ISSN 2735-6590

AI-Driven Precision Medicine: Challenges and Opportunities in Training the Next Generation of Physicians

FERNANDO VERA[1]

[1]International Network of Education Researchers (REDIIE)
fernandovera@rediie.cl

Abstract

Artificial Intelligence (AI) is transforming precision medicine by enabling more accurate diagnoses, personalized treatment plans, and predictive analytics based on genomic, clinical, and environmental data. This paradigm shift has profound implications for medical education, requiring future physicians to develop competencies that integrate clinical expertise with advanced digital and analytical skills. This article explores the challenges and opportunities of AI-driven precision medicine, focusing on its integration into medical training programs. Special attention is given to the Latin American context, where disparities in technology access, interoperability, and regulatory frameworks may hinder adoption. The discussion draws on data from the Questionnaire on the Use of Artificial Intelligence in Precision Medicine (QUAI-PM), which evaluates four key dimensions: knowledge, clinical application, barriers, and attitudes toward AI in precision medicine. By addressing these domains, the paper highlights strategies for embedding AI competencies into curricula, fostering interdisciplinary collaboration, and ensuring ethical and equitable implementation in diverse healthcare systems.

Keywords: Precision medicine, Artificial Intelligence, Medical education, Clinical application.

Introduction

The rapid convergence of Artificial Intelligence (AI) and precision medicine is transforming healthcare by enabling highly personalized interventions. Advances in machine learning, big data analytics, and multi-omics integration now allow for more accurate disease prediction, individualized treatment plans, and continuous patient monitoring (Filetti et al., 2024; Ranjan et al., 2025). This paradigm shift is not only technological but also educational, requiring future physicians to acquire competencies that merge clinical expertise with data science, bioinformatics, and ethical reasoning (Kurniawan Budi Susilo et al., 2024).

While AI-driven precision medicine holds great promise, its integration into medical education faces significant challenges. Disparities in technological infrastructure, data interoperability, and regulatory readiness—particularly in Latin America—pose barriers to implementation (Filetti et al., 2024; Ranjan et al., 2025). Moreover, ethical issues, such as algorithmic bias and patient data confidentiality, demand careful attention to ensure equitable and trustworthy AI adoption (Kurniawan Budi Susilo et al., 2024). Addressing these complexities is essential for training the next generation of physicians.

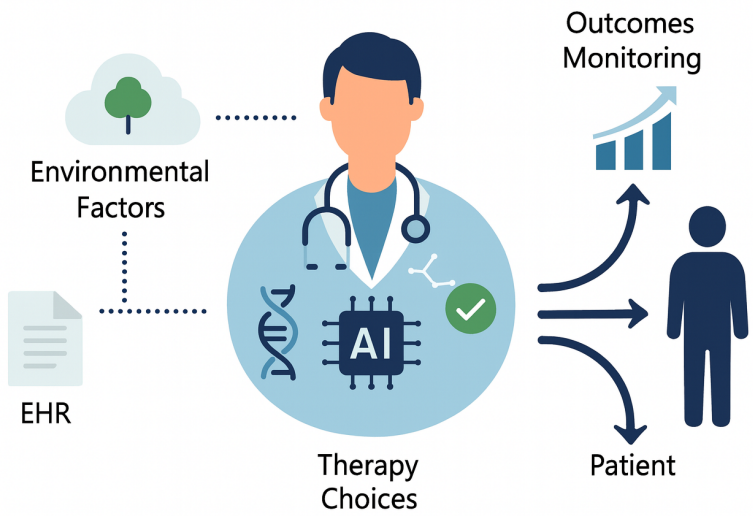
In this context, the present study employs the Questionnaire on the Use of Artificial Intelligence in Precision Medicine (QUAI-PM) to explore four key domains: knowledge, clinical application, barriers, and attitudes toward AI in precision medicine. The general objective is to analyze physicians' and medical trainees' perceptions across these domains to inform curriculum design and policy. Specific objectives are:

1. Assess the level of conceptual and procedural knowledge about AI-driven precision medicine.
2. Examine the extent and nature of its clinical application in diverse healthcare settings.
3. Identify perceived barriers to implementation, including infrastructural, regulatory, and ethical constraints.
4. Explore prevailing attitudes toward the integration of AI in precision medicine and medical education.

AI-Driven Precision Medicine

AI-driven precision medicine integrates artificial intelligence, big data analytics, and genomics to deliver healthcare tailored to the unique biological and contextual characteristics of each patient. Through advanced machine learning algorithms, vast datasets from genomic sequencing, Electronic Health Records (HER), and environmental factors are analyzed to predict disease susceptibility, guide treatment choices, and monitor therapeutic outcomes (Filetti et al., 2024; Johnson et al., 2021; Ranjan et al., 2025). This paradigm moves beyond the "one-size-fits-all" model, enabling dynamic, evidence-based decisions that evolve alongside patient needs and scientific discovery (Kurniawan Budi Susilo *et al.,* 2024).

Figure 1. *Core components and process flow of AI-driven precision medicine.*



Source: Own elaboration.

The application of AI in precision medicine is particularly evident in oncology, where predictive modeling and biomarker identification inform personalized cancer treatments (Chen et al., 2023; Huang et al., 2023). However, its scope extends to cardiovascular disease, neurology, and rare genetic disorders (Li et al., 2023; Esteva et al., 2019). These advances demand not only technological readiness but also clinician proficiency in interpreting AI-generated outputs, ensuring that medical judgment remains central in-patient care (Parimbelli *et al.,* 2018).

ISSN 2735-6590

For AI-driven precision medicine to reach its full potential, medical education must incorporate interdisciplinary forums where students, physicians, data scientists, and bioinformaticians collaboratively analyze case studies and ethical dilemmas (Filetti et al., 2024; Parimbelli et al., 2018). Such spaces facilitate critical discussions on algorithmic bias, data governance, and the sociocultural implications of AI adoption. Forums can bridge the gap between theory and practice, fostering problem-solving skills and preparing future physicians to lead in technologically augmented healthcare systems.

Ultimately, AI-driven precision medicine is not solely a technological breakthrough; it is a systemic shift in how healthcare is conceptualized, delivered, and taught. By embedding AI competencies into curricula and fostering collaborative forums, academic institutions can ensure that graduates are equipped to navigate the opportunities and challenges of this evolving field (Chen et al., 2023; Johnson et al., 2021). Ethical stewardship, continuous learning, and patient-centered care will remain the guiding principles as AI continues to reshape precision medicine across diverse healthcare settings.

Challenges and Opportunities for Medical Education

The integration of AI-driven precision medicine into medical education presents both formidable challenges and transformative opportunities. One major challenge is the knowledge gap among current and future healthcare professionals. Many physicians have limited exposure to AI concepts, data science, and bioinformatics, making it difficult to fully interpret and apply AI-generated recommendations in clinical contexts (Filetti et al., 2024; Parimbelli et al., 2018). Without structured learning pathways, there is a risk that AI tools will be underutilized or misinterpreted, potentially compromising patient outcomes.

From a clinical application perspective, the primary barrier is insufficient hands-on training with AI-enabled systems. While theoretical modules are increasingly available, opportunities for practical engagement—such as simulation-based training, interdisciplinary projects, and exposure to AI-integrated clinical workflows—remain scarce (Chen et al., 2023; Huang et al., 2023). These limitations hinder the development of proficiency in navigating AI outputs, integrating them with patient data, and aligning them with clinical guidelines.

Additional barriers include technological disparities between institutions, lack of interoperability among health information systems, and ethical concerns such as algorithmic bias and patient data confidentiality (Johnson et al., 2021; Kurniawan Budi Susilo et al., 2024). In Latin America, these challenges are amplified by uneven infrastructure and regulatory frameworks, which can delay the adoption of AI-enabled clinical decision-making tools (Ranjan et al., 2025).

Despite these hurdles, significant opportunities exist. AI-driven precision medicine offers a platform for reimagining medical curricula to include interdisciplinary forums where students, clinicians, and data scientists collaboratively address real-world cases and ethical dilemmas (Filetti et al., 2024). Such forums encourage critical thinking, foster a culture of innovation, and build confidence in using AI responsibly. Moreover, early exposure to AI applications in diagnostics, treatment planning, and patient monitoring can cultivate positive attitudes and openness toward technological adoption in clinical practice (Huang et al., 2023; Li et al., 2023).

ISSN 2735-6590

By embedding AI literacy, ethical reasoning, and collaborative problem-solving into medical training, academic institutions can prepare future physicians to lead the transformation toward personalized, data-driven healthcare. In doing so, they not only enhance patient care but also ensure equitable and ethical AI implementation across diverse healthcare systems (Chen et al., 2023; Esteva et al., 2019).

Methodology

Study Design

This study will follow a quantitative, cross-sectional, descriptive-exploratory design aimed at assessing physicians' and medical trainees' perceptions, knowledge, and experiences regarding AI-driven precision medicine. The approach will allow for identifying trends and relationships among the four key domains of the Questionnaire on the Use of Artificial Intelligence in Precision Medicine (QUAI-PM), which has been previously validated by a panel of experts.

Participants

The study will target physicians and advanced medical trainees (final-year students and residents) who are actively involved in academic activities such as teaching, curriculum development, or clinical research. Participants will be recruited from universities and teaching hospitals in Chile and Colombia through institutional networks, professional associations, and academic forums. Inclusion criteria will be: (a) holding a medical degree or being in the final year of a medical program, (b) active involvement in academia, and (c) provision of informed consent to participate.

Instrument

The QUAI-PM (Questionnaire on the Use of Artificial Intelligence in Precision Medicine), originally developed in Spanish as the *Cuestionario sobre Medicina de Precisión Basada en IA en la Práctica Clínica* (CuMP-IA) by Fernando Vera, PhD, is designed to assess perceptions, attitudes, and professional practices related to the integration of artificial intelligence in precision medicine.It consists of 25 items distributed across four dimensions: (1) Knowledge, which evaluates understanding of AI concepts and principles; (2) Clinical Application, which examines the use of AI in diagnosis, treatment, and patient management; (3) Barriers, which identifies challenges to AI adoption in clinical settings; and (4) Attitudes, which explores beliefs and dispositions toward the use of AI in precision medicine.

Pilot Testing

Before large-scale application, the instrument will be piloted with a group of 15–20 physicians engaged in academic medicine. The pilot phase will aim to evaluate clarity, response distribution, and practical applicability in academic and clinical contexts. Feedback from this stage will guide potential adjustments to wording, structure, or item sequencing.

Data Collection Procedure

Following the pilot adjustments, the final version of the QUAI-PM will be distributed online through a secure survey platform. Participation will be voluntary and anonymous, with electronic informed consent obtained before accessing the questionnaire. Data collection will be carried out over a four-week period, with reminder emails sent at the second and third weeks to encourage participation.

Data Analysis

Once the data are collected, reliability will be examined using Cronbach's alpha and McDonald's omega for internal consistency. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) will be conducted to verify the four-dimensional structure of the instrument. Item analysis will include discrimination indices and inter-item correlations to refine the tool if necessary. Inferential statistical tests—such as independent-samples t-tests or ANOVA—will be used to explore differences by demographic and professional variables (e.g., country, years of experience, academic involvement). All analyses will be performed using JASP and SPSS software, with significance set at $p < 0.05$.

Ethical Considerations

The study protocol will be submitted for review and approval by the ethics committees of the participating institutions. All research activities will comply with the Declaration of Helsinki principles for studies involving human participants.

Expected Results

It is anticipated that the QUAI-PM will demonstrate satisfactory psychometric properties, with internal consistency coefficients (Cronbach's alpha and McDonald's omega) exceeding the commonly accepted threshold of 0.70 for each of the four dimensions. The exploratory and confirmatory factor analyses are expected to confirm the proposed structure—Knowledge, Clinical Application, Barriers, and Attitudes—providing evidence of construct validity.

In terms of substantive findings, it is expected that participants will show varying levels of AI literacy, with higher scores in clinical application among those with prior exposure to AI tools in their professional practice. Differences may also emerge between respondents from Chile and Colombia, reflecting variations in technological infrastructure, institutional policies, and training opportunities.

The pilot study will serve as a foundation for refining the instrument and scaling up the research to a larger and more diverse sample across Latin America. In the next phases, it is expected to continue collecting data from other countries in the region, enabling cross-national comparisons and the identification of regional trends in AI adoption within precision medicine. Ultimately, the findings are expected to inform targeted interventions in medical curricula and continuing education programs, supporting the development of competencies required for the ethical and effective integration of AI into clinical practice.

Conclusions

The integration of AI into precision medicine offers unprecedented opportunities to enhance diagnostic accuracy, personalize treatment, and improve patient outcomes. However, realizing these benefits will require targeted efforts in medical education to equip physicians with the necessary knowledge, technical skills, and ethical awareness. The QUAI-PM instrument, validated by expert review, represents a structured and context-sensitive approach to assessing readiness for AI adoption in clinical practice and academic settings. Its future application will provide empirical evidence to guide curriculum development and professional training initiatives.

As the study advances through pilot testing and subsequent large-scale implementation, it is expected to generate actionable insights that inform both institutional strategies and regional policies for AI integration in healthcare. By identifying gaps, strengths, and specific needs within the Latin American medical community, this research will contribute to building a competent,

adaptable, and ethically grounded medical workforce capable of leveraging AI to advance precision medicine in diverse and resource-variable environments.

References

Chen, Y., Zhang, X., & Wang, L. (2023). AI-driven precision medicine: Transforming personalized cancer treatment. *Journal of Personalized Medicine, 13*(9), 1268. https://doi.org/10.3390/jpm13091268

Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., DePristo, M., Chou, K., Cui, C., Corrado, G. S., Thrun, S., & Dean, J. (2019). A guide to deep learning in healthcare. *Nature Medicine, 25*(1), 24–29. https://doi.org/10.1038/s41591-018-0316-z

Filetti, M., Petti, M., & Farina, L. (2024). Precision medicine: Beyond AI. *Computer Methods and Programs in Biomedicine Update, 5*, 100157. https://doi.org/10.1016/j.cmpbup.2024.100157

Huang, K., Li, S., & Wang, Y. (2023). Advances in AI-enabled precision oncology. *Frontiers in Medicine, 10*, 1227168. https://doi.org/10.3389/fmed.2023.1227168

Johnson, K. W., Torres Soto, J., Glicksberg, B. S., Shameer, K., Miotto, R., Ali, M., Ashley, E., & Dudley, J. T. (2021). Artificial intelligence in cardiology. *NPJ Digital Medicine, 2*(1), 1–11. https://doi.org/10.1038/s41746-019-0191-0

Kurniawan Budi Susilo, Y., Abdul Rahman, S., Amgain, K., & Yuliana, D. (2024). Artificial intelligence-powered precision medicine for cardiovascular disease prevention and management. *International Journal of Operations and Quantitative Management, 30*(2), 123–145. https://doi.org/10.2139/ssrn.5178201

Li, X., Liu, F., & Zhang, Z. (2023). AI in rare diseases: From diagnosis to therapy. *Journal of Translational Medicine, 21*(1), 250. https://doi.org/10.1186/s12967-023-04085-5

Parimbelli, E., Marini, S., Sacchi, L., & Bellazzi, R. (2018). Patient similarity for precision medicine: A systematic review. *Journal of Biomedical Informatics, 83*, 87–96. https://doi.org/10.1016/j.jbi.2018.05.019

Ranjan, A., Kulkarni, A., Gabbeta, S., & Gopal, M. (2025). Artificial intelligence in personalized medicine: A paradigm shift in healthcare. *International Journal of Development Research, 15*(6), 68493–68497. https://doi.org/10.37118/ijdr.29596.06.2025

Vera, F. (2025). *Cuestionario sobre Medicina de Precisión Basada en IA en la Práctica Clínica (CuMP-IA)*. Red Internacional de Investigadores en Educación (REDIIE). https://rediie.cl/cump-ia/