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Artificial intelligence in medical education: a scoping review

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Abstract

This study presents a scoping review aimed at identifying, within the scientific literature, the integration of artificial intelligence into the professional training of medical students, considering ethical implications and effects on the doctor-patient relationship. Ten databases were consulted and, after screening conducted by three independent reviewers of 150 initially selected documents, 16 articles composed the corpus of analysis. The results indicate that artificial intelligence is being incorporated into medical education in various ways, ranging from clinical simulation software to chatbots designed for data collection and organization. However, studies also highlight relevant ethical concerns, such as the impact on the doctor-patient relationship, the need for faculty and student preparedness, and the limits of technology in comprehensive care. It is concluded that the integration of artificial intelligence into medical education should occur in an ethical and critical manner, preserving the human nature of clinical practice.

Keywords: Students, medical. Physician-Patient relations. Artificial intelligence. Scoping review.

Resumo

Inteligência artificial na formação médica: revisão de escopo

Este estudo apresenta uma revisão de escopo com o objetivo de identificar, na produção científica, a inserção da inteligência artificial na formação profissional de estudantes de medicina, levando em consideração implicações éticas e efeitos na relação médico-paciente. Foram consultadas dez bases de dados e, após triagem realizada por três avaliadores independentes em 150 documentos inicialmente selecionados, 16 artigos compuseram o *corpus* da análise. Os resultados indicam que a inteligência artificial está sendo incorporada de diferentes formas à educação médica, desde *softwares* de simulação clínica até *chatbots* voltados à coleta e organização de dados. Entretanto, estudos também evidenciam preocupações éticas relevantes, como o impacto na relação médico-paciente, a necessidade de preparo docente e discente e os limites da tecnologia no cuidado integral. Conclui-se que a integração da inteligência artificial na formação médica deve ocorrer de maneira ética e crítica e de modo a preservar o caráter humano da prática clínica.

Palavras-chave: Estudantes de medicina. Relações médico-paciente. Inteligência artificial. Revisão de escopo.

Resumen

Inteligencia artificial en la formación médica: revisión de alcance

Este estudio presenta una revisión de alcance con el objetivo de identificar, en la producción científica, la incorporación de la inteligencia artificial en la formación profesional de estudiantes de medicina, teniendo en cuenta las implicaciones éticas y los efectos en la relación médico-paciente. Se consultaron diez bases de datos y, tras una selección realizada por tres evaluadores independientes sobre 150 documentos inicialmente identificados, 16 artículos conformaron el corpus de análisis. Los resultados indican que la inteligencia artificial está siendo incorporada de diversas formas en la educación médica, desde softwares de simulación clínica hasta chatbots orientados a la recolección y organización de datos. Sin embargo, los estudios también evidencian preocupaciones éticas relevantes, como el impacto en la relación médico-paciente, la necesidad de preparación docente y estudiantil, y los límites de la tecnología en el cuidado integral. Se concluye que la integración de la inteligencia artificial en la formación médica debe ocurrir de manera ética y crítica, preservando el carácter humano de la práctica clínica.

Palabras clave: Estudiantes de medicina. Relaciones médico-paciente. Inteligencia artificial. Revisión de alcance.

The authors declare no conflict of interest.

Research

Artificial intelligence (AI) is conceived as a field of technological development aimed at simulating human cognitive abilities, such as pattern recognition, information analysis, task execution, and decision-making. AI uses techniques such as machine learning, artificial neural networks, natural language processing, and computer vision to achieve these goals [1]. These technologies operate based on large volumes of data, the so-called big data, which feeds algorithms capable of learning and continuously improving their performance [2].

AI can be understood as a multidisciplinary field that integrates the fundamentals of logic, mathematics, statistics, computer science, and neurobiology, among others. Its application has expanded across various domains, such as financial, banking, security, and health systems, as well as virtual assistants and other everyday technologies [1,2].

In the health field, there is a growing digitization of medical records, coupled with the continuous enrichment of epidemiological and clinical databases. This context provides fertile ground for AI applications, not only in healthcare but also in professional training. Medicine, as a field in constant technological transformation, has incorporated intelligent algorithms across various stages of diagnosis, prognosis, and teaching and learning processes. Tools such as simulators, adaptive platforms, and virtual patients have been used for this purpose, although there are inherent limitations, such as the complexity and unpredictability of real-life situations [3].

If algorithms are capable of recognizing patterns, generating recommendations, anticipating outbreaks, predicting disease evolution, and proposing personalized interventions to assist in clinical decision-making [4], how does this complex technological mechanism connect with medical training? In medical training, these technological resources also play a significant role by enabling skills training, simulation of care, and automated feedback to undergraduate students [5].

The current panorama demonstrates that medical practice is being reconfigured by emerging technologies that are reshaping how healthcare is organized. AI, as an unfolding of this advance in the field of development, not only participates in clinical reasoning but is also an influential element in the formation and construction of medical professional identity [6].

In this context, studies mapping the possibilities for applying AI in medical practice are necessary, as are investigations analyzing how scientific production has addressed the ethical challenges involved in this process. Such aspects can be based, for example, on the four classic principles of bioethics: autonomy, beneficence, non-maleficence, and justice [7], or even on other perspectives. Recent scientific literature indicates that AI continues to raise ethical and legal concerns among professionals [8].

In addition, it is essential to identify in the literature how AI has been incorporated into medical students' professional training. Given its potential to transform the learning process, especially the acquisition of knowledge and skills, it is equally important to understand its potential impacts on future medical practice. This includes diagnostic accuracy, therapeutic decision-making, the quality of the physician-patient relationship, and comprehensive care within health systems for the community.

Therefore, the question guiding this study is: "How is AI being incorporated into the professional training of medical students, and what are the ethical implications, including effects on the physician-patient relationship?" Based on this guiding question, the present study aims to identify, in the scientific literature, the integration of AI into medical students' professional training, while accounting for its ethical implications and effects on the physician-patient relationship.

Method

This is a scoping review of the literature that used the population, concept and context (PCC) strategy [9], with the population being medical students, the concept being medical training, and the context being artificial intelligence. These three elements guided the construction of the research question and the

delimitation of the inclusion and exclusion criteria of the studies analyzed [10].

In this scoping review, some methodological steps were followed, from guidance provided by the Extension for Scoping Reviews (PRISMA ScR) [11] to the development of a consolidated, peer-reviewed search strategy using the PRESS checklist for librarians, to the collection and export of references. The search was conducted in ten databases: PubMed, Embase, Scopus, Web of Science, Lilacs, SciELO, and Redalyc, as well as grey literature via ProQuest Dissertations & Theses Global, La Referencia, and Google Scholar.

The search expression combined terms from the Medical Subject Headings (MeSH), DeCS, and free terms. The search expression was adapted for each database based on its needs, language, and advanced search operators. The requirement at the intersection of the terms "students, medical," "physician-patient relations," "social skills," and "artificial intelligence" narrowed the document retrieval parameters yielding 150 initial documents. The strings with the syntax used in each database can be consulted in the scoping review protocol published on the Open Science Framework (OSF) [12].

There was a cutoff for the documents' chronology, limiting the survey to indexed documents from January 2014 to June 2024. Documents in English, Spanish, and Portuguese were selected, restricted to articles, dissertations, and theses.

The metadata of the respective documents were exported to the Mendeley reference manager. After excluding duplicates, 109 documents were sent to the Rayyan review manager. In it, three independent reviewers participated in the blind screening process. First, they evaluated the titles, abstracts, and keywords. The discrepancies were resolved in a consensus meeting. In the second stage, the analysis was of the full text, and the discrepancies were again resolved in a consensus meeting.

While the search covered ten databases, which is broad in terms of information sources, the final number of studies included (n=16) reflects a precise search strategy for the subject matter, informed by the combination of descriptors, resulting in a smaller volume of potentially eligible records.

Figure 1 presents the flowchart of the study selection process in accordance with the PRISMA ScR recommendations.

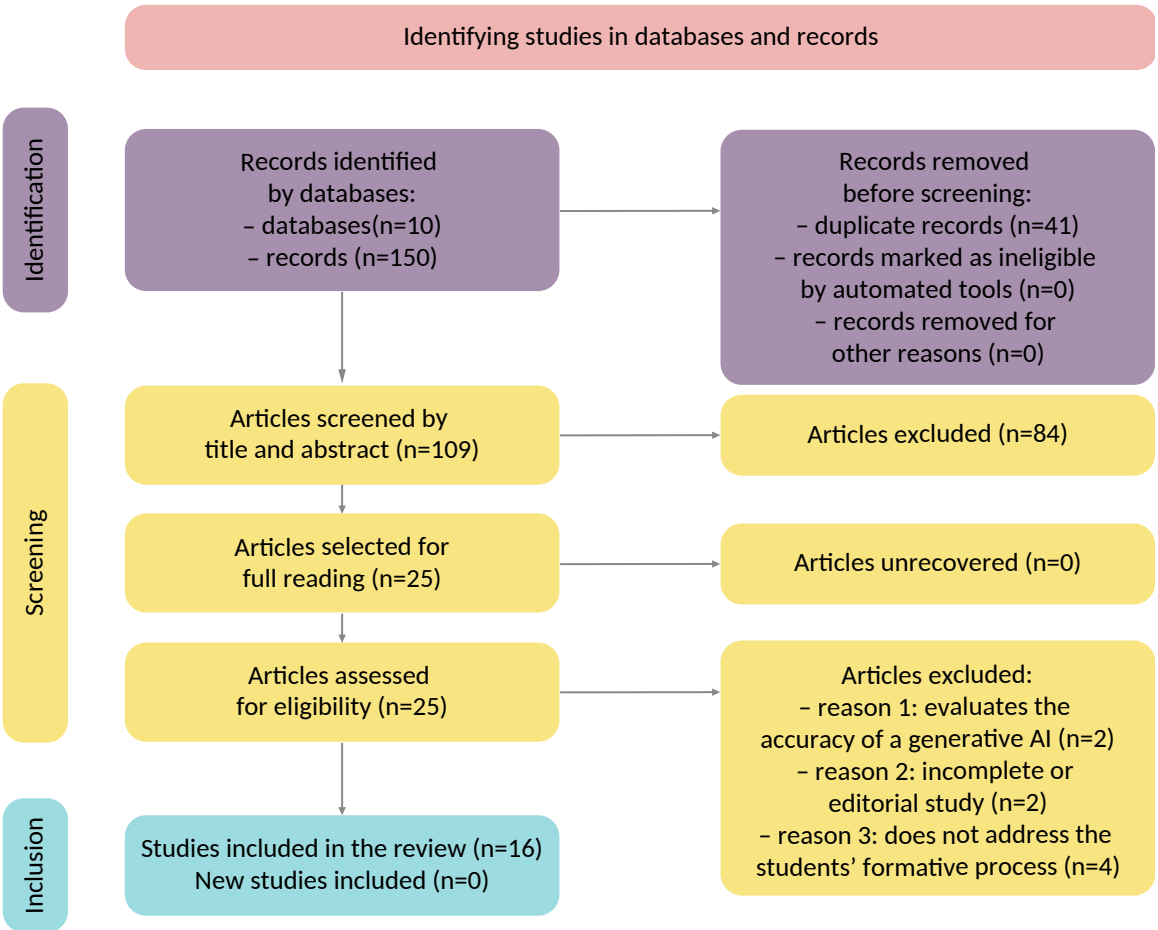
Data extraction was performed by two reviewers using a standardized Excel spreadsheet. For each included study, the following data were extracted: article identification, title, authorship, year, study location, objectives, methodology, population, and analytical fields focused on bioethics, such as ethical aspects in medical training, main results, main defenses, main problematizations, and observations.

The data were then synthesized in two stages: 1) description of the studies (year, country/locations, design, and population); and 2) content analysis related to the ethical field, with coding and grouping of findings into emerging categories, which underpinned the presentation of the results and the discussion.

Categorization was performed using an inductive procedure, starting with a floating reading of the texts in order to identify the nuclei of singularity present in the semantic records. These nuclei were isolated as units of analysis (incidents) and systematically compared, with a view to constructing an organization that synthesized the central idea of the findings. This approach followed the principles of Bardin's content analysis to guarantee homogeneity, relevance, exhaustiveness, productivity, objectivity, and fidelity in the classification [13].

Following the descriptive-analytical process, the identified meaning cores were systematically evaluated in pairs using the "constant comparative" methodology proposed by Glaser and Strauss [14], which identifies recurring patterns. Properties of the categories are saturated through the evaluation of data contrasts (e.g., empirical versus theoretical studies), aiming to simultaneously maximize differences between large categories and refine the conceptual boundaries between closely related categories. This strategy enabled the progressive inclusion of data into mutually exclusive categories, ensuring both fidelity to the original texts and theoretical coherence [14].

Figure 1. Flowchart of the study selection process



In addition to the descriptive characterization of the studies, content analysis and constant comparison allowed the identification of three categories: 1) the compromise of the physician-patient relationship due to the inappropriate use of technologies, highlighting risks of dehumanization of care, weakening of trust and displacement of clinical responsibility to algorithmic recommendations; 2) AI-controlled environments as a strategy to improve the safety of medical learning and future clinical practice, by enabling simulations and feedback in protected scenarios, with the potential to reduce harm and improve decision-making, although dependent on data quality and pedagogical design; and 3) critical reflections on the use of AI in data collection and its limitations in the context of comprehensive healthcare, pointing out that efficiency gains can coexist with biases, loss of contextualization, and reduction of subjective and social dimensions of illness, requiring critical supervision and integration with clinical judgment and bioethical principles.

Results

Table 1 presents the 16 selected articles, including the authors, years, objectives, and summaries of the main results.

The studies selected in this review were also organized into three main characteristics: 1) articles of a theoretical and/or opinion-based nature, which present conceptual reflections and points of view of the authors [17,18,24-27,29]; 2) empirical studies that carried out tests with the target population investigated [15,16,21]; 3) studies based on interviews or the collection of students' perceptions [19,20,22,23,28,30].

Research

Table 1. Articles selected in the scoping review

Authorship; year	Objectives	Summary of results
Tejeda Orozco, Burgos Rodrigues, 2019 [15]	Development of clinical simulation software.	The respiratory semiology simulation software is 80% complete and in the pre-testing phase, with a scientific basis justifying its development. The goal is to strengthen science and prevent medical errors.
Maicher and collaborators, 2019 [16]	Evaluate a virtual standardized patient (VSP) system that uses AI and natural language processing to allow medical students to practice and receive immediate feedback on their information-gathering skills during anamnesis.	The system's accuracy (87%) was similar to that of human evaluators (90%). The use of convolutional neural networks (CNNs), a specialized type of deep learning algorithm, along with ChatScript, can further improve performance.
Yeoh, 2019 [17]	Discuss the future of medical education by surveying the current state of medical education in Singapore, identifying trends that will shape the future of medicine, and explaining how physicians should prepare for these future needs.*	Physicians should prepare for five major trends: technological advancement, changes in the professional role, new clinical practices, scientific innovations, and future-oriented medical training. Technology supports, but does not replace, the physician.
Menéndez, 2020 [18]	Analyze the possibility of altering the hegemonic medical model in light of technological advances.	Medicine is increasingly linked to the pharmaceutical industry, AI, genetic medicine, and nanotechnology. Despite advances, it is necessary to rethink biomedicine to ensure equity and avoid exclusion.
Castelani, 2020 [19]	Identify the opinion of medical students and teachers on the impact of the use of clinical decision support systems in clinical practice and its relationship with medical education.	Clinical decision support systems require caution, as they can reduce medical autonomy and humanization, promote excessive standardization, and raise ethical and economic issues.
Civaner and collaborators, 2022 [20]	Analyze future physicians' perceptions of AI's potential influence on medicine and assess the demand for curricular restructuring.	85.8% of students believe that AI facilitates access to information; 58.6% fear the devaluation of the profession; 70.5% believe in reducing errors; and 93.8% highlight the importance of ethics in training.
Alemán Belando; 2022 [21]	Evaluate the effectiveness of a training program that combines traditional and innovative methods (such as the use of chatbots) to improve students' clinical skills in anamnesis and physical examination.	47.5% of students evaluated the use of chatbots positively; 50.3% considered the cases balanced; 42.3% agreed that bots improve the construction of the clinical history.
Navos Iglesias, Rabino, Zocchi; 2023 [22]	Identify the opinions of medical students on AI.	Fifth-year students showed a more humanized view of AI, while first-year students focused on technical aspects. Medical training should include bioethics and anthropology for the ethical use of technology.
Moldt and collaborators, 2023 [23]	Provide an overview of medical students' current knowledge and attitudes toward AI technologies to determine what is needed for future implementation in the curriculum.	50% were able to explain AI, and 83.3% are not afraid of losing their jobs because of it. Fears such as loss of contact with the patient (63.6%) and communication problems (81.8%) decreased after the course.
Seth and collaborators, 2023 [24]	Describe a framework and a list of topics that will facilitate today's medical students in becoming data-literate clinicians.*	Understanding AI and data science is essential for current and future physicians, but implementation depends on the medical school, region, and healthcare system.

continues...

Table 1. Continuation

Authorship; year	Objectives	Summary of results
Tokuç, Varol, 2023 [25]	Address how technological advancements can affect and change the medical education system, and how to optimize this system without losing the human dimension of physician-patient relationships.*	Technology transforms medical education by facilitating interaction, expanding networks, personalizing teaching, and improving access to information.
Gutiérrez-Cirlos and collaborators, 2023 [26]	Offer an overview of the metaverse, its origin, and potential in medicine, with some proposals for its use in the fields of teaching and evaluation.	The metaverse can revolutionize medical education by integrating real and virtual environments and transferring cognitive capabilities to the cloud.
Villca Roso, Choque Medrano; 2023 [27]	Analyze the impact of medical simulation and AI on quality medical education for medical students.*	AI has great educational and clinical potential, as demonstrated by models that identify diabetes risk factors with 95% accuracy.
Bautista Huaytalla, Flores Larzo, 2024 [28]	Assess the perception of AI use among medical students at a university in Huancayo, Peru.	61% of participants believe that AI will bring great medical advances. There was no relationship with age or year of study, but the most advanced see AI as an ally in disease research.
Baños Díez, Guardiola Pereira; 2024 [29]	Reflect on the potential for new technologies to lead to conflicts in the field of medical humanism.	The appropriate use of technology and AI can improve diagnoses and strengthen a more humanized medical practice.
Sravani and collaborators, 2024 [30]	Assess medical students' knowledge and perceptions of AI in a tertiary care university hospital.	92% believe that AI improves access to medical information, and 72% advocate for ethical training on its use. However, 41% fear impacts on the healthcare job market.

** The original article does not clearly state its objective, and therefore, the authors of this review completed the field with their interpretation of the primary texts.*

The analysis of the origin of the publications reveals a predominance of studies in Latin America [15,18,19,22,26-28], but with ramifications in Asia [17,20,25,30], Europe [21,23,29], and North America [16,24]. This distribution reflects a global interest in the topic, with emphasis on Latin American production, possibly driven by local discussions about technology and humanization in medicine.

Regarding the methodological design, 9 articles predominated, all qualitative. These studies were primarily dedicated to understanding perceptions, opinions, experiences, and contexts related to the integration of AI into medical education [16-19,22,24-26,29]. Four articles adopted a quantitative approach focusing on tests of the application of AI technologies in medical training, such as virtual patients and automated assessments [20,21,28,30]. Finally, three studies were classified as having a mixed, or qualitative-quantitative, approach, as they combined techniques to broaden the understanding of the phenomena investigated [16,23,27].

As for the population involved in the studies, seven articles had exclusively undergraduate students as participants [16,20-23,28,30]. Only one article expands the study population to include, in addition to undergraduate students, practicing physicians and teacher educators in the health field [19]. The other articles do not fit into this classification, as they address theoretical discussions of the subject [15,18,24-27,29].

When comparing the methodological approach with the study population, all quantitative studies used exclusively undergraduate students as participants [20,21,28,30]. In the three studies with a

mixed approach, two involved only undergraduate students [16,23], and one did not clearly specify the population [27]. On the other hand, among the nine qualitative studies, only two involved exclusively undergraduate students [16,23], one included students and other healthcare professionals [19], while the remaining six did not address a specific population [17,18,24-26,29].

Discussion

The first category (compromise of the physician-patient relationship due to the inappropriate use of technologies) [18-20,22,29] discusses the potential harmful effects of technology use on the bond between physicians and patients. These effects can be observed, for example, when some patients turn to the internet to seek diagnoses and treatments, which may lead to unfounded concerns and/or self-medication, especially when there are discrepancies between medical guidelines and online information.

Physicians, in turn, recognize that in certain contexts, patients change their attitudes toward technology-mediated information and exhibit greater questioning or insecurity about the proposed courses of action. In these situations, part of the consultations begins to include the need for clarification and reorientation in the face of misinterpretations of content researched on the web [31].

Advances in AI and the widespread availability of medical information have expanded patients' access to general data and to evidence-based decision-making, which can, in certain contexts, influence the physician-patient relationship. Similarly, there is a growing emphasis on complementary and laboratory tests at the expense of clinical examination. This movement does not imply replacement but may contribute to a reorganization of care practices. These transformations tend to strain the care relationship, historically central to the profession, by favoring more objective approaches, thereby risking reduced attention to the subjective and contextual dimensions that integrate the biopsychosocial perspective of care [32].

The second category (AI-controlled environments as a strategy to enhance the safety of medical learning and future clinical practice) [15,16,21,28] presents AI as a controlled environment for graduates and users who will need their knowledge. In this context, the practice of medical skills in simulation and virtual reality environments integrated with AI enhances the development of critical decision-making, the improvement of technical procedures, and the preparation of students for highly complex and high-pressure situations similar to those found in clinical practice—without exposing patients to risk [33].

While it is plausible to assume that the use of AI benefits medical training, this study's findings reveal a less promising scenario: studies with heterogeneous designs, conducted in a single research center, with small samples and limited duration, characteristics that point to weak evidence, in addition, there is a risk that graduates will develop limited authenticity in their relationship with real patients, since AI-based technologies lack deep physical and emotional interactions. In addition, there is a risk of excessive reliance on applications whose accuracy is questionable, especially given that their methodological errors may not be fully elucidated [34].

The third category (critical reflections on the use of AI in data collection and its limits in the context of comprehensive health care) [17,23-27,30] proposes AI as a mechanism for collecting information. It supports reflection on the debate between technology use and the promotion of comprehensive health care. The use of AI in health involves applying computer systems that analyze big data in order to propose solutions to medical problems. These systems can support decision-making at different stages of care, from early diagnosis to medication administration and the evaluation of their effects in the post-treatment period [35].

It is important to consider that applying AI in healthcare requires access to patients' personal records for model training, raising complex ethical issues. Among them, the most important aspects are data ownership, informed consent for its use, and the attribution of responsibilities in cases of

failures, whether resulting from medical action or the performance of algorithms [36]. Biases should also be included in this discussion. For example, data bias, a recurring problem in machine learning, can distort AI systems and lead them to operate in a discriminatory manner. Added to this is automation and disqualification bias, which leads many professionals to over-rely on technology, reduce their efforts to verify the results generated by machines, and consequently expose their patients to risks [37].

In this study, a comprehensive analysis of the texts showed that ethical aspects permeate the works, forming a recurring dimension of the discussions. In this context, the application of principlist ethics to the use of AI in medical education stands out, serving as an axis that guides the development and implementation of these technologies in the teaching-learning relationship and in future professional practice.

The principle of autonomy, grounded in the right of individuals to self-determination, arises in situations involving the transfer of medical skills, the loss of critical judgment, and threats to the human-patient relationship. The principle of justice, in turn, presupposes equity in the distribution of the benefits and burdens of AI, including the recognition of data sources and the development of accessible systems that guide the use of AI to avoid inequalities [7].

The principle of non-maleficence in the selected articles is related to the responsibility to avoid harm, i.e., it involves the careful development of reliable algorithms, adequate training of users regarding risks and biases, as well as the protection of privacy and confidentiality of data, in addition to the continuous improvement of the model to prevent clinical risks. The principle of beneficence, for its part, guides the promotion of well-being, which implies adequately training all those involved in the use of AI to maximize benefits, aiming to ensure that AI in medical education is ethical, safe, and effective [7].

Finally, most articles indicate that applying AI in medical training requires a critical approach. While its use has the potential to improve teaching and learning processes, the main challenges include ensuring transparent, safe systems guided by ethical and reflective principles. The expansion of knowledge about AI tends to favor its future adoption by health professionals. However, neglecting ethical aspects can compromise the quality of care.

A significant limitation of this study is that the field of AI applied to medical education is extremely dynamic, characterized by a continuous and accelerating flow of publications, especially after the adopted time frame, which may have led to the exclusion of more recent innovations. The rapid advancement of AI tools demands periodic updates in any study that aims to identify emerging themes in the field or investigate its use in a specific field, making it a subject of continuous review.

Final considerations

The scientific literature panorama has been transformed by the incorporation of new technologies, expanding the possibilities in healthcare and reconfiguring care and training practices. AI stands out as a significant technological development, requiring reflection that extends beyond its practical applications to encompass its ethical and pedagogical impacts.

The findings of this review indicate that scientific production on the use of AI in Brazilian medical training is still relatively incipient, with descriptive studies predominating. Among the potential benefits are pedagogical gains from the use of simulators and virtual patients, which support the safe practice of complex procedures, as well as chatbots, which reinforce anamnesis and diagnostic reasoning and provide immediate feedback to students. On the other hand, concerns emerge regarding the risk of distancing in the physician-patient relationship, the reproduction of biases, and legal liability.

The research field reflects the predominance of studies with varying methodological rigor, many based on small samples or isolated reports, which limits the robustness and generalizability of findings on the use of AI in medical education. In this scenario, future investigations could qualitatively examine professors' and preceptors'

perceptions of the risks and benefits of integrating AI into medical school curricula and explore the ethical implications of this process in greater depth. Furthermore, multidisciplinary research focused on professionals already working in the field and using AI in their daily practice could help strengthen an increasingly technological, ethical, and interdisciplinary educational ecosystem.

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