Precision Medicine in Cancer Therapy: Comparative Insights from AI-Driven Genomics and Multi-Omics Approaches

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Abstract

Precision medicine is transforming cancer therapy by enabling treatments tailored to the molecular and genetic characteristics of individual patients. Advances in artificial intelligence (AI) and multi-omics integration have improved the ability to analyze tumor heterogeneity, identify biomarkers, and predict therapeutic outcomes. This review summarizes evidence from 2015 onward on the application of AI-based genomic analysis and multi-omics approaches in cancer therapy. AI-driven genomics allows rapid interpretation of genetic variants and prioritization of therapeutic options, while multi-omics provides comprehensive biological insights to guide diagnosis and treatment decisions. Challenges include complex data integration, computational limitations, ethical concerns, and the need for clinical validation. Continued research and standardization are essential for translating these technologies into routine oncology practice.

Keywords

Precision Medicine; Cancer Therapy; Artificial Intelligence; Genomics; Multi-Omics; Precision Oncology

Introduction

Cancer is a complex disease driven by genetic, epigenetic, and molecular changes. Standard therapies often fail to account for individual tumor differences, leading to variable responses and outcomes. Precision medicine seeks to customize treatment based on each patient's molecular profile, improving therapeutic efficacy while minimizing side effects [(1)]. Genomic profiling identifies driver mutations and potential therapeutic targets, while multi-omics approaches integrate genomic, transcriptomic, proteomic, and epigenomic data to provide a more complete understanding of tumor biology [(2)]. AI and machine learning help analyze large, complex datasets, enabling predictive modeling, biomarker discovery, and personalized treatment strategies [(3)]. Together, these technologies form the foundation of precision oncology

Objectives

- Evaluate the role of AI-driven genomics in cancer therapy.
- Assess the contribution of multi-omics integration to personalized oncology.
- Compare AI-based genomic and multi-omics approaches in guiding treatment
- Identify challenges and future directions in precision cancer care.

Methodology

A literature search was conducted in PubMed, Google Scholar, and Scopus for articles

published from 2015 to 2025. Keywords included “precision medicine cancer therapy,” “artificial intelligence genomics,” “multi-omics integration cancer,” and “AI precision oncology.”

Randomized controlled trials, systematic reviews, narrative reviews, and translational research studies were included. Non-English publications, case reports, and studies published before 2015 were excluded.

Review of Literature Table

Author & Year	Study Design	Population / Context	Intervention / Focus	Key Outcomes	Conclusion
Topol (2019)	Review	Oncology informatics	AI in medicine	Enhances diagnostic and decision support	AI is pivotal for precision oncology
Kourou et al. (2015)	Review	Cancer omics data	ML for prognosis	Improves prediction and classification	Supports precision diagnostics
Esteva et al. (2017)	Review	Healthcare AI	Deep learning	Accurate disease classification	Advances personalized medicine
Vamathevan et al. (2019)	Review	Drug discovery	AI in drug development	Accelerates target identification	Improves therapy optimization
Chaudhary et al. (2018)	Cohort	Liver cancer	Multi-omics integration	Better survival prediction	Aids risk stratification
Huang et al. (2017)	Review	Precision oncology	AI + genomics	Predicts therapy response	Supports personalized therapy

Discussion

AI-Driven Genomics in Cancer Therapy

Genomic profiling identifies actionable mutations and therapeutic targets. AI-driven analysis allows rapid interpretation of these variants and prioritization of treatment options, improving patient-specific therapy selection [(6)]. AI models also facilitate biomarker discovery and risk prediction, enhancing early detection and clinical decision-making [(3)(4)].

Multi-Omics Integration

Multi-omics integrates genomic, transcriptomic, proteomic, and epigenomic data, offering a complete molecular profile of tumors. Studies show that multi-omics improves survival prediction, tumor classification, and patient stratification compared to single-omics approaches [(5)(7)]. AI helps harmonize diverse datasets, increasing the accuracy of predictive models and supporting clinical decisions [(8)].

Comparative Insights

AI-driven genomics focuses on variant interpretation and therapeutic prioritization, whereas multi-omics provides comprehensive biological context. Combined, these approaches offer superior diagnostic and prognostic capabilities, enabling more precise treatment strategies [(2)(10)].

Challenges and Ethical Considerations

Challenges include integrating large, heterogeneous datasets, computational demands, model interpretability, and potential algorithmic bias. Ethical concerns such as patient privacy, data security, and informed consent must also be addressed to implement these technologies safely in clinical practice [(9)].

Conclusion

AI-driven genomics and multi-omics integration are revolutionizing precision cancer therapy by enabling personalized diagnostics, prognostic modeling, and treatment selection. Despite significant potential, challenges remain in data integration, ethical considerations, and clinical validation. Continued research and standardization are necessary to fully implement these technologies in routine oncology care.

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List of Abbreviations

AI – Artificial Intelligence
ML – Machine Learning
NGS – Next-Generation Sequencing XAI – Explainable Artificial Intelligence ctDNA – Circulating Tumor DNA
PD – Precision Oncology