Int J Adv Life Sci Res. Volume 7(3) 55-64
https://doi.org/10.31632/ijalsr.2024.v07i03.005

International Journal of Advancement in Life Sciences Research
Online ISSN: 2581-4877
Journal homepage http://ijalsr.org

Review Article

Cognitive Computing in Respiratory Health: Revolutionizing Medicine Through Artificial Intelligence (AI) And Machine Learning (ML)

V. Agilandeswari[1], Muddasir Basheer[2], Shayari Bagchi[3], Gowtham Menon[4*], P. Muthu Prasanna[5]

[1] Madurai Kamaraj University, Madurai -625021, India
[2] Department of Zoology, Government Degree College for Women, Anantnag, Jammu and Kashmir, India.
[3] Department of Computer Science and Engineering, VIT University, Chennai, India
[4]Department of Pharmaceutics, Sanjivani College of Pharmaceutical Education and Research, Kopargaon, Maharashtra, India
[5]Department of Pharmaceutical Biotechnology, Surya School of Pharmacy, Vikiravandi–605 652, Villupuram Dt. Tamil Nadu, India

***Correspondence E-mail:** gowthamm1984@yahoo.com*

Abstract

Human errors in medical practice can lead to misdiagnosis, resulting in inappropriate treatment and serious risks to patient health. Artificial Intelligence (AI) and Machine Learning (ML) have emerged as valuable tools for reducing such errors, particularly in medical diagnostics. These technologies can rapidly and accurately analyze large volumes of data, providing additional insights that help healthcare professionals to make more accurate decisions. AI excels in providing solid evidence to guide clinical decisions, reducing reliance on subjective judgments. It can analyse complex datasets and identify patterns that have chances to be overlooked by human eyes, thus leading to improved diagnostic accuracy and treatment plans. ML, a component of AI, uses adaptive models that learn from extensive datasets, though these models must be trained on high-quality data to avoid perpetuating errors or biases. In pulmonary medicine, AI and ML have shown considerable potential in diagnosing and treating conditions such as asthma, chronic obstructive pulmonary disease (COPD), and pulmonary fibrosis. These technologies help determine disease staging, forecast exacerbations, and estimate survival rates. By harnessing AI and ML, clinicians can make more precise diagnoses, customize treatments to individual needs, and detect early signs and ultimately enhance patient outcomes. Moreover, AI and ML can minimize patient risks by providing a broader and more in-depth analysis of medical data. This review explores how these technologies can process large datasets to deliver insights that surpass human capability, fostering error-free diagnosis and treatment.

Keywords: *Artificial intelligence, AI in Pulmonary Function Tests, COPD Treatment, Machine learning, Respiratory diseases.*

Introduction

The application of artificial intelligence (AI) in the field of health care, particularly in respiratory medicine, is a progressive subject. Machine learning (ML) is a subset of AI in which computers use analytical techniques to acquire knowledge and to improve their performance without the need for

Received on : 2nd May 2024; Revised version received on :17th June 2024; Accepted: 1st July 2024

specific algorithm programming (Kibria *et al.*, 2018). Computer learning, often compared to a "black box," can be complex and challenging to decipher. In general, online training and aggregation methods can improve prediction accuracy, it can lead to learn from flawed instances, arising from human errors. Investment in health initiatives using AI surpasses development in any other area in the worldwide market (Mhlanga, 2023).

The healthcare sector had a significant surge in interest in AI from 2019, with investors allocating $3.8 million to this field. This is a substantial increase from the $3 billion spent in healthcare AI in 2018(Kumar *et al.*, 2023). In this domain, for pulmonary medicine, several studies have been reported, demonstrating encouraging outcomes in AI integration (Mekov *et al.*, 2020). The foundation of evidence-based healthcare (Walshe & Rundall, 2001) is based on clinician judgement using available data employing statistical techniques, that identify similarities in the information and represent these as numerical calculations, such as logistic extrapolation. ML enables AI to develop intricate connections that are not expressible by a mathematical formula using neuronal networks models representing information using a complex network of linked neurons, that resembles the structure of the human brain (Nwadiugwu, 2020). ML systems can analyze data similar to physician or health care providers, handling large amounts of datas simultaneously and acquiring knowledge with each instance. They rely on information integrity for reliability and predictability. Extraction of extensive datasets from electronic health records (EHR) is a common approach, since at several medical establishments, a large number of EHR are generated on a daily basis. This data may be obtained in an anonymous version and examined using traditional statistical techniques to address a particular research inquiry (Zhang, 2020).

There are reported studies for clinical decision support that uses immediate time dynamic analysis of all the knowledge stored in electronic health records (EHRs) (Liu *et al.*, 2022). In order to utilize the data within the EHRs effectively, it is essential to integrate computational abilities with Natural Language Processing (NLP). NLP is a specialized field that combines linguistics, computer science, information engineering, and AI to analyses and comprehend text, using algorithm language. The NLP system has the ability to analyses and collect the desired knowledge from a vast volume of datas (Fanni *et al.*, 2023). The integration of NLP and computational prowess in EHRs is critical for efficient data analysis. NLP, an interdisciplinary field, enables systematic data analysis and insight extraction from large volumes of data. While AI and ML advancements aid healthcare decision-making, the physician has the final responsibility for making decisional choices (Stamer *et al*., 2023).

This review explores the use of AI in creating complex algorithms for medical decision-making, particularly in the field of lung disease. It highlights the importance of AI in situations where physicians lack sufficient information to make informed decisions and supports the usage of overall presence of extensive dataset and the advancing capabilities of computer intelligence techniques enhancing the therapeutic advantages and reduce patient’s risks (figure 1).

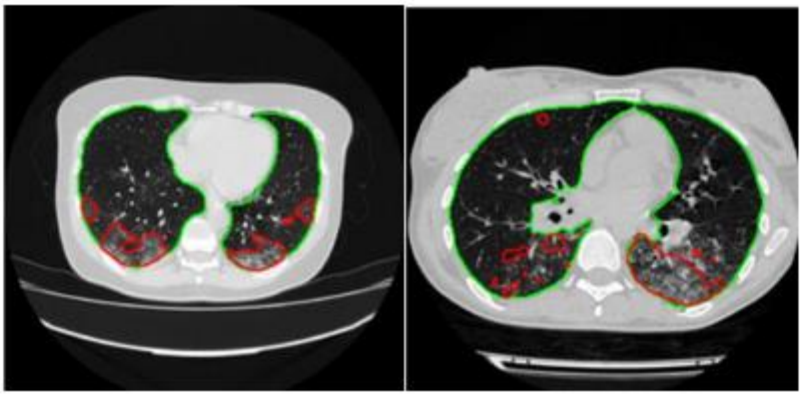

Figure 1: Shows AI predicted red colour masks of specific site in lungs of COVID 19 infection from machine learning algorithms models: A) lung segmentation network (AI model-DenseNet 161 UNet):

B) Lung lesion segmentation network (AI model-DenseNet201 FPN). Ref (Qiblawey et al., 2021), This image is used under the Creative Commons Attribution License 4.0 (CC BY).

AI for Chronic Obstructive Pulmonary Disease Diagnosis (COPD)

Chronic Obstructive Pulmonary Disease (COPD) is a prevalent and manageable condition characterized by chronic pulmonary obstruction and restricted airway. This is triggered by allergens in the airways and/or alveoli, typically resulting from substantial contact to harmful particulates or gas. At present, COPD represents the fourth most prevalent source of mortality worldwide and on a global scale, the incidence of COPD would rise (Chen *et al.*, 2023). In the near future, substantially increased prevalence of COPD due to ongoing exposure to risk conditions and the ageing population can exist. AI systems analyze a dataset to identify trends that can be utilized for predicting clinical outcomes or identifying obstructive characteristics (Bhaskaran *et al.*, 2023). ML is effectively employed for the automated interpretation of pulmonary function tests and the differential diagnosis of obstructive lung disorders. Computed tomography (CT) is a sophisticated imaging method used to identify and analyze emphysema, as well as evaluate airway conditions (figure 2). The neuronal networking approach is a cutting-edge field for recognizing obstructing patterns in CT scans (Ohno *et al.*, 2023). Gene and ECLIPSE studies were used to assess the feasibility of utilizing CT imaging approach for diagnosing and classifying COPD, as well as predicting relapse and fatality rates (Liu *et al.*, 2023). The authors of this reported study trained a model using CT scan datas from COPD Gene patient's database and applied it to 1672 ECLIPSE patient's software. The model achieved a concord index of 0.856 for COPD and accurately classified 50% of participants according to GOLD criteria. However, it had slightly lower performance in ECLIPSE, with a correct staging rate of 29% and 75% for staging inside the same or earlier stage. The model also predicted terminal condition in COPD Gene participants.

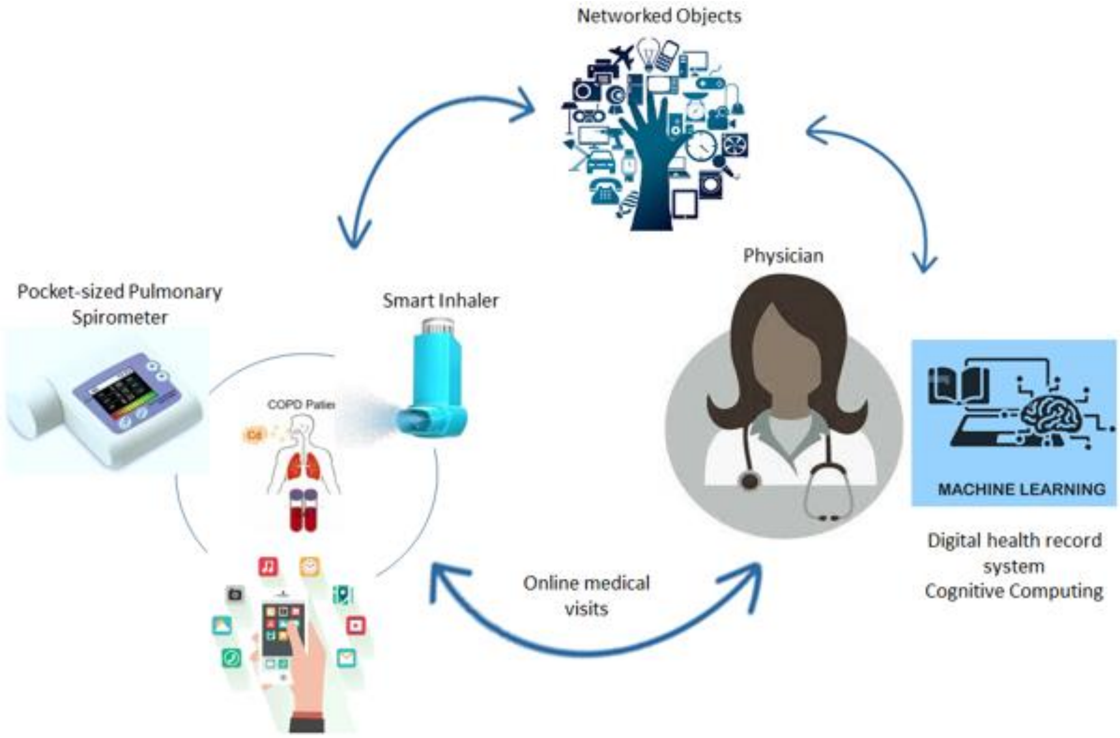

Figure 2: AI in COPD Diagnosis (image credit:author: Gowtham Menon)

Inhalation devices have a key role in the management of COPD. The utilization of these devices entails multiple procedural stages, and a significant number of patients commit errors during their usage. Supervising the accurate method of inhaling and adherence to treatment are critical for enhancing the efficacy of therapy. Amiko Respiro's Sense Technology, which is a standalone aerosol or an accessory device, monitors the user's adherence to medication and inhaling method, and has the capability to transmit this information onto a doctor for analysis and guidance (Hardinge *et al.*, 2015). Amiko Respiro's Sense Technology is a revolutionary innovation in respiratory health management, integrating advanced sensors and data analytics to monitor and treat respiratory conditions. It offers real-time monitoring, personalized insights, and a user-friendly interface, empowering patients to actively manage their health. This technology not only enhances patient care, but also facilitates proactive healthcare interventions, allowing healthcare providers to remotely monitor individuals with chronic conditions like asthma or COPD. It enables early detection of exacerbations or changes in respiratory conditions, potentially reducing hospitalizations and improving overall respiratory health outcomes. Amiko Respiro's Sense Technology thus stands as a promising advancement, empowering both patients and healthcare providers with comprehensive respiratory monitoring, personalized care, and improved management of chronic respiratory conditions.

The integration of AI in the sensor enables users to receive reminders for medication dosage and guidance on how to enhance their inhaling method. Adherium's Hailie™ tools increase adherence to therapy in children and in adults. The integration of AI in COPD encompasses several vital stages. Beginning with comprehensive data collection from diverse sources like patient records, medical imaging, and wearable devices, this process involves meticulous data preprocessing and feature extraction to identify pertinent variables crucial for COPD diagnosis and treatment (Rogueda *et al*.,2019). Utilizing various ML algorithms, such as supervised and unsupervised learning, facilitates the development of predictive models for early detection, prognosis, and personalized management of COPD. Rigorous validation and evaluation of these models ensure their accuracy and performance before seamless integration into clinical practice. Continuous refinement, updates based on real-world feedback, and compliance with ethical standards and regulatory requirements are integral to ensuring the reliability, usability, and ethical application of AI in COPD healthcare solutions (figure 3).

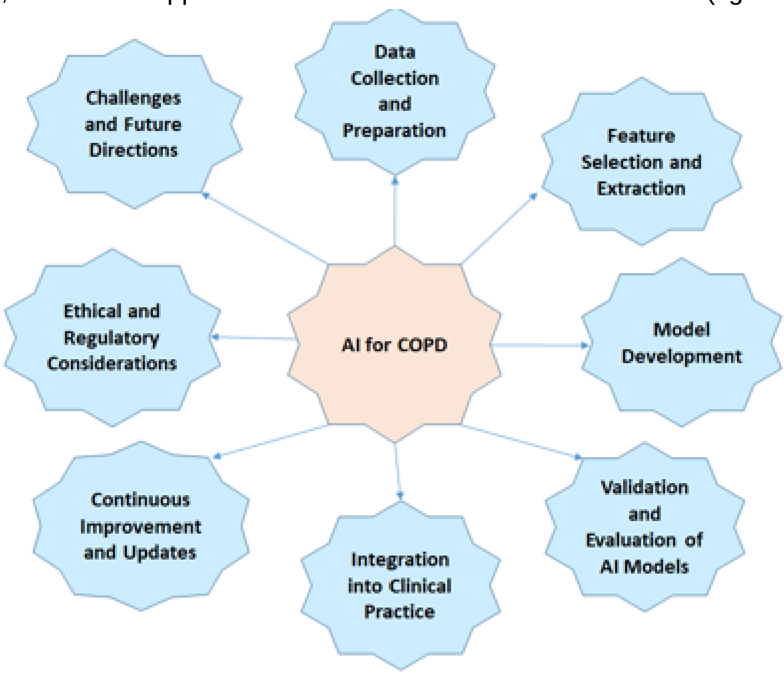

Figure 3: AI advancements for COPD therapy

AI in Pulmonary Function Tests

The diagnostics of pulmonary diseases by Pulmonary Function Tests (PFT) is determined by professional judgement, that utilizes symptoms and clinical context to identify a particular condition. Research was conducted including 120 pulmonologists from 16 European hospitals. These experts examined 50 cases, which included pulmonary function tests (PFTs) and diagnostic details. In total, there were six thousand independent assessments made during the research (Gonzalez *et al.*, 2018). An AI also analyzed the identical information. Pulmonary experts accurately assessed seventy-four percent of patients compared to the gold standard, which includes the American Thoracic Society (ATS) / European Respiratory Society (ERS) PFT interpreting standards, clinical history, and further investigations. The level of agreement between the specialists' interpretations and the gold standards was moderate, having a κ value of 0.67. The accurate identification was achieved in 44.6% of the cases, with significant variation. The AI accurately analyzed all PFTs with a 100% success rate and accurately diagnosed the condition in eighty-two percent of cases (p<0.0001 for both). In the realm of pulmonary healthcare, specialists play a pivotal role in assessing patients' conditions, striving for accuracy akin to gold standard protocols like the American Thoracic Society (ATS) / European Respiratory Society (ERS) PFT interpreting standards. Contrastingly, AI in this field showcases unparalleled proficiency (Topalovic *et al.*, 2019). AI demonstrates an even higher accuracy in diagnosing conditions, showcasing an eighty-two percent success rate surpassing the performance of human specialists. This AI-driven capability not only ensures comprehensive analysis, but also significantly enhances diagnostic precision. It stands as a promising advancement, potentially revolutionizing the landscape of pulmonary healthcare by offering consistently accurate analyses and diagnoses, thereby augmenting patient care and outcomes. The assessment of PFTs by a pulmonologist is linked to significant fluctuations and errors, but AI offers a more precise and reliable analysis, which makes it a valuable tool for enhancing the practice of medicine or aiding in decision-making processes.

AI for Exacerbation

An essential objective of treating individuals with COPD includes the timely identification of exacerbation/aggravation. The AI system acquires knowledge through the information provided by the participants. Regardless of the criteria used for exacerbation, all models demonstrate a strong predictive capability (Das *et al.*, 2023). Among these models, the Probabilistic Neural Network (PNN) exhibits the highest level of accuracy, achieving higher accuracy compared to the K-means model and the radial basis function neural network. In a study, the probabilistic neural network demonstrated the ability to forecast the onset of exacerbation having a precision of about 81% and an erroneous rate of only three percent from the monitoring of indicators via residential remote monitoring. This prediction was made approximately 5 days prior to the actual appearance of the episode (Omer *et al.*, 2023). The significance of this research findings must be approached with caution, particularly when derived from studies involving small population sizes.

In a recent trial with 15 patients, a total of 40 exacerbation events were recorded. While the outcomes revealed comparable results, it is crucial to acknowledge the limitations imposed by the small sample size. Despite this constraint, the researchers' observations are critical. They identified that among the 33 exacerbations experienced by the 15 patients, 30 were identified early with an average of 4.5 ± 2.1 days before the exacerbation onset. These early detections coincided with the patients seeking clinical attention. The study suggests early detection of exacerbations for effective intervention and management, but its small sample size suggests the need for larger research and larger sample sizes. The approach could benefit both medical practitioners and patients by facilitating timely identification of exacerbations, but further investigation and validation are needed. This evaluation was done using a smartphone software called my mhealth (Fernandez-Granero *et al.*, 2015). Forty percent of exacerbations exhibited an alarm signaling within the 3 days preceding a patient's initiation of treatment.

AI in Fibrosis

ML can be used to classify lung fibrosis illnesses using high-resolution images CT scans, deviating from the existing criteria established by the 2011 ATS/ERS/ALAT and Fleischner Society for idiopathic pulmonary fibrosis (McLean *et al.*, 2011). ML system demonstrated a reliability rate of 76% in the initial set of cases, with 92.7% of the diagnoses falling inside the correct or relevant category. The duration needed to analyse the four-slice frames (each of which image representing a distinct example from the second series) was 2.31 seconds. In the subsequent sequence, the average reliability of radiologists was 71%, whereas the software achieved an efficiency of 73%, surpassing

66% of the thoracic radiologists. The system accurately differentiates among UIP and non-UIP with a similar level of precision as an imaging specialist (HR 2.88 versus 2.74). Using ML to assess high-resolution CT scans is a convenient, reliable, and nearly immediate approach to categorise pulmonary fibrosis. Its performance is comparable to that of a radiologist (Horst *et al.*, 2019). CALLIPER (Computer-Aided Lung Informatics for Pathology Evaluation and Rating) is used to conduct an in-depth analysis of lung tissue abnormalities, includes honeycombing, reticular abnormalities, ground-glass opacities, and emphysema. This advanced technology facilitates the assessment of the severity of these abnormalities within the lung tissue. High-resolution CT scans were employed to track and evaluate the progression of these conditions over time, with a median duration of 289 days (Walsh *et al.*, 2020).

The application of CALLIPER allowed for a comprehensive examination of these specific abnormalities, enabling a more detailed understanding of their nature and severity. This sophisticated approach provided researchers with a precise tool to observe and measure changes occurring in the lung tissue, offering valuable insights into disease progression and its temporal characteristics. Employment of high-resolution CT scans and CALLIPER technology expanded our understanding of these lung-related abnormalities and their evolution over time. The utilization of such cutting-edge methodologies not only enhanced the accuracy of assessment, but also contributed significantly to the development of potential diagnostic and treatment strategies for lung-related conditions. The methodology demonstrated significant predictive capability depending on reticular anomalies, the severity of interstitial abnormalities and the proportion of interstitial abnormalities. In addition, CALLIPER has the capability to accurately calculate the volume of the pulmonary vessels (PVV)and possess the capacity to enhance the categorization of idiopathic pulmonary fibrosis.

AI for Other Respiratory Diseases

Various techniques were reported for assessing pressure-volume curves in patients with acute respiratory distress syndrome (ARDS) who were receiving artificial ventilation (Sayed *et al*., 2021). The utilization of ML greatly enhanced the outcomes of statistical regression by including patient data, hence facilitating personalized therapeutic options. AI revolutionizes ARDS care via early detection, predicting disease progression, personalized treatments, image analysis, clinical decision support, and outcome prognostication. AI rapidly identifies ARDS indicators, predicting its severity and progression based on patient data (Figure 4). Tailored treatment plans emerge from AI analysis, considering individual histories and responses. Precision in image interpretation aids clinicians in accurate diagnoses. Clinical decision systems provide real-time guidance, integrating data and best practices. Moreover, AI forecasts patient outcomes, optimizing care strategies. These facets of AI usage in ARDS stresses its pivotal role, enhancing early intervention, treatment precision, and prognostic accuracy for better patient management.

AI serves as a promising tool for conflict resolution within professional domains. AI demonstrates remarkable proficiency in analyzing chest X-rays. AI has ability to detect respiratory tuberculosis with an impressive and appreciable sensitivity rate. This capability signifies AI's capacity to contribute significantly to medical diagnostics, potentially revolutionizing healthcare systems worldwide. In the context of professional’s decision variation, AI's adeptness in discerning intricate details and making accurate assessments could serve as a mediator or an unbiased third-party arbitrator. Its impartial analysis, devoid of human biases or subjective inclinations, may facilitate fair and informed decision-making in contentious situations among professionals. By leveraging AI, disputes stemming from diverse fields could find resolution through data-driven, objective evaluations. AI's consistent and evidence-based approach, as exemplified in its precise diagnosis of respiratory conditions, can offer a standardized framework for resolving conflicts, ensuring positive outcomes and fostering trust within professional communities. Employing AI as a conflict resolution mechanism, presents an opportunity to harness technology for fair, evidence-based solutions, potentially transforming the way disputes are managed and resolved across various professions. As AI continues to evolve and refine its capabilities, its potential as a reliable mediator in professional disputes becomes increasingly promising and impactful. Algorithms of AI for the diagnosis of bronchial asthma based on an extensive survey, medical data, and medical documents were also reported (Khemasuwan *et al.*, 2020).

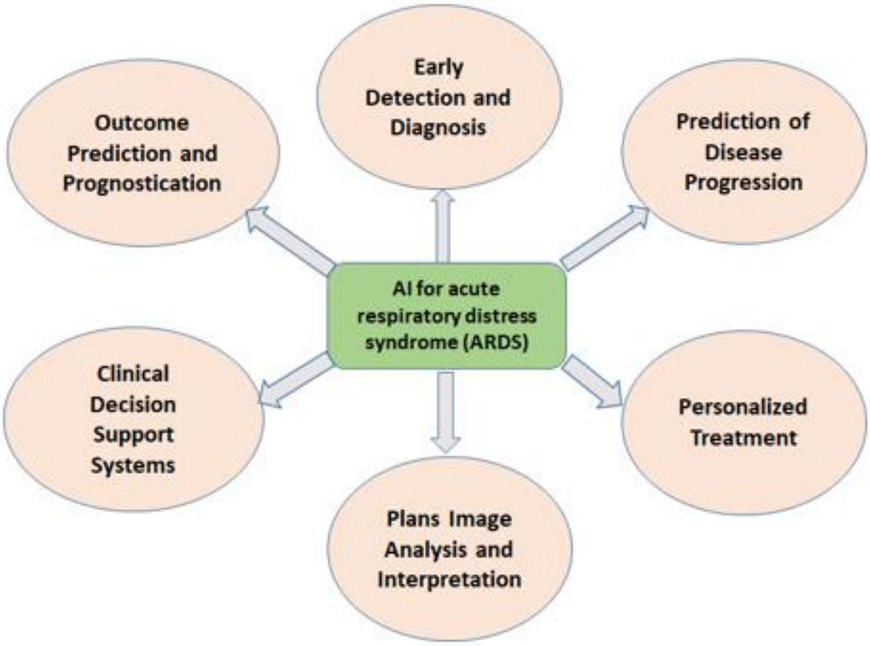

Figure 4: AI beneficial and salient features for acute respiratory distress syndrome (ARDS)

The computations presented in this research exhibited a precision, exceeding eighty percent. By employing dependable data training, the model incorporating automatic associative memory to the neural network algorithm achieved an accuracy surpassing 90%, with only one percent of results being unresolved. Furthermore, the mobile applications developed in this study attained an accuracy of 94%. AI plays a pivotal role in managing bronchial asthma across various facets (Figure 5). AI aids in asthma diagnosis, treatment planning, and monitoring, providing accurate diagnoses, personalized treatments, remote support, and resource optimization. It also expedites drug development and optimizes healthcare resource allocation. AI's integration in education interventions can reduce medical errors and improve patient outcomes, ultimately transforming asthma care. Integrating AI-powered platforms into medical curriculum equips healthcare professionals with advanced tools for accurate diagnosis and personalized treatment strategies (Vidhya *et al.*, 2019). By mitigating diagnostic errors and improving decision-making skills, AI-driven educational initiatives play a crucial role in minimizing medical errors, ensuring better outcomes, and optimizing patient care in asthma management. Through predictive analytics and ML algorithms, AI analyzes vast data sets to anticipate environmental patterns and identify high-risk areas. It aids in early diagnosis by recognizing symptom patterns, assists in treatment planning by suggesting personalized interventions, and facilitates remote monitoring to manage exacerbations. AI-driven decision support systems enhances healthcare professionals' capabilities, optimizing timely interventions and improving outcomes for patients grappling with respiratory and other lung cancer issues intensified by climate change (Ghosh *et al.*, 2023). Medical errors caused by human result in significant losses, which could be mitigated by utilizing AI and ML technologies. According to a study, the incorporation of diuretics in ML algorithm analysis for treatment suggestion, resulted in decrease of mortality by 18% and a shorter stay in an intensive care unit by an average of 5.9 to 8.4 days (Sethu *et al.*, 2022; Romana *et al.*, 2012). AI is valuable when there is a lack of definitive proof to inform decision-making processes. In order to construct association-based models, it is crucial to have access to pertinent, superior data and gold standards for testing and validation. Furthermore, there is a requirement for multiple scales, interconnected computerized models, that produce medically significant results at the individual basis and are specifically designed to address certain medical inquiries.

Figure 5: AI features for Broncial Asthma

The U-BIOPRED (Unbiased Biomarkers in Prediction of Respiratory Disease Outcomes) program represents a pioneering research effort focused on comprehensively examining asthma across diverse age groups, encompassing both adults and children (Paladugu *et al.*, 2023). U-BIOPRED is an initiative aiming to understand the complexities of asthma by combining data and biological samples from individuals across different life stages. It aims to create a holistic understanding of asthma subtypes, triggers, and disease progression. The initiative aims to advance diagnostic capabilities and treatment approaches, potentially revolutionizing asthma diagnosis, management, and personalized treatment strategies. It represents collaborative efforts in the scientific community.

Conclusion

The application of AI in medicine, particularly in respiratory care, has become increasingly important. ML, a subset of AI, uses statistical methods to learn from data and improve performance without manual programming. Healthcare initiatives leveraging AI received the highest investment globally, surpassing other industries.ML has the potential to support clinical decision-making, but it cannot entirely replace the role of healthcare professionals. Human errors in medicine lead to significant avoidable mistakes, many of which could be mitigated through AI and ML solutions. AI is particularly useful in situations, where concrete evidence to guide medical decisions is lacking. New research in respiratory therapy is yielding promising results, further highlighting the growing relevance of AI and ML in healthcare. While these technologies offer significant benefits, they should complement, not replace, the expertise and judgment of physicians.

Acknowledgment

The authors acknowledge Sanjivani college of pharmaceutical education and research providing support and motivation to write the review.

Conflict of Interest

The authors report no financial or any other conflicts of interest in this work.

References

Bhaskaran, S., & Marappan, R. (2023). Enhanced personalized recommendation system for machine learning public datasets: generalized modeling, simulation, significant results and analysis. *International Journal of Information Technology*, *15*(3), 1583–1595. https://doi.org/10.1007/s41870-023-01165-2

Chen, S., Kuhn, M., Prettner, K., Yu, F., Yang, T., Bärnighausen, T., Bloom, D. E., & Wang, C. (2023). The global economic burden of chronic obstructive pulmonary disease for 204 countries and territories in 2020-50: a health-augmented macroeconomic modelling study. *The Lancet. Global Health*, *11*(8), e1183–e1193. https://doi.org/10.1016/S2214-109X(23)00217-6

Das, N., Happaerts, S., Gyselinck, I., Staes, M., Derom, E., Brusselle, G., Burgos, F., Contoli, M., Dinh-Xuan, A. T., Franssen, F. M. E., Gonem, S., Greening, N., Haenebalcke, C., Man, W. D.-C., Moisés, J., Peché, R., Poberezhets, V., Quint, J. K., Steiner, M. C., … Janssens, W. (2023). Collaboration between explainable artificial intelligence and pulmonologists improves the accuracy of pulmonary function test interpretation. *The European Respiratory Journal*, *61*(5), 2201720. https://doi.org/10.1183/13993003.01720-2022

Fanni, S. C., Febi, M., Aghakhanyan, G., & Neri, E. (2023). Natural Language Processing. In *Imaging Informatics for Healthcare Professionals* (pp. 87–99). Springer International Publishing. https://doi.org/10.1007/978-3-031-25928-9_5

Fernandez-Granero, M. A., Sanchez-Morillo, D., Lopez-Gordo, M. A., & Leon, A. (2015). A Machine Learning Approach to Prediction of Exacerbations of Chronic Obstructive Pulmonary Disease. In *Artificial Computation in Biology and Medicine* (pp. 305–311). Springer International Publishing. https://doi.org/10.1007/978-3-319-18914-7_32

Gonzalez, G., Ash, S. Y., Vegas-Sánchez-Ferrero, G., Onieva Onieva, J., Rahaghi, F. N., Ross, J. C., Díaz, A., San José Estépar, R., Washko, G. R., & Investigators, Copdg. and E. (2018). Disease Staging and Prognosis in Smokers Using Deep Learning in Chest Computed Tomography. *American Journal of Respiratory and Critical Care Medicine*, *197*(2), 193–203. https://doi.org/10.1164/rccm.201705-0860OC

Hardinge, M., Rutter, H., Velardo, C., Shah, S. A., Williams, V., Tarassenko, L., & Farmer, A. (2015). Using a mobile health application to support self-management in chronic obstructive pulmonary disease: a six-month cohort study. *BMC Medical Informatics and Decision Making*, *15*, 46. https://doi.org/10.1186/s12911-015-0171-5

Horst, C., Gholipour, B., Nair, A., & Jacob, J. (2019). Differential diagnoses of fibrosing lung diseases. *BJR Open*, *1*(1), 20190009. https://doi.org/10.1259/bjro.20190009

Khemasuwan, D., Sorensen, J. S., & Colt, H. G. (2020). Artificial intelligence in pulmonary medicine: computer vision, predictive model and COVID-19. *European Respiratory Review : An Official Journal of the European Respiratory Society*, *29*(157), 200181. https://doi.org/10.1183/16000617.0181-2020

Kibria, M. G., Nguyen, K., Villardi, G. P., Zhao, O., Ishizu, K., & Kojima, F. (2018). Big Data Analytics, Machine Learning, and Artificial Intelligence in Next-Generation Wireless Networks. *IEEE Access*, *6*, 32328–32338. https://doi.org/10.1109/access.2018.2837692

Kumar, K., Kumar, P., Deb, D., Unguresan, M.-L., & Muresan, V. (2023). Artificial Intelligence and Machine Learning Based Intervention in Medical Infrastructure: A Review and Future Trends. *Healthcare (Basel, Switzerland)*, *11*(2), 207. https://doi.org/10.3390/healthcare11020207

Liu, N., Xie, F., Siddiqui, F. J., Ho, A. F. W., Chakraborty, B., Nadarajan, G. D., Tan, K. B. K., & Ong, M. E. H. (2022). Leveraging Large-Scale Electronic Health Records and Interpretable Machine Learning for Clinical Decision Making at the Emergency Department: Protocol for System Development and Validation. *JMIR Research Protocols*, *11*(3), e34201–e34201. https://doi.org/10.2196/34201

Liu, Y., Tang, J., & Sun, Y. (2023). Impact of Interstitial Lung Abnormalities on Disease Expression and Outcomes in COPD or Emphysema: A Systematic Review. *International Journal of Chronic Obstructive Pulmonary Disease*, *18*, 189–206. https://doi.org/10.2147/COPD.S392349

McLean, S., Nurmatov, U., Liu, J. L., Pagliari, C., Car, J., & Sheikh, A. (2011). Telehealthcare for chronic obstructive pulmonary disease. *The Cochrane Database of Systematic Reviews*, *2011*(7), CD007718–CD007718. https://doi.org/10.1002/14651858.CD007718.pub2

Mekov, E., Miravitlles, M., & Petkov, R. (2020). Artificial intelligence and machine learning in respiratory medicine. *Expert Review of Respiratory Medicine*, *14*(6), 559–564. https://doi.org/10.1080/17476348.2020.1743181

Mhlanga, D. (2023). Artificial Intelligence and Machine Learning for Energy Consumption and Production in Emerging Markets: A Review. *Energies*, *16*(2), 745. https://doi.org/10.3390/en16020745

Nakamura, H., Hirai, T., Kurosawa, H., Hamada, K., Matsunaga, K., Shimizu, K., Konno, S., Muro, S., Fukunaga, K., Nakano, Y., Kuwahira, I., & Hanaoka, M. (2024). Current advances in pulmonary functional imaging. *Respiratory Investigation*, *62*(1), 49–65. https://doi.org/10.1016/j.resinv.2023.09.004

Nwadiugwu, M. C. (2020). Neural networks, artificial intelligence and the computational brain. *arXiv preprint arXiv:2101.08635*. https://doi.org/10.48550/arXiv.2101.08635

Ohno, Y., Ozawa, Y., Nagata, H., Bando, S., Cong, S., Takahashi, T., Oshima, Y., Hamabuchi, N., Matsuyama, T., Ueda, T., Yoshikawa, T., Takenaka, D., & Toyama, H. (2023). Area-Detector Computed Tomography for Pulmonary Functional Imaging. *Diagnostics (Basel, Switzerland)*, *13*(15), 2518. https://doi.org/10.3390/diagnostics13152518

Omer, N., Samak, A. H., Taloba, A. I., & Abd El-Aziz, R. M. (2023). A novel optimized probabilistic neural network approach for intrusion detection and categorization. *Alexandria Engineering Journal*, *72*, 351–361. https://doi.org/10.1016/j.aej.2023.03.093

Paladugu, P. S., Ong, J., Nelson, N., Kamran, S. A., Waisberg, E., Zaman, N., Kumar, R., Dias, R. D., Lee, A. G., & Tavakkoli, A. (2023). Generative Adversarial Networks in Medicine: Important Considerations for this Emerging Innovation in Artificial Intelligence. *Annals of Biomedical Engineering*, *51*(10), 2130–2142. https://doi.org/10.1007/s10439-023-03304-z

Qiblawey, Y., Tahir, A., Chowdhury, M. E. H., Khandakar, A., Kiranyaz, S., Rahman, T., Ibtehaz, N., Mahmud, S., Maadeed, S. Al, Musharavati, F., & Ayari, M. A. (2021). Detection and Severity Classification of COVID-19 in CT Images Using Deep Learning. *Diagnostics (Basel, Switzerland)*, *11*(5), 893. https://doi.org/10.3390/diagnostics11050893

Rogueda, P., Grinovero, M., Ponti, L., Purkins, G., Croad, O. (2019). Telehealth ready: performance of the Amiko Respiro sense connected technology with Merxin DPIs. *Journal Aerosol Med Pulm Drug Delivery*,*32(2)*, A26-A26. http://doi.org/10.1089/jamp.2019.ab01.abstracts

Romana, A., Kamath, L., Sarda, A., Muraraiah, S., & Cr, J. (2012). Polypharmacy leading to adverse drug reactions in elderly in a tertiary care hospital. *mortality*, *6*(7).

Sayed, M., Riaño, D., & Villar, J. (2021). Predicting Duration of Mechanical Ventilation in Acute Respiratory Distress Syndrome Using Supervised Machine Learning. *Journal of Clinical Medicine*, *10*(17), 3824. https://doi.org/10.3390/jcm10173824

Sethu, M., Kotla, B., Russell, D., Madadi, M., Titu, N. A., Coble, J. B., Boring, R. L., Blache, K., Agarwal, V., Yadav, V., & Khojandi, A. (2022). Application of Artificial Intelligence in Detection and Mitigation of Human Factor Errors in Nuclear Power Plants: A Review. *Nuclear Technology*, *209*(3), 276–294. https://doi.org/10.1080/00295450.2022.2067461

Somenath Ghosh, D., Sanjeev Kumar Jha, D., Elamin Bushara, M. O., Asit Kumar, D., & Ghate, V. U. (2023). Climate Changes and Cancer. *International Journal of Trends in OncoScience*. https://doi.org/10.22376/ijtos.2023.1.4.23-31

Stamer, T., Steinhäuser, J., & Flägel, K. (2023). Artificial Intelligence Supporting the Training of Communication Skills in the Education of Health Care Professions: Scoping Review. *Journal of Medical Internet Research*, *25*, e43311–e43311. https://doi.org/10.2196/43311

Topalovic, M., Das, N., Burgel, P.-R., Daenen, M., Derom, E., Haenebalcke, C., Janssen, R., Kerstjens, H. A. M., Liistro, G., Louis, R., Ninane, V., Pison, C., Schlesser, M., Vercauter, P., Vogelmeier, C. F., Wouters, E., Wynants, J., & Janssens, W. (2019). Artificial intelligence outperforms pulmonologists in the interpretation of pulmonary function tests. *European Respiratory Journal*, *53*(4), 1801660. https://doi.org/10.1183/13993003.01660-2018

Vidhya, P. V., Jeena, S., Sambathkumar, R., & Venkateswaramurthy, N. (2019). Assessment and Educational Interventions in Inhalation Technique among Asthma and Copd Patients at a Tertiary Care Hospital In Erode (Tamilnadu-India). *Int. J. Life Sci. Pharma Res*, *9*(3), 61-69. https://doi.org/10.22376/ijpbs/lpr.2019.9.3.p61-69

Walsh, S. L. F., Humphries, S. M., Wells, A. U., & Brown, K. K. (2020). Imaging research in fibrotic lung disease; applying deep learning to unsolved problems. *The Lancet Respiratory Medicine*, *8*(11), 1144–1153. https://doi.org/10.1016/s2213-2600(20)30003-5

Walshe, K., & Rundall, T. G. (2001). Evidence-based management: from theory to practice in health care. *The Milbank Quarterly*, *79*(3), 429–V. https://doi.org/10.1111/1468-0009.00214

Zhang, Z. (2020). Big data analysis with artificial intelligence technology based on machine learning algorithm. *Journal of Intelligent & Fuzzy Systems*, *39*(5), 6733–6740. https://doi.org/10.3233/jifs-191265