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THE ROLE OF ARTIFICIAL INTELLIGENCE IN PUBLIC HEALTH SURVEILLANCE: A POST-PANDEMIC PERSPECTIVE

Original Article

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ABSTRACT

Background: The integration of artificial intelligence (AI) into public health surveillance has gained significant momentum, particularly following the COVID-19 pandemic. With global health systems facing unprecedented challenges, AI has demonstrated utility in outbreak detection, disease forecasting, and healthcare resource optimization. Its relevance continues to grow as public health authorities seek tools that can provide timely, accurate, and scalable responses to current and future health threats.

Objective: This narrative review aims to explore the evolving role of AI in public health surveillance from a post-pandemic perspective, highlighting its applications, benefits, limitations, and future potential in clinical and policy contexts.

Main Discussion Points: The review synthesizes recent literature across eight high-quality studies, focusing on thematic areas such as AI-enabled outbreak detection, predictive modelling, healthcare system optimization, and global surveillance integration. It critically examines the methodological strengths and weaknesses of current studies, including biases, variability in outcome measures, and issues related to generalizability and ethical implementation. Limitations such as selection bias, inconsistent validation practices, and lack of real-world implementation data are discussed in depth.

Conclusion: AI holds transformative promise in enhancing public health surveillance, yet its integration must be guided by rigorous, inclusive, and context-sensitive research. Policymakers and clinicians are encouraged to adopt AI cautiously while further studies—especially those involving diverse populations and robust study designs—are needed to ensure ethical and effective deployment.

Keywords: Artificial Intelligence, Public Health Surveillance, Pandemic Preparedness, Disease Forecasting, Health Policy, Narrative Review.

INTRODUCTION

Artificial Intelligence (AI) has rapidly ascended from a niche technological interest to a cornerstone of global health infrastructure, especially in the wake of the COVID-19 pandemic. The global health crisis underscored the pressing need for real-time, accurate, and adaptive health surveillance systems that can preempt and mitigate public health emergencies. In this context, AI emerged as an indispensable tool. It has been widely applied in diverse facets of public health, including outbreak detection, epidemic forecasting, misinformation control, and health systems optimization. As global health systems strain under the burdens of aging populations, increasing prevalence of chronic diseases, and emerging infectious threats, AI offers a transformative solution capable of leveraging vast datasets to generate actionable insights for timely intervention and response (1). Epidemiologically, the importance of AI in health surveillance is underscored by the global toll of communicable diseases and health emergencies. The World Health Organization estimates that respiratory infections alone account for more than four million deaths annually. During the COVID-19 pandemic, AI was pivotal in accelerating drug and vaccine development, contact tracing, and viral genome sequencing, proving its practical utility in real-time health crisis management (2). AI's ability to synthesize fragmented health data, including social media trends, electronic health records, mobility patterns, and meteorological data, enabled health authorities to monitor outbreaks with unprecedented precision and speed (3).

Despite these advances, substantial gaps remain in the literature concerning the long-term integration and sustainability of AI in public health surveillance. While there is growing evidence of AI's efficacy in specific contexts, such as COVID-19 response or urban epidemic modeling, research often lacks generalizability across different geographical, socioeconomic, and infrastructural settings (4). Low- and middle-income countries, in particular, face challenges in data infrastructure, technical capacity, and regulatory frameworks that inhibit AI deployment (5). Furthermore, ethical concerns—such as data privacy, algorithmic bias, and lack of transparency—pose significant barriers to AI adoption at scale (6). This narrative review aims to critically explore the evolving role of AI in public health surveillance through a post-pandemic lens. It seeks to evaluate current applications, delineate technological and ethical challenges, and identify strategic opportunities for future integration of AI within surveillance frameworks. The review synthesizes findings from recent literature, focusing on empirical studies, systematic reviews, and expert analyses conducted over the last five years. Specifically, it assesses how AI has been deployed for disease forecasting, real-time monitoring, misinformation tracking, and healthcare resource optimization, while also considering disparities in global deployment and acceptance (7,8).

The scope of this review encompasses peer-reviewed studies, systematic reviews, and narrative analyses published since 2020, with a focus on real-world applications of AI in public health surveillance. Emphasis is placed on both high-income and low-resource settings to provide a balanced view of capabilities and constraints. Literature included spans diverse technological domains, such as machine learning, natural language processing, predictive modeling, and big data analytics. The significance of this review lies in its potential to guide policymakers, public health professionals, and researchers by providing a cohesive synthesis of how AI can augment surveillance capacities in the post-pandemic world. Unlike earlier works that focus exclusively on either technological potentials or ethical dilemmas, this review takes an integrative approach to bridge the existing knowledge gaps. By aligning AI capabilities with public health objectives, the review underscores the necessity for cross-sectoral collaboration, data governance frameworks, and equitable access to technological innovations. Ultimately, this review not only captures the current landscape but also illuminates pathways for future research and implementation strategies that can fortify global health security.

THEMATIC DISCUSSION

1. AI-Driven Disease Surveillance and Early Outbreak Detection

Artificial Intelligence (AI) has significantly redefined the landscape of disease surveillance, particularly in the wake of the COVID-19 pandemic. Its capacity to process large datasets in real time enables early detection of anomalies suggestive of outbreaks. Numerous studies illustrate the utility of machine learning (ML) and deep learning models in identifying early warning signals from social media, search engine queries, and epidemiological databases. For example, algorithms that integrated digital data with traditional surveillance tools enhanced the timeliness and accuracy of outbreak predictions (1). These AI-driven systems outperformed conventional surveillance methods by predicting spikes in cases days in advance, particularly during COVID-19 and influenza outbreaks. The strength of AI in this domain lies in its adaptability to diverse data sources and rapid scalability during health emergencies. Nonetheless, real-time accuracy remains dependent on data quality, coverage, and representativeness, which vary significantly across regions and populations (2).

2. Predictive Modelling and Forecasting of Public Health Trends

Beyond detection, AI excels in predictive modelling—forecasting the trajectory of diseases and evaluating the impact of interventions. During the pandemic, predictive algorithms were developed to estimate the spread of infection, mortality trends, and hospital resource demands. Studies consistently report that models trained on diverse datasets—including mobility data, vaccination rates, and climatic variables—were able to generate high-fidelity forecasts of COVID-19 caseloads and ICU occupancy (3). However, variability in forecasting performance remains a challenge, often arising from incomplete data inputs or abrupt policy changes that are difficult to model. Comparative reviews suggest that ensemble models integrating AI with traditional statistical approaches outperform standalone techniques, offering more robust and adaptable projections (4).

3. Augmenting Health System Management and Resource Allocation

AI systems also demonstrated considerable value in optimizing healthcare logistics, especially under crisis conditions. During the COVID-19 peak periods, AI tools were used to manage supply chains, triage patients, and allocate ventilators and beds efficiently. These applications were crucial in resource-limited settings where decision-making under uncertainty was critical. Machine learning algorithms guided allocation decisions based on patient risk scores and hospital capacity forecasts, improving outcomes and minimizing preventable deaths (5). Yet, these systems must be contextually adapted; reliance on models developed in high-income countries may not translate well to settings with different healthcare dynamics, exacerbating inequalities.

4. Integration into National and Global Surveillance Systems

AI's integration into national and global public health architectures is expanding, evidenced by its incorporation into platforms by the World Health Organization and the CDC. Initiatives such as the WHO's Hub for Pandemic and Epidemic Intelligence reflect institutional shifts toward AI-enabled surveillance networks (6). These systems utilize AI for real-time disease monitoring across borders, promoting faster, coordinated responses to emerging threats. However, operationalizing AI at this scale raises questions about data interoperability, standardization, and sovereignty. Multilateral efforts are needed to ensure equitable access and effective data-sharing agreements that respect privacy while maximizing utility.

5. Ethical and Legal Considerations in AI Surveillance

The use of AI in surveillance has intensified discussions around ethics, particularly in areas involving personal data, informed consent, and algorithmic bias. Several studies note that AI systems trained on biased datasets can propagate health disparities, particularly among marginalized communities. For instance, surveillance tools may underperform in populations underrepresented in training data, leading to misclassification and suboptimal intervention targeting (7). Legal frameworks are still catching up with these ethical concerns. Researchers advocate for clear guidelines on algorithm transparency, auditability, and accountability to prevent misuse and build public trust (8).

6. Challenges in Adoption in Low-Resource Settings

Despite its promise, AI remains underutilized in many low- and middle-income countries due to infrastructure deficits, limited technical capacity, and lack of funding. Even when high-performing models exist, their implementation is hindered by insufficient digital infrastructure and skilled personnel. Moreover, many AI tools are built on datasets from high-income countries, making them less applicable to regions with different disease profiles and healthcare systems (9,10). This digital divide risks widening global health disparities. Closing this gap requires international cooperation, capacity-building initiatives, and the development of context-specific AI models.

7. Opportunities for Future AI-Driven Public Health Innovations

There is growing momentum to integrate AI into more nuanced aspects of public health, including mental health monitoring, vaccine hesitancy prediction, and misinformation mitigation. Advanced natural language processing (NLP) tools are being piloted to detect harmful health misinformation online, while sentiment analysis is used to gauge public responses to health policies (11,12). These emerging applications highlight the versatility of AI beyond disease tracking. Still, interdisciplinary collaboration is essential to ensure technological solutions align with public health goals and community needs.

8. Unresolved Questions and Areas for Further Research

Despite widespread enthusiasm, the scientific community acknowledges that many questions remain. There is limited consensus on best practices for AI governance, model validation, and real-world evaluation. The current literature often lacks rigorous empirical assessments of AI's impact on health outcomes, especially in diverse population settings. Further research is needed to explore long-term sustainability, cost-effectiveness, and public perception of AI-based surveillance tools. These knowledge gaps present both a challenge and an opportunity to refine AI strategies that are equitable, evidence-based, and ethically grounded (13,14).

CRITICAL ANALYSIS AND LIMITATIONS

Despite the growing body of literature highlighting the promising applications of artificial intelligence (AI) in public health surveillance, critical examination of the existing research reveals notable limitations that warrant careful consideration. One of the most frequently observed weaknesses in the reviewed studies is the reliance on observational designs, with very few employing randomized controlled trials (RCTs) or robust longitudinal methodologies. Most studies focused on retrospective data analyses or narrative overviews, which inherently limit the strength of causal inferences. For example, while a study presented a broad scoping review of AI use cases during pandemics, the majority of included studies lacked rigorous experimental design and often failed to include control groups or standardized intervention comparisons, reducing the internal validity of their findings (15,16). Methodological biases were also prevalent across the literature. A common issue was selection bias, with many studies disproportionately sampling data from high-income countries or urban settings, while low- and middle-income contexts were underrepresented. This bias limits the applicability of AI models in global health contexts, particularly in regions with constrained infrastructure or differing disease burdens (17). Performance bias, including lack of blinding and standardized outcome assessments, was also observed. In several studies that implemented AI models for forecasting and outbreak detection, validation procedures were either insufficiently described or not externally tested, calling into question the replicability of results (18).

Publication bias further complicates interpretation of the literature. There appears to be a tendency to publish studies with positive or promising outcomes, while studies reporting inconclusive or negative findings—such as failures to improve prediction accuracy or instances of algorithmic misclassification—are underrepresented. This skew creates an inflated perception of AI efficacy and may mislead policymakers regarding the readiness of these tools for real-world deployment (19). As AI technologies continue to advance rapidly, ensuring transparency in both success and failure is critical to build trust and guide ethical implementation. Another prominent limitation lies in the heterogeneity of measurement outcomes across studies. AI applications are evaluated using various performance metrics—such as sensitivity, specificity, accuracy, and AUC scores—without standard benchmarks, making cross-study comparisons difficult. Moreover, the lack of consistency in outcome definitions, especially for public health interventions like outbreak containment or behavioral response effectiveness, contributes to this variability (20). Some studies measure success in terms of algorithmic performance, while others emphasize operational efficiency or public engagement, leading to fragmented evidence that complicates the synthesis of best practices.

The generalizability of findings remains a critical concern, as most AI models are trained and validated on datasets from specific geographic, demographic, or institutional contexts. The overrepresentation of data from technologically advanced health systems limits the extrapolation of findings to more diverse or underserved populations. For instance, AI tools that performed well in urban hospital networks in the United States or Europe may not account for the epidemiological, infrastructural, and cultural variables present in Sub-Saharan Africa or Southeast Asia (21). Even within high-income countries, socio-economic disparities and differences in digital literacy further constrain the equitable use of AI technologies. In sum, while the reviewed literature underscores the vast potential of AI in enhancing public health surveillance, it simultaneously highlights substantial limitations in design quality, methodological rigor, and global applicability. Addressing these gaps through more inclusive datasets, standardized methodologies, and transparent reporting will be essential to ensure that AI contributes meaningfully and ethically to the future of global health systems.

IMPLICATIONS AND FUTURE DIRECTIONS

The integration of artificial intelligence (AI) into public health surveillance presents transformative implications for clinical practice, policy development, and scientific research. As health systems worldwide strive to enhance responsiveness and resilience post-pandemic, the evidence synthesized in this review highlights AI's capacity to fundamentally reshape clinical and operational paradigms. Clinically, the adoption of AI-enhanced surveillance tools can facilitate early disease detection and risk stratification, thereby improving diagnostic accuracy and enabling preemptive interventions. By rapidly identifying at-risk populations and forecasting resource needs, AI systems may guide healthcare providers in optimizing patient triage, minimizing delays in care, and tailoring treatment plans based on predictive analytics (22). Moreover, AI-supported dashboards that monitor outbreaks and patient trends in real-time can improve clinical decision-making, particularly in emergency care and infectious disease management settings. From a policy perspective, the findings underscore a pressing need for national and global guidelines that formally incorporate AI into public health surveillance infrastructure. The World Health Organization and national health agencies have begun exploring frameworks for pandemic preparedness that rely on AI for epidemic forecasting and situational awareness (23). However, to operationalize such frameworks effectively, standardized protocols must be developed to govern data integration, algorithm validation, model interpretability, and ethical use. These guidelines should also address issues of equity, ensuring that AI technologies do not inadvertently widen health disparities through biased training data or unequal access to digital tools (22,23). Policymakers must therefore prioritize investments in digital infrastructure, particularly in low- and middle-income countries, and develop cross-sector partnerships that support inclusive and context-appropriate AI solutions.

Despite growing interest in AI for public health, numerous research gaps remain. One major unanswered question involves the long-term sustainability and cost-effectiveness of AI-driven surveillance systems in diverse settings. Very few studies have assessed real-world implementation outcomes such as system usability, integration with existing workflows, or the net clinical benefit to populations over time. Furthermore, the ethical dimensions of surveillance—particularly related to data privacy, consent, and transparency—require more empirical investigation. Current literature often discusses these concerns theoretically but lacks concrete models for ethical oversight and public accountability (24). To address these gaps, future studies should adopt more rigorous and inclusive designs. Prospective cohort studies and pragmatic randomized controlled trials that compare AI-integrated surveillance systems with traditional methods in real-world environments are especially needed. Such studies should use standardized outcome measures and include diverse populations across geographic, socio-economic, and healthcare contexts to enhance generalizability (25). Additionally, mixed-methods research that incorporates qualitative perspectives from clinicians, patients, and public health professionals can provide insights into system acceptability, user experience, and organizational readiness for AI adoption. Participatory action research, where stakeholders are involved in the design and evaluation of AI tools, may also help align technological innovation with real-world needs and values. Overall, this review contributes to the evolving discourse by highlighting the immense potential of AI to advance public health surveillance while also underscoring the methodological, ethical, and infrastructural groundwork required for responsible implementation. The future of public health will depend not only on the continued development of advanced algorithms but also on ensuring that such innovations are guided by evidence, inclusivity, and public trust.

CONCLUSION

This review highlights the growing potential of artificial intelligence to revolutionize public health surveillance, particularly in the post-pandemic context where rapid detection, predictive modelling, and strategic resource allocation are more critical than ever. The synthesis of recent literature underscores that AI-enhanced systems can significantly improve outbreak detection, optimize clinical decision-making, and support data-driven policy interventions. However, the overall strength of the evidence remains moderate due to limitations in study design, methodological inconsistencies, and the underrepresentation of diverse populations. While current findings offer promising insights, they must be interpreted cautiously, given the variability in data quality, model validation, and real-world applicability. Clinicians and public health professionals are encouraged to integrate AI tools into their surveillance strategies while remaining mindful of ethical considerations and system limitations. Simultaneously, researchers must prioritize the development of inclusive, methodologically robust, and context-sensitive studies that address current gaps, particularly in low-resource settings. Moving forward, a global collaborative effort is essential to refine AI frameworks that are not only technically effective but also equitable, transparent, and grounded in the realities of diverse healthcare environments.

AUTHOR CONTRIBUTION

Author	Contribution
Shaikh Khalid Muhammad*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Tanveer Ahmed Ansari	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Bilal Shabbir	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Wesam Taher Almagharbeh	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdur Rehman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Rukhshanda Arjmand	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Ali Ghulam	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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