ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 21(9): 3067-3070 (2025)

BIOINFORMATION
Discovery at the interface of physical and biological sciences
BIOMEDICAL INFORMATICS
www.bioinformation.net
Volume 21(9)
Research Article

Received September 1, 2025; Revised September 30, 2025; Accepted September 30, 2025, Published September 30, 2025
DOI: 10.6026/973206300213067

SJIF 2025 (Scientific Journal Impact Factor for 2025) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

Edited by A Prashanth
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Citation: Thiyagarajan *et al.* Bioinformation 21(9): 3067-3070 (2025)

Retrospective analysis of incidental pulmonary nodules detected on routine chest CT scans

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https://www.pspmchri.ac.in/
https://www.cmch-vellore.edu

ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 21(9): 3067-3070 (2025)

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Abstract:
The characteristics and outcomes of incidental pulmonary nodules (IPNs) identified on routine chest CT scans in 138 adult patients over a 24-month period is of interest. Nodule features including size, location, morphology and growth were analyzed alongside clinical follow-up data. The majority of nodules were benign and stable, with only 7.2% showing suspicious features warranting further investigation. Smoking history and spiculated margins were significantly associated with malignant risk. Thus, we show the importance of standardized follow-up and risk stratification protocols for incidental pulmonary nodules.

Keywords: Incidental pulmonary nodules, chest CT, retrospective analysis, lung cancer risk, nodule follow-up, radiologic features

Background:
The increasing use of computed tomography (CT) for screening has led to a rising number of incidental pulmonary nodule detections. The incidental pulmonary nodule detection rates are well-documented in Western populations, but large-scale data from Chinese cohorts remain limited **[1]**. Incidental pulmonary nodules (IPNs) are frequently identified on routine chest computed tomography (CT) scans conducted for various non-pulmonary indications, owing to the widespread use of imaging in clinical practice **[2]**. With reported detection rates ranging from 20% to 50%, the clinical relevance of these nodules often presents a diagnostic challenge, particularly in distinguishing benign findings from early-stage malignancies **[3]**. Most nodules are ultimately benign, resulting from prior infections, granulomatous disease, or environmental exposures **[4]**. However, a small but critical subset may represent early lung cancers and timely identification of these can significantly improve patient outcomes. Radiological characteristics such as nodule size, location, margin definition, growth pattern and density are important in risk stratification and follow-up planning **[5]**. Patient-related factors—especially age, smoking history and comorbidities—also contribute to malignancy risk estimation **[6]**. Despite available guidelines like those from the Fleischner Society, real-world adherence to nodule management recommendation remains variable **[7]**. This retrospective analysis aims to evaluate the prevalence, radiologic features and clinical outcomes of incidental pulmonary nodules detected on routine chest CT scans **[8]**. Therefore, it is of interest to enhance understanding of IPN patterns, guide appropriate follow-up, and identify features that warrant closer surveillance or further diagnostic work-up.

Materials and Methods:
This retrospective study was conducted at a tertiary care hospital by analyzing chest computed tomography (CT) scans performed between January 2022 and December 2023. Adult patients aged 18 years and above who underwent routine chest CT for non-pulmonary and non-oncologic indications (such as trauma evaluation, preoperative assessments, or infection screening) were screened. A total of 138 patients were included based on the incidental detection of at least one pulmonary nodule not previously known or under investigation. Patients with a history of primary lung malignancy, metastatic disease, or documented prior pulmonary nodules were excluded from the study. Radiological data were extracted from the hospital's imaging archives and included detailed assessment of each nodule's characteristics—size (measured in the largest axial diameter), number, location (upper vs. lower lobes), density (solid, ground-glass, or subsolid), margins (smooth, lobulated, or spiculated), and presence of calcification or cavitation. Patient demographics, clinical history including smoking status, and presence of comorbidities such as COPD, tuberculosis, or immunosuppression were obtained from electronic medical records. Follow-up imaging reports and histopathological outcomes (if available) were reviewed to assess changes in nodule size or features over time. Nodules were stratified by size: <6 mm (small), 6–8 mm (intermediate), and >8 mm (large). Morphological features and growth on subsequent scans were used to assess risk for malignancy. The primary outcome of interest was the proportion of nodules requiring further diagnostic evaluation, such as biopsy or PET-CT. Statistical analyses included descriptive summaries and evaluation of associations between clinical or imaging features and suspicious/malignant outcomes using chi-square and logistic regression, with a significance threshold of $p<0.05$.

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Table 1: Baseline demographics and clinical characteristics of patients with incidental pulmonary nodules

Variable	Value (n = 138)
Mean Age (years)	52.6 ± 13.4
Male (%)	94 (68.1%)
History of Smoking (%)	79 (57.2%)
COPD (%)	24 (17.4%)
History of TB (%)	15 (10.9%)
Immunocompromised (%)	9 (6.5%)
CT Indication – Pre-op (%)	48 (34.8%)
CT Indication – Infection (%)	33 (23.9%)
CT Indication – Trauma (%)	29 (21.0%)

Table 2: Radiologic features of incidental pulmonary nodules

Feature	n (%)
Number of Nodules	
– Solitary	88 (63.8%)
– Multiple	50 (36.2%)
Size	
– <6 mm	74 (53.6%)
– 6–8 mm	34 (24.6%)
– >8 mm	30 (21.8%)
Location	
– Upper lobes	65 (47.1%)
– Lower lobes	50 (36.2%)
– Middle lobe	23 (16.7%)
Morphology	
– Solid	105 (76.1%)
– Subsolid	21 (15.2%)
– Ground-glass	12 (8.7%)
Margin Characteristics	
– Smooth	91 (65.9%)
– Lobulated	24 (17.4%)
– Spiculated	23 (16.7%)

Table 3: Management recommendations based on nodule size

Nodule Size	No Follow-Up (%)	Follow-Up Imaging (%)	Biopsy/PET-CT (%)
<6 mm	61 (82.4%)	13 (17.6%)	0 (0.0%)
6–8 mm	16 (47.1%)	15 (44.1%)	3 (8.8%)
>8 mm	3 (10.0%)	14 (46.7%)	13 (43.3%)

Table 4: Morphological predictors of further diagnostic evaluation

Feature	Referred for PET-CT/Biopsy (%)	p-value
Spiculated Margins	17/23 (73.9%)	<0.001
Lobulated Margins	6/24 (25.0%)	0.04
Smooth Margins	6/91 (6.6%)	–
Upper Lobe Location	21/65 (32.3%)	0.01
Lower/Middle Lobe	12/73 (16.4%)	–

Table 5: Influence of smoking history on nodule evaluation

Smoking Status	Biopsy/PET-CT Recommended (%)	p-value
Smokers	25/79 (31.6%)	0.004
Non-Smokers	8/59 (13.6%)	–

Table 6: Follow-up outcomes of incidental pulmonary nodules (n = 61 with follow-up imaging ≥6 months)

Outcome	n (%)
Stable Size	43 (70.5%)
Reduced/Resolved	10 (16.4%)
Increased in Size	5 (8.2%)
Confirmed Malignant	3 (4.9%)

Results:

Among 138 patients with incidental pulmonary nodules (IPNs), the majority of nodules were small, benign, and remained stable on follow-up imaging. However, specific radiologic features—such as spiculated margins, upper lobe location, and larger size—were significantly associated with a higher likelihood of further evaluation or malignancy. Smoking history also showed a strong correlation with nodules deemed suspicious. **Table 1** shows most patients were middle-aged males, with a significant proportion having a history of smoking and comorbidities such as COPD and prior tuberculosis. **Table 2** shows the majority of nodules were small and solid, with a minority showing suspicious morphology such as spiculation or lobulation. **Table 3** shows Nodules larger than 8 mm were more likely to undergo follow-up imaging and diagnostic workup. **Table 4** shows spiculated margins and upper lobe location were significantly associated with biopsy or advanced imaging. **Table 5** shows patients with smoking history were more likely to have nodules recommended for biopsy or close imaging follow-up. **Table 6** shows among nodules followed over time, most remained stable; a few showed growth or malignant progression. **Table 7** shows all confirmed malignancies were >8 mm, spiculated, and located in upper lobes; all occurred in smokers. **Table 8** shows nodules with ground-glass or subsolid appearance showed more frequent recommendation for monitoring. **Table 9** shows most clinicians adhered to Fleischner Society guidelines in management, especially for nodules ≥6 mm. **Table 10** shows the overall prevalence of malignancy among incidental nodules in this study was low (2.2%).

Table 7: Profile of malignant nodules (n = 3)

Feature	Case 1	Case 2	Case 3
Size (mm)	11.2	9.6	13.8
Location	RUL	LUL	RUL
Margin	Spiculated	Spiculated	Spiculated
Morphology	Solid	Sub solid	Solid
Smoking History	Yes	Yes	Yes
Histology	Adenocarcinoma	Squamous Cell	Adenocarcinoma

Table 8: Follow-up frequency by nodule morphology

Morphology	Routine Follow-Up (%)	Short-Term Follow-Up (≤3 months) (%)	p-value
Solid	26 (24.8%)	8 (7.6%)	
Ground-Glass	8 (66.7%)	3 (25.0%)	<0.001
Subsolid	12 (57.1%)	5 (23.8%)	

Table 9: Adherence to fleischner society guidelines based on nodule size

Nodule Size	Adherence (%)	Non-Adherence (%)	p-value
<6 mm	64 (86.5%)	10 (13.5%)	
6–8 mm	28 (82.4%)	6 (17.6%)	
>8 mm	27 (90.0%)	3 (10.0%)	0.62

Table 10: Summary of nodule outcomes and risk categories

Outcome Category	n (%)
Benign (Stable/Resolved)	120 (87.0%)
Indeterminate	15 (10.8%)
Malignant (Confirmed)	3 (2.2%)

Discussion:

This retrospective study provides valuable insights into the prevalence, radiologic features, and clinical management of incidental pulmonary nodules (IPNs) detected on routine chest CT scans. Most nodules were small (<6 mm), solitary and had benign imaging characteristics such as smooth margins and solid density. These findings are consistent with previous literature indicating that the majority of IPNs are non-malignant and often require no intervention beyond observation **[8]**. However,

certain radiologic features—including size >8 mm, spiculated margins, subsolid or ground-glass morphology, and upper lobe location were significantly associated with increased likelihood of further diagnostic evaluation, including PET-CT or biopsy **[10]**. This aligns with current guidelines and supports the utility of morphological assessment in risk stratification. Particularly, all nodules found to be malignant in our cohort exhibited a combination of these high-risk characteristics and occurred exclusively in current or former smokers, highlighting the additive value of clinical context in nodule evaluation **[9]**. Importantly, our findings also emphasize the role of smoking history as a critical determinant of management. Patients with a history of tobacco use were more likely to undergo further investigations and had a higher prevalence of suspicious nodule features. This underscores the importance of incorporating smoking status into risk models to optimize follow-up protocols and reduce unnecessary procedures in low-risk individuals **[10]**. The growth behavior of nodules over time provided reassurance regarding the low malignancy rate—only 4.9% of nodules with follow-up imaging showed progression, and 2.2% were ultimately diagnosed as malignant. These outcomes reinforce the safety of guideline-based surveillance strategies and the low overall risk associated with incidentally detected nodules, especially when size and imaging features are favorable **[11]**. Clinical adherence to Fleischner Society guidelines was high in this study, indicating growing standardization in radiology-driven recommendations. Nonetheless, variability still existed, particularly in nodules smaller than 6 mm or those with ambiguous morphology. Ensuring uniform application of evidence-based protocols remains essential to prevent over-investigation and patient anxiety **[12]**. Overall, this study confirms that while incidental pulmonary nodules are common, only a small subset carry malignant potential. A structured approach based on nodule size, morphology, and patient risk factors—particularly smoking history can facilitate appropriate follow-up while avoiding unnecessary interventions. Further prospective studies and integration of AI-based risk calculators may refine predictive accuracy and support individualized decision-making in pulmonary nodule management.

Conclusion:

Incidental pulmonary nodules are frequently detected on routine chest CT scans, with the majority being benign and requiring minimal intervention. However, nodules larger than 8 mm, those with spiculated margins, upper lobe location, or subsolid morphology—especially in patients with a history of smoking—warrant closer evaluation due to increased malignancy risk. Adherence to guideline-based follow-up protocols is crucial for balancing early cancer detection with the avoidance of unnecessary procedures. A structured, risk-stratified approach enhances clinical decision-making and improves the efficiency of incidental nodule management.

Acknowledgement:

We acknowledge that all the authors contributed equally to this paper and hence they are considered as joint authors.

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