

Quantum Computing and AI in Medicine

Rafael Vargas-Bernal

 <http://orcid.org/0000-0003-4865-4575>

Polytechnical University of Guanajuato, Mexico

Emmanuel Vargas-Cisneros

 <http://orcid.org/0009-0000-4489-1237>

University of Guanajuato, Mexico

ABSTRACT

The integration of quantum computing and artificial intelligence represents a paradigm shift in the ability of medicine to solve complex challenges. Quantum computing's unparalleled processing power enables the simulation of molecular interactions, decoding of genomic data, and modeling of biological systems at a scale and speed unattainable by classical computers. When paired with advanced AI algorithms, this technological synergy accelerates drug discovery, enhances diagnostic precision, and enables the development of highly personalized therapies. Moreover, these technologies are poised to reduce the time and cost of drug development, improve patient outcomes, and facilitate real-time clinical decision-making. This chapter highlights the importance of promoting the joint application of quantum computing and artificial intelligence to solve complex medical problems. Despite the progress achieved to date, there are current challenges to achieving widespread applications and prospects for this research topic.

INTRODUCTION

Currently, clinical trials face high failure rates and significant inefficiencies due to suboptimal trial simulations, inadequate site selection, and inadequate cohort identification (Doga et al., 2024). These computationally intensive steps have, with classical computers, created bottlenecks in the development of new drugs. Conventional methods have so far been restricted to topics such as simulating drug effects, optimizing testing protocols, and being unable to handle large, heterogeneous patient data sets. Conventional drug development methods require expensive and time-consuming computational processes lasting 10 to 15 years from the discovery stage to market availability (Cao, 2018). One of the strategies for solving current healthcare problems involving computational tools that could represent transformative potential is quantum computing (How, 2023). Quantum computing is expected to provide unprecedented opportunities for medical innovation and overcome current challenges to achieving widespread adoption.

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Quantum computing can also facilitate optimized treatment plans for the development of individualized therapies, making personalized medicine a reality and optimizing treatment regimens in real time. Although advances in quantum computing applied to medicine are still in their infancy in some medical areas, many proof-of-concept studies are currently underway to achieve significant emerging impact around the world (Flöther, 2023). Quantum computing is poised to revolutionize healthcare in areas such as drug discovery, disease treatment, and the modeling of complex biochemical reactions (Guenot, 2025).

The convergence of quantum computing and artificial intelligence (AI) marks a pivotal moment in the evolution of medical science, offering unprecedented opportunities to address some of the most complex challenges in healthcare (Blunt, 2022). As medicine grapples with vast and intricate datasets – from genomic sequences to high-resolution medical imaging – the limitations of classical computational approaches have become increasingly apparent. Quantum computing, with the ability to process and analyze information at speeds and scales previously unimaginable, promises to revolutionize critical domains such as drug discovery, diagnostics, and personalized treatment planning. When integrated with advanced AI algorithms, quantum systems can decode genetic data transfer, simulate molecular interactions for novel therapeutics, and enable ultra-precise disease prediction, fundamentally transforming clinical decision-making and patient outcomes.

Recent breakthroughs demonstrate quantum computing's capacity to enhance diagnostic accuracy in medical imaging, optimize oncology treatments, and enable real-time clinical interventions that are essential for timely and effective care in diseases such as cancer, Alzheimer's, and rare genetic disorders (Fairburn et al., 2025). Moreover, the synergy between quantum computing and AI is accelerating the development of tailored therapies, improving resource allocation, and supporting preventive medicine through earlier disease detection. Despite current challenges related to hardware scalability and ethical considerations, the exhaustive adoption of quantum computing and AI in medicine holds the promise of delivering safer, more efficient, and highly individualized healthcare, heralding a new era of precision medicine and medical innovation.

This chapter presents a state-of-the-art overview of the advantages and disadvantages, as well as the challenges and prospects of using quantum computing and artificial intelligence in medical applications that can be exploited by specialists in both technological development and scientific research areas. This has been divided into six sections as follows: In the section titled “*Background about the Quantum Computing*”, the fundamentals associated with quantum computing have been explained using the following subsections: 1. Hardware and software for implementing quantum computing, 2. Advantages of quantum computing, 3. Disadvantages of quantum computing, 4. Current limitations of quantum computing, and 5. Prospects for future growth and development of quantum computing. Then, in the section titled “*Controversies and Problems about the Use of Quantum Computing and Artificial Intelligence in Medicine*”, the different contradictions that are presented when quantum computing and artificial intelligence are used in medicine are analyzed with a special emphasis in disadvantages and concerns associated with this topic. Next, in the section titled “*Key Healthcare Applications of Quantum Computing and Artificial Intelligence*”, the main applications of the quantum computing and artificial intelligence in medicine are discussed through eight sections as follows: 1. Simulation of biomolecules, 2. Machine learning for disease subtyping, 3. Genomics and drug design, 4. Medical imaging and clinical phenotyping, 5. Health logistics and data management, 6. Telemedicine and quantum Internet, 7. Comparative studies between an approach based on quantum computing and artificial intelligence versus traditional medicine, and 8. Summary applications in medicine. Subsequently, the section titled “*Next-Generation Precision Medicine*” describes the novel innovations where quantum computing and artificial intelligence have interference with medical applications

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