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Leveraging AI for early cholera detection and response: transforming public health surveillance in Nigeria

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Abstract

Cholera continues to pose a significant public health challenge in Nigeria, driven by poor sanitation, inadequate water quality, and climatic factors that create favorable conditions for outbreaks. Since the first epidemic in 1972, Nigeria has experienced recurrent outbreaks, with the most severe in 1991, resulting in over 7,000 deaths. Current surveillance systems and diagnostic methods are limited by infrastructural gaps, insufficient skilled personnel, and inadequate reporting, leading to delays in outbreak detection and response. These limitations exacerbate the public health burden, increasing mortality and the economic impact of cholera epidemics. This paper explores the potential of artificial intelligence (AI) and machine learning (ML) to address these challenges. AI technologies, including predictive modeling and ML algorithms such as random forests and convolutional neural networks (CNNs), can analyze diverse data sources—such as meteorological, environmental, and health records—to detect patterns and predict outbreaks. Case studies from other cholera-endemic regions, where AI achieved high predictive accuracy, demonstrate its transformative potential. By integrating AI into Nigeria's public health infrastructure, early detection and response can be improved, resource allocation optimized, and disease transmission

minimized. However, challenges such as data quality, standardization, and infrastructural deficits must be addressed. Multi-sectoral collaboration involving public health authorities, AI specialists, and policymakers is essential for the successful deployment of these technologies. This article concludes that AI-powered cholera surveillance systems have the potential to revolutionize public health outcomes, reducing cholera-related morbidity and mortality in resource-limited settings like Nigeria.

Keywords

Cholera, artificial intelligence, public health, Nigeria

Cholera remains a major health concern worldwide, particularly in underdeveloped societies. Cholera is endemic in many countries, including Nigeria, and recent studies have reported that global warming creates a favorable environment for these gram-negative bacteria to thrive [1]. The disease is an acute public health issue with a high potential to cause many deaths and spread rapidly [2]. Although reports of cholera epidemics in Nigeria have not been consistent, the disease is very dynamic and appears to be endemic to the northern part of the country [2]. In Nigeria, cholera surveillance systems are frequently poor, with many cases unreported owing to constraints in surveillance infrastructure and fear of economic consequences [3]. This results in an underestimate of the actual cholera load. Conventional culture methods, the gold standard for cholera diagnosis, require skilled technicians and laboratory infrastructure that is often lacking in remote, cholera-endemic areas [4]. Rapid diagnostic tests can be useful but also have limitations in detecting non-culturable cholera bacteria [4]. The lack of timely and accurate surveillance data hinders the ability to rapidly detect and respond to cholera outbreaks [5].

Global shortages and delays in the supply of essential cholera medical commodities such as treatment kits can lead to preventable deaths during outbreaks [5]. The increasing number of concurrent outbreaks, including cholera, in resource-limited settings, has increased the capacity of healthcare systems to mount a comprehensive multisectoral response [5]. This is exacerbated by factors such as the emigration of skilled medical personnel and the destruction of healthcare infrastructure during crises. The limited global supply of oral cholera vaccines (OCV) has constrained the use of this important control measure, especially in high-risk populations [5]. The negative consequences of delayed cholera discovery and response include greater illness and death, wider disease transmission, overwhelmed healthcare systems, depletion of medical supplies, and economic and social disruptions. Early detection and declaration of outbreaks, as well as a timely multi-sectoral response, are critical for mitigating detrimental effects on communities.

Nigeria and other afflicted countries could greatly benefit from improved cholera epidemic management by utilizing artificial intelligence (AI) and machine learning (ML). AI and ML have emerged as game-changing technologies in many sectors, including public health. The ability of AI-based models to increase their efficacy would aid in the prediction of cholera epidemics in Nigeria, allowing medical professionals to plan and respond better. Many AI techniques have been used to address specific infectious diseases and outbreaks through early identification. ML can use clinical and epidemiological data to identify risk variables and predict disease outbreaks. For example, algorithms such as the random forest and gradient boosting machines have demonstrated efficacy in disease prediction [6]. Techniques such as Convolutional Neural Networks (CNNs) can process complex datasets, including environmental data, to detect patterns related to cholera outbreaks [6].

AI can forecast cholera outbreaks using various techniques to analyze meteorological, environmental, and health data. Historical cholera case data can be used to simulate epidemic trends and evaluate the risk factors. Data on water quality and sanitation can be integrated to understand the environmental triggers of cholera [7]. For instance, by merging climatic data from Earth-orbiting satellites with AI approaches, a study employed ML algorithms to predict cholera outbreaks in the coastal regions of India with an 89% success rate [8]. Artificial intelligence models can include meteorological variables, such as temperature, humidity, and rainfall, to gain a deeper understanding of the correlation between weather patterns and cholera epidemics. This aids in pinpointing particular meteorological circumstances that favor the spread of

cholera. AI can be a key player in anticipating cholera outbreaks by utilizing these techniques, which will allow prompt action to stop the spread of the disease and lower mortality rates. The Cholera Artificial Learning Model (CALM) uses ML techniques like XGBoost to anticipate cholera infections in Yemen, taking into account data such as rainfall, previous cholera cases, and civil war mortality [9]. CALM accurately forecasts cholera incidence, indicating AI's promise for cholera surveillance [9]. AI-driven health data analytics have proven essential in early diagnosis and response to infectious diseases in the United States, improving disease monitoring and forecasting through ML and predictive modeling [10]. This enables public health officials to allocate resources as efficiently as possible both before and during cholera epidemics, resulting in more focused, proactive, and efficient interventions that preserve lives and reduce the effects of the disease. Data quality and infrastructural difficulties in Nigeria are significant topics for future research. Addressing these difficulties is critical to increasing the accuracy and dependability of AI-powered forecasts. Concrete solutions should prioritize data standardization, cleaning, and integration, as these are critical for good data management.

It is imperative that public health authorities, epidemiologists, AI specialists, and government agencies work together to fully realize AI's potential for improving disease surveillance and outbreak response. The implementation of AI-based cholera surveillance systems in Nigeria requires a structured approach encompassing several critical steps. This includes data acquisition, model training, validation, and deployment while addressing integration challenges with the existing public health infrastructure. To ensure the appropriate and efficient deployment of AI in public health projects, a thorough policy framework and adequate funding are required. Governmental and non-governmental organizations (NGOs) must work together to integrate AI into public health programs to ensure their responsible and efficient execution. In developing nations such as Nigeria, cholera is still a problem, worsened by inadequate infrastructure and environmental changes. AI can improve outbreak prediction and early detection by analyzing environmental data and optimizing response and resource allocation. While AI has transformative potential for cholera monitoring, it must be implemented with prudence, prioritising ethical considerations and data integrity to prevent unintended consequences.

Abbreviations

AI: artificial intelligence

CALM: Cholera Artificial Learning Model

ML: machine learning

Declarations

Author contributions

AMI: Conceptualization, Formal analysis, Methodology, Project administration, Data curation, Visualization, Supervision, Writing—original draft, Writing—review & editing. MMA: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Project administration, Data curation, Investigation, Visualization, Writing—original draft, Writing—review & editing. SSM, UAH, MRH, OJO, and AMS: Writing—original draft, Writing—review & editing. DELPIII: Supervision, Writing—review & editing.

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The authors declare that they have no conflicts of interest or competing interests related to this study.

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