Artificial intelligence in Medical Parasitology between hopes and fears

Review Article

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ABSTRACT

Artificial intelligence (AI) and machine deep learning interaction with human intellect emerged in the medical field. Application of AI may serve the field of Parasitology in clinical diagnosis, higher education institutes, and in Parasitology research. The anticipated implementation of AI includes: 1) the serving of large-scale populations in the diagnostic labs, 2) the capabilities to exploit huge data in no time, 3) the performance of autonomous calibration and experimentation, and 4) dealing with unsafe experimental tasks. Yet, fears appeared concerning the possible substitution of human abilities, the susceptibility to cyber threats, and the lack of wisdom and experience to execute decisions. Therefore, AI is determined to assist not replace Parasitologists in their profession. The present report aims to overview AI relevance in the field of Medical Parasitology.

Keywords: artificial intelligence; clinical diagnosis; diagnostic labs, higher education institutes, Parasitologist, Parasitology research

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INTRODUCTION

Artificial intelligence is when technology, particularly computer systems, mimics human intelligence. During the past half-century, AI conquered healthcare services, aiming at the development of automated expert programs that mimic a professional's planned procedure. Formerly, the potentiality of AI was not considered due to limited data and funding. Since then, funding to improve computational power increased and millions of digital devices were manipulated for the performance of difficult tasks such as the analysis of images, recognition of terms and definitions, and interpretation of linguistics[1].

Medical anthropology is a sub-branch of general anthropology dealing with employment in health departments, schools of medicine, nursing staff, centers of public health, and hospitals[2]. In the field of medical Parasitology, medical anthropology in diagnostic and research Parasitology laboratories involve the professional Parasitologist and his team (chemist, lab technician, and sanitation worker). Besides, in higher education institutions, medical anthropology includes the teaching staff, the students, and the school dean, who should be accustomed with recent AI improvements. Yet, in order to conserve and improve human abilities it is important to understand the goals of human-AI interactions.

Accordingly, the current review aimed to introduce worthy questions and define convenient answers from previously published works of literature e.g., 1) to what extent can human power interplay with AI in diagnostic laboratories? 2) to what extent introduction of robotics can impact the teaching of medical Parasitology? 3) can robotics be introduced in Parasitology research as an assistant to human resources or is it going to be a competitor in the laboratory workplaces?

METHODOLOGY

The protocol for this publication was assembled, and articles were gathered through explorations using the keywords of three online databases: Google Scholar, PubMed, and Egyptian Knowledge Bank (EKB). Inclusion criteria comprised studies that were peer-reviewed and published in English between 2002 and 2023 and revealed definitions or studies related to AI, deep learning, functional behavior, skill acquirement, human resource management, Black-box system, Neural Networks, self-driving laboratories, autonomous experimentation, and calibration. Earlier articles that met the set criteria were included. Reviews and studies that didn’t complement the set protocol were excluded.

Applications of AI in Medical Parasitology

[I] Diagnostic Parasitology laboratories

Computer self-efficiency is increasingly important to influence the acquirement of human skills. Since early times, Garcia *et al.*[3] proposed automated devices to enhance the diagnosis of blood parasites e.g., *P. falciparum* and *P. vivax*. Besides, portable smartphones were contemplated as simple, low-cost, and automated medical diagnostic tools to replace conventional microscopy[4]. Respectively, automated multiplex-tandem PCR was introduced for the diagnosis of nematodes[5].

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The Parasitologist's experience versus deep machine learning: Deep machine learning is derived from the practical methodology of inventing robotics that learn data attained from human experience. Nevertheless, the key challenge in the development of robotics is the continual need for machine learning. This necessitates repeated data analysis and experimentation of algorithms that may improve the cognitive capabilities of the machine to produce correct outcomes[6] (Figure 1).

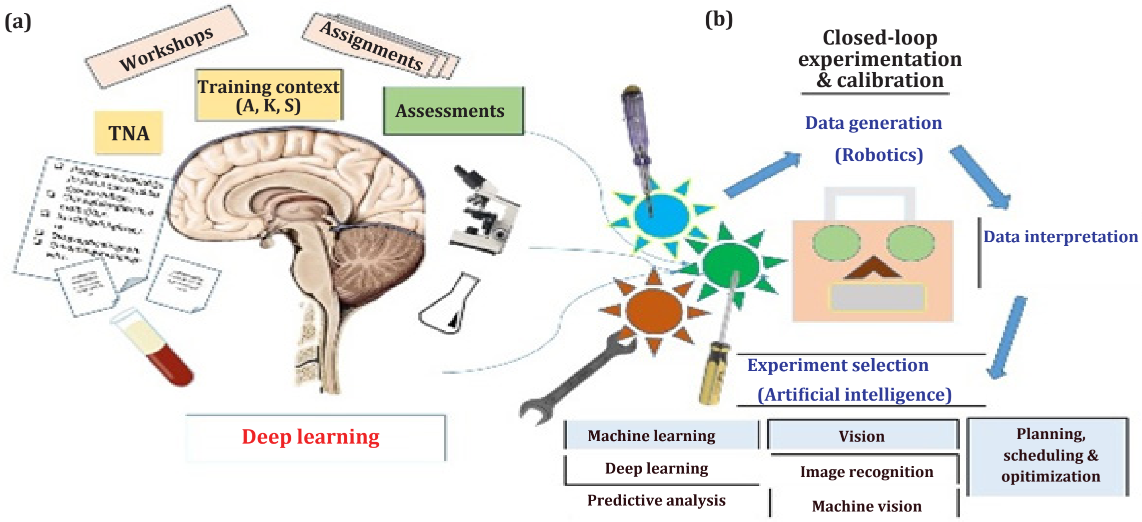

Fig. 1. Generation of a laboratory-borne AI by: **(a)** human deep learning; **(b)** closed-loop of autonomous experimentation and calibration. **TNA:** training needs assessment; **A:** Attitude; **K:** Knowledge; **S:** Skill. Illustrated by the author.

In 2008, a study was conducted to introduce the idea of "Web-Based Virtual Microscopy for Parasitology" as an original means to guarantee quality assurance in the diagnosis of neglected tropical parasites. The method relied on using parasitological samples as a "gold standard" in the absence of a strong internet signal using a PC or laptop[7]. Also, AI has been introduced in Mega labs and central health care units to perform an automatic full analysis of semen specimens via software called "computer-aided semen analyzers or CASA" e.g., Sperm Vision® SAR and SCA® CASA System. The tool is composed of a PC and monitor that investigates the morphology and motility of spermatozoa in line with the World Health Organization database[8]. It is worth contemplating if this idea might be adopted in Parasitology research using software provided with the descriptive analysis of the parasites!

Can the Black box system mimic human vision in conventional microscopy? The main concept of this Black box system relies chiefly on the adaptation of the deep learning of the machine and the setup of artificial neural networks and their ability to function together. It is worth mentioning that the Black box is a system where inputs are dragged through inner works in the machine then outputs are executed. Upon introducing an image (input) e.g., a microscopically detected parasite, the most relevant identification (output) would be predicted depending on the analysis of its gradient. The sensitivity of this technique depends on several calculations and equations to execute the precise diagnosis. Herein, it is important to introduce the term "the Heatmap" which demonstrates the important pixels of the introduced (input) image on which AI can build its decision, as well as those pixels that need to be altered or refined in the input image so that it appears more or less resembling the AI-predicted identification. Thus, the question is: may AI assist parasitologists in the large-scale screening of parasitic infections? If a basic part of the diagnostic stage in a fecal specimen is hidden by an artifact e.g., spine of a Schistosoma egg, the Heatmap would indicate this obscured part and AI would work intentionally to "guess" a precise output (diagnosis)[9] (Figure 2).

In general, the robotization of workplaces is predicted to replace at least 30% of human power. This fact was stated by Bank of America, Merill Lynch, the United Nations (UN), the World Economic Forum, the McKinsey Global Institute, and Oxford University[10]. Here arises the concern that the introduction of AI might trigger behavioral changes among the staff in a Parasitology lab such as "Knowledge-hiding behavior", so as to protect their jobs.

The more serious question "Would it be obligatory to be well-trained and precisely work like a machine to keep the job in Mega labs and large healthcare centers that serve large populations"? This inquiry is inspired by history when the bodies and minds of workers in the 19th century industrial revolution were disciplined to work unthinkingly and efficiently to achieve competitive profits[11]. In the field of diagnostic Parasitology to approach human power at a meticulous level, El Saftawy[12] showed that this necessitates huge and hard effort to execute purposeful training on analytic procedures. This demands updated training tactics, the manipulation of recent online facilities, assignments, assessments, and close follow-up by the Parasitology trainers to approach the intellectual and cognitive engagement of the trainees.

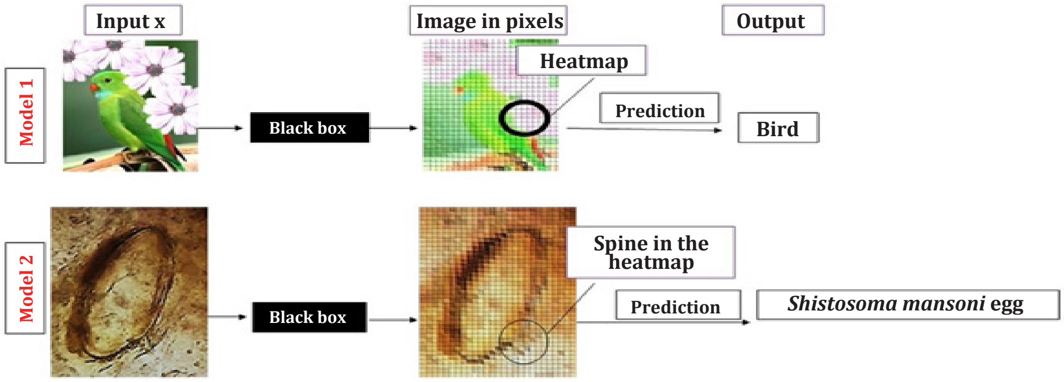

Fig. 2. Visual predictions in AI. **In model 1:** if the input image was categorized as "green bird" after applying the Black box system, the Heatmap should have recognized pixels of the wing in the image as important to identify the image as a bird. **In model 2:** if the spine is the basis for predicting the "*S. mansoni* egg" and was obscured by fecal artifacts, the Heatmap should have identified pixels of the spine in the image as important to predict the output. Therefore, the Heatmap confirms the sensitivity of AI. Inspired from Samek *et al*.[9], and illustrated by the author.

Herein the question is "how to beneficially drag AI into the ecosystem of the Parasitology laboratory without affecting human power?" Of importance is the interactive role of human resource management (HRM) with the Parasitology staff and their assistants, particularly in Mega labs and central health care labs in tropical and subtropical countries. AI and automated technologies might be theoretically introduced to improve lab staff cognition and the overall performance of the Parasitology workplace. Yet, the actual application of AI is challenged by considerable anthropological and ethical issues that range from Parasitologist-robot cooperation to the entire replacement of a professional Parasitologist[10].

Can cyber threats challenge the application of AI in Parasitology labs? A computer virus can easily ruin a digital electronic file especially when repair data is restricted. Hence, patients' privacy and data protection can be simply threatened by an anonymous operator. In Mega labs, the patient code number in one unit is often interconnected to the full data dragged from other laboratory units. This was witnessed during the COVID-19 epidemic when hackers launched attacks on a large number of patients' accounts. Therefore, AI should be designated to deeply teach a machine to distinguish different patterns on the network and identify deviations or security forms prior to answering them. In other words, cyber challenges could be ultimately assisted by 'AI against AI'. Thereby, the chief goals that should be targeted involve: 1) data security where the challenge is to hinder entrance to secured data through multiple defensive and offensive programs; 2) controlling the network by preventing the taking over of a network or directing it; 3) intrusion detection by preventing the penetration of the network through an unnoticed hacker; 4) zero-day patching by finding, patching, and reporting security deviations in a timely pattern; 5) retained overall system running and even if it is partially undermined some fundamental parts are operating and the protection is achieved [Figure 3][13].

[II] Teaching Parasitology

The issue of could robots possess functional communication behavior and take over the mission of teaching to substitute Parasitology staff members, means that it is essential to transform the teaching practices in order to cope with these swift changes in technology.

Lectures and tutorial classes: Having to cope with a large number of students, the concerned universities implemented interactive learning to enhance the capability of staff members to deliver knowledge successfully, ascertain deeper understanding by the students, and attain feedback. Yet, this necessitates the development of an AI-empowered "Learning Management System" (LMS) to achieve interactive learning. It is noteworthy that intelligent tutoring systems exhibited better achievement compared with traditional classrooms and hard-copy materials[14].

Using technology would facilitate and improve the approach of clinical vignette-based learning. Students are trained to use AI-empowered software to obtain information from a given case, uncover differential diagnoses, select proper therapy, and predict risk factors. This improves productivity of the medical student. However, it is worth mentioning that the intelligent performance of the machine is chiefly a result of the authenticated knowledge and experience supplied by professional Parasitologists i.e., "AI agents are knowledge-rich, but methods-poor"[15].

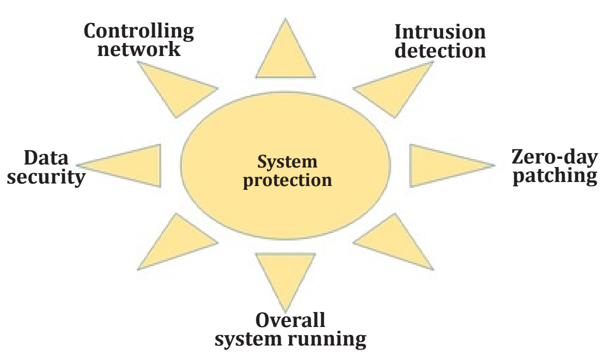

Fig. 3. Strategies of cybersecurity. Illustrated by the author.

Parasitology practical classes: The invention of virtual microscopy has been applied at Copperbelt University Medical School for Histology and Histopathology. In virtual microscopy, fields and images seen in conventional microscopy, can be projected as computer images[16]. Conversely, this tool can be easily adapted to be an educational tool suitable for Parasitology. Nevertheless, the entire replacement of human impact in teaching deprives students of vital social interactions thus improving behavioral and psychological characteristics that can't be handled by AI teachers.

Students' assignments: Generating 'Power-Point' slides is a time-consuming mission. Yet, manipulation of AI programs can facilitate the exploration and perception of information, execution of well-arranged texts, and suggest interesting inquiries about the proposed topic of assignment through a chat between the student and the robot. For example, NB2Slides which is an AI system has been proposed to facilitate the composition of presentation slides. NB2Slides is an example of machine deep learning to create a context in the form of a presentation derived from electronic books[17]. The generated presentation is informative and well-sectioned. Nevertheless, AI-empowered tools lack paralinguistic signs such as eye contact and body gesture[18]. Therefore, the face-to-face interaction between Parasitology staff members and their students remains to be important.

Student assessment: AI-based assessment relies on the identification of weak learning points identified by precise evaluation of the student's performance using tablets in classrooms. For example, the laboratory in University of Grenoble, Alpes, France, supervises students while solving a given task or assignment; thus, a teacher can evaluate a group of students efficiently. Moreover, in these AI-empowered systems, the students are not exposed to stress during the exam[19]. This application appears useful for the creation of graded checklists in Parasitology practical classes to promptly assess students' activities.

[III] Parasitology research

Can AI aid researchers to obtain proposals for research? Currently, PubMed is the most manipulated information retrieval system. It introduces high-quality information from a large volume of medical data. This in turn aids researchers to present supreme systematic reviews that serve medical and patients' health care. Nevertheless, the retrieval system takes time searching for data targeted with convenient keywords. It is worth mentioning that answering many points is not always possible. This raises the question of whether the application of "AI in Parasitology" weakens the real philosophy of research or improves it. By AI, vast amounts of data can be evaluated, introducing and explaining unexpected outcomes, experimental designs, adequate sample size, relationships, conclusions, references, and even recommending titles for the manuscript or the thesis with one click by the researcher.

Applied AI affords the exact answers in a few seconds instead of a full list of documents as in the case of the retrieval system. The AI and deep learning of a machine can also offer the next most vital experiment to accomplish certain research points. Competition in the technology of AI continues; e.g., SemBioNLQA software is introduced for its better performance in supplying summaries and answers to assay and yes/no questions compared with state-of-the-art systems. During the years 2019-2022 there has been a vast evolution in the world of algorithms and computers. Amazingly, more than 133 million roles have been developed to replace the older 75 million[20].

Despite the fact that AI automatically investigates a vast number of reviews and research articles, the keywords introduced by the users to the robot are important for accurate semantic or language analysis from the large database. Notably "semantic network" aids computers to understand the relationship between words similar to a dictionary. In real use, inaccurate keywords may lead to misunderstanding by the robot.

Restriction of AI involves the inability to pass the 'Turing test' in several situations. In 1950, Alan Turing conducted the original "Turing test" to determine if computers have achieved moral standing in determining priorities of medically critical conditions ("triage" situation) in a hospital. Accordingly, AI selects one patient to save his/her life bit is unable to manage another one[21].

Yet, the morality of AI will remain distinguished from the ethical attitude of humans guarded by the sense of God's teachings. Naik *et al.*[22] described AI as "nice to have". Herein, the development of a Turing-like test may be commended to help decide the practicality of AI in Clinical Parasitology and Tropical Medicine if a further clinical view can be provided by the robot; for example, in tissue-invading parasites e.g., neurocysticercosis, and cancer-triggering organisms such as *S. haematobium* and *C. sinensis*. As a disadvantage, AI would play the same role as calculators, and users of AI are going to be deprived of the passion to think, criticize, and search for information; thus this will lessen their mental capabilities[23].

Chat GPT is an Open-AI settled language in which a robot can yield a human-like manuscript depending on an enriched database. The GPT third-generation is now present and it relies on deep learning[24]. Yet, it failed to pass the aforementioned Turing Test[21]. Thus, it can be hypothesized that it still remains far for AI to manipulate information efficiently substituting human years-built experiences.

Autonomous experimentation and deep learning of machines to serve Parasitology research: The use of autonomous (self-directed) experimentation would enable the categorization of enormous amounts of information to produce fast replies to researchers. With the progression of computation, neural networks and communication channels entangle mimicking synaptic junctions in the human brain. Thus, autonomous experimentation aims to improve shallow learning of the machine to deep learning, where one neuron can respond to numerous stimuli from adjacent neurons and the entire network can adjust itself according to various inputs from the surroundings[25]. Recently Arias-Pérez *et al.*[26] deduced that AI and machine learning may simulate human minds to deep learning, analysis, and experimentation. Thus, the robot would be obliged to attain efficacious deep learning.

This demands continual checking, and fixing of any developing algorithmic errors; hence, increasing the precision of predictions[27,28]. This can be achieved via three methods: 1) supervised learning, where the task relies on an input that infers an output; 2) unsupervised learning, where the task is to learn from "test data" that have no labels and the machine reaction is based on the presence or absence of recognized mutual features in earlier data; 3) reinforced learning, where the machine ought to act within assumed circumstances. Amazingly, the robot may attain "rewards and penalties" via algorithms applied to the machine![29].

Can AI generate self-governing Parasitology research labs with autonomous calibration, i.e., independent adjustment and standardization? In autonomous experimentation, physical tests, simulations, or data deletion occur without human interference to produce outputs from registered inputs. Thereafter, the outcomes are automatically evaluated and represented. Lastly, the machine generates algorithms to propose for the subsequent experimental stage and the new sets of required inputs[30] [Figure 1-b]. Hence, the robot through a closed loop of independent adjustments generates new discoveries and results while saving the time and effort of a researcher doing repetitive tasks. Recently, Spiking Neural Network (SNN) was invented to estimate errors and autonomously adapt in order to acquire information. The network can fine-tune the speed and improve neuronal actions to absorb a huge dataset[29].

The expected role of AI to produce useful Parasitology research: The goal is to improve generalized machine learning, reasoning, problem-solving, interpreting quantitative data, and decision. Nevertheless, medicine requires knowledge rather than intelligence. Therefore, it is better to describe AI as a supplement to Parasitology researchers rather than a tool to replace them. Lichtenthaler[31] deduced that in unsafe workplaces, machine-driven power would be an advantageous substitute for humans. For example, in the field of Parasitology, using robots might be preferred for dealing with specimens containing the highly infectious eggs of *E. vermicularis* or *E. granulosus*. In Medical Parasitology, AI is increasingly important owing to development of anthelmintic multi-drug resistance. It is also important to overcome the broad spectrum of risks and the well-known pitfalls related to anti-parasite vaccine production. Indeed, AI may serve humanity by introducing innovative control measures for parasitic infections in poor countries. Examples of beneficial AI-assisted research are the production of a subunit multicellular parasite vaccine to control endemic infections in livestock and the determination of more precise therapeutic molecular targets[32,33].

CONCLUDING REMARKS

1. In Medical Parasitology, AI promises upcoming useful developments between the currently established AI-enabled technologies and future perspectives.
2. In Parasitology diagnostic facilities, robotic analysis of specimens may encourage the assessment of vast populations.
3. It would aid students and faculty staff members in higher educational institutes to fulfill their tasks professionally.
4. In Parasitology research, it would safeguard researchers working with infectious material, and encourage the development of vaccinations and other medicines.
5. Nonetheless, there are numerous shortcomings with AI. For example, it lacks the experience required by professional instead of experienced Parasitologists in a diagnostic lab. Furthermore, in the field of research, it should be recognized that AI has the potential to degrade the true philosophy of research as well as undermine cognition. In higher educational institutes, the lack of intellectual and social connections between AI-empowered technologies and students continues to be an essential point.
6. Accordingly, AI so far appears to be inadequate in replacing genuine professional Parasitologists in performing their multi-tasks.

Dr. Enas asked for this correction. Please check. I did not understand where she wanted to place her words?

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