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Review paper: Low-cost AI healthcare solutions for lung cancer

Serah Sommers - s1015986

Abstract

Lung cancer is the most common type of cancer worldwide and due to its high costs of treatment, many people die from it each year. Artificial intelligence (AI) has the potential to significantly reduce costs and improve the effectiveness of lung cancer detection and treatment. AI techniques can be used to analyze medical images for tumor detection and classification, predict patient prognoses, help in treatment planning, and aid in drug discovery. Using AI in the field of lung cancer has the potential to improve accuracy and efficiency, ultimately leading to reduced healthcare costs and increased access to treatment, especially in low- to middle-income countries. However, further research is necessary to improve existing AI techniques and potentially discover new AI techniques in this field. This paper aims to provide an overview of current AI techniques and applications in lung cancer, identify any gaps in the field, and propose directions for future low-cost AI systems in the detection and treatment of lung cancer.

Introduction

Lung cancer is the most common type of cancer worldwide, with an estimated 2.21 million cases in 2020 [1]. Unfortunately, due to the high cost of treatments, not all lung cancer patients have access to the necessary procedures and therapies. As a result, approximately 1.80 million people die from lung cancer each year, representing an 81% mortality rate, with the majority of these deaths occurring in low- to middle-income countries[1].

As lung cancer is a leading cause of mortality worldwide, reducing the costs of detection and treatment is needed in order to decrease the mortality rate, particularly in low- to middle-income countries. Artificial Intelligence (AI) techniques may offer a solution, as they can potentially reduce lung cancer healthcare costs significantly. There are already many AI systems that have demonstrated effectiveness in tasks such as identifying tumor regions, classifying tumor microenvironments, predicting prognoses, making treatment plans, and drug discovery [2][3].
The use of AI in lung cancer detection and treatment has the potential to improve accuracy and efficiency, resulting in reduced healthcare costs and increased access to treatment. This could ultimately lead to a decrease in the worldwide mortality rate from lung cancer. However, further research is necessary to improve existing AI techniques and potentially discover new ones in this field. This paper aims to provide an overview of current AI techniques and applications in lung cancer to show its great potential, and tries to identify potential gaps in the field. It proposes to following research question:

'What are the existing low-cost AI applications for detection and treatment of lung cancer and what are the possible gaps in this field?'

We hypothesize that there is still room for improvement in the development of AI applications that detect and treat lung cancer in a low-cost manner.
In this paper, we will begin by discussing the background of AI applications in lung cancer, by listing the types of AI applications that can be used in this field. We will also explain how these AI applications can reduce costs. We will then examine the current state of the field while giving examples of low-cost AI applications that already have been developed. Next, we will identify any gaps in this field and discuss what types of low-cost AI systems for lung cancer should be developed in the future. Finally, we will provide a summary and draw conclusions on the use of low-cost AI in the field of lung cancer.

Background

Lung cancer is a common and deadly type of cancer that affects millions of people worldwide [1]. AI systems can be used to perform tasks related to lung cancer detection and treatment more efficiently, potentially reducing healthcare costs. This section will outline the most important tasks that AI systems can fulfill in the field of lung cancer. It will also explain the ways AI systems can reduce healthcare costs.

Types of AI's for lung cancer

There are several tasks that AI systems can perform in the field of lung cancer detection and treatment[2][3]:
The first task that AI can fulfill is *tumor detection*. It can be used to analyze medical images, such as CT scans or X-rays, to identify the presence and location of tumors. This can help doctors diagnose lung cancer earlier, which increases the chance of successful treatment.
Secondly, it can be used for *tumor classification*. AI can classify different types of lung tumors based on their appearance in medical images. This can contribute to the doctor making the best treatment plan for each patient.
Next, it can *predict prognosis* of patients. It can do this by analyzing medical data, such as tumor size and patient age, to predict the likelihood of a patient's survival. This can also help doctors make informed treatment decisions.
Additionally, AI can help with *treatment planning*. AI can assist doctors in developing personalized treatment plans for lung cancer patients by analyzing medical data and identifying the most effective treatment options and timelines.
Lastly, AI can be used in *drug discovery*, to speed up the process of discovering new drugs for the treatment of lung cancer.

Reduce healthcare costs

AI has the potential to significantly improve the diagnosis and treatment of lung cancer, which can save costs [4].
First, AI can improve the accuracy of diagnosis and treatment in various ways [5]. It can do this by analyzing and interpreting complex data sets, such as CT scan images, and making decisions based on that analysis. This can help to identify patterns and abnormalities that may not be immediately apparent to humans, leading to more accurate predictions and earlier detection of lung cancer. Early detection can help to reduce the need for more costly and complex treatments, and can also help to prevent lung cancer from getting worse. Additionally, accurate diagnosis and treatment can help to reduce the risk of misdiagnosis, which can save money by preventing patients from receiving unnecessary or inappropriate treatment and can also prevent serious consequences for the patient's health. Finally, accurate treatment can help to reduce the risk of lung cancer returning [6], which can lower the overall cost of care.
Second, the use of AI in the field of lung cancer can also improve the efficiency of diagnosis and treatment, and consequently reduce healthcare costs [5]. Automated processes can speed up the overall process, which can help to prevent lung cancer from worsening and leading to more complex and costly interventions. Additionally, automation can save money on personnel costs, as some tasks can be taken over by the AI system, allowing healthcare professionals to focus on more complex tasks that require their expertise.

Existing AI's for lung cancer

To show the great potential of cost-saving AI systems in lung cancer healthcare, this section discusses various examples of these systems for tumor detection, tumor classification, prognosis prediction, treatment planning, and drug discovery.

Tumor detection

AI can play a significant role in improving the accuracy and efficiency of lung cancer detection. AI systems have the potential to assist in early detection, improve the accuracy of diagnoses, and reduce the evaluation time required by radiologists [7]. There are a number of AI systems that have been developed for this purpose, a few of which will be discussed here.
One research group developed a deep learning system that was trained on existing chest radiographs containing malignant nodules [8]. The system used the segmentation methods with five-fold cross-validation. This resulted in high performance in detecting lung cancer in radiographs with a sensitivity of 0.73. However, the system may produce false positives on calcified nodules, leading to the possibility of incorrect diagnoses. Despite this limitation, the system has the potential to be cost-effective and accessible, with the added benefit of a low radiation dose.
Another AI system developed for lung cancer detection can analyze X-ray images and provide a heatmap of the probability of each area being cancerous or normal [9]. This way, areas of concern can be highlighted. When tested, it proved to improve the performance of detecting lung cancer significantly. However, this was only the case when it was used alongside a radiologist. Future research could try to improve the system so it is able to work independently.
Another example is an AI that was developed to automatically detect lung cancer nodules in low-dose chest CT scans of patients [10]. There was found high agreement with experts, as well as a sensitivity of 1.0 and a specificity of 0.708. This system has the potential to save costs and be used in countries with limited numbers of radiologists, as it can automate the process of detecting lung cancer nodules.
Overall, these examples demonstrate the potential of AI in improving the accuracy and efficiency of lung cancer detection. However, further research is necessary to improve the performance and reliability of these systems.

Tumor classification

After a tumor has been detected, it is important to classify its type in order to determine the most appropriate treatment plan. We will discuss some of the many AI systems for tumor classification that have been developed to show their great potential.
One study used convolutional neural networks (CNNs) to classify the type of lung cancer cells by analyzing CT scan images. It focused on classifying sub-types of non-small cell lung cancer (NSCLC), which represents 85% of all lung cancer types [11]. The model was able to predict between the types adenocarcinoma, squamous cell 53 carcinoma, and large-cell carcinoma, with an accuracy of 0.71. Other machine learning classifiers, such as k-nearest neighbors and support vector machines, also demonstrated similar accuracy in this task. This suggests that various AI techniques can be effective for classifying lung cancer cells in CT scan images.
Similarly, another study used a CNN to classify CT scan images into adenocarcinoma, squamous cell carcinoma, and normal lung tissue [12]. The model slightly outperformed human pathologists in terms of sensitivity and specificity, with an average area under the curve (AUC) of 0.97. It was also able to predict the presence of certain gene mutations in lung adenocarcinoma with an accuracy ranging from 0.733 to 0.856.

Deep learning models have the potential to accurately and inexpensively classify cancer types, which could improve treatment outcomes. Future research could focus on using these models to classify less common cancer types in addition to NSCLC.

Prognosis prediction

AI can be used to make predictions about a patient's prognosis, which can help in developing personalized treatment plans. There are three main ways to use AI for prognosis prediction: using imaging, genomics, or pathology [13].

One example of using AI for prognosis prediction based on imaging is a study that used deep learning to predict clinical outcomes in patients with NSCLC using time series CT images [14]. The models were able to predict survival, progression, distant metastases, and recurrence, and were able to divide patients into low and high mortality risk groups and predict their body response in a separate group of patients. The authors suggest that this AI system may be useful in clinical practice due to its low cost and minimal human input requirements.

Another study developed a fully automated AI system to predict prognosis based on genomics [15]. The system used CT images to predict the epidermal growth factor receptor (EGFR) genotype, with an AUC between 0.748 and 0.813. The discovery of a mutation in this genotype can predict a high risk of tyrosine kinase inhibitor (TKI) drug resistance, allowing the AI system to help with treatment and prognosis prediction.

An example of using AI for prognosis prediction based on pathology is a study that developed a framework to predict the 5-year survivability of lung cancer patients using the Surveillance, Epidemiology, and End Results (SEER) dataset [16]. The study applied six different AI algorithms, including logistic regression, decision trees, random forests, AdaBoost, artificial neural networks, and Naïve Bayes. The best results were obtained using random forests and AdaBoost models, which had an AUC of 0.94. Important factors in predicting survivability were found to be the number of lymph nodes with metastases, the number of tumors a patient has had in their lifetime, the patient's age, and the microscopic composition of cells. This information can be useful in predicting prognosis and developing suitable treatment plans.

Treatment planning

AI can also be used to improve the effectiveness and efficiency of cancer treatment by providing personalized treatment recommendations based on an elaborate analysis of a patient's individual characteristics.

One paper mentions an AI approach, which divides patients into groups according to their unique characteristics [17]. It then more accurately evaluates the potential efficacy of treatments, recommends treatment sequences, and predicts the effects of specific drugs and clinical outcomes. It may for example provide an alternative noninvasive diagnosis strategy that can lower the risks, prevent complications, and allow for suitable treatment. In addition to improving patient outcomes, AI-based treatment recommendations can also reduce time loss and costs.

Another paper gives many examples of AI systems that can help in treatment planning based on three categories [18]. First, automated rule implementation and reasoning (ARIR) automates the process of deciding the right treatment actions based on many if-then rules. Second, systems that model prior knowledge in clinical practice can be used. They use previous cases and their outcomes to make prediction models for new cases, so the best treatment decisions can be made. The last category of AI systems for treatment planning is called multi-criteria optimization. It can be used to find the best plan by generating multiple plans at the same time, of which each optimizes a different aspect of the treatment plan. A clinician can then choose

the best plan based on their evaluation of different criteria. This approach is faster and more efficient than re-optimizing a single plan when certain criteria change.
These examples show that AI can significantly improve treatment planning for lung cancer and has the potential to do even more so in the future.

Drug discovery

AI already has been used to discover many new drugs against cancer [19], and it can do this in various ways, such as improving the drug discovery process, reducing research and development costs, decreasing the number of failures in drug trials, and producing better medicines [20].
One of the few papers that mentioned the use of AI for drug discovery for lung cancer specifically tried to overcome the problem of NSCLC becoming resistant to various anticancer agents due to mutations [21]. As this is one of the most common types of lung cancer, finding new drug candidates is very essential [22]. The researchers in the paper used AI to discover potential new drugs while addressing limitations of current drug discovery methods, such as high costs and slow development. They used a type of neural network called LSTM-based transfer learning to create new potential drugs for NSCLC. They started by collecting data about similar drugs and fed this information into the AI model, which successfully led to the development of improved drugs for this type of lung cancer in a faster and more cost-effective way.
However, there are not many other AI systems for drug discovery in the field of lung cancer specifically at this time. This could be an area for future research to focus on, as it does show great potential in other types of cancers.

Gaps in the field

There are several gaps discovered in the field of AI for lung cancer detection and treatment that could be addressed in future research.
One area that could be further developed is the use of AI for tumor detection. While some AI systems show the ability to detect lung cancer with high sensitivity, they may still produce false positives and may not work independently from humans [7]. Improving the performance and reliability of these systems could lead to more accurate and efficient detection of lung cancer.
Another gap in the field is the use of AI for tumor classification. While some studies have shown the potential for AI to accurately classify different types of lung cancer, further research could focus on the possibility of these systems classifying less common cancer types in addition to NSCLC. This could improve treatment outcomes for more cancer types.
In the area of prognosis prediction and personalized treatment, AIs already show great potential. However, future research could focus on using AI to improve the prediction of treatment outcomes, identify drug resistance, and predict cancer development. Additionally, they could be improved by increasing treatment options and creating more personalized treatment plans. These improvements could lead to more effective treatment and better patient outcomes.
Additionally, in the area of drug discovery, many more steps can be taken. Currently, there are no FDA-approved drugs for lung cancer that have been developed using AI [23]. More research is needed to come to the point where AI systems discover drugs that are actually used in practice.
Finally, there is still a transnational gap between the development and research of AI applications for lung cancer and the actual use of them in clinical practice [24]. Further research is necessary to determine how these AI systems can be effectively implemented in clinical practice and what steps need to be taken to make that happen.

Conclusion

In this paper, we aimed to examine and show the potential of low-cost AI systems in the field of lung cancer detection and treatment. We reviewed various AI applications that have already been developed and identified potential gaps in the field. We found that these systems can be used for tumor detection, tumor classification, prognosis prediction, treatment planning, and drug discovery. Overall, we proved that AI systems have the potential to improve the accuracy and efficiency of healthcare, leading to improved patient outcomes and cost savings. These low-cost AI healthcare solutions make the application of these technologies more feasible in low- and middle-income countries.

However, there are still some areas where improvement is needed in the use of low-cost AI in lung cancer detection and treatment. These include improving the performance and reliability of AI systems for tumor detection, expanding the ability of AI systems to classify a wider range of cancer types, improving AI systems for prognosis prediction and treatment planning, and increasing the use of AI in drug discovery to develop FDA-approved drugs. Additionally, there is a need for further research on the implementation of AI systems in clinical practice.

Overall, this demonstrates that there is still much room for improvement in this field and that we should continue to research and develop low-cost AI solutions for lung cancer healthcare.

References

[1] World Health Organization. Cancer, Feb 2022.

[2] Shidan Wang, Donghan M. Yang, Ruichen Rong, Xiaowei Zhan, Junya Fujimoto, Hongyu Liu, John Minna, Ignacio Ivan Wistuba, Yang Xie, and Guanghua Xiao. Artificial intelligence in lung cancer pathology image analysis. *Cancers*, 11(11):1673, Oct 2019.

[3] Hwa-Yen Chiu, Heng-Sheng Chao, and Yuh-Min Chen. Application of artificial intelligence in lung cancer. *Cancers*, 14(6):1370, 2022.

[4] Sri Sunarti, Ferry Fadzlul Rahman, Muhammad Naufal, Muhammad Risky, Kresna Febriyanto, and Rusni Masnina. Artificial intelligence in healthcare: opportunities and risk for future. *Gaceta Sanitaria*, 35:S67–S70, 2021.

[5] Christopher Joy Mathew, Ashwini Maria David, and Chris Mariya Joy Mathew. Artificial intelligence and its future potential in lung cancer screening. *EXCLI journal*, 19:1552, 2020.

[6] Yong Tang, Guibin Qiao, Enwu Xu, Yiwen Xuan, Ming Liao, and Guilin Yin. Biomarkers for early diagnosis, prognosis, prediction, and recurrence monitoring of non-small cell lung cancer. *OncoTargets and therapy*, 10:4527, 2017.

[7] Macedo Firmino, Antônio H Morais, Roberto M Mendoça, Marcel R Dantas, Helio R Hekis, and Ricardo Valentim. Computer-aided detection system for lung cancer in computed tomography scans: review and future prospects. *Biomedical engineering online*, 13(1):1–16, 2014.

[8] Akitoshi Shimazaki, Daiju Ueda, Antoine Choppin, Akira Yamamoto, Takashi Honjo, Yuki Shimahara, and Yukio Miki. Deep learning-based algorithm for lung cancer detection on chest radiographs using the segmentation method. *Scientific reports*, 12(1):1–10, 2022.

[9] Hyunsuk Yoo, Sang Hyup Lee, Chiara Daniela Arru, Ruhani Doda Khera, Ramandeep Singh, Sean Siebert, Dohoon Kim, Yuna Lee, Ju Hyun Park, Hye Joung Eom, et al. Ai-based improvement in lung cancer detection on chest radiographs: results of a multi-reader study in nlst dataset. *European Radiology*, 31(12):9664–9674, 2021.

[10] Jordan Chamberlin, Madison R Kocher, Jeffrey Waltz, Madalyn Snoddy, Natalie FC Stringer, Joseph Stephenson, Pooyan Sahbaee, Puneet Sharma, Saikiran Rapaka, U Joseph Schoepf, et al. Automated detection of lung nodules and coronary artery calcium using artificial intelligence on low-dose ct scans for lung cancer screening: accuracy and prognostic value. *BMC medicine*, 19(1):1–14, 2021.

[11] Tafadzwa L Chaunzwa, Ahmed Hosny, Yiwen Xu, Andrea Shafer, Nancy Diao, Michael Lanuti, David C Christiani, Raymond H Mak, and Hugo JWL Aerts. Deep learning classification of lung cancer histology using ct images. *Scientific reports*, 11(1):1–12, 2021.

[12] Nicolas Coudray, Paolo Santiago Ocampo, Theodore Sakellaropoulos, Navneet Narula, Matija Snuderl, David Fenyö, Andre L Moreira, Narges Razavian, and Aristotelis Tsirigos. Classification and mutation prediction from non–small cell lung cancer histopathology images using deep learning. *Nature medicine*, 24(10):1559–1567, 2018.

[13] Jingwei Li, Jiayang Wu, Zhehao Zhao, Qiran Zhang, Jun Shao, Chengdi Wang, Zhixin Qiu, and Weimin Li. Artificial intelligence-assisted decision making for prognosis and drug efficacy prediction in lung cancer patients: a narrative review. *Journal of Thoracic Disease*, 13(12):7021, 2021.

[14] Yiwen Xu, Ahmed Hosny, Roman Zeleznik, Chintan Parmar, Thibaud Coroller, Idalid Franco, Raymond H Mak, and Hugo JWL Aerts. Deep learning predicts lung cancer treatment response from serial medical imaginglongitudinal deep learning to track treatment response. *Clinical Cancer Research*, 25(11):3266–3275, 2019.

[15] Shuo Wang, He Yu, Yuncui Gan, Zhangjie Wu, Encheng Li, Xiaohu Li, Jingxue Cao, Yongbei Zhu, Liusu Wang, Hui Deng, et al. Mining whole-lung information by artificial intelligence for predicting egfr genotype and targeted therapy response in lung cancer: a multicohort study. *The Lancet Digital Health*, 4(5):e309–e319, 2022.

[16] Marina Johnson, Abdullah Albizri, and Serhat Simsek. Artificial intelligence in healthcare operations to enhance treatment outcomes: a framework to predict lung cancer prognosis. *Annals of Operations Research*, pages 1–31, 2020.

[17] Tania Pereira, Cláudia Freitas, José Luis Costa, Joana Morgado, Francisco Silva, Eduardo Negrão, Beatriz Flor de Lima, Miguel Correia da Silva, António J. Madureira, Isabel Ramos, Venceslau Hespanhol, António Cunha, and Hélder P. Oliveira. Comprehensive perspective for lung cancer characterisation based on ai solutions using ct images. *Journal of Clinical Medicine*, 10(1), 2021.

[18] Chunhao Wang, Xiaofeng Zhu, Julian C Hong, and Dandan Zheng. Artificial intelligence in radiotherapy treatment planning: present and future. *Technology in cancer research & treatment*, 18:1533033819873922, 2019.

[19] Paul Workman, Albert A Antolin, and Bissan Al-Lazikani. Transforming cancer drug discovery with big data and ai. *Expert Opinion on Drug Discovery*, 14(11):1089–1095, 2019.

[20] P Agrawal. Artificial intelligence in drug discovery and development. *Journal of Pharmacovigilance*, 6(2):1000e173, 2018.

[21] Geunho Choi, Daegeun Kim, and Junehwan Oh. Ai-based drug discovery of tkis targeting l858r/t790m/c797s-mutant egfr in non-small cell lung cancer. *Frontiers in Pharmacology*, 12:660313, 2021.

[22] David S Ettinger. Overview and state of the art in the management of lung cancer. *Oncology (Williston Park, NY)*, 18(7 Suppl 4):3–9, 2004.

[23] Prashansa Agrawal. Artificial intelligence in drug discovery and development. *Journal of Pharmacovigilance*, 06, 01 2018.

[24] David F. Steiner, Po-Hsuan Cameron Chen, and Craig H. Mermel. Closing the translation gap: Ai applications in digital pathology. *Biochimica et Biophysica Acta (BBA) - Reviews on Cancer*, 1875(1):188452, 2021.