
RESEARCH ARTICLE

AI in Precision Oncology: Revolutionizing Cancer Treatment Through Personalized Drug Discovery

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ABSTRACT

Artificial intelligence (AI) is revolutionizing precision oncology by enabling early detection of cancer, accurate diagnosis, and personalized treatment plans. This research aligns the mechanisms and techniques stemming from AI with their implications towards advancements in cancer treatment, with particular focus on its role in personalization for the sake of precision medicinal diagnoses. AI-powered technologies have revolutionized cancer treatment from genetic profiling and pathology interpretation to predictive analytics and medical imaging analysis. Case examples show how AI can tailor treatments to individual patients, improve diagnostic accuracy, guide optimal treatment and monitor treatment response in real time. The Future of AI in Oncology section delves into potential future advancements in the field, discussing how AI technologies could accelerate drug discovery and development, enhance therapy outcomes, and facilitate greater patient engagement. Ultimately, artificial intelligence is not only reshaping cancer treatment; it is also providing patients worldwide with new hope for greater survival and quality of life. This study highlights some revolutionary frontiers of artificial intelligence, like virtual tumor boards, liquid biopsies, and the speeding of drug discovery processes," the paper said in part. This article uses a narrative review approach to provide a holistic understanding of the transformative potential that artificial intelligence holds for cancer treatment, highlighting its current significance in cancer care and its future potential.

KEYWORDS

Artificial Intelligence, Precision Oncology, Personalized Medicine, Cancer Treatment, Drug Discovery.

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1. Introduction

Cancer is one area where artificial intelligence (AI) is transforming the future of health care (Ahmed et al., 2025). As the diagnosis and treatment of cancer grows increasingly complex, the ability of AI to go through vast data sets, identify tiny patterns, and generate predictive models is becoming essential (Akter, Nilima, et al., 2024). AI-powered solutions are enhancing clinical decision-making and streamlining processes across a diverse range of domains, spanning pathology, genomics, medical imaging, and electronic health records. Beyond improving early detection and diagnosis, AI could revolutionize precision oncology by enabling highly tailored treatment plans (Al Mahmud et al., 2025). Having machine learning, natural language processing, and computer vision allows for much more precise interpretation of medical data. It allows oncologists to tailor treatments in line with genetics, lifestyle and clinical history unique to each patient (Ali Linkon et al., 2024; Bhuiyan et al., 2025a). One of the most promising areas is personalized drug discovery (Mia Md Tofayel Gonee et al., 2021). Drug development traditional way is slow and costly (Prova, 2024b). AI accelerates this process by identifying promising medicinal compounds, enhancing medication design, and generating remarkably accurate and timely treatment outcome predictions (Miah et al., 2025). These advances not only reduced development costs but also accelerated the delivery of life-saving drugs to patients (Biswas et al., 2024; Lee et al., 2018).

Additionally, by providing evaluations of patient responses in real time, AI systems are enhancing therapy monitoring by allowing for quick adjustments that increase efficacy and reduce adverse effects (Chowdhury et al., 2023; Debnath et al., 2024). This level of precision helps oncologists hit the right marker when making decisions and leads to better patient outcomes (Prova, 2024a). Because cancer remains one of the leading causes of death in the world, the incorporation of AI in oncology provides an opportunity to deliver more effective, equitable, and personalized care (Nirupam Das 2025). Advancements in AI-supported diagnostics and therapies are already paving the way for cancer therapy to become a more personalized, patient-oriented procedure (Abdallah et al., 2023; Fakoor et al., 2013).

2. AI in Medical Technology

AI in healthcare: Decision-making, by enhancing efficiency, precision, and customization in a range of medical services (Siddiqua et al., 2024). The double-edged sword of AI technologies for precision medicine and drug discovery has been the game-changer in oncology through the converging realm of machine learning (ML), computer vision, robotics and natural language processing (NLP) (Ahmed et al., 2025; Bhuiyan et al., 2025b). ML algorithms are capable of finding patterns, detecting anomalies, and predicting treatment outcomes with impressive accuracy, which is indispensable in managing cancer (Goffer et al., 2025). Natural language processing pinpoints meaningful information from unstructured data used throughout healthcare, thus streamlining clinical reporting, supporting data-driven strategies, and accelerating discovery of the relevant genetic markers or treatment options (Hasan et al., 2025; Khan et al., 2024). By leveraging algorithms to analyze images from MRIs, CT scans, and X-rays, computer vision improves diagnostic outcomes and facilitates earlier and more accurate cancer detection. AI-driven robotics is transforming how cancers are treated by aiding in minimally invasive procedures, releasing medication with high precision, and tracking patient health data in real time (Hossain et al., 2024).

AI technologies are working in personalized drug discovery, speeding the discovery and development of targeted therapies (Kamal et al., 2025). Through simulating molecular interactions, predicting drug responses, and alerting clinicians to potential side effects early in the process (Khair et al., 2025), AI is shortening development time and reducing the cost of bringing new cancer drugs to market, maximizing the chances that patients will receive the most effective medications for their individual genetic and clinical profiles (Das et al., 2023). These breakthroughs in medical technology are proof of how AI is redefining and improving healthcare, moving the needle for cancer treatment and providing customized solutions that could save more lives, more accurately and faster than the current standard (Carlier et al., 2018; Hossain et al., 2025). Fig. 1 shows machine learning classifier workflows.

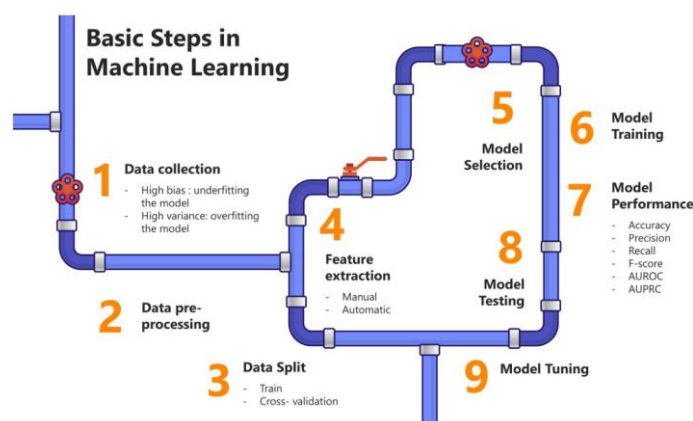


Fig. 1. Machine learning classifier workflows (Mahmud, Barikdar, et al., 2025).

3. AI's Advantages for Patient Care and Treatment

AI is revolutionizing the field with advances in cancer diagnosis, monitoring, and therapy (Imran et al., 2024). Its primary advantage is that it can prompt early identification of diseases and therefore a timely reaction, and such increased survival. Considering a patient's genetic profile, lifestyle, and medical history, AI can develop personalized treatment plans that reduce side effects while optimizing the success of the treatment (M. A. Islam et al., 2025). It can also predict how a patient will respond to individual treatments, helping oncologists adjust dosages accordingly for optimal results (Manik et al., 2025). AI is also critical in long-term patient care, as it can quantify vital signs and wellness indicators through wearable devices and remote monitoring systems. For chronic/ progressive disorders, real-time monitoring works to ensure uniform handling and reduce complications (Md Habibullah Faisal, 2022). AI-powered tools can also provide individuals with diabetes or heart disease with tailored dietary, workout and medicine guidance (Mia Md Tofayel Gonee et al., 2022). In other words, AI enhances the quality, precision, and individualization of cancer care, bringing us one step closer to a future in which all therapies are not only more effective but also

customized to meet each patient's individual needs (Kamruzzaman et al., 2024; Kaur et al., 2023). Fig. 2 shows a schematic representation of the main stages during the drug discovery and drug development process.

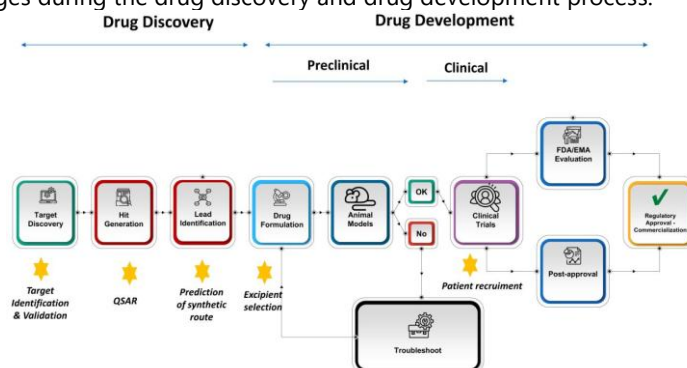


Fig. 2. shows a schematic representation of the main stages during the drug discovery and drug development process (Miah, 2025; Serrano et al., 2024).

4. Difficulties and Ethical Issues

AI in precision oncology has the potential to significantly enhance cancer treatment despite several ethical challenges (Manik et al., 2025; Nilima et al., 2024). Their accuracy and reliability are essential since AI systems rely on large amounts of high-quality medical data. These datasets can include errors, biases, or gaps that could result in patients being misdiagnosed or predictions being inaccurate. Data security and privacy are critical because AI systems handle sensitive patient data. Patients need to provide informed consent and be transparent about what their data will be used for (Mohammad Abdul et al., 2024). Another challenge is health equity, as AI models trained on specific populations would not generalize well to underrepresented populations, and might further deepen existing disparities (Saimon et al., 2023). Frameworks must clearly define the responsibilities of developers, regulators and physicians in overseeing the AI-based oncology choices. Despite these challenges, artificial intelligence (AI) is driving significant breakthroughs in personalized medicine, such as improving patient outcomes, accelerating drug development and tailoring treatments for cancer (Syed Nazmul Hasan, 2025).

5. AI Advances in the Identification and Treatment of Cancer

AI is revolutionizing cancer diagnosis, treatment, and detection. Deep learning algorithms can help analyze medical imaging data by spotting minute discrepancies in MRIs, CT scans, X-rays and mammograms. These are often more precise than experienced radiologists at distinguishing between normal and abnormal results (Ahmed et al., 2023). Artificial intelligence has greatly enhanced the sensitivity and specificity of breast cancer diagnosis by mammography, resulting in earlier detection, fewer false positives, and shorter diagnostic delays (Chowdhury et al., 2023). AI also assists radiologists in prioritizing cases, streamlining workflow, and flagging areas of confusion for closer inspection (Prabha et al., 2024). AI is propelling pathology beyond imaging through the analysis of biopsy samples and histopathological images to identify the presence of cancerous cells, classify the form of tumors, automate such processes as feature extraction, and cell counting. AI can demonstrate itself in molecular diagnostics by searching for unique biomarkers of cancer, thereby aiding tumor categorization, prognosis, and targeted treatments. AI in liquid biopsies provides a non-invasive approach to monitor tumor evolution, assess therapy efficacy in real-time, and guide ongoing therapeutic decisions. These advancements hold promise for chemotherapy success through more intelligent personalized cancer treatment, an area known as precision medicine (Sadik et al., 2024; Sobuz et al., 2025).

6. AI-Powered Personalized Cancer Treatment

Precision medicine, also called personalized medicine, is changing the cancer treatment paradigm by tailoring therapy to individual patient-specific characteristics, including genetic makeup, lifestyle, and disease characteristics (Tiwari et al., 2025). AI is critical to enabling personalized cancer treatment by analyzing complex data, such as genomes, proteomics, clinical history, and imaging. With the help of AI, oncologists can develop treatment plans that specifically target the genetic abnormalities responsible for tumor formation. Using an amalgamation of different datasets, AI can produce holistic tumor profiles and identify biomarkers for clinical outcome, treatment response, and cancer subtype. Genomic profiling is important as AI algorithms can detect mutations in biopsy samples and predict how patients will respond to specific drugs. AI-assisted sequencing helps show better treatment options and outcomes. AI is likewise critical for ongoing observing, measuring changes in molecular markers, excessive metabolic activity, and tumor expansion (Goffer, 2025). Clinical Decision Support Systems (CDSS) improve the standardization of care across healthcare settings and provide evidence-based recommendations for treatment. AI-based personalized cancer care is a paradigm shift in oncology and offers new avenues to improve patient outcomes and quality of life (Akter, Kamruzzaman, et al., 2024; Yeasmin et al., 2025).

7. AI-Powered Oncology Support Systems

There has been a rising number of AI-powered Clinical Decision Support Systems (CDSS), which are fundamentally changing the way we treat cancer by generating evidence-based recommendations from the assessment of patient data, medical literature, and treatment guidelines. These tools ensure more accurate and individualized treatment choices by aiding oncologists in cross-referencing complex datasets and finding relevant studies. They also assist in patient recruitment for clinical trials, tracking therapeutic response and disease progression and choosing and designing personalized treatment regimens (M. Islam et al., 2025).

CDSS also enhances prognosis and risk assessment by predicting patient outcomes and determining patients who have a higher risk for the development or recurrence of their disease. These technologies aid patients via individualized prognostic modelling by guiding long-term therapeutic approaches and tailoring treatment regimens based on tumor characteristics and biomarker profiles. AI-powered CDSS might also assist with administrative tasks in oncological practices, as well as increase workflow efficiency by automating processes such as data recording, appointment scheduling, and order input. The technologies that will deliver precision medicine at scale will depend on how successfully they are integrated into everyday cancer practice as they mature.

8. Case Studies of Effective AI Use in Cancer Treatment

AI has proven to be very promising in transforming cancer care, especially in early detection, diagnosis, treatment planning, and patient monitoring. An expanding breadth of case studies demonstrates the utility of AI in oncology, highlighting areas in which these tools can augment clinical judgement and improve patient outcomes across the continuum of the cancer journey.

AI is being used to better diagnose difficult picture treatments, for example, people whose systems have been trained on enormous mammography arrangements are better at distinguishing breast cancer than specialists. Survival rates for patients are ultimately improved through earlier diagnosis and more effective treatments. A new AI-powered system has been developed that classifies prostate cancer diagnoses directly from images of tissue obtained through digital biopsy slides, an example of how AI has transformed the field of pathology. Some argue that this technology allows clinicians to make better-informed, patient-specific decisions with greater confidence.

One study published this week in The New England Journal of Medicine showed that A.I. could predict how patients with melanoma would respond to therapy. AI-powered clinical decision support systems (CDSS) are also assisting patients with treatment decisions. To track tumor evolution and morphological changes over time, researchers are employing tools that process imaging data from CT and MRI scans. AI is also applied for assessing response to therapy and tracking disease progression. It allows oncologists to adjust treatment regimens in real-time as patients respond, resulting in more effective and adaptable methods of care (Faheem & Dutta, 2023; Kaur et al., 2023). Table 1 shows a summary of software platforms

Table 1. Summary of software platforms (Md Ekrim et al., 2024; Mia Md Tofayel Gonee et al., 2020).

Software Platform	Description	Key Features
DeepMind Alpha Fold	Deep learning model for protein structure prediction	Predicts protein structures with high accuracy
Atomwise	AI-driven drug discovery platform	Virtual screening, lead optimization
Recursion Pharmaceuticals	High-throughput screening platform	Cellular phenotypic analysis, rare diseases
BenevolentAI	Drug discovery and development platform	Predictive modeling, target identification
Schrödinger Maestro	Molecular modeling and simulations	Molecular docking, QSAR modeling
Insilico Medicine	Drug discovery and biomarker development	Generative modeling, drug repurposing, and aging research
XtalPi	AI-driven drug crystal prediction	Predicts drug crystal forms, stability
Cyclica	AI-driven drug discovery platform	Polypharmacology prediction, target deconvolution

9. Prospective Pathways and Advancements

While its full potential is yet to be realized, AI has fundamentally transformed the landscape of cancer care. AI-based predictive models are being developed to identify individuals with high cancer risk. These algorithms use population data to inform risk

profiles and guide appropriate preemptive measures. By using radiomics (the AI-enforced extraction and analysis of imaging data for quantitative use), clinicians may supply individualized advice on treatment. Radiomics yields deep insights into tumor biology, therapy response, and prognosis. Using genetic, imaging, clinical, and outcome data to predict patient response to treatment, AI-based predictive analytics models are transforming treatment planning and optimization (Khair et al., 2024). Novel AI platforms for precision oncology are being developed to integrate clinical and genomic data into daily practice (6), to facilitate clinical trial matching, provide evidence-based therapy recommendations, and produce robust molecular profiles of tumors. AI-driven drug discovery and repurposing, predicting therapeutic effectiveness, discovering new drug targets, and improving treatment plans are another revolutionary area. Virtual screening methods can additionally accelerate this process by identifying pre-existing drugs with potential anticancer properties. AI-powered mobile health and digital health solutions are Swedish Royal Institute of Technology, Stockholm, Sweden. With personalized assistance, real-time monitoring, and educational resources, virtual assistants and AI chatbots can help cancer patients engage in their care. Incorporating it further into clinical practice will lead to greater clinical utility of AI to drive precision oncology forward and improve the lives of every patient with cancer. Table 2 illustrates the potential applications of AI.

Table 2. The potential applications of AI (Mahmud, Orthi, et al., 2025; Serrano et al., 2024).

AI Application	Paraphrased Overview	Example Use Case
Synthesis Pathway Prediction	AI identifies efficient synthetic routes for APIs using chemical data and research.	IBM's 'Rxn for Chemistry' tool streamlines synthetic planning.
Automated Chemical Synthesis	Robotic systems powered by AI conduct chemical synthesis for quicker drug development.	University of Glasgow's 'Chemputer' automates synthesis steps.
AI-Driven Drug Design	AI forecasts molecular makeup and targetability for drug candidates.	Insilico Medicine developed a fibrosis drug in 18 months using AI.
Gene-Based Drug Discovery	AI with CRISPR tech finds genes linked to treatment resistance or sensitivity.	AstraZeneca applied AI to improve gene-targeting via CRISPR.
AI Compound Screening	AI filters chemical libraries to find effective drug candidates based on key traits.	Exscientia used AI to discover compounds for inflammatory diseases.
Manufacturing Process Enhancement	AI enhances manufacturing by spotting and addressing inefficiencies through data.	Pfizer improved COVID-19 vaccine output using AI-driven insights.
Smart Manufacturing with AI	AI streamlines pharmaceutical production from raw materials to packaging.	Pharma firms used AI to enhance production continuity.
AI in Radiology	AI assists radiologists by automating image analysis and improving workflow.	Bayer employs AI for quicker diagnostics and reduced load on radiologists.
Virtual Replication (Digital Twin)	AI builds digital models of production systems for real-time improvements.	Johnson & Johnson used digital twins for real-time process optimization.
Predictive Equipment Maintenance	AI analyzes machine data to forecast failures and schedule upkeep.	Pfizer reduced downtime via predictive AI for maintenance.
Optimized Pharma Supply Chain	AI handles logistics, demand, and inventory to streamline supply chains.	Novartis improved supply flow and cut costs using AI logistics tools.

10. Conclusion

Artificial intelligence (AI) will transform the way cancer is treated by enhancing clinical decision-making, improving patient outcomes, and redefining the diagnosis, treatment, and care of cancer. AI systems have performed with impressive accuracy in the analysis of medical images, detecting small anomalies and cancers that human specialists might miss. This enables early detection, providing the opportunity for effective treatment and reducing the burden of disease through timely intervention. AI-powered precision medicine has revolutionized treatment planning by enabling customized medicines to be created and treatment advice to be generated according to each patient's distinct cancer profile. Tailored regimens can optimize treatment's effectiveness while minimizing toxic and adverse effects, improving quality of life and survival.

AI is equally critical for patient tracking and management. To predict medication response and illness progression and allow for rapid adjustment of treatment strategies, predictive analytics algorithms analyze longitudinal data. AI clinical decision support systems CDSS integrate clinical guidelines with real-world evidence and patient data to individualize treatment decisions, standardize care and improve consistency across clinical settings. But challenges around algorithmic bias, data privacy and transparency remain. Ensuring AI models are reflective of different groups of patients, accurate and generalizable is paramount. Additional research and validation are needed to further improve the reliability and applicability of AI technologies in real-world clinical practice. Thanks to data-driven, personalized and increasingly AI-enhanced approaches, we are moving closer to a cancer future where every patient receives the right care at the right time.

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