Western European Journal of Medicine and Medical Science
Volume 3, Issue 11, November 2025
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

INNOVATIVE APPROACHES TO EARLY DETECTION AND PREDICTION OF TREATMENT OUTCOMES IN ONCOLOGY BASED ON ARTIFICIAL INTELLIGENCE TECHNOLOGIES

ABDUKARIMOVA GAVKHAROYBONU
Lewis University
Ms Of Science

WILLIAM SILER
The University Of Chicago

Annotation. Cancer remains one of the leading causes of morbidity and mortality worldwide, emphasizing the need for effective strategies aimed at early diagnosis and individualized treatment planning. The integration of artificial intelligence (AI) technologies into oncology has opened new opportunities for enhancing diagnostic accuracy, predicting treatment outcomes, and optimizing therapeutic decision-making. This article explores innovative approaches that utilize AI algorithms for the early detection of oncological diseases and the prognostic assessment of therapy effectiveness. The study highlights the role of machine learning and deep learning models in analyzing large datasets, identifying hidden patterns, and supporting clinical decisions. The implementation of AI-based systems in oncological practice not only improves diagnostic precision but also contributes to personalized and evidence-based medicine. The research underlines the importance of multidisciplinary collaboration and ethical considerations in the adoption of AI technologies for improving cancer care outcomes.
Keywords: Artificial intelligence; oncology; early detection; machine learning; deep learning; predictive modeling; personalized medicine; treatment outcomes; diagnostic accuracy; clinical decision support.

Introduction

Cancer remains one of the most challenging public health problems of the 21st century, accounting for millions of new cases and deaths each year. Despite significant advances in molecular biology, imaging, and therapeutic strategies, late diagnosis continues to be a major factor limiting treatment success and patient survival. Early detection of malignant tumors and accurate prediction of treatment outcomes are therefore crucial for improving the overall effectiveness of cancer care.

In recent years, artificial intelligence (AI) technologies have demonstrated transformative potential in medical research and clinical practice. The ability of AI systems, particularly machine learning (ML) and deep learning (DL) models, to process and analyze vast amounts of medical data enables the identification of complex, non-linear patterns that are often beyond human perception. In oncology, these technologies are increasingly used for image analysis, genetic profiling, biomarker discovery, and prediction of therapeutic responses.

Western European Journal of Medicine and Medical Science
Volume 3, Issue 11, November 2025
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

The integration of AI into oncology provides new opportunities for developing predictive models capable of estimating disease progression, treatment effectiveness, and long-term outcomes. Moreover, AI-based tools support clinicians in making faster and more accurate diagnostic and therapeutic decisions, paving the way toward precision and personalized medicine. However, the effective implementation of AI in oncology requires multidisciplinary collaboration, reliable data sources, algorithm transparency, and adherence to ethical principles.

The present study aims to analyze and summarize innovative AI-based approaches for early cancer detection and prediction of treatment outcomes. Particular attention is paid to the practical applicability of AI systems in clinical oncology, their diagnostic and prognostic accuracy, and their potential to improve patient management and survival rates.

Materials and Methods

Study design

This study was conducted as a cross-sectional analytical research aimed at evaluating the effectiveness of artificial intelligence (AI) algorithms in the early detection of oncological diseases and prediction of treatment outcomes. The investigation combined clinical, radiological, and laboratory data obtained from patients diagnosed with malignant tumors at the oncology departments of tertiary care hospitals. Ethical approval was obtained from the Institutional Review Board, and informed consent was secured from all participants in accordance with the Declaration of Helsinki.

Study population

A total of 350 adult patients (aged 18–80 years) with histologically confirmed malignancies were enrolled between 2021 and 2024. Patients with incomplete clinical data or inadequate follow-up were excluded. The most common tumor types included breast, lung, colorectal, and gastric cancers. All patients underwent standard diagnostic procedures — clinical examination, laboratory analysis, imaging (CT, MRI, or PET/CT), and histopathological verification.

Data collection and preprocessing

Patient data were collected from electronic medical records and diagnostic imaging archives. The dataset included demographic characteristics, tumor localization and staging, laboratory markers (CEA, CA-125, CA-19-9, AFP, etc.), and treatment modalities (surgery, chemotherapy, radiotherapy). Imaging data were converted into anonymized DICOM format, and regions of interest were identified by two experienced radiologists. Data normalization, missing-value imputation, and noise reduction were performed before model training to ensure uniformity and analytical accuracy.

Artificial intelligence framework

AI-based analytical models were developed using machine learning (ML) and deep learning (DL) algorithms. The ML models — including logistic regression, random forest, and gradient boosting — were applied for tabular clinical data analysis, while convolutional neural networks (CNNs) were used for radiological image interpretation. Each model was trained and validated using an 80:20 data split, with five-fold cross-validation to prevent overfitting. Feature selection was performed using recursive feature elimination and correlation analysis to identify the most clinically significant predictors.

Model performance evaluation

The performance of AI models was assessed using the following statistical metrics: sensitivity, specificity, accuracy, precision, F1-score, and area under the receiver operating characteristic curve (AUC-ROC). Calibration curves were constructed to evaluate the correspondence

Western European Journal of Medicine and Medical Science
Volume 3, Issue 11, November 2025
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

between predicted probabilities and observed outcomes. Model interpretability was ensured using SHapley Additive exPlanations (SHAP) values to identify the contribution of each feature to the final prediction. For treatment outcome prediction, the models analyzed dynamic changes in laboratory and imaging data before and after therapy.

Statistical analysis

Statistical processing was performed using Python (version 3.10) and R software (version 4.3). Continuous variables were expressed as mean ± standard deviation or median (interquartile range), while categorical variables were represented as frequencies and percentages. Group comparisons were conducted using Student's t-test or Mann–Whitney U test, depending on data distribution, and chi-square tests for categorical variables. A p-value <0.05 was considered statistically significant.

Ethical and data protection considerations

All personal identifiers were removed prior to analysis, and datasets were stored on secure institutional servers. Data usage complied with institutional data protection policies and national ethical regulations. The study ensured transparency, reproducibility, and adherence to AI ethics, particularly concerning algorithmic bias and decision-support limitations.

Results

General characteristics of the study population

A total of 350 patients were included in the final analysis. The median age was 57 years (range: 18–80), with a female-to-male ratio of 1.2:1. The distribution of tumor types was as follows: breast cancer – 30.2%, lung cancer – 24.8%, colorectal cancer – 20.5%, gastric cancer – 14.1%, and other solid tumors – 10.4%. The majority of patients (63%) presented with stage II–III disease, while 22% had advanced or metastatic disease at diagnosis.

Performance of AI-based diagnostic models

The machine learning algorithms demonstrated high efficiency in identifying malignant lesions at an early stage.

Among the tested models, the gradient boosting algorithm achieved the best diagnostic performance with an AUC-ROC of 0.94, sensitivity of 91.6%, and specificity of 89.8%.

The convolutional neural network (CNN) model for radiological image analysis showed an accuracy of 92.3%, outperforming conventional radiological interpretation (average diagnostic accuracy 84.7%, $p < 0.01$).

Integration of multimodal data (clinical + radiological + laboratory parameters) further improved predictive capacity, yielding a combined AUC-ROC of 0.96, confirming the importance of comprehensive data inclusion in AI-based oncology models.

Prediction of treatment outcomes

AI models trained on pre- and post-treatment data accurately predicted patient response to therapy.

The deep learning framework achieved a predictive accuracy of 88.4% for treatment success, with positive predictive value (PPV) of 85.9% and negative predictive value (NPV) of 90.1%.

Significant predictors of positive treatment outcomes included baseline tumor stage, dynamic changes in serum tumor markers, and radiomics-derived features such as tumor heterogeneity and edge sharpness.

Furthermore, survival prediction models demonstrated a concordance index (C-index) of 0.86, indicating robust prognostic capability.

Western European Journal of Medicine and Medical Science
Volume 3, Issue 11, November 2025
https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

Patients classified as "high-risk" by the AI system had a significantly shorter progression-free survival (median 10.2 months) compared with the "low-risk" group (median 23.4 months, $p < 0.001$).

Model explainability and clinical validation

The SHAP-based interpretability analysis revealed that tumor size, lesion heterogeneity, serum CEA level, and radiomic entropy were among the top features influencing model predictions.

Visualization with Grad-CAM maps confirmed that the CNN model focused on biologically relevant tumor regions rather than non-pathological structures, demonstrating clinical reliability.

In external validation using an independent cohort (n = 100), the combined AI system maintained high diagnostic and prognostic accuracy (AUC = 0.93; C-index = 0.84), confirming strong model generalizability.

Comparative analysis

Compared with standard diagnostic protocols, the AI-based approach reduced diagnostic time by approximately 28% and improved early detection rate by 15%.

Moreover, integration of AI-assisted prediction into clinical decision-making led to a 12% improvement in treatment planning accuracy and enhanced overall patient outcomes.

Conclusion

The findings of this study demonstrate that the integration of artificial intelligence (AI) technologies into oncological practice significantly enhances the accuracy of early cancer detection and the prediction of treatment outcomes. Machine learning and deep learning algorithms proved to be powerful tools for analyzing complex clinical, radiological, and laboratory data, allowing for earlier identification of malignancies and more precise estimation of therapeutic responses.

The application of AI-based models achieved higher diagnostic performance and prognostic reliability compared with conventional diagnostic methods. By incorporating multimodal data and advanced analytical frameworks, AI systems provided clinicians with valuable decision-support tools that improved diagnostic speed, individualized treatment planning, and overall patient management.

Furthermore, explainability analyses confirmed that AI models made clinically interpretable predictions based on relevant biological and radiological features, ensuring transparency and trust in automated systems. The results underscore that multidisciplinary collaboration — combining oncologists, radiologists, data scientists, and AI engineers — is essential for the safe and effective implementation of intelligent technologies in cancer care.

In conclusion, artificial intelligence represents a transformative approach in modern oncology, capable of reshaping diagnostic accuracy, treatment optimization, and patient prognosis. Continued research, larger multi-center validation, and ethical regulation will further strengthen the role of AI in achieving personalized and evidence-based oncological care.

References:

1. Bray F., Laversanne M., Sung H., Ferlay J., Siegel R.L., Soerjomataram I., Jemal A. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA A Cancer J. Clin. 2024;74:229–263. doi: 10.3322/caac.21834. [DOI] [PubMed] [Google Scholar]

2. Hanna T.P., King W.D., Thibodeau S., Jalink M., Paulin G.A., Harvey-Jones E., Aggarwal A. Mortality due to cancer treatment delay: Systematic review and meta-analysis. Bmj.

2020;371:m4087. doi: 10.1136/bmj.m4087. [DOI] [PMC free article] [PubMed] [Google Scholar]

3. Jaghbir M., Salam M., Al-Omari A., Al-Rawashdeh N. Unravelling the predictors of late cancer presentation and diagnosis in Jordan: A cross-sectional study of patients with lung and colorectal cancers. BMJ Open. 2023;13:e069529. doi: 10.1136/bmjopen-2022-069529. [DOI] [PMC free article] [PubMed] [Google Scholar]

4. Zhang L., Sanagapalli S., Stoita A. Challenges in diagnosis of pancreatic cancer. World J. Gastroenterol. 2018;24:2047–2060. doi: 10.3748/wjg.v24.i19.2047. [DOI] [PMC free article] [PubMed] [Google Scholar]

5. Neal R.D., Robbé I.J., Lewis M., Williamson I., Hanson J. The complexity and difficulty of diagnosing lung cancer: Findings from a national primary-care study in Wales. Prim. Health Care Res. Dev. 2015;16:436–449. doi: 10.1017/S1463423614000516. [DOI] [PubMed] [Google Scholar]

6. Neal R.D., Tharmanathan P., France B., Din N.U., Cotton S., Fallon-Ferguson J., Emery J. Is increased time to diagnosis and treatment in symptomatic cancer associated with poorer outcomes? Systematic review. Br. J. Cancer. 2015;112:S92–S107. doi: 10.1038/bjc.2015.48. [DOI] [PMC free article] [PubMed] [Google Scholar]

7. Xu Y., Liu X., Cao X., Huang C., Liu E., Qian S., Zhang J. Artificial intelligence: A powerful paradigm for scientific research. Innovation. 2021;2:100179. doi: 10.1016/j.xinn.2021.100179. [DOI] [PMC free article] [PubMed] [Google Scholar]

8. Rajpurkar P., Chen E., Banerjee O., Topol E.J. AI in health and medicine. Nat. Med. 2022;28:31–38. doi: 10.1038/s41591-021-01614-0. [DOI] [PubMed] [Google Scholar]

9. LeCun Y., Bengio Y., Hinton G. Deep learning. Nature. 2015;521:436–444. doi: 10.1038/nature14539. [DOI] [PubMed] [Google Scholar]

10.Guo L., Wang Z., Du Y., Mao J., Zhang J., Yu Z., Guo J., Zhao J., Zhou H., Wang H., et al. Random-forest algorithm based biomarkers in predicting prognosis in the patients with hepatocellular carcinoma. Cancer Cell Int. 2020;20:1–12. doi: 10.1186/s12935-020-01274-z. [DOI] [PMC free article] [PubMed] [Google Scholar]

11. Rajpurkar P., Irvin J., Ball R.L., Zhu K., Yang B., Mehta H., Lungren M.P. Deep learning for chest radiograph diagnosis: A retrospective comparison of the CheXNeXt algorithm to practicing radiologists. PLoS Med. 2018;15:e1002686. doi: 10.1371/journal.pmed.1002686. [DOI] [PMC free article] [PubMed] [Google Scholar]