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Editorial

Artificial intelligence in oncology: A physician's perspective

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The use of AI in medicine began in the 1970s, with early efforts focused on developing expert systems for diagnosis. AI in oncology specifically began with the development of algorithms to analyze large volumes of medical data, primarily focusing on cancer diagnosis and early detection through medical imaging.[1–3] The evolution of AI in oncology has transitioned from early rule-based systems to the rise and subsequent pivot of high-profile platforms, such as IBM Watson, leading to today's era of deep learning and generative AI for precision medicine. Table 1 below summarizes the selected milestones associated with Oncology Research and Practice.

Learning from the failure of the IBM Watson for Oncology (WOF) is critical for oncology practice research and industrial investment. Although there are many speculations of failure reasons, the failure of IBM Watson Oncology to its primary goal is likely due to 1) clinical data complexity, limitation of medical record in real world, and lack of communication between the IBM engineers and oncologists, 2) data collection and technical integration problems (electronic health records [EHRs]), and 3) most critically, the use of poor-quality, unscientifically structured data for hypothesis modeling, thus generating unsafe/inaccurate treatment advice.[4]

Today, AI-based systems are increasingly used across various oncology fields, most notably in radiology, pathology, and radiation oncology, with numerous devices receiving U.S. FDA approval for clinical use. These AI-enabled medical devices use algorithms to analyze complex data (images, genomics, EHRs) for earlier decision, more accurate cancer detection (skin and breast cancers), better treatment planning (radiotherapy, drug selection via omics), biomarker discovery, and outcome prediction, indicating potential to transform diagnostics and guide precision medicine. These Software as a Medical Device (SaMD) solutions automate tasks, reduce variability, and assist clinicians in making faster, data-driven decisions across radiology, pathology, genomics, and cancer therapy such as radiotherapy. The FDA clearance is increasing rapidly, as presented in the American Society of Radiation Oncology[5] and evidence analyzed in *npj Digital Medicine*,[6] according to data from the FDA's list of AI-enabled medical devices.

AI is indeed revolutionizing cancer care from multiple aspects by enhancing early detection, improving diagnostic accuracy in radiology and pathology, guiding treatment decision-making, predicting treatment outcome, personalizing treatment plans, and accelerating drug discovery through analyzing complex data (imaging, genomics, and EHRs), aiming to support clinicians and improve patient outcomes.

There has been extensive use of AI in research for nodule diagnosis, image analysis research, such as radiomics, genomic profiling and testing for targeted therapy, clinical decision, and radiotherapy.[7] Figure 1 demonstrates a good summary of AI in current oncology applications.

It is worth mentioning that there has been a rapid expansion of AI in every specialty in health, including oncology, after DeepSeek announced the powerful, cost-efficient large language models including DeepSeek-V2 and the reasoning-focused DeepSeek-R1, gaining global attention in early 2025. Specifically, DeepSeek for Cancer leveraged DeepSeek-R1 LLM to develop diagnostic tools, such as the specific blood test called HPV-DeepSeek. DeepSeek has been evaluated in several studies for its potential use in assisting oncologists with diagnosis, treatment planning, and patient education. DeepSeek-R1 has demonstrated high accuracy in answering complex medical questions and can outperform junior oncologists in specific scenarios related to lung, bone, and soft tissue tumors. In a new NIH-funded study, published in the *Journal of the National Cancer Institute*, researchers showed that a novel liquid biopsy tool they developed, HPV-DeepSeek, could identify HPV-associated head and neck cancers up to 10 years before cancer symptoms appear.[9] By detecting cancers earlier with this novel technique, patients may require less intense yet radical regimen and better chance of treatment success.

In this upcoming issue, there are original research and comprehensive literature reviews on several fields of AI Oncology. Early Detection & Screening: AI analyses scans (computed tomography, magnetic resonance imaging) and pathology slides for subtle signs of cancer to improve diagnosis accuracy and efficiency. Diagnosis & Pathology: Deep learning helps pathologists identify tumor features and predict gene activity from images, revealing tumor microenvironments (ecosystems) linked to outcomes. Personalized Treatment: AI integrates genomic, clinical, and molecular data to recommend tailored therapies and match patients to clinical trials, moving towards precision medicine. Drug Discovery & Biomarker Development: AI identifies patterns in omics data (genomics, proteomics) to find new biomarkers that predict drug responses for personalized precision

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Table 1
Key milestones in Al oncology practice and research.

Year	Milestone	AI technology/ highlight	Relevance to practice and research
2011	Watson for Healthcare Announced	IBM Watson (Cognitive Computing)	IBM turned Watson toward healthcare, specifically oncology.
2012	MSKCC & MDACC Partnership	IBM Watson, MSKCC and MDACC Oncology Expert Advisor (OEA)	Partnership began to train WFO using expert-curated clinical data; MDACC OEA enlisted a congnitive computing system enpowered by IBM Watson
2014	Pilot Testing Phase	WFO Clinical Trials	Oncologists at MSKCC tested Watson on hypothetical cases; early gaps in knowledge were identified.
2015	Commercial Launch	IBM WFO	Officially launched and adopted globally in countries including India, Republic of Korea, and Thailand.
2016	Training and Validation	NLP	Watson processed 25 millions research papers/week; WFO with 49%-99% concordance with tumor boards.
2017	Crisis & Criticism Adoption in China	Cognitive Computing Scrutiny; More WFO Clinical Trials	Trial results revealed WFO recommendation concordance with MDT tumor board varied with cancer and often not satisfactory for clinical practice
2018	Cancellations	Adoption Setbacks	Major institutions, including MDACC, canceled multimillion-dollar Watson implementations.
2019	Breakthrough in Diagnostics	Deep Learning (CNNs)	AI models began outperforming experts in lung cancer detection on CT scans (e.g., Google Health studies).
2021	Surge in FDA Approvals	Clinical AI Tools	Significant increase in FDA-cleared AI tools for radiology and pathology (e.g., Paige Prostate).
2022	IBM Watson Health Sale	Strategic Pivot	IBM sold Watson Health assets to Francisco Partners (rebranded as Merative), marking the end of its original ambitious era.
2024	Integration Milestone	Multimodal AI	Widespread peak in patents and clinical trials for AI models that integrate imaging, genomics, and EHR data.
2025	Generative AI Era	LLMs & Foundation Models	Launch of oncology-specific tools, i.e., ASCO's Guidelines Assistant and City of Hope's HopeLLM.

Abbreviations: 1. AI: artificial intelligence 2. MSKCC: Memorial Sloan Kettering Cancer Center 3. MDACC: MD Anderson Cancer Center 4. NLP: natural language processing 5. CNNs: convolutional neural networks 6. CT: computed tomography 7. FDA: Food and Drug Administration 8. EHR: electronic health records 9. LLMs: large language models 10. ASCO: American Society of Clinical Oncology 11. WFO: Watson for Oncology 12. MDT: multidisciplinary team.

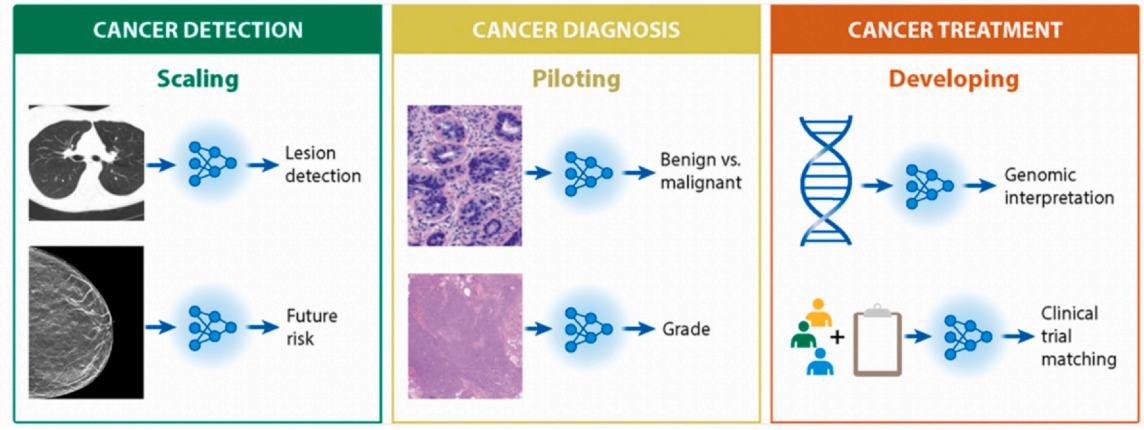


Figure 1. Overview of current status of AI in oncology.[8] AI has been widely used in oncology for cancer detection, diagnosis and treatment.

therapy. Clinical Decision Support: AI systems synthesize vast patient data (laboratory results, images, records) to provide evidence-based recommendations, aiding tumor boards and treatment planning. Data Integration: AI creates "data lakes" to combine diverse data types (radiology, pathology, clinical notes) for comprehensive analysis. Feature Extraction: AI extracts key features from images or data.

For AI in oncology,the ultimate destination is to collect the data of full spectrum, link the data with intelligent models in person, and identify personalized treatment for best outcome, i.e., the establishment of a "digital twin" for each patient, a comprehensive virtual representation of the data that integrates all available data, including clinical patient factors, omic, imaging, and tumor behavioral features, to simulate disease progression with and without treatment and test treatment strategies before they are applied in each patient and adjust the real world. They act as a dynamic, data-driven in silico laboratory for testing therapies before applying them to the real patient, reducing trial-and-error and improving precision medicine. This vision may usher in an era of true precision medicine, fundamentally transforming how we understand, detect, and fight cancer in millions of individuals (Figure 2).[10,11]

Current challenges

Despite the potential, current research on AI is challenged in every field, such as data accuracy, data privacy, the need for robust clinical validation through randomized trials, regulatory frameworks for AI-based devices, and the risk of algorithmic bias. Training data needs to be diverse and representative to ensure equitable performance across all patient populations. Data quality and data infrastructure are the most important fundamental steps, so future research will not repeat the failure of IBM WOF.

Future directions

In summary, AI in oncology has evolved from diagnosis to prognosis, with early AI focused on the question "Is there cancer?" and modern AI on more complex ones: "How will this specific cancer behave?", " What matters to the treatment outcome", and "Which treatment is the best?". From a data integration aspect, there is a shift from analyzing single data types (i. e., X-rays) to "multi-modal" AI model that synthesizes pathology, genomics, and clinical records simultaneously. Importantly, although once limited to high-

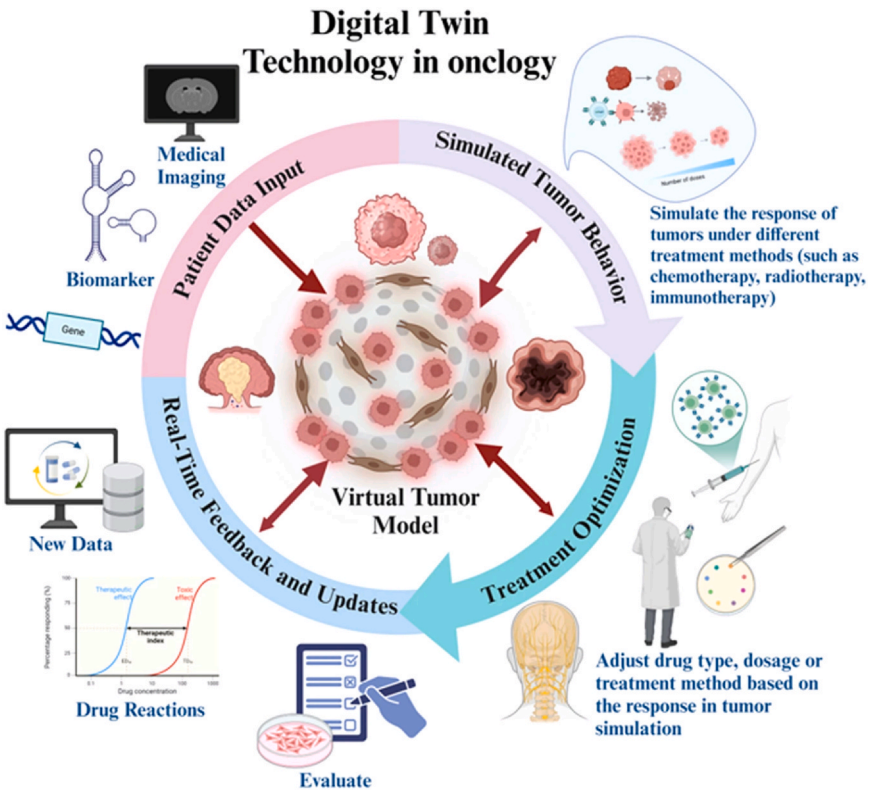


Figure 2. Digital twin technology in oncology.[11] This cancer digital twin is a dynamic closed-loop, reflecting that each stage of cancer treatment can be updated and optimized based on real-time data. This can help clinicians use the data and continuously adjust treatment plans through the virtual model to guide more personalized therapy. This system enables clinicians to make the most appropriate adjustments during the course of the treatment based on the latest data, improving treatment outcomes.

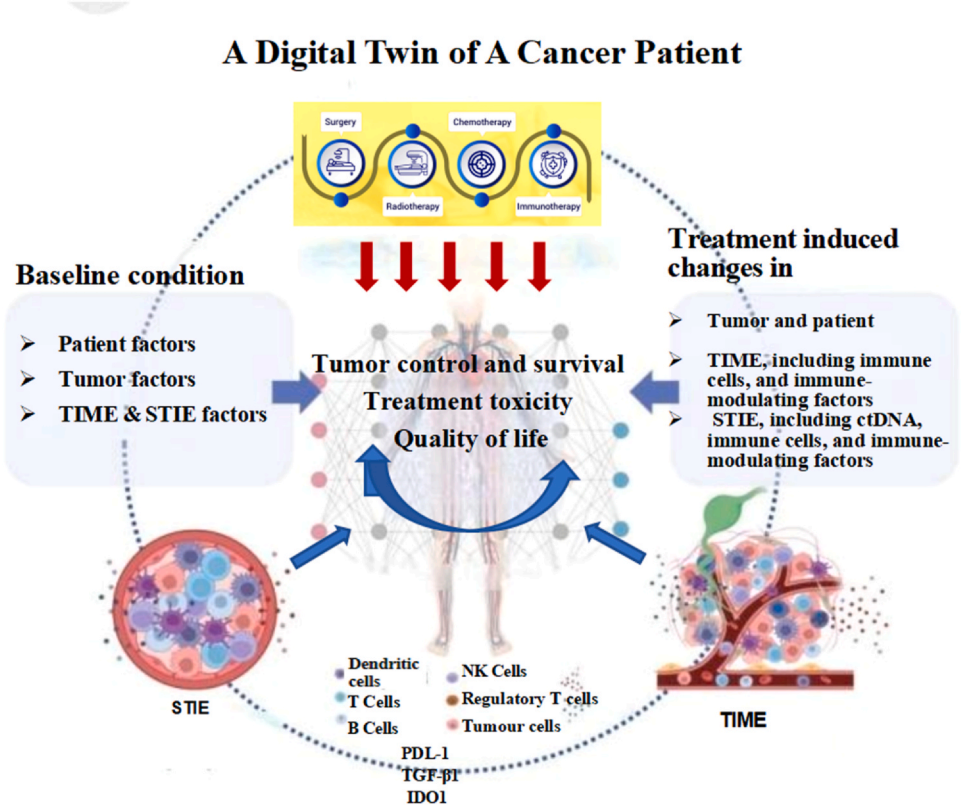


Figure 3. A digital twin of a cancer patient. This digital twin, as a virtual presentation of a person, demonstrates that the treatment outcomes (tumor control, treatment toxicity, and quality of life of a patient) are determined by tumor factors, patient factors, treatments regimen and treatment responses, which are largely determined by the immune environment TIME and STIE. The digital twin can be simulated for treatment decisions at baseline to select the most appropriate initial treatment for each patient at their personal level of preference. This can also help the physician use the data and continuously adjust treatment plans throughout the course of their diseases, for dynamically personalized therapy, to improve tumor control and patient survival, minimize treatment toxicity and improve quality of life of millions of individuals. Abbreviations: 1. TIME: tumor immune microenvironment 2. STIE: systemic tumor immune environment 3. PDL-1: programmed death-ligand 1.

performance research laboratory, AI tools are now becoming standard in clinical pathology and radiology workflows. Virtual dynamic digital twins at different levels of complexity can be used for each patient at each step of care for patient-centered approach with comprehensive consideration of benefits and risks (Figure 3).

AI in oncology is advancing rapidly from a supportive tool to an integral part of the entire cancer care continuum, with future applications pointing toward a highly personalized, efficient, and data-driven approach to prevention, diagnosis, and treatment. AI will primarily augment, not replace, human oncologists, allowing them to concenctrate more on patient interaction and complex personalized decision-making in each patient and each step of the cancer care path. Every physician needs to learn AI and use AI with human wisdom, ultimately helping us care for cancer patients better, faster, and more cost-effectively.[12]

CRediT authorship contribution statement

Feng-Ming (Spring) Kong: Conceptualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

Feng-Ming (Spring) Kong is a co-Editor-in-Chief for Intelligent Oncology and was not involved in the editorial review or the decision to publish this article. The author declares no conflicts of interest.

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