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ARTIFICIAL INTELLIGENCE IN ONCOLOGY: FROM MULTIMODAL RISK PREDICTION TO EQUITABLE CANCER PREVENTION

Oncology

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ABSTRACT

Artificial intelligence (AI) is rapidly transforming oncology, shifting the field from a predominantly treatment-centric paradigm toward one centered on early detection, risk prediction, and prevention. Advances in machine learning (ML), deep learning (DL), and multimodal data integration now enable the synthesis of imaging, molecular biomarkers, clinical records, lifestyle patterns, and environmental exposures—revealing cancer risk trajectories years before clinical disease manifests. This narrative review synthesizes evidence from 2019–2026 on AI applications across early detection, multimodal risk prediction, and personalized oncology, with a particular emphasis on pre-clinical prevention and equitable global deployment. Unlike prior reviews focused primarily on diagnostic AI, this article highlights continuous risk intelligence—integrating physiological, environmental, and behavioral data—as a foundation for proactive cancer prevention. We critically examine performance gains (20–30% projected reductions in late-stage diagnoses in pilot and modeling studies), ethical challenges including bias and privacy, and the role of AI in low-resource settings. We propose a conceptual framework for AI-driven cancer prevention that aligns technological innovation with public health priorities, equity, and clinical integration. When responsibly deployed, AI has the potential to avert a substantial proportion of preventable cancers and redefine oncology as a discipline of foresight rather than reaction.

KEYWORDS

Artificial intelligence, cancer prevention, early detection, risk prediction, multimodal data, health equity

INTRODUCTION

Cancer remains one of the defining public health challenges of our time, with over 20 million new cases and nearly 10 million deaths projected annually by 2026, according to updated GLOBOCAN estimates (1). Despite remarkable advances in surgery, chemotherapy, immunotherapy, and precision oncology, global incidence continues to rise, driven by cumulative environmental exposures, lifestyle patterns, metabolic stress, and social determinants that quietly shape biological risk over decades (2). Artificial intelligence (AI) is catalyzing a paradigm shift (3). By processing vast, heterogeneous datasets-beyond human cognitive limits-AI enables not only enhanced diagnosis and treatment but also predictive risk assessment long before symptoms emerge (4).

Machine learning (ML), deep learning (DL), and multimodal architectures integrate imaging, genomics, circulating biomarkers, electronic health records (EHRs), lifestyle metrics, and environmental data into cohesive models (5,6). While prior reviews have focused on AI in diagnostic imaging or precision therapeutics (7,8), fewer address its role in continuous cancer risk prediction and primary prevention, particularly incorporating environmental and lifestyle determinants or in low-resource settings (9). This review fills that gap, synthesizing evidence from 2019–2026 on AI-driven early detection, multimodal risk integration, and equitable deployment (10). We emphasize AI's potential to transform oncology from reactive care to proactive prevention, proposing a conceptual framework for global implementation (11).

AI IN EARLY CANCER DETECTION

Early detection is pivotal, as stage I–II cancers boast 5-year survival rates >90% for many types, versus <20% for stage IV (12). AI augments detection by analyzing complex data patterns.

Imaging-Based Detection

DL algorithms, such as CNNs, achieve dermatologist-level accuracy in skin cancer classification (95% sensitivity for melanoma) (13). For lung cancer, end-to-end DL on low-dose CT detects nodules with 94% sensitivity, outperforming radiologists in prospective studies (14). In gastroenterology, AI-assisted endoscopy identifies polyps and esophageal neoplasms with 90% accuracy, reducing miss rates by 20% (15). Recent multimodal enhancements incorporate environmental factors (e.g., pollution exposure) to refine risk stratification (16).

Biomarker And Genomic Integration

AI analyzes cfDNA and microRNA signatures for MCED, with sensitivities of 40–70% for stage I diseases (17). Random forest models predict hepatocellular carcinoma prognosis from genomic data, integrating environmental cofactors like aflatoxin (18).

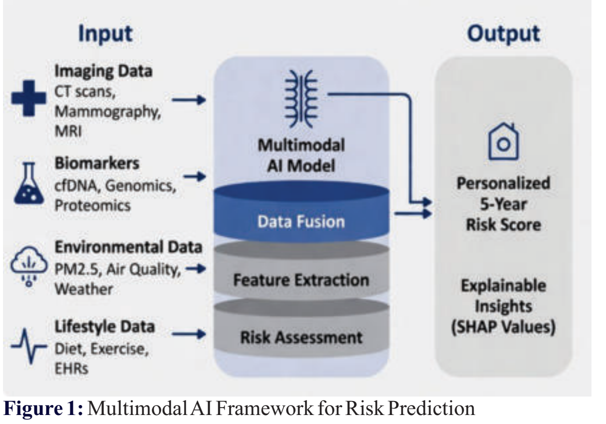

Figure 1: Multimodal AI Framework for Risk Prediction

MULTIMODAL RISK PREDICTION AND INTEGRATION

AI's strength lies in modeling nonlinear, cumulative risks.

Risk Prediction Models

DL using mammography predicts breast cancer risk more accurately than density scores (AUC 0.75 vs. 0.62) (19). For lung nodules, AI assesses malignancy with 85% accuracy, incorporating PM2.5 exposure (20). In LMICs, ML from limited EHRs predicts outcomes with 80% accuracy (21).

Multimodal Approaches

Multimodal AI combines imaging, genomics, and clinical data for superior performance (22). Generative AI reconstructs images from sparse inputs (23). Multi-omics integration predicts immunotherapy responses (24). Environmental factors improve accuracy by 15–20% in urban cohorts (25).

Table 1: Summary Of AI Applications In Early Detection

Modality	Key AI Technique	Accuracy/ Sensitivity (2025–2026)	Challenges
Imaging (e.g., CT, Mammography)	CNNs/DL	90–95%	Data bias, interpretability
Biomarkers (cfDNA, microRNA)	Random Forest/ML	40–70% for stage I	False positives in low-prevalence
Multimodal (Env + Lifestyle)	Transformers	AUC 0.82–0.89	Integration complexity, privacy

PERSONALIZED CANCER TREATMENT

AI tailors therapies by mapping mutations and optimizing plans.

4.1 Mutation Mapping and Drug Design DL predicts mutations from histopathology (e.g., EGFR in lung cancer) with 90% accuracy (26). AI accelerates drug discovery by screening compounds, reducing timelines (27). AI-optimized dosing improves outcomes 25% in trials (28).

4.2 Applications in Low-Resource Settings Mobile AI apps enable remote diagnosis with 85% accuracy for skin cancers (29). Frugal ML predicts risks in disadvantaged areas (30).

5. CHALLENGES: BIAS, ETHICS, AND TRUST

Bias in data leads to 10–20% underperformance in non-White populations (31). Privacy concerns from monitoring require federated learning (32). Mitigation: Diverse datasets, adversarial training reduce disparities 15–25% (33). In LMICs, Western bias needs local retraining (34).

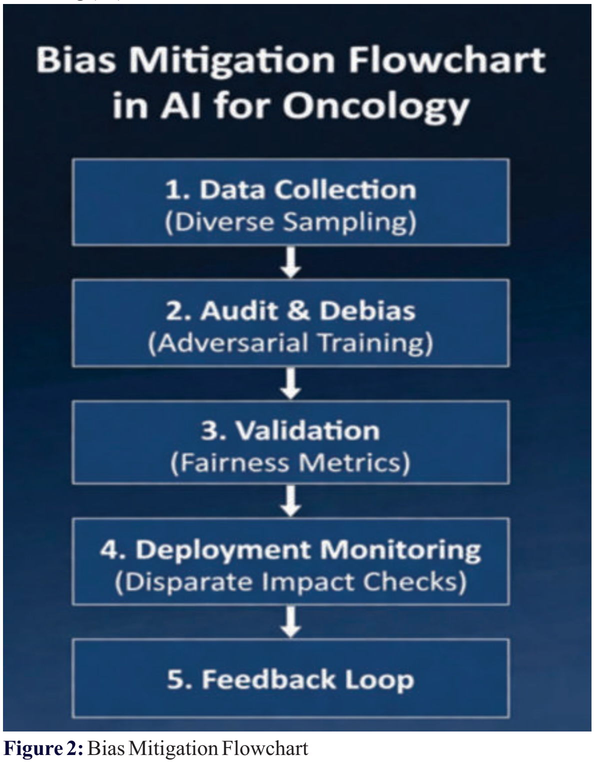

Figure 2: Bias Mitigation Flowchart

6. DISCUSSION:

Toward Predictive Cancer Prevention AI could reduce mortality 20–30% through prediction and personalization (35). Equitable deployment is critical—global collaborations address LMIC needs (36). Future: Quantum AI for synergies; ethical frameworks build trust (37).

7.CONCLUSION

AI heralds a preventive oncology era, integrating multimodal data to avert preventable cancers. To maximize impact, we call for: (1) Policy mandating diverse datasets in AI training (e.g., international standards by 2030); (2) Funding for LMIC deployments ($10B global investment by 2035); (3) Cross-sector collaborations between tech, health, and env agencies; (4) Regulatory frameworks ensuring XAI and privacy. These actions will realize AI's promise, reducing disparities and saving lives worldwide.

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