Applications, opportunities and challenges of implementing artificial intelligence in medicinea

Javier Santiago Álvarez-Guachichulca [a], Damary Jaramillo-Aguilar [b], Andrea Ximena López-Becerra [c]

a. Physician. University of Cuenca, Cuenca, Ecuador. ORCID: https://orcid.org/0000-0002-1462-8144

b. Physician. School of Medicine, Faculty of Medical Sciences, University of Cuenca. Cuenca, Ecuador. ORCID: https://orcid.org/0000-0002-8676-2473

c. Physician. Private Hospital Tungurahua. ESMEDICAS S.A. ORCID: https://orcid.org/0009-0005-2425-7235

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Abstract

Artificial intelligence is widely used in various fields of medicine. The aim of this review is to describe the main applications, opportunities and challenges of artificial intelligence in medicine, providing an overview of the current context. A narrative review of the literature was performed to identify the most recent and relevant information on the topic. The electronic databases PubMed, Scopus and SciELO were consulted, from January 2019 to March 2024, in both English and Spanish. Systematic and non-systematic literature reviews, scoping reviews, original articles and book chapters were included. Duplicate articles, unclear scientific articles, articles with low scientific rigor and gray literature were excluded. The application of artificial intelligence in medicine has brought remarkable benefits, ranging from the capture of medical information to the discovery of new drugs. It has brought about a revolution in the traditional way of practicing medicine. On the other hand, it has brought challenges in terms of accuracy, reliability, ethics, privacy, and others. It is critical to maintain a patient-centered approach and ensure that these technologies are used to improve health outcomes and promote equity in access to medical care. Collaboration among healthcare professionals, researchers, regulators, and technology developers will be critical to addressing these challenges and realizing the full potential of artificial intelligence.

Keywords: artificial intelligence, healthcare, machine learning.

Resumen

La inteligencia artificial se está usando ampliamente en diversos campos de la medicina. El objetivo de esta revisión es describir las principales aplicaciones, oportunidades y desafíos de la inteligencia artificial en medicina brindando una perspectiva del contexto actual. Se realizó una revisión narrativa de la literatura, identificando la información más actualizada y relevante sobre el tema. Se consultaron las bases de datos electrónicas PubMed, Scopus y SciELO, desde enero de 2019 a marzo de 2024, tanto en inglés como en español. Se incluyeron revisiones sistemáticas y no sistemáticas de la literatura, scoping reviews, artículos originales y capítulos de libros. Se excluyeron artículos duplicados, trabajos científicos poco claros, aquellos de bajo rigor científico y literatura gris. La implementación de la inteligencia artificial en medicina ha traído consigo notables beneficios, que van desde el registro de información médica hasta el descubrimiento de nuevos fármacos. Ha generado una revolución en la forma tradicional de hacer medicina. Por otro lado, ha traído consigo desafíos en materia de precisión, confiabilidad, ética, privacidad, entre otros. Es crucial mantener un enfoque centrado en el paciente y garantizar que estas tecnologías se utilicen para mejorar los resultados en salud y promover la equidad en el acceso a la atención médica. La colaboración entre profesionales de la salud, investigadores, entidades reguladoras y desarrolladores de tecnología será fundamental para enfrentar estos desafíos y aprovechar todo el potencial de la inteligencia artificial.

Palabras clave: inteligencia artificial, atención médica, aprendizaje automático.

Introduction

Artificial Intelligence (AI) is a discipline that has undergone accelerated development in recent years. John McCarthy coined the term in 1955, defining it as "the science and engineering of creating intelligent machines" (1). AI uses computer technology to research and develop methods, techniques, and application systems for simulating, extending, and augmenting human intelligence (2). In recent years, the development of AI has attracted great interest with the implementation of new models and practical applications. In addition, AI has been widely used in various fields and plays an important role in technological improvement. The combination of AI and medicine is particularly promising and has changed the traditional medical

model (3). For example, the diagnosis of a patient based on radiological, pathological, endoscopic, ultrasonographic, and biochemical examinations has been effectively promoted with increased accuracy and reduced human workload (4-9). Medical treatments during the perioperative period, including preoperative preparation, surgical period, and postoperative recovery period, have been significantly improved with superior surgical outcomes (10-13). In addition, AI-based technology has also played a crucial role in drug manufacturing, medical management, and medical education, taking them in a new direction (14-17).

The need to implement advanced digital devices has become a requirement to provide greater patient satisfaction by enabling tracking, health status verification, and improved medication adherence (18). Digital health technologies include health information technology, wearable devices, telehealth, telemedicine, mobile Internet devices, personalized medicine, and others (19). These technologies have contributed to the early detection of life-threatening diseases and the remote management of chronic diseases, following a novel method to monitor adherence to treatment (20).

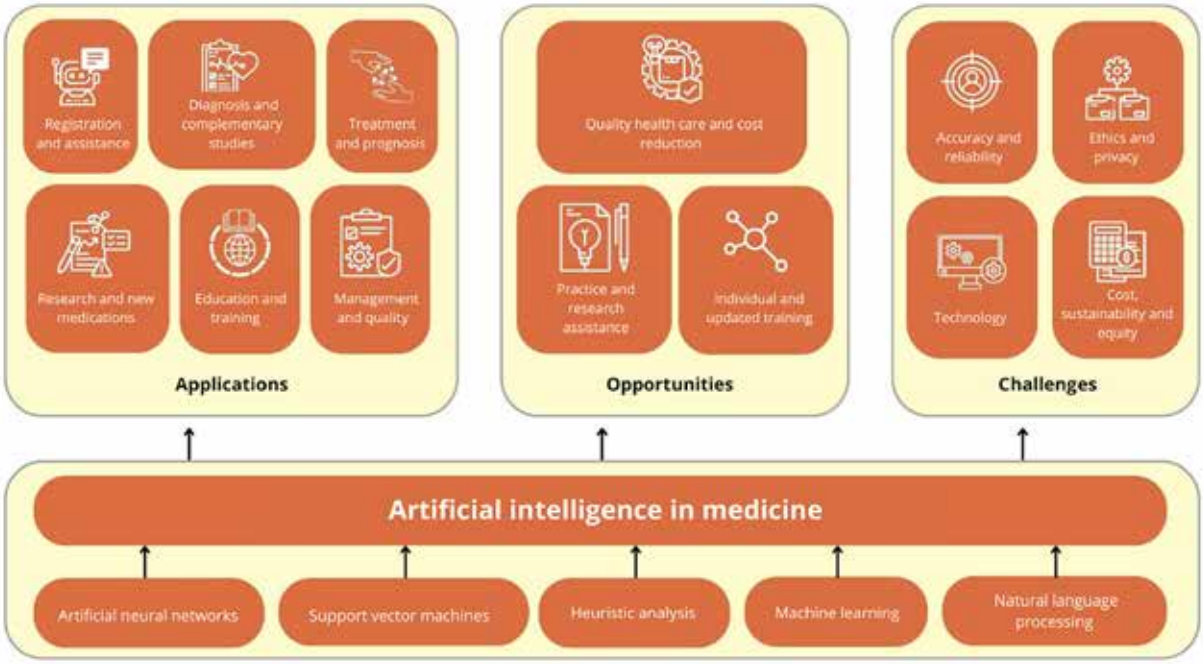
New AI-powered digital tools offer healthcare providers a broader view of a patient's health by giving them access to a wealth of information in a very short time. In this context, there are real opportunities to improve the therapeutic outcomes of modern medicine, while new challenges are emerging. The aim of this review is to describe the main applications, opportunities and challenges of AI in medicine by providing an overview of the current context.

Materiales y métodos

A narrative review of the literature was conducted to identify the most recent and relevant information on the topic of study to answer the following research question: what are the applications, opportunities and challenges of implementing AI in medicine? For this purpose, a literature search was conducted in the electronic databases PubMed, Scopus and SciELO, from January 2019 to March 2024, in both English and Spanish, using the keywords: application, opportunities, challenges, artificial intelligence and medicine, as well as their respective translations and variations. To combine these terms, AND was used as the Boolean operator. A manual review of the bibliographic references of the selected articles was also performed. A total of 75 articles included in the bibliographic references of the manuscript were selected and grouped into the following categories: applications,

opportunities, and challenges, as shown in Figure 1. These included systematic and non-systematic literature reviews, scoping reviews, original articles, and book chapters published in high-impact journals that made a major contribution to the topic under review. The authors independently assessed the methodological quality of the studies; discrepancies were discussed and resolved jointly. Duplicate articles, unclear scientific papers, papers of low scientific rigor and gray literature were excluded.

Figure 1. Analytical categories of literature review



Results

1. Applications

The implementation of artificial intelligence (AI) and advanced digital technologies has led to a proliferation of opportunities in the healthcare sector (21). The following section will delineate the current applications and benefits derived from the adoption of AI in this field.

1.1 Information gathering, medical care and communication

The integration of artificial intelligence (AI) has led to significant advancements in the realm of medical data collection, transcription, and analysis. Specifically, the application of AI in the context of electronic medical records (EMRs) has been instrumental in the transcription of doctor-patient conversations, as well as the analysis of EMRs generated from direct patient interactions. The significance of EMRs in healthcare systems cannot be overstated, as they encompass a wealth of patient-related information, including personal and family history, diagnoses, additional tests, and treatments. Subsequent to collection, these data are stored, processed, and analyzed by the AI according to the needs of the patient and the physician (see Figure 1) (26, 27). Moreover, these records serve as the foundation for the development of AI-based research, including the optimization and personalization of medical treatments, the discovery of new drugs and therapies, and the design of predictive models of risk or disease, among others (26).

Conversely, these tools facilitate physician-patient communication and interaction in multilingual environments through the automatic translation of medical documents, clinical notes, and interviews in real time (25,28). Additionally, they provide assistance to the patient in answering health queries, thereby improving accessibility to medical information, facilitating the identification and understanding of the reason for the consultation or the patient's current health status, and the encounter between the patient and the healthcare provider (25,29). Nonetheless, the analysis of complex clinical-surgical cases and nonverbal language represents potential limitations of artificial intelligence in this domain (22). Consequently, a review and correction of the content generated by the medical staff is required to ensure comprehensive, accurate, quality, and compassionate care.

1.2 Assisted diagnosis and complementary studies

During physical examination, AI significantly improves diagnostic accuracy and compensates for poor auscultatory skills (30,31). These technologies allow the detection of pathological heart and lung sounds, as well as the

identification of characteristic patterns for diseases such as Parkinson's and COVID-19 (23,32). In addition, AI enables accurate assessment of dermatological lesions (24,32,33). Analysis of these data, along with other data such as medical images, laboratory studies, and previous electronic medical records, provides the physician with a wide range of potential differential diagnoses using machine learning algorithms, which automatically detect diseases and classify them (24,29,34,35). Also, AI tools facilitate understanding and support the discussion of complex clinical and surgical diagnoses (24,25,32). Their performance has been found to be comparable to that of specialized physicians and outperforms those with less experience (36,37). However, more prospective studies or trials on the subject are needed (38). Integrating AI into medical care not only streamlines the process and improves diagnostic accuracy, but also improves medical outcomes, optimizes workflow, and reduces procedural burden (29,34,39).

Another important aspect is that AI algorithms can analyze and interpret laboratory test results (e.g., blood, urine, cerebrospinal fluid, etc.), and identify patterns and alterations suggestive of certain diseases or medical conditions (35,40-42). In addition, these models have enabled accurate assessment of complex molecular data to facilitate the diagnosis and management of genomic disorders (43). AI can predict results based on previous laboratory tests and recommend sensitive and specific laboratory tests based on the patient's symptoms and signs, medical history, and risk factors (40-42). In turn, they can continuously monitor the results of laboratory tests, detecting significant changes and facilitating the follow-up of the evolution of the disease (42).

Regarding the application of AI in structural pathology, it has allowed the precise classification of images of prostatic, dermatological and gynecological neoplasms by identifying specific morphological patterns (23,24,32,39). Similarly, in radiology, AI has proven to be highly effective in the classification of pulmonary nodules, thyroid and tumor lesions, as well as in the early diagnosis of various diseases (e.g., retinal conditions, gastrointestinal and breast cancers, cerebrovascular events, neurological diseases, rheumatoid arthritis, etc.) (23,24,32-34,39,44). These tools facilitate report generation, follow-up planning, data storage and image acquisition. In addition, they offer personalized recommendations for clinical and surgical applications (24,25,33). All of this is accomplished through the use of deep learning algorithms and the processing of medical images and multimedia data (28,33).

1.3 Personalized treatment, evolution and prognosis

AI has improved patient outcomes and the overall healthcare experience by developing accurate and personalized treatment plans through the analysis of genomic and phenotypic data for various diseases (24). AI algorithms have the ability to identify disease-associated genetic variations, predict patient outcomes, and tailor key treatment options (23,25,39). In addition, AI tools are used in real-time or retrospectively to plan complex clinical and surgical interventions, monitor patient health data, predict potential adverse events, perform minimally invasive procedures, and assist in patient recovery and rehabilitation in the postoperative period (10-13,22,25,25,39,45). Also, AI can accurately predict the risk of developing certain diseases, their evolution and prognosis by analyzing big data and using predictive models (23,34,35). Similarly, AI also helps physicians make informed decisions about patient care, management and treatment, which contributes to more effective, personalized and safer medical care (35,46). AI has even been used for patient video surveillance (28).

1.4 Medical research and development of new drugs

In terms of research, AI has revolutionized big data analysis and the identification of predictive patterns, while at the same time accelerating patient recruitment, improving screening processes, assisted diagnosis and treatment, and risk stratification (23,24,39,47). AI has also facilitated the exchange of medical data between different institutions, which has accelerated advances in public health by generating evidence on the safety and effectiveness of medical interventions (28,48,49). It has also provided solid support to researchers by facilitating the search for information, identification of barriers and facilitators, data analysis, hypothesis generation, scientific writing, translation, objective evaluation, among others (25,29). In addition, AI has been applied in the prediction, detection, classification, control and prevention of health emergencies, using automatic and deep learning techniques (23,24,34). The handling of the pandemic by COVID-19 is a clear example of the effectiveness of AI applied in this field.

For their part, both the pharmaceutical and biotechnology industries have developed models that have simplified and accelerated the design, classification and prediction of the properties, drug-receptor interactions and reactions of the most effective pharmacological compounds (22,24). These innovative tools have not only streamlined clinical trials and reduced the costs associated with research, but have also paved the way for the de-

velopment of new drugs (24).

1.5 Management and quality of care services

The application of AI has significantly transformed the traditional form of hospital management by taking advantage of the use of automation and optimization technologies, among others (22,29). Predictive models have been implemented to anticipate waiting times and in-hospital complications (e.g., sepsis, respiratory infections, depression, etc.), reduce hospitalization times and in-hospital mortality rates, optimize resources, increase the efficiency of services and predict readmission rates (22,23,29,39). In addition, AI has significantly improved clinical record generation, data integration and standardization, fraudulent claims detection and operational cost reduction (24,28).

1.6 Medical education and continuing training

AI-based systems have been employed to enhance the experience and complement the learning and continuing education of undergraduate and graduate medical students through intelligent tutoring and immersive and interactive virtual learning environments (50-54). In such a way, AI has helped students to recognize and diagnose various diseases and conditions, as well as predict outcomes, optimize treatment plans, identify potential complications, make clinical decisions, and improve their surgical skills (51-53). In addition, AI has been used in the objective assessment of learning and curricula (50,53).

Knowing this, after the incorporation of AI, patients, healthcare personnel, healthcare institutions and the healthcare sector in general have experienced remarkable benefits, with promising prospects for the future (34,55). AI tools have introduced innovative and relevant solutions, improving the quality of user care, communication and interaction in multilingual medical environments, and accelerated the process of diagnosis, treatment and research (25,28,29,34).

2. Opportunities

As the volume of data grows and new methodologies and learning approaches are developed, AI tools are expected to become increasingly accurate (56). For, their implementation promises to significantly improve the quality of care, reduce medical costs, and streamline work across specialty areas and care services (21). These technologies will also perform routine administrative and operational tasks with solvency, without human assistance (21). Therefore, it is anticipated that, in the future, machine learning and

automated assistance will be an integral part of health care institutions (57). Although it has been posited that AI could overtake expert physicians, these tools are and will continue to be an adjunct in daily medical practice (58,59). Similarly, AI will completely transform medical education systems through active and individualized learning, writing and research assistance (60,61); it is imperative to carefully integrate it now (60). In addition, the evolution of these technologies will generate new jobs in software development, data management and patient care (56).

On the other hand, it is important to highlight that the patient will be able to actively participate in the diagnostic and therapeutic process of the disease, as well as to explore new and personalized treatment options, and to follow his or her progress in an informed and independent manner. In addition, the integration of physiological, psychological, behavioral and environmental data into clinical analysis will allow a holistic understanding of the patient's condition and personalization of treatment (56). It is also believed that these tools will boost public health research and provide support in the identification of at-risk populations, health promotion, as well as in prediction, prevention, surveillance, disease management, and outcome assessment (21,62). They will also facilitate evidence-based decision making through systematic and automated real-time reviews of the medical literature (62). Finally, new drug development will benefit from the incorporation of biology and chemistry knowledge into AI models (56). Thus, as these technologies mature and new forms of AI emerge, opportunities will arise that will transform traditional medicine (59).

3. Challenges

Although we can predict an optimistic future for AI in healthcare, where its capabilities and possibilities are practically unlimited, we must also be aware of the challenges and problems presented by its integration into healthcare. The diversity of healthcare settings and situations combined with a purely mechanical technology based on machine learning may generate certain difficulties (28). The challenges of AI in the healthcare sector are related to the following aspects:

3.1 Accuracy and reliability challenges

The complexity of medical care, with its multiple environmental and situational variables, hinders the application of AI in the diagnosis and treatment of disease. These factors, often not digitized or too complex to code, are crucial for accurate and personalized care. The lack of contextual informa-

tion in AI training data limits the validity and applicability of its decisions, making it difficult for medical staff to understand and justify them. AI cannot yet replace human judgment in medical decision making, as its approach is based on existing data and not on the particularities of each case (25,28). The paucity of high-quality data for training and evaluation of AI models can lead to biases, predictions, and inaccurate diagnoses. AI algorithms may be biased if the data used to train them are not representative of the target population. Investment in research and development of more transparent algorithms, along with the implementation of control and monitoring mechanisms, are key to overcoming these obstacles (63).

3.2 Ethical and privacy challenges

It is important to keep in mind that AI can make mistakes in certain situations because its decision making is based on probabilistic predictions. Therefore, it requires strict adherence to laws, regulations, and clear rules about who is legally responsible in cases where AI fails or causes harm (64). Clinical judgment has always been the domain of trained and certified health care professionals. However, the increased use of AI decision support systems to assist with clinical tasks may affect the professional liability of health care providers to their patients (65). In addition, for AI models to work effectively, a large amount of data will be needed, which may raise concerns about the privacy and security of those providing that data, both clinicians and patients (66,67). The implementation of AI in healthcare faces major challenges in data management, technical security, and ethical approval. Therefore, it is crucial to ensure issues of privacy, accountability, intellectual property rights, transparency, human oversight, nondiscrimination, equity, social welfare, and affordability in the use of AI in healthcare (68). However, the lack of uniformity in health care systems across countries, regions, and hospitals makes it difficult to collect data and thus to regulate these systems legally and ethically (33,69).

3.3 Technological challenges

The transition from traditional to AI computing architectures presents considerable technological challenges. Implementing AI on a large scale requires a robust and scalable infrastructure that can support computational and data load. In addition, integrating AI with existing computing systems can be complicated and require custom solutions. New processors for AI offer greater power and efficiency but also require changes to traditional computing infrastructure (57). However, implementing these infrastructu-

res and storages can be complex and costly for organizations with limited resources (70). On the other hand, low familiarity with digital technology among some healthcare professionals, such as physicians, nurses, nursing assistants, etc., may be a barrier to the adoption of AI in healthcare. Healthcare professionals may be reluctant to use new technologies such as AI. The learning curve for AI tools can be steep, difficult, and overwhelming for some users, especially those unfamiliar with digital technologies (21). Healthcare professional medical students may not be able to use AI tools effectively if they do not have the necessary training, skills, and knowledge for implementing it in medical settings (54,58,71). Therefore, it is necessary for medical schools to teach future physicians the necessary skills to work, manage and interact with AI (53,72), only in this way will the quality of patient care be improved and assured (54).

3.4 Economic, sustainability and equity challenges

New advances in hardware and training techniques have created larger and more accurate neural networks with remarkable advances in the accuracy of various language processing tasks. However, their accuracy depends on considerable computational resources, which in turn demand significant energy consumption. Consequently, training and development of these models is costly, both financially (for hardware, electricity, or cloud computing time) and environmentally (for the carbon footprint of the processing hardware) (73). The high cost of the models could limit access to this technology, so solutions are needed to make AI more sustainable and accessible. So too, the implementation of AI in healthcare in high-income countries represents a challenge for low- and middle-income countries (LMICs). The data used to develop AI in high-income countries do not reflect the context of LMICs, leading to biases in predictive models. This bias threatens the promise of AI to democratize health services. AI systems are trained with data specific to the context in which they are developed so implementation of AI created in high-income countries and applied in LMICs may generate erroneous results due to differences in health systems, epidemiology, and socioeconomic factors (74). Building decision-support tools for primary care with erroneous data may generate inaccurate results and harm patients. Advantaged AI development in high-income countries may concentrate resources and decision-making power in a limited group, increasing inequity in access to care (75).

Conclusion

The integration of AI in medicine has brought about a significant change in the way healthcare is delivered. It has been implemented in a variety of medical situations, from disease diagnosis to data management and pharmaceutical research. AI's ability to improve diagnostic accuracy, personalized treatment and optimize resource management has been central to its adoption in the healthcare field. However, along with the benefits, there are also challenges to consider. The accuracy and reliability of AI algorithms, data ethics and privacy, technological challenges, and cost and equity issues are areas that require attention and solutions. Addressing these challenges is essential to ensure that AI is used responsibly and equitably.

As AI continues to develop and expand in medicine, it is crucial to maintain a patient-centered approach and ensure that these technologies are used to improve health outcomes and promote equity in access to care. Collaboration between healthcare professionals, researchers, regulators, and technology developers will be critical to address these challenges and harness the full potential of AI for the benefit of human health.

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