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Review Article

Lung Cancer Screening in India: Role of Digital healthcare and Artificial Intelligence: Where do we stand and future perspectives.

Kulshrestha Ritu[1], Meenu Rani[2]

[1]*Director Professor & Head, Department of Pathology, V.P.Chest Institute, University of Delhi.*
[2]*PhD Scholar, Department of Pathology, V.P.Chest Institute, University of Delhi.*

Abstract

Lung cancer has a high prevalence and low survival rate in India due to patients presenting at late-stage. The National Cancer Control programs and Tobacco cessation programs are working to improve their diagnosis and management. However, there are no public health programs for Lung Cancer Screening in India.

The early detection/Screening for Lung Cancer in India is vital for improving patient outcomes and is the emergent need of this decade. The unique risk factors predisposing to lung cancer, epidemiological variations across various geographical regions of India, multistep carcinogenesis, proteogenomics associated with lung cancer are focus areas of developing screening parameters specific to our country.

In this review, we collate the available data of Lung Cancer from India. We explore the potential applicability of the National Digital health Mission started in India in 2020, for initiating the lung cancer screening programme. Further we assess the applicability of upcoming newer technologies using Artificial intelligence in creating a Lung cancer screening module in association with Digital healthcare programme in India to benefit the 1.5 billion population of India.

Keywords : *Lung Cancer Screening, India, Artificial Intelligence, LDCT.*

INTRODUCTION

Lung cancer is the leading cause of cancer-related death worldwide, with 1.8 million deaths annually. In India, Lung cancer is the 4th most prevalent cancer, with 81,742 new cases reported in 2022 alone (Bray et al, GLOBOCAN 2022). Despite the advancements in cancer treatment and care, lung cancer patients in India have a poor survival rate (75,031 deaths reported in 2022) (Globocan, 2022; Parikh, 2016). The survival rate from lung cancer is estimated to be approximately 5% in India as compared to ~20% survival in Western Nations (Jemal, 2011). The reasons for this poor prognosis include: 1) An advanced stage of presentation of most cases of lung cancer in India at time of initial diagnosis, 2) Lack of Screening Program for Lung Cancer in India, 3) unique risk factor for different geographic region in the country (Noronha, 2016), 4) indoor air pollution/domestic-biomass fuel exposure, 5) the presence or lack of micronutrients in our diet 6) Environmental/occupational exposure, 7) contribution of infectious pathogens such as Mycobacterium tuberculosis, 8) tobacco- Chewing/Smoking cigarettes, beedis, both 9) Lack of advanced Radiological scan facilities and Pathological/ Molecular diagnosis in far reach areas.

Since, the most significant factor which determines the survival of a patient newly-diagnosed with lung cancer is the stage at which the disease has been diagnosed (Read, 2006, Scagliotti, 2001). Traditionally lung cancer screening has been attempted using sputum analysis and radiological X Ray scans as the primary methods. However, these had low sensitivity and specificity for early diagnosis with additional radiation exposure and therefore did not find favour for epidemiological studies. From the 1970s and 1980s three large, ambitious, randomized studies conducted at Mayo Clinic, Johns Hopkins Oncology Center, and Memorial Sloan-Kettering Cancer Center (MSKCC), failed to demonstrate a disease-specific mortality benefit from screening smokers for

***Corresponding Author:** **Dr. Ritu Kulshrestha**, Director Professor and Head, Department of Pathology, Vallabhbhai Patel Chest Institute, University of Delhi, New Delhi, India, 110007, **Phone:** +919891334373, **E-mail:** ritukumar71@yahoo.com.
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lung cancer (Melamed, 1987). As a result, no recommendation for screening patients for lung cancer was made and there was no public health strategy for early detection, intervention, or prevention of lung cancer.

GUIDELINES FOR EARLY DETECTION/ SCREENING OF LUNG CANCER

In the present decade, with the introduction of Low-dose computed tomography (LDCT), various Guidelines have been defined for Screening of lung cancer. Some of these include: National Comprehensive Cancer Network (NCCN) Guidelines, China guideline for the screening and early detection of lung cancer (CGSL), The United States Preventive Services Task Force (USPSTF), and International Early Lung Cancer Action Program (I-ELCAP) etc. These guidelines define the ideal screening tests as having (1) improve outcomes; (2) be scientifically validated (eg, have acceptable levels of sensitivity and specificity) with low false-positive rates, preventing unnecessary additional testing; and (3) be low risk, reproducible, accessible, and cost-effective.

The NCCN Clinical Practice Guidelines in Oncology (NCCN Guidelines) for Cancer Screening recommend to screen all high-risk Individuals with a ≥20-Year History of Cigarette Smoking for lung cancer (Wood, NCCN Guidelines-Version-1.025, 2025). The results of such screening have shown promise with up to 18.1% of eligible individuals having undergone lung cancer screening in 2022 (based on the 2021 USPSTF criteria (Henderson, 2024; Bandi, 2024). Even with this low degree of uptake, lung cancer screening was found to be likely responsible for the observed stage shift at diagnosis from advanced- to early-stage cancer in the USA (Potter, 2022; Vachani, 2022). The NCCN Guidelines differ from the USPSTF and CMS national coverage recommendations by not including time since quitting smoking as an eligibility criterion for lung cancer screening (Krist, 2021). However, the high cost and availability of advanced Radiology centers is a major deterrent in many developing parts of the world.

FEASIBILITY STUDIES ON LUNG CANCER SCREENING IN INDIA

The implementation of lung cancer screening (LCS) using low-dose computed tomography (LDCT) among high-risk individuals has been advocated since 2011 (Aberle, 2011) to reduce lung cancer mortality (de Koning, 2020). In 2019, a Feasibility Study for the Integration of Low Dose Computed Tomography (LDCT) for Lung Cancer Screening in the National Cancer Program in India was carried out (Meena, 2019). This descriptive online survey of specialists doctors in northern India included key questions on: lung cancer screening, LDCT awareness, the feasibility of its integration in the National cancer program, using Google survey tool.The survey revealed that 71.69% specialists practiced smoking cessation counselling but only one fourth (25.47%) counted LDCT screening as potentially beneficial, with Nearly half (50.94%) being vary of the harm caused by false positive results of LDCT. Majority of the Specialists (80.75%) favored integration of LDCT screening for reducing lung cancer-related mortality. Poor patient knowledge (55.28%), Poor finances and logistics (67.92%), human resource (38.11%) and denial of cancer risk (36.03%) were quoted as primary causes of refusal for screening (Meena, 2019). Thus, highlighting the need for including lung cancer screening protocols for high risk persons along with strengthening of smoking cessation counselling across the country.

In high tuberculosis-burden countries (HTBC), such as India, there are concerns about high false-positive rates of Lung cancer on LDCT due to persistent lung lesions from prior tuberculosis (TB) infections. Damaraju et al, 2024, performed systematic review and concluded that Lung cancer screening by LDCT in HTBC demonstrates comparable screen-positive rate (SPR) and lung cancer detection rate (LCDR) to regions with lower TB incidence rates (Damaraju, 2024). The secondary analysis of the National Lung Screening Trial (NLST), one-third of the patients from histoplasmosis endemic regions were more likely to have positive results at baseline, necessitating follow-up scans to confirm their benign nature (Balekian, 2016).

The National Digital Health Mission (NDHM)

The National Digital Health Mission (NDHM) was launched in India on August 15, 2020, to create a compact digital health ecosystem and is revolutionising healthcare sector of India with the health care Initiatives like Ayushman Bharat Digital Mission, CoWIN App, Aarogya Setu, e-Sanjeevani, e-Hospital which make health care facilities and services reach every corner of India. Using the Digital India Programme network and the AI derived algorithms the high risk tobacco consuming population of India can be identified across different geographical regions of the country. This will help offset the disadvantage of peripheral centers that lack having trained radiologists and pathologists that remains as a deterrent for lung cancer screening program in populous countries such as India. The high risk person can be given the opportunity for radiological scan and molecular tests at tertiary centres for early diagnosis. This will enable adequate therapeutic interventions and improve the overall morbidity and survival of lung cancer patients.

Magnitude of Tobacco menace in India

Tobacco is used in smokeless form as well as by Smoking (mainly in the form of bidi, followed by cigarette, hukah, chilum, chutta, etc) in India (Bhonsle, 1992). The habit of

smokeless tobacco (also referred as tobacco chewing) is also very common. Some common forms of smokeless tobacco include khaini, Mainpuri tobacco, mawa, mishri, etc. Tobacco has been associated with three disease entities: coronary artery disease, chronic obstructive lung diseases and cancers of oral cavity, pharynx, larynx, lungs & oesophagus. The Government of India Survey estimated that in 1996, 184 million persons (150 million males and 34 million females) in India used tobacco with about 112 million persons smoking tobacco, while 96 million used it in smokeless form (GOI, 2001).

Types of Lungs Cancer and their prevalence in India

The recent 2021 WHO Classification of Thoracic Tumours classified lung tumors using their morphological features, immunohistochemistry, and molecular signatures (Nicholson, 2022) in small diagnostic samples as well as in lung resections. These small diagnostic samples can be obtained in tertiary pulmonary care centres such as the Vallabhbhai Patel Chest Institute, University of Delhi and other Pulmonology Departments across the country, in medical colleges and Private sector. Lung cancers have been observed on radiological scans to present as mass lesions as well as diffuse multiple cavitary nodules (Spalgais, 2025). Using histopathology and immunohistochemistry these lung cancer cases are differentiated from other diffuse parenchymal lung diseases and classified as per WHO guidelines (Kulshrestha, 2009). Their genomic subtyping based on PD-L1 expression, tumour histopathology and mutation burden -EGFR and KRAS (Kulshrestha, 2021) has been performed in patients from North India (Kulshrestha, 2023). The use of Tumor cell phagocytosis (cannibalism) in lung cancer has been suggested as a possible biomarker for tumor immune escape and prognosis (Kulshrestha, 2023).

The use of Empirical Anti-tubercular therapy in our patients can lead to delayed diagnosis of pneumonic type adenocarcinoma (Spalgais, 2021). Given the large geographical diversity in India and the lack of expert doctors in far flung villages across the country, there is an unmet need of designing predictive algorithms to screen and diagnose early cases of lung cancer. These need to incorporate the LDCT results with biopsy pathology and molecular signatures of progression in high risk cases, in order to reduce the prevalence of lung cancer burden in India.

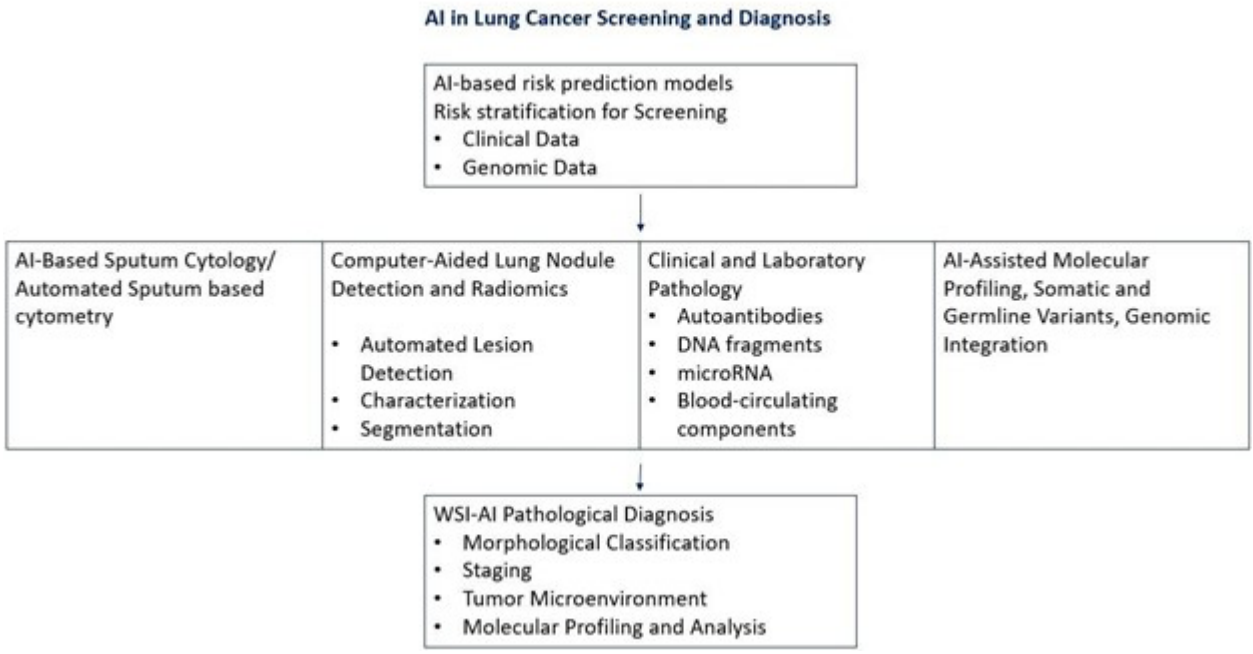
AYBA and its integration with Predictive AI for Lung Cancer Screening

The use of the latest Artificial Intelligence models using predictive algorithms has the potential to identify the high risk individuals and screen their low-dose CT (LDCT) scans to calculate their risk of development of lung cancer (Duranti, 2025). These AI derived algorithms can integrate the data pertaining to each and every enrolled Ayushman Bharat-AYBA card holder with their radiology and pathological profile for identification of high risk individuals. Next using predictive algorithms and the (a) Clinical profile (Age, Sex, geographic region, occupation, family history, Tobacco- smoking history-cigarette, beedi, indoor air pollution, vaccination status, infectious disease history. (b) Radiological profile (Xrays, CT scan etc performed in Govt or Private sector if any), radiological annotation of lesions in high risk individuals and their progression. (c) Pathological markers of progression including sputum cytology, FNAC/Biopsy Pathology, (d) Molecular profile- Genomics, Proteomics, metabolomics- these high risk patients can be screened for early diagnosis of lung cancer in high risk individuals. Correlating with the epidemiological profile will help us understand the alarming rise in the incidence of lung cancer among nonsmokers and women in India.

AI in Lung Radiology/ Radiological Diagnosis of Lung Cancer

Several studies have explored the role of AI in detecting lung cancer, particularly in analyzing CT scans and aiding radiologists in screening and diagnosis (Duranti, 2025). The FDA has approved several AI programs in CXR and chest CT reading, which enables AI systems to take part in lung cancer detection. These AI-based tools (**Figure 1**) in lung cancer imaging use machine automated lesion detection from the scanned images and differentiation from normal lung, characterization, segmentation of the lesion, prediction of outcome, and treatment response.

Figure 1.



Radiological imaging computation using algorithms allows for faster, more accurate and consistent evaluation of lesions. The use of AI algorithms to enhance diagnostic accuracy of lung radiology images is therefore progressing exponentially. By automating image analysis and reducing inter-reader variability, it has shown much potential in the screening and diagnosis of lung cancer, firstly to distinguish whether a solitary pulmonary nodule is benign or malignant, secondly to allow early diagnosis, which enable operable lung cancer diagnosis with curative intent (Walia, 2016; Sampedro, 2014). At the forefront of this approach are Tomas Vykruta and Joe Bertolami from the Microsoft Kinect project. Using computer algorithms it would be possible to distinguish pulmonary tuberculosis from lung cancer with a high degree of accuracy. Another emerging application is radiogenomics that integrates image phenotype to genomics using supervised learning (SL) to solve the clinical question (Lee, 2021). The widespread diffusion of artificial intelligence (AI), radiomics, and machine learning is dramatically changing the current diagnostic landscape. AI-driven lung cancer screening can achieve over 90% sensitivity, compared to 70–80% with traditional methods, and can reduce false positives by up to 30%. AI also boosts specificity to 85–90%, with faster processing times (a few minutes vs. 30–60 min for radiologists) (Duranti, 2025).

PATHOLOGICAL DIAGNOSIS OF LUNG CANCER

At a cellular level, lung cancer arises by multistep carcinogenesis process with accumulation of genetic mutations which drive the cell to dysplasia (reversible) and neoplasia (Irreversible). The in-situ lung carcinoma is defined as neoplasia that has not penetrated the basement membrane of the mucosa. The first signs of invasive cancer are invasion of the basement membrane and infiltration of malignant cells into the underlying connective tissues and blood vessels. This process may take between 10 and 20 years to develop (Read, 2006). This is the Golden period for screening for identification of potential patients using latest molecular pathology techniques

Sputum screening for lung cancer has been significantly researched by different groups, since the 1970s when sputum cytology was mooted as the new non-invasive screening revolution for lung cancer (Fontana, 1984). However, the diagnostic yield of sputum cytology was found to vary in relation to tumour location. While sputum smears could identify central lung tumours they had limited or no value in the identification of peripheral cancers (Thunnissen , 2003).

Since 2021, the ICMR has initiated the process of Geo-mapping of Pathology Services at Government and Privately owned hospitals/medical colleges/diagnostic labs across every state, region and district of India. This will help in developing the Test availability resource status for routine and Specialised test (Immunohistochemistry, electron microscopy, Immunofluorescence, flow cytometry, molecular studies-cytogenetics, FISH, PCR, Sequencing, Omics) etc across India. This Geo-map will enable clinicians and patients better access to diagnostic, screening and therapeutic options available locally and Nationally.

AI deep learning neural networks have demonstrated utility in lung cancer detection, classification, microenvironment analysis and prognosis estimation through microscopic image analysis and biomarker detection. In sputum cytology for lung cancer screening, AI reduces inter-observer variability and improves accuracy(Kim, 2023; Hays, 2024)

Similarly, AI-generated prediction models in clinical pathology based on multi-biomarker panels including autoantibodies, complement proteins, tumor DNA, RNA and serum proteins in blood and body fluids, have improved the specificity and sensitivity of early screening and diagnostic tests (Hirales, 2014; Batra, 2024). If the AI algorithms of multi-modal imaging (e.g., CT and PET scans) are combined with liquid biopsy findings the screening for the early molecular alterations in lung cancer can be done (Duranti, 2025).

Additionally, convolutional neural networks (CNN) as well as fully convolutional neural networks (FCN), mask-regional convolutional neural network (Mask-R CNN) and conditional random field (CRF) (Wang, 2018; Yi, 2018; Wang, 2019; Saltz, 2018; Coudray, 2018) have been tested to characterize the tumor microenvironment of lung cancer; tumor cells, stroma cells, lymphocytes at a single cell level (Wang, 2018), angiogenesis using automatic micro-vessel segmentation (Yi, 2018). There is much potential to determine patient prognosis using deep learning algorithms combining cytological, histo-morphological, radiological and clinical features (Wang, 2019; Saltz, 2018; Coudray, 2018)

In India, there have been AI-based pipelines for the screening and diagnosis of lung cancer which factor in resource-limited constraints (Batra, 2019; Zhong, 2024; Gandhi, 2023).The largest series of patients of lung cancer from India, showed pharmacogenomic differences in our population and recommended personalized therapy to optimise outcome of lung cancer patients (Parikh, 2013).

Previously A study at Massachusetts General Hospital established a framework to apply sustainable development goals in AI-digital pathology in low- to middle-income countries. Adopting and tailoring this approach to lung cancer evaluation in the Indian clinical and pathological setting would be beneficial in addressing gaps in validation, clinical workflow integration and generalizability across diverse datasets (Piya, 2023).

Integrating complex imaging biomarkers with clinical, epidemiological data and pathological data will pave the way to identify high risk persons for lung cancer and predict survival outcomes and early personalized treatment (Lee, 2020).

CONCLUSION

The parallel developments in digital healthcare networking with automation in radiology, molecular Pathology and artificial intelligence provides the prospect of providing a screening model for detecting early lung cancers in India and improving the prognosis of high risk populations

It is estimated that Effective lung cancer screening may prevent an estimated 48,000 lung cancer deaths per year in the United States, with up to 21% more deaths averted by removing the 15-YSQ criterion(Wolf, 2024; Sands, 2021) using the eligibility criteria for screening to include individuals with a ≥20-year smoking history, along with pack-years, to assess the risk associated with smoking exposure.

The potential benefits of implementing lung cancer screening in India will include a reduction in mortality but also an improvement in quality of life (de, 2020; Aberle, 2019; Mazzone, 2021; Sands, 2021; Becker, 2020; Detterbeck, 2014) include: (1) reduction in disease-related morbidity; (2) reduction in treatment-related morbidity; (3) alterations in health that affect lifestyle; and (4) reduction in anxiety and psychological burden.

The risks associated with lung cancer screening include false-negative and false-positive results, radiation exposure, overdiagnosis of incidental findings, futile detection of indolent disease, anxiety about test findings, unnecessary testing and procedures, physical complications from diagnostic workup, and financial costs (Detterbeck, 2014; –63 The risks and benefits of lung cancer screening would be discussed with the individual before a screening LDCT scan, as is done for other screening tests(Mazzone, 2021; Lillie, 2017; Woloshin, 2012; de,2014).

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