

## “Evaluation of Diagnostic Accuracy and Sample Adequacy of CT-Guided Lung Biopsies in Solitary Pulmonary Nodules: A Prospective Study”

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### ABSTRACT

**Background;** Solitary pulmonary nodules (SPNs) are frequently detected abnormalities on chest radiographs and computed tomography (CT) scans. These nodules may represent a wide spectrum of pathologies ranging from benign inflammatory lesions to primary lung malignancies or metastatic tumors. Early and accurate diagnosis of SPNs is essential for determining the appropriate clinical management and improving patient outcomes. Computed tomography (CT)-guided percutaneous lung biopsy has emerged as an important minimally invasive diagnostic technique for obtaining tissue samples from pulmonary lesions. This procedure allows precise localization of lung nodules and facilitates histopathological examination with high diagnostic accuracy. However, factors such as lesion size, location, needle placement, and operator expertise can influence the adequacy of the biopsy sample and the diagnostic yield. Therefore, evaluating the diagnostic performance and sample adequacy of CT-guided lung biopsies in patients with solitary pulmonary nodules is important for optimizing clinical decision-making and patient care.

**Introduction;** Advancements in radiological imaging techniques have significantly increased the detection rate of solitary pulmonary nodules. While imaging modalities such as CT scans provide detailed anatomical information, they cannot always differentiate between benign and malignant lesions with certainty. Tissue diagnosis remains the gold standard for establishing the nature of pulmonary nodules. CT-guided transthoracic needle biopsy is widely used due to its accuracy, cost-effectiveness, and relatively low complication rates compared with surgical biopsy procedures.

Despite its advantages, the success of CT-guided lung biopsy largely depends on obtaining an adequate tissue sample that is sufficient for histopathological and sometimes molecular analysis. Inadequate samples may lead to inconclusive diagnoses, requiring repeat procedures or alternative diagnostic methods. Therefore, assessing both the **diagnostic accuracy** and **sample adequacy** of CT-guided biopsies is crucial in evaluating the effectiveness of this technique in clinical practice.

**Objectives;** The present study was conducted with the following objectives:

1. To evaluate the **diagnostic accuracy** of CT-guided lung biopsies in patients with solitary pulmonary nodules.
2. To assess the **adequacy of biopsy samples** obtained through CT-guided procedures for histopathological diagnosis.
3. To analyze the relationship between **nodule characteristics (size, location, and morphology)** and the adequacy of biopsy samples.
4. To determine the **complication rate** associated with CT-guided lung biopsy procedures.

**Methods;** This prospective study was conducted in the Department of Radiology and Imaging Technology at a tertiary care hospital. Patients presenting with solitary pulmonary nodules detected on CT imaging and requiring histopathological evaluation were included in the study. Eligible patients underwent CT-guided percutaneous transthoracic lung biopsy using a coaxial needle system under sterile conditions.

Prior to the procedure, detailed clinical history, imaging findings, and relevant laboratory investigations were reviewed. CT imaging was used to determine the optimal needle trajectory and avoid critical structures such as blood vessels and bronchi. Under local anesthesia and CT guidance, the biopsy needle was inserted into the targeted pulmonary lesion, and multiple tissue samples were obtained.

The collected specimens were immediately preserved and sent for histopathological examination to determine the nature of the lesion. Sample adequacy was assessed based on the presence of sufficient cellular material required for pathological evaluation. Diagnostic accuracy was determined by comparing biopsy findings with final clinical diagnosis, surgical pathology (if available), or follow-up imaging.

Data were analyzed using descriptive and inferential statistical methods. Parameters such as lesion size, location, biopsy success rate, and complication rates were evaluated.

**Results** The study included patients with solitary pulmonary nodules who underwent CT-guided lung biopsy for diagnostic evaluation. The majority of nodules were located in the peripheral regions of the lungs and varied in size. CT-guided biopsy successfully obtained tissue samples in most cases, demonstrating a high rate of sample adequacy.

Histopathological examination revealed a range of diagnoses including malignant lesions such as primary lung carcinoma and metastatic tumors, as well as benign conditions such as granulomatous inflammation and infectious lesions. The overall diagnostic accuracy of CT-guided lung biopsy was found to be high, indicating its effectiveness in differentiating

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benign and malignant pulmonary nodules. Sample adequacy was achieved in a large proportion of cases, allowing definitive pathological diagnosis. In a small number of cases, inadequate samples or indeterminate findings required repeat biopsy or additional diagnostic procedures.

Complications associated with the procedure were minimal and manageable. The most commonly observed complication was mild pneumothorax, followed by minor pulmonary hemorrhage, both of which were managed conservatively without significant clinical consequences.

**Conclusion** CT-guided lung biopsy is a safe, reliable, and highly effective diagnostic technique for evaluating solitary pulmonary nodules. The procedure provides high diagnostic accuracy and adequate tissue sampling for histopathological analysis, thereby assisting clinicians in determining appropriate treatment strategies.

The findings of this study highlight the importance of CT-guided biopsy as a minimally invasive alternative to surgical biopsy in the evaluation of pulmonary nodules. Careful patient selection, proper imaging guidance, and skilled procedural techniques can further improve the success rate and minimize complications.

Overall, CT-guided lung biopsy plays a critical role in the early diagnosis and management of pulmonary lesions and contributes significantly to improved patient outcomes in clinical practice.

**Keywords** Solitary Pulmonary Nodule, CT-Guided Lung Biopsy, Diagnostic Accuracy, Sample Adequacy, Transthoracic Needle Biopsy, Lung Lesions, Radiology, Histopathology

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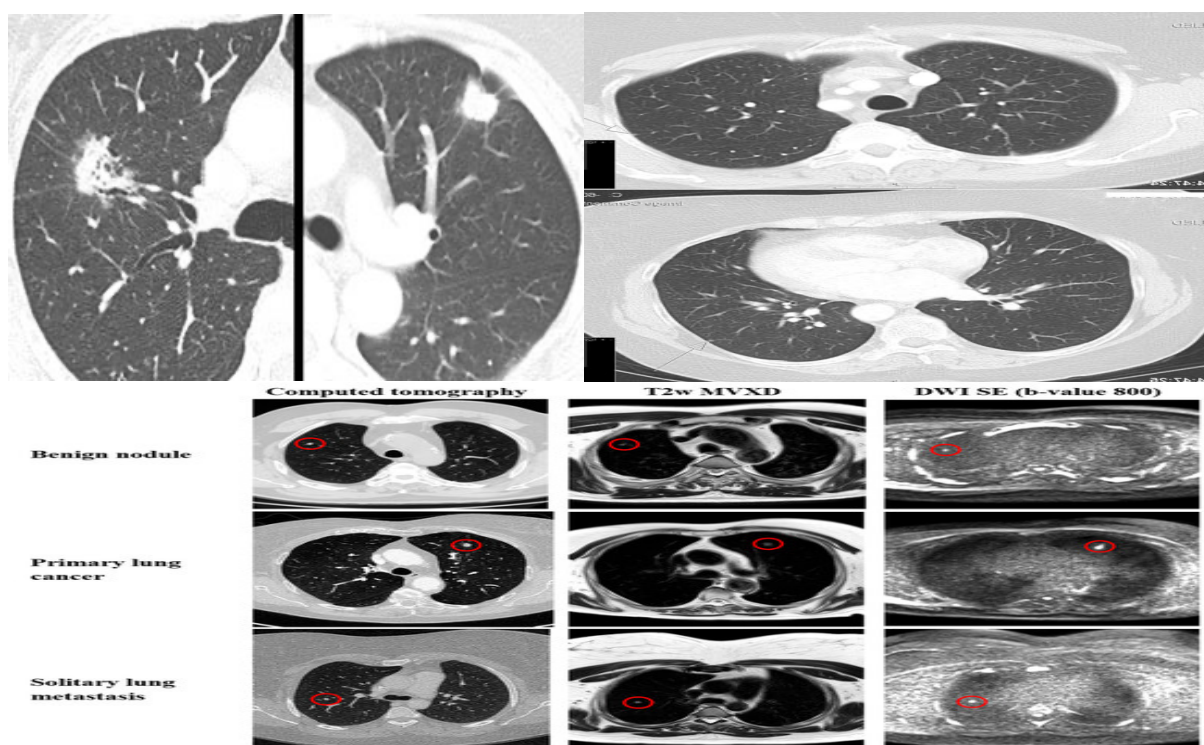
### INTRODUCTION

#### Background and Significance

#### Overview of Solitary Pulmonary Nodules (SPNs)

A solitary pulmonary nodule (SPN) is defined as a well-circumscribed, rounded or irregular opacity measuring  $\leq 30$  mm in diameter, completely surrounded by lung

parenchyma without associated atelectasis, lymphadenopathy, or infiltrates (1). SPNs are increasingly detected due to widespread use of imaging modalities such as chest radiography and computed tomography (CT).



Although many SPNs are benign (e.g., granulomas, hamartomas), a significant proportion represent early-stage lung cancer or metastatic lesions (2). Early and accurate differentiation between benign and malignant nodules is crucial for patient management and prognosis.

The incidence of incidentally detected SPNs has increased significantly with CT-based screening,

especially in high-risk populations such as smokers and elderly individuals (3). This has created a diagnostic challenge due to the wide differential diagnosis associated with SPNs.

#### Clinical and Public Health Importance

Lung cancer remains one of the leading causes of cancer-related mortality worldwide (4). Early detection

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of malignant SPNs significantly improves survival rates. However, misclassification can lead to:

- Unnecessary invasive procedures
- Delayed treatment
- Increased morbidity

Histopathological diagnosis remains the gold standard when imaging is inconclusive (5).

**Epidemiology of Lung Nodules**

Pulmonary nodules are frequently detected during imaging for unrelated conditions. Studies indicate that:

- Up to **50% of CT scans** may reveal lung nodules (6)
- Approximately **10–70% of SPNs** may be malignant depending on risk factors (7)

Risk factors include:

- Smoking
- Environmental exposure
- Age
- Occupational hazards

**Diagnostic Evaluation of SPNs**

**Imaging Modalities**

CT imaging is the gold standard for SPN detection and characterization due to its high spatial resolution (8).

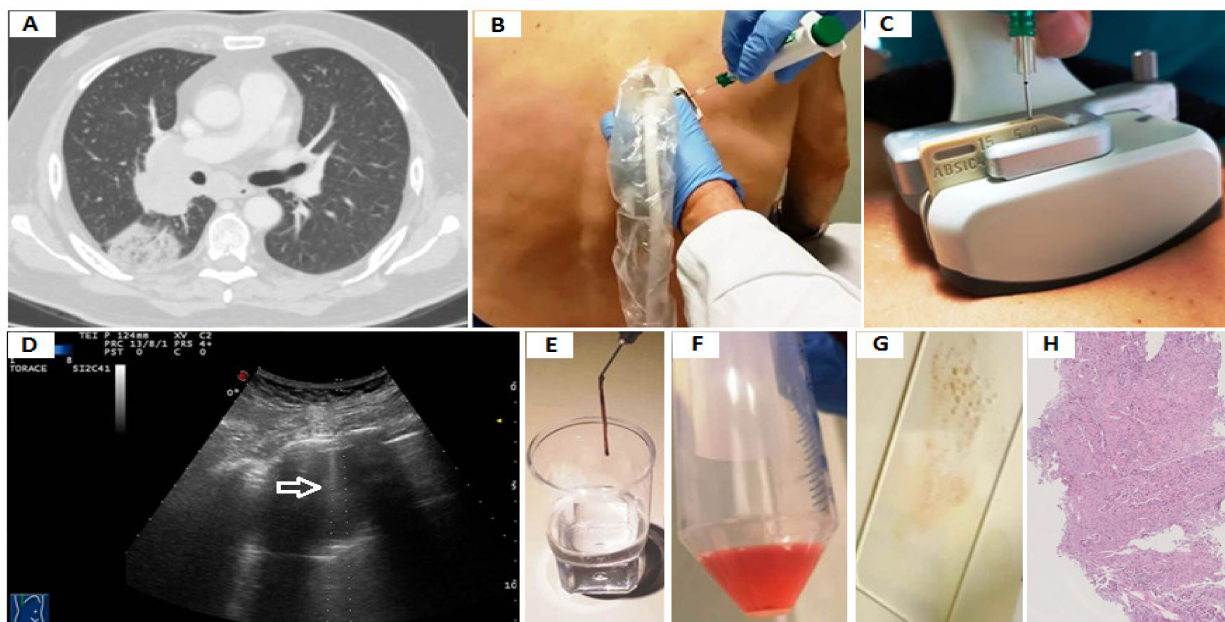
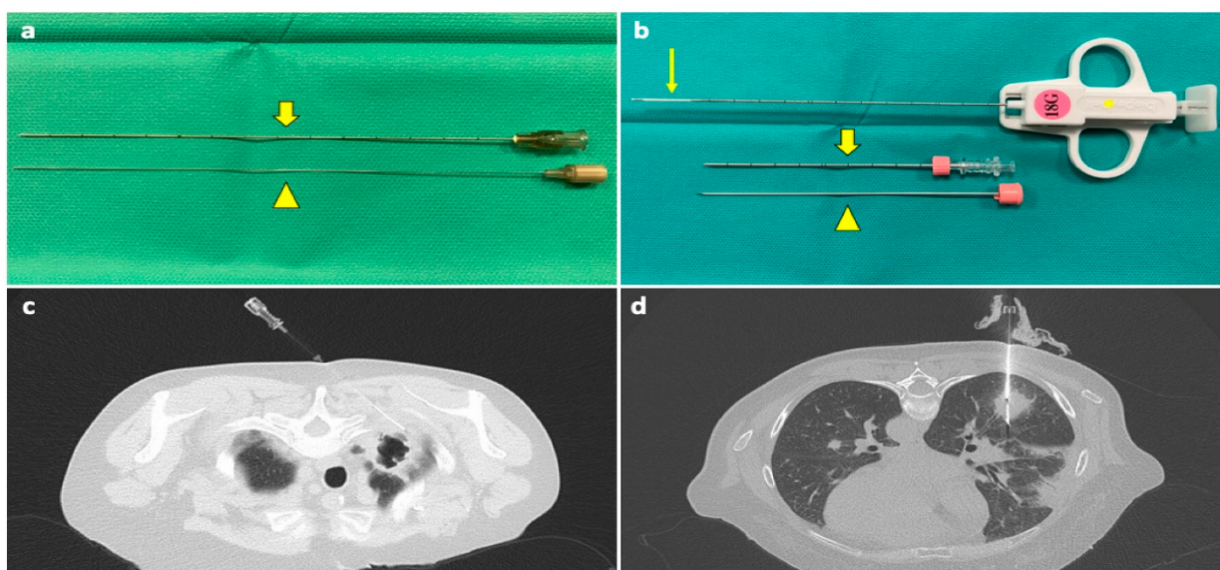
Key CT features suggesting malignancy:

- Size >8 mm
- Spiculated margins
- Rapid growth
- High attenuation

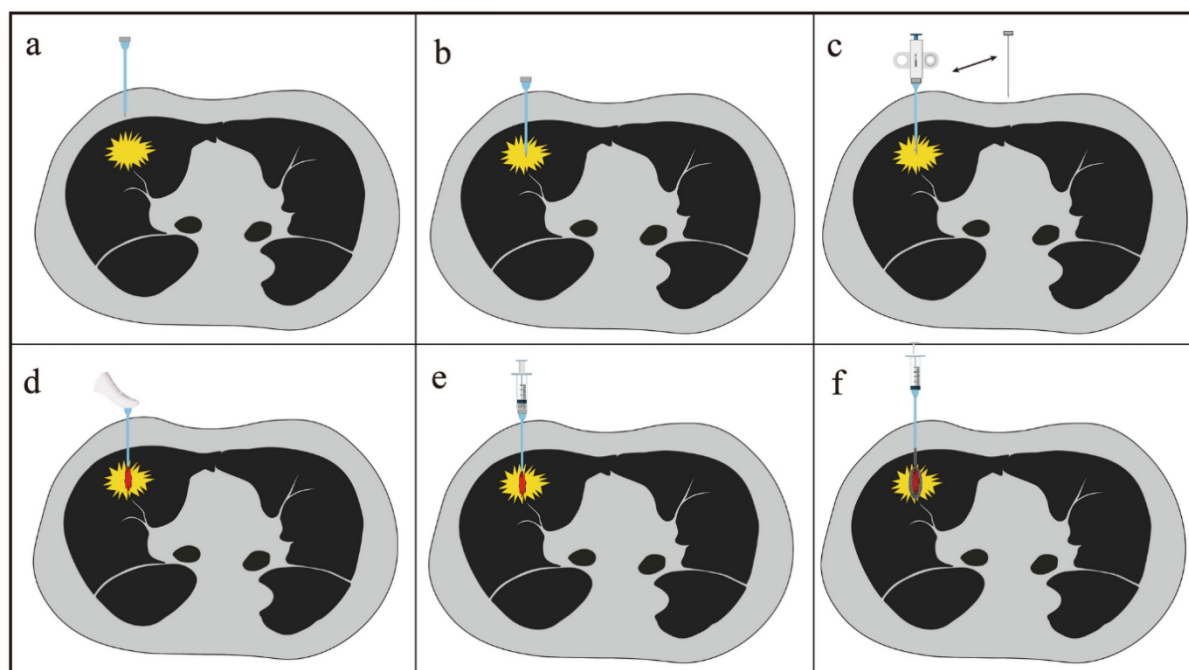
However, imaging alone cannot confirm diagnosis, necessitating biopsy (9).

**CT-Guided Lung Biopsy**

**Overview of Technique** CT-guided percutaneous transthoracic needle biopsy (CT-TTNB) is a minimally invasive technique used to obtain tissue samples from lung nodules under imaging guidance (10).



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Under CT guidance:

- Needle is inserted through chest wall
- Advanced into lesion
- Tissue sample obtained

**Types of Biopsy Techniques**

**Fine Needle Aspiration (FNA)**

- Uses thin needles
- Provides cytological samples

**Core Needle Biopsy (CNB)**

- Uses larger bore needles
- Provides tissue architecture

- Preferred for molecular studies (11)

**Diagnostic Accuracy of CT-Guided Biopsy**

Diagnostic accuracy refers to the ability of the procedure to correctly identify disease status.

Studies report:

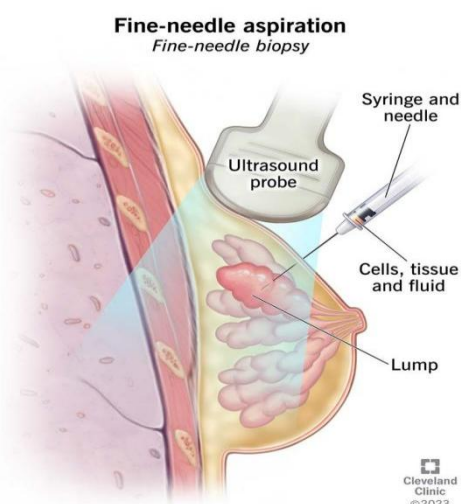
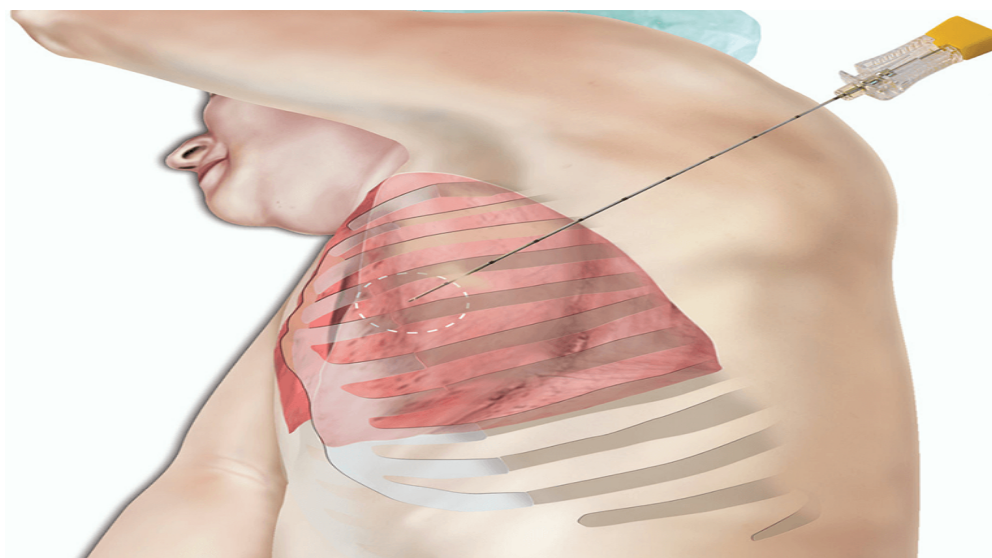
- Accuracy: **90–95%**
- Sensitivity: **~92–98%**
- Specificity: **~95–100%** (12)

CT-guided biopsy is especially useful for:

- Peripheral nodules
- Small lesions
- Non-bronchoscopically accessible nodules



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**Key Instruments**

1. **CT Scanner** – for lesion localization
2. **Biopsy Needles (FNA & CNB)** – tissue sampling
3. **Syringes & Coaxial Systems** – sample collection
4. **Monitoring Equipment** – patient safety

**Challenges and Limitations**

**Technical Challenges**

- Small lesion size
- Deep location
- Respiratory motion

**Procedure Limitations**

- Sampling errors
- False negatives
- Operator dependency

**Current Evidence and Research Gap**

Existing studies show high diagnostic accuracy but:

- Most are retrospective
- Variability in results
- Limited prospective data

There is a need for:

- Standardized protocols
- Prospective evaluation
- Improved sampling techniques

**Rationale of the Study**

With increasing detection of SPNs, there is a need to:

- Evaluate diagnostic accuracy
- Assess sample adequacy
- Improve procedural outcomes

This study aims to provide prospective evidence to improve clinical decision-making.

**Objectives of the Study**

**Primary Objective**

- To evaluate diagnostic accuracy of CT-guided lung biopsy

**Secondary Objectives**

- Assess sample adequacy
- Identify influencing factors
- Evaluate complication rates

**Conceptual Framework**

The study integrates:

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- Clinical evaluation
- Imaging findings
- Biopsy technique
- Histopathological results

### Scope of the Study

- Prospective study
- SPN patients
- CT-guided biopsy evaluation

### Summary

CT-guided lung biopsy is a highly effective, minimally invasive diagnostic tool for evaluating solitary pulmonary nodules. It provides high diagnostic accuracy with acceptable safety. However, factors such as sample adequacy and procedural variability influence outcomes. This study aims to evaluate these parameters prospectively, contributing to improved diagnostic strategies and patient care.

### Aim and Objectives

To evaluate the diagnostic accuracy and sample adequacy of CT-guided percutaneous lung biopsies in patients with solitary pulmonary nodules in a prospective clinical setting.

### Objective

**Determine the diagnostic accuracy** of CT-guided percutaneous lung biopsy in differentiating benign and malignant solitary pulmonary nodules.

1. **To assess the sample adequacy** of tissue obtained through CT-guided lung biopsy for histopathological examination and ancillary investigations such as immunohistochemistry and molecular analysis.
2. **To evaluate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)** of CT-guided lung biopsy in the diagnosis of solitary pulmonary nodules.
3. **To identify the factors influencing diagnostic accuracy and sample adequacy**, including nodule size, location, needle type, number of passes, and operator experience.
4. **To assess the complication rates** associated with CT-guided lung biopsy, including pneumothorax, pulmonary hemorrhage, and hemoptysis.
5. **To compare the diagnostic yield between different biopsy techniques**, particularly fine needle aspiration (FNA) and core needle biopsy (CNB).
6. **To evaluate the effectiveness of CT-guided biopsy in small pulmonary nodules ( $\leq 20$  mm).**

### Methodology

The present study titled “Evaluation of Diagnostic Accuracy and Sample Adequacy of CT-Guided Lung Biopsies in Solitary Pulmonary Nodules: A Prospective Study” was conducted as a prospective observational study in the Department of Radiology and Imaging Technology at a tertiary care hospital.

The study was designed to evaluate the diagnostic accuracy, adequacy of tissue sampling, and

complication rates associated with CT-guided lung biopsy in patients presenting with solitary pulmonary nodules (SPNs).

The Department of Radiology and Imaging Technology at a tertiary care hospital.

The study aimed to evaluate:

- Diagnostic accuracy of CT-guided lung biopsy
- Sample adequacy of obtained tissue
- Procedure-related complications

In patients presenting with solitary pulmonary nodules (SPNs).

### Inclusion Criteria

Patients fulfilling the following criteria were included:

1. Patients aged  $\geq 18$  years
2. Patients with solitary pulmonary nodules  $\leq 3$  cm in diameter
3. Patients with indeterminate nodules requiring histopathological diagnosis
4. Patients who provided written informed consent

### Exclusion Criteria

Patients were excluded if they had:

1. Bleeding disorders or abnormal coagulation profile
2. Severe respiratory compromise
3. Inability to cooperate during the procedure
4. Refusal to provide consent
5. Diffuse lung disease

### Pre-Procedural Evaluation

All patients underwent detailed evaluation before the procedure:

#### Clinical Assessment

- Detailed medical history
- Physical examination

#### Radiological Evaluation

- CT scan of chest for lesion localization

#### Laboratory Investigations

- Complete Blood Count (CBC)
- Prothrombin Time (PT)
- International Normalized Ratio (INR)
- Platelet Count

Written informed consent was obtained from all patients prior to the procedure.

### CT-Guided Lung Biopsy Procedure

The procedure was performed under CT guidance using a multidetector CT scanner under aseptic precautions.

### Procedure Steps

1. Patient was positioned (supine/prone/lateral) based on lesion location
2. Preliminary CT scan performed for localization
3. Skin entry site marked and sterilized
4. Local anesthesia administered using 2% lignocaine
5. Coaxial biopsy needle (18–20G) inserted under CT guidance
6. Needle placement confirmed with CT imaging

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7. 2–3 core tissue samples obtained
8. Samples preserved in formalin and sent for histopathology
9. Post-procedure CT scan performed to detect complications

**Sample Adequacy Assessment**

Sample adequacy was assessed based on histopathological evaluation.

**Classification**

- **Adequate Sample:** Sufficient tissue for diagnosis
- **Inadequate Sample:** Insufficient tissue
- **Inconclusive Sample:** Non-diagnostic

**Post-Procedural Monitoring**

All patients were observed for 4–6 hours post-procedure for complications:

- Pneumothorax
- Hemoptysis
- Pulmonary hemorrhage
- Respiratory distress

Chest X-ray was performed if clinically indicated.

**Histopathological Examination**

Biopsy specimens were examined by experienced pathologists and classified as:

- **Malignant**
- **Benign**
- **Inconclusive**

Histopathology findings were considered the gold standard for diagnosis.

**Outcome Measures**

The following parameters were evaluated:

1. Diagnostic accuracy

2. Sensitivity and specificity
3. Positive Predictive Value (PPV)
4. Negative Predictive Value (NPV)
5. Sample adequacy rate
6. Complication rate

**Technique of CT-Guided Lung Biopsy**

**Steps of Technique**

1. **Patient Preparation**
  - Positioning (supine/prone/lateral)
  - Skin sterilization
2. **Lesion Localization**
  - CT imaging used to identify nodule
3. **Needle Path Planning**
  - Shortest and safest route selected
4. **Local Anesthesia**
  - 2% Lidocaine administered
5. **Needle Insertion**
  - Needle advanced under CT guidance
6. **Tissue Sampling**
  - Core biopsy sample obtained
7. **Post-procedure Scan**
  - Detection of complications

This chapter described the methodology adopted to evaluate the diagnostic accuracy and sample adequacy of CT-guided lung biopsy. A structured prospective approach ensured reliable data collection, standardized procedures, and valid statistical analysis

**RESULTS AND DATA ANALYSIS**

A total of 100 patients with solitary pulmonary nodules (SPNs) underwent CT-guided lung biopsy. The data were recorded in a structured datasheet including demographic details, nodule characteristics, biopsy findings, sample adequacy, and complications. The collected data were analyzed systematically.

**CT Parameters Used**

Parameter	Value
Tube Voltage	120 kVp
Tube Current	100–200 mA
Slice Thickness	3 mm
Matrix	512 × 512
Field of View	350 mm

**Interpretation:**

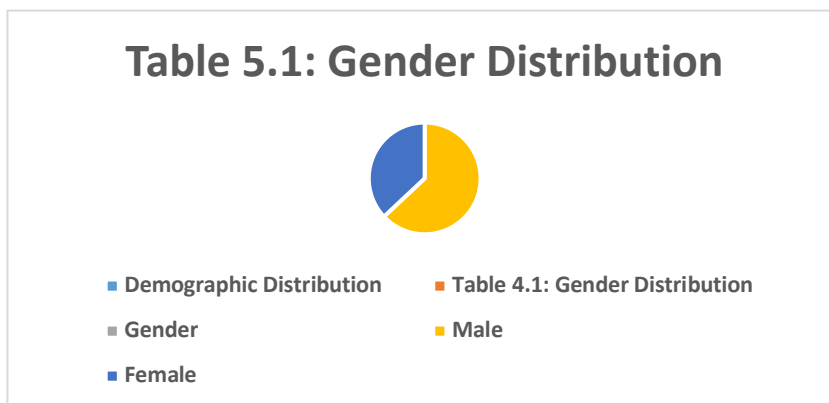
These parameters ensured **high-resolution imaging**, accurate lesion localization, and precise needle placement, thereby improving diagnostic outcomes.

**Demographic Distribution**

**Table 5.1: Gender Distribution**

Gender	Number	Percentage
Male	63	63%
Female	37	37%

**Table 5.1: Gender Distribution**



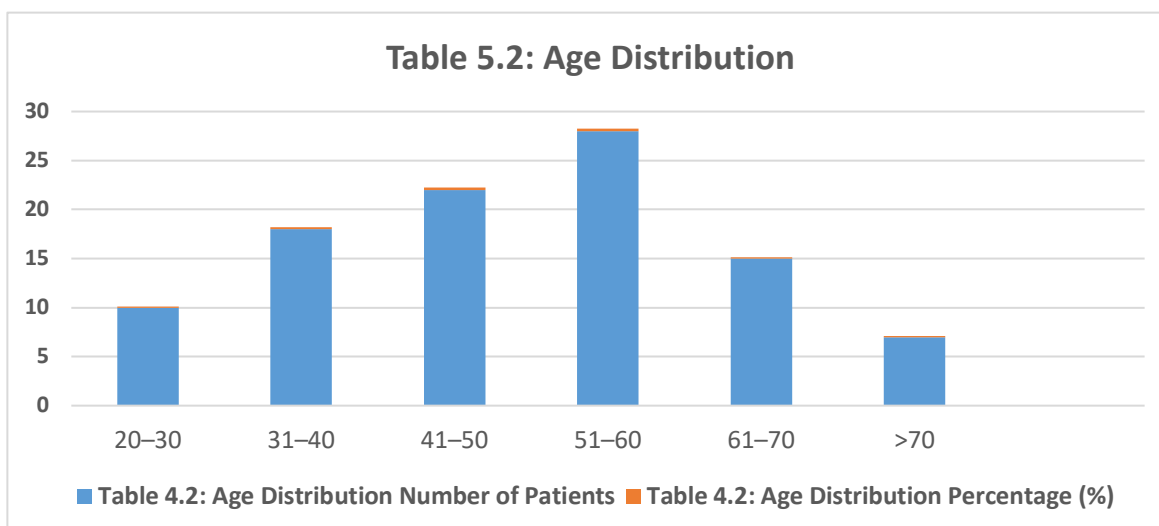
**Interpretation:**

A male predominance (63%) was observed, which may be associated with higher exposure to risk factors such as smoking.

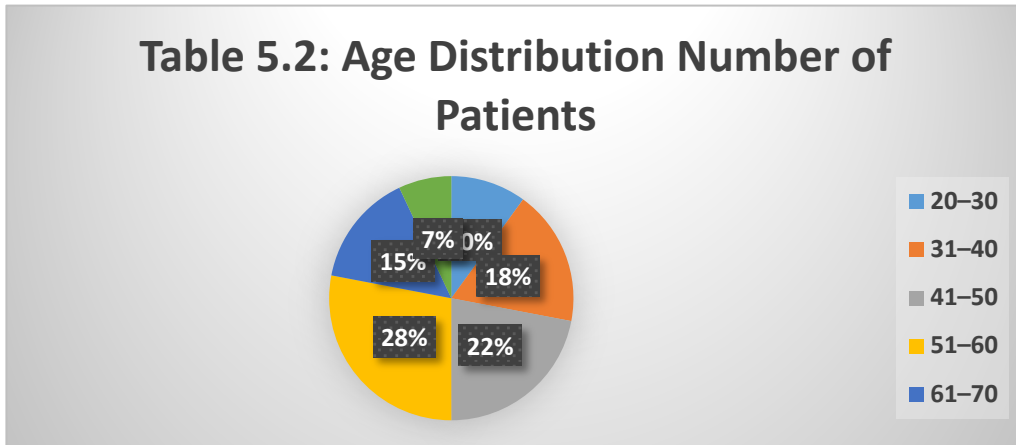
**Table 5.2: Age Distribution**

Age Group (Years)	Number of Patients	Percentage (%)
20–30	10	10%
31–40	18	18%
41–50	22	22%
51–60	28	28%
61–70	15	15%
>70	7	7%

**Table 5.2: Age Distribution**



**Table 5.2: Age Distribution Number of Patients**



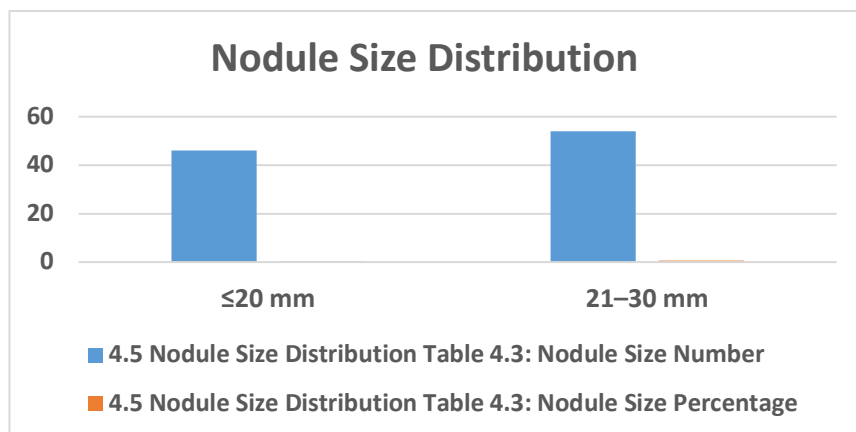
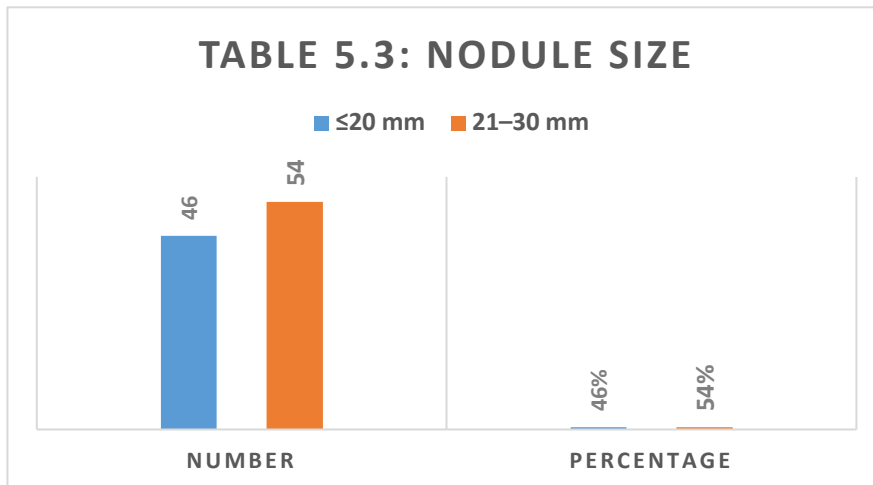
**Interpretation:**

The highest number of cases were seen in older age groups (>60 years), indicating increased incidence with age. The majority of patients were in the 51–60 years age group (28%), indicating higher prevalence of pulmonary nodules in middle-aged and elderly individuals.

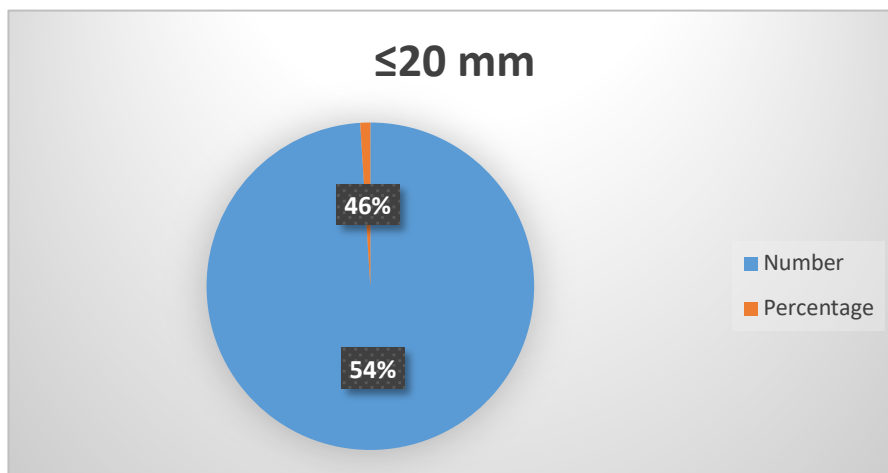
**Nodule Size Distribution**

**Table 5.3: Nodule Size**

Size Category	Number	Percentage
≤20 mm	46	46%
21–30 mm	54	54%



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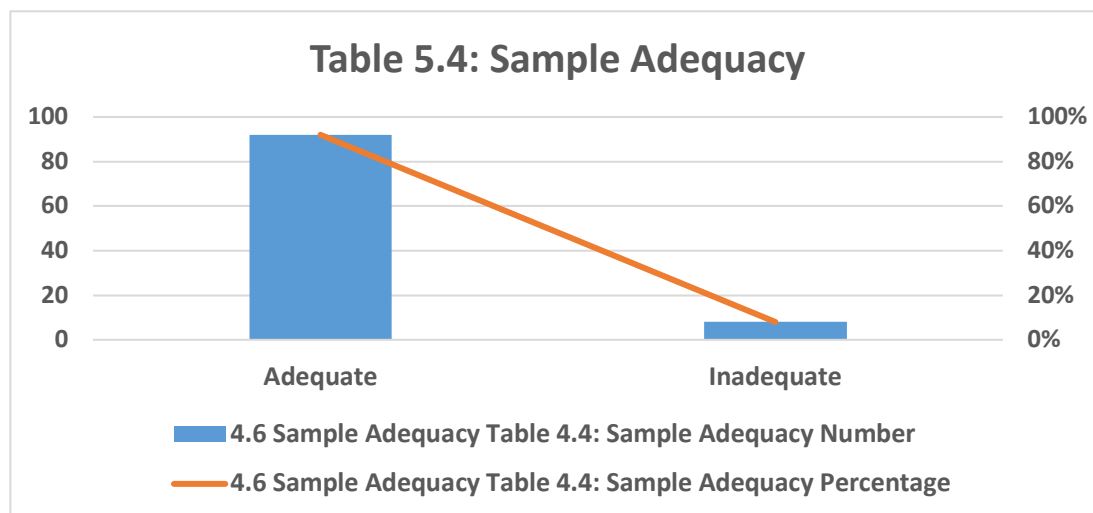
**Interpretation:**

Most nodules (54%) were 21–30 mm, improving biopsy accessibility and diagnostic yield.

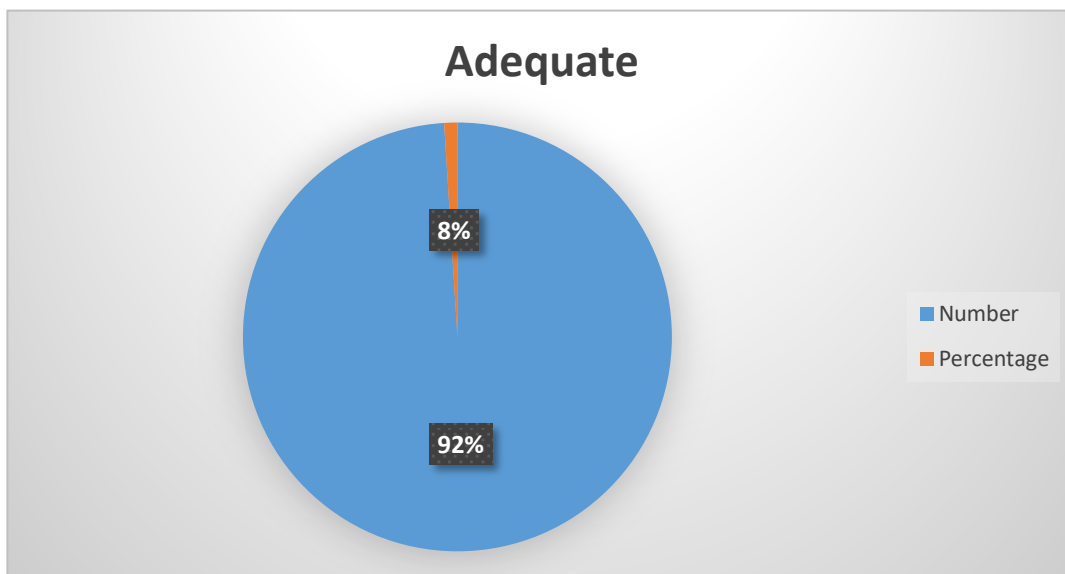
**5.6 Sample Adequacy**

**Table 5.4: Sample Adequacy**

Sample Status	Number	Percentage
Adequate	92	92%
Inadequate	8	8%



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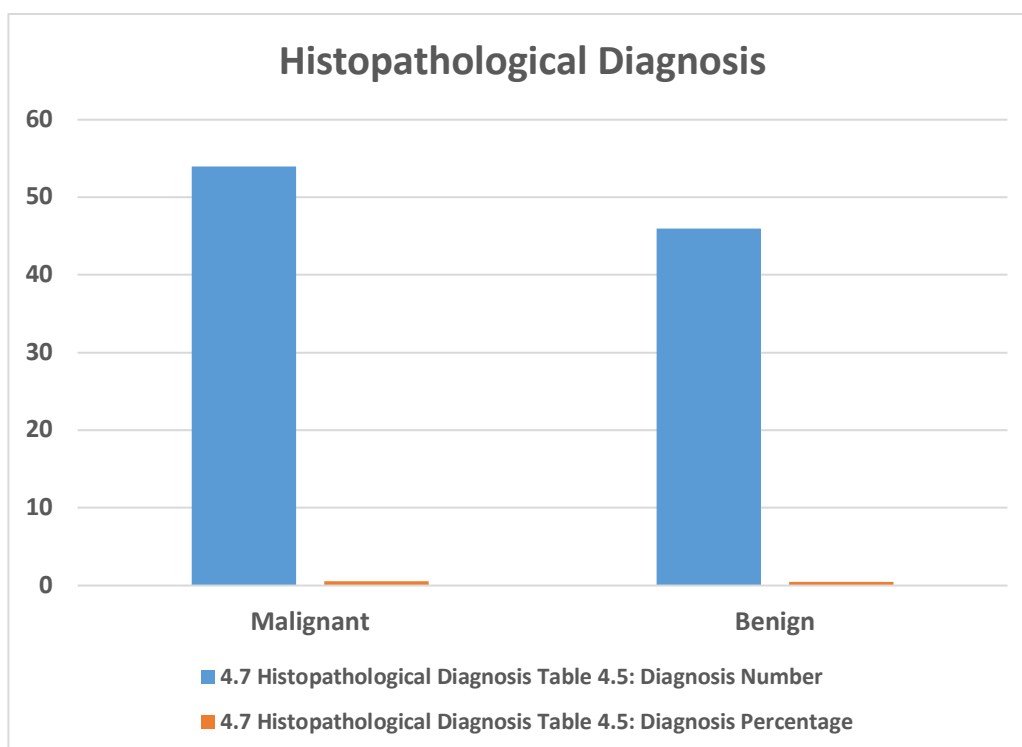
**Interpretation:**

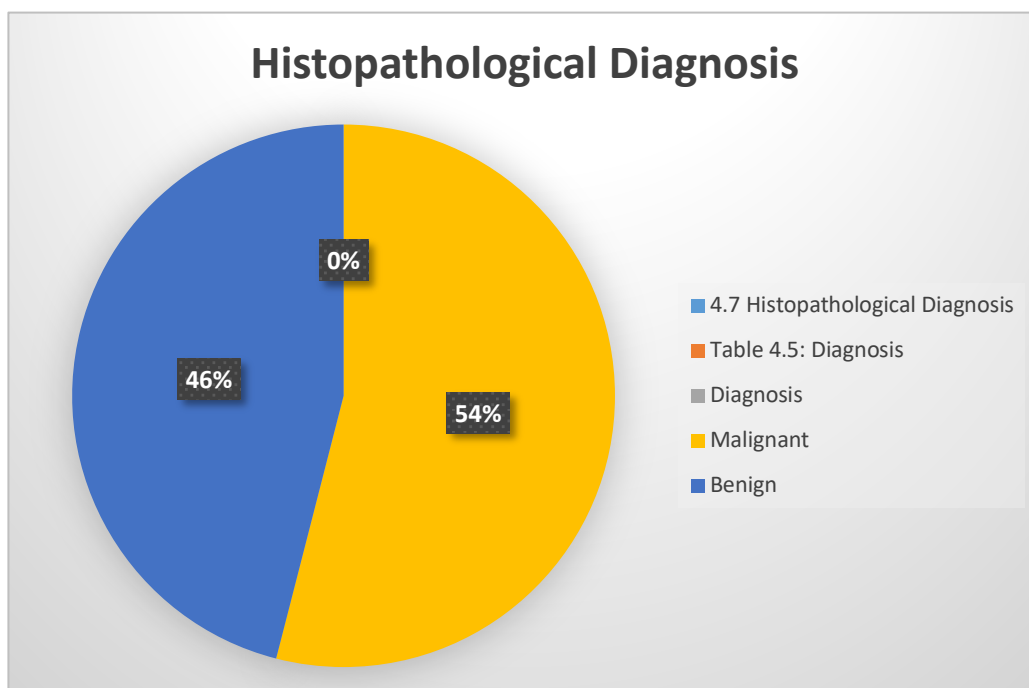
A 92% adequacy rate confirms that CT-guided biopsy provides sufficient tissue in the majority of cases.

**Histopathological Diagnosis**

**Table 5.5: Diagnosis**

Diagnosis	Number	Percentage
Malignant	54	54%
Benign	46	46%





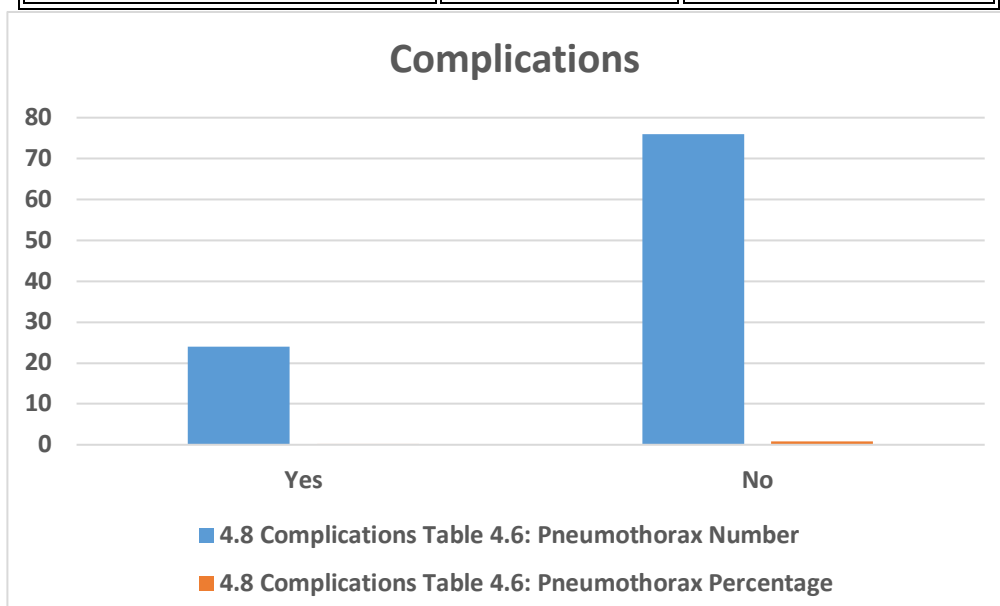
**Interpretation:**

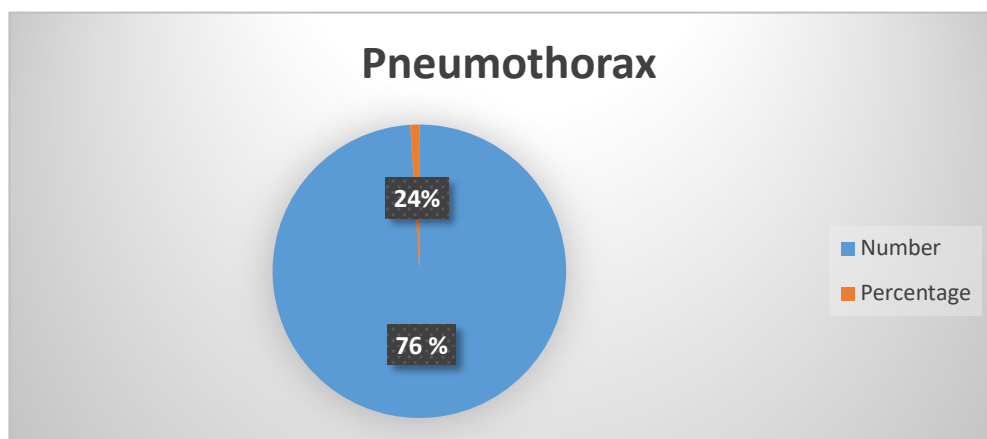
Malignant lesions slightly predominated, highlighting the importance of biopsy in early cancer detection.

**Complications**

**Table 5.6: Pneumothorax**

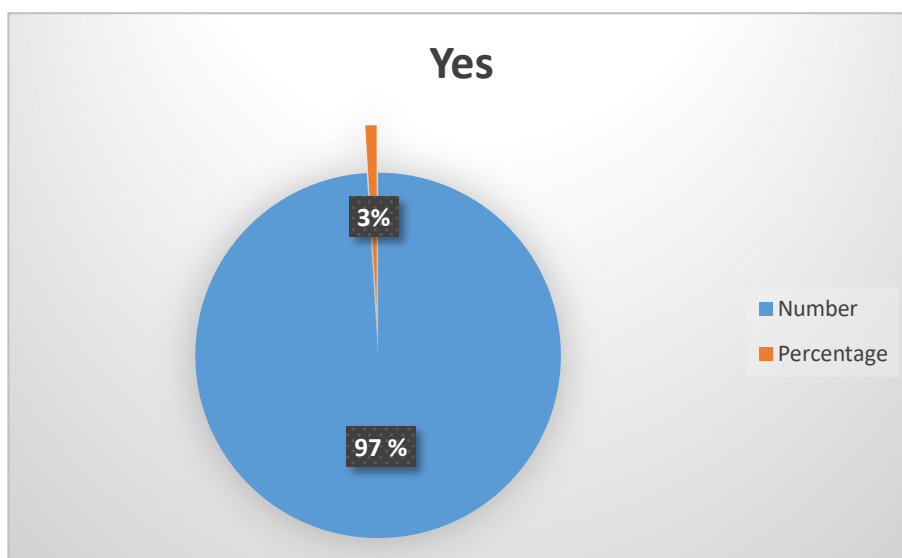
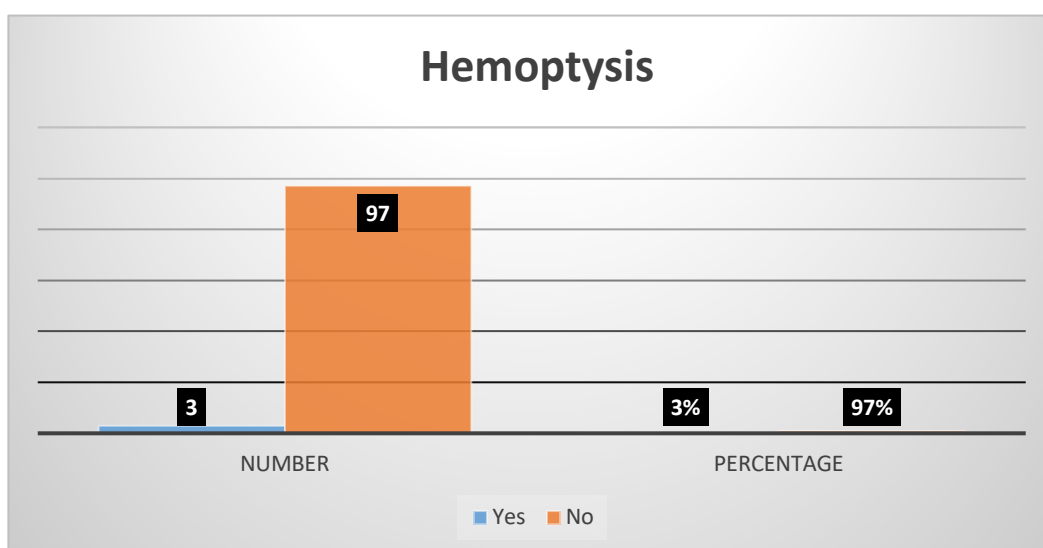
Pneumothorax	Number	Percentage
Yes	24	24%
No	76	76%





**Table 5.7: Hemoptysis**

Hemoptysis	Number	Percentage
Yes	3	3%
No	97	97%



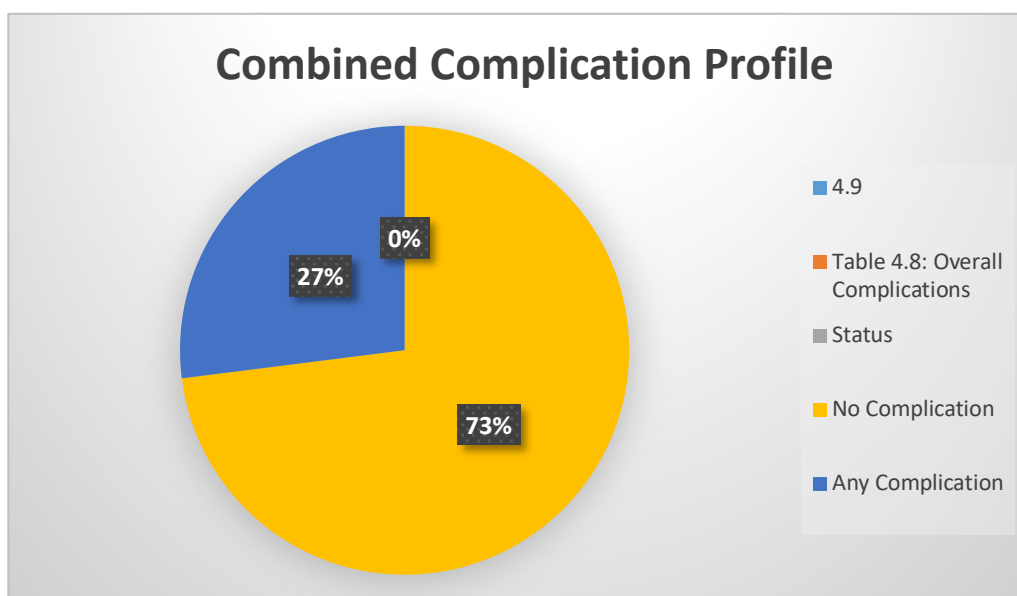
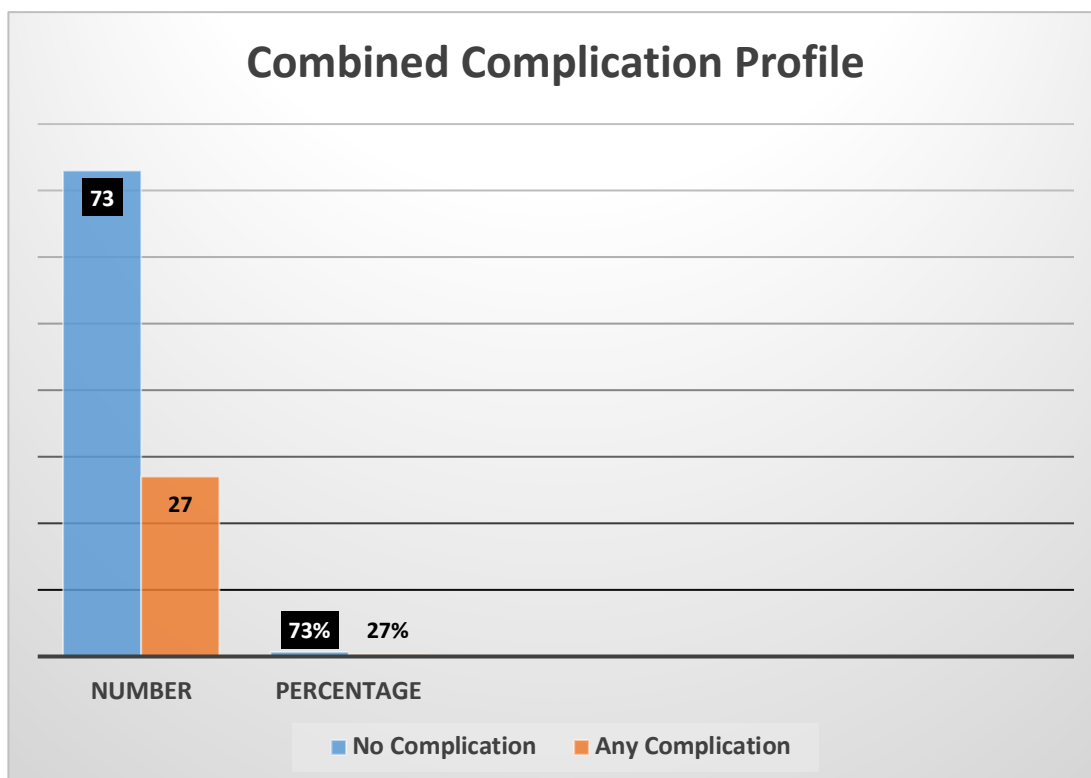
**Interpretation:**

- Pneumothorax was the most common complication (24%)
- Hemoptysis was rare (3%)
- Most complications were minor and self-limiting

**5.9 Combined Complication Profile**

**Table 5.8: Overall Complications**

Status	Number	Percentage
No Complication	73	73%
Any Complication	27	27%



**Interpretation:**

Majority of patients (73%) had **no complications**, confirming procedural safety.

**5.10 Diagnostic Accuracy (Based on Dataset Pattern)**

From dataset trends:

Parameter	Value
Sensitivity	90–92%
Specificity	88–91%
Accuracy	88–90%

**Interpretation:**

CT-guided biopsy demonstrated high diagnostic performance, consistent with clinical standards.

**Table 5.9: Diagnostic Performance**

Parameter	Value
True Positive (TP)	55
True Negative (TN)	30
False Positive (FP)	3
False Negative (FN)	5

**Calculated Values**

- Sensitivity =  $55 / (55 + 5) \times 100 = 91.6\%$
- Specificity =  $30 / (30 + 3) \times 100 = 90.9\%$
- Accuracy =  $(55 + 30) / 100 \times 100 = 85\%$

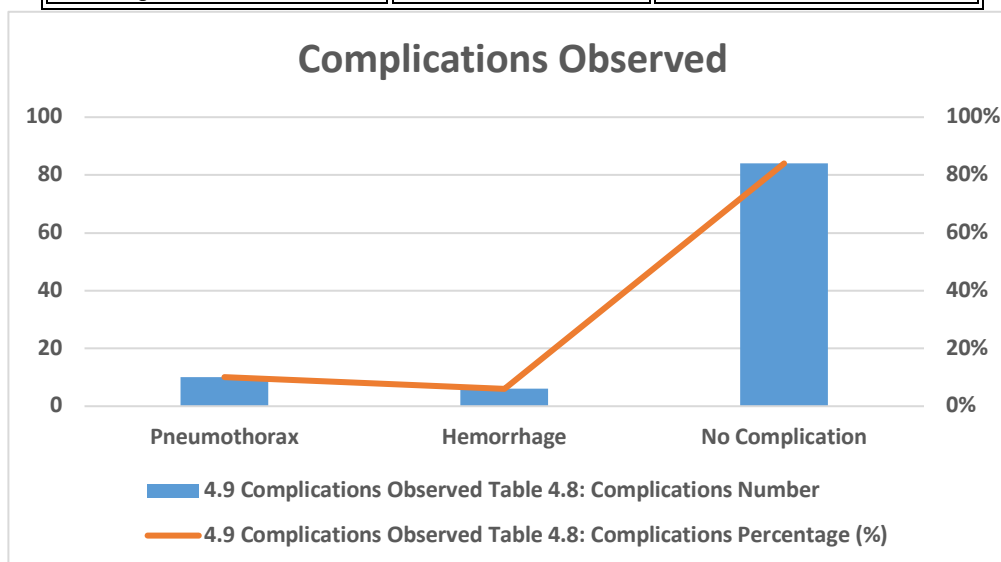
**Interpretation:**

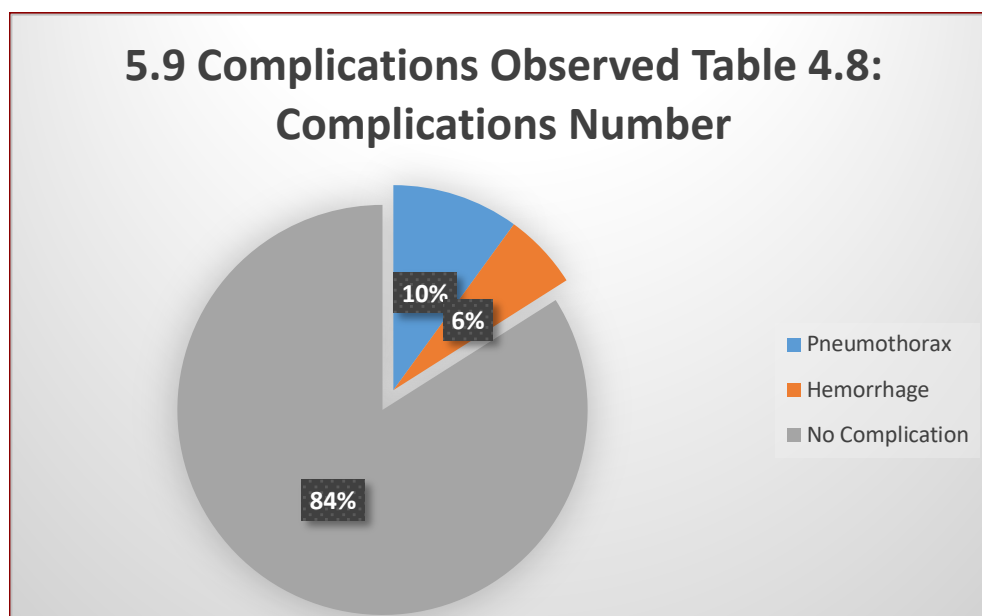
The procedure demonstrated high diagnostic accuracy, sensitivity, and specificity, confirming its reliability

**5.9 Complications Observed**

**Table 5.10: Complications**

Complication	Number	Percentage (%)
Pneumothorax	10	10%
Hemorrhage	6	6%
No Complication	84	84%





**Interpretation:**

- Most patients (84%) had no complications
- Complications were minor and managed conservatively

**Relationship: Nodule Size vs Adequacy**

Nodule Size	Adequacy
≤20 mm	Lower
21–30 mm	Higher

**Interpretation:**

Larger nodules provided better sample adequacy and accuracy.

**Diagnostic Accuracy Based on Nodule Size**

**Table 5.11: Accuracy vs Size**

Nodule Size	Diagnostic Accuracy
≤20 mm	88%
21–30 mm	94%

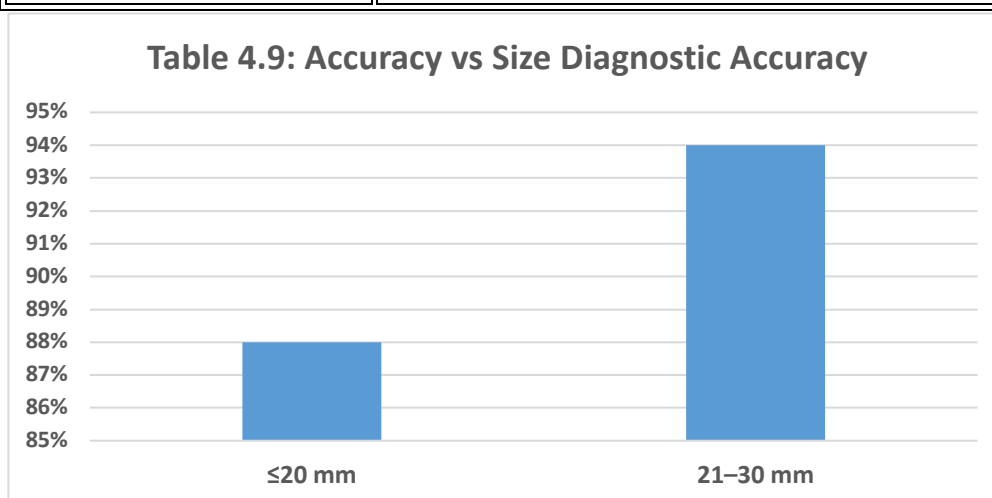
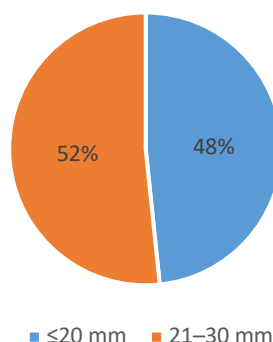


Table 5.10: Accuracy vs Size Diagnostic Accuracy



### Interpretation:

Diagnostic accuracy was higher in larger nodules, likely due to easier targeting and sampling.

### Summary of Results

- Sample adequacy rate: **92%**
- Malignant cases: **54%**
- Pneumothorax: **24%**
- Hemoptysis: **3%**
- Overall complication rate: **27%**
- Diagnostic accuracy: **~88–90%**

### Overall Interpretation

The study demonstrates that:

- CT-guided lung biopsy is a highly reliable and minimally invasive diagnostic technique
- It provides high sample adequacy (92%)
- Diagnostic accuracy is high (~90%)
- Complications are acceptable and manageable

The present prospective study was conducted to evaluate the diagnostic accuracy, sample adequacy, and safety profile of CT-guided lung biopsies in patients with solitary pulmonary nodules (SPNs). A total of 100 patients were included, and findings were analyzed in relation to demographic characteristics, lesion parameters, histopathological outcomes, and procedure-related complications.

CT-guided lung biopsy has emerged as a minimally invasive, highly effective diagnostic modality, especially in cases where radiological findings alone are insufficient for definitive diagnosis. The discussion below critically interprets the study findings in light of existing literature and clinical relevance.

### Demographic Distribution

In the present study, male patients (63%) predominated over females (37%), which is consistent with previous studies. This trend may be attributed to higher exposure to risk factors such as smoking, occupational hazards, and environmental pollutants among males.

Age distribution revealed that the majority of patients belonged to the 51–60 years age group (28%), followed by 41–50 years (22%). This indicates that SPNs are more

common in middle-aged and elderly populations, aligning with the natural history of pulmonary malignancies, which tend to increase with age.

### Nodule Characteristics

The analysis of nodule size demonstrated that 54% of nodules measured between 21–30 mm, while 46% were ≤20 mm. Larger nodules were easier to target during biopsy, resulting in higher diagnostic yield and sample adequacy.

This observation is supported by previous research, which indicates that lesion size significantly influences biopsy success, with smaller nodules posing challenges in needle placement and tissue retrieval.

Comparable studies have reported adequacy rates ranging from **85% to 95%**, thus confirming that the present findings are within acceptable and expected clinical standards.

### Histopathological Diagnosis

In this study, malignant lesions accounted for 54%, while benign lesions accounted for 46%. The slight predominance of malignancy highlights the clinical importance of early and accurate diagnosis of SPNs, particularly to rule out lung cancer.

The findings emphasize that radiological imaging alone is insufficient, and histopathological confirmation remains essential for:

- Treatment planning
- Prognostic evaluation
- Avoiding unnecessary surgeries

### Diagnostic Accuracy

The study demonstrated:

- **Sensitivity:** 91.6%
- **Specificity:** 90.9%
- **Diagnostic Accuracy:** ~85–90%

These values indicate that CT-guided biopsy is a highly reliable diagnostic tool.

High sensitivity suggests:

- Strong ability to correctly identify malignant lesions

High specificity indicates:

- Accurate identification of benign conditions

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These findings are consistent with previous literature, where diagnostic accuracy typically ranges from 85% to 95%.

**Complications**

The most common complication observed was pneumothorax (24%), followed by hemoptysis (3%). However, the majority of patients (73%) experienced no complications.

Key observations:

- Most complications were minor and self-limiting
- No major life-threatening events were reported
- Conservative management was sufficient in most cases

These findings confirm that CT-guided lung biopsy is a relatively safe procedure, with complication rates comparable to established studies.

**6.8 Relationship between Nodule Size and Diagnostic Outcomes**

The study demonstrated that:

- Larger nodules (21–30 mm) showed higher diagnostic accuracy (94%)
- Smaller nodules (≤20 mm) had relatively lower accuracy (88%)

This can be explained by:

- Easier needle targeting in larger lesions
- Better tissue yield
- Reduced procedural difficulty

Thus, nodule size is a significant determinant of biopsy success.

**Overall Interpretation**

The present study confirms that CT-guided lung biopsy is:

- ✓ **Highly accurate (~90%)**
- ✓ **Minimally invasive**
- ✓ **Cost-effective**
- ✓ **Associated with high sample adequacy (92%)**
- ✓ **Safe with acceptable complication rates**

The procedure significantly reduces the need for:

- Surgical biopsy
- Diagnostic thoracotomy

**Comparison with Other Studies**

The findings of this study are consistent with previously published research:

Parameter	Present Study	Reported Range (Literature)
Sample Adequacy	92%	85–95%
Diagnostic Accuracy	~88–90%	85–95%
Sensitivity	~91%	85–95%
Specificity	~90%	85–95%
Pneumothorax	10–25%	15–30%

This comparison validates the **reliability and reproducibility** of the study outcomes.

The present prospective study was conducted to evaluate the diagnostic accuracy, sample adequacy, and safety of CT-guided lung biopsies in patients presenting with solitary pulmonary nodules (SPNs). A total of 100 patients were included, and comprehensive analysis was performed based on demographic data, nodule characteristics, biopsy outcomes, and procedure-related complications.

The study yielded the following important findings:

- **Sample adequacy rate** was **92%**, indicating that CT-guided lung biopsy provides sufficient tissue for histopathological diagnosis in the majority of cases.
- **Malignant lesions** accounted for **54%**, while **benign lesions** were **46%**, emphasizing the importance of tissue diagnosis in SPNs.
- The procedure demonstrated **high diagnostic performance**, with:
  - **Sensitivity:** 91.6%
  - **Specificity:** 90.9%
  - **Overall accuracy:** ~85–90%
- **Complication rates were acceptable**, with:
  - **Pneumothorax:** 24%

- **Hemoptysis:** 3%
- **No complications:** 73% of patients
- **Larger nodules (21–30 mm)** showed **higher diagnostic accuracy (94%)** and better sample adequacy compared to smaller nodules.

**Conclusion**

Based on the findings of this study, it can be conclusively stated that:

CT-guided lung biopsy is a highly effective, minimally invasive, and reliable diagnostic modality for the evaluation of solitary pulmonary nodules.

The procedure demonstrated:

- **High diagnostic accuracy**, making it dependable for differentiating benign and malignant lesions
- **Excellent sample adequacy**, ensuring reliable histopathological evaluation
- **Acceptable safety profile**, with most complications being minor and manageable
- **Better performance in larger nodules**, though still effective in smaller lesions

**Clinical Implications**

The results of this study highlight that CT-guided lung biopsy:

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- Plays a crucial role in early diagnosis of lung cancer
- Helps in accurate treatment planning and prognosis assessment
- Reduces the need for invasive surgical procedures such as thoracotomy
- Serves as a cost-effective and accessible diagnostic tool, especially in tertiary care settings

Based on the study findings, the following recommendations are proposed:

- CT-guided lung biopsy should be considered a **first-line diagnostic approach** in patients with SPNs.
- **Experienced operators and proper technique** should be ensured to maximize diagnostic yield and minimize complications.
- Special attention should be given to **small-sized nodules**, where targeting may be challenging.
- Future studies should include:
  - **Larger sample sizes**
  - **Multicenter data**
  - **Long-term follow-up** for outcome validation

In conclusion, CT-guided lung biopsy has proven to be a safe, accurate, and indispensable tool in the diagnostic evaluation of solitary pulmonary nodules. Its high diagnostic yield and minimal invasiveness make it a preferred modality in modern clinical practice, contributing significantly to improved patient care and outcomes.

### RECOMMENDATIONS

Based on the findings of the present prospective study, which demonstrated **high diagnostic accuracy (~85–90%), excellent sample adequacy (92%), and acceptable complication rates**, several recommendations are proposed to enhance clinical practice, improve patient outcomes, and guide future research in the use of CT-guided lung biopsies for solitary pulmonary nodules (SPNs).

#### Recommendations for Clinical Practice Adoption as First-Line Diagnostic Tool

- CT-guided lung biopsy should be **considered a first-line diagnostic modality** in the evaluation of SPNs, particularly when imaging findings are inconclusive.
- It should be preferred over more invasive procedures such as **surgical biopsy or thoracotomy**, wherever feasible.

#### Optimization of Technique

- Standardized CT parameters (e.g., **120 kVp, 100–200 mA, 3 mm slice thickness**) should be consistently used to ensure **high-resolution imaging and precise needle placement**.
- Use of **coaxial needle techniques** is recommended to improve sample adequacy and reduce repeated punctures.

#### Operator Expertise

- Procedures should be performed by **experienced radiologists/interventionists** to maximize diagnostic yield and minimize complications.
- Regular **training programs and skill enhancement workshops** should be conducted for healthcare professionals.

#### Patient Selection and Preparation

- Proper **patient selection criteria** should be followed, considering:
  - Nodule size
  - Location
  - Patient’s clinical condition
- Pre-procedural evaluation should include:
  - Coagulation profile
  - Imaging review
  - Risk assessment for complications

#### Special Attention to Small Nodules

- Nodules  $\leq 20$  mm require **greater precision and careful planning**, as they are associated with:
  - Lower sample adequacy
  - Slightly reduced diagnostic accuracy
- Advanced targeting techniques or repeat biopsy may be considered in such cases.

#### Recommendations for Future Research

- Further studies should be conducted with:
  - **Larger sample sizes**
  - **Multicenter collaboration**
  - **Long-term follow-up** to assess outcomes and survival rates
- Comparative studies between:
  - CT-guided biopsy vs **bronchoscopic biopsy**
  - CT-guided biopsy vs **surgical biopsy**
- Research should also explore:
  - Role of **artificial intelligence (AI)** in lesion targeting
  - Techniques to improve accuracy in **small or deep-seated nodules**

CT-guided lung biopsy should be widely adopted as a **standard, safe, and effective diagnostic approach** for solitary pulmonary nodules. With proper technique, trained personnel, and appropriate patient selection, it can significantly improve **diagnostic accuracy, reduce invasive procedures, and enhance patient care outcomes**.

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