

Disease X/Virus X: AI-Driven Pathogen Mapping and Multi-Platform Vaccine Design, Strategic Blueprint for Combating Prophylaxis in India & Global, Therapeutic Interventions Against 3D Hypothetical Pathogen X

Yash Srivastav^{1*}, Shivani Singh¹, Vivek Kumar¹, Stuti Verma², Kamini Prajapati¹,
Amita Singh¹, Anup Kumar Sirbaiya³

¹D.K.R.R Pharmacy College, Amberpur, Sitapur (Uttar Pradesh), India. 261303

²Aryakul College of Pharmacy and Research, Sitapur, Uttar Pradesh, India. 261303

³KP Singh Memorial Institute of Pharmacy, Sitapur, Lucknow, 261207

*Corresponding Author E-mail: yashsrv.108@gmail.com

Abstract:

The rise in the prevalence of infectious diseases and the likelihood of more pandemics in the future calls for an increased need for innovative and effective preparedness solutions and rapid response technologies in healthcare. Disease X refers to an entirely novel pathogen that may trigger global health crises, economic and social disruptions, and healthcare system failure. This review discusses how AI technology can be used to map pathogens, conduct genomic surveillance, deliver precision medicine, and develop vaccine platforms in the context of addressing hypothetical infectious diseases like Disease X. Clinical evidence from human pandemics, such as COVID-19, Ebola, and Nipah, highlights the significance of mRNA vaccines, viral vector vaccines, and tailored treatment approaches in mitigating severity and mortality. Additionally, this review examines the impact of human immunological variability, socio-economic inequality, medical disparity, and inadequate digital frameworks on pandemic management, especially in developing nations such as India. Future possibilities include the development of novel technologies such as precision medicine utilizing AI, real-time genomics, nanoparticle-based medicines, biosensing devices, and CRISPR antivirals, among others. The implications from this literature indicate that the integration of technologies, such as AI and vaccine technology, in conjunction with an efficient public health framework is critical for increasing global preparedness to potential pandemics, such as those caused by Disease X.

Keywords: Artificial Intelligence; Disease X; Genomic Surveillance; Precision Medicine; mRNA Vaccines; Viral Vector Vaccines; Pandemic Preparedness; Infectious Disease Management

Received: March 18, 2026

Revised: April 21, 2026

Accepted: May 18, 2026

Published: June 5, 2026

DOI: <https://doi.org/10.64062/JPGMB.Vol2.Issue3.7>

<https://jpgmb.com/1/issue/archive>

This is an Open Access article distributed under the terms of the Creative Commons Attribution (CC BY NC), which permits unrestricted use, distribution, and reproduction in any medium, as long as the original authors and source are cited. No permission is required from the authors or the publishers. (<https://creativecommons.org/licenses/by-nc/4.0/>)

1. INTRODUCTION

The development of novel infectious diseases in recent years has brought into focus the vulnerability of health care systems in the face of pandemics, which can spread swiftly across the globe. Pandemics such as severe acute respiratory syndrome (SARS), Middle East Respiratory Syndrome (MERS), Ebola virus disease, Nipah virus infection, Zika virus, and coronavirus disease 2019 (COVID-19) have exemplified the devastating effects of the infectious agents on human health, socio-economic stability, and overall functioning of societies around the world¹. These pandemics have shed light on critical areas of inadequacy in health care readiness, early disease diagnosis, vaccinations, and therapeutic approaches, particularly in densely populated countries where access to health care facilities is difficult. To address future global pandemics, the idea of "Disease X" was developed as a representation of an as yet unknown infectious agent that could be responsible for future pandemics or epidemics. Disease X may occur as a result of transmission from animals, viral mutation, antimicrobial resistance, environmental changes, or synthetic biology.

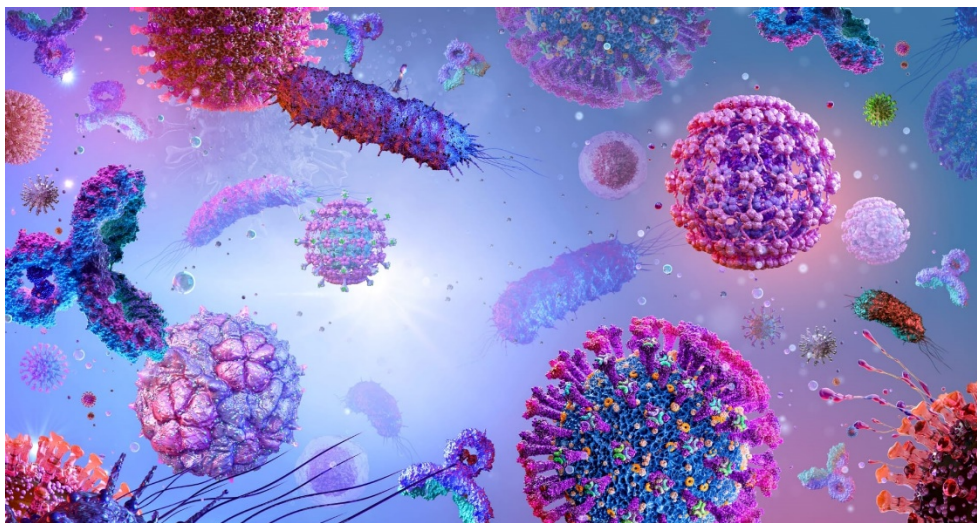


Figure 1: Infectious Diseases²

Innovations in the areas of Artificial Intelligence (AI), genome surveillance, computational biology, and vaccine biotechnology have revolutionized the entire spectrum of infectious disease management and pandemic preparedness. With the help of intelligent pathogen-mapping software, which makes use of artificial intelligence, epidemiological analysis is carried out, along with prediction of potential pathogens, identification of any mutations in the pathogens, and public health decision-making. At the same time, multi-modal vaccine technology in terms of mRNA vaccines, viral-vector vaccines, protein subunit vaccines, and nanoparticle-based immunization techniques have shown tremendous success in preventing severe cases of infectious diseases amid the ongoing COVID-19 pandemic³. Furthermore, human trials have also highlighted the significance of precision medicine, personalized treatment, and digitalized healthcare systems. It is equally important for emerging nations like India to focus on improving their healthcare infrastructure and vaccine production capabilities.

1.1 Background Information and Context

"Disease X" is defined as an unknown pathogen having the capability to trigger widespread global pandemics and public health emergencies. Previous pandemics such as COVID-19,

Ebola, and Nipah viruses showed that existing healthcare frameworks were constrained due to delays in diagnosis, surveillance, and lack of treatments⁴. Artificial Intelligence has been established as a revolutionary technology that can enhance disease surveillance, outbreak predictions, genomic analysis, and therapeutic discovery through big data analytics based on human health care data sets, as well as tracking transmission dynamics in real-time. Technological progress in genomics, immunology, and vaccine biotechnologies has increased pathogen discovery and vaccination. Recent outbreaks' clinical information has shown that elderly, immune-compromised groups, and chronic illness patients were susceptible to infection. However, socioeconomic disparities, misinformation, and inadequate healthcare facilities have also posed limitations during the management of pandemics⁵.

1.2 Objectives of the Review

The primary objectives of this review are:

- To analyze the role of Artificial Intelligence in pathogen mapping, infectious disease surveillance, and outbreak prediction for hypothetical Disease X.
- To evaluate the effectiveness of multi-platform vaccine technologies, including mRNA and viral vector vaccines, in preventing emerging infectious diseases.
- To examine human immune response variability and the impact of genetic, clinical, and socioeconomic factors on disease severity and vaccine efficacy.
- To explore AI-driven precision medicine, therapeutic interventions, and advanced healthcare technologies for future pandemic preparedness and management.
- To assess strategic public health preparedness measures for India and global healthcare systems, including digital surveillance, healthcare infrastructure, and international collaboration.

1.3 Importance of the Topic

The increasing prevalence of new infections has led to pandemic preparedness becoming an important aspect of global health because theoretical diseases like Disease X can have the ability to lead to high mortality rates, breakdowns of the healthcare systems, and socio-economic crises⁶. Combining Artificial Intelligence with genomic surveillance and vaccine technology presents an efficient method for detecting outbreaks, analyzing mutations, producing vaccines, and providing personalized treatment. It has been proven through human trials that early detection, vaccination, and precision medicine approaches are capable of minimizing the impact of diseases during a pandemic. For nations like India, developing better healthcare systems and vaccine production facilities is crucial for building a better resistance against the threats posed by a pandemic in the future⁷.

2. AI-DRIVEN PATHOGEN SURVEILLANCE AND ADVANCED VACCINE DEVELOPMENT STRATEGIES

Artificial intelligence-based pathogen mapping and advanced vaccine technologies played an important role in the improvement of infectious disease surveillance, mutation detection, and outbreak prediction during COVID-19. It was found from clinical studies in humans that

mRNA and viral vector vaccines could produce a robust immune response and prevent severe disease outcomes⁸.

2.1 AI-Driven Pathogen Mapping

Key Research Studies

Some research studies carried out during the time of COVID-19 have shown that Artificial Intelligence can be quite helpful in disease surveillance and predicting outbreaks. Machine learning algorithms were used by researchers to study human mobility patterns, hospitalization data, travel history, and demographic information to pinpoint areas where infection spreads faster and predict its future course. Some other research conducted on Ebola and Nipah viruses has also pointed towards the usefulness of AI surveillance systems⁹.

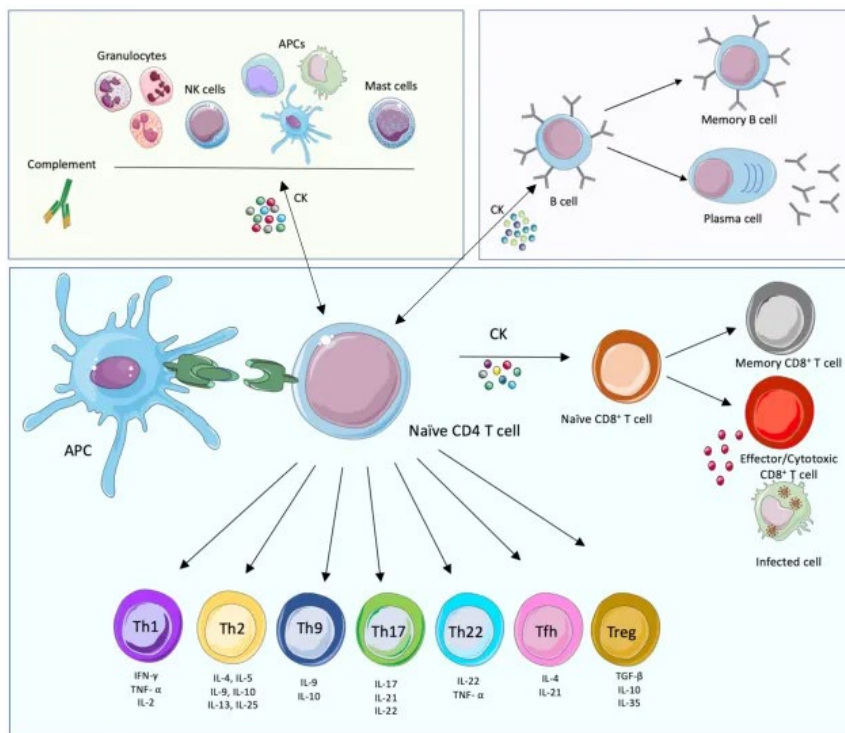


Figure 2: Ebola And Nipah Virus¹⁰

Genomic surveillance research indicated that artificial intelligence-enabled bioinformatics systems accurately detected new variants of SARS-CoV-2 due to the analysis of the virus's genomic changes through infections in humans. Furthermore, epidemiological studies of human populations demonstrated that elderly people, immunocompromised individuals, and those suffering from chronic ailments had higher risks of hospitalization and deaths from diseases.

Methodologies and Findings

The majority of research relied on machine learning models, deep learning approaches, and Natural Language Processing (NLP). The researchers used electronic health records, epidemiology databases, genomic sequencing data, and public health data to identify disease trends and mutation trends¹¹.

The deep learning approach for analyzing genomic data made it possible to predict faster the mutations associated with high infection and immune escape probability. The epidemiology

modeling research studies revealed that AI-based prediction methods helped enhance early warning systems and facilitated rapid containment measures. The human clinical data suggested that fast surveillance and contact tracing helped reduce infection rates during Ebola and Nipah epidemics.

Strengths and Weaknesses

Strengths

- Fast real-time monitoring is enabled by AI tools.
- Big data from human healthcare helps increase predictability.
- Sequencing speeds up mutation discovery and variation detection.
- Surveillance backed by AI contributes to faster health decision-making.

Weaknesses

- Privacy and security issues cannot be overlooked.
- The AI model can result in biases because of the inadequate human data that is being used.
- The lack of proper digital health infrastructure prevents its application in areas where resources are lacking.
- The models become inaccurate while making predictions about unpredictable viruses.

2.2 Multi-Platform Vaccine Design

Key Research Studies

Human clinical trials carried out during the SARS-CoV-2 outbreak revealed that mRNA-based vaccines stimulated powerful immune reactions in response to viral pathogens. The effectiveness of the vaccines was evaluated through extensive studies on large numbers of human subjects, where significant reductions in hospitalization cases and severe conditions were found among vaccinated people¹². Further evaluation included vaccine reactions in aged people, immunocompromised subjects, and chronic sufferers.

Methodologies and Findings

Almost all research employed methods such as randomized human clinical trials, immunogenicity testing, and follow-up approaches. Neutralizing antibodies, T-cell responses, and adverse reactions were recorded after administering vaccines to test subjects.

It was discovered that mRNA-based vaccines provided quick adaptation to virus mutations and had excellent efficacy rates in protecting against infections. Nevertheless, reduced immune responses were recorded for people who were older and immunosuppressed. Human participants developed some inflammatory and allergic reactions to the vaccine administered to them¹³.

Strengths and Weaknesses

Strengths

- Ability to quickly develop and produce vaccines.

- Evokes robust immune responses.
- Capable of adaptation to novel strains of the pathogen.
- Extremely effective at preventing severe disease.

Weaknesses

- Vulnerability to cold chain storage.
- Inadequate long-term stability information.
- Weakened vaccine efficacy in at-risk human groups.
- Seldom seen inflammatory effects and immune system responses.

2.3 Viral Vector Vaccines

Key Research Studies

Human clinical trials on viral vector-based vaccines showed sustained immunity and efficient resistance to serious infectious illnesses. Research studies performed during the time of the coronavirus pandemic assessed the efficacy of vaccines for various demographic and geographic locations¹⁴.

Methodologies and Findings

Vaccine effectiveness was evaluated using human clinical trials conducted in multiple centers, serological testing, and immune response monitoring. The research evaluated how the vaccine elicited antibody production, T-cell response, and adverse events after vaccination¹⁵.

It was established that viral vector vaccines elicited strong immune activation and were effective in lowering hospitalization and mortality. However, some negative side effects such as thrombosis and lower efficacy against emerging variants were experienced by some populations.

Strengths and Weaknesses

Strengths

- High strength and sustainability of immune response.
- Increased shelf life and better ease of transport than RNA-based vaccines.
- Effectiveness of delivering antigens into cells.
- Appropriate for mass vaccination campaigns.

Weaknesses

- Immunity to viral vector systems might make them less effective.
- Thrombosis side effects have been seen in some cases.
- Mutating microorganisms may be difficult to combat.
- Long-term safety studies are not available for some platforms.

3. INTEGRATED HUMAN IMMUNE VARIABILITY, AI-DRIVEN PRECISION MEDICINE, AND SOCIOECONOMIC CHALLENGES IN PANDEMIC PREPAREDNESS

Responses by humans to diseases through their immune system are dependent on their age, genetics, nutrition, and preexisting illnesses. The most vulnerable groups were seen to be affected severely and have poor responses to vaccines. Artificial intelligence aided precision medicine to predict outbreaks, provide personalized treatment, and clinical decision-making amid the pandemics. Yet, some issues include socio-economic disparities, poor health care facilities, misinformation, and lack of access to health care services¹⁶.

3.1 Human Immune Response Variability

Human immune system reactions to infections caused by diseases vary greatly based on age, genetic factors, nutrition status, lifestyle, and underlying conditions¹⁷. Studies done among human subjects during the pandemic due to COVID-19 virus and other virus epidemics show that aged persons, immunocompromised subjects, and those suffering from other diseases like diabetes, cardiovascular disease, and obesity have higher chances of infection, admission, and fatalities. Infections with weakened immunity due to malnutrition were more severe. Genetic variations that affect the human immune response also affected the efficacy of vaccination¹⁸.

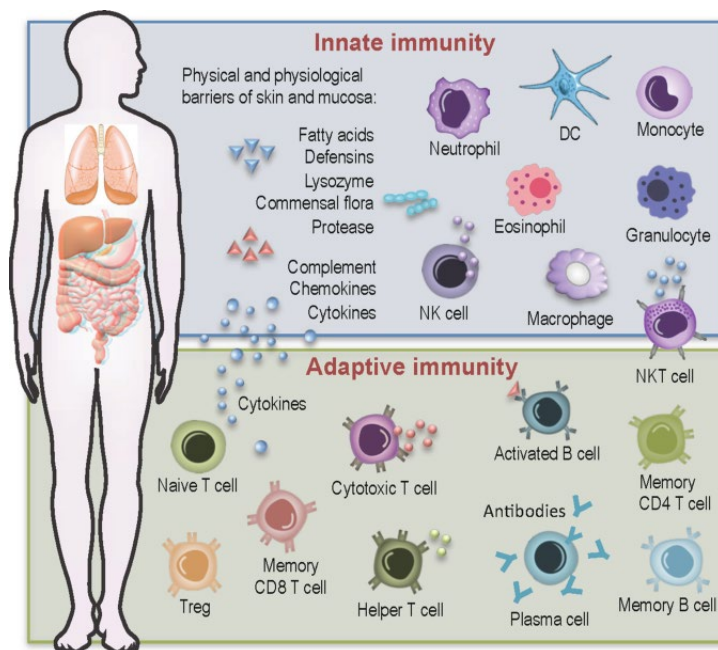


Figure 3: Human Immune Response¹⁹

Key Findings

- Chronic conditions make infections more likely.
- Obesity and diabetes exacerbate inflammation.
- Nutritional deficiencies weaken immunity.
- Different genes affect vaccine efficacy and severity of the disease²⁰.

3.2 AI in Precision Pandemic Medicine

AI has proved to be useful in the field of precision pandemic medicine by helping achieve personalized interventions based on genomic, clinical, and epidemiological information. AI technology helps in the analysis of large amounts of patient data for predicting disease progression and helping detect patients at high risk to optimize the treatment process²¹. AI technology was helpful during the COVID-19 outbreak where it played an essential role in diagnosing the disease, predicting its severity, and recommending vaccines to patients. It was also used to enhance the decision-making processes in the field of clinical practice.

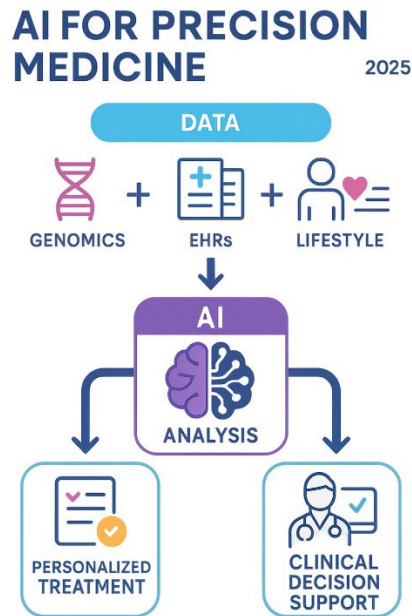


Figure 4: AI For Precision Medicine²²

Applications

- Individualized vaccine advice
- Risk prediction
- Fast detection of disease severity
- AI-based clinical decision-making
- Outbreak surveillance and response planning in real time

3.3 Socioeconomic and Public Health Challenges

Pandemics are likely to adversely impact disadvantaged groups due to factors like poor healthcare facilities, poverty, overcrowding, misinformation, and lack of access to quality medical care²³. In the case of developing nations such as India, healthcare issues became apparent due to the COVID-19 pandemic in areas that were not sufficiently developed to tackle the disease effectively. Poor healthcare facilities, inadequate availability of healthcare workers, digital healthcare disparities, and uneven allocation of medical facilities made the management of the disease difficult. Public vaccine hesitancy, spread of misinformation on social media, and ignorance also hindered vaccination drives and preventive healthcare efforts²⁴.

Challenges in India

- Challenges of rural healthcare
- Shortage of healthcare workers
- Gaps in digital healthcare
- Vaccine hesitancy and myths
- Inequalities in healthcare centers and technology usage

4. FUTURE PERSPECTIVES AND EMERGING INNOVATIONS IN AI-BASED PANDEMIC PREPAREDNESS

The future of pandemic preparation will rely increasingly on the application of technologies such as Artificial Intelligence, biotechnology, precision medicine, and digital health infrastructure across the world²⁵. Technologies like drug discovery through quantum computers, epidemiology through AI, synthetic biology, and autonomous diagnosis can be said to herald the future in the face of hypothetical disease threats such as Disease X²⁶.

Future healthcare delivery systems might embrace genomic surveillance and real-time monitoring using wearable biosensors and cloud-based platforms to detect disease threats at a nascent level²⁷. Governments and health organizations can leverage AI-based models for prediction of high risk groups, outbreak predictions, and efficient resource deployment²⁸.

With advanced vaccine technologies such as self-amplifying RNA vaccines, universal coronavirus vaccines, nasal vaccination approaches, and personalized immune therapy, there is potential for more widespread and sustained immunity to highly variable pathogens. Meanwhile, nanotechnology-based drug delivery systems and CRISPR technology-based antiviral treatments are also proving promising forms of treatment²⁹.

Key considerations in preparation for future infectious disease outbreaks in India and other developing countries include:

- Maintaining growth in AI-driven public health systems
- Vaccine and biopharmaceutical development in country
- Enhancing digitization of rural health care
- Genomic data exchange with other countries³⁰
- Smart warning systems using AI technology
- Digital epidemiology training programs

Table 1: Summary of Literature Review on AI-Driven Pathogen Mapping, Computational Therapeutics, and Pandemic Preparedness Technologies³¹

Author & Year	Study Focus	Methodology/Approach	Key Findings
Simpson et al. (2020) ³²	Disease X and pandemic preparedness	Review of global healthcare preparedness, surveillance systems, and medical countermeasures	Highlighted the need for rapid vaccine development, global collaboration, and

			accelerated therapeutic strategies for future pandemics.
Singh et al. (2024)³³	Omics technologies in drug discovery and therapeutics	Genomics, proteomics, metabolomics, and bioinformatics approaches	Found that omics technologies improved therapeutic target identification and supported precision medicine and personalized treatments.
Skariyachan et al. (2026)³⁴	Computational approaches for Ebolavirus therapeutics	Computational biology, molecular docking, and bioinformatics analysis	Reported that computational methods accelerated antiviral drug discovery and improved therapeutic development efficiency.
Uddin & Rafi (2017)³⁵	Structural and functional characterization of hypothetical proteins	Bioinformatics tools and computational modeling techniques	Demonstrated that computational analysis effectively identified potential therapeutic targets and functional protein properties.
Yu et al. (2026)³⁶	AI-based agricultural intelligence systems	Perception-Decision-Execution framework with AI and automation technologies	Emphasized the importance of AI-driven predictive systems, real-time monitoring, and data analytics applicable to healthcare surveillance and pandemic preparedness.

Even with all the scientific progress that has been made, success in the future would rely on good governance, healthcare access, proper data handling, and cooperation at the international level. Future sustainable investment in research and healthcare systems would be critical in safeguarding humanity from future pandemics such as Disease X.

5. DISCUSSION

AI systems, genomic monitoring, and new vaccine technology played a critical role in enhancing prediction and treatment of pandemics. They enabled the advancement of public

health preparedness and personalized medicine; nevertheless, some issues like data privacy, healthcare disparities, vaccine resistance, and weak infrastructure continue to persist³⁷. Further studies need to explore universal vaccines, the application of AI for precision medicine, genomics monitoring, and ethical utilization of advanced healthcare technologies.

5.1 Interpretation and Analysis of Findings

The results of the literature review show that the use of AI technology, genomic monitoring, and vaccine technology has greatly enhanced infectious disease monitoring, epidemic prediction, mutation analysis, and drug discovery during epidemics like SARS-CoV2, Ebola, and Nipah viruses. The AI-powered healthcare system allowed quick detection of infection patterns and high-risk populations, while multi-component vaccines comprising mRNA and viral vector vaccines showed good immunogenicity and decreased severity of disease outcomes³⁸. Clinical experience involving humans has shown that older adults, immunocompromised groups, and those suffering from chronic conditions have had worse outcomes from the infection.

5.2 Implications and Significance

The convergence of AI, genomics sequencing, and digitalization of the healthcare system is highly significant in boosting future pandemic preparedness and building resilience. The benefits include early detection of outbreaks, accelerated vaccine creation, optimization of treatment protocols, and decision making informed by science across countries and globally. For developing nations such as India, there is need to strengthen its healthcare infrastructure and use of AI in early detection systems, and develop its ability to produce vaccines domestically for increased preparedness for future infectious disease outbreaks³⁹.

5.3 Gaps and Future Research Directions

Despite advancements made through technology, some problems still linger and include concerns regarding data privacy, algorithm bias, cybersecurity threats, resistance toward vaccines, and inequitable access to health care services in areas with few resources. Additionally, the efficacy of vaccination and treatments is influenced by factors such as age, genetics, nutrition, and pre-existing health issues within individuals because immunity varies between individuals⁴⁰. Future studies should concentrate on developing global vaccines, artificial intelligence prediction models, personalized immunotherapies, live genomic surveillance, and governance in relation to AI-powered healthcare systems. Additional interdisciplinary studies combining various technologies could prepare the world for a pathogen like Disease X.

6. CONCLUSION

The current study is thus concluded by stating that Artificial Intelligence, Genomic Surveillance, Precision Medicine, and Multi-Platform vaccine technology are key determinants for making progress towards improving infectious disease surveillance, prediction of outbreaks, identification of mutations, and interventions for treating hypothetical pathogens like Disease X. The current study is also concluded on the basis that mRNA and viral vector vaccines were highly effective in lowering the severity of diseases during the recent pandemics, while the use of AI-powered healthcare systems was highly instrumental in providing rapid diagnosis, personalized medicine and healthcare decisions. But despite all these advantages,

some of the main challenges faced include healthcare inequity, inadequate digital infrastructure, concerns relating to data privacy, vaccine hesitancy, and lack of access to healthcare facilities, which need to be overcome. Hence, it is imperative to strengthen the healthcare infrastructure and make use of AI technology for surveillance purposes, develop universal vaccines, and adopt a precision medicine approach.

REFERENCES

1. Al-Ewaidat, O. A., & Naffaa, M. M. (2025). Emerging AI-and biomarker-driven precision medicine in autoimmune rheumatic diseases: from diagnostics to therapeutic decision-making. *Rheumato*, 5(4), 17.
2. Arega, A. M., Dhal, A. K., Nayak, S., & Mahapatra, R. K. (2022). In silico and in vitro study of Mycobacterium tuberculosis H37Rv uncharacterized protein (RipD): an insight on tuberculosis therapeutics. *Journal of Molecular Modeling*, 28(6), 171.
3. Asha, I. J., Gupta, S. D., Hossain, M. M., Islam, M. N., Akter, N. N., Islam, M. M., ... & Barman, D. N. (2024). In Silico characterization of a hypothetical protein (PBJ89160. 1) from neisseria meningitidis exhibits a new insight on nutritional virulence and molecular Docking to uncover a therapeutic target. *Evolutionary Bioinformatics*, 20, 11769343241298307.
4. Ashizawa, T., Öz, G., & Paulson, H. L. (2018). Spinocerebellar ataxias: prospects and challenges for therapy development. *Nature Reviews Neurology*, 14(10), 590-605.
5. Asif, S., Zhao, M., Li, Y., Tang, F., Ur Rehman Khan, S., & Zhu, Y. (2024). AI-based approaches for the diagnosis of Mpox: challenges and future prospects. *Archives of Computational Methods in Engineering*, 31(6), 3585-3617.
6. Bhat, S., & Mukherjee, D. (2025). The Intersection of Artificial Intelligence, Automation, and CRISPR-Cas9 in the Design of Universal Pandemic Vaccines.
7. Bhat, T., Kumar, M., Ballamoole, K. K., Deekshit, V. K., & Gollapalli, P. (2025). Pangenome-based network analysis of Acinetobacter baumannii reveals the landscape of conserved therapeutic targets. *Molecular Diversity*, 1-20.

8. Chua, C. Y. X., Jimenez, M., Mozneb, M., Traverso, G., Lugo, R., Sharma, A., ... & Grattoni, A. (2024). Advanced material technologies for space and terrestrial medicine. *Nature Reviews Materials*, 9(11), 808-821.
9. Faizan, R., Naveed, M., Estevez, I. B., Hanif, N., Arshad, A., Aziz, T., ... & Alhomrani, M. (2025). Computational exploration of natural inhibitors against toxin-associated proteins in *Naegleria fowleri* Karachi strain. *Pathology-Research and Practice*, 156184.
10. Gazi, M. A., Mahmud, S., Fahim, S. M., Kibria, M. G., Palit, P., Islam, M. R., ... & Ahmeed, T. (2018). Functional prediction of hypothetical proteins from *Shigella flexneri* and validation of the predicted models by using ROC curve analysis. *Genomics & informatics*, 16(4), e26.
11. Gurung, B. D. S., Rayamajhi, M., Maharjan, N., Do, T., Bhandari, D., Yadav, R., ... & Gnimpieba, E. Z. (2025). Forecasting urban wastewater microbiome dynamics using a digital twin framework. *bioRxiv*.
12. Hanif, N., Arshad, S., Asim, M., Nadeem, A. S., & ur Rehman, T. (2024). In silico characterization of hypothetical protein AZJ53_10480 in *Streptococcus pneumoniae*. *BioScientific Rev*, 6(4), 1-12.
13. Hasib, F. Y., & Islam, M. S. (2025). Structural, Functional and Inhibitory Annotations of Lumpy Skin Disease Virus Hypothetical Protein LSDV004: An In-Silico Study. *Veterinary Medicine and Science*, 11(4), e70437.
14. Hassan, A., Ikram, A., Raza, A., Saeed, S., Zafar Paracha, R., Younas, Z., & Khadim, M. T. (2021). Therapeutic potential of novel mastoparan-chitosan nanoconstructs against clinical MDR *Acinetobacter baumannii*: In silico, in vitro and in vivo Studies. *International Journal of Nanomedicine*, 3755-3773.
15. Hossain, M. M., Apu, M. J. H., Aziz, M. F. B. A., Tanjil, M. T. R., Das, L. C., Kar, A., ... & Morshed, M. M. (2025). Exploring Dolichos lablab compounds as potential inhibitors for fusion (F) protein of human metapneumovirus (HMPV): A systematic computational approach. *Plos one*, 20(9), e0332170.
16. Kant, R., Khan, M. S., Chopra, M., & Saluja, D. (2024). Artificial intelligence-driven reverse vaccinology for *Neisseria gonorrhoeae* vaccine: Prioritizing epitope-based candidates. *Frontiers in Molecular Biosciences*, 11, 1442158.
17. Khan, K., Jalal, K., Khan, A., Al-Harrasi, A., & Uddin, R. (2022). Comparative metabolic pathways analysis and subtractive genomics profiling to prioritize potential drug targets against *Streptococcus pneumoniae*. *Frontiers in Microbiology*, 12, 796363.
18. Koshy, C. M., Asirvatham, D., Majumdar, R., & Sugumar, S. (2022). In silico Structural and Functional Characterization of a Hypothetical Protein from *Stenotrophomonas maltophilia* SRM01. *Journal of Pure & Applied Microbiology*, 16(2).
19. Kumar, C. K., Sands, K., Walsh, T. R., O'Brien, S., Sharland, M., Lewnard, J. A., ... & Laxminarayan, R. (2023). Global, regional, and national estimates of the impact of a maternal *Klebsiella pneumoniae* vaccine: A Bayesian modeling analysis. *PLoS medicine*, 20(5), e1004239.
20. Naumov, V., Zagirova, D., Lin, S., Xie, Y., Gou, W., Urban, A., ... & Zhavoronkov, A. (2025). Dora ai scientist: Multi-agent virtual research team for scientific exploration discovery and automated report generation. *bioRxiv*.

21. Naveed, M., Chaudhry, Z., Ali, Z., & Amjad, M. (2018). Annotation and curation of hypothetical proteins: prioritizing targets for experimental study. *Advancements in Life Sciences*, 5(3), 73-87.
22. Naveed, M., Makhdoom, S. I., Abbas, G., Safdari, M., Farhadi, A., Habtemariam, S., ... & Tehreem, S. (2022). The virulent hypothetical proteins: the potential drug target involved in bacterial pathogenesis. *Mini Reviews in Medicinal Chemistry*, 22(20), 2608-2623.
23. Oliveira, C. S., & Negut, I. (2025). Precision Medicine and Omics Approaches for Managing Infectious Diseases: Technologies, Applications, and Current Achievements. In *AI and Precision Medicine in Infectious Disease Management* (pp. 71-97). CRC Press.
24. Omeershffudin, U. N. M., & Kumar, S. (2019). In silico approach for mining of potential drug targets from hypothetical proteins of bacterial proteome. *Int J Mol Biol Open Access*, 4(4), 145-152.
25. Oso, B. J., Adeoye, A. O., & Olaoye, I. F. (2022). Pharmacoinformatics and hypothetical studies on allicin, curcumin, and gingerol as potential candidates against COVID-19-associated proteases. *Journal of Biomolecular Structure and Dynamics*, 40(1), 389-400.
26. Páez, D. J., Grady, C., Gregg, J., Batts, B., Ferreiro-Luce, S., Herron, V. L., ... & Hershberger, P. (2026). The impacts of co-circulating pathogens in Pacific herring depend on interactions between viral life-cycle traits and transmission parameters, highlighting interdependencies between pathogen epizootics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 381(1945).
27. Parvez, A., Islam, M. T., Zaman, R., Hasan, M. H., Mim, N. J., Hasan, M. M., ... & Biswas, P. (2026). Emerging flu-like illnesses and Disease X in Africa with insights into therapeutic strategies and pandemic preparedness. *Discover Public Health*, 23(1), 127.
28. Pranavathiyani, G., Prava, J., Rajeev, A. C., & Pan, A. (2020). Novel target exploration from hypothetical proteins of *Klebsiella pneumoniae* MGH 78578 reveals a protein involved in host-pathogen interaction. *Frontiers in cellular and infection microbiology*, 10, 109.
29. Rabbi, M. F., Akter, S. A., Hasan, M. J., & Amin, A. (2021). In silico characterization of a hypothetical protein from *Shigella dysenteriae* ATCC 12039 reveals a pathogenesis-related protein of the type-VI secretion system. *Bioinformatics and biology insights*, 15, 11779322211011140.
30. Rahman, A., Sarker, M. T., Islam, M. A., Hossain, M. U., Hasan, M., & Susmi, T. F. (2023). Targeting essential hypothetical proteins of *Pseudomonas aeruginosa* PAO1 for mining of novel therapeutics: an in silico approach. *BioMed Research International*, 2023(1), 1787485.
31. Rao, D. F., Patel, S. K., & Pandya, H. A. (2026). Inhibition of viral fusion via HR1-binding peptides: a machine learning and molecular dynamics-guided strategy against Nipah virus. *Network Modeling Analysis in Health Informatics and Bioinformatics*, 15(1), 67.

32. Simpson, S., Kaufmann, M. C., Glozman, V., & Chakrabarti, A. (2020). Disease X: accelerating the development of medical countermeasures for the next pandemic. *The Lancet Infectious Diseases*, 20(5), e108-e115.
33. Singh, B., Mal, G., Kalra, R. S., & Marotta, F. (2024). Omics Technologies in Drug Discovery and Therapeutics. In *Probiotics as Live Biotherapeutics for Veterinary and Human Health, Volume 2: Functional Foods and Post-Genomics* (pp. 655-678). Cham: Springer Nature Switzerland.
34. Skariyachan, S., Niranjana, V., Setlur, A. S., Vijayan, S., & Sebastian, D. (2026). Integrative computational approaches in the quest for novel Ebolavirus therapeutics. *Expert Opinion on Drug Discovery*, 21(1), 117-131.
35. Uddin, R., & Rafi, S. (2017). Structural and functional characterization of a unique hypothetical protein (WP_003901628. 1) of Mycobacterium tuberculosis: a computational approach. *Medicinal Chemistry Research*, 26(5), 1029-1041.
36. Yu, S., Li, X., Zhao, S., Sun, Q., & Liu, Q. (2026). Agricultural Intelligence: A Technical Review Within the Perception-Decision-Execution (PDE) Framework.
37. Yu, S., Li, X., Zhao, S., Sun, Q., & Liu, Q. (2026). Agricultural Intelligence: A Technical Review Within the Perception-Decision-Execution (PDE) Framework.
38. Zhao, M., Lei, L., Jiang, Y., Tian, Y., Huang, Y., & Yang, M. (2025). Unveiling the threat of disease X: preparing for the next global pandemic. *Journal of Medical Virology*, 97(2), e70227.
39. Zope, V., & Dhage, S. N. (2025, August). Leveraging Technology Against Wildlife Trafficking and Fighting Disease. In *2025 5th Asian Conference on Innovation in Technology (ASIANCON)* (pp. 1-7). IEEE.
40. Zumla, A., Rao, M., Wallis, R. S., Kaufmann, S. H., Rustomjee, R., Mwaba, P., ... & Maeurer, M. (2016). Host-directed therapies for infectious diseases: current status, recent progress, and future prospects. *The Lancet Infectious Diseases*, 16(4), e47-e63.