A Comprehensive Review of Integrating LDCT and Radiomics for Improved Early Diagnosis of Lung Cancer and Role in Treatment

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Abstract

Carcinoma, the medical abbreviation of cancer is the most typical cause of deaths not only in world but also in India and among them the most regular cases of deaths are associated with Lung Cancer or Bronchogenic Carcinoma. Though the recent application of Low-dose Computed Tomography (LDCT) screening has significantly reduced the risk of loss by giving a comprehensive monitoring of the lesions, it comes with certain limitations linked with false positive outcomes, over or unnecessary diagnosis. And here comes the discussion of the integration of radiomics with LDCT (Low-dose Computed Tomography) aid scans. In this literature we review the limitations of LDCT and how the working of radiomics and its application is helping the early diagnosis of lung carcinoma and also how it can be further used to evaluate a more accurate prognosis. This review concludes that radiomics has the potential to become a valuable diagnostic and prognostic tool for the physicians and a comfort partner for the patients by reducing the parameters of all risk factors.

Keywords: *LDCT (Low-dose Computed Tomography), Radiomics, Quantitative Analysis, PET (Positron Emission Tomography), NSCLC (Non-small Cell Lung Cancer), SSNs (Sub Solid Nodules).*

I. Introduction

Lung cancer is one of the most common causes which results increase in the number of deaths by cancer not only in India but also in most of the developed countries, and one of the main reasons behind it could be negligence in monitoring the growth of the malignancy [1].

The 2020 health reports by WHO (World Health Organization) states that 1 in every 10 people will have cancer and 1 of 15 will die [2] and according to the press release by ICMR (Indian Council of Medical Research) there is an expected 15.7 lakhs new cases by 2025 which was 13.9 lakhs in 2020[3], that means there is a 12.8% growth in cancer cases compared to 2020[4]. Among all the carcinogenic cases the most common case is Lung Cancer which is mostly influenced by Tobacco smoking and it is one of the leading causes of cancer related deaths not only in India but also in all over the world. In India, Lung Cancer contributes for 5.9% in total cancer cases and 8.1% among all cancer related deaths [5].

The life expectancy of lung cancer patients has slightly increased than 5 years for last 50 years and one who can demand credit is the patient-centered chemotherapy in the early phases of the mutations of the cells [6].

In radiology, imaging such as CT (Computed Tomography), PET (Positron Emission Tomography) and MRI (Magnetic Resonance Imaging) do play a vital role in diagnosing, grading the cancer stage, planning further treatment, monitoring the growth or the effects of the treatments that have been provided in management of Lung Cancer. Among the CT scans protocols, LDCT (low-dose Computed Tomography) Chest/Thorax protocol could be one of the best imaging modalities which reduced 20% mortality from lung cancer after 3 rounds of scans [7][8].

Adding up radiomics which includes a range of biomarkers with the imaging reports can be a game changing duo in the early diagnosis of lung cancer. Radiomics is the field where they deal with extracting high efficiency data from a wide series of medical images and a large quantitative analysis of images is done [6]. Radiomics pulls out the anatomical and functional features of the medical images which is able to reflect the structural and functional details of the masses [9][10].

In this review article we describe how an imaging modality by using radiomics can improve the conventional diagnostic process and predicting the possible prognosis of lung cancer and also, we wrote the significance of the application of these two in daily management of patients in radiology department of a hospital.

II. Objective

This review paper focuses to dive into the novel approach of integrating Radiomics with Low-dose Computed Tomography (LDCT) to enhance the accuracy of early detection of lung cancer. By analyzing existing literatures, we will discuss the certain limitations of traditional LDCT scans and how Radiomics have the potential to counter the same limitations of LDCT by its quantitative analysis of the medical images. Furthermore, we will explore the ability of Radiomics in risk satisfaction and personalized treatment planning, ultimately contributing to enhanced patient satisfaction.

III. LDCT (Low-Dose Computed Tomography) in evaluating lung cancer

During 1960s to 1970s the only way to evaluate the imaging of lung cancer was chest x-rays (CXR) but it comes with a special limitation that was for a certain age group the prognosis of the disease is near to impossible. And here comes the LDCT (Low-dose Computed Tomography) Chest/Thorax protocol, during 90s it grabbed attention for identifying stage I cancer with an annual screening. LDCT uses a very low radiation exposure which delivers 1.5 mSv of radiation dose is very promising for such patients with cancer compared to other imaging scans like other CT scan protocols and PET (Positron Emission Tomography) [11].

a. **Advantages of using LDCT screening protocol** – There are several advantages of using LDCT imaging of individuals having lung carcinoma-

i. **Early diagnosis –** If a patient has some early symptoms of lung cancer which was supposed to occur in advanced stage, then LDCT can be a very reliable imaging to detect a carcinogenic mass at an early stage which significantly reduce stress of the patient and wealth giving an opportunity to treat the tumor by early medical intervention [12].

ii. **Reduced Mortality Rate –** LDCT screening not only provide a very low dose to your body but also it relatively reduces the mortality rate by 20% to 24% [13][14]. However, it is likely to be more useful for female because studies have shown that women are getting more benefits than men in terms of LC (Lung Cancer) mortality [15].

iii. **Prognosis is better –** Ongoing researches have shown that the prognosis of individuals with a lung cancer is likely to be more predictive and it have also shown that the patients who do a regular screening is more likely to improve their health [16].

iv. **Impact on smoking habits –** There is no actual evidence that attending in LDCT screening can change the smoking habits of the patients, and studies showed that cessation of smoking or continuation of smoking cannot be change after undergoing LDCT screening [17][18].

v. **Improved well-being –** According to NELSON and DLCST trails, LDCT screening does not have any significant effect on the quality of life and also it does not relate to any long-term anxiety. In short-term period, there is a slight increase in anxiety or distress but in long-term period the ability of LDCT protocol in evaluating lung cancer reduces the stress of the individuals with baseline symptoms [19]. Also, it is very useful to decrease the fear of lung cancer and stress compared with those with negative diagnosis [20].

b. **Limitations or harms of LDCT screening protocol –** Though LDCT have several advantages from the both diagnostic and patient satisfaction perspective, it comes with numbers of limitations or risks associated with scan. Among them the most 2 important limitations are –

i. **False positive results –** LDCT protocol have a high chance of getting false positive results, which can mislead to unnecessary tests and other diagnostic procedures which can create distress in terms of patient outcome and finance both. False positive diagnosis can find lesions or masses which are not cancerous or they are just incidental findings [16][21].

ii. **Unnecessary diagnosis –** A metanalysis of randomized controlled trails (RCTs) have found that 49% detected cancers may be over diagnosed and this harm can lead to unnecessary diagnostic tests and financial stress which may lead to psychological harm to the patient [22]. So, to balance the potential benefits and unintended harms an assessment of unnecessary diagnosis is very required [22][23][24]. The over management of sub solid nodules (SSNs) are the main risk factor for misdiagnosis [25].

iii. **Time Consuming Diagnostic process –** The traditional path to interpret the images by human intervention and human eyes are capable of identifying the visible characteristics like the size and margins of the tumor but the relation of the tumor with the surrounding structures is unpredictable until further diagnosis process such as Biopsy which influence the clinical treatment planning [26].

IV. Radiomics in Evaluating Lung Cancer

The term "Radiomics" first coined by Dutch scholar Lambin in 2012 [27]. Radiomics involves the quantitative image analysis by using the conventional biometry or artificial intelligence (AI) methods. It uses statistical analysis and deep learning methods to interpret the features of a radiographic image by identifying the disease, tumor grading or staging [28]. The workflow of radiomics can be described in several steps including image acquisition, segmentation of the image, extraction of the characteristics [29].

a. Workflow of Radiomics –

In summary, Radiomics works in mainly 2 phases: i. Image Acquisition and Segmentation of ROI, ii. Clinical Features extraction and selection of the image. The workflow of radiomics is summarized in Figure 1.

i. Image Acquisition & Segmentation of ROI –

Though Radiomics can be applied in all digital imaging, it is commonly used in CT scans. The technique of image acquisition in CT scans may vary depending upon many institutions as they use different image parameters and the imaging parameters may also vary depending upon the manufacturing unit, so there is a large number of imaging features of a same image [30].

Many studies have shown that the output of the radiomics also depends upon the imaging parameters that are used to obtain the scans [31][32][33]. So, to have a good output of using radiomics it is necessary that they should have a standardize imaging protocols.

Segmentation is a quantification process in which the medical images are labeled and extracting of features is done based on the labeled segment providing a statistical analysis about the structure such as the size/volume [34][35].

In aspects of radiomics segmentation can be done manually or automatically. The manual segmentation is quite inaccurate and time-consuming process [36], whereas the semi-automated or fully automated methods comes with efficiency, accuracy and consistency and hence they are more useful in assessing lung tumors [37][38].

In case of CT scans images, the widely used segmentation techniques are level-set method, or region-growing method beside it for 3D images the GrowCut method have more potential than manual segmentation [39][40].

ii.Clinical features extraction and selection of the image –

Next step to evaluate the imaging features of the segmented area such as the size, density and texture from the image where the size indicates the measurement of the width of tumor, density indicates the volume and texture means the various shades of grey-scale [41][42].

After the extraction of the features statistical analysis is done and obtained the clinically useful information such as tumor histology, biological behavior and prognosis [30].

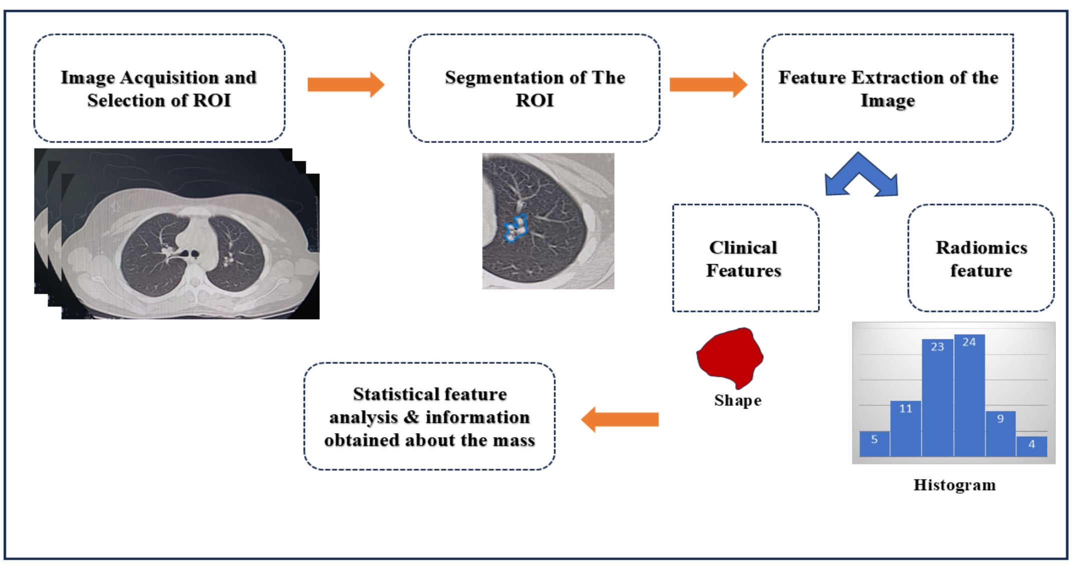

Figure 1 Summarized workflow of radiomics in flow-chart

b. Role of Radiomics in lung cancer screening - The application of radiomics that uses a quantitative image data evaluation from the scans and aids in diagnosis which further the treatment planning. In Radiology, radiomics can help in various ways, including

i. **Classifying the type of tumor –** Until a few months ago the one and only way to evaluate the type of tumor was biopsy but nowadays radiomics has shown the potential to use as a statistical tool not only for the characterization of lung masses but also other types glioma by using a large amount of CT scan images [43][44][59]. The development of various machine learning based models can be used to differentiate between the benign and malignant masses which plays as a very important assessment before operating a patient significantly reducing the risk of over-management/treatment of the disease [45].

ii. **Prediction of the risk –** Radiomics can be used as an effective non-invasive tool for assessing the risk of malignancy and studies have shown that radiomics based combined models plays an important role in this task [46][47].

iii. **Assessment of the treatment –** One of the main therapies which have shown the potential to treat lung tumors is TKI therapy. The TKIs (Tyrosine Kinase Inhibitors) can be used to treat the patients with non-small cell lung cancer (NSCLC) by genetic mutation process [48][49]. Using the computational methods and machine learning algorithms increases the accuracy in monitoring the effectiveness of the treatment.

In context of TKI (Tyrosine Kinase Inhibitors) therapy radiomics can be used as a survey meter which can help to find the patients who are more likely to respond to the TKI (Tyrosine Kinase Inhibitors) therapy [50].

Another application of radiomics may be a monitor to assess the efficacy of the therapies and the combined model of radiomics and molecular data can make a tool to predict the prognosis of the disease after the treatment [51][52].

iv. **Staging of malignancy-** There are several studies which have successfully stated a potential of radiomics based algorithms to grade the magnitude of the staging of malignancy. Like, in a research study which used a database of 657 patients with NSCLC (Non-small Cell Lung Cancer) [53], they used a radiomic based learning methods to guess the staging of malignancy.

V. Integration of LDCT with Radiomics and its role in lung cancer management

The combination of Low-Dose Computed Tomography (LDCT) with radiomics has been an innovative approach where in one hand the LDCT uses low exposure to screen and monitor the treatment growth of the lung carcinoma [54] on the other hand radiomics has been successfully shown the potential to forecast the prognosis of the disease which significantly helps in planning further treatment or calculate further risks [55].

The working of LDCT scanning protocol by using radiomics is demonstrated in Figure 2.

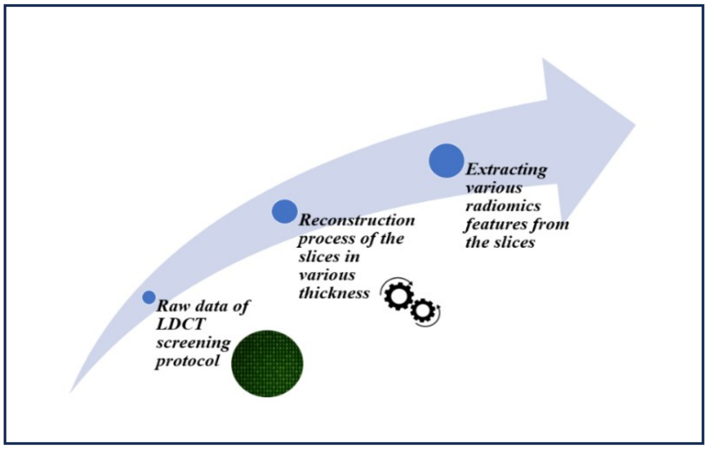

Figure 2 Working of LDCT protocol with radiomics

VI. Future directions

Radiomics is proving himself as a promising tool for lung cancer screening. In near future radiomics can be used for building personalized prediction models [44], making precise oncological study of the malignant masses [56] beside that they can be helpful in more accurate staging tumor [57] and can also be used to make a standard centralized database to make the system failure proof [58].

VII. Conclusion

In conclusion, the integration of Low-Dose Computed Tomography (LDCT) and radiomics represents a promising advancement in the early diagnosis of lung cancer. LDCT, with its reduced radiation exposure, allows for safer, widespread screening, while radiomics extracts high-dimensional quantitative features from medical images that are invisible to the human eye. This combination enhances diagnostic accuracy, enabling the identification of subtle tissue characteristics and early-stage malignancies. As technology advances and machine learning models improve, the use of LDCT and radiomics has the potential to transform lung cancer screening, facilitating personalized treatment strategies and improving patient outcomes including the enhanced clinical decision and low-cost treatment. It has a wide range of potential application from assessing the risk to prognosis of lung cancer. However, further clinical validation and standardization are necessary to fully integrate these tools into routine clinical practice.

VIII. Abbreviations

WHO – World Health Organisation

ICMR – Indian Council of Medical Research

CT – Computed Tomography

PET – Positron Emission Tomography

MRI – Magnetic Resonance Imaging

LDCT – Low-dose Computed Tomography

LC – Lung Cancer

RCTs – Randomized Controlled Trails

SSNs – Sub Solid Nodules

TKI – Tyrosine Kinase Inhibitors

NSCLC – Non-small Cell Lung Cancer

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