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Current trends in medical education with generative artificial intelligence.

Actualidad en la educación médica con la inteligencia artificial generativa.

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Summary:

Objective: To analyze the current changes emerging in medical education following the arrival of Artificial Intelligence (AI) and to present some published initiatives from various Faculties of Medicine in this area. **Methodology**: A brief review of recent literature, in the form of a qualitative narrative synthesis, was conducted, along with university websites (2020-2025) on the introduction of generative artificial intelligence in medical training. **Results**: We present a wide variety of implemented initiatives identified in universities dedicated to medical education. The most frequently used resource is structured training at both the undergraduate and postgraduate levels, incorporating courses, master's programs, expert certificates, workshops, and specific training for faculty. Simulation with AI has also been promoted as a training tool. Other noteworthy initiatives include the creation of multidisciplinary cross-cutting groups to address the digital transformation of teaching, the development of guides and recommendations by universities for use by faculty and students, and the establishment of research groups, among other current university implementations. **Conclusions**: AI is transforming medical education, redefining content, methodologies, and assessments. Its integration fosters interdisciplinary models and learning experiences based on simulation, automated tutoring, and virtual environments. This evolution demands ensuring competencies in clinical AI, preserving professional judgment, and strengthening ethical, regulatory, and collaborative training for the responsible use of technology in medical practice.

Keywords: artificial intelligence, university medical education, simulation, medical training.

Resumen:

Objetivo: Analizar los cambios actuales que están surgiendo en la educación médica tras la llegada de la Inteligencia Artificial (IA) y presentar algunas iniciativas publicadas de algunas Facultades de Medicina en este ámbito. **Metodología**: Revisión Breve de la literatura reciente, en forma de síntesis narrativa cualitativa, además de fuentes web de las Universidades (2020-2025) sobre la introducción de la inteligencia artificial generativa en la formación médica. **Resultados**: Exponemos una amplia variabilidad de iniciativas implementadas detectadas en universidades con dedicación a la educación médica. El recurso más utilizado es la formación estructurada en pre y postgrado, con incorporaciones de; asignaturas, másteres, títulos de experto, jornadas y formación específicas para docentes, tambien se ha potenciado la simulación con la IA como elemento formativo. Se pueden destacar también; la creación de grupos transversales multidisciplinares para abordar la

transformación digital de la enseñanza, la elaboración de Guías y recomendaciones elaboradas por las universidades para utilización de los docentes y alumnos, la constitución de grupos de investigación entre otras implementaciones en la actualidad Universitaria. **Conclusiones**: La IA está transformando la educación médica, redefiniendo contenidos, metodologías y evaluaciones. Su integración impulsa modelos interdisciplinarios y experiencias formativas basadas en simulación, tutoría automatizada y entornos virtuales. Esta evolución exige garantizar competencias en IA clínica, preservar el juicio profesional, y fortalecer la formación ética, regulatoria y colaborativa para un uso responsable de la tecnología en la práctica médica.

Palabras clave: inteligencia artificial, educación médica universitaria, simulación, formación médica.

1. Introduction

The emergence of AI, particularly generative models such as large language models (LLMs), has brought about a significant transformation in the clinical and scientific training of medical students (1). Some of the leading universities dedicated to medical education are pioneers in the adoption of these technologies, reorganizing curricula, teaching and assessment methods, and directly addressing ethical dilemmas and regulatory challenges.

The integration of AI into medical education is driving substantial changes in curricula (2). It is impossible to remain indifferent to technological advances and cultural shifts in society; however, adapting traditional teaching methods, historically associated with valuable and predictable outcomes, presents significant challenges. While the incorporation of new technologies has long been part of medicine, AI represents a true paradigm shift in the learning process, especially in the medical field, and generates far-reaching social impacts. Therefore, it is essential to understand how to properly integrate AI into educational methodologies (3).

The aim of this work is to analyze the current changes in medical education after the incorporation of AI and to present some initiatives published by different Faculties of Medicine in our environment and in this field.

2. Methods

This article is a brief review, presented as a qualitative narrative synthesis, of recent literature (2020–2025) on the use of generative AI in medical training. It also analyzes the main initiatives published and disseminated by several universities in this field.

The literature search was conducted in Scopus and PubMed, using combinations of terms such as "AI" and "university medical education," as well as "generative AI" and "medical training." Initially, 126 articles were identified, of which 12 were selected according to the following criteria: publications from the last five years that analyzed general aspects of AI integration in medical education, excluding anecdotal projects, unavailable documents, or those without evidence of implementation. Review articles and systematic reviews with full text available, in English or Spanish, were included.

Additionally, other analytical articles with a high number of citations were examined, as well as the websites and publications of the selected Universities, in order to identify changes and developments in their programs related to the incorporation of AI in medical education.

3. Results

3.1. There is great variability between Universities in their programs and strategies designed for the incorporation of AI in medical teaching.

The most common activities are educational, notably training courses, which offer online or in-person programs at both the undergraduate and postgraduate levels, including doctoral and microcredential programs. Their objectives combine technical, ethical, implementation, and governance aspects, which are especially evident in programs aimed at healthcare leaders and courses on implementation strategies (4). There are also, although fewer, specific subjects in Big Data and AI in Medicine, such as the Faculty of Medicine at the Autonomous University of Madrid, which will incorporate -a cross-disciplinary subject in AI in Biomedicine in the 2025-2026 academic year (5); and the Complutense University of Madrid, with an elective AI subject for medical students, which began in the second semester of the 2024-2025 academic year -for first- and second-year students (6). The University of Barcelona, which offers an Expert Diploma in "Advanced Use of AI in Teaching in Health Sciences", in distance learning mode and attached to the Faculty of Medicine (7); the Faculty of Medicine of the University of Zaragoza, which organized a "Generative AI Course for students" within the ASISA Chair, aimed at medical students (8).

Also noteworthy is the existence of master's degrees, such as those announced by the Autonomous University and the University of Barcelona, the International University of Andalusia, the Complutense University, the Autonomous University and the Polytechnic University of Madrid (this one including Big Data and Machine Learning), and the Carlos III University; some in online format, most face-to-face, with official status and 60 ECTS credits.

Other training programs are designed as micro-credentials and short courses aimed at healthcare professionals on the fundamentals and applications of AI in health, promoted by foundations and centers linked to universities: For example, the Foundation of the Autonomous University of Madrid (FUAM) (9). The holding of various specific training days for teachers has had a significant presence and educational importance: At least 10 days have been identified in Spanish universities, highlighting the importance of training educators in didactics, technical skills, and the use of AI in teaching; these have also served as forums for debate in each center.

In addition to all these courses and training programs, we have also found that guides and recommendations for teachers and students have been developed by universities such as the Autonomous University of Madrid (10), Cádiz (11), Granada (12), and Málaga (13), as well as by leading organizations such as UNESCO (14) and the Network of University Libraries (15). These are key documents at present for taking confident steps in accordance with UNESCO's recommendations.

In the university setting, new multidisciplinary structures, called "specialized cross-cutting centers," have been developed. Their purpose is to foster research and innovation in AI applications in both teaching and clinical practice. These centers aim to guarantee the practical applicability of the tools, ensuring they are safe, fair, useful, and accessible, while also promoting data sharing and the creation of an interdisciplinary community that integrates medicine, engineering, ethics, and other related fields. Examples include:

- AIMI Center (Center for Artificial Intelligence in Medicine & Imaging) at Stanford Medicine.
- The Malone Center at Johns Hopkins University, with programs to prepare students and physicians in the interpretation and research of clinical AI applications.

- The Temerty Centre for AI Research and Education in Medicine (T-CAIREM) at the University of Toronto develops interdisciplinary programs (MSc/Master pathways) linking AI with medicine and collaborating with research institutes and clinical centers.
- Artificial Intelligence Centre of the University of Valladolid.

Big Data research groups have also been established: For example, the Healthcare Data Science (EPSRC CDT) at the University of Oxford, which integrates AI with clinical research and large cohorts, emphasizing computational statistics and data ethics. It offers doctoral programs in computational statistics, machine learning, data engineering, and infectious disease analysis within an ethical health research context.

3.2. Role of AI in simulation.

We have gathered some available examples that show that AI is already being used in simulation (Table 1), highlighting the scope of a more realistic scenario, incorporation of virtual reality, personalization and feedback of practices

3.3. Validation of AI applications in the healthcare field, through collaborative projects between industry, startups, universities and healthcare professionals.

These projects focus on analyzing programs that apply AI to medical diagnoses and devices, establishing close collaboration with health services and universities to ensure rigorous clinical validation.

4. Discussion

4.1. Contents and training programs.

Currently, it is considered essential to include basic content on AI and medical informatics in undergraduate medical training (16). As we saw in the results, several universities have implemented the aforementioned interdisciplinary initiatives. To promote them, they have incentive mechanisms such as awards, scholarships, and endowed professorships, although underlying this is the faculty's own concern about adapting to the technological revolution and integrating it into teaching without losing educational impact. The "National Artificial Intelligence Strategy" (ENIA) endowed professorship program serves as an example, with the objective of *"promoting professional and university training programs focused on the development of this technology (AI)" and "strengthening research and knowledge transfer capabilities"* in different fields, including health sciences (17). However, mandatory AI courses in Medicine have not been established. The main objective of these initiatives is to prepare medical professionals capable of identifying, formulating, and solving clinical problems using digital tools. It is expected that, in the near future, multidisciplinary teams composed of doctors, mathematicians, computer engineers, and statisticians will become common practice.

In parallel, society is experiencing an increase in the acquisition of digital skills and basic medical knowledge, transforming the traditional doctor-patient dynamic and increasing the need for specific training for future healthcare professionals (18) . After reviewing the literature, we highlight that currently, there is no good coordination between universities and guidelines, as proposed by the ENIA (17) . Most initiatives are highly commendable experiences and projects from different universities, but with little coordination, which will likely emerge from experience and the sharing of results obtained in communities or discussion forums. We detect significant teaching activity aimed at updating its curriculum to incorporate this technology into teaching, but a major debate is lacking —perhaps due to the limited experience accumulated—regarding whether it will lead to a decline in the learning of fundamental skills; in this respect, there are differing opinions. Some argue that it can lead to a significant decline in communication and clinical diagnosis skills (19) or that "there is a risk *that students will delegate their critical thinking process to machines, which would stunt the development of*

fundamental skills such as clinical judgment and decision-making under uncertainty " (20) . However, reported teaching experiences indicate that *"when the use of AI is accompanied by critical mentoring and ethical protocols, it can become a valuable tool for developing research skills"* (21). Therefore, current doubts exist regarding these learning models, and a lack of experience and established practices prevents a definitive conclusion.

4.2. Changes in teaching and assessment methods.

One of the most evident proposed changes in several institutions is the partial replacement of traditional lectures with AI-enhanced practical activities. This transition is necessary due to students' access to digital tools that facilitate knowledge acquisition and clinical decision-making (22). Despite the increasing integration of AI in medical training, the importance of face-to-face teaching and knowledge transfer from expert instructors remains. The transmission of knowledge through face-to-face instruction, with the possibility of sharing "experience," creating dialogues, and making observations based on comments and questions in the classroom, is understood to be something that should not be lost (23). It is true that innovations such as the combination of intelligent tutoring, advanced simulation, and personalized learning offer a complementary approach, enhancing medical education without replacing the essential pedagogical values of traditional training. Therefore, hybrid models are proposed where AI handles the transfer of factual knowledge, freeing up class time for the development of critical thinking skills and clinical application (24).

Conversational assistants or chatbots such as "ChatGPT," "BingGPT," and "Bard" (among others), trained on large amounts of textual data, are capable of generating educational materials, producing academic texts, answering clinical questions, and summarizing bibliographic information (25-26). Other applications based on large linguistic models (LLM) are specifically designed for searching for scientific evidence and conducting literature reviews, including tools such as "Open Evidence," "Consensus," and "Elicit," among others. These applications are becoming a quick reference tool in medical practice, as well as in research and scientific publication. Another very important aspect to discuss is that AI also influences how students are assessed and the development of their clinical skills. Although these applications still require refinement, they have demonstrated significant levels of accuracy in medical knowledge assessments and examinations (27). Tools like "ChatGPT" have raised concerns about the validity of traditional assessment methods (28). Their ability to generate consistent responses in written tasks makes it essential to diversify assessment strategies, including oral exams, group projects, and practical exercises that cannot be completed solely with AI assistance. Furthermore, anti-plagiarism systems and clear standards are required to ensure academic integrity. Therefore, it appears that medical education requires a rethinking of traditional assessment methods. The emergence of generative AI tools has driven the diversification of assessment strategies, incorporating oral exams, collaborative tasks, and face-to-face assessments assisted by verification systems, such as facial or voice recognition. However, assessment using multiple-choice tests is not necessarily threatened; logical thinking and the ability to select the most probable answer remain essential skills that are subsequently applied in clinical practice.

Some universities have begun implementing automated grading systems, which allow students to identify strengths and weaknesses and receive recommendations to improve their learning. These performance analysis tools can evaluate multiple-choice exams or short-answer questions almost in real time, providing immediate feedback. This innovation accelerates the grading process and optimizes teaching resources, which is especially useful in courses with large cohorts of students (29). Its application has shown greater performance and reliability when based on a structured and concrete rubric, although there is a lack of experience and uniformity in studies on the impact of this and other innovations (30).

4.3. Application of AI in clinical simulation

AI is increasingly integrated into simulators and virtual or augmented reality environments that realistically replicate clinical situations (31). These environments include virtual patients and sophisticated simulators that provide immediate and objective feedback. AI can detect technical errors and dynamically adjust the difficulty level based on the user's performance. AI-powered simulators have been shown to contribute to the development of clinical skills and diagnostic reasoning in a safe environment, reducing risks to real patients. AI-enhanced virtual patients allow for the practice of communication and decision-making skills with real-time feedback, while specific models have been designed for surgical training to facilitate the acquisition of surgical techniques. Gamification through adaptive educational games maintains high levels of motivation, and intelligent 3D objects, along with augmented reality tools, enhance anatomical visualization and guide clinical procedures (32). Various LLM platforms and conversational assistants, such as "ChatGPT," "Gemini 2.5," "LLaMA 2," "Bard," "Aleph Alpha," and "Claude," are complemented by devices like Android XR smart glasses and speakers integrated into simulation mannequins ("SimVox"), optimizing educational interaction and clinical practice. Table 1 presents some of the most recognized AI-based simulation products.

4.4. Personalized learning strategies

More adaptive, student-centered teaching and learning strategies are being explored, with a personalized approach. Algorithms analyze individual progress and adjust content, pace, and teaching style according to each student's specific needs. This allows for the provision of customized materials, tailored to previously identified deficiencies or needs, optimizing the educational process and improving the acquisition of clinical and cognitive skills. Currently, it is a promising possibility, but with heterogeneous evidence (33), showing utility for personalized study plans and supporting self-directed learning. However, its performance depends on the use of resources, prompts, and continuous assessment. Positive experiences have been reported when models are based on well-defined tasks (structured learning path, deliberate practice with immediate feedback, adaptive exercises), but with limitations for situational and non-cognitive skills (empathy, complex reasoning in novel scenarios). Currently, the most reliable solutions combine AI with human review and supervision.

4.5. Intelligent tutoring and conversational assistants

Another functionality under development is intelligent tutoring systems, also known as tutorbots. These AI-based tools assess students' prior academic performance, identify knowledge gaps, and offer specific recommendations (e.g., "ChatPDF" and "Bard" in tutor mode) (34). Tutorbots can be trained using the curriculum content and syllabi for each subject, acting as intelligent assistants with in-depth knowledge of the academic program. This allows tutoring to focus more effectively on the student's most challenging topics. Currently, there is promising but insufficient evidence regarding their applicability. It requires the use of LLMs that have been previously designed and validated with dialogues and pedagogical interaction by humans; only in this way can counterproductive interaction be avoided (33). In addition to this prior supervision, the intelligent tutoring tool must also incorporate a "Retrieval-Augmented Generation (RAG)" architecture, which consists of text generation combined with a search in real knowledge bases. This improves its knowledge base and provides more accurate and contextualized answers (35). This method is practical in academic environments where accuracy and context are fundamental, but the results of its use must be interpreted with caution.

4.6 Teaching practices in clinical care environments, AI skills.

Teaching practices in clinical care services are beginning to transform with the incorporation of AI-based tools. Computer vision algorithms, capable of analyzing radiological or echocardiographic images, are increasingly used, especially in predictive medicine, personalized treatment, and monitoring of complex conditions such as mental health disorders (36-37). These technologies have achieved levels of diagnostic accuracy comparable to or exceeding those of specialists in fields such as radiology and dermatology (38). Students, the future physicians of the healthcare system, must become familiar with these applications and uses during their clinical rotations.

Intensive Care Units (ICUs) are environments where data management is fundamental to patient safety (39). The implementation of AI systems is particularly intensive in these environments, making the use of predictive models and data management platforms indispensable (40-41). AI has been reported in the weaning of critically ill patients from mechanical ventilation (42). This area is of particular interest for the training of medical and biomedical engineering students, who need to become familiar with the integration of AI in clinical practice.

AI can also reduce the administrative burden on physicians and students. Automatic transcription tools facilitate the entry of data and clinical notes into electronic health records, freeing up time for direct patient care. Therefore, these technologies are said to have the potential to humanize healthcare by allowing physicians to focus on patient interaction rather than routine tasks in front of a screen. However, some educators warn that intensive use could hinder the development of essential skills, generate technological dependence, and reduce the human dimension of care (43). Therefore, there are arguments both for and against facilitating the humanization of care; it will ultimately depend on how it is used.

4.7 Knowledge of limitations, risks, ethical and regulatory content.

After analyzing the applications of AI in medical education, it is equally essential that future healthcare professionals receive training on the current limitations of AI and the associated ethical dilemmas (44). Clinicians must understand these issues, as they can significantly affect patients' health and well-being. Key aspects include identifying algorithmic biases, the risks associated with data privacy, liability arising from clinical decisions assisted by automated systems, and the frequent lack of transparency in AI processes—factors that could generate technological dependence and inequalities in access to technology.

Regarding *technological dependence* among professionals, there is a risk that it will become accentuated, leading to an increase in the demand for diagnostic tests for multifactorial conditions, without applying probabilistic reasoning or relying on clinical judgment developed through experience. This judgment allows clinicians to identify the most common and plausible explanations for a set of symptoms and signs. AI can enhance learning, but it cannot replace the essential training process for developing clinical judgment. The risk is that, if used without an appropriate pedagogical strategy, future physicians will develop "cognitive and technological dependence" and reduce their critical thinking skills. Therefore, it is crucial that they receive training in clinical reasoning and AI literacy, even in the early years of their academic training (45-46). In real clinical settings, this requires medical students to develop a dual competence: mastering technological tools while preserving independent clinical reasoning, avoiding excessive dependence on automation.

It is also essential to consider ethics in the generation of academic texts and publications, conflicts arising from patents and intellectual property in research and clinical trials, as well as the digital divide, which can impact both individuals and organizations. Integrating this content into

academic training allows students to anticipate and manage the potential risks of technology, promoting safe and equitable medical practice.

Understanding the regulatory framework is another critical component of training, providing legal certainty for professionals and citizens. Including AI regulation and governance content in undergraduate and postgraduate programs ensures that students develop strong ethical and professional competencies, necessary to practice in an informed, responsible, and critical manner in an increasingly digitalized clinical environment (47).

Overall, medical education in the age of AI must combine technical, clinical, and ethical competencies, ensuring that future physicians not only manage technological tools but also retain independent clinical judgment, critical analysis skills, and sensitivity to the human and social aspects of clinical practice.

The main limitation of this review is that, for its analysis, we currently find mostly pilot studies, systematic reviews, and benchmarking studies marked by heterogeneity and the reporting of isolated experiences, but lacking large-scale, multicenter trials with long-term impact on learning, teaching practices, and educational outcomes. It is difficult to see the impact these innovations will have on the training of future physicians until there is more data available on their track record.

5. Conclusions

- AI is redefining both the content and methodologies of medical education, progressively incorporating training programs on machine learning, medical informatics and data management at the undergraduate and postgraduate levels.
- There is an ongoing debate about the relevance of traditional lectures, with some proposing their replacement with AI-enhanced learning experiences—simulators, automated tutoring, and self-assessments—although concerns persist about the loss of pedagogical value from direct contact with expert instructors. Limited evidence exists regarding the effectiveness of these tools in terms of pedagogical value, and further experience is needed to draw definitive conclusions.
- This transformation promotes the creation of interdisciplinary university structures that integrate educators, clinicians, engineers, and educational technology experts, fostering collaborative medical training adapted to new digital demands.
- AI optimizes and enriches clinical simulation and the learning of diagnostic and procedural skills through virtual patients, surgical simulators, and immersive augmented reality tools that reproduce realistic and safe clinical environments.
- The introduction of generative AI requires a review of assessment methods, promoting diversified and hybrid formats such as oral exams, collaborative tasks, and face-to-face assessments.
- Early exposure to AI tools in clinical settings demands a dual competence: handling predictive and automated diagnostic technologies without compromising independent clinical reasoning or professional autonomy.
- The integration of AI raises ethical and legal challenges that require specific training. Ethical and regulatory literacy is essential for critical and responsible medical practice.
- National coordination is required to guarantee minimum competencies in clinical AI, aligning curricula with strategic frameworks such as the National Artificial Intelligence Strategy and promoting clinical practices with validated tools and shared resources among universities.

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Table 1. AI applications in simulation environments as a training tool .

Company	AI-enabled products	AI application	Advanced technology
CAE Health (Canada)	CAE Ares, Lucina, Vimedix	- Adaptive scenarios - Smart Report	- Detection of response patterns, analysis of clinical decisions and automatic adaptation to the complexity of the scenario. - Autonomous evolution of the clinical case.
Laerdal Medical (Norway)	SimMan 3G PLUS, SimCapture, vrClinicals for nursing	- Automated feedback. - Session analysis using AI.	- It allows for the automatic evaluation of clinical and technical skills, providing immediate feedback based on intelligent algorithms. - SimCapture is used to record, evaluate, and analyze simulation sessions. - Partnership with B-Line Medical to incorporate automated video analytics. - Integration of AI into neonatology simulators in collaboration with SIMCharacters to predict complications and reactions.
3D Systems (USA)	RobotiX Mentor, GI* Mentor, Angio's Mentor	- Real-time surgical evaluation with AI	- Real-time feedback during simulated surgical procedures. - Analyzes movement patterns, applied force, and precision of surgical gestures. - Simulation based on real-world case data and machine learning to adapt scenarios. - It uses neural networks trained on thousands of recorded surgical procedures.
VirtaMed (Swiss)	ArthroS, GynoS, UroS™, Laparos	- Customized simulation - Learning curve analysis	- Uses AI algorithms to adapt the difficulty of procedures (e.g., arthroscopies, laparoscopies, gynecology). - Analyzes the user's learning curve to suggest personalized training. - Hybrid physics simulators and VR $^{+}$ with AI that evaluates accuracy, speed, trajectory, and applied pressure.

* , GI Gastrointestinal, $^{+}$VR Virtual Reality