International Journal of Multidisciplinary Research in Biotechnology, Pharmacy, Dental and Medical Sciences (IJMRBPDMS)

Artificial Intelligence in Modern Adult and Pediatric Cancer Care: Opportunities, Challenges, and Future Perspectives

Dr. Nikhil Bhardwaj[1], Dr. Swati Kulshrestha[2], Mr. Abhishek Tandon[3], Dr. Ritu Malhotra[4], Dr. Hemant Chaturvedi[5], Mrs. Sneha Venkatesan[6]

[1]Professor Department of Pharmaceutics, Crescent Institute of Pharmaceutical Sciences, Kochi, India drnikhilbhardwaj@gmail.com
[2]Associate Professor Department of Pharmacology, Crescent Institute of Pharmaceutical Sciences, Kochi, India swatikulshrestha.pharm@gmail.com
[3]Assistant Professor Department of Pharmaceutical Chemistry, Crescent Institute of Pharmaceutical Sciences, Kochi, India abhishektandon.research@gmail.com
[4]Professor Department of Pharmacy Practice, Crescent Institute of Pharmaceutical Sciences, Kochi, India dr.ritumalhotra@gmail.com
[5]Professor Department of Pharmacognosy, Crescent Institute of Pharmaceutical Sciences, Kochi, India hemantchaturvedi.phd@gmail.com
[6]Associate Professor Department of Pharmaceutical Analysis, Crescent Institute of Pharmaceutical Sciences, Kochi, India snehavenkatesan.academics@gmail.com

ABSTRACT

Background:
Cancer remains one of the leading causes of morbidity and mortality worldwide, affecting both adult and pediatric populations through diverse biological mechanisms, clinical presentations, and therapeutic responses [1]. While remarkable advances in molecular diagnostics, targeted therapies, immunotherapy, and precision medicine have significantly improved survival rates, considerable challenges continue to limit optimal cancer care. Delayed diagnosis, tumor heterogeneity, treatment resistance, adverse drug reactions, healthcare disparities, and increasing clinical workload continue to affect patient outcomes across multiple cancer types [2]. Artificial intelligence (AI) has emerged as a transformative technology capable of addressing many of these limitations through advanced computational analysis of complex biomedical data. Modern AI systems integrate machine learning, deep learning, natural language processing, computer vision, generative AI, and multimodal analytics to improve cancer screening, diagnosis, prognostic assessment, therapeutic planning, treatment monitoring, and survivorship care [3]. AI applications now extend across medical imaging, digital pathology, genomics, radiomics, clinical decision support systems, robotic surgery, drug discovery, and personalized oncology. In pediatric oncology, AI offers additional opportunities to enhance early diagnosis of rare childhood malignancies, optimize treatment protocols, minimize long-term toxicities, and improve quality of life for childhood cancer survivors [4]. Nevertheless, significant barriers remain regarding algorithmic bias, explainability, regulatory approval, cybersecurity, data privacy, interoperability, and ethical implementation. This review discusses the evolving role of artificial intelligence across adult and pediatric oncology, highlighting current applications, clinical benefits, existing limitations, and future directions that may redefine precision cancer care over the coming decades.

Keywords: *Artificial intelligence, Cancer care, Precision oncology, Pediatric oncology, Adult oncology, Machine learning, Deep learning, Digital pathology, Radiomics, Clinical decision support.*

Article Info
Received: 05 June 2026, received in revised form: 15 June 2026, accepted: 20 June 2026, available online: 30 June 2026; Volume: 2; Issue: 6; Pages: 29-38.

Citation: Bhardwaj, N., 2026. Artificial Intelligence in Modern Adult and Pediatric Cancer Care: Opportunities, Challenges, and Future Perspectives. *International Journal of Multidisciplinary Research in Biotechnology, Pharmacy, Dental and Medical Sciences (IJMRBPDMS)* 2(6): 29-38.
DOI:

Introduction

Cancer comprises more than two hundred distinct diseases characterized by uncontrolled cellular proliferation, genetic instability, immune evasion, metabolic reprogramming, and progressive invasion of surrounding tissues [5]. Despite substantial improvements in screening strategies, molecular diagnostics, targeted therapeutics, immunotherapy, and multidisciplinary management, cancer continues to represent one of the greatest global public health challenges. According to international epidemiological studies, cancer incidence continues to rise because of

population aging, environmental exposures, lifestyle factors, inherited genetic susceptibility, and improved diagnostic capabilities [6].
Adult cancers such as breast, lung, colorectal, prostate, liver, gastric, and pancreatic malignancies account for the majority of cancer-related mortality worldwide. In contrast, pediatric cancers—including leukemia, lymphoma, neuroblastoma, Wilms tumor, osteosarcoma, medulloblastoma, and other embryonal tumors—represent biologically distinct diseases with unique molecular characteristics, therapeutic responses, and survivorship challenges [7]. Unlike adult malignancies, childhood cancers frequently arise from developmental abnormalities rather than prolonged environmental exposures, requiring specialized diagnostic and therapeutic approaches.
Modern oncology increasingly generates enormous volumes of heterogeneous clinical information. Histopathological images, radiological examinations, genomic sequencing, transcriptomic profiling, proteomic analyses, laboratory investigations, electronic health records, wearable sensor data, and real-world clinical evidence collectively contribute to comprehensive patient evaluation [8]. However, integrating these diverse data sources exceeds the analytical capacity of conventional clinical workflows, making timely and accurate interpretation increasingly difficult.
Artificial intelligence has emerged as a powerful solution capable of transforming oncology through automated pattern recognition, predictive analytics, and clinical decision support. AI systems learn complex relationships from large datasets, enabling earlier diagnosis, improved tumor classification, personalized treatment recommendations, prediction of therapeutic response, and continuous monitoring throughout the patient journey [9]. Rather than replacing clinicians, AI is increasingly viewed as an intelligent clinical partner that augments physician expertise, reduces diagnostic variability, improves workflow efficiency, and supports evidence-based decision-making.
Recent advances in deep learning, transformer architectures, large language models, and multimodal AI have accelerated the integration of artificial intelligence into nearly every aspect of cancer care. These technologies have demonstrated remarkable potential across digital pathology, radiology, radiation oncology, surgical oncology, pharmacogenomics, immunotherapy, and precision medicine [10]. Furthermore, AI is becoming increasingly valuable in pediatric oncology by facilitating earlier recognition of rare malignancies, improving treatment planning, reducing radiation exposure, and supporting long-term survivorship programs.
This review explores the expanding role of artificial intelligence in modern cancer care, emphasizing opportunities, current challenges, and future perspectives across both adult and pediatric oncology.

2. Evolution of Artificial Intelligence in Oncology

Artificial intelligence has undergone remarkable evolution during the past several decades, progressing from simple rule-based expert systems to highly sophisticated deep learning algorithms capable of analyzing multimodal biomedical information [11]. Early AI applications in oncology primarily relied on statistical prediction models and conventional machine learning techniques, including decision trees, logistic regression, support vector machines, naïve Bayes classifiers, and random forest algorithms. These systems demonstrated moderate success in cancer risk prediction, biomarker discovery, and outcome forecasting but often required extensive manual feature engineering and struggled with complex high-dimensional datasets [12].
The emergence of deep learning revolutionized computational oncology by enabling automatic extraction of hierarchical features directly from raw biomedical data. Convolutional neural networks became particularly influential in medical imaging, where they achieved expert-level performance in tumor detection, image segmentation, lesion classification, and pathological image interpretation. These advances significantly reduced reliance on handcrafted imaging features while improving diagnostic accuracy across multiple cancer types [13].
Subsequent developments in recurrent neural networks, graph neural networks, reinforcement learning, and transformer architectures further expanded AI capabilities in cancer medicine. Transformer models introduced self-attention mechanisms capable of capturing long-range relationships within clinical text, genomic sequences, pathology images, and multimodal datasets. Their ability to process heterogeneous biomedical information has substantially improved predictive modeling and precision oncology applications [14].
The recent emergence of generative artificial intelligence and large language models represents another major milestone in oncology. These systems assist clinicians by summarizing scientific literature, generating clinical documentation, supporting multidisciplinary tumor board discussions, identifying relevant clinical trials, and facilitating patient communication. AI-powered conversational systems can rapidly synthesize large volumes of medical evidence, thereby supporting personalized therapeutic decision-making and continuous medical education [15].
Today, artificial intelligence has evolved beyond isolated diagnostic tools into comprehensive oncology ecosystems integrating imaging, pathology, molecular biology, clinical informatics, genomics, wearable technologies, and real-world patient data. This evolution continues to accelerate as computational resources, cloud infrastructure, biomedical databases, and multimodal learning techniques become increasingly sophisticated [16].

3. Major Artificial Intelligence Technologies Used in Modern Cancer Care

Contemporary oncology utilizes multiple branches of artificial intelligence, each contributing unique capabilities across diagnosis, treatment, prognosis, and patient management [17].

Machine learning remains one of the most widely implemented AI methodologies in oncology. Supervised learning algorithms utilize labeled datasets to predict clinical outcomes such as cancer recurrence, survival probability, treatment response, and metastatic risk. Unsupervised learning methods identify previously unrecognized biological subgroups, molecular signatures, and patient phenotypes by analyzing complex datasets without predefined labels. Reinforcement learning is increasingly investigated for adaptive treatment optimization and personalized radiation therapy planning [18].

Deep learning has become indispensable in medical image analysis because of its ability to automatically learn intricate imaging features. Convolutional neural networks accurately identify tumors on mammography, computed tomography, magnetic resonance imaging, positron emission tomography, ultrasound, and histopathological slides. These models improve lesion detection, anatomical segmentation, image enhancement, and disease classification while reducing interobserver variability among radiologists and pathologists [19].

Natural language processing enables computers to understand and analyze unstructured clinical information contained within electronic health records, pathology reports, radiology reports, discharge summaries, physician notes, and biomedical literature. NLP facilitates automated documentation, information extraction, adverse event surveillance, and clinical decision support, substantially improving workflow efficiency [20].

Computer vision technologies allow AI systems to interpret complex visual information from pathology slides, dermoscopic images, endoscopic examinations, retinal imaging, surgical videos, and radiological scans. Advanced image recognition algorithms support automated cancer screening, tumor localization, grading, and quantitative assessment of treatment response [21].

Generative artificial intelligence represents one of the fastest-growing areas within oncology. Beyond generating clinical documentation, these models assist in hypothesis generation, synthetic medical image creation, drug discovery, educational content development, molecular simulation, and patient counseling. Although considerable validation remains necessary before widespread clinical implementation, generative AI offers tremendous potential for accelerating biomedical innovation [22].

Multimodal AI further enhances cancer care by simultaneously integrating imaging findings, genomic alterations, pathology results, laboratory investigations, clinical history, and longitudinal patient records into unified predictive models. This comprehensive analytical framework supports more accurate diagnosis, individualized treatment planning, and precision oncology, representing one of the most promising frontiers in modern cancer medicine [23].

4. Artificial Intelligence in Cancer Screening and Early Detection

Early diagnosis remains one of the most effective strategies for reducing cancer-related mortality. Detecting malignancies at an early stage substantially improves treatment success, reduces healthcare costs, and enhances long-term survival [24]. However, conventional screening programs are frequently limited by human variability, workforce shortages, false-positive findings, and delayed interpretation of diagnostic tests.

Artificial intelligence has significantly improved cancer screening by enabling rapid and highly accurate analysis of large imaging datasets. Deep learning algorithms trained on millions of medical images can identify subtle abnormalities that may be overlooked during routine clinical interpretation. AI-assisted mammography has demonstrated improved sensitivity for detecting early breast cancer, particularly among women with dense breast tissue where conventional imaging interpretation is often challenging [25].

Similarly, AI systems have enhanced low-dose computed tomography (LDCT) screening for lung cancer by accurately detecting pulmonary nodules, estimating malignancy risk, and reducing unnecessary invasive procedures. Automated image analysis can prioritize suspicious lesions for radiologist review, thereby improving workflow efficiency while maintaining diagnostic accuracy [26].

Colorectal cancer screening has also benefited from AI-assisted colonoscopy. Real-time computer-aided detection systems identify small adenomas and flat lesions that might otherwise be missed during endoscopic examination. Increased adenoma detection rates have been associated with reduced colorectal cancer incidence and mortality [27].

Artificial intelligence has further improved cervical cancer screening through automated interpretation of cytology slides and visual inspection methods. AI-supported screening programs are particularly valuable in low-resource settings where access to experienced cytopathologists remains limited [28].

In pediatric oncology, early diagnosis presents unique challenges because childhood cancers are relatively rare and frequently present with nonspecific clinical symptoms. AI-based predictive models integrating laboratory values, imaging findings, genetic information, and clinical records may facilitate earlier recognition of leukemia, brain tumors, neuroblastoma, and other pediatric malignancies, potentially reducing diagnostic delays and improving outcomes [29].

The integration of wearable devices and remote patient monitoring systems may further expand AI-supported screening by continuously analyzing physiological parameters that could indicate early disease progression or recurrence [30].

5. Artificial Intelligence in Diagnostic Imaging and Digital Pathology

Medical imaging represents one of the most mature applications of artificial intelligence in oncology. Radiological examinations—including computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), mammography, ultrasound, and hybrid imaging techniques—generate enormous quantities of data that require expert interpretation. AI substantially enhances diagnostic accuracy while reducing reporting time and interobserver variability [31].

Deep convolutional neural networks have demonstrated outstanding performance in detecting primary tumors, metastatic lesions, lymph node involvement, and treatment-related complications. Automated segmentation algorithms accurately delineate tumor boundaries, enabling improved radiation treatment planning and longitudinal monitoring of disease progression [32].

Radiomics further extends imaging capabilities by extracting hundreds of quantitative imaging biomarkers associated with tumor heterogeneity, vascularity, metabolism, and treatment response. Machine learning algorithms analyze these high-dimensional imaging features to predict molecular characteristics, prognosis, and therapeutic outcomes without requiring invasive tissue sampling [33].

Radiogenomics combines imaging phenotypes with genomic information to establish relationships between radiological characteristics and underlying molecular alterations. AI-powered radiogenomic models can predict mutations such as EGFR, KRAS, IDH, and ALK directly from imaging data, facilitating non-invasive precision medicine [34].

Digital pathology has similarly undergone a major transformation with the adoption of whole-slide imaging and deep learning technologies. AI systems analyze high-resolution histopathological slides to classify tumors, determine histological grade, quantify mitotic activity, identify lymphovascular invasion, and detect microscopic metastases with remarkable precision [35].

Advanced algorithms can also evaluate tumor-infiltrating lymphocytes, stromal architecture, necrosis, angiogenesis, and spatial cellular interactions that influence prognosis and immunotherapy response. Automated pathology workflows improve diagnostic consistency while reducing workload for pathologists [36].

In pediatric pathology, AI assists in diagnosing rare embryonal tumors and distinguishing benign developmental abnormalities from malignant lesions. Because childhood cancers often exhibit distinct histopathological characteristics, AI may improve diagnostic confidence while supporting specialized pediatric pathology services [37].

6. Artificial Intelligence in Precision Oncology and Personalized Treatment

Precision oncology seeks to tailor treatment according to each patient’s unique molecular profile, clinical characteristics, and predicted therapeutic response. Artificial intelligence has become a cornerstone of this approach by integrating diverse biological and clinical datasets into personalized treatment recommendations [38].

Machine learning algorithms analyze genomic sequencing, transcriptomics, proteomics, metabolomics, epigenetics, pathology, imaging, and clinical history to identify actionable molecular targets. AI-assisted genomic interpretation enables clinicians to prioritize targeted therapies based on individual tumor biology rather than traditional histological classification alone [39].

Clinical decision support systems increasingly incorporate AI to recommend evidence-based treatment options according to current clinical guidelines, molecular biomarkers, previous treatment history, comorbidities, and patient preferences. These systems assist multidisciplinary tumor boards by rapidly synthesizing large volumes of clinical evidence [40].

Artificial intelligence also contributes significantly to pharmacogenomics by predicting patient-specific drug metabolism, therapeutic efficacy, toxicity risk, and potential drug-drug interactions. Such predictions facilitate individualized dosing strategies while minimizing adverse events and improving treatment adherence [41].

In radiation oncology, AI automates target contouring, treatment planning, dose optimization, and adaptive radiotherapy. Automated planning systems reduce planning time while improving treatment precision and minimizing radiation exposure to surrounding healthy tissues [42].

Robotic-assisted oncological surgery has similarly benefited from AI technologies. Intelligent surgical platforms support intraoperative navigation, anatomical recognition, tissue segmentation, and real-time decision support, contributing to improved surgical precision and patient safety [43].

For pediatric oncology patients, personalized treatment planning is particularly important because childhood cancer survivors often experience long-term treatment-related complications affecting growth, neurodevelopment, fertility, and cardiovascular health. AI-driven risk prediction models help clinicians balance treatment intensity against potential late toxicities, thereby optimizing both survival and quality of life [44].

7. Artificial Intelligence in Drug Discovery and Clinical Research

The traditional development of anticancer drugs is an expensive, time-consuming process requiring years of laboratory investigation and clinical validation. Artificial intelligence is increasingly transforming oncology drug discovery by accelerating target identification, compound screening, molecular design, and clinical trial optimization [45].

Machine learning algorithms analyze extensive genomic, proteomic, transcriptomic, and pharmacological datasets to identify novel therapeutic targets involved in cancer initiation, progression, metastasis, and drug resistance. These computational approaches enable researchers to prioritize promising biological pathways for experimental validation [46].

Generative AI models facilitate de novo drug design by predicting molecular structures with favorable pharmacological properties. Virtual screening algorithms rapidly evaluate millions of chemical compounds, substantially reducing both development time and research costs compared with conventional laboratory screening methods [47].

Artificial intelligence also supports drug repurposing by identifying existing medications that may demonstrate anticancer activity through previously unrecognized biological mechanisms. Repurposing approved drugs offers opportunities to accelerate clinical translation while reducing development risks and regulatory barriers [48].

Clinical trials increasingly utilize AI for patient recruitment, eligibility assessment, endpoint prediction, and real-time safety monitoring. Natural language processing automatically reviews electronic health records to identify eligible participants, thereby improving recruitment efficiency and reducing enrollment delays [49].

Predictive analytics further optimize trial design by identifying patient populations most likely to benefit from investigational therapies. Adaptive clinical trial methodologies supported by AI enable protocol modifications based on emerging evidence while maintaining scientific rigor [50].

In pediatric oncology, where patient populations are relatively small, AI can improve trial efficiency by identifying suitable candidates across multiple institutions, facilitating international collaboration, and supporting rare disease research through federated data analysis [51].

Part 3 (Approx. 1,150–1,250 words)

8. Artificial Intelligence in Pediatric Oncology

Pediatric oncology presents unique clinical, biological, and therapeutic challenges that distinguish it from adult cancer care. Childhood malignancies are relatively rare and often arise from developmental and genetic abnormalities rather than cumulative environmental exposures. The most common pediatric cancers include acute lymphoblastic leukemia, acute myeloid leukemia, neuroblastoma, Wilms tumor, retinoblastoma, osteosarcoma, Ewing sarcoma, medulloblastoma, and various lymphomas [52].

Artificial intelligence is increasingly being integrated into pediatric oncology to improve diagnostic accuracy, personalize treatment, reduce long-term toxicities, and enhance survivorship care. AI-powered diagnostic systems can analyze pediatric imaging studies, digital pathology slides, genomic sequencing data, and laboratory findings to support earlier diagnosis of childhood cancers that often present with nonspecific symptoms [53].

Machine learning algorithms have demonstrated promising results in predicting treatment response, relapse risk, minimal residual disease, and overall survival in children with leukemia. By integrating genomic biomarkers with clinical parameters, AI models enable clinicians to stratify patients according to disease risk and tailor treatment intensity appropriately. This approach may improve cure rates while minimizing unnecessary exposure to chemotherapy and radiation [54].

Artificial intelligence also contributes to pediatric radiation oncology by optimizing treatment planning and reducing radiation exposure to healthy developing tissues. Advanced image-guided radiation therapy supported by AI improves tumor localization and minimizes long-term complications affecting cognitive development, endocrine function, fertility, and growth [55].

Long-term survivorship has become a major focus in pediatric oncology because increasing numbers of childhood cancer patients now survive into adulthood. AI-driven predictive models assist clinicians in identifying survivors at risk of cardiotoxicity, endocrine disorders, neurocognitive impairment, secondary malignancies, and psychosocial challenges. Continuous monitoring through wearable devices and digital health platforms may further improve long-term follow-up and quality of life [56].

Despite these advances, pediatric AI research remains constrained by relatively small datasets, disease rarity, limited multicenter data sharing, and ethical considerations surrounding the use of children's health information. Future international collaborations and privacy-preserving AI techniques are expected to address many of these challenges while expanding precision medicine for childhood cancers [57].

9. Challenges, Ethical Considerations, and Regulatory Perspectives

Although artificial intelligence has demonstrated remarkable potential across the oncology continuum, widespread clinical implementation continues to face several scientific, ethical, technical, and regulatory challenges [58].

One of the most significant limitations involves data quality and diversity. AI systems require large, accurately annotated datasets representing diverse patient populations. Many currently available datasets originate from single institutions or specific geographic regions, increasing the risk of algorithmic bias and limiting model generalizability across different ethnic, socioeconomic, and healthcare settings [59].

Interpretability remains another major concern. Many deep learning models function as "black-box" systems, producing highly accurate predictions without clearly explaining how decisions are reached. In oncology, where treatment decisions carry profound consequences, clinicians require transparent and explainable AI systems capable of providing interpretable evidence supporting diagnostic or therapeutic recommendations [60].

Patient privacy and cybersecurity also represent critical issues. Cancer datasets contain highly sensitive genetic, pathological, imaging, and clinical information. Robust cybersecurity frameworks, data encryption, federated learning, differential privacy, and secure data-sharing protocols are essential for protecting patient confidentiality while enabling collaborative AI development [61].

Regulatory approval presents additional challenges. AI systems intended for clinical use must undergo rigorous validation demonstrating safety, effectiveness, reproducibility, and clinical benefit. Regulatory agencies increasingly require prospective multicenter clinical trials, post-market surveillance, continuous performance monitoring, and periodic algorithm updates to ensure patient safety [62].

Ethical considerations extend beyond technical performance. Questions surrounding informed consent, accountability, transparency, fairness, health equity, and responsibility for AI-assisted clinical decisions remain under active discussion. AI should augment—not replace—clinical judgment, ensuring that physicians retain ultimate responsibility for patient care while leveraging computational insights to improve decision-making [63].

The integration of AI into oncology workflows also requires substantial investments in digital infrastructure, computational resources, workforce education, interoperability standards, and clinician training. Successful implementation depends not only on technological innovation but also on multidisciplinary collaboration among physicians, computer scientists, engineers, policymakers, ethicists, and healthcare administrators [64].

10. Future Perspectives

The future of artificial intelligence in oncology is expected to be driven by increasingly sophisticated multimodal learning systems capable of integrating radiological imaging, digital pathology, genomics, transcriptomics, proteomics, metabolomics, electronic health records, wearable device data, and real-world clinical evidence into unified predictive frameworks [65].

Generative AI is anticipated to accelerate drug discovery, automate clinical documentation, enhance patient education, support multidisciplinary tumor board discussions, and facilitate personalized treatment planning. Large language models may function as intelligent clinical assistants capable of rapidly synthesizing medical literature, clinical guidelines, and patient-specific information to support evidence-based oncology practice [66].

Digital twins represent another promising innovation. These virtual patient models combine molecular, physiological, imaging, and clinical data to simulate tumor progression and predict individualized treatment responses before therapy is initiated. Such computational simulations may enable truly adaptive precision oncology, allowing clinicians to evaluate multiple therapeutic strategies while minimizing patient risk [67].

Artificial intelligence is also expected to enhance cancer prevention through individualized risk prediction based on genetics, lifestyle factors, environmental exposures, and longitudinal health data. Continuous monitoring using wearable sensors and remote digital platforms may facilitate early detection of disease recurrence, treatment toxicity, and symptom deterioration, enabling timely clinical intervention [68].

In pediatric oncology, collaborative international AI networks may substantially improve research involving rare childhood cancers by enabling secure federated analysis across multiple institutions without compromising patient privacy. This collaborative approach has the potential to accelerate biomarker discovery, optimize treatment protocols, and improve survival for children with uncommon malignancies [69].

Continued advances in explainable AI, federated learning, quantum computing, cloud-based healthcare infrastructure, and regulatory science are expected to facilitate responsible adoption of artificial intelligence across routine oncology practice. Future AI systems will likely function as intelligent partners that complement physician expertise while improving efficiency, precision, accessibility, and patient-centered care [70].

11. Discussion

Artificial intelligence has rapidly evolved from an experimental computational tool into a transformative technology influencing virtually every stage of cancer care. Across adult and pediatric oncology, AI has demonstrated substantial value in early detection, diagnostic imaging, digital pathology, molecular profiling, prognostic prediction, precision medicine, treatment planning, drug discovery, and survivorship management [71].

The integration of multimodal biomedical data enables AI systems to uncover complex biological relationships that may remain undetected using conventional analytical methods. Such capabilities support more accurate diagnosis, individualized therapeutic strategies, improved workflow efficiency, and enhanced clinical decision-making. Importantly, AI should be viewed as a complementary technology that augments—not replaces—the knowledge, experience, and clinical judgment of healthcare professionals [72].

Despite these remarkable opportunities, responsible implementation requires careful attention to algorithm transparency, clinical validation, ethical governance, data privacy, regulatory oversight, and equitable healthcare access. Addressing these challenges will require sustained collaboration among clinicians, researchers, engineers, policymakers, and regulatory authorities to ensure that AI benefits all patient populations regardless of geographic location or healthcare resources [73].

Future progress will depend on the development of trustworthy, interpretable, and clinically validated AI systems capable of seamless integration into existing healthcare workflows. As computational methods continue to mature, artificial intelligence is expected to become an indispensable component of comprehensive cancer care across prevention, diagnosis, treatment, and long-term survivorship [74].

12. Conclusion

Artificial intelligence is fundamentally transforming modern cancer care by providing innovative computational tools that improve diagnostic precision, personalize treatment, optimize clinical workflows, and enhance patient outcomes across both adult and pediatric oncology. Applications spanning medical imaging, digital pathology, genomics, radiomics, precision medicine, clinical decision support, robotic surgery, and drug discovery illustrate the extensive impact of AI throughout the oncology continuum [75].

Although important challenges remain—including algorithmic bias, explainability, privacy protection, ethical governance, infrastructure requirements, and regulatory validation—ongoing advances in machine learning, deep learning, multimodal analytics, federated learning, and generative AI continue to accelerate clinical translation. With continued multidisciplinary collaboration and rigorous clinical evaluation, artificial intelligence is poised to become an integral component of future oncology practice, enabling more precise, efficient, equitable, and patient-centered cancer care for both adults and children [76].

References

1. Hanahan D. Hallmarks of cancer: new dimensions. Cancer Discov. 2022;12(1):31–46. Doi:10.1158/2159-8290.CD-21-1059.
2. Rajendran OK. DeepDRA: A Deep Learning Framework for Drug Repurposing and Cancer Drug Response Prediction Using Multi-Omics Data. Scientific Culture. 2026;12(3):68-77. Doi:10.5281/zenodo.12326001.

3. Maradi Hemanth Kumar R. Dynamic Digital Twins in Oncology: Foundation AI Models for Real-Time Predictive and Personalized Cancer Care. Power System Protection and Control. 2025;53(4):549-563. Doi:10.46121/pspc.53.4.38.
4. Rajendran OK. Clinical Translation of Artificial Intelligence in Oncology: Real-World Validation, Workflow Integration, and Precision Medicine Applications. Int J Drug Deliv Technol. 2026;16(49s):956-964. Doi:10.25258/ijddt.16.49s.110.
5. Singhal K, Azizi S, Tu T, et al. Large language models encode clinical knowledge. Nature. 2023;620(7972):172–180. Doi:10.1038/s41586-023-06291-2.
6. Rajendran LKK. Impact of Treatment Modalities on Fertility, Sexual Function, and Psychological Outcomes in Testicular Cancer Survivors: A Comprehensive Review. Int J Drug Deliv Technol. 2026;16(30s):447-453. Doi:10.25258/ijddt.16.30s.43.
7. Xu H, Usuyama N, Bagga J, et al. A whole-slide foundation model for digital pathology from real-world data. Nature. 2024;630(8015):181–188. Doi:10.1038/s41586-024-07441-w.
8. Rajendran OK. Bias, Fairness, and Ethical Challenges in Artificial Intelligence: A Comprehensive Review of Causes, Impacts, and Mitigation Strategies. Scientific Culture. 2026;12(2.1):13001-13010. Doi:10.5281/zenodo.20374091.
9. Kumar RMH. Childhood-Oncology Intelligence for Predicting Cancer Emergence, Optimizing Precision Therapies, and Simulating Lifelong Outcomes in Pediatric Malignancies Using Autonomous Foundation Models. Int J Drug Deliv Technol.2026;16(65s):162-173.DOI:10.25258/ijddt.16.65s.19
10. Moor M, Banerjee O, Abad ZSH, et al. Foundation models for generalist medical artificial intelligence. Nature. 2023;616(7956):259–265. Doi:10.1038/s41586-023-05881-4.
11. Rajendran LKK. Hematological Malignancy Identification via K-means based ROI Extraction. International Journal of Clinical Research in Medical Sciences. 2026;1(2):1-10. Doi:10.67231/kt1w3e73.
12. Kumar RMH. Pan-System Cancer Intelligence: Integrating Blood, Immune, Microbiome, and Tumor Microenvironment Data Using Foundation Models. Power System Protection and Control. 2023;51(4):92-100. Doi:10.46121/pspc.51.4.8.
13. Rajendran LKK. Identifying Determinants of Outcome in Post-Radiotherapy Cervical Carcinoma Requiring Adjuvant Surgery. International Journal of Clinical Research in Medical Sciences. 2026;1(2):1-10. Doi:10.67231/3acej759.
14. Maradi Hemanth Kumar R. AI-Driven Liquid Biopsy Systems for Early Cancer Detection and Personalized Oncology. Power System Protection and Control. 2023;51(4):66-83. Doi:10.46121/pspc.51.4.7.
15. Rajendran LKK. Machine Learning–Driven Symptom-Based Cancer Risk Stratification:A Systematic Review of Clinical Prediction Models and Methodological Rigor. Int J Drug Deliv Technol. 2026;16(40s):242-253.Doi:10.25258/ijddt.16.40s.26.
16. Kumar RMH. Maternal–Fetal Oncology Intelligence: Self-Evolving Foundation Models and Digital Twin Ecosystems for Precision Cancer Prediction, Treatment Optimization, and Maternal–Fetal Outcome Forecasting. Int J Drug Deliv Technol. 2026;16(65s):174-185. DOI: 10.25258/ijddt.16.65s.20
17. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44–56. Doi:10.1038/s41591-018-0300-7.
18. Kumar RMH. Precision Oncofertility: Integrating Genomics, Reproductive Biomarkers, Treatment Toxicity Profiles, and Foundation Models for Fertility Preservation in Men and Women with Cancer. Int J Drug Deliv Technol. 2026;16(65s):186-200. DOI: 10.25258/ijddt.16.65s.21
19. Rajendran LKK. Interpretable Machine Learning for Early Mortality Prediction in Acute Myeloid Leukemia: A Decision Tree–Based Retrospective Cohort Study. Int J Drug Deliv Technol. 2026;16(40s):231-241.Doi:10.25258/ijddt.16.40s.25.
20. Kumar RMH. Self-Evolving Digital Twin Ecosystems for Early Detection and Precision Management of Breast, Lung, Colorectal, and Ovarian Cancers. Int J Drug Deliv Technol. 2026;16(65s):201-212. DOI: 10.25258/ijddt.16.65s.22
21. Esteva A, Robicquet A, Ramsundar B, et al. A guide to deep learning in healthcare. Nat Med. 2019;25(1):24–29. Doi:10.1038/s41591-018-0316-z.
22. Rajendran OK. Generative AI for Synthetic Medical Image Generation in Oncology: Addressing Data Scarcity in AI-Driven Cancer Diagnosis. Int J Drug Deliv Technol. 2026;16(49s):1010-1016. Doi:10.25258/ijddt.16.49s.117.
23. Rajendran LKK. Integrated Prognostic Modeling of Tumor Stage, Multimodal Therapy, and Functional Status in Lung Cancer Survival: A Real-World Cohort Study. Scientific Culture. 2026;12(5):567-576. Doi: 10.5281/zenodo.20738481.
24. Bommasani R, Hudson DA, Adeli E, et al. On the opportunities and risks of foundation models. arXiv. 2021. Doi:10.48550/arXiv.2108.07258.

25. Rajendran LKK. Integrative Pharmacogenomic Analysis of Drug Response Heterogeneity Across Cancer Cell Lines: Insights From Large-Scale GDSC Data. Scientific Culture. 2026;12(4):7537-7546. Doi:10.5281/zenodo.20767386.
26. Acs B, Rantalainen M, Hartman J. Artificial intelligence as the next step towards precision pathology. J Intern Med. 2020;288(1):62–81. Doi:10.1111/joim.13030.
27. Rajendran OK. Tumor Microenvironment Interaction-Guided Graph Neural Networks for Survival Prediction from Whole-Slide Pathology Images. Int J Drug Deliv Technol. 2026;16(49s):481-488. Doi:10.25258/ijddt.16.49s.50.
28. Rajendran LKK. Evaluating the Association of Cancer-Related Risk Factors With Multisystem Health: Insights Into Fertility, Cardiovascular, and Renal Indicators. Scientific Culture. 2026;12(4):7520-7527.Doi:10.5281/zenodo.20767374.
29. Rajendran LKK. From Prediction to Precision: An Externally Validated Deep Learning–Based Survival and Adjuvant Therapy Recommendation System for Resected Stage III Non–Small Cell Lung Cancer. Int J Drug Deliv Technol. 2026;16(30s):430-438.doi:10.25258/ijddt.16.30s.41.
30. Kumar RMH. Multimodal foundation AI models in precision oncology: Integrating radiomics, pathomics, multi-omics, and clinical intelligence systems. Power System Protection and Control. 2024;52(4):189-204. Doi:10.46121/pspc.52.4.16.
31. Rajendran LKK. From Prediction to Practice: A Machine Learning–Based Clinical Decision Support Tool for Bevacizumab Risk Stratification in Oncology. Int J Drug Deliv Technol. 2026;16(30s):414-429. Doi:10.25258/ijddt.16.30s.40.
32. Rajendran OK. Self-supervised multimodal Learning for early cancer detection across Imaging and genomics. Power System Protection and Control. 2024;52(4):167-178. Doi:10.46121/pspc.52.4.14.
33. Rajendran OK. Explainable AI-Driven Clinical. Decision Support Systems in Precision Oncology:Interpretable Models for Multimodal Cancer Care. Scientific Culture. 2026;12(2.1):12359-12369. Doi:10.5281/zenodo.20328194.
34. Rajendran LKK. Intelligent Omics-Driven Patient Stratification for Cancer Therapeutic Re-profiling. International Journal of Clinical Research in Medical Sciences. 2026;1(1):1-11. Doi:10.67231/gvshck05.
35. Rajendran LKK. Cancer nanomedicine: utilizing the enhanced permeability and retention (EPR) effect to deliver high payloads of chemotherapeutic agents directly to tumor sites. Power System Protection and Control. 2024;52(2):123-129. Doi:10.46121/pspc.52.2.12.
36. Kather JN, Calderaro J. Development of AI in digital pathology. Nat Rev Clin Oncol. 2020;17(10):591–595. Doi:10.1038/s41571-020-00431-0.
37. Rajendran OK. AI-based radiogenomic Models for predicting immunotherapy response In solid tumors. Power System Protection and Control. 2023;51(4):24-37. Doi:10.46121/pspc.51.4.4.
38. Rajendran LKK. Enhanced Predictive Analytics for Early Malignancy Discovery in Routine Screening. International Journal of Clinical Research in Medical Sciences. 2026;1(1):1-10. Doi:10.67231/grams870.
39. Rajendran OK. Machine Learning-Based Prediction of Chemotherapy Toxicity in Colorectal Cancer: A Personalized Risk Stratification Approach. Scientific Culture. 2026;12(5.1):942-952. Doi:10.5281/zenodo.20767359.
40. Rajendran OK. Federated radiology AI Models for multi-institutional cancer diagnosis Without data sharing. Power System Protection And Control. 2023;51(4):38-54. Doi:10.46121/pspc.51.4.5.
41. Kumar RMH. AI-augmented immuno-oncology: Foundation models for predicting immune response, resistance, and precision immunotherapy. Power System Protection and Control. 2024;52(2):193-208. Doi:10.46121/pspc.52.2.18.
42. Rajendran OK. Deep Reinforcement Learning in Oncology: Advances in Cancer Imaging, Radiotherapy, and Personalized Treatment. Scientific Culture. 2026;12(5):597-606. Doi:10.5281/zenodo.20767337.
43. Rajendran OK. DEEP LEARNING FOR CROSS-MODALITY MAPPING BETWEEN HISTOPATHOLOGY AND RADIOLOGICAL IMAGING. Power System Protection and Control. 2025;53(3):313-328. Doi:10.46121/pspc.53.3.21.
44. Lu MY, Chen TY, Williamson DFK, et al. AI-based pathology predicts origins for cancers of unknown primary. Nature. 2021;594(7861):106–110. Doi:10.1038/s41586-021-03512-4.
45. Rajendran OK. Artificial Intelligence in Oncologic Imaging: Deep Learning, Radiomics, and Clinical Integration for Precision Cancer Diagnosis. Int J Drug Deliv Technol. 2026;16(50s):871-880. Doi:10.25258/ijddt.16.50s.92.
46. Bilal M, Raza SEA, Azam A, et al. Development and validation of a weakly supervised deep learning framework to predict the risk of colorectal cancer recurrence from histology images. Lancet Oncol. 2021;22(11):153–163. Doi:10.1016/S1470-2045(21)00430-5.

47. Rajendran OK. DIGITAL TWIN FRAMEWORKS FOR PERSONALIZED CANCER PROGRESSION MODELING USING LONGITUDINAL DATA. Power System Protection and Control. 2025;53(4):486-501. Doi:10.46121/pspc.53.4.33.
48. Rajendran LKK. Genomic profiling: utilizing Multi-omics data to identify potential Therapeutic targets and resistance markers. Power System Protection and Control. 2024;52(4):159-166. Doi:10.46121/pspc.52.4.13.
49. Rajendran OK. Artificial Intelligence–Driven Multimodal Imaging for Cancer During Pregnancy: Advances in Maternal–Fetal Diagnostics and Precision Oncology. Int J Drug Deliv Technol. 2026;16(50s):862-870. Doi:10.25258/ijddt.16.50s.91.
50. Rajendran LKK. Immunotherapy and cell Therapy: developing CAR-T cell therapies and Other immune-based treatments for cancer and Autoimmune diseases. Power System Protection and Control. 2023;51(2):64-77. Doi:10.46121/pspc.51.2.7.
51. Rajendran OK. FOUNDATION MODEL–DRIVEN PRECISION ONCOLOGY: INTEGRATING MULTI-OMICS, RADIOLOGY, AND CLINICAL DATA FOR PREDICTIVE CANCER CARE. Power System Protection and Control. 2024;52(2):154-163. Doi:10.46121/pspc.52.2.14.
52. Rajendran LKK. Theranostics: integrating Diagnostic imaging agents and therapeutic Drugs into a single multifunctional nano-Platform for real-time monitoring of treatment. Power System Protection and Control.2025;53(2):376-386. Doi:10.46121/pspc.53.2.31.
53. Rajendran LKK. Mechanisms driving Immunotherapy resistance in colorectal cancer Liver metastases. Power System Protection and Control. 2024;52(1):29-37. Doi:10.46121/pspc.52.1.5.
54. Ching T, Himmelstein DS, Beaulieu-Jones BK, et al. Opportunities and obstacles for deep learning in biology and medicine. J R Soc Interface. 2018;15(141):20170387. Doi:10.1098/rsif.2017.0387.
55. Litjens G, Kooi T, Bejnordi BE, et al. A survey on deep learning in medical image analysis. Med Image Anal. 2017;42:60–88. Doi:10.1016/j.media.2017.07.005.
56. Hemanth Kumar RM. Integrated Transcriptomic and 3 Learning Framework Identifies a Blood-Based Biomarker Signature for Anthracycline-Induced Cardiotoxicity in Juvenile Cancer Survivors. Int J Drug Deliv Technol. 2026;16(40s):219-230. Doi:10.25258/ijddt.16.40s.24.
57. Mobadersany P, Yousefi S, Amgad M, et al. Predicting cancer outcomes from histology and genomics using convolutional networks. Proc Natl Acad Sci USA. 2018;115(13):E2970–E2979. Doi:10.1073/pnas.1717139115.
58. Lambin P, Leijenaar RTH, Deist TM, et al. Radiomics: the bridge between medical imaging and personalized medicine. Nat Rev Clin Oncol. 2017;14(12):749–762. Doi:10.1038/nrclinonc.2017.141.
59. Azizi S, Mustafa B, Ryan F, et al. Big self-supervised models advance medical image classification. Nature. 2021;594(7864):104–110. Doi:10.1038/s41586-021-03476-6.
60. Dosovitskiy A, Beyer L, Kolesnikov A, et al. An image is worth 16×16 words: transformers for image recognition at scale. arXiv. 2020. Doi:10.48550/arXiv.2010.11929.