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EDITORIAL

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From Outbreak to Algorithm: Artificial Intelligence as the New Sentinel in Emerging Infectious Diseases Surveillance

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The emergence and re-emergence of infectious diseases constitute a growing global health threat . Globalization, migration, and international mobility have facilitated the spread of diseases previously confined to specific geographic regions (1). In this context, early outbreak detection is essential to mitigate the impact on public health. Artificial intelligence (AI) has emerged as a key tool in modern epidemiological surveillance systems (2).

Technological advances have raised high expectations regarding AI's role in improving global health and achieving health-related Sustainable Development Goals. AI's ability to integrate and analyze data from diverse sources—such as clinical records, social media, public health reports, and environmental variables—makes it an indispensable ally for contemporary healthcare systems (3).

AI is currently being applied to tackle communicable diseases such as tuberculosis and malaria through machine learning techniques and signal processing. These tools have shown promise in critical areas including diagnosis, clinical risk assessment, outbreak prediction, and health policy planning (4). However, important aspects such as outbreak forecasting and surveillance, along with ethical, regulatory, and logistical considerations for large-scale implementation, remain underexplored in scientific literature.

AI-driven predictive modeling is transforming preparedness and response to health emergencies, becoming a strategic axis of public health management. Through the analysis of large datasets, these models can identify patterns and trends in disease incidence. For instance, Google search data were initially used to predict influenza outbreaks with notable accuracy, although later versions of the tool faced limitations due to overfitting and media influence (5). Similarly, predictive models have been developed for dengue and Zika virus transmission in Americas (6). Other algorithms incorporating atmospheric and historical case data have proven effective in forecasting malaria incidence.

Beyond outbreak prediction, AI is now transforming another crucial front in disease monitoring: genomic surveillance. The rise of genomic sequencing has enabled the tracking of mutations in pathogens such as SARS-CoV-2 and influenza viruses. AI facilitates the analysis of these sequences to detect emerging variants, predict their transmissibility, and assess their resistance to treatments or vaccines (7). During the COVID-19 pandemic, AI algorithms allowed real-time monitoring of the emergence and spread of variants like Delta

and Omicron. Several studies reported that AI models achieved 95% accuracy in identifying variants of concern, enabling more informed decision-making by health authorities (8).

Platforms such as BlueDot, which employ machine learning algorithms, demonstrated their effectiveness by detecting anomalies in Wuhan days before the World Health Organization issued its first alert on COVID-19 (9). Overall, AI-based predictive models have helped anticipate outbreaks of diseases like malaria, dengue, and influenza, enabling more timely and effective responses.

One of AI's main advantages in epidemiological surveillance is its ability to process large volumes of information with speed and accuracy, surpassing the limitations of traditional methods. Neural network models can analyze extensive databases within minutes, allowing epidemiologists to focus on interpreting results and informing decision-making (10). The integration of AI with geospatial data has also been crucial for mapping disease spread in real time, aiding governments in resource allocation and mitigation planning. For instance, in the province of Isfahan, geospatial AI combining machine learning algorithms with geographic information systems (GIS) was used to map the distribution of cutaneous leishmaniasis and identify high-risk areas (11).

However, the use of AI in public health is not without challenges. Data quality, availability, and representativeness directly influence the accuracy of predictive models. Data errors or biases may result in inaccurate predictions, compromising equity in outbreak responses, not to mention that, the reliance on algorithms requires constant validation to ensure relevance and fairness across diverse populations (12). Additionally, the absence of clear regulations raises ethical concerns regarding privacy and personal data protection. Another key challenge is technological dependence, which could lead to the neglect of fundamental public health strategies, such as health education and medical infrastructure (13). This could facilitate the re-emergence of previously controlled health problems.

To maximize AI's potential in detecting emerging diseases, it is essential to foster interdisciplinary collaboration among data scientists, epidemiologists, and public health decision-makers (14). The international standardization of data collection and analysis, alongside the development of transparent and explainable models, will strengthen trust in these tools. Moreover, sustained investment in technological infrastructure and health workforce training is necessary for effective AI integration. Simultaneously, the global health community must urgently establish guidelines to regulate the development, validation, and application of AI in epidemiological surveillance, ensuring its ethical, equitable, and secure use.

Conclusion

Artificial intelligence holds immense potential as the first line of defense against emerging diseases by providing timely and accurate information for effective health responses. However, its implementation must be accompanied by a robust ethical and regulatory framework that ensures fairness, transparency, and privacy protection. Artificial intelligence will not replace epidemiologists, but those who harness its power will lead the next era in future pandemics control and infectious disease surveillance.

Authors' contributions

Kovy Arteaga-Livias: Conceptualization, Writing- Original draft preparation, Writing- Reviewing and Editing. **Alfredo Chiappe-Gonzalez**: Writing- Original draft preparation, Writing- Reviewing and Editing. **Gustavo Valencia-Mesías**: Writing- Original draft preparation, Writing- Reviewing and Editing.

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Conflict of interest

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