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Artificial intelligence applications in common pulmonary diseases

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Abstract

Artificial intelligence (AI) is a branch of computer science where machines are trained to imitate human-level intelligence and perform well-defined tasks. AI can provide accurate results as well as analyze vast amounts of data that cannot be analyzed *via* conventional statistical methods. AI has been utilized in pulmonary medicine for almost two decades and its utilization continues to expand. AI can help in making diagnoses and predicting outcomes in pulmonary diseases based on clinical data, chest imaging, lung pathology, and pulmonary function testing. AI-based applications enable physicians to use enormous amounts of data and improve their precision when treating pulmonary diseases. Given the growing role of AI in pulmonary medicine, it is important for practitioners caring for patients with pulmonary diseases to understand how AI can work in order to implement AI into clinical practices to help improve patient care. The goal of this mini-review is to discuss the use of AI in pulmonary medicine and imaging in cases of obstructive lung disease, interstitial lung disease, infections, nodules, and lung cancer.
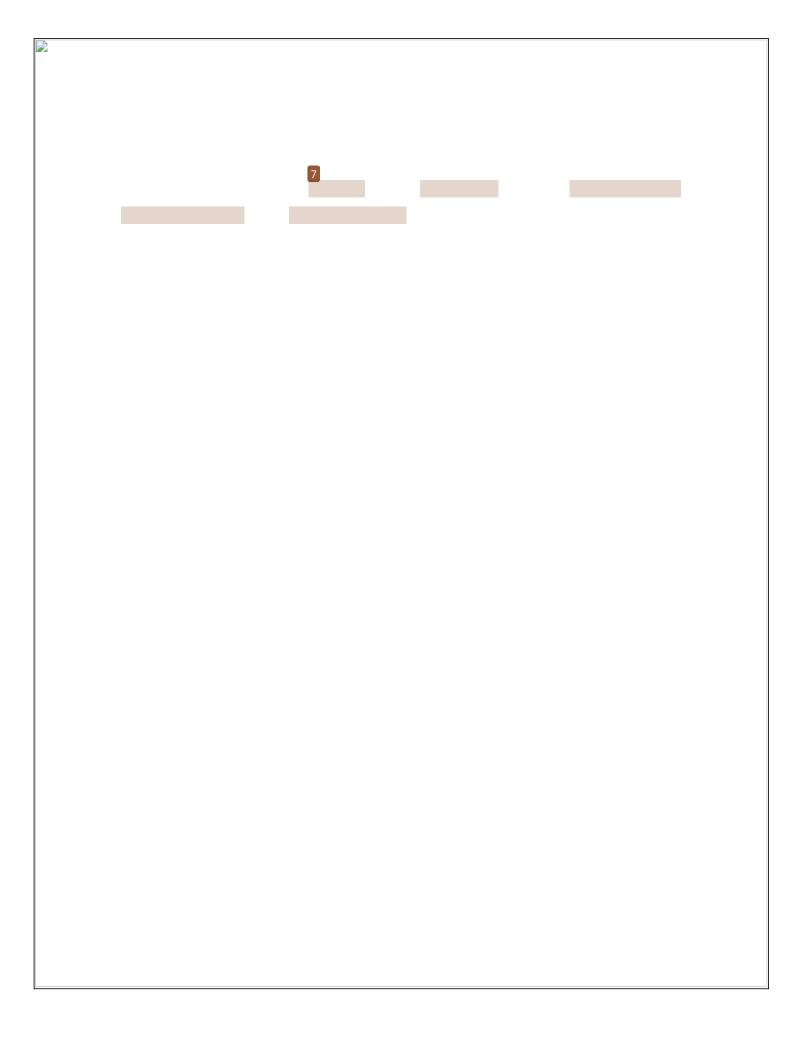
INTRODUCTION

Artificial Intelligence (AI) is a branch of computer science that aims to imitate human thinking ability, learning, planning, and reasoning to solve complex problems. Originally started in 1956, scientists at that time began theorizing a computer's ability to

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this field and how it can aid them in caring for patients. In this narrative mini-review, we provided an overview of the pulmonary diseases that are commonly diagnosed and managed by general pulmonologists for which AI has been applied including obstructive lung disease, interstitial lung disease, pulmonary tuberculosis (TB), coronavirus disease 2019 (COVID-19) pneumonia, lung nodules and lung cancer.

PubMed was searched from inception to November 30, 2021, using keywords: "artificial intelligence, lung disease", " artificial intelligence, pulmonary disease", "artificial intelligence, COPD, asthma", " artificial intelligence, interstitial lung disease", "artificial intelligence, tuberculosis", "artificial intelligence, COVID-19", and "artificial intelligence, lung nodule, lung cancer". All types of published publications were included, *e.g.*, reviews, observational studies, and meta-analyses. We prioritized recent articles within five years in this narrative mini-review.

OBSTRUCTIVE LUNG DISEASES

The gold standard of diagnosis in obstructive lung diseases like asthma and chronic obstructive pulmonary disease (COPD) involves a combination of signs, symptoms, and spirometry. While AI cannot replace the clinicians' role, it can complement clinicians' interpretation of the data available at the bedside. A study by Topalovic *et al.* compared the accuracy of pulmonologists' interpretation of pulmonary function testing to an AI-based software that used more than 1430 historical patient cases[7]. Both groups were asked to study 50 patient cases and correctly interpret the pulmonary function test while placing them in diagnostic categories. AI-based software was found to outperform the pulmonologist interpretation by a substantial margin[7].

Chronic Obstructive Pulmonary Disease (COPD)

According to the Global Strategy for Diagnosis, Management and Prevention of Chronic Obstructive Pulmonary Disease (GOLD) reports 2022, COPD is one of the top three causes of death in the world[8]. Moll *et al* also proposed a machine learning mortality

prediction model for patients with COPD based on six-minute walk tests, percent predicted of forced expiratory volume in 1 s (FEV1), and age[9]. While the gold standard of diagnosis of COPD is spirometry, studies have suggested that artificial intelligence and deep learning can potentially be utilized to screen patients for COPD. Tang *et al.* suggests that low dose computed tomography (CT) screening of the lungs of both smokers and ex-smokers can be examined using deep residual networks to potentially identify patients who may have COPD but remain undiagnosed[10]. The Genetic Epidemiology Study (COPDGene) is one of the largest data sets obtained over ten years, consisting of chest imaging, spirometry, and molecular data from patients with COPD. This has been used as the source for studies relating specific COPD phenotypes to genetic and molecular mechanisms and mapping the disease progression of various COPD subtypes[11]. The study by Fischer *et al.* describes an algorithm that can perform lung lobe segmentation and emphysema quantification, which has been shown to correlate with different GOLD stages in patients with COPD per their spirometry data[12]. AI-based applications have also been suggested to help patients identify if they may be having an exacerbation at home and when they should seek help from a medical professional[13]. This will promote patient responsibility and potentially save on resources, including emergency department visits.

Asthma

Asthma is an intermittent and reversible obstructive lung disease with multiple phenotypes. AI may improve diagnosis, phenotype classification, prediction of asthma exacerbations and treatment response[1,15]. Multiple studies have shown good accuracy of ML-based algorithms in screening and diagnosis of asthma in adult patients[1]. When using the machine learning approach as well as cluster analysis, the highest corticosteroid-responsiveness phenotype was identified in patients with low pulmonary function, high serum eosinophils, nasal polyps, and late-onset asthma[14]. The least corticosteroid-responsiveness phenotype was also found in young, obese females with early-onset asthma[14]. Phenotype identification can help tailor asthma management

and possibly improve outcomes. Qin *et al.* adopted deep learning algorithms-based high-resolution computed tomography (HRCT) chest images to assess small airway thickness with the aim of steroids response evaluation in asthma patients with small airway obstruction[15].

INTERSTITIAL LUNG DISEASE

Interstitial lung disease (ILD) is an umbrella term that encompasses all disease processes that can cause pleural/parenchymal inflammation and scarring. Deep learning algorithms can help with the diagnosis of ILD using HRCT chest images. In a case-control study by Walsh *et al.*, a database of 1157 de-identified HRCT images showing evidence of diffuse fibrotic lung disease were classified using the American Thoracic Society/European Respiratory Society/ Japanese Respiratory Society/Latin American Thoracic Association (ATS/ERS/JRS/ALAT) idiopathic pulmonary fibrosis guidelines. These images were divided into multiple groups and read by a deep learning algorithm as well as 91 thoracic radiologists. Walsh *et al.* found the algorithm outperformed thoracic radiologists' interpretation with the median accuracy of 73.3% vs. 70.7%[16]. This study showed that deep learning algorithms could serve as a helpful tool in the diagnosis of ILD[16]. Other studies have used AI algorithms to evaluate HRCT images of patients with interstitial pulmonary fibrosis and have successfully been able to quantify airway volumes and parenchymal lesions[17,18]. Choe *et al.* revealed that deep learning increases the diagnostic accuracy of chronic hypersensitivity pneumonitis, cryptogenic organizing pneumonia, nonspecific interstitial pneumonia, and usual interstitial pneumonia patterns[18].

PULMONARY INFECTIONS

The utilization of AI has also been investigated in multiple pulmonary infections. Here, we briefly review the utilization of AI in pulmonary tuberculosis and COVID-19.

Tuberculosis

TB remains a significant cause of mortality in many parts of the world. Due to the variable presentations on TB in chest radiography, diagnosis remains a challenge. The first conventional computer-aided diagnosis (CAD) was made in 2016 to aid in the detection of TB. Over the years, investigators have also developed multiple CAD algorithms that can detect various radiographic findings in TB, for example, cavitary and focal TB[19]. AI has been suggested as an aid to review records, identify symptomatic patterns, surveillance, and factors that may contribute to the treatment and medication adherence failure in TB[20]. Doshi *et al.* describe innovative ways in which AI-based software can provide access to care and facilitate the management of TB patients worldwide[21].

COVID-19

In recent times, COVID-19 has taken the world by storm. Morbidity and mortality around the world have risen as treatment options for COVID-19 remain largely experimental. AI software has been developed to aid in the early diagnosis of COVID-19. In the retrospective, multi-center study by Li *et al.*, a deep learning model, COVID-19 detection neural network was developed to identify CT findings of COVID-19 infection and differentiate it from findings in community-acquired pneumonia[22]. Another study developed a deep learning convolution neural network to effectively stage the severity of COVID-19 infection *via* scoring of various radiographic features[23]. This can help in early prognostication of the disease, which can help in making early treatment decisions. Another study by Burdick *et al.* used ML algorithm to build a model which uses inputs of diastolic blood pressure (DBP), systolic blood pressure (SBP), heart rate (HR), temperature, respiratory rate (RR), oxygen saturation (SpO2), white blood cell (WBC), platelet count, lactate, blood urea nitrogen (BUN), creatinine, and bilirubin to predict the need for mechanical ventilation[24]. Furthermore, investigators have developed deep learning algorithms which help to identify protein structures and shapes. The data provided using this algorithm has been invaluable in the development of the COVID-19 vaccine[6].

PULMONARY NODULES AND LUNG MALIGNANCY

Despite recent advances in the treatment of pulmonary malignancies, the World Health Organization (WHO) still considers them among the deadliest of all solid malignancies[25]. Early and accurate diagnosis remains paramount in improving patient outcomes. CAD systems use deep learning algorithms as an aid for radiologists in analyzing CT images by lung segmentation, providing a more focused analysis, allowing nodule detection and classification. One such state-of-the-art algorithm implemented by Siemen Healthcare uses statistical finite element analysis or three-dimensional lung segmentation in adversarial neural network training[26]. A study by Chauvie et al. compared different machine learning algorithms and lung-RADs criteria and concluded that neural network algorithms enhanced the positive predictive value in chest digital tomosynthesis (DTS) in lung cancer detection[27]. The main disadvantage of deep learning is that it does not provide uniform features for identifying malignant vs. benign nodules. This problem can be addressed using Radiomics[28]. Radiomics is a method of identifying and using features from one image in order to provide data-characterization algorithms. This tool can help in finding characteristics of malignancies otherwise not seen by human experts. The combination of Radiomics and deep learning will provide radiologists around the world the advantage in diagnosing pulmonary malignancies. Finally, a study by Afshar et al. has even proposed a deep learning-based Radiomics model to predict the time-to-event outcome prediction, that utilizes raw images of CT and PET (Positron Emission Tomography) scans and can calculate the image-based risk of death or recurrence, for each patient[29].

LIMITATIONS OF AI IN CLINICAL PRACTICE

Despite the promising outcomes of AI, missing data, small or unstructured databases may result in unsatisfactory AI quality. For example, in the diagnosis of lung nodules and lung malignancy, the software's ability is compared to the ability of expert radiologists. However, since the ultimate goal is to diagnose malignancies and not just

identify lung nodules, algorithms should be made to focus on identifying malignancies with a different reference standard[30]. Regarding the use of AI in diagnosing early COVID-19 infection *via* CT images, it should be noted that CT scan has high sensitivity but does not have very high specificity for COVID-19. So, diagnosing the disease based solely on CT images with the help of AI may lead to overdiagnosis[31]. Furthermore, the cooperation of physicians and AI researchers is needed to be able to develop well-structured AI applications that can be validated in real-world study before launching AI models into clinical fields.

CONCLUSION

The implementation of AI and machine learning algorithms is an evolving and relevant topic in pulmonary medicine. Human errors can occur in the medical field. It can be associated with missed, late, and incorrect diagnoses leading to health and economic burden. AI is an efficient tool that can be implemented to prevent this problem by aiding in the fast, accurate, and early diagnosis, prognostication, as well as treatment of pulmonary diseases. Nonetheless, the lack of knowledge and confidence in applying AI into practice may hinder the utilization of AI in the medical field. Moreover, well-performed AI algorithms require a large well quality database. Physician and AI algorithm developers should work closely to minimize these limitations. While AI alone cannot replace clinician expertise, it can add to their armamentarium and improve patient care and healthcare worldwide.

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and COPD diagnosis", The Journal of Allergy and Clinical Immunology: In Practice, 2021

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