

# Deciphering the Pathways towards Analysis of Existing Health care services by use of AI to Respiratory Diseases concerning Cough study: Future Challenges and Applications

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## Abstract

The rate of using artificial intelligence (AI) methods in the healthcare industry has been accelerating. Numerous scholars and health advisers are interested in the possible application of AI in the healthcare industry. Due to significant advancements in contemporary technologies, particularly AI and ML, the healthcare system has recently gained more attention. Current study is aimed to review the role of AI in healthcare services and analyze various respiratory diseases. This paper also highlights the review of various respiratory diseases, introduction to AI and its significant role in COVID-19 analysis, research gaps and challenges concerning cough analysis, and future scope.

**Keywords:** Artificial Intelligence, Machine learning, Respiratory diseases, Healthcare services, COVID-19 analysis, Cough analysis

## 1. Introduction

In today's world there has been an enormous growth in digitization and widespread utilization of Artificial Intelligence in various sectors such as finance, banking, IT, automobiles, aviation, manufacturing, health care services etc. The healthcare industry is important not just for sake of people's physical health but also for the economy as a whole. While the healthcare industry continues to be evolving, its quickly growing population is constantly in need of basic [1, 2]. AI is a broad term in health sector that signify use of AI to replicate human awareness in the examination, presentation and comprehension of complex healthcare data [3-5]. AI applications in healthcare are grouped into certain fields such as surgery, medical consultation, administration, cyber security etc. that uses AI as operations [6]. There are various applications of Artificial intelligence in medicine that can be utilised in a variety of medical domains [7]. Certain techniques could be employed based on AI to transform the health sector system. In critical scenarios such as pandemic, the healthcare sector is swamped with a massive rise in number of patient and AI can assist them as fast as possible while incurring the least amount of cost for treatment and diagnosis [8]. Furthermore, multiple ML based frameworks are used for the broad evaluation of infectious diseases affecting diverse systems such as the neurological, cardiovascular, digestive and respiratory systems [9]. The role of AI and ML is very crucial and important taking into

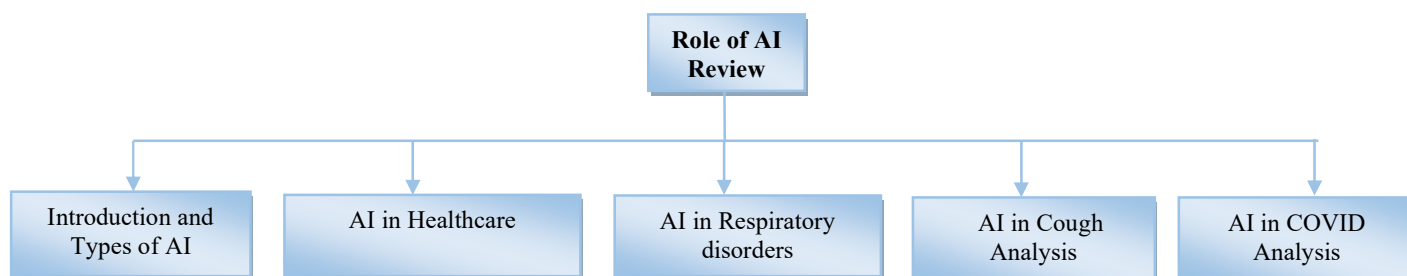
account the respiratory syndromes in health care services. The AI algorithms recognise patterns and properly advise therapeutic therapy in a long term screening [10, 11]. Among various respiratory sounds, cough is one the most distinctive. Cough offers important information for a variety of respiratory disorders that present as a sign of over 20 medical problems. By utilising powerful and unique ML or DL algorithm trained on cough acoustic data, specific latent patterns in cough can be utilised for the identification of various diseases [12]. According to some of the researchers, cough alone can be utilised as a diagnostic tool to categorise respiratory disorders with over 70% sensitivity [13, 14].

Thus, it has been clearly observed that the role of AI and ML is been crucial in various domains. Significant researches is been carried out to investigate AI in healthcare services utilising AI and ML algorithms. Also from above, it cannot be denied that AI also possess very important role in data acoustic in certain respiratory disorders. Some researchers highlighted the role of AI in various domains specifically in healthcare and analyse the importance of AI in various respiratory diseases. The ultimate objective that is required to study structured review of contribution of AI in healthcare targeting respiratory diseases specifically in detection of cough analysis.

## 2. Various aspects of AI Review and its Contribution in Healthcare

This section is classified into various segments. In the first segment, the introduction, types of AI and their applications are discussed. The second segment is followed by the role of AI in healthcare services discussing its overall tabular review. In the next segment various respiratory disorders are discussed along with the significant role of AI. The next section describes a brief introduction and review of role of AI in detection of cough analysis along with challenges and future scope. The last section discussed the contribution and review of several authors towards role of AI in COVID-19 analysis.

The complete layout of the review paper is shown in Figure 1.



**Figure 1. Layout structure of review paper**

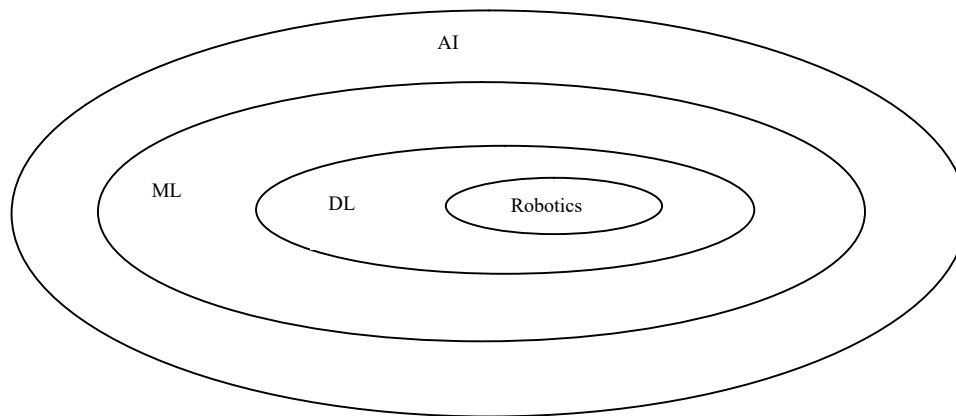
### 2.1. Introduction and types of AI

#### 2.1.1. Introduction to AI

A common approach to describe AI as the “biopsychological potential to process information to solve problems or generate products of value in a society.” Various scholars have defined AI in their own way. Some research project described AI in 1955 as the task of “making a machine act in manner that would be termed intelligent if a person did likewise” [15]. Similarly, Marvin Minsky, a cognitive scientist, defined AI as “the science of having robots accomplish things that would require intelligence if done by men” [16]. As such it’s a bit of a misconception – AI

is not a system; its a tool embedded in one. At its core, it is a tool that attempts to emulate human brain power and decision-making processes through the initial development of algorithms that learn from themselves and continue to learn from their own experience much like people. This enables the system (powered by AI) to use that knowledge to perform particular activities better, faster or more efficiently than people [17]. With respect to above definitions it is clear that AI have more broader meanings and concepts and its role is very important in today's modern era. AI also employs algorithms from machine learning to find underlying rules and patterns based on external information acquired from IoT (Internet of Things) or other big data sources.

In modern day world, we can define AI as the collective combination of Machine learning (ML), Deep learning (DL) and Robots as shown below in Figure 2.



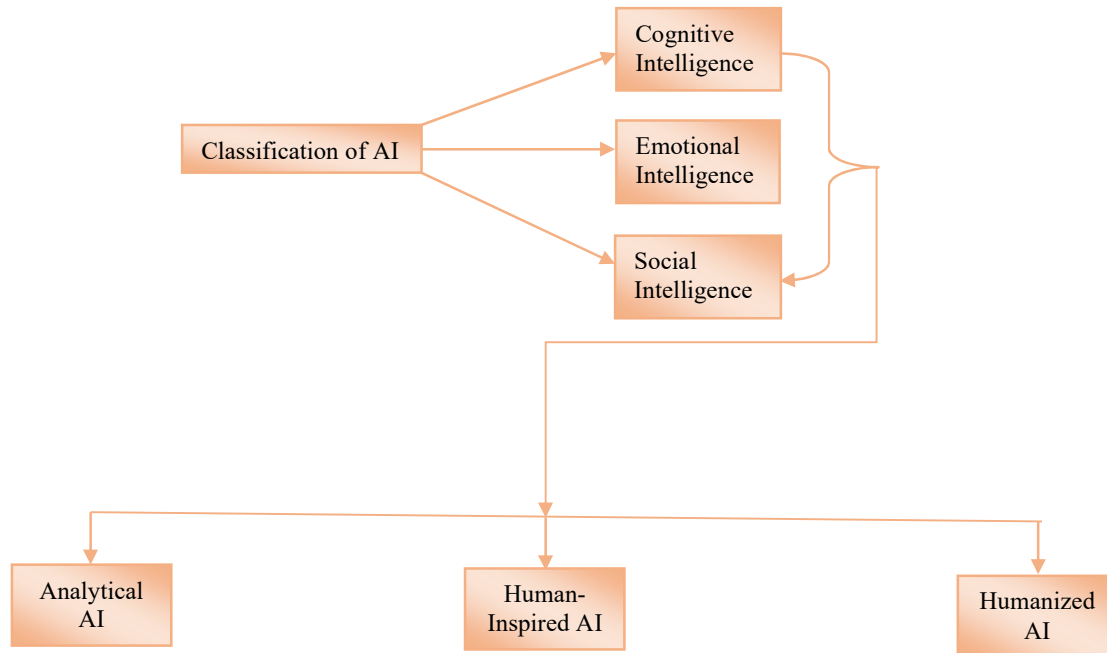
**Figure 2. Collective meaning of AI**

### 2.1.2. Classification of AI

On the basis of extensive literature and studies [18, 19, 20, 21] AI can be classified with respect to certain skills and type of competencies as –

- a) **Cognitive Intelligence** – Based on pattern identification and systematic thinking.
- b) **Emotional Intelligence** – Based on adaptability and emotional self-awareness.
- c) **Social Intelligence** – Based on teamwork and inspirational leadership.

Based on above competencies, we can also categorise AI into three groups as shown in Figure 3.



**Figure 3. Classification layout of AI [22]**

- **Analytical AI** – Analytical AI solely exhibits cognitive intelligence-like features. For example – image recognition, self-driving cars, fraud detection in financial services etc.
- **Human-Inspired AI** – Cognitive and emotional intelligence are both present in Human-Inspired AI. For example – an advanced vision system employed by AI firm to identify emotion characteristics such as joy, anger, surprise etc.
- **Humanized AI** – Humanized AI exhibits traits with all abilities. While advances in identifying and emulating human behaviours have been made, developing AI systems that really perceive the world in a significant way is a challenge.

### 2.1.3. Applications of AI

On AI is used in multiple applications such as in healthcare, education, e-commerce, banking, finance, lifestyle, navigation, robotics, human resource, aviation, automobiles etc. Some of the applications are as below:

- **AI application in E-Commerce**
  - AI-powered assistant – Chatbots significantly improve the user experience when buying online. Natural Language Processing (NLP) is employed in order to make discussion appear as human.
  - Fraud prevention – Fraud with respect to credit card and some bogus reviews are the main concern that online retailers face. AI can aid in the detection and management of bogus reviews.
- **AI application in Education**
  - Voice assistant – A student can obtain additional learning material or support with Voice assistants without event the direct engagement of a teacher. This reduces the printing expenses of books while making

it simple to obtain answers to more complicated and frequently asked issues.

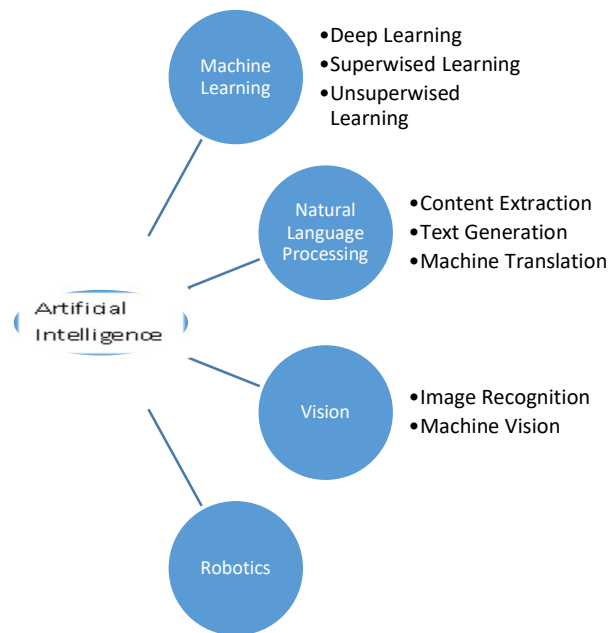
- Smart content creation – AI can be used to digitise information such as video lectures, conferences etc. AI contributes to a rich learning experience.

- **AI application in Lifestyle**

- Facial recognition
- Autonomous vehicles
- Spam filters

## 2.2. Role of AI in Healthcare review

The healthcare sector is changing rapidly. Prior to 2010, healthcare technology firms focused on the advancements offered by medical products that provided historical and evidence based therapy. Since 2010, work has been centred on real-time medical platforms. Beginning in 2020, technology has been shifted towards medical solutions that provide intelligent solutions based on health with an emphasis on preventive care. These intelligent solutions can be realised through the use of robotics, augmented reality and AI [23]. There are certain AI methods that commonly used in healthcare applications as shown in Figure 4 such as – ML, Neural network (NN), DL, NLP, Machine vision (MV), Physical robots and Robotic process automation [6, 24]. Various authors have described the role of AI in healthcare firm that are being discussed as below.



**Figure 4. AI methods used in healthcare services [6]**

The Hao et al. [25] studied the role of text mining in medical research. The study and research were carried out and found out that text mining discloses previously undiscovered information

Santos et al. [26] reviewed the importance of DM and ML techniques to solve general health concerns. These can be achieved through data mining and machine learning approach.

Choudhury et al. [27] conducted a survey on the application of machine learning to better the care of elderly people, identifying research that are particularly relevant to psychological illness and visual ailments.

Connelly et al. [28] studied regarding robot-assisted surgeries. The study revealed the expansion of robot-assisted surgeries in recent years.

Lee et al. [29] conducted a review survey and analysed the role of ML algorithms to help in the treatment selection and user experience of therapies among people suffering from depression through analysis utilizing Google Scholar databases, MEDLINE/PubMed etc. from earliest publications up to 8 Feb 2018.

Anderson [30] investigated the feasibility of merging DL technology. According to this study, identifying patients with rLVEF might be beneficial in cases where echocardiography or other modalities are unavailable and it can also be found out that early detection of rLVEF may have a direct impact on patient diagnosis and mortality rates.

Kavakiotis et al. [31] conducted thorough review on the use of ML and DM approaches in diabetes research. The authors discovered that Support Vector Machines (SVM) was employed in 85% of the studies and was recognised as the most commonly used technology, while 15% of studies employed unsupervised learning relied on association rules.

Nindrea et al. [32] performed a meta-evaluation to assess the accuracy of ML in predicting breast cancer. In this approach along with 11 more studies, it was discovered that SVM outperformed the other approaches mentioned such as ANN, DT, NB and KNN.

Houssami et al. [33] examined the application of AI for Breast Cancer, emphasising its ability to reduce human detection mistakes.

Vongsingthong and Smachat [34] outlined the role of mobile healthcare systems. As per the research, it include patient tracking and monitoring via wearable devices to provide therapy, medical advice etc.

Javed et al. [35] discussed the role of combination of AI with medical devices that can replace expensive specialist consultants and examined the problems of detecting cardiovascular disorders particularly in rural regions. The study involved creation of a knowledge-based system to provide judgement on the risk of heart disease.

Hussain et al. [36] stressed the importance of employing AI to fight the COVID-19 outbreak. The study provided a basic survey of several technologies for several based on clinical experience.

The above literature review successfully highlighted the role of AI in healthcare services and its importance and significance. With respect to above review it is quite evident that tremendous research has been carried out to explore and utilize AI in the field of healthcare. This segment discussed the overall review of role of AI in healthcare sector as shown in Table 1 and it can be found out from the table that most of the researchers followed the ML as one the common method of AI in healthcare. Some of the descriptions of review as per Table 1 are as above. It can also been observed from table 1 that, significant research is being carried out to enhance the role of AI in the field of certain diseases and disorders in healthcare that will be the part of discussion in the next segment.

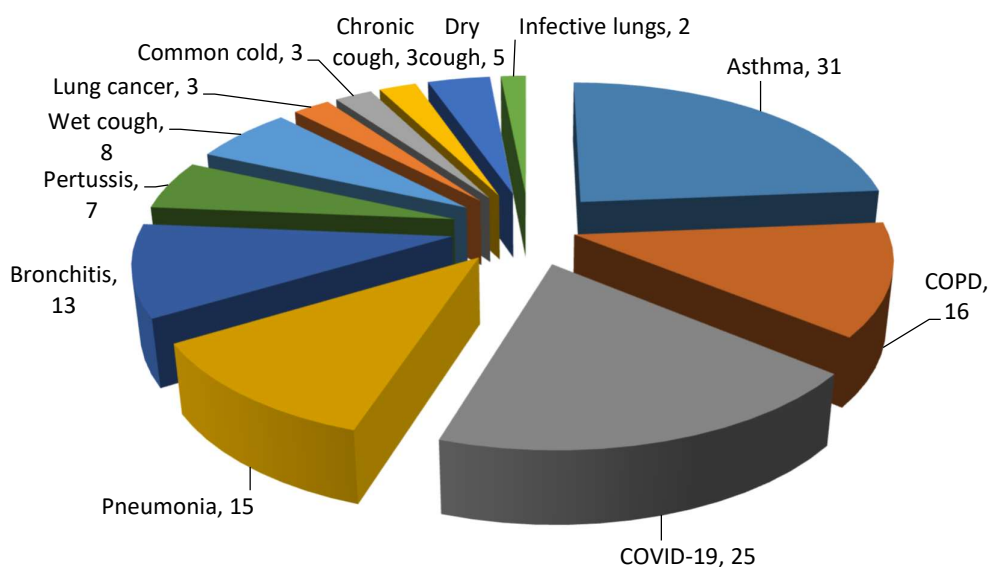
**Table 1.Role of AI in healthcare tabular review**

Author	Field of study	AI method	Results/Description	Refer
Hao et al.	Text mining in medical research	Text Mining	The importance of text mining in the analysis of medical data	25
Santos et al.	Data mining (DM) and ML approaches are being used to public health challenges	DM, ML	The importance of DM and ML in public health issues.	26
Choudhury et al.	Machine learning is used in clinical care for chronic diseases.	ML	ML is being used to improve the care of elderly in areas such as psychological disease and visual impairment.	27
Connelly et al.	Influential manuscripts in robotic surgery: a bibliometric analysis.	Robotics	The robot-assisted surgeries expansion in recent years including urology, colorectal, cardiothoracic, orthopaedic and neurosurgery applications.	28
Lee et al.	Machine learning algorithms to predict therapeutic outcomes in depression	ML	ML algorithms helps in the selection of treatment among people suffering from depression.	29
Anderson	Artificial intelligence-augmented ECG assessment.	DL, ML	Merging of DL technology applications .	30
Kavakiotis et al.	ML and data mining methods in diabetes research	ML, DM	Supervised learning with SVM was recognized as the most commonly used technology.	31
Nindrea et al.	Diagnostic accuracy of different machine learning algorithms for breast cancer risk calculation	ML	SVM super-performed the other approaches	32

### 2.3. Role of AI in Respiratory diseases review

The current use of AI and improvements in detecting respiratory disorders has resulted in a plethora of potential outcomes in the medical sector. According to a study published in 2016, different respiratory infections in young and adults caused 4.3% deaths or more than million deaths [37]. In order to avoid this in the future, one approach is to develop technologies for early diagnosis of probable respiratory tract infections, which would lower the possibility of serious problems later on. The utilization of AI in respiratory medicine is becoming increasingly important [38].

There are several respiratory diseases that possess a severe threat and a growing concern nowadays as shown below in Figure 5 where COPD, COVID-19, Pneumonia etc were regarded as severe pulmonary diseases. ML is a subset of AI which computers self-learn using statistical approaches rather than being explicitly programmed [39]. Artificial intelligence can use machine learning to develop complex correlations that would be difficult to represent using an equation [38]. A set of data is analyzed by artificial intelligence algorithms to look for patterns that could be utilized to forecast clinical outcomes or identify obstructive characteristics. The neural network approach is cutting-edge for detecting obstructive patterns in CT [40-44]. Various authors have studied and discussed their contribution towards the role of AI and ML in respiratory disorders that are being discussed as below.



**Figure 5. Respiratory diseases overview [45]**

Hua et al. [46] presented the first identification findings of lung nodules using the DL algorithm on CT in 2015, with a sensitivity of 73% and a specificity of 80%. (Computed Tomography). The findings show that CAD (computer-aided detection) and DL outperform the classic CAD approach.

Hagan et al. [47] produced a tailored medical prediction tool that can anticipate the respiratory support ahead of time, increasing clinical judgement precision and lowering the occurrence of incorrect mechanical ventilation.

Ma et al. [48] created a classification model utilising an SVM-based method. The resulting model diagnosed Obstructive sleep apnea syndrome. The system allows gathering and processing of data. The preliminary test of the algorithm using real patient data revealed sensitivity, accuracy etc.

Hwang et al. [49] demonstrated the DL algorithm's supremacy and investigated trained algorithm on certain dataset to differentiate between normal and tumour.

Kukreja et al. [50] developed and evaluated algorithms for diagnosing bronchial asthma using a thorough data, medical records and questionnaire.

Gonzalez et al. [51] used chest CT to find out whether this approach is used to diagnose and stage COPD, as well as forecast exacerbation and death. Following



model training with CT data from participants was put to test on more than 500 patients. The results showed that COPDGene participants have greater chance as compared to who are not at risk, however in ECLIPSE, the model was unable to identify people at risk. Overall, the utilization of AI in the detection of obstructive lung disorders shows encouraging outcomes.

Hardinge et al. [52] examined an algorithm with customised physiologic threshold, patient-reported symptoms, and prescriptions via mobile app (inhalers, antibiotics etc.). According to the findings, 40% of exacerbations were preceded by a warning signal within three days of a patient beginning medication.

Maldonado et al. [53] examined and rated the severity of parenchymal lung abnormalities. In a 2.4 year follow-up, the algorithm revealed predictive power based on reticular abnormalities, interstitial abnormality severity etc.

The above literature review successfully illustrated the outcomes of AI in several respiratory syndromes and highlighted the importance of ML algorithms in respiratory diseases. With respect to above review we could analyse that researchers have significant work in healthcare segment and respiratory diseases. This segment discussed the overall review of role of AI in respiratory diseases as shown in Table 2 and it can be found out from the table that most of the researchers followed the ML and Neural Network techniques such as (CNN, PNN, ANN) as one the common method of AI and ML in study of respiratory disorders. Some of the descriptions of review as per Table 2 are as above. It can also been observed from table 2 that, enormous research is being carried out to analyse and implement AI in the field of certain respiratory disorders in healthcare but there is little or less work to study role of AI in cough analysis that will be the part of discussion in the next segment.

**Table 2.Role of AI in respiratory diseases tabular review**

Author	Disease/ Disorder	Method	Results/Description	Refer.
Kukreja et al.	Asthma	A questionnaire data, Machine learning approach, Associative Memory Neural Network Model Bayesian and Particle Swarm Optimization	The algorithms suggested in this study have an accuracy of more than 75%. Neural network algorithm has an accuracy of more than 85%.	50
Gonzalez et al.	COPD	1,000 nonoverlapping COPD Gene participants and 1,672 ECLIPSE participants for Convolutional neural network, Logistic regression, Cox regression	COPD Gene participants have a 2.15 times higher chance of exacerbation. ECLIPSE model was unable to identify individuals at risk.	51
Hardinge et al.	COPD	Personalized physiological cutoffs, medications	The results revealed, 40% of exacerbations had a warning signal.	52
Maldonado et al.	Idiopathic pulmonary fibrosis	CALIPER	The algorithm demonstrated predictive power based on reticular and interstitial abnormalities.	53
Lakhani and Sundaram	Tuberculosis	Deep CNN pre-trained and untrained models	The pre-trained models were found to be greater than untrained models.	54
Topalovic et al.	Respiratory diseases	Machine Learning approach, CNN	AI correctly interprets all PFTs (Pulmonary Function Test)(100%) and made the correct diagnosis.	55
Fernandez-Granero et al.	COPD	Probabilistic Neural Network mode	Early detected exacerbations with 80.5% accuracy	56

#### 2.4. Role of AI in detection of cough analysis

Respiratory infections are a major modern medical problem that has a massive global health impact [57]. Cough is a crucial and necessary early sign in the majority of respiratory infections [57, 58]. Coughs are typically caused by viral or bacterial respiratory illnesses. There are various varieties of coughs, each with distinct sound characteristics that healthcare practitioners can identify. These

distinguishing cough characteristics allow AI models to be trained and useful to identify the disease in a quick time, hence assisting medical personnel [59]. Several AI-based methods have been created in recent years to detect and distinguish cough noises from various types of environmental sounds or to pre-diagnose various respiratory illnesses using pre-recorded cough sounds [60, 61].

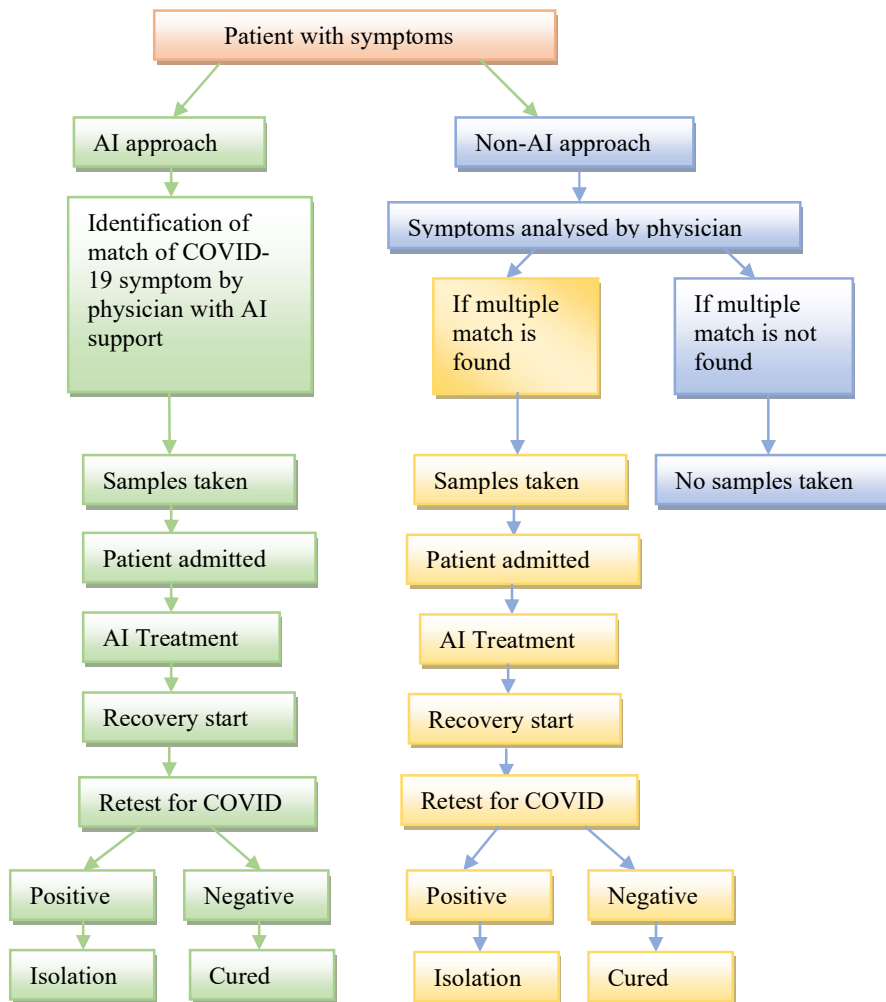
Few authors have studied and analysed detection of cough analysis by use of AI algorithms as shown in Table 3. With respect to below table, it can be found that several authors have analysed detection of cough with different AI methods and CNN being the most accurate method as compared to other AI algorithm methods. Therefore, algorithms capable of assigning coughs to the individuals that produced them are necessary.

**Table 3. Role of AI in detection of cough analysis algorithm review [59]**

Author	Disease/ Disorder	AI algorithm	Accuracy	Refer.
Windmon et al.	COPD	RF	79%	62
Sharan et al.	Pneumonia, asthma, bronchiolitis	SVM	86%	63
Laguarta et al.	COVID-19, alzheimer	CNN	98%	64
Dunne et al.	COVID-19	CNN	97%	65
Mouawad et al.	COVID-19	XGBoost	-	66
Swarnkar et al.	Pneumonia	Logistic Regression	77%	67
Brown et al.	COVID-19, asthma	LR	69-72%	68

## 2.5. Role of AI in detection of COVID-19 analysis

Health care centre is a critical field that must use latest technologies to have accurate diagnosis of disease [69]. Coronavirus-2 leads to severe respiratory problems, resulting in the novel coronavirus. In order to fight with new diseases, healthcare domain prompt the use of new technologies such as AI, IoT and ML. AI is one such alternative used as tool to identify high-risk patients as shown in Figure 6 [70]. Various authors have discussed their contribution towards role of AI in COVID-19 analysis that are being discussed below as shown in Table 4.



**Figure 6. Generalised approach to identify COVID-19 symptoms [70]**

**Table 4. Significance of AI in COVID-19 analysis tabular review**

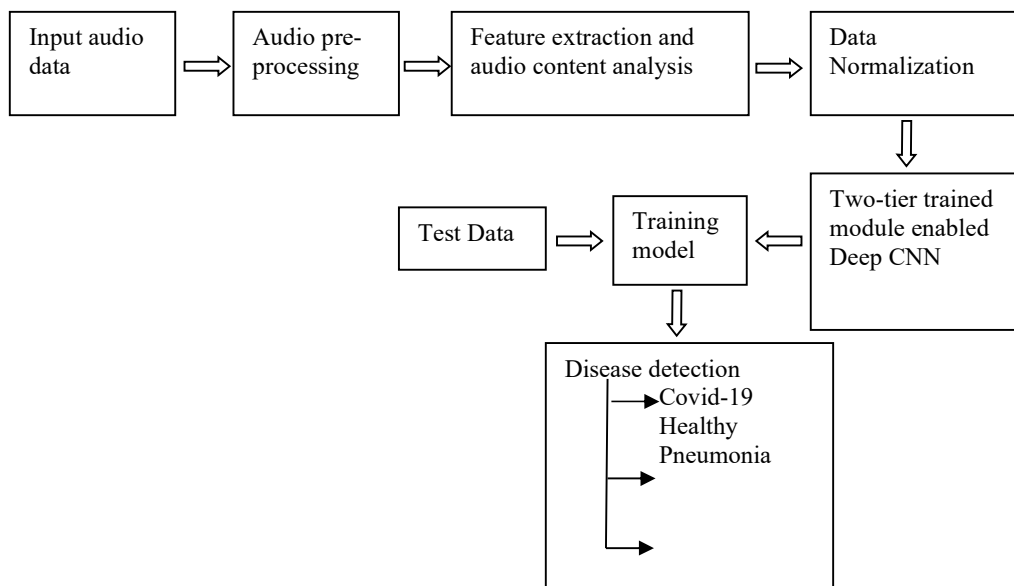
Author	AI Method	AI Algorithm	Results/Description	Refer.
Khanday et al.	Supervised Learning (SL)	Classification Logistic Regression (LR) and Naïve Bayes	LR and multinomial NB were found to be more effective than the most widely used algorithms based on the findings' 96% accuracy	71
Brunese et al.	SL	k-NN	In this study, a method is proposed for automatically detecting the COVID-19.	72
Anastasopoulos et al.	SL	CNN	The results demonstrated that the algorithm for completely automated lung segmentation and reached human-level performance even in challenging COVID-19 situations.	73
Scarpone et al.	SL	NB	They concentrated on variables and factors that contribute to COVID-19 occurrence using the multi-method ESDA strategy.	74
Chekole .et al.	SL	LR	The findings revealed that more than half of the participants in the research experienced perceived stress from coronavirus disease.	75
Mollalo et al.	SL	ANN	The findings provided significant insights for public health decision makers in classifying the impact of putative risk variables related with COVID-19 incidence level.	76

The above literature review as shown in Table 4 successfully demonstrated AI algorithms in detection of COVID-19 analysis. With respect to above review it can be concluded that there have been significant work done in field of COVID-19 detection and analysis and studied the role of AI using ML algorithms in detection of COVID-19. It can also be found out from the table that most of the researchers followed the ML (Supervised Learning) technique as one the common method of AI and ML in study of COVID-19 detection.

With respect to Table 3 and Table 4, it can be found that several authors have analysed detection of cough and COVID-19 with different AI methods such as SVM, ANN, Deep NN, Deep CNN and ML (Supervised Learning). CNN being the most accurate method as compared to other AI algorithm methods and can be used as a future research method.

From the entire literature review section it can be concluded that little or no work is being carried out for disease prediction with the cough sound analysis and for detecting and classifying the disease as Covid-19, Healthy, or Pneumonia and also to carry out comparative analysis using the Covid 19 cough sounds dataset and Respiratory Sound Database.

So, considering all the above criteria in mind, research work could be carried out as a conceptual model as shown in Figure 7 as a future prospective with different classifiers and datasets and the analysis of the cough sound for disease prediction along with comparative analysis using the Covid 19 cough sounds dataset and Respiratory Sound Database.



**Figure 7. Conceptual model for cough sound analysis with different classifiers and datasets for disease prediction**

### 3. Conclusion

This paper discussed the introduction to AI and the review of role of AI in healthcare services and it has been concluded that –

- 1) AI possess significant role in various domains and healthcare sector is more prominent among all domains.
- 2) Among all various methods of AI, most of the researchers opted ML as a common AI method to study healthcare sector.
- 3) In healthcare field, AI possesses a crucial role in study of respiratory syndromes.
- 4) Most of the researchers selected ML and Neural Network techniques to study and analyse role of AI in respiratory diseases.

- 5) Among all respiratory disorders, cough detection analysis is very crucial. For cough detection, several authors have used various algorithms and out of all algorithms CNN was found to be more accurate.
- 6) Most of the researchers followed the ML (Supervised Learning) technique as one the common method of ML in study of COVID-19 detection.
- 7) Conceptual model could be prepared as a future research work for cough sound analysis with different classifiers and datasets for disease prediction.

#### 4. Research Gaps and Challenges

- Author Significant research is been carried out by various researchers in the domain of AI. Various researchers have studied the role of AI in various domains and from literature review it can be found out that AI plays a significant role in healthcare services. From extensive literature review, among healthcare services – AI also plays a most promising role in study of various respiratory disorders. From literature review, it is quite clear that in order to study various respiratory diseases, authors selected various AI based algorithms. Most of the researchers adopted ML and Neural network AI methods to study and analyse various respiratory diseases due to its greater accuracy as compared to other methods. Moreover very little work has been done in the field of cough detection as a major respiratory syndrome. In earlier work of cough detection, CNN method proved to be a accurate method. The accuracy of the conventional respiratory detection model is not good enough for large-scale gathering of labelled cough data. In order for filling up the research gap more work should be done by the authors in the field of cough detection analysis.
- The conventional algorithms fail to distinguish coughs from other sounds such as speech or background noise, which negatively influence the system performance.
- The identification of the distinct features of cough sounds is found to be the challenging task in conventional method to interpret diagnostic system performance.

#### 5. Future Scope

- To explore and analysis various disease detection model based on the cough audio signal to know various limitation in the existing models.
- To design and develop the DL model for the effective detection of disease using cough-audio signal.
- To design and develop an algorithm to tune the hyper parameters of deep learning classifier to attain high accurate detection.

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