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Review article

An insight into the role of artificial intelligence in combating malaria: recent developments

Heena SACHDEVA, Manish SHARMA

Department of Zoology, Multani Mal Modi College, Patiala, Panjab, India, 147001
Corresponding Author: Manish Sharma; email: heenamanishsharma@gmail.com

ABSTRACT. In order to overcome obstacles in diagnosis, surveillance, treatment, and vector control, artificial intelligence (AI) has emerged as a crucial weapon in the fight against malaria. The eradication of malaria has benefited greatly from the exceptional accuracy and efficiency of AI-driven solutions. This review of the literature examines several uses of AI in the fight against malaria, emphasizing new developments. AI-driven solutions have the potential to improve malaria prevention and eradication efforts with sustained innovation and investment, ultimately enhancing global health security. AI is transforming the treatment of malaria by facilitating personalised medicine, speeding up drug discovery, and enhancing diagnostics. AI is improving treatment approaches and tackling the problems caused by drug-resistant malaria parasites through machine learning, deep learning, and in silico drug repurposing. Achieving long-term malaria eradication targets will require sustained investment in AI-driven malaria research. In epidemiological tracking, artificial intelligence (AI) has also become a potent instrument. AI-driven methods offer creative ways to find novel treatment approaches, maximize drug discovery, and forecast the dynamics of malaria transmission, especially in light of the growing resistance of *Plasmodium* parasites to current medications. Thus, this review paper provides insights into the developments made by AI in combating malaria.

Keywords: malaria, artificial intelligence, control, treatment, *Plasmodium*

Introduction

Every year, malaria claims the lives of about three-quarters of a million people worldwide. Asia and Sub-Saharan Africa, where the disease is endemic, account for the majority of reported morbidity and mortality. Despite recent improvements and efforts in elimination initiatives, malaria remains the leading source of imported infection in non-endemic countries and is linked to high fatality rates. In addition to cerebral malaria, respiratory distress, acute renal injury, bleeding problems, and co-infection, severe malaria frequently necessitates hospitalization to an intensive care unit. Prompt diagnosis, early beginning of effective antimalarial medication, identification of complications, and adequate supportive care are all components of intensive care management. However, a barrier to the efficient identification and treatment of malaria is the lack of diagnostic capabilities brought on by a lack of advancements in infrastructure, manpower, and equipment. However, through developments in medication discovery, customized medicine, and therapy optimization, artificial intelligence (AI) is revolutionizing the treatment of malaria. AI offers creative alternatives for creating novel medicines and refining therapeutic approaches as malaria parasites become resistant to current medications. This paper examines how artificial intelligence is influencing the treatment of malaria, emphasizing significant advancements in in silico medication repurposing, machine learning applications, and drug discovery. AI's incorporation into efforts to eradicate malaria signifies a radical change in public health tactics. AI-driven technologies have the potential to accelerate the global reduction of malaria by increasing management practices, optimizing vector control, and boosting diagnosis accuracy. The recent developments that have been made are discussed here (Table 1).

Table 1. Role of artificial intelligence in malaria control

AI application	Role in malaria control	Benefits
Disease prediction & surveillance	AI models analyse climate, population, and infection data to predict malaria outbreaks	Early warning systems help in proactive interventions
Medical imaging & diagnosis	AI-powered image recognition detects malaria parasites in blood samples more accurately	Faster and more reliable diagnosis, reducing human error
Drug discovery & development	AI accelerates the identification of potential antimalarial drugs	Reduces research time and costs for new treatments
Vector control & mosquito monitoring	AI analyzes mosquito behavior and breeding patterns using remote sensing and big data	Improves targeted insecticide use and environmental management
Personalized treatment plans	AI assesses patient data to recommend optimal malaria treatments	Enhances treatment efficacy and reduces drug resistance
Chatbots & AI assistants	AI-driven virtual assistants provide healthcare guidance and symptom assessment	Improves access to information in remote areas
Genetic research	AI deciphers genetic data of malaria parasites to track mutations and resistance	Aids in developing more effective vaccines and treatments

Integration of AI in global malaria initiatives

The promise of AI to hasten the eradication of malaria is acknowledged by the international health community. In order to improve surveillance, diagnostic, and treatment efforts, the World Health Organization's Global Malaria Programme operating strategy for 2024–2030 places a strong emphasis on integrating cutting-edge technologies, such as artificial intelligence. This deliberate inclusion highlights AI's contribution to the ambitious objective of lowering malaria incidence and mortality globally [1].

AI in malaria epidemiology and transmission tracking

By accurately predicting the patterns of disease transmission, artificial intelligence is also revolutionizing the science of malaria epidemiology. Researchers can now track the movement and transmission dynamics of *Plasmodium vivax* with high precision due to machine learning models that have been built to evaluate genetic variants of the parasite [2]. Researchers can help with targeted therapies by predicting the geographic origins of malaria cases using AI-driven genetic barcodes.

Additionally, deep learning and drone technologies have been used with AI to find mosquito breeding grounds in areas where malaria is endemic. Compared to conventional methods, this methodology maps high-risk areas more accurately, allowing targeted vector management [3].

AI in malaria surveillance and prediction

By examining epidemiological and environmental aspects, AI has proven crucial in forecasting malaria epidemics. Regional differences in malaria prevalence have been successfully discovered using machine learning models trained on patient symptoms and demographic data, which has aided in the allocation of resources and the implementation of focused interventions [4]. Additionally, AI has been used to predict malaria transmission dynamics in mosquito populations, leveraging mass spectrometry and deep learning techniques to identify high-risk areas [5].

AI in malaria vector control

One of the most important methods for preventing malaria is vector control. AI has been utilized to track pesticide resistance and mosquito populations, guaranteeing efficient control strategies. AI-driven analysis of mosquito genetic structure helped forecast the spread of insecticide resistance, enabling prompt interventions, according to a genomic study [6]. Furthermore, to ensure the sustainability of intervention programs, AI-based entomological monitoring has been used to optimize decision-making in vector control techniques [7].

AI in malaria diagnosis

In order to manage malaria, an early and precise diagnosis is essential. Conventional diagnostic techniques, such examining blood smears under a microscope, take a lot of time and call for trained staff. Deep learning techniques are used by AI-driven diagnostic tools to improve speed and accuracy. Convolutional neural networks (CNNs) have been shown in studies to enhance diagnostic efficiency by classifying blood samples as malaria infected and uninfected with over 99% accuracy [8]. According to a different study, AI-powered diagnostic solutions that used machine learning models fared better than traditional techniques in terms of efficiency, memory, and precision [9].

AI in malaria drug discovery

The process of finding new drugs to treat malaria has historically been costly and time-consuming. The discovery of novel antimalarial drugs has been sped up by AI-driven computational methods like machine learning and deep learning. Large datasets are analyzed by AI-powered models to forecast drug-target interactions, greatly cutting down on the amount of time needed for drug testing and screening.

DeepMalaria is one such model that uses deep learning to forecast the inhibitory properties of certain antimalarial medications. This algorithm has proven to be highly accurate in discovering novel therapeutic candidates, having been trained on 13,446 publicly available antiplasmodial chemicals [10]. Likewise, AI has been included into quantum machine learning techniques to enhance malaria medication discovery [11].

AI and precision medicine in malaria treatment

AI is also significantly contributing to the development of precision medicine for the treatment of malaria. Machine learning methods can forecast malaria risk based on mutation locations by evaluating vast amounts of genomic data, opening the door to individualized treatment plans [12]. These methods minimize medication resistance and enhance treatment results by enabling more efficient treatment plans catered to individual patient profiles.

AI-driven mosquito surveillance and vector control

Eliminating malaria requires effective vector control. To transform mosquito surveillance in Africa, researchers at the University of South Florida have created an AI-based system. This system analyses photos of the anatomical features of mosquitoes, like their wings and legs, and uses algorithms to automatically identify species. This technology allows for targeted actions to stop the spread of disease by precisely differentiating between species, particularly those such as *Anopheles stephensi*, a recognized vector of malaria [13].

AI in malaria diagnosis and therapy optimization

For malaria to be effectively treated, an accurate and prompt diagnosis is essential. AI-driven diagnostic technologies have demonstrated impressive efficacy in detecting cells infected with malaria. By examining pictures of red blood cells, a study developed a deep learning model based on the Efficient Net architecture that achieved a 97.57% diagnostic accuracy. This development has a lot of potential for use in environments with limited resources, when quick and accurate diagnosis is essential [14].

Through the use of convolutional neural networks (CNNs), which accurately classify cells infected with malaria, artificial intelligence (AI) has enhanced the diagnosis of malaria. AI's promise for early and accurate malaria detection was demonstrated by a study that used CNN models to detect infected blood smear images with an accuracy of 82.7% [15]. By ensuring prompt

Table 2. Future challenges for AI in malaria control

Challenge	Description	Impact
Data availability & quality	Lack of high-quality, labelled malaria datasets	AI models may produce inaccurate or biased results
Generalization across regions	AI models trained in one region may not work in another due to different malaria strains and environments	Reduced effectiveness in global malaria control efforts
Computational requirements	AI algorithms require significant computing power and infrastructure	Limits deployment in resource-poor settings
Integration with healthcare systems	Difficulty in incorporating AI into existing healthcare workflows	Slower adoption and resistance from healthcare providers
Ethical & privacy concerns	Issues around patient data privacy and AI decision-making transparency	Potential mistrust and regulatory hurdles
Vector & parasite evolution	Rapid mutations in malaria parasites and resistance in mosquitoes	AI models may become outdated quickly, requiring frequent updates
Cost & accessibility	High costs of AI technology and limited access in low-income regions	Widening healthcare disparity in malaria-prone areas

treatment, this improved diagnostic capacity lowers the risk of consequences.

AI in malaria management and strategy development

AI is also enhancing malaria management through predictive modelling and strategic planning. Zzapp Malaria, for instance, employs AI to create tailored malaria elimination strategies. Their platform analyses various data inputs to optimize intervention plans, which are then implemented via a dedicated mobile application. This approach ensures that resources are efficiently allocated, and interventions are effectively executed in the field [16].

AI in personalized malaria medicine

Machine learning is playing a critical role in developing personalized malaria treatment strategies. By analysing genetic variations in *Plasmodium* parasites and patient data, AI models can predict drug resistance patterns and recommend tailored treatment plans. AI-based computer-aided drug design (CADD) is also emerging as a crucial tool for malaria therapy, enabling the development of drugs customized for specific parasite strains and patient populations [17].

AI in drug repurposing for malaria

Another promising application of AI in malaria treatment is drug repurposing. AI-driven in silico screening platforms analyze existing drugs to identify potential antimalarial candidates. Machine learning-based molecular docking methods and deep learning approaches enhance the precision of drug repurposing efforts, offering cost-effective solutions for developing new malaria therapies [18].

Challenges and future directions

Despite the progress AI has made in malaria treatment, challenges remain. These include data limitations, ethical concerns regarding AI in healthcare, and the need for greater collaboration between AI researchers and malaria experts. Future research should focus on refining AI models to enhance their predictive accuracy and expanding datasets to ensure broad applicability across different malaria-endemic regions. Future research should focus on improving AI interpretability, expanding datasets to include diverse populations, and developing cost-effective AI solutions for resource-limited settings. In order to ensure broad application across various malaria-endemic regions, future research should concentrate on improving AI models to increase their predictive accuracy and growing datasets (Table 2).

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