Production—Current State of Knowledge. Vaccines. 2025 Apr 4;13(4):389. doi: 10.3390/vaccines13040389.
18. Saleh M, El-Moghazy A, Elgohary AH, Saber WI, Helmy YA. Revolutionizing Nanovaccines: A New Era of Immunization. Vaccines, 13 (2): 126 [Internet]. 2025. doi:10.3390/vaccines13020126.
19. Olawade DB, Teke J, Fapohunda O, Weerasinghe K, Usman SO, Ige AO, David-Olawade AC. Leveraging artificial intelligence in vaccine development: A narrative review. Journal of microbiological methods. 2024 Sep 1;224:106998. doi:10.1016/j.mimet.2024.106998.
20. Stern PL. Key steps in vaccine development. Annals of Allergy, Asthma & Immunology. 2020 Jul 1;125(1):17-27. doi: 10.1016/j.anai.2020.01.025.
21. Curlin G, Landry S, Bernstein J, Gorman RL, Mulach B, Hackett CJ, Foster S, Miers SE, Strickler-Dinglasan P. Integrating safety and efficacy evaluation throughout vaccine research and development. Pediatrics. 2011 May 1;127(Supplement_1):S9-15. doi: 10.1542/peds.2010-1722C
22. Amankwah-Amoah J. COVID-19 and counterfeit vaccines: Global implications, new challenges and opportunities. Health policy and technology. 2022 Jun 1;11(2):100630. doi: 10.1016/j.hlpt.2022.100630.
23. Scott GY, Aborode AT, Adesola RO, Khan M, Elebesunu EE, Oluwaseun AA, Ahmad M, Nibokun EO, Kwaku SD, Bakre AA, Chukwu PN. Enhancing vaccine quality and accessibility: strategies for efficient storage and distribution in resource-constrained environment. Outbreak Management and Response. 2025 Dec 29;1(1):2443439. doi:10.1080/29947677.2024.2443439.
24. Amankwah-Amoah J. COVID-19 and counterfeit vaccines: Global implications, new challenges and opportunities. Health policy and technology. 2022 Jun 1;11(2):100630. doi: 10.1016/j.hlpt.2022.100630.