Revista Bioética
Print version ISSN 1983-8042 | On-line version ISSN 1983-8034

Rev. Bioét. vol.33 Brasília 2025

Artificial intelligence: a bridge to the future of medicine

Rui Nunes [1], *Sofia B Nunes* [1]

1. Faculdade de Medicina da Universidade do Porto, Porto/Portugal.

Abstract

Artificial intelligence has become an essential tool across various fields of medicine, enabling new patterns of innovation such as precision medicine, neurosciences, genomics, and proteomics. This article aims to synthesize the main ethical challenges arising from the application of artificial intelligence in medicine, in order to promote responsible implementation of these digital technologies, always serving people and humanity. Additionally, it proposes a set of recommendations for developing trustworthy artificial intelligence in the medical context. Methodologically, an in-depth analysis was conducted of the main international ethical and legal instruments regulating artificial intelligence. It is concluded that effective ethical governance is essential to preserve human agency in the application of artificial intelligence systems and to ensure full transparency in research and development processes.

Keywords: Artificial intelligence. Medical ethics. Regulation of artificial intelligence. Transparency in research. Bioethics. Technology and health.

Resumo

Inteligência artificial: uma ponte para o futuro da medicina

A inteligência artificial tornou-se ferramenta essencial em diversos domínios da medicina, possibilitando novos padrões de inovação, como medicina de precisão, neurociências, genômica e proteômica, entre outros. Este artigo busca sintetizar os principais desafios éticos suscitados pela aplicação da inteligência artificial na medicina, a fim de promover uma implementação responsável dessas novas tecnologias digitais, sempre a serviço das pessoas e da humanidade. Além disso, propõe-se um conjunto de recomendações para o desenvolvimento de uma inteligência artificial confiável no contexto médico. Do ponto de vista metodológico, realizou-se análise aprofundada dos principais instrumentos éticos e jurídicos internacionais voltados à regulação da inteligência artificial. Conclui-se que a exigência de uma governança ética eficaz torna imprescindível garantir a preservação da agência humana na aplicação dos sistemas de inteligência artificial, bem como assegurar total transparência nos processos de pesquisa e desenvolvimento dessas tecnologias.

Palavras-chave: Inteligência artificial. Ética médica. Regulação da inteligência artificial. Transparência na pesquisa. Bioética. Tecnologia e saúde.

Resumen

Inteligencia artificial: un puente hacia el futuro de la medicina

La inteligencia artificial se ha convertido en una herramienta esencial en diversos campos de la medicina, posibilitando nuevos patrones de innovación, como medicina de precisión, neurociencias, genómica y proteómica. Este artículo busca sintetizar los principales desafíos éticos surgidos de la aplicación de la inteligencia artificial en la medicina, con el objetivo de promover una implementación responsable de estas tecnologías digitales, siempre al servicio de las personas y la humanidad. Además, se proponen un conjunto de recomendaciones para el desarrollo de una inteligencia artificial confiable en el contexto médico. Metodológicamente, se realizó un análisis exhaustivo de los principales instrumentos éticos y jurídicos internacionales orientados a la regulación de la inteligencia artificial. Se concluye que una gobernanza ética eficaz es fundamental para preservar la agencia humana en la aplicación de los sistemas de inteligencia artificial y garantizar total transparencia en los procesos de investigación y desarrollo.

Palabras clave: Inteligencia artificial. Ética médica. Regulación de la inteligencia artificial. Transparencia en la investigación. Bioética. Tecnología y salud.

The authors declare no conflict of interest.

Dossier

Artificial intelligence (AI) is dramatically changing the lives of people across the planet, influencing fundamental aspects of our social lives in areas such as the economy, financial system, creative arts, education, and even public health or health care service delivery. Today, scientific research and technological development are already controlled on a large scale by AI, enabling new patterns of innovation, such as proteomics, which implies serious ethical challenges [1].

Numerous international institutions—such as the World Health Organization (WHO) [2], European Commission [3], European Parliament [4], Office of Science and Technology Policy (United States) [5], Nuffield Council on Bioethics [6] and the National Ethics Council for Life Sciences of Portugal [7]—have expressed important reservations in the application of AI, suggesting the need for effective supervision in its development and human control in its application. Brazil's Federal Council of Medicine (CFM) has also expressed special concerns regarding the subject, having created a working group to address it.

This article aims to synthesize the main ethical challenges arising from the application of AI in medicine to promote a responsible implementation of the new digital technologies, always serving humanity. It also seeks to provide a set of recommendations for developing reliable AI in medicine. To this end and from a methodological point of view, we conducted a detailed analysis of the main international ethical and legal instruments regulating AI.

Dossier

Artificial intelligence in research and medicine

The development of artificial intelligence—defined as a human-designed system that, given a complex objective, acts in the physical and digital dimensions, perceiving its setting through data acquisition, interpreting the obtained data in a structured or unstructured manner, reasoning on knowledge or processing the information derived from these data and deciding the best course of action to achieve this objective [8]—is part of a broad digital transition that is widespread in our society. This phenomenon is characterized by a rapid expansion of different information and communication technologies (ICT), an unprecedented development of quantum computing, the implementation of robotics in the most different fields of activity, or the generation of meta data, big data and lake data, without effective control and supervision.

Artificial intelligence systems have distinct characteristics that imply a paradigm shift, not constituting simply a new digital tool. In fact, AI has the capacity to learn and self-learn, automatically (machine learning), deeply (deep learning) or by association between different concepts. Another hallmark of AI is networking, that is, the capacity to work in an interactive network: the activity of autonomous robots, for example, is independent, but also interconnected. The very concept of "social robot" refers not only to interaction with humans, but to connectivity between different AI systems.

On the other hand, autonomous robots move in human physical space. Thus, AI is not spatially restricted to a computer, but can move and even contact anyone through the proficient use of human language. This poses a huge challenge for humanity, given that the capacity to master language can lead to the capture of essential aspects of human culture and civilization, even before the singularity is achieved [9]. Singularity is understood as a phase in which artificial intelligence, intentionally or unintentionally, acquires the ability to control the collective development of humanity without our species being able to understand the mechanisms of activity and functioning of AI systems [10]. Therefore, understanding how AI is evolving is critical [11].

More speculative is the possibility of AI developing sentience [12] (ability to have subjective experiences) or even cybernetic personality [13]. Based on software that operates in the virtual setting (voice assistants, image analysis software, search engines, facial recognition systems, etc.), or embedded in hardware (social robots, autonomous vehicles, drones, etc.), AI seems to have no technological limits to its development. In other words, it has the potential to revolutionize how scientific knowledge is taught, learned, researched and applied.

In education and research, generative AI—which has ChatGPT, DeepSeek, Claude, Gemini and DALL-E as good examples—has led to disruptive scientific and pedagogical innovation due to it

streamlined production and rapid implementation. If properly used, with integrity and professionalism, it can encourage students to acquire technical skills more easily [14].

Generative AI enables the implementation of a more personalized and attractive active learning model in all scientific domains, quickly contributing to the development of useful pedagogical content to support students (summaries, flashcards, content questions, etc.) and teachers (preparation of materials for use in lesson plans, reports, slides, discussion questions and exam questions). It can also be important to help formulate scientific questions that boost reflection and research on a given topic, or even enable using bibliographic material provided by teachers instead of simply consulting the internet. It is an excellent tool for translating texts and writing papers, also enabling the development of new applications, with inexhaustible potential [15].

However, generative AI raises serious reservations that must be addressed, namely in terms of scientific and academic integrity. As it uses primary databases that flow freely on the internet (some data can be exponentiated in a segmented way and, therefore, the results are biased), it is possible to question whether it is plagiarism to use a previously published generative text that uses the intellectual creation of third parties. This is a circumstance that raises natural reservations in terms of ethics and that has implications for the enjoyment of copyright, or the generation of commercial patents, especially in medicine. Consequently, a new legal and regulatory framework is needed to define the use of generative AI in academia, research centers and translation for companies, considering the following ethical aspects:

1. Data protection and individual privacy.
2. Copyright.
3. Prevention of plagiarism.
4. Obtaining credible references.
5. Guarantee of verifiability, reliability and veracity of information.
6. Fighting disinformation.
7. Control of information flow.
8. Guarantee of digitally included users.

On the other hand, scientific creativity—fundamental for a consistent evolution of medicine—can be limited with the systematic use of artificial intelligence, since the perspective introduced by the primary databases that feed AI and generative AI limits the intellectual creativity that is a hallmark of the scientific spirit. On contemporary times, it is already difficult for scientists to think "outside the box," due to the systematic administrative constraints raised by institutional scientific policies, in the future it will be more complex to avoid the algorithm of convergence between AI and the scientific evidence systematized by meta-analyses. In addition, chance in science (serendipity)—responsible for incredible scientific benefits in medicine (discovery of penicillin, heparin or X-rays)—will surely remain residual.

The enormous potential of artificial intelligence poses risks, which require extreme caution in its employment. One of the main risks is the lack of explainability of AI, that is, the inability to understand how AI is processed and how certain results are achieved. The lack of reproducibility (the possibility of another research exhibiting the same behavior under the same conditions, with the same method, with corresponding scientific evidence) and replicability (the capacity of an independent research to reach similar, albeit non-identical, conclusions when there are differences in the sample, research procedures and data analysis methods) should be carefully assessed, so the reliability of medical science [16] and its applications is not questioned [17].

For several reasons, there is a crisis of reliance on medical science, of which the crisis of reproducibility is only one aspect [18]. Other factors, such as the dangerously decreased levels of freedom in the planning, conduct and analysis of scientific studies [19], the progressive commodification of science, the requirement of criteria, by peer review, which objectively limit intellectual creativity, can be exponentiated by AI in the future, being essential to have creative solutions to deal ethically with such phenomena.

In medicine, AI poses a considerable ethical-social challenge. It can be extremely useful in providing new diagnostic and treatment modalities, as well as preventing potentially fatal diseases. Additionally, it can provide physicians with a more accurate and detailed analysis, supporting the diagnosis and treatment of several diseases [20]. In radiology, for example, AI is extremely useful,

assisting in the detection of suspicious images and in the enhancement of images, or even in screening [21]. Radiology is one of the areas in which AI will have an impact in the short term, with expectation of increased accessibility to this type of service, especially if combined with telemedicine and other forms of e-health [22]. However, this efficient image interpretation may generalize its use and interpretation by health care professionals not specialized in the field, which implies less ability to critically analyze the results and to detect failures by AI.

All areas of medicine will be impacted by AI, such as dermatology [23], breast cancer screening and treatment [24], cardiovascular sciences [25], antibiotic production [26] , and even clinical nutrition. In this area, AI can assist in the analysis of complex data, suggestion of personalized nutritional interventions, assessment of nutritional needs, prevention of diseases or monitoring of dietary intake, orienting patients toward healthier food choices [27].

In palliative care, AI has the enormous potential to support clinicians in decision-making and in tracing patients at high risk of mortality or inappropriate treatment. Moreover, AI tools can facilitate some central aspects of palliative care, such as supporting the clinical interview with the objective of providing advanced care planning or adjusting the treatment plan to the patients' needs and choices [28]. In long-term care, AI can support caregivers of older adults or be useful for monitoring patients in real time, possibly from long distances, such as in telemedicine. In medicine, AI has seen unexpected evolution; however, the lack of explainability—leading to the issue known as "black box" (users are unable to comprehend the device or how it works)—poses a complex challenge.

The progressive transition to the "digital physician"—context in which physicians can assume the role of co-pilot of AI in clinical practice—requires a redefinition of the framework of responsibilities and new forms of professional and organizational accountability. It should be noted, however, that modern AI applications in clinical medicine, through the transcription of medical consultation [29], already have the ability to make differential diagnosis, make suggestions for complementary means of diagnosis, and produce treatment recommendations. This "scribe and coach" function has the possibility of distorting the physician-patient relationship, affecting essential aspects of this relationship, such as the experience-based medical intuition or the empathy and compassion that are so necessary in interpersonal relationships. On the other hand, it may be questioned whether therapeutic guidance resulting from prompts and their responses would be recommended according to *leges artis*, and what effective mechanisms exist to prevent undesirable harm and complications.

The ethical nature of the relationship with the patient should always be deepened, and this is the best capital that medicine has to offer in a deeply technological society [30]. It is important to ensure that the clinical relationship with the patient is not distorted by estrangement between health care providers and patients, and it is necessary to develop measures to deepen the relationship of trust in clinical practice and research in human beings.

In short, at the interface between medicine, biomedicine, science and research, AI poses serious challenges that can become important opportunities for collective development. It will have an extraordinary impact on health care management, both in operational management and the transnational regulation of access to health care, for example, through generalization of the health wallet—a mobile digital application with personal health-related data—a technology that will combine not only data collected in the electronic medical record, but all other stored health-related data, for example:

1. Digital systems of the private and social sector.
2. Telemedicine and other forms of e-health.
3. Mobile health applications.
4. Virtual service solutions.
5. Remote monitoring applications.
6. Wearable electronic devices (smart watches, smart jewelry, digital glasses, bluetooth headphones, fitness trackers, etc.).

In any case, this astonishing evolution in recent years raises significant ethical reservations that must be addressed in depth and clarified.

Artificial intelligence, ethics and regulation

The implementation of artificial intelligence, especially artificial general intelligence (AGI), raises

fundamental ethical issues, both for society and for medicine, science and research. These issues are constantly evolving, as emerging AI applications raise novel, previously unanticipated issues. Still, the implementation of AI should particularly consider the respect for core ethical values such as human autonomy, non-discrimination, data protection and individual privacy, justice, and the rights of vulnerable populations such as children, older adults, and persons with disabilities. It also implies fostering digital inclusion and tackling the disinformation that digital exclusion can cause, with an undeniable impact on the labor market, including medicine and other health-related professions.

It is important to ensure constant human supervision and control during the development and use of AI; however, this effort alone is not sufficient. It is necessary to ensure that companies that conduct research with and on artificial intelligence promote the transparency of procedures and always incorporate an ethical perspective into the design of these systems. Only thus will AI be truly reliable and contribute to sustainable human development. According to the Independent High-Level Expert Group on Artificial Intelligence [31], it is crucial to ensure seven essential ethical criteria in the development and application of AI:

1. Human agency and supervision.
2. Technical robustness and safety.
3. Data privacy and good governance.
4. Transparency.
5. Diversity, non-discrimination and justice.
6. Social and environmental well-being.
7. Accountability.

Another important issue raised by the use of AI is the evolution of the social values framework, considering that it can be informed by the very perspective of the technology. This is a long-term core issue, as the primary sources that feed generative AI are heavily influenced by principles such as the doctrine of human rights, respect for human dignity, the protection of individual identity, equality and non-discrimination, as well as the preservation of the environment and biodiversity—founding values of pluralistic democracies and pillars of modern medical ethics. However, nothing prevents that, in a more or less near future, new ideologies feed generative AI, forming currents of opinion less committed to these values and their ethical framework, and more oriented toward citizen control. In addition, it is possible that AI is used to alter previously established currents of thought [32]. Currently, AI seems to rely on a solid core of ethical principles [33], which is especially relevant in areas that are sensitive from a human perspective, such as medicine.

On the other hand, freedom of expression can be seriously conditioned, favoring the mass propagation of disinformation and misinformation, with a significant impact on the health care sector. A recent example was the spread of false information during universal vaccination campaigns, which resulted in public health consequences. All efforts should be directed at creating a vibrant civil society, enlightened and well-informed about scientific facts validated by agencies of recognized credibility, which implies increasing the general levels of literacy, especially on how to interact with different social networks and with AI itself [34]. New forms of social cooperation, such as "collective intelligence" applied to the public decision-making process, can also be considered [35].

The WHO recognizes that AI has the enormous potential to expand access to health care [36]. With the expanded use of digital systems, significant gains in equity in access to services of appropriate quality are expected, considering that health is a universal right [37]. Solidarity—a pillar of social life and the foundation of the welfare State—must be preserved, ensuring that AI does not place these rights at risk or contribute to the creation of new forms of social exclusion or restriction of access to health care systems. Justice, equality and non-discrimination must be ensured at the national and international levels. In other words, the expected benefits should be shared by society as a whole, and not just by specific groups. The adoption of AI must respect a common humanitarian principle, being desirable that it contributes toward increasing global justice and reducing inequalities between the North and the South.

Sharing findings of research with and on AI will contribute not only toward increasing productivity on a global scale, but also to fostering greater social justice. That is because digital technologies and AI, if properly implemented, can play a decisive role in achieving equality as a universal goal [38], fostering the creation and strengthening of inclusive,

safe, resilient and environmentally sustainable communities[39]. It is essential to promote gender equality, ensuring that women and men have the same conditions to fully exercise their human rights, as well as to contribute to and enjoy the benefits of economic, social, cultural and political development. The World Economic Forum, in this sense, emphasizes the need to invest in research focused on women, including the collection of scientific data on women, the expansion of women's access to good quality health care services and the fostering of female leadership[40].

AI and generative AI pose relevant ethical challenges to medicine and other life sciences, requiring special consideration in the health care sector. Therefore, the following are some recommendations for an ethical and responsible implementation of AI:

1. Promotion of respect for individual freedom and prevention of harm to human beings: one of the core values of civilized societies is the exercise of individual freedom and responsible citizenship[41]. In medicine, the exercise of individual ethical freedom transformed the physician-patient relationship and led, for example, to the widespread implementation of informed consent and advance directives and living wills[42]. Artificial intelligence can and should contribute to the exercise of a person's freedom and self-determination, which implies ensuring adequate digital literacy for the general population and for patients in particular, given that several currently used tools—such as the AI-processed electronic medical record, or the use of generative AI to interpret informed consent[43]—require substantial digital inclusion. To achieve these goals, it is important to involve stakeholders throughout the life cycle of AI systems, as well as redefine the liability system, including the provision of activity-specific insurance. It is critical that the implementation of AI systems—from design and research to implementation and operationalization—is always under human control. Robust AI governance and supervision mechanisms should be implemented, such as the European Union's Artificial Intelligence Regulation[44]. Special attention is required as to the so-called "existential risk " (X-Risk) for humanity and civilization[45], resulting from the development of cybernetic personality or technological singularity[46].
2. Protection of individual privacy, safeguarding of personal data and promotion of good governance of data and metadata: individual privacy is one of the most protected rights, as the intimacy of private life is part of the most identitarian and exclusive sphere of the human person. Directly related to this right is the protection of personal data, another hallmark of the democratic rule of law[47]. In the field of health care, the protection of privacy and personal data is especially relevant, as it is an essential matter for the free development of personality. In science and research, there is an enormous desire for personal health data, which by nature are sensitive and private; therefore, AI and related technologies—such as quantum computing – must be developed under the paradigm of respect for these values[48]. Researchers—even if well-intentioned—should not allow the *ethos* of science to override individual rights, being subject to expanding the scope of the innovative right to be forgotten, that is, the possibility of a patient requesting the removal of their personal data from digital systems[49]. The use of synthetic AI-generated data can be a solution to circumvent the limitation of anonymization and pseudonymization (de-identification) in ensuring full protection of sensitive personal data[50], which requires the adoption of a global cybersecurity and data protection strategy[51].
3. Guarantee of scientific integrity and prevention of conflicts of interest: science, especially medicine, has overcome all technological barriers; however, there arises the issue its ethical and social limits. Scientific integrity and ethics in biomedical research apply to all phases of scientific development, from project conception to commercial use. The use of generative AI, such as ChatGPT[52], requires redefining the rules for consulting previously published studies, clarifying the original author; it also requires rethinking the criteria of originality, measures to combat plagiarism, editorial rules and supervision criteria for scientific journals, in addition to reinforcing mechanisms that ensure research replicability and reproducibility as proof of its scientific

value [53]. Modern mechanisms for verifying researchers' conflicts of interest must be implemented, ensuring that the scientific *ethos* is not distorted by the new technologies. It is also critical that AI systems are designed to respect these universal scientific values and principles [54], avoiding turbocharging misinformation and algorithmic bias [55], and that there is assessment as to the creation of a specific code of conduct for the use of AI [56].

4. Protection of vulnerable groups, such as children, older adults, persons with disabilities, migrants and patients in general: it is a civilizing principle that AI contributes toward inclusion, not exclusion. The contemporary conception of a social well-being model that ensures equal opportunities for all, regardless of the "lottery of life," must find in AI an ideal partner for the full accomplishment of this goal. To this end, it is necessary to restructure value chains around new digital technologies, to promote improvements in quality of life and social well-being. While AI systems provide undeniable benefits, they also pose risks that can affect more vulnerable populations negatively—and in a way that is difficult to predict, identify, or measure. In mental health, for example, it is estimated that virtual reality can have an especially relevant impact, producing concrete results for patients [57]. Therefore, it is urgent to implement an AI literacy strategy [58] that addresses the new digital health technologies, conducted in a participatory and positive manner, so everyone can benefit from it, especially in access to health care and scientific advances [59].
5. Guarantee of the positive impact of AI on global health and the promotion of One Health: both in access to health care systems and in situations of public health emergency, AI is considered an indispensable tool for the management of individual and collective health. A new wave of personalized and precision medicine finds in AI the ideal resource for its rapid implementation. In public health, AI has shown high effectiveness in China and Canada in contact tracing, identifying all people exposed to respiratory droplets or secretions from COVID-19 cases. This tracing enabled stratifying exposure risks and implementing measures such as prophylactic isolation and epidemiological surveillance, thus preventing the spread of the infectious disease. Responses of this type are even more important on a global scale, in the context of global health, which requires a supranational and coordinated strategy. To ensure efficient epidemiological tracing, with concrete benefits for the global health of populations, it is essential to standardize classification procedures and systems. Coding is essential to enable the comparison of strategies and results, as exemplified by the International Classification of Health Interventions [60]. Thus, One Health is promoted—a concept that recognizes the deep interconnection between human health, animal health and the environment around us [61].
6. Recognition of reliable artificial intelligence as the 18th Sustainable Development Goal (SDG): given the transversal and interconnected impact of AI across all domains of activity, the 17 SDGs currently in effect will be, in some way, influenced by this technology [62]. The 2030 Agenda includes several dimensions of sustainable development, with the purpose of promoting peace, justice and the creation of effective institutions. In this context, establishing clear limits for the application of AI arises as an inevitable measure, which is especially relevant in the fields of medicine and life and health sciences.

Final considerations

For AI to be considered reliable in medicine, health care, research, and society as a whole, some steps seem inevitable. First, it is essential to develop and use AI systems while respecting the freedom and self-determination of the human person, preventing potential harm and ensuring justice in its use, especially by means of effective human control. There should be special consideration as to the most vulnerable groups, such as children, older adults and persons with disabilities, in addition to those at risk of social exclusion caused by labor relation changes introduced by AI or the so-called "generational dividend," resulting from the natural acquisition of

digital skills by younger generations compared to previous generations.

On the other hand, ensuring full human development and sustainable and specialized economic growth requires fostering innovation and the acquisition of digital skills, including by further developing explainable AI (XAI). This requires a new approach to transgenerational academic education and the introduction of universal AI education in schools, so young persons quickly acquire transversal skills in the area. In turn, medical schools should adapt to this context and adopt an educational approach oriented toward responsible use of AI in medical training.

It can be concluded that, since AI is a technology under rapid international expansion, ensuring these ethical values requires redefining global governance mechanisms so as to ensure not a ban but effective and comprehensive regulation. As effective ethical governance is required, it is essential to preserve human agency in the application of AI systems (human in the loop) and ensure full transparency and rigorous *accountability* in research with and on artificial intelligence.

The author Rui Nunes holds the position of honorary scientific editor of Revista Bioética. *This article is part of the journal's tribute to the 80th anniversary of Brazil's Federal Council of Medicine.*

References

1. Stahl BC. Artificial intelligence for a better future. An ecosystem perspective on the ethics of AI and emerging digital technologies [Internet]. Cham: Springer; 2021 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/ftu75btx
2. World Health Organization. Ethics and governance of artificial intelligence for health. Guidance on large multi-modal models [Internet]. Geneva: WHO; 2024 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/z8cwb4nf
3. European Commission. European health data space [Internet]. 2024 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/5n6nbbt2
4. European Parliament. Artificial intelligence in healthcare [Internet]. 2022 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/5n97dsvk
5. Office of Science and Technology Policy. Blueprint for an AI Bill of Rights: making automated systems for the American people [Internet]. 2022 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/2cua5m8v
6. Nuffield Council on Bioethics. Artificial intelligence (AI) in healthcare and research. London: Nuffield Council on Bioethics; 2018.
7. Nunes R, Ricou M, Godinho I, Neves MP, coordenadores. Livro branco sobre inteligência artificial (IA): inquietações sociais, propostas éticas e orientações políticas [Internet]. Lisboa: Conselho Nacional de Ética para as Ciências da Vida; 2024 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/fzavv5ma
8. European Commission. A definition of AI: main capabilities and scientific disciplines. Brussels: European Commission; 2018.
9. Harari YN. Nexus: a brief history of information networks from the stone age to AI. New York: Random House; 2018.
10. Ananthaswamy A. How close is AI to human-level intelligence?. Nature [Internet]. 2024 [acesso 29 jul 2025];636(5):22-5. Disponível: https://tinyurl.com/3mwefdhu
11. Jones N. How should we test AI for human level intelligence?: Open AI's o3 electrifies quest. Nature [Internet]. 2025 [acesso 29 jul 2025];637(8047):774-5. DOI: 10.1038/d41586-025-00110-6
12. Butlin P, Long R, Elmoznino E, Bengio Y, Birch J, Constant A, Deane G *et al*. Consciousness in artificial intelligence: insights from the science of consciousness (Preprint). Arxiv [Internet]. 2023 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/5n8hnjfy
13. Lenharo M. What should we do if AI becomes conscious? These scientists say it's time for a plan. Nature [Internet]. 2024 [acesso 29 jul 2025];636:533-4. DOI: 10.1038/d41586-024-04023-8

14. Lee P, Bubeck S, Petro J. Benefits, limits, and risks of GPT-4 as an AI chatbot for medicine. N Engl J Med [Internet]. 2023 [acesso 29 jul 2025];388(13):1233-9. DOI: 10.1056/NEJMsr2214184
15. Haug CJ, Drazen J. Artificial intelligence and machine learning in clinical medicine. N Engl J Med [Internet]. 2023 [acesso 29 jul 2025];388(13):1201-8. DOI: 10.1056/NEJMra2302038
16. Ioannidis J. Why replication has more scientific value than original discovery. Behav Brain Sci [Internet]. 2018 [acesso 29 jul 2025];41:e137. DOI: 10.1017/S0140525X18000729
17. National Academies of Sciences. Reproducibility and replicability in science. Washington: National Academies Press; 2019.
18. Baker M. Is there a reproducibility crisis?. Nature [Internet]. 2016 [acesso 29 jul 2025];533(7604):452-4. Disponível: https://tinyurl.com/2hc44u9n
19. Wicherts J, Veldkamp C, Augusteijn H, Bakker M, van Aert RCM, van Assen MALM. Degrees of freedom in planning, running, analyzing, and reporting psychological studies: a checklist to avoid p-Hacking. Front Psychol [Internet]. 2016 [acesso 29 jul 2025];7:1832. DOI: 10.3389/fpsyg.2016.01832
20. Ahuja AS. The impact of artificial intelligence in medicine on the future role of the physician. PeerJ [Internet]. 2019 [acesso 29 jul 2025];7:e7702. DOI: 10.7717/peerj.7702
21. Rajpurkar P, Lungren MP. The current and future state of AI interpretation of medical images. New Eng J Med [Internet]. 2023 [acesso 29 jul 2025];388(21):1981-90. DOI: 10.1056/NEJMra2301725
22. Hosny A, Parmar C, Quackenbush J, Schwartz LH, Aerts HJ. Artificial intelligence in radiology. Nat Rev Cancer [Internet]. 2018 [acesso 29 jul 2025];18:500-10. Disponível: https://tinyurl.com/56sdzn6m
23. Esteva A, Kuprel B, Novoa RA, Ko J, Swetter SM, Blau HM *et al*. Dermatologist-level classification of skin cancer with deep neural networks. Nature [Internet]. 2017 [acesso 29 jul 2025];542:115-8. DOI: 10.1038/nature21056
24. McKinney SM, Sieniek M, Godbole V, Godwin J, Antropova N, Ashrafian H *et al*. International evaluation of an AI system for breast cancer screening. Nature [Internet]. 2020 [acesso 29 jul 2025];577:89-94. Disponível: https://tinyurl.com/whe4pfbj
25. Zargarzadeh A, Javanshir E, Ghaffari A, Mosharkesh E, Anari B. Artificial intelligence in cardiovascular medicine: an updated review of the literature. J Cardiovasc Thorac Res [Internet]. 2023 [acesso 29 jul 2025];15(4):204-9. DOI: 10.34172/jcvtr.2023.33031
26. Marchant J. Powerful antibiotics discovered using AI. Nature [Internet]. 2020 [acesso 29 jul 2025]. DOI: 10.1038/d41586-020-00018-3
27. Bond A, Mccay K, Lal S. Artificial intelligence & clinical nutrition: what the future might have in store. Clin Nutr [Internet]. 2023 [acesso 29 jul 2025];57:542-9. DOI: 10.1016/j.clnesp.2023.07.082
28. Peruselli C, De Panfilis L, Gobber G, Melo M, Tanzi S. Artificial intelligence and palliative care: opportunities and limitations. Recenti Prog Med [Internet]. 2020 [acesso 29 jul 2025];111(11):639-45. DOI: 10.1701/3474.34564
29. Yadav GS, Longhurst CA. Will AI make the electronic health record more efficient for clinicians?. N Eng J Med AI [Internet]. 2025 [acesso 29 jul 2025];2(3). DOI: 10.1056/AIe2500020
30. Mittelstadt B. The impact of artificial intelligence on the doctor-patient relationship [Internet]. Strasbourg: Council of Europe; 2021 [acesso 29 jul 2025]. Disponível: https://bit.ly/4mcgv9Z
31. European Commission. Ethics guidelines for trustworthy AI. Brussels: European Commission; 2019.
32. Mann PS, Earp BD, Møller N, Vynn S, Savulescu J. AUTOGEN: a personalized large language model for academic enhancement. Ethics and proof of principle. Am J Bioeth [Internet]. 2023 [acesso 29 jul 2025];23(10):28-41. DOI: 10.1080/15265161.2023.2233356
33. Nuñez M. Anthropic just analyzed 700.000 Claude conversations and found its AI has a moral code of its own. VentureBeat [Internet]. 2025 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/ykf5s9by
34. Hub France IA. ChatGPT: usages, impacts et recommendations – note de synthèse [Internet]. Paris: Hub France IA; 2023 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/yvpnef7r
35. Ryan M, Gambrell D, Noveck BS. Using collective intelligence to solve public problems [Internet]. New York: The Govlab; 2020 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/bdtsmjwt

36. World Health Organization. Global diffusion of eHealth: making universal health coverage achievable. Report of the third global survey on eHealth [Internet]. Geneva: WHO; 2016 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/mry9f6vb

37. Nunes R. Healthcare as a universal human right: sustainability in global health. New York: Routledge; 2022.

38. Venkatapuram S. Health justice. Cambridge: Polity Press; 2011.

39. Ren S. How much water does AI consume? The public deserves to know [Internet]. OECD AI Policy Observatory; 2023 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/2rjyfpnh

40. World Economic Forum. Closing the women's health gap: a $1 trillion opportunity to improve lives and economies [Internet]. Geneva: WEF; 2024 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/52h3hkkc

41. Nunes R. Ensaios em bioética [Internet]. Brasília: CFM; 2017 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/2se5p2yp

42. Nunes R. Diretivas antecipadas de vontade [Internet]. Brasília: CFM; 2016 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/354nv2jm

43. Mirza FN, Tang OY, Connolly ID, Abdulrazeq HA, Lim RK, Roye GD *et al*. Using ChatGPT to facilitate truly informed medical consent. N Eng J Med AI [Internet]. 2024 [acesso 29 jul 2025];1(2). DOI: 10.1056/AIcs2300145

44. European Union. Proposal for a regulation of the European parliament and of the council laying down harmonised rules on artificial intelligence (artificial intelligence act) and amending certain union legislative acts [Internet]. Brussels: European Union; 2023. Disponível: https://tinyurl.com/yczhtmnj

45. Jecker NS, Atuire CA, Bélisle-Pipon JC, Ravitsky V, Ho A. AI and the falling sky: interrogating X-Risk. J Med Ethics [Internet]. 2024 [acesso 29 jul 2025];50(12):811-7. DOI: 10.1136/jme-2023-109702

46. Penrose R, Severino E, Scardigli F, Testoni I, Vitiello G, D'Ariano G *et al*. Artificial intelligence versus natural intelligence. Cham: Springer; 2022.

47. European Union. General data protection regulation. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data [Internet]. Brussels: European Union; 2016 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/y93u93bh

48. European Commission. Study on health data, digital health and artificial intelligence in healthcare [Internet]. 2022 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/2rn8snf5

49. Correia M, Rego G, Nunes R. Gender transition: is there a right to be forgotten? Health Care Anal [Internet]. 2021 [acesso 29 jul 2025];29(4):283-300. DOI: 10.1007/s10728-021-00433-1

50. Kokosi T, Harron K. Synthetic data in medical research. BMJ Med [Internet]. 2022 [acesso 29 jul 2025];26:1(1):e000167. DOI: 10.1136/bmjmed-2022-000167

51. World Health Organization. Global strategy on digital health 2020-2025 [Internet]. Geneva: WHO; 2021 [acesso 29 jul 2025]. Disponível: https://tinyurl.com/54z2rpew

52. Kung TH, Cheatham M, Medenilla A, Sillos C, De Leon L, Elepaño C *et al*. Performance of ChatGPT on USMLE: potential for AI-assisted medical education using large language models. MedRxiv [Internet]. 2022 [acesso 29 jul 2025]. DOI: 10.1101/2022.12.19.22283643

53. Bianchini S, Müller M, Pelletier P. Artificial intelligence in science: an emerging general method of invention. Res Policy [Internet]. 2022 [acesso 29 jul 2025];51(10):104604. DOI: 10.1016/j.respol.2022.104604

54. Constantinescu M, Crisp R. Can robotic AI systems be virtuous and why does this matter?. Int J Soc Robot [Internet]. 2022 [acesso 29 jul 2025];14(6):1547-57. DOI: 10.1007/s12369-022-00887-w

55. Chen J. Who's training whom? N Eng J Med AI [Internet]. 2024 [acesso 29 jul 2025];1(5). DOI: 10.1056/AIp2400006

56. Daley K. Two arguments against humanfriendly AI. AI Ethics [Internet]. 2021 [acesso 29 jul 2025];1:435-44. DOI: 10.1007/s43681-021-00051-6

57. Freeman D, Reeve S, Robinson A, Ehlers A, Clark D, Spanlang B *et al*. Virtual reality in the assessment, understanding, and treatment of mental health disorders. Psychol Med [Internet]. 2017 [acesso 29 jul 2025];47(14):2393-400. DOI: 10.1017/S003329171700040X

58. Organization for Economic Cooperation and Development. Empowering learners for the age of AI: an AI literacy framework for primary and secondary education. Paris: OECD; 2025.

59. Ratwani RM, Classen D, Longhurst C. The compelling need for shared responsibility of AI oversight: lessons from Health IT Certification. JAMA [Internet]. 2024 [acesso 29 jul 2025];332(10):787-88. DOI: 10.1001/jama.2024.12630

60. Wübbeler M, Geis S, Stojanovic J, Elliott L, Gutierrez-Ibarluzea I, Lenoir-Wijnkoop I. Coding public health interventions for health technology assessments: a pilot experience with WHO's International Classification of Health Interventions (ICHI). Front Public Health [Internet]. 2021 [acesso 29 jul 2025];9:620637. DOI: 10.3389/fpubh.2021.620637

61. Vithanage M, Prasad MNV. One health: human, animal, and environment triad. Hoboken: John Wiley & Sons; 2023.

62. Nunes R, Nunes SB. Reliable artificial intelligence: the 18th sustainable development goal. J Ethics Legal Technol [Internet]. 2024 [acesso 29 jul 2025];6(2):5-20. DOI: 10.14658/pupj-JELT-2024-2-2

Dossier

Rui Nunes – PhD – ruinunes@med.up.pt
0000-0002-1377-9899

Sofia B Nunes – PhD student – asnunes@med.up.pt
0000-0002-7182-9890

Correspondence
Alameda Prof Hernâni Monteiro, 4200-319. Porto, Portugal.

Participation of the authors
The authors contributed equally to the preparation of this article.

Editor in charge: Dilza Teresinha Ambrós Ribeiro

Received: 8.4.2025
Revised: 8.10.2025
Approved: 8.14.2025