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ARTIFICIAL INTELLIGENCE IMPLEMENTATIONS IN PARASITOLOGY: A MINI-REVIEW ARTICLE

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Abstract

Blood parasites such as leishmaniasis, malaria, and trypanosomiasis continue to affect vulnerable populations worldwide. By using AI programmer develops as an innovative tool that has the potential to develop diagnosis, treatment, prevention, control, and the prediction of parasitic disease outbreaks, vector control, mobile health, epidemic detection, predictive modeling, disease burden estimation in endemic areas, and understanding transmission patterns. The revolution in the previously mentioned items helps improve patient health and provide early warnings, enabling healthcare authorities to implement preventive measures and allocate resources efficiently. AI expedites drug discovery in treating parasites by analyzing large datasets, predicting drug efficacy and safety profiles, streamlining drug development, and optimizing drug formulation and delivery methods. This reduces time and cost for production of more effective parasitic medications, and aids in repurposing existing drugs with transformative impacts on the healthcare sector. However, AI's potential in the field of medical parasitology is limited by complex parasite life cycles, heterogeneity, and specialized knowledge needs, while lack of data and ethical issues restrict its implementation. Therefore, obstacles need to be solved to efficiently realize AI's potential in real applications. With more research and cooperation in this field, we can develop creative techniques to combat parasitic infections and obtain a deeper understanding of them.

Keywords: artificial intelligence, machine learning, health care, parasitic diseases

Introduction

Artificial intelligence (AI) is the creation of intelligent machines, primarily computer pro-grams, by combining the best aspects of science and engineering. Even if the idea originated in the 1950s, the AI spring was felt in the early 2020s (Jiang *et al,* 2017),but, funding to boost computational capacity increased, and millions of digital devices were manipulated for performance of challenging tasks including picture analysis, terms and definition recognition, and linguistics interpretation (Zhang and Lu, 2021). Nowadays, the AI revolution, driven by advancements in computation and machine learning (ML) models, was practically permeated all aspect of human life and was set to revolutionize the healthcare field (Jiang *et al,* 2017).

Review and Discussion

The management of infectious diseases is a top concern in the healthcare field (Bloom and Cadarette, 2019), with the need for a stronger ecosystem due to the increasing risks posed by newly discovered and reemerging diseases, where frequent outbreaks and pandemics are an inevitable part of the near future (Samimian-Darash, 2013), with the global climatic changes (Morsy *et al,* 2024). Of all biological threat parasites, especially zoonotic ones, are risky and affect millions of people, mainly in Africa led to death (Zhang *et al,* 2022). Many of these infectious diseases annoyed healthcare workers, despite all of the scientific and technical improvements that have led to a significant educations in the medical field (Parija, 2022). Therefore, making an accurate diagnosis is necessary for appropriate medications and preventing drug misuse, and allow for feasible control measures. Also, medical professionals find it challenging to study parasites in microscopic images due to morphological changes and limited sensitivity with low parasitic levels (Picot *et al,* 2020). In this regard, AI has several advantages, including the ability to foresee and diagnose diseases, streamline laboratory procedures, and aid in drug research and discovery (Parija and Poddar, 2024). Medical parasitology is now one of the fields of medicine where AI-driven methods such as machine learning algorithms have emerged as a powerful tool that opens up new avenues for the study and management of parasite infections through its potential to analyze large volumes of data and then uncover complex patterns that challenging for human specialists to notice (Elmehankar *et al,* 2023). Thus, parasitologists, lab technicians, sanitation workers, physicians in hospitals, public health centers, and health departments must be familiar with the latest advancements in AI education and training in order to equip medical personnel to use AI technology efficiently (Bhasin, 2007). But, it's critical to comprehend objectives of human-AI interactions to preserve and enhance human abilities (El Saftawy, 2023).

Integration with electronic health records (EHR): AI technology improves efficiency and accuracy of parasitic diagnosis and treatment with EHR decision support systems. Using EHRs and AI algorithms evaluated patient's data such as symptoms, medical history, and laboratory results, and provided better health care (Haick and Tang, 2021).

Artificial intelligence (AI) accomplished research and predicted disease transmission patterns by combining environmental, climate-dependent, social media sources, and incidence and prevalence diseases, expecting early outbreaks (Agrebi and Larbi, 2020). Variations of climatic shifts, vector, reserveoirs and human migration by AI-driven suggest feasible control measures, direct public health initiatives and resource allocation (Wang *et al,* 2022). Also, AI algorithms evaluated and integrated data from zoonotic records, animal monitoring, and human health data enabling prompt identification and diseases prediction (Pillai *et al,* 2022).

AI-based diagnosis: A precise diagnosis and treatment plan depend on the ability to identify and classify parasites. Traditional techniques often depend on microscopy; a labor-intensive, time-consuming, and prone to human error (Chiodini *et al,* 2007). Nonetheless, a paradigm shift occurred in field as a result of the machine learning (ML) and AI (Nayak *et al,* 2023). This minimized misdiagnosis, improved treatment choices, and reduced workload and human error. The AI algorithms on large databases of parasite images gave specific diagnostic morphological patterns and easier-to-access treatments (Liu *et al,* 2023). AI application in laboratories increased productivity and lower operating times (Shi, 2019). This allowed doctors in limited resources to depend on AI diagnosis without specific lab. technician (Noureldeen *et al,* 2023).

Telemedicine: AI-based technology can help in telemedicine for parasites by merging with telemedicine platforms; healthcare workers may digitally diagnose and analyze parasites, and gave proper treatment mainly in areas where access to medical knowledge is limited or nonexistent (Dacal *et al,* 2021).

Malaria: A vector-borne protozoan parasite affects millions of people globally (WHO, 2024), and now five *Plassmodium* species infect man (Morsy *et al,* 2919). Detection of malaria parasites using thick smear images has been made possible by using a deep learning system for smartphones (Yang *et al,* 2019). No doubt, microscopic diagnosis may cause dilemma in early infection time with babesiosis and malignant malaria or this malignant form when co-infected with HIV (Saleh *et al,* 2016). For malaria parai- tes diagnosis in thick blood smear images, single-shot multibox detectors "SSD", convolutional neural networks "faster R-CNNs", RetinaNet, and Internet of Medical Things "IoMT" have been used (Nayak *et al,* 2022). Once such AI or "iPalm" system de-veloped for malaria parasites in microscopic images of blood smears with dependable accuracy in identifying malaria (Cooper *et al,* 2023). Also, AI revolutionized malaria diagnosis in creation of AIDMAN, or AI-ba-sed method for detecting malaria parasites in blood smears using smartphones. For cells and blood smears images, it gave diagnostic accuracy of 98.62% and 97%, respectively.

Clinical validation accuracy was 98.44%, that on par with those of microscopists with extensive experience (Zarella *et al,* 2019).

Schistosomiasis: this trematod-blood parasite; weather S. *haematobium, S. mansoni* or *S. japonicum* is a tropical and subtropical disease often ignored (Vlaminck *et al* 2021). Egyptian men workers in farming, especially those who have never smoked, but suffered from S. haematobium, had increased odds of having bladder cancer (Amr *et al,* 2014). *S. mansoni* is directly and indirectly involved in hepato-carcinogenesis (Abo-Madyan *et al,* 2024). In chronic cases eggs may be difficult to diagnose due to granulomata around eggs or dead worms, primarily in lower urinary tract in *S. haematobium*, and colon and rectum with *S. mansoni* (Barsoum *et al,* 2013). AI algorithms digital microscope Schistoscope is an automated method speeds up diagnosis and reduces the workload, especially in endemic schistosomiasis regions (Oyibo *et al* 2022). Also, AI algorithms can accurately diagnose *S. mansoni* granulomatous infections, by automatically classifying microscopic images and categorizing different cellular granuloma levels with high recognition rates and accuracy using advanced image analysis techniques and textural features taken from the Grey-Level Co-occurrence Matrix and Grey Gradient Co-occurrence Matrix (Shi, 2019).

Leishmaniasis: Cutaneous form or ZCL (Mangoud *et al,* 2005), which may predispose to skin cancer and visceral leishmaniasis or IVL (El Bahnasawy *et al,* 2013) are encountered in Egypt. Apart from sandflies transmission of leishmaniasis species (Morsy and Dahesh, 2023), needle-stick injury and blood transfusion are involved in IVL nosocomial infection (Abdel-Motagaly *et al,* 2017).

In IVL stained blood, bone marrow, splenic smears or in ZCL ulcers smears may or may not diagnose leishmaniasis (Saleh *et al,* 2017). Serological assays as dot-ELISA, IHAT didn't differentiate between the active and past infections (Morsy *et al,* 1986). Also, PCR with highest sensitivity and specificity, but is an expensive, time-consuming, and challenging procedure that requires specific materials (De Brito *et al* 2020). So, AI algorithms have the potential to facilitate the treatment choices and aid in precise diagnosis of leishmaniasis different clinical forms (Zare *et al* 2022).

Numerous vectors-borne parasites as Chagas disease in the United States (Pérez-Molina and Molina, 2018) and lymphatic filariasis and onchocerciasis are parasitic nematode infections responsible for a major disease burden in the African continent (Hoerauf *et al,* 2011), as well as zoonotic *Trypanosoma evansi* (Haridy *et al,* 2011), were diagnsed and treated by AI using a variety of imaging datasets and clinical records (Dedhiya *et al,* 2022). Elvana and Suryanto (2022) used first-time machine learning over thermal imaging to detect *Onchocerca* worm survivability.

Parasite genome analysis: The AI algorithms analyzed large amounts of genomic data related to malignant malaria pathogen *Plasmodium falciparum* associated with drug resistance, predict prospective therapeutic targets, and facilitate the creation of novel antimalarial drug (Tsebriy *et al* 2023). Besides, genomic sequencing of trypanosomes causing Chagas disease and African sleeping sickness, which generates extensive genetic databases were analyzed using AI systems to identify virulence factors and potential vaccine targets (Uran *et al,* 2023).

The AI--driven in epidemiology: AI systems integrate several data sources, including genetic information, environmental factors, and demographic data for epidemiological parasitosis studies. By analyzing and modeling these diverse datasets, AI can assist in predicting disease outbreaks, pinpointing high-risk areas, and understanding the dynamics of parasitic infection propagation (Rostami *et al,* 2023). An innovative approach to managing epidemics in public health is predictive disease modeling (Scarpino and Petri, 2019). This allowed professionals to plan ahead, make informed decisions, distribute resources wisely, and carry out targeted interventions before an outbreak becomes a disaster (Myers *et al,* 2000). The predictive AI-based models were useful in various contexts, such as prediction of outbreaks, as data from 2013 to 2017 of malaria parasites, and viruses of both dengue, and chikungunya were used to build a convolutional neural network (CNN) algorithm (Raizada *et al,* 2020). Trained model correctly predicted illness outbreaks by 80% of malaria epidemics, several additional prediction algorithms were created associated with atmospheric changes, tracked cases over time, and accurate predictions of future occurrences (Oguntimilehin *et al,* 2015).

Artificial intelligence in vector control: AI assisted in vector control by detecting vector breeding places, mapping high-risk areas, and vector population dynamics and disease transmission patterns by analyzing environmental and climatic data of remote sensors and satellite imagery (Kaur *et al,* 2022).

Artificial intelligence in drug discovery: The conventional method to find new drugs is incredibly time-consuming and involves multiple processes such as target identification, lead compound identification, optimization, preclinical testing, and clinical trials, which often take ten years or more (Berdigaliyev and Aljofan, 2020). A substantial failure rate from the absence of prediction techniques was up to 90% of possible medication candidates don't get past preclinical testing (Sun *et al,* 2022). Numerous variables, such as poor target selection, insufficient efficacy, inadmissible toxicity, and unfavorable pharmacokinetic features, contribute to high failure rate (Waring *et al,* 2015).
For pharmaceutical corporations, this results in considerable financial losses and delays drug discovery process (DiMasi *et al,* 2003). To address the ongoing global health issues, particularly those resulting from an increase in the emerging incidence and re-emerging infectious diseases, it is imperative that drug discovery activities be intensified (Parija and Poddar, 2023). By computationally analyzing enormous volumes of chemical databases, compounds with desirable properties, such as high potency and low toxicity, that may have potential anti-parasitic action are found utilizing virtual screening approaches. AI-driven drug discovery techniques assisted in finding novel compounds, repurposing current medications to treat parasitic diseases (Philip and Faiyazuddin, 2023). The AI-assisted methods, anti-parasitic medication discovery become reasonable, such as LabMol-167, which identified as a new potential PK7 inhibitor with anti-malarial activity in vitro by combined shape-based and machine-learning models with an AI-assisted virtual screening. At nanomolar concentrations, LabMol 167 suppressed *P. falciparum* while displaying no cytotoxicity in mammalian cells (Lima *et al,* 2021). Besides, the development of deepmalaria, a Graph CNN-based deep learning method identified putative antimalarial drugs (Arshadi *et al,* 2019). GlaxoSmithKline provided a dataset for a model's training, identifying compounds with anti-parasitic activity of 50% to more than 85% of them, as DC 9237 was the most promising anti-malarial candidate, and Novartis used an ML-based profile-quantitative structure-activity relationship (pQSAR) platform for screening potential antimalarial candidates (Martin *et al,* 2019). The training with blood-stage *P. falciparum* 3D7 data resulted in a potential chemical library for the model. As possible antimalarial medications, the compounds detected unique pharmacological qualities are screened for in medications using pQSAR (Rao *et al,* 2023).

Moreover, Leonardi *et al.* (2009) used a machine learning model based on neural networks to optimize oral benznidazole absorption, the drug of choice for treating American trypanosomiasis. The model included analysis of several process parameters to produce benznidazole chitosan microparticles with the best possible outcome. In an effort to identify potential therapeutic targets, the target protein structures of *Trypanosoma* were predicted by AI-based Deep-

Mind Technologies (De Rycker *et al,* 2023). This discovery has opened the door to more effective treatments for trypanosomiasis to support the use of AI to integrate existing chemical and genomic datasets and to select target and focus areas for combat against trypanosomes (Urán *et al,* 2023).

The repurposing of drugs is a growing application of AI. Repurposing pharmaceuticals that are currently licensed for use in treating other medical conditions to address novel medical problems has several advantages for patients, the healthcare system, and the pharmaceutical business (Parija and Poddar, 2024). There were many attempts to repurpose certain new drugs for schistosomiasis and malaria (Winkler, 2019). Formerly, Williams *et al*. (2015) created eve®, which integrates a process pipeline comprising library screening, hit confirmation, and led creation to economically accomplish drug repurposing by use of the AI. Eve discovered that fumagillin, an antibacterial molecule, may be able to stop *P. falciparum* strains from growing in a mouse model and inhibited parasitaemia (Parija and Poddar, 2024).

Artificial intelligence in drug resistance: AI technologies help track and predict drug resistance that developed resistance to standard treatment, mainly schistosomiasis and malaria (Muflikhah *et al,* 2023), by analyzing genetic data and treatment response patterns, enabling early detection of resistance, and modifying treatment regimens to offer innovative to target drug-resistant (Caldwell *et al,* 2023).

Artificial intelligence aided in developing of specialized treatment plans for parasites. By evaluating specific patient data, such as genetic profiles, treatment histories, and clinical manifestations to generate therapy recommendations tailored to distinct characteristics of each patient (Rao *et al,* 2023), this tactic can lessen adverse effects, increase with efficacy, and help patients overcome challenges caused by drug resistance.

Challenges and limitations of AI in parasitology: AI has significant potential in medical parasitology, but it faces several challenges (Owens *et al,* 2023), including the complex life cycle of parasites, sample type heterogeneity, and the need for specialized knowledge. The AI implementation in this field was complicated by people's hesitant use of technology, as allowed by healthcare science projects (Ciasullo *et al,* 2022). Also, access to well-annotated datasets covering various parasite species and clinical settings is crucial for developing reliable AI systems (Parija and Poddar, 2023). Also, ethical issues such as bias redu-ction, algorithm transparency, patient appro-val, data protection, and balancing ethical considerations with technological advancements are indicated with more discussions about AI ethics globally (UNESCO, 2021). WHO created a different set of guidelines on AI in healthcare, outlined the dangers and obstacles associated with using AI carelessly. It offered six sets of suggestions for so-und governance of AI. Partnerships between medical physicians and AI specialists were essential to create effective use of AI solutions in line with clinical requirements and best practices (Gurevich *et al,* 2023). Also, using AI to control parasitic diseases is challenged with difficulties because of a lack of data resulting from a lack of investment in data collection, especially in areas where the disease is endemic. This has made it difficult to design and validate AI models, especially with a lack of AI development for neglected tropical diseases, such as parasitic infections causing millions of people to suffer from avoidable diseases (Eubanks *et al,* 2019). To combat these diseases, the WHO, in its latest roadmap for NTDs, recommends integrating AI and other cutting-edge technologies like drones, digital health, and satellite images in the innovation landscape (WHO, 2023). So, AI can be used to diagnose diseases, develop personalized treatment plans, and assist clinicians with decision-making. Rather than simply automating tasks, AI is about developing technologies enhance patient care across healthcare settings. But, challenges related to data privacy, bias, and human expertise must be addressed to responsible and efficacy of AI in healthcare (Alowais *et al,* 2023).

Conclusions

AI is a potent tool addresses the challenges head-on, particularly in medical parasitology, where AI technologies like machine learning and image recognition with marked progress in drug discovery, epidemiology, and prevention. AI algorithms also expedite data analysis and decision-making, enabling effective drug and interventions as well as increase accuracy in patients' satisfactory.

Recommendations

To have a global AI ecosystem, developed nations must corporate with other low income ones. Otherwise, there will be gaps in transparency, safety, and ethical standards

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