Artificial Intelligence in Lung Cancer: Advances in Screening, Diagnosis, and Treatment Planning

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Abstract

Lung cancer remains the leading cause of cancer-related death worldwide, with late-stage diagnosis being a major factor in poor survival rates. In recent years, advances in artificial intelligence (AI) have created new opportunities to improve early detection, diagnosis, prognosis, and treatment planning in lung cancer care. AI tools, especially those based on machine learning (ML) and deep learning (DL), have shown promise in increasing the accuracy of screening methods like low-dose computed tomography (LDCT), as well as in interpreting radiological and histopathological images. By integrating imaging, clinical, and genomic data, AI can help stratify patients by risk and support personalised treatment approaches. However, challenges such as algorithm bias, lack of transparency, data variability, and ethical concerns about privacy and accountability continue to limit widespread adoption.

This review explores the current and emerging applications of AI in lung cancer screening and diagnosis, evaluates its potential impact on patient outcomes, and highlights the key obstacles that must be addressed for broader clinical integration.

Keywords: : *lung Cancer, artificial Intelligence, machine learning, early detection of cancer, positron emission tomography*

Introduction

According to the Global Cancer Statistics 2022 (GLOBOCAN), approximately 20 million new cancer cases and 9.7 million cancer-related deaths occurred worldwide in 2022. Among these, lung cancer accounted for 12.4% (2.5 million) of all new cases and 18.7% (1.8 million) of cancer-related deaths [1]. Lung cancer has two histological subtypes: small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC), with NSCLC being more prevalent, comprising 85–90% of all lung cancer cases. NSCLC includes squamous cell carcinoma, large-cell carcinoma, and adenocarcinoma, while SCLC is less common but more aggressive, classified as pure (with neuroendocrine features) or combined SCLC [2].

Lung cancer is associated with high mortality, largely due to its late-stage diagnosis. Early detection, especially in high-risk populations, is critical: stage I patients have a 5-year survival exceeding 75%, versus below 10% for stage IV [3,4].

Artificial intelligence (AI), capable of simulating human cognition and analysing large datasets, has emerged as a promising tool for early lung cancer detection [5,6].

The increasing application of AI in radiology is primarily driven by two developments: machine learning (ML) and deep learning (DL). ML uses statistical methods to learn rules from training data autonomously and is effective in identifying patterns within large datasets—often outperforming manual evaluation. DL, a subfield of ML, processes raw data without human-designed feature extraction, learning key representations directly from input data [7].

AI in Lung Cancer Screening

Low-dose computed tomography (LDCT) is the standard screening modality for lung cancer; however, its effectiveness is limited by high false-positive rates, missed diagnoses, and inter-reader variability [8]. Artificial intelligence (AI), particularly deep learning (DL) techniques, can help overcome these limitations by minimising human error in image interpretation and enhancing diagnostic accuracy [9]. DL models are capable of detecting subtle malignant patterns, including small pulmonary nodules that may be overlooked by radiologists, as demonstrated by the LUNA16 model [4].

By rapidly analysing large volumes of imaging data, AI augments radiologist performance, reduces diagnostic fatigue, and improves consistency in radiological assessments—an advantage that is especially relevant for large-scale lung cancer screening programmes [10]. In addition, AI algorithms can integrate clinical, radiological, and biological data, including electronic medical records, fluid biomarkers, and metagenomic information, to further improve the precision and personalisation of lung cancer screening [11].

AI also improves reporting systems like Lung-RADS, aiding risk stratification, distinguishing benign from malignant nodules, and reducing unnecessary biopsies and scans [8, 11].

Although AI has much to offer, key challenges remain. The main one is generalisability: as most AI models are trained on datasets that may not reflect global diversity, factors such as age, ethnicity, comorbidities, and regional practices can affect performance [6]. Another challenge is interpretability—many AI systems act as "black boxes", and clinicians may hesitate to trust outputs without understanding the reasoning [5].

AI in Lung Cancer Diagnostics

Early diagnosis is critical in lung cancer, yet over 70% of patients are diagnosed at advanced stages and are often ineligible for surgery [6]. CT scans and biopsies are standard but have limits —CT risks misdiagnosis, and biopsies are invasive—so better noninvasive methods are needed.

Tumour location, pathology, metastasis, and complications add challenges. AI aids not only detection but also staging, typically based on positron emission tomography-computed tomography (PET-CT) [12]. Various machine learning algorithms—such as logistic regression, support vector machines, neural networks, Bayesian models, K-nearest neighbours, decision trees, and random forests—have been applied in this field. These AI systems can autonomously analyse clinical data, identify relevant variables, and provide decision support for diagnosis and treatment. DL techniques, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), generative adversarial networks (GANs), and transformers, have shown considerable clinical value in lung cancer screening, diagnosis, and prognosis [5].

AI in Prognosis and Treatment Planning in Lung Cancer

In digital histopathology, AI models process H&E-stained whole-slide images to segment cellular morphology, characterise the tumour microenvironment (TME), and extract survival-predictive features, enabling rapid tumour classification and prognosis assessment; however, performance is limited by data quality, nonstandard protocols, and incomplete datasets [12,13]. By combining histopathological, PET, and CT features, machine learning and deep learning models can predict survival, recurrence, and treatment response in lung cancer, improving clinical decision-making and personalised treatment planning [14,15,16].
Biomarkers with clinical data improve prognostic accuracy [17]. Radiomic nomograms and CNNs trained on radiotherapy datasets identify high-risk patients and predict 2-year post-surgery survival [18,19,1]. Tumour microenvironment cell organisation is another key prognostic factor [20].
AI has shown promise in forecasting responses to chemotherapy, targeted therapy, immunotherapy, and radiation therapy [21]. Radiomics-based models can predict pathologic complete response to chemoradiation in NSCLC [10], as well as responses to frontline epidermal growth factor receptor tyrosine kinase inhibitor (EGFR-TKI) and Programmed Death-1 (PD-1)/Programmed Death-Ligand 1 (PD-L1) immunotherapies [22]. Deep learning algorithms can estimate EGFR mutation likelihood and response to EGFR-TKIs and checkpoint inhibitors. By identifying specific radiomic features, AI supports personalised treatment planning and can anticipate outcomes such as local failure and chemotherapy effectiveness [23].
In risk stratification, AI models—including CNNs using chest X-rays and minimal EHR data—predict long-term cancer risk more accurately than traditional criteria, identifying individuals for targeted screening [24, 25].
In the pre-treatment setting, AI predicts prognosis to guide therapy intensity—high-risk patients may receive intensive care, while lower-risk patients avoid overtreatment. After surgery, AI identifies recurrence risk to guide adjuvant chemotherapy decisions [18].

Examples of Case-Based Models

Several case-based studies have demonstrated the potential of AI in guiding prognosis and treatment planning. Table 1 summarises key examples, including radiomics-based response prediction [10], EGFR mutation identification [23], early failure prediction after SBRT [18], and integration of genomic data for adjuvant therapy decisions [16].

Conclusion

Despite rapid progress, AI adoption in lung cancer care remains limited by several challenges. Model bias from unrepresentative training data can reinforce health disparities, while the “black box” nature of deep learning reduces clinician trust. Ethical concerns around data privacy, consent, and accountability further complicate implementation. Standardisation of imaging protocols and data formats is also essential to improve model generalisability. Looking ahead, AI's ability to integrate imaging, clinical, genetic, and biomarker data offers promise for early detection, risk stratification, and personalised treatment. Efforts to improve interpretability, data quality, and clinician training are critical for implementing AI in routine practice. Addressing these barriers through collaboration among clinicians, researchers, and developers will enable AI to realise its full potential in improving lung cancer screening, diagnosis, and outcomes.

Table 1. Case-based studies demonstrating AI's potential in prognosis and treatment planning

Study	AI Application	Clinical Context	Key Outcome
Binczyk F, et al. (2021)	Radiomics-based AI model	Prediction of treatment response to nivolumab, docetaxel, gefitinib	Accurately predicted response based on CT radiomic features
Khorrami M, et al. (2020)	Prognostic AI model	Early-stage NSCLC treated with SBRT or chemoradiation	Predicted early death and treatment failure
Mobadersany P, et al. (2018)	Integrated AI model (genomic + clinicopathological data)	Adjuvant therapy decision-making	Identified patients at recurrence risk who may benefit from adjuvant treatment

References:

1. Kratzer TB, Bandi P, Freedman ND, Smith RA, Travis WD, Jemal A, Siegel RL. Lung cancer statistics, 2023. Cancer. 2024 Apr 15;130(8):1330-48.
2. Lung Cancer Awareness Month 2024 [Internet]. Who.int. 2024. Available from: https://www.iarc.who.int/news-events/lung-cancer-awareness-month-2024/
3. Li Y, Yan B, He S. Advances and challenges in the treatment of lung cancer. Biomedicine & Pharmacotherapy. 2023 Dec 31;169:115891.
4. Li C, Wang H, Jiang Y, Fu W, Liu X, Zhong R, Cheng B, Zhu F, Xiang Y, He J, Liang W. Advances in lung cancer screening and early detection. Cancer biology & medicine. 2022 May 15;19(5):591-608.
5. Huang S, Yang J, Shen N, Xu Q, Zhao Q. Artificial intelligence in lung cancer diagnosis and prognosis: Current application and future perspective. In Seminars in cancer biology 2023 Feb 1 (Vol. 89, pp. 30-37). Academic Press.
6. Xie Y, Meng WY, Li RZ, Wang YW, Qian X, Chan C, Yu ZF, Fan XX, Pan HD, Xie C, Wu QB. Early lung cancer diagnostic biomarker discovery by machine learning methods. Translational oncology. 2021 Jan 1;14(1):100907.
7. Quanyang W, Yao H, Sicong W, Linlin Q, Zewei Z, Donghui H, Hongjia L, Shijun Z. Artificial intelligence in lung cancer screening: Detection, classification, prediction, and prognosis. Cancer Medicine. 2024 Apr;13(7):e7140.
8. Cellina M, Cacioppa LM, Cè M, Chiarpenello V, Costa M, Vincenzo Z, Pais D, Bausano MV, Rossini N, Bruno A, Floridi C. Artificial intelligence in lung cancer screening: the future is now. Cancers. 2023 Aug 30;15(17):4344.
9. Ye M, Tong L, Zheng X, Wang H, Zhou H, Zhu X, Zhou C, Zhao P, Wang Y, Wang Q, Bai L. A classifier for improving early lung cancer diagnosis incorporating artificial intelligence and liquid biopsy. Frontiers in oncology. 2022 Mar 2;12:853801.
10. Binczyk F, Prazuch W, Bozek P, Polanska J. Radiomics and artificial intelligence in lung cancer screening. Translational lung cancer research. 2021 Feb;10(2):1186.
11. Espinoza JL, Dong LT. Artificial intelligence tools for refining lung cancer screening. Journal of clinical medicine. 2020 Nov 27;9(12):3860.
12. Pei Q, Luo Y, Chen Y, Li J, Xie D, Ye T. Artificial intelligence in clinical applications for lung cancer: diagnosis, treatment and prognosis. Clinical Chemistry and Laboratory Medicine (CCLM). 2022 Nov 25;60(12):1974-83.
13. Alturkistani HA, Tashkandi FM, Mohammedsaleh ZM. Histological stains: a literature review and case study. Global journal of health science. 2015 Jun 25;8(3):72
14. Cellina M, Cè M, Irmici G, Ascenti V, Khenkina N, Toto-Brocchi M, Martinenghi C, Papa S, Carrafiello G. Artificial intelligence in lung cancer imaging: unfolding the future. Diagnostics. 2022 Oct 31;12(11):2644.
15. Gandhi Z, Gurram P, Amgai B, Lekkala SP, Lokhandwala A, Manne S, Mohammed A, Koshiya H, Dewaswala N, Desai R, Bhopalwala H. Artificial intelligence and lung cancer: impact on improving patient outcomes. Cancers. 2023 Oct 31;15(21):5236.
16.Mobadersany P, Yousefi S, Amgad M, Gutman DA, Barnholtz-Sloan JS, Velázquez Vega JE, Brat DJ, Cooper LA. Predicting cancer outcomes from histology and genomics using convolutional networks. Proceedings of the National Academy of Sciences. 2018 Mar 27;115(13):E2970-9
17. Luo YH, Chiu CH, Kuo CH, Chou TY, Yeh YC, Hsu HS, Yen SH, Wu YH, Yang JC, Liao BC, Hsia TC. Lung cancer in Republic of China. Journal of Thoracic Oncology. 2021 Apr 1;16(4):519-27
18. Khorrami M, Bera K, Leo P, Vaidya P, Patil P, Thawani R, Velu P, Rajiah P, Alilou M, Choi H, Feldman MD. Stable and discriminating radiomic predictor of recurrence in early stage non-small cell lung cancer: Multi-site study. Lung Cancer. 2020 Apr 1;142:90-7.
19. Shelhamer E, Long J, Darrell T. Fully convolutional networks for semantic segmentation. IEEE transactions on pattern analysis and machine intelligence. 2016 May 24;39(4):640-51
20. Pham B, Gaonkar B, Whitehead W, Moran S, Dai Q, Macyszyn L, Edgerton VR. Cell counting and segmentation of immunohistochemical images in the spinal cord: Comparing deep learning and traditional approaches. In 2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) 2018 Jul 18 (pp. 842-845). IEEE.
21. Adam G, Rampášek L, Safikhani Z, Smirnov P, Haibe-Kains B, Goldenberg A. Machine learning approaches to drug response prediction: challenges and recent progress. NPJ precision oncology. 2020 Jun 15;4(1):19.
22. Wang C, Yu X, Wang W. A meta-analysis of efficacy and safety of antibodies targeting PD-1/PD-L1 in treatment of advanced nonsmall cell lung cancer. Medicine. 2016 Dec 1;95(52):e5539.
23. Jiang J, Hu YC, Liu CJ, Halpenny D, Hellmann MD, Deasy JO, Mageras G, Veeraraghavan H. Multiple resolution residually connected feature streams for automatic lung tumor segmentation from CT images. IEEE transactions on medical imaging. 2018 Jul 23;38(1):134-44.
24. Elliss-Brookes, L.; McPhail, S.; Greenberg, D.; Jones, T.; Rous, B.; O'Dowd, G.; Verne, J.; Coleman, M.P.; Richards, M.A. Stage at diagnosis and early mortality from cancer in England. British Journal of Cancer 2015, 112, S108–S115.
25. Ardila D, Kiraly AP, Bharadwaj S, Choi B, Reicher JJ, Peng L, Tse D, Etemadi M, Ye W, Corrado G, Naidich DP. End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. Nature medicine. 2019 Jun;25(6):954-61