Artificial Intelligence: The New Frontier in Predicting Oncology Treatment Response

Rasit Dinc

Rasit Dinc Digital Health & AI Research

Published: August 25, 2025 | Medical Imaging AI

DOI: 10.5281/zenodo.17996581

Abstract

Artificial Intelligence: The New Frontier in Predicting Oncology Treatment Response The promise of personalized medicine in oncology—delivering the righ...

Artificial Intelligence: The New Frontier in Predicting Oncology Treatment Response

The promise of personalized medicine in oncology—delivering the right treatment to the right patient at the right time—is challenged by the inherent complexity and heterogeneity of cancer. Predicting individual treatment response remains a critical challenge. However, a new frontier is emerging: **Artificial Intelligence (AI)**. Driven by massive clinical datasets and advanced computational power, AI is rapidly transforming cancer care by building sophisticated predictive models to guide clinical decision-making and optimize patient outcomes [1].

The Challenge of Treatment Response Prediction

Traditional methods for predicting treatment response rely on a limited set of clinical and pathological factors (e.g., tumor stage, grade, biomarker status). These often fall short, leading to unnecessary toxicity for non-responders and delayed effective treatment. The complexity of cancer—involving genetic mutations, tumor microenvironment interactions, and immune responses—demands a holistic, data-driven approach. This is where AI, particularly Machine Learning (ML) and Deep Learning (DL), offers a paradigm shift.

Key AI Methodologies Driving Precision Oncology

AI models excel at identifying subtle, non-linear patterns within vast, multi-dimensional datasets. In oncology, three primary data modalities are being leveraged to build these predictive models:

1. Radiomics and Deep Learning

Radiomics involves the high-throughput extraction of quantitative features from medical images, such as CT, MRI, and PET scans. These features—related to tumor shape, intensity, and texture—can serve as powerful biomarkers. Deep Learning models, especially Convolutional Neural Networks (CNNs), have further advanced this field by automatically learning the most predictive features directly from the raw image data, a concept known as **Deep Learning Radiomics** [2]. ***Application:*** *Studies have shown that AI-based systems using radiomics can outperform traditional radiological interpretation in predicting the response to treatment in cancers like lung cancer, offering superior sensitivity and accuracy [3]. This non-invasive approach provides a real-time assessment of the tumor's biological state.*

2. Multi-Omics Data Integration

Cancer response is fundamentally a biological process, governed by the patient's unique molecular profile. AI is proving indispensable in integrating and interpreting complex ***multi-omics data*** *(genomics, transcriptomics, proteomics, and metabolomics). ML algorithms fuse these disparate data types to create a comprehensive molecular signature of the tumor and the host [4].*

Application: Explainable Machine Learning (XML) models are being developed to not only predict outcomes but also to reveal the underlying biological drivers of treatment resistance or sensitivity, paving the way for truly personalized therapeutic strategies [5].

3. Predicting Immunotherapy Response

Immunotherapy, particularly Immune Checkpoint Inhibitors (ICIs), has revolutionized cancer treatment, but only a fraction of patients respond. Predicting which patients will benefit is a major clinical priority. AI models are being trained on clinical data, imaging features, and tumor mutational burden to forecast ICI response with increasing accuracy [6].

Application: *A proof-of-concept study demonstrated an AI-driven model for predicting ICI response in advanced cancer, highlighting the potential to spare non-responders from ineffective and costly treatments [6].*

The Path to Clinical Integration and Future Outlook

While the academic promise of AI in oncology is clear, clinical integration requires rigorous validation, standardization of data collection, and addressing ethical considerations [7]. Developing robust, generalizable models that perform reliably across different institutions and patient populations is the next critical step.

The future of oncology is undeniably intertwined with AI. As models become more sophisticated and integrate real-world data (RWD) from electronic health records, they will move from being purely predictive tools to prescriptive ones, recommending optimal treatment sequences and dosages. AI is not replacing the oncologist, but rather augmenting their capabilities, providing a powerful co-pilot in the complex journey toward precision cancer care.

*

References

[1] J. Wang, et al. (2025). The clinical application of artificial intelligence in cancer precision medicine. Translational Medicine*. [2] M. Tez, et al. (2025). Deep learning radiomics: Redefining precision oncology.* PMC*. [3] N.A. Guevara Rodriguez, et al. (2025). Artificial intelligence versus radiologist interpretation in predicting lung cancer treatment response.* Journal of Clinical Oncology*. [4] B. Zhang, et al. (2023). Machine Learning and AI in Cancer Prognosis, Prediction, and Treatment.* PMC*. [5] Multi-omic explainable machine learning improves cancer treatment response prediction. (2025).* Clinical Cancer Research*. [6] M. Rakaee, et al. (2025). Deep Learning Model for Predicting Immunotherapy Response in Advanced Cancer.* JAMA Oncology*. [7] E.M. Froicu, et al. (2025). Artificial Intelligence and Decision-Making in Oncology: Ethical and Legal Considerations.* PMC*.

[1]: https://translational-medicine.biomedcentral.com/articles/10.1186/s12967-025-06139-5 "The clinical application of artificial intelligence in cancer precision medicine" [2]: https://pmc.ncbi.nlm.nih.gov/articles/PMC12278257/ "Deep learning radiomics: Redefining precision oncology" [3]: https://ascopubs.org/doi/10.1200/JCO.2025.43.16_suppl.e23192 "Artificial intelligence versus radiologist interpretation in predicting lung cancer treatment response" [4]: https://pmc.ncbi.nlm.nih.gov/articles/PMC10312208/ "Machine Learning and AI in Cancer Prognosis, Prediction, and Treatment" [5]: https://aacrjournals.org/clincancerres/article/31/13_Supplement/A051/763383/Abstract-A051-Multi-omic-explainable-machine "Multi-omic explainable machine learning improves cancer treatment response prediction" [6]: https://jamanetwork.com/journals/jamaoncology/fullarticle/2828578 "Deep Learning Model for Predicting Immunotherapy Response in Advanced Cancer" [7]: https://pmc.ncbi.nlm.nih.gov/articles/PMC12423120/ "Artificial Intelligence and Decision-Making in Oncology"
