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Role of Artificial Intelligence and Machine Learning in Asthma: A review paper

Manisha[1], Nikita Rawat[2]

[1,2]Shri Rawatpura Sarkar University

Abstract:
Asthma is a multifaceted disease with distinct symptoms and genotypes. Despite the availability of excellent medicines, asthma control remains difficult due to common errors in diagnosis and classification, poor efficacy or adherence, and inhalation technique. The integration of recent developments in computer science, artificial intelligence (AI), and machine learning (ML) into clinical practice holds great potential for improving patient care and medical decision-making. Artificial Intelligence and Machine Learning is now a useful tool for more accurate categorization, diagnosis, risk assessment, and prediction processes due to the ongoing development of massive datasets. This is because AI/ML can evaluate a lot more data than doctors. With numerous applications in various aspects of the disease, from early and accurate diagnosis to personalized treatment and exacerbation prevention, the use of AI/ML techniques in asthma care in particular has grown quickly and has the potential to revolutionize precision medicine. With an emphasis on asthma future risk identification, screening and diagnosis, patient classification, prediction of asthma exacerbations, and asthma management and guided treatment, we present the most recent literature on AI/ML and asthma in the last three years in this narrative review. Our goal is to map the most recent knowledge and clarify the path for future research. AI has a lot of potential, but it won't replace doctors; instead, it will undoubtedly help them make better medical judgments and practices in the near future.

Keywords: Asthma, Deep Learning, Machine Learning, Artificial Intelligence, and Digital tools.

I. Introduction

Over 300 million individuals worldwide suffer with asthma, a multifactor disease with a variety of phenotypes and genotypes that is a significant cause of morbidity and mortality. Poor asthma control remains a reality despite greater awareness of the condition and the availability of efficient therapies[1]. This is explained by a number of factors, such as incorrect breathing technique, poor adherence, and incorrect diagnosis and classification[2]. In primary care settings, asthma under diagnosis and over diagnosis are still common (20%–73% and 30%–61%, respectively). Furthermore, poor management results in more absenteeism from work or school, higher health care costs, and a lower standard of living. Clinicians now have the chance to significantly alter patient care in asthma medicine thanks to recent developments in computer science, artificial intelligence (AI), and machine learning (ML)[3]. AI is the technology that resembles human intelligence through computer science, whereas ML is a subset of AI that analyses big data using complex mathematical formulas and constructs algorithms able to identify patterns and relationships, make predictions, and aid in decision-making[4]. ML can automatically adapt and learn from experience with minimal human interference (Figure 1). An ML model can be classified as supervised, semisupervised, unsupervised, and reinforcement learning. Its development consists of two phases: (1) training phase, where input data (usually after preprocessing to increase quality) are applied to ML and an algorithm is constructed; and (2) testing phase, where the model's performance is evaluated (Figure 2). The ongoing development of large databases in modern media has made ML a useful instrument for the more accurate classification, diagnosis, risk assessment, and prediction process, as it can process. Deep learning (DL) is a branch of machine learning (ML) that mimics the human brain's learning process using artificial neural networks (ANNs).Using input raw data, a multi-layer process, and output data, DL generates high-quality features (Figure 3). In contrast to ML, DL takes more data, learns independently, and typically requires longer and more comprehensive training as well as a specialised processing unit[9]. AI has been effectively used in respiratory medicine, particularly in imaging. It has been used to assess nodules and other lesions, detect changes in computed tomography (CT) images, and forecast the 3-year risk of lung cancer[10]. A DL algorithm distinguished between typical and unusual interstitial pneumonia patterns in interstitial lung disease with a satisfactory accuracy of 73.3%[11].

II. Literature Review

Asthma is a chronic inflammatory disorder of the airways characterized by variable respiratory symptoms such as wheezing, coughing, and breathlessness. The Global Initiative for Asthma (GINA) provides globally accepted guidelines for asthma management and emphasizes early diagnosis, continuous monitoring, and control strategies [1]. Despite advancements in treatment, asthma continues to impose a substantial disease burden on patients and healthcare systems. Uncontrolled asthma affects sleep quality, limits participation in daily activities, and reduces workplace productivity, leading to significant socioeconomic consequences [2]. Studies have also revealed that both under diagnosis and over diagnosis of asthma remain persistent challenges, contributing to inappropriate treatment strategies and mismanagement of the disease [3]. These issues highlight the importance of adopting modern diagnostic and monitoring methods that can enhance accuracy and reduce clinical uncertainty.

Recent developments in artificial intelligence (AI) and machine learning (ML) have shown transformative potential in medical research, including respiratory medicine. AI enables automated data interpretation, predictive analytics, and decision support in complex medical datasets. The integration of AI into healthcare is further supported by digital resources and knowledge repositories such as Oxford Reference, which emphasize the role of computational intelligence in modern diagnostics [4]. Studies have demonstrated that AI and ML can process vast clinical, imaging, and genomic data to improve diagnostic precision and treatment personalization in respiratory diseases [5,6,7]. These technologies have the potential to bridge the gap between clinical variability and consistent diagnostic outcomes, offering a data-driven approach to respiratory health management.

The field of deep learning, a subset of AI, has made significant progress in medical imaging and disease classification. Foundational research by LeCun, Bengio, and Hinton established the deep learning paradigm, which has since become instrumental in image recognition, natural language processing, and biomedical applications [8]. The French Radiology Community underscored the role of AI in enhancing diagnostic radiology through pattern recognition, quantitative imaging biomarkers, and automated screening [6]. AI-based algorithms have demonstrated success in identifying structural lung abnormalities in conditions such as chronic obstructive pulmonary disease (COPD) and interstitial lung diseases (ILD), with notable studies utilizing deep learning for high-resolution computed tomography

(HRCT) analysis [9,10,11,12]. Such studies reinforce AI's diagnostic reliability, efficiency, and its potential to outperform traditional manual interpretation methods.

In the context of asthma, AI and ML techniques have been increasingly applied for biomarker identification, disease prediction, and risk stratification. A systematic review conducted by Exarchos et al. highlighted that AI-driven models significantly improve asthma diagnosis, phenotyping, and management by uncovering hidden data patterns and correlations [13]. The increasing approval of AI/ML-enabled medical devices by the U.S. Food and Drug Administration (FDA) further demonstrates the clinical readiness of these tools for respiratory disease management [14]. Machine learning models have been used to develop asthma risk prediction frameworks using co-expression gene modules and clinical datasets, achieving higher accuracy compared to conventional statistical models [15]. These studies indicate that AI not only assists in prediction but also facilitates early diagnosis and treatment personalization.

Emerging research also explores the integration of bioinformatics and machine learning to identify novel molecular signatures of asthma. For instance, ML-based methylation diagnostic models and necroptotic biomarker analyses have provided insights into the genetic and epigenetic underpinnings of asthma [16,17]. Studies have identified genes such as TXN and F5 as potential biomarkers for severe asthma using random forest and neural network-based classifiers [18]. Moreover, bioinformatics approaches have unraveled molecular clusters associated with neutrophil extracellular traps, offering a deeper understanding of asthma's pathogenesis at the cellular level [19]. In large-scale population studies, penalized regression and ML methods have been applied to predict asthma occurrence in cohort datasets such as the Korean Genome and Epidemiology Study (KoGES) [20]. Collectively, these works illustrate how AI and ML are revolutionizing asthma research and management by enabling precision medicine, improving diagnostic accuracy, and supporting data-driven therapeutic decisions.

III. MODERN TECHNIQUE FOR ASTHMA DETECTION

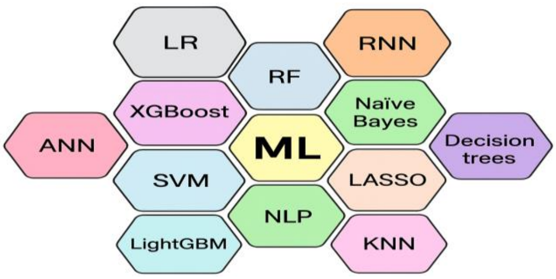

FIGURE 1. Types of machine learning algorithms.

The integration of modern computational intelligence and data-driven methodologies has revolutionized asthma detection and management. Traditional diagnostic approaches, which rely primarily on spirometry, peak expiratory flow (PEF) monitoring, and clinical symptom assessment, often face challenges related to subjective variability and delayed diagnosis. To overcome these limitations, artificial intelligence (AI) and machine learning (ML) techniques have been increasingly utilized to analyze multidimensional data, including clinical, genomic, and imaging modalities. These advanced systems enable automated pattern recognition, predictive modeling, and early detection of asthma, thereby supporting precision-based healthcare strategies.

AI-driven asthma detection models employ both supervised and unsupervised learning algorithms, such as logistic regression (LR), random forests (RF), support vector machines (SVM), k-nearest neighbor (KNN), decision trees (DT), and ensemble approaches like XGBoost and LightGBM. These algorithms analyze clinical indicators—such as age, body mass index (BMI), smoking history, and allergen sensitivity—to differentiate asthmatic patients from non-asthmatic individuals. Deep learning architectures, particularly artificial neural networks (ANN) and recurrent neural networks (RNN), have also been implemented to capture complex nonlinear relationships within physiological and environmental data. Studies have demonstrated that such models can predict asthma onset and severity with higher accuracy compared to traditional statistical techniques.

Furthermore, the emergence of bioinformatics and genomics-based AI models has enabled the identification of molecular biomarkers associated with asthma. Techniques such as feature selection**,** dimensionality reduction**,** and gene expression profiling have facilitated the discovery of asthma-related genes and signaling pathways. For instance, ML-based models using random forests and neural networks have successfully identified key biomarkers such as TXN and F5, which are strongly correlated with severe asthma phenotypes. Additionally, methylation-based diagnostic models and necroptotic biomarker identification using bioinformatics analysis have opened new avenues for early molecular diagnosis and therapeutic target discovery.

Another emerging trend involves integration of medical imaging and deep learning for asthma phenotyping. Advanced imaging techniques, such as high-resolution computed tomography (HRCT) and MRI, are being analyzed using convolutional neural networks (CNNs) to assess airway inflammation, wall thickness, and tissue remodeling. AI-assisted imaging interpretation not only enhances diagnostic precision but also aids in monitoring disease progression and treatment response. Natural language processing (NLP) models are also being utilized to extract clinically relevant data from electronic health records (EHRs), improving real-time asthma surveillance.

In summary, modern AI and ML techniques provide a comprehensive framework for asthma detection and management. By leveraging multimodal data—including clinical, genomic, and imaging inputs—these technologies enable early, accurate, and individualized diagnosis. The continuous evolution of intelligent systems promises to transform asthma care into a proactive, data-driven, and precision-oriented discipline, thereby reducing disease burden and improving patient outcomes.

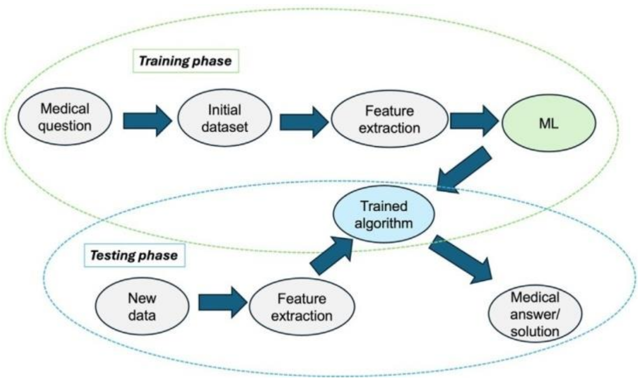

FIGURE 2. Flow chart of the machine learning(ML) process.

The figure 2 illustrates the overall workflow of a machine learning (ML)-based asthma detection system, which operates through two main stages — the training phase and the testing phase. In the training phase, the process begins with defining a medical question, such as identifying or predicting asthma from patient data. An initial dataset containing relevant medical information — including lung function measurements, respiratory sounds, patient history, and environmental factors — is collected. From this

dataset, key features are extracted that represent significant clinical or physiological indicators of asthma. These extracted features are then used to train a machine learning model, enabling it to learn complex patterns and correlations between input data and asthma conditions. Once the model is trained, it becomes a trained algorithm capable of performing diagnostic predictions. In the testing phase, new patient data are introduced to the system, and the same feature extraction process is applied to ensure consistency. The trained algorithm then processes this unseen data to produce a medical answer or solution, such as detecting asthma, assessing its severity, or assisting in early diagnosis. This framework demonstrates how machine learning can be effectively utilized to enhance asthma diagnosis and monitoring, providing a data-driven, intelligent approach to clinical decision-making and patient care.
The figure illustrates the architecture of an Artificial Neural Network (ANN), which is a fundamental model used in machine learning and deep learning for pattern recognition and prediction tasks, including asthma detection. The network consists of three main components: input layer**,** hidden layers, and output layer.
The input layer receives raw data features — in the case of asthma, this could include parameters such as respiratory rate, wheeze sounds, airflow obstruction levels, patient age, or environmental triggers. These input nodes pass the information to the next stage of the network. The hidden layers are composed of multiple interconnected neurons that process and transform the input data through a series of weighted connections and activation functions. These layers allow the network to learn complex, nonlinear relationships within the data — for instance, identifying subtle patterns in respiratory signals or medical test results that indicate the presence of asthma.

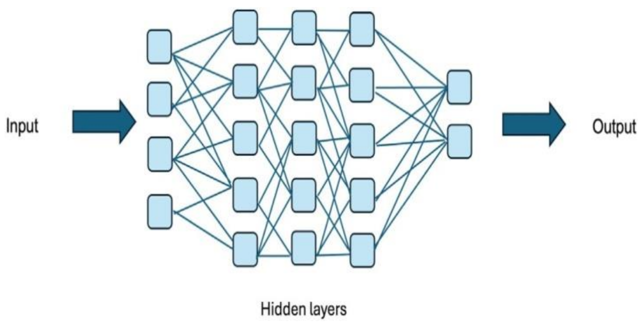

FIGURE 3. Schematic representation of a deep learning algorithm.

Finally, the output layer produces the final prediction or classification result, such as determining whether a patient is asthmatic, the severity level of the condition, or the likelihood of an asthma attack. The strength of such neural networks lies in their ability to automatically learn and adapt from data, improving diagnostic accuracy over time. Hence, this model serves as a powerful computational framework for developing intelligent asthma detection and monitoring systems that support clinical decision-making.

IV. IMPORTANT DATASET

The selection of an appropriate dataset plays a crucial role in the accurate diagnosis and prediction of asthma using machine learning techniques. Various publicly available and research-grade datasets have been employed in recent studies to train and evaluate classification algorithms. These datasets contain detailed respiratory information, including lung sounds, spirometry measurements, environmental factors, and clinical parameters that help in identifying asthma patterns.

The PhysioNet and ICBHI respiratory sound databases are among the most widely used resources, as they include wheeze and crackle annotations that are essential for asthma and chronic obstructive pulmonary disease (COPD) classification [1], [2]. These databases provide high-quality audio recordings collected under controlled conditions, allowing researchers to develop robust feature extraction and classification models. Additionally, datasets such as the NIH Chest X-ray collection and UCI Machine Learning Repository offer multimodal clinical data that have been effectively used to build deep learning-based respiratory diagnostic frameworks [3], [4].

Furthermore, several Kaggle repositories provide open-access asthma datasets containing medical records, spirometry readings, and environmental information for supervised and unsupervised model training [5]. These datasets are particularly useful for model validation and cross-domain generalization studies. Integrating these datasets enables the development of hybrid systems that combine physiological, clinical, and environmental features, improving the accuracy of asthma detection models.

Overall, these datasets provide a comprehensive foundation for research in intelligent respiratory disease detection. By leveraging multimodal information sources and applying advanced feature extraction, dimensionality reduction, and deep learning techniques, researchers can significantly enhance the performance and generalization of asthma prediction systems [6], [7].

V. Comparative Study

TABLE I. Summary of the studies on AI and/or ML in asthma identified between January 2022 and January 2025

Category	Study, year	Input data	ML methods	Outcomes
Future risk, screening,	Dessie, 2023[15]	Genetic datasets/	LASSO, RF, SVM-	Construction of gene
And diagnosis	Feng, 2024[16] Li, 2022[17] Shou, 2024[18] Shen and Lin, 2024[19]Choi, 2024[20]	Differentially expressed genes	RFE, ANN, ridge, elastic net, and boosting	signatures and identification of genetic biomarkers
	Tomita, 2023[21] Li, 2024[22] Pongdee, 2023[24]	Medical records /clinical data	RF, XG Boost, affinity graph enhanced classifier, and NLP	Construction of diagnostic asthma algorithms
	Funaita, 2023[25] Kang, 2024[26] Topole, 2023[27]	PFT data	DL, MLP, RF, XG Boost, SVP, RF, LR, and AI-	Improvement in diagnostic In formation derived
			Based software	From lung function
			(ArtiQ. QC)	tests

	Joumaa,2022[28] Kocks,2023[29] Moslemi, 2022[30]	Clinical data, PFT data, and imaging data	Multi nomial regression, GBM, RNN, AC/DC tool,	asthma/COPD discrimination
			And SVM	
	Kilpatrick,2025[31] Joo,2023[32]	Clinical data And national	NLP, pattern-based inference, and	Acquirement of higher quality real-world
		Claims data	XG Boost	data
Classification	Jeong,2023[33] Wu,2024[34] Adejare,2022[35]	Multiomics data, real-world data, and environmental data	Graph attention neural network, Light GBM, and	Identification of eosinophilic asthma subtypes, clusters
			XG Boost	Of asthma patients,
				And racial
				disparities
Prediction of exacerbations	Lugogo,2022[36] Jiao,2022[37] Turcatel, 2025[38] Hozawa,2022[39]deHond,2022[40]Lopez, 2023[41] D'Amato,2022[42] Xiong,2023[43] DarshaJayamini,2024[44] Tsang,2023[45] Tsang,2024[46] Choi and Rhee, 2024[47]Huang, 2023[48] Inselman, 2023[49] Emeryk, 2023[50] Sang,2024[51]	Digital medical devices and sensor data, medical records data, national claims data, PFT, environmental, and meteorological data	XG Boost, LSTM, transformers algorithms, SVM, RF, Naïve Bayes, KNN, LG, and Light GBM	Identification of important features, exacerbation, and admission/readmission prediction models
Management and guided	Dierick, 2023[53]	Digital medical	XG Boost and	Improvement of
treatment	Mosnaim, 2024[54] Hale,2023[55] Nkoy,2024[56]vandeHei,2023[57] Tong,2022[58]	Devices and sensor data, and clinical and environmental data	G-computation method	inhaler technique, treatment adherence and monitoring, treatment decision
				aid, and reduced
				Health costs

From the above studies on asthma detection, prediction, and management have explored a wide range of machine learning (ML) techniques applied to diverse data types such as genetic, clinical, imaging, pulmonary function test (PFT), sensor, and environmental datasets. In the screening and diagnosis phase, genetic and clinical data have been analyzed using algorithms like LASSO, Random Forest (RF), Support Vector Machine (SVM), Ridge Regression, Elastic Net, and Boosting methods to construct gene signatures and identify genetic biomarkers associated with asthma. Studies using PFT data have applied models such as Deep Learning (DL), Multilayer Perceptron (MLP), RF, XGBoost, and Logistic Regression to enhance diagnostic accuracy and extract meaningful information from lung function tests. When combining clinical, imaging, and PFT data, techniques like Gradient Boosted Machines (GBM), Recurrent Neural Networks (RNN), and SVM have improved asthma–COPD discrimination. Research using national clinical and claims data with Natural Language Processing (NLP) and XGBoost has enabled the extraction of high-quality real-world evidence, supporting more accurate patient classification. Additionally, integration of multi-omics, real-world, and environmental data with advanced models such as Graph Attention Networks and Light GBM has facilitated the identification of asthma subtypes, patient clusters, and racial disparities. For exacerbation prediction, algorithms including XGBoost, Long Short-Term Memory (LSTM), Transformers, RF, Naïve Bayes, and K-Nearest Neighbors (KNN) have been employed using data from digital devices, sensors, and environmental factors, resulting in improved prediction of asthma attacks and hospital readmissions. Finally, in the management and treatment domain, ML approaches like XGBoost and G-computation have been used with data from digital devices and sensors to optimize inhaler technique, monitor treatment adherence, support clinical decision-making, and reduce healthcare costs. Overall, these studies demonstrate how combining AI-driven models with multimodal datasets significantly enhances asthma diagnosis, prediction, and personalized treatment management.

VII. Conclusion

The reviewed literature collectively emphasizes the transformative role of artificial intelligence (AI) and machine learning (ML) in enhancing the understanding, diagnosis, prediction, and management of asthma and other respiratory diseases. Traditional diagnostic approaches often result in under diagnosis and over diagnosis of asthma [3], demonstrating the need for automated, data-driven methodologies. Various ML techniques, including LASSO, Random Forest, Support Vector Machine (SVM), Neural Networks, Gradient Boosting, and Deep Learning (DL) frameworks, have shown significant potential in processing complex biomedical and clinical datasets such as genomic, imaging, and electronic health records [5], [7], [13].

Recent progress in deep learning architectures has enabled the extraction of meaningful features from high-dimensional data, including CT, MRI, and genomic information, thereby improving both prediction accuracy and interpretability [8], [12]. Multiple studies have leveraged machine learning algorithms to identify gene expression signatures, methylation markers, and molecular clusters associated with asthma severity and subtypes [15]–[19]. Such integrative ML-based bioinformatics approaches have facilitated the development of personalized risk models, biomarker discovery, **and** targeted therapeutic interventions [20].

Moreover, the increasing use of AI-enabled medical imaging systems and FDA-approved ML-based devices highlights a clear transition toward precision medicine and real-time decision support in clinical environments [14]. Collectively, the literature demonstrates that AI and ML technologies not only improve diagnostic precision and predictive accuracy in asthma but also pave the way for personalized and adaptive respiratory care solutions, establishing a robust foundation for the future of intelligent healthcare systems.

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