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Review Article

An Overview of Revolutionizing Lung Cancer Management with AI: Current Advances and Future Prospects

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ABSTRACT

Worldwide health authorities identify lung tumors as one of the most critical medical concerns because patients often die from the condition and discover it too late. Recent technology breakthroughs have made it possible to come up with innovative methods of improving early detection, accurate diagnosis, and successful treatment methods. Modern computer systems enhance medical image examination which reduces misdiagnosis errors and boosts accurate detection of pulmonary diseases. Genomic research obtained advantages from these developments through lab tests which speed up mutation discovery and create individualized therapeutic plans. The use of automated technology in histopathological analysis now leads to optimized tumor classifications as well as better prognosis evaluations. The execution of treatments becomes more individualized because predictive models predict how patients will react to therapeutic interventions during planning stages. Digital tools used for clinical decision support now simplify patient management by assessing combined biological and clinical information. The research momentum for novel therapeutic choices has increased because it presents promising therapeutic options. Healthcare systems and data consistency together with possible biases remain unresolved issues for future improvement. With the advancement of the multi-dimensional data analysis, the refinement of the diagnostic instruments, and the precision guided treatment, it is expected that the prognosis of the lung cancer will be greatly improved, and the patients will get such medical treatment more efficiently and patient centered.

INTRODUCTION

Setting the stage for AI in Lung cancer management

Lung cancer remains one of the most important public health problems worldwide by incidence and mortality rates. The various variables such as socioeconomic inequalities, genetic

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susceptibilities, and environment are so complicated that it is more difficult to study and deal with the cancer. This article demonstrates currently conducted research on the impact which the cancer has imposed on global health, the challenges experienced in the detection and the treatment of the cancer, the causes, and research to discover cures that are efficient. The cancer is surprisingly the death which accounts for about 18% of all cancer related death with a death toll of about 1.8 million a year, making it the cancer related mortality global leader [1]. Lung cancer, as occurs in most follicular subtypes, is divided into two major types: small cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC), which accounts for some 85% of all the disease [2]. Demographic and geographical variations have been experienced in the incidence and mortality. Efforts have resulted in a decrease in incidence and death in higher-income areas, especially for males; nonetheless, rates among women exhibit alarming patterns, particularly in specific nations [3]. For instance, despite a decrease in the overall incidence of lung cancer in the US, disparities persist based on socioeconomic status, gender, and access to healthcare[4]. Furthermore, the trajectory of lung cancer shows a concerning rise in areas with high levels of urbanization, increased tobacco use, and exposure to air pollution [5]. As previously mentioned, a greater lung cancer death rate is correlated with modest socioeconomic development, suggesting that there may be wider public health consequences that call for focused measures [6]. The primary reason behind the high mortality rate is late diagnosis, making the need to implement enhanced early detection and therapy strategies essential [7,8]. Despite being valuable, the routine diagnostic techniques are fraught with poor availability, sensitivity, and specificity [9,10]. Artificial intelligence (AI) has the potential to revolutionize lung cancer therapy, hence new approaches must be used [11,12,13]. Its application ranges from early identification to therapy optimization to the various phases of the ailment. The recent breakthroughs in pathomics, radiomics, deep learning, and integration of multi-omics are enhancing the prognostication, making personalized therapy strategies possible, and enhancing the precision of the diagnosis.

AI in Diagnostic Imaging: Revolutionizing Early Detection

AI has played a huge role in improving early identification of lung cancer through use of imaging modalities such as CT scans, MRIs, and chest X-rays as they reflect the increasing volume and complexity of medical images and human limits on interpretation, which are why AI powered solutions are needed[14, 15]. Accuracy, diagnosis and planning of treatment are enhanced, patients benefit in terms of patient outcomes[16–18].The topic of Deep Learning in Medical Imaging is based on the use of Multi layer neural networks as part of the deep learning framework of machine learning to extract complex properties from raw image data. On the contrary, medical picture analysis is well suited for deep learning, as compared with common machine learning, deep learning can independently identify the relevant patterns [19–21]. One such deep learning model, convolutional neural networks (CNNs), as they can record spatial correlations, are good at finding even the limest abnormality in medical pictures [19,20]. CNNs in Lung Cancer Detection: CNNs are very effective at lung cancer detection from CT and X-ray images nodules, and subtle density variations, and are sensitive to more than human radiologists [22,23]. CNN based analysis identified tumors at an early stage that cannot be distinguished from benign nodules[24]. As shown by studies, CNNs lead to high sensitivity and specificity, and thus improve diagnose accuracy as well as reduce missed detections [16,19]. Merging AI into clinical workflows: AI needs to be smoothly embedded in clinical workflows in order to be adopted widely. First, we believe AI systems should only be decision support tools, rather than replacing radiologists, and second, they should have intuitive interfaces to enable interpretation [15]. AI reduces workforce and speeds up the case prioritization, making process more efficient and diagnostic confidentie[18]. AI as a Second Reader: AI is a good "second reader" in radiology, decreasing the false positives and false negatives and giving an extra layer of review[15,18]. It also identifies the ambiguous cases that require further scrutiny and does not miss on critical diagnoses. AI makes radiologists prioritize high risk cases on urgent evaluations and improves radiology workflow efficiency[15, 18]. This resulted in enhanced accuracy and speed combined with reduction in errors of human interpretation[15,16]. However, true positive detection and false positives scenarios are improved by AI based analysis[16, 17]. By processing the images rapidly, AI reduces the diagnostic delays to minimize delays in initiation of treatment that is important for quick treatment of aggressive cancers like lung cancer [17]. Overcome Faults: The fact that human radiologists are nutrition to fatigue and inter observer variability will lead to diagnostic inconsistency. AI addresses these problems by providing objective, consistent, and low fatigue analysis with reduced potential for the misclassification or missing diagnosis. Both studies confirm these facts and highlights the advantages of AI analysis for psychiatric diagnosis. AI Driven Imaging: Helps detect lung cancer in a quicker time and at a much lesser workload of radiologists that results in faster time of treatment initiation [15]. Automated abnormality detection tremendously shortens the diagnosis time in that patients can be diagnosed before the disease progresses and earlier intervention can be performed, such as for aggressive malignancies [1,17].

AI in Clinical Practice: Notable Tools:

DeepMind in Lung Cancer Detection:

i. Google's DeepMind uses Large amounts of medical imaging datasets to detect lung cancer with high accuracy. These models help radiologists identify these faint visual cues that may be irrelevant to the radiologists themselves[16–18]. DeepMind's tech illustrate how AI can work with radiology but while clinical adoption is ongoing.

ii. IBM Watson Health in Oncology: Watson Oncology assists oncologists in planning treatment through NLP and ML as it analyzes imaging data, clinical guidelines and medical records[16]. Based on evidence, the ability to develop synthesize vast patient data allows evidence based therapy recommendations, and personalized treatment strategies[17,18]. Integration of AI driven imaging solutions in lung cancer diagnosis is making diagnosis faster and more accurate while keeping elderly and patients waiting in the room for a short time.

Genomics and AI: Tailoring Precision Medicine for Lung Cancer

Lung cancer being a common cause of cancer mortality worldwide[28] has high genetic heterogeneity requiring genetic profiling with precision for personalized therapy. However, it is time-consuming to analyze the genetic datasets with traditional genomic analysis, but AI can quickly scan this vast genetic dataset[29,30]. The development of deep learning models has enabled to accurately detect mutations from liquid and tissue biopsies towards targeted therapy selection [31,32]. AI also proves effective to detect driver mutations, including EGFR and ALK rearrangements, particularly for rare alterations that are not detected by traditional methods in NSCLC[33–35]. However, there are currently insufficient high-quality genomics datasets and rigorous validation needed before adopting such AI-driven genomics for clinical reliability [29]. This provides for a rapid, sensitive and specific scan of genetic data with AI to enhance the detection of actionable mutations needed for treatment decisions[36–38]. This is a capability that allows precise therapeutic interventions to the rare mutations, MET exon 14 skipping and ROS1 fusions for example. Beyond this, AI refines cancer characterisation and improves therapeutic accuracy by integrating data from various multi-omics data such as the genomic, transcriptomics, proteomics and metabolomics, and the specific mutations[29,30,40–42]. In addition, genomics and imaging (radiomics) are integrated through AI powered means for enhancing neither diagnostic accuracy nor treatment planning[43, 44]. Pretty much in precision medicine, AI predicts the response to treatment based on genomics as well as clinical data and minimizes adverse effects in selecting therapy [30,39,40,45]. One of the biggest breakthroughs of AI models is also in helping oncologists personalize treatment strategies based on their forecasts of the responses the immunotherapy and TKIs [38, 46–48]. In addition, AI can also deter drug resistance by monitoring genetic profiles or treatment history of the disease and suggest intervention and alternative therapy early on [36, 46, 49, 50]. Although both publications describe patient case studies demonstrating the utility of AI driven models to predict responses to therapeutic targets based on EGFR mutations and ALK gene rearrangements [37,38,50], they vary from standard printed free-text books by focusing on the reviewer bias of an expert panel and on the assumptions built into current state-of-the-art and static models (appendix). Newer models extend AI's scope beyond EGFR and ALK to also employ total mutational burden and newly matured driver mutations such as ROS1 and MET alterations to improve patient stratification[36,52]. In the future of AI in lung cancer therapy, taking advantage of the multi-omics integration is expected as an important means to obtain better clinical results and therapeutic tailoring [40,41].

AI in Histopathology: Transforming Biopsy Analysis and Cancer Prognosis

By making the hand of artificial intelligence (AI) to help complete the task of tumor classification, biopsy analysis and prognosis prediction, histopathology is revolutionized[53]. Together with doctors this technology provides precise and fast histopathological assessment integration by deep learning models and completing pathologist expertise[54,55]. Categorization systems based on AI power, allow reliable identification of a benign versus malignant tumors[56]. WSI can be deeply learned algorithms to effectively classify adenocarcinoma, adenoma, and non neoplastic tissues with high accuracy and robust diagnostic performance [57]. Moreover, they also aid in tumor staging, metastasis prediction, and providing crucial prognoses for providing the personalized treatment strategies [55, 58]. The image recognition that is AI powered identifies features in our tumor that we cannot see, such as size, shape, and spatial organization, which makes it possible to grasp not only how the tumor looks and sounds, but also begins to understand the heterogeneity and progression of the tumor [59]. Since cells interact with each other in complex patterns and with cellular microenvironment called 'stroma' which is themselves organized in more complex ways, advanced machine learning models such as graph neural networks (GNNs) predict that these networks are analyzed to understand cellular interactions and stromal components as the sources of improved insights into cancer behavior and therapeutic response [60,61]. Moreover, AI reduces interobserver variablity among pathologists and helps to achieve reproducible and objective histological assessment, thanks to AI [62, 64, 65]. Outsourcing routine tasks such as cell counting or image segmentation increases the speed at which the pathology workflow can be completed – early cancer detection and therapy planning [62,63]. Based on AI driven and chemical imaging techniques, biopsy analysis is optimized, greatly speeding up and making the analysis diagnostic more efficient [63].

AI for Predicting Treatment Response and Prognosis

The management of lung cancer is being revolutionized by artificial intelligence (AI), which is improving predicting models for patient survival and treatment response.By integrating clinical, radiological, and genetic data, AI-driven models enable precision medicine and improve decision-making [66–68].

Table 1: Predictive Models for Therapy Response: AI algorithms leverage deep learning (DL) and machine learning (ML) to predict how patients will respond to various treatments [67].

Treatment Type	AI Application
Chemotherapy	AI identifies key factors affecting chemotherapy efficacy and helps tailor treatment regimens.
Immunotherapy	AI models that forecast how advanced non-small cell lung cancer (NSCLC) patients will react to immune checkpoint inhibitors (ICI) and platinum-based chemotherapy include multimodal ensemble models [68,69].
Targeted Therapy	AI refines individualized treatment plans by analyzing molecular markers [68].

Table 2: AI in Survival Prediction: AI models assess survival likelihood based on cancer stage, genetic markers, and clinical data, providing more accurate prognostic insights[67].

Predictive Factors	Role in Survival Prediction
Cancer Stage [70]	AI analyzes staging data to refine survival estimates.
Molecular Markers [71]	Genetic mutations and protein expressions influence prognosis.
Clinical Data [72]	Patient demographics and medical history enhance predictive accuracy.

Benefits of AI in Survival Forecasting

- **Higher Accuracy**: AI detects complex survival patterns beyond traditional methods [73].
- **Personalized Prognostics**: AI tailors survival predictions based on individual patient profiles [67].
- **Improved Decision-Making**: AI-driven insights assist oncologists in treatment planning [66].

Table 3: AI-Based Predictors for Lung Cancer

AI Model/Algorithm	Application
Logistic Regression [74]	Predicts survival probability using clinical variables.

Random Forest [70]	enhances accuracy by the integration of several decision trees.
Support Vector Machines (SVM) [72]	Classifies patients into risk groups.
XGBoost Classifier [75]	Accurately predicts ICI response.

Specialized AI Tools

- **Multimodal Ensemble Models**: Combine imaging and clinical data to predict ICI-platinum therapy response in NSCLC [69].
- **Radiomics-Based Models**: Extract quantitative imaging data (CT, PET/CT) for treatment outcome predictions [76].
- **Genomic Biomarkers**: AI-generated biomarkers improve survival forecasting and therapy selection [77].

AI-driven predictive models continue to advance precision oncology, optimizing treatment selection and improving patient outcomes in lung cancer management.

Optimizing Treatment Plans: AI in Clinical Decision Support Systems

Artificial intelligence (AI) is revolutionizing lung cancer management through clinical decision support systems (CDSSs), enhancing individualized treatment planning and improving patient outcomes[78,79]. These systems integrate multimodal data sources and assist in real-time treatment adaptation.

Clinical Decision Support (CDS): AI-driven CDSSs analyze imaging, pathology, genomic, and clinical data to provide precise treatment recommendations [80-83].

Table 4 : Functions of AI in CDS

Function	Description
Data Integration	AI processes data from imaging, pathology, genomics, and clinical records for diagnosis[84].
Imaging Analysis	AI detects and characterizes lung nodules in CT, PET-CT, and radiographs[85,86].
Pathology Data Processing	AI classifies tumor subtypes and analyzes gene mutations[87,88].
Genomic Data Utilization	AI predicts gene mutations and therapy targets[89,84].
Clinical Data Extraction	NLP processes EHRs to extract relevant clinical information[85].

Personalized Treatment Recommendations: AI-generated recommendations include therapy selection, radiation optimization, and clinical trial identification, improving treatment efficacy and resource utilization[86,90-93].

Table 5 : Real-Time Adaptation & Dynamic Treatment Regimes

Feature	Function
Monitoring Therapy Response	AI assesses response using imaging and biomarkers[86].

Predicting Outcomes	AI estimates survival, recurrence, and therapy efficacy[90,78].
Treatment Plan Adjustment	AI modifies dosage, therapy type, or treatment method dynamically[97].
Expertise Accessibility	AI ensures access to the latest clinical guidelines, reducing disparities[95,96].

Response-Adaptive Radiotherapy (ART): AI-driven ART dynamically adjusts radiation therapy based on patient-specific biological and clinical parameters, optimizing dose and reducing toxicity[92,97].

Table 6: Examples of AI-Driven CDSS Tools

CDSS Tool	Function
IBM Watson For Oncology	Provides evidence-based treatment recommendations [100,101].
Radiomics-Based Ai	Predicts EGFR mutation and PD-L1 expression in NSCLC [102].
Arclids	Supports adaptive radiotherapy through multi-omics analysis [97].
Xdecide	Generates structured personal records and ranked treatment options [81].
Clarify Dsp	Consolidates real-time clinical data for risk stratification and personalized follow-up[103].

AI-driven CDSSs significantly enhance diagnostic accuracy, optimize treatment plans, and facilitate real-time therapy adaptation, ultimately improving lung cancer outcomes[78,85,90].

AI in Drug Discovery: Opening Up New Treatment Options

AI is transforming drug discovery by using sophisticated computer tools to quickly identify treatment possibilities for lung cancer. AI-driven predictive modeling integrates genetic data, clinical information, and chemical structures, with machine learning models like CNNs and RNNs achieving over 95% accuracy in analyzing drug-target interactions[105]. Deep learning methods, including GANs, enhance gene identification linked to poor clinical outcomes, refining target selection[108]. AI also facilitates virtual screening by predicting drug-protein interactions with improved accuracy, utilizing vector representations of chemical structures and protein sequences[108]. Platforms such as AIGEN ChemTailor integrate human expertise with AI-driven drug discovery frameworks, enhancing compound selection[109]. QSAR models incorporating gradient boosting and neural networks predict active compounds against non-small cell lung cancer, employing SHAP plots for molecular feature analysis[110].AI is essential to drug repurposing because it can anticipate novel therapeutic applications for already-approved medications using computational techniques like network medicine and homology modeling[112]. Pharmacoinformatics-driven strategies leverage AI-powered docking simulations to evaluate FDA-approved drugs for affinity, bioavailability, and solubility[114]. AI-driven Mendelian randomization (MR) predicts targeted therapy efficacy by analyzing druggable genes and overcoming chemotherapy resistance[115]. Virtual clinical trials (VCTs) simulate patient responses, optimizing treatment evaluations while reducing ethical and financial constraints[117]. AI-generated digital twins, such as DT-GPT, analyze EHRs to refine clinical trial design and therapy selection[118]. Additionally, AI optimizes clinical pharmacology by personalizing drug dosing, predicting interactions, and improving treatment safety through AI-augmented clinical pharmacology (AI/CP) frameworks[119]. Deep learning models analyze diverse data sources to identify prognostic and predictive indicators, enhancing personalized treatment strategies[119]. AI-driven advancements in drug discovery, repurposing, and virtual trials are transforming lung cancer treatment, making it more efficient, cost-effective, and precise, ultimately improving patient survival rates.

AI in Monitoring and Surveillance: Real-time Patient Management

AI is revolutionizing lung cancer care by enabling real-time monitoring, early recurrence detection, and personalized treatment adjustments. AI-driven technologies analyze diverse data sources, including imaging and biomarkers, to assess patient responses accurately [120]. By predicting recurrence and detecting minimal residual illness, biomarkers such as circulating tumor DNA (ctDNA) improve therapy choices.Deep learning models evaluate imaging data, identifying subtle tumor changes that may indicate progression or treatment failure [121]. Integrating these data streams provides a comprehensive view of patient health, supporting timely interventions [122]. Continuous monitoring offers early treatment failure detection, improved patient outcomes, and optimized therapy adjustments [123]. AI excels in identifying lung cancer recurrence by analyzing medical images and patient biomarkers. It can detect recurrence signs earlier than traditional methods, improving precision and risk assessments [124].For broad adoption, issues including data availability, heterogeneity, and clinical validation need to be resolved [125]. AI-driven personalized monitoring tailors follow-ups and treatment plans based on predictive models, improving care efficiency and patient well-being [126]. By continuously analyzing patient data, AI refines treatment strategies, enhances survival rates, and minimizes adverse effects, ensuring more effective and personalized lung cancer management.

Challenges in Implementing AI in Lung Cancer Care

Ensuring High-Quality and Diverse Datasets: AI in lung cancer treatment relies on high-quality, annotated datasets for accurate predictions [127]. However, challenges such as limited data diversity, inconsistent annotations, and lack of standardized data formats hinder AI performance. Lung cancer exhibits genetic and clinical variations, making it essential for AI models to be trained on diverse datasets.Data dependability is further complicated by the time-consuming and inconsistent nature of expert manual annotation.

Strategies for Addressing Data Challenges: To overcome data-related obstacles, techniques such as data augmentation, federated learning, and AI-driven annotation tools can be employed [128]. Federated learning allows AI models to train on decentralized data while preserving privacy. Encouraging data-sharing initiatives among institutions can improve dataset diversity, and AI-powered annotation tools can enhance efficiency and accuracy.

Integration with Healthcare Systems: The complexity of existing healthcare infrastructure poses a challenge for AI adoption [129]. Outdated IT systems, fragmented data silos, and workflow disruptions can slow implementation. Healthcare professionals may resist AI adoption due to concerns about job roles and lack of proper training [130]. Additionally, AI integration requires significant investment in hardware, software, and training, making cost a key barrier [131].

Solutions for Seamless AI Integration: To facilitate AI adoption, healthcare systems can implement open-source AI platforms, establish clear data governance policies, and provide comprehensive training [131]. A phased approach—starting with pilot programs—can help identify challenges early and ensure smooth integration. For AI to function well with electronic health records and other healthcare systems, standardized data formats and interoperability frameworks are essential.

Addressing Algorithmic Bias in AI: Bias in AI models can lead to unequal healthcare outcomes, disproportionately affecting certain patient groups [132]. AI models trained on non-representative data may show performance disparities, limiting their effectiveness across diverse populations [133]. Bias can arise from sample selection, feature choices, and inconsistencies in data collection or labeling.

Mitigating Bias for Fair AI Applications: Ensuring diverse and representative training data is essential for reducing bias. Regular audits should assess AI performance across different demographics, and fairness-aware algorithms can help address disparities. Increasing transparency in AI decision-making improves trust and helps detect biases, ensuring AI benefits all lung cancer patients equitably.

Future Directions: The Road Ahead for AI in Lung Cancer

The treatment of lung cancer is being quickly transformed by artificial intelligence (AI), which holds great promise for improved patient outcomes, tailored treatment plans, and improved diagnosis [134,135,136]. As AI technologies advance and are integrated with other cutting-edge advancements, lung cancer therapy may see yet another revolution. This paper explores the future of AI in lung cancer, focusing on how it promotes immunotherapy, how it combines with other technologies, and how collaboration and research are essential for enhancing AI models. AI's integration with cutting-edge technologies is shaping the future of lung cancer management, enhancing precision surgery, treatment planning, and personalized therapies. By working alongside robotics, augmented reality (AR), and 3D printing, AI can drive significant advancements in surgical accuracy, visualization, and patient-specific treatments. By increasing surgical accuracy, decreasing invasiveness, and boosting patient recovery, AI-powered robotic devices are transforming lung cancer operations in precision surgery.By evaluating intraoperative imaging data, such as CT and MRI images, AI integration enables real-time decision assistance by giving surgeons information about tumor margins, important anatomical features, and possible problems, guaranteeing total tumor removal while protecting good tissue [137]. Augmented reality further enhances visualization by overlaying AI-generated data onto the surgeon's field of view, highlighting tumor borders, blood vessel locations, and surgical risks. Additionally, AI-powered robotics automate complex surgical tasks like tissue manipulation and suturing, reducing surgeon fatigue and improving outcomes. AI combined with augmented reality is also transforming treatment planning by providing interactive and detailed anatomical visualizations. Radiation oncologists can use AR to overlay radiation therapy plans onto real-time CT images, enabling precise dose distribution that minimizes damage to healthy tissue while maximizing tumor control [136]. AR-driven interactive treatment simulations allow surgeons to rehearse complex procedures in a virtual setting, helping them refine their techniques and anticipate potential challenges before operating on actual patients. AI and 3D printing are further advancing personalized therapies by enabling the creation of customized medical devices, implants, and drug delivery systems. AI-driven analysis of patient anatomical data facilitates the design and 3D printing of implants and prosthetics tailored to individual anatomy, improving comfort, functionality, and aesthetic outcomes [137]. The development of personalized drug delivery systems receives enhancement through AI because it uses patient-specific physiological and genetic profiles to optimize drugs for better treatment effects. Lung cancer treatment achieves higher clinical outcomes together with better patient care through the combination of AI with robotics and AR and 3D printing systems. Through AI advancements the treatment of lung cancer grows better with newly developed bioprinting technologies as well as stronger immunotherapy approaches. BI-based fabrication of organ tissues and organs for transplant remains a promising response for patients who need lung function restoration due to lung cancer conditions. AI-guided precise bioprinting methods will allow medical professionals to develop patient-specific bioengineered lung tissues which represent a possible replacement for organ transplants in forthcoming medical practices. Lung cancer treatment sees immune checkpoint inhibitors (ICIs) as a revolutionary approach but medical professionals face difficulties when predicting which patients will benefit from them. The application of AI technology helps detect more suitable patients as well as discover new biomarkers together with better treatment plans to enhance immunotherapy outcomes [138,139]. The combination of genetic data evaluation with histopathological images and clinical characteristics enables AI to detect which patients will gain the most benefit from ICIs thus decreasing both medical hazards and financial burdens. Through analyzing histopathological images AI systems evaluate the TIL density and PD-L1 expression level because these factors indicate ICI response [140,141]. A predictive analysis using AI can detect two prognostic markers called MSI and TMB which indicate ICI treatment response [142]. Confirmation of prognostic findings through patient clinical variable integration including age, performance status and smoking history allows for enhanced personalized immunotherapy decision-making [143]. AI serves as a key instrument to discover fresh indicators beyond normal biomarkers that will help assess how patients respond to ICI therapy. Artificial intelligence uses radiomics to extract quantitative characteristics from CT and PET scans for the detection of tumor attributes and microenvironment modifications that standard human observation cannot detect [145]. Proteomics allows scientists to discover protein pathways that cause ICI resistance so new therapeutic targets can be developed [146]. AI technology describes microbiome analysis to determine gut microbial composition because this information helps understand immune system modulation while assessing immunotherapy effectiveness [147]. AI is also transforming immunotherapy by optimizing treatment regimens tailored to individual patients. Through dose optimization, AI can determine the most effective ICI dosage based on tumor burden, immune status, and body weight, ensuring maximal therapeutic benefits while minimizing adverse effects [136]. AI-driven models can also refine the timing and duration of ICI administration to enhance the anti-tumor immune response. Furthermore, AI aids in selecting the best combination therapies by analyzing tumor molecular profiles and immune system interactions, identifying synergistic approaches that integrate ICIs with chemotherapy, radiation, or targeted therapies for improved treatment outcomes [148]. Collaboration amongst oncologists is necessary for the effective integration of AI in the treatment of lung cancer, AI experts, and regulatory authorities. Oncologists contribute clinical insights and expertise in lung cancer biology, while AI specialists refine machine learning algorithms and data analytics methodologies. Experienced regulatory entities play an essential part by evaluating AI-driven solutions to confirm their compliance with security protocols and moral principles and legal requirements [149]. The development of specific AI models for lung cancer patients requires collaboration between different fields that would involve data sharing agreements and standardized data formats for appropriate AI training and validation. Data safety requires organizations to handle ethical and regulatory factors in order to protect patient privacy and maintain transparency of AI decision processes. The advancement of medical care toward enhanced patient success will occur as a result of these developments.

Ongoing Research and Refinement of AI Models

AI model improvement through ongoing research and refinement will advance their clinical potential in lung cancer management yet researchers must perform more tests to determine their therapeutic efficacy in terms of cost-effectiveness and real-world survival and patient quality of life outcomes [150]. The evaluation of AI models for diverse patient populations requires planned clinical research to establish their steady performance in guiding therapeutic decisions. Doctors' acceptance of AI-generated recommendations requires authors to make AI models more understandable for medical staff [151]. The elimination of AI model biases represents a fundamental topic because disparate training data produces wrong and discriminatory results. The research must concentrate on detecting biases and eliminating them to guarantee that AI technological healthcare systems present fair and bias-free healthcare solutions equally to all patient demographics [152]. These innovative technological treatments for lung cancer treatment based on Artificial Intelligence continue to evolve through methods such as combination therapy optimization and digital biopsies and toxicity prediction [153]. AI enables the search for optimal treatment pairs through comprehensive patient records because it determines which therapies yield better results when combined than when used separately[148]. A determined sequence of treatments improves both therapeutic effectiveness by selecting the best drug administration order which gives optimal tumor responses and reduces treatment resistance. Through clinical and imaging and genomic data integration AI develops individualized treatment plans for patient-specific therapy. Digital biopsies have brought about a significant progression in cancer diagnostics approaches that require no invasiveness. AI radiomics enables medical imaging systems to retrieve tumor-specific features which permits monitoring tumor aggressiveness together with genetic alterations without performing invasive tissue biopsies [154,155]. The examination of biomarkers through liquid biopsies by using circulating tumor cells (CTCs) and circulating tumor DNA (ctDNA) further improves detection of resistance mechanisms [142]. AI technologies create better treatment prediction models through combination of medical images with test data collected from liquid biopsies that enables better environmental microenvironment understanding. AI possesses the ability to forecast treatment side effects which enables clinicians to use preventive measures to minimize these effects that influence patient results. The evaluation of clinical data enables AI systems to recognize toxicity-linked risk variables which leads to prompt therapeutic measures [156]. Genomic analysis reveals natural abilities to experience adverse effects which enables healthcare providers to give personalized risk reviews to decide proper treatment modifications. Advanced predictive models built through AI unify clinical data with genomic analysis to reach higher accuracy in toxicity detection which supports better care outcomes for patients. The progression of AI technology demands sustained inter-disciplinary joint work as well as robust clinical testing and ethical supervision to achieve secure and efficient health care usage of these systems.

CONCLUSION:

Harnessing AI for a Transformative Future in Lung Cancer Care

Summary: AI Revolutionizing Lung Cancer Management

The therapy of lung cancer experiences revolution through AI technology because it delivers better patient results and treatments tailored to individual needs and detects conditions early[157]. Analysis capabilities that exceed human performance for medical images and genetic profiles and clinical records serve to move the field forward [158]. The technology of AI has arrived in lung cancer care to enhance all aspects of diagnosis and prognosis along with treatment planning [159]. The advanced methodology of AI diagnostics achieves high accuracy through its methodologies of image analysis and predictive modeling [157]. Techniques like natural language processing (NLP) and convolutional neural networks (CNNs) enhance early detection, distinguishing benign from malignant nodules and optimizing treatment planning [159].Moreover, AI supports personalized treatment by analyzing multi-omics data, optimizing therapy, and minimizing side effects [160]. Clinical decision-making is aided by AI-powered Clinical Decision Support Systems (CDSS), and precision medicine is improved by AI's predictive powers, especially in non-small cell lung cancer (NSCLC)[158].

Key Aspect	Role of AI in Lung Cancer Management
Early Detection & Diagnosis	AI improves CT and CXR analysis, enhancing accuracy in detecting lung nodules and personalizing screening programs.[161–163]
Personalized Treatment	AI tailors treatments by analyzing imaging, clinical, and genetic data, optimizing therapy effectiveness.[164–165]
Prognosis Prediction	AI forecasts survival rates and recurrence risks, aiding in treatment and post-surgical planning.[166]
Efficiency & Accuracy	AI reduces errors, automates tasks, enhances diagnostics, and supports clinical decision-making.[167–168]
Thoracic Surgery	AI improves surgical outcomes with better risk assessment, real-time guidance, and predictive modeling.[169–170]

Challenge	Description
Data Quality and Quantity	AI performance depends on high-quality, diverse data. Limited or biased datasets reduce model generalizability and accuracy. Ensuring data privacy and security is also essential.[158, 171]

Model Interpretability	Deep learning in particular is one of the many AI models that operate as "black boxes," making judgments difficult to make. The goal of explainable AI (XAI) techniques is to increase transparency[158, 172]
Ethical Considerations	AI in healthcare raises concerns about bias, fairness, and accountability. Responsible development and safeguards are needed to ensure ethical use.[157]
Integration into Clinical Workflows	Logistical and technical challenges make AI adoption in healthcare complex. Seamless integration and adequate training for clinicians are necessary.[159]

Future Outlook: AI as a Central Force in Transforming Lung Cancer Treatment

The ongoing development and incorporation of AI technologies will have a substantial impact on the treatment of lung cancer in the future. From early detection and diagnosis to individualized treatment planning and prognosis prediction, artificial intelligence will be crucial in revolutionizing many facets of lung cancer care.

Future Impact of AI	Description
Enhanced Early Detection and Screening	AI improves screening accuracy, detecting subtle lung tissue changes missed by human observers. It also enables personalized screening plans based on individual risk factors.[173, 174]
Personalized Treatment Planning	AI predicts patient responses to treatments by analyzing clinical and multi-omics data, leading to targeted therapies with fewer side effects and improved outcomes.[164, 174]
Improved Prognosis Prediction	AI-driven models integrate clinical, genetic, and imaging data to provide accurate survival and disease progression forecasts, aiding treatment decisions.[175]
Accelerated Drug Discovery and Development	AI expedites drug research by evaluating clinical and genetic data to find novel drug targets and forecast treatment efficacy, resulting in more potent treatments[158, 176]
Reduced Healthcare Burdens	AI improves productivity, automates tedious jobs, and allocates resources optimally, freeing up healthcare workers to concentrate on intricate patient care[177, 178]

Dedicated to Innovation and Ethical Stewardship Together

There is no denying AI's revolutionary influence on the treatment of lung cancer.As AI technologies advance, they will play an increasingly significant role in improving patient outcomes, transforming the treatment of lung cancer, and reducing healthcare costs globally [157]. The comprehensive use of AI in the treatment of lung cancer requires a shared commitment to innovation, collaboration, and ethical stewardship [169]. We can use AI to transform the treatment of lung cancer and enhance the lives of patients everywhere by tackling its drawbacks and restrictions and making sure it is used responsibly [179].

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