eVitroKhem. 2025; 4:213
doi: 10.56294/evk2025213

ORIGINAL

Medicine of the future: artificial intelligence, gene editing, and planetary health

Medicina del futuro: inteligencia artificial, edición genética y salud planetaria

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Cite as: Pinargote CA, Mero JG, Macías VD, Rodríguez D, García MA. Medicine of the future: artificial intelligence, gene editing, and planetary health. eVitroKhem. 2025; 4:213. https://doi.org/10.56294/evk2025213

Submitted: 02-09-2024 **Revised:** 08-12-2024 **Accepted:** 25-06-2025 **Published:** 26-06-2025

Editor: Prof. Dr. Javier Gonzalez-Argote

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ABSTRACT

This article analyzed the main advances and challenges associated with the medicine of the future, focusing on four fundamental pillars: personalized medicine based on genomics, artificial intelligence applied to diagnosis and clinical management, emerging therapies using CRISPR-based gene editing, and the comprehensive One Health approach that links human, animal, and environmental health. Through a narrative review, recent evidence was examined to illustrate how these technologies are transforming healthcare systems worldwide. Ethical, social, and regulatory implications were also discussed, highlighting the need for interdisciplinary integration to achieve preventive, personalized, and sustainable medicine.

Keywords: Personalized Medicine; Artificial Intelligence; Gene Editing; CRISPR; One Health.

RESUMEN

Este artículo analizó los principales avances y desafíos asociados con la medicina del futuro, enfocándose en cuatro ejes fundamentales: medicina personalizada basada en genómica, inteligencia artificial aplicada al diagnóstico y gestión clínica, terapias emergentes mediante edición genética tipo CRISPR y el enfoque integral One Health que vincula salud humana, animal y ambiental. A través de una revisión narrativa, se analizaron evidencias recientes que ilustran cómo estas tecnologías están transformando los sistemas de salud en distintas regiones del mundo. También se discutieron implicaciones éticas, sociales y regulatorias, resaltando la necesidad de una integración interdisciplinaria para lograr una medicina preventiva, personalizada y sustentable.

Palabras clave: Medicina Personalizada; Inteligencia Artificial; Edición Genética; CRISPR; One Health.

INTRODUCTION

Scientific and technological advancements have profoundly reconfigured the foundations of contemporary medicine, paving the way for a new clinical era centered on prevention, personalization, and sustainability. Among the most disruptive innovations are the integration of genomics with artificial intelligence,(1) the therapeutic application of gene editing technologies such as CRISPR,(2) and the consolidation of the One Health as a paradigm of global public health.(3)

Personalized medicine, driven by population genetic analysis and clinical data mining, has been shown to significantly improve diagnosis and therapeutic efficacy in areas such as oncology and pediatrics.(4) At the

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same time, artificial intelligence has begun to outperform human physicians in specific diagnostic tasks such as dermatological or retinal image analysis, while also optimizing hospital management and clinical intervention planning.[5]

Regarding gene editing, the approval of CRISPR therapies by regulatory agencies such as the FDA and the EMA [6] marks a significant milestone in the treatment of monogenic diseases, opening up new therapeutic possibilities in cancer, neuromuscular disorders, and rare diseases. Finally, One Health has gained relevance in the face of the increasing prevalence of zoonotic diseases and the climate crisis, underscoring the need to address health from an ecosystem perspective.[7,8]

In this context, this article aimed to narratively analyze recent advances in artificial intelligence, gene editing, and ecosystem medicine, with an emphasis on their impact on the future of human health and clinical practice.

Strategic axes for the medicine of the future

Table 1 summarizes the main thematic axes identified in the analysis of future medicine, highlighting the most representative technological advances, specific application cases, and associated emerging challenges. Each axis reflects a key dimension of transformation in the biomedical and healthcare fields, from the integration of genomics into personalized care to the use of artificial intelligence for diagnosis and clinical management, the emergence of gene editing technologies such as CRISPR, and the adoption of the One ecosystem approach. Health. These lines of development are not only redefining healthcare models but also raising ethical, social, and regulatory questions that require responsible governance, interoperable infrastructure, and inclusive public policies. This creates a scenario where scientific innovation must be intertwined with equity, sustainability, and patient rights in both local and global contexts.

Table 1. Summary of the strategic axes for the analysis of the medicine of the future

Axis thematic	**Key advances**	**Examples concrete**	**Challenges and considerations**
Personalized medicine and genomics	Genomic sequencing, pharmacogenetics, human pangenome, and genetic biclustering software (MOEBABIO).	– Strategy in Navarra for oncology – Guardian Study in Neonates – CNIO Biomarker (2025)	Ethics of the use of genetic data, equity of access, and platform interoperability
Intelligence (AI)	AI in diagnosis, mortality prediction, clinical care, telemedicine, and clinical language in Spanish.	– EyeArt AI for retinopathy – Promise Score at Vall d'Hebron – DxGPT, JANUS, Blua Sanitas Valdebebas	Algorithm transparency, data privacy, professional acceptance, biases in clinical data
Edition genetics (CRISPR)	CRISPR-Cas9 and Cas12a therapies, base editing, CAR-T immunotherapy.	– Casgevy for sickle cell anemia (FDA and EMA) – EDIT-301 – Trials in muscular and neurodegenerative dystrophies	Genetic security (off-target), regulated access, bioethical dilemmas
One Health	Ecosystem-based health monitoring, zoonotic surveillance, climate impact, and AMR, AI in outbreak prediction.	– Redistribution of vectors such as Aedes aegypti – Algorithms for zoonotic outbreaks – Overuse of antibiotics	Intersectoral coordination, integrated policies, and increasing antimicrobial resistance

Personalized medicine and genomics

Personalized medicine has established itself as a clinical model that focuses on tailoring diagnoses and treatments to individual patient characteristics, particularly their genetic information. Recent sources highlight the integration of genomics with artificial intelligence and extensive population data as key elements for advancing this field.[1]

In Spain, the Regional Government of Navarre launched an ambitious Comprehensive Personalized Medicine Strategy in 2023, which incorporates genomic sequencing in oncology care to improve individual treatments and prevent adverse effects.[4] This strategy places the patient at the center of care, achieving more accurate diagnoses and more effective therapies based on genetic profiling.

A notable advance is the development of tools in biomedicine, such as MOEBA-BIO, created at the University of Málaga in 2025. This open-source software identifies gene co-expression patterns through biclustering, enabling the classification of patient subgroups based on similar genetic profiles and facilitating personalized medicine.[9]

Neonatal genetic sequencing is also transforming pediatric medicine. A Guardian study in New York sequenced more than 150 treatable genetic disorders in newborns, detecting conditions not visible through traditional screening. This represents a significant advancement in early intervention and personalized prevention.[10]

A recent discovery at the CNIO and the United Kingdom, made in June 2025, reveals a biomarker capable of predicting which patients are unlikely to respond to chemotherapy (platinum, taxane, and anthracyclines). This discovery, based on genomic instability, will enable the avoidance of ineffective treatments and the personalization of therapy for breast, ovarian, prostate, and sarcoma cancers.[11] A systematic review on pharmacogenetics highlights the impact of genetic variants on the response to multiple drugs, ranging from antidepressants to biological antibodies. The authors emphasize that genetic knowledge enables dose adjustment and the anticipation of adverse effects, thereby optimizing therapeutic outcomes.[12]

The human pangenome, presented in 2023, represents a significant leap in diagnostic precision. By representing global genetic diversity (African, American, Asian, and European), it offers new bases for identifying variants that were previously overlooked and improving the diagnosis of rare diseases.[13] A review of challenges in genomic medicine highlights the need for adequate infrastructure, ethical regulations, clinical training, and population representation in Spain. It also highlights the role of the IMPaCT-Genomics program at the University of Santiago de Compostela, which emphasizes the need for advances in data interoperability and equitable access to clinical genotyping.[14]

In Latin America, Paz-y-Miño[15] examines how AI applied to genomics enables the identification of relevant mutations and genetic patterns in ethnically diverse populations. He highlights its usefulness in diagnosis, genetic research, and preventive health. Similarly, the Pan American Health Organization[1] emphasizes a genetics-based preventive paradigm, where interventions from pregnancy and the first thousand days of life, combined with socio-environmental contexts, dramatically reduce infant mortality and offer more sustainable personalized health strategies.

AI in diagnosis, treatment, and healthcare management

Artificial intelligence (AI) is significantly transforming clinical diagnosis, treatment personalization, and healthcare management efficiency. A recent publication reveals that AI models achieve an average sensitivity of 90,1 % and specificity of 93,3 %, even outperforming human physicians in certain specialties, such as dermatology and diabetic retinopathy. For instance, systems like EyeArt AI achieve a sensitivity of 97 % compared to 59,5 % for specialists.[16] This collaboration between professionals and AI significantly improves diagnostic accuracy.

Vall d'Hebron Hospital has developed an AI-based tool called the Promise Score, which can predict 90-day mortality in patients with metastatic cancer who are admitted to the emergency department. This tool analyzes clinical variables, including LDH, neutrophils, and ECOG functional status, which enables informed therapeutic decisions between palliative and intensive management.[17]

In the field of systemic autoimmune diseases (SAD), the Spanish Society of Internal Medicine (SEMI) has highlighted the potential of AI to facilitate more accurate diagnoses, personalize treatments, predict flares, and provide telemedicine and clinical support through tools such as DxGPT and Glass Health.[18]

AI is also improving the primary care experience. The JANUS conceptual model proposes virtual assistants, automated triage, consultation transcription, and clinical suggestions derived from the electronic medical record, all of which free up physician time and enhance empathy during consultations.[19]

From a public health perspective, AI enables real-time epidemiological surveillance, resource management, and the design of personalized preventive interventions. However, the need to establish ethical frameworks that ensure privacy, transparency, and equity is emphasized.[5]

In specialized care, the Blua Sanitas Valdebebas digital hospital integrates AI into diagnostic imaging, oncology, and hospital management, optimizing waiting times and minimizing invasive procedures.[20,21] An innovative case in Murcia, led by Dr. Alberto Baroja, utilizes AI to analyze exosomes in liver transplants, thereby anticipating rejections or postoperative complications and enhancing organ allocation.[22]

Large language models (LLMs) are also being adapted for clinical Spanish. A recent study achieved an accuracy of 84 % and an F1 score of up to 0,82 in detecting dermatological pathologies in medical notes, utilizing hybrid models that combine AI and medical ontologies.[19] Another analysis using LLMs trained in Spanish demonstrated high efficacy in recognizing clinical symptoms.

CRISPR and gene editing

Over the past decade, CRISPR-Cas gene-editing technology has revolutionized the field of biomedicine, and since 2021, it has entered the clinical arena with remarkable results. In particular, the CRISPR-Cas9 technique has been successfully used to treat monogenic diseases such as sickle cell anemia and beta-thalassemia, two hematological pathologies with a high global prevalence.[2]

In December 2023, the U.S. Food and Drug Administration (FDA) approved for the first time a CRISPR-Cas9-based therapy, called exagamglogene autotemcel (exacel), marketed as Casgevy.[6]

https://doi.org/10.56294/evk2025213 ISSN: 3072-7944

This therapy involves editing the patient's hematopoietic stem cells to inactivate the regulatory gene BCL11A, which reactivates the production of fetal hemoglobin (HbF), significantly improving oxygenation and reducing vaso-occlusive crises. The clinical impact has been remarkable: more than 90 % of patients treated with Casgevy did not experience severe pain events (vaso-occlusive crises) during the 12 months following the intervention, and many achieved transfusion independence in the case of beta-thalassemia.[6]

This therapy was approved by the European Medicines Agency (EMA) in February 2024, setting a precedent for the large-scale therapeutic application of gene editing. Furthermore, new variants of CRISPR technology, such as Cas12a (previously known as Cpf1), have begun to demonstrate additional advantages. In the case of the experimental treatment EDIT-301, this nuclease has been used to modify the promoter of the HBG1/2 genes, also to induce fetal hemoglobin. The first results in humans have shown stable HbF levels above 40 %, without serious adverse effects.[23]

These advances are not without challenges, as the accuracy of CRISPR remains a matter of debate, and there are potential risks of off-target editing and unexpected genomic rearrangements. Therefore, high-fidelity variants such as SpCas9-HF1 and double-strand-free base editing techniques are being developed, which improve safety and minimize errors.[24]

In addition to monogenic diseases, current research is exploring applications in cancer, muscular dystrophies, and neurodegenerative diseases. Clinical trials combining CRISPR with cellular immunotherapy, such as gene-edited CAR-T cells, are underway to expand the therapeutic potential of this tool.[25]

One Health and the link between human, animal, and environmental health

One Health, also known as One Health approach, is an interdisciplinary paradigm that recognizes the close interdependence among *human health, animal health, and environmental health. Although its conceptual roots can be traced back to the 19th century with the work of Rudolf Virchow and William Osler—who already spoke of the connection between human and veterinary medicine—it was in the 21st century that it was consolidated as a global strategy to* address the rise of zoonotic diseases, climate change, and antimicrobial resistance. Institutions such as the WHO, FAO, and the World Organization for Animal Health have formally adopted this approach to design policies that integrate epidemiological surveillance, ecological sustainability, and public health.

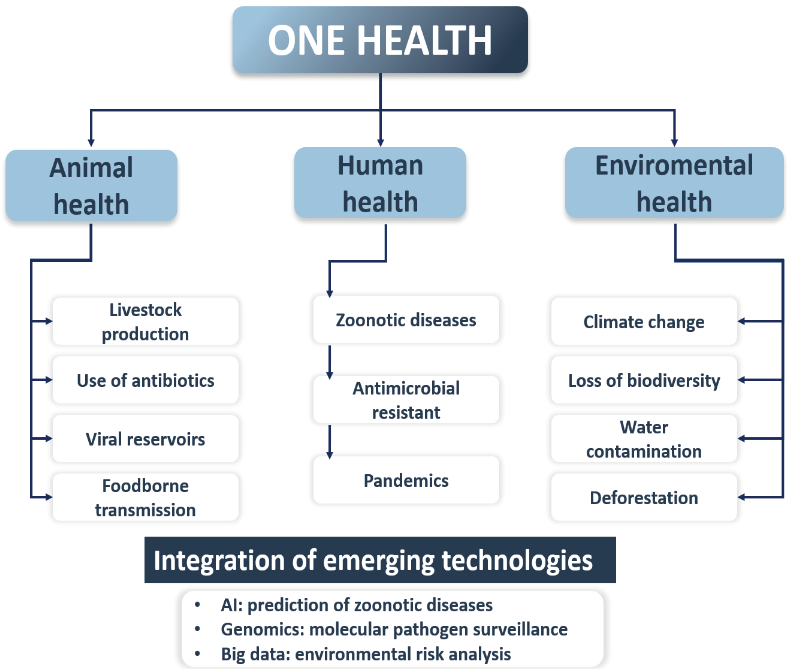

Figure 1. Conceptual map of the One Health approach

The relevance of One Health is evidenced by compelling data: more than 75 % of emerging infectious diseases in humans have animal origins, and environmental degradation has increased the likelihood of wild pathogens crossing the interspecies barrier.[3] Thus, One Health is not simply a conceptual framework, but a practical tool for anticipating, preventing, and responding to complex health crises in a world that is increasingly biologically and ecologically interconnected.

More than 75 % of emerging infectious diseases in humans have a zoonotic origin, that is, they are transmitted from animals to humans.[3] The COVID-19 pandemic—possibly originating in an animal reservoir—is only the latest manifestation of a pattern that includes SARS, MERS, Ebola, avian flu, Rift Valley fever, and Nipah, among others. This is no coincidence: deforestation, wildlife trafficking, urban sprawl, and intensive livestock farming have altered ecological balances, exposing humans to viral reservoirs with which we did not coexist before.[7]

Climate change has also contributed to the redistribution of disease vectors. *Aedes aegypti*, the mosquito that transmits dengue, Zika, and chikungunya, has expanded its geographic range due to rising global temperatures, generating epidemic outbreaks in previously non-endemic areas.[8] This reality demands that the medicine of the future be not anthropocentric, but ecosystemic.

From clinical practice, the One approach Health involves developing diagnostic tools, prevention policies, and therapies that consider the patient's environment as part of the medical history. For example, a Leptospira infection in a child is not fully understood without knowing that they live near stagnant water contaminated with rodent urine. Alternatively, chronic lead poisoning may not be detected early if environmental exposure is not thoroughly investigated. In resource-limited countries, where humans, animals, and natural resources interact without regulation, integrating this data is vital to prevent silent epidemics.

In addition, antimicrobial resistance (AMR) —one of the greatest threats to global health—has deep roots in the indiscriminate use of antibiotics in livestock farming. More than 70 % of the antibiotics produced worldwide are used in animals, often without medical indication.[26] This favors the selection of multidrug-resistant bacteria that can be transmitted to humans through the food chain or direct contact. Without a coordinated approach between veterinary medicine, public health, and human medicine, the post-antibiotic era will become a reality sooner rather than later.

In this context, emerging technologies such as artificial intelligence (AI) and predictive genomics can be great allies of the One Health approach. For example, machine learning algorithms are being used to predict zoonotic outbreaks based on ecological patterns and satellite data.[27] Likewise, genomic sequencing of animal pathogens enables the anticipation of escape mutations before they can reach humans. This ability to "see the invisible" is a key element in the medicine of the future: proactive, preventative, and connected.[28,29]

In short, One Health is not an environmentalist discourse, but an evidence-based health strategy. Human health cannot be dissociated from its ecological context or from the species with which we share the planet. To deny this is to repeat the mistakes that have led us to preventable pandemics and environmental crises. Integrating this vision is not only an ethical duty for future doctors, but also a vital tool for survival.

CONCLUSIONS

The medicine of the future is marked by an unprecedented technological convergence that redefines models of care, diagnosis, and prevention. Artificial intelligence enables the optimization of clinical processes, improves diagnostic accuracy, and facilitates personalized treatments, while gene editing offers previously unattainable therapeutic solutions for hereditary diseases. At the same time, personalized medicine based on genomic data and the integration of the One Health advances broaden our understanding of health as an interdependent and systemic phenomenon. However, these advances entail ethical, regulatory, and equity of access challenges, which must be addressed through public policies, interdisciplinary professional training, and global health governance that is sensitive to local needs.

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FUNDING

The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Writing - review & editing: Camil A. Pinargote, Jeisson G. Mero, Valeria D. Macías, Daliannis Rodríguez, Mario A. García.