JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Exploring AI/ML/DL Approaches for Respiratory Disease Classification: A Comparative Analysis

[1]Supritha Ravishankar, [2]Uma K M, [3]Yamini M R, [4]Suneetha S L, [5]Thaheera M

[2]Assistant Professor, Dept. of CSE
[1,3,4,5]Student, Dept. of CSE
[1,2,3,4,5]Dr. Ambedkar Institute of Technology-Bengaluru, India

Abstract: Respiratory diseases pose significant challenges to public health, necessitating accurate and timely diagnosis for effective management and treatment. In the recent years, there has been a surge in research that explores the applications of artificial intelligence (AI), machine learning (ML), and deep learning (DL) involved techniques to classify respiratory diseases. This survey paper aims to impart a comprehensive overview of the diverse methodologies employed in the classification of respiratory diseases using AI/ML/DL across various modalities, including images, sounds, spirometry data, and the integration of patient symptoms, genomic data, and environmental factors. By synthesizing the existing techniques, this paper sheds light on the state-of-the-art approaches in this critical area of medical research, ultimately contributing to the evolution of respiratory disease diagnosis and management.

Index Terms – *Respiratory diseases, Artificial Intelligence, Machine Learning, Deep Learning, Spirometry, Sound analysis*

I. INTRODUCTION

In the domain of medical science, advancements facilitated by computer science technologies such as Artificial Intelligence (AI), Machine Learning (ML), as well as Deep Learning (DL) have significantly enhanced disease detection and recognition processes. For instance, Dawadikar et al. conducted a comprehensive survey on techniques for classifying pulmonary diseases utilizing deep learning methods [1]. This paper provided insights into various methodologies and steps involved in the detection/recognition of pulmonary diseases, particularly utilizing lung sound data. Their findings exemplify on the effectiveness of varied approaches and experiments, aiming to guide the development of new and improved classification techniques with higher accuracy.

Sfayyih et al. conducted a comprehensive review focusing on lung disease recognition through acoustic signal analysis employing deep learning networks [2]. Their study highlighted the significance of auditory analysis alongside medical imaging for enhancing predictive accuracy in the early detection of diseases, including lung cancer as well as respiratory illnesses. This review fills a significant gap in the literature, as only a limited number of studies have focused on signal analysis for lung disease diagnosis in previous years. By examining the implementation of Deep Learning Convolutional Neural Networks (DLCNN) in diagnosing obstructive lung diseases, Sfayyih et al. identified promising developments in this field, emphasizing the necessity for further large-scale investigations to validate these findings and promote acceptance within the medical community.

Sabry et al. conducted a thorough exploration of lung disease recognition methods using audio-based analysis using machine learning approaches [3]. The paper highlights various elements crucial for sound-based lung disorder classification employing machine learning algorithms, such as datasets, feature extraction techniques, pre-processing methods, artifact removal techniques, and deep learning algorithms. Sabry et al. also identify literature gaps in existing studies and emphasize the promising results of sound-based machine learning in the categorization of respiratory diseases. Their work serves as a significant advancement in the field, offering valuable insights for researchers.

Our survey diverges from existing surveys by encompassing a broad spectrum of techniques for respiratory disease classification. Unlike previous surveys primarily focusing on images and sounds, we explore methods utilizing diverse data sources including spirometry data, patient symptoms, genomic data, and environmental factors.
Structured into three sections, our paper offers a comprehensive examination of the subject matter. Section 2 presents methodologies with technical papers tabulated based on each technique. Section 3 addresses limitations and challenges of existing methods, while Section 4 concludes our findings.

II. METHODOLOGIES

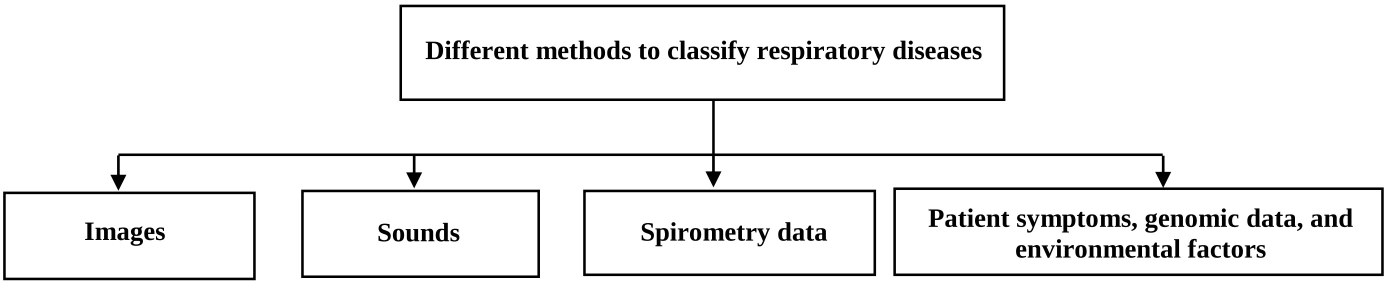

Image based classification

This method involves collecting and preprocessing large datasets of CT scans or chest X-ray images. Characteristics are extracted using conventional techniques or learned directly through deep learning models like CNNs.
In [4], the method proposed involves the development as well as the evaluation of a convolutional neural network (CNN) specifically tailored for classifying chest diseases. This architecture comprises convolutional layers, ReLU activations, pooling layers, with a fully connected layer with fifteen output units. Additionally, each output unit also predicts the likelihood of one of fifteen chest diseases.

In [5], the authors present AI-CenterNet CXR, an artificial intelligence (AI)-enabled system designed for both localizing and classifying chest X-ray diseases. The approach integrates CenterNet, a state-of-the-art object detection framework, utilizing deep learning model to classify diseases. Through experimentation and evaluation, the system demonstrates promising results in both localization and classification tasks, exhibiting its prospects for enhancing diagnostic capabilities in chest X-ray analysis.
In [6], the authors introduce a deep learning method for multi-class lung disease classification using chest X-ray (CXR) images. Their method employs transfer learning, leveraging a pre-trained EfficientNet v2-M model for feature extraction and disease category identification. By directly inputting raw CXR images into the model, meaningful features are extracted to distinguish between normal, pneumonia, pneumothorax, and tuberculosis cases.

In [7], the authors address the challenges of detecting and classifying chest diseases from X-ray images by proposing the CXray-EffDet model. This deep learning method utilizes the EfficientDet architecture, specifically the EfficientNet-B0-based EfficientDet-D0 model, to extract reliable features from X-ray images for disease detection and classification. The complex nature of chest radiographs, including varying exposure levels and image artifacts, poses difficulties for automated systems. However, the CXray-EffDet model demonstrates effectiveness in accurately localizing and categorizing eight classes of chest abnormalities.

In [8], the authors tackle the challenge of accurately detecting pneumonia using chest X-ray images by using deep learning techniques, particularly the MobileNet model. Variability in image acquisition and processing further adds complexity to the task, necessitating robust algorithms trained on large, diverse datasets. The proposed system employs eight pre-trained models, including ResNet50, ResNet152V2, DenseNet121, DenseNet201, Xception, VGG16, EfficientNet, and MobileNet, trained on datasets comprising 5856 and 112,120 chest X-ray images.

Table 2.1 Summary of image-based techniques

Ref	Year	Objective	Model	Techniques	Dataset	Accuracy
4	2021	To design a convolutional neural network to classify lung diseases using X-ray images and patient data.	Deep Learning and Machine Learning	CNN and CapsNet	Chest X-Ray 14	89.77%
5	2022	Propose an AI-enabled system to identify chest abnormalities such as Pneumonia, COVID-19 etc.	Artificial Intelligence/Deep Learning	CenterNet, DenseNet	National Institutes of Health (NIH) Chest X-ray	88.8%
6	2022	Classification of four classes of lung diseases using raw CXR images.	Deep Learning	Transfer Learning, EfficientNet	Soonchunhyang University Hospital (SCH)	82.20%
7	2023	Recognize chest X-ray illnesses such as bronchiectasis, lung lesions based on images.	Deep Learning	CXray-EffDet	NIH CXR Database	90.8%
8	2023	Develop a model that detects Pneumonia using chest X-ray images.	Deep Learning	MobileNet	Chest X-Ray 14	94.3%

Sound based classification

This method of classification entails collecting and preprocessing audio data, often comprising lung sounds such as wheezes and crackles or cough sounds. Feature extraction techniques, including time-frequency analysis and spectrogram representation, are applied to capture relevant characteristics.

In [9], the authors explore the implementation of Convolutional Neural Network-based deep learning methodologies for analysing respiratory audio data for detecting Chronic Obstructive Pulmonary Disease (COPD). Their study involves utilizing features extracted using the Librosa machine learning library, including MFCC, Mel-Spectrogram, Chroma, Chroma (Constant-Q), and Chroma CENS. Additionally, to optimize the model's performance, the authors employ K-fold Cross-Validation with ten splits.

In [10], the authors investigate leveraging voice recordings to predict pulmonary function, aiming to offer a non-invasive method for self-monitoring asthma symptoms. Their study employs machine learning techniques predict lung function together with the severity of abnormal lung function in asthma patients. A threshold-based mechanism is utilized to separate speech and breathing in 323 recordings, with features extracted and combined with biological factors for prediction. Predictive models are implemented using Random Forest (RF), Support Vector Machine (SVM), and linear regression algorithms.

In [11], the authors present a diagnostic tool designed to automatically identify and classify respiratory diseases by analyzing the statistical characteristics of respiratory sounds. A comprehensive elimination process refines the variable list, followed by classification using various algorithms such as Light GBM and Random Forest Classifier through the PyCaret library's 'compare models' function. Employing advanced classifiers, models, and segmentation approaches, the method efficiently separates respiratory sounds, aiding in accurate diagnosis and treatment. Furthermore, two-stage classification (binary and multiclass) is performed 500 times using Extra Tree Classifier, AdaBoost, and a deep neural network.

In [12], the authors aim to develop a deep learning model for classifying respiratory disorders using lung sounds. Leveraging techniques like Convolutional Neural Networks (CNN), MFCC, Chroma STFT, and Mel-spectrogram. The developed model achieves a classification accuracy of 83.3%, promising its potential for detecting chronic lung disorders.

In [13], authors introduce a novel approach that utilizes digital stethoscope technology for automatic respiratory disease classification and biometric analysis. Their method employs Empirical Mode Decomposition (EMD) and spectral analysis techniques to isolate clinically relevant bio signals within acoustic data captured by digital stethoscopes.

Table 2.2 Summary of sound-based techniques

Ref	Year	Objective	Model	Techniques	Dataset	Accuracy
9	2021	Detection of COPD based on respiratory sounds.	Deep Learning	CNN, MFCC, Mel-Spectrogram, Chroma, Chroma (Constant-Q) and Chroma CENS.	ICBHI	92%
10	2022	To design models that predicts in a binary and multi-class approach using speech segments.	Machine Learning	Random forest, SVM, linear regression algorithms	Olympus DM450 Speech recorder	85% (binary) 73.2% (multi-class)
11	2024	Model to differentiate between healthy respiratory disease-affected sounds.	Deep/Machine Learning	ANN, Ada Boost classifier, Extra Trees classifier	Respiratory Sound Database	94.7%
12	2022	Develop deep learning model to classify respiratory diseases based on lung sounds.	Deep Learning	CNN, MFCC, Chroma, Mel-spectrogram	Kaggle Respiratory Sounds	83.3%
13	2023	Binary and multi-class categorization of respiratory diseases using digital stethoscope recorded sounds.	Machine Learning	Biosignals, EMD, Spectral analysis, multi-layer perceptron (MLP)	ICBHI17	89% (binary) 94% (multi-class)

Spirometry data-based classification

Spirometry data-based classification of respiratory diseases begins with the collection and preprocessing of spirometry measurements, which typically include parameters such as forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). Feature engineering techniques extract relevant features from the measurements, such as airflow patterns and lung function indices.

The authors in [14] address the challenge of distinguishing between obstructive and non-obstructive pulmonary diseases, which exhibit symptomatic similarities. The researchers aim to develop machine learning models for classifying these diseases based on spirometry data. Supervised learning models, such as support vector machine (SVM), random forest (RF), Naive Bayes (NB), and multi-layer perceptron (MLP) algorithms, are trained and validated using spirometry data from 1163 patients, employing 5-fold cross-validation. Additionally, the MLP model is deployed on a web server for use in a web application, enabling early prediction of obstructive and non-obstructive pulmonary diseases.

In [15] the authors propose leveraging machine-learning algorithms to analyze spirometry data for identifying structural phenotypes of chronic obstructive pulmonary disease (COPD), a task not adequately addressed by traditional spirometry outputs. The study utilizes a large dataset from the COPDGene study and trains a deep-learning model on expiratory flow-volume curves to predict structural phenotypes of COPD on CT scans. Results indicate that the neural network outperforms traditional spirometry metrics and an optimized random forest classifier in discriminating predominant emphysema/airway and emphysema/small airway phenotypes.

Table 2.3 Summary of Spirometry data-based techniques

Ref	Year	Objective	Model	Techniques	Dataset	Accuracy
14	2022	To classify Spirometry data as obstructive and non-obstructive pulmonary disease.	Machine Learning	SVM, Random Forest, NB, MLP	Institute of Pulmocare and Research (IPCR)	83.7%
15	2020	COPD detection by analysis of spirometry metrics in comparison with a DL model to predict structural phenotypes using CT scans.	Deep Learning	FCN, random forest classifier	COPDGene	91%

Patient symptoms, environmental factors, and genomic data-based classification

This method involves collecting diverse datasets encompassing symptoms reported by patients, environmental exposures, and genomic profiles. Challenges include data heterogeneity, feature selection bias, and model interpretability.

In [16] the authors propose a machine learning model to support symptom-based referral and identification of bronchitis and pneumonia in these settings, aiming to lessen the impact of pneumonia. Utilizing a dataset of 4500 patients from a middle-income country, the study focuses on easily measurable clinical symptoms for feature selection. Three common machine learning methods—logistic regression, decision tree as well as and support vector machine—are tested and compared.

The authors in [17] focused on developing a prediction system for the early detection of Acute Exacerbation of Chronic Obstructive Pulmonary Disease (AECOPD) within the upcoming 7 days, using lifestyle data, environmental factors, and patient symptoms. Wearable devices, a home air quality-sensing device, and a smartphone app were utilized to collect data on lifestyle, temperature, humidity, and fine particulate matter. Machine learning models such as the random forest, decision trees, k-nearest neighbour, linear discriminant analysis, adaptive boosting, and a deep neural network model were evaluated for prediction performance.

In [18], the study explores various modalities utilized in lung cancer diagnosis, including medical imaging, genomics, and clinical data, each posing distinct challenges. Their proposed Multimodal Fusion Deep Neural Network (MFDNN) architecture integrates information from diverse modalities to enhance diagnostic accuracy. Emphasis is placed on integrating clinical data and electronic health records to improve diagnostic reliability. Ethical considerations surrounding AI deployment in clinical settings and the significance of robust validation and regulatory guidelines are discussed.

In [19] the authors explore the application of a diagnostic system for lung cancer, focusing on predicting the attributes of chest CT pulmonary nodules. Their research enhances the diagnostic method utilizing convolutional neural network (CNN) as well as recurrent neural network (RNN), leveraging both algorithms' dual effects to classify benign in addition to malignant nodules. Pathological slices from 652 patients' lung lesions are collected, and the improved 3D U-net system's output results are differentiated with two-person reading. Sensitivity, specificity, positive predictive value, together with negative predictive value of different lung nodule detection methods are analyzed. ROC curves are drawn based on the AI system's and radiologists' judgment results.

Table 2.4 Summary of patient symptoms, genomic data and environmental factors-based techniques

Ref	Year	Objective	Model	Techniques	Dataset	Accuracy
16	2021	To diagnose diseases such as bronchitis and pneumonia with the aid of patient symptoms.	Machine Learning	Decision Tree	Hospital Sarjevo	93%

17	2021	Develop an AECOPD predictor using environmental factors and patient symptoms.	Machine Learning and deep-neural network	Random forest, Decision Tree, KNN, linear discriminant analysis, adaptive boosting	Fitbit Versa, EDIMAX Airbox, National Taiwan University Hospital	92.1%
18	2023	Classification of lung cancer using Genomic data, clinical records and medical imaging	Deep Learning	MFDNN	TCIA, TCGA	92.5%
19	2022	Develop an AI-based model to diagnose lung cancer using pathological slices.	Artificial Intelligence/Deep Learning	CNN, RNN	Jiangxi Provincial People's Hospital	92.3%

III. DISCUSSION

Despite the prospects of sound-based approaches for respiratory disease classification, several challenges must be addressed. Variability in sound patterns poses a significant obstacle. Respiratory sounds exhibit considerable variability based on factors like the type and severity of the respiratory condition, patient demographics, and comorbidities. This variability complicates the developing of algorithms capable of accurately distinguishing between various respiratory diseases based solely on sound patterns.

Moreover, relying solely on X-ray images of the lung may not suffice in assessing a patient's illness accurately. Patient symptoms provide valuable clinical insights, but subjective interpretation and variability in reporting can impact the reliability of classification. Genomic data holds promise for personalized medicine but requires robust computational frameworks for integration and interpretation.

Environmental factors, although crucial in understanding disease etiology, pose challenges in data aquisition and interpretation due to complex interactions and confounding variables. Moreover, variability in disease presentation challenges the usage of spirometry data alone for diagnosis. Diseases like asthma, chronic obstructive pulmonary disease (COPD) and restrictive lung diseases often exhibit overlapping symptoms and spirometry patterns, necessitating additional clinical information for accurate diagnosis.

IV. CONCLUSION

We have meticulously analyzed existing methodologies, identified limitations, and outlined challenges inherent in respiratory disease diagnosis, emphasizing the pioneering identity of the dataset under study and the necessity for innovative approaches to tackle its size and noise levels effectively. Despite hurdles such as variability in sound patterns, background noise interference, and the intricacy of interpreting spirometry data, the promise of sound-based methods, particularly cough analysis, shines through as a beacon of hope for accurate and non-invasive respiratory disease diagnosis. Through collaborative efforts and interdisciplinary collaboration, we envision a future where robust computational frameworks and algorithms harness the rich information embedded in respiratory data, ultimately improving patient care and clinical outcomes on a global scale.

REFERENCES

[1] A. Dawadikar, A. Srivastava, N. Shelar, G. Gaikwad and A. Pawar, "Survey of Techniques for Pulmonary Disease Classification using Deep Learning," 2022 IEEE 7th International conference for Convergence in Technology (I2CT), Mumbai, India, 2022, pp. 1-5, doi: 10.1109/I2CT54291.2022.9824879. keywords: {Shape;Pulmonary diseases;Pipelines;Noise reduction;Lung;Pattern classification;Feature extraction;Pulmonary Diseases;CNN;MLP;RNN;MFCC},

[2] Sfayyih AH, Sulaiman N, Sabry AH. A review on lung disease recognition by acoustic signal analysis with deep learning networks. J Big Data. 2023;10(1):101. doi: 10.1186/s40537-023-00762-z. Epub 2023 Jun 12. PMID: 37333945; PMCID: PMC10259357.

[3] Ahmad H. Sabry, Omar I. Dallal Bashi, N.H. Nik Ali, Yasir Mahmood Al Kubaisi, Lung disease recognition methods using audio-based analysis with machine learning, Heliyon, Volume 10, Issue 4, 2024, e26218, ISSN 2405-8440, https://doi.org/10.1016/j.heliyon.2024.e26218.

[4] Tripathi, Siddhanth & Shetty, Sinchana & Jain, Somil & Sharma, Vanshika. (2021). Lung Disease Detection Using Deep Learning. 10.35940/ijitee.H9259.0610821.

[5] Albahli S, Nazir T. AI-CenterNet CXR: An artificial intelligence (AI) enabled system for localization and classification of chest X-ray disease. Front Med (Lausanne). 2022 Aug 30;9:955765. doi: 10.3389/fmed.2022.955765. PMID: 36111113; PMCID: PMC9469020.

[6] Kim S, Rim B, Choi S, Lee A, Min S, Hong M. Deep Learning in Multi-Class Lung Diseases' Classification on Chest X-ray Images. *Diagnostics*. 2022; 12(4):915. https://doi.org/10.3390/diagnostics12040915

[7] Tripathi, Siddhanth & Shetty, Sinchana & Jain, Somil & Sharma, Vanshika. (2021). Lung Disease Detection Using Deep Learning. 10.35940/ijitee.H9259.0610821.

[8] Reshan MSA, Gill KS, Anand V, Gupta S, Alshahrani H, Sulaiman A, Shaikh A. Detection of Pneumonia from Chest X-ray Images Utilizing MobileNet Model. *Healthcare*. 2023; 11(11):1561. https://doi.org/10.3390/healthcare11111561

[9] Srivastava A, Jain S, Miranda R, Patil S, Pandya S, Kotecha K. Deep learning based respiratory sound analysis for detection of chronic obstructive pulmonary disease. PeerJ Comput Sci. 2021 Feb 11;7:e369. doi: 10.7717/peerj-cs.369. PMID: 33817019; PMCID: PMC7959628.

[10] Alam MZ, Simonetti A, Brillantino R, Tayler N, Grainge C, Siribaddana P, Nouraei SAR, Batchelor J, Rahman MS, Mancuzo EV, Holloway JW, Holloway JA, Rezwan FI. Predicting Pulmonary Function From the Analysis of Voice: A Machine Learning Approach. Front Digit Health. 2022 Feb 8;4:750226. doi: 10.3389/fdgth.2022.750226. PMID: 35211691; PMCID: PMC8861188.

[11] Oğuzhan Karaarslan, Kristen Dominica Belcastro, Onur Ergen,Respiratory sound-base disease classification and characterization with deep/machine learning techniques,Biomedical Signal Processing and Control,Volume 87, Part A,2024,105570,ISSN 1746-8094,https://doi.org/10.1016/j.bspc.2023.105570.

[12] A. H.S, P. K.R, S. G, P. Rao and T. S.K, "Detection of Chronic Lung Disorders using Deep Learning," *2022 Fourth International Conference on Cognitive Computing and Information Processing (CCIP)*, Bengaluru, India, 2022, pp. 1-5, doi: 10.1109/CCIP57447.2022.10058633.

[13] Casado, C. Á., Cañellas, M. L., Pedone, M., Wu, X., Nguyen, L., & López, M. B. (2023). Respiratory Disease Classification and Biometric Analysis Using Biosignals from Digital Stethoscopes. *ArXiv*. /abs/2309.07183

[14] Sudipto Bhattacharjee, Banani Saha, Parthasarathi Bhattacharyya, Sudipto Saha, Classification of obstructive and non-obstructive pulmonary diseases on the basis of spirometry using machine learning techniques,Journal of Computational Science,Volume 63,2022,101768,ISSN 1877-7503, https://doi.org/10.1016/j.jocs.2022.101768.

[15] Bodduluri S, Nakhmani A, Reinhardt JM, Wilson CG, McDonald ML, Rudraraju R, Jaeger BC, Bhakta NR, Castaldi PJ, Sciurba FC, Zhang C, Bangalore PV, Bhatt SP. Deep neural network analyses of spirometry for structural phenotyping of chronic obstructive pulmonary disease. JCI Insight. 2020 Jul 9;5(13):e132781. doi: 10.1172/jci.insight.132781. PMID: 32554922; PMCID: PMC7406302.

[16] Katy Stokes, Rossana Castaldo, Monica Franzese, Marco Salvatore, Giuseppe Fico, Lejla Gurbeta Pokvic, Almir Badnjevic, Leandro Pecchia,A machine learning model for supporting symptom-based referral and diagnosis of bronchitis and pneumonia in limited resource settings,Biocybernetics and Biomedical Engineering,Volume 41, Issue 4,2021,Pages 1288-1302,ISSN 0208-5216,https://doi.org/10.1016/j.bbe.2021.09.002.

[17] Wu C, Li G, Huang C, Cheng Y, Chen C, Chien J, Kuo P, Kuo L, Lai F Acute Exacerbation of a Chronic Obstructive Pulmonary Disease Prediction System Using Wearable Device Data, Machine Learning, and Deep Learning: Development and Cohort Study JMIR Mhealth Uhealth 2021;9(5):e22591 URL: https://mhealth.jmir.org/2021/5/e22591 DOI: 10.2196/22591
.

[18] Sangeetha S.K.B, Sandeep Kumar Mathivanan, P Karthikeyan, Hariharan Rajadurai, Basu Dev Shivahare, Saurav Mallik, Hong Qin,An enhanced multimodal fusion deep learning neural network for lung cancer classification,Systems and Soft Computing,Volume 6,2024,200068,ISSN 2772-9419, https://doi.org/10.1016/j.sasc.2023.200068.

[19] Chen S. Models of Artificial Intelligence-Assisted Diagnosis of Lung Cancer Pathology Based on Deep Learning Algorithms. J Healthc Eng. 2022 Mar 26;2022:3972298. doi: 10.1155/2022/3972298. Retraction in: J Healthc Eng. 2023 Oct 11;2023:9874292. PMID: 35378943; PMCID: PMC8976635.