

# The evolution of health in science: future perspectives

## O caminhar da saúde na ciência: perspectivas futuras

## El camino de la salud en la ciencia: perspectivas futuras

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### ABSTRACT

This editorial discusses the future perspectives of artificial intelligence in healthcare delivery, research, and education, highlighting its potential to integrate multiple sources of information, support clinical decision-making, personalize care, and broaden access to advanced healthcare technologies. Challenges related to data quality and representativeness, algorithmic bias, interoperability, model transparency, legal accountability, and the continuous monitoring of artificial intelligence systems following implementation are also discussed. Furthermore, the editorial emphasizes the importance of using artificial intelligence to automate administrative processes, enabling healthcare professionals—particularly nurses—to devote more time to direct patient care, communication, and the establishment of therapeutic relationships. In professional education, it underscores the need to develop digital competencies without compromising the acquisition of independent clinical reasoning, drawing attention to the potential risk of never-skilling. Finally, the editorial examines the growing adoption of predictive technologies, multimodal models, biosensors, and digital health applications, reinforcing the urgent need for robust frameworks for governance, regulation, and clinical validation. It concludes that the impact of artificial intelligence on healthcare will depend on successfully integrating technological innovation with ethical principles, equity, transparency, and social responsibility, ensuring that scientific advances translate into meaningful improvements for both individuals and populations.

**Descriptors:** Artificial Intelligence; Digital Health; Health Personnel.

### RESUMO

Este editorial discute as perspectivas futuras da inteligência artificial na assistência, na pesquisa e na educação em saúde, destacando seu potencial para integrar múltiplas fontes de informação, apoiar a tomada de decisão clínica, personalizar o cuidado e ampliar o acesso a tecnologias de alta complexidade. São abordados desafios relacionados à qualidade e à representatividade dos dados, aos vieses algorítmicos, à interoperabilidade, à transparência dos modelos, à responsabilidade jurídica e ao monitoramento contínuo dos sistemas após sua implementação. O editorial enfatiza, ainda, a importância de utilizar a inteligência artificial para automatizar processos administrativos, permitindo que profissionais, especialmente de enfermagem, dediquem maior tempo ao cuidado direto, à comunicação e ao vínculo terapêutico. No campo da formação profissional, ressalta-se a necessidade de desenvolver competências digitais sem comprometer a construção do raciocínio clínico independente, alertando para o risco do never-skilling. Por fim, discute-se a expansão de tecnologias preditivas, modelos multimodais, biossensores e aplicativos em saúde, reforçando a urgência de modelos robustos de governança, regulação e validação clínica. Conclui-se que o impacto da inteligência artificial na saúde dependerá da integração entre a inovação tecnológica, os princípios éticos, a equidade, a transparência e o compromisso social, assegurando que os avanços científicos resultem em melhorias efetivas para indivíduos e populações.

**Descritores:** Inteligência Artificial; Saúde Digital; Pessoal de Saúde.

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## RESUMEN

Este editorial analiza las perspectivas futuras de la inteligencia artificial en la atención sanitaria, la investigación y la educación en salud, destacando su potencial para integrar múltiples fuentes de información, apoyar la toma de decisiones clínicas, personalizar la atención y ampliar el acceso a tecnologías sanitarias de alta complejidad. Asimismo, se abordan los desafíos relacionados con la calidad y la representatividad de los datos, los sesgos algorítmicos, la interoperabilidad, la transparencia de los modelos, la responsabilidad jurídica y el monitoreo continuo de los sistemas de inteligencia artificial tras su implementación. El editorial también enfatiza la importancia de utilizar la inteligencia artificial para automatizar los procesos administrativos, permitiendo que los profesionales de la salud, especialmente el personal de enfermería, dediquen más tiempo a la atención directa, la comunicación y el establecimiento del vínculo terapéutico. En el ámbito de la formación profesional, se destaca la necesidad de desarrollar competencias digitales sin comprometer la adquisición del razonamiento clínico independiente, advirtiendo sobre el posible riesgo del never-skilling. Por último, se analiza la creciente adopción de tecnologías predictivas, modelos multimodales, biosensores y aplicaciones de salud digital, reforzando la urgente necesidad de establecer marcos sólidos de gobernanza, regulación y validación clínica. Se concluye que el impacto de la inteligencia artificial en la salud dependerá de la integración de la innovación tecnológica con los principios éticos, la equidad, la transparencia y el compromiso social, garantizando que los avances científicos se traduzcan en mejoras significativas para las personas y las poblaciones.

**Descriptores:** Inteligencia Artificial; Salud Digital; Personal de Salud.

## Highlights

1. The greatest challenge is not merely developing AI, but defining which decisions should remain essentially human.
2. AI systems require validation, transparency, and continuous monitoring to reduce biases, inequalities, and risks to patient care.
3. The future of AI in healthcare must be guided by ethics, equity, social responsibility, and the strengthening of human care.

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## Artificial intelligence and the new directions of healthcare

Health has consistently evolved alongside scientific and technological advances. Throughout different historical periods, innovations such as microscopy, antibiotics, and genomic sequencing have redefined the understanding of diseases and transformed clinical practice. Artificial intelligence (AI) represents the latest chapter in this trajectory. However, unlike previous innovations, it not only enhances diagnostic and therapeutic capabilities but also transforms the very production of scientific knowledge<sup>1,2</sup>. Once regarded primarily as a decision-support tool, AI is progressively playing increasingly autonomous roles in healthcare delivery, research, and education. Its scope encompasses systems capable of integrating multiple sources of information and coordinating clinical, scientific, and educational workflows. Consequently, AI marks a new stage in digital transformation, with implications that extend beyond clinical practice to reshape the production of scientific knowledge itself.

Science has incorporated systems that assist with stages traditionally reserved for researchers, ranging from hypothesis generation to experimental design and literature synthesis, thereby reshaping the expansion of biomedical knowledge. Today, AI has dramatically expanded access to forms of care that were once limited to centers of excellence. Systems capable of managing clinical cases from start to finish—from triage to therapeutic decision-making—are already undergoing experimental assessment<sup>1</sup>. This progress, however, does not imply that combining AI with healthcare professionals invariably produces the best outcomes. Evidence suggests that, in certain medical imaging tasks, AI systems operating independently may outperform the combination of clinician and AI, particularly when clinicians disregard correct algorithmic recommendations. Conversely, when AI itself is responsible for collecting patient information by conducting the clinical interview, rather than analyzing previously collected data, its accuracy tends to decline, as it still lacks the contextual sensitivity required to determine which questions should be asked in response to incomplete or ambiguous answers. Therefore, the most promising approach is not the indiscriminate combination of human and machine, but rather a deliberate allocation of responsibilities between them. The challenge is no longer merely to develop AI, but to determine which decisions should remain fundamentally human.

However, technological enthusiasm should not obscure the structural limitations of AI. In other words, the quality of an AI system depends on the representativeness of the data used to train it, and biased datasets can amplify existing health inequalities. Studies have shown that economic uncertainty, regulatory fragmentation across countries, and practical barriers, such as healthcare professionals' distrust, cognitive overload, and lack of interoperability, are as significant as technical challenges<sup>1,2</sup>. In addition, the opacity of certain AI models remains a major concern, as their internal decision-making processes cannot be fully explained, even by their developers. Furthermore, important legal questions remain unresolved: when an AI-generated recommendation contributes to patient harm, should responsibility rest with the healthcare professional, the institution, the developer, or the regulatory authority that approved the system? There is growing consensus that AI systems should meet validity standards comparable to those required for pharmaceuticals, supported by a form of algorithmic pharmacovigilance, i.e., continuous post-deployment monitoring of system performance, analogous to the post-marketing surveillance already established for medications<sup>2</sup>.

There is also a human dimension that warrants particular attention. Experience with electronic health records provides a valuable warning: healthcare professionals have come to spend nearly twice as much time on administrative tasks as on direct patient care. The most promising approach is to automate

administrative rather than relational tasks, thereby allowing healthcare teams—and nursing professionals in particular, who have historically been responsible for direct care and the establishment of therapeutic relationships—to devote more time to listening, empathy, and patient care. At the same time, the challenge of the coming decades is also educational: to train professionals who are capable of critically interpreting and effectively using data and technological solutions<sup>2</sup>. AI itself is already emerging as a pedagogical tool, offering adaptive learning environments for healthcare students.

A recently described risk in this context has been termed “never-skilling”—the hypothesis that students exposed to AI too early in their training may never develop the independent clinical reasoning required for safe practice. This phenomenon is distinct from both the loss of skills among experienced professionals and the uncritical internalization of AI-generated errors by learners.<sup>1,2</sup> Although direct evidence in healthcare remains limited, the hypothesis is grounded in well-established learning theory and underscores the need for curricula that foster a solid foundation of independent clinical reasoning before the supervised integration of AI into training. This gap is closely related to the increasing digitalization of healthcare systems, which requires healthcare professionals to develop and maintain digital competencies throughout their careers.

The future of healthcare is expected to become increasingly predictive, personalized, and distributed. The convergence of multimodal models, intelligent agents, and connected sensors is likely to enable systems capable of continuously monitoring individuals and populations by integrating data, medical images, physiological signals, and environmental information into a unified decision-making process. Algorithms that incorporate genomic, environmental, and lifestyle data are already making it possible to predict individual health risks and anticipate interventions, thereby scaling up preventive strategies that public health has pursued for decades. Population aging adds another important dimension, with AI supporting the early detection of frailty, the management of multimorbidity, and the prevention of falls. Low-cost, lightweight technologies, mobile diagnostic tools, biosensors, and AI-assisted risk stratification in Primary Health Care have the potential to promote equity in low-resource settings, provided that these technologies are developed in partnership with local communities to prevent further widening of the existing digital divide. Governance models that combine economic assessment, data standardization, and multidisciplinary collaboration are emerging as key pathways toward the safe, sustainable, and socially responsible adoption of AI in healthcare.

At the same time, a rapidly expanding market of health applications and chatbots is developing largely outside traditional regulatory oversight and the formal healthcare system. These applications and chatbots are reaching the public without prior clinical validity, without the involvement of healthcare professionals in decision-making processes, and without the same data protection safeguards required by law, creating a regulatory gap that is expanding at the same pace as the market itself. This mismatch gained international recognition in 2026, when the first independent scientific panel of the United Nations on AI warned that global governance remains far behind the pace of technological advances and the worldwide concentration of computational infrastructure. As the panel concluded, the scientific knowledge is already available. The challenge now is to ensure that its implementation is guided by the principles of equity, transparency, and the collective good.

The history of healthcare has always been shaped by humanity’s ability to transform knowledge into care. AI may accelerate this trajectory, but it will ultimately be science—guided by ethics, equity, and social responsibility—that determines whether this transformation produces merely new technologies or a genuinely healthier society.

## Author Contributions

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Salvador ME: Conception and design of the research; Data acquisition; Drafting the manuscript; Critical revision of the manuscript for important intellectual content. Bandiera-Paiva P: Conception and design of the research; Data acquisition; Drafting the manuscript; Critical revision of the manuscript for important intellectual content. Barbosa DA: Conception and design of the research; Data acquisition; Drafting the manuscript; Critical revision of the manuscript for important intellectual content.

## Conflict of Interest

The authors declare that they have no conflicts of interest.

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