DOI: 10.7860/JCDR/2025/81348.21969

Original Article

Internal Medicine Section

Diagnostic Yield of Different Bronchoscopic Procedures for Lung Cancer: A Retrospective Study

URJITABEN PARMAR[1], NISARG PATEL[2], DHRUMINKISHAN PRAJAPATI[3], RUCHIT NAWAL[4]

ABSTRACT

Introduction: Lung cancer represents the leading cause of cancer-related mortality globally, accounting for 1.76 million deaths annually worldwide. Flexible bronchoscopy remains the cornerstone diagnostic procedure for suspected pulmonary malignancy, offering multiple sampling techniques with varying diagnostic efficacy. Limited comparative data exists regarding optimal technique selection across different tumour presentations and morphological patterns in resource-constrained healthcare settings.

Aim: To study comparison between different bronchoscopy techniques like Bronchial Brushings (BB), bronchial biopsy, and Bronchoalveolar Lavage (BAL) for diagnosis of lung cancer across different tumour locations and morphological patterns.

Materials and Methods: The present hospital-based retrospective observational study was conducted at the Department of Pulmonary Medicine, BJ Medical College, Ahmedabad, Gujarat, India, data was collected from September 2018 to September 2020 and analysed during 2024-2025. A total of 50 patients aged ≥18 years with histopathologically confirmed lung malignancy who underwent diagnostic bronchoscopy were included. Given the retrospective nature utilising de-identified data, formal ethical clearance was exempted with verbal departmental approval obtained. Parameters which were evaluated include diagnostic yields of BBs, bronchial biopsy, and BAL across different tumour locations and morphological patterns, demographic characteristics, clinical presentations, smoking associations, radiological findings, and procedural complications. Statistical analysis was done using Microsoft Excel 2019 and R software version 4.0, utilising Chi-square tests for categorical variables, Fisher's-exact test when expected frequencies were <5, independent t-tests for continuous variables, and proportion tests for diagnostic yield comparisons, with significance defined as $p < 0.05$.

Results: Patient demographics were male predominance with 34 patients (68.0%) versus 16 females (32.0%), and elderly clustering with 34 patients (68.0%) between 66-80 years. Exposure to smoking affected 33 patients (66.0%), with strong association with squamous cell carcinoma (14/16 cases, 87.5%) whereas adenocarcininoma was equally distributed as in smokers (10 cases, 20.0%) versus non-smokers (10 cases, 20.0%). BBs yielded superior diagnostic yields of 16/25 procedures (64.0%, 95% CI: 42.5-82.0) in central tumours and 10/14 procedures (71.4%, 95% CI: 41.9-91.6) in peripheral lesions significantly better than bronchial biopsy (12/22 procedures, 54.5% central; 7/12 procedures, 58.3% peripheral) and Bronchial Washing (BW) (4/30 procedures, 13.3% central; 3/20 procedures, 15.0% peripheral). Brushings continued to outperform all patterns of morphology, with 66.7% yield in difficult mucosal irregularity cases. Adenocarcinoma was the most frequent (20 cases, 40.0%), followed by squamous cell carcinoma (16 cases, 32.0%). Total complications affected 16 patients (32.0%), primarily bleeding (12 cases, 24.0%) and pneumothorax (3 cases, 6.0%).

Conclusion: These findings provide evidence-based support for prioritising BBs in lung cancer diagnostic protocols, particularly valuable for resource-limited healthcare settings seeking optimal conventional techniques.

Keywords: Bronchoalveolar lavage, Bronchial brushing, Bronchial washing

INTRODUCTION

Cancer is a leading cause of global mortality, with lung cancer being the deadliest of cancers in multi-ethnic societies [1]. The most recent estimates provided by the Global Cancer Observatory (GLOBOCAN) suggest that lung cancer kills 1.76 million people annually worldwide, equivalent to 18.0% of all cancer mortality [2]. The poor past prognosis of lung cancer, as reflected by five-year survival rates that rarely exceed 20% in much of the health care infrastructure, underscores the paramount importance of early detection and accurate histopathological diagnosis [3].

The India-specific epidemiological pattern of lung cancer exhibits distinctive trends that are significantly different from those observed in Western populations. According to the National Cancer Registry Programme (NCRP) data under the Indian Council of Medical Research (ICMR) aegis, lung cancer ranks as the fifth most frequent malignancy among Indian men, with age-standardised incidence rates exhibiting marked variation from one geographic region to another [4]. The composite analysis by the NCRP for the years 2012-2016, which covers data from 28 Population-Based Cancer Registries (PBCRs), points to maximal heterogeneity in lung cancer incidence with the highest rates being recorded in the northeastern states, prominently in Aizawl district. There, age-standardised rates reach up to 269.4 per 100,000 males [4]. This regional disparity is a reflection of the intricate interaction between tobacco consumption patterns, environmental risk factors, and genetic susceptibility unique to Indian populations. Histopathological distribution in Indian lung cancer patients reveals squamous cell carcinoma in smokers and adenocarcinoma in non-smokers in urban metropolitan cities [5]. This epidemiological pattern follows the change in exposure patterns like rising ambient air pollution, occupational exposure, and alteration in the use of tobacco products, necessitating altered diagnostic responses to the Indian healthcare context.

Flexible bronchoscopy is currently the first-line diagnostic modality for identification of suspected pulmonary malignancies, with direct endoscopic visualisation of the tracheobronchial tree and simultaneous tissue acquisition through a variety of sampling techniques [6]. The advanced diagnostic modalities of the modern bronchoscopy include Endobronchial Forceps Biopsy (EBB) for

centrally located tumours, Transbronchial Forceps Biopsy (TBB) for peripherally located lesions, and cytological sampling through BAL, BW, and BB procedures [7]. These conventional techniques remain a mainstay in resource-constrained healthcare facilities, where advanced navigational devices like Electromagnetic Navigation Bronchoscopy (ENB) and Endobronchial Ultrasound (EBUS) may not be practically feasible.

Literature currently suggests significant heterogeneity in diagnostic yields between various bronchoscopic sampling modalities. Systematic reviews suggest 30-80% diagnostic yields for bronchial brushing cytology and 15-50% diagnostic yields for bronchial washing, with highly variable institutional and operator-dependent influences on performance outcomes [8,9]. The American College of Chest Physicians (ACCP) evidence-based guidelines recognise this variability with a focus on the importance of technique choice based on tumour characteristics, location, and patterns of morphological presentation [10]. The majority of the evidence for diagnostic performance comes from healthcare systems in the West that have developed bronchoscopic technologies, i.e., real-time imaging guidance, electromagnetic navigation technology, and sophisticated cytopathological facilities [11]. However, the applicability of the evidence to practice in resource-poor environments necessitates systematic testing, as diagnostic algorithms for technology-assisted procedures cannot be transferred to routine bronchoscopic practice in a significant manner.

Indian healthcare facilities are confronted with some challenges in lung cancer diagnosis, such as heterogeneity of patient populations, variability in disease presentation, and resource availability that directly affect the choice of diagnostic approach and outcome [12]. Hospital-based cancer registry (HBCR) data from 58 centers based on NCRP data indicate that most lung cancer patients have locally advanced disease, distant metastasis being more common in males (44.0%) and females (47.6%) at presentation [4]. This advanced stage of presentation gives high priority to maximising the diagnostic efficiency and accuracy within available technological and economic constraints. The absence of region-specific standards for diagnostic performance of standard bronchoscopic techniques creates uncertainty in best sampling method selection and may be a causative agent of suboptimal diagnostic yields in the clinical setting. Further, the absence of universally standardised protocols for technique selection as a function of location and morphology of tumours is a strong knowledge gap that has an immediate impact on patient care quality and diagnostic accuracy. Thus, the current research tries to quantify the comparative diagnostic effectiveness of conventional bronchoscopic sampling techniques in lung cancer diagnosis in the setting of an average Indian tertiary care centre.

MATERIALS AND METHODS

The present research was conducted as a hospital-based retrospective observational analysis at the Department of Pulmonary Medicine, BJ Medical College, Ahmedabad, Gujarat, India, with data collection encompassing the period from September 2018 to September 2020, followed by systematic data analysis and interpretation conducted during November 2024 to March 2025. The institution operates as a major tertiary reference hospital which provides medical care to people from different socioeconomic statuses across western Gujarat including patients from urban and rural areas. Given the retrospective nature of this investigation utilising de-identified patient data from existing medical records, formal written ethical clearance from the Institutional Review Committee (IRC) was not mandated according to institutional guidelines for retrospective chart reviews involving anonymised data. Verbal approval was obtained from the department and institutional authorities prior to study initiation, ensuring compliance with established research protocols while maintaining patient confidentiality and data protection standards throughout the investigation.

Sample size selection: The sample size of 50 patients was determined through institutional feasibility assessment and clinical considerations specific to the study context. This sample represents the total eligible patient population meeting strict inclusion criteria during the two-year data collection period at the institution.

Inclusion and Exclusion criteria: The study included patients who were at least 18-year-old with diagnosed lung cancer who underwent diagnostic flexible bronchoscopy during the specified study period, with complete medical records available for retrospective analysis. Inclusion criteria specifically required histopathologically confirmed lung cancer through any bronchoscopic sampling technique (bronchial brushing, bronchial washing/lavage, or bronchial biopsy) with adequate documentation of procedural details and patient demographics. Patients were not eligible for this study if they had medical reasons against bronchoscopy or received cancer treatment before the procedure or did not have complete records or developed cancer from other body sites.

Study Procedure

Pulmonologists who are experts at the institution conducted all bronchoscopy procedures with Olympus flexible bronchoscopes (BF-1T180, Olympus Corporation, Tokyo, Japan). Patient preparation for bronchoscopy included obtaining consent while also ensuring fasting status and sedation with midazolam combined with 2% lidocaine topical anaesthesia. The standard procedure started with a complete examination of the tracheobronchial tree before the selected samples based on lesion features and accessibility. During the course of the study, bronchoscopic sampling employed a standard institutional technique when clinically appropriate and technically feasible. The standard procedure was bronchial washing or BAL with 20-40 mL normal saline and bronchial brushing with sterile cytology brushes, and concluded with bronchial biopsy using routine forceps (endobronchial for central lesions, transbronchial for peripheral lesions when fluoroscopy was used). Clinical records on study dates indicated that the choice of sampling method was modified according to lesion accessibility, patient status, risk of bleeding, and procedural safety issues. All three sampling methods were not used in all patients due to clinical contraindication or technical issues, and the reason was noted in the patient's medical records.

Specimens of cytology received between 2018-2020 were processed according to standard laboratory procedures with bronchial wash samples centrifuged at 1500 rpm for 10 minutes and brushing samples prepared by conventional smear methods with fixation in 95% alcohol. Diagnosis for malignancy was positive with nuclear pleomorphism with raised nuclear-to-cytoplasmic ratio (>0.7), irregular chromatin pattern, prominent nucleoli (>2 micrometers), and cellular architectural disarray. Histopathological samples were fixed in 10% neutral buffered formalin and stained with haematoxylin and eosin, graded according to World Health Organisation (WHO) criteria for classification of lung cancer [12]. Suspicious for cytology was graded as negative for analysis to offer diagnostic specificity.

Bronchoscopic appearances documented during the study period were retrospectively graded into four morphologic patterns: endoluminal growth (intraluminal tumour mass), external compression (extrinsic luminal narrowing), infiltrative growth (asymmetrical mucosal thickening), and mucosal irregularity (mild surface changes) [6], Grading was done based on the initial bronchoscopy reports and photographic documentation where these were available.

Medical staff retrieved comprehensive data through structured proforma entries from medical records which contained demographic information together with clinical data, radiological data and procedural details. The data collection included patient age, gender, presenting symptoms, smoking history, radiological findings as well as bronchoscopy appearances and sampling methods and

histopathological results and complications experienced during the procedure.

STATISTICAL ANALYSIS

Statistical analysis was performed using Microsoft Excel 2019 for initial data organisation and R software version 4.0 for advanced statistical computing. The study produced descriptive statistics which included standard deviations for continuous variables together with frequency distributions and percentages for categorical variables. The diagnostic yields received 95% confidence interval calculations when needed. Chi-square tests evaluated associations between categorical variables such as gender, histological subtypes and smoking exposure, while Fisher's-exact test was used when expected frequencies were less than five. Independent t-tests compared continuous variables including age distributions and pack-year variations, while proportion tests assessed diagnostic yield differences between sampling techniques and tumour locations. Bonferroni correction was applied for multiple comparisons, and statistical significance was defined as p-values <0.05 for all analyses.

RESULTS

A total of 50 patients with confirmed lung malignancy who underwent diagnostic bronchoscopy were included in this analysis. The cohort demonstrated a significant male predominance with 34 patients (68.0%) compared to 16 females (32.0%), yielding a male-to-female ratio of 2.1:1 (χ^2=6.48, p=0.011). The age distribution revealed a predominant elderly population with 34 patients (68.0%) in the 66-80 years age group. The mean age was 73.2 years (SD±8.4 years, range: 23-80 years). Age distribution analysis showed statistically significant clustering in the elderly demographic (p<0.001, one-sample χ^2 test against uniform distribution) [Table/Fig-1].

Characteristic	n (%)	95% CI
Gender		
Male	34 (68.0)	53.3-80.5
Female	16 (32.0)	19.5-46.7
Age groups (years)		
21-35	3 (6.0)	1.3-16.5
36-50	5 (10.0)	3.3-21.8
51-65	8 (16.0)	7.2-29.1
66-80	34 (68.0)	53.3-80.5

[Table/Fig-1]: Demographic distribution of study population.

The clinical presentation was predominantly respiratory with constitutional symptoms forming a secondary pattern. Cough emerged as the most prevalent symptom, affecting 45 patients (90.0%, 95% CI: 78.2-96.7), followed by chest pain in 42 patients (84.0%, 95% CI: 70.9-92.8) and haemoptysis in 40 patients (80.0%, 95% CI: 66.3-90.0) [Table/Fig-2].

Smoking history analysis revealed 33 patients (66.0%) with positive smoking exposure compared to 17 non-smokers (34.0%). Among males, smoking prevalence was significantly higher at 79.4% (27/34) compared to females at 37.5% (6/16) (χ^2=8.73, p=0.003) [Table/Fig-3].

Among the 33 smokers, pack-year analysis demonstrated that 12 patients (36.4%) fell within the 31-40 pack-year category, representing the highest exposure group. The distribution showed: <10 pack-years (5 patients, 15.2%), 11-20 pack-years (7 patients, 21.2%), 21-30 pack-years (9 patients, 27.3%), and 31-40 pack-years (12 patients, 36.4%). Adenocarcinoma emerged as the predominant histological subtype, affecting 20 patients (40.0%), followed by squamous cell carcinoma in 16 patients (32.0%), small cell carcinoma in 8 patients (16.0%), and large cell carcinoma in six patients (12.0%) [Table/Fig-4]. Notably, adenocarcinoma

Clinical symptom	Frequency (n)	Percentage (%)	95% CI
Cough	45	90.0	78.2-96.7
Chest pain	42	84.0	70.9-92.8
Haemoptysis	40	80.0	66.3-90.0
Dyspnoea	35	70.0	55.4-82.1
Weight loss	30	60.0	45.2-73.6
Hoarseness of voice	22	44.0	30.0-58.8
Fever	21	42.0	28.2-56.8
Lymphadenopathy	10	20.0	10.0-33.7
Other presentations			
Stridor	8	16.0	7.2-29.1
Generalised weakness	6	12.0	4.5-24.3
Anorexia	4	8.0	2.2-19.2

[Table/Fig-2]: Clinical symptoms distribution in the sample population (n=50). Constitutional symptoms including weight loss and fever were present in 60.0% and 42.0% of patients respectively, indicating the systemic impact of malignancy at presentation.

Smoking status	Male n (%)	Female n (%)	Total n (%)	p-value*
Smokers	27 (79.0)	6 (37.5)	33 (66.0)	0.003
Non-smokers	7 (21.0)	10 (62.5)	17 (34.0)	
Total	34 (100)	16 (100)	50 (100.0)	

[Table/Fig-3]: Smoking status distribution by gender category. *Chi-square test for association between gender and smoking status.

Tumour type	Smokers n (%)	Non-smokers n (%)	Total n (%)	p-value*
Adenocarcinoma	10 (30.30)	10 (58.82)	20 (40.0)	0.047
Squamous cell carcinoma	14 (42.42)	2 (11.76)	16 (32.0)	
Small cell carcinoma	6 (18.18)	2 (11.76)	8 (16.0)	
Large cell carcinoma	3 (9.09)	3 (17.64)	6 (12.0)	
Total	33 (100)	17 (100)	50 (100.0)	

[Table/Fig-4]: Histological subtypes by smoking status. *Fisher's-exact test for association between histological type and smoking status

demonstrated equal distribution between smokers and non-smokers (10 cases each), while squamous cell carcinoma showed strong association with smoking exposure (87.5% of cases occurred in smokers, p=0.001). Chest radiographic findings varied significantly according to histological subtype (p<0.001, Fisher's-exact test). Squamous cell carcinoma demonstrated characteristic patterns with cavitation being the most frequent finding (12 cases, 24.0% of total cohort), followed by consolidation (10 cases, 20.0%) and mass lesions (8 cases, 16.0%) [Table/Fig-5].

Chest X-ray Finding	SCC n (%)	ADC n (%)	SCLC n (%)	LCC n (%)	Total n (%)
Cavitation	12 (24.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (24.0)
Consolidation	10 (20.0)	0 (0.0)	0 (0.0)	0 (0.0)	10 (20.0)
Mass	8 (16.0)	3 (6.0)	15 (30.0)	2 (4.0)	28 (56.0)
Nodule	2 (4.0)	11 (22.0)	0 (0.0)	0 (0.0)	13 (26.0)
Collapse	7 (14.0)	3 (6.0)	4 (8.0)	1 (2.0)	15 (30.0)
Wide mediastinum	4 (8.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (8.0)

[Table/Fig-5]: Radiological findings by histological subtype classification. SCC: Squamous cell carcinoma; ADC: Adenocarcinoma; SCLC: Small cell lung carcinoma; LCC: Large cell carcinoma

Adenocarcinoma predominantly presented as nodular lesions (11 cases, 55.0% of adenocarcinomas), consistent with its peripheral location preference. Small cell carcinoma characteristically manifested as mass lesions (15 cases, 30.0% of total cohort), reflecting its typical central location and aggressive growth pattern. Diagnostic yield analysis revealed significant performance differences across sampling techniques and tumour locations. For central tumours, bronchial brushings achieved the highest

diagnostic yield at 64.0% (16/25 procedures, 95% CI: 42.5-82.0), followed by bronchial biopsy at 54.5% (12/22 procedures, 95% CI: 32.2-75.6) [Table/Fig-6].

For peripheral tumours, bronchial brushings demonstrated superior performance with 71.4% yield (10/14 procedures, 95% CI: 41.9-91.6), outperforming transbronchial biopsy at 58.3% (7/12 procedures, 95% CI: 27.7-84.8). The difference in yield between brushings and other techniques was statistically significant (p=0.032, Fisher's-exact test). Bronchoscopic morphological patterns significantly influenced diagnostic yield (p=0.029, Chi-square test). Endoluminal growth pattern was the most common morphological appearance, observed in 22 cases (44.0%), followed by external compression in 15 cases (30.0%), infiltrative growth in 7 cases (14.0%), and mucosal irregularity in 6 cases (12.0%) [Table/Fig-7,8]. Bronchial brushings consistently demonstrated superior yield across all morphological patterns, with the highest performance observed in mucosal irregularity cases four out of 6 (66.7%) and external compression patterns in 9 out of 15 (60.0%). Squamous cell carcinoma predominantly presented with endoluminal growth in 11 out of 16 cases (68.8%), while adenocarcinoma showed more diverse morphological patterns with external compression being most frequent in 7 out of 20 cases (35.0%). Large cell carcinoma uniquely presented exclusively with external compression pattern in six out of six cases (100.0%) [Table/Fig-9]. Overall procedural complications occurred in 32.0% of patients (16/50, 95% CI: 19.5-46.7). Major complications included bleeding in 12 patients (24.0%, 95% CI: 13.1-38.2), pneumothorax in 3 patients (6.0%, 95% CI: 1.3-16.5), and post-procedural respiratory failure in 1 patient (2.0%, 95% CI: 0.1-10.6) [Table/Fig-10]. Minor complications comprised infection (8 patients, 16.0%), hypotension (7 patients, 14.0%), and aspiration (3 patients, 6.0%). One procedure-related mortality (2.0%) occurred in a patient with advanced disease and multiple comorbidities. The overall major complication rate of 32.0% falls within acceptable ranges for diagnostic bronchoscopy as reported in contemporary literature. Statistical analysis revealed no significant association between complication rates and patient age (p=0.156), gender (p=0.423), or histological subtype (p=0.089), suggesting consistent safety profile across patient demographics and tumour characteristics.

DISCUSSION

The improved diagnostic yield of bronchial brushings observed in the present study is a reflection of early tenets of bronchoscopic cytology and pathobiology of lung cancer. Mechanistic advantage of brushings lies in mechanical abrasion of the bronchial epithelium, thus causing exfoliation of surface malignant cells along with cells from deeper epithelial layers [9]. The cellular harvest aggregates in intact architectural patterns that maintain diagnostic morphological features important for accurate cytopathological interpretation [13]. Pathophysiologic rationale for this improved yield lies in the heterogeneous distribution of malignant cells in the bronchial tree in which surface sampling only will often miss the deeper infiltrative elements of bronchogenic carcinomas [14].

Current literature underpins the present study's findings, with Chen AC et al., demonstrating in their meta-analysis that bronchial brushing cytology is moderately sensitive with high specificity for lung cancer diagnosis [15]. Their systematic review reported diagnostic yields of 24.5-73%, placing our 64.0% central and 71.4% peripheral tumour yields at the upper end of existing performance data. Mechanistic superiority of brushings over lavage techniques, as demonstrated by our 13.3-15.0% yields for bronchial washing, is supported by the work of Hou G et al., who demonstrated that pre-biopsy brushing is significantly superior to post-biopsy techniques (49.2 vs 31.8%, p=0.007) [16].

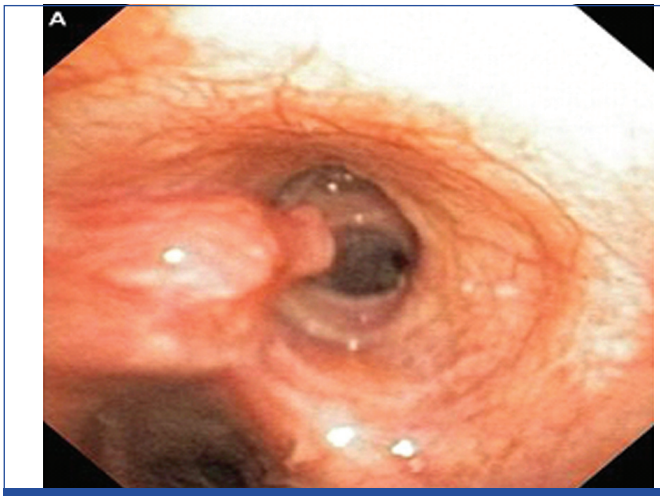
Demographic characteristics of the population are in line with widely documented epidemiological trends of lung cancer in the Indian

Technique	Central tumours (30)			Peripheral tumours (20)			p-value
	Attempted	Positive	Yield (%) (95% CI)	Attempted	Positive	Yield (%) (95% CI)	
Bronchial brushings	25	16	64.0 (42.5-82.0)	14	10	71.4 (41.9-91.6)	0.032*
Bronchial biopsy	22	12	54.5 (32.2-75.6)	12	7	58.3 (27.7-84.8)	
Bronchial wash/lavage	30	4	13.3 (3.8-30.7)	20	3	15.0 (3.2-37.9)	

[Table/Fig-6]: Diagnostic yield by sampling technique and tumour location.
*Fisher's-exact test for comparison between three techniques for central tumours

Morphological pattern	Total cases n (%)	Bronchial wash/lavage n (%)	Brushings n (%)	Biopsy n (%)	p-value
Endoluminal growth	22 (44.0)	4 (18.2)	10 (45.5)	8 (36.4)	0.029*
External compression	15 (30.0)	3 (20.0)	9 (60.0)	3 (20.0)	
Infiltrative growth	7 (14.0)	1 (14.3)	4 (57.1)	2 (28.6)	
Mucosal irregularity	6 (12.0)	1 (16.7)	4 (66.7)	1 (16.7)	

[Table/Fig-7]: Diagnostic yield by morphological pattern and sampling technique.
*Chi-square test for association between morphological patterns and diagnostic yield



[Table/Fig-8]: Bronchossopic image of endobronchial mass.

Tumour type	Endoluminal growth n (%)	Infiltrative growth n (%)	External compression n (%)	Mucosal irregularity n (%)
Adenocarcinoma (n=20)	6 (30.0)	3 (15.0)	7 (35.0)	4 (20.0)
Squamous cell carcinoma (n=16)	11 (68.8)	3 (18.8)	1 (6.3)	1 (6.3)
Small cell carcinoma (n=8)	5 (62.5)	1 (12.5)	1 (12.5)	1 (12.5)
Large cell carcinoma (n=6)	0 (0.0)	0 (0.0)	6 (100.0)	0 (0.0)

[Table/Fig-9]: Morphological appearance distribution by histological subtype.

Complication category	Complication type	Frequency n (%)
Major complications	Bleeding	12 (24.0)
	Pneumothorax	3 (6.0)
	Post-procedural respiratory failure	1 (2.0)
Minor complications	Infection	8 (16.0)
	Hypotension	7 (14.0)
	Aspiration	3 (6.0)
Mortality	Procedure-related death	1 (2.0)
Total complications		16 (32.0)

[Table/Fig-10]: Complication profile following bronchoscopy.

subcontinent. Male predominance (68.0%) and age distribution (68.0% aged 66-80 years) agree with international trends, though the male-to-female ratio of 2.1:1 reflects a smaller gender gap than in traditional Western populations [1]. This is explained by changes in smoking behaviour and environmental risk exposure in developing nations, where occupational and ambient air pollution play significant roles in the pathogenesis of lung cancer [4].

The pathobiological association between smoking exposure and histological subtypes revealed in our series is of major significance in carcinogenetic pathways. Squamous cell carcinoma's consistent correlation with smoking (87.5% of the cases among smokers) reflects the direct mutagenic action of tobacco carcinogens on bronchial epithelium, inducing sequential dysplastic alterations and subsequent malignant transformation [17]. Adenocarcinoma's even distribution among smokers and non-smokers (10 cases each) is consistent with the rising evidence for adenocarcinoma as a heterogeneous malignancy with diverse molecular pathways, some of which are tobacco exposure-independent [18].

Diagnostic performance analysis and technical considerations: The diagnostic advantage of bronchial brushings over all morphological patterns seen in the present study establishes the technique's adaptability to varied patterns of tumour growth. The best performance in mucosal irregularity cases (66.7%) and external compression patterns (60.0%) establishes brushings' ability to collect malignant cells from both surface irregularities and submucosal infiltrative processes. This observation contradicts traditional wisdom that brushings are best in exophytic lesions [19].

The current findings are supported by recent literature in the field of technique-specific diagnostic yields. Matsumoto Y et al., stated that washing specimens obtained following bronchial brushings yielded higher diagnostic yields (46.4% vs 37.3% with brushing alone), implying that the mechanical abrading effect of brushings improves subsequent cellular recovery [20]. The pathophysiologic rationale is on brush-induced microtrauma leading to augmented cellular exfoliation that continues with subsequent lavage maneuvers [21].

The analysis of morphologic patterns provides extremely significant clinical correlates. Squamous cell carcinoma's high correlation with endoluminal growth (68.8%) mirrors its usual central bronchial origin with endobronchial extension. The pattern is starkly different from adenocarcinoma's multiple morphologic presentations, mirroring its peripheral site and variable patterns of growth [22]. Large cell carcinoma's single presentation with external compression patterns (100.0%) mirrors its infiltrative growth pattern and aggressive growth beyond bronchial margins [23].

Recent advances in bronchoscopic navigation have significantly enhanced diagnostic yields for peripheral pulmonary lesions. Robotic bronchoscopy platforms now achieve diagnostic yields of 75.9 to 94.7%, substantially exceeding conventional techniques [24]. These advanced modalities utilise electromagnetic navigation and robotic precision to access previously unreachable peripheral locations, potentially addressing the traditional limitations of flexible bronchoscopy in peripheral lesion evaluation [25].

The integration of EBUS with conventional sampling techniques has further improved diagnostic accuracy. Meta-analyses demonstrate that radial EBUS-guided transbronchial lung biopsy achieves diagnostic yields of 70.6% with complication rates of only 2.8% [26]. These findings suggest that while our conventional brushing technique performed admirably, future studies should explore combinations of advanced navigation with optimised sampling sequences to maximise diagnostic potential [27].

Safety profile and complication analysis: The overall complication rate of 32.0% warrants careful contextualisation within contemporary literature. Recent large-scale analyses report significantly lower complication rates, with multinational studies demonstrating overall severe complication rates of 0.85% and mortality rates of 0.01% [28]. The discrepancy between the findings of the study and contemporary reports likely reflects differences in complication definitions, patient populations, and procedural complexity.

Bleeding complications, occurring in 24.0% of our patients, exceed reported incidences of 0.5 to 5.3% in recent literature [29]. This elevated rate may reflect our institution's tertiary referral status, with patients presenting advanced disease and compromised respiratory function. Additionally, our aggressive brushing technique, designed to maximise cellular yield, may contribute to increased bleeding frequencies. Contemporary studies emphasise that most bronchoscopic bleeding is self-limited and manageable with conservative measures [28-30].

Incidence of pneumothorax (6.0%) falls within the expected range for transbronchial procedure (0.1% to 5%) [31]. Pneumothorax is now an accepted, anticipated complication requiring standard monitoring protocols according to the latest British Thoracic Society guidelines [32]. Failure to observe significant correlation between the rate of complications and patient demographics or tumour features ($p>0.05$) testifies to uniform procedural safety in a broad patient population [33].

Histopathological correlations and molecular implications: The incidence of adenocarcinoma (40.0%) among our population also reflects global epidemiologic trends toward more adenocarcinoma than squamous cell carcinoma [34]. The shift is likely due to changing exposure patterns, increased diagnostic ability for peripheral lesions, and altered tobacco product formulations [35]. The equal division of adenocarcinoma among smokers and non-smokers supports the importance of non-tobacco carcinogenic pathways, including genetic predisposition, environmental exposure to toxins, and indoor air pollution [36].

Current molecular studies have recognised distinct adenocarcinoma subtypes with alternative driver mutations, and the study findings on morphology could be secondary to molecular diversity [36,37]. Epidermal Growth Factor Receptor (EGFR) mutations, Anaplastic Lymphoma Kinase (ALK) rearrangements, and ROS1 fusions all occur with various frequencies in various population groups, and this could be the cause of the divergent patterns of morphology in our adenocarcinoma cases [38].

Limitation(s)

The present single-center retrospective study design restricts generalisability to varied healthcare environments and patient populations. The lack of molecular characterisation prohibits correlation of morphological results with the underlying genetic alterations that increasingly dictate treatment. Our study also precedes more widespread use of liquid biopsy technology that might complement standard bronchoscopic sampling.

CONCLUSION(S)

This research proves that bronchial brushing is a very effective diagnostic method for lung cancer detection with superior performance than other bronchoscopic sampling methods. The efficacy of the method against various morphological patterns

and locations of the tumour, coupled with the ability to be used in resource-constrained environments, retains the role of a pillar of bronchoscopic diagnosis. In spite of the need for close monitoring of complications and standardised treatment algorithms, the overall risk-benefit ratio supports routine use of bronchial brushings in combined lung cancer diagnostic protocols. These results bring evidence-based support to optimise traditional bronchoscopic methods while further incorporating new advanced technologies to enhance diagnostic performance and patient protection.

REFERENCES

[1] Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2018;68(6):394-424.
[2] Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021;71(3):209-49.
[3] Allemani C, Matsuda T, Di Carlo V, Harewood R, Matz M, Nikšić M, et al. Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): Analysis of individual records for 37,513,025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. Lancet. 2018;391(10125):1023-75.
[4] Mathur P, Sathishkumar K, Chaturvedi M, Das P, Sudarshan KL, Santhappan S, et al. Cancer statistics, 2020: Report from national cancer registry programme, India. JCO Glob Oncol. 2020;6:1063-75.
[5] Noronha V, Prabhash K, Thavamani A, Chougule A, Purandare N, Joshi A, et al. The demographic, clinical and histological profile of lung cancer patients in India: Analysis from a tertiary cancer center. South Asian J Cancer. 2019;8(2):109-15.
[6] Mason RJ, Broaddus VC, Martin TR, King TE Jr, Schraufnagel DE, Murray JF, et al. Murray and Nadel's textbook of respiratory medicine. 6th ed. Philadelphia: Elsevier; 2016.
[7] Wang KP, Mehta AC, Turner JF Jr. Flexible bronchoscopy. 3rd ed. Oxford: Blackwell Science; 2019.
[8] Schreiber G, McCrory DC. Performance characteristics of different modalities for diagnosis of suspected lung cancer: Summary of published evidence. Chest. 2003;123(1 Suppl):115S-128S.
[9] Rivera MP, Mehta AC, Wahidi MM. Establishing the diagnosis of lung cancer: Diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest. 2013;143(5 Suppl):e142S-e165S.
[10] Detterbeck FC, Boffa DJ, Kim AW, Tanoue LT. The eighth edition lung cancer stage classification. Chest. 2017;151(1):193-203.
[11] Folch EE, Mahajan AK, Oberg CL, Maldonado F, Toloza E, Krimsky WS, et al. Standardized definitions of bleeding after transbronchial lung biopsy: A Delphi consensus statement from the Nashville Working Group. Chest. 2020;158(1):393-400.
[12] Jindal SK, Shankar PS, Raoof S, Gupta D. Textbook of pulmonary and critical care medicine. 2nd ed. New Delhi: Jaypee Brothers Medical Publishers; 2019.
[13] Liam CK, Pang YK, Poosparajah S. Diagnostic yield of flexible bronchoscopic procedures in lung cancer patients according to tumour location. Singapore Med J. 2007;48(7):625-31.
[14] Ishiwata T, Gregor A, Inage T, Yasufuku K. Bronchoscopic navigation and tissue diagnosis. Gen Thorac Cardiovasc Surg. 2020;68(7):672-78.
[15] Chen AC, Pastis NJ, Mahajan AK, Khandhar SJ, Simoff MJ, Machuzak MS, et al. Evaluation of the diagnostic accuracy of bronchial brushing cytology in lung cancer: A meta-analysis. Cancer Cytopathol. 2021;129(9):748-57.
[16] Hou G, Miao Y, Hu XJ, Zhang B, Chen H. The optimal sequence for bronchial brushing and forceps biopsy in lung cancer diagnosis: A randomized controlled study. J Thorac Dis. 2015;7(2):270-76.
[17] Singh N, Aggarwal AN, Gupta D, Behera D, Jindal SK. Unchanging clinico-epidemiological profile of lung cancer in north India over three decades. Cancer Epidemiol. 2010;34(1):101-04.
[18] Janssen-Heijnen ML, Coebergh JW, Klinkhamer PJ, Schipper RM, Splinter TA, Mooi WJ. Is there a common etiology for the rising incidence of and decreasing survival with adenocarcinoma of the lung? Epidemiology. 2001;12(2):256-58.
[19] Tomar V, Vijay N, Nuwal P, Dixit R. Lung malignancy: Diagnostic accuracies of bronchoalveolar lavage, bronchial brushing, and fine needle aspiration cytology. J Cytol. 2016;33(4):210-13.
[20] Matsumoto Y, Nakai T, Tanaka M, Iizasa T, Nakajima T. The optimal sequence of bronchial brushing and washing for diagnosing peripheral lung cancer using non-guided flexible bronchoscopy. Sci Rep. 2020;10(1):3211.
[21] Lee HS, Kwon SY, Kim DK, Yoon HI, Lee SM, Lee JH, et al. Bronchial washing yield before and after forceps biopsy in patients with endoscopically visible lung cancers. Respirology. 2007;12(2):277-82.
[22] Travis WD, Travis LB, Devesa SS. Lung cancer. Cancer. 1995;75(1 Suppl):191-202.
[23] Behera D, Balamugesh T. Lung cancer in India. Indian J Chest Dis Allied Sci. 2004;46(4):269-81.
[24] Chen A, Chenna P, Loiselle A, Massoni J, Mayse M, Misselhorn D. Robotic bronchoscopy in lung cancer diagnosis. Cancers (Basel). 2024;16(6):1124.
[25] Giri M, Dai H, Puri A, Han Y, Kaye F, Maldonado F. Advancements in navigational bronchoscopy for peripheral pulmonary lesions: A review with special focus on virtual bronchoscopic navigation. Front Med (Lausanne). 2022;9:989184.
[26] Wang Memoli JS, Nietert PJ, Silvestri GA. Meta-analysis of guided bronchoscopy for the evaluation of the pulmonary nodule. Chest. 2012;142(2):385-93.
[27] Park S, Yoon HY, Han Y, Lee JH, Lee CT, Lee JH. Advanced bronchoscopic diagnostic techniques in lung cancer. Tuberc Respir Dis (Seoul). 2024;87(3):282-91.
[28] Zhang W, Chen S, Dong X, Liu R, Wang J, Kishimoto J, et al. The hemorrhage risk of patients undergoing bronchoscopic examinations or treatments. BMC Pulm Med. 2021;21(1):307.
[29] Carr IM, Koegelenberg CF, von Groote-Bidlingmaier F, Stepien RL, Diacon AH. Blood loss during flexible bronchoscopy: A prospective observational study. Respiration. 2012;84(4):312-18.
[30] Centonze G, Rossi SW, Guerrero F, Spagnolo P, Gasparini S. Routine chest radiography for the evaluation of pneumothorax following bronchoscopy. Acad Radiol. 2019;26(9):1208-13.
[31] de Blic J, Midulla F, Barbato A, Clement A, Dab I, Eber E, et al. Bronchoalveolar lavage in children. ERS Task Force on bronchoalveolar lavage in children. Eur Respir J. 2000;15(1):217-31.
[32] Roberts ME, Rahman NM, Maskell NA, Bibby AC, Corcoran JP, Hallifax RJ, et al. British Thoracic Society guideline for pleural disease. Thorax. 2023;78(Suppl 3):s1-s42.
[33] Burgei JW, Alsheimer K, Lantry JF. Retrospective review of pneumothorax rates in a rural, micropolitan area after bronchoscopic lung volume reduction. Chronic Obstr Pulm Dis. 2024;11(5):534-37.
[34] American Cancer Society. Cancer facts & figures 2024. Atlanta: American Cancer Society; 2024.
[35] Wingo PA, Ries LA, Giovino GA, Miller DS, Rosenberg HM, Shopland DR, et al. Annual report to the nation on the status of cancer, 1973-1996, with a special section on lung cancer and tobacco smoking. J Natl Cancer Inst. 1999;91(8):675-90.
[36] Kashyap S, Mohopatra PR, Negi RS. Pattern of primary lung cancer among bidi smokers in north-west Himalayan region of India. Lung Cancer. 2003;41(1):111-15.
[37] Zappa C, Mousa SA. Non-small cell lung cancer: Current treatment and future advances. Transl Lung Cancer Res. 2016;5(3):288-300.
[38] Alberg AJ, Samet JM. Epidemiology of lung cancer. Chest. 2003;123(1 Suppl):21S-49S.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Respiratory Medicine, B J Medical College, Ahmedabad, Gujarat, India.
2. Associate Professor, Department of Respiratory Medicine, GMERS Medical College, Himmatnagar, Gujarat, India.
3. Assistant Professor, Department of Respiratory Medicine, GMERS Medical College, Sola, Ahmedabad, Gujarat, India.
4. Resident, Department of Community Medicine, B J Medical College, Ahmedabad, Gujarat, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Nisarg Patel,
19, alok-4, Behind Hotel Flora, Sardar Patel Ringroad, Vastral-382418,
Ahmedabad, Gujarat, India.
E-mail: nisarg130490@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jun 30, 2025
- Manual Googling: Jul 17, 2025
- iThenticate Software: Aug 11, 2025 (4%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? No
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jun 16, 2025**
Date of Peer Review: **Jul 08, 2025**
Date of Acceptance: **Aug 13, 2025**
Date of Publishing: **Nov 01, 2025**