

Review Article

Artificial intelligence for healthcare and medical education: a systematic review

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Abstract: Background: Human society has entered the age of artificial intelligence, medical practice and medical education are undergoing profound changes. Artificial intelligence (AI) is now applied in many industries, particularly in healthcare and medical education, where it deeply intersects. The purpose of this paper is to overview the current situation and problems of “AI+medicine/medical” education and to provide our own perspective on the current predicament. Methods: We searched PubMed, Embase, Cochrane and CNKI databases to assess the literature on AI+medical/medical education from 2017 to July 2022. The main inclusion criteria include literature describing the current situation or predicament of “AI+medical/medical education”. Results: Studies have shown that the current application of AI in medical education is focused on clinical specialty training and continuing education, with the main application areas being radiology, diagnostics, surgery, cardiology, and dentistry. The main role is to assist physicians to improve their efficiency and accuracy. In addition, the field of combining AI with medicine/medical education is steadily expanding, and the most urgent need is for policy makers, experts in the medical field, AI and education, and experts in other fields to come together to reach consensus on ethical issues and develop regulatory standards. Our study also found that most medical students are positive about adding AI-related courses to the existing medical curriculum. Finally, the quality of research on “AI+medical/medical education” is poor. Conclusion: In the context of the COVID-19 pandemic, our study provides an innovative systematic review of the latest “AI+medicine/medical curriculum”. Since the AI+medicine curriculum is not yet regulated, we have made some suggestions.

Keywords: Artificial intelligence, healthcare, medical education, review

Introduction

Health care spending in the U.S. accounted for about approximately 16.77% GDP in 2019, and that spending had continued to grow at 5.4%, reaching \$21.8 trillion [1-3] in 2022, according to the World Health Organization. In 2020, the total cost of health care reached about 1 trillion yuan, or 7% of GDP. In recent years, the country has formulated a “Healthy China” action plan, highlighting the importance of health care [4]. For physicians, there are some worrying about the healthcare field, firstly, the increasing speed of knowledge renewal, medical students will experience a fivefold increase in knowledge in their first year, the pressure they will be under is unimaginable in the already tight cur-

riculum of medical students, and the rate of knowledge mastery will most likely drop dramatically; nowadays after the COVID-19 pandemic, many offline practice courses may not be available, which is unacceptable for clinical students. Without the help of other facilities or tools, developments in the health care field will be hit like never before [5].

Artificial intelligence, an important branch of computer science, was formally introduced at the Dartmouth Society in 1956. It is now called one of the three leading technologies in the world [6, 7]. Currently, artificial intelligence is vaguely defined and commonly referred to as having the ability to “mimic human brain”, which is the ability to think through computers, includ-

Artificial intelligence

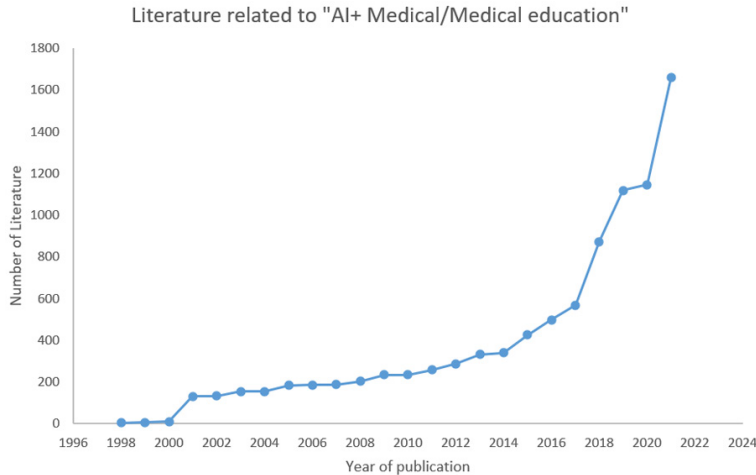


Figure 1. Number of literature on AI+medical/medical education in the last two decades.

ing perception, decision-making and action. In short, AI is about learning how to use machines to mimic the expansion and expansion of human intelligence, for example, by enabling machines to listen, see, speak, think, and do decisions like we humans do [8, 9].

Depending on the level of intelligence, AI is roughly divided into two categories: weak and strong. Weak AI only focuses on specific tasks, such as language and image recognition, intelligent translation, including Apple's Siri, Amazon's Alexa, and self-driving cars [10]. They can handle a lot of information perfectly, but they can't really understand it. Strong AI refers to machines that have the same intelligence and abilities as humans, and Artificial Super Intelligence means machines have intelligence and abilities that surpass humans. At present, strong AI is still in theoretical stage [11].

AI technology is already being used in education, security, finance, transportation, healthcare, education, gaming and entertainment, among other fields, and the application scenarios is getting richer. In healthcare, AI research focuses on deep learning algorithms, data mining analysis, intelligent impact recognition, and medical informatics [12]. Research on AI and medicine/medical education has also increased annually, and we have a graphic summary of the number of relevant papers published over the last two decades, as detailed in **Figure 1**. This study is globally based and focuses on illustrating the current status of AI applications and its dilemmas in the field of healthcare and

medical education and tries to give recommendations.

Methods

Design and search

A full-text review was conducted from June 2022 to July 2022 using a reproducible search strategy. This study was evaluated using the Cochrane Handbook for the systematic evaluation of interventions and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines.

We collected relevant studies in English databases: PubMed, Embase, Cochrane, and Chinese database CNKI from 2017 to July 1, 2022. We searched the key words of "Artificial Intelligence" OR "Machine Learning" OR "Deep Learning" AND "medical education" OR "medical training".

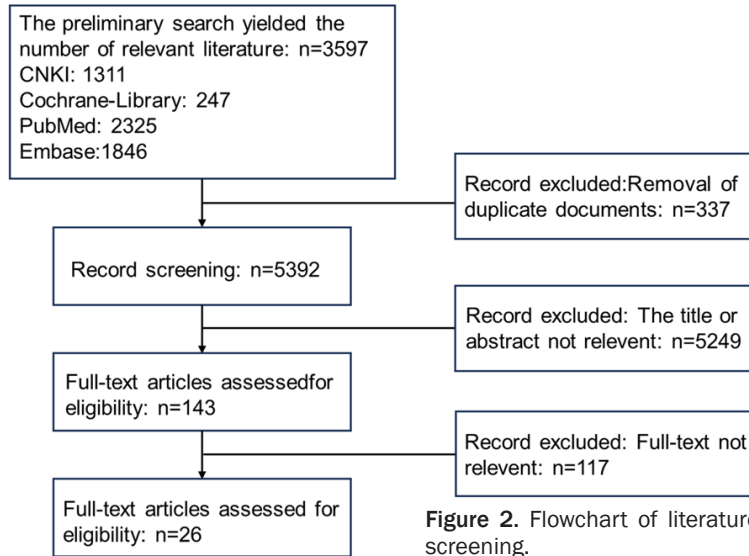
Inclusion criteria: 1. research must include "the current state of AI in healthcare or medical education"; 2. research must include "the plight of AI in healthcare or medical education". Exclusion criteria: 1. no original article; 2. newspaper or irrelevant article.

Data extraction and risk of bias assessment

Two researchers independently performed the data extraction and assessed the quality, and the disagreements were solved by discussing with the other author. The following information was extracted from each study: author's name, year of publication, title, study purpose, application, level of evidence, and study results.

Results

A total of 5729 documents met the search criteria and, after the deletion of duplicates and the review of titles and summaries, 143 documents were available for full-text review, resulting in the inclusion of 25 papers. A flowchart of literature screening is shown in **Figure 2**. All the data included in the study were from published articles and supplementary information. **Table**



1 summarizes the relevant content of all 25 papers, and the studies were evaluated using the Oxford Evidence-Based Medicine (OEBM) Evidence Scale [13]. This study intended to discuss two questions as follows.

1) What aspects of AI in medical education have been discussed in the literature? Or the current state of AI applications in medical education.

At present, AI technology is mainly used in undergraduate/postgraduate medical education, training of clinical professionals and continuing medical education. AI-assisted medical education includes virtual reality, 5G, cloud computing technology, big data analysis, wearable devices, the Internet of Things, etc. [14-17]. The main fields of AI application in medicine involve radiology, diagnostics, dentistry, ophthalmology, cardiology, psychiatry, etc. In response to the development of intelligent medicine, some universities have started new medical courses to meet the needs of future intelligent medicine in clinical practice. The courses cover computer science, coding, algorithms and electrical engineering [18-22].

Most of the studies describe the application of AI in clinical expertise training and continuing education, for example: in diagnostics and radiology, where big data or cloud computing can be used to assist physicians in making decisions, physicians need to learn how to use AI to improve their efficiency and accuracy in prac-

tice through professional training, self-study, or online courses [17, 18, 23-29]. In undergraduate or graduate education, a small number of studies describe the role of AI, such as flipping the classroom and using virtual reality to exercise to improve students' hands-on skills [21, 22, 30].

Most Chinese literature summarizes and discusses the future of AI in medical education, possibly because of state policies [14-17, 23-27, 31]. In 2018, China Higher Education Action Plan for Artificial Intelligence Innovation (HEAI) was presented [31]. New models of

healthcare development for "AI+medicine" have been emerging, with more and more research on AI and medical education. At present, AI is widely used in medical education. IBM "Waston" system uses evidence-based learning models to support medical students in making multiple oncology treatment decisions. The Virtual Patient Learning System (VPLS) helps simulate the reality of patients and enables medical students to independently make appropriate exam steps and decisions to train their clinical thinking and judgment [18]. Microsoft's precision medicine machine, Hanover, uses machine reading and cancer decision support systems to help medical students identify the most targeted cancer treatments among a wide range of treatment options and focus on precision medicine [25, 26]. The U.S. licensure exam began testing subjects such as AI, mobile health APPs and Telemedicine. China's AI robots have even passed the National Medical licensing exam [16-18].

Overall, although the intelligence of educational technology has accelerated modern medical education, there are still relatively few medical students or residents who are familiar with AI, mobile health applications and telemedicine. In recent years, a series of domestic and international policy documents or plans have been issued in the fields of AI, education and health care [17, 32]. A consensus has been reached calling for accelerating the innovative application of AI in education, promoting demonstration application of intelligent health care, and

Artificial intelligence

Table 1. Characteristics of included studies

Authors	Year of publication	Title	Main research objectives	Applications	Level of Evidence*	Study results
Wang Yan [14]	2022	Reform status and exploration of higher medical education under the background of artificial intelligence.	Proposes important measures to promote medical education in the age of AI.	Complementary medicine; Medical robot; Intelligent health management.	V	It is recommended that the government introduce relevant policies to support the development of AI.
Zou Luxi [15]	2021	Research on the current situation and problems of applying artificial intelligence in medical education.	Advancing research on AI in the field of medical education.	Apple Watch; Smartphone monitoring system; Predicting disease risk.	V	Increase investment and focus in "AI+Healthcare Education".
Dai Shaochun [16]	2021	Development Prospect of Artificial Intelligence in Medical Assistant Education.	Introducing the future of AI in paramedical education.	Analysis of the learning situation; Personalized Learning.	V	Summarized the possible development direction of future artificial intelligence.
Ai Feiyan [31]	2021	The Application of Artificial Intelligence in Diagnostics Teaching.	Analyze the disadvantages of AI teaching and the advantages of teaching.	Teaching Diagnostics.	V	Academic hardware and software equipment still needs to be strengthened, and teachers need to fully understand artificial intelligence.
Liu Dalu [23]	2021	Cultivating practical literacy of machine learning for medical students.	Describe the current state of machine learning practice goals.	Auxiliary diagnosis; Help with treatment decisions.	IV	Work still needs to continue on adding machine learning to medical student practice.
Li Xinchun [24]	2021	Application Prospects of Artificial Intelligence Assisting Teaching Mode in Medical Imaging.	Discussing the value of AI to inform training in Integrative Medicine.	Promote the integration and optimization of impact expertise and educational resources; Help promote the construction of a new type of education; Promoting faculty development.	V	Artificial intelligence + medical education will be the direction of the times.
Li Honghao [17]	2020	Status, problems and countermeasures of artificial intelligence application in medical education.	The problems of AI in medical education are analyzed and corresponding solutions are proposed.	Virtual Reality Technology; 5G technology; cloud computing; big data analysis; wearable devices; Internet of things technology.	V	"Artificial Intelligence + Medical Education" to enhance technology, maintain equity and promote development.
Liu Jizhou [25]	2020	A Brief Introduction to the Practice of Artificial Intelligence in Medicine as an Inspiration for Medical Education.	A call for physicians and medical students in the new context of AI to actively adapt themselves to the new era of smart medicine.	Ancillary Diagnosis; Virtual Reality Technology.	V	In the future, physicians should strengthen their data processing capabilities.
Zhong Min [26]	2020	Current Situation and Consideration of Artificial Intelligence Application in Medical Education.	The current situation of AI application in medical education is analyzed, and its application prospect, ethics, and safety protection are deeply considered and discussed.	Comprehensive Course Analysis; Assisted Learning; Learning Assessment.	V	In the future, more research is needed to assess the value of AI in medical education.
Li Yi [27]	2018	On Application of Artificial Intelligence in the Clinical Skill Training of Medical Students.	Exploring the application of AI in teaching clinical skills to medical students education.	Aids in analyzing test results and helping physicians make decisions; Aids in developing medical students' interrogation and clinical practice skills.	V	The role of artificial intelligence technology in medical diagnosis and teaching will become increasingly prominent.
Simpson SA [28]	2020	Artificial Intelligence and the Trainee Experience in Radiology.	Exactly what role AI will play in the future practice of radiology remains undefined.	Flipped Classroom; Support radiologists in making decisions.	V	Predicted the future of artificial intelligence in medical education.
Michael Tran Duong [29]	2019	Artificial intelligence for precision education in radiology.	We highlight an AI-integrated framework to augment radiology education and provide use case examples informed by our own institution's practice.	Developed an adaptive radiology interpretation and education system to assist radiologists.	V	Integrating AI into radiology precision education requires a dynamic collaboration from research, clinical, and educational perspectives.

Artificial intelligence

Ken Masters [18]	2019	Artificial Intelligence in Medical Education.	The impact of AI on the methods and content of medical education is pointed out.	Using Big Data to Impact Medical Education.	V	In the future, medical students need to be educated about artificial intelligence.
Juehea Lee [18]	2021	Artificial Intelligence in Undergraduate Medical Education: A Scoping Review.	Aims to identify gaps and key themes in the peer-reviewed literature on AI training in UME.	Facilitating clinician decision-making through big data; facilitating learning for undergraduate and graduate medical students.	IV	Proposal to include artificial intelligence in medical education curriculum.
Fischetti C [19]	2022	The Evolving Importance of Artificial Intelligence and Radiology in Medical Trainee Education.	Survey of radiology education in the current medical education curriculum.	Auxiliary radiology undergraduate studies.	V	AI has the potential to impact the opportunity to triage and organize excess medical images.
Nita G [20]	2021	Impact of Artificial Intelligence on Medical Education in Ophthalmology.	Exploring AI in ophthalmology, the medical community's view of AI, the need to adopt AI in medical education.	Assist physicians in ophthalmology to improve diagnostic accuracy and efficiency.	V	It is recommended that the government take the lead in designing a comprehensive artificial intelligence curriculum.
Charlotte Blease [21]	2022	Machine learning in medical education: a survey of the experiences and opinions of medical students in Ireland.	Assessing the experiences and opinions of final year medical students throughout Ireland about their exposure to AI/ML during their entire degree programme.	Undergraduate Medical Student Education.	IV	In Ireland, about two-thirds of respondents said they had no time to learn AI/ML. Most medical students believe that AI/ML should be included in the main curriculum.
Wartman SA [22]	2018	Medical Education Must Move From the Information Age to the Age of Artificial Intelligence.	Advocate more in-depth educational reform and bring AI into medical education.	Undergraduate medical education, postgraduate medical education, and continuing medical education.	V	Future medical students need to take artificial intelligence courses.
Han ER [30]	2019	Medical education trends for future. Physicians in the era of advanced technology and artificial intelligence: an integrative review.	To identify and synthesize the values that medical educators need to implement in the curricula and to introduce representative educational programs.	Undergraduate Medical Education.	IV	Doctors of the future will use AI to do their work.
Kirubarajan A [38]	2022	Artificial Intelligence and Surgical Education: A Systematic Scoping Review of Interventions.	To synthesize peer-reviewed evidence related to the use of AI in surgical education.	Surgical education.	IV	Identified the current status of the use of various interventions of AI in surgical education.
Bisdas S [34]	2021	Artificial Intelligence in Medicine: A Multinational Multi-Center Survey on the Medical and Dental Students' Perception.	Sources of information about AI, AI applications, AI status as a topic in medicine, and students' feelings and attitudes.	Medical Education and Dentistry;	IV	The majority of dental students across all continents have a positive attitude toward AI and want to include it in their curriculum.
Briganti G [35]	2020	Artificial Intelligence in Medicine: Today and Tomorrow.	Discusses the recent scientific literature on AI+medicine and provides a perspective on its dilemma.	The detection of atrial fibrillation, epilepsy seizures, and hypoglycemia, or the diagnosis of disease based on histopathological examination or medical imaging.	V	The current state of AI in healthcare is discussed and recommendations for ethical issues are made.
Dumić-Čule I [33]	2020	The importance of introducing artificial intelligence to the medical curriculum - assessing practitioners' perspectives.	To assess attitudes toward the importance of introducing AI education in the medical school curriculum and to assess medical students' attitudes toward the introduction of AI in the curriculum.	Radiology undergraduate and graduate education.	IV	There is a strong consensus among radiologists and radiology residents about the need for AI education as part of the medical school curriculum.
Park CJ [36]	2021	Medical Student Perspectives on the Impact of Artificial Intelligence on the Practice of Medicine.	To assess U.S. medical students' perceptions of radiology and other medical specialties as they relate to AI.	Radiology Field.	IV	AI will play a significant role in medicine, particularly in radiology.
Pinto Dos Santos D [37]	2019	Medical students' attitude towards artificial intelligence: a multicentre survey.	To assess undergraduate medical students' attitudes towards AI in radiology and medicine.	Radiology and Medical Training.	IV	Medical students' attitudes toward AI are diametrically opposed to media reports that they are not worried about being replaced by AI.

*Evidence levels were as described by the Oxford Centre for Evidence-Based Medicine Levels of Evidence.

actively exploring effective measures for innovation in modern medical education and the practice model of modern medical education [18, 19].

2) What are the current dilemmas for the application of AI in healthcare education? Despite the unstoppable trend in the use of AI in medical education, there are still many problems amid the avalanche of publicity.

Duong TM's study [29] illustrated the dilemma of using AI in radiology education. Radiology education still faces inherent challenges. Some are unique to the field, including the lack of hi-fi simulation training that immerses trainees in simulated real-life situations. AI technology is still in the early stages of development and requires extensive research and long-term real-world data to verify its accuracy. In addition, many high-quality clinical imaging datasets for training and validation are unavailable and often not publicly available, creating the current predicament [18, 20]. Successful use of AI in medical education also requires consent. First, clinicians, technicians and related engineers are troubled by the fact that learning about AI takes up their time that is already little. A 2020 study found that 89.6% of participants support the introduction of AI in medical education, and the need for AI is more pronounced among practitioners than students [33].

Other dilemmas were discussed, such as the lack of accreditation standards and licenses to introduce AI into medical education, the lack of core AI competitiveness and AI faculty, and the lack of evidence on how AI affects healthcare and medical education [33-36].

Several studies have found that the current attitude of medical students toward AI is not as resistant as advertised in the media; on the contrary, the attitude of most physicians or medical students is very positive, believing that the introduction of AI in the medical curriculum is necessary and that they are learning AI or have plans to learn AI [33, 34, 36, 37].

Discussion

With the advent of the fourth industrial revolution, AI has become one of the focus areas for scientists' attention, and the convergence of AI with other fields has become a trend. The devel-

opment of AI+medical/medical education has been greatly enhanced in the last decade, especially in the wake of COVID-19, with the global shift to online courses and online conferences accelerating the development of AI. As AI technology matures, so does the role of clinicians. Upgrading decision-making processes in healthcare settings, as well as the promulgation of AI-based management standards and decision-making processes, portends the future direction of AI-analyzing vast amounts of data to inform diagnostic and therapeutic decisions [33, 37, 38]. Since late 2022, Chat GPT came out as an AI model that interacts in a conversational way and in just half a year, it has been widely used in various fields, especially in the field of education. Although it still had many limitations such as errors in answering some questions and data cut-off to 2021 years, this still does not hinder its great potential in the future.

After searching and reading a large amount of literature, we were surprised to find that most of the literature related to "AI+medical/medical education" was of low quality, mostly grade IV (n=9) or grade V (n=16). This suggests us to conduct new research or improve the quality of research related to AI and medical/medical education.

While there is a lack of data to verify the accuracy and effectiveness of AI in medical education, researchers have proposed solutions and are moving to create an international consortium database with high-quality data, integrate large amounts of data and images into AI networks, and develop standardized rather than personalized guidelines to address this [39]. Today, many countries and regions are already incorporating AI courses into medical education, which can not only address the low use of clinical AI and the lack of awareness of AI among doctors, but also facilitate further development of AI. It is important to note that policy support from local governments is critical to educating AI. More high-quality evidence of the effectiveness, feasibility, and economics of AI+medical/medical education is needed before governments can enact supportive policies [17].

Ethical issues have always been the center of public concern, with some fearing privacy

breaches and even the stigma that some data can cause, such as chronic illnesses [40, 41]. These concerns are mainly due to the lack of unified standards and norms in AI technology, resulting in uneven application of different AI technologies and public skepticism about AI. It is suggested that AI should be integrated with fields such as healthcare, and standards should be developed to reach a common understanding to make the use of AI more regulated.

This review summarized the latest literature from home and abroad, looks at developments over the past five years (2017-2022), and provides an innovative description of the development of AI in medical education in the post-pandemic era. The main findings of the systematic review: (1) While AI+medicine/medical education has become a trend after the pandemic, AI courses are not yet part of medical student education; (2) There is a lack of accreditation standards of AI applications in healthcare, and the effectiveness of AI is uncertain; and (3) Using the Oxford Evidence Scale, most of the studies were classified into categories 4 and 5, indicating the poor quality of current research.

Limitation

Much effort has been devoted to this study, but there are still some unresolved questions. First, the study only included literature published in Chinese and English, which may lead to bias in selection. Secondly, the current low quality of research on AI+medical/medical education has a negative impact on the quality of our research. Finally, the number of documents that meet the criteria is limited due to the late start of AI, especially in healthcare and medical education.

Conclusion

Artificial intelligence technology not only drives global medical education reform, but also reshapes the medical education ecology, changing the space-time landscape and supply levels of medical education, making it possible to personalize and diversify medical education on a large scale.

In the future, we need to pay close attention to the problems and challenges that AI poses to medicine and medical education, and work

with the scholars and society to drive medical education toward higher quality, efficiency, and sustainability.

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None.

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Artificial intelligence

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Artificial intelligence

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