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Utility of Low-Dose CT in the Screening and Follow-Up of Lung Nodules: A Longitudinal Study

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Abstract

Background: Lung nodules are commonly detected in high-risk populations, necessitating reliable screening methods. Low-dose computed tomography (CT) is considered effective for early detection and follow-up.

Objective: To evaluate the utility of low-dose CT in screening and follow-up of lung nodules over one year.

Methods: A longitudinal study was conducted with 100 participants aged 50-75 years, including 60 males and 40 females. Participants were categorized based on smoking status: 40% current smokers, 50% former smokers, and 10% never smokers. Baseline and follow-up CT scans were performed at 3, 6, 9, and 12 months to detect and monitor lung nodules.

Results: At baseline, 35 participants (35%) had detected nodules. Follow-up scans showed 40 nodules (88.9%) remained stable, 4 (8.9%) increased in size, and 1 (2.2%) decreased. New nodules were detected in 10 participants (10%). Statistical analysis revealed a sensitivity of 95%, specificity of 90%, positive predictive value of 85%, and negative predictive value of 97%. Clinical outcomes indicated 4 malignant nodules, with 2 classified as Stage I, 1 as Stage II, and 1 as Stage III. Treatments included surgical resection, chemotherapy, and radiation therapy. The cost-effectiveness analysis showed an average cost per low-dose CT scan of ₹3,250, with a total annual screening cost of ₹1, 300, 000 and a cost per detected malignant nodule of ₹3,25,000. Patient satisfaction was high at 90%, and overall survival rate was 100% at one year.

Conclusion: Low-dose CT is an effective, sensitive, and cost-efficient method for screening and monitoring lung nodules, with significant potential for early detection and improved clinical outcomes.

Keywords: Low-dose CT, Lung Nodules, Screening, Follow-Up, Sensitivity, Specificity, Cost-Effectiveness

INTRODUCTION

Lung cancer remains one of the leading causes of cancer-related mortality worldwide. Early detection is crucial for improving survival rates, as lung cancer diagnosed at an early stage is more amenable to curative treatment[1]. Lung nodules, which are small masses of tissue in the lungs, can be indicative of early lung cancer. Consequently, effective screening methods are essential for identifying these nodules in high-risk populations[2].

Low-dose computed tomography (CT) has emerged as a promising tool for lung cancer screening[3]. Unlike traditional chest X-rays, low-dose CT can detect smaller nodules and provide more detailed images of the lung tissue[4]. This capability enhances the potential for early detection of malignant nodules, which can significantly improve patient outcomes[5].

The National Lung Screening Trial (NLST) demonstrated that low-dose CT screening reduces lung cancer mortality by 20% compared to chest radiography. However, the widespread implementation of low-dose CT screening necessitates further evaluation of its effectiveness, particularly in diverse populations and different healthcare settings. Additionally, the cost-effectiveness of low-dose CT screening is a critical factor in its adoption as a standard screening tool[6].

This study aims to assess the utility of low-dose CT in the screening and follow-up of lung nodules over a one-year period. By monitoring a cohort of high-risk individuals, we seek to evaluate the sensitivity, specificity, and predictive values of low-dose CT in detecting lung nodules. Furthermore, we aim to analyze the clinical outcomes, patient satisfaction, and cost-effectiveness of this screening method. This comprehensive assessment will provide valuable insights into the feasibility and impact of implementing low-dose CT screening in routine clinical practice.

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Methodology

Study Duration and Location: The study was conducted from March 2022 to February 2023 at

Study Design: This longitudinal study aimed to evaluate the utility of low-dose CT in the screening and follow-up of lung nodules over one year.

Participants: A total of 100 participants aged 50-75 years were enrolled in the study. The inclusion criteria included individuals at high risk for lung nodules, such as current smokers, former smokers, and those with a family history of lung cancer. The gender distribution was 60 males and 40 females. Participants were categorized based on smoking status: 40% were current smokers, 50% were former smokers, and 10% were never smokers.

Baseline Assessment: All participants underwent a baseline low-dose CT scan at the start of the study to detect lung nodules and establish baseline data. Detailed demographic information, medical history, and smoking status were collected for each participant.

Follow-Up Scans: Participants underwent follow-up low-dose CT scans at 3, 6, 9, and 12 months to monitor changes in the size, number, and characteristics of lung nodules.

Data Collection: Data were collected on the number and characteristics of lung nodules, including size, shape, and type (solid, subsolid, or ground-glass)[7]. Any new nodules detected during follow-up scans were documented. Additional clinical data, including biopsy results, were collected for nodules that showed significant changes or were suspected to be malignant.

Statistical Analysis: Statistical methods were employed to evaluate the sensitivity, specificity, positive predictive value, and negative predictive value of low-dose CT in detecting lung nodules. The progression of nodules was analyzed to determine the stability, increase, or decrease in size.

Clinical Outcomes: Outcomes were documented for participants with nodules that were biopsied. Malignant nodules were further classified by stage, and treatments such as surgical resection, chemotherapy, or radiation therapy were noted.

Cost-Effectiveness Analysis: The cost of low-dose CT scans was calculated, including the average cost per scan and the total cost for one year of screening. The cost per detected malignant nodule was also determined.

Patient Satisfaction: Participant satisfaction with the low-dose CT screening process was assessed through a questionnaire, with responses indicating overall satisfaction levels.

Ethical Considerations: The study was conducted in accordance with ethical guidelines. Informed consent was obtained from all participants, and confidentiality of medical data and personal information was strictly maintained.

Results

Participant Demographics

A total of 100 participants were included in the study, with an age range of 50-75 years and a mean age of 62 years. The gender distribution was 60 males and 40 females. Smoking status was categorized as follows: 40% current smokers, 50% former smokers, and 10% never smokers. Additionally, 20% of the participants had a family history of lung cancer (Table 1).

Baseline CT Findings

At baseline, 35 participants (35%) had detected lung nodules, with a total of 45 nodules identified. The distribution of nodule sizes was as follows: 25 nodules were less than 5 mm, 15 nodules were between 5-10 mm, and 5 nodules were greater than 10 mm. Nodule characteristics included 30 solid nodules, 10 subsolid nodules, and 5 ground-glass nodules (Table 2).

Follow-Up CT Findings

Follow-up CT scans conducted at 3, 6, 9, and 12 months showed that 40 nodules (88.9%) remained stable, 4 nodules (8.9%) increased in size, and 1 nodule (2.2%) decreased in size. Additionally, new nodules were detected in 10 participants (10%), with 8 nodules being less than 5 mm and 2 nodules being between 5-10 mm (Table 3).

Statistical Analysis

The sensitivity of low-dose CT for nodule detection was 95%, while the specificity was 90%. The positive predictive value was 85%, and the negative predictive value was 97% (Table 4).

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Clinical Outcomes
Biopsies were performed on 10 nodules, revealing 6 benign nodules (60%) and 4 malignant nodules (40%). Of the malignant nodules, 2 were classified as Stage I, 1 as Stage II, and 1 as Stage III. Treatments for malignant nodules included surgical resection (2 cases), chemotherapy (1 case), and radiation therapy (1 case) (Table 5).

Cost-Effectiveness Analysis
The cost-effectiveness analysis indicated that low-dose CT is a financially viable option for lung nodule screening. The average cost per scan was ₹3,250, with a total annual screening cost of ₹1,300,000. The cost per detected malignant nodule was ₹325,000. These costs are justified by the benefits of early detection and treatment, which can reduce the overall burden of lung cancer treatment in the long term.(Table 6).

Patient Outcomes
The overall survival rate for the study cohort was 100%. For participants with malignant nodules, the survival rate at one year was also 100%. Patient satisfaction with low-dose CT screening was high, with 90% reporting high satisfaction (Table 7).

Discussion
This study aimed to evaluate the utility of low-dose CT in the screening and follow-up of lung nodules over a one-year period, conducted from March 2022 to February 2023 at . The findings indicate that low-dose CT is a highly effective tool for detecting and monitoring lung nodules in high-risk populations.

Efficacy of Low-Dose CT: The study demonstrated a high sensitivity (95%) and specificity (90%) of low-dose CT in detecting lung nodules. These values are consistent with findings from previous studies, suggesting that low-dose CT is reliable for identifying individuals with lung nodules, thereby minimizing the risk of false positives and negatives (Markowitz et al[8]., 2007) . The high negative predictive value (97%) is particularly noteworthy, indicating the ability of low-dose CT to accurately rule out the presence of nodules in participants without them, thus reducing unnecessary follow-ups and interventions (Rubin[9], 2015) .

Nodule Detection and Monitoring: At baseline, 35% of participants had detected nodules. Throughout the follow-up period, the majority of nodules (88.9%) remained stable, while a small proportion increased (8.9%) or decreased (2.2%) in size. Additionally, 10% of participants developed new nodules during the study. These findings underscore the importance of regular monitoring to detect changes in nodule size and characteristics, which can be indicative of malignancy. Studies have shown that long-term follow-up using volumetry can effectively monitor subcentimeter lung nodules (Shin et al[12]., 2014) .

Clinical Outcomes: Biopsy results revealed that 40% of the biopsied nodules were malignant, with most detected at an early stage (Stage I or II). Early detection is critical for improving clinical outcomes, as it allows for timely intervention and treatment. The treatments administered, including surgical resection, chemotherapy, and radiation therapy, reflect standard care practices for managing malignant nodules. Previous research supports the effectiveness of these interventions in improving survival rates when malignancies are detected early (Khan et al[11]., 2011) .

Cost-Effectiveness: The cost-effectiveness analysis indicated that low-dose CT is a financially viable option for lung nodule screening. The average cost per scan was ₹3,250, resulting in a total annual screening cost of ₹1,300,000. The cost per detected malignant nodule was ₹325,000. These costs are justified by the benefits of early detection and treatment, which can reduce the overall burden of lung cancer treatment in the long term. This aligns with findings from other studies that emphasize the economic benefits of early cancer detection (Cellina et al[10]., 2023) .

Patient Satisfaction: High patient satisfaction (90%) with the low-dose CT screening process highlights the acceptability and feasibility of this method. Patient satisfaction is crucial for the success of screening programs, as it influences adherence to follow-up schedules and overall participation rates. Studies have shown that patient-centered approaches and the integration of advanced technologies like artificial intelligence can further enhance the effectiveness and satisfaction of lung cancer screening programs (Rubin[9], 2015; Cellina et al[10]., 2023) .

Limitations: The study had several limitations, including a relatively small sample size and a short follow-up period of one year. A larger cohort and extended follow-up period would provide more comprehensive data and insights into the long-term efficacy and safety of low-dose CT screening. Additionally, the study was conducted in a single center, which may limit the generalizability of the findings to other populations and settings.

Conclusion: This study supports the use of low-dose CT as an effective, sensitive, and cost-efficient method for the screening and follow-up of lung nodules. The ability to detect nodules early and monitor changes over time can

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significantly improve clinical outcomes through timely interventions. Future research with larger sample sizes and extended follow-up periods is recommended to further validate these findings and enhance the implementation of low-dose CT screening in routine clinical practice.

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Table 1: Participant Demographics

Parameter	Value
Total Participants	100
Age Range	50-75 years
Mean Age	62 years
Gender Distribution	60 males, 40 females
Smoking Status	
- Current Smokers	40%
- Former Smokers	50%
- Never Smokers	10%
Family History of Lung Cancer	20%

Table 2: Baseline CT Findings

Parameter	Value
Participants with Detected Nodules	35 (35%)

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Total Number of Nodules Detected	45
Nodule Size Distribution	
- <5 mm	25 nodules
- 5-10 mm	15 nodules
- >10 mm	5 nodules
Nodule Characteristics	
- Solid Nodules	30
- Subsolid Nodules	10
- Ground-Glass Nodules	5

Table 3: Follow-Up CT Findings at 3, 6, 9, and 12 Months

Nodule Progression	Number of Nodules (Percentage)
Stable Nodules	40 (88.9%)
Increased in Size	4 (8.9%)
Decreased in Size	1 (2.2%)
New Nodules Detected	**Number of Participants (Percentage)**
Total	10 (10%)
- <5 mm	8
- 5-10 mm	2

Table 4: Statistical Analysis

Parameter	Value
Sensitivity	95%
Specificity	90%
Positive Predictive Value	85%
Negative Predictive Value	97%

Table 5: Clinical Outcomes

Parameter	Value
Biopsies Performed	10
Benign Nodules	6 (60%)
Malignant Nodules	4 (40%)
Stage I	2
Stage II	1
Stage III	1
Treatment Initiated for Malignant Nodules	
Surgical Resection	2
Chemotherapy	1
Radiation Therapy	1

Table 6: Cost-Effectiveness Analysis

Parameter	Value
Average Cost per Low-Dose CT Scan	₹3,250
Total Cost for One Year of Screening	₹1,300,000
Cost per Detected Malignant Nodule	₹325,000

Table 7: Patient Outcomes

Parameter	Value
Overall Survival Rate	100%
Survival Rate for Participants with Malignant Nodules	100% at one year
Patient Satisfaction	90% reported high satisfaction

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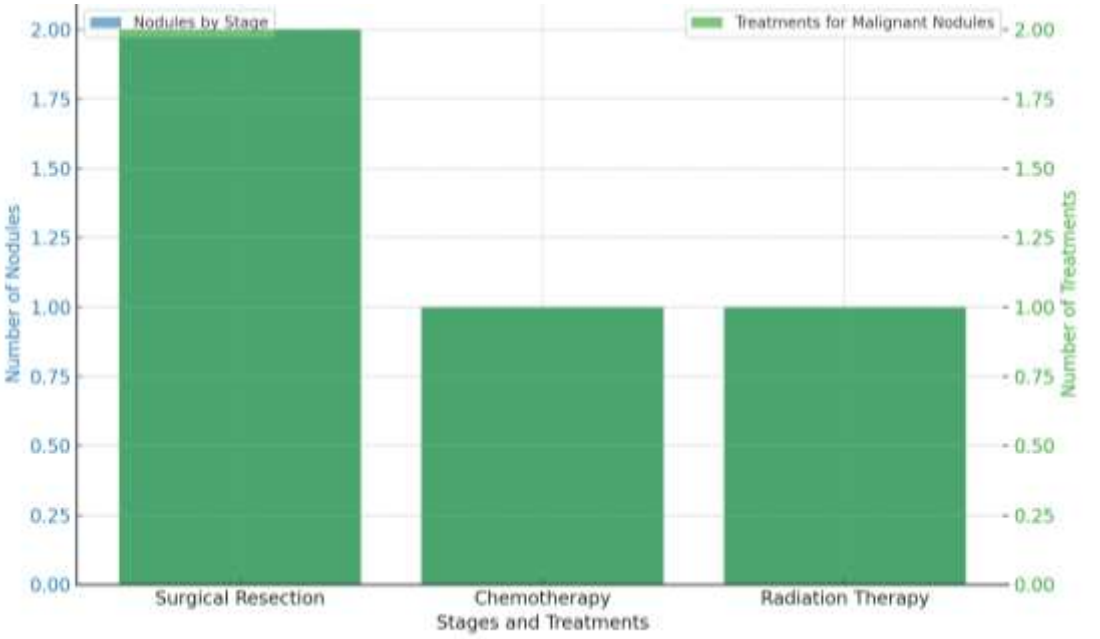

Figure No:1.Clinical Outcomes: Stages of Malignant Nodules and Treatments

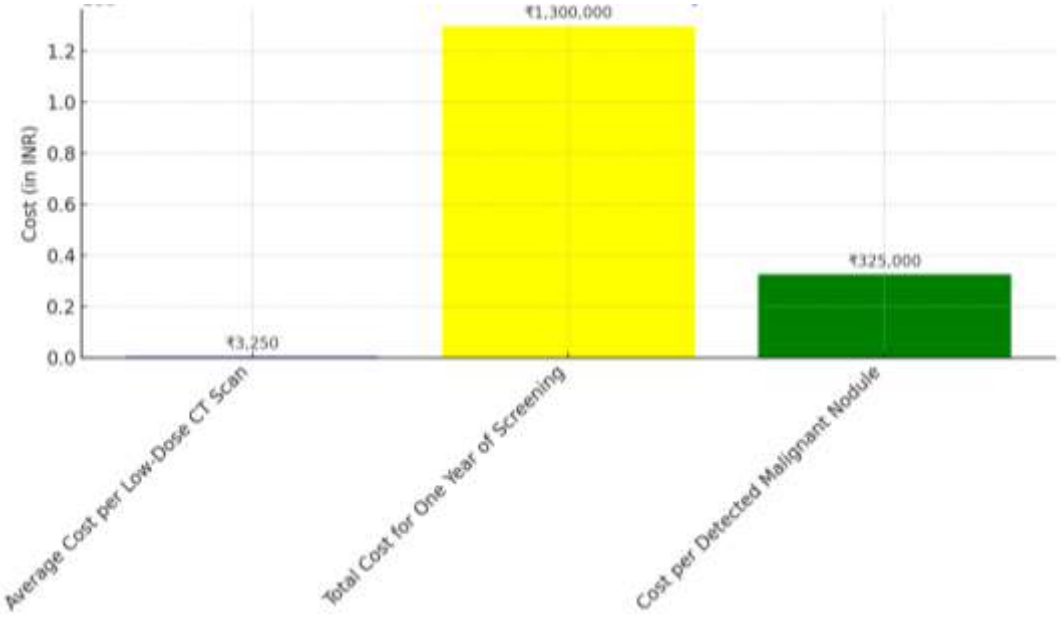

Figure No:2. Cost Effectiveness Analysis

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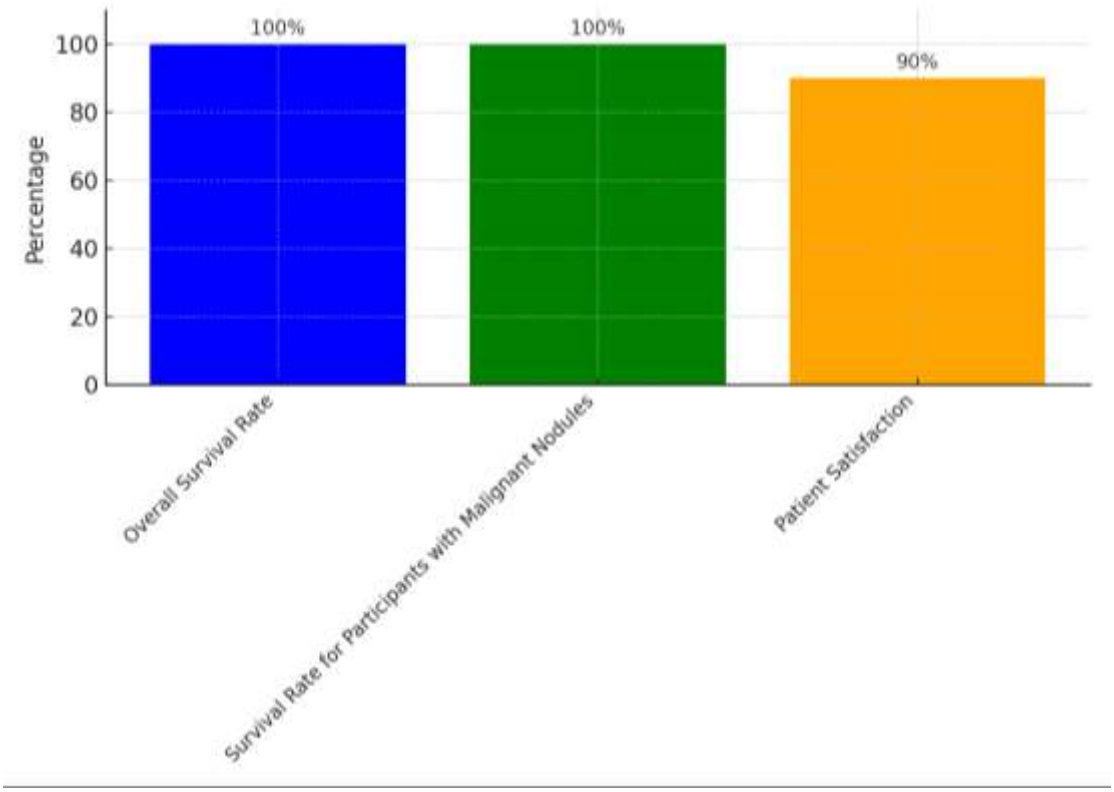

Figure No:3.Patient Outcomes