Application of Artificial Intelligence in Pediatric Pulmonology: Current Scenario and Future Prospective

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Abstract

Background: Artificial intelligence is well poised to be a multi-dimensional resource for children and their health in the future. Recent advancement in machine learning and algorithms have helped tackle diseases like asthma, pneumonia, and lung nodules.
Objectives: Present study aims to provide a detailed overview of AI application in Pediatric Pulmonology.
Methods: Many articles, published in review journals have been included to write the current review. The literature search was done by using electronic databases such as PubMed, Google Scholar, ResearchGate, Frontiers. Pictorial descriptions of AI efficiency have been included for better understanding. Studies have been reviewed to highlight the pandemic scenario and its effect on children.
Results: Various studies have shown promising results of AI application in Pediatric Pulmonology through efficient imaging and digital technology-based devices. The utility of AI technique has been included under the following subheadings 1) Artificial Intelligence in Pediatric Auscultation, 2) Artificial Intelligence in Pediatric Imaging, 3) Artificial Intelligence based Pediatric PFTs, 4) Machine learning in prediction of childhood asthma persistence, 5) AI in Pneumonia diagnosis in children, 6) AI in Pediatric Pulmo-oncology, 6) Covid-19 scenario, 7) Current and Future Perspective of AI, 8) Challenges and Pitfalls of AI in Pediatric Pulmonology.
Conclusion: AI technology has come a long way in the field of Pediatrics especially during the post-covid scenario through novel digital devices and automation. Lack of technology awareness, funding and AI in study curriculum are a few challenges faced by the health care professionals currently. These limitations must be addressed for more clinical utility in daily practice.

Keywords: Artificial Intelligence; Machine learning, Pediatrics; Pediatric pulmonology; Deep learning. pulmonary function test.
DOI: 10.21608/svuijm.2023.195963.1544
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Received: 28 March, 2023.
Revised: 7 May, 2023.
Accepted: 1 July, 2023.
Published: 9 July, 2023
Cite this article as: Abdullah Abdullah Alzayed. (2023). Application of Artificial Intelligence in Pediatric Pulmonology: Current Scenario and Future Prospective. *SVU-International Journal of Medical Sciences*. Vol.6, Issue 2, pp: 501-510.

Introduction

Given that the volume of healthcare-related data generated from different sources is continuously increasing every year by 48 percent, only artificial intelligence (AI) with its branches machine learning and deep learning, can analyze without any complications **(Khemasuwan et al., 2020)**. Overflowing research activities and development into digital technologies was put to ensure higher quality and to overcome existing problems and challenges in healthcare. AI was firstly introduced in the 1990s, as "the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable **(Ronquillo et al., 2021)**." Therefore, it is defined as the capability of computers and machines to simulate human intelligence **(Clancy, 2020)**.

The constant advancement of AI in the healthcare industry aims to aid medical professionals and introduce improvements in care delivery, such as utilizing past data to predict the progression of a disease through extensive database analysis **(Park et al., 2020; Schaefer et al., 2020)**.

Regarding AI application in pulmonary medicine, research increased by 5 folds from 171 articles published between 2010 and 2014 to 930 papers during the period of 2015- 2019 **(Khemasuwan et al., 2020)**.Applications of AI or its sub-entities machine learning and deep learning in clinical pulmonary medicine included: A) Computer vision (image and video recognition) used for identifying lung nodule and prediction of the risk for malignancy **(Ardila et al., 2019; Baldwin et al., 2020; Massion et al., 2020)**, B) Computer vision and molecular signatures used in identifying fibrotic lung diseases **(Christe et al., 2019; Walsh et al., 2018)**, and lastly C) Prediction models in pulmonary hypertension-related injuries, asthma, and pleural infections **(Khemasuwan et al., 2020)**. Furthermore, AI was also found to be very useful tool in battling the novel COVID-19 pandemic by early detecting and diagnosing the cases, automatically monitoring and predicting the virus spread and developing drugs **(Vaishya et al., 2020)**.

The application of AI in pediatric pulmonology is still largely lacking when compared to adult pulmonology even during SARS-CoV-2 infection. However, learning from the currently developed adult models may substantially aid in improving the accuracy of pediatric AI healthcare **(Dayan et al., 2021)**. Even among the pediatric population, there is clear difference between newborns, infants, children, and adolescents in terms of clinical characteristics setting higher obstacles for the adaptation of AI in this domain **(Nino and Linguraru, 2022)**. A novel method, the federated learning approach (also called collaborative learning) apply the algorithm on various decentralized databases. This allows different locations to train and contribute to a global AI model in a secure manner, by only sharing specific model weights **(Dayan et al., 2021)**.

It has been noted that AI is primarily utilized for automating tasks that would otherwise be done by humans, with the advantage of increased efficiency and cost savings. However, many individuals in the field view AI as a potential risk to their employment, due to a lack of understanding and familiarity with its applications **(Das et al., 2018)**. For example, professionals need to have an understanding of how AI works with

different lung conditions that have similar characteristics **(Kaplan et al., 2021)**.

The purpose of this review is to provide an overview of the current use of AI in pediatric pulmonology and to discuss potential future developments in the field.

Artificial Intelligence in Pediatric Pulmonology

The AI solutions for accumulating data in healthcare such as electronic medical records, medical imaging techniques, and electronic diagnostic tools are slowly emerging, facilitating better patient diagnosis, optimal prognosis, and accurate treatment plan **(Castro et al., 2009)**. Artificial intelligence is now steadily finding its way in Pediatric medicine especially in Pulmonology owing to the increase in COVID-19 cases and absurd symptoms among children. Millions of children today suffering from various lung diseases such as wheezing, asthma, pneumonia, pediatric sleep apnea, bronchopulmonary dysplasia should also benefit from artificial intelligence soon. AI finds its application in Pediatric Pulmonology in terms of pulmonary auscultation, pulmonary imaging, and pulmonary function tests **(Nino and Linguraru, 2022)**.

Artificial intelligence in Pediatric pulmonary auscultation

Lung auscultation plays a vital role in the physical examination of any lung/pulmonary disease. It has been a vital part since the time of Hippocrates. The results depend on the clinician's experience and capability to recognize and differentiate various sound abnormalities heard via a 'Stethoscope'. It was first introduced by Laennec over 200 years ago **(Roguin, 2006)**. Now, a new method using automatic sound analysis based on neural networks (NNs) is being implemented in a system that utilizes an electronic or digital stethoscope for recording respiratory sounds **(Leng et al., 2015)**. There has been a rapid advancement in the diagnosis and follow-up methodology of lung pathologies, the auscultation of breath sounds using a stethoscope remains a vital part of initial lung diseases. The use of stethoscope-based examination is easy, cost-effective, and non-invasive, which allows for quick and convenient repeated examination, particularly for pediatric patients. Conventional stethoscope-based examination can be prone to bias and rely heavily on the physician's clinical experience and auditory skills. Additionally, it can be difficult to repeat the examination, there is a lack of ability to save or share sound signal, and it is challenging to repeatedly monitor breath sounds- these are some of the known limitations of conventional stethoscope **(Leng et al., 2015)**. To overcome such limitations, AI based electronic stethoscope is used to collect breath sounds of children with lung diseases. Auscultatory sounds are of 4 types: fine sound, wheezes, rhonchi, and coarse crackles. A study by Kevat and colleagues discovered that the accuracy of AI algorithms were comparable to that of experienced pediatric respiratory physicians **(Kevat et al., 2020)**.

Auscultatory sounds were accumulated by the respiratory department of Shanghai Children's Medical Centre (SCMC) with a digital stethoscope. Chest location specific results were determined using a benchmark (Gold Standard) established by two specialists in pediatric lung medicine and six general pediatricians (Fig.1). The performance of an AI algorithm and general pediatricians was assessed in terms of accuracy, sensitivity, and F-1 score in relation to the Gold Standard **(Scrafford et al., 2016)**. A total of 112 children diagnosed with lung diseases participated in the study from

May to December 2019. A total of 672 breath sounds were collected of which 261 were wheeze, 149 were crackles and 263 were normal breath sounds, which completely examined by AI algorithm. The precision of detection of breath sounds by general pediatricians and AI algorithm using GS were found to be 59% and 78% respectively. The precision, specificity, sensitivity, and F-1 score in crackles and wheeze detection from the AI algorithm were significantly more than as compared to the general pediatricians **(Zhang et al., 2021)**.

Artificial Intelligence in Pediatric Pulmonary Imaging

Presently, AI has been widely used around the world for analyzing medical images and identifying, diagnosing, and predicting lung conditions. One of the most common types of images used is chest X-rays, which are frequently analyzed with AI technology. Chest radiographs are ideally used to detect critical and developing diseases **(Zhang et al., 2021)**. Nevertheless; it is not easy to obtain a radiographic report by the radiologist in an urgent situation which requires prompt decisions to be made based on their radiographic interpretations. As a result, there is a growing need for AI-based systems that can identify abnormalities on chest X-rays **(Shin et al., 2022)**. The initial AI programs for chest X-ray analysis were developed to detect lung nodules and lower the number of missed lung cancer cases. These systems have since been expanded to also identify other conditions such as pneumonia, pneumothorax, and rib fractures on chest radiographs **(Davendralingam et al., 2021)**.

Artificial Intelligence leads Pediatric Chest Radiography

A study was conducted by Shin et al **(Shin et al., 2022)** to investigate whether AI software designed for adult chest X-rays could also be used on pediatric chest X-rays. The study retrospectively included pediatric patients (age 18 or younger) who had chest X-rays taken between March and May 2021. The AI-based lesion detection software was used to evaluate the presence of nodules, consolidation, fibrosis, cardiomegaly, pleural effusion, pneumothorax, and pneumoperitoneum. The software's diagnostic performance was assessed by comparing its results to those of pediatric radiologists. The study included 2273 chest X-rays, and the AI software had a sensitivity of 67.2%, specificity of 91.1%, positive predictive value of 57.7%, negative predictive value of 93.9%, and accuracy of 87.5%. The results were found to be affected by age, with sensitivity, specificity, positive predictive value, negative predictive value, and accuracy all increasing when cardiomegaly and children 2 years old or younger were excluded. The study concluded that AI software designed for adult chest X-rays showed diagnostic accuracy of up to 96.9% for pediatric chest X-rays when cardiomegaly and children 2 years old or younger were not included, but it need to be further validated in younger children **(Zhang et al., 2021)**.

Artificial Intelligence Based Pediatric Computed Tomography (CT)

Chest CT (Computed Tomography) scans are not as frequently used in children but can be beneficial in evaluating children with respiratory illnesses, infections, or lung diseases **(Manson, 2012)**. The main use of chest CT in pediatrics is for identifying lung cancer and its characteristics. Other applications include identifying pneumonia, particularly in cases of COVID-19, identifying obstructive lung disease, and analyzing emphysema. However, the detection of blood clots in the lungs, analysis of emphysema, and identifying and evaluating COVID-19 and fibrosis are not as relevant for children **(Schalekamp et**

al., 2022). CT scan makes its way in pediatrics in the diagnosis and evaluation of lung nodules using a combination of Low Dose Computed Tomography (LDCT) and High-resolution Computed Tomography (HRCT). HRCT significantly improves the visualization of fine structural details of lung nodules/ pathologies **(Davendralingam et al., 2021)**.

Pediatric Pulmonary Function Tests (PFT)/ Lung Assessment Tests

Pulmonary function tests (also called lung function tests) are a commonly used method to evaluate the performance of the respiratory system **(Liu et al., 2021)**. These tests are typically interpreted by experts based on the pattern they observe (normal, restrictive, obstructive, or mixed) **(Giri et al., 2021)**. PFTs commonly done in children include- spirometry and forced oscillometer.

Artificial Intelligence-based Pediatric PFT

In 2005, the American Thoracic Society and European Respiratory Society (ATS/ERS) created a streamlined approach for assessing lung function in medical settings **(Baemani et al., 2008)**. When the recommended guidelines were added to the software for diagnostic support, accuracy of disease identification was only 38%. However, when patient characterizations were added into the algorithm the accuracy improved to 68%. This indicates a vast potential for computerized diagnostic labelling when combining PFTs with clinical information **(Giri et al., 2021)**. Successful application of artificial intelligence is rising significantly in Pediatric Pulmonology domain.

Machine Learning (ML) in Prediction of Childhood Asthma Persistence

Asthma is a chronic condition characterized by inflammation and constriction of the airways, leading to increased mucus production and difficulty breathing. It is a prolonged condition which has no cure hence the focus is on long-term management. Machine learning can effectively predict which children diagnosed with asthma before the age of 5 will continue to experience symptoms as they age **(Topalovic et al., 2019)**.

Investigators from Children's Hospital Philadelphia and Perelman School of Medicines used 5 ML models to train them to differentiate between children with transient asthma and children whose symptoms would persist in future and required treatment between ages 5 and 10 years. A retrospective data set containing Electronic Health Records (EHR) of 9934 children was utilized to check which children ended up with persistent diagnosis of asthma. The XBoost ML model performed the best among the other models. The study found that machine learning models can effectively predict which children diagnosed with asthma before the age of 5 will continue to experience symptoms as they age. The models determined that the age at diagnosis and previous utilization of healthcare services were important predictors of asthma. This information could be useful for guiding clinicians and parents on treatment options for asthma in early childhood **(Topalovic et al., 2019)**. The study included children between the ages of 2 and 5 who had an initial asthma diagnosis recorded during an inpatient stay, ambulatory visit, or emergency department visit between 2005 and 2016. To qualify as having persistent asthma, the child must have had at least one additional asthma diagnosis between the ages of 5 and 10 and have been prescribed an asthma-related medication at least once after their initial diagnosis at or after age 2 **(Topalovic et al., 2019)**.

There were 8802 children (89%) having persistent asthma diagnosis in the sample, and remaining 1132 children (11%) had transient asthma. The National Heart, Lung and Blood Institute Expert Report Panel guided the development of models for asthma diagnosis which set certain guidelines. This divides the childhood asthma diagnosis and management into 3 age groups: 0-4, 5-11, 12-17 years. The asthma diagnosis in youngest group was controversial because this could be misguided by a viral wheeze that could be mistaken for the classic asthma symptoms **(Topalovic et al., 2019)**. An important predictor of persistent asthma is the Capillary blood lead testing, along with the use of montelukast, an asthma control medication according to the study **(Bose et al., 2021)**.

Artificial Intelligence in Pneumonia diagnosis in Children

Pneumonia is a serious condition that can lead to death in children, but prompt diagnosis and appropriate antibiotic treatment can greatly improve the outcome. Pulmonary ultrasound proves to be an effective tool to detect lung consolidation **(Yu et al., 2020)**. The use of image analysis and pattern recognition is an effective method for automating the diagnosis of pneumonia consolidation without the need for expert analysis. One approach to this is to analyze the distribution of brightness patterns in characteristic vectors derived from ultrasound images. The standard NNs using AI method is used for the evaluation of the vectors **(Correa et al., 2018)**. The pulmonary sounds of healthy and pneumonia patients are recorded using an electronic stethoscope. These are represented in a wave format. Audacity Software is used to remove the unwanted external noise which affect its efficiency. The accumulated dataset is divided into training and test data. The efficiency of these audio files is determined using the SVM (Support Vector Machine) classifier, gradient boosting algorithm and KNN (K nearest neighbors) classifier **(Xia et al., 2016)**.

AI based Pediatric Pulmo-Oncology

By utilizing machine learning (ML) algorithms, the accuracy and efficiency of tumor diagnosis can be increased, as well as the selection of appropriate therapy and prediction of long-term outcomes. Deep CNNs have the capability to process large amounts of imaging and clinical data, as well as medical history, quickly, which can accelerate the diagnosis process and enable personalized treatment **(Vidhya et al., 2022)**. To improve the long-term results, cancer detection at an early stage of development is important. By utilizing ML tools, it is possible to identify patients at high risk of a certain condition, recommend the most appropriate screening test for each individual, and improve the selection of patients who would benefit from advanced imaging tests.

HRCT scans help in accurately diagnosing the lung pathologies in a short period of time and hence facilitate detection and treatment in early phases **(Manson, 2012)**. Deep convolutional neural networks (CNNs) are used to enhance standard-dose Fludeoxyglucose F18-positron emission tomography (FDG-PET) scans by reconstructing them from lower-dose images. This is achieved through techniques such as ordered subset expectation maximization, convolutional de-noising auto-encoders, and commercially available software **(Ramesh et al., 2021)**.

Covid-19 Scenario in Pediatric Pulmonology

Covid-19 ignited a huge health crisis globally that challenged many

physicians with an unprecedented workload and lack of resources for patient care. Application of AI in healthcare immensely improved patients' clinical outcomes during Covid-19 pandemic **(Daldrup-Link, 2019)**. Many studies have been conducted to evaluate the efficiency of AI during the pandemic in adults. Unfortunately, such studies are yet to be conducted in Pediatric population. There has been a false perception of covid-19 affecting only the older patients, since in 2022 pediatric hospitals were overwhelmed with increase in hospitalization of children affected by the virus **(Nino & Linguraru, 2022)**. Currently, 18.9% of total Covid-19 cases are among children. Before the pandemic, respiratory illnesses were a leading cause of hospitalization and death among children. To combat pediatric Covid-19, new strategies should be implemented, including the use of AI technology specifically designed for children to aid in early detection, risk assessment, and prediction of outcomes for Covid-19 and other respiratory illnesses in children **(Daldrup-Link, 2019)**.

Current and Future Perspective of AI in Pediatric Pulmonology

Despite the significant research showing the potential benefits of AI in healthcare, a limited number of AI-powered devices have been approved by the FDA. The FDA recognizes the potential of AI devices that can improve over time through machine learning algorithms. AI technology has the potential to revolutionize healthcare in a number of ways, including improving the identification of biomarkers to treat cancer, assisting in mental health diagnosis, increasing patient safety, speeding up drug development and enhancing overall effectiveness **(Chauhan et al., 2022)**.

Challenges and Pitfalls

AI faces challenges in the field of Pediatrics in many ways, there are few sectors which require improvisation. Robotic devices pose a threat to privacy and security issues of an individual. AI has a risk of meeting the terms and norms of regulatory policies. Data collection using the AI algorithms leads to under standardization all the limitations associated with AI; quality management is a serious obstacle **(Knake, 2023)**. Due to the high maintenance of the ML devices, it makes them less cost-efficient. Furthermore, ethics and morality are vital features that is difficult to incorporate into an AI. Human connections which form the basis of any team cannot be replaced by computers **(Li et al., 2020)**.

Conclusion

AI is significantly expanding in the field of pediatrics owing to its faster diagnosis, accuracy, improved decision-making, more specific and sensitive identification high-risk and improved clinical results. AI algorithms have been used to analyze chest X-rays and computed tomography scans, aiding in the detection and diagnosis of lung conditions in children. Machine learning models have also been successful in predicting childhood asthma persistence and automating pneumonia diagnosis. While AI in pediatric pulmonology is still in its early stages compared to adult pulmonology, the advancements made in adult models can be adapted and refined for pediatric use. There are various legal issues pertaining to the use of AI especially in under-developed and developing countries. To overcome the obstacles, academic institutions should support and reward the development of AI capability and capacity in medical students.

Funding
No external funding was received for this research project.

Disclosure
The author reports no conflicts of interest in this work.

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