



A Review and Performance Study of AI Techniques in Asthma Prediction

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Abstract—Asthma is a chronic respiratory disease that affects millions of people worldwide and continues to impose a significant burden on healthcare systems due to frequent exacerbations, hospitalizations and treatment costs. Recent advances in Artificial Intelligence (AI) have made the development of intelligent prediction models possible for early diagnosis, risk assessment and personalized disease management. This review discusses recent studies for AI-based asthma prediction and role of structured and unstructured clinical data, Machine Learning (ML), Deep Learning (DL) and Natural Language Processing (NLP) techniques. Some of the commonly used algorithms include Random Forest, XGBoost, Support Vector Machines, Convolutional Neural Networks (CNNs), Long Short-Term Memory (LSTM) networks and transformer-based NLP models. The studies reviewed show that ensemble learning and deep learning approaches tend to outperform the traditional statistical methods in terms of prediction. Moreover, intelligent healthcare systems have growing potential as manifested by AI applications such as smart inhalers, EHR-based symptom extraction and non-invasive breath analysis. However, promising results are still hindered by important challenges such as data imbalance, model interpretability, privacy, and dataset standardization. Future work should focus on developing explainable, privacy-preserving, and clinically deployable AI frameworks for the prediction of asthma.

Keywords—Asthma prediction, Machine learning, Deep learning, Explainable AI, Electronic Health Data, IoT, NLP.

I. INTRODUCTION

Asthma is a chronic respiratory disease that involves airway inflammation, bronchial hyperresponsiveness, and repetitive symptoms such as wheezing, coughing, chest tightness, and difficulty breathing[1]. There are many different kinds of asthma, ranging from mild to severe, that are experienced differently from person to person. Symptoms may be continuous or intermittent, and frequently symptomatic patients need to be evaluated for the severity of their disease. According to the WHO (World Health Organization), asthma affects over 260 million people all over the planet. Approximately 450,000 people die each year as a result of asthma worldwide [2].

Asthma is placing an increasing strain on global health care systems because of repeated admissions to the hospital and ongoing high costs related to treatment. In conjunction with overall clinical evaluation of asthma, spirometry testing is often included as part of the diagnostic process for asthma. There are general treatment options such as inhaled

corticosteroids or tailored treatment approaches based on individual patient needs. Diagnosis of asthma, classification of control, severity assessment and documentation of symptoms are often conducted through documentation in electronic health records (EHRs). One major barrier to identifying symptoms from EHRs is the lack of a standardized coding format and reliance on free-text clinical notes for documenting the symptoms associated with asthma. The limitations in identifying symptoms in EHRs have led to the increased demand for asthma prediction using AI and ML-based solutions[3].

A variety of different techniques have been utilized by research teams in attempts to develop AI methods for predicting asthma; these techniques include classical algorithms such as Random Forests and XGBoost and deep learning models such as Convolutional Neural Networks (CNNs), Long Short Term Memory (LSTM) networks and hybrid CNN-RNN networks. Other methodologies include Natural Language Processing (NLP) for identifying asthma symptoms in EHRs. In addition to classical and deep learning-based methods, a number of new approaches to asthma prediction are being explored including smart inhalers enabled with the Internet of Things (IoT), Explainable Artificial Intelligence (XAI) utilizing SHAP and LIME, and federated learning techniques for privacy-preserving predictions of asthma [4].

This review provides a systematic overview of 20 published studies focusing on algorithmic performance, dataset analysis and feature extraction methodology in order to compare algorithm performance, analyze datasets and evaluate current challenges and future directions for AI-based asthma prediction.

A. Structure of the Paper

The remainder of this paper is organized as follows: Section II discusses the data sources used for asthma prediction. Section III presents AI techniques applied in asthma prediction. Section IV highlights AI applications in asthma management. Section V outlines key challenges in AI-based asthma prediction. Section VI reviews relevant literature, while Section VII concludes the paper and discusses future research directions.

II. DATA SOURCES FOR ASTHMA PREDICTION

Clinical data used for asthma prediction are usually categorized into structured and unstructured sources. Structured data refers to information that is organized in a

predefined format and can be easily stored, processed, and analyzed by computer systems. Examples include tabular records, spreadsheets, laboratory test results, demographic information, and data stored in relational databases. Such data are machine-readable and support the efficient application of machine learning and statistical analysis techniques.

A. Sources of Structured Data

In an asthma prediction model, the clinical data sources contain a group of quantitative clinical laboratory tests, and a categorised list of behaviours of the patients using these test results. The dataset contained all symptoms from the patients[5], all of the results from laboratory tests, all lung function measurements and all biomarkers for airway inflammation for each of the sources contained in the dataset classified in order to represent all clinical records from structured datasets. There are many classical machine learning techniques (e.g., Random Forest, XGBoost, Support Vector Machines) that can reuse and build new models based upon the information contained in a structured clinical dataset very rapidly and efficiently (i.e., cross-validation/benchmarking). However, there are limitations to structured datasets - structured datasets do not record those variables (i.e. behaviours and clinical narrative) that weren't explicitly recorded in accordance with established standards [6].

B. Sources of Unstructured Data

Unstructured data refers to free-text notes written by the physician or clinical staff in electronic health applications (EHR) such as physical exam notes (e.g., progress notes), discharge summaries, and narrative descriptions of the findings by the physician, among others. Although there are numerous data-rich areas with varying levels of detail about symptoms, there are many issues regarding automated processing because of all the differences in terms, abbreviations, and how each physician documents things. For example, Xie et al recently demonstrated that information about the frequency of cough, wheezing, and shortness of breath, all related to asthma, could be extracted from the unstructured text within EHR free-text and written using NLP techniques. The ability to extract unstructured EHR data using NLP opens up vast retrospective datasets that otherwise would not be available through traditional AI-based methods. The combined use of structured and unstructured datasets is also being used to gain more benefit from both forms of data by giving them complementary benefits to generate more accurate predictions with a clinical relevance [7].

III. AI TECHNIQUES FOR ASTHMA PREDICTION

Artificial Intelligence (AI) has emerged as a powerful tool for helping asthma prediction, mostly because it can look through huge amounts of clinical data along with patient-generated information[8]. A bunch of AI methods, like Machine Learning (ML), Deep Learning (DL) and Natural Language Processing (NLP) are used to dig up asthma risk factors, estimate when the disease might start, and even forecast exacerbation events. In other words, they help pull out useful signals from both organized records and messy, unstructured healthcare data, so clinicians can move toward earlier detection and more individualized care plans. The next parts, below, kind of give an overview of the main AI techniques used for asthma prediction and what each one contributes to predictive healthcare in particular[9]. An overview of these techniques is shown in Fig. 1.

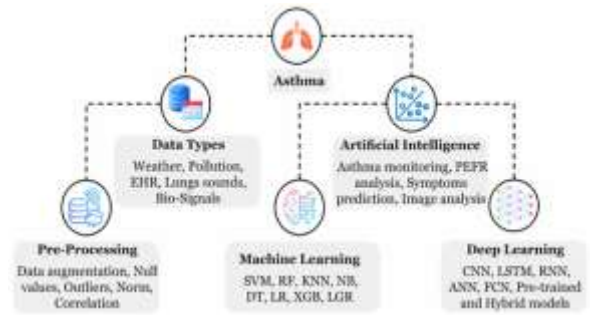


Fig. 1. Overview of AI Techniques for Asthma Prediction

A. Machine Learning Models for Asthma Prediction

Machine Learning (ML) is a subset of Artificial Intelligence that enables systems to learn patterns from data and make predictions without being explicitly programmed. In healthcare, ML techniques have been widely applied for disease prediction, diagnosis, and risk assessment. Asthma prediction studies mainly use supervised learning algorithms since clinical data is usually tagged with specific outcomes[10][11]. The main models include Random Forest, XGBoost, Support Vector Machines, Decision Trees, Logistic Regression, and Naive Bayes classifiers.

Among the many machine learning algorithms used for predicting asthma, Random Forest and XGBoost are among the most frequently used algorithms due to their ability to handle complex clinical datasets and achieve high predictive performance. Support Vector Machines and Logistic Regression also fit in a lot for sorting through data on asthma diagnosis and risk. Plus, studies show that ensemble learning methods typically do better than standard stats methods, especially with big electronic health record sets and various clinical data.

B. Deep Learning Models for Asthma Prediction

Deep Learning (DL) models have become increasingly popular in predicting asthma because they can automatically learn complex patterns from large healthcare datasets. Unlike traditional machine learning methods, deep learning doesn't need much manual feature engineering. It does a great job processing all sorts of info like patient records, signals, and sensor data.

Commonly used deep learning architectures include Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Long Short-Term Memory (LSTM) networks[12]. These models have demonstrated strong predictive performance in asthma diagnosis, risk assessment, and exacerbation prediction.

Hybrid methods that use deep learning for feature extraction and machine learning for classification have gotten more focus recently. Though these models work well, they need substantial computational resources, big datasets, and lots of memory. This can make it hard to use them in healthcare settings with limited resources.

C. NLP Approaches for Asthma Prediction

NLP techniques play an important role in asthma prediction, because they help pull out clinically relevant information from unstructured EHRs, those physician notes, and discharge summaries. In the older style, traditional NLP usually relies on word embedding approaches like Word2Vec, GloVe, and FastText to turn language into numbers that

machine learning models can actually use[13]. But more recently, contextual embedding models including ELMo and transformer-based systems such as BERT, made things better for understanding clinical language, since they can model how words relate to each other depending on the surrounding context. With that kind of setup, it becomes easier to spot asthma-related signs, for example cough, wheezing, chest tightness and even shortness of breath, directly from free-text clinical entries. Consequently, NLP has become a key part of AI-driven asthma prediction pipelines, because it converts huge amounts of messy healthcare text into predictive signals that are useful.

IV. APPLICATIONS OF AI IN ASTHMA MANAGEMENT

The use of AI in medical diagnosis has drastically changed the way that healthcare systems operate through improved efficiency. By using vast amounts of clinical data, AI is able to detect abnormalities more accurately than humans are able to do in many areas of the medical field. The major applications of AI in asthma management are illustrated in Fig. 2, highlighting the interconnected roles of risk prediction, IoT-enabled monitoring, NLP-based EHR analysis, and non-invasive diagnostic systems in improving clinical decision-making and patient care.

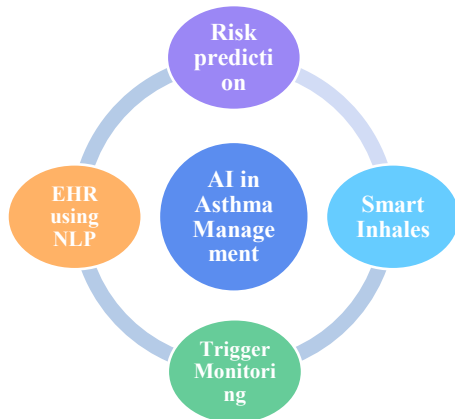


Fig. 2. Framework of AI Applications in Asthma Management

- **Early Diagnosis and Risk Prediction:** ML algorithms such as Random Forests and XGBoost can take into consideration a patient's EHR, and perform analysis to determine which patients have higher likelihood of developing asthma so that the necessary care can be provided to prevent the progression of the disease before it occurs [14][15].
- **IoT Smart Inhaler Symptom Monitoring:** Smart inhalers that are equipped with the IoT can provide real-time data related to the frequency of use and the environment in which the inhaler is being used, and these are then analysed by AI algorithms to look for patterns in the creation of asthma triggers, such as air quality, pollen count, etc. [16][17].
- **EHR Extraction using NLP:** NLP can be used to extract asthma-related symptoms from unstructured free-text clinical notes provided by healthcare professionals to an EHR, eliminating the need for extensive manual labour by healthcare professionals and thereby increasing the ability to monitor and track the symptoms of asthma.
- **Non-Invasive Breath Analysis:** Deep learning models, including CNNs and LSTM networks, have

been used for non-invasive diagnosis through the analysis of exhaled breath VOCs [18].

V. CHALLENGES OF USING AI FOR ASTHMA PREDICTION

There are some challenges phases when using AI models for prediction given below:

A. Class Imbalance and Data Scarcity in Clinical Datasets

- Data imbalance is a significant challenge in asthma prediction, where the number of non-asthmatic cases far exceeds those with asthma or experiencing attacks.
- The model ends up seeing more examples of people without asthma during training.
- It is a problem where the distribution of samples across the classes is skewed [19].

B. Limited Model Interpretability and Black-Box Opacity:

- Model interpretability is a critical challenge in applying ML models to predict asthma while complex models like deep learning & ensemble methods can perform better.
- Many AI models, especially deep learning ones, produce results without any explanation.
- Clinicians need to understand the reasoning behind a prediction before acting on it [20].

C. Patient Data Privacy and Regulatory Compliance:

- Asthma management faces significant challenges due to the rapid adoption of digital health technologies including smart devices and sensors generate vast amounts of personal data.
- Research using large datasets requires robust techniques to prevent re-identification attacks.
- Clinicians worry about managing the sheer volume of incoming data, which if not properly managed.

D. Lack of Dataset Standardization and Benchmarking Protocols

- Different studies use different datasets, different features and different ways of measurement that becomes complex to compare one study's results with another.
- Standardized, precise assessment of severe asthma is challenging, leading to limited delayed access to specialized care & biologic treatments.
- No agreed standards for how the models are built and tested before trusting any single result [21]

VI. LITERATURE REVIEW

This section provides a comprehensive review of the literature on AI techniques for asthma prediction, with a summarized overview presented in Table 1.

Valappil, Uddin and Al Heialy, (2026) explore the role of AI-integrated multi-omic approaches in asthma research, highlighting how AI-driven models can analyse vast datasets to uncover patterns often missed by traditional methods. These insights can improve diagnostic precision, predict therapeutic responses and guide the development of novel, targeted therapies. Key areas of focus include genetic loci associated with asthma severity, single-cell RNA sequencing to uncover cellular heterogeneity, and proteomic profiles that differentiate asthma phenotypes. Through this review, we aim to provide readers with a clear understanding of the current landscape in severe asthma research, highlighting the

breakthroughs achieved through AI-integrated multi-omic approaches[22].

Cilluffo et al. (2026) evaluate the application of ML-style models, including the use of logistic regression, decision trees, gradient boosting machines, support vector machines, and deep learning approaches such as long short-term memory networks, for the prediction of asthma exacerbations. Our findings indicate that from model performance assessment point of view ensemble learning methods, particularly random forests and boosting, consistently achieve higher accuracy than the traditional statistical models[23].

L. Tan et al. (2025) explore the transformative potential of artificial intelligence (AI) in improving asthma management through predictive analytics, personalized treatment, and continuous patient engagement. A search of the United States National Library of Medicine’s PubMed database was performed for articles pertaining to asthma and artificial intelligence, machine learning (ML), neural networks, or deep learning. The current research on AI applications in asthma care was then reviewed, including algorithms, AI-driven tools for personalized medicine, and digital platforms for patient engagement. Case studies and clinical trials assessing AI’s impact on predictive accuracy and treatment adherence were reviewed[24].

Zhou et al. (2025) aim to assess the application of ML techniques in pediatric asthma exacerbation and explore their effectiveness and potential value. Studies from four electronic databases, including PubMed, EBSCO, Elsevier, and Web of Science, from Jan 2000 to Jan 2025, were searched. Studies applying the ML methods for pediatric asthma exacerbation and published in English were eligible. The risk of bias and applicability of the included studies were assessed using the

Effective Public Health Practice Project (EPHPP) quality assessment tool[25].

Votto et al. (2024) aim to systematically evaluate and quantify the performance of machine learning (ML) algorithms in predicting the risk of hospitalisation and emergency department (ED) admission for acute asthma exacerbations in children. They performed a systematic review with meta-analysis, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The risk of bias and applicability for eligible studies were assessed according to the prediction model study risk of bias assessment tool (PROBAST)[26].

Budiarto et al. (2023) aim to critically evaluate ML-based models derived using EHRs for the prediction of asthma attacks. They systematically searched PubMed and Scopus for papers meeting the following inclusion criteria: (1) used EHR data as the main data source, (2) used asthma attack as the outcome, and (3) compared ML-based prediction models’ performance. We excluded non-English papers and non-research papers, such as commentary and systematic review papers. In addition, they also excluded papers that did not provide any details about the respective ML approach and its result, including protocol papers. The selected studies were then summarized across multiple dimensions including data preprocessing methods, ML algorithms, model validation, model explainability, and model implementation[27].

Table I presents a comparative summary of recent studies on artificial intelligence techniques for asthma prediction and management. The main focus, key findings, major challenges, limitations, and future research directions identified in different machine learning, deep learning, and AI-based approaches for asthma-related healthcare applications are tabulated

TABLE I. SUMMARY OF RECENT STUDIES ON AI TECHNIQUES FOR ASTHMA PREDICTION

Authors	Focus	Key Findings	Challenges	Limitations	Future Work
Valappil, Uddin and Al Heialy (2026)	AI-integrated multi-omic approaches for severe asthma research	AI-driven analysis of genomic, transcriptomic, and proteomic data improves diagnostic precision, predicts therapeutic response, and supports targeted treatment development	Integration and interpretation of large-scale multi-omic datasets	Complexity of multi-omic data integration and limited clinical translation	Develop more robust AI frameworks for personalized asthma diagnosis and precision medicine
Cilluffo et al. (2026)	Machine learning models for asthma exacerbation prediction	Ensemble learning methods, particularly Random Forest and boosting algorithms, consistently outperformed traditional statistical models in predictive accuracy	Handling heterogeneous clinical data and ensuring model generalizability	Variability in datasets and evaluation methodologies across studies	Develop standardized benchmarking frameworks and externally validated prediction models
L. Tan et al. (2025)	AI applications in asthma management and personalized care	AI improves predictive analytics, treatment personalization, patient engagement, and adherence through intelligent healthcare platforms	Integration of AI tools into routine clinical workflows	Limited large-scale clinical validation of AI-driven interventions	Conduct real-world clinical trials to assess long-term effectiveness and adoption of AI systems
Zhou et al. (2025)	Machine learning techniques for pediatric asthma exacerbation prediction	ML approaches demonstrated promising performance in identifying children at risk of asthma exacerbations	Ensuring model reliability and minimizing bias in pediatric populations	Limited availability of large, high-quality pediatric datasets	Develop robust pediatric-specific prediction models using diverse and multicenter datasets
Votto et al. (2024)	ML-based prediction of hospitalization and emergency department admissions in children with acute asthma exacerbations	Machine learning algorithms showed good predictive capability for hospitalization and ED admission risk assessment	Maintaining prediction accuracy across different healthcare settings	Risk of bias and heterogeneity among included studies	Improve model validation and establish standardized evaluation protocols
Budiarto et al. (2023)	EHR-based machine learning models for asthma attack prediction	Several ML models demonstrated high predictive performance using EHR data; preprocessing and explainability significantly influenced results	Data imbalance, model explainability, and lack of implementation standards	Limited reporting consistency and insufficient external validation across studies	Develop interpretable, standardized, and clinically deployable ML models for asthma attack prediction

VII. CONCLUSION & FUTURE WORK

Asthma is one of the most common chronic respiratory diseases worldwide, affecting millions of individuals and placing a significant burden on healthcare systems. Early and accurate prediction of asthma is essential for timely intervention, reducing disease severity, preventing exacerbations, and improving patient outcomes. Traditional diagnostic approaches often rely on clinical assessments, pulmonary function tests, and patient-reported symptoms, which may not always capture the complex and heterogeneous nature of the disease. With the rapid growth of healthcare data and advancements in computational technologies, Artificial Intelligence (AI) has emerged as a powerful tool for enhancing asthma prediction and management. AI techniques, including Machine Learning (ML), Deep Learning (DL), and Natural Language Processing (NLP), can analyze large volumes of structured and unstructured medical data to identify hidden patterns and predictive indicators. These technologies enable more accurate risk assessment, disease monitoring, and personalized treatment planning. Furthermore, AI-driven systems such as smart inhalers, wearable sensors, and electronic health record analytics are transforming modern asthma care. As research continues to advance, AI has the potential to support healthcare professionals in making informed clinical decisions and improving the overall quality of asthma diagnosis, prediction, and patient management.

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