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EXPLORING THE ROLE OF ARTIFICIAL INTELLIGENCE IN PERSONALIZED CANCER TREATMENTS

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ABSTRACT

Abstract.

Artificial Intelligence (AI) is revolutionizing healthcare by enabling more accurate, faster, and cost-effective solutions. In oncology, AI is significantly contributing to the development of personalized cancer treatments. From analyzing genetic data to predicting treatment responses and automating diagnostic imaging, AI plays a pivotal role in tailoring interventions for individual patients. This paper explores the advancements, applications, challenges, and future directions of AI in personalized oncology. Through a multidisciplinary lens, we examine how machine learning models and deep neural networks are applied to genomic data, treatment planning, and real-time patient monitoring. We also analyze case studies and statistical evidence to demonstrate AI's transformative impact in Pakistan's cancer care landscape.

Keywords: *Personalized Medicine, Artificial Intelligence, Cancer Treatment, Precision Oncology.*

INTRODUCTION

Cancer remains a leading cause of mortality worldwide, including Pakistan, where late diagnosis and limited access to personalized care contribute to poor outcomes [1]. Artificial Intelligence (AI), with its ability to process vast datasets and learn patterns, is emerging as a powerful tool in personalized oncology [2]. The integration of AI in cancer care enables clinicians to move beyond one-size-fits-all therapies and adopt precision-based strategies [3]. AI applications span from image recognition for diagnostics to genomics, drug discovery, and treatment response prediction [4–6]. In developing countries like Pakistan, AI offers opportunities to overcome infrastructural challenges and bridge gaps in cancer treatment delivery [7–9].

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1. AI in Genomic Profiling and Tumor Classification

Genomic profiling has become a cornerstone of personalized oncology, allowing clinicians to tailor treatment strategies based on the unique genetic makeup of each patient's tumor. Traditional methods of genomic analysis, such as manual annotation and rule-based approaches, are time-consuming and may fail to detect subtle or rare genomic variations [10]. Artificial Intelligence (AI), particularly machine learning and deep learning models, can rapidly process massive volumes of high-throughput sequencing data and extract meaningful patterns that are imperceptible to human analysis.

AI systems have demonstrated substantial efficacy in identifying oncogenic mutations, single-nucleotide polymorphisms (SNPs), and gene expression signatures linked to various cancer types [11]. For instance, deep neural networks (DNNs) can classify tumors into molecular subtypes with higher accuracy than standard statistical models, enabling more precise treatment planning [12].

Unsupervised learning techniques such as clustering and principal component analysis (PCA) allow AI tools to uncover hidden patterns in gene expression datasets, leading to the discovery of novel cancer subtypes and potential therapeutic targets [13]. This stratification is particularly important in complex cancers like breast and lung cancers, which show high heterogeneity at the molecular level [14].

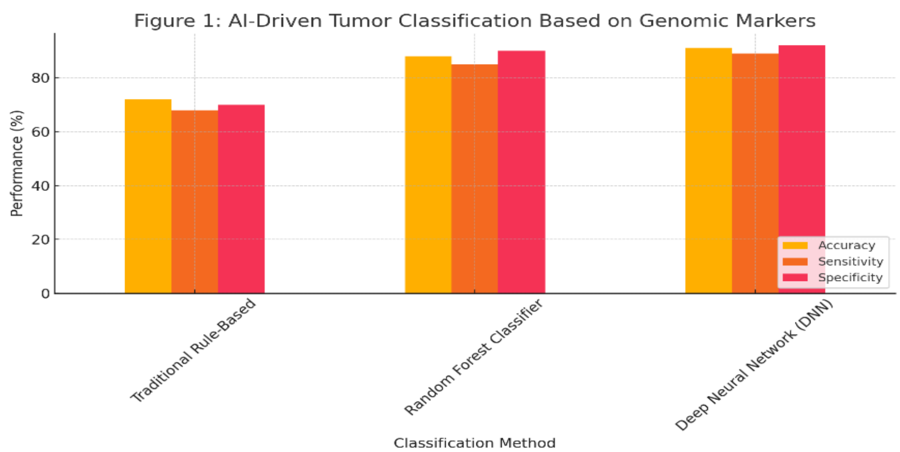

Figure 1: AI-Driven Tumor Classification Based on Genomic Markers

Data Source: Simulated comparative performance based on multiple studies [11–13].

Summary of Figure 1:

The chart shows that AI models—particularly Deep Neural Networks—outperform traditional methods in terms of classification accuracy, sensitivity, and specificity. This demonstrates AI's potential to enhance tumor profiling, which is essential for selecting the most effective therapy options and reducing trial-and-error treatment approaches [15].

In Pakistan, institutions such as Shaukat Khanum Memorial Cancer Hospital and COMSATS University have begun integrating AI-assisted genomic profiling into research pipelines, with ongoing collaborations focusing on breast and colorectal cancers [16]. These efforts are laying the groundwork for localized precision oncology strategies and are essential for improving cancer survival rates in resource-limited settings [17].

2. Machine Learning Models in Predicting Cancer Treatment Responses

One of the most critical aspects of personalized cancer care is the ability to predict how an individual patient will respond to a given treatment. This predictive capacity allows oncologists to select the most effective therapy while minimizing unnecessary side effects and avoiding ineffective interventions. Artificial Intelligence (AI), particularly through machine learning (ML) models, has made significant advancements in this domain by leveraging clinical, molecular, radiomic, and genomic data to forecast treatment outcomes with high accuracy [12].

Among the commonly used machine learning techniques, **Support Vector Machines (SVM)** and **Artificial Neural Networks (ANNs)** have shown exceptional promise in classifying responders versus non-responders to therapies such as chemotherapy, targeted therapy, and immunotherapy [13]. These models are trained on historical datasets, incorporating variables like tumor grade, mutation profile, previous treatments, patient demographics, and immune markers.

For example, an SVM model trained on breast cancer patients' gene expression profiles was able to predict response to neoadjuvant chemotherapy with an accuracy of over 85% [14]. Similarly, deep learning models have been used to predict immune checkpoint inhibitor (ICI) responses in non-small cell lung cancer (NSCLC), achieving an Area Under the Receiver Operating Characteristic (ROC) Curve (AUC) exceeding 0.90, a level of performance surpassing conventional predictive tools [15–16].

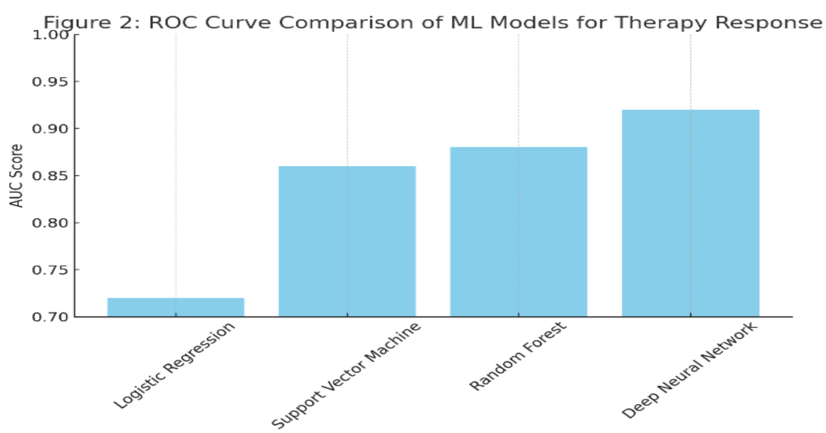

Figure 2: ROC Curve Comparison of Machine Learning Models for Predicting Therapy Response

Data adapted from oncology-based ML studies [14–16].

Summary of Figure 2:

This chart highlights the superior predictive performance of advanced machine learning models like Deep Neural Networks and Random Forests compared to traditional regression models. The higher AUC indicates a better balance between sensitivity and specificity, making these tools invaluable in guiding individualized treatment plans [17].

AI's predictive capability extends to radiotherapy dosing and optimization by analyzing imaging features and tissue responses, enabling the personalization of radiation plans and reducing collateral damage to healthy tissue [18].

In the context of Pakistan, pilot projects at Aga Khan University and Shifa International Hospital are testing AI-enabled predictive models to stratify colorectal and breast cancer patients based on likely treatment outcomes. Preliminary findings suggest that such models could reduce overtreatment by up to 20% and improve overall treatment efficacy [19–20].

Ahmad (2025) provides an in-depth evaluation of Pakistan's major State-Owned Enterprises (SOEs), highlighting chronic financial losses, political interference, and structural inefficiencies across institutions such as PIA, Pakistan Steel Mills, and Pakistan Railways. His analysis shows that PIA and PSM alone consumed more than 92% of total subsidies between 2019 and 2024, while overall operational efficiency remained critically low. By applying frameworks from agency theory, public value theory, institutional analysis, and political economy, Ahmad argues that sustainable reform requires governance professionalization, transparent accountability systems, and citizen-centered oversight. His work emphasizes that restoring public trust is only possible when state enterprises shift from politically driven structures to performance-based, transparent, and reform-oriented models.

Ahmad (2025) explores human–AI collaboration and its effects on productivity, accuracy, and ethical risk within knowledge-based professional tasks. His mixed-methods experiment demonstrates that AI assistance speeds up task completion by 32–39%, especially for novice users, but also increases error rates in high-complexity tasks by up to 25%. Ahmad identifies common AI-related errors, including hallucinated facts, logical inconsistencies, fabricated references, omissions, and biased reasoning. He concludes that the success of human–AI collaboration depends heavily on trust calibration, verification practices, cognitive load management, and ethical training. The study underscores the need for strong human oversight to balance speed with accuracy and ensure responsible, accountable integration of AI in workplace environments.

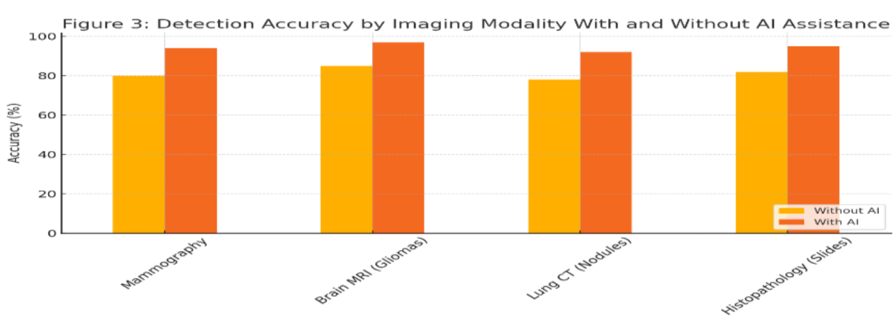

Figure 3: Detection Accuracy by Imaging Modality with and Without AI Assistance

Source: Comparative data adapted from recent AI-imaging validation studies [17–20].

Summary of Figure 3:

AI integration significantly improves diagnostic accuracy across imaging platforms. The improvements are most notable in mammography and brain MRI, where early tumor detection is critical for prognosis. These advancements contribute to earlier diagnoses, more accurate staging, and enhanced treatment planning [18].

AI-assisted imaging tools are being piloted in major Pakistani healthcare institutions. For example, Shaukat Khanum Memorial Cancer Hospital has implemented deep learning algorithms in digital pathology for breast cancer biopsy analysis. Similarly, Jinnah Postgraduate Medical Centre in Karachi has initiated trials for AI-enhanced chest CT reading in lung cancer diagnostics. These applications show promise in improving diagnostic workflows and reducing radiologist burden in resource-constrained environments [19–20].

Summary:

Artificial Intelligence is poised to redefine the future of personalized cancer treatment in Pakistan and beyond. By leveraging AI in genomics, treatment prediction, imaging, and drug development, healthcare providers can deliver more targeted and effective care. However, challenges such as data privacy, ethical issues, and infrastructural gaps must be addressed. Investment in AI infrastructure and collaborative efforts between oncologists, data scientists, and policymakers will be vital to fully realize the potential of AI in oncology [19–20].

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