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Original Article

Role of Bronchoscope in Acute Respiratory Failure

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ABSTRACT

Background: Bronchoscopy was introduced in the late nineteenth century and its use is tremendously increased for several diagnostic and therapeutic purposes. However, it role for acute respiratory failure in our institution is still lacking. The aim of this study was to make an updated revision on the clinical conditions for bronchoscopy in adults with acute respiratory failure and to assess the high risky patients during the bronchoscopy procedure

Patients and Methods: This was a cross-sectional study. It included 90 patients with acute respiratory failure with hypoxemia. According to initial (provisional) diagnosis, there were 6 groups (each 15 patient): 1) Pneumonic hypoxemic group, 2) ILD hypoxemic group, 3) Neoplastic hypoxemic group, 4) Hemoptysis hypoxemic group, 5) Perioperative hypoxemic group, and 6) Foreign body aspiration hypoxemic group. All were evaluated by full history taking, clinical examination, and laboratory investigations. Furthermore, bronchoscopy was performed for all patients and results were documented

Results: The findings from this study demonstrated that bronchoscopy was particularly effective in resolving airway obstruction, clearing mucus plugs, managing hemoptysis, and obtaining diagnostic samples for cytological and histopathological evaluation. The procedure produced diagnostic yield and improved patient outcomes, especially in cases of pneumonia, neoplastic obstruction, and postoperative lung collapse. Bronchoscopy is generally a safe procedure when performed with proper monitoring and patient selection, even in critically ill individuals.

Conclusion: Bronchoscopy plays a pivotal role in the diagnosis and management of patients with acute respiratory failure. Its use provides direct visualization of the airways, enabling accurate identification of underlying causes such as infection, malignancy, airway obstruction, and foreign body aspiration. The findings from this study demonstrated that bronchoscopy significantly contributed to both diagnostic clarification and therapeutic intervention across a variety of clinical conditions.

Keywords: **Bronchoscopy; Rigid; Flexible; Interstitial Lung Disease; Foreign Body; Tumors.**

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INTRODUCTION

Bronchoscopy was first introduced in 1897 for an emergent removal of an inhaled foreign body. Since then, bronchoscopy use has been tremendously increased for several diagnostic and therapeutic purposes in patients admitted to respiratory high-dependency care units (RHDCU) and intensive care units [1,2].

Bronchoscopy is an important tool for pulmonary and critical care physicians to diagnose as well as treat various pulmonary diseases, Various conditions like vocal cord dysfunction, trachea-bronchomalacia, airway obstruction, foreign bodies, pneumonia, diffuse parenchymal lung disease, and lung cancer can be easily diagnosed with bronchoscopy. It can also help treat several conditions including airway obstruction, foreign bodies, hemoptysis, mucus plugging, and others [3].

Acute respiratory failure is defined as the inability of the respiratory system to meet the oxygenation, ventilation, or metabolic requirements of the patient. Respiratory failure has been divided into two main types. Type 1 respiratory failure is defined by a partial pressure of oxygen in arterial blood (PaO_2) less than 60 mm Hg and type 2 respiratory failure is defined by a partial pressure of carbon dioxide in arterial blood ($PaCO_2$) of greater than 50 mm Hg. Respiratory failure can be acute or chronic in nature, related to the onset and duration of the failure [4,5].

Bronchoscopy may be done with flexible and rigid instruments. Flexible bronchoscopy (FOB) is more widely employed due to its less invasiveness, deeper capability for exploration of bronchial tree, and quicker learning curve; its "ancillary techniques" allow sampling to be taken from lung and mediastinum, such as broncho-alveolar lavage (BAL), protected-specimen brush (PSB), trans-bronchial needle aspiration (TBNA), and trans-bronchial lung biopsy (TBLB) [1,2].

Rigid bronchoscopy (RB) has a more limited field of applications, but represents a mandatory safe and effective technique to perform interventional procedures, such as ablative treatments (laser, argon-plasma, electro-cautery, cryotherapy), airway's stenting, as well as foreign bodies removal [6].

It had been reported that, the main indications for bronchoscopy in ARF patients are: (1) to support difficult intubation and percutaneous dilatational tracheostomy (PDT) [7,8]; (2) to help in the diagnosis of infective and non-infective lung infiltrates in non-ventilated and ventilated patients [9,10]; (3) to manage acute airway obstruction of different origins, such as mucous plugs, foreign bodies and benign/malignant trachea-bronchial disorders [11,12]; (4) to manage massive hemoptysis [13].

As a newly introduced tool in our institution, we are concerned about determination of bronchoscope role in different clinical conditions, to add our experience to available literature. Thus, the aim of this study was to make an updated revision on the clinical conditions for bronchoscopy in adults with acute respiratory failure and to assess the high risky patients during the bronchoscopic procedure.

PATIENTS AND METHODS

Study Design and Setting:

This was a cross-sectional study. It included 90 patients with acute respiratory failure with hypoxemia. They were selected from the department of pulmonary medicine (Bronchoscopy and respiratory critical care units), Al-Azhar University hospital (Damietta). According to initial (provisional) diagnosis, there were 6 groups: 1) Pneumonic hypoxemic group (n=15), 2) ILD hypoxemic group (15 patients), 3) Neoplastic hypoxemic group (15 patients), 4) Hemoptysis hypoxemic group (15 patients), 5) Perioperative hypoxemic group (15 patients), and 6) Foreign body aspiration hypoxemic group (15 patients).

Inclusion and exclusion criteria:

The inclusion criteria were 1) The age of the patients should be 18 years old or above, and 2) Patients presented by signs and symptoms of acute respiratory failure in various respiratory problems.

The exclusion criteria were 1) Refractory hypoxemia (hypoxemia which cannot be corrected (PaO_2) less than 75 mmHg, PaO_2/fiO_2 less than 150 or (SpO2) less than 90% despite supplemental oxygen; 2) Severe thrombocytopenia with platelet count less than 50,000 cells/ml) 3) Coagulation disorders or severe renal dysfunction. In addition, NIV should be avoided if the patient has one of the following: Facial deformity, upper airway obstruction, inability to protect the airway, significantly altered mental status, upper gastrointestinal bleeding, acute coronary syndromes, severe hemodynamic instability, and respiratory or cardiac arrest, finally, risky patients with (active bronchospasm, recent MI, unstable arrhythmia, increase intracranial pressure, electrolyte disturbance and BEEP >10 cm H_2O)

Methods

All patients were submitted to full history taking (detailed history of personal, complaint, present, past, associated comorbid conditions and family history). Then, each patient was assessed clinically in a standard manner (general examination, and local chest examination). This was followed by laboratory investigations (CBC, atrial blood gases (ABGs), renal and liver function tests. Finally, radiological investigations in the form of chest x ray and

computed tomography were performed. This was followed by electrocardiography and echocardiography.

After complete assessment, the patient was introduced to flexible bronchoscopy. A flexible bronchoscope was used with the size ranged from 4 to 6.4 mm external diameter depending on the procedure intended. Both nasal and oral routes were equally safe and used according to physician preference. A special adapter was used to be attached to endotracheal tube (ETT) to allow the insertion of the bronchoscope without a significant effect on tidal volume.

In pneumonia group

A fiber-optic bronchoscopy was performed, and distal airways were sampled and a bronchoalveolar lavage (BAL) was taken for cytology and culture.

For neoplastic group

Forceps and cryobiopsy sampling were performed. The sequence of the biopsies was randomized with a closed envelope method. The number of biopsies were 2 biopsies for the forceps versus one cryobiopsy. The cryoprobe used in this study was flexible cryorecanalization probe (78 cm in length/2.4 mm in diameter) which was connected to cryomachine, while the forceps used in the study were Endo-Flex biopsy forceps 2.3 mm diameter and 180 cm length.

Tissue sampling:

Bronchoscopic forceps biopsy was done as usual from the visualized endobronchial lesions. Two forceps biopsies were taken per patient. After the second biopsy the amount of bleeding was evaluated, categorized and evaluated. The method used to control it was recorded and documented. The cryobiopsy samples were obtained by advancement of the cryoprobe into the working channel of the bronchoscope to touch the tip of the endobronchial tumor. The freezing time was approximately 4 seconds then, forceps biopsy together with tissue sample attached to the tip of the frozen probe were extracted outside the bronchial tree. The tissue sample was released from the probe's tip by plunging it into saline at room temperature. Fiberoptic bronchoscope was reintroduced after cryobiopsy to evaluate and control the bleeding.

Histopathology:

Specimens were sent for pathological examination. The diagnostic yield of each technique was demonstrated. A diagnostic technique was only defined when a final histopathological diagnosis was obtained.

For ILD group

Bronchoscopy was performed using standard white light flexible bronchoscopy through a placed endotracheal tube or intranasally as per clinician preference with clinician choice of directed conscious or moderate sedation.

For hemoptysis group

Bronchoscopic examination was considered positive only if it proved an endobronchial bleeding lesion and/or provided histopathological and/or microbiological specimens, helpful for a definitive etiological diagnosis. Furthermore, we evaluated the ability of bronchoscopy to detect the bleeding source (i.e., anatomic site, lobe and lung). The site of the bleeding was defined as the exact visible hemorrhage source (e.g., a visible bleeding endobronchial malignancy). Direct visualization of active bleeding/oozing was considered suggestive of a bleeding source.

For Lung collapse

Bronchoscope was advanced through the patient airways toward the collapsed area and then was wedged into the collapsed segment or all the segments of the collapsed lobe and suction of secretions and mucus plug was done.

For foreign body group

Before flexible bronchoscopy was performed in the bronchoscopy unit, lidocaine (max 8 mg/kg) as a topical anesthetic and if needed, intravenous midazolam (0.05mg/kg) for conscious sedation were administered. All patients underwent endoscopy with the oral approach. Before rigid bronchoscopy, following pre-anesthesia consultation and necessary tests, in the operating room, rigid bronchoscopy, under intravenous anesthesia was performed. If required, distal airways were evaluated with flexible bronchoscopy through rigid bronchoscopy. Foreign objects detected in the bronchoscopic examination were removed using alligator forceps, grasping forceps, biopsy forceps, and basket forceps. To evaluate complications directly related to bronchoscopy, we considered events reported during procedure or within 12 h of procedure completion.

Data Analysis:

Data was analyzed using SPSS (statistical package for social sciences) version 22 (IBM Inc., USA). Qualitative data were presented as number (frequency) and percentage. Quantitative data were tested for normality by Shapiro-Wilk test then described as mean and standard deviation for normally distributed data and median and interquartile range for abnormally distributed data. The appropriate statistical test was applied according to data type with

the following tests: Chi-Square for categorical variable, and independent samples student's "t" test for comparison between two groups. P value < 0.05 was considered significant.

Ethical Considerations:

The Local Ethics Committee of Scientific Research, Faculty of Medicine, Al-Azhar University approved the study protocol. Informed consent was obtained from each patient before data collection; aim and methodology of this study were explained to the selected subjects, all data, which were obtained from the present study, were in private consideration and for scientific purposes only.

RESULTS

The current work included 90 subjects with acute respiratory failure due to different causes. Males represented 53.3%, the mean age of all patients was 57± 11.5 years, and active smoking was reported for 40.0%. Associated comorbid conditions were in the form of COPD, hypertension, DM, history of TB, bronchiectasis, malignancy, chronic liver diseases and ischemic heart disease, and were reported in 14, 17, 4, 14, 14, 5 and 5 subjects, respectively. The mean arterial pressure was 69.2±14.7 mmHg and PaO_2/FiO_2 was 180±11.5 mmHg. Most of study subjects were intubated (88.89%), and 11.1% were on nasal cannula. The complications of bronchoscopy were bleeding, infection and hypoxia in 7.78%, 2.22% an d3.33%, respectively; and no mortality was recorded in relation to bronchoscopy (Table 1).

In the endobronchial tumor group the main site of biopsy was right main bronchus followed by left main bronchus (36.4% and 27.3%) in the cryobiopsy, while the main site of biopsy in forceps biopsy was the left main bronchus (50.0%) with no significant difference between cryobiopsy and forceps biopsy. The diagnostic yield of cryobiopsy was 54.5% and it was 100.0% of forceps biopsy. The main cause of ARF in this group was post-obstruction pneumonia (53.3%) followed by airway obstruction (46.7%). The histopathological diagnosis was obtained in 66.7% (adeno-carcinoma in 26.7%, small cell lung cancer in 6.7%, squamous cell carcinoma in 20.0% and carcinoid tumor in 13.3%. No final diagnosis was detected in 33.3% (Table 2).

In foreign body group, the commonest symptom was cough (100.0%) and the least was hemoptysis and chest pain (each in 6.7%). The rigid bronchoscope was the most common used (93.3%) and the commonest x-ray finding was radiopaque foreign body (53.3%) and commonest aspirated foreign body was pin (33.3%) and undefined plastic object (33.3%) followed by undefined metal object (20.0%). The commonest risk factor was neurological disorders (33.3%) followed by advanced age (20.0%). The accidental risk factor was reported in 46.7% (Table 3).

In pneumonia group, 6 (40.0%) was community acquired pneumonia (CAP) and hospital acquired pneumonia (HAP) in 60.0%. There was no significant difference between CAP and HAP regarding comorbid conditions, mortality, bilateral opacities, cytological analysis of BAL pathogens. Airway inflammation with hyperemia, and secretions which may include pus was reported in all cases regardless of type of pneumonia (Table 4).

The clinical and bronchoscopic characteristics for hemoptysis with acute hypoxemia was demonstrated in table (5). Most cases with mild (80.0%), and flexible bronchoscopy with endotracheal intubation were used for 80.0% and no cases treated with rigid bronchoscopy. The bleeding was diffuse in 60.0% and localized in one lobe in 40.0%. The diagnostic cause was unknown for 40%, tumors for 33.3% and pneumonia for 20.0%.

Regarding ILD group, the connective tissue disease was reported for 33.33%, hypersensitivity pneumonitis in 40.0% and idiopathic pulmonary fibrosis was reported in 26.7%. The bronchoscopy on general floor was performed in 7 cases and in IUC for 8 cases. Of cases with bronchoscopy on general floor, 71.6% not need to be admitted to ICU, while 2 were transferred within 12 hours (one intubated and the other not intubated). In the bronchoscopy in ICU 75% were already intubated and ventilated, 12.5% not intubated during bronchoscopy and 12.5% were intubated to perform bronchoscopy (Table 6).

In IPF, the cause of acute respiratory failure was hemorrhage and infection. The cases with hemorrhage needed IV steroids with use of antibiotics and the patient died. Cases with infection were due to staphylococcus aureus, with no need to change of initial management, but with antibiotics and all were discharged (Table 7).

In cases with perioperative lung collapse, 13.3% had preexisting pulmonary disease, dyspnea was the main presentation (80.0%), lobar collapse was reported in 66.7%, the lower lobe was the main cause of collapse (40.0%), the thoracic surgery was reported for 53.3%. The mucous plug was the main cause of collapse (86.7%) and complete resolution was reported in 60.0% (Table 8).

Table (1): Summary of studied subjects according to their demographics, associated comorbid conditions, mean atrial pressure, oxygenation, ventilation and bronchoscopy complications.

Variable	Category	Number (n=90)
Gender	Male	48 (53.3%)
	Female	42 (46.7%)
Age (years)	57± 11.5	
Smoking	Smoker	36 (40.0%)
	Nonsmoker	53 (58.9%)
	Ex-smoker	1 (1.1%)
Associated comorbid conditions	COPD	14 (15.6%)
	Hypertension	17 (18.8%)
	Diabetes mellitus	17 (18.8%)
	History of tuberculosis	4 (4.4%)
	Bronchiectasis	14 (15.6%)
	Malignancy	14 (15.6%)
	Chronic liver disease	5 (5.6%)
	Ischemic heart disease	5 (5.6%)
MAP (mmHg)		69.2±14.7
PaO2/FiO2 (mmHg)		180±11.5
Ventilation	Intubated	80 (88.89 %)
	On nasal cannula	10 (11.1 %)
Complications of bronchoscopy	Bleeding	7 (7.78%)
	Infection	2 (2.22%)
	Hypoxia	3 (3.33%)
Mortality from bronchoscopy		0 (0.0%)

Table (2): Results of the second group (endobronchial tumor group) with acute hypoxemia.

		Cryobiopsy (n=11	Forceps biopsy (n=4)	test	P value
Site of biopsy	Right main bronchus	4 (36.4%)	1 (25.0%)	1.36	0.714
	Bronchus intermedius	2 (18.2%)	1 (25.0%)		
	Left main bronchus	3 (27.3%)	2 (50.0%)		
	Left lower lobe	2 (18.2%)	0 (0.0%)		
Diagnostic yield		6 (54.5%)	4(100.0%)	2.72	0.231
Cause of ARF in endobronchial tumor	Airway obstruction (collapse)			7(46.7%)	
	Post-obstruction pneumonia			8(53.3%)	
Histopathological Diagnosis in endobronchial tumors	Adenocarcinoma			4 (26.7%)	
	Small cell lung cancer			1(6.7%)	
	Squamous cell carcinoma			3(20%)	
	Carcinoid tumor			2(13.3%)	
	No final diagnosis			5(33.3%)	

Table (3): Data of Foreign body group

		Foreign body group (n=15)
Symptoms	Cough	15 (100.0%)
	SOB	7(46.7%)
	Chest pain	1(6.7%)
	Hemoptysis	1(6.7%)
Bronchoscopy	Rigid	14 (93.3%)
	Flexible	1(6.7%)
x-ray findings	Hyperinflation	3(20%)
	Atelectasis	4 (26.7%)
	Radiopaque foreign body	8(53.3%)
Type of aspirated foreign body	Pin	5(33.3%)
	Pencil-cap	1(6.7%)
	Undefined organic object	1(6.7%)
	Undefined Plastic object	5(33.3%)
	Undefined Metal object	3(20%)
Risk factors	Advanced age	3(20%)
	Neurological disorders	5(33.3%)
	Accidental	7(46.7%)

Table (4): Data about Pneumonia with acute hypoxemia group

Variable		(CAP) (n=6)	(HAP) (n=9)	Test	P value
Comorbidities	Cardiac failure	0 (0.0%)	4 (44.4%)	6.66	0.155
	Neoplastic disease	1 (16.7%)	0 (0.0%)		
	Chronic RF	2 (33.3%)	1 (11.1%)		
	Cirrhosis	1 (16.7%)	0 (0.0%)		
Ventilation, days before BAL		2.0±0.1	6.0±2.5	***4.29***	***0.001****
Length of stay in ICU		5.0±2.5	16.0±3.6	***5.28***	***<0.001****
Mortality		4(66.7%)	5(55.6%)	0.185	0.667
Bilateral opacities		4 (66.7%)	6(66.7%)	0.001	1.00
Tracheobronchial Tree	Airway inflammation and hyperemia	15(100%)			
	Secretions which may include pus	15(100%)			
	airway obstruction	5(33.3%)			
	mucus plugs	5 (33.3%)			
	Endobronchial mass lesion	2(13.3%)			
Cytological analysis	Neutrophil predominance	6(100.0%)	6 (66.7%)	2.50	0.229
BAL pathogens	Streptococcus pneumoniae	2 (33.3%)	0(0.0%)	7.36	0.289
	Haemophilus influenzae	1 (16.7%)	0(0.0%)		
	Klebsiella pneumoniae	1 (16.7%)	2 (22.2%)		
	Pseudomonas aeruginosa	0(0.0%)	1 (11.1%)		
	Staphylococcus aureus	1 (16.7%)	2 (22.2%)		
	Candida sp.	0(0.0%)	3 (33.3%)		
	No isolated pathogens	1 (16.7%)	1 (11.1%)		

Table (5): Clinical and bronchoscopic characteristics for hemoptysis with acute hypoxemia group

Variable			(N=15)
Hemoptysis severity		Mild	**12 (80%)**
		Moderate	**3 (20%)**
		Severe	**0 (0%)**
Flexible bronchoscopies		endotracheal intubation	**12 (80%)**
		No intubation	**3 (20%)**
Rigid bronchoscopies, n (%)			**0 (0%)**
Bleeding localization		Localized in one lobe	**6 (40%)**
		Diffuse	**9 (60%)**
Diagnosis (Cause)	Tumors	Adenocarcinoma	**2 (13.3%)**
		Squamous cell carcinoma	**1(6.7%)**
		Carcinoid	**2 (13.3%)**
	Pneumonia	Streptococcus pneumoniae	**2 (13.3%)**
		Klebsiella pneumonia	**1(6.7%)**
		Lung abscess	**1(6.7%)**
	Unknown		**6 (40%)**

Table (6): Data about ILD with acute hypoxemia group

Variable				N = 15
Type of ILD	CTD		Total	**5 (33.33%)**
			RA	**4 (26.7%)**
			SLE	**1 (0.06%)**
	HP			**6 (40%)**
	IPF			**4 (26.7%)**
Outcome	Bronchoscopy on general floor (n=7)	Not transferred to ICU afterwards		**5 (71.6%)**
		Transferred to ICU within 12 hours of bronchoscopy	Intubated	**1 (14.2%)**
			Not intubated	**1 (14.2%)**
	Bronchoscopy in ICU (n=8)	Patients have already been intubated and ventilated		**6 (75%)**
		Not intubated during bronchoscopy		**1 (12.5%)**
		Patients intubated to safely perform bronchoscopy		**1 (12.5%)**

*CTD, connective tissue disease, HP, hypersensitivity pneumonitis, ILD, interstitial lung disease, IPF, idiopathic pulmonary fibrosis, RA, rheumatoid arthritis, SLE, systemic lupus erythematosus

Table (7): Causes of acute respiratory failure in IPF.

ILD type	Infection/ alveolar hemorrhage	Change in initial Management	Antibiotics	outcome
IPF	Hemorrhage	Yes (added i.v. steroids)	Yes	Died
IPF	Infection (s. aureus)	No	Yes	discharged

Table (8): Data in the perioperative lung collapse with acute hypoxemia group.

Variable			Frequency (n=15)	Percent (%)
Pre-existing pulmonary disease	Yes		2	13.3%
	No		13	86.7%
Main presentation:	dyspnea		12	80%
	chest pain		3	20%
Type of collapse	Lobar collapse		10	66.7%
	Total lung collapse		5	33.3%
Site of collapse	Lower lobes		6	40%
	Middle lobe		4	26.7%
	Total lung collapse		5	33.3%
Type of surgery	Thoracic		8	53.3%
	Abdomen		7	46.7%
Cause of collapse	Mucus plugs		13	86.7%
	Compression collapse		2	13.3%
Radiological outcome	Complete resolution		9	60.0%
	No resolution	Due to endobronchial lesion	1	6.7%
		Due to compression collapse	2	13.3%
		Due to unknown cause	3	20.0%

DISCUSSION

The role of bronchoscopy in respiratory failure is a crucial area of pulmonary and critical care medicine, as bronchoscopy serves both diagnostic and therapeutic functions in patients with compromised respiratory function. Bronchoscopy enables direct visualization of the tracheobronchial tree, allowing for identification of airway obstructions, infections, tumors, and other pathological changes that may contribute to respiratory distress. It can be particularly valuable in cases of unexplained respiratory failure, where radiologic findings are inconclusive, by facilitating sampling through bronchoalveolar lavage or tissue biopsy for microbiological and histopathological analysis. Recent studies have shown that timely bronchoscopy can improve diagnostic accuracy in up to 80% of mechanically ventilated patients with pulmonary infiltrates, thereby guiding appropriate and targeted therapy[14].

Beyond its diagnostic capabilities, bronchoscopy also plays a vital therapeutic role in managing respiratory failure by removing airway obstructions, aspirated foreign bodies, mucus plugs, or secretions that impair gas exchange. In the presented research, a substantial proportion of patients experienced clinical improvement after bronchoscopic intervention, including resolution of atelectasis and restoration of ventilation, with a 60% radiological improvement rate following the procedure. Such findings align with previous reports demonstrating that broncho-scopy-assisted airway clearance can rapidly improve oxygenation and pulmonary mechanics, particularly in cases of lobar or total lung collapse secondary to mucus plugging or postoperative complications [15].

Furthermore, bronchoscopy has been shown to be a relatively safe procedure in critically ill patients when performed under appropriate monitoring and ventilatory support. In this study, complication rates were low, with bleeding and hypoxia being the most commonly observed but manageable adverse events, and no procedure-related mortality was recorded. This safety profile reinforces the utility of bronchoscopy as a minimally invasive yet high-yield intervention in respiratory failure management. It also highlights the importance of multidisciplinary coordination between pulmonologists, anesthesiologists, and intensive care specialists to optimize patient outcomes [7].

In the present study, we evaluated the role of bronchoscopy across diverse clinical indications including endobronchial tumors, foreign body aspiration, pneumonia, hemoptysis, interstitial lung disease, and perioperative lung collapse. Overall, the procedure demonstrated a favorable safety profile with low complication rates

and no procedure-related mortality, consistent with contemporary reports that bronchoscopy is generally safe when performed in experienced centers [16].

Our study showed a nearly balanced gender distribution and a mean age of 57 years. These findings align with previous bronchoscopy studies in respiratory failure, which reported similar mean ages around the sixth decade and slight male predominance[17]. This demographic consistency reflects the typical patient profile for bronchoscopic evaluation in respiratory diseases.

Hypertension and diabetes mellitus were the most common comorbidities, followed by COPD and bronchiectasis. Comparable distributions have been reported by **Leiten *et al.*** [17], who also identified metabolic and pulmonary comorbidities as predominant among bronchoscopy patients. These overlapping findings confirm the expected comorbidity spectrum in this population.

The mean arterial pressure (MAP) was 69.2±14.7 mmHg, while the PaO_2/FiO_2 ratio averaged 180 ± 11.5 mmHg, indicating moderate hypoxemia. These values are consistent with those described by **Cracco *et al.*** [18] in mechanically ventilated bronchoscopy patients, who reported similar oxygenation impairment. Such similarity reinforces the representativeness of this study.

Although bleeding occurred in 7.8% of cases and transient hypoxemia in 3.3%. These values are within the ranges previously described, particularly in studies involving advanced sampling techniques such as cryobiopsy, where bleeding is recognized as the most frequent adverse event [19].

In patients with endobronchial tumors, forceps biopsy achieved a diagnostic yield of 100%, whereas cryobiopsy yielded 54.5%. This contrasts with published series in which cryobiopsy often provides a higher diagnostic yield and larger, better-preserved specimens compared with forceps biopsy [19].

Respiratory failure in our cohort was mainly attributable to post-obstructive pneumonia and airway collapse, in keeping with previous observations that malignant obstruction frequently results in secondary infections and atelectasis [20]. The lower cryobiopsy yield observed in our cohort may be explained by the predominance of intubated and critically ill patients, in whom cryotechniques may be technically limited and bleeding risk more consequential. Despite these differences, our findings reinforce the continued value of forceps biopsy in unstable patients, while highlighting the need for careful patient selection when applying cryobiopsy. Histologically, adenocarcinoma was the most common malignancy, followed by squamous cell carcinoma and carcinoid tumors. These findings are similar to other reports in which non-small cell lung cancer predominates, with carcinoid tumors contributing a smaller but notable fraction [19].

Foreign body aspiration represented another significant indication for bronchoscopy. Cough was the universal presenting symptom, with shortness of breath also common. Rigid bronchoscopy served as the main therapeutic modality, and radiopaque objects such as pins and plastics were the most common aspirated materials (each 33.3%). These results align closely with the experience of **Özdemir *et al.*** [21], who reported cough as the most frequent presenting symptom (96%) and rigid bronchoscopy as the preferred intervention (89%).

Radiopaque foreign bodies were detected in 53.3% of patients, followed by atelectasis and hyperinflation. These findings are similar to those of **Swanson and Edell** [22], who reported that about half of aspirated objects are radiopaque. This emphasizes the continued role of plain radiography as an initial diagnostic tool.

The differences in the types of aspirated objects—pins and plastics in our study versus scarf needles in their Turkish cohort—likely reflect regional and cultural practices. Importantly, both series support rigid bronchoscopy as the gold standard for foreign body removal, with flexible bronchoscopy reserved for carefully selected cases. Accidental aspiration was the leading risk factor (46.7%), followed by neurological disorders. Similar trends were observed with previously reported patterns [21].

Pneumonia was a frequent indication for bronchoscopy, particularly in ventilated patients. Hospital-acquired pneumonia (HAP) cases were characterized by longer ventilation days before bronchoalveolar lavage and longer ICU stays compared with community-acquired pneumonia (CAP), whereas mortality remained high in both groups. These findings are consistent with prior reports showing that HAP typically affects more severely ill patients with prolonged ventilation and ICU stays, and that mortality rates remain elevated irrespective of pneumonia type [23].

Bilateral and multilobar opacities were common in both CAP and HAP. These findings agree with **Gadsby and Musher** [24], who documented extensive radiographic involvement in severe pneumonia, particularly in ICU settings. The similarity highlights the diffuse nature of pneumonia in critical illness.

The present study demonstrated that all pneumonia patients (100%) had airway inflammation and hyperemia as well as purulent secretions visible during bronchoscopy. These findings are strongly with previous studies showing that mucosal erythema, edema, and increased purulent secretions are nearly universal in bronchoscopic evaluation of patients with pneumonia. In a study by **Pratomo *et al.*** [25], almost all patients with severe pneumonia or COVID-19–related respiratory failure exhibited diffusely

hyperemic bronchial mucosa and thick purulent secretions obstructing the segmental bronchi. Similarly, **Brownback *et al.*** [26] found that 96% of pneumonia patients undergoing diagnostic bronchoscopy had visible mucosal inflammation and copious secretions. These results confirm that hyperemia and secretions are the hallmark bronchoscopic features of pneumonia reflecting the inflammatory exudation within the tracheobronchial tree.

Cytological analysis in our study showed universal neutrophilic predominance in CAP and a lower prevalence in HAP, echoing findings that severe bacterial pneumonia is associated with neutrophilic alveolitis and cytological evidence of alveolar damage[23].

Airway obstruction was detected in 33.3% of patients in the current study. This finding is with earlier reports indicating that bronchial obstruction, usually by secretions or inflammatory debris, occurs in a considerable subset of pneumonia cases. **Al-Qadi *et al.*** [27] found endobronchial obstruction in 29% of patients with nonresolving pneumonia, while a study by **Röder *et al.*** [28] showed that 35% of pneumonia patients had bronchial narrowing or obstruction visible on bronchoscopy.

However, it is against studies in ventilator-associated or severe necrotizing pneumonia where obstruction rates can exceed 50%, possibly because the present study included a broader spectrum of pneumonia severity. Thus, while obstruction is a common bronchoscopic feature, its frequency is influenced by disease chronicity and mucus burden [29].

Mucus plugs were found in one-third (33.3%) of patients, which is with prior studies emphasizing that inspissated mucus contributes to airway blockage in pneumonia. **Turk *et al.*** reported mucus plugging in 31% of bacterial pneumonia cases [30]. **Pratomo *et al.*** [25] noted similar findings in COVID-19 pneumonia where mucus impaction was observed in roughly 36% of bronchoscopies. This level of agreement suggests that mucus plug formation is a frequent secondary effect of inflammation, impaired clearance, and high sputum viscosity in pneumonia. It is against reports in certain ICU series where mucus plugs were observed in more than half of patients, likely due to differences in ventilator management and sedation leading to reduced mucociliary clearance.

Endobronchial mass lesions were identified in 13.3% of patients in the pneumonia group, a finding with literature describing occasional detection of underlying obstructive lesions (e.g., tumors, granulation tissue) during bronchoscopy for non-resolving pneumonia. **Ling *et al.*** [31] reported that approximately 14% of patients with radiologically suspected pneumonia had endobronchial growths responsible for post-obstructive infection. Likewise, **Al-Qadi *et al.*** [27] found malignancy or benign masses in about 12% of pneumonia cases evaluated bronchoscopically. The current finding, therefore, aligns well with published ranges and emphasizes the diagnostic importance of bronchoscopy in pneumonia to identify unsuspected endobronchial pathology contributing to infection.

Overall, the present results are consistent with the major body of evidence showing that airway inflammation, hyperemia, and purulent secretions are nearly universal in pneumonia, while obstruction and mucus plugs occur in about one-third and mass lesions in about one-tenth of cases. Discrepancies between studies mainly reflect variations in patient selection, disease severity, and timing of bronchoscopy. These results reinforce that bronchoscopy not only aids in diagnosis and microbiologic sampling but also provides therapeutic benefit by clearing obstructing secretions or plugs, improving aeration, and identifying underlying lesions that sustain infection [25].

CAP samples yielded Streptococcus pneumoniae and *Haemophilus influenzae*, while HAP cases grew Klebsiella and Pseudomonas. This distribution parallels global microbiologic profiles distinguishing community versus hospital pathogens [32]. Thus, the microbiologic findings validate expected etiology patterns.

Hemoptysis represented a diagnostic challenge, with the majority of cases classified as mild. Bronchoscopy was performed in most patients and succeeded in localizing bleeding in 40%, although a definitive etiology was established in only 60%. Tumors were the most common identified cause, followed by pneumonia, a distribution consistent with other bronchoscopy-based series where malignancy is a leading etiology. The high proportion of cases with no final diagnosis underscores the recognized limitation of bronchoscopy in hemoptysis, particularly when bleeding has subsided or originates from peripheral lesions not directly visualized [19].

In the present study, mild hemoptysis (<20 mL) was the predominant finding, observed in 80% of patients, while moderate hemoptysis (20–200 mL) was seen in 20%, and no cases of severe hemoptysis (>200 mL) were recorded. These results are largely with most studies showing that mild hemoptysis is by far the most common presentation among hospitalized or bronchoscopically evaluated patients. **Hirshberg *et al.*** [33] reported that 90% of hemoptysis cases were mild, with only 5% classified as severe. Similarly, **O'Gurek and Choi** [34] found that mild bleeding accounted for nearly 80% of all hemoptysis presentations. The predominance of mild cases can be explained by early medical evaluations, effective management of underlying conditions, and the tendency for patients with smaller-volume bleeding to undergo diagnostic bronchoscopy more frequently than those with massive bleeding who require emergent stabilization.

The absence of severe hemoptysis (>200 mL) in this study is also with findings from several reports conducted in tertiary care settings where massive bleeding was relatively uncommon. The present result is against older studies from tuberculosis-endemic regions, such as **Bhalla *et al.*** **[35],** where massive hemoptysis accounted for up to 20% of cases due to more extensive pulmonary destruction and bronchiectatic changes. Therefore, the absence of severe bleeding in the current cohort may reflect improved control of chronic lung diseases and the exclusion of unstable patients who could not undergo bronchoscopy safely.

The relatively higher proportion of mild cases compared with moderate or severe cases is consistent with the epidemiologic shift observed in recent years, as the etiologic spectrum of hemoptysis has changed from infectious causes such as tuberculosis to malignancy and bronchitis, which often presents withsmall-volume bleeding. **Röder *et al.*** **[28]** noted that the majority of hemoptysis patients (over 75%) experienced small or self-limited bleeding episodes, with malignancy, pneumonia, and bronchitis being the most frequent causes—findings that parallel those of the present study. Conversely, this result is against reports in regions where bronchiectasis and tuberculosis remain prevalent, as these conditions are often associated with more severe or recurrent bleeding. Thus, the predominance of mild hemoptysis in this cohort may also reflect the changing pattern of respiratory disease and improved early detection through imaging and bronchoscopy.

Diffuse bleeding was observed in 60% of hemoptysis cases. Previous studies, such as those by **Hirshberg *et al.*** **[33],** described diffuse sources in up to 50–60% of patients, supporting your observed frequency. This indicates bronchoscopy's key role in localization even when bleeding is widespread

In the present study, tumors accounted for 33.3% of the underlying causes of hemoptysis, including adenocarcinoma (13.3%), squamous cell carcinoma (6.7%), and carcinoid tumors (13.3%). These findings are strongly with previous research indicating that bronchogenic carcinoma remains one of the leading causes of hemoptysis detected during bronchoscopy. **Röder *et al.*** **[28]** reported that malignant tumors represented 25–35% of bronchoscopically diagnosed causes of hemoptysis, with adenocarcinoma being the most common histologic subtype, similar to the present data.

Likewise, **Mohammad *et al.*** **[36]** found that 31% of their patients with hemoptysis had endobronchial malignancy. However, the relative proportion of carcinoid tumors (13.3%) in the current study is slightly higher than in most published series, where carcinoid tumors typically account for 2–6% of cases. This variation could be related to the small sample size or regional epidemiologic differences.

The current study found pneumonia to be the second most common cause of hemoptysis (26.7%), with Streptococcus pneumoniae and *Klebsiella pneumoniae* each responsible for several cases, and one patient having a lung abscess. This result is with numerous reports showing that pneumonia and lung abscess are important infectious etiologies of hemoptysis. **Hirshberg *et al.*** **[33]** noted that pneumonia accounted for 20–25% of hemoptysis episodes, while a more recent study by **O'Gurek and Choi** **[34]** found infectious causes in 27% of cases, closely matching the present percentage. It is against older Western series where tuberculosis predominated as the infectious cause; the lower incidence here may reflect changing infection patterns and effective TB control in many regions.

Interestingly, 6 patients (40%) in the hemoptysis group had no definitive diagnosis even after bronchoscopy. This aligns with studies showing that a substantial proportion of hemoptysis cases remain idiopathic after full bronchoscopic and radiologic evaluation. **Khalil *et al.*** **[37]** reported 38% idiopathic cases in their cohort. These consistent figures suggest that, despite technological advances, bronchoscopy may still fail to identify a source when bleeding arises from peripheral or microscopic lesions beyond its visual reach. However, it is against series with a much lower idiopathic rate (<20%), which often incorporate high-resolution CT angiography to identify bleeding sources that standard bronchoscopy may miss.

Bronchoscopy in interstitial lung disease (ILD) was performed in patients with connective tissue disease-associated ILD, hypersensitivity pneumonitis, and idiopathic pulmonary fibrosis. Although most patients tolerated the procedure, some required ICU transfer, and complications such as alveolar hemorrhage and infection were observed in the idiopathic pulmonary fibrosis subgroup. These findings are broadly consistent with the large series from Mayo Clinic, where bronchoscopy during acute respiratory failure in ILD demonstrated a low diagnostic yield of 13% and rarely changed management, while carrying notable procedural risks. Taken together, these results suggest that although bronchoscopy may occasionally identify infections or hemorrhage, its routine use in unstable ILD patients should be carefully weighed against the risks **[38].**

Most ILD patients tolerated bronchoscopy without ICU transfer (71.6%), but 28.4% deteriorated post-procedure. Similar complication rates were noted by **Arcadu and Moua[38]** emphasizing that bronchoscopy in ILD patients carries measurable risk and must be used selectively.

Two IPF patients developed acute respiratory failure secondary to hemorrhage or infection, with one fatality. This mirrors findings from **Suzuki *et al.*** **[39],** where IPF exacerbations triggered by

infection or alveolar hemorrhage carried high mortality despite intervention.

Dyspnea was the most common symptom (80%) among perioperative collapse cases, and lobar collapse predominated. This matches findings by **Mahajan *et al.* [40],** who observed lobar collapse as the typical postoperative complication.

Mucus plugging was the cause in 86.7% of perioperative collapses, and thoracic surgery was the most frequent preceding operation. Comparable results were found by **Toolsie *et al.* [20],** who highlighted mucus plugs as the leading cause of postoperative atelectasis.

Following bronchoscopy, 60% of collapse cases achieved complete resolution, while 40% showed no improvement—mainly due to endobronchial lesions, compression collapse, or unknown causes. This aligns with **Haenel *et al.* [41],** who reported radiographic improvement in up to two-thirds of patients after bronchoscopic clearance. The consistency reinforces bronchoscopy's therapeutic efficacy in airway obstruction.

Our success rate was somewhat lower, likely due to greater disease severity and delayed timing in some patients, reinforcing the importance of early intervention, particularly when mucus plugging is suspected. Furthermore, consistent with the literature, transient desaturation was more frequent among patients with pre-existing lung disease, and recurrence was more common in smokers [42].

Conclusion: Bronchoscopy significantly contributed to both diagnostic clarification and therapeutic intervention across a variety of clinical causes of respiratory failure. It was particularly effective in resolving airway obstruction, clearing mucus plugs, managing hemoptysis, and obtaining diagnostic samples for cytological and histopathological evaluation. The procedure allowed for targeted treatment decisions that improved patient outcomes, especially in cases of pneumonia, neoplastic obstruction, and postoperative lung collapse. In addition, it is a generally safe procedure, even in critically ill individuals.

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