PERCEPTION OF HEALTH CARE WORKERS ON ARTIFICIAL INTELLIGENCE BASED MALARIA DIAGNOSIS IN SOUTHWESTERN NIGERIA

O.S. Michael[1], E. Bukoye[2], P. Whiley[2], N. Idusuyi[2], P. Casserly[2,3], D. Ademola[2], A.O. Coker[2,4]

1. Department of Pharmacology and Therapeutics, College of Medicine, University of Ibadan, Nigeria
2. Department of Biomedical Engineering, Faculty of Technology, University of Ibadan, Nigeria
3. Institute for Global Health Technologies, Rice University, Texas, United States of America
4. Department of Civil Engineering, Faculty of Technology, University of Ibadan, Nigeria

Correspondence:
Dr. O.S. Michael
Dept. of Pharmacology and Therapeutics,
College of Medicine,
University of Ibadan,
Nigeria
Email: micobaro@gmail.com

Submission Date: 6th Sept., 2024
Date of Acceptance: 25th Dec., 2024
Publication Date: 31st Dec., 2024

ABSTRACT

***Background*: Effective control of malaria is anchored on accurate diagnosis. Conventional Methods of diagnosis include microscopy, and malaria rapid diagnosis. Many factors, particularly human error, diagnostic inaccuracies of microscopy due to human errors. The study reports the results of an online survey designed to assess the perception of health workers on artificial intelligence methods in the diagnosis of malaria.**

***Methodology*: An online, cross-sectional survey, conducted in April to August 2022. The study was conducted using Google forms. The knowledge of conventional methods of malaria diagnosis and willingness to accept artificial intelligence-based automated malaria diagnosis and parasite counts were assessed. The form (questionnaire) was delivered to emails and several WhatsApp groups.**

***Results*: Sixty seven responses were received over the study period, comprising medical doctors (30, 44.8%), medical laboratory scientists (18, 26.9%), postgraduate students (8, 11.9%), nurses (7, 10.4%), and students (4, 6.0%). All the respondents knew about conventional methods of malaria diagnosis. Majority of the respondents (41/67, 61.2%) reported that light microscopy was the most commonly used conventional method of malaria diagnosis. All the respondents reported that they were unaware of artificial intelligence-based malaria diagnosis. The respondents affirmed that artificial intelligence based malaria diagnosis will be a better alternative to the conventional methods and will improve the accuracy of malaria diagnosis.**

***Conclusion*: None of the respondents had knowledge of artificial intelligence-based malaria diagnosis; however, respondents affirmed that artificial intelligence-based malaria diagnosis will be a better alternative to conventional methods of malaria diagnosis.**

Keywords: Artificial intelligence, Malaria diagnosis, Nigeria

BACKGROUND

In 2021, an estimated 619,000 malaria deaths were recorded worldwide, with most deaths recorded in sub-Saharan Africa.[1] In Nigeria, malaria is highly endemic, accounting for about 60% of out-patient visits to almost all hospitals.[2] Prompt and accurate diagnosis of Malaria is essential for effective management and control of the disease. To date, microscopy remains the gold standard and the most widely used method of diagnosis in malaria endemic countries.[3] This method of diagnosis has many challenges.

In resource constrained settings microscopists are few and opportunities for qualitative training are scarce.[4] Regular quality control measures (to ensure that screening results are not affected by the physical state of microscopes and expertise of microscopists) are often not in place at primary and secondary health centers. Light microscopy is time consuming and may be significantly operator dependent. The results are variable from one microscopist to another and may be affected by user fatigue and expertise. There may also be frequent power outages. All these factors, particularly human errors, affect the quality of results of malaria microscopy.

Over the years, there has been a gradual shift from microscopy to rapid diagnosis using antigen and monoclonal antibody based techniques.[5] However, a potentially more powerful solution is the deployment of automated, artificial intelligence-based, techniques. The use of deep learning or artificial intelligence, software for image recognition and interpretation may hold the key to improving qualitative optical malaria

diagnosis[6]. Computer vision and image analysis devices are increasingly being used to diagnosis malaria[7]. Matthew P and colleagues in 2021[8] tested a fully automated malaria diagnosis system on a World Health organization (WHO) validated set of malaria parasite-positive slides. The system achieved a diagnostic accuracy of 94.3%. Emerging literature reveals that automated systems coupled with artificial intelligence are increasingly being developed as alternatives to manual laboratory procedures.[9]

With the rise in applications of artificial intelligence in optical-based diagnosis globally, to date, there is little research on the perception of their availability and use in the diagnosis of malaria among medical health practitioners in Nigeria. To address this gap, we conducted an online survey to assess the perception of health workers in southwestern Nigeria, on the availability and use of artificial intelligence techniques in the diagnosis of malaria. In this study, "perception" refers to the way respondents interpreted, understood, or viewed the emerging use of AI in malaria diagnosis based on their personal experiences, beliefs, and knowledge. The study aim included the assessment of how respondents perceived and made sense of various aspects of a AI in malaria diagnosis, their insights, attitudes, opinions, and behaviors. At the time of the study, there was scarcity of empirical data on health workers' perceptions of AI in malaria diagnosis. The study also sought to identify misconceptions about AI in malaria diagnosis and to evaluate areas where further education is needed so as inform strategies that could enhance the adoption and effective use of AI technologies in malaria diagnosis.

METHODOLOGY

Study design: This was an online cross-sectional survey carried conducted between April and August 2022.

Study population and inclusion criteria: Health workers reached during the survey were medical doctors, nurses, medical laboratory scientists, malaria microscopists, pharmacists and students of the different health professions. Most of the participants were workers at a Teaching Hospital in Ibadan, Oyo State, Nigeria. Investigators targeted those who were currently practicing at healthcare facilities as doctors, nurses, pharmacists, or laboratory scientists or students in biological fields, nursing, and medicine. Health workers were identified by the inclusion criteria stated in the questionnaire introductory statement and through a combination of demographic and professional questions which included professional title, occupation, department, field of specialization, years of experience, type of health facility, geographic location, and primary duties.

Survey questionnaire: The study was carried out using Google forms, a free service available on the Google platform. The questionnaire used for the survey was newly designed, pre-tested, and the link to it was sent by email and through WhatsApp groups to students and health workers of different specialties. The knowledge of conventional methods of malaria diagnosis (presumptive, light microscopy, and malaria rapid diagnosis) and willingness to accept artificial intelligence-based automated malaria diagnosis and parasite density estimation. Presumptive diagnosis of malaria was defined as the diagnosis of malaria based on the presenting symptoms, without laboratory diagnosis (microscopic confirmation of parasitaemia or RDT). The questionnaire was distributed to as many WhatsApp handles of health care professionals and students as could be reached. Responses that came in after set deadline (two weeks) for submission were set aside and were not used in the analysis.

Items covered in the survey questionnaire: The items covered included respondents (1) areas of specialization (2) knowledge of malaria diagnosis methods employed at healthcare facilities (3) knowledge of the most widely used method of malaria diagnosis (4) perception of the most reliable (accurate) method of malaria diagnosis (5) familiarity with automated (computer-based) methods of malaria diagnosis (6) knowledge of the use of artificial intelligence (AI) in malaria diagnosis (7) willingness to allow the use of AI methods of malaria diagnosis at healthcare centers (8) rating of AI based malaria diagnosis by respondents who have ever used them (9) willingness to accept the use of AI software in the diagnosis of malaria. Open responses on the challenges associated with conventional methods of malaria diagnosis were summarized under the categories of presumptive diagnosis, microscopy, malaria rapid diagnosis, and artificial intelligence based malaria diagnosis.

Sample size: This was a pilot study. There was no calculated or expected sample size.

Data analysis: The data was analyzed using Statistical Package for Social Sciences (SPSS) for Windows, version 23.0. Descriptive statistics were used. Categorical variables were reported as frequencies and percentages. Continuous variables were reported as mean and standard deviation.

Ethical considerations: Participation was voluntary and a cover letter enclosed in the questionnaire stated that the submission of a completed questionnaire was considered as consent to participate in the survey. Participants were informed that they could decline participation if they so desire. The letter also offered

a brief and concise description of the study, the benefits, respect for all participants, and confidentiality of respondents. Participants were assured of non-disclosure of identifiers. The questionnaire was sent to the emails and whatsapp groups daily during the first week of the study. At the end of the first week responses were collated as they were received.

RESULTS

Characteristics of the respondents: Sixty-seven responses were received over the set study period, comprising medical doctors (30 responses), medical laboratory scientists (18 responses), postgraduate students (eight responses), nurses (seven responses), and undergraduate students (four responses). The majority of respondents were medical doctors aged between 40 to 60 years. Table 1 summarizes the demographic characteristics of the sixty seven respondents.

Table 1: Demographic characteristics of the sixty seven respondents

Group	Number (%)	Male (%)	Age groups		
Age groups			20 – 39 years	40 – 60 years	Greater than 60 years
Doctors	30 (44.8)	18 (60)	9	17	4
Medical Laboratory Scientists	18 (26.9)	8 (44.4)	11	7	0
Postgraduate Students	8 (11.9)	7 (87.5)	5	3	0
Nurses	7 (10.4)	0	0	7	0
Undergraduate Students	4 (6.0)	2 (50)	4	0	0
Total (%)	67 (100)	35 (52.2)	29 (43.3)	34 (50.7)	4 (6.0)

All the respondents were aware of conventional methods of malaria diagnosis including presumptive, malaria microscopy, and rapid diagnosis test (RDT). When asked about their knowledge of the most commonly used malaria diagnosis methods, the responses varied with the groups. A majority of the respondents (41/67, 61.2%) reported that light microscopy was the most commonly used conventional method of malaria diagnosis. Seven respondents reported that presumptive malaria diagnosis was the most commonly used method. On the question of their perception of the most reliable conventional method of malaria diagnosis, a majority (59/67, 88.1%) responded that light microscopy was the most reliable conventional method of malaria diagnosis. The different groups also provided varied responses to their perception of which of the conventional methods was considered as the most reliable method of malaria diagnosis. Table 2 summarizes responses to perception of the reliability and accuracy of conventional methods of malaria diagnosis.

When asked about their awareness of the use of artificial intelligence software in the diagnosis of malaria, none of the respondents reported that they were aware of artificial intelligence-based malaria diagnosis. On their willingness to use an artificial intelligence based malaria diagnosis software in the diagnosis of malaria, majority of the respondents (60/67, 89.5%) replied that they were willing to use artificial intelligence-based platforms for the diagnosis of malaria. However, all respondents responded that they would accept the results of artificial intelligence-based malaria diagnosis. On the question of their perception of the acceptance of artificial intelligence based malaria diagnosis results by Nigerians, all respondents (67/67, 100%) reported that they believe that artificial

Table 2: Perception of the reliability and accuracy of conventional methods of malaria diagnosis

	Most commonly used conventional method of malaria diagnosis			Most reliable conventional method of malaria diagnosis		
	Presumptive	Light Microscopy	Rapid Diagnosis (RDT)	Presumptive	Light Microscopy	Rapid Diagnosis (RDT)
Doctors	3	17	10	1	26	3
Medical Laboratory Scientists	0	15	3	0	18	0
Postgraduate Students	1	6	1	0	6	2
Nurses	2	2	3	1	5	1
Undergraduate Students	1	1	2	0	4	0
Total (%)	7 (10.4)	41 (61.2)	19 (28.4)	2 (3.0)	59 (88.1)	6 (8.9)

intelligence-based malaria diagnosis results will be accepted by the community. Table 3 summarizes respondents' awareness of the use of artificial intelligence software in the diagnosis of malaria.

Table 3: Awareness of the use of and willingness to use artificial intelligence software in the diagnosis of malaria

	Awareness of the use of Artificial Intelligence-based software for malaria diagnosis			Willingness to use an artificial intelligence based malaria diagnosis software		
	Yes	**No**	**No response**	**Yes**	**No**	**No response**
Doctors	0	30	0	24	6	0
Medical Laboratory Scientists	0	18	0	18	0	0
Postgraduate students	0	8	0	8	0	0
Nurses	0	7	0	6	1	0
Undergraduate Students	0	4	0	4	0	0
Total (%)	0	67 (100)	0	60 (89.5)	7 (10.5)	0

All the participants provided responses and comments to open ended options of the questionnaire questions. These were categorized under the different conventional methods of malaria diagnosis. On their perception of presumptive diagnosis of malaria, they responded that the method was not objective, not accurate; prone to errors due to many other diseases with symptoms similar to malaria, and that the method should be discouraged. Respondents recommended that presumptive diagnosis of malaria should be combined with the other objective methods of malaria diagnosis (light microscopy and rapid diagnosis). On the use of light microscopy for the diagnosis of malaria, the respondents provided responses to challenges of the method. They commented that light microscopy was stressful to the eyes especially when the microscopist had to screen multiple slides in a busy setting; this increases the likelihood of human error. They also responded that light microscopy had a long turnaround time, frequently hampered by power outages, poor preparation of blood smears, scarcity of reagents for Giemsa and other stains, poor reagent storage conditions, pain during finger pricks, difficulty with parasite identification especially where parasite density is low, poor maintenance of microscopes, results highly dependent on expertise of the microscopist, and scarcity of expert microscopists.

Respondents provided their perception of the use of malaria rapid diagnosis test (mRDT). Reported challenges with the method were scarcity of test kits, proliferation of substandard and often expired test kits, high frequency of false negative results especially with low parasite densities, pain during finger pricking, not useful in the quantification of parasite density, persistence of positivity even after effective malaria treatment, most of the kits can test for only *Plasmodium falciparum* and not the other malaria species, and low knowledge of how to use the kits by the end users. All the respondents stated that the use of automated methods of malaria diagnosis (artificial intelligence) will make the diagnosis of malaria easier, faster, and more accurate.

DISCUSSION

The study received 67 responses from various health professionals, including medical doctors, medical laboratory scientists, postgraduate and undergraduate students, and nurses. Most respondents were medical doctors aged between 40 to 60 years. All respondents were knowledgeable about conventional malaria diagnostic methods, with the majority considering light microscopy as the most commonly used and most reliable method. Despite this, none of the respondents were aware of the use of artificial intelligence (AI) for malaria diagnosis. However, a significant majority expressed willingness to adopt AI-based diagnostic software, with all believing that the community would accept AI-based results. All respondents agreed that AI-based methods could improve accuracy, speed, and ease of malaria diagnosis.

Malaria causes a high burden of morbidity and mortality in malaria endemic countries. The three routine methods of malaria diagnosis are presumptive, light microscopy, and malaria rapid diagnosis. Presumptive diagnosis is the diagnosis of malaria made on the basis of the presenting symptoms, without microscopic confirmation of parasitaemia.[10] This method of diagnosis is associated with significant risk of error and wrong treatment.[11] Despite this, presumptive diagnosis of malaria is common especially in resource constrained settings. Respondents in our study stated that presumptive diagnosis was too subjective, had a high rate of errors, and that the method should be should be discouraged. This view is held by many stakeholders in malaria endemic countries. These contributed to the world health

organization recommendation that the diagnosis of malaria should be parasite based, that it should be supported by a laboratory test.[12] With this recommendation light microscopy and malaria rapid diagnosis methods have been the corner stone of malaria diagnosis.

For many decades light microscopy was the only available laboratory method for the detection of peripheral malaria parasites in the blood. Light microscopy is the recommended method and current gold standard used for the routine laboratory diagnosis of malaria. This is done through the microscopic examination of stained thin and thick blood films. Unfortunately, the method has challenges. Respondents in our survey mentioned that the requirement for skilled laboratory scientists, human fatigue, human error, power outages, long turnaround time, scarcity of expert malaria microscopists, problems with blood smear preparation, poorly maintained microscopes, and the need for repeated training of microscopists are some of the challenges of manual malaria microscopy. The diagnosis of malaria is essential to the treatment and thus determining the probability of an infection case progressing to severe and complicated malaria.[13] Respondents identified the time lapse before getting a diagnosis result as a major challenge in the diagnosis of malaria in resource constrained settings. A lot of these challenges have been reduced to minimal by the introduction of immunochromatographic tests (malaria rapid diagnosis tests).

Immunochromatographic dipsticks offer the possibility of more rapid, non-microscopic methods of malaria diagnosis, thereby saving on the need for training and retraining of expert malaria microscopists.[14] The tests are easy to perform and require little training and time. Again there are challenges with the use of rapid malaria diagnosis tests. Malaria rapid diagnosis tests have varying accuracies depending on factors that include peripheral parasite density and technical limitations that include inability to differentiate between species.[15] To date a negative report on malaria rapid diagnosis may still require confirmation by light microscopy. In very busy clinics reliance on light microscopy becomes very challenging. A potential solution to these challenges is automation and the use of artificial intelligence. This has the potential of eliminating human error and significantly reducing the turn around time of manual light microscopy.

Automation of laboratory processes offers many advantages; one advantage is significant reduction in human fatigue and error. Coupled with artificial intelligence, image recognition, potential applications in malaria diagnosis are very promising. The development of automated malaria detection techniques is gaining increasing attention globally.[16] Automated detection of malaria parasites is faster with higher accuracy compared to the traditional technique using microscopy.[16] Jung Yoon and colleagues in 2021[17] reported an automated microscopic malaria parasite detection system using digital image analysis with impressive accuracy. They reported that the automated microscopic malaria parasite detection system showed a high degree of linearity for *Plasmodium falciparum* culture ($R = 0.958$, $p = 0.005$) and *Plasmodium vivax* infected samples ($R = 0.931$, $p = 0.008$). The system was able to detect parasitemia lower than that for microscopic examination for all parasite densities. They reported a limit of detection of approximated 0.00066112%. The authors also reported that the sensitivity and specificity of the system was 100% (n = 21/21) and 100% (n = 50/50), respectively, and that the system correctly identified all *P. vivax* and *P. falciparum* species in the blood samples. They concluded that the automated microscopic malaria parasite detection system offered several advantages over conventional microscopy for rapid diagnosis and parasite density monitoring of malaria. This degree of accuracy from automation will be a big boost in the present era of malaria elimination. Malaria endemic countries will definitely benefit from the rise in the use of automation and artificial intelligence in the diagnosis of malaria.

Nigeria currently bears the largest burden of malaria in the world[1] and it is very likely that artificial intelligence malaria diagnosis platforms will be deployed in the country in the near future. Effective integration of new technologies requires studies of perception of members of the community. Our survey revealed that those that responded to the questions had no knowledge of this new development. It also showed that respondents were eager to have the technology functional at healthcare centers in the country. There is thus the need to further generate data on the likelihood of effective use of the technology.

Nina Schwalbe and BrianWahl in 2020[18] wrote that concurrent advances in information technology infrastructure and mobile computing power in many low and middle-income countries have raised hopes that artificial intelligence might help to address challenges unique to the field of global health and accelerate achievement of the health-related sustainable development goals. They concluded that although some challenges of developing and deploying these interventions may exist at these settings, the global health community will need to work quickly to establish guidelines for development, testing, and use, and

develop a user-driven research agenda to facilitate equitable and ethical use of these emerging technologies.

STUDY LIMITATIONS

Our study is limited by small sample size and errors inherent in online surveys. The population of those that responded, their biases, reason that motivated their responses, those that received the questionnaire but did not respond could not be described. This significantly limits the generalization of our research findings. We recommend more studies along this area of artificial intelligence in the diagnosis of malaria. More data will provide a better description of the perception of the use of artificial malaria diagnosis among more members of the community.

CONCLUSION

All the respondents from the survey stated that they were not aware of artificial intelligence based malaria diagnosis; however, respondents affirmed that artificial intelligence based malaria diagnosis would be a better alternative to the conventional methods and that it would improve the accuracy of malaria diagnosis. Respondents stated that they would be willing to accept results of artificial intelligence based malaria diagnosis and to use artificial intelligence based software for malaria diagnosis. With increasing development of artificial intelligence based malaria diagnosis platforms in recent years, the integration of the technology into the healthcare delivery holds the promise of increasing accuracy and supporting malaria control and elimination drives in malaria endemic countries.

Conflict of Interest Declaration

Authors have no conflict of interest to declare.

REFERENCES

1. WHO. World malaria report 2022: World Health Organization; 2022.
2. **Michael GC,** Aliyu I, Grema BA. Knowledge of malaria and adherence to its preventive measures among adults attending out-patient clinics of a Nigerian tertiary hospital: Has anything changed? African Journal of Medical and Health Sciences¦ Volume. 2017;16(1).
3. **Wilson ML.** Laboratory diagnosis of malaria: conventional and rapid diagnostic methods. Archives of Pathology and Laboratory Medicine. 2013;137(6):805-811.
4. **Varo R,** Balanza N, Mayor A, Bassat Q. Diagnosis of clinical malaria in endemic settings. Expert Review of Anti-infective Therapy. 2021;19(1):79-92.
5. **Mukkala AN,** Kwan J, Lau R, *et al.* An update on malaria rapid diagnostic tests. Current infectious disease reports. 2018;20(12):1-8.
6. **Thakur A,** Kumar A. Role of Artificial Intelligence-Based Technologies in Healthcare to Combat Critical Diseases. Digital Health Transformation with Blockchain and Artificial Intelligence: CRC Press; 2022. 195-218.
7. **Tek FB,** Dempster AG, Kale I. Computer vision for microscopy diagnosis of malaria. Malaria journal. 2009;8(1):1-14.
8. **Horning MP,** Delahunt CB, Bachman CM, *et al.* Performance of a fully automated system on a WHO malaria microscopy evaluation slide set. Malaria journal. 2021;20(1):1-11.
9. **Herman DS,** Rhoads DD, Schulz WL, Durant TJ. Artificial intelligence and mapping a new direction in laboratory medicine: a review. Clinical Chemistry. 2021;67(11):1466-1482.
10. **Carosi G,** Casteli F. Handbook of malaria infection in the tropics. Handbook of Malaria infection in the tropics1997; 250.
11. **Olivar M,** Develoux M, Abari AC, Loutan L. Presumptive diagnosis of malaria results in a significant risk of mistreatment of children in urban Sahel. Transactions of the Royal Society of Tropical Medicine and Hygiene. 1991;85(6):729-730.
12. WHO. Universal access to malaria diagnostic testing: an operational manual. 2011.
13. **Stauffer W,** Fischer PR. Diagnosis and treatment of malaria in children. Clinical infectious diseases. 2003;37(10):1340-1348.
14. **Moody A.** Rapid diagnostic tests for malaria parasites. Clinical microbiology reviews. 2002;15 (1):66-78.
15. **Murray CK,** Bell D, Gasser RA, Wongsrichanalai C. Rapid diagnostic testing for malaria. Tropical Medicine & International Health. 2003;8(10):876-883.
16. **Mustafa WA,** Alquran H, Aihsan MZ, *et al.*, editors. Malaria parasite diagnosis using computational techniques: a comprehensive review. Journal of Physics: Conference Series; 2021: IOP Publishing.
17. **Yoon J,** Jang WS, Nam J, Mihn D-C, Lim CS. An automated microscopic malaria parasite detection system using digital image analysis. Diagnostics. 2021;11(3):527.
18. **Schwalbe N,** Wahl B. Artificial intelligence and the future of global health. The Lancet. 2020; 395 (10236):1579-1586.