

FLEXIBLE FIBEROPTIC BRONCHOSCOPY: WHAT IS IT, HOW IS IT PERFORMED, AND WHERE IS IT USED?

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Flexible fiberoptic bronchoscopy (FFB) is a minimally invasive endoscopic procedure that plays an important role in the diagnosis and management of a wide range of respiratory and airway disorders. It enables direct visualization of the larynx, trachea, and tracheobronchial tree and provides access for diagnostic sampling and therapeutic interventions. Bronchoscopy may be performed using either a flexible or a rigid bronchoscope, although flexible instruments are preferred for most diagnostic procedures in contemporary clinical practice. Flexible bronchoscopy can be performed under topical anesthesia alone or in combination with systemic sedation. Adequate topical airway anesthesia reduces cough and procedural discomfort, while carefully titrated sedation and analgesia may further improve patient tolerance and provide more favorable operating conditions for the bronchoscopist. Benzodiazepines, opioids, and propofol, either alone or in appropriate combinations, are among the agents commonly used for procedural sedation and analgesia. The indications for flexible bronchoscopy are both diagnostic and therapeutic and include evaluation of tracheobronchial abnormalities, acquisition of respiratory samples, bronchoalveolar lavage, removal of retained secretions or foreign bodies, and selected airway interventions. The decision to perform bronchoscopy should always be based on an individualized assessment of the expected clinical benefit and potential procedural risk. Appropriate patient preparation, physiological monitoring, and postprocedural observation are essential for maintaining safety. Particular caution is required

in critically ill patients, in whom impaired respiratory reserve and associated comorbidities may increase the risk of procedure-related adverse events. Hypoxemia is among the most clinically relevant complications, particularly in patients with pre-existing impairment of gas exchange. Nevertheless, when performed by appropriately trained clinicians with adequate monitoring and safety measures, flexible bronchoscopy has a favorable overall safety profile, and serious complications are uncommon.

Keywords: flexible fiberoptic bronchoscopy; airway; sedation; analgesia; intensive care

FLEKSIBILNA FIBEROPTIČKA BRONHOSKOPIJA: ŠTA JE, KAKO SE IZVODI I GDE SE PRIMENJUJE?

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Fleksibilna fiberoptička bronhoskopija (FFB) predstavlja minimalno invazivnu endoskopsku proceduru koja ima značajnu ulogu u dijagnostici i lečenju širokog spektra respiratornih oboljenja i poremećaja disajnog puta. Omogućava direktnu vizualizaciju larinksa, traheje i traheobronhijalnog stabla, kao i pristup disajnim putevima radi uzimanja dijagnostičkih uzoraka i izvođenja terapijskih intervencija. Bronhoskopija se može izvoditi fleksibilnim ili rigidnim bronhoskopom, pri čemu se u savremenoj kliničkoj praksi fleksibilni instrumenti koriste za većinu dijagnostičkih procedura. Fleksibilna bronhoskopija može se izvoditi u topikalnoj anesteziji ili uz dodatnu primenu sistemske sedacije. Adekvatna topikalna anestezija disajnog puta smanjuje kašalj i neprijatnost tokom procedure, dok pažljivo titrirana sedacija i analgezija mogu dodatno poboljšati toleranciju pacijenta i obezbediti povoljnije uslove za izvođenje bronhoskopije. Benzodiazepini, opiodi i propofol, pojedinačno ili u odgovarajućim kombinacijama, spadaju među lekove koji se najčešće koriste za proceduralnu sedaciju i analgeziju. Indikacije za fleksibilnu bronhoskopiju mogu biti dijagnostičke i terapijske i obuhvataju procenu traheobronhijalnih abnormalnosti, uzimanje respiratornih uzoraka, bronhoalveolarnu lavažu, uklanjanje zadržanog sekreta ili stranih tela i izvođenje odabranih intervencija na disajnom putu. Odluka o izvođenju bronhoskopije treba da bude zasnovana na individualnoj proceni očekivane kliničke koristi i potencijalnog proceduralnog rizika.

Adekvatna priprema pacijenta, fiziološki monitoring i postproceduralna opservacija od ključnog su značaja za bezbedno izvođenje procedure. Poseban oprez potreban je kod kritično obolelih pacijenata, kod kojih smanjena respiratorna rezerva i pridruženi komorbiditeti mogu povećati rizik od neželjenih događaja povezanih sa procedurom. Hipoksemija predstavlja jednu od klinički najznačajnijih komplikacija, naročito kod pacijenata sa prethodno kompromitovanom razmenom gasova. Ipak, kada je izvode adekvatno obučeni lekari uz odgovarajući monitoring i primenu mera bezbednosti, fleksibilna bronhoskopija ima povoljan ukupni bezbednosni profil, dok su ozbiljne komplikacije retke.

Ključne reči: fleksibilna fiberoptička bronhoskopija; disajni put; sedacija; analgezija; intenzivna nega

Introduction

Fiberoptic bronchoscopy is a well-established endoscopic technique that enables direct visualization and systematic assessment of the tracheobronchial tree. Bronchoscopic examination allows inspection of the larynx, trachea, and bronchial system using either a rigid or a flexible instrument, although flexible bronchoscopy is considerably more common in contemporary clinical practice (1, 2). Flexible fiberoptic bronchoscopy (FFB) is a minimally invasive procedure with a long-standing role in both the diagnosis and treatment of respiratory disorders and is generally associated with a favorable safety profile when performed under appropriate clinical conditions (2, 3). The bronchoscope incorporates an illumination and imaging system that provides real-time visualization of the airways and facilitates diagnostic and therapeutic interventions. Depending on the clinical circumstances, the instrument may be introduced through the nasal or oral route or through an established artificial airway, including a tracheostomy (1, 4).

FFB plays an important diagnostic role in a broad spectrum of pulmonary and airway disorders. Common indications include the evaluation of hemoptysis, pulmonary parenchymal abnormalities, lung nodules or masses, respiratory infections, persistent or unexplained pulmonary infiltrates, and other suspected tracheobronchial abnormalities (2, 3, 5). In addition to its diagnostic applications, flexible bronchoscopy provides direct access to the airways for a variety of therapeutic interventions, including removal of aspirated foreign bodies, management of airway obstruction and stenosis, bronchoscopic lavage, and selected interventions involving endobronchial lesions (5–8).

The development of bronchoscopy dates back to the late nineteenth century. In 1897, the German laryngologist Gustav Killian performed what is widely regarded as the first bronchoscopic intervention, using a rigid instrument to remove a foreign body from a patient's airway. The procedure was performed in an awake patient with topical anesthesia. During the early twentieth century, Chevalier Jackson substantially advanced rigid bronchoscopy and contributed to its standardization and wider clinical application. Rigid bronchoscopes subsequently remained the principal instruments for direct airway examination and intervention for several decades, until the development of flexible bronchoscopy transformed endoscopic assessment of the respiratory tract (9, 10).

A major milestone in the evolution of bronchoscopy occurred in the 1960s, when Shigeto Ikeda and colleagues developed and introduced the flexible fiberoptic bronchoscope. This technological innovation fundamentally changed bronchoscopic examination by allowing improved maneuverability and access to more distal portions of the tracheobronchial tree (10, 11). Early flexible bronchoscopes utilized fiberoptic bundles for image transmission and external illumination systems. Their relatively small diameter and controllable distal tip enabled bronchoscopists to advance beyond the central airways and directly visualize lobar and segmental bronchi, establishing the foundation for modern flexible bronchoscopy (10, 11).

Today, flexible bronchoscopy is routinely incorporated into respiratory medicine, anesthesiology, critical care, and airway management. Its thin and maneuverable design enables detailed assessment of the tracheobronchial system while simultaneously allowing diagnostic

sampling and selected therapeutic interventions (2, 5, 6). The procedure may be performed under topical anesthesia with or without systemic sedation, depending on the patient's clinical condition, anticipated procedural complexity, and institutional practice (2, 12). Consequently, flexible bronchoscopy has become an essential technique for the evaluation and management of a wide variety of respiratory and airway disorders.

Patient comfort, procedural tolerance, and optimal operating conditions are important determinants of successful flexible bronchoscopy; therefore, the selection and depth of sedation represent important considerations during the procedure (2, 12). Appropriate sedation may reduce anxiety, discomfort, coughing, and procedural intolerance while improving patient satisfaction and providing more favorable conditions for the bronchoscopist (13–17). Flexible bronchoscopy is particularly valuable in the intensive care unit (ICU), where it can be employed for both diagnostic and therapeutic purposes in critically ill patients (6, 18, 19). Beyond these applications, flexible fiberoptic bronchoscopy is also an established tool for airway management and may facilitate endotracheal intubation, particularly when conventional airway management is difficult or when direct visualization of the airway is required (1, 20, 21).

Types of Bronchoscopy

Bronchoscopy can be performed using either a rigid or a flexible bronchoscope, with both types available in different sizes and diameters according to their intended clinical application. A rigid bronchoscope is a hollow, straight metal tube that provides a wide working channel and secure access to the central airways. Although rigid bronchoscopy may be used for both diagnostic and therapeutic purposes, its role in contemporary clinical practice is predominantly therapeutic (2, 5, 10). It is particularly valuable for the removal of aspirated foreign bodies because it provides effective airway control while allowing the operator to manipulate and retrieve the foreign object under direct visualization (7, 8, 22). Furthermore, its relatively large working lumen facilitates efficient suctioning and permits the introduction of a variety of instruments required for therapeutic airway interventions.

Flexible bronchoscopes are longer, narrower, and considerably more maneuverable than rigid instruments. Traditional flexible bronchoscopes utilize fiberoptic bundles for image transmission, whereas contemporary systems increasingly incorporate digital video technology. The distal tip of the instrument can be actively deflected through controls located on the handle, enabling navigation through the tracheobronchial tree and access to lobar and segmental bronchi (1, 10, 11). Modern flexible bronchoscopes are generally equipped with a working channel that allows suctioning, removal of secretions, bronchoalveolar lavage, tissue sampling, and a variety of diagnostic and therapeutic interventions. However, the working channel is substantially smaller than that of a rigid bronchoscope, which may limit the size of instruments and the volume of material that can be removed during certain interventions (1, 2, 5).

The introduction and subsequent technological development of flexible bronchoscopy have fundamentally transformed endoscopic evaluation of the respiratory tract. Compared with rigid bronchoscopy, flexible bronchoscopy is generally better tolerated by patients and can usually be performed under topical anesthesia, with or without moderate sedation, rather than requiring general anesthesia (2, 12). Its smaller diameter, greater maneuverability, and ability to access

more distal portions of the bronchial tree have established flexible bronchoscopy as the preferred approach for most diagnostic bronchoscopic examinations and for an increasing range of therapeutic procedures in contemporary clinical practice (2, 5, 6).

Topical Anesthesia, Analgesia, and Sedation During Flexible Bronchoscopy

Flexible bronchoscopy may be performed under topical anesthesia alone or with the addition of systemic sedation, depending on the clinical setting, patient characteristics, and complexity of the procedure (2, 12). Historically, concerns regarding sedation-related respiratory and cardiovascular adverse events led to cautious use of sedative medications during bronchoscopy. Earlier studies demonstrated that diagnostic flexible bronchoscopy could be performed safely without routine systemic sedation; however, patient comfort, procedural tolerance, and preference increasingly became important considerations when selecting the appropriate anesthetic and sedation strategy (13, 23). Subsequent clinical studies demonstrated that sedation can improve patient tolerance, reduce discomfort and anxiety, and increase overall satisfaction with the procedure while also providing more favorable operating conditions for the bronchoscopist (13–17). These benefits must be balanced against potential sedation-related adverse effects and a possible prolongation of postprocedural recovery (2, 12, 14).

Topical airway anesthesia is a fundamental component of flexible bronchoscopy and is generally used regardless of whether systemic sedation is administered (2, 12). Several local anesthetic agents have historically been employed, including cocaine, benzocaine, tetracaine, and lidocaine, although lidocaine has become the most commonly used agent in contemporary practice. Various methods can be used to anesthetize the upper and lower airways, including direct instillation, anesthetic-soaked pledgets, nebulization, aerosol spray, regional airway nerve blocks, transtracheal administration, and delivery of local anesthetic through the working channel of the bronchoscope using the “spray-as-you-go” technique (24–29).

Lidocaine is the preferred topical anesthetic for flexible bronchoscopy because of its rapid onset of action, effective suppression of cough and airway reflexes, and favorable safety profile when appropriately administered (30, 31). Its local anesthetic effect is mediated primarily through reversible blockade of voltage-gated sodium channels, thereby inhibiting the initiation and propagation of action potentials in sensory nerves. Following administration to the respiratory mucosa, lidocaine is systemically absorbed, and clinically relevant plasma concentrations may develop during the procedure (31, 32). Because systemic toxicity is dose-dependent, careful attention should be paid to the cumulative amount administered. Excessive plasma concentrations may produce neurological manifestations, including circumoral paresthesia, altered sensorium, and seizures, as well as cardiovascular toxicity such as conduction disturbances and cardiac arrhythmias. Particular caution is warranted in patients in whom metabolism or clearance may be impaired and when repeated topical doses are required during prolonged bronchoscopic procedures (2, 12, 31, 32).

Benzodiazepines have traditionally played an important role in procedural sedation for flexible bronchoscopy. Their pharmacological effects result from enhancement of γ -aminobutyric acid (GABA)-mediated inhibitory neurotransmission within the central nervous system. Clinically, they provide anxiolysis, sedation, and anterograde amnesia, characteristics that can

substantially improve patient tolerance of bronchoscopy (12, 33). An additional advantage is the availability of flumazenil, a specific benzodiazepine receptor antagonist that may be administered when reversal of excessive benzodiazepine effects is required. Among the benzodiazepines used for procedural sedation, midazolam is particularly suitable because of its relatively rapid onset and shorter duration of action compared with longer-acting agents (12, 33). Clinical studies have demonstrated that benzodiazepine-based sedation can reduce patient discomfort and improve tolerance of flexible bronchoscopy, although careful titration remains essential because excessive sedation may result in respiratory depression, particularly when benzodiazepines are combined with opioids or administered to high-risk patients (13–17, 23, 34).

Because benzodiazepines undergo predominantly hepatic metabolism, their effects may be prolonged in elderly patients and in individuals with significant hepatic dysfunction. Careful dose titration is therefore required in these populations to minimize excessive sedation, prolonged drowsiness, confusion, impaired coordination, and delayed recovery (12, 33). Clinical studies evaluating benzodiazepine-based sedation during flexible bronchoscopy have demonstrated beneficial effects on procedural tolerance, patient comfort, and anterograde amnesia (13–17, 23, 34). Sedated patients generally report less discomfort and better overall tolerance of the procedure, while bronchoscopists may experience more favorable procedural conditions (13–17). When appropriately titrated and accompanied by adequate monitoring, benzodiazepine-based sedation has generally demonstrated an acceptable safety profile, although deeper sedation and combination with other respiratory depressant agents may increase the risk of adverse events and prolong postprocedural recovery (2, 12, 14–17).

Opioids represent another important component of sedation and analgesia during flexible bronchoscopy. Their effects are mediated predominantly through μ -opioid receptors, resulting in analgesia and suppression of the cough reflex. The availability of naloxone as a specific opioid antagonist provides an additional safety measure in cases of excessive opioid effect or clinically significant respiratory depression (12). Fentanyl is frequently used during procedural sedation because of its rapid onset and relatively short duration of action. Evidence from clinical studies indicates that combining an opioid with a benzodiazepine may improve patient comfort, procedural tolerance, and cough suppression compared with benzodiazepine-based sedation alone (35, 36). However, concomitant administration of opioids and benzodiazepines may produce additive respiratory depression and increase the risk of oxygen desaturation. Consequently, both agents should be carefully titrated, with appropriate respiratory and hemodynamic monitoring maintained throughout the procedure (2, 12, 35, 36).

Propofol is an intravenous hypnotic agent characterized by a rapid onset and relatively short duration of action. It produces dose-dependent hypnosis, sedation, and amnesia but lacks clinically significant analgesic properties (37). Propofol has been extensively evaluated as an alternative to conventional benzodiazepine-based sedation for flexible bronchoscopy. Randomized clinical trials have demonstrated that propofol-based sedation provides effective procedural conditions and patient tolerance comparable to conventional sedation regimens (38, 39). An important advantage of propofol is its rapid redistribution and recovery profile, which may facilitate earlier awakening and shorter postprocedural recovery (37–39). Nevertheless,

propofol may cause dose-dependent respiratory depression, hypotension, and loss of protective airway reflexes and has no specific pharmacological antagonist. Its administration therefore requires careful titration, appropriate patient selection, and continuous monitoring of respiratory and cardiovascular function (12, 37–39).

Anticholinergic agents, particularly atropine and glycopyrrolate, have historically been administered before bronchoscopy to reduce airway secretions and attenuate vagally mediated responses. These agents competitively inhibit muscarinic acetylcholine receptors, thereby reducing glandular secretion while also producing cardiovascular effects. In a randomized, double-blind, placebo-controlled study evaluating atropine and glycopyrrolate as premedication for flexible bronchoscopy, glycopyrrolate was associated with a reduction in bronchoscopist-assessed airway secretions. However, neither agent significantly improved patient comfort, cough, procedural duration, or oxygen desaturation. Anticholinergic premedication was also associated with increases in heart rate and blood pressure. These findings suggest that routine anticholinergic premedication provides limited clinical benefit and is therefore not necessary for all patients undergoing flexible bronchoscopy (40).

Table 1. Drugs used for sedation and analgesia during bronchoscopy

Agent	Fentanyl	Alfentanil	Meperidine	Morphine	Diazepam	Lorazepam	Midazolam	Propofol	Fospropofol
Onset of action	5-10 min	Immediate	5-10 min	5-10 min	1 min	8-15 min	30 s to 1 min	30 s	6.5 min
Peak effect	5 min	Immediate	15 min	15-30 min	2-3 min	15-30 min	5-10 min	2 min	12 min
Duration of action	1-2 h	1-2 h	3-4 h	1-6 h	1-3 h	8 h	2 h	3-5 min	17 min
Metabolism	Hepatic	Hepatic	Hepatic	Hepatic	Hepatic	Hepatic	Hepatic	Hepatic	Hepatic
Renal excretion	< 5%	< 1%	< 5%	90%	< 1% Unchanged, 75% of metabolites	< 1% Unchanged, 60%-80% metabolites	< 1% Unchanged, 70%-75% metabolites	70%	70%
Elimination half-life	3-4 h	1 h	3-4 h	2 h	20-50 h	11-22 h	1.6-3.2 h	3-12 h	45 min
Major adverse events	Respiratory depression	Respiratory depression	Respiratory depression, bronchospasm, hypotension, nausea, reduction of seizure threshold	Respiratory depression, histamine release (itching and hypotension), bronchospasm)	Respiratory depression, chemical phlebitis	Respiratory depression	Respiratory depression, hypotension	Injection site pain, respiratory depression, bradycardia, hypotension	Paresthesia, pruritus, hypoxemia and hypotension

Indications for Fiberoptic Bronchoscopy

Table 2. Principal uses of fiberoptic bronchoscopy

Diagnostic	Therapeutic
Diagnosis of lung cancer	Insertion of endotracheal tube
Staging of lung cancer	Tamponade for bleeding
Diagnosis of diffuse lung disease	Foreign body removal
Identification of infecting agents	Aspiration of secretions
	Relief of tracheobronchial obstruction

Flexible fiberoptic bronchoscopy has become an established diagnostic and therapeutic procedure and has largely replaced rigid bronchoscopy for routine diagnostic evaluation of the tracheobronchial tree. Its ability to provide direct visualization of the airways and access more distal bronchial segments has made it particularly valuable for the assessment of suspected bronchial malignancy, hemoptysis, persistent pulmonary abnormalities, and a variety of other tracheobronchial disorders (2, 3, 5). Flexible bronchoscopy also enables transbronchial biopsy, bronchoalveolar lavage (BAL), microbiological and cytological sampling, and other diagnostic procedures in patients with parenchymal and interstitial lung diseases (2, 5).

Flexible bronchoscopy is particularly valuable in patients with pulmonary infiltrates of uncertain etiology, including immunocompromised and critically ill patients. Bronchoscopic sampling techniques, including BAL and transbronchial biopsy, may provide microbiological, cytological, and histopathological information that contributes to establishing the underlying diagnosis and guiding subsequent treatment (2, 6, 18, 19). However, in critically ill patients, the potential diagnostic or therapeutic benefit of bronchoscopy should always be balanced against the risk of respiratory and hemodynamic deterioration associated with the procedure (6, 18, 19).

Direct visualization of the airway lumen remains one of the principal advantages of flexible bronchoscopy in the evaluation of tracheobronchial pathology. The procedure allows identification and assessment of endobronchial lesions, airway obstruction, stenosis, inflammatory changes, bleeding sites, and other structural abnormalities that may not be adequately characterized by non-invasive diagnostic methods alone (2, 5, 41, 42). Consequently, flexible bronchoscopy remains an important reference procedure for direct endoscopic assessment of the tracheobronchial tree.

Foreign body aspiration represents another important indication for bronchoscopy. Although particularly relevant in children, foreign body aspiration may also occur in adults and should be considered in appropriate clinical circumstances (7, 8, 22). Adults at increased risk include

patients with impaired airway protective mechanisms, neurological or neuromuscular disorders, altered consciousness, head trauma, or alcohol-related impairment. Delayed recognition and removal of an aspirated foreign body may result in clinically significant complications, including recurrent or post-obstructive pneumonia, atelectasis, airway obstruction, and chronic inflammatory changes (7, 8). Both flexible and rigid bronchoscopy may have a role in foreign body management, with the choice of technique depending on the patient's age, clinical condition, characteristics and location of the foreign body, and available expertise.

Bronchoalveolar lavage is another important diagnostic application of flexible bronchoscopy. During BAL, the distal tip of the bronchoscope is positioned in a selected segmental or subsegmental bronchus, after which sterile saline is instilled and subsequently aspirated through the working channel. The recovered fluid can then undergo microbiological, cytological, immunological, and other laboratory analyses. BAL provides a representative sample of cells and soluble components from the distal airways and alveolar compartment and is particularly useful in the evaluation of infectious and diffuse parenchymal lung diseases. Alveolar macrophages normally represent the predominant cellular population recovered from the lower respiratory tract, although the cellular profile may vary considerably according to the underlying pulmonary disorder (2, 43). The procedure is generally well tolerated, although transient fever, hypoxemia, cough, and other minor adverse events may occur.

Flexible fiberoptic bronchoscopy also has an important role in airway management and endotracheal intubation. When adequate visualization of the laryngeal inlet and vocal cords cannot be achieved using conventional direct laryngoscopy, a flexible bronchoscope may be advanced under direct endoscopic vision through the upper airway and into the trachea. An endotracheal tube can subsequently be advanced over the bronchoscope into the appropriate intratracheal position (1, 20, 21). This technique is particularly valuable when difficult tracheal intubation is anticipated or conventional laryngoscopy has failed.

The likelihood of successful fiberoptic intubation depends on several factors, including appropriate patient preparation, preservation of adequate oxygenation, effective topical anesthesia when awake intubation is planned, operator experience, and the condition of the airway. Repeated unsuccessful attempts at conventional laryngoscopy may cause airway trauma, bleeding, edema, and distortion of normal anatomy, potentially making subsequent fiberoptic visualization more difficult. Therefore, when difficult airway management is anticipated, early use of flexible bronchoscopic intubation may be preferable to its use as a rescue technique after multiple unsuccessful conventional attempts (1, 20, 27). Successful performance of the technique requires appropriate equipment and adequate training and experience in flexible bronchoscopic airway management.

In the intensive care unit (ICU), flexible bronchoscopy has several important diagnostic and therapeutic applications. Retention of bronchial secretions is frequently encountered in critically ill patients, particularly following major surgery, during prolonged mechanical ventilation, and in patients with impaired cough due to neurological or neuromuscular dysfunction. Accumulation of secretions and mucus plugging may contribute to airway obstruction and the development or persistence of atelectasis, resulting in impaired gas exchange and an increased risk of pulmonary infection (18, 19, 44–46). Flexible bronchoscopy

enables direct visualization of the affected airways and targeted aspiration of retained secretions and mucus plugs and may therefore be considered in selected patients with persistent lobar or segmental atelectasis when conventional respiratory therapy is insufficient (45–47).

Contraindications

Flexible bronchoscopy should be performed only when the anticipated diagnostic or therapeutic benefit outweighs the potential procedural risk. Therefore, contraindications are not always absolute and should be evaluated individually according to the patient's clinical condition, urgency of the procedure, available monitoring and airway support, and the experience of the bronchoscopist (2, 6, 48). Particular caution is required in patients with severe or refractory hypoxemia, significant hemodynamic instability, unstable or recent major cardiovascular events, clinically relevant bleeding disorders, or an inability to cooperate when an awake or moderately sedated procedure is planned. In addition, bronchoscopy should not be undertaken when appropriate expertise, monitoring, resuscitation equipment, or facilities for managing potential complications are unavailable (2, 6, 48).

Table 3. Contraindications to bronchoscopy

Absolute contraindications	Relative contraindications
Acute respiratory failure with hypercapnia (unless the patient is intubated and ventilated)	Recent myocardial infarction
High-grade tracheal obstruction	Uncooperative patient
Inability to adequately oxygenate the patient during the procedure	Uncorrectable coagulopathy
Untreatable life-threatening arrhythmias	

Certain clinical conditions do not necessarily preclude airway inspection but may substantially influence the safety of invasive bronchoscopic sampling. Patients with uremia, pulmonary hypertension, superior vena cava obstruction, thrombocytopenia, coagulation abnormalities, or other conditions associated with an increased risk of bleeding require careful preprocedural assessment. In such patients, inspection of the tracheobronchial tree and bronchoalveolar lavage may be feasible, whereas transbronchial biopsy requires greater caution because of its higher potential for clinically significant hemorrhage (2, 6).

Procedure

Flexible bronchoscopy is an invasive procedure and requires appropriate patient preparation, clinical assessment, monitoring, and equipment. Before the procedure, informed consent should be obtained from the patient or, when appropriate, an authorized representative after explaining the indication, expected benefits, procedural steps, available alternatives, and potential complications. Preprocedural assessment should include relevant medical history, allergies, current medications, cardiopulmonary status, and factors that may increase the risk of bleeding, respiratory compromise, or sedation-related adverse events (2, 12).

Patients should follow appropriate fasting recommendations before elective bronchoscopy, particularly when sedation is planned. Regular medication should be reviewed individually, with particular attention to anticoagulant and antiplatelet therapy when biopsy or another invasive intervention is anticipated. Before starting the procedure, baseline vital signs should be documented, intravenous access should generally be established when systemic sedation or intravenous medication is anticipated, and any clinically significant physiological abnormalities should be addressed whenever possible (2, 12).

Physiological monitoring is essential throughout flexible bronchoscopy. Heart rate, blood pressure, and peripheral oxygen saturation (SpO₂) should be assessed before, during, and after the procedure. Continuous pulse oximetry is recommended during bronchoscopy, while supplemental oxygen should be readily available and administered according to the patient's baseline oxygenation and the development of clinically significant desaturation. Patients receiving systemic sedation require particularly careful respiratory and cardiovascular monitoring because sedative and analgesic medications may contribute to hypoventilation, airway obstruction, hypoxemia, and hemodynamic instability (2, 12).

Routine anticholinergic premedication is generally not recommended before flexible bronchoscopy. Evidence from a randomized, double-blind, placebo-controlled study demonstrated that although glycopyrrolate may reduce airway secretions, neither glycopyrrolate nor atropine produced meaningful improvements in patient comfort, cough, procedural duration, or oxygen desaturation, while both may influence heart rate and blood pressure (40). Topical airway anesthesia, in contrast, is an important component of patient preparation and improves procedural tolerance. Lidocaine is the most commonly used topical anesthetic because of its rapid onset, effective suppression of airway reflexes and cough, and favorable safety profile when administered in appropriate doses (24, 25, 30, 31).

Systemic sedation may be used to improve patient comfort, reduce anxiety, facilitate tolerance of the bronchoscope, and provide more favorable procedural conditions. The decision to administer sedation and the appropriate depth of sedation should be individualized according to patient characteristics and procedural requirements (2, 12). Benzodiazepines, particularly midazolam, have traditionally been widely used, while opioids may be added when analgesia and additional cough suppression are required (13–17, 23, 33–36). Propofol represents an effective alternative and is characterized by rapid onset and recovery, although its potential to cause respiratory depression and hypotension requires careful titration and appropriate monitoring (37–39).

Flexible bronchoscopy may be performed with the patient in a supine, semi-recumbent, or sitting position, depending on the clinical setting and operator preference. The bronchoscope may be introduced through either the nasal or oral route. The nasal approach may provide stable instrument control and permits examination of the upper airway during insertion, whereas the oral route may be preferred when nasal access is limited or contraindicated. The choice of insertion route should therefore be individualized according to patient anatomy, comfort, procedural requirements, and operator experience (2, 4).

Following insertion, the bronchoscope is advanced under direct visualization through the upper airway into the trachea and subsequently through the bronchial tree. The airways should be examined systematically, with attention to anatomical abnormalities, secretions, bleeding, mucosal changes, stenosis, and endobronchial lesions. When clinically indicated, diagnostic material may be obtained using bronchial washing, brushing, bronchoalveolar lavage, needle aspiration, endobronchial biopsy, or transbronchial biopsy. Additional imaging or navigation techniques, including fluoroscopic guidance, computed tomography-based navigation, and electromagnetic navigation, may facilitate sampling of selected peripheral pulmonary lesions (2, 5, 49, 50).

Flexible bronchoscopy can also be performed through an artificial airway in mechanically ventilated or critically ill patients. In intubated patients, the bronchoscope is introduced through an appropriate adapter connected to the endotracheal or tracheostomy tube, allowing ventilation to continue during the procedure. Selection of bronchoscope diameter is particularly important because the relationship between the bronchoscope and the internal diameter of the artificial airway influences airflow, airway resistance, delivered tidal volume, and the ability to maintain adequate ventilation (6, 18, 19, 51). Bronchoscopy in critically ill patients may transiently worsen oxygenation and ventilation; therefore, ventilatory settings, oxygen supplementation, and hemodynamic status should be carefully monitored and adjusted according to the patient's clinical response (6, 18, 19).

Postprocedural observation is an important component of safe bronchoscopic practice. Monitoring should continue until the patient's respiratory and cardiovascular status is stable and the clinically relevant effects of sedative medications have resolved. Oral intake should be delayed until adequate airway protective reflexes have returned following topical pharyngeal anesthesia. Patients should also be observed for complications such as persistent hypoxemia, respiratory distress, significant bleeding, chest pain, or hemodynamic instability (2, 12).

Following transbronchial biopsy, the possibility of pneumothorax should be considered, particularly when suggestive clinical signs or symptoms develop. Chest imaging may be indicated according to the patient's clinical condition and procedural findings rather than being required routinely in every asymptomatic patient. Patients who develop clinically significant pneumothorax, persistent bleeding, respiratory deterioration, or other major complications require appropriate treatment and, when necessary, continued hospital observation or admission (2).

Finally, appropriate cleaning, high-level disinfection, and reprocessing of reusable bronchoscopic equipment are essential for preventing procedure-associated transmission of infection. Reprocessing should be performed according to current institutional protocols, manufacturer recommendations, and applicable infection-control standards rather than relying on a single disinfectant or decontamination method.



Figure 1. Bronchoaspiration in a patient with an atelectatic field

Complications

Complications of flexible fiberoptic bronchoscopy may occur during the procedure or in the early postprocedural period and may be related to the bronchoscopy itself, diagnostic or therapeutic interventions, topical anesthesia, or systemic sedation. Reported adverse events include transient fever, hypoxemia or oxygen desaturation requiring supplemental oxygen, clinically significant bleeding, hypotension or hypertension, and cardiac arrhythmias. The incidence and clinical significance of these complications depend on several factors, including the patient's underlying cardiopulmonary condition, procedural complexity, duration of bronchoscopy, type of intervention performed, and medications administered for anesthesia and sedation (2, 3, 6, 12, 52).

Respiratory complications are among the most important adverse events associated with flexible bronchoscopy. Passage of the bronchoscope through the airway, suctioning, bronchoalveolar lavage, and sedative medications may contribute to transient deterioration in ventilation and gas exchange. Hypoxemia is particularly relevant in patients with pre-existing impairment of pulmonary function and in critically ill patients with limited respiratory reserve (2, 6, 18, 19). Bronchospasm and laryngospasm are uncommon but potentially significant complications, particularly in patients with reactive airway disease or following airway manipulation. Coughing is common during and shortly after bronchoscopy and may become more pronounced following bronchoalveolar lavage or extensive airway manipulation.

Complications may also result from topical anesthesia and systemic sedative or analgesic medications. Lidocaine is generally well tolerated when administered in appropriate doses; however, systemic absorption may result in dose-dependent neurological and cardiovascular toxicity. Manifestations of local anesthetic systemic toxicity may include neurological symptoms, seizures, conduction abnormalities, and cardiac arrhythmias (31, 32). Similarly, benzodiazepines, opioids, and propofol may cause dose-dependent respiratory depression, hypoventilation, airway obstruction, hypoxemia, and hemodynamic instability. These risks may be increased when sedative and analgesic agents are administered in combination, emphasizing the importance of careful dose titration and continuous physiological monitoring (2, 12, 35–39).

Cardiovascular complications associated with flexible bronchoscopy are generally uncommon and transient. They may include changes in heart rate and blood pressure as well as cardiac arrhythmias, particularly in patients with pre-existing cardiovascular disease, hypoxemia, or significant physiological stress during the procedure. Both tachyarrhythmias and bradyarrhythmias may occur, although clinically significant cardiovascular events remain uncommon when appropriate patient selection and monitoring are applied (2, 3, 52).

Bleeding is another recognized complication of bronchoscopy, with the risk largely determined by the type of intervention performed. Minor mucosal bleeding may occur following brushing, needle aspiration, or endobronchial biopsy and is usually self-limiting. The risk of clinically significant hemorrhage is greater following transbronchial biopsy and in patients with thrombocytopenia, coagulation abnormalities, pulmonary hypertension, or other conditions associated with an increased bleeding tendency (2). Careful assessment of bleeding risk before invasive bronchoscopic sampling is therefore essential.

Procedure-related complications of flexible bronchoscopy may include:

- hypoxemia and transient deterioration in gas exchange;
- respiratory depression or hypoventilation associated with sedation;
- bronchospasm or laryngospasm;
- cardiac arrhythmias and hemodynamic instability;
- minor or, less commonly, clinically significant airway bleeding;
- fever and cough, particularly following bronchoalveolar lavage;
- laryngeal irritation, edema, or transient hoarseness;
- pneumothorax, particularly following transbronchial biopsy; and
- procedure-associated transmission of infection when appropriate equipment reprocessing and infection-control procedures are not followed (2, 3, 6, 12, 52).

Pneumothorax is an important complication specifically associated with transbronchial lung biopsy rather than with airway inspection alone. Its occurrence should be suspected when patients develop new chest pain, dyspnea, unexplained hypoxemia, or respiratory deterioration

following the procedure. Transbronchial biopsy may also result in clinically significant pulmonary hemorrhage, although severe bleeding is considerably less frequent than minor self-limiting bleeding. The risks associated with biopsy should therefore be considered in relation to the expected diagnostic benefit, particularly in critically ill patients and those with significant cardiopulmonary or coagulation abnormalities (2, 6).

Overall, serious complications and procedure-related mortality following flexible bronchoscopy are uncommon. Nevertheless, the risk is not uniform across all patients. Elderly individuals, critically ill patients, and those with severe chronic obstructive pulmonary disease, significant cardiovascular disease, baseline hypoxemia, advanced malignancy, or other major comorbidities may have reduced physiological reserve and a greater likelihood of clinically relevant adverse events (2, 3, 6, 18, 19). Careful patient selection, appropriate preprocedural assessment, continuous monitoring, judicious use of sedation, and immediate availability of equipment and personnel capable of managing airway, respiratory, cardiovascular, and bleeding complications are therefore essential for maintaining procedural safety.

Conclusions

Flexible fiberoptic bronchoscopy has an important role in the diagnosis and management of a wide range of respiratory and airway disorders. Its ability to provide direct visualization of the tracheobronchial tree, obtain diagnostic samples, and facilitate therapeutic interventions has made it an essential procedure in respiratory medicine, anesthesiology, critical care, and airway management.

When performed by appropriately trained clinicians with adequate patient selection, preparation, and monitoring, flexible bronchoscopy has a favorable overall safety profile. The use of topical anesthesia together with carefully titrated analgesia and sedation may improve patient comfort, reduce procedural intolerance, and provide better operating conditions for the bronchoscopist. However, the choice and depth of sedation should always be individualized according to the patient's clinical condition, comorbidities, anticipated procedural complexity, and risk of respiratory or hemodynamic compromise.

Although flexible bronchoscopy may be associated with respiratory, cardiovascular, bleeding-related, infectious, and medication-related adverse events, serious and life-threatening complications remain uncommon. Particular attention should be given to critically ill patients and those with substantial cardiopulmonary comorbidities, in whom the physiological consequences of bronchoscopy and sedation may be more pronounced. In every case, the anticipated diagnostic or therapeutic benefit should be carefully weighed against the potential procedural risk.

Overall, flexible bronchoscopy remains a fundamental diagnostic and therapeutic modality in contemporary clinical practice. Its versatility, relatively low complication rate, and applicability even in critically ill patients make it particularly valuable in the intensive care setting, provided that appropriate indications, monitoring, airway management strategies, and safety precautions are observed.

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