Evaluation of the diagnostic yield of lung cancer on various Bronchoscopic modalities.

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ABSTRACT

Introduction: Lung cancer is responsible for a major portion of cancer-related mortality worldwide, despite advancements in diagnostic technologies and treatment modalities. Bronchoscopy plays a central role in the diagnosis of lung cancer by allowing direct visualization of the airways and facilitating tissue sample collection through endobronchial brush, endobronchial wash, and endobronchial biopsy.

Objective: To analyze the histomorphological patterns of lung malignancies and compare the diagnostic efficacy of different bronchoscopic techniques, like specifically bronchial wash cytology, endobronchial brush cytology, and endobronchial biopsy.

Methods: A retrospective analysis of fiberoptic bronchoscopy (FOB) morphological findings, including bronchial wash and endobronchial brush cytology and endobronchial biopsy, was conducted in 78 patients aged 18 years and older with findings suspicious for malignancy on CT scan. Frequencies of various histopathological subtypes of lung cancer were tallied with the different diagnostic procedures and corresponding FOB findings. Diagnostic accuracy, sensitivity, and specificity of endobronchial brush cytology and bronchial wash cytology, both individually and in combination, were evaluated using biopsy as the reference standard. Associations between demographic variables, tumor and nodal staging, and bronchoscopic findings were also assessed.

Results: Of the 78 patients, 63 (80.8%) had a confirmed diagnosis of malignancy on biopsy. The most frequently identified histopathological subtypes of lung cancer were squamous cell carcinoma (47.4%), followed by non-small cell lung carcinoma, not otherwise specified (14.1%), and small cell carcinoma (10.3%). On FOB, the tumors most frequently appeared as endobronchial growths (68.3%), followed by areas of unhealthy mucosa (55.6%) and polyploidal lesions (19%). Endobronchial brush cytology yielded a sensitivity of 49.2%, a specificity of 60%, and an overall diagnostic accuracy of 51.28%. In comparison, endobronchial wash cytology showed lower sensitivity (12.7%), higher specificity (86.7%), and a reduced diagnostic accuracy of 26.92%. When combined, these cytological methods yielded a sensitivity of 55.65%, a specificity of 52.02%, and a diagnostic accuracy of 54.4%. There was no significant association between clinical or bronchoscopic variables and malignancy status.

Conclusions: The study reinforces the critical diagnostic role of bronchoscopic modalities in detecting pulmonary malignancies. The combination of endobronchial brush and bronchial wash cytology marginally improved sensitivity but with moderate specificity. The relatively low sensitivity of cytological techniques, especially endobronchial wash, highlights their limitations as standalone diagnostic tools.

Keywords: Lung Cancer; Fiberoptic Bronchoscopy; Endobronchial Biopsy; Endobronchial Brush; Bronchial Wash

INTRODUCTION

An estimated 1.8 million deaths worldwide are attributed to lung cancer each year, making it the world's biggest cause of cancer-related mortality[1]. Lung malignancies are usually diagnosed late because of the late presentation, even though diagnosing lung cancer has become easier due to advancements in diagnostic modalities in the present era. Nepal experiences a steep increment in the burden of lung cancer every year, which now ranks among the top causes of cancer-related morbidity and mortality[2]. The prevalence, which is reportedly higher among males, is contributed to exposure to pertinent risk factors like tobacco smoking, indoor biomass fuel exposure, and ambient air pollution3.

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Histologically, non-small cell lung carcinoma (NSCLC) constitutes the majority of lung cancer cases, with adenocarcinoma and squamous cell carcinoma being the most common subtypes[1,2]. Histomorphological classification directs the choice of targeted therapies and prognosis. However, resource constraints and limited access to advanced diagnostic modalities often hinder timely and definitive diagnosis in low-income settings like Nepal[2].

Particularly for centrally placed lung lesions near the vicinity of larger airways, flexible bronchoscopy is a crucial diagnostic technique. It enables direct visualization of airways and facilitates tissue sampling through various techniques such as bronchial wash cytology, endobronchial brush cytology, and endobronchial biopsy. Although endobronchial biopsy is considered the gold standard among these, combining it with cytological methods has been shown to improve diagnostic sensitivity[4,5]. Nonetheless, diagnostic yields can vary based on tumor location, histologic subtype, and procedural expertise[6].

In light of the growing incidence of lung cancer in Nepal and the demand for prompt, affordable diagnostic strategies, it is imperative to assess the relative diagnostic performance of commonly utilized bronchoscopic modalities. This study aims to evaluate and compare the diagnostic yields of bronchial wash cytology, endobronchial brush cytology, and endobronchial biopsy and to correlate these findings with histomorphological subtypes in patients undergoing bronchoscopy for suspected lung cancer.

METHODS

This retrospective analytical study included records of 78 patients aged 18 years and above who underwent evaluation for suspected lung malignancy based on computed tomography (CT) findings. The study was conducted in the Department of Respiratory Medicine at Shree Birendra Hospital (SBH), Chhauni, over two years period from April 2022 to April 2024. Ethical clearance was obtained from the Institutional Review Committee of the Nepalese Army Institute of Health Sciences (NAIHS) (ID: 1177). The patients were selected using a convenience sample technique that was not randomized. The study eliminated patients whose clinical data and reports were incomplete. Prior to the diagnostic procedures, all participants provided written informed consent.

All bronchoscopic examinations were performed using a flexible bronchoscope system from Pentax Medical. The system included the EB19-J10 video bronchoscope (featuring a 2.8 mm working channel, 6.1 mm distal tip diameter, and a 600 mm working length), paired with the EPK-1000 video processor and a 24-inch EndoVue medical-grade display monitor. The experienced consultant pulmonologists conducted all procedures of bronchoscopy and bronchoscopic biopsies.

Relevant clinical data, which included age, sex, CT scan reports, FOB findings, and results of the three bronchoscopic sampling techniques, were retrieved from the patient reports and departmental records. The data were compiled and organized using Microsoft Excel 2016 and analyzed using SPSS version 20. Frequencies of different histopathological subtypes of lung cancer were analyzed in relation to each diagnostic technique and the corresponding FOB morphology.

Diagnostic performance metrics like sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated separately for endobronchial brush cytology and bronchial wash cytology, as well as for their combined diagnostic value, using endobronchial biopsy as the reference standard. Additionally, the diagnostic yield was calculated respectively. Since the Shapiro–Wilk test revealed that the data did not follow a normal distribution, non-parametric statistical tests were employed. The distributions of age, sex, tumor stage, nodal stage, and bronchoscopic morphological findings were compared between malignant and non-malignant cases using the Mann–Whitney U test.

RESULTS

At first, only 78 of the 96 patients who consented to FOB had all the necessary data that could be collected. Of the 78 patients included in the study, 63 (80.8%) were confirmed to have malignancy on histopathological examination (biopsy). The most common histological subtype was squamous cell carcinoma (47.4%), followed by non-small cell lung carcinoma, not otherwise specified (NSCLC, NOS) (14.1%), and small cell carcinoma (10.3%) (Table 1).

Table 1. Bronchoscopic morphological appearance of various tumor cell types.

Tumor type	Endobronchial growth (n=43)	Unhealthy mucosa (n=35)	Extrinsic compression (n=5)	Multiple nodules (n=3)	Polypoidal lesion (n=12)
Squamous cell carcinoma	24	12	4	2	5
Small cell carcinoma	5	4	0	0	0
NLCSC, NOS	5	7	0	0	3
Poorly differentiated carcinoma	2	1	0	0	1
Adenocarcinoma	0	3	0	0	1
Leiomyoma	1	0	0	0	0
Dysplasia	3	4	1	0	1
Hyperplastic lining	0	2	0	0	0
Necrosis	2	0	0	0	0
Normal	1	2	0	1	1

The bronchoscopic appearances of these lesions, including various endobronchial morphologies, are illustrated in Figure 1 A to F.

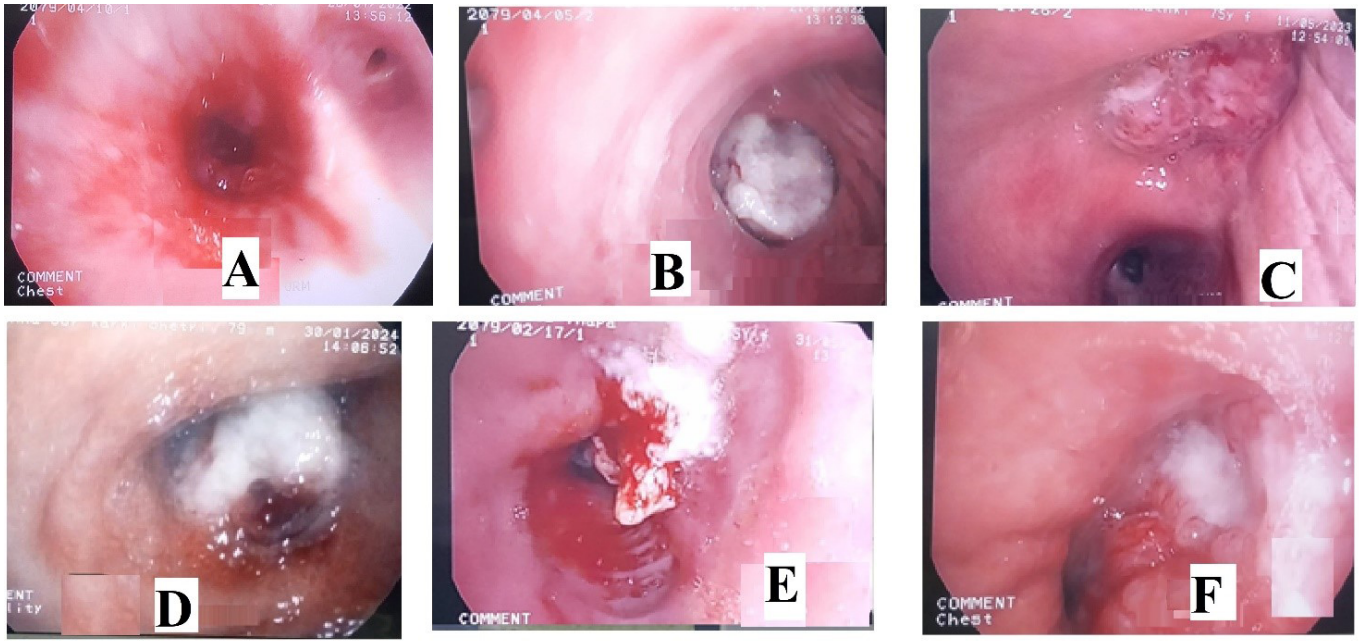

Figure 1 A to F: Bronchoscopic appearance of endobronchial lesions: A) unhealthy mucosa in right lower lobe segments. B) bronchus intermedius lobe obstructed due to polypoidal growth. C) endobronchial growth in the RUL bronchus, completely occluding the right upper bronchus. D) Growth with unhealthy mucosa, completely obstructing the right main bronchus. E) LUL completely blocked due to growth and lower lobe partially blocked due to polypoidal growth. F) LUL segment blocked due to endobronchial growth with irregular surface, narrowed lower lobe lumen, and multiple nodules in trachea.

On analyzing the diagnostic yields of bronchoscopic procedural techniques—bronchial brush, bronchoalveolar lavage (BAL), and biopsy—for various central airway lesions observed during bronchoscopy, it was found that biopsy consistently achieves the highest diagnostic yield across all lesion types (Table 2).

Table 2: Yield of bronchoscopic procedural techniques versus tumor morphology on bronchoscopy.

Type of lesion	Bronchial Brush	Broncho-alveolar lavage	Biopsy
Endobronchial growth (n = 43)	22	6	36
Unhealthy mucosa (n = 35)	14	5	27
Extrinsic compression (n = 5)	1	0	4
Multiple nodules (n = 3)	2	0	2
Polyploidal lesion (n = 12)	8	1	11

Bronchial brush cytology identified 37 cases as malignant, of which 31 were true positives and 6 were false positives (Table 3). Conversely, 41 cases were cytologically negative, with 32 being false negatives. This resulted in a sensitivity of 49.2%, specificity of 60%, positive predictive value (PPV) of 83.8%, negative predictive value (NPV) of 22.0%, and diagnostic accuracy of 51.28%.

BAL cytology identified 10 cases as malignant, 8 of which were true positives. Among the 68 cytologically negative cases, 55 were false negatives. This yielded a sensitivity of 12.7%, specificity of 86.7%, PPV of 80%, NPV of 19.1%, and an overall diagnostic accuracy of 26.92%.

Table 3. Yield from bronchoscopic techniques.

Diagnostic procedure	Positive yield number of patients	Dysplasia/ Atypical Cells	Percentage
Bronchial Brush	37	9	47.4%
Bronchoalveolar lavage	10	9	12.8%
Biopsy	63	7	80.8%

When both bronchial brush and BAL cytology were combined, the sensitivity increased to 55.65%, while the specificity decreased slightly to 52.02%. The PPV, NPV, and diagnostic accuracy were 82.08%, 22.41%, and 54.4%, respectively. These results are summarized in Table 4.

Table 4: Comparison of the diagnostic utility between bronchial brush and bronchoalveolar lavage, and their combined diagnostic yield.

Parameter	Bronchial Brush	Bronchoalveolar Lavage	Combined
Sensitivity	49.2%	12.7%	55.65%
Specificity	60%	86.7%	52.02%
Positive Predictive Value (PPV)	83.8%	80%	82.08%
Negative Predictive Value (NPV)	22.0%	19.1%	22.41%
Diagnostic Accuracy	51.28%	26.92%	54.4%
Prevalence (from study)	—	—	80%

The most frequent malignancy detected via biopsy was squamous cell carcinoma (47.4%), followed by non-small cell lung carcinoma, not otherwise specified (NSCLC, NOS) (14.1%), and small cell carcinoma (10.3%). Notably, brush cytology detected NSCLC, NOS in 28.2% of cases but was less effective in identifying squamous and small cell subtypes. BAL cytology demonstrated limited sensitivity for all subtypes, with a predominant number of negative or atypical cell findings (75.6% negative; 9.0% atypical cells) (Table 5).

Table 5: The cytological findings from bronchial brush, bronchoalveolar lavage and biopsy.

Finding	Bronchial Brush (n=78)	Bronchoalveolar Lavage (n=78)	Biopsy Finding (n=78)
Squamous Cell Carcinoma	8 (10.3%)	4 (5.1%)	37 (47.4%)
Squamous Cell Carcinoma with spindle cell	-	-	1 (1.3%)
Small Cell Carcinoma	4 (5.1%)	-	8 (10.3%)
NSCLC, NOS	22 (28.2%)	5 (6.4%)	11 (14.1%)
Adenocarcinoma	3 (3.8%)	1 (1.3%)	3 (3.8%)
Negative	32 (41.0%)	59 (75.6%)	-
Atypical Cells	9 (11.5%)	7 (9.0%)	-
Acellular	-	2 (2.6%)	-
Necrosis	-	-	2 (2.6%)
Leiomyoma	-	-	1 (1.3%)
Hyperplastic lining	-	-	2 (2.6%)
Dysplasia	-	-	7 (9.0%)
Normal	-	-	3 (3.8%)

Representative histopathological images are provided in Figure 2 A to D for squamous cell carcinoma, E to G for adenocarcinoma, and H to I for small cell carcinoma, highlighting key morphological features.

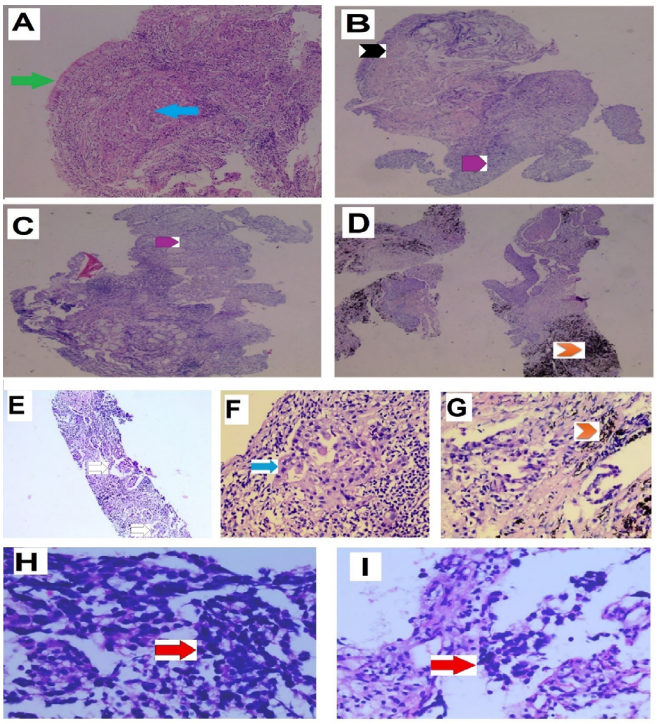

Figure 2. ***A to D:*** *Histopathological findings of Squamous Cell Carcinoma. A) 4x magnification. Hyperplastic lining epithelium (green arrow). Infiltration of tumor cells arranged in nests exhibiting nuclear pleomorphism. (Blue arrow). B) 4x magnification. Dysplastic lining epithelium (black arrowhead). Tumor cells exhibiting pleomorphism, increased nuclear-to-cytoplasmic ratio, and hyperchromatic nuclei with moderate cytoplasm (pink arrowhead). C) 4x magnification. Tumor cells in nests. (pink arrowhead). D) 4x magnification. Tumor cells arranged in nests. Anthracotic pigments (orange arrowhead).* ***E to G:*** *Histopathological findings of adenocarcinoma. E) 4X magnification view, tumor cells arranged in a glandular pattern (white arrow). F) 40x magnification, tumor cells exhibiting mild pleomorphism, high nuclear-to-cytoplasmic ratio, moderate amount of eosinophilic cytoplasm, and hyperchromatic nuclei. (Blue arrow). G) 40x magnification view, anthracotic pigments dispersed in tumor cells. (Orange arrowhead).* ***H and I:*** *Histopathological findings of small cell carcinoma. H) 40x magnification, tumor cells in sheets. Tumor cells exhibit a scant amount of cytoplasm, uniform with round to oval-shaped hyperchromatic nuclei. (Red arrow). I) 40x magnification, tumor cells in clusters (red arrow).*

The distribution of gender and age did not differ significantly between malignant and non-malignant groups ($p = 0.500$ and $p = 0.737$, respectively). Tumor size (T stage), lymph node involvement (N stage), and bronchoscopic features such as endobronchial growth, unhealthy mucosa, extrinsic

compression, multiple nodules, and polypoidal lesions also showed no statistically significant association with biopsy-proven malignancy ($p > 0.05$ for all variables). A detailed distribution is provided in Table 6.

Table 6: Distribution of variables across the two groups with their level of significance.

Parameter Group	Subcategory	Malignancy Present (n=63)	Malignancy Absent (n=15)	p-value
Gender	Male	36 (57.1%)	10 (66.7%)	0.500
	Female	27 (42.9%)	5 (33.3%)	
Age	Mean (SD)	66.73 (7.96)	63.80 (12.31)	0.737
T (primary tumor)	>7cm	18 (28.6%)	1 (6.7%)	0.360
	5–7 cm	19 (30.2%)	7 (46.7%)	
	4–5 cm	17 (27.0%)	5 (33.3%)	
	3–4 cm	3 (4.8%)	1 (6.7%)	
	1–2 cm	1 (1.6%)	1 (6.7%)	
	≤1cm	5 (7.9%)	0 (0.0%)	
N (regional lymph nodes)	No regional node mets	8 (12.7%)	4 (26.7%)	0.235
	I/L pulmonary or hilar	1 (1.6%)	0 (0.0%)	
	I/L mediastinal or subcarinal	54 (85.7%)	11 (73.3%)	
Endobronchial growth	Yes	36 (57.1%)	7 (46.7%)	0.463
	No	27 (42.9%)	8 (53.3%)	
Unhealthy mucosa	Yes	27 (42.9%)	8 (53.3%)	0.463
	No	36 (57.1%)	7 (46.7%)	
Extrinsic compression	Yes	4 (6.3%)	1 (6.7%)	1.000
	No	59 (93.7%)	14 (93.3%)	
Multiple nodules	Yes	2 (3.2%)	1 (6.7%)	0.478
	No	61 (96.8%)	14 (93.3%)	
Polypoidal lesion	Yes	11 (17.5%)	1 (6.7%)	0.443
	No	52 (82.5%)	14 (93.3%)	
Pleural effusion	Yes	19 (30.2%)	4 (26.7%)	1.000
	No	44 (69.8%)	11 (73.3%)	

DISCUSSION

The application of fiberoptic bronchoscopy to obtain samples of pulmonary lesions has allowed for a greater range over which tissue may be obtained. It is ubiquitous that fiberoptic bronchoscopy has made visualization and diagnosis of bronchogenic carcinoma relatively safe and efficient. Conflicting results have been published regarding the diagnostic sensitivity and specificity of various bronchoscopic procedures like bronchoalveolar lavage, bronchial brush, and endobronchial biopsy. However, there is a relative scarcity of studies comparing the yield of these procedures.

We fully understand that the diagnostic yield of these procedures is limited by the operator's skills, the size and site of the lesion, the morphology of the lesion as visualized on bronchoscopy, technical factors like staining techniques, and the expertise of lab assistants and pathologists[7]. 80.8% of the patients included in our study were confirmed to have malignancy using endobronchial biopsy. The best diagnostic

accuracy (54.4%) was obtained when both bronchial brush and BAL cytology were combined, followed by the diagnostic accuracy of 51.28% using bronchial brush and 26.92% using bronchoalveolar lavage. This result is in conformity with a study conducted by Mak et al., where the best diagnostic accuracy was obtained when both diagnostic measures were combined, followed by brushings and washings, respectively[8].

The prevalence of particular bronchoscopic morphology associated with different tumor cell types in our study is summarized in the results section. It showed that endobronchial growth was the most common (43 cases) morphological picture observed under bronchoscopy, with squamous cell carcinoma accounting for the majority of the cases (24 cases, 55.8%). This finding aligns with the observations by Lee et al. in their study[9]. The predominance of endobronchial growth (36 cases, 83.7%) in malignant conditions in our study is in conformity with a 2016 study by Park et al., which noted that malignant tumors are more likely to present with endobronchial growth, causing airway obstruction[10]. But the presence of endobronchial growth in normal conditions as well as in dysplasia suggests that other conditions might mimic malignant features, so bronchoscopic diagnosis without histopathological confirmation is complicated.

Similarly, unhealthy mucosa was observed in 35 cases in bronchoscopy, with SCC and NSCLC, NOS being the most common, with 12 (34.3%) and 7 (20%) cases, respectively. Adenocarcinoma and dysplasia also showed unhealthy mucosa in 3 and 4 cases, respectively. These findings align with a 2021 review by Kim et al., which describes that although unhealthy mucosa is a frequent feature of malignant lesions, premalignant conditions like dysplasia can also present with such features[11].

External compression identified in bronchoscopy was comparatively rare, observed in only 5 cases - 4 cases of SCC and 1 case of dysplasia. This low prevalence of extrinsic compression in tracheobronchial tumors was also explained in a study by Prince et al. to be due to the lesions originating within airways rather than from external structures[12].

In our study, multiple nodules in bronchoscopy were identified in only 3 cases: 2 cases with SCC and 1 case with normal tissue. This low prevalence contrasts with a 2021 study by Chen et al., which reported multiple nodules to be associated with increased risk of malignancy in peripheral lung lesions[13].

Under bronchoscopy, polypoidal lesions were identified in 12 cases, with SCC (5 cases, 41.7%), NSCLC, NOS (3 cases, 25%), and adenocarcinoma, poorly differentiated carcinoma, and dysplasia (1 case each) contributing. This is in conformity with observations by Park et al. (2016), who described polypoidal lesions to be characteristic of malignant lesions, though benign lesions can also appear polypoidal[10].

On analyzing the diagnostic yields of bronchoscopic procedural techniques—bronchial brush, bronchoalveolar lavage (BAL), and biopsy—for various central airway lesions observed during bronchoscopy, the data from our study demonstrate that biopsy consistently achieves the highest diagnostic yield across all lesion types, followed by bronchial brush, with BAL showing the lowest effectiveness. For endobronchial growth, biopsy yielded a diagnosis in 36 cases (83.7%), which was significantly better than bronchial brush (22 cases, 51.2%) and BAL (6 cases, 14%). Similarly, for unhealthy mucosa, biopsy was diagnostic in 77.1% of cases (27), followed by bronchial brush (14 cases, 40%) and BAL (5 cases, 14.3%). Biopsy also was of the highest yield in diagnosing external compression (4 cases, 80%), bronchial brush in 1 case (20%), and BAL in none. As for multiple nodules, both bronchial brush and biopsy yielded a diagnosis in 2 cases each (66.7%), while BAL provided no diagnosis. For polypoidal lesions, biopsy was diagnostic in 11 cases (91.7%), bronchial brush in 8 cases (66.7%), and BAL in 1 case (8.3%). The high diagnostic yield of biopsy, as observed in our study, is in conformity with existing literature, notably a comprehensive review by Herth and Ernst (2011), for central airway lesions, as endobronchial lesions are directly visible and accessible within the airway lumen, allowing for precise tissue sampling[14]. The study by Herth and Ernst also suggests that the bronchial brush, although being less effective than biopsy, remains a valuable adjunct for cytological diagnosis, particularly when biopsy is inconclusive. For example, the 66.7% yield for polypoidal lesions and multiple nodules suggests that brush cytology can be effective for superficial or exophytic lesion's while BAL's low yield reinforces its limited role in diagnosing central airway lesions, i.e., lesions not involving the airway lumen[14].

The diagnostic yields in this study align with existing literature, but some differences exist, which might be due to differences in patient demographics, lesion characteristics, and procedural techniques. A study by Fernández-Villar et al. (2004) reported a diagnostic yield of 79% (50/63) for endobronchial biopsy in patients with visible lung cancer lesions, while our study reported a nearly equal yield of 80.8%[15]. But the diagnostic yields of bronchial brush and BAL are low in our study, which is in contrast with other studies like that of Singh et al. (2015) and Gaur et al. (2014)[16,17].

Our study showed the sensitivity of brush cytology to be 49.2% and the specificity to be 60.0%, with the positive predictive value being 83.8% and the negative predictive value being 22.0%. These findings are in conformity with other similar studies–most notably a study by Schreiber and McCrory, which reported a sensitivity range of 30-60% for bronchial brushings in the diagnosis of lung cancer[18]. In contrast, a study by Karahalli et al. reported a higher sensitivity of 67% but a slightly lower specificity of 55%, which might be due to differences in patient demographics, sample size, and techniques used during the procedure[19].

In our study, the sensitivity of BAL cytology was found to be 12.7%, while the specificity was 86.7%. These findings highlight the diagnostic challenges of using BAL cytology alone

for the diagnosis of lung cancer, particularly in comparison to endobronchial biopsy. The low sensitivity of BAL cytology found in our study, as compared to other studies like that of Binesh et al., may be attributed to several factors like patient demographics, lesion characteristics, and techniques used during the procedure[20]. The specificity of 86.7% obtained in our study is in conformity with available literature, where BAL cytology is generally reported to have high specificity, ranging from 75% to 100%.

As expected, squamous cell carcinoma, which is usually centrally located, was the most common (47.4%) subtype of lung malignancy diagnosed in our study (using bronchoscopic techniques), followed by non-small cell lung carcinoma, not otherwise specified (NSCLC, NOS) (14.1%). The diagnosis of squamous cell carcinomas as the most common subtype is in conformity with other studies too, most notably the one conducted in Kasturba Medical College Hospital, Mangalore[21]. Similarly, in conformity with other studies, adenocarcinomas, which are usually peripherally located, were diagnosed using biopsy in only 3.8 % of the cases in our study.

The distribution of gender and age did not differ significantly between malignant and non-malignant groups ($p = 0.500$ and $p = 0.737$, respectively). Tumor size (T stage), lymph node involvement (N stage), and bronchoscopic features such as endobronchial growth, unhealthy mucosa, extrinsic compression, multiple nodules, and polypoidal lesions also showed no statistically significant association with biopsy-proven malignancy ($p > 0.05$ for all variables). These findings suggest that none of the evaluated variables independently distinguished between the malignancy-present and malignancy-absent groups among our study participants, highlighting the complexity of diagnosing lung cancer based solely on these clinical and bronchoscopic features. The lack of significant differences in gender distribution ($p=0.500$) between the malignancy-present (57.1% male) and malignancy-absent (66.7% male) groups aligns with some studies but contrasts with others. A study by Rivera et al. (2013) reported a higher prevalence of lung cancer in males, who are historically associated with being more likely to smoke[22]. However, a recent study by Jemal et al. (2018) showed a comparable gender distribution to our study, reporting a narrowing gender gap in lung cancer incidence in younger populations and nonsmokers[23]. The absence of a significant gender association in our study may also be due to a small sample of the malignancy-absent group (n=15).

Similarly, in our study, greater primary tumor size (>7 cm) was more often present in the malignancy-diagnosed patients (28.6%) as compared to the malignancy-absent group (6.7%), though this was not statistically significant ($p=0.360$). This finding is consistent with a study by Wang et al., which reported that though larger tumors were more likely to exhibit features of malignancy, size alone is not a definitive predictive factor of malignancy[24].

Ipsilateral, mediastinal, or subcarinal lymph node involvement was present more in the malignancy-present group (85.7%) than in the malignancy-absent group (73.3%); however, the difference was not statistically significant ($p=0.235$) in our study. The trend is in conformity with the findings published by Kim et al. in 2023, which highlighted that malignant lesions are more likely to involve regional lymph nodes than benign lesions[25]. The involvement of regional lymph nodes in our study may reflect the heterogeneity of benign lesion's as some benign lesions can also cause secondary lymphadenopathy due to recurrent infections.

Our study showed that endobronchial growth was observed in 57.1% of the malignancy-diagnosed group and 46.7% of the malignancy-absent group ($p=0.463$), while unhealthy mucosa was present in 42.9% and 53.3% of the respective groups ($p=0.463$). These statistically insignificant findings suggest that these features cannot be used to differentiate malignant from benign lesions reliably. A 2023 review by Lee et al. showed that malignant lesions often present with endobronchial masses and unhealthy mucosa, but even benign lesions can mimic such features, which may indicate reactive/inflammatory changes[9].

Extrinsic compression and multiple nodules were rare in both groups in our study. These findings contrast with a study by Chen et al., which showed that multiple pulmonary nodules were mostly associated with increased malignancy risk in non-small cell lung cancer[24]. The low occurrence of extrinsic compression in our study may be due to the predominance of endoluminal growth over extrinsic invasion.

Likewise, the polypoidal lesions were more frequent in the malignancy-diagnosed group than in the malignancy-absent group, though the difference was not statistically significant. This trend conforms with the observations by Kim et al., who described polypoidal lesions to be characteristic of malignant lesions, though benign lesions like hamartomas can also appear polypoidal[25]. This overlap in features presents significant diagnostic challenges in attempting to diagnose lesions by morphological features alone.

Therefore, despite the marginal enhancement in diagnostic sensitivity for lung malignancies on combined use of endobronchial brush and bronchial wash cytology, there exist some limitations in specificity and reliability, which are consistent with the findings from studies on flexible fiberoptic bronchoscopy's diagnostic utility, the noteworthy studies being one by Halima et al. (2020) and another by Popescu et al. (2022)[26,27].

CONCLUSION

This study reinforces the critical diagnostic role of bronchoscopic modalities in evaluating pulmonary malignancies, particularly in resource-limited settings. Among the techniques assessed, the combination of bronchial brush and bronchoalveolar lavage cytology marginally improved

sensitivity but with moderate specificity. The relatively low sensitivity of cytological techniques, especially BAL, highlights their limitations as standalone diagnostic tools. Squamous cell carcinoma emerged as the predominant histologic subtype, reflecting the central location of lesions accessible by bronchoscopy.

The findings emphasize that while bronchoscopic sampling remains indispensable in the diagnostic algorithm for lung cancer, its efficacy is influenced by lesion characteristics, sampling technique, and pathological processing. Future studies with larger, multi-institutional cohorts and incorporation of advanced modalities such as EBUS-TBNA and molecular profiling are warranted to enhance diagnostic precision and guide targeted therapeutic strategies.

LIMITATION

It is important to acknowledge the presence of inter-operator variability in the performance of bronchoscopy, as well as inter-observer variability in the interpretation of cytological and histopathological findings in our study. Established bronchoscopic techniques such as transbronchial needle aspiration (TBNA) and transbronchial lung biopsy (TBLB) were not included, as they were beyond the scope of this investigation. Furthermore, the single-center design of the study limits the generalizability of the findings.

AUTHOR CONTRIBUTIONS:

The listed authors have all contributed to the research and have granted their consent for this version of the work to be published and accept the responsibility for the integrity of the work.

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None.

INFORMED CONSENT STATEMENT:

During the procedure of bronchoscopy, all the patients and relatives were counselled regarding the procedure, and informed written consent was taken and duly signed by the patients' relatives according to the protocol of the department of respiratory medicine.

DATA AVAILABILITY STATEMENT:

The data and analyzed sets are available with the corresponding author and can be provided upon reasonable request,

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CONFLICT OF STATEMENT:

None.

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